



Fish Kill Events and Habitat Losses of the Richmond River, NSW Australia: An Overview

Author: Dawson, Katryna

Source: Journal of Coastal Research, 36(sp1) : 216-221

Published By: Coastal Education and Research Foundation

URL: <https://doi.org/10.2112/1551-5036-36.sp1.216>

BioOne Complete (complete.BioOne.org) is a full-text database of 200 subscribed and open-access titles in the biological, ecological, and environmental sciences published by nonprofit societies, associations, museums, institutions, and presses.

Your use of this PDF, the BioOne Complete website, and all posted and associated content indicates your acceptance of BioOne's Terms of Use, available at www.bioone.org/terms-of-use.

Usage of BioOne Complete content is strictly limited to personal, educational, and non - commercial use. Commercial inquiries or rights and permissions requests should be directed to the individual publisher as copyright holder.

BioOne sees sustainable scholarly publishing as an inherently collaborative enterprise connecting authors, nonprofit publishers, academic institutions, research libraries, and research funders in the common goal of maximizing access to critical research.

Fish Kill Events and Habitat Losses of the Richmond River, NSW Australia: An Overview

Katryna Dawson

Independent Environmental Scientist, Australia/UK
dawsonovich@lineone.net
dawsonovich@yahoo.com



ABSTRACT

Early February 2001, the Richmond River, Northern NSW Australia, suffered an immense fish kill, affecting over 35 kilometres of riverine and estuarine habitat, and the surrounding coastal ecosystem. A flood, combined with summer heat, pasture grasses, drainage channels, and sediment, triggered a chain reaction that left the coastal river devoid of oxygen and life.

The Richmond River has many forms of agriculture within its catchment, as well as commercial and recreational fishing and a high tourism industry. Much of the floodplain has been cleared for crops or grazing, with a marked increase in drainage channels being developed to take floodwaters back off the land and into the river. Erosion from cleared lands and developing areas caused large quantities of sediment to smother in-river habitats of the river system. Towns, such as Lismore and Ballina, are built on the riverbanks, causing strain on where floodwaters can go. These factors have caused massive losses in habitat for fish and other aquatic species, as well as terrestrial species that are crucial to the balance of the coastal riverine ecosystem.

The decision was made to allow the river to regenerate on its own accord. Early monitoring over six to eight months, suggests rapid recovery of the river habitat. The general community and Governments need to help reduce the probability of this event occurring again by re-vegetating river banks and floodplains, and implementing better drainage and land management solutions. To help ensure that this scale of event does not happen again in the future within other coastal catchments, improved management of land, river and coasts need to occur.

ADDITIONAL INDEX WORDS: *oxygen depletion, mangroves, seagrasses, land clearance, land management, river recovery*

INTRODUCTION

Habitat Loss in NSW – A General Overview

New South Wales has had 214 years of White settlement. During that time, habitat for wildlife – both terrestrial and aquatic – has been reduced. The people of NSW rely on rivers, streams and coastal waters to provide the water essential for agriculture, mining, industrial and urban development, recreational boating and fishing, and for food. Our waterways also provide water, food, shelter and breeding sites for fish and other aquatic animals and plants (FISHNOTE DF/33). The coastal regions are under particular stress as 87.5% of the population of NSW resides within the coastal area of the state, covering 17.4% of NSW's land area (EPA 1997).

Human activities, mainly over the past 40 years, have severely altered the condition of our rivers and streams, and as a result, we have substantially reduced the available fish habitat (FISHNOTE DF/33).

The floodplains of most temperate rivers have been altered somehow. Rivers are mostly contained within their channels through construction of levee walls and river deepening. To increase the speed at which water is removed from the area, many streams and channels have been straightened and, especially in urban areas, concrete-lined. Riparian vegetation, instream debris and aquatic vegetation have been cleared, as they impede river flow and increase the risk of flooding. These activities all reduce the variability and number of habitats available (MOSS 1988).

Run-off containing fertilisers and pesticides from agricultural land, disposal of urban sewage and storm water, and disposal of industrial wastes have all contributed to the decline in the quality of water in rivers and streams (MOSS, 1988). Land clearing for development or agriculture has led to an increase in erosion and sedimentation within our rivers. Grasses, crops, cement and bitumen have replaced vegetation that once held the soil in place and soaked up water, resulting in altered flow regimes (SPONSELLER *et al.*, 2001).

Dredging, pollution and sedimentation have destroyed much of the seagrass beds in NSW. By 1999, there was only 21.9 km² of seagrass beds remaining in estuaries and sheltered coastal waters from the Hunter River to the NSW-QLD border (TANNER and LIGGINS, 2000). In Jervis Bay, aerial photographs show clear circular areas within beds – a result of bombing in the Military Bombing Range some 50 years ago. Seagrasses recolonise very slowly, therefore extra care of the beds is crucial (MOSS, 1988)

Wetlands have, in the past and even now, been seen as wastelands, useless as they stand but convertible into fertile agricultural lands by drainage, or as storage for irrigation by permanent flooding. They are now realised for their flood protection, sediment and nutrient retention, and wildlife. They act as biological filters, improving water quality as well as improving the productivity of associated aquatic and terrestrial ecosystems (MOSS 1988, FISHNOTE DF/32). Yarrhapinni Swamp, on the mid north coast, is an example of a drained wetland which is currently undergoing studies in an effort to reopen the wetland to its original saline influences.

Much of the NSW coast is susceptible to acid sulphate soils (ASS). The artificial draining of floodplains and wetlands results in permanently saturated ASS becoming exposed to the atmosphere. This causes a number of chemical reactions, resulting in a build-up of sulphuric acid, iron and aluminium. With the first rains, these chemicals are washed out into waterways, resulting in a decrease in water quality. This can result in well-known fish diseases such as "red spot" or epizootic ulcerative disease, or in worse cases, fish kills (ASSMAC (TC), 1996)

Regulation of rivers through dams, weirs and other instream structures have caused migratory problems for fish, a decline in floodplain habitats downstream, as well as changes in habitats either side of the structure. The Shoalhaven River on the south coast has lost much of its migratory fish population above the dam wall. Studies by NSW Fisheries have shown that fish such as the Australian bass (*Macquaria novemaculeata*) and the Striped mullet (*Mugil cephalus*) have sharply declined shortly after the construction of one of several water supply dams for the Sydney Greater Metropolitan Region (GEHRKE *et al.*, 2001).

The increasing frequency of toxic blooms of blue-green algae is mostly due to the disposal of urban sewage effluent into rivers, as well as run-off of animal waste and excess fertiliser from agricultural land (FISHNOTE DF/33). Myall Lakes, on the central coast, experienced several large cyanobacteria blooms in 2000-2001, causing closure of the lake from fishing, swimming and all other direct contact. Several commercial fishermen operating in the lake system lost their income as a result of the blooms.

CASE STUDY

Richmond Catchment

The Richmond River catchment is situated on the north coast of New South Wales, Australia. It covers a land area of approximately 6900 square kilometres, stretching from Kyogle in the west to Ballina in the east, Whian Whian in the north to Woodburn in the south. The catchment consists of two rivers, the Richmond and the Wilson, meeting at Coraki to continue to be the Richmond. The catchment has a water area of approximately 19km² (ROY, *et al.*, 2001), with the saline waters reaching Coraki. Some of the issues that are affecting the Richmond River catchment are (PATTINSON, 1996):

- Development pressure (one of the fastest growing populations in NSW)
- Water quality
- Flood plain management and drainage
- Streambank erosion
- Sedimentation
- Weed control
- Clearing
- Wetland management
- Fish decline

Land Management

The catchment has four large towns within its area, Casino, Kyogle, Lismore and Ballina, and several smaller towns, villages and settlements. The land use varies from grazing, dairy farming, horticulture (eg. tea tree and cane farming on the floodplains, to macadamia and other crop orchards in the hills), forestry, tourism and National Parks (PATTINSON, 1996). Wetlands once covered over 20% of the catchment, whereas now it covers only 6% (M. Wood, pers. comm.). River uses include commercial fishing (there are 17 licences for trawl fishing), aquaculture (oysters), recreational fishing, and boating.

The majority of the natural creeks, rivers and waterways have been straightened in the Richmond River Catchment. The creation of so many man-made drainage channels has brought the residence time of floodwaters on the land from about 100 days down to five days (C. Copeland, pers. comm.).

Land clearing occurs everywhere within the catchment. In the upper reaches, where the land is quite steep, clearing for agriculture and logging are most dominant, while in the lower reaches, where the land is more flat, development and cropping dominate. Erosion from the upper reaches is relatively high, as the steep slopes, now bare or covered in only pasture grasses, cannot hold the soils in place. Riverbanks that are cleared of riparian vegetation erode,

depositing more sediment within the river system (RICHARDS *et al.*, 1996; FISHNOTE DF/29).

The floodplain vegetation has changed from wetland, native grasses and riparian vegetation, to pasture grasses, such as *kykuyu*, *paspalum* and couch, and sugar cane fields.

The Flood

On 1st February 2001, a major rain event (200-400mm) occurred on the upper catchment of the Richmond and Wilson Rivers. Another large rainfall, this time only 100mm, fell on 2nd February, and the town of Lismore flooded. Floodwaters in the lower Richmond River peaked over 3rd and 4th February (SLAVICH, 2001). The floodwaters took 2-5 days to recede.

On 7th February, the first sightings of fish kills were reported to NSW Fisheries. Within 2-3 days, masses of fish, shellfish, benthic and sedimentary organisms were washed up on shores stretching 30 kilometres from the river mouth to Coraki. "Beachworms and yabbies (pink nippers) were coming out of the estuary bottom in thousands, dying and being washed up into the mangroves, so many that you could scoop large handfuls at a time", as witnessed by W.J Gallagher, commercial fisher and Region 1 Habitat Monitor. The main commercial/recreational fish species that died during the fish kill include yellowfin bream, sand whiting, eels, sea mullet and Australian bass, as well as sole, luderick and forktail catfish (MACBETH *et al.*, 2001).

Water quality analysis showed dissolved oxygen levels to be extremely low – levels as low as 0.03 mg/L were recorded. The Australia-New Zealand Environment and Conservation Council (ANZECC) Guidelines 1992 outlines the requirements for fish is a minimum of 6 mg/L (ANZECC, 1992). At 5 mg/L, stress in fish and other organisms start to occur (ANZECC, 1992). Two weeks after the initial fish kill, the dissolved oxygen within the river ranged from 2.4 mg/L near the river mouth, to 0.06 mg/L at The Barrage (a structure below Tuckean Swamp).

Acidity levels were slightly less than normal (pH of 6.3) throughout the affected area. The north coast, as with much of the Australian eastern coastline, suffers from a problem of acid sulphate soils – iron sulphide (pyrite) becomes exposed to the air to form, among other molecules, hydrogen sulphate (acid). The fact that the pH in the area was so high was crucial in eliminating ASS as the cause for the fish kills although it might have contributed to the stress of fish. Water quality results at The Barrage two weeks after the initial event showed acidity at 3.9 pH. Acidity levels within the lower and middle reaches of the catchment all dropped as time passed, as the chemicals from reactions in the acid sulphate soils began to wash into the river.

It was clear from initial sampling that the cause of the kills was from lack of dissolved oxygen. However, over time pH levels dropped in the river and tributaries, indicating that chemical reactions within potential ASS were occurring as a result of the flooding. Table 1 shows the water quality during the fish kill event as well as two weeks after the event.

Oxygen Depletion

The new grasses of the floodplain, *paspalum* and couch, planted as feed for grazing animals such as cattle, sheep and horses, are prone to the effects of inundation. Within 24 hours of inundation, these pasture grasses start to decompose, stripping the surrounding water of dissolved oxygen (WILKINSON, 2000).

The floodwaters also carried a lot of sediment, eroded from cleared lands. There is the potential for heavy sediment loads in a river to reduce the dissolved oxygen levels by half through the oxidation of compounds in organic matter and soil sediments (SLAVICH, 2001). Sediment, especially when it is thick, blocks out sunlight to aquatic plants, reducing or even stopping photosynthesis (URI, 2001). When plants cannot photosynthesise, they start taking in oxygen, instead of producing it. Sediment

Table 1. Initial water quality (pH and dissolved oxygen) levels, taken at the time of the flood and two weeks later. (NSW Fisheries, on file). Only four sites were studied initially. Study sites expanded to seven sites two weeks later to determine the extent of the problem (Broadwater was not surveyed in the second recordings).

Location	9 February 2001		20/21 February 2001	
	pH	DO2	pH	DO2
Emigrant Creek	6.1	0.13	7.1	2.4
Pimlico	6.3	0.03	7.1	2.6
Wardell	6.3	0.08	6.8	1.2
Boundary Creek	-	-	6.7	1.2
Broadwater	6.4	0.05	-	-
Barrage	-	-	3.9	0.06
Rocky Mouth Creek	-	-	6.9	0.57
Sandy Creek	-	-	6.3	0.11

within the water column can also increase surface water temperature (URI, 2001). Other anecdotal evidence from the flood event reported that "there was over a foot and a half of sediment throughout the house, whereas usually there is only an inch or two after floods". This indicated a much more severe erosion event, which would greatly assist in the oxygen-stripping process occurring instream.

Mono-sulphide black oozes (MBO's) are common to drainage channels leading from acid sulphate soils. MBO's also have a high potential to react and deoxygenate water within minutes if disturbed. These sludges were mobilised during the discharge of drainage water into the main river system, coinciding with the rapid decrease in dissolved oxygen of the river (SLAVICH, 2001). These MBO's were identified as a major contributor to the fish kill event.

The hot weather conditions that followed the rain would have increased the decomposition process. The waters began to warm up, which caused the level of dissolved oxygen that the water could hold to be reduced (MOSS, 1988). Drainage waters recorded on the 6th February showed temperatures of 22-24°C (SLAVICH, 2001). The drainage channels allowed this black water (water with little or no dissolved oxygen) to drain back into the main river channel, taking with it debris and leaf litter which also decomposes.

Habitat Losses of the Richmond River

Mangroves

Mangroves provide permanent and temporary habitats for many aquatic animals. Numerous fish move on to the submerged mangrove flats to find food and shelter as the tide rises. Yellowfin bream, sea mullet, silver biddy, luderick and dusky flathead are common inhabitants. The mangroves are also important nursery grounds for juvenile fish. Fish such as the silver biddy and flat-tail mullet settle into the mangrove habitat from birth (FISHNOTE DF/30). Within the Richmond River, mangrove forests cover 4.95 km² (ROY *et al.*, 2001).

Each square metre of sediment within a mangrove forest can hold up to a hundred individual invertebrates. The most common are crabs and molluscs, including three commercially important crustaceans - king prawns, blue swimmer crabs and mud crabs (FISHNOTE DF/30).

Instream Habitats

Submerged plants, such as seagrasses, provide habitat for fish and invertebrates to lay their eggs, fingerlings to hide from predators, food and shelter for fish and crustaceans (FISHNOTE DF/29, MOSS 1988). As a result, there is commonly a greater diversity and abundance of fish and other species in seagrasses, than in unvegetated areas. Fish species include the young of many commercially and recreationally important species such as bream, luderick,

tarwhine, sea mullet, dusky flathead, trumpeter whiting, blue groper, fan-bellied leatherjacket, king prawns and blue swimmer crabs. The growing fish later migrate from the seagrass beds to a range of estuarine and marine habitats, including Posidonia beds, mangroves and kelp beds. (FISHNOTE DF/29). The Richmond River has a seagrass bed area of 0.189 km² (ROY, *et al.*, 2001).

The Richmond and Wilson Rivers were once utilised as main transport routes, conveying barges and other boats up and down river, laden with goods and materials. The removal of river snags such as logs and boulders has occurred for many years to assist in navigation. These snags provide habitat diversity for fish, invertebrates and other animals, however with the removal of these structures comes the decrease in animal biodiversity. The losses of breeding, resting and feeding sites, as well as the long-term changes in stream morphology are results of the desnagging (SLAVICH, 2001; WHITTON, 1975).

Floodplains and Wetlands

Natural floodplains often have large populations of birds, mammals, and fish. This is because of the great diversity of habitats and high productivity of the vegetation (MOSS 1988). Many wetland plants and animals leave seeds and eggs buried in the wetland floor between inundations. Animals such as yabbies burrow into the mud and emerge when the wetland fills. Cropping and clearing of vegetation, such as lignum for agriculture, destroys many of these organisms, reducing the diversity of wetland life (FISHNOTE DF/32).

Wetlands are filled naturally at irregular periods by flooding, allowing the area to dry out between inundations. Native plants and animals have adapted to this irregular cycle and depend on it for breeding and survival. The flooded wetlands provide a rich source of nutrients for plant and animal growth. Many native fish species rely on the periodic flooding of wetlands for breeding and survival. Another issue within wetland areas is the presence of grazing animals, which trample sensitive vegetation and increase turbidity in wetland waters (FISHNOTE DF/32).

Wetlands act as sponges, and can have large surface areas. A small rise in water level results in temporary storage of water which would have otherwise gone down stream, possibly causing damage to human settlements. The effect is to spread the peak of the flood over time, thus reducing its height and minimising erosion of riverbanks (MOSS 1988).

As mentioned previously, wetland coverage within the Richmond Catchment has reduced considerably over the years. The area of wetland estimated before

drainage and clearing was approximately 1,300 km², while the existing or post drainage/clearing wetland covers approximately 278 km² (M.Wood, pers. comm.) This has been through activities such as land clearing, drainage and

reclamation. One example of this is on the Tuckean Floodplain, where the wetlands once covered approximately 5000 hectares. Human impact on the floodplain has reduced its wetland area dramatically, and has caused drainage-related vegetation changes (M. Wood, pers. comm). Melaleuca stands have colonised some drained areas that were not utilised by land owners. Tuckean Floodplain is an area of high acid sulphate soil content, and as such has regularly low pH levels in water quality discharging from the wetland due to the presence of drainage channels (EPA, 1997).

Actions Taken

The State Minister for Fisheries officially closed the Richmond River, from Coraki to the sea (a 2km in distance), and from Lennox Head to Evans Head, on February 9, for an initial period of three months. This period was extended to six months, resulting in the river being closed to commercial fishing until the end of September. Limited recreational fishing was allowed from 1 July, with restrictions imposed on fishing hours (daylight only) and bag limits (MACBETH *et al.*, 2001).

Calls for restocking the river were rejected on the basis of scientific studies on the restocking abilities of estuarine fish. Only two predatory fish species, Snapper and Mulloway, have been studied for restocking success, and it was decided that it was not beneficial to the river ecosystem, or the efforts, to restock the river with fish when there was no food. The decision was made by NSW Fisheries to allow the river to recover naturally, as this was a chance to see how such a river system would recover.

Other actions conducted by NSW Fisheries included:

- The establishment of community based River Recovery Groups;
- Conducting creek surveys to establish recreational impacts;
- Conducting economic surveys of fish co-operatives and commercial fisheries;
- Seeking assistance for the affected commercial fisheries;
- Conducting surveys of impacts on fishers and broader community;
- Employment of additional staff to deal with public response; and
- Monthly surveys of fish stocks in the rivers by the NSW Fisheries Research Team.

NSW Fisheries are monitoring the recovery of the Richmond River. A final report, compiling of the cause of the fish kill, the surveys and final recommendations for future management of the Richmond River, will be completed in early 2002. It will also be posted on the NSW

Fisheries website:

<http://www.fisheries.nsw.gov.au/>

Early indications from the monitoring program (6-8 months after flooding) suggest that the Richmond River is recovering well.

The Future

Managing riverine environments and their surrounds is both a government and community responsibility. While there are many laws governing the management of these areas, it is the responsibility of all stakeholders to ensure that protection occurs (FISHNOTE DF/32). Current legislation and policies that assists with the management of NSW's coastlines include the Water Management Act (2001), the NSW Coastal Policy (1997), and the Protection of the Environment (Operations) Act (1999).

Actions such as fencing off sensitive wetland and riparian areas from stock, avoiding overgrazing, minimising the use of agricultural chemicals, disposal of unused or out-of-date chemicals responsibly and preventing soil erosion all increase the chances of sensitive areas being conserved (FISHNOTE DF/32). Riparian wetlands that border agricultural land have been shown to retain up to 100% of nitrate inputs from runoff (BISCHOFF *et al.*, 2001). Source control of pollutants is the most cost effective and logical management option (BERKA *et al.*, 2001).

The Richmond River is subject to both a Water Management Committee and a Catchment Management Board, both created by the NSW Department of Land and Water Conservation over the past few years. Such committees and boards are found throughout NSW. The Northern Rivers Catchment Management Board (NRCMB) is now focussing its attention to the issues surrounding the fish kill events, and seeking ways to reduce the likelihood of such events occurring in the future (R. Learmouth, pers. comm.). Aspects include:

- The call for the development of a catchment estuary management committee, combining all councils that have jurisdiction over areas of the Richmond River catchment;
- The creation of better riparian management plans;
- The creation of better tillage techniques;
- Acid Sulphate Soil management;
- Riparian re-vegetation in the upper catchment areas;
- Creating better monitoring techniques and coordination; and
- Better drain management

There are also established cane management committees throughout the north coast, which are looking into further work on drain and floodgate management. The NSW Department of Agriculture is working with landholders to

improve drainage water quality, and land management. Recommendations from a meeting held to discuss the fish kill include shallowing drains, retaining rainfall runoff, encouraging inundation tolerant vegetation, and having managed opening floodgates to reduce the build up of MBO's within the drains (SLAVICH, 2001). NSW Fisheries also recommend the opening of floodgates, and that low-lying areas and mangroves should not be drained (FISHNOTE DF/30).

The fish kill event has shown that increases in pressures applied on a catchment system can accumulate to a point where it topples over its stress limits. The future lies in proper management and monitoring. Better management of the Richmond River came about after the events of February 2001. However, this has hopefully shown many other Governments and communities around Australia that the death of a river can occur overnight, and may act to help prevent such events from occurring elsewhere.

For further information, please contact the NSW Department of Fisheries— details:
Office of Chief Scientist
NSW Fisheries
Cronulla Fisheries Centre,
PO Box 21, Cronulla, 2230, NSW, Australia
+61 2 9527 8591

ACKNOWLEDGEMENTS

Mr George Baker, Mr John Gallagher and the fishermen of both the Richmond and the Clarence; Mr Simon Walsh NSW Fisheries; Ms Megan Westlake NSW Fisheries; Ms Sarah Fairful NSW Fisheries; Mr Craig Copeland NSW Fisheries; Dr Steve Kennelly NSW Fisheries; Mr Michael Wood Richmond River County Council ; Mr Rob Learmouth DLWC Alstonville; Ms Samantha Newton Nature Conservation Council; and many research assistants in Australia!

LITERATURE CITED

- ANZECC, 1992. *National Guidelines for Water Quality*, Australia-New Zealand Environment and Conservation Council.
- ASSMAC (TC), 1996. *Acid Sulphate Soils Analytical Methods June 1996*. Acid Sulphate Soils Management Advisory Committee (Technical Committee) (http://www.scu.edu.au/sponsored/tcm/library/PDF/Acid_sulfate.pdf)
- BERKA, C.; SCHREIER, H.; and HALL, K., 2001. Linking water quality with agricultural intensifications in a rural watershed. *Water, Air and Soil Pollution*, 127 389-401.
- BISCHOFF, J.M.; BUKAVECKAS, P.; MITCHELL, M.J.; and HURD, T., 2001. N storage and cycling in vegetation of a forested wetland: Implications for watershed N processing. *Water, Air and Soil Pollution*, 128, 97-114.
- EPA, 1997. *NSW State of the Environment Report*. Environmental Protection Authority, Sydney.
- FISHNOTE DF/29, *Fishcare - Saving Our Seagrasses*. Peter Lynch, Fisheries Advisory Officer, Grafton Jenny Burchmore, former Principal Fisheries Manager (Habitat) Tom Johnson, Former Biologist/Editor, NSW Fisheries, Cronulla.
- FISHNOTE DF/30, *Fishcare - Our Mangrove Forest*. Peter Lynch, Fisheries Advisory Officer, Grafton, Jenny Burchmore, former Principal Fisheries Manager (Habitat), NSW Fisheries, Cronulla.
- FISHNOTE DF/32, *Fishcare - Our Freshwater Wetlands*. R. Billyard, former Fisheries Advisory Officer, Narrandera, NSW Fisheries, Cronulla.
- FISHNOTE DF/33, *Fishcare-Our Freshwater Rivers and Streams*. R. Billyard, former Fisheries Advisory Officer, Narrandera, NSW Fisheries, Cronulla.
- GEHRKE, P.C.; GILLIGAN, D.M.; and BARWICK, M. 2001. *Fish communities and migration in the Shoalhaven River - Before construction of a fishway*. 2001 NSW Fisheries Final Report Series No. 26. NSW Fisheries Office of Conservation, Taylors Beach, NSW.
- MACBETH, W.; ALDO, S.; and POLLARD, D., 2001. *Richmond River: Relative abundances of fish and crustaceans and water quality following the fish kill of early February 2001 – Survey VII August 2001*. NSW Fisheries, September 2001.
- MOSS, B., 1988. *Ecology of Freshwaters: Man and Medium*. 2nd ed. Blackwell Scientific Publications, Oxford.
- PATTINSON, V., 1996. *The Richmond River Catchment – fact sheet*. Richmond Catchment Management Committee.
- RICHARDS, C.; JOHNSON, L.B.; and HOST, G.E., 1996. Landscape-scale influences on stream habitats and biota. *Canadian Journal of Fisheries and Aquatic Sciences*, 53 295-311.
- ROY, P.S.; WILLIAMS, R.J.; JONES, A.R.; YASSINI, I.; GIBBS, P.J.; COATES, B.; WEST, R.J.; SCANES, P.R.; HUDSON, J.P.; and NICHOL, S., 2001. Structures and functions of south-east Australian estuaries. *Estuarine, Coastal and Shelf Science*, 53 351-384.
- SLAVICH, P. 2001. *Technical review of the impacts of February 2001 Richmond River floods on water quality and fish kill*. Workshop Proceedings, NSW Agriculture, February 2001.
- SPONSELLER, R.A.; BENFIELD, E.F.; and VALETT, H.M., 2001. Relationships between land use, spacial scale and stream macroinvertebrate communities. *Freshwater Biology*, 46 (10).
- TANNER, M.; and LIGGINS, G.W., 2000. *New South Wales Commercial Fisheries Statistics 1998/99*. NSW Fisheries, Cronulla (ISSN 1320-3371)
- URI, N.D., 2001. A note on soil erosion and its environmental consequences in the United States. *Water, Air and Soil Pollution*, 129 181-197.
- WHITTON, B.A. (ed). 1975. *River Ecology*. Blackwell Scientific, Oxford.
- WILKINSON, G., 2000. *Effects of flooding on pasture plant survival and subsequent influences on water quality within Rocky Mouth Creek Catchment, NSW*. Southern Cross University Honours Thesis, unpublished.