KOORAGANG WETLANDS: RETROSPECTIVE OF AN INTEGRATED ECOLOGICAL RESTORATION PROJECT IN THE HUNTER RIVER ESTUARY

P Svoboda
Hunter Local Land Services, Paterson NSW

Introduction:

At first glance, the Hunter River estuary near Newcastle NSW is a land of contradictions. It is home to one of the world's largest coal ports and a large industrial complex as well as being the location of a large internationally significant wetland. The remarkable natural productivity of the Hunter estuary at the time of European settlement is well documented. Also well documented are the degradation and loss of fisheries and other wildlife habitat in the estuary due to over 200 years of draining, filling, dredging and clearing (Williams et al., 2000).

However, in spite of extensive modification, natural systems of the estuary retained enough value and function for large areas to be transformed by restoration activities that aimed to show industry and environmental conservation could work together to their mutual benefit. By establishing partnerships and taking a collaborative and adaptive approach, the project was able to implement restoration and related activities on a landscape basis, working across land ownership and management boundaries (Kooragang Wetland Rehabilitation Project, 2010).

The Kooragang Wetland Rehabilitation Project (KWRP) was launched in 1993 to help compensate for the loss of fisheries and other wildlife habitat at suitable sites in the Hunter estuary. This paper revisits the expectations and planning for the project as presented in a paper to the INTECOL's V international wetlands conference in 1996 (Svoboda and Copeland, 1998), reviews the project's activities, describes outcomes and summarises issues faced and lessons learnt during 24 years of implementing a large, long-term, integrated, adaptive and community-assisted ecological restoration project.

Background:

For thousands of years the Hunter estuary traditionally used by the Worimi, Awabakal and Pambalong peoples (Australian Government Department of Environment and Energy, 2016) was rich in fish, shellfish and water birds and other resources needed for thriving communities.

Aquatic productivity of the Hunter estuary at European settlement was legendary. European settlers and naturalists in the 1800s noted the almost unbelievable banks of oysters lining the Hunter River estuary, the lushness of the floodplain forests, the abundant water fowl and the use of these natural resources by Aboriginal inhabitants. Lt. Col. Paterson told Governor King in 1801 that:

> *The quantity of oyster shells on the beaches inland (from the mouth of the Hunter River) is beyond conception: they are in some places for miles. These*

> *are four feet deep* (later recorded to be up to 18ft deep) *without either sand or earth*. (Turner and Melville, 2009)

The floodplain rainforest on the islands of the Hunter estuary was also a source of inspiration. Natural history artist Elizabeth Gould visited Mosquito Island in 1839 and wrote that:

> …*nature appeared in her wild luxuriance. The Immense parasites twining round the trees taking root some of them at the tops of the trees and hanging down to the ground, others surrounding the trees like a crown – heard the bell bird with his incessant ting ting, the coachwhip bird &c – a heavy shower of rain accompanied by lightning – soon cleared up – every green thing looked more beautiful for its sprinkling.* (Albrecht and Albrecht, 1992, p. 7)

Ludwig Leichhardt, German natural scientist and explorer, was a friend of Alexander Walker Scott, naturalist, entrepreneur and land grant owner of Ash Island. Leichhardt was impressed with the local flora and wrote of Ash Island in 1842:

> *…it is a remarkably fine place, not only to enjoy the beauty of nature, a broad shining river, a luxuriant vegetation, a tasteful comfortable cottage with a plantation of orange trees, but to collect a great number of plants which I had never seen before.* (Ord, 1988, p. 13)

A. W. Scott lived on Ash Island with his wife and daughters from 1829 to 1866. A relatively small portion of the property near the homestead was put under cultivation. Much of the island was left wild to be studied and documented by A. W. and his daughters, Helena and Harriet, all of whom were scientists and artists (Ord, 1988). Information produced by the Scott sisters has been used to guide the revegetation of Ash Island some 130 years later (Ord, 1988; Scott, 1862). After the Scott family left, Ash Island was divided into smaller blocks and entered a farming era with scores of dairies providing milk and vegetables to the local community, lifestyles which have added a rich social history component to the restoration project.

Red cedar and ash trees were harvested from the floodplain rainforest between 1797 and the early 1800s with forest being cleared in earnest for agriculture from the mid-1800s leaving isolated remnants of original vegetation. Oyster banks were mined and dredged from for production of cement. Since the 1859, the river has been dredged to create and maintain facilities for Newcastle harbour (Williams et al., 2000).

Extensive mudflats of Fullerton Cove in the estuary provide an abundance of feeding habitat for shorebirds, many of which migrate from the northern hemisphere. However, high tide roosts for shorebirds have been lost following construction of ring drains, levees and floodgates which were designed to turn wetlands into improved grazing land, provide stormwater drainage and flood protection. As a result, saltmarsh was invaded by reeds, exotic weeds and woody plants making these areas unsuitable for shorebirds (Geering and Winning, 1993).

The single most significant activity affecting intertidal habitat in the Hunter estuary was the ambitious Kooragang Island reclamation scheme that used dredge material from the harbour to create industrial land connected to port facilities (NSW Public Works and Services, 1979). This major engineering project began in the 1950s and connected four islands into one named Kooragang in 1968. Flows between the north and south arms of the Hunter River along Mosquito Creek were blocked with the construction of a railway line servicing the industrial area (Williams et al., 2000).

Justification:

During the late 1960s as community attitudes towards natural areas changed, a large part of Kooragang Island was yet to be reclaimed. A lengthy battle ensued primarily because of air pollution from industries on Kooragang Island and the rise of environmentalism in Newcastle and beyond. The NSW Government acknowledged that areas of the Hunter estuary were being degraded and the Coffey inquiry into pollution from Kooragang Island identified an ideal ecological unit and suggested a minimum area for preservation (NSW State Pollution Control Commission, 1973). This report found that:

> *Elimination of the entire natural area of Kooragang Island would not only destroy the ecological and aesthetic values of that area, but would threaten the ecological viability of the adjacent area*. (NSW SPCC, 1973, p.71)

By the late 1990s, records for the Hunter estuary confirmed earlier observations by showing an estimated decrease since European settlement of over 80% of saltmarsh and non-tidal forests (Manly Hydraulics Laboratory, 2003), 13% of open water (Williams et al., 2000), 50% of shoreline length and at least 50% of migratory shorebird numbers (Kingsford and Ferster Levy, 1997). In the lower estuary not including Hexham Swamp, saltmarsh had decreased by over 1400ha and mangroves had increased by 400ha between 1954 and 1994 (Williams et al., 2000). The number of deltaic islands in the lower estuary had been reduced from 21 to 6 (Williams et al., 2000).

Fish habitat had been lost or degraded with most of the tidal creeks being filled, constricted by floodgates or crossed by roads with constricting culverts. Hydrological regimes had been significantly altered resulting in reduced tidal flushing and fragmented habitat. Structures affecting hydrology had increased from 0 in 1801 to 112 (59 culverts, 42 bridges and 11 floodgates) and 77km of drains and levees (57km and 20km respectively) being constructed by 1994 (Williams et al., 2000).

Surveys documented natural attributes of the estuary in the 1970s (Moss, 1983) and in 1984 an area of 2900ha in the estuary was listed as the internationally significant Hunter Estuary Wetlands Ramsar site. It is considered the most important locality in NSW for migratory shorebirds whose habitat is protected by treaties with Japan, China and South Korea (National Parks and Wildlife Service, 1998). As such, the project included a range of elements centred on restoration of saline and freshwater wetlands and adjacent floodplain rainforest and woodland.

Planning:

In the early 1990s, as a result of concern for the loss of fisheries habitat in the Hunter estuary, Craig Copeland from NSW Fisheries brought together NSW Public Works, Hunter Catchment Management Trust and Newcastle City Council to produce a feasibility study after extensive consultation with agencies and special interest groups (Shortland Wetlands Centre Ltd and TUNRA, 1992). It was at this stage that the integrated nature of the project was established with three strands based on habitat restoration informed by research; integrated education and recreation facilities including a city farm sustainable agriculture demonstration site; and an integrated nature reserve complex that would link Ash Island with other natural areas of the estuary. Extensive community and stakeholder consultation

was an integral feature of each stage of the project's planning and continued throughout implementation of on-ground works.

By 1994, three sites in the Hunter estuary had been identified as being suitable for restoration to help redress the loss of fisheries and other wildlife habitat: Ash Island (780ha), Tomago Wetlands (800ha) (Land Systems EBC, 1994) and Stockton Sandspit (10ha) (Geering and Winning, 1993). A value management study and economic appraisal were done prior to the management plan being produced (NSW Department of Land and Water Conservation, 1996; NSW Public Works and Services, 1996). The management plan included Landscape plans illustrated proposed outcomes and added details of administrative, staffing and financial support required to turn the vision into reality (Kooragang Wetland Rehabilitation Project, 1996). Landscape plans were essential as a management tool to track progress of the project and also used effectively for communication throughout the project to show the context of how specific works related to the intended outcome.

On Ash Island, a key result of the project was that over 500ha of estuarine wetlands and associated floodplain ecosystems were rezoned from general industrial to environmental conservation in 2000 leading to gazettal as part of Hunter Wetlands National Park in 2010.

For the Tomago site, KWRP provided preliminary landscape designs, hydrologic modelling, environmental assessment and monitoring (Patterson and Britton Pty Ltd, 1998; 2000). The proposed restoration action was to open and manage floodgates to increase tidal flows and re-establish coastal saltmarsh. The priority outcome was to re-establish coastal saltmarsh as shorebird habitat recognising that fisheries habitat would also be improved.

At Tomago, works were implemented as the Tomago Wetlands Rehabilitation Project by National Parks and Wildlife Service (NPWS) on land within the Hunter Wetlands National Park. Hunter LLS provided grant funding to NPWS and to NSW Fisheries to help modify floodgates. The major performance indicator was a spectacular increase in use of the area by shorebirds from 0 pre-opening to 1000s post-opening of floodgates (Stuart, 2016).

In partnership with Awabakal and Worimi Local Aboriginal Land Councils, an Aboriginal cultural heritage management plan was written for Kooragang Wetlands and Hexham Swamp which will further integrate both traditional and contemporary Aboriginal culture with the project's objectives (Awabakal Local Aboriginal Land Council, 2010).

Over the past two decades, climate change adaptation plans have become an accepted feature of the planning landscape (Umwelt, 2016**).** Predicted sea level rise and effects of climate change has meant that serious consideration is being given to identifying migration areas for Hunter estuary vegetation especially to retain the ecological character of the Kooragang Estuary Wetlands Ramsar site.

A key to KWRP's achievements was the time it had for staged implementation. Essential continuity was provided for administration, management and financial accountability by Hunter's regional natural resource and catchment management organisation throughout the project: Hunter Catchment Management Trust (to 23 Jan 2004), Hunter-Central Rivers Catchment Management Authority (to 31 Dec 2013) and Hunter Local Land Services (to present).

Project vision, aims and objectives revisited:

The KWRP vision was for *an estuary in which healthy, restored fisheries, shorebird, threatened species and other wildlife habitat is in balance with a thriving port, the whole providing opportunities for research, education and recreation* (Kooragang Wetland Rehabilitation Project, 2010). The initial focus on fisheries habitat and shorebirds was expanded as information was collected on a variety of other components of the ecosystem. Early surveys showed that the project area contained at least one (now five) endangered ecological community and 27 threatened species (1 frog, 17 bird, 7 bat and 2 plant species). It provided habitats for more than 341 native plant species, 191 (now 206) native bird, 67 fish/decapod crustacean, 15 frog and 12 mammal species.

KWRP aims reflected the integrated approach of the project and were to:

- help redress the loss of fisheries, shorebird, threatened species and other wildlife habitat in the Hunter Estuary due to clearing, draining and filling over the past 200 years by conserving, restoring and continuously improving Kooragang and Tomago wetlands for nature conservation;
- maintain viability of the estuarine ecosystems including threatened ecological communities and critical habitat for migratory waders and threatened species; and
- link applied research to wetland management and develop and promote complementary opportunities for environmental education, outdoor recreation and nature-based tourism and demonstrate that environment conservation and local industry can work together to their mutual benefit.

KWRP restoration objectives can serve as a model for continued work across the estuary and as additional suitable sites are identified; objectives were to:

- protect threatened/protected species and communities along with other species and communities of conservation significance;
- enhance habitat for estuarine flora, in particular saltmarsh, and fauna, in particular migratory shorebirds, fish and crustaceans;
- increase flushing of tidal creeks which have become stagnant and restore creek beds, taking into account habitat requirements for threatened and protected species and maintaining saltmarsh;
- manage floodgates at Tomago Wetlands to reinstate shorebird roost and feeding habitat;
- enhance riverine corridor vegetation for biodiversity and riverbank stability;
- manage pest and weed species;
- develop Kooragang City Farm as a demonstration site and training facility for farming in harmony with wetlands and management based on holistic decision-making;
- consider the contribution of KWRP to the larger estuarine wetland complex of the Hunter estuary in the development a long-term management framework for the Green Corridor and regional network of protected natural areas;
- assist research initiatives through facilitating collaborative projects and providing research sites;
- assess rehabilitation/creation success and guide management actions of this and other rehabilitation projects through applied research;
- protect Aboriginal and European cultural heritage values;
- contribute to the promotion of the value of the Lower Hunter estuary wetlands;
- facilitate community involvement and training activities through an education and extension program that features Kooragang City Farm;

- encourage use of Kooragang and Tomago wetlands for educational purposes;
- enhance opportunities for passive outdoor recreation and nature appreciation;
- promote the Hunter estuary as a centre of excellence in sustainable wetland management;
- maintain international profile of wetlands of the Hunter River estuary.

Transformations and lessons learnt:

Tidal wetlands:

Since the project was launched in 1993, it has protected over 350ha of fisheries habitat including mangroves, saltmarsh and open water. A lesson learnt was to repair damaged habitat as quickly as possible to avoid it attracting further damage. The current challenge is to retain the ability to protect and maintain these habitats that are close to urban areas.

Remarkable changes to tidal wetlands were made by removing cattle grazing and improving hydraulic connectivity by removing obstructions to tidal flows where possible. Wetlands associated with these creeks were allowed to self-design. A lesson learnt was to leave buffers of exotic pasture grass around the wetlands to serve as saltmarsh migration zones as water levels rise.

New habitats have also been constructed. A 10ha area of coastal saltmarsh has been created by slightly lowering degraded pasture, introducing tidal flows and allowing the saltmarsh to self-design. This created saltmarsh now provides habitat for shorebirds including Pacific Golden Plover and Eastern Curlew and other waterbirds including the occasional Black-necked Stork. A series of non-tidal rainwater fed swales of varying designs were constructed adjacent to the saltmarsh as ‘stepping stone’ ponds for green and golden bell frog (*Litoria aurea*) which are found elsewhere on Ash Island.

Stockton Sandspit is a manmade feature built during construction of the Stockton Bridge which was opened in 1971. Initial works at the Stockton Sandpit were implemented by KWRP based on recommendations in Geering and Winning (1994). Motor vehicles were excluded from the sandpit by installation of bollards, cable and gates and invasive weeds were removed. A shallow tidal lagoon with an island was constructed with a weir that overtopped at a 1.8m tide. Mangrove seedlings were removed from a relatively narrow opening to create a link between the river and the lagoon. A slight increase in shorebirds using the sandspit resulted from these initial works but the most significant increase in use occurred when NPWS removed mangroves from the edge of the sandspit and established a wide line of sight between the lagoon and the river (Hunter-Central Rivers Catchment Management Authority, 2013). The sandspit has been reinstated as one of best shorebird roosts in NSW.

Non-tidal wetlands:

Some 32ha of ephemeral freshwater/brackish swales have been rehabilitated, largely by controlling cattle grazing. Swales were fenced to be protected from grazing and allowed to self-design with native wetland plant species. Cattle were allowed to graze these wetland areas only if biomass needed to be reduced for a defined biological objective or to study

the effects of grazing. This technique was used once to create more open water and patchy vegetation for Latham's Snipe habitat.

Floodplain rainforest and riparian woodland:

Over 8km of riverbank have been rehabilitated by removing cattle, excluding motor vehicles, filtering rainwater runoff through native vegetation, controlling weeds and re-establishing native riparian vegetation.

Floodplain rainforest and woodland remnants have been connected and extended across Ash Island with a rainforest type being most similar to the littoral rainforest and coastal vine thickets of eastern Australia, a nationally threatened ecological community. Over 200,000 seedlings of about 190 local native species have been planted primarily by volunteers since 1996. Some 30 missing species that historical records show once grew on the island have been re-introduced including red cedar (*Toona ciliata*) (Scott, 1862; Winning, 1991). This planting program has helped the recovery of the endangered rainforest vine, White Cynanchum (*Cynanchum elegans*) and established over 12ha of new wildlife corridor and over 4km of revegetated riverbank. Many seedlings have been planted of hard quandong or blueberry ash (*Elaeocarpus obovatus*) – the ash tree of Ash Island.

Re-establishment of the floodplain forest has attracted a number of bird species back to Ash Island. In 2003, 191 native bird species had been recorded on Ash Island with the number increasing to 206 in September 2017. The eastern whipbird was recorded in 2014 for the first time since the early 1800s; its presence along with rufous fantail and black-faced monarch are good indicators of the successful revegetation of kikuyu paddocks to floodplain forest. Two of the three project sites, Ash Island and Stockton Sandspit have been listed in the top 100 bird observing areas in Australia (Taylor, 2013).

Sustainable agriculture:

Kooragang City Farm was included in the ecological restoration project as a demonstration site for sustainable agricultural practices that improve productivity while looking after the health of the estuary and its catchment. It used managed grazing methods that included rotational grazing of kikuyu pasture, off-stream watering and shade to take grazing pressure off the riverbank, windbreaks and shelterbelts of local native plant species, wet pasture management, reduced nutrient run-off, and community garden and farm forestry to diversify production (Henderson, 1995). The changed management resulted in the land and cattle being in better condition during drought than they had been under a set grazing regime in an average rainfall year. The grazing demonstration was discontinued in July 2017 and a video is being produced to summarise its design, results and lessons learnt.

Community awareness:

In the late 1980s, the NSW Government recognised the value of estuaries and their degraded state and implemented an estuary management program. This program supported the research, works and education required to protect and rehabilitate estuaries

and provided the foundational grant for KWRP (NSW Government, 1992) which was matched by funding from local sources. The revised Hunter Estuary Coastal Zone Management Plan (BMT WBM, 2016) when certified will underpin applications for estuary funding while a new plan is produced using a new framework. This process presents an opportunity to review current strategies in light of recent research and community expectations.

Community attitudes are central to building the political will for legislation to protect natural areas of the estuary and to initiate projects such as KWRP. Therefore, tied to the habitat work has been the creation of opportunities for education, recreation and tourism to promote appreciation and wise use of wetlands. The project plan included the establishment a range of visitor facilities on Ash Island including walking paths, boardwalks and cycleways that would allow access without damaging the environment. A jetty was constructed to help reconnect the community with the river. The 1890s Schoolmasters House was restored to serve both as the project office and an information centre for visitors.

One of the messages that KWRP delivers to visitors and groups is in three parts: defining what an estuary is and what type of estuary the Hunter estuary is; explaining why estuaries are valuable and why the Hunter estuary in particular is valuable; and describing how to look after estuaries generally and how a person can help look after the Hunter estuary.

Research and adaptive management:

Research for KWRP was started in 1993 by NSW Fisheries with the first three years being supported by the project's first sponsor, Port Waratah Coal Services. Monitoring fish and crustaceans was continued by NSW Fisheries for 16 years (14 years post-culvert removal) to document the effects of opening tidal creeks (Boys and Williams, 2012).

A number of research partnerships have been established over the years resulting in a significant body of research. Studies by undergraduate, Honours and PhD students from the University of Newcastle and other universities have provided information on biophysical and socioeconomic aspects of the project. Results of research are used directly in management as with the study of hydrodynamics of shorebird habitat (Howe, 2008; Spencer and Howe, 2008).

The project has provided field sites and other support for a range of research into estuarine ecosystems. A particularly valuable tool for students to learn about monitoring design and collecting field data is the monitoring manual produced for the Phoenix Flats saltmarsh creation site (Laegdsgaard, 2009).

The challenge remains to make the information gained through the project more accessible to other wetland projects and wetland managers. A current initiative is to place years of water quality monitoring on a database accessible to the public. In addition, the library on the Kooragang Wetlands website (kooragangwetlands.com) will eventually hold or link to key research documents.

Partnerships:

KWRP has been a collaborative project with a number of organisations working together to achieve a shared vision: Hunter LLS, NSW Office of Environment and Heritage – NPWS, Newcastle City Council, Port Stephens Council, NSW Department of Primary Industries (Fisheries), Australian Government, Kooragang volunteers, Hunter Bird Observers Club, University of Newcastle, Awabakal and Worimi Local Aboriginal Land Councils, Hunter Wetlands Centre, Wetlands Environmental Education Centre, Conservation Volunteers Australia and TAFE.

Many other organisations have assisted with specific aspects of the project. A good example of a number of organisations joining forces to tackle a topic of common concern was the committee chaired by the NSW Premier's Department to develop the *Living with Mosquitoes* report (Webb and Russell, 2005).

Major funding has come from the NSW Estuary Management Program, Hunter Catchment Contributions, other government grants, local sponsors including Newcastle City Council and Kooragang volunteers (approximately 13,000hrs of volunteer labour each year).

Discussion:

Natural resource management in an urbanised estuary is as much a challenge today as it was in 1996, if not more. Estuaries continue to be viewed as prime industrial real estate. At the same time, research produces more evidence of the essential role played by estuarine habitats, especially saltmarsh, in aquatic food production. Since 1996, climate change and sea level rise have become of increasing concern and now are routinely taken into consideration when developing plans.

An effort is being made to quantify the economic value of ecosystem services given the increasing requirement for business cases to be made to justify environmental projects. A major challenge is to accurately quantify the value provided by improved ecosystem function so that it can be reasonably assessed against other development options.

The continued state of degradation although partly due to poor communication could be easily improved by actions associated with well-designed monitoring and research programs and a strong emphasis on communication.

Acknowledgments:

Heartfelt appreciation goes to all those who have helped with the project over many years, starting with Craig Copeland and members of the original steering committee. Financial support has come from all levels of government, private industry and the local community. Dedicated people within the natural resource management network of the Hunter Region including professionals, community groups, students and Kooragang volunteers have provided invaluable assistance and encouragement. I would like to acknowledge the contribution of managers and staff especially Glenn Evans, Rob Henderson and Terry Sullivan with a special tribute to Sue Rostas who was a communicator extraordinaire and colleague much missed.

References:

Albrecht, G. and Albrecht, J. (1992). The Goulds in the Hunter Region of N.S.W. 1839-1840. Naturae, No. 2.

Australian Government Department of the Environment and Energy, (2016).

Hunter Estuary Wetlands. [online] Available. at: www.environment.nsw.gov.au/wetlands/HunterEstuaryWetlands.htm [accessed 19/10/17]

Awabakal Local Aboriginal Land Council. (2010). Aboriginal Cultural Heritage Management Plan for the Burralinban estuary wetlands incorporating the Kooragang Wetland Rehabilitation Project (KWRP) & Hexham Swamp Rehabilitation Project (HSRP). Paterson: Hunter-Central Rivers Catchment Management Authority.

BMT WBM. (2016). Draft Hunter estuary coastal zone management plan: revised September 2016; original final report September 2009. Newcastle: Newcastle City Council.

Boys, C and Williams, R. (2012). Fish and decapod assemblages in Kooragang Wetlands: the impact of tidal restriction and responses to culvert removal. Cronulla: NSW Department of Primary Industries.

Geering, D. and Winning, G. (1993). Waders of the Hunter River estuary: threats to habitat and opportunities for habitat restoration. Report prepared by Shortland Wetlands Centre. Paterson: Hunter Catchment Management Trust.

Geering, D. and Winning, G. (1994). Recommended rehabilitation strategy for migratory shorebird habitat at Stockton Bridge Sandspit. Report prepared by Shortland Wetlands Centre. Paterson: Hunter Catchment Management Trust.

Henderson, R. (1995). Kooragang City Farm management report. Paterson: Hunter-Central Rivers Catchment Management Authority.

Howe, A. (2008). Hydrodynamics, geomorphology and vegetation of estuarine wetlands in the Hunter, Australia: implications for migratory shorebird high tide roost availability. Ph.D. Callaghan: University of Newcastle.

Hunter-Central Rivers Catchment Management Authority. (2013). Stockton Sandpit – one for the birds: fact sheet. Paterson.

Kingsford, R.T. and Ferster Levy, R. (1997). Changes to the Hunter River estuary, 1801 – 1996, and their implications for migratory wading birds and other waterbirds. Report prepared by National Parks and Wildlife Service for Environment Australia. Hurstville: NSW National Parks and Wildlife Service.

Kooragang Wetland Rehabilitation Project. (1996). Kooragang Wetland Rehabilitation Project management plan. Paterson: Hunter Catchment Management Trust.

Kooragang Wetland Rehabilitation Project (KWRP). (2010). Revised Kooragang wetland rehabilitation project management plan: moving from establishment to sustainable management. Paterson: Hunter-Central Rivers Catchment Management Authority.

Laegdsgaard, P. (2009). Phoenix Flats monitoring manual: timing and methods for future monitoring. Paterson: Hunter-Central Rivers Catchment Management Authority.

Land Systems EBC Pty Ltd. (1994). Kooragang Wetland Rehabilitation Project strategic landscape plan. Paterson: Hunter Catchment Management Trust.

Manly Hydraulics Laboratory. (2003). Hunter Estuary processes study. DPWS Report No. 01010. Sydney: Department of Public Works and Services.

Moss, J., ed. (1983). Investigation of the Natural Areas of Kooragang Island, Hunter River. Sydney: NSW Department of Environment and Planning.

NSW Department of Land and Water Conservation. (1996). Economic appraisal on Kooragang Wetlands Rehabilitation Project. Sydney: Economics Unit, Urban Water Division.

NSW Government. (1992). Estuary management manual. Sydney.

NSW Healthy Rivers Commission. (2002). Hunter River: independent inquiry into Hunter River system. Sydney: Healthy Rivers Commission of New South Wales.

NSW National Parks and Wildlife Service. (1998). Kooragang Nature Reserve and Hexham Swamp Nature Reserve plan of management. Sydney: NSW Government.

NSW Public Works and Services. (1979). Kooragang Island advisory committee. Report No. 1. Newcastle West: NSW Government.

NSW Public Works and Services. (1996). Kooragang Wetland Rehabilitation Project – value management study. Paterson: Hunter Catchment Management Trust.

NSW State Pollution Control Commission. (1973). Inquiry into pollution from Kooragang Island. E.J Coffey, Commissioner, Sydney: NSW Department of Environment.

Ord, M., ed. (1988). Ash Island Series Volume I. Historical drawings of moths and butterflies: Harriet and Helena Scott. From the Collections of the Australian Museum. Introduced and selected by Marion Ord. Roseville: Craftsman House in association with the New South Wales Bicentennial Council.

Ord, M., ed. (1988) Ash Island Series Volume II. Historical drawings of native flowers: Harriet and Helena Scott. From the Collections of the Australian Museum. Introduced and selected by Marion Ord. Roseville: Craftsman House, in association with the New South Wales Bicentennial Council.

Patterson Britton & Partners Pty Ltd. (1998). Tomago Wetlands rehabilitation environmental impact statement: issue No. 3 September 1998. Paterson: Hunter Catchment Management Trust.

Patterson Britton & Partners Pty Ltd. (2000). Draft Tomago Wetlands rehabilitation revised site environmental impact statement: Issue No. 1 June 2000. Paterson: Hunter Catchment Management Trust.

Scott, H. (1862). *Botany of Ash Island*. [list] Australian Museum. Sydney.

Shortland Wetlands Centre Ltd and the Newcastle University Research Associates, (1992). Kooragang Island wetland compensation project feasibility study. Report prepared for NSW Fisheries, Hunter Catchment Management Trust, NSW Public Works and Newcastle City Council. Paterson: Hunter Catchment Management Trust.

Spencer, J. and Howe, A. (2008). Estuarine wetland rehabilitation and ecohydraulics: the links between hydraulics, sediment, benthic invertebrates, vegetation and migratory shorebird habitat - summary of major findings and recommendations. Final report prepared for Kooragang Wetland Rehabilitation Project and Energy Australia. Paterson: Hunter-Catchment Management Catchment Management Authority.

Stuart, A., ed. (2014). Hunter region annual bird report number 21 (2013). New Lambton, Australia: Hunter Bird Observers Club Inc.

Svoboda, P. and Copeland, C. (1998). Kooragang wetland rehabilitation project: evolution of an Australian rehabilitation project in an urban setting. In: *Wetlands for the future: contributions from INTECOL'S V international wetlands conference*. Adelaide: Gleneagles Publishing, pp. 749-759.

Taylor, S. (2013). Best 100 birdwatching sites in Australia. Sydney: NewSouth Publishing.

Turner, J and Melville, R. (2009). Draft manuscript of the history of Hunter River islands. Paterson: Hunter-Central Rivers Catchment Management Authority.

Umwelt. (2016). Climate change implementation plan: final draft. Paterson: Hunter Local Land Services.

Webb, C. and Russell, R. (2005). Living with mosquitoes in the lower Hunter and mid north coast region of NSW. Report prepared by Department of Medical Entomology, Westmead Hospital. Newcastle: NSW Premier's Department.

Williams, R., Watford, F. and Balashov, V. (2000). Kooragang Wetland Rehabilitation Project: history of changes to estuarine wetlands of the lower Hunter River. Final Report Series No. 22. Cronulla: NSW Fisheries Research Institute.

Winning, G. (1991). Western Kooragang Island vegetation study. Report prepared by Shortland Wetlands Centre. Newcastle: NSW Fisheries.