2. METHODS

The information on the distribution and abundance of freshwater fish of the Upper Murrumbidgee that underpins this report has been drawn from an array of sources. The majority of information comes from both the published and unpublished work of the Wildlife Research and Monitoring (WR&M) unit of Environment ACT. Unpublished information from WR&M consists of the results of both regular and irregular monitoring of fish populations in the rivers and urban lakes of the ACT. For some water bodies, survey/monitoring has been funded by agencies other than Environment ACT. Monitoring of Lake Burley Griffin after 1993 has been funded by the National Capital Authority, the 1994–97 monitoring of the Murrumbidgee/Molonglo rivers was funded by ACTEW Corporation, and the 1998 survey of the Queanbeyan River was supported by the National Fishcare Program. Information is also included from a threatened fish survey of the Upper Murrumbidgee catchment, which was jointly funded by Environment ACT and the Cooperative Research Centre for Freshwater Ecology. Unpublished information has also been sourced from a number of undergraduate and postgraduate theses completed at the Australian National University.

The broad distribution for each species is outlined, but is not intended to be an exhaustive list of locations where the species can be found. Information on the biology and ecological requirements of each species is summarised from the scientific literature. Potential threats to individual species are outlined (where known). There is a bias in some sections of the report towards fish populations in the ACT, which simply reflects the much larger information base for this part of the catchment. However the descriptions of general biology, habitat preferences and potential threats are applicable across the Upper Murrumbidgee catchment

The conservation status of each species is reviewed at both a national and local scale. An annotated bibliography of local studies on freshwater fish is presented as an appendix to the main body of the report.

A glossary of the technical terms used is presented at the end of this report.

Nomenclature of fish species follows that of McDowall (1996). Alternative common names are indicated where applicable.

2.1 The Study Area

The Upper Murrumbidgee catchment (Figure 1) for the purposes of this report is defined as the catchment upstream of Burrinjuck Dam.

Major Streams

There are 14 rivers in the catchment with the major river being the Murrumbidgee. The Murrumbidgee River rises in the Fiery Range in Kosciuszko National Park at an altitude of around 1,500 m where snow commonly occurs between June and October. From its source, the Murrumbidgee River flows southeast for approximately 140 km towards Cooma, near where the river turns north and flows for some 70 km before turning northwest and entering the ACT at Angle Crossing. The Murrumbidgee River flows for approximately 66 km through the ACT in a northerly direction until it exits near Camp Sturt. The river enters Burrinjuck Reservoir at an altitude of around 370 m approximately 40 km downstream of the ACT.

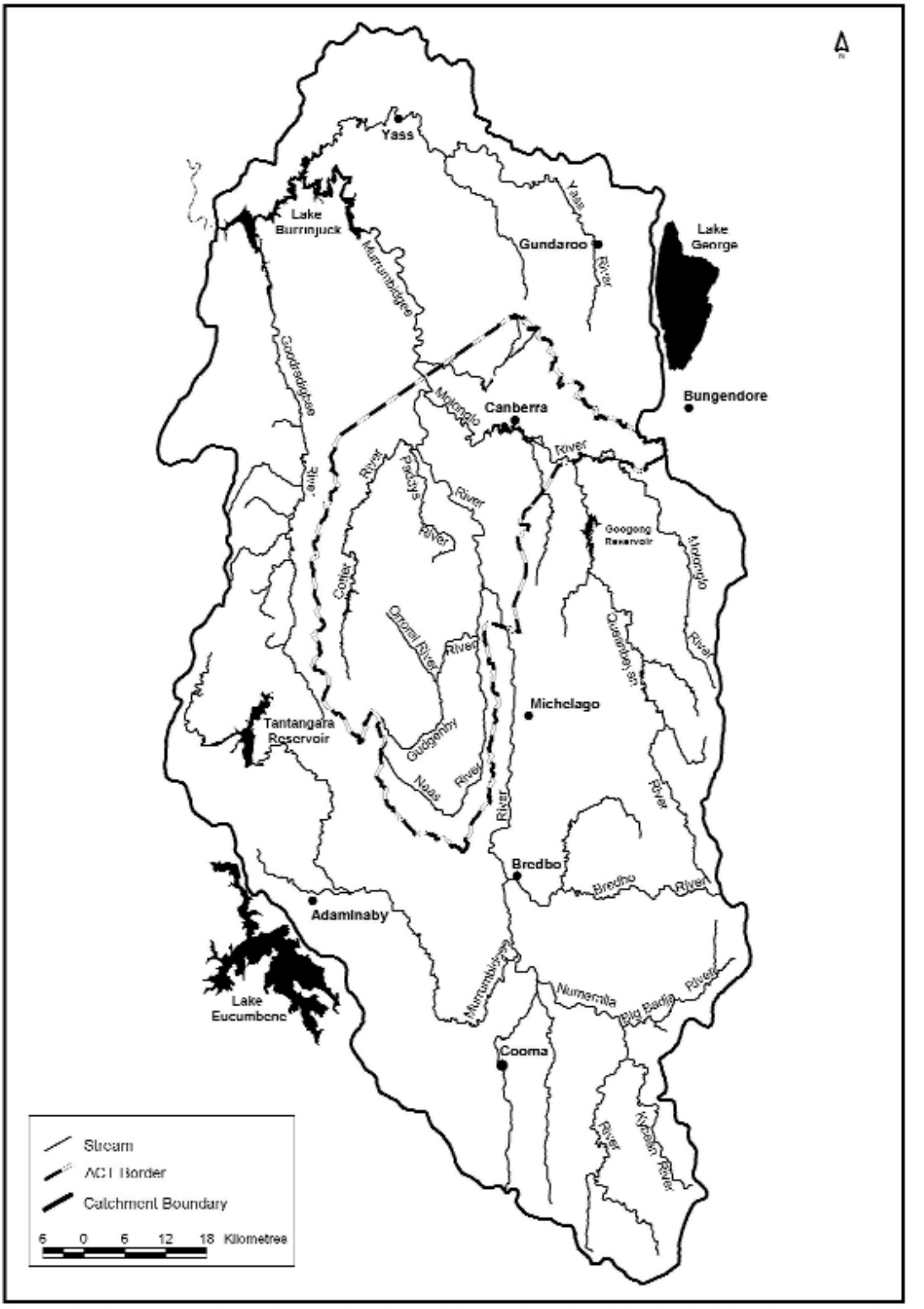

Figure 1: Waters of the upper Murrumbidgee catchment.

The historic flow patterns in the Murrumbidgee River have been altered by the construction of Tantangara Reservoir in 1960. This reservoir is part of the Snowy Mountains Hydroelectric Scheme and diverts approximately 99% of the average natural flow (ANF) in the upper catchment through a tunnel to Lake Eucumbene on the headwaters of the Snowy River (Pendlebury 1997). Inflow from tributaries downstream of Tantangara slowly restores the stream to a more natural flow regime with 54% ANF downstream of the Numeralla River confluence and 84% ANF by the time the river enters Burrinjuck Reservoir (Table 1) (Pendlebury 1997).

Table 1: Approximate percentage of (pre Snowy Scheme) Murrumbidgee River flow diverted by Tantangara Dam (from Pendlebury 1997).

Location	Approx % water diversion	Location	Approx % water diversion
Tantangara Dam	99	Gigerline Gorge (ACT)	43
Yaouk	73	Pine Island (ACT)	33
Mittagang Crossing	63	Above Molonglo River confluence	30
Above Bredbo	46	Burrinjuck Dam	16

Major tributaries of the Murrumbidgee River upstream of the ACT include the Kybean, Big Badja, Numeralla and Bredbo rivers, as well as the Queanbeyan River which joins the Molonglo River near Canberra. North of the ACT, the major tributaries are the Yass and Goodradigbee rivers which flow into Burrinjuck Reservoir.

The majority of the streams in the Upper Murrumbidgee catchment can be characterised as relatively narrow, upland, rocky streams. Floodplains where they occur, are narrow, localised and confined. The Bredbo River is an exception in that it is a shifting, sand bed stream, whereas the Numeralla River has changed significantly from a narrow, shallow, pebbly-bottomed stream with a well developed pool/riffle or pool/rockbar sequence to a broad, deeply incised, depositional stream characterised by extensive sand deposits (Starr 1995; Starr *et al*. 1997). Such sand deposits are now common in the Upper Murrumbidgee and are slowly moving downstream reducing fish habitat and filling previously deep holes (Lintermans 2001b).

Within the ACT there are eight tributary rivers of the Murrumbidgee River. These are:

- Molonglo River;
- Queanbeyan River;
- Cotter River;
- Paddys River;
- Tidbinbilla River;
- Orroral River;
- Naas River; and
- Gudgenby River.

The Orroral/Naas/Gudgenby system enters the Murrumbidgee River near Tharwa, whilst the Tidbinbilla/ Paddys and Cotter systems enter near Casuarina Sands (Figure 1). All these tributary rivers are contained within the ACT except for the Molonglo River, which rises in New South Wales near Captains Flat to the

southeast of Canberra, and the Queanbeyan River which rises in New South Wales in the Tinderry Ranges near Michelago.

Lakes and Reservoirs

There are nine major impoundments and a number of minor impoundments in the Upper Murrumbidgee catchment. The major impoundments (and the streams they impound) are Burrinjuck and Tantangara (Murrumbidgee River), Corin, Bendora, Cotter (Cotter River), and Googong (Queanbeyan River) reservoirs, and Lake Burley Griffin (Molonglo River), Lake Ginninderra (Ginninderra Creek) and Lake Tuggeranong (Tuggeranong Creek). The capacities of these reservoirs are listed in Table 2. Burrinjuck, Tantangara and Googong reservoirs all lie outside the ACT. The majority of these impoundments have been stocked with fish either by NSW Fisheries or the ACT Government, with the fishery in Googong being jointly managed by the ACT and NSW. The only major impoundments which have not been stocked are Corin and Bendora reservoirs. Further information on the ACT Government's fish stocking program is presented below.

Table 2: Storage capacities of major impoundments in the Upper Murrumbidgee River catchment.

Impoundment	Year Completed	Storage Capacity (GL)
Tantangara	1961	254
Corin	1968	76
Bendora	1961	11
Cotter	1912 & 1951	4.7
Lake Burley Griffin	1964	33
Googong	1978	125
Lake Ginninderra	1974	3.7
Lake Tuggeranong	1988	2.6
Burrinjuck	1907–27 & 1956	1,026

Smaller impoundments in the ACT include Gungahlin Pond, and Yerrabi Pond (Ginninderra Creek). All of these impoundments have been stocked with fish by the ACT Government.

The majority of impoundments have been constructed since the 1960s, the two exceptions being Burrinjuck (1907) and Cotter reservoirs (1912). The three reservoirs on the Cotter River and Googong Reservoir were all constructed for domestic water supply purposes. Burrinjuck is used primarily to supply irrigation water to the downstream Murrumbidgee Irrigation Area (MIA). Tantangara diverts water into Lake Eucumbene where it is used primarily for hydro-electric power generation. Lake Burley Griffin and the smaller impoundments were constructed primarily for aesthetic and sediment retention purposes to protect downstream waters from the effects of urban development.

The majority of these impoundments have significantly altered the downstream in-stream conditions. Flows have been significantly altered, in their quantity, quality and timing. Most of the dams do not have multiple level offtakes, consequently water releases are generally from the lower levels of impoundments resulting in lower water temperatures and oxygen levels than are desirable. Many native fish species are known to use

rising water temperatures and an increase in water level as cues for the initiation of spawning activity. Consequently, the disruption from impoundments to natural flow regimes has resulted in lowered reproductive success in native fish populations.

Land Use

Much of the upper catchment of the Murrumbidgee River is forested with substantial areas reserved for nature conservation purposes as Kosciuszko National Park, Namadgi National Park, Tinderry Nature Reserve, Googong Foreshores and Tidbinbilla Nature Reserve. More than 60% of the ACT is protected as nature conservation reserves in one form or another. The full length of the Murrumbidgee River in the ACT is managed primarily for nature conservation purposes as the Murrumbidgee River Corridor (Environment ACT 1998a).

Pastoral enterprises are common along the Murrumbidgee River from the Cooma area down to Burrinjuck Reservoir with sheep grazing predominating. Some irrigated cropping is carried out on the small floodplains of the Molonglo River near Canberra, and around the confluence of the Numeralla and Murrumbidgee rivers.

The Cotter River originates in the granitic Scabby Range at an altitude of 1,760 m and flows north for about 70 km along the Cotter Fault through granite and Ordovician sediments before entering the Murrumbidgee River at an altitude of 460 m. Mean annual discharge for the Cotter River above Corin Reservoir is 46.9 gigalitres (1963–1987) with maximum discharges occurring from August to September and minimum discharge in February/March. The Cotter catchment supplies approximately 85–90% of Canberra's domestic water supply. Mean annual rainfall at Cotter Hut in the upper catchment is 945 mm (1932–1987) with maximum rainfall occurring from August to October. The waters of the study area are clear, slightly alkaline and of low conductivity.

The primary use of the upper and middle Cotter catchment since 1912 has been supply of domestic water to Canberra. Much of the Cotter catchment is covered with native forest with the ridgetop vegetation consisting mainly of sub-alpine woodland dominated by Snow Gum, *Eucalyptus pauciflora*. Montane and sub-alpine heaths and grasslands, herb fields, sphagnum bogs, fens and swamps are also found. (Helman *et al*. 1988; Lintermans 2001c). Some land clearing was undertaken in the upper catchment for early grazing leases in the 1830s, but there has been virtually no stock grazing in the catchment since its acquisition by the Commonwealth Government. Approximately 3,600 ha of the lower Cotter catchment are covered by pine plantations, with planting commencing in 1926. These forests are managed mainly as production forests. Hardwood logging was carried out in the lower catchment from 1930–38 and 1947–62. (ANU Department of Forestry 1973).

The Paddys River catchment covers 24,600 ha and is drained by the Paddys and Tidbinbilla rivers. The Paddys River originates in the Mt Tennant area at an altitude of approximately 1,400 m and flows northwest through predominantly rural land for about 40 km before joining the Cotter River just before its confluence with the Murrumbidgee. The headwaters are forested and contained within Namadgi National Park, but the majority of the land has been cleared for grazing. Approximately 65% of the catchment is forested with the remainder rural lands. Approximately 3,000 ha is developed as *Pinus* plantations. Stream flow is seasonal with maximum discharges occurring in spring.

The Naas-Gudgenby catchment covers some 72,000 ha and is drained by the Naas, Gudgenby and Orroral Rivers. Mean annual discharge of the Gudgenby River at Mt Tennant is 72.4 gigalitres (1964–85) and streamflows for all three rivers are seasonal with maximum discharge occurring from August to October. Many of the smaller streams cease to flow during late summer, either drying or forming a series of pools (Jones *et al*. 1990). The majority of the catchment is mountainous and is covered by a mosaic of wet and dry sclerophyll forest, montane woodland and savannah woodland (National Capital Development Commission 1984).

The Molonglo River rises at an altitude of approximately 1,100 m and flows for about 50 km through predominantly grazing land until it enters the ACT at Burbong. The catchment covers approximately 198,900 ha. Mean annual discharge is 55 gigalitres with seasonal streamflows peaking between September and November. Aquatic life was almost totally eliminated from the river as a consequence of heavy metal pollution from the Captains Flat mine. Mining for copper, gold, lead and zinc had first commenced at Captains Flat in 1882 but was abandoned at about the turn of the century. Full scale mining recommenced in 1939. Collapse of mine waste dumps at Captains Flat in 1939 and again in 1942 and 1945 resulted in mine waste contamination of the stream and floodplain (Weatherley *et al*. 1967; Joint Government Technical Committee on Mine Waste Pollution of the Molonglo River 1974). Prior to the collapse of these waste dumps, the river had supported good numbers of cod and perch. Heavy metal contamination of the stream and floodplain persists, even after extensive remediation works (Norris 1986; Dames & Moore 1993).

The Queanbeyan River rises at an altitude of approximately 1,300 m in the Tinderry Range southeast of Canberra and flows for some 90 km before entering the ACT just before its confluence with the Molonglo River. The total catchment area of the river is approximately 96,000 ha (Queanbeyan City Council 1998). The river flows through predominantly dry sclerophyll forest in the upper catchment, with grazing becoming more common as the stream approaches Queanbeyan. The mean annual flow of the river is approximately 114 gigalitres. The construction of a number of weirs in the Queanbeyan township in the 1920s and 1930s has restricted upstream fish passage from the Molonglo River. The Queanbeyan River was originally known as the Fish River and supported good numbers of cod and perch (National Trust of Australia 1980). The river was impounded in 1978 by the construction of Googong Reservoir, approximately 5 km upstream of Queanbeyan.

The Kybean River rises in the Kybean Range southeast of Cooma and joins the Numeralla River approximately six kilometres upstream of the Numeralla village. Much of the middle catchment of the Kybean is forested with grazing in the upper and lower catchment. There are no impoundments on the river. Prior to European settlement, many of the tributaries of the Kybean River would have been 'chains of ponds' rather than linear gully systems (Starr 1995).

The Big Badja River, originates in the Kybean Range at an elevation of around 1,100 m. The river flows from the Badja Swamp in the head of the catchment and joins the Numeralla River at the Numeralla village. There are no impoundments on the river.

The Numeralla River (sometimes referred to as the Umaralla River) originates to the east of Nimmitabel in the Kybean Range at an altitude of approximately 1,100 m. The Numeralla catchment (including the Big Badga and Kybean sub-catchments) covers an area of 164,900 ha. Extractive industries, (sand and gravel), operate

in the lower river. Prior to European settlement the river was originally a wide shallow stream, braided in spots. However extensive hillslope and gully erosion has deposited large quantities of sediment, and the channel has incised considerably (Starr 1995; Starr *et al*. 1997). This sediment has been exported to the Murrumbidgee River where it is stored in the channel and is being repeatedly reworked and will be for the foreseeable future (Erskine 1997).

The Bredbo River rises in the Tinderry Range at an altitude of approximately 1,260 m and flows west to join the Murrumbidgee near the township of Bredbo. The catchment covers an area of 73,500 ha. Much of the upper and middle catchment is forested with grazing the predominant landuse in the lower catchment. There are no impoundments on the river. Extractive industries, (sand and gravel), operate in the lower river. The Bredbo River contributes significant quantities of sand to the Murrumbidgee River.

The Yass River rises near the north-eastern ACT border at an altitude of approximately 800 m and flows north then east to enter Burrinjuck Reservoir. The catchment is 160,800 ha in area. The majority of the catchment (>90%) is used for rural enterprises and the river is impounded by a weir at the Yass township.

The Goodradigbee River originates near Tantangara Reservoir at an altitude of 1,260 m and flows north to enter Burrinjuck Reservoir. The majority of the catchment (~95%) is forested with the upper catchment protected in Kosciuszko National Park. The catchment is 110,100 ha in area. There are no impoundments on the Goodradigbee although Burrinjuck Dam on the Murrumbidgee River has flooded part of the lower Goodradigbee valley. A small amount of flow in the headwaters is diverted into Tantangara Reservoir by the Goodradigbee aqueduct.

2.2 ACT Government Fish Stocking Program

The majority of impoundments in the ACT and Googong Reservoir have been regularly stocked with a variety of both native and introduced fish species. The aim of the stocking program is to provide a range of recreational fishing opportunities close to the population centres of Canberra, and by providing such opportunities, decrease the fishing pressure on the more fragile riverine environments. Details of the species and number stocked into each impoundment are summarised in Table 3. The rivers in the ACT are not stocked except for conservation reasons, such as the reintroduction of the nationally endangered Trout Cod.

Fish populations in the rivers are considered to be a valuable biological indicator of the health of aquatic environments and to augment these populations artificially by stocking would compromise the value of such an indicator (ACT Government 2001).

Table 3: Species and number of fish stocked into Canberra's lakes and Googong Reservoir between 1981 and 2001.

Year	Location	Murray Cod	Golden Perch	Silver Perch	Rainbow Trout	Brown Trout
1981–83	Lake Burley Griffin	7,000	86,500	27,500		
	Lake Ginninderra	14,700	38,000	23,000	1,000	1,000
	Googong Reservoir	20,000	36,000	100,000[a]		
1984–86	Lake Burley Griffin	20,000	30,000		3,000	
	Lake Ginninderra	7,000	30,000		3,000	
	Googong Reservoir	32,000	50,000	26,000	30,000	
1987–89	Lake Burley Griffin		40,000			28,000
	Lake Ginninderra	18,180	40,000		1,000	
	Googong Reservoir	17,280	100,000[a]	75,000	10,000	
	Cotter Reservoir			30,000		
1990–92	Lake Burley Griffin	45,670				
	Lake Ginninderra	9,000				
	Lake Tuggeranong		16,000[b]			
	Googong Reservoir	13,330	15,000	15,000	10,000[a]	
1993–95	Lake Burley Griffin	29,000[c]	20,000		15,000[c]	
	Lake Ginninderra	11,000	40,000			
	Lake Tuggeranong		15,000			
	Gungahlin Pond		10,000			
	Googong Reservoir	20,000[a]	63,000[a]	30,000[a]	20,000[a]	20,000[a]
1996–98	Lake Burley Griffin	30,000[c]	50,000[c]			
	Lake Ginninderra	30,000	30,000			
	Lake Tuggeranong	15,000	15,000			
	Gungahlin Pond	5,000	10,000			
	Yerrabi Pond		5,000			
	Googong Reservoir	23,000	60,000[a]	10,000[a]	30,000[a]	5,000[a]
1999–01	Lake Burley Griffin	27,500[c]	50,000[c]			
	Lake Ginninderra	12,000	30,000			
	Lake Tuggeranong	10,000	15,000			
	Gungahlin Pond	5,000	10,000			
	Yerrabi Pond		10,000			
	Googong Reservoir	36,000	60,000[a]	50,000[a]	20,000[a]	
TOTAL		367,160	854,500	336,500	123,000	54,000

a = Stock provided by NSW Fisheries

b = Stocked in conjunction with Tuggeranong Valley Fishing Club

c = Funding provided by National Capital Authority

2.3 NSW Government Fish Stocking Program

NSW Fisheries has also been stocking fish in the upper catchment for many years, with native fish predominantly stocked in lakes and dams, and introduced salmonids stocked in lakes and streams. A summary of their stocking activities is shown in Table 4.

Table 4: Species and number of fish stocked in NSW Lakes and Reservoirs (excluding Googong) in the Canberra region by NSW Fisheries between 1981 and 2001.

Year Cod	Location Perch	Murray Perch	Golden Salmon	Silver Trout	Atlantic Trout	Brook Trout	Rainbow	Brown
1981–83	Lake Burrinjuck			26,225	404,750			
1984–86	Lake Burrinjuck				511,170		4,000	
	Lake George						25,500	
	Lake Tantangara			25,500				2,750
1987–89	Lake Burrinjuck				710,000		43,700	
1990–92	Lake Burrinjuck	46,000			188,000		56,000	
	Lake George	26,200	207,000	116,600				7,000
1993–95	Lake Burrinjuck	37,000	328,000	70,000	180,000		122,000	
	Lake George			127,000				
1996–98	Lake Burrinjuck	30,000	264,000	332,000	145,000		200,000	
1999–01	Lake Burrinjuck	40,000	171,000	209,000	290,000		315,000	
	Yass weir	4,000	10,600	5,000				
	Captains Flat dam	5,000						
	Queanbeyan weir	5,000		10,000				

2.4 Long-term Fish Monitoring in the Upper Murrumbidgee Catchment

There have been a number of long-term fish monitoring programs in the Upper Murrumbidgee catchment, particularly in the ACT, most of which commenced in the late 1970s. These programs provide useful baseline data against which present and future fish populations can be compared.

The urban lakes monitoring program has documented the relative abundance of angling species in Canberra's urban lakes and Googong Reservoir. This monitoring program is still active with these water bodies monitored regularly, although the sampling frequency has changed over the years. Data is available for Lake Burley Griffin from 1976, Lake Ginninderra from 1978, Googong Reservoir from 1978, Lake Tuggeranong from 1992 and Gungahlin Pond from 1995. This program relies on gill netting as the sampling technique and has documented the spread of Redfin Perch and the decline of trout species in urban lakes.

Fish populations in the Murrumbidgee River have been monitored since 1979 with irregular sampling conducted at a number of sites including Angle Crossing, Tharwa Sandwash, Point Hut Crossing, Pine Island, Kambah Pool, Casuarina Sands and Retallacks Hole (see Figure 2). Originally this monitoring program concentrated on the larger fish species targeted by anglers. However, in 1994 the program was modified to include smaller fish species as well. The decline in numbers of Macquarie Perch in the Murrumbidgee River is clearly evident (Table 5). This program originally relied on gill netting as the major sampling technique but since 1994 employs an array of sampling methods including electrofishing, fyke netting, spotlighting and bait traps as well as gill nets. This monitoring program was last conducted in 2000 with six sites monitored biennially.

Table 5: Captures of Macquarie Perch at three sites on the Murrumbidgee River in the ACT (Retallacks Hole, Casuarina Sands, Kambah Pool) between 1979 and 2000. Between 1979 and 1998 the sampling technique used was gill nets, in 2000 this changed to boat electrofishing.

YEAR	NUMBER OF NET/NIGHTS	NUMBER of MACQUARIE PERCH
[a]1979	6	16
1980	15	7
1981	36	19
1982	32	20
1984	33	3
1985	24	–
1986	20	–
[b]1987	15	–
[c]1988	15	1
1994	18	–
1996	18	1
1998	18	–
2000	18	–

a= Only 1 site sampled (Retallacks Hole)

b= Only 2 sites sampled (Casuarina Sands, Kambah Pool)

c= Only 1 site sampled (Kambah Pool)

Another monitoring program on the Murrumbidgee River was based at Casuarina Sands where a weir was fitted with a fishway and trap. The trap was operated from 1980 until 1991 when the weir and associated structures were removed. The trap was monitored on a weekly or twice-weekly basis during the spring to autumn period. This provided important information on fish movements and relative abundance at this site, and provides evidence of a general decline in native fish species in the early to mid 1980s. A summary of the information from the fish trap is provided in Table 6. It can be seen that species such as Macquarie Perch and Murray Cod were rarely recorded after 1983, whilst the abundance of Carp and Redfin Perch increased dramatically.

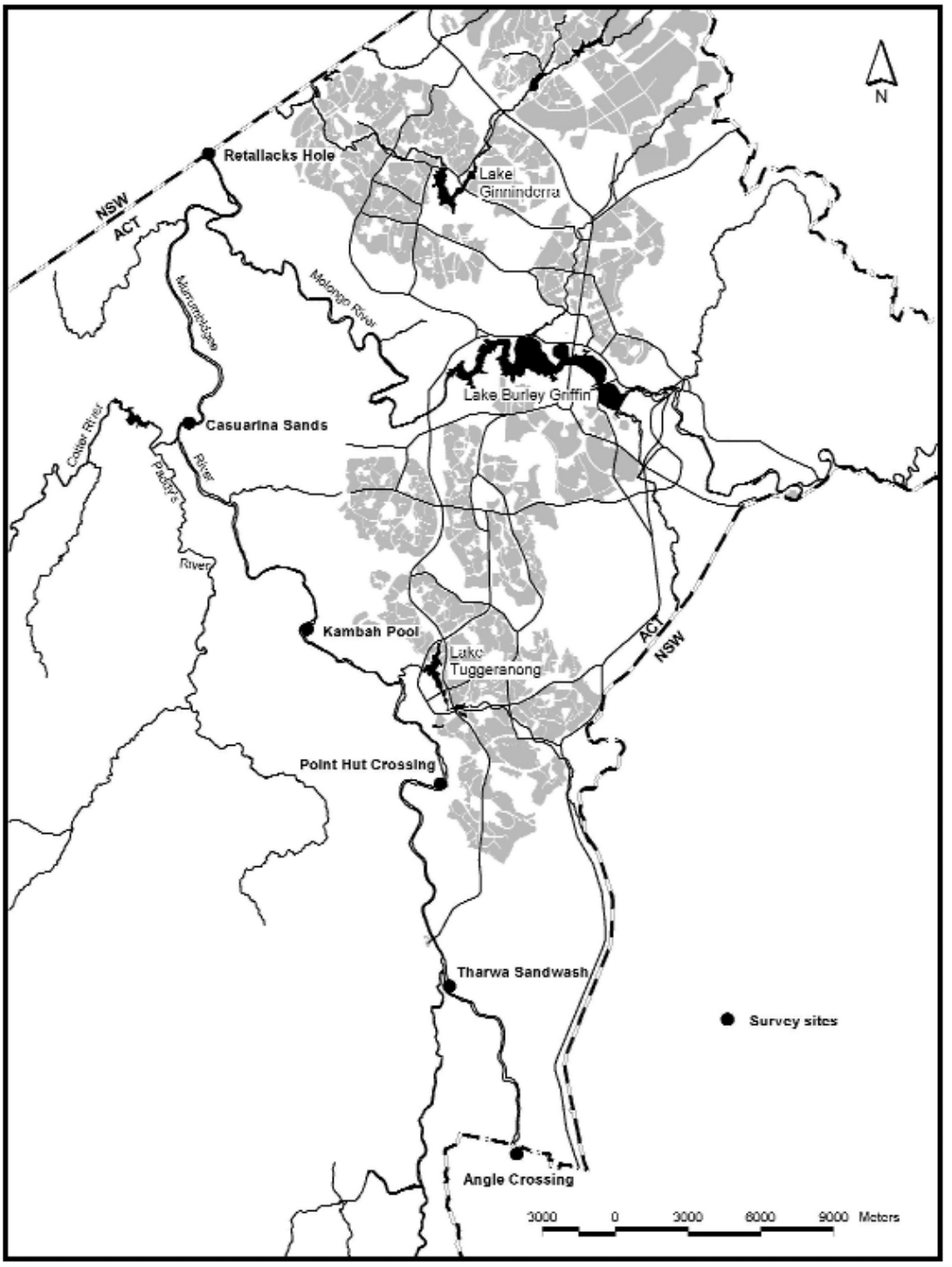

Figure 2: Location of long-term fish sampling sites on the Murrumbidgee River in the ACT.