4 Fish, Crayfish and Macroinvertebrates in ACT Rivers

4.1

Aquatic Habitats

The physical characteristics of ACT rivers and their riparian zones have been outlined in s. 2.1.1 to s. 2.1.3. Before European settlement, the upper reaches of these rivers were characterised by bogs and seepage lines developing into creeks and narrow, often rocky, stream channels. Through the undulating elevated plains around Canberra, stream channels became broader with deep pools separated by rock bars, and deposits of sand, silt, logs and debris. Floods formed river terraces within the normally confined valleys, but there was no substantial floodplain development. Snow melt and winter rainfall in the mountains was the main factor in providing an annual flow cycle, with high flows of colder water in spring, and flows reducing and water becoming warmer through the summer. Late spring and summer storms could bring temporary rises in water level, but it is likely that flows dropped to a trickle or dried up altogether in some seasons. During these times, aquatic life would find refuge in the deep river pools.

The European pastoral economy (see s. 2.3.1) brought rapid changes to rivers and streams, following clearing in catchments, intensive stock grazing and cultivation of some areas. Clearing of riparian vegetation removed the major source of logs, woody debris and leaves to the streams. Increased runoff following clearing and grazing resulted in stream channel incision and gully erosion, loss of the ‘chain-of-ponds’ structure in tributary streams (permanent pools separated by shallow or ephemeral areas), and substantial sedimentation of the rivers (that began to fill the deep pools) (Eyles 1977a, 1977b; NSW DLWC 2000). The drainage system within the Upper Murrumbidgee Catchment altered from grassed depressions flowing into swampy meadows and through chains-of-ponds into creeks and rivers to a connected channelled system. This was characterised by the development of a connected gully system on hillsides and many hundreds of kilometres of incised channels along valley floors. The incision of hillsides, hillslope depressions, valley floors and beds of rivers and creeks has resulted in a system that is more energetic and efficient in transporting sediment (Starr *et al.* 1999).

Sediments released upstream of the ACT from the mid-1800s, especially in the Bredbo River and Numeralla River catchments formed a series of slugs or bedload waves that accumulated in the ACT in the Tharwa depositional zone (Gigerline to Point Hut). This is the last major channel sand storage area in the Upper Murrumbidgee River, below which the river maintains a relatively steep gradient all the way to Burrinjuck Dam. The Tharwa reach is likely, therefore, to remain a depositional zone for as long as the inflow is equal to or greater than sediment export downstream, or sediment is extracted by other means (AWT and Fluvial Systems 1999, pp. 60–66).

In the 20th century, harnessing the rivers for irrigation, hydro-electric power and urban water supply brought a period of major dam construction. The Murrumbidgee River was dammed downstream of the ACT (Burrinjuck Reservoir), and later, in its headwaters, as part of the Snowy Mountains Hydro-Electric Scheme (Tantangara Reservoir) with the water being diverted to Eucumbene Reservoir. The first of three Cotter River storages (Cotter Reservoir) was constructed between 1912 and 1915, followed by Bendora and Corin Dams in the 1960s. In the 1970s, taking up water rights contained in the *Seat of Government Acceptance Act 1909*, the Commonwealth constructed Googong Dam on the Queanbeyan River. Beginning with Scrivener Dam in the 1960s, a series of dams and other structures have been constructed on rivers and creeks as part of the urban development of Canberra and Queanbeyan. These included weirs on the Murrumbidgee and lower Cotter rivers.

These developments brought changes to the rivers and streams that are the focus of this *Strategy*.

These included flow regimes (loss of high and low flows, and changed seasons of flows); changes in water temperatures (cold water releases from the bottom of dams and in some instances removal of shading riparian vegetation); and dislocation of upstream–downstream linkages due to the barriers created by dams and weirs. There have also been declines in water quality (addition of sediments, nutrients, pollutants), and modification of streambanks by adjacent land uses (removal of riparian vegetation, growth of exotic vegetation, trampling and destruction of bank structure). These changes have had a wide range of mostly detrimental impacts on the fish fauna of the region's rivers.

4.2

Aquatic Fauna: Fish, Crayfish and Macroinvertebrates

4.2.1 Fish

Historical accounts indicate that rivers in the ACT region sustained large numbers of native fish and these were important in the pre-European Aboriginal economy of the area (Flood 1980). There are twelve species of native fish from eight families recorded from the Upper Murrumbidgee catchment (Lintermans 2002). Two of these fish are not considered native to the region, but have been translocated from adjacent areas or are rare vagrants. There has been a substantial decline in naturally occurring native fish populations and alien fish species now constitute up to 96% numerically of the total catch recorded in fish monitoring programs in the Murrumbidgee, Molonglo and Queanbeyan rivers (Lintermans and Osborne 2002). The main groups of native fish in the ACT are:

(a) **Large native fish:** Murray Cod (*Maccullochella peelii peelii*), Trout Cod (*Maccullochella macquariensis*), Macquarie Perch (*Macquaria australasica*), Golden Perch (*Macquaria ambigua*), Silver Perch (*Bidyanus bidyanus*). Natural populations of these fish have all declined dramatically in the ACT and region. All five species are angling species, with Murray Cod and Golden Perch stocked in Canberra's urban lakes and Googong Reservoir, and Silver Perch in Googong Reservoir. (For further information on those species declared threatened in the ACT, see Appendix 2.2, 2.3, 2.5. Distribution of these species in ACT rivers is shown in Figure 4.1).

(b) **Fish of upland streams:** Mountain Galaxias (*Galaxias olidus*), Two-spined Blackfish (*Gadopsis bispinosus*) (see Appendix 2.1 for more information on Two–spined Blackfish. Distribution of this species in ACT rivers is shown in Figure 4.1).

(c) **Small fish of lower elevation streams and lakes:** Australian Smelt (*Retropinna semoni*), Western Carp Gudgeon (*Hypseleotris klunzingeri*).

4.2.2 Crayfish

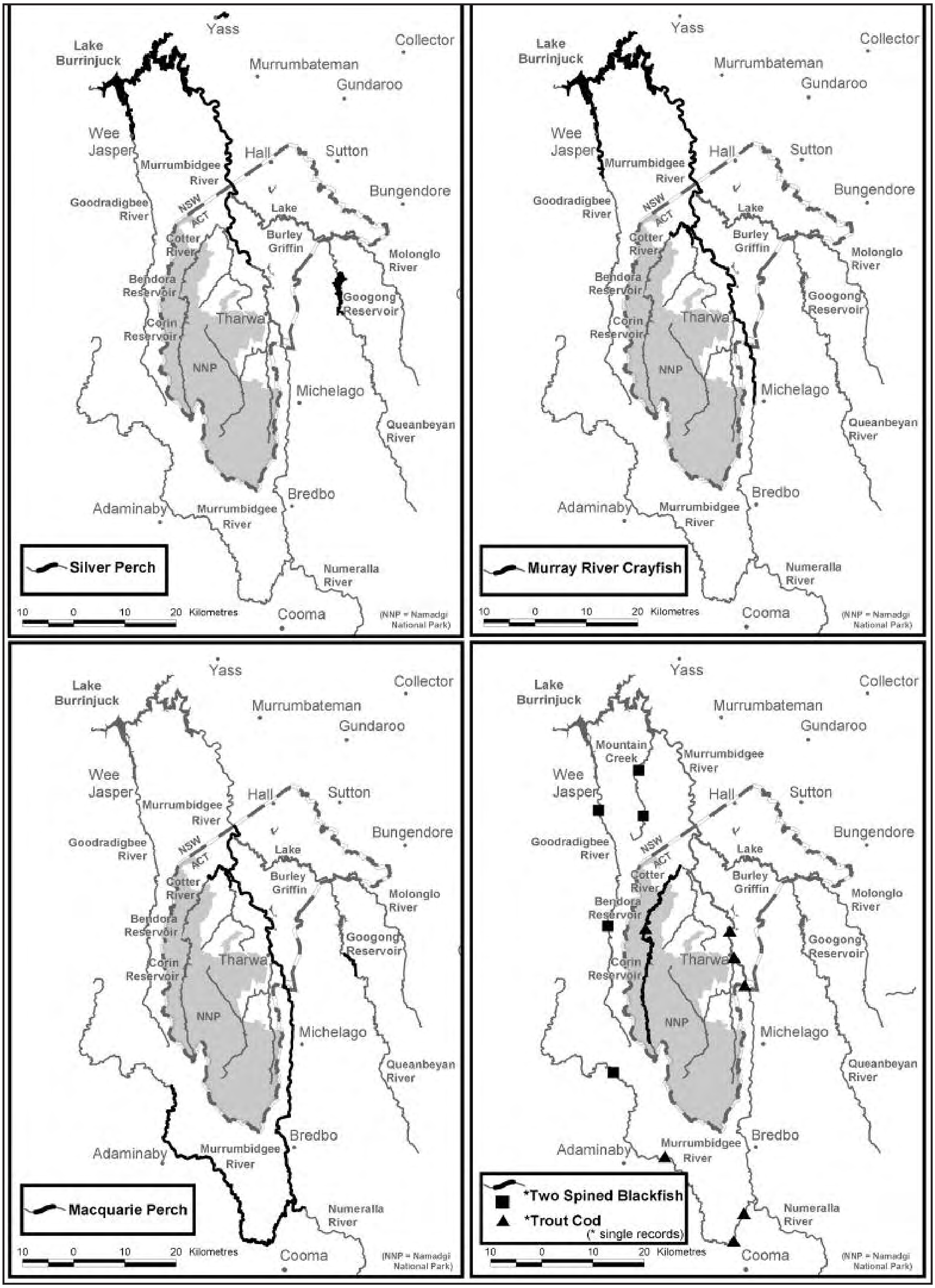
Riverine crayfish species found in the ACT are Murray River Crayfish (*Euastacus armatus*) (see Appendix 2.4, Figure 4.1), Yabby (*Cherax destructor*), and two species of small spiny crayfish. One of these lives predominantly in streams (*Euastacus crassus*); the other lives mainly in upland bogs (*E. rieki*). The Yabby is the most common freshwater crayfish and is abundant in most lowland freshwater habitats. Small spiny crayfish are found in upland areas including the upper Cotter River, but are not commonly seen and little is known of their ecology. It is known that *E. rieki* can suffer considerable predation by foxes (Carey *et al.* 2003) and that trout prey on young individuals of *E. crassus* (Lintermans and Osborne 2002). Also present in the ACT and the upper Murrumbidgee catchment is the burrowing crayfish *Engaeus cymus* (Lintermans 2002). This species occurs near creeks and seepages in forest areas of south-eastern Australia but little is known of its biology or ecology.

4.2.3 Aquatic Macroinvertebrates

Aquatic macroinvertebrates are diverse, representing a range of insect, crustacean and molluscan groups, including snails, water boatmen, dragonflies, stoneflies, mayflies, mites and aquatic worms. They are generally visible to the naked eye and occur in all freshwater habitats. They are an important food source for fish and platypus (Ball *et al.* 2001). Numerically dominant taxa in macroinvertebrate sampling of ACT rivers include Oligochaeta (aquatic worms), Chironomidae (aquatic larval and pupal stages of adult flies (midges, gnats)), Hemiptera (waterbugs), Ephemeroptera (nymphal stage of mayflies), Trichoptera (larval and pupal stages of caddis flies) (Environment ACT 2004e).

The diversity and abundance of aquatic macroinvertebrates are used as indicators of the health of aquatic ecosystems. They are widespread, easy to collect, relatively immobile and responsive to environmental changes in stream ecosystems. Their composition reflects the aggregate of environmental changes impacting on the stream ecosystem for up to several months prior to sampling (Ball *et al.* 2001). In the ACT, they have been used extensively in a well developed program as indicators of water quality, habitat degradation and ecological condition.

Figure 4.1: Distribution of Threatened Fish and Crayfish Species in ACT and Region Rivers



Macroinvertebrate sampling formed the basis of the First Australia-Wide Assessment of River Health, undertaken in the 1990s under the National River Health Program with approximately 6000 sites being assessed including about 200 in the ACT and upper Murrumbidgee river catchment (Environment Australia 2003). Under this program, the Cooperative Research Centre for Freshwater Ecology developed the Australian River Assessment Scheme (AUSRIVAS) predictive models for the biological assessment of river health. AUSRIVAS is a rapid, standardised method of assessing the ecological health of rivers, based on biological monitoring and habitat assessment. AUSRIVAS river health assessment scores are based on the ratio of the number of aquatic macroinvertebrate families found at 'test sites' to the number predicted to occur there under undisturbed conditions. The predictions are derived from a large set of 'reference' river sites with similar geographic, physical and chemical features.

Macroinvertebrate sampling based on AUSRIVAS now forms part of the annual ACT water quality monitoring program. Reference sites (three) are located on the Paddys, Tidbinbilla and Murrumbidgee rivers, and test sites (ten) on the Murrrumbidgee, Gudgenby, Molonglo and Queanbeyan rivers and major urban creeks. The same methods are used to regularly sample six sites in the Cotter River and tributaries and six sites in the Goodradigbee River and tributaries. A further sixteen sites have been sampled in the ACT pine forest estate as part of a study to establish the effectiveness of several riparian zone treatments. Six ad hoc sampling sites have been used to assess the effects of water transfers to Googong Reservoir and the Queanbeyan River. Standard AUSRIVAS methods are used for all sampling, ensuring data comparability. This biological assessment provides a basis for developing actions and priorities to improve water quality and aquatic and riparian habitat (Table 6.1.5).

Macroinvertebrate data is also collected by ACT Waterwatch Groups during the spring and autumn Water Bug snapshot. Waterwatch is a community water quality monitoring program that aims to equip local communities with the skills and knowledge to become actively involved in the protection and management of their local waterways and catchments (see www.act.waterwatch.org.au).

The National River Health Program assessments that concluded in 1999 indicated that most river systems in the ACT and New South Wales showed evidence of adverse human pressures on macroinvertebrate communities, with urban waterways most severely affected (Ball *et al.* 2001). The main habitat and water quality issues in the upper Murrumbidgee catchment are chemical pollutants (urban waterways), trace metal contamination (Molonglo River downstream of the abandoned Captains Flat mine), nutrient enrichment (treated sewage effluent and rural and urban runoff), habitat degradation and sedimentation, and river regulation (which affects most larger streams in the ACT). Low flows related to drought conditions also affect sampling results (Keen 2001). AUSRIVAS assessments, included in the ACT water quality monitoring program since 2000, show that urban streams have significant levels of impairment with an annual decline in spring and improvement in autumn. Non-urban Reference and Test sites generally have maintained a healthy condition though the Murrumbidgee River exhibits seasonal decline (ACT SOE 2003a). There was a noticeable decline in stream health in autumn 2003 following the major bushfires of January 2003 and dry conditions that extended from autumn 2002 to autumn 2003 (Dickson *et al.* 2003).

4.3

Threatened Fish and Crayfish in the ACT

Four of the native fish species recorded from the ACT and the Murray River Crayfish are declared as threatened under ACT legislation, as well as in other jurisdictions. Murray Cod has recently been listed as vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) but is not declared in the ACT (Table 4.1).

The following sections 4.4 to 4.7 discuss those factors considered to have contributed to the decline of native fish species in the Murray–Darling Basin, including the ACT, and which continue to be ongoing threats. As well as these general threats to fish populations, there are some specific threats applying to fish declared as threatened in the ACT (s. 4.8). These are the continuing impacts of the January 2003 bushfires and the potential impacts of native predators on localised populations. A summary ranking of the importance of particular threats to threatened fish and crayfish species is contained in section 4.9.

Table 4.2 provides a brief description of stream morphology, and the distribution of fish and crayfish species, including threatened species, for ACT rivers included in this *Strategy*. The river sections in Table 4.2 correspond to those in Table 2.2 and Table 5.1.

Table 4.1: Conservation Status Nationally of Threatened Fish and Crayfish Species Occurring in ACT Rivers

	Statutory			Non-statutory
	ACT	NSW	Other	ASFB/IUCN/VDSE
FISH Two-spined Blackfish (*Gadopsis bispinosus*)	V	—	—	—
Trout Cod (*Maccullochella macquariensis*)	E (SPS)	E	P (SA) T (Vic) E (Cwlth)	(CE) ASFB (E) IUCN (CE) VDSE
Macquarie Perch (*Macquaria australasica*)	E (SPS)	V	T (Vic) E (Cwlth)	(E) ASFB (DD) IUCN (E) VDSE
Silver Perch (*Bidyanus bidyanus*)	E (SPS)	V	T (Vic) P (SA)	(V) ASFB (V) IUCN (CE) VDSE
Murray Cod (*Maccullochella peelii peelii*)	—	—	T (Vic) V (Cwlth)	(V) VDSE
CRAYFISH Murray River Crayfish (*Euastacus armatus*)	V (PI)	—	T (Vic) E (SA)	(V) IUCN

CE: Critically Endangered; **E:** Endangered; **V:** Vulnerable; **T:** Threatened; **SPS:** Special Protection Species; **DD:** Data Deficient; **P:** Protected; **PI:** Protected Invertebrate

LEGISLATION:

Commonwealth: *Environment Protection and Biodiversity Conservation Act 1999*

ACT: *Nature Conservation Act 1980*

NSW: *Fisheries Management Act 1994*

Vic: *Flora and Fauna Guarantee Act 1988* (Note that under this Act, species are listed as 'threatened' and specific conservation status (e.g. endangered) is assessed in advisory lists prepared by the Victorian Department of Sustainability and Environment (VDSE 2006).)

NON-STATUTORY:

ASFB: Australian Society for Fish Biology (Conservation Status of Australian Fishes–2001 (ASFB 2001))

IUCN: IUCN (The World Conservation Union) Red List of Threatened Species (IUCN 2004)

VDSE: Victorian Department of Sustainability and Environment, *Flora and Fauna Guarantee ACT: Taxa and Communities of Flora and Fauna which are Threatened* (VDSE 2006).

Table 4.2: River Sections—Brief Description of Stream Morphology, Fish and Crayfish Species

Current Planning and Management	Description of Stream and Banks	Key Features of Aquatic Fauna	Threatened/ Uncommon/ Aquatic Fauna	Threats to Species and/or Communities
Murrumbidgee River (Murrumbidgee River Corridor (MRC)) (*Special Requirements* apply to the MRC and Lanyon Bowl Area under the *National Capital Plan*.)				
MU 1: Angle Crossing to Tharwa				
Territory Plan ■ Gigerline Nature Reserve ■ Special Purpose Reserve (Tharwa) ■ Rural leasehold ***Management*** MRC Management Plan 1998	**Angle Crossing to Gigerline Gorge** For approximately five km immediately to the north of Angle Crossing (ACT/NSW border), the Murrumbidgee River is a series of relatively shallow pools with prominent rock bars, rapids and riffles. Some sandy beaches are present with previous small-scale sand extraction activities occurring in the reach. The river then narrows, turning north-west to flow through the steep, rugged Gigerline Gorge with extensive rocky terraces composed of boulders, bedrock and large stones.	**Angle Crossing to Gigerline Gorge** ■ The fish community is largely defined by the barrier presented by Gigerline Gorge and so represents a more 'upland' fish fauna. Lowland species such as Murray Cod, Golden Perch and the alien Redfin Perch are absent or extremely rare. ■ Common alien species include Carp, Goldfish, Brown Trout, Rainbow Trout, Eastern Gambusia, Oriental Weatherloach.	**Angle Crossing to Gigerline Gorge** ■ Trout Cod ■ Macquarie Perch ■ Murray River Crayfish ■ Silver Perch (anecdotal evidence only)	**Angle Crossing to Gigerline Gorge** ■ Illegal fishing (recreational fishing banned in this section) ■ Sedimentation ■ Reduction in flows (Tantangara and rural extraction upstream) ■ Alien species
	Gigerline Gorge to Tharwa Upon exiting the Gigerline Gorge, the river abrubtly changes, widening to become a depositional stream with a sandy bed, long pools occasional beaches. Previous sand extraction activities at the old Tharwa Sandwash have resulted in a long, flat sandy terrace. The Gudgenby River enters at this point, although fish access to this river is restricted by the large quantities of sand in the Gudgenby channel.	**Gigerline Gorge to Tharwa** ■ The fish fauna of this reach contains more of the lowland elements including Murray Cod, Golden Perch and the alien Redfin Perch. ■ The full complement of alien species is present including Carp, Goldfish, Redfin Perch, Brown Trout, Rainbow Trout, Oriental Weatherloach and Eastern Gambusia.	**Gigerline Gorge to Tharwa** ■ Trout Cod ■ Murray Cod ■ Macquarie Perch ■ Murray River Crayfish	**Gigerline Gorge to Tharwa** ■ Sedimentation ■ Lack of riparian trees ■ Illegal fishing ■ Alien species
MU 2: Tharwa to Point Hut Crossing				
Territory Plan ■ Special Purpose Reserve (including Lanyon Landscape Conservation reserve) ■ Rural leasehold ***Management*** MRC Management Plan 1998	North of Tharwa the river passes through broad river flats in an undulating, pastoral landscape. In this deposition zone, the channel is shallow and contains significant quantities of sand that has filled pools and smothered the previously stony substrate for several kilometres. The riverbanks have been largely cleared of the former stands of Ribbon Gum (*Eucalyptus viminalis*), leaving some isolated remnant individual trees as evidence of the earlier vegetation type. Stock access to the river has been limited in recent years by fencing off the river corridor.	■ The fish fauna of this reach contains most of the lowland elements including Murray Cod, Golden Perch and the alien Redfin Perch ■ The full complement of alien species is present including Carp, Goldfish, Redfin Perch, Brown Trout, Rainbow Trout, Oriental Weatherloach and Eastern Gambusia.	■ Trout Cod ■ Murray Cod ■ Macquarie Perch ■ Murray River Crayfish	■ Sedimentation ■ Lack of riparian trees ■ Illegal fishing ■ Barrier to fish movement (Point Hut Crossing) ■ Alien species

Table 4.2: *(Continued)*

Current Planning and Management	Description of Stream and Banks	Key Features of Aquatic Fauna	Threatened/ Uncommon/ Aquatic Fauna	Threats to Species and/or Communities
MU 3: Point Hut Crossing to Kambah Pool				
Territory Plan ■ Special Purpose Reserve (Point Hut Crossing to Pine Island, Pine Island, Kambah Pool) ■ Bullen Range Nature Reserve (Pine Island to Kambah Pool) ■ Rural leasehold ***Management*** MRC Management Plan 1998	Downstream from Point Hut Crossing the open valley environments give way to steeper slopes with elevated terraces of sandy or rocky banks, with shrub vegetation and scattered trees. The recreation area at Pine Island Reserve takes advantage of the river's broad channel and deep pools and occasional beaches and rocky substrate. Downstream of the Reserve is Red Rocks Gorge, a relatively less accessible area of high cliffs and rugged rock formations. Red Rocks Gorge meets the Bullen Range Nature Reserve near Kambah Pool recreation area. This part of the Murrumbidgee River has high ecological, scenic and conservation value, with some elements such as the Peregrine Falcon nesting sites requiring special attention in order to ensure they are protected from human disturbance.	■ The fish fauna of this reach contains most of the lowland elements including Murray Cod, Golden Perch and the alien Redfin Perch ■ The full complement of alien species is present including Carp, Goldfish, Redfin Perch, Brown Trout, Rainbow Trout, Oriental Weatherloach and Eastern Gambusia.	■ Trout Cod ■ Murray Cod ■ Macquarie Perch ■ Murray River Crayfish	■ Sedimentation ■ Urban impacts ■ Lack of riparian trees ■ Illegal fishing ■ Alien species
MU 4: Kambah Pool to Cotter River Confluence/Casuarina Sands				
Territory Plan ■ Bullen Range Nature Reserve ■ Special Purpose Reserve (upslope areas on eastern side of Murrumbidgee R. above nature reserve) ■ Special Purpose Reserve (Cotter Reserve/ Casuarina Sands) ***Management*** MRC Management Plan 1998	The Bullen Range is a controlling influence on the course of the river downstream of Kambah Pool. The Bulgar, New Station and McQuoids creeks drain the undulating pastoral land between the river and Weston Creek urban area. The river is deeply entrenched below surrounding terrain. The streambed is rocky with pools, rapids, rock bars, islands and sandy margins. Riverine vegetation is well developed with River Oaks along almost the entire stretch. This section was severely burnt in the bushfires of January 2003.	■ Full complement of lowland fish present. Silver Perch historically common but now rare. ■ The full complement of alien species is present including Carp, Goldfish, Redfin Perch, Brown Trout, Rainbow Trout, Oriental Weatherloach and Eastern Gambusia.	■ Trout Cod ■ Macquarie Perch ■ Silver Perch ■ Murray River Crayfish ■ Murray Cod	■ Willows ■ Illegal fishing ■ Sedimentation ■ Alien species
MU 5: Cotter River Confluence/Casuarina Sands to ACT/NSW Border				
Territory Plan ■ Stony Creek Nature Reserve ■ Swamp Creek Nature Reserve ■ Woodstock Nature Reserve ■ Special Purpose Reserve (upslope areas above nature reserves) ■ Special Purpose Reserve (Uriarra Crossing) ***Management*** MRC Management Plan 1998	Between the Cotter/Casuarina Sands area and the point at which the Murrumbidgee River leaves the ACT, the river passes through deeply dissected slopes cut through the surrounding undulating terrain. Stony Creek Nature Reserve protects much of the river's course as far as Uriarra Crossing where a small recreation area has been developed in association with a road crossing. North of Uriarra Crossing, and a few kilometres south of the ACT/NSW border, the Molonglo River joins the Murrumbidgee River. High up on the eastern edge of the confluence is the Lower Molonglo Water Quality Control Centre.	■ Full complement of lowland fish. Silver Perch historically common but now rare. ■ The full complement of alien species is present including Carp, Goldfish, Redfin Perch, Brown Trout, Rainbow Trout, Oriental Weatherloach and Eastern Gambusia.	■ Trout Cod ■ Macquarie Perch ■ Silver Perch ■ Murray River Crayfish ■ Murray Cod	■ Willows ■ Illegal fishing ■ Sedimentation ■ Alien species

Table 4.2: *(Continued)*

Current Planning and Management	Description of Stream and Banks	Key Features of Aquatic Fauna	Threatened/ Uncommon/ Aquatic Fauna	Threats to Species and/or Communities
Gudgenby River **(Tributaries: Naas and Orroral rivers)** (*Special Requirements* apply to the Namadgi National Park Area under the *National Capital Plan*. This 'Area' is the Park and adjacent areas in the Gudgenby and Cotter catchments.)				
GU 1: In Namadgi NP				
Territory Plan ■ Namadgi National Park ***Management*** Namadgi National Park Management Plan 2005	Landscape characterised by deep open valleys, with small streams meandering through flood plains. Rivers and creeks are small in dimensions and flow and may partly dry up in extreme dry seasons. There are significant wetland areas in upper reaches, including a morass (Gudgenby) and fens (e.g. Nursery Creek, upper Naas River).	■ Smaller streams dominated by Mountain Galaxias where trout are absent. ■ *Euastacus crassus* widely distributed. ■ Rainbow Trout and Brown Trout common in most streams.	■ Two-spined Blackfish (anecdotal, historical reports)	■ Willows ■ Alien species
GU 2: Namadgi NP to Murrumbidgee River				
Territory Plan ■ Special Purpose Reserve (possible Tennent Dam site) ■ Rural leasehold	The Naas–Gudgenby River confluence is in undulating to flat terrain north of the Billy Range. The Gudgenby River then follows a northward course through incised gorge-like areas including a rocky gorge near Mt Tennent. Under low flow conditions the river is shallow and the streambed comprises sand and gravel as well as granitic rocks.	■ Mountain Galaxias present but only common in dry seasons. ■ Trout dominate fish fauna in wet or average years. ■ Alien Oriental Weatherloach, Carp, Eastern Gambusia and Redfin Perch present in lower reaches.	■ Murray River Crayfish present in lower reaches.	■ Willows ■ Sedimentation ■ Degradation of banks from uncontrolled stock grazing ■ Alien species
Cotter River **(Tributary: Paddys River)** (*Special Requirements* apply to the Namadgi National Park Area under the *National Capital Plan*. This 'Area' is the Park and adjacent areas in the Gudgenby and Cotter catchments.)				
CO 1: Paddys River (Tributary: Tidbinbilla River)				
Territory Plan ■ Tidbinbilla Nature Reserve ■ Rural leasehold ■ Plantation forestry ***Management*** Tidbinbilla Nature Reserve Management Plan 1999	Paddys River is a small stream in a broad valley. Streambed carries sediments sourced from upper catchment. Bank erosion is common. Streambed contains pools, sand and gravel (often vegetated) and stretches of boulders. Condition of riparian areas is poor (ACT SOE 2003c). Paddys River catchment was severely burnt in the January 2003 bushfires. Significant areas of the lower catchment are dominated by pine plantations.	■ Macquarie Perch still present in lower reaches, formerly more abundant and widely distributed. ■ Alien trout, Carp, Oriental Weatherloach, Eastern Gambusia and Redfin Perch present in lower reaches.	■ Murray River Crayfish ■ Macquarie Perch ■ Two-spined Blackfish (historically)	■ Sedimentation (fire, roads, forestry) ■ Riparian degradation ■ Weeds ■ Lack of connection with Murrumbidgee River ■ Alien species

Table 4.2: *(Continued)*

Current Planning and Management	Description of Stream and Banks	Key Features of Aquatic Fauna	Threatened/ Uncommon/ Aquatic Fauna	Threats to Species and/or Communities
CO 2: Cotter River (Headwaters to Corin Dam)				
Territory Plan ■ Namadgi National Park ***Management*** Namadgi National Park Management Plan 2005	The Cotter River and tributary streams in the upper catchment are narrow, moderately incised, have dense overhanging vegetation (grasses, shrubs), and contain woody debris where larger shrubs and trees are present. Streambeds may be silty, stony, sandy or be comprised of rocks and cobbles. Wider open reaches have alluvial banks. Following the January 2003 bushfires and subsequent storms, there has been widening and deepening of some tributary creeks (ACT SOE 2003c). This area was moderately and patchily burnt in the January 2003 bushfires. Stream flows are natural (i.e. not affected by up stream structures).	■ The fish fauna is that of an upland or montane stream with only two native species present (Mountain Galaxias and Two-spined Blackfish). ■ The crayfish fauna is represented by a single stream species (*Euastacus crassus*), with a bog-dwelling species (*Euastacus rieki*) also present in the montane areas of the catchment. ■ There is only a single alien species present (Rainbow Trout) due to the barriers to colonisation from downstream habitats presented by Corin and Bendora dams	■ Two-spined Blackfish	■ Sedimentation after 2003 fires ■ Pressure for recreational fishing access ■ Fire impacts on riparian zone ■ Introduction of Brown Trout ■ Inter-basin water transfers (from Tantangara)
CO 3: Cotter River (Below Corin Dam to Bendora Dam)				
Territory Plan ■ Namadgi National Park ***Management*** Namadgi National Park Management Plan 2005	The river occupies a more deeply incised valley with vegetation communities characteristic of high altitude valley areas usually extending down to the river. Streambed is relatively narrow, commonly containing rocks and boulders. This section was severely burnt in the bushfires of January 2003. River flow is regulated by releases from Corin Dam.	■ The fish fauna is that of an upland or montane stream with only two naturally occurring native fin fish species present (Mountain Galaxias and Two-spined Blackfish) plus two species introduced for conservation reasons (Trout Cod and Macquarie Perch). ■ The crayfish fauna is represented by two stream species (*Euastacus crassus* and Yabby), with a bog-dwelling species (*Euastacus rieki*) also present in the montane areas of the catchment. Yabbies are largely confined to the Bendora Reservoir in this river reach. ■ There is only a single alien species present (Rainbow Trout) due to the barriers to colonisation from downstream habitats presented by Bendora Dam.	■ Two-spined Blackfish ■ Trout Cod ■ Macquarie Perch	■ Thermal pollution ■ Altered flow patterns ■ Sedimentation after 2003 fires ■ Introduction of Brown Trout ■ Pressure for recreational fishing access ■ Inter-basin water transfers (from Tantangara)

Table 4.2: *(Continued)*

Current Planning and Management	Description of Stream and Banks	Key Features of Aquatic Fauna	Threatened/ Uncommon/ Aquatic Fauna	Threats to Species and/or Communities
CO 4: Cotter River (Below Bendora Dam to Cotter Dam)				
Territory Plan ■ Namadgi National Park ■ Special Purpose Reserve (upstream from Cotter Dam to boundary of Namadgi National Park) ***Management*** ■ Namadgi National Park Management Plan 2005 ■ Lower Cotter Catchment: Strategic Management Plan 2006	Narrow, deeply incised river valley flanked by dry forest, variable shrub cover and extensive weed invasion (especially Blackberry). Streambed commonly narrow and rocky but gravelly-bottomed pools occur in areas with gentler gradients. This section was severely burnt in the bushfires of January 2003. River flow is regulated by releases and diversions from Bendora Dam.	■ The fish fauna is that of an upland or montane stream with three naturally occurring native fish species present (Mountain Galaxias, Two-spined Blackfish and Macquarie Perch) plus one species introduced for conservation reasons (Trout Cod). ■ The crayfish fauna is represented by two stream species (*Euastacus crassus*, Yabby and Murray River Crayfish), with a bog-dwelling species (*Euastacus rieki*) also present in the montane areas of the catchment. ■ There are five alien species present (Rainbow Trout, Brown Trout, Oriental Weatherloach, Eastern Gambusia, Goldfish). The barrier to colonisation from downstream habitats presented by Cotter Dam prevents invasion by other alien species (Carp and Redfin Perch).	■ Macquarie Perch ■ Trout Cod ■ Murray River Crayfish	■ Thermal pollution ■ Altered flow patterns ■ Sedimentation (fire, roads, forestry) ■ Fire impacts on riparian zone ■ Barriers to fish passage (road crossings) ■ Introduction of Redfin Perch, Carp ■ Cormorant predation on Macquarie Perch and Trout Cod ■ Pressure for recreational fishing access to Cotter Reservoir ■ Pressure for other recreational use of Cotter Reservoir ■ Water extraction from Cotter Reservoir ■ Inter-basin water transfers
CO 5: Cotter River (Below Cotter Dam to Murrumbidgee River)				
Territory Plan ■ Special Purpose Reserve	The river and adjacent riparian areas have been extensively modified related to the construction of the nearby Cotter Dam and the Cotter recreation area. The streambed includes cobbles, low rocky areas, sand and gravel and there are low weirs. Near the Paddys River confluence there is a sandy bottomed pool used for swimming. River flow is regulated by releases from Cotter Dam.	■ The fish fauna in this section largely reflects that of the lower Murrumbidgee River. It lacks Two-spined Blackfish due to environmental degradation associated with decades of reduced flows and increased sedimentation. ■ The crayfish fauna is represented by two stream species (Murray River Crayfish and Yabby). ■ The full complement of alien species is present including Carp, Goldfish, Redfin Perch, Brown Trout, Rainbow Trout, Oriental Weatherloach and Eastern Gambusia.	■ Macquarie Perch ■ Murray Cod ■ Silver Perch (rare) ■ Murray River Crayfish	■ Altered flow patterns ■ Sedimentation ■ Fire impacts on riparian zone ■ Barriers to fish passage (weirs and fish passage to the Paddys River) ■ Alien species ■ Recreational fishing pressure (on Macquarie Perch)

Table 4.2: *(Continued)*

Current Planning and Management	Description of Stream and Banks	Key Features of Aquatic Fauna	Threatened/ Uncommon/ Aquatic Fauna	Threats to Species and/or Communities
Molonglo River (*Special Requirements* apply to the Molonglo River Corridor under the *National Capital Plan*.)				
MO 1: Burbong to Blue Tiles (Immediately Upstream of Molonglo Gorge)				
Territory Plan ■ Nature Reserve ■ Rural leasehold ■ Pine plantation	The Molonglo River is a relatively small stream in a moderately incised valley containing pools, small rapids and shallow areas. The river may be only a series of pools in extended dry periods. The stream channel is sandy or stony and fringing emergent vegetation is common e.g. *Typha* spp. (Anway *et al.* 1975). Approaching Molonglo Gorge, valley sides become steeper, more rugged and rocky and flow is confined. Blue Tiles is a large deep pool.	■ Mountain Galaxias and trout are the only fish known, but anecdotal reports of carp. ■ Yabbies present.	None recorded	■ Heavy metal pollution events ■ Invasion by alien species from downstream (Carp, Redfin Perch, Oriental Weatherloach) ■ Urban edge (potential impact if urban development occurs in Kowen)
MO 2: Molonglo Gorge to Lake Burley Griffin				
Territory Plan ■ Nature Reserve ■ Rural leasehold ■ Other leasehold	Molonglo Gorge has steep valley sides. The streambed is rocky (including large rock outcrops) with pools and rapids. Willows are common in the river channel. There are extensive areas of river-washed rocks where the river exits the gorge. Downstream of the gorge the Molonglo River is joined by the Queanbeyan River before entering the backed up waters of Lake Burley Griffin. The Pialligo area contains a former flood plain and old river channels (filled by the waters of Lake Burley Griffin).	■ Stocked impoundment (Lake Burley Griffin) influences fish community. ■ Yabbies common. ■ The full complement of alien species is present including Carp, Goldfish, Redfin Perch, Brown Trout, Rainbow Trout, Oriental Weatherloach and Eastern Gambusia.	■ Silver Perch (stocked, overflow from Googong Reservoir) ■ Murray Cod	■ Willows ■ Urban/industrial runoff ■ Weeds
MO 3: Scrivener Dam to Coppins Crossing				
Territory Plan ■ Urban Open Space (Scrivener Dam to Tuggeranong Parkway) ■ Special Purpose Reserve (Tuggeranong Parkway to Coppins Crossing) ■ Rural leasehold	Streambed contains shallow areas, pool, rock bars, cobbles and is heavily overgrown by a wide variety of woody weeds. In some places these completely overshadow the stream channel. Poor water quality related to bottom releases from Scrivener Dam. Occasional overbank flows due to releases from Scrivener Dam after high rainfall events. Valley contains relatively flat areas along stream in places.	■ Spill over from Lake Burley Griffin stockings. ■ The full complement of alien species is present including Carp, Goldfish, Redfin Perch, Brown Trout, Rainbow Trout, Oriental Weatherloach and Eastern Gambusia.	■ Murray River Crayfish ■ Murray Cod	■ Willows ■ Weeds ■ Potential barriers and urban edge effects (with proposed urban development) ■ Recreational use ■ Poor water quality discharge from Scrivener Dam
MO 4: Coppins Crossing to Murrumbidgee River				
Territory Plan ■ Lower Molonglo River Corridor Nature Reserve ***Management*** Lower Molonglo River Corridor. Management Plan 2001	In this section, the river valley becomes more deeply incised and in the lower sections forms the Lower Molonglo Gorge (approximately 2 km in length) in volcanic rocks. Below the steep gorge sides, the riverbed contains rapids, deep and shallow pools, with rock bars across the river visible in low flow conditions. Features of the section are the terraces bordering the river from 2–5 m above normal (low) flow (NCDC 1988b).	■ Spill over from Lake Burley Griffin stockings. ■ The full complement of alien species is present including Carp, Goldfish, Redfin Perch, Brown Trout, Rainbow Trout, Oriental Weatherloach and Eastern Gambusia.	■ Murray River Crayfish ■ Murray Cod ■ Macquarie Perch (historical)	■ Willows ■ Weeds ■ Recreational use ■ Discharge from Lower Molonglo Water Quality Control Centre ■ Poor water quality discharge from Scrivener Dam

4.4

Habitat Destruction or Modification

Alteration or destruction of habitat is widely regarded as one of the most important causes of native fish decline in Australia (Cadwallader 1978a; Koehn and O'Connor 1990a, b; Lintermans 1991; Hancock 1993) and overseas (Moberly 1993; Maitland 1987).

Habitat modifications occur in many forms but the major classes are:

- habitat degradation: damage to riparian zones, sedimentation, removal of in-stream habitat;
- barriers to fish passage;
- reduction in floodplain habitat;
- alteration to flow regimes by dams and weirs;
- thermal pollution; and
- reduction in water quality. (Lawrence 1991, MDBC 2004a)

4.4.1 Habitat Degradation

DAMAGE TO RIPARIAN ZONES

The quality of aquatic habitat is closely related to both the condition of the stream catchment and the riparian zone. The importance of native streamside vegetation to aquatic ecosystems cannot be over-emphasised. Riparian zone vegetation acts as a buffer from surrounding activities and interacts continuously with the stream (Koehn and O'Connor 1990a). Much of the in-stream habitat used by fish originates from the surrounding vegetation e.g. fallen trees, logs, woody debris, leaves and bark. Combined with aquatic and emergent vegetation, this organic matter forms the major primary source of nutrients for the aquatic food chain. Additional fish food in the form of terrestrial invertebrates also originates from bankside vegetation. Introduced plant species that provide a highly seasonal leaf input, such as willows and poplars, alter the timing, quality and consistency of this energy supply (Schulze and Walker 1997). Leaf fall and decomposition in streams has been studied in detail in the Lees Creek catchment (in the northern Cotter catchment), ACT, by Thomas *et al.* (1992). In this catchment, litter-fall is seasonal, occurring in late summer, and the material may decompose very quickly.

As well as providing significant carbon sources, large logs and branches in a stream provide a number of important structural functions for aquatic ecosystems. For fish, this includes the provision of spawning sites, shade, formation of scour pools, territorial markers or 'signposts', velocity refuges, ambush sites for predators, and refuges from both aerial and in-stream predators. Large woody debris is not so important in upland Australian streams where instream cover is largely provided by substrate (e.g. boulders, cobbles).

The root systems of bank vegetation help prevent erosion and sedimentation and submerged roots may also provide in-stream habitat. Streamside vegetation acts as a buffer strip by filtering sediment, pasture effluent and chemicals in runoff from surrounding areas and can be important in protecting bank areas from disturbances such as stock trampling. Shading is also important in helping to reduce summer stream temperatures and providing habitat areas for species avoiding predators (Koehn and O'Connor 1990a).

In the ACT, significant changes to the riparian zone have occurred since European settlement including loss of native vegetation (e.g. *Eucalyptus viminalis* Tableland Riparian Woodland along the Murrumbidgee River in the Lanyon area), loss of streamside vegetation complexity, and both planting and natural spread of introduced species, in particular willows (*Salix* spp.) and blackberries. Clearing of native riparian tree cover and the spread of willows mean that the opportunity for the natural replenishment of hardwood into streams is much reduced. Submerged roots of willows may also smother habitat in small streams.

SEDIMENTATION

Sediment in streams may derive from point sources (e.g. roads, stock access points, construction activities), from broad-scale catchment land use or as a result of extreme events such as fires and floods. High levels of suspended solids in streams may be lethal to fish and their eggs but the major damage is to aquatic habitat. Sediment fills pools and scour holes, decreases substrate variation and reduces usable habitat areas. Clogging of the substratum removes spaces between rocks used as rearing, refuge and habitat areas by juvenile fish, small species and stream invertebrates (Koehn and O'Connor 1990a).

Sedimentation and the associated increase in turbidity are likely to affect visual feeders like Trout Cod and Two-spined Blackfish more severely, as both the abundance and diversity of prey items are reduced and feeding success declines because of lowered water clarity. Addition of sediments to rivers is particularly detrimental to fish such as Two-spined Blackfish and Macquarie Perch that lay adhesive eggs on the substrate, as sediment may smother the eggs and prevent their attachment (Cadwallader 1978a). Increased sedimentation is also known to be damaging to benthic macroinvertebrate communities (Doeg and Koehn 1990a, b), which form the majority of the dietary items of the Two-spined Blackfish and Macquarie Perch.

In the Murrumbidgee River, there has been a decline in the quality and quantity of habitat through sediment filling spaces between rocks. This process has occurred over a 150-year period since the mid to late 1800s when poor land management practices and a series of large floods in the upper Murrumbidgee catchment resulted in extensive erosion and sediment addition to the river (Starr 1995; Olley 1997). Over-clearing, the effects of rabbit plagues in the 1920s, establishment of sand and gravel extraction and urban development contributed to the general siltation of the river. This sediment is still working its way through the river system and is slowly filling the deeper pools that are important as refuges for the larger native fish species such as cod and perch and the Murray River Crayfish. The establishment of several sand and gravel extraction facilities on rivers upstream of the ACT exacerbated the problem by destabilising river channels and resuspending fine sediments into the water column. A similar situation with land degradation existed in the catchment of the Molonglo River with reports in the 1960s documenting severe gully, sheet and stream bank erosion (Durham 1958; Eyles 1977b; NSW DLWC 2000).

Infill of sediment into spaces between rocks in the Murrumbidgee River reduces habitat for Murray River Crayfish and large bodied fish species, and results in a loss of sites for frogs to lay eggs. These spaces are used as refuges because the banks are generally not suitable for constructing burrows or there is little structural woody habitat (snags) available. Increased turbidity and sediment loads also have detrimental effects on submerged aquatic plant beds through reductions in light penetration, thus reducing an important food source for Murray River Crayfish. Sedimentation following the January 2003 bushfires in the ACT has smothered submerged macrophyte beds in the Cotter River catchment (M. Lintermans, pers. comm.).

The construction of Tantangara Dam in 1960, as part of the Snowy Mountains Hydro-electric Scheme probably contributed substantial amounts of sediment to the upper Murrumbidgee River. Tantangara Dam has reduced the frequency of winter flooding and increased the occurrence of low flows (<1000 megalitres/day) in winter (Jorgensen 1983). This has probably led to the continued accumulation of sediments in the river as there are now fewer and smaller high flow events that previously would have scoured the finer sediments out of the riverbed (Pendlebury 1997).

An important source of sediment addition to the Murrumbidgee River since the 1980s has been the urban development of Tuggeranong. A study of the effects of sediment addition in the Tuggeranong Creek catchment in 1987–88 found that platypus and aquatic invertebrate communities were noticeably depleted in the Murrumbidgee River, downstream of the confluence of Tuggeranong Creek (Hogg and Norris 1988). A follow up study of invertebrates in 1993 revealed that there had been little or no recovery in invertebrate numbers and that fine inorganic sediments were still a major component of the downstream sites (Grimes 1993). This was despite the incidence of several large flushing flows in the intervening years that would have removed the prior accumulations of fine inorganic material. Platypus are still uncommon in this sediment affected river reach, some 18 years after the initial impacts were first examined.

REMOVAL OF IN-STREAM HABITAT

In the ACT there has been little direct removal of in-stream habitat (such as the removal of logs from rivers and channelisation) as has occurred in lowland streams elsewhere in Australia (Koehn and O'Connor 1990a; MDBC 2004a).

4.4.2 Barriers to Fish Passage

It is estimated that there are now more than 4000 barriers to fish passage (weirs or dams) within the Murray–Darling Basin (MDBC 2004a). These 'river regulation' structures have had a significant deleterious impact on fish populations in the Basin. As well as major barriers, there is a plethora of minor barriers such as culverts and road crossings. Uniform channels (such as urban creeks) with no shelter from high water velocities may also pose passage problems for some fish species.

The unimpeded passage of fish throughout streams is crucial for spawning migrations, recolonisations, general movement and habitat selection (Koehn and O'Connor 1990a). For example, Golden Perch *Macquaria ambigua* are migratory, with adult and juvenile movements thousands of kilometres upstream being recorded, though migratory movements are usually much shorter. Murray Cod *Maccullochella peelii peelii* move up to 120 km upstream to spawn, on late winter/early spring high river levels, then return to the same area (Koehn 1997).

EFFECTS OF BARRIERS TO FISH PASSAGE IN THE UPPER MURRUMBIDGEE RIVER CATCHMENT

Two-spined Blackfish: This is not thought to be a migratory species and barriers to movement are unlikely to have played a substantial role in its decline (ACT Government 1999a; Lintermans 2002).

Trout Cod: The biology of Trout Cod is not well understood, but it appears to inhabit deep pools with in-stream cover (logs, boulders) and does not have a substantial spawning migration. However, it is known that this species can make significant exploratory movements of tens of kilometres. Barriers to movement are likely to have played a lesser role in the decline of this species, but have probably affected dispersal and recolonisation after substantial disturbance (ACT Government 1999b; Lintermans 2002).

Macquarie Perch: Construction of dams and other structures on ACT rivers and on the Queanbeyan River has fragmented the population of Macquarie Perch. Scrivener Dam effectively isolated the Molonglo and Queanbeyan rivers from the Murrumbidgee River and has prevented any recolonisation. The construction of Cotter Dam in 1915 also isolated the Cotter River population from the Murrumbidgee River stock. The Cotter River has three major impoundments. Macquarie Perch is now largely confined to the Cotter Reservoir and the 5.5 km stretch of river between the backed-up waters and Vanitys Crossing. The species was unable to traverse the concrete ford constructed at Vanitys Crossing in the late 1970s. The construction of a rock-ramp fishway at the Crossing in 2002 has allowed the species to commence colonisation of the river reach between the crossing and Bendora Dam, but the extent of this colonisation is currently unknown. The steeper gradient of the river downstream of the crossing, coupled with the reduction in flows caused by river regulation, is thought to have exacerbated fish passage problems posed by a number of natural barriers such as rock bars and cascades. These barriers are thought to severely restrict the capacity of fish in the reservoir to access the fishway at Vanitys Crossing (Lintermans 2004c).

On the Queanbeyan River, the construction of Googong Dam resulted in the flooding of all available Macquarie Perch spawning sites for a remnant population of this species. In addition, the species is unable to reach the river above the reservoir because of a waterfall, Curleys Falls, that forms a natural barrier to upstream movement (Lintermans 2003).

Silver Perch: This species matures at 3–5 years and spawns in spring and summer after an upstream migration when large schools often form. The construction of the Burrinjuck Dam in the 1920s effectively isolated the upper Murrumbidgee catchment from downstream populations, Scrivener Dam isolated the Molonglo and Queanbeyan rivers, and Cotter Dam isolated the Cotter River. The former ‘run’ of Silver Perch upstream from Lake Burrinjuck has not been recorded since the early 1980s (Lintermans 2002).

4.4.3 Reduction in Floodplain Habitat

The ACT is located in an upland area of the Murrumbidgee River catchment where floodplain development is not part of the morphology of the river. Reduction in this habitat is significant, however, for the overall decline in species found throughout the Murray–Darling Basin (MDBC 2004a). Two ACT threatened aquatic species (Macquarie Perch and Two-spined Blackfish) inhabit cooler upland waters not associated with floodplains while the remainder are more widely distributed into the lowland areas. Loss of floodplain habitat along with other impacts is likely to have been a contributing factor in the decline of the Trout Cod in lowland rivers such as the Murray, Macquarie and lower Murrumbidgee rivers where woody debris in backwaters and flood channels may have been a favoured spawning and larval development habitat.

4.4.4 Alterations to Flow Regimes above and below Dams and Weirs

The construction of dams and weirs has a severe effect on the quality of fish habitat through the modification of both the natural flow regimes and water quality of rivers below these structures. The effect of some dams (e.g. Corin Dam and Burrinjuck Dam) on downstream river flows is to partially reverse the seasonal nature of flows as water from autumn to spring rain and snow-melt is collected and stored for release in summer for irrigation or peak domestic water demand. Peak flows would have originally occurred in late winter to early summer with streams falling to a pool and riffle sequence in late summer. These former large flows and rising water temperatures are thought to have provided the natural environmental ‘cues’, as well as a sufficient water level, for upstream spawning migrations of species such as Murray Cod, Golden Perch, Silver Perch and Macquarie Perch, although some of these species are known to spawn under low-flow conditions (Humphries *et al.* 1999).

Other ACT and region impoundments such as Bendora, Cotter and Googong reservoirs (domestic water supply) and Lake Burley Griffin (ornamental) have a different impact in that insufficient water is released to maintain suitable environmental conditions in the rivers downstream. Long periods of low flow result in reduced water quality, altered channel morphology and significant changes to riparian vegetation, in particular, infestation of willows and other pest species. The quality of water released is also a problem in that it may be released from the lower levels of the reservoir and is much colder than the surface waters. Temperature is now more tightly controlled in dam releases from ACT water storages and a new eWater project should provide more information on the impacts of ACT releases. Bottom-release water may also be deoxygenated, and contain high levels of iron, manganese and other minerals liberated from sediments (e.g. see s. 4.4.6 in relation to Scrivener Dam).

The large areas of still water created by dams may also have an impact on the egg and early larval stages of fish species and flood suitable spawning areas. Macquarie Perch is dependent on high quality habitat, with access to spawning gravels in flowing waters essential for successful reproduction. The construction of Googong Dam resulted in the flooding of the majority of suitable spawning areas in the Queanbeyan River. Regular monitoring of fish stocks within the impoundment showed that the species was not recruiting. Consequently in 1980, 57 individuals were captured and translocated past a natural barrier on the Queanbeyan River upstream of the impounded waters. This translocation is the basis of the remnant population now present in the Queanbeyan River above the reservoir (Lintermans 2003). Construction of the three dams on the Cotter River also probably resulted in the flooding of suitable spawning areas. In the case of Silver Perch, the drifting semi-buoyant eggs and newly hatched larvae may settle in unfavourable habitats such as the backed up waters of dams and weir-pools, making them susceptible to sedimentation and low oxygen levels.

A major effect of fewer and smaller high flow events below dams is a build up of sediments (particularly finer material) that previously would have been scoured out of the riverbed. The effects of such sedimentation have been discussed above.
Low-flows downstream of dams can also result in previously insignificant natural channel characteristics (e.g. rock bars, chutes) becoming significant fish passage barriers.

4.4.5 Thermal Pollution

Thermal pollution is increasingly being recognised as having significant impacts on aquatic ecosystems (Lugg 1999; Phillips 2001; Astles *et al.* 2003; Preece 2004; Ryan *et al.* 2003). Thermal (or cold-water) pollution occurs when cold-water from the bottom layers of large reservoirs is released to streams. The water stored in large reservoirs tends to stratify between spring and autumn, with a warm surface layer (the epilimnion) overlying cold bottom layers (the hypolimnion). The hypolimnion can be 12–15°C colder than surface water temperatures (Astles *et al.* 2003). Many dams only have release valves or outlets that draw water from the hypolimnion, or for dams with multi-level off-takes, current operating practices mean that water has been preferentially drawn from the lower levels. Thermal pollution can have severe effects on growth, activity, survival and reproduction of aquatic organisms.

The release of a cold slug of water during the breeding season is thought to inhibit spawning behaviour of Silver Perch and other native fish species. Macquarie Perch respond to increasing water temperature associated with late spring to early summer flows as a cue to commence spawning (Llewellyn and MacDonald 1980; Cadwallader and Backhouse 1983). Koehn *et al.* (1995) found that two separate populations of the species in the Mitta Mitta River, Victoria, have disappeared since the construction of Dartmouth Dam from 1973–80. The demise of the Macquarie Perch and Murray Cod in this river is attributed to the effects of cold-water releases from the dam during the spawning season. Cold-water pollution can also delay the occurrence of critical thermal cues to initiate spawning, resulting in a reduced growing season for larval and juvenile fish before the onset of winter. Such delays can mean that juvenile fish are smaller when entering winter, potentially exposing them to increased risk of predation, particularly where cold-water species such as trout are present.

Astles *et al.* (2003) reported that Silver Perch grown in cold-water treatments for 31 days were approximately half the weight of those from warm-water treatments, and that three times as many fish survived in the warm-water treatment. Similarly, Murray Cod held for three months at 12.6°C did not increase in weight, whereas fish held at 21.2°C tripled in weight over the same period (Ryan *et al.* 2003).

Thermal pollution is a significant issue in the Cotter catchment, where there are two large dams (Corin and Bendora) and four threatened fish species. A recent study has demonstrated that the growth rate of Two-spined Blackfish was significantly less under cold-water conditions simulating thermal pollution (Hall 2005). Reduced growth rates mean that small fish will remain for a longer time-period in the size-class susceptible to predation, thus exacerbating the impacts of alien predators (see s. 4.6.2).

4.4.6 Reduction in Water Quality

Water provides dissolved oxygen for respiration, appropriate temperatures for metabolism and a flow of nutrients through the ecosystem. Reduction in water quality in the Murray–Darling Basin is due to increased nutrients, turbidity, sedimentation, salinity, artificial changes in water temperature, pesticides and other contaminants (MDBC 2004a). While fish deaths due to short-term toxic spills are readily recognisable, sub-lethal water pollution and long-term changes to water quality parameters are less obvious in their effects.

River regulation, including dams and reservoirs in particular, has the capacity to seriously alter these parameters. The effects of seasonal flow reversal and low water temperatures from bottom releases from dams have been referred to above. These bottom releases are usually low in dissolved oxygen and may have excessive nutrient loads due to release of nutrients from bottom sediments under anaerobic conditions, as in the case of low to normal flow releases from Lake Burley Griffin through Scrivener Dam (NCPA 1995). In some instances impoundments may also act as nutrient traps by allowing organic particles that normally flow down the stream to settle out. Consequently, the water released downstream is not as rich in nutrients as the inflow to the storage and the productivity of the stream may be reduced (Koehn and O'Connor 1990a).

Evidence is now well established of another significant threat to water quality, the addition of endocrine disrupting chemicals to waterways. Endocrine disrupting chemicals cause adverse effects by interfering with hormones, either disrupting normal hormone function, or mimicking hormones to give an unnatural response. Research has shown the impacts of endocrine disruptors on aquatic fauna such as frogs, mussels and fish (Jobling *et al.* 1998; Matthiessen *et al.* 2002; Quinn *et al.* 2004; Rodgers-Gray *et al.* 2001, 2002; Solé *et al.* 2002; Sonnenschein and Soto 1998).

A wide variety of chemicals released into the aquatic environment are believed to disrupt normal endocrine function in fish, thereby causing reproductive disorders and abnormalities (Sumpter 2002). Potentially, they could have a severe impact on the ability of species to successfully reproduce. One group of endocrine disruptors is the environmental oestrogens that can mimic the female hormone, oestrogen. Major sources of environmental oestrogens are pesticides, detergents and prescription drugs such as antibiotics. These chemicals enter waterways either via runoff from agriculture, or discharge of treated sewage effluent. In the ACT, Kalish (1999) demonstrated, through cell assays, oestrogenic activity in discharge from the Lower Molonglo Water Quality Control Centre (the sewage treatment works for the ACT), but there has been no follow-up work on fish in the Molonglo or Murrumbidgee rivers. It is unlikely to be an issue for the Cotter River. Endocrine disruption represents a threat to Australian aquatic life and further investigation is urgently required (Lintermans 2002).

Reductions in water quality that are likely to have had major effects on fish in the ACT and region are addition of sediment (see s. 4.4.1) and the catastrophic pollution of the Molonglo River following the collapse of slimes dumps at the Captains Flat mine in 1939 and again in 1942. These collapses released large quantities of heavy metals including zinc, copper and lead, which virtually removed the entire fish population in the Molonglo River (Joint Government Technical Committee on Mine Waste Pollution of the Molonglo River 1974). The river is still unable to support fish life for at least 15 km downstream of Captains Flat, an area that would probably have supported populations of Macquarie Perch, Golden Perch, Murray Cod and Murray River Crayfish prior to the collapse of the mine dumps.

4.5

Over-exploitation

Over-exploitation is an important contributor to the decline of native fish stocks across the Murray–Darling Basin. Historically, a commercial fishery operated, which responded opportunistically to seasonal changes in flow conditions. Murray Cod, Golden Perch, Silver Perch and Common Yabby (*Cherax destructor*) were the main species sought (Reid *et al.* 1997). There is no longer a riverine native fish based commercial industry in the Murray–Darling Basin (except for Common Yabby) with the last of the operators ceasing in 2003. Commercial fishing is not known to have operated in the ACT. Illegal take of threatened fish species and illegal 'trade' (barter or sale) in some recreationally desirable species (e.g. Murray Cod and Murray River Crayfish) still occurs in the Canberra region and is an ongoing threat.

Recreational angling is popular on inland rivers and lakes (including in the ACT) and can place significant pressure on fish stocks, especially threatened species. The National Recreational and Indigenous Fishing Survey (Henry and Lyle 2003) concluded that approximately 566 000 recreational fishers fished in the Murray–Darling Basin during the 12 month period prior to May 2000. In the ACT an estimated 53 500 fishers (19.2 per cent of the population) took an annual catch of 35 735 fin fish and 19 936 freshwater crayfish within the Territory. Golden Perch was the most commonly caught native species, comprising 16 per cent of the total catch. Overfishing has been shown to be important in the decline of many native fish and crayfish species including the threatened Macquarie Perch (Cadwallader 1978a; Harris and Rowland 1996), Trout Cod (Douglas *et al.* 1994; Berra 1974), Murray Cod (Rowland 1989; Jackson *et al.* 1993) and the Murray River Crayfish. While the major impact on Silver Perch is thought to have been river regulation, intense fishing pressure was often applied during its upstream 'runs' (Lintermans 2002). Overfishing was cited as one of the contributing factors in the decline of blackfish in Victoria in the late 1800s (Lewis 1917; Roughley 1953), however, Two-spined Blackfish is unlikely to have been affected by overfishing as its small size means it is generally not sought by anglers. Most captures are probably accidental (ACT Government 1999a). Under the provisions of the ACT *Fisheries Act 2000*, fishing is prohibited in the Cotter River catchment above Bendora Dam, thus providing some protection for Two-spined Blackfish.

Berra (1974) in discussing the now locally extinct 'wild' ACT Trout Cod population noted that the ACT was subject to heavy angling pressure directed primarily at Murray Cod. As Trout Cod was only described as a separate species in 1972, it is highly likely that anglers would not have distinguished between the two cod species, and that anglers took many Trout Cod individuals.

Macquarie Perch has been sought after as an angling species, and previously, heavy pressure was placed on its spawning runs (Battaglene 1988; Cadwallader and Rogan 1977). Illegal fishing of small remnant populations probably remains a threat, including targeting of spawning runs. Surveys of the population in the Queanbeyan River (above Googong Reservoir) in the 1990s showed that the abundance of the species increased with increasing distance from easy public access, suggesting that the population was still being illegally fished (ACT Government 1999c).

Murray River Crayfish is a sought after species in NSW and Victoria that has been overfished (Geddes 1990). Even though the species has been protected by bag, size and gear limits in NSW for many years, the species is still illegally targeted, particularly in the reservoirs on the Tumut River (ACT Government 1999d). The crayfish are particularly abundant in Blowering Reservoir and Jounama Pondage where they are actively sought by anglers in the cooler months (Lintermans and Osborne 2002). Regulations introduced in NSW from 2000, including an increased minimum size limit, and smaller bag limits, along with a closed season from September to April inclusive will assist in protecting these populations

In the ACT, overfishing is considered a major factor in the decline of Murray River Crayfish. Surveys of the Murrumbidgee River in the late 1980s found the abundance and size of crays at individual sites to be inversely proportional to the ease of recreational access (and hence fishing pressure), with the majority of large crays removed from one site in a twelve month period (Lintermans and Rutzou 1991). Based on monitoring data (Environment ACT), there has been some recovery of ACT populations following their protection under the *Nature Conservation Act 1980*.

4.6

Alien Species

In Australia, with regard to fish and crayfish species, the term 'alien' has largely replaced the term 'exotic'. Alien fish/crayfish species are those from both other countries and other parts of Australia, which have been intentionally or accidentally dispersed by human agency outside their historically known native range (Koehn and MacKenzie 2004). Currently, the known major detrimental impacts derive from the introduction and establishment (formation of self-sustaining populations) of species from other countries rather than native species. Little is known of the impacts of alien native species.

In the Murray–Darling Basin, eleven alien fish species from other countries are established and make up a quarter of the Basin's total fish species. Nine of these species have established populations or have been recorded in the upper Murrumbidgee catchment of the ACT and region (Lintermans 2002; MDBC 2004a). These are listed in Table 4.3 with information on their origin, distribution and abundance in the Upper Murrumbidgee Catchment, and impacts on native species. The two species not established or ever recorded in the ACT are Tench (*Tinca tinca*), found at lower elevations in the Murray–Darling Basin, and Roach (*Rutilus rutilus*), which occurs in Victoria.

There are also two native fish species present in the Murray–Darling Basin that are not native to the Basin's rivers. The Broad-finned Galaxias (*Galaxias brevipinnis*) has been transferred to the upper Murray drainage by the Snowy Mountains Scheme and has been recorded recently in a tributary of the Tumut River, the first record for the Murrumbidgee drainage (Lintermans and Osborne 2002). The other species is Spotted Galaxias (*Galaxias truttaceus*), found in a Victorian tributary of the Murray River, which was probably introduced via bait-bucket transfers (Lintermans 2004a).

Table 4.3: Alien Fish Species (Excluding Natives) in the Murray–Darling Basin and the Upper Murrumbidgee Catchment

Fish Species	Origin, Distribution and Abundance in the Upper Murrumbidgee Catchment	Impacts on Native Species
Family: Salmonidae (Salmons, Trouts, Chars)		
Rainbow Trout (*Oncorhynchus mykiss*)	Origin: North America. Established in the majority of rivers of ACT and region. Found throughout catchments including smallest headwater streams. Survival poor in urban lakes and no longer stocked.	Species has had a significant impact (predation) on the distribution and abundance of native Mountain Galaxias with galaxids unable to survive where trout are present. Carrier of parasitic copepod *Lernaea* sp. Likely significant predators on larval stages of riverine frog species (see s.4.6.2).
Brown Trout (*Salmo trutta*)	Origin: Europe and western Asia. Prefers cool upland streams and lakes and is found in most suitable streams in the region. Not suitable for ACT urban lakes. No longer stocked at Googong Reservoir or streams where threatened native species known to be present. Stocked in lakes throughout region.	Species has had a significant impact (predation) on the distribution and abundance of native Mountain Galaxias. Suspected of having deleterious impacts on threatened fish species such as Trout Cod and Macquarie Perch. May feed on juvenile Murray River Crayfish. Carrier of parasitic copepod *Lernaea* sp. Likely significant predators on larval stages of riverine frog species (see s.4.6.2).
Atlantic Salmon (*Salmo salar*)	Origin: Rivers draining to North Atlantic ocean. Stocked into Lake Jindabyne and Burrinjuck Dam, no natural recruitment. Occasional unconfirmed angler reports from Murrumbidgee River but mis-identification likely (with Brown Trout).	Not considered a threat in the ACT.
Brook Char (Brook Trout) (*Salvelinus fontinalis*)	Origin: East coast North America. Cool water species of clear streams and lakes that does not coexist well with other salmonids. Stocked in ACT urban lakes in 1970s. Has also been stocked into Lake Burrinjuck.	No known surviving population in the ACT.
Family: Cyprinidae (Carps, Minnows, etc.)		
Goldfish (*Carassius auratus*)	Origin: Eastern Asia. Associated with warm, slow-flowing lowland rivers and lakes. Abundant after filling of Canberra's urban lakes but declined after stocking of predatory fish. Widespread throughout region.	Goldfish in the ACT region often heavily infected with the parasitic copepod *Lernaea* sp. A consignment of Goldfish from Japan to Victoria is believed to have brought in the disease 'Goldfish ulcer' that also affects salmonid species such as trout. Otherwise few or no adverse impacts have been documented for this species.
Carp (European Carp, Common Carp, Koi Carp) (*Cyprinus carpio*)	Origin: Central Asia. Usually associated with warm, slow-flowing lowland rivers or lakes. Tolerant of a wide variety of environmental conditions including low levels of dissolved oxygen. Widespread in ACT and region. Not yet established in Googong Reservoir. Form ~ 70% of fish biomass in ACT rivers and 70–90% of fish biomass in Canberra's urban lakes.	Now the dominant species in the Murray–Darling Basin and likely to compete with native species for food and space. Feeding behaviour 'mumbling' in sediments raises turbidity. Carp carry the parasitic copepod *Lernaea* sp. that affects other native and introduced species.
Family: Cobitidae (Loaches)		
Oriental Weatherloach (*Misgurnus anguillicaudatus*)	Origin: Central and eastern Asia. Imported as an aquarium fish from the 1960s, detected in the wild in 1984 and importation banned in 1986. Found in slow-flowing or still water with sand or mud substrates. They occur in habitats ranging from degraded rural and urban streams to relatively pristine headwater streams. Found in streams and some lakes throughout ACT and region. Illegal use as live bait by anglers considered significant factor in their spread.	Impacts on native species have not been studied. Diet has significant overlap with that of native Mountain Galaxias. Their feeding habits indicate they may be an egg predator of some native fish species. Weatherloach are known to carry a range of parasites not previously recorded in Australia.

Table 4.3: *(Continued)*

Fish Species	Origin, Distribution and Abundance in the Upper Murrumbidgee Catchment	Impacts on Native Species
Family: Poeciliidae (Livebearers)		
Eastern Gambusia (Mosquito Fish) (*Gambusia holbrooki*)	Origin: Rivers draining Gulf of Mexico. Widely distributed throughout Australia and widespread in warmer lowland waters in the ACT and region. Not generally recorded from higher cooler waters but can survive if introduced. Tolerant of wide range of environmental conditions, breed rapidly and assume plague proportions in many habitats.	An aggressive species that will chase and fin-nibble tadpoles and fish much larger than themselves. Prey on eggs of native fish and amphibians. Implicated in the decline of 30 species world-wide (nine in Australia). Listed as a key threatening process for amphibian populations in NSW and implicated in decline of more than 10 frog species in Australia.
Family: Percidae (Freshwater Perches)		
Redfin Perch (*Perca fluviatilis*)	Origin: Cool temperate waters of Northern Hemisphere. Mainly occurs in slow flowing or still water where there is aquatic vegetation. Present in ACT urban lakes, Googong Reservoir and Murrumbidgee River (upstream to Tharwa). Not recorded from Naas, Gudgenby or Orroral rivers, or the Cotter River upstream of Cotter Dam.	Known to prey on native Western Carp Gudgeon (*Hypseleotris klunzingeri*) and possibly juvenile Murray River Crayfish. Redfin Perch is the main host for a virus, Epizootic Haematopoietic Necrosis Virus (EHNV) first isolated in 1985 and unique to Australia. It causes sudden high mortalities in fish. Experimental work has shown that Macquarie Perch, Silver Perch and Mountain Galaxias are extremely susceptible to the disease. The virus also affects trout species, which can act as vectors to spread the disease.

(Sources: Koehn and O'Connor 1990a; Lintermans 2000a; Lintermans 2002; Lintermans and Osborne 2002)

Detrimental effects of alien fish species on native fish populations derive from:

- competition for food and habitat (spawning areas, territory);
- predation;
- introduction and spread of diseases and parasites; and
- habitat degradation.

The establishment of alien fish species is often cited as a cause of native fish declines in Australia, however there is little scientific documentation of this. This is because the majority of alien species (in particular, predatory trout and the Redfin Perch) became established in the mid to late 1800s when the distribution and abundance of native fish was poorly known or documented and 'acclimatisation' was seen as a way of enhancing Australia's fauna, which was assumed by some to be deficient. Salmonid (mainly Brown Trout and Rainbow Trout) stocking has a long history of community and government support without attention to assessing and managing the potential environmental impacts (Jackson *et al.* 2004). Past probable negative impacts, e.g. predation on fish, frogs and spiny crayfish by salmonids are inferred from current knowledge as well as the fact that these species have colonised almost the entire catchment in cooler upland areas of Australia. There is a small number of scientific studies that clearly support the inferred impacts of trout on native galaxid species (Fletcher 1979; Lintermans 2000b; Tilzey 1976).

In the case of Carp, now the dominant species in the Murray–Darling Basin, many native species were already well in decline by the time Carp began their rapid expansion in the late 1960s and 1970s. Increases in Carp populations were probably facilitated by the already reduced native fish populations, rather than the commonly held perception that Carp caused these declines (Koehn *et al.* 2000). In turn, the major causes of the decline in native fish species have been river regulation and habitat degradation, resulting in waterways suited to Carp but much less suited to native species. In this way Carp may be seen as a symptom of river degradation rather than a cause.

4.6.1 Competition for Food and Habitat

Competition between newly introduced species and native species is believed to be common but is difficult to demonstrate (Li and Moyle 1993 in Koehn *et al.* 2000). Competition occurs when the niches of two or more species overlap and food and/or habitat are limited in some way that requires the species to compete for particular survival requirements.

Dietary overlap is one consideration, but the important factor is whether the food sources are in such limiting amounts so as to cause competition (Koehn *et al.* 2000). The diets of trout and Redfin Perch are similar to those of many native species, particularly freshwater blackfish, Murray Cod and Golden Perch. In the ACT, dietary overlap has been recorded between Two-spined Blackfish and Rainbow Trout (Lintermans 1998a) and between Mountain Galaxias and Oriental Weatherloach (Lintermans and Osborne 2002). Competition may also occur between Macquarie Perch and Carp, Redfin Perch and trout (Battaglene 1988; Butcher 1945; Jackson 1981; Cadwallader 1978a; Lintermans 2006a). Overlap in the diet of Carp with small native fish such as Australian Smelt (*Retropinna semoni*) and Western Carp Gudgeon (*Hypseleotris klunzingeri*) has been reported. It is possible that Carp have an advantage over other species by early spawning, which gives larvae and juveniles access to food earlier than native species that spawn later (Roberts and Ebner 1997). However, such competition for limited food resources has not been demonstrated (Koehn *et al.* 2000).

There is little information on competition for spawning sites and territory. Two-spined Blackfish appears to be able to coexist with trout in its preferred habitat, but its ability to do so in sub-optimal habitats is unclear (ACT Government 1999a). This coexistence is probably due to utilisation of different habitats, as trout prefer faster flowing waters and blackfish slower flowing waters (Koehn and O'Connor 1990a).

There has been speculation on the effects of habitat interactions between Carp and other species, but these have not been quantified. Koehn and Nicol (1998) found overlap in habitat use by Carp and native species, with both using snags and areas of slower flowing water. Harris (1997) suggested that Carp have been able to utilise under-used aquatic habitat, resulting from the decline of native species. However, the large numbers, large size and density of Carp may be placing behavioural pressures on smaller native species forcing them from preferred habitats. Concern has been expressed that Carp may interfere with the nesting sites of Freshwater Catfish (*Tandanus tandanus*), affecting spawning, guarding of nests and survival of deposited eggs (Koehn *et al.* 2000). Benthivorous feeding and destruction of aquatic vegetation by Carp may reduce the suitability of habitat for native fish species.

Murray River Crayfish are potentially threatened by non-local crayfish species such as Marron (*Cherax tenuimanus*) and Redclaw (*C. quadricarinatus*) should they become established in the ACT. There is now extensive movement of crayfish species throughout Australia associated with aquaculture.

4.6.2 Predation

Murray Cod were formerly the top predators in the larger, lowland streams of the Murray–Darling Basin with Trout Cod and Golden Perch also predatory on other fish. In the upland streams, Two-spined Blackfish and Macquarie Perch would have been the top predators until the arrival of the alien trout species. Amongst the alien species found in the Upper Murrumbidgee catchment, Koehn and O'Connor (1990a) describe Brown Trout, Rainbow Trout and Redfin Perch as 'voracious predators' and native species may form a large part of their diet.

In upstream waters like the ACT, Brown Trout and Rainbow Trout have been clearly identified as predators of Galaxiidae with the latter eliminated from many streams (Tilzey 1976; Frankenberg 1966, 1974; Fletcher 1979; Cadwallader 1979; Cadwallader and Backhouse 1983; Jackson 1981; Jackson and Williams 1980; Lintermans and Rutzou 1990a; Lintermans 2000b). In such situations galaxiids are generally only found above waterfalls or swamps that prevent trout access. An experiment to remove Rainbow Trout from a section of Lees Creek (Brindabella Range) in the ACT has resulted in the recolonisation by galaxiids of the trout-free section of the stream (Lintermans 2000b). However, Rainbow Trout are still expanding their range in the ACT, recently becoming established above Gibraltar Falls and threatening the local population of Mountain Galaxias. This range expansion required human assistance, as the falls are too high to be bypassed naturally. It is unknown what impact trout have had on Murray River Crayfish, but predation on juvenile and immature crays is likely.

Brown Trout are suspected of having deleterious impacts on the threatened species, Trout Cod and Macquarie Perch (Wager and Jackson 1993). Consequently, Brown Trout are no longer stocked in Googong Reservoir (where there is an existing trout population from earlier stocking) or streams of the Upper Murrumbidgee catchment in which threatened species are known to be present (Lintermans 2002; NSW Fisheries 2003). Trout predation on tadpoles exerts significant population pressure on some riverine frog species and is probably a major factor in causing the low density of some species in upland streams (Gillespie and Hero 1999; Gillespie and Hines 1999).

The diet of Redfin Perch includes crustaceans, zooplankton and small fish. In the ACT region, the species is known to prey on the native Western Carp Gudgeon (*Hypseleotris klunzingeri*), Murray Cod and the alien Eastern Gambusia, and is suspected to prey on Macquarie Perch. The Western Carp Gudgeon is abundant in ACT urban lakes and the population in Lake Burley Griffin appears to have increased following depletion of the Redfin Perch population by the Epizootic Haematopoietic Necrosis Virus (EHNV) (Lintermans and Osborne 2002). Redfin Perch are a potential threat to remnant populations of threatened species such as the small populations of Macquarie Perch located in the Queanbeyan River above Googong Reservoir, and in the Cotter Reservoir. Redfin Perch are currently not known from the either of these two locations. Redfin Perch may also prey on juvenile and immature Murray River Crayfish.

Carp are often accused of damaging populations of native fish by feeding on their eggs and larvae or eating whole fish. However, the evidence available and the feeding morphology (mouth shape and location, and type of teeth) of Carp suggest that fish are a negligible component of carp diets (Koehn *et al.* 2000). Eastern Gambusia is an aggressive species that has been implicated in the decline of many fish species and feeds on the eggs of native fish and amphibians (Table 4.3).

4.6.3 Introduction and Spread of Diseases and Parasites

A potentially serious impact of alien species is their capacity to introduce or spread (mostly foreign) diseases and parasites to native fish species. Carp or Redfin Perch are considered to be the source of the Australian populations of the parasitic copepod *Lernaea cyprinacea* (Langdon 1989a). This copepod has been recorded on trout and Goldfish (*Carassius auratus*) as well as a number of native fish species in the Murray–Darling Basin, including Murray Cod, Golden Perch, Silver Perch (Langdon 1989a), Macquarie Perch, and Mountain Galaxias (M. Lintermans. unpubl. data). *Lernaea* has been recorded on Peron's Tree Frog (*Litoria peroni*) in the Cotter River (Lintermans unpubl data), and may infect other stream-dwelling frog species in the ACT. Carp are susceptible to a range of parasites and disease organisms, some of which are known to occur in native fish (see Koehn *et al.* 2000).

Carp, Goldfish or Eastern Gambusia are probably implicated as the source of the Asian fish tapeworm *Bothriocephalus acheilognathi*, which has been recorded in native fish species in the ACT (Dove *et al*. 1997). This tapeworm causes widespread mortality in juvenile fish overseas and may have similar effects on local native species. The tapeworm has low host-specificity at both stages of its life cycle with the adult stage recorded from at least 50 species of fish in five taxonomic orders (Dove *et al.* 1997).

The most serious disease threat from alien fish species may lie in the impacts of Epizootic Haematopoietic Necrosis Virus (EHNV). This virus, unique to Australia, was first isolated in 1985 on Redfin Perch (Langdon *et al.* 1986). It is characterised by sudden high mortalities of fish, which display necrosis of the renal haematopoietic tissue, liver spleen and pancreas (Langdon and Humphrey 1987). The disease also affects trout species and these can act as vectors. Experimental work by Langdon (1989a, b) demonstrated that Silver Perch and Macquarie Perch were two of several species found to be extremely susceptible to the disease, but other native species such as Trout Cod and Two-spined Blackfish have not been examined for susceptibility.

EHNV was first recorded from the Canberra region in 1986 when an outbreak occurred in Blowering Reservoir near Tumut (Langdon and Humphrey 1987). Subsequent outbreaks have occurred in Lake Burrinjuck in late 1990, Lake Burley Griffin in 1991 and 1994, Lake Ginninderra in 1994 and Googong Reservoir, also in 1994 (Lintermans 2000a; Whittington *et al.* 1996). Its robust characteristics and the ease with which it can be transmitted from one geographical location to another on nets, fishing lines, boats and other equipment have aided the spread of EHNV. Langdon (1989b) found that the virus retained its infectivity after being stored dry for 113 days. Once EHNV has been recorded from a water body it is considered impossible to eradicate.

The Murrumbidgee River and Googong Reservoir populations of Silver Perch and Macquarie Perch have been exposed to the virus. It is highly likely the Queanbeyan River population of Macquarie Perch (upstream of Googong Reservoir) has been exposed through the movement of infected adult trout between the reservoir and the river. It is now speculated that the sudden and severe depletion of the Lake Eildon (Victoria) Macquarie Perch population may have in part been due to EHNV (Langdon 1989b).

The Cotter River and reservoirs above Cotter Dam are not affected by EHNV, and restrictions or prohibitions on recreational fishing in these river sections are aimed at maintaining that status by preventing the establishment of Redfin Perch.

4.7

Translocation and Stocking (Native Fish)

As natural populations of native fish have declined, there has been growing interest in aquaculture of native species and stocking of waterways with hatchery-bred native fish. Stocking has enabled the maintenance of recreational fisheries, especially in artificial lakes, where natural breeding is rarely possible because of unsuitable habitat and barriers to upstream movement to potential spawning areas. The presence of these stocked fish may assist in reducing angling pressure on remnant natural populations. Artificially propagated native fish have been used to rehabilitate depleted populations of a number of threatened fish species in south-eastern Australia (see Lintermans *et al.* 2005). In the ACT, hatchery bred Trout Cod have been released into Bendora Reservoir and the Murrumbidgee River at Angle Crossing as part of a National Recovery Plan. However, the composition and evolution of naturally occurring native fish populations can be threatened by the liberation of fish outside their natural range or stocking from hatcheries (MDBC 2004a; Phillips 2003).

Natural populations of native fish are threatened by the potential release of genetically restricted material from native fish aquaculture or stocking with hatchery-bred fish using limited brood stock. The release of such material has potential to reduce the genetic fitness and hence viability of fish populations especially where the existing wild population is small in number (Harris 1997; MDBC 2004a). Large numbers of hatchery fish added to a small residual wild population can out-compete the wild fish for food and habitat (Harris 1997). Stocking and translocation also have the potential to introduce diseases and unwanted species, inadvertently included in hatchery supplied fish consignments. The apparent success of hatchery breeding of native fish and their growth in stocked waterways potentially draws attention away from the need to conserve natural populations.

Human assisted dispersal of fish (both deliberate and inadvertent) is widespread (Lintermans 2004a). All Australian States and Territories have adopted the *National Policy for the Translocation of Live Aquatic Organisms* (MCFFA 1999). The ACT has a *Fish Stocking Plan* (Environment ACT 2000a) that sets out principles for fish stocking in the ACT, and a five-year rolling stocking program for urban lakes.

4.8

Localised Threats

4.8.1 Impacts of the 2003 Bushfires in the ACT

In 2003 bushfires burnt 70% (164 914 hectares) of the ACT including 90% of Namadgi National Park (Cotter, Gudgenby, Naas rivers) and Tidbinbilla Nature Reserve (Tidbinbilla River). The fires also affected the Murrumbidgee River Corridor, and the Lower Molonglo Nature Reserve. The geographic extent and severity of the fires was unprecedented in the ACT and is likely to have significant short and long-term consequences for the natural ecosystems of the Territory (Carey *et al.* 2003). Impacts of bushfire on aquatic communities can include:

- Sedimentation from denuded catchments following rain events.
- A decrease in dissolved oxygen concentrations as organic material (leaves, ash) washed into streams following rain events begins to decompose.
- Chemical changes in water quality as ash is deposited in streams.
- Impacts from the loss of the riparian (streamside) vegetation including:
  - —loss of food resources because there is no insect fall from overhanging vegetation;
  - —increase in water temperature due to lack of shade; and
  - —increase in algal abundance due to increased sunlight reaching the stream.
- Increased algal growth due to increased nutrient load.
- Changes to streamflow patterns as upland swamps and bogs (sponges/filters) are damaged and runoff increases after rainfall because there is no vegetative cover remaining.

Studies on the Cotter River have shown that river regulation has exacerbated the effects of the fires and sediment addition. A North American study documented increases in summer water temperatures of 8–10 °C following fire, due to the increased light reaching streams as a result of the removal of riparian vegetation (Minshall *et al.* 1989). Such a rise could have significant effects on cool water species such as the Two-spined Blackfish, which only occurs in the Cotter River Catchment in the ACT (Lintermans 2002; Lintermans and Osborne 2002) and has a restricted distribution in the Canberra region.

A total of almost 840 km of streamside vegetation was burnt in 2003 with a relatively even split between three categories of burn severity (Table 4.4). Only 30.8% of stream length would have retained its riparian canopy cover as the vegetation in the 'Very High' and 'High Severity' categories lost its canopy during or post-fire.

Table 4.4: Length (km) of Stream Within the Burnt Area in Three Fire Severity Categories Following the 2003 Bushfires in the ACT

Fire Severity Category	Length of Stream (km)	Percent of Stream Length
Very High	291.95	34.8
High	288.3	34.4
Moderate to Low	258.41	30.8

(Source: Carey *et al*. 2003, p. 50)

Inputs of sediment and ash can cause fish kills, and significantly change habitat leading to reduction in available food supplies (aquatic and riparian macro-invertebrates), reduction in breeding opportunities for fish (smothering of spawning sites), and increased vulnerability to predators (trout and cormorants). Although no fish kills were recorded for the Cotter catchment upstream of Cotter Reservoir, fish kills were recorded in the Murrumbidgee River and the Cotter River below Cotter dam following local rainfall events (Carey *et al.* 2003). It is likely that other localised fish kills caused by the fires occurred in the Canberra region. However, the largely uninhabited terrain of the national parks, nature reserves and forestry plantations where the fires occurred, probably reduced the chances of such kills being detected or reported.

Significant erosion and sediment input to the Cotter River and tributaries has been evident following the fires (Starr 2003; Wasson *et al.* 2003; CRCFE 2004) and it is expected that this sediment supply to the river and reworking of in-channel sediment will continue for many years.

4.8.2 Impacts of Native Predators

Recent research on Macquarie Perch and Trout Cod in the Cotter and Murrumbidgee rivers has suggested that bird predators such as cormorants or mammalian predators such as the Eastern Water Rat may be significantly limiting population size or hampering reintroduction efforts for these two species (Environment and Recreation unpubl. data). The population of Macquarie Perch in Cotter Reservoir must leave the reservoir to spawn in the upstream section of the Cotter River. Radiotelemetry investigations indicate that a small population of cormorants may prey on a significant proportion of adult fish as they leave the deep-water habitats of the reservoir and move up the shallow river channel. Encouragement of research into the effects of cormorant predation and, if desirable, means to limit the impact is an action identified in Table 5.1. In the Murrumbidgee River, a trial reintroduction of adult and sub-adult Trout Cod is thought also to have been affected by high predation rates, as there appears to be little refuge habitat available to accommodate these larger fish.

4.9

Summary: Threats to Threatened Fish and Crayfish Species

Table 4.5 contains a summary of the importance of particular threats to threatened fish and crayfish species, discussed in sections 4.4 to 4.7.

4.10

Threatened Fish and Crayfish: Conservation Goals, Objectives and Actions

Consistent with the requirements for threatened species in the *Nature Conservation Act 1980*, the Protection Goal adopted for threatened fish and crayfish in this *Strategy* is to:

> **Conserve in perpetuity, viable, wild populations of all aquatic and riparian native flora and fauna species in the ACT.**

The Management Goal incorporates the possible reinstatement of fish species to ACT and/or regional streams where they no longer occur naturally:

> **Aquatic and riparian communities and habitats in the ACT are maintained and where degraded, rehabilitated to support the range of flora and fauna typical of the ACT. Rehabilitation may include the re-introduction of threatened or locally extinct fish species to ACT and/or regional streams where they no longer occur naturally.**

To achieve the conservation goal the following strategic actions are necessary:

(a) **Information (Survey, Monitoring, Research):** Improve understanding of the biology and ecology of threatened fish and crayfish species as the basis for managing the species and their habitat. Give specific attention to establishing causes of population decline. Investigate translocation as a

Table 4.5: Summary—Ranking of Importance of Particular Threats to Threatened Fish and Crayfish Species in the Murray–Darling Basin and the Upper Murrumbidgee Catchment

Threats	ACT Threatened Species					Other
	Two-spined Blackfish	Trout Cod	Macquarie Perch	Silver Perch	Murray River Crayfish	Murray Cod
Habitat destruction and modification (s. 4.4)						
Habitat degradation						
■ damage riparian veg.	H	H	H	M	M	M
■ sedimentation	H	H	H	L	M	H
■ removal of in-stream habitat	L (N/A)	M (L)	M (L)	M (L)	M (L)	M (L)
Barriers to fish passage	L	M	H	M	L	M
Flow regime alteration	M	H (M)	H	M (L)	M (L)	M
Reduced water quality	M	M	H (M)	M	L	M
Thermal pollution	M	H (L)	H (M)	M (L)	N/A	M (L)
Over-exploitation (s. 4.5)						
Illegal harvesting	L	M	M	L	M	M
Recreational angling	L	H	H	M	H	L
Alien species (s. 4.6)						
Competition for food/habitat	M	M	M	M	M	M
Predation	H	H	H	L	L	L
Diseases/parasites	L	M	H	H	L	M
Translocation and stocking (s. 4.7)						
Disease/genetic effects/competition	L	M	M	M	M	
Localised threats in the ACT (s. 4.8)						
Impacts 2003 bushfires	H	M	H	L	L	M
Native predators	L	M	M	N/A	N/A	N/A

Notes: Threat ranking (high, medium, low, not applicable):

1. The table provides a generalised ranking of the importance of particular threats to threatened fish/crayfish species:
   H (High): Highly significant threat to existing populations or re-introductions. Likely to result in local extinctions.
   M (Medium): Moderately significant threat to existing populations or re-introductions. Likely to result in significantly reduced populations and could result in local extinctions over the long term.
   L (Low): Less significant threat. Unlikely by itself to result in significantly reduced population or extinction.
2. **Importance in parentheses** indicates importance in the upper Murrumbidgee Catchment, where this is different to the Basin as a whole.
3. Threat ranking only applies to current or potential threats and should not be used as an indication of the relative importance of these issues in past declines. Many threats are inter-related (e.g. potential for stocking to introduce diseases) and are not well documented scientifically.

management option for establishing new sub-populations (see s. 4.11).

(b) **Protection and Management:** Protect sites and habitats that are critical to the survival of threatened fish and crayfish species. Manage activities in the Murrumbidgee, Cotter and Paddys River catchments in the ACT to minimise or eliminate threats to fish and crayfish populations. Evaluate means and undertake actions to maintain and expand existing populations. Re-introduce Trout Cod to their former habitat in the ACT (see s. 4.12).

(c) **Education:** Increase community awareness of the need to protect aquatic species and their habitats (see s. 4.13).

(d) **Regional and National Cooperation:** Maintain links with, and participate in, regional and national recovery efforts for threatened aquatic species (see s. 4.14). Closely liaise with NSW DPI (Fisheries) in the management of the Queanbeyan River population of Macquarie Perch.

The following sections identify specific actions for the conservation of declared threatened fish and crayfish species in the ACT, and are framed within the objectives and actions of the *Strategy* in Table 6.1. The actions outlined here are based on an evaluation of progress with the actions contained in the previously published Action Plans for the four threatened fish species and the Murray River Crayfish (ACT Government 1999a–d, 2003), as well as new actions identified as being necessary for the next few years.

4.11

Conservation Actions: Information

4.11.1 Survey

There has been an ongoing survey program for fish in the ACT since the mid 1980s, with most major catchments having some survey information (Lintermans 2002) (Table 4.6). Additional surveys and monitoring in the upper Murrumbidgee Catchment have been carried out by NSW DPI (Fisheries).

The previous Action Plans for threatened fish and crayfish species noted the deficiencies in knowledge of the distribution, abundance and dispersal of species in ACT and regional streams and included relevant survey actions. There was a better knowledge of Silver Perch due to the more recent date of the Action Plan (2003) and the parlous state of this species within the ACT. Progress with previous *Survey* actions and new and continuing actions required are contained in Table 4.7.

Table 4.6: Fish Surveys Conducted in the Upper Murrumbidgee Catchment 1986 to 1999

Catchment	No. of Sites Sampled	Year Sampled	Reference
Naas/Gudgenby/Orroral rivers	22	1986–87	Jones *et al.* 1990
Ginninderra Creek	21	1988	Lintermans *et al.* 1990a
Upper Cotter River (above Corin Dam)	28	1988–89	Lintermans & Rutzou 1990a
Middle Cotter River (between Corin and Bendora dams)	14	1989–90	Lintermans unpubl. data
Lower Cotter River (below Bendora Dam)	31	1990	Lintermans unpubl. data
Molonglo River	23	1992–93	Lintermans unpubl. data
Tidbinbilla River	16	1992	Rutzou *et al.* 1994
Lower Cotter/Lower Paddys rivers	16	1992	Lintermans 1993
Middle Paddys River	3	2000	Lintermans unpubl. data
Middle Queanbeyan River	3	1996–97	Lintermans 2006a
Lower Queanbeyan River	3	1998, 2001, 2004	Lintermans 1998c, Lintermans *et al.* 2001 Jekabsons & Lintermans 2005
Upper Murrumbidgee Catchment	5	1994–96	Harris & Gehrke 1997
Upper Murrumbidgee Catchment	20	1998–99	Lintermans unpubl. data

Table 4.7: Survey—Progress with actions in previous Action Plans and new and continuing actions for this *Strategy*

Species (Issue)	Knowledge Requirement or Deficiency Identified in Original Action Plan*	Actions Proposed 1999–2003*	Progress with Actions (to April 2005)	Actions for ths *Strategy*
Two-spined Blackfish (Distribution)	(a) Incomplete knowledge of distribution in upper Murrumbidgee River catchment. (b) Species identity unknown of unconfirmed reports of blackfish from upper Lachlan River catchment, north of the ACT.	(a) Survey of the upper Murrumbidgee River catchment (E&R). (b) Investigation of specific identity of blackfish from Gunning/Dalton area.	(a) Survey of major streams completed (1998–9) and a single small population located in Murrumbidgee River above Yaouk. Population previously reported from below Yaouk not located. (b) Specific identity of blackfish in the Gunning/Dalton area confirmed as River Blackfish (*Gadopsis marmoratus*) not Two-spined Blackfish.	(a) Undertake more detailed survey for the presence of Two-spined Blackfish in the upper Murrumbidgee River catchment. (b) Undertake detailed survey of Condor Creek to ascertain extent of population. (c) Undertake specific surveys to confirm identity when blackfish reported from other locations in the region (e.g. unconfirmed report from the Tinderry Range, NSW).
Trout Cod (Dispersal)	Incomplete knowledge of the extent of dispersal of stocked Trout Cod in the upper Murrumbidgee River catchment.	Survey of the upper Murrumbidgee River catchment to examine whether the sub-adults and adults of the species are dispersing downstream from stocking sites (E&R).	Survey completed (1998–9) and species not detected away from stocking sites.	Continue to encourage reporting by anglers of incidental captures.
Macquarie Perch (Distribution and Abundance)	Incomplete knowledge of distribution and abundance of Macquarie Perch in upper Murrumbidgee River catchment.	To assess distribution and status: (a) Survey upper Murrumbidgee River catchment (outside ACT). (b) Survey Paddys River. (c) Survey Queanbeyan River outside Googong Foreshores area.	(a) Upper Murrumbidgee River survey completed (1998–9). Good populations above Cooma, small population at Michelago. Population in Goodradigbee River now considered not viable. (b) Paddys River surveyed 2000. Species recorded in extremely low numbers from one site near Cotter River confluence. (c) Lower Queanbeyan River surveys 1998–2004 did not record the species. Above Googong Reservoir, species occupies 15 km of river. Waterfall at Silver Hills blocks upstream movement.	Maintain original action for Queanbeyan River: (a) Survey the Queanbeyan River upstream of the Googong Foreshores area to assess the distribution and status of Macquarie Perch (E&R, 2006–7). (b) Assess status of population in Cotter River downstream of Cotter Dam. (c) Monitor spread of species upstream of Vanitys Crossing on Cotter River. (d) Investigate reports of Macquarie Perch upstream of Tantangara Reservoir.
Silver Perch (Distribution and Abundance)	Knowledge of distribution of Silver Perch in upper Murrumbidgee River catchment is largely complete. Status of Lake Burrinjuck population not assessed since mid-1980s when concern expressed about the impact of Redfin Perch. ACT population thought to be largely dependent upon Lake Burrinjuck population.	Liaise with NSW Fisheries regarding an assessment of the status of the Lake Burrinjuck Silver Perch population (E&R).	Issue raised informally with NSW DPI (Fisheries) scientists, but NSW has not had the resources to undertake a targeted survey to date. Monitoring at two sites in Lake Burrinjuck in 2004 failed to locate any specimens (Gilligan 2005).	Maintain original action: (a) Liaise with NSW DPI (Fisheries) regarding an assessment of the status of the Lake Burrinjuck Silver Perch population (E&R). (Status of Lake Burrinjuck population will be raised when NSW prepares State Recovery Plan for the species.)
Murray River Crayfish (Distribution and Abundance)	Knowledge of distribution and abundance in Paddys River catchment incomplete.	Survey the Paddys River catchment for the species (E&R).	Not undertaken to date.	Maintain original action: (a) Survey the Paddys River catchment for the species (EAR). (b) Assess status of newly located population upstream of Cotter Dam.

Notes: * Summary form only. For detail see previous Action Plans (ACT Government 1999a–d, 2003) **E&R:** Environment and Recreation (TAMS)

4.11.2 Monitoring

The previous Action Plans noted the need for a long-term monitoring program to detect changes in the distribution and abundance of threatened fish and crayfish species. Monitoring of catchments in the region outside of the ACT was also needed to place the ACT program in regional context. Regular monitoring of the Murrumbidgee River was established well before preparation of the first Action Plans for aquatic species in 1999 and continues in the form of a biennial monitoring at six sites (Lintermans 2002). Other specific monitoring programs were undertaken e.g. for environmental flow monitoring in the Cotter and Queanbeyan rivers. Progress with previous monitoring actions and new and continuing actions required are contained in Table 4.8.

Monitoring of the impacts of the January 2003 bushfires on fish communities, and of their subsequent recovery, has been undertaken from 2003 to 2005. The need for continued monitoring of the recovery following the bushfires encompasses a number of the threatened fish species and fish communities in general, and so is not specifically identified in Table 4.8 (see Table 6.1).

Currently, there is no centralised database to hold the results of aquatic survey and monitoring programs. This will potentially hamper data management and retrieval as the amount of information increases. The development of a database to house survey and monitoring information on aquatic species is an overarching action for all threatened fish and crayfish species, and so is not specifically identified in Table 4.8 (see Table 6.1).

Table 4.8: Monitoring—Progress with actions in Previous Action Plans and New and Continuing Actions for this *Strategy*

Species (Issue)	Knowledge Requirement or Deficiency Identified in Original Action Plan*	Actions Proposed 1999–2003*	Progress with Actions (to April 2005)	Actions for ths *Strategy*
Two-spined Blackfish **(Distribution and Abundance)**	The disappearance of Two-spined Blackfish from the Cotter River below Cotter Dam and the Murrumbidgee River in the ACT raises concerns as to whether other sub-populations of the species are declining. A long-term monitoring program is required to evaluate these concerns. To place the results from the ACT monitoring program in a regional context, it is proposed to monitor a small number of sites in adjacent NSW waters.	(a) Establish a monitoring program for Two-spined Blackfish at representative sites in the Cotter River catchment (E&R). (b) Monitor the fish population in the Murrumbidgee River in the ACT. Include monitoring techniques suited to detecting the presence of Two-spined Blackfish (E&R). (c) Liaise with NSW DPI (Fisheries) in the ACT region to exchange information on the species (E&R). (d) Encourage monitoring of populations of Two-spined Blackfish in areas of NSW adjacent to the ACT. Potential streams include Goodradigbee River, Micalong Creek, Mountain Creek, Murrumbidgee River near Yaouk (E&R).	(a) Monitoring program implemented on the Cotter River (2001, 2003, 2004, 2005), now covers nine sites. (b) Biennial fish monitoring of Murrumbidgee River undertaken (2000, 2002, 2004) with no individuals detected. (c) There is on-going liaison with NSW DPI (Fisheries). Species was included in review of threatened species of Murray–Darling Basin being prepared by NSW Fisheries. (d) Monitoring undertaken by EACT at three NSW sites: Mountain Creek, Micalong Creek (Goodradigbee River catchment), Goobarragandra River in 2001, 2003, 2004, 2005. **Note:** Monitoring recorded significant decline in the species following bushfires of January 2003 and substantial recovery at most sites in 2004. **Other monitoring (not specified in original Action Plan):** Monitoring of impacts of environmental flows on blackfish recruitment 2001, 2003, 2005. Continue actions from original Action Plan adapted to recognise new information (all E&R):	(a) Continue Two-spined Blackfish monitoring program in the Cotter River. (b) Continue to include techniques suited to Two-spined Blackfish in the biennial Murrumbidgee River monitoring. (c) Continue liaison with NSW DPI (Fisheries) to exchange information on the species. (d) Continue monitoring of Two-spined Blackfish populations in streams adjacent to the ACT. (e) Continue monitoring of impacts of environmental flows on blackfish recruitment. (f) Monitor success of 2004 reintroduction to the lower Paddys River. (g) Liaise with NSW DPI (Fisheries) about cooperative approaches to regional monitoring for threatened fish populations.

Table 4.8: *(Continued)*

Species (Issue)	Knowledge Requirement or Deficiency Identified in Original Action Plan*	Actions Proposed 1999–2003*	Progress with Actions (to April 2005)	Actions for ths *Strategy*
Trout Cod (Distribution, Abundance, Dispersal)	There are currently two stocked populations of Trout Cod in the ACT: Bendora Reservoir on the Cotter River (monitored since 1992) and Angle Crossing on the Murrumbidgee River (monitored since 1997). The site-specific monitoring aims to determine growth rate and survival of stocked fish and detect natural recruitment. Regular monitoring of fish populations in the Murrumbidgee River in the ACT should be capable of detecting dispersal of Trout Cod from the Angle Crossing stocking site.	(a) Continue monitoring program for the two ACT stocking sites for Trout Cod (E&R). (b) Monitor the fish population in the Murrumbidgee River in the ACT. Include monitoring techniques suited to detecting the presence of Trout Cod (E&R). (c) Liaise with Victorian and NSW fisheries agencies to ensure there is an exchange of information on the species (E&R).	(a) Annual monitoring undertaken at both sites. **Angle Crossing:** (i) Good survival of stocked fish but unable to catch individuals more than 3 years old; (ii) dispersal downstream detected in 2000. **Bendora Reservoir:** Catch rate low as it is more than 15 years since stocking, and fish are thought to be largely beyond reach of sampling equipment. Juvenile fish (estimated 1–2 years old) collected in 2004, indicating a successful breeding event. (b) Biennial monitoring of Murrumbidgee River undertaken. Downstream dispersal from Angle Crossing detected in 2000 but not in 2002 or 2004. (c) Regular contact with researchers and managers in NSW and Vic. maintained. ACT is member of National Trout Cod Recovery Team and actively participates.	Continue actions from original Action Plan adapted to recognise new information (all E&R): (a) Continue annual monitoring program for the two ACT stocking sites for Trout Cod (E&R). (b) Liaise with NSW DPI about cooperative approaches to regional monitoring for threatened fish populations (c) Continue to include Trout Cod in the biennial Murrumbidgee River monitoring. (d) Continue membership of the National Trout Cod Recovery Team and other liaison forums.
Macquarie Perch (Distribution and Abundance)	Decline of Macquarie Perch in the Murrumbidgee River and small distribution and population sizes in the Queanbeyan and Cotter rivers raises concerns about the long-term viability of these sub-populations. A long-term monitoring program is required. To place the results from the ACT monitoring program in a regional context, it is proposed to monitor a small number of sites in adjacent NSW waters.	(a) Establish a monitoring program for the Cotter, Murrumbidgee and Queanbeyan river sub-populations of Macquarie Perch (E&R). (b) Based on results of upper Murrumbidgee River survey (see Table 4.7), monitor a small number of sites in NSW waters adjacent to the ACT (E&R). (c) Liaise with Victorian and NSW fisheries agencies to ensure there is an exchange of information on the species (E&R).	(a, b) Macquarie Perch monitoring program implemented from 2001 including Queanbeyan, Cotter, Goodradigbee and upper Murrumbidgee rivers. Individuals also detected in Murrumbidgee River biennial fish monitoring in 2000. Monitoring in 2001 produced numbers considerably lower than previously. Monitoring in 2003, 2004 and 2005 failed to record species at Goodradigbee River site and no recruitment in the Queanbeyan River. Spawning and recruitment were successful in the Cotter River under drought modified environmental flows in 2004 and 2005. (Increased monitoring undertaken, related to drought affected environmental flow regime.) (c) Regular contact with researchers and managers in NSW and Vic. maintained. ACT is involved in preparation of National Recovery Plan for the species.	Continue actions from original Action Plan adapted to recognise new information (all E&R): (a) Continue monitoring program for Macquarie Perch in ACT and adjacent NSW streams. (b) Commence monitoring of population in Cotter River downstream of Cotter Dam and in lower Paddys River. (c) Continue to participate in liaison forums and in preparation of National Recovery Plan for Macquarie Perch. (d) Liaise with NSW DPI (Fisheries) about cooperative approaches to regional monitoring for threatened fish populations.

Table 4.8: *(Continued)*

Species (Issue)	Knowledge Requirement or Deficiency Identified in Original Action Plan*	Actions Proposed 1999–2003*	Progress with Actions (to April 2005)	Actions for ths *Strategy*
Silver Perch (Distribution and Abundance)	The decline of Silver Perch in the Murrumbidgee River raises concerns about the long-term viability of this population. A long-term monitoring program capable of detecting changes in distribution and abundance of the species, which are outside the normal variation in these parameters is required.	(a) Monitor the fish population in the Murrumbidgee River in the ACT. Include monitoring techniques suited to detecting the presence of Silver Perch (E&R). (b) Liaise with Victorian and NSW fisheries agencies to ensure there is an exchange of information on the species (E&R).	(a) Suitable techniques for detecting the species have been included in Murrumbidgee River biennial fish monitoring since its inception in 1994. No individuals detected. (b) Liaison with NSW and Vic. fisheries agencies through forums such as the Murray–Darling Basin Commission Fish Management and Science Committee.	(a) Continue to include suitable techniques for Silver Perch in the biennial Murrumbidgee River monitoring (E&R). (b) Continue liaison with NSW and Vic. fisheries agencies (E&R).
Murray River Crayfish (Distribution and Abundance)	The recreational fishery for Murray River Crayfish in the ACT was closed in 1991 to allow populations to recover. Monitoring in the Murrumbidgee River in 1994 and 1996 indicated some recovery. In order to detect trends in population abundance and size structure of ACT populations of the species, a long-term monitoring program needs to be established.	(a) Establish a monitoring program for Murray River Crayfish at representative sites in the ACT (E&R). (b) Liaise with Victorian and NSW fisheries agencies and research institutions to ensure there is an exchange of information on the species (E&R).	(a) Murray River Crayfish has been collected in the biennial Murrumbidgee River fish monitoring with individuals detected at several sites in 2000, and 2002#. Monitoring program for the species designed, covering 10 sites in the Murrumbidgee River Monitoring conducted during 1998 (under draft Action Plan). Sampling scheduled for 2003 not yet done due to change of priorities following bushfires. (b) Regular contact with researchers and managers in NSW and Vic. maintained, including through Murray–Darling Basin Commission Fish Management and Science Committee. In 2005, ACT and NSW secured funds from MDBC to review ecological knowledge and identify knowledge gaps for the species.	(a) Undertake monitoring for Murray River Crayfish by 2006 and thereafter 5 yearly (E&R). (b) Continue liaison with NSW and Vic. fisheries agencies and involvement in Murray–Darling Basin Commission Fish Management and Science Committee (E&R). (c) Liaise with NSW DPI (Fisheries) about cooperative approaches to regional monitoring for threatened fish populations.

Notes:

* Summary form only. For detail see previous Action Plans (ACT Government 1999a–d, 2003)

The major sampling technique for the biennial Murrumbidgee River fish monitoring program has changed from gill nets to boat electrofishing. The majority of Murray River Crayfish were previously sampled in gill nets, and boat electrofishing is not effective for their capture.

E&R: Environment and Recreation, Department of Territory and Municipal Services

NSW DPI: NSW Department of Primary Industries

4.11.3 Research

This section focuses on research needs for ACT threatened aquatic species, however, there is also a need for research on other species closely associated with streams and riparian areas such as the spiny crayfish and land burrowing crayfish (s. 4.2.2). The nature of their habitat and difficulty in locating the species hinder such research work.

Previous Action Plans for threatened aquatic species in the ACT outlined knowledge gaps needing to be researched, as well as the presence of existing information on the biology and ecology of most species, much of this unpublished. Recognition of the significant decline in native fish stocks in the Murray–Darling Basin since the 1950s and the need to rehabilitate native fish communities (MDBC 2004a) has resulted in more research being undertaken, as well as compilations of existing knowledge combining both research and the results from monitoring programs (Lintermans 2002). Koehn (2004) has noted a progression in freshwater fish science based on field-based research with greater scientific rigour, replacing previous natural history and hatchery-based research, largely centred around major angling species. However, there is still often little systematic integration of the results of scientific research into river and fish habitat rehabilitation projects. Progress with previous *Research* actions and new and continuing actions required are contained in Table 4.9.

Some research needs are common to all or most ACT threatened aquatic species. These are habitat management, effects of alien species, effects of EHN Virus in the wild, movement ecology and requirements, effective mechanisms for establishing new populations and aspects of breeding:

(a) **Habitat management:** While there is knowledge of broad habitat requirements, research is needed on:

- seasonal use of microhabitat by different age classes of fish;
- the effects of land use and management that cause disturbance in catchments;
- the benefits and techniques of habitat rehabilitation; and
- the extent and impacts of sedimentation (stemming from bushfire damage) on aquatic habitats.

(Two-spined Blackfish, Trout Cod, Macquarie Perch, Murray River Crayfish)

(b) **Effects of alien species:** The effects of alien fish species on native species are discussed in s. 4.6 and summarised in Table 4.3. Lack of information on the historical distribution of native species means that the specific impacts of alien species are largely unknown. It is not known whether some species (e.g. Two-spined Blackfish, Trout Cod) have changed habitat preferences or utilisation patterns (as galaxids have done) in response to the presence of trout. Useful lines of research would include:

- dietary niche and habitat preferences for Two-spined Blackfish at sites where trout are present (currently the majority of known blackfish sites) and not present (if sufficient sites can be located);
- types (egg, larval, juvenile) and level of predation by trout and Redfin Perch; and
- the effects of ecosystem alterations attributed to, or exacerbated by, the presence of Carp and Redfin Perch.

(All native fish and crayfish species especially threatened species)

(c) **Effects of EHN Virus in the wild:** The threat posed to native fish species by introduced diseases and parasites is discussed in s. 4.6.3. EHN Virus was first isolated on Redfin Perch in 1985. Susceptibility of Trout Cod and Two-spined Blackfish to the virus is not known. Macquarie Perch and Silver Perch have been shown to be susceptible in laboratory studies. Important research needs are to:

- investigate the effects of EHN Virus on wild populations of native fish species;
- design a testing procedure to determine if fish species have been exposed to EHN Virus;
- design a water-testing procedure to determine if EHN Virus is present in water body; and
- investigate susceptibility of other native fish species.

(All native fish species especially threatened species)

(d) **Movement ecology and requirements:** The timing (diel and seasonal), life-stage involved (adult, sub-adult, juvenile, larval) and extent of spawning, foraging and other movements are largely unknown for most of the ACT's threatened fish species. The swimming capabilities of all ACT threatened fish species are unknown. This knowledge is essential for effective fish passage to be maintained or restored. Information on movement requirements and potential barriers is essential for effective management. Some aspects of adult and sub-adult movement and the home-range of Macquarie Perch and Trout Cod have been recently investigated, but nothing is known of juvenile or larval movements of these species (Macquarie

Perch, Trout Cod, Two-spined Blackfish, Murray River Crafish).

(e) **Effective mechanisms for establishing new populations:** The establishment of additional sub-populations of threatened fish is required to minimise risks associated with local catastrophic events. There is little information on the effectiveness and cost-benefits of using different life stages (juveniles, sub-adults, adults) in such re-establishment attempts, and whether hatchery stock is preferable to wild stock. Techniques to increase the survival of released fish (that might be predator naïve) need to be investigated or developed (Trout Cod, Macquarie Perch, Two-spined Blackfish).

(f) **Aspects of breeding and recruitment:** Details about breeding are unknown for some threatened aquatic species. While the basic reproductive ecology of Two-spined Blackfish and Macquarie Perch is known, the spawning cues have not been identified. Two-spined Blackfish has low fecundity and protection of spawning cues under flow management activities such as environmental flow releases is an important management action. Macquarie Perch are reduced to a single population in the Cotter, and protection of spawning cues under environmental flow releases is critical. While Trout Cod have been bred in captivity, little is known of the flow regime and temperature cues for the species to spawn in the wild. It has been established that there is geographic variation in the size at which female Murray River Crayfish mature, resulting in the minimum legal length for Victorian individuals being larger than in NSW. Age at first breeding is not known for populations in the ACT (Trout Cod, Macquarie Perch, Two-spined Blackfish, Murray River Crayfish).

Table 4.9: Research—Progress with Actions in Previous Action Plans and New and Continuing Actions for this *Strategy*

Species	Knowledge Requirement or Deficiency Identified in Original Action Plan*	Actions Proposed 1999–2003*	Progress with Actions (to April 2005)	Actions for ths *Strategy*
Two-spined Blackfish	There is considerable existing information on biology and ecology of Two-spined Blackfish, much unpublished. Information available on distribution, diet, reproduction, home range but critical knowledge gaps remain: —longevity; —spawning requirements; —effects of alien species; —population genetics; —habitat management.	(a) Encourage research into a number of priority areas with key information gaps. These include longevity, spawning requirements, effects of alien species, population genetics, habitat management (E&R). (b) Cooperate with other agencies in a coordinated study of the population genetics of the sub-populations of Two-spined Blackfish in the Canberra region, including those in the Cotter, Goodradigbee, Goobarragandra and upper Murrumbidgee rivers and Mountain Creek (E&R).	(a) Research completed: —Investigation of effects of environmental flows on the species (Lintermans 2001b, 2005). —Honours project completed at Univ. of Canberra examining genetic relationships between Two-spined Blackfish populations in eastern Australia. Thesis showed that there is little variation between populations in the Canberra region (Beitzel 2002). —Effects of habitat changes under environmental flow scenarios investigated (Maddock *et al.* 2004). —Honours project completed at Univ. of Canberra on potential impacts of thermal pollution from impoundments on growth rates. Thesis showed that there may be significant growth rate depression associated with cold-water releases (Hall 2005). (b) Research commenced: —Impacts of fires and sediment on parental care behaviour (PhD, ANU).	(a) Continue to encourage research into the species related to the evolving knowledge of its biology and ecology and to management issues (EACT). Important knowledge gaps are: —longevity; —spawning requirements; —effects of alien species; —susceptibility to EHN Virus; —habitat management; —movement ecology; —establishment techniques for new populations.

Table 4.9: *(Continued)*

Species	Knowledge Requirement or Deficiency Identified in Original Action Plan*	Actions Proposed 1999–2003*	Progress with Actions (to April 2005)	Actions for ths *Strategy*
Trout Cod	Lack of knowledge of ecological requirements and tolerances of Trout Cod makes management in the wild difficult. Critical knowledge gaps are: —breeding requirements; —effects of alien species; —habitat management; —dispersal; —stocking strategy.	Encourage research into a number of priority areas with key information gaps. These include breeding requirements, effects of alien species, habitat management, dispersal and stocking strategies (E&R).	(a) An experimental habitat rehabilitation undertaken at Tharwa, ACT is discussed in s. 4.12.3. (b) Research completed: —Pilot project (NHT funded) to examine movements of Trout Cod in Cotter River using radio-transmitters (Ebner *et al.* 2005). (c) Research commenced: —Project (FRDC funded) using radiotelemetry to examine movement of wild fish and hatchery-reared fish in Murrumbidgee River at Narrandera (2003). Project continued in Cotter and Murrumbidgee rivers in ACT (2004–2005). —Project (NHT funded) to examine fine scale spatial and temporal movements and habitat use by Trout Cod in Cotter River. Uses same radio-collared fish as in FRDC project (2004–2005).	(a) Continue to encourage research into the species related to the evolving knowledge of its biology and ecology and to management issues (E&R). Important knowledge gaps are: —breeding requirements; —effects of alien species; —habitat management; —susceptibility to EHN Virus; —movement ecology; —establishment techniques for new populations.
Macquarie Perch	There is some existing information on the biology and ecology of Macquarie Perch, much unpublished. Distribution, diet and reproduction have been studied to some degree. Critical knowledge gaps are: —resolution of the taxonomic status (inland and coastal populations); —effects of alien trout and Redfin; —effects of EHN Virus in the wild.	Encourage research into a number of priority areas with key information gaps. These include resolution of the taxonomic status (inland and coastal populations), effects of alien trout and Redfin, and effects of EHN Virus in the wild (E&R).	(a) An experimental habitat rehabilitation project undertaken at Tharwa, ACT is discussed in s. 4.12.3. (b) Research completed: —Honours project (Univ. of Canberra) on predicting suitable habitat (Broadhurst 2002). —Project on impacts of environmental flows on species (Lintermans 2001b, 2005). —Project (NHT funded) investigating movement requirements of species in Cotter Reservoir and lower Cotter River. Fish had relatively restricted daytime home-sites, with more extensive night-time movements. Important river reach for breeding identified immediately upstream of Cotter Reservoir. *(Continues next page)*	(a) Develop an ARC Linkage grant application to investigate issues around EHN Virus and threatened fish species (E&R). (b) Continue to encourage research into the species related to the evolving knowledge of its biology and ecology and to management issues (E&R). Important knowledge gaps are: —effects of alien trout and Redfin Perch; —movement ecology of riverine populations; —swimming capabilities of different life stages; —spawning cues and timing of spawning; —techniques to enhance adult habitat (cover) during reservoir drawdown; —impacts of bird or mammalian predation on remnant populations; *(Continues next page)*

Table 4.9: *(Continued)*

Species	Knowledge Requirement or Deficiency Identified in Original Action Plan*	Actions Proposed 1999–2003*	Progress with Actions (to April 2005)	Actions for ths *Strategy*
Macquarie Perch *(continued)*			(c) Researched commenced: —Genetic study to resolve taxonomic issues (NSW DPI). (d) Workshop on EHN Virus held mid-2004.	—techniques to maintain pool habitats after bushfire related sedimentation; —genetic structure of existing populations in the upper Murrumbidgee River; —effective adult population size of the Cotter Reservoir population; —strategies for establishing new sub-populations (translocation).
Silver Perch	There is some existing information on the biology and ecology of Silver Perch, much unpublished. Diet, movement and reproduction have been studied to some degree, but many studies are from aquaculture ponds or laboratories with few studies from the wild. Critical knowledge gaps are: —effects of Carp and Redfin Perch; —effects of EHN Virus in the wild.	(a) Encourage research into a number of priority areas with key information gaps. These include effects of Carp and Redfin Perch and effects of EHN Virus on wild fish populations (E&R). (b) Encourage investigations into the identification of the genetic composition of Lake Burrinjuck populations of Silver Perch (E&R).	(a) Priority research areas raised at forums such as Murray–Darling Basin Commission Fish Management and Science Committee. (b) Investigations into genetic composition of Lake Burrinjuck populations not yet undertaken.	(a) Develop an ARC Linkage grant application to investigate issues around EHN Virus and threatened fish species (E&R). (b) Continue to encourage research into the species related to the evolving knowledge of its biology and ecology and to management issues (E&R). An important knowledge gap is: —effects of alien species such as Carp and Redfin Perch. (c) Continue to encourage investigations into the identification of the genetic composition of Lake Burrinjuck populations of Silver Perch (E&R).
Murray River Crayfish	There is little published information on the biology and ecology of Murray River Crayfish. Some information is available on broad distribution and response to recreational catch. Most research has been on lowland river systems. Critical knowledge gaps are: —habitat management; —effects of alien species; —age at first breeding.	Encourage research into a number of priority areas with key information gaps. These include habitat management, effects of alien species and age at first breeding (E&R).	(a) Honours thesis on Murray River Crayfish completed 1999 (Charles Sturt University). (b) Terms of reference of MDBC Fish Management & Science Committee expanded in 2004 to include Murray River Crayfish. (c) Review of Murray River Crayfish ecology and knowledge gaps commissioned by MDBC (2005). (d) Honours thesis on movement ecology of Murray River Crayfish completed (Ryan 2005).	(a) Continue to encourage research into the species related to the evolving knowledge of its biology and ecology and to management issues. Incorporate results of MDBC review to establish research priorities (E&R). Important knowledge gaps are: —movement ecology; —effects of alien species; —age at first breeding; —habitat requirements and usage; and —juvenile ecology.

Notes:

* Summary form only. For detail see previous Action Plans (ACT Government 1999a–d, 2003)

E&R: Environment and Recreation, Department of Territory and Municipal Services

FRDC: Fisheries Research and Development Corporation (Cwlth)

NHT: Natural Heritage Trust (Cwlth)

EHN Virus: The exotic fish disease Epizootic Haematopoietic Necrosis Virus

MDBC: Murray–Darling Basin Commission

4.12

Conservation Actions: Protection and Management

4.12.1 Legislative Protection

SPECIES

The legislative status of ACT threatened fish species and the Murray River Crayfish in jurisdictions other than the ACT is shown in Table 4.1. Two species warrant further consideration in relation to these listings:

(a) **Silver Perch:** This species is in decline across the Murray–Darling Basin (MDBC 2004a; Clunie and Koehn 2001a; Morris *et al.* 2001). A non-statutory recovery plan for the species in the Basin was prepared in 2001 (Clunie and Koehn 2001b), but has not been implemented, and a recovery plan has been prepared for NSW (NSW DPI 2006). Though it is declared endangered in the ACT, vulnerable in NSW, threatened (critically endangered) in Victoria, and protected in South Australia, the species is not declared under Commonwealth legislation. It is listed as vulnerable by the Australian Society for Fish Biology (ASFB 2004), however, this listing has no statutory effect. Its status warrants a national statutory nomination.

(b) **Murray Cod:** Previously widespread and abundant, Murray Cod now have a fragmented distribution and are found in low abundance (Kearney and Kildea 2001; Lintermans and Phillips 2005; MDBC 2004a; MDBC 2004b). The species is declared threatened (vulnerable) in Victoria and vulnerable under Commonwealth legislation. Formerly abundant in major ACT streams (Lintermans 2002), the species is now only maintained in ACT urban lakes through stocking. There is anecdotal evidence of further decline of the species in streams since the 2003 bushfires. A review is appropriate to consider if Murray Cod warrant the preparation of a nomination as a threatened species in the ACT.

HABITAT

Aquatic habitats of threatened species have little legislative protection under the *Nature Conservation Act 1980.* It is currently an offence to disturb 'nests' of native animals, and it is assumed that this provides some protection to spawning sites, but other potentially critical habitats are not identified or protected.

ACTIONS

1. Support the preparation of a nomination for Silver Perch as a threatened species under the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth).
2. Review ACT information on Murray Cod to see if it warrants the preparation of a nomination as a threatened species in the ACT.
3. Review mechanisms in the ACT for declaring critical or important habitat for aquatic species and enhance legislative protection for aquatic habitats.

4.12.2 Environmental Flows

The adverse impacts on native fish species of alterations to flow regimes above and below dams and weirs have been discussed in s. 4.4.4. All of the larger streams in the ACT and region have structures that affect stream flow (Googong Dam and Queanbeyan Weir on the Queanbeyan River, Scrivener Dam on the Molonglo River, Tantangara Dam and Burrinjuck Dam on the Murrumbidgee River, Corin, Bendora and Cotter dams on the Cotter River). The smaller Paddys–Tidbinbilla River and Gudgenby–Naas River (tributaries of the Murrumbidgee River) in the southwest of the ACT are not currently affected by dams or weirs.

Dams and weirs on ACT rivers and most of those in the Murray–Darling Basin were constructed when there was limited understanding of the ecology of native fish species and of the effects of such abstraction and diversion on aquatic communities. Managing riverine structures is one of the most significant issues for native fish recovery in the Murray–Darling Basin (MDBC 2004a). Removal of obsolete weir structures and redesigning other barriers, construction of fish-ways, and instigating environmental flows are measures aimed at improving opportunities for native fish species.

The natural flow regime in ACT streams is highly variable. Rivers and streams have periods of low flow and floods of different sizes. Flows in ACT streams also vary seasonally with the higher flows usually occurring in the spring months. Environmental flows are specific releases of water from storages aimed at ensuring that flows in rivers and streams best mimic the flows that would occur naturally, therefore allowing the healthy functioning of in-stream and riparian ecosystems. For the ACT, environmental flows are defined as:

> the streamflow (including aquifer discharge) necessary to sustain habitats (including channel morphology and substrate), provide for spawning

and the usual migration of fauna species to previously unpopulated habitats, enable the processes upon which succession and biodiversity depend, and maintain the desired nutrient structure within lakes, streams, wetlands and riparian areas. Environmental flows may comprise elements from the full range of flow conditions, which describe long-term average flows, variability of flows including low flows and irregular flooding events (ACT Government 2006a).

Determining appropriate environmental flows is an inexact science involving the integration of ecological information and requirements with social and economic considerations. A range of approaches has been used in Australia.

Environmental flows are part of the ACT Government's long-term strategy for managing the water resources of the Territory set out in *Think water, act water* (ACT Government 2004d). Preparation of environmental flow guidelines is a requirement of the *Water Resources Act 1998* (ACT). The first guidelines established in 1999 have been reviewed after a five-year period, and revised guidelines prepared (ACT Government 2005b). These will again be reviewed in five years (or earlier, if evidence indicates this is warranted). The guidelines cover all water-bodies in the ACT as well as Googong Reservoir, managed by the ACT Government. Given the uncertainties in determining appropriate environmental flows, an adaptive management approach has been taken.

Major changes in the revised (2006) guidelines include (ACT Government 2006a):

1. Identification of specific ecological objectives for environmental flows in the different ecosystems. For the Cotter River (Water Supply Catchment Ecosystem) specific objectives are to maintain populations of the threatened Two-spined Blackfish, Macquarie Perch and the Cotter River Frog.
2. Refinement of the flow components based on recent research and monitoring, particularly in the Cotter Catchment. This work has led to identification of more precise base flows, and riffle, pool, and channel maintenance flows.
3. Specification of Drought Flow Rules recognising that during dry periods when the urban population experiences water restrictions, it is appropriate that environmental flows also be reduced.

Environmental flows are a crucial consideration for this *Strategy*, however, two major rivers (Molonglo and Murrumbidgee) have their headwaters in New South Wales for which environmental flow guidelines have not yet been established. For the Murrumbidgee River, it is anticipated that future environmental flows from NSW would pass through the ACT unaffected by activity in the ACT (ACT Government 2006a).
For the Molonglo River, to ensure protection of the Commonwealth's paramount rights to water, it is expected that only the current limited uses would be permitted and this should ensure adequate environmental flows (ACT Government 2006a).
The operation of Scrivener Dam in relation to environmental flows for the Molonglo River is being reviewed by the National Capital Authority. No specific environmental flows are currently released from the dam (see s. 4.4.6 and s. 5.6.13) (ACT Government 2006a). As part of the decision to return some water to the Snowy River, the NSW Government has committed to a program to return environmental flows to the Murrumbidgee River. This will increase flows in the river both upstream of and within the ACT; however, Burrinjuck Dam is still an impenetrable barrier to upstream fish movement.

The construction of new water treatment facilities at Mt Stromlo following the 2003 bushfires has allowed the reinstatement of Cotter Reservoir as part of Canberra's domestic water supply. Prior to 2003, Cotter Reservoir had been rarely used because of poor water quality, and the abundance of higher quality water supplies in Bendora, Corin and Googong reservoirs. It has been proposed to transfer water from the Cotter catchment (including Cotter Reservoir) to Googong Reservoir, to provide greater security for domestic water supply. Such transfers will result in drawdown of the water level in Cotter Reservoir, potentially isolating macrophyte beds (important Macquarie Perch habitat) in the reservoir. The drawdown could also affect access to riverine spawning sites for Macquarie Perch.

With regard to environmental flows in the Cotter River, there are some matters needing further investigation; including the flow conditions antecedent to the recent natural recruitment of Trout Cod in Bendora Reservoir; the adequacy of the drought flows in allowing blackfish recruitment in the lower 5 km of the Cotter River; the effects on Macquarie Perch of drawdown of Cotter Reservoir; and the effectiveness of flushing flows in moving sediment from the pools and riffles below Bracks Hole (upstream of the Cotter Reservoir). More specific information related to spawning flows for Macquarie Perch in the Cotter River between Corin and Bendora dams is contained in Lintermans (2005). Results of investigations into various environmental flow regimes including drought flows is discussed in CRCFE (2004) and Lintermans (2001b, 2004c).

ACTIONS

1. Keep environmental flow requirements under review and liaise with ACTEW AGL to ensure that the appropriate drawdown levels and flows under the ACT Environmental Flow Guidelines are maintained or released from storages operated by the company. Special attention needs to be given to the requirements for threatened fish such as Macquarie Perch and Two-spined Blackfish and for the Cotter River Frog.
2. Continue monitoring of the ecological effects of the environmental flow program in the Cotter River, with the impacts on pools and riffles in the lower river reaches to be incorporated into the monitoring program.
3. Investigate the age of naturally recruiting Trout Cod in Bendora Reservoir, and determine the antecedent flow conditions for this spawning event.

4.12.3 Habitat Rehabilitation

As discussed in s. 4.4, the majority of riverine ecosystems in eastern Australia have been adversely affected by human activities with a resultant modification of aquatic habitats. Rivers in the ACT region have been impacted by the effects of adjacent rural and urban land uses and dam construction. Poor land management and a series of major floods in the mid to late 1800s in the upper Murrumbidgee catchment resulted in extensive soil erosion and sediment addition to rivers. Clearing of the riparian zone in some areas removed nearly all the large eucalypts which were previously common, hence there remains no source of large woody debris (snags) to provide in-stream structural complexity and habitat diversity for both fish and invertebrate populations.

All previous Action Plans for threatened fish/crayfish species in the ACT, except for Two-spined Blackfish (ACT Government 1999b–d, 2003) included an action to 'investigate options for rehabilitating critical fish habitats'. It was noted that such rehabilitation is costly and that funding partnerships would be sought. Subsequently, a habitat rehabilitation experiment has been undertaken on a section of the Murrumbidgee River in the ACT, downstream of Tharwa. The Murray–Darling 2001 FISHREHAB component of the Natural Heritage Trust provided funds for the project. This 1.5 km section of the Murrumbidgee River, formerly a pool and riffle sequence, has been largely filled in with sandy sediment. The shallow, featureless riverbed forms a barrier to upstream and downstream dispersal of fish. The riparian zone is also degraded, particularly with the removal of large eucalypt species formerly common in the area. The two major elements of the rehabilitation works were (Lintermans 2004b):

- A series of regularly spaced flow deflectors (rock walls) to create scour holes to improve habitat for fish dispersal.
- A habitat pool with large woody debris (snags) added for structural complexity. Snags were also incorporated into seven of the deflectors.

Some early observations on the results of the experiment are (Lintermans 2004b):

- Scour holes can be created and maintained by deflectors even under low flow conditions, but to provide linked scour holes, deflector spacing needs to be closer than that suggested in the international literature.
- It is important to investigate whether the location of the thalweg (thread of deepest water) in the stream channel is constant, as even a minor change in thalweg position can isolate individual deflectors.
- The benefits of incorporating woody debris into deflectors appear minimal where sediment loads are high, as sediment displaced by scour holes tends to swamp the snags.
- In streams with high sediment loads, it may be necessary to extract sand from the riverbed upstream of rehabilitation works to prevent scour holes being swamped by sand (not undertaken in this experiment).
- Fish sampling in 2000 and 2001 recorded the endangered Trout Cod immediately adjacent to two of the small trial deflectors.
- The habitat pool has completely filled with sand, with the snags totally buried.

The success of the rehabilitation works for recovery of threatened fish can only be assessed through long-term monitoring, which is being undertaken on a biennial basis.

The 2003 bushfires have resulted also in the deposition of large quantities of sediment into streams such as the Cotter, Paddys, Tidbinbilla and Naas–Gudgenby rivers, with many of these streams demonstrating significant loss of deep pool habitats through the accumulation of fire-related sediment. Rehabilitation activities in these smaller streams are necessary, but smaller-scale approaches than those used in the Murrumbidgee River need to be investigated and developed.

ACTIONS

1. Monitor and assess the success of rehabilitation works undertaken on the Murrumbidgee River at Tharwa. Based on this assessment, investigate further options for rehabilitating critical fish habitats in a range of stream sizes. These options include selective removal of sand, construction of in-stream deflectors to restore critical pool/riffle habitats, and provision of additional cover such as snags or boulders.
2. Investigate mechanisms for rehabilitating and improving the protection of riparian vegetation along the Murrumbidgee River in the ACT.
3. Release environmental flows combined with natural flows to flush sediments.

4.12.4 Potential Impacts of Future Water Supply Options

One of the three potential future water supply sources for the ACT is the lower Cotter River, with the Gudgenby River (Tennent Reservoir) and the Murrumbidgee River (Tantangara Reservoir) the other two sources (ACTEW 2005). Of the four options fully investigated for the lower Cotter, the preferred option is the construction of a new, large (78 GL) Cotter Dam, which would have a crest height approximately 50 m above the existing dam. The new dam would have a multi-level off-take tower, and be located approximately 125 m downstream of the existing dam (ACTEW 2005).

As part of the review of water supply options, Lintermans (2004c) has reviewed the potential issues, benefits and knowledge gaps for threatened fish related to the construction of a new Cotter Dam. These are listed in Appendix 3. Considerations include habitat changes and their effects on threatened fish species, environmental flows, predation on threatened fish species, maintaining an enlarged reservoir free of Carp and Redfin Perch, and the effects of EHN Virus on Macquarie Perch.

ACTIONS

1. Continue to liaise with ACTEW regarding the potential impacts on native fish and crayfish species of future water supply options.
2. Should the construction of an enlarged water storage on the lower Cotter River proceed, provide advice to ACTEW on the means to maximise opportunities for threatened fish conservation and habitat enhancement in the reservoir design and the construction program.
3. Monitor or assess the effects of inter-basin water transfers.
4. Encourage research into knowledge gaps associated with Future Water Supply Options.

4.12.5 Protection of the Cotter River Catchment from Invasion by Alien Fish Species

The Cotter River is one of the few rivers in the Murray–Darling Basin in which Carp or Redfin Perch are not established, though both are now widespread in the Basin and the Canberra region. Cotter Dam provides a barrier to invasion from the Murrumbidgee River (Lintermans *et al.* 1990b; Lintermans 1991).

Prior to the drought of 2002–5, Cotter Reservoir was not regularly used for the supply of domestic water to Canberra, with the water usually drawn from Corin and Bendora reservoirs. However, new scientific knowledge on climate change, the likely reduction in runoff following vegetation regrowth in fire-affected catchments, the projected growth of the ACT population, and the forecast need to augment existing water storages to avoid prolonged or severe water restrictions mean that Cotter Reservoir could be substantially increased in volume through construction of a new dam (ACTEW 2004). It is important that the significance of this barrier continues to be recognised during further evaluation or construction (see Appendix 3). Similarly, Bendora Dam acts as a barrier to the colonisation of the upper and middle Cotter catchment by Brown Trout, which are present in the Cotter River and Cotter Reservoir below Bendora Dam.

Another mechanism for the unwanted introduction of exotic fish species is the use by anglers of live fish as bait. It is illegal to use live fish as bait under the *Fisheries Act 2000* (ACT), however discouraging bait fishing of any kind provides further safeguards against such introductions. The designation of the Cotter River between Bendora Dam and the junction of the Cotter River with Pierces Creek (approximately 1 km upstream of Cotter Reservoir) as a 'trout water' with only artificial fly or lures allowed as a fishing method assists in the prevention of establishment of unwanted fish. The stocking of fish species for recreational purposes in the Cotter catchment is not undertaken, as the introduction of additional species would encourage bait fishing and potentially impose further stress on threatened fish populations (ACT Government 2000).

In 1986 the waters (streams and reservoirs) of the Cotter catchment from the headwaters downstream to the Bendora Dam wall were closed to recreational fishing. This was to protect threatened fish and their habitats in the catchment (ACTP&CS 1986). The (then) ACT Environment Advisory Committee reviewed recreational usage of the Cotter Reservoir in 1997 and recommended that the reservoir should remain closed to recreational fishing because of the threat posed to native fish species by the establishment of introduced fish. The Government adopted this recommendation, which remains current policy for the area (ACT Government 2000). Following the 2003 bushfires, the ACT Government reviewed opportunities for non-urban areas, resulting in the *Shaping Our Territory* reports (Non-Urban Study Steering Committee 2003; Shaping Our Territory Implementation Group 2004). These reports discussed recreational opportunities on Cotter Reservoir, including fishing. The introduction of recreational fishing is not desirable as it greatly enhances the risk of introduction of the alien fish species Carp and Redfin Perch (and enhances the risk of EHN Virus establishing (see section 4.6.3)). Consequently, the introduction of recreational fishing to Cotter Reservoir would be strongly opposed by Environment ACT.

ACTIONS

1. Highlight the importance of maintaining the integrity of the Cotter Dam barrier to upstream fish colonisation in the event of reconstruction or augmentation of Cotter Dam.
2. Highlight the importance of maintaining the integrity of the Bendora Dam barrier to upstream fish colonisation.
3. Continue the policy of maintaining the Cotter River below Bendora Dam as a declared 'trout water' for artificial fly or lure fishing only (under the Fishing Act 2000).
4. Continue the policy of prohibiting fishing in the waters (streams and reservoirs) of the Cotter catchment from the headwaters downstream to Bendora Dam wall.
5. Maintain the policy of not stocking fish for recreational purposes in water supply reservoirs in the Cotter River catchment as outlined in the ACT Fish Stocking Plan (ACT Government 2000).
6. Continue the policy of prohibiting fishing in Cotter Reservoir.

4.12.6 Monitoring and Control of alien fish species

Alien fish species continue to expand their distribution in the ACT and the upper Murrumbidgee catchment. Rainbow Trout have recently become established in Gibraltar Creek upstream of Gibraltar Falls, with likely devastating effects on the previously secure population of Mountain Galaxias in this stream. Similarly, the Oriental Weatherloach has established new populations in the Queanbeyan and Molonglo rivers (Lintermans *et al.* 2001). Both of these new incursions are likely to be the result of illegal human-assisted dispersal (see Lintermans 2004b).

Control options for alien fish are limited, particularly where threatened native species are present, because of the potential of control measures to affect non-target fauna. Any control program is likely to have a greater chance of success if control is attempted whilst the population of alien fish is small. Consequently, early detection and monitoring programs are critical in the successful control of alien fish. Additional research is also required into potential control techniques, along with the development of rapid response plans for new pest fish incursions. The new Invasive Animals Cooperative Research Centre (IACRC) (of which Environment and Recreation is a member) is establishing a research program for freshwaters that will deal with a number of these knowledge or management gaps.

ACTIONS

1. Keep a watching brief on new developments in alien fish control methods, through participation in the IACRC.
2. Seek to develop rapid response plans for new pest fish incursions through participation in the IACRC.
3. Investigate the feasibility of control options for Rainbow Trout upstream of Gibraltar Falls.
4. Establish a program to monitor the ACT distribution of the most important alien fish species, utilising existing monitoring sites where possible.

4.12.7 Policy of Not Stocking Fish in Natural Streams in the ACT for Recreational Purposes

A program of fish stocking is undertaken in ACT urban lakes and Googong Reservoir, but stocking of streams is no longer practised in the ACT except in special circumstances (e.g. a release or relocation of a threatened species for conservation purposes). The major reasons why stream stocking is not undertaken are outlined in the ACT *Fish Stocking Plan* (ACT Government 2000). They include concerns about habitat suitability, possible pressure on remnant natural populations, and potential loss of stocked fish out of the ACT. Limited funds for fish stocking mean that it is best to direct these funds to where there is the greatest opportunity to effectively augment the fishery.

The effects on genetic integrity are a further consideration. Hatchery-bred fish used in fish stocking programs are usually derived from a small number of brood fish, and so may lack the normal range of genetic variation present in wild populations. For example, an investigation into the genetic variability of

Silver Perch in rivers and dams within the Murray–Darling Basin has revealed that stocked populations have less genetic diversity than wild populations (Keenan *et al.* 1996; Bearlin and Tikel 2003). The introduction of hatchery-bred fish into remnant wild populations may lead to reduced genetic variability in the population as a whole, and reduction in its adaptive capacity. The remnant population of Silver Perch in Lake Burrinjuck has been augmented with hatchery-bred fish for many years, and it is not known whether 'wild' levels of genetic diversity remain in this population. The investigation of the genetic variability within stocked and wild populations of Silver Perch is identified as a recovery action in the NSW recovery plan for this species (NSW DPI 2006). The plan also identifies the need to implement the Freshwater Fish Stocking Management Strategy (see NSW Fisheries 2003) to prevent significant impacts from stocking of Silver Perch on wild (riverine) populations.

ACTION

1. Maintain the policy of not stocking fish for recreational purposes in ACT streams. Fish may be stocked for special purposes (e.g. a release or relocation of a threatened species for conservation purposes, or a release for research purposes).

4.12.8 Stocking and Translocation of Fish in Natural Streams in the ACT for Conservation Purposes

STOCKING

There are no captive breeding programs for Macquarie Perch or Murray River Crayfish currently operational within fisheries agencies in the Murray–Darling Basin. The previous breeding program for Macquarie Perch in Victoria has ceased.

There are large hatchery-breeding programs for Silver Perch in the Basin. These programs are directed towards recreational fishing or aquaculture, rather than conservation purposes (NSW DPI 2006; Clunie and Koehn 2001a). Until the genetic status of the Lake Burrinjuck population of Silver Perch is known, it is not considered desirable to stock this species for conservation purposes into the Murrumbidgee River in the ACT (see s. 4.12.7).

Trout Cod have been stocked for conservation purposes in Bendora Reservoir (1989–1990, 8740 fish) and in the Murrumbidgee River at Angle Crossing (1996–2005, 99 500 fish). These populations are included in fish monitoring programs (see Table 4.8). The majority of fish released in the stocking program have been supplied from the NSW Department of Primary Industries fish hatchery at Narrandera. In 2002, fish were purchased from the Snobs Creek hatchery in Victoria. The ACT does not have a facility for breeding native fish, and such a facility could not be justified on a cost-benefit analysis, given the relatively small demand for native fish breeding in the ACT. In the 2004 Trout Cod monitoring program for Bendora Reservoir, a number of small (90–250 mm) Trout Cod were captured, indicating that stocked fish had bred in the previous 2–3 years. This demonstrates the need for long-term monitoring of stocked populations (it is now more than 15 years since the species was stocked) and highlights the long time-frames often required before the success or otherwise of the stocking program can be ascertained.

The ACT stocking program for Trout Cod is part of a broader national recovery effort for the species across the Murray–Darling Basin. In the upper Murrumbidgee catchment, fish have been stocked in several locations, including sites near Cooma and Adaminaby that were stocked between 1988 and 1997. Modelling of alternative Trout Cod stocking programs revealed that programs that release large numbers of fish over a relatively short time-frame produced the highest probability of establishing a large population after 20 years, However the risk of total failure was also high with this approach. Lower risk strategies (fewer fish over a longer time period) produced a lower probability of establishing large populations, but a higher probability of establishing small populations over 20 years, with an almost zero chance of total failure (Bearlin *et al.* 2002). The ACT has pursued a low-risk stocking program for Trout Cod, primarily because of the lack of availability of fingerlings for large stockings.

Recent research into the movement ecology of adult and sub-adult Trout Cod has revealed that fish can make relatively extensive movements (10–60 km) along a river. Similarly, in the 1990s there were a number of reports of Trout Cod being caught by anglers in the ACT, with these fish thought to represent downstream dispersal from the stocking sites around Cooma. These results suggest that there may be benefits in increasing the number of stocking sites (without decreasing the number of fish stocked per site), allowing fish from adjacent sites to interact with each other. Additional stocking sites could be located within the ACT or in adjacent areas of NSW. In 2005 an additional site on the Murrumbidgee River (just downstream of the NSW/ACT border) was incorporated into the NSW Trout Cod stocking program.

ACTION

1. Continue to stock Trout Cod for conservation purposes in the ACT.

2. Investigate the potential for additional Trout Cod stocking sites in the ACT, and liaise with NSW DPI (Fisheries) about the potential for additional sites in adjacent areas of the Murrumbidgee River.
3. Liaise with NSW DPI (Fisheries) about the genetic status of Lake Burrinjuck Silver Perch populations, and consider stocking Silver Perch into the Murrumbidgee River if appropriate.

TRANSLOCATION

- **Macquarie Perch**

In 1985, forty-one Macquarie Perch were removed from Cotter Reservoir when it was drained for dam wall maintenance. These fish were released into Bendora Reservoir, however, there have been no records of the fish in subsequent monitoring. Occasional reports of fish in the stilling pool below the dam wall were made for several years after the translocation. This failure is probably due to the release of cold water from Corin Dam, disrupting natural reproductive cycles of this species.

Though a fishway has been constructed at Vanitys Crossing on the Cotter River between Cotter and Bendora reservoirs (s. 4.4.2), it may still be useful to accelerate the establishment of a viable population of Macquarie Perch upstream of the crossing by translocating individuals above the crossing. The expansion of the Macquarie Perch population in the Cotter catchment would reduce the extinction risk associated with local catastrophic events. Translocation of Macquarie Perch to the Cotter River upstream of Corin Dam may also be worthwhile, as it would establish a population in a river reach not subject to recreational angling, land use impacts such as forestry, and flow regulation. Such translocation and population establishment is a long-term process as it could take ten or more years to establish a viable population.

Historically. Macquarie Perch were probably present in the Molonglo River and lower reaches of the Queanbeyan River, with populations likely to have been affected by heavy metal pollution from the Captains Flat Mines (see s. 2.1.2). The remnant populations of this species in the Murrumbidgee River and the Queanbeyan River above Googong Reservoir are unable to recolonise these areas because of barriers to fish movement (Scrivener Dam, Queanbeyan Weir, Googong Dam, Molonglo Gorge) and the small size of the remnant populations. Potential exists to re-establish a population in the Molonglo River upstream of Molonglo Gorge, as Redfin Perch (and hence EHN Virus) is not present in this river reach, public access is relatively limited, and fishing pressure is low. Similarly there are anecdotal records of Macquarie Perch from the Paddys River near Murray Corner, but they are no longer thought to be present in the reach. Translocation of individuals from existing populations in the upper Murrumbidgee catchment is worth investigating as a mechanism for re-establishing these populations. Genetic characterisation of existing donor populations is a prerequisite to translocation between rivers to ensure that disruption of existing genetic structure does not occur (see Table 4.9).

In an attempt to prevent the local extinction of a population of Macquarie Perch in Googong Reservoir, 57 adult fish were removed from the Reservoir in November 1980 and released into the Queanbeyan River upstream. This translocation was successful, with a reproducing population established in the river that was recruiting regularly in the late 1990s (Lintermans 2003). There is also potential habitat for Macquarie Perch in the Queanbeyan River in the Silver Hills area (NSW) upstream of Googong Dam, where a large waterfall blocks upstream dispersal from the previous translocation. Fish in this area would have some protection from angling pressure due to its remoteness from access.

ACTION

1. Evaluate the conservation benefit of translocating Macquarie Perch to the river section above Vanitys Crossing on the Cotter River upstream of the Cotter Reservoir.
2. Evaluate the conservation benefit of translocating Macquarie Perch above Corin Dam.
3. Evaluate the feasibility and conservation benefit of translocating Macquarie Perch into the Molonglo River above Molonglo Gorge and into the Paddys River.
4. Liaise with NSW DPI (Fisheries) regarding the desirability of translocating Macquarie Perch in the Queanbeyan River past the natural barrier posed by the Silver Hills waterfall upstream of Googong Reservoir.

- **Two-spined Blackfish**

Two-spined Blackfish were previously present in the Cotter River downstream of Cotter Dam and in the lower Paddys River. There also is a museum record of this species from the Murrumbidgee River at Casuarina Sands, at the Cotter confluence (Lintermans 1998a). It is thought that sedimentation is responsible for the disappearance of this species from the Paddys and Cotter rivers below the dam. A trial translocation of 55 sub-adult and adult Two-spined Blackfish from the Cotter catchment to the lower Paddys River occurred in late 2004. These fish had been held in aquaria for a number of months as part of research projects, and they were translocated rather than being returned to the Cotter River. Monitoring of the fate of these fish has not yet been conducted, but is planned for 2005/06. If this translocation has proved successful, there is potential for additional translocations aimed at reinstating a population of this species in the Cotter River below Cotter Dam.

ACTIONS

1. Monitor the fate of the Two-spined Blackfish translocated in 2004 into the lower Paddys River.
2. Investigate the feasibility of additional translocations of Two-spined Blackfish into the Cotter River downstream of Cotter Dam.

■ **Murray River Crayfish**

The previous Action Plan for Murray River Crayfish (ACT Government 1999d) included an action to 'investigate the possibility of re-establishing a population of Murray River Crayfish in Cotter Reservoir'. There are previous records and unconfirmed reports of the crayfish in the Cotter River above and below the present reservoir. It was proposed to relocate individuals from below the dam to the reservoir, where Carp and Redfin Perch are not present and fishing is prohibited. Subsequently, a number of individuals were discovered in the Cotter River above the reservoir. On this basis translocation is not considered necessary, however further survey to determine the extent and abundance of the population is required.

Monitoring between 1994 and 2003 of the potential impacts of discharge of treated effluent from the Lower Molonglo Water Quality Control Centre on fish and crayfish populations of the Molonglo and Murrumbidgee Rivers suggests that Murray River Crayfish are absent from the discharge zone in the Molonglo River (Lintermans 1998b, 2004d). It has been hypothesised that crayfish may be avoiding the discharge zone, and this prevents colonisation from the Murrumbidgee River. A translocation of crayfish past the discharge zone may be effective in re-establishing the species in the lower Molonglo River.

ACTIONS

1. Survey the Cotter River between the Cotter Reservoir and Bendora Dam to determine the extent of the Murray River Crayfish population.
2. Investigate the feasibility of translocating Murray River Crayfish into the Lower Molonglo River.

4.12.9 Remediation of Barriers to Fish Passage

The ACT has relatively few major barriers that require remediation, and fish passage is incorporated into structures during scheduled maintenance work or upgrades. Examples are the vertical slot fishways constructed on the Cotter River lower weir and Casuarina Sands low weir during scheduled maintenance in 2001, and the Vanitys Crossing rock-ramp fishway constructed in 2002 (s. 4.4.2). There are still some low weirs on the Cotter River, between its junction with the Murrumbidgee River and its confluence with the Paddys River, that do not have fishways. These weirs need to be assessed for their suitability for fish passage, and fishways incorporated during future upgrades or maintenance. It is intended that eventually, the provision of fishways will reconnect the fish populations in the Murrumbidgee, lower Cotter and Paddys rivers. It is not proposed to provide fish passage past Cotter Dam, as the dam provides a barrier to invasion by alien fish species (see s. 4.12.5).

There are a number of road crossings of the Cotter River between Vanitys Crossing and Bendora Reservoir that are likely to pose barriers to Macquarie Perch as the population expands up the river. These barriers need to be assessed and fish passage options examined. Similarly, in other ACT catchments there are a number of road or management trail crossings that may pose fish passage problems, with opportunities to improve fish passage often available during maintenance, upgrading or realignment.

Similarly, the impacts of Point Hut Crossing on fish passage in the Murrumbidgee River have not been formally assessed, but it is thought likely that fish passage is impeded under some flow conditions, and this needs verification. There are now engineering guidelines available to facilitate fish passage past road crossings (Fairfull and Witheridge 2003), and these guidelines should be incorporated into existing and future road construction and maintenance programs.

ACTIONS

1. Monitor the performance of the fishway for Macquarie Perch at Vanitys Crossing on the Cotter River.
2. Investigate the requirements and design options for fish passage at existing road crossings on the Cotter River between Vanitys Crossing and Bendora Reservoir.
3. Incorporate stream-crossing guidelines into existing and future road works programs in the ACT.

4. Assess the need for fish passage at low weirs on the Cotter River between the Paddys and Murrumbidgee river confluences, and Point Hut Crossing. Incorporate construction of fishways (where necessary) into future upgrades or maintenance works on these weirs and crossing.

4.12.10 Control of Trade in Freshwater Crayfish

Horwitz (1990) considered that the uncontrolled translocation of Australian freshwater crayfish posed a considerable threat to native crayfish through the potential spread of parasites and diseases, and the potential for disruption of natural crayfish communities.

Merrick (1995) expressed concerns about the demands of the burgeoning aquaculture industry for freshwater crayfish, and noted that the biological attributes of desirable aquaculture species (frequent breeding and rapid growth), also make them a potential threat to local endemic species should they escape or be deliberately stocked. The spread of the popularly cultured Hairy Marron (*Cherax tenuimanus*) in southern Victoria, the establishment of Redclaw Crayfish (*Cherax quadricarinatus*) in Lake Argyle, the decline of endemic Hairy Marron in the Margaret River after the introduction of the Smooth Marron (*Cherax cainii*) in Western Australia (D. Morgan pers. comm.), and the spread of the Yabby (*C. destructor*) in Western Australia are cases in point.

The regulations governing the intra- and interstate movement of freshwater crayfish in Australia are not consistent between jurisdictions, with few controls applicable in the ACT.

ACTION

1. Liaise with other Australian States and Territories in order to inform the development of an ACT policy on trade in freshwater crayfish.

4.13

Conservation Actions: Education

The previous Action Plans for threatened aquatic species in the ACT (ACT Government 1999a–d, 2003) identified the need to improve both public knowledge about the reasons for decline of native fish and crayfish and angler ability to properly identify fish species.

Large sections of the general community are unaware of the reasons for the decline of native fish, and the actions that can help to halt this. In addition, some anglers either cannot, or choose not to discriminate between threatened and non-threatened fish species. Consequently some individuals of threatened species are not returned unharmed to the water after accidental capture. Since 2000, a range of information materials has been developed aimed at enhancing community understanding of threatened species and engendering community support for research and management actions. These include:

(a) Information on angling and threatened fish and crayfish species on the Environment and Recreation website.

(b) A poster on *Australian Capital Territory Freshwater Fishes* (funded by the Natural Heritage Trust).

(c) Publication of *Wet and Wild: A Field Guide to the Freshwater Animals of the Southern Tablelands and High Country of the ACT and NSW* (Lintermans and Osborne 2002) and *Fish in the Upper Murrumbidgee Catchment: A Review of Current Knowledge* (Lintermans 2002) (funded by the Natural Heritage Trust).

(d) Employment of a Fisheries Action Program coordinator from 1997–2003 and publication of ACT Fisheries Action Program Newsletter (funded by the Natural Heritage Trust).

(e) Employment of an Aquatic Education Officer in 2003–04 (funded by the Natural Heritage Trust).

This is additional to a wide range of website information now available e.g. from NSW DPI, Australian Society for Fish Biology (ASFB), Australian and New Guinea Fisheries Association (ANGFA), and the Murray–Darling Basin Commission.

ACTIONS

1. In cooperation with State and Commonwealth government agencies and community organisations, review existing education and community awareness materials and programs with a view to providing new or updated information. The aim of this is to increase

awareness of threatened aquatic species and threatening processes, and how the community can contribute to the conservation and recovery of aquatic species.
2. Pursue funding opportunities to expand the extent of public information and education activities in aquatic conservation and management.

4.14 Conservation Actions: Regional and National Cooperation

Actions taken in the ACT to conserve and rehabilitate aquatic ecosystems are carried out in the context of integrated catchment management for the Murray–Darling Basin as a whole. The degraded state of riverine and riparian ecosystems is well documented as is the generally parlous state of native fish populations. It is important, therefore, for the initiatives in this *Strategy* to be linked, as appropriate, to regional and national policies and programs.

The ACT Government participates in a number of regional and national forums that deal with the conservation or management of aquatic resources. Examples include:

- the MDBC Fish Management and Science Committee (which guides implementation of the Native Fish Strategy for the Murray–Darling Basin 2003–2013);
- the Murray Cod Reference Group;
- the National Recovery programs for Trout Cod, Murray Cod, and Macquarie Perch;
- the Invasive Animals Cooperative Research Centre; and
- the eWater Cooperative Research Centre.

ACTIONS

1. Maintain links with, and participate in national recovery efforts for threatened aquatic species to ensure that ACT conservation actions are coordinated with national programs.
2. Liaise with relevant NSW Government agencies with the aim of achieving a coordinated, regional approach to the conservation of threatened aquatic species.