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SKM

Australian Government
Department of the Environment, Water, Heritage and the Arts

An overview of the impacts of translocated native fish species in Australia

- Final
- 11 August 2008

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Glossary

ABARE	Australian Bureau of Agricultural and Resource Economics
ACT	Australian Capital Territory
DEWHA	Department of the Environment, Water, Heritage and the Arts
DNR	Department of Natural Resources
DPI	Department of Primary Industries
DPIF	Department of Primary Industry and Fisheries
DSE	Department of Sustainability and Environment
EPBC Act	Environment Protection and Biodiversity and Conservation Act
IFC	Inland Fisheries Commission
IUCN	International Union for Conservation of Nature
MDBC	Murray Darling Basin Commission
QFMA	Queensland Fisheries Management Authority
WAMP	Water Allocation and Management Planning

1. Introduction

1.1 Background

Translocation of native species has been occurring to various extents throughout Australia since the time of European settlement. The definition of translocations varies across the literature and has historically been considered to be the intentional movement of species to an area outside their natural range. The definition of translocation which has been used in this report encompasses species that have been moved within and outside their natural range. The definition to be applied in this report is:

> *Translocation is the movement of living organisms from one area with free release in another (1999). This includes intentional and unintentional movement of individuals within and outside their natural range. This term includes introductions, re-introductions and re-stocking (IUCN 2000).*

The definitions of the above terms are as outlined in IUCN (2000):

- **Introduction** means the movement, by human agency, of a species, subspecies, or lower taxon (including any part, gametes or propagule that might survive and subsequently reproduce) outside its natural range (past or present). This movement can be either within a country or between countries.
- **Re-introduction** means an attempt to establish a species in an area which was once part of its historical range, but from which it has been extirpated or become extinct. (From IUCN Guidelines for Re-Introductions)
- **Re-stocking** is the movement of numbers of plants or animals of a species with the intention of building up the number of individuals of that species in an original habitat (where the same species is already known to exist).

The species covered in this report are limited to translocated native fish species which spend all, or part of their life-cycle in freshwater systems as well as saline inland lakes and waterways. This includes translocations into natural and artificial waterbodies – but excludes the location of aquaculture facilities.

The movement of fish species beyond their natural range is potentially one of the most ecologically damaging of human activities (Koehn 2004a) and management of alien and translocated species may be one of the biggest challenges that conservation biologists face in coming decades (Harris and Battaglene 1990; Harris 2003; Lintermans 2004). The translocation of native species can have impacts upon indigenous populations of native fish, the general ecosystem into which translocations occur, as well as subsequent social and economic impacts over time (Morgan *et al.* 2004). The presence of fish outside their natural range can affect indigenous fish populations via predator-prey interactions as well as direct and indirect competition for food, habitat and resources.

The introduction of disease and parasites is also possible via translocated species from other regions and hybridisation potential exists if non-indigenous and indigenous species interbreed. This interbreeding can compromise the genetic integrity of native fish (Barlow *et al.* 1987; DPI 2005a).

The translocation of native species has been associated with the decline of some native fish species via predation. The abundance of Lake Eacham rainbowfish, (*Melanotaenia eachamensis*) in Lake Eacham Queensland has been significantly affected by the translocation of native species such as the mouth almighty (*Glossamia aprion*) being introduced into the lake prior to 1983 (Barlow *et al.* 1987; Leggett and Merrick 1997). At the time of the abovementioned studies, the Lake Eacham rainbowfish was thought to be endemic to Lake Eacham suggesting that the species may have been pushed toward extinction as a result of this translocation. It has since been identified to persist in the associated streams (Pusey *et al.* 1997).

Human-mediated movement of fish has a long history in Australia with both alien and native species moved since the mid 1800s (Clements 1988). The reasons and/or mechanisms for moving fish within and between drainages are many and varied. Prior to 1940, translocations in NSW have been performed for the purposes of stock enhancement for fisheries and by acclimatisation societies (DPI 2005a). Similar activities were conducted in other States, particularly in eastern and southern Australia. For example, common species, including the large-bodied native species Murray cod, (*Maccullochella peelii peelii*) and golden perch (*Macquaria ambigua*), have both been legally and illegally stocked for the purpose of enhancing fisheries (Lintermans 2004).

Water diversions and transfers have led to translocations of native species in Australia. A drastic example of this in Tasmania was the flooding of Lake Pedder as a hydro electric storage. This inundation allowed the translocation through natural dispersal of climbing galaxias (*Galaxias brevipinnis*) into the home range of the endemic species, Pedder galaxias (*Galaxias pedderensis*). The competition for habitat from climbing galaxias combined with the introduction and predation from brown trout (*Salmo trutta*) has driven the Pedder galaxias to the point of extinction in the wild (Sanger 2001). In order to save the Pedder galaxias from extinction, a founder population was translocated into a small natural lake south of Lake Pedder (Sanger 2001). This example highlights the means by which translocation of native species can also be employed as a tool for the conservation of threatened species. Further, the Midgley's carp gudgeon (*Hypseleotris* sp. 1), an established translocated species in the River Torrens South Australia, could have been introduced via a number of pathways including inter-basin transfer of Murray water into the catchment (also with fingerlings of angling species, aquarium escapees, etc) (M. Hammer, pers. comm.).

Escape from professional and amateur freshwater aquaculture facilities has been suggested as a means for native species to be translocated outside their natural range. Freshwater aquaculture escapes of silver perch (*Bidyanus bidyanus*) have recently been recorded in Western Australia (Cross 2000).

Galaxiid species have also been moved outside their natural range. Golden galaxias (*Galaxias auratus*) became established in Lake Crescent as a result of invasion from Lake Sorell, in Central Tasmania via a man-made channel (Allen *et al.* 2002). There have been anecdotal reports of translocated populations of spotted galaxias (*Galaxias truttaceus*) north of the Great Dividing Range in the Loddon and Campaspe River systems, central Victoria since at least the early to mid 1980's (G. Closs, University of Otago, pers. comm.). Climbing galaxias have also been translocated into the Murray River via transfers from the Snowy Mountain hydro electric scheme (Waters *et al.* 2002).

The translocation of native species has had significant social and economic impacts. Translocation has created viable recreational fisheries in many areas where the indigenous native fish fauna are generally small bodied species. There are a number of successful fisheries in Australia which are based upon non-indigenous natives such as the translocated species of golden perch (*Macquaria ambigua*) in the Wimmera River, western Victoria. Native fish such as barramundi (*Lates calcarifer*) have also been successfully farmed in freshwater aquaculture schemes outside their natural distribution providing economic benefits.

1.2 Objectives

The Threatened Species Scientific Committee, which advises the Environment Minister on matters relating to the Environment Protection and Biodiversity and Conservation (EPBC) Act, is considering a nomination to list the introduction of live native or non-native fish into Australian watercourses that are outside their natural geographic distribution as a key threatening process. Similar listings have occurred in NSW and Victoria. SKM has been engaged by Department of Environment, Water, Heritage and the Arts (DEWHA) to undertake an assessment of the "*Impacts of translocating native fish species throughout Australia*". The following document aims to put the Department in a proactive position of having up-to-date knowledge on introduced and/or translocated fish in Australia in the event that the nomination is successful and a Commonwealth threat abatement plan is required. DEWHA will use the information in this document to determine priority research projects for potential funding, including projects which may address similar gaps/recommendations across the various reports, and projects which may be specific to individual groups of fish or issues.

This document outlines the distribution of native fish translocations throughout Australia, the impacts of translocations, the management of translocations and the policies governing translocations. This information is set out in the following sections:

- **Native fish translocations** – summary of the data collection methods employed through this study and subsequent species translocated throughout Australia;
- **Environmental impacts of translocated native fish species** – review of the research findings on the environmental impacts (positive and negative) of translocating native fish species throughout Australia. Where possible Australian examples have been used with international examples where Australian examples are limited;
- **Social and economic impacts of translocated native fish species** – review of the social and economic impacts of translocated native fish species in Australia;
- **Management of translocated native fish species** – evaluation of the current tools, techniques and practices used in relation to the humane capture, handling or destruction of translocated native fish species; and
- **Policies and regulations –** description of current policies and discussion of the degree to which identified state policies integrate with national policies

2. Project approach

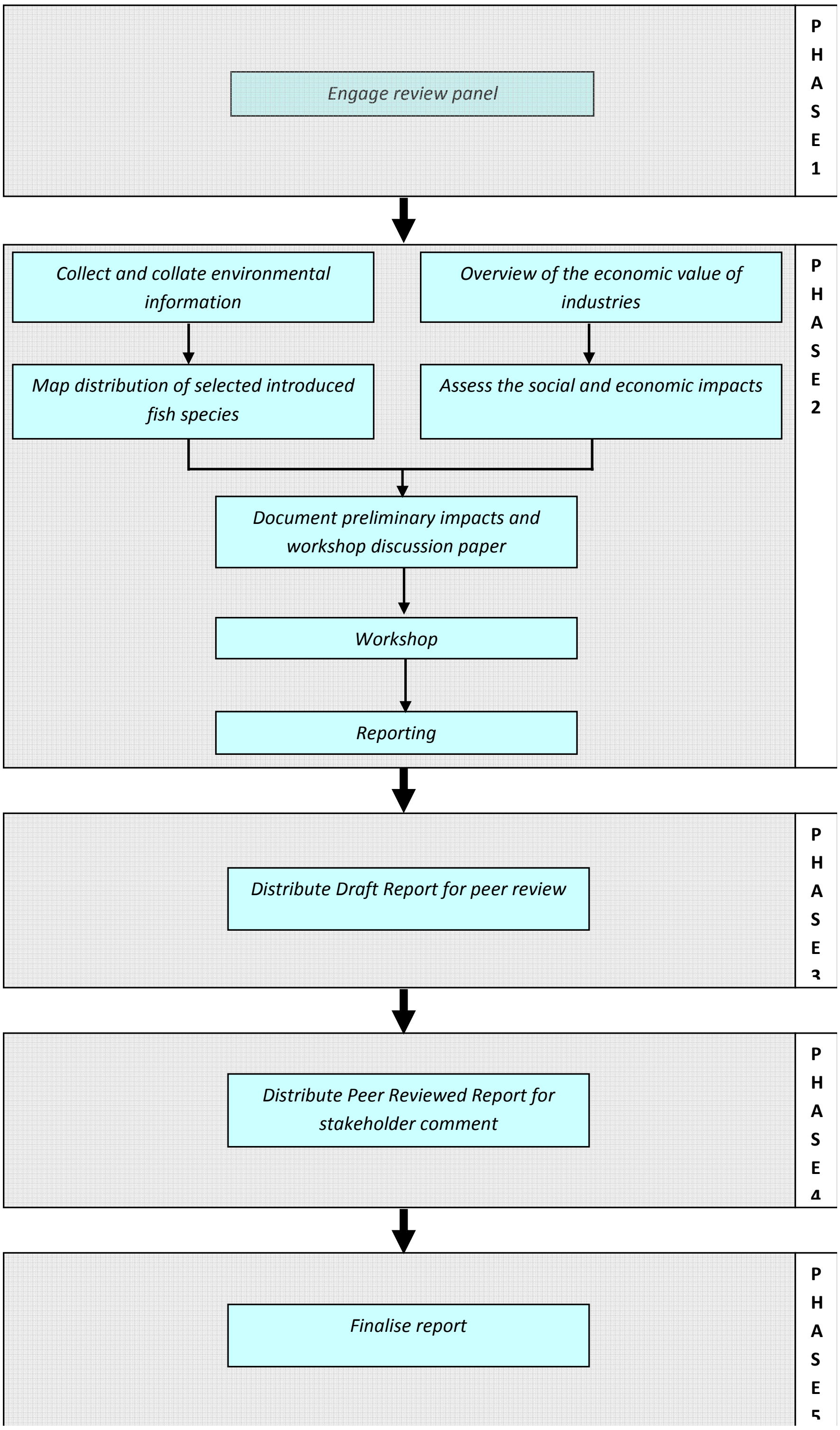
The first stage of this project was to establish a project specific Review Panel to contribute to key project outputs. This was followed by the collation of data from a range of sources, plotting of distributional data and literature review. A project workshop was held in the latter stages of the project. The final stages of project have been a period of rigorous peer review and public comment. The project process is described in Figure 2-1.

2.1 Project review panel

The Review Panel comprised members from throughout Australia and New Zealand who were selected for their knowledge of fish ecology and fish translocations throughout Australia. These members were: Prof. Angela Arthington, Dr Gerry Closs, Dr John Harris, Assoc. Prof. Mark Lintermans and Dr Peter Davies. The review panel provided input to the preliminary information search, attended and contributed to the project workshop, and reviewed the draft report. Their involvement was important so as to produce a scientifically defensible project document and ensure that all avenues of information had been assessed for their veracity.

2.2 Collation of information

Relevant information was collected through a comprehensive search of available information obtained from literature, databases, personal communications. In additional questionnaire was sent to relevant people throughout Australia. A copy of the questionnaire is presented in Appendix A and a summary of all persons contacted as part of this project is presented in Appendix B. This information was used not only to inform discussion within this document but also to identify translocated species and their distribution within Australia.



- **Figure 2-1 Native fish translocation project approach by task indicating five project phases**

2.2.1 Distributional data

A preliminary list of 49 native translocated fish species was obtained from Lintermans (2004) with further distributional data obtained from various other sources. The primary source of distribution data was stocking data for each State and Territory. Stocking data from Queensland (DPIF 2007), Australian Capital Territory (M Jekabsons, Parks, Conservation & Lands, pers. comm.) and New South Wales (NSW Fisheries 2007) was obtained from the State/Territory run databases while Victorian stocking data was obtained from a combination of website downloads (DPI 2007) and Barnham (1991). The primary source of information for translocations within South Australia was Hammer and Walker (2004). The key sources of information for translocations in Western Australia, Northern Territory and Tasmania have been obtained from discussions with Greg Jenkins (Challenger TAFE, WA), David Morgan (Murdoch University, WA), Phil Hall (Northern Territory Fisheries, NT) and Scott Hardie (Department of Primary Industry and Water, TAS).

The natural distribution of most species has been transcribed from Allen *et al*. (2002). The exception to this was the natural distribution of two-spined blackfish (*Gadopsis bispinosus*) and Rendahl's tandan (*Porochilus rendahlii*) which were translated from Lintermans (2007). The distribution of the wet tropics tandan (*Tandanus* sp., a subspecies of freshwater catfish (*Tandanus tandanus*) (D. Burrows, James Cook University, pers. comm.) along with Cooper Creek catfish (*Neosiluroides cooperensis*), desert rainbowfish (*Melanotaenia splendida tatei*), Flinders Ranges mogurnda (*Mogurnda clivicola*), northwest glassfish (*Ambassis* sp.), silver tandan (*Porochilus argenteus*) and Welch's grunter (*Bidyanus welchi*) is yet to be described. The natural distribution of all species has been undertaken by highlighting the catchments from which these species have been known to occur using ArcGIS and then using the map presented in Allen *et al*. (2002) and Lintermans (2007) to more accurately represent the natural distribution for respective species. This latter stage was undertaken as it was clear from the map presented in the Allen *et al*. (2002) that many species had not been recorded from the whole of the catchment. The distribution of translocated native species has been plotted over the natural species distribution of each species. The location of translocations has been plotted to broadly represent the location of translocations, and given the inaccuracy of some data obtained, should not be taken as exact locations. The data has been divided into five year classes – <1960, >1960 (no specific year available), 1960-1980, >1980 and undated (no year specified) to identify the distribution of translocations over time.

2.3 Project workshop

A project workshop was held in Melbourne in late December 2007 to evoke discussion on the information collected to date and access and collate further information – literature and distributional data. This workshop was attended by members of the SKM project team (Sam Hannon and Dr Simon Treadwell), DEHWA (Julie Quinn) and the project review panel (Prof.

Angela Arthington, Dr Gerry Closs, Dr John Harris and Assoc. Prof. Mark Lintermans). All information was checked and updated following the workshop.

2.4 Quality assurance

This document has been reviewed at many stages to assure the quality and accuracy of the final document. Document reviews have been undertaken by core project team members, project review panel members, client representatives as well as through a public comment process. All relevant information has been incorporated accordingly. The final review stage has been a rigorous scientific review undertaken by Dr Gerry Closs.

Significant effort was made at the time of preparing this document to ensure all available data have been presented, but much of the data is not centrally held and collated. This data collected includes both the natural distribution of species and the translocated distribution plotted from two distinct data sources. The natural distribution was interpreted as accurately as possible however there is no doubt there is some uncertainty as to the exact natural distribution of each species. This is not seen as an issue affecting the outcomes of this report as the natural distribution is plotted on large scale maps and should be considered to be indicative only.

3. Native fish translocations in Australia

The species covered in this report are limited to translocated native fish species which spend all, or part of their life-cycle in freshwater systems as well as saline inland lakes and waterways. This includes translocations into natural and artificial waterbodies – but excludes the location of aquaculture facilities.

A review of existing information has identified a total of 77 native fish species that have been translocated within Australia. The translocated distribution and data source for each species is summarised in Table 3-1. The native distribution and translocated distribution is represented in Appendix C. A large number of records of fish translocations (including stocking) have been identified as having occurred after 1980. The majority of these translocation locations have occurred in the Murray-Darling Basin primarily due to stocking programs. Fish have been translocated to a large number of locations along the eastern sea board compared with the remaining coastline of the country. Golden perch (*Macquaria ambigua*), Murray cod and silver perch (*Bidyanus bidyanus*) have been widely translocated (primarily after 1980) inside and outside their natural range in Victoria, New South Wales and Queensland. Anecdotal information also suggests that Murray cod have been translocated into Western Australia but specific locations cannot be identified. Australian bass (*Macquaria novemaculeata*) has been translocated along the eastern seaboard in Victoria, New South Wales and Queensland. A large proportion of Macquarie perch (*Macquaria australasica*) translocation occurred prior to 1960 in Victoria and New South Wales primarily outside its natural range. River blackfish (*Gadopsis marmoratus*) have been translocated inside and outside its natural range in Tasmania. Translocations in South Australia, Northern Territory and Western Australia are limited to a few locations.

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- **Table 3-1: Native species which have been translocated within Australia (77 species) indicating source of translocation data.**

Map Number	Common name	Species name	undated	<1960	1960-1980	> 1960	>1980	Data Source
1	Archerfish	*Toxotes chatareus*	QLD					(Barlow *et al.* 1987; McKay 1989; Hogan 1995)
2	Australian bass	*Macquaria novemaculeata*	SA, QLD	VIC			NSW, VIC, QLD	(McKay 1989; Hogan 1995; Hammer and Walker 2004; DPI 2007; NSW DPI 2007) S Challen, DPIF, pers. comm., J Smith, DPI, pers. comm.
3	Australian grayling	*Prototroctes maraena*			VIC			G Paras, La Trobe University pers. comm.
4	Australian smelt	*Retropinna semoni*			VIC			G Paras, La Trobe University pers. comm., (Lintermans 2007)
5	Banded grunter	*Amniataba percoides*	QLD				NSW	(Barlow *et al.* 1987; Hogan 1995; DNR 1999; Rowland 2001)
6	Barramundi	*Lates calcarifer*	QLD				NT, QLD	P Hall, NT Fisheries, pers. comm., G Ship, NT DPI, pers. comm., , S Challen, DPIF, pers. comm., D Morgan, Murdoch University, pers. comm., A Hogan pers. comm., B Bayn, pers. comm., G Werren, pers. comm., (MacKinnon and Cooper 1987; McKay 1989; White 1991; Hogan 1995; Pearce 2000; Russell *et al.* 2003; Hammer and Walker 2004; Pusey *et al.* 2006)
7	Black bream	*Acanthopagrus butcheri*	WA				WA	GJenkins, Challenger TAFE, pers. comm. (Department of Fisheries 2004)
8	Black catfish	*Neosilurus ater*	QLD					(Hogan 1995; Russell *et al.* 2003)
9	Bony herring	*Nematalosa erebi*	QLD					T Vallance, pers. comm. (Barlow *et al.* 1987; McKay 1989; Hogan 1995; Werren 1997; Russell *et al.* 2003; Lintermans 2007)
10	Clarence galaxias	*Galaxias johnstoni*					TAS	The Inland Fisheries Commission Ledger of samples lodged with the Tasmanian Museum and Art Gallery
11	Climbing galaxias	*Galaxias brevipinnis*	VIC		TAS, VIC		ACT	(Waters *et al.* 2002; Lintermans 2007) G Paras, La Trobe University pers. comm., Raadik unpublished data,
12	Common galaxias	*Galaxias maculatus*	TAS, VIC		VIC	TAS		P. Davies, University of Tasmania, pers. comm., G Paras, La Trobe University pers. comm.,(Lintermans 2007)
13	Cooper Creek catfish	*Neosiluroides cooperensis*						**Actual translocated distribution not formally described**
14	Desert rainbowfish	*Melanotaenia splendida tatei*						**Actual translocated distribution not formally described**
15	Dwarf flathead gudgeon	*Philypnodon sp.*	SA					(Hammer and Walker 2004; Lintermans 2007)
16	Dwarf galaxias	*Galaxiella pusilla*			VIC		VIC	G Paras, La Trobe University pers. comm.
17	Eastern rainbowfish	*Melanotaenia splendida splendida*	QLD	QLD				(McKay 1989)
18	Empire gudgeon	*Hypseleotris compressa*	QLD					(DNR 1999)
19	Estuary perch	*Macquaria colonorum*		VIC			VIC	(Barnham 1991; DPI 2007)
20	Fire-tailed gudgeon	*Hypseleotris galii*	QLD					(McKay 1989; DNR 1999)
21	Flathead goby	*Glossogobius giurus*						(DNR 1999)
22	Flathead gudgeon	*Philypnodon grandiceps*						G Paras, La Trobe University pers. comm.
23	Flinders Ranges Mogurnda	*Mogurnda clivicola*						**Actual translocated distribution not formally described**
24	Fly-specked hardyhead	*Craterocephalus stercusmuscarum stercusmuscarum*						(DNR 1999)
25	Freshwater catfish	*Tandanus tandanus*	QLD, SA		ACT		NSW, QLD, VIC	M Jekabsons, ACT Government, pers. comm., S Challen, DPIF, pers. comm., S Wedderburn, University of Adelaide, pers. comm., P Clunie, DSE, pers. comm., (McKay 1989; Hogan 1995; Russell *et al.* 2003; Hammer and Walker 2004; DPI 2007; Lintermans 2007)
26	Freshwater longtom	*Strongylura kreftii*	QLD					(McKay 1989; DNR 1999)
27	Freshwater sole	*Brachirus selheimi*	QLD					(DNR 1999)
28	Gertrude's blue-Eye	*Pseudomugil gertrudae*	QLD					(Webb *et al.* 1996; Werren 1997; DNR 1999)
29	Giant gudgeon	*Oxyeleotris selheimi*	QLD					(DNR 1999)
30	Glass perchlet	*Ambassis macleayi*	QLD					(Russell *et al.* 2003)

Map Number	Common name	Species name	undated	<1960	1960-1980	> 1960	>1980	Data Source
31	Golden galaxias	*Galaxias auratus*					TAS	(Hardie 2003), P. Davies, University of Tasmania, pers. comm.
32	Golden perch	*Macquaria ambigua*	NSW, QLD, SA, VIC	VIC	ACT, NSW, VIC		ACT, VIC, NSW, QLD	M Jekabsons, ACT Government, pers. comm, S Challen DPIF, pers. comm., , Julia Smith, DPI, pers. comm., A Atkinson, pers. comm. (Cadwallader and Backhouse 1978; Cadwallader and Backhouse 1983; Rowland *et al.* 1983; Brumley 1987; McKay 1989; Barnham 1991; Hogan 1995; Pusey 2002; Hammer and Walker 2004; DPI 2007)
33	Gulf saratoga	*Scleropages jardini*	QLD					A Hogan, pers. comm. (McKay 1989; Hogan 1995; Russell and Hales 1997)
34	Hyrtl's tandan	*Neosilurus hyrtlii*	QLD					(Shipway 1947)
35	Jungle perch	*Kuhlia rupestris*	QLD					(Hogan 1995)
36	Khaki Bream	*Hephaestus tulliensis*	QLD					(Hogan 1995; Russell *et al.* 2003)
37	Lake Eacham rainbowfish	*Melanotaenia eachamensis*	QLD					(Zhu *et al.* 1998)
38	Leathery grunter	*Scortum hillii*	QLD					E. Riddle pers. comm.
39	Macleay's glassfish	*Ambassis macleayi*	QLD					(DNR 1999; Russell *et al.* 2003)
40	Macquarie perch	*Macquaria australasica*		VIC	NSW, VIC		ACT, NSW, VIC	Lintermans unpubl data, (Cadwallader 1981; Rowland *et al.* 1983; Cadwallader and Gooley 1984; McKay 1989; Barnham 1991; Lintermans 2006; DPI 2007; NSW DPI 2007)
41	Mangrove Jack	*Lutjanus argentimaculatus*	QLD				QLD	S Challen DPIF, pers. comm.,
42	Mary River cod	*Maccullochella peelii mariensis*					QLD	S Challen DPIF, pers. comm.
43	Midgley's carp gudgeon	*Hypseleotris sp.1*	SA					S Wedderburn, University of Adelaide, pers. comm. (Hammer and Walker 2004)
44	Mountain galaxias	*Galaxias olidus*			VIC		ACT	M Lintermans, MDBC, pers. comm., G Paras, La Trobe University pers. comm.
45	Mouth almighty	*Glossamia aprion*	QLD					B. Pusey, Griffith University, pers. comm.,(Barlow *et al.* 1987; Russell 1987; McKay 1989; Webb *et al.* 1996; DNR 1999)
46	Mueller's glassfish	*Ambassis muelleri*	QLD					(DNR 1999)
47	Murray cod	*Maccullochella peelii peelii*	NSW, SA,QLD	VIC	ACT, VIC		VIC, NSW, WA, QLD	M Jekabsons, ACT Government, pers. comm., S. Challen DPIF, pers. comm., D. Morgan Murdoch Uni, pers. comm., A Hogan, pers. comm. (Cadwallader and Gooley 1984; McKay 1989; Barnham 1991; Hammer and Walker 2004; DPI 2007; NSW DPI 2007)
48	Murray Darling carp gudgeon	*Hypseleotris sp.3*	SA					(Hammer and Walker 2004)
49	Murray-Darling rainbowfish	*Melanotaenia fluviatilis*	SA					(Hammer and Walker 2004) S Wedderburn, University of Adelaide, pers. comm.
50	Northwest glassfish	*Ambassis sp.*						**Actual translocated distribution not formally described**
51	Olive perchlet	*Ambassis agassizii*	SA					(Hammer and Walker 2004)
52	Pedder galaxias	*Galaxias pedderensis*					TAS	Records taken from electrofishing surveys, netting surveys and various reports held by the Inland Fisheries Commission.
53	Pikey bream	*Acanthopagrus berda*	QLD					(Hogan 1995; Hollaway and Hamlyn 2001)
54	Purple spotted gudgeon	*Mogurnda adspersa*	SA				NSW	(Hammer and Walker 2004; NSW DPI 2007)
55	Queensland lungfish	*Neoceratodus forsteri*	QLD	QLD			QLD	(McKay 1989; Arthington and McKenzie 1997)
56	Rendahl's tandan	*Porochilus rendahli*	QLD					(Russell *et al.* 2003)
57	River blackfish	*Gadopsis marmoratus*	SA, TAS, QLD		VIC		TAS	Records taken from electrofishing surveys, netting surveys and various reports held by the Inland Fisheries Commission., P. Davies,. Unpublished data, M. Read, Unpublished data, G Paras, La Trobe University pers. comm., (Merrick and Schmida 1984; McKay 1989; Jackson *et al.* 1996; Hammer and Walker 2004)
58	Saratoga	*Scleropages leichardti*	QLD		QLD		QLD	S Challen DPIF, pers. comm., (Hogan 1995; QFMA 1996)

Map Number	Common name	Species name	undated	<1960	1960-1980	> 1960	>1980	Data Source
59	Short-finned eel	*Anguilla australis*	TAS, VIC			TAS	ACT	P. Davies, University of Tasmania, (Lintermans 2007)
60	Shovel-nosed catfish	*Arius midgleyi*	QLD					T. Holman pers. comm., (Hogan 1995; DNR 1999)
61	Silver perch	*Bidyanus bidyanus*	QLD, SA, WA		QLD, ACT, NSW		ACT, NSW, QLD, VIC	M Jekabsons, ACT Government, pers. comm, S Challen DPIF, pers. comm, , S Wedderburn, University of Adelaide, pers. comm, P Clunie, DSE, pers. comm, D Morgan, Murdoch University, pers. comm. (McKay 1989; Barnham 1991; Hogan 1995; Webb 1996a; Pusey 2002; Russell *et al.* 2003; Hammer and Walker 2004; DPI 2007; Lintermans 2007; NSW DPI 2007)
62	Silver tandan	*Porochilus argenteus*						**Actual translocated distribution not formally described**
63	Sleepy cod	*Oxyeleotris lineolata*	QLD, SA		QLD		QLD	S Challen, DPIF, pers. comm., (Wager 1993; Hogan 1995; Pusey 2002; Russell *et al.* 2003; Pusey *et al.* 2006; Pusey 2007)
64	Snub-nosed garfish	*Arrhamphus sclerolepis*					QLD	S Challen, DPIF, pers. comm., (DNR 1999)
65	Sooty grunter	*Hephaestus fuliginosus*	QLD		QLD		QLD	S Challen, DPIF, pers. comm., R. Pearson pers. comm., A. Atkinson pers. comm., Anecdotal angler report, T. Vallance pers. comm., pers. obs., E. Riddle pers. comm., (McKay 1989; Hortle and Pearson 1990; Wager 1993; Herbert *et al.* 1995; Hogan 1995; Webb 1996b; Sheppard and Helmke 1999; Russell *et al.* 2003)
66	Southern pygmy perch	*Nannoperca australis*	SA		VIC		NSW	(Hammer and Walker 2004; Lintermans 2007; NSW DPI 2007)G Paras, La Trobe University pers. comm.,
67	Spangled perch	*Leiopotherapon unicolor*	QLD					A. Hogan pers. comm., , Pusey in press, B. Pusey pers. comm., J. Russell, QDPI, pers. comm. (Wager 1993; Webb 1996b; Webb *et al.* 1996; DNR 1999; Pearce 2000; Hollaway and Hamlyn 2001; Pusey 2002)
68	Spotted galaxias	*Galaxias truttaceus*	VIC		VIC			G Paras, La Trobe University pers. comm., (Lintermans 2007)
69	Swan galaxias	*Galaxias fontanus*					TAS	Records taken from electrofishing surveys, netting surveys and various reports held by the Inland Fisheries Commission.
70	Trout cod	*Maccullochella macquariensis*	QLD	VIC			ACT, NSW, VIC	Lintermans unpubl data, M Jekabsons, ACT Government, pers. comm, Julia Smith, DPI, pers. comm. (Cadwallader and Gooley 1984; McKay 1989; Barnham 1991; DPI 2007; Lintermans 2007; NSW DPI 2007)
71	Tupong	*Pseudaphritis urvillii*			VIC			G Paras, La Trobe University pers. comm.
72	Two-spined blackfish	*Gadopsis bispinosus*					ACT	Lintermans unpubl data
73	Welch's grunter	*Bidyanus welchi*						**Actual translocated distribution not formally described**
74	Western carp gudgeon	*Hypseleotris klunzingeri*	QLD					(McKay 1989; Arthington and McKenzie 1997)
75	Western rainbowfish	*Melanotaenia australis*	QLD					(McKay 1989; Arthington and McKenzie 1997)
76	Wet tropics tandan	*Tandanus sp.*	QLD					**Actual translocated distribution not formally described**
77	Yarra pygmy perch	*Nannoperca obscura*			VIC			G Paras, La Trobe University pers. comm.

4. Environmental impacts (positive and negative)

The following section outlines the positive and negative environmental impacts of translocations of Australian native fish. The examples of impacts relate to identified translocated native fish species in Australia. Where such examples are not available, examples from exotic fish or other fauna species have been used. The impacts outlined below relate to genetic issues, predation and competition.

4.1 Genetic issues

Australian freshwater fauna must contend with waters that are spatiotemporally variable. This can prevent gene flow between populations and may lead to isolated populations becoming genetically divergent over time (Hammer *et al.* 2007). Molecular methods have been used to identify the similarity and differences between fresh water fish populations. If molecular methods are not used to identify the differences between populations then these unique populations can go unnoticed, especially when they are similar morphologically (Hammer *et al.* 2007). Translocation of individuals between these genetically divergent populations can have adverse effects through the loss of genetic diversity.

There are three key effects that can cause loss of genetic diversity from a population due to translocation;

1) **direct effects**; hybridisation (interspecific and intraspecific), and out breeding
2) **indirect**; through competition for food and space, predation and disease
3) **hatchery selection**; genetic changes occur through hatchery selection

4.1.1 Direct effects

The loss of genetic integrity through introduced exotic species hybridising with native species is well documented (Arthington 1991). The loss of genetic diversity from Australian fish species has the potential to occur through hybridisation with other Australian fish species (Arthington and McKenzie 1997) and hybridisation with exotic species of like families. This can either be interspecific or intraspecific hybridisation. Examples of this have occurred within Australia in the past, with water being moved from one river to another, escapees from aquaculture facilities, escapees from farm dam stockings, disposal of live bait fish and deliberate releases from fish hatcheries for stock enhancement (Arthington 1991).

Stocking from one native population to another should ideally only occur when the populations are genetically the same. If populations are genetically distinct, out breeding depression may occur if the size of the original population that is to be enhanced is small compared to that of the new translocated stock. The majority of the breeding occurs either between the translocated stock or hybridisation can occur between original and translocated stock. When this hybridisation occurs it dilutes the genetic make-up of the original population, and over the course of generations some of the genetic material from the original population may not be passed on, subsequently becoming lost from the population (Gillanders *et al.* 2006).

Geographically close populations are not always genetically the same. Miller et al. (2004) used genetic techniques to compare mitochondrial DNA of populations of river blackfish (*Gadopsis marmarutus*) (Miller *et al.* 2004) . It was found when the MacDonald River in northern New South Wales and Wannon River in south west Victoria, which are over 1200 km apart, they were only 2.8% divergent/genetically different. In contrast the Glengallan Creek and Darlots Creek, which are less than 50 km apart and both in south west Victoria, were 6% divergent. This was considered to be a sufficiently different to recognise them as two separate species, the northern and southern river blackfish. It is suggested that there is a barrier somewhere between Glengallan Creek and Darlots Creek. This barrier is either biological, (e.g. competitive exclusion), or geological, but both will restrict gene flow between the two catchments. Also it is likely that in the past a connection existed between the Murray Darling catchment's population and the Glenelg catchment's population because of the low genetic difference found between the McDonald and Wannon Rivers (Ryan *et al.* 2004). Translocation between these two genetically distinct populations could have adverse effects, through the loss of genetic diversity, leading to direct effects such as hybridisation or indirect effects such as competition (Miller *et al.* 2004; Ryan *et al.* 2004).

In addition, Waters *et al*. (2002) indicates a risk of hybridization between climbing galaxias (G*alaxias brevipinnis*) and mountain galaxias (*Galaxias olidus*). Also Murray cod have been translocated to the Mary River Queensland where there is potential that the hybridization with Mary River cod (*Maccullochella peelii mariensis*) could threaten the survival of the latter species (Douglas *et al.* 1994; Wager 1994; Phillips 2002). Such hybridization has occurred between trout cod (*Maccullochella* macquariensis) and Murray cod in Cataract dam in NSW (Harris and Dixon 1986a). These studies have shown how molecular techniques can be used to identify and to manage discrete fish stocks.

It is sometimes not possible to trace the processes causing loss of genetic diversity as it is usually found well after the occurrence of the translocation, or may go unnoticed. Unless fine-scaled molecular markers can be distinguished and used before a translocation has taken place, then these unique genetic populations may be lost (Hammer *et al.* 2007)

4.1.2 Indirect effects

Loss of genetic variability due to competition, predation and disease are called indirect effects. These indirect effects can be more difficult to identify compared with direct effects because they can occur at a faster rate than direct impacts and can go undiscovered (Hammer *et al.* 2007).

Specific examples of indirect translocation effects on native Australian fish species have not been identified by researchers, however the following example in a crustacean may also be applicable to fish species. An example of indirect loss of genetic diversity from a population is well illustrated by the rapid genetic displacement of a freshwater crayfish species in the south-west of Western Australia. This came about due to inadvertent translocation of a closely related and more common species of marron (*Cherax cainii*) (Austin and Ryan 2002). It was believed that there was only one species of marron and therefore its range was managed accordingly. Marron were translocated between rivers and catchments through stocking events and aquaculture. Although morphologically very similar, Austin and Ryan (2002) discovered that the endemic marron (*C. tenuimanus*) from the Margaret River, Western Australia was sufficiently genetically distinct to be considered a separate species. The introduction of the common and more widespread species, *C. cainii*, into Margaret River has resulted in the reduction of the endemic Margaret River marron to a point of near extinction in less than 20 years. Although some hybridisation has occurred, competition for food and space seems to the primary driver for this reduction in genetic diversity (Austin and Ryan 2002).

Genetic information may assist in protecting a population from disease. The specific genetic information that protects a population from disease can be lost due to outbreeding depression. Disease introductions are often irreversible and may have a genetic impact due to the loss of a large proportion of the population. This results in a small remaining breeding population which can lead to inbreeding (Arthington 1991). Therefore the issue associated with disease is not the disease itself but rather the resulting indirect impact on the population.

4.1.3 Hatchery selection

Hybridisation between indigenous species and translocated species escaped from an aquaculture facility can also occur. As a result of the use of too few broodstock in aquaculture and their reduced genetic variability this can have an adverse effect on wild populations if these aquaculture stocks are released into the wild (Ministerial Council on Forestry Fisheries and Aquaculture 1999). Fish from aquaculture with reduced genetic variability that enter the natural environment due to escaping or accidental releases maybe a concern. The introduced fish may have a competitive advantage over unmodified indigenous fish or may breed earlier, providing progeny exclusive use of the environment and possibly resulting in native species becoming displaced (Ministerial Council on Forestry Fisheries and Aquaculture 1999; DEH 2006)

The impact of a translocated population is directly related to the breeding success of the translocated population. A study by Doupe and Lymbery (1999) on the Ord River in Western Australia found that hatchery reared barramundi escaped and had the potential to genetically contribute to the wild Ord River population. The risk of hybridization then depends on the rate of escape of the cultured fish, the numbers of cultured fish which survive to reproductive maturity and the number which achieve reproductive success. The long-term effects of hybridization depend upon the effective population size of the existing Ord River population compared to the size of the hatchery reared population that survives and contributes genetic material to it (Doupe and Lymbery 1999).

Genetic changes within a wild population through translocation, on the whole is considered undesirable. However genetic improvement of Australian native freshwater fish through conservation stocking may be of some benefit to small and/or inbred populations (Gillanders *et al.* 2006). Although it is impossible to reintroduce genetic diversity back into a population, if the loss cannot be identified, it may be advantageous to have genetic information on populations that are decreasing in numbers. This then can be used at a later date to assist hatchery managers to select genetically sound broodstock that will maintain the genetic integrity in the target population. In addition, conservation stocking may be used following drought. In instances where drought has led to a significant reduction in the native fish populations such stockings may be used to boost abundances. However, such stocking may lead to adverse impacts and the impacts should be quantified prior to any action being taken.

It is important to have a sound understanding of the genetic implications when transferring freshwater fish stocks. Currently this is not occurring within Australia (Gillanders *et al.* 2006). This lack of understanding will continue to risk the genetic integrity of natural populations, unless molecular testing is employed to identify these differences within and between populations of native Australian freshwater fishes (Hammer *et al.* 2007).

The use of genetic, physical and chemical markers are ways of identifying introduced stock in natural waterways. Although these methods can be expensive they can give a good indication of the success of the translocation (Burrows 2002) and also can, if genetic markers are used, give an indication of the rate of genetic change to natural populations (Gillanders *et al.* 2006).

4.2 Predation

Positive and negative predation effects can occur when stocking or translocating fish. Fish from a stocking program may act as prey for the existing fish, subsequently providing a positive benefit for the local population and a negative effect for the stocked fish. Conversely stocked fish may prey upon local fish and therefore negatively impact local fish whilst improving the survival of the stocked fish. Also, in areas where resources (e.g. food, habitat etc) are scarce, the predation pressure upon a newly formed population may increase, leading to behavioural changes associated with the lack of these resources (Gillanders *et al.* 2006).

The disappearance of Lake Eacham rainbowfish (*Melanotaenia eachamensis*) from Lake Eacham on the Atherton Tablelands, Queensland, has been associated with unauthorised translocations (Barlow *et al.* 1987), specifically the introduction of mouth almighty (*Glossamia aprion*), archerfish (*Toxotes chatareus*), bony herring (*Nematolosa erebi*) and banded grunter (*Amniataba percoides*). Predation by mouth almighty and banded grunter is considered to have been particularly important in the disappearance of the Lake Eacham rainbowfish. Other impacts of the translocated species include predation on Lake Eacham rainbowfish larvae or fry by archerfish. Diseases and parasites may have also been introduced with these translocated species (Barlow *et al.* 1987). The Lake Eacham rainbowfish was thought to be extinct in the wild until a population was found in surrounding waterways (Leggett and Merrick 1997). Similarly, the spread of sleepy cod (*Oxyeleotris lineolatus*) in the Burdekin River, Queensland appears to correlate with a decline in abundance of purple-spotted gudgeon (*Mogurnda aspersa*) and may be due to direct predation (Pusey *et al.* 2006).

Studies in controlled environments have shown that predation by translocated stock does occur. This is highlighted in an experiment conducted by Hogan (1995) to identify predation by barramundi on other fish species. Barramundi, a large predatory fish, were stocked into a pond following the stocking of rainbowfish, hardyheads, banded grunter, archer fish and bony herring. At the end of the trial the numbers of the smaller foraging type fish, rainbow fish and hardyheads were greatly reduced by predation from barramundi (Hogan 1995). Similarly, stocked species such as Murray cod and golden perch regularly prey on small native species such as Australian smelt and carp gudgeons in impoundments (Lintermans unpublished data).

The introduction of large piscivorous species may provide benefits for controlling exotic fish species. Such introductions must however be conducted under controlled conditions. Murray cod have been shown to consume carp (*Cyprinus carpio*). A study by Ebner (2006) identified carp in the stomach contents of Murray cod, and other exotic species such as redfin perch (*Perca fluviatilis*) and gambusia (*Gambusia holbrooki*) have been regularly recorded in the diet of golden perch (Lintermans unpublished data). Studies have also identified that a reduction in the abundance of carp has been attributed to predation by Australian bass (Harris 1997). Further, Australian native fish species have been identified to assist in the control of mosquitoes as a replacement for gambusia (Hurst *et al.* 2005). This includes some species which are listed as being translocated in Table 3-1.

Spangled perch in Queensland have been used beneficially by the Queensland DPI to assist in the control of an exotic species, Tilapia (*Oreochromis massambicus*). In 2003 Queensland DPI translocated spangled perch into a weir on the upper Herbert River in part to act as a predator to control tilapia juveniles. The spangled perch were taken from another weir a couple of hundred metres downstream of the target weir (J. Russell, QDPI, pers.comm.).

Native fish populations are not the only organisms at risk from fish translocation. Frogs, tadpoles and frog eggs come under direct predation from fish, as do a range of invertebrates. Predation by fish is considered to be the most important biotic factor influencing the composition of many frog communities (Burrows 2002). Some frog species will actively select spawning sites that have no predatory fish within them (Burrows 2002). Many frog species have been excluded from prime frog habitat due to an inability to co-exist with predatory fish species. An example of this is where two frog species, *Litoria nannotis* and *L. rheocola,* (both listed as 'Endangered' under the EPBC Act 1999) have been restricted to small tributaries of the Tully River, Queensland, that do not support predatory fish species. The primary species believed responsible for the contraction of frog distribution is the translocated sooty grunter (*Hephaestus fuliginosus)* (Burrows 2002).

4.3 Competition and habitat alteration

Changes in abundance and behaviour primarily arise through competitive interactions between stocked and wild fish. Changes due to competition can be either direct (for food and habitats) or indirect (habitat alteration, behavioural changes, expansion of species range and displacement of wild stocks) (Fletcher 1986; Gillanders *et al.* 2006).

An example of both direct and indirect competition occurred following the construction of the Lake Pedder impoundment in Tasmania during the 1970s and the subsequent establishment of a connection between the original Lake Peddar and the Gordon River. The pedder galaxies (*Galaxias pedderensis*) was once abundant in the Lake Pedder system but is now restricted to two small isolated tributaries in the Pedder system (Sanger 2001). Construction of the impoundment is believed to have reduced the availability of preferred habitat of native Pedder galaxias and may in turn have reduced their numbers. More importantly the expansion in range of the climbing galaxias (*Galaxias brevipinnis*) through the connection with the Gordon River may have had a direct impact on native Pedder galaxias through competition and/or predation. In areas where the two species co-exist, the Pedder galaxias is possibly out competed by the climbing galaxias for food and space (Jackson 2004; Threatened Species Section 2006). Moreover the predation and/or competition resulting from an increased population abundance of brown trout, due to the connection with the Gordon River, may also have led to the reduction in numbers of Pedder galaxias.

The impact of stocked/translocated fish (and their offspring) on food resources is likely to depend on fish density, available resources, size of fish stocked and the adaptive abilities of stocked fish. The stocking of fish may cause an increase in abundance within a given habitat, which may lead to increased intra- and inter-specific competition for food, which may include vegetation and invertebrates species. Outcomes of increased competition include reduced growth, changes in resource use, displacement of stocks, and in extreme cases, starvation. (Gillanders *et al.* 2006)

Other organisms may also experience the impact of fish translocation. For example, frogs and birds may compete for similar resources as fish species. Increased competition for resources may occur if a fish community is supplemented through translocations. However, translocations of small fish or fish at the fingerling stage can prove a possible positive for bird life where they can feed on these new arrivals (Burrows 2002), although such potential benefits are rarely planned.

Impacts of translocation on habitat resources (space) also require consideration. Specific impacts are likely to depend on the abundance of stocked and wild fish, and extent of suitable habitat. The addition of stocked fish can result in competition for space and habitat. Competition will be extreme if habitat is a limited resource and stocked and wild fish have similar habitat requirements. Competition for habitats may be either aggressive (interference) or passive (exploitation); however, this largely depends on the territorial nature and behaviour of species. This unfortunately is difficult to assess because few studies have been conducted (Gillanders *et al.* 2006).

Little work has been undertaken on the likely effects of fish stocking on habitat alteration and degradation. Of the work available there is little evidence that introduced fish have seriously altered aquatic habitats in Australia (Arthington 1991). Habitat alterations caused by stocking native fish may occur if individuals exceed the carrying capacity for a particular habitat. Habitat alterations may arise indirectly via additional grazing on macrophytes, which can alter habitat site conditions, such as sediment stability (Gillanders *et al.* 2006). A potential impact of stocked native species is the increased need for food resources, such as macrophytes, the additional grazing of which may alter biomass and, therefore, associated habitats (Gillanders *et al.* 2006). Impacts of habitat alteration may be restricted to a small scale where the introduction of fish has occurred.

4.4 Disease

Fortunately Australia is generally free of many freshwater finfish diseases found around the world (Kailola 1990). There are few examples of disease transfers directly from one native to another without the introduction of the disease through a non-native fish(Langdon 1990; Cadwallader 1996). One example of a native disease transfer is associated with juvenile barramundi (*Lates calcarifer*) and a barramundi picornia-like virus, (BPLV). It has been recognised that Macquarie perch, Murray cod and silver perch are susceptible to BPLV and when moving barramundi all precautions must be taken so not to introduce BPLV into a new environment (Glazebrook *et al.* 1990).

Murray cod have also shown to be susceptible to disease from imported aquarium species. The mass mortality of Murray cod in an aquaculture facility in 2003 is believed to be attributed to a virus that entered the country from the importation of ornamental fish, namely gourami. The outbreak of the gourami iridovirus caused up to 90% mortality of Murray cod fingerlings in farms. The lack of host specificity of this virus means that a number of other native species may also be vulnerable to this virus including Trout cod, Mary River cod and eastern freshwater cod

(*Maccullochella ikei*) (Go *et al.* 2006; Whittington and Chong 2007). The introduction of this virus may therefore lead to the transmission between native species with the potential to impact a large population of iconic species.

Also the introduced redfin perch is known to carry diseases and pathogens and has introduced them into Australian waterways (Langdon 1988; Langdon 1989). Redfin carry the epizootic haematopoietic necrosis (EHN) virus that can affect silver perch, mountain galaxias, macquarie perch and murray cod (Arthington and McKenzie 1997). In the Australian Capital Territory, mass mortality of juvenile Macquarie perch has been attributed to EHN virus. It is considered likely that this disease has been responsible for major declines in populations of macquarie perch in this region (Lintermans 1991). Precautions and strict quarantine protocols must be followed when moving native stock from affected areas to new waterways. As highlighted, the risk from disease and parasites can be a real threat to native fish populations (Gillanders *et al.* 2006).

4.5 Conservation

Translocations have occurred in many States in Australia for the benefit of conservation. Conservation translocation may be the only option available for some species or populations which would otherwise be exposed to dire conditions. Freshwater catfish have been translocated in the Wimmera River in the early 20th century which has significantly contributed to the conservation of this species in Victoria. Further, one of the most successful translocations in Victoria was that of Macquarie perch from the King Parrot Creek nearly 90 years ago into the Plenty River from where the fish have moved into the Yarra River to become a significant self sustaining population outside their natural range (Cadwallader 1981) G. Creed, Native Fish Australia, pers. comm.). In addition, a translocated population of trout cod in the Sevens Creeks near Euroa in Victoria is one of only two breeding populations remaining in Australia (NFA 2007b).

4.6 Summary

The environmental impacts of translocated native fish in Australia are summarised in Table 4-1. The impacts of translocation are generally in the negative as a result of predation, competition, habitat alterations, disease outbreaks or infections, and the loss of genetic integrity. Poor stocking management, illegal stocking, and escapees from farm dams and aquaculture have had, and can have, adverse effects on native fish stocks. The use of molecular techniques, to identify genetic diversity and distinctive populations, and a better understanding of biotic environmental interactions is needed if more translocations are to take place in the future, and to minimize the impacts of translocations. The potential environmental benefits of stocking may include species conservation and introduction as a control against exotic species.

Numerous knowledge gaps associated with native fish translocation have been identified. These include:

- **Ecological impacts of translocations:** these are very poorly understood and many may go unnoticed due to lack of monitoring or for want of sensitive monitoring methods.
- **Biological controls**: the applicability and potential impact of using translocated native fish species as a biological control against pest or weed species needs research.
- **Identification of genetic markers**: fish of the same species are generally considered to be suitable for stocking, however they may be genetically distinct and thus a risk to the resident population. Much more work is required to determine the degree of genetic differentiation within species to identify genetic markers so as to ensure that only like populations are to be stocked.
- **Use of chemical markers:** fish being translocated for stock enhancement can be marked with a chemical agent providing managers a way to separate natural and introduced stocks. However the most appropriate chemical marker for doing so is yet to be identified.

Table 4-1: Summary of environmental impacts of translocated native fish species in Australia.

Species	Predation	Competition	Habitat alterations	Diseases	Hybridisation (Genetic)
General impacts	Predation (Wager 1994; DEH 2006; Gillanders *et al.* 2006); Predation can have positive effects (increased food source for native fish) or negative effects (native fish are preyed upon, native fish become dependent on introduced species). Where habitat and resources are scarce predation may interact with competition (Gillanders *et al.* 2006); Many frog species cannot coexist with fish that prey on frog tadpoles(Fickling 1995; Burrows 2002). Introduction of Australian native species has been used favourably to control the distribution of exotic fish (Hurst *et al.* 2005)(J. Russell, QDPI, pers. comm.)	Competition effects may be direct (food, habitat) or indirect (habitat alteration, behavioural changes, expansion of species range, displacement of wild stock) (Fletcher 1986; Arthington *et al.* 1990; Arthington 1991; DEH 2006; Gillanders *et al.* 2006); Behavioural differences can result from rearing fish in hatcheries. May result in detrimental changes in behaviour of wild fish (Gillanders *et al.* 2006). When stocked outside natural range, interspecific competition is likely to occur(Mills *et al.* 2004) <u>Spatial/trophic alterations</u> Carrying capacity of an ecosystem is difficult to determine (Gillanders *et al.* 2006). Repeated stockings may exceed carrying capacity. Carrying capacity is likely to be variable depending on flow regime, food availability and temperature (Aprahamian *et al.* 2003; Gillanders *et al.* 2006) Stocking will influence lower levels n the trophic cascade (Carpenter et al 1985) High abundance of released fish may lead to localized extirpation of a species occupying the same ecological niche. No observation of extinction as a result of stocking of native species exists (Gillanders *et al.* 2006). (Arthington and McKenzie 1997; DEH 2006; Gillanders *et al.* 2006) Stocking may increase availability of prey for native predators (Lever 1996) which can influence diet, growth, condition and breeding success of native species (DEH 2006).	Uninhabitable by native species (Arthington *et al.* 1990; Arthington 1991; Wager 1994; Arthington and McKenzie 1997; DEH 2006; Gillanders *et al.* 2006); Stocking by native fish most likely causes only minimal alterations (Gillanders *et al.* 2006).	Introduction of disease will have a negative impact on wild populations (Arthington 1991; Wager 1994; Arthington and McKenzie 1997; DEH 2006; Gillanders *et al.* 2006). Hatchery fish are prone to proliferation of pathogens, which they may spread into wild populations on stocking (Gillanders *et al.* 2006; Go *et al.* 2006; Whittington and Chong 2007)	Genetics (Arthington 1991; Wager 1994; Arthington and McKenzie 1997; Cross 2000; DEH 2006; Gillanders *et al.* 2006) Limited genetic variation in hatchery fish may reduce viability of wild populations (Phillips 2002). Translocation of species between drainage basins may lead o catastrophic consequences due to hybridization especially to relict wild populations in restricted habitat (Musyl and Keenan 1992; Phillips 2002).
Australian bass (*Macquaria novemaculeata)*	Australian bass have been identified to assist in controlling carp (Harris 1997)			High mortality rate if infected with a nodavirous that causes viral encephalopathy and retinopathy (Gillanders *et al.* 2006).	
Australian smelt (*Retropinna semoni*)				Susceptible to *Chilodonella cyprini* (Cadwallader 1996)	(Hammer *et al.* 2007) Possible hybridisation between subspecies
Banded grunter (*Amniataba percoides*)	The endangered Eastern Freshwater cod *M. ike*i and Oxleyan Pigmy Perch are threatened by predation from Banded Grunter (Rowland 2001)				
Barramundi (*Lates calcarifer*)	Believed to be responsible for the decline of hardyheads and rainbowfish to negligible numbers when introduced into same habitat. (Hogan 1995).			Highly vulnerable to infections by BPLV (barramundi picorna-like virus) (Glazebrook *et al.* 1990). A small number of infected fish in a translocated batch could cause catastrophic consequences (Munday 1994; Arthington and McKenzie 1997).	Genetic variation in barramundi populations has been investigated across northern Australia in several studies. A total of 16 genetically discrete stocks have been identified (Keenan and Salini 1990; Doupe and Lymbery 1999). Degree of hybridization depends on number of escaped hatchery reared fish that live to maturity (Doupe and Lymbery 1999).
Bony herring (*Nematalosa erebi*)				Susceptible to*Chilodonella*	

Species	Predation	Competition	Habitat alterations	Diseases	Hybridisation (Genetic)
				cyprini (Langdon 1990)	
Climbing galaxias (*Galaxias brevipinnis*)		Competition with *G. pedderensis* for food and space (Jackson 2004; Threatened Species Section 2006). Invasion of the upper Murray River system and potential impacts on Galaxias spp. and previously fish free communities (Waters et al. 2002).			Hybridization risk between climbing galaxias and mountain galaxias *G.brevipinnis* and native *G.olidus* (Waters *et al.* 2002)
Freshwater catfish (*Tandanus tandanus*)					Catfish exhibited genetic variability that suggested a degree of population structuring. (Musyl and Keenan 1996; Gillanders *et al.* 2006)
Galaxias sp.			Many species are in serious conservation crisis for a diversity of reasons, including habitat deterioration which allows competitors to move in (McDowall 2006; Threatened Species Section 2006)	Susceptible to *Chilodonella cyprini* (Cadwallader 1996) (McDowall 2006; Threatened Species Section 2006)	
Golden galaxias (*Galaxias auratus*)	Reduced habitat diversity and availability which increases competition with other fish species and the risk of predation (Hardie 2003; Threatened Species Section 2006)	Reduced habitat diversity and availability which increases competition with other fish species and the risk of predation and predation (Hardie 2003; Threatened Species Section 2006)	Reduced habitat diversity and availability which increases competition with other fish species and the risk of predation (Hardie 2003; Threatened Species Section 2006)		Hybridization risk between *G.auratus* and *G.maculatus (Hardie 2003)* (Threatened Species Section 2006)
Golden perch (*Macquaria Ambigua*)					Hybridisation between sub species (Musyl and Keenan 1992; Wager 1994; Gillanders *et al.* 2006)
Lake Eacham rainbowfish (Melanotaenia eachamensis)	Extinction caused by predation by Mouth Almighty (Barlow *et al.* 1987) (Leggett and Merrick 1997)			Diseases and parasites introduced with translocated species may have impacted on rainbowfish (Barlow *et al.* 1987)	
Mountain galaxias (*Galaxiasolidus*)				Susceptible to a large range of disease including, but by no means limited to epizootic haematopoietic necrosis virus (EHNV) (Cadwallader 1996)	
Macquarie perch (*Macquaria australasica*)		Possible reduction in number from redfin and trout competition (Cadwallader 1981)		Susceptible to Epizootic haematopoietic necrosis virus (EHNV) (Cadwallader 1996) Susceptible to *Chilodonella cyprini* (Cadwallader 1996) Susceptible to BPLV (barramundi picorna-like virus) (Glazebrook *et al.* 1990; Arthington and McKenzie 1997)	
Mary River cod (*Maccullochella peelii mariensis*)				Exotic disease may spread through cod species and lead to mass mortailities (Go *et al.* 2006; Whittington and Chong 2007)	If Murray cod are translocated to the Mary River, Queensland there is potential that the hybridization with Mary River cod with threaten the survival of the latter species (Harris and Dixon 1986b; Douglas *et al.* 1994; Wager 1994; Phillips 2002).
Murray cod (*Maccullochella peelii peelii*)	Carp have been identified in the gut conditions of Murray cod (Ebner 2006)			*Lernaea cyprinacea, Chilodonella cyprini* (Langdon 1990). Potential carrier of epizootic haematopoietic necrosis virus	Detrimental effects of hybridisation of *Maccullochella* species and subspecies has been demonstrated (Rowland 1985; Wager 1994). If

Species	Predation	Competition	Habitat alterations	Diseases	Hybridisation (Genetic)
				(EHNV) (Cadwallader 1996). Susceptible to BPLV (barramundi picorna-like virus) (Glazebrook *et al.* 1990; Arthington and McKenzie 1997) Exotic disease may spread through cod species and lead to mass mortailities (Go *et al.* 2006; Whittington and Chong 2007)	Murray cod are translocated to the Mary River, Queensland there is potential that the hybridization with Mary River cod with threaten the survival of the latter species (Harris and Dixon 1986b; Douglas *et al.* 1994; Wager 1994; Phillips 2002)
Pedder galaxias (*Galaxias pedderensis*)		Competition with *G. brevipinnis* and brown trout (*Salmo trutta*) for food and space (Crook and Sanger 1997; Crook 2001; Jackson 2004; Threatened Species Section 2006)	Habitat loss due to alterations to Lake Pedder increased pressure from trout because of alterations(Jackson 2004; Threatened Species Section 2006)		
River blackfish (*Gadopsis marmoratus*)				*Lernaea cyprinacea, Chilodonella cyprini* (Langdon 1990)	Possible hybridisation between Northern *g. marmoratus* and Southern *g. marmoratus* (Ryan *et al.* 2004)
Silver perch (*Bidyanus bidyanus*)				Susceptible to epizootic haematopoietic necrosis virus (EHNV) (Cadwallader 1996) Susceptible to BPLV (barramundi picorna-like virus) (Glazebrook *et al.* 1990; Arthington and McKenzie 1997)	Southern pygmy perch likely comprises two species, risk of hybridisation between the two (Phillips 2002; Gillanders *et al.* 2006)
Sleepy cod (*Oxyeleotris lineolatus*)	Decline of Purple-spotted gudgeon (*M. adspersa*) from competition and predation from Sleepy cod (Pusey *et al.* 2006; Pusey 2007) See also (Pusey 2007) for predation by sleepy cod.				
Southern pygmy perch				Susceptible to *Chilodonella cyprini* (Cadwallader 1996)	
Striped gudgeon (*Gobiomorphus australis*)				Susceptible to *Chilodonella cyprini* (Cadwallader 1996)	
Swan galaxias (*Galaxias fontanus*)	Possible predation from brown trout and redfin. (Jackson 2004)	Possible competition of brown trout (Jackson 2004)			
Trout cod (*Maccullochella macquariensis*)				Susceptible to *Chilodonella cyprini* (Cadwallader 1996) Exotic disease may spread through cod species and lead to mass mortailities (Go *et al.* 2006; Whittington and Chong 2007)	Detrimental effects of hybridisation of Maccullochella species and subspecies has been demonstrated (Rowland 1985; Wager 1994)..

5. Social and economic impacts (positive and negative)

5.1 Socio-economic assessment

This section sets out to provide an overview of the socio-economic value of the industries that are reliant on native translocated fish species within Australia. This has been undertaken through a review of the literature with consideration of the values associated with the following aspects of freshwater native species:

- Commercial fishing;
- The recreational and tourism fishing sector; and
- Aquatic species conservation.

The focus of the literature review was the identification of papers that relate directly to translocations. In particular, the economic and social values identified with the translocated species where translocated species represent a significant proportion or influence upon the resource quality available for recreation, commercial and conservation activities. As part of the assessment, key value indicators were developed to describe the values of industries reliant on native translocated fish and these are used to assess impacts.

5.2 Commercial Fishing Industry and Aquaculture

Aquaculture dominates the commercial industries based on translocated native species. This is because inland fisheries have largely closed with the cessation of commercial fisheries in the Murray-Darling Basin (ABARE 2007). Particular effort is put into culturing the following species in Australia for stocking and table fish:

- Barramundi;
- Eel species;
- Silver perch;
- Murray cod;
- Golden perch; and
- Barcoo grunter.

The following information summary is based on the latest ABARE fisheries report, *Australian Fisheries Statistics 2006* (2007). Overall, aquaculture remains a significant sector of the total Australian fishery production. Barramundi production has more than doubled from 2000-01 to 2005-06, while the diadromous and marine species of salmon, trout, tuna and pearl oysters remain the most valuable aquaculture production systems. Table 5-1 provides a production value for translocated native species for each state for 2004-05.

▪ **Table 5-1 State based aquaculture value of translocated native species.**

	Barramundi ($'000)	Eel species ($'000)	Silver perch ($'000)	Golden perch ($'000)	Barcoo Grunter ($'000)	Total value 2004-05 ($'000)
NSW	1,238	-	2,770	-	-	4,008
VIC	-	1,241	1,678 [a]	-	-	2,919
Queensland	13,900	3,050 [b]	510	-	320 [c]	17,780
South Australia	2,029	-	13,643 [d]	-	-	15,672
Total	17,167	4,291	18,601	-	320	40,379

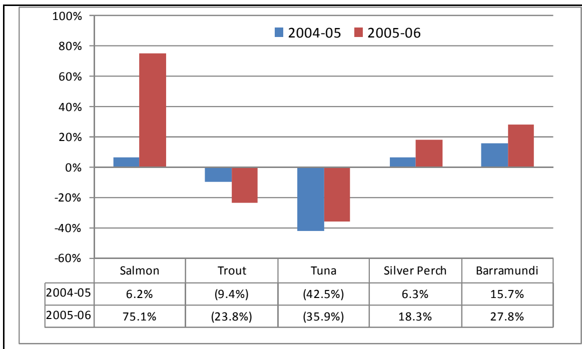
[a] Includes Australian bass, barramundi, catfish, golden perch, murray cod and silver perch
[b] Includes eels and aquarium fish
[c] Marketed as Jade Perch
[d] Includes snapper, microalgae, murray cod, yellowtail kingfish, golden perch and aquarium fish
[e] It is understood an eel fisheries exists in Tasmania although no official data could be sourced

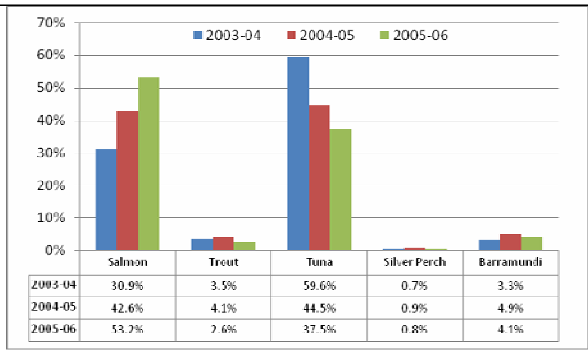
Translocated native species represent 9% of the total aquaculture value in New South Wales. Victorian production of translocated species is split between eels and finfish, comprising Australian bass, barramundi, catfish, golden perch, Murray cod and silver perch. Queensland aquaculture production is dominated by prawns (70% of total value), however barramundi has the second highest aquaculture value in the state, representing 27% of the state's total aquaculture output. Other important aquaculture species include silver perch, eel and Barcoo grunter. The South Australian aquaculture industry is dominated by bluefin tuna while the aquaculture industry based on native translocated species represents 7% of the total aquaculture industry value.

The Western Australian aquaculture industry is dominated by pearl production and does not support significant production of native freshwater fish species. The Tasmanian aquaculture industry is dominated by salmonid production and likewise does not have significant production based on native fish species. Northern Territory production is dominated by pearl and aquarium species.

The industry based on native species which have been translocated remains a relatively small but not insignificant part of the aquaculture industry in Australia. Overall, the estimated value of $40 million represents around 5% of the total aquaculture production in Australia for 2005-06 of $748 million.

The below figures show the shows the change in production value of the five major aquaculture fish species from 2003-04 (Figure 5-1) and the value of aquaculture species as a percent of total value of aquaculture (Figure 5-2). There is a declining value of trout and tuna while a steep rise in salmon production value. Silver perch and barramundi have had more moderate gains. Overall the native species remain only a small proportion of the total aquaculture production value.





Source: ABARE (2007)

- **Figure 5-1 Percent change in value of major aquaculture fish species from 2003-04**
- **Figure 5-2 Value of aquaculture species as a percent of total fish value aquaculture**

Aquarium species are not separately listed in the ABARE statistics but are jointly listed within an ‘Other’ category. Along with aquarium species, this category includes eel, and other native species. In 2005-06, less than two per cent of production was in this category, of which only a small proportion is likely to be native aquarium species (ABARE 2007).

The following employment information is contained in the latest ABARE (2007) report but is based on the 2001 ABS census data (Table 5-2). Data is only available for the total aquaculture industry, rather than disaggregated employment data based on the native fish species sector. As such employment based on translocated native species is estimated by the production value of the translocated native species relative to the total aquaculture production. This should be considered an order of magnitude estimate of the employment levels only given the lack of specific data and the age of the data. This is the direct employment relating to aquaculture and does not include additional indirect employment such as that associated with fish wholesale marketing and seafood processing. Again, the data confirms that aquaculture in Australia based on translocated species is a small part of the overall aquaculture industry. These levels do not include the flow on (indirect) employment such as supporting industries.

- **Table 5-2 Total employment numbers in Australian aquaculture by state and estimated employment based on translocated native species as a per cent of production value.**

	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Total employment in aquaculture	926	320	592	764	601	846	166	6	4,221
Estimated employment based on translocated native species	83	45	143	54	-	-	-	-	325

5.3 Recreational Fishing Sector

The recreational fishing sector has played a large role in the translocation of fish species through stocking programs and unlicensed movements of species. While trout and salmonids are the dominant recreational species (with regard to numbers stocked) and have been extensively translocated, native species including golden perch, Australian bass, silver perch, Murray cod and freshwater catfish have also been widely stocked for recreational angling purposes (Lintermans 2004).

The National Recreational and Indigenous Fishing Survey (Henry and Lyle 2003) provided the latest comprehensive data on the values of recreational fishing across Australia. The study involved a sample of approximately 44,000 people selected from Australian telephone listings during March and April 2000. Each person was asked their level of participation in recreational fishing in the last 12 months and the likelihood to fish in the coming 12 months. A diary survey was also undertaken of those who agreed to participate, which provided detailed information further to the telephone survey. The overall survey indicated that in the 12 months prior to May 2000 an estimated 3.36 million Australian residents aged 5 years or more fished at least once.

The value of the recreational fishing sector associated with translocated native species is not clear. A total of 80% of fishing events undertaken during the survey occurred in seawater rather than freshwater, consequently the majority of fish catch is of marine species. Of the translocated freshwater species of interest, significant numbers of golden perch, Australian bass, Murray cod and barramundi were caught. By way of comparison, 10 marine species each had a harvest of over one million fish indicating that translocated native species are a very small proportion of the overall recreational catch. Table 5-3 outlines the estimated annual catch of significant native species that are known to have been translocated based on the study by Henry and Lyle(Henry and Lyle 2003). Note, this includes species taken from within native home ranges and translocated areas, and hence includes wild fish as well as stocked fished of the same species. As such the data presented does not indicate the recreational catch specific to translocated species. An estimation could be made by using the proportion of the fish ranges known to have translocated species and interpolating those results to the total harvest. This would only provide a vague estimate and is not considered sufficiently precise for the purposes of this assignment.

Table 5-3 Estimated annual harvest of native translocated species by state (number of each species caught).

Species	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	Total
Golden Perch	542,107	142,276	261,688	86,732	1,258	-	-	5,846	**1,039,907**
Australian Bass/Perch	93,150	74,931	97,789	8,530	5,059	51	1,100	-	**280,612**
Barramundi	-	-	88,155	-	22,570	-	105,131	-	**215,857**
Murray cod	93,973	11,943	158	2,278	-	-	-	-	**108,352**

The socio-economic value of recreational fishing based on translocated fish species can be valued both by the expenditure of recreational fishers and the value (or utility) placed in the fishing experience of fishers. The National Recreational and Indigenous Survey (Henry and Lyle 2003) estimated the total attributable expenditure by Australian recreational fishers from May 2000 to April 2001 to be $1.86 billion. On average Australian recreational fishers spent $552 per fisher per annum. Table 5-4 outlines the attributed expenditure, number of fishers and average expenditure by state. While perhaps not significant to the overall Australian economy, these figures confirm that fishing remains a significant recreational industry in Australia. However, it is very difficult to disaggregate these figures down to a value associated with native translocated species given that catch data is only provided on a state by state level and no information is provided about the species targeted during fishing events.

Table 5-4 Expenditure data for recreational fishing industry

State/Territory	Attributable expenditure $'000	Numbers of fishers	Fishing effort (fishing events - millions)	Average Fisher expenditure $
New South Wales	554,200	998,501	7.67	555
Victoria	396,300	549,803	2.81	721
Queensland	319,600	785,045	5.77	407
South Australia	148,500	328,227	2.22	452
Western Australia	338,400	479,425	3.44	906
Tasmania	51,800	124,590	0.91	416
Northern Territory	26,700	43,932	0.35	608
Tasmania	19,400	53,467	0.03	362
Total	**1,854,000**	**3,362,990**	**23.2**	**552**

While the expenditure figures provide an initial estimate, in economic analysis the gross consumer benefit from an activity is generally valued at the maximum amount that consumers are willing to pay for it. The difference between what people are willing to pay and what they actually pay is known as the consumer surplus. There is evidence to suggest that the community would be willing to pay more than the average fisher expenditure outlined above. This relates to factors such as relaxation associated with fishing and the values associated with being in the natural surrounds.

The National Recreational and Indigenous survey also looked at the importance of the motivation for fishing based a five point scale (very, quite, not very, not at all, unsure) for a number of factors. A key results is that to relax and unwind was identified as being important (ie ‘very important’ or ‘quite important’) by 90% of respondents. Fishing for enjoyment of catching fish was important for 80% of respondents. As well, 73% of those surveyed considered it important ‘to be with friends’. These figures indicate that it is likely the community values fishing above what it actually spends on it.

To calculate the actual consumer surplus from recreational fishing would require the estimation of a demand curve for the activity. This is not possible in this instance for a number of reasons, including that recreational fishing is not a fully competitive market, where the supply and demand for recreational fishing can be influenced significantly by price. Also, to obtain the total consumer surplus for native translocated species, separate demand curves would need to be constructed, probably on a state by state basis, to reflect differing demands for species. A number of economic methods are available to ascertain these curves (Campbell and Brown 2003). It is not the intention in this section to provide a detailed description of them, however they fall into two main groups – revealed and stated preference methods. Revealed preference methods use actual behaviour data to construct values. Stated preference methods are based on questioning survey participants in a hypothetical market. This is usually undertaken to understand the ‘willingness to pay’ or ‘willingness to accept’ for a particular environmental or policy change. Rolfe and Prayaga (2007) estimated the value of recreational fishing at freshwater dams in Queensland. The impoundments studied were Boodooma and Bjelke-Petersen Dams in South-East Queensland and Fairbairn Dam close to Emerald. While Redclaw are the target species in Fairbairn, the other dams are stocked with native species. The study employed a travel cost methodology and found individual consumer surpluses ranged from $59 per angler at Bjelke-Petersen Dam to $904 per angler at Fairbairn Dam. The total consumer surplus over a one year period at all sites was estimated at around $8.8 million. The study also found that recreational values vary between groups and across sites making it difficult to extend the results to other non-regulated freshwater systems.

Overall it is difficult to put an exact monetary figure on the value of recreational fishing based on translocated species. Catch data is generally only collected on a state basis, so it is unclear if the recreational fishing of the species occurs in their home range or in the areas to which fish have been translocated. Moreover, it is virtually impossible to distinguish angling effort between stocked and wild fish unless stocked fish are tagged and anglers report their catches. While the average spend per year provides some estimate of the value fishers place on fishing, there is difficulty in disentangling the value of catching fish from value of the total fishing experience (Wheeler and Damania 2001) to gain the total consumer surplus associated with recreational fishing. Thus it would be unwise to place an actual value on recreational fishing for translocated species, suffice to say that freshwater fishing is a major recreational activity with significant economic and social value in Australia.

5.3.1 Fish stocking

An important part of the recreational fishing sector based on translocated native fish species is the activity of fish stocking, which could be considered an enabler to the recreational fishing industry. That is, the stocking of fish encourages recreational fishing in a particular waterbody due to the availability or abundance of a particular species. In NSW, it is estimated that a total of 32 people working in private hatcheries are involved in stocking with around half of these being employed full time. In public hatcheries, approximately 14 people are employed in stocking activities with a statewide investment in public and private hatcheries involved in stocking estimated at $33 million (NSW Fisheries 2003). The other states also have significant stocking programs of native and non-native species however employment and investment data are not available. Fishery agency and enforcement staff are also part of the overall translocated fish industry, as are scientific research positions involved with threatened species recovery.

5.4 Tourism

The Australian Bureau of Tourism Research (BTR) is the government agency tasked with the collection and analysis of information regarding the Australian international tourism industry. During 2001 BTR estimate that about 191,000 overseas visitors engaged in fishing activities while visiting Australia, representing 4.2% of total visitors (Henry and Lyle 2003). Whilst the total visitor numbers are significant, again a lack of detailed information about regions fished, effort or fishing related expenditure means it is difficult to estimate the value associated with international tourism for native translocated species. Domestic tourism is not separately evaluated as much of this tourism is captured in the average expenditure of recreational fishers discussed in Section 5.3.

5.5 Social and cultural values

Total economic value (TEV) represents what people are willing to pay for a change in well-being due to a project or policy (Campbell and Brown 2003). The TEV is a useful way of being able to provide an overview of the value of translocated native species as it can be divided into two main components, the use value and non-use value. The use value can be split into consumptive and non-consumptive uses. The consumptive uses are essentially described by the value of aquaculture and value of recreational fishing while the non-consumptive value could include the viewing and photography of fishing activity, or being with friends, etc, as discussed above.

Non-use values can be divided into existence and bequest value (Navrud 2001). The existence value relates to the fact that the community are willing to pay to know fish stocks exist (this can particularly be the case for iconic or endangered species). The bequest value relates to being able to deliver the existence of fish stocks to future generations. These values have particular relevance where there are particular social or cultural values.

Native fish species can also have significant cultural and indigenous value. The National Recreational and Indigenous Fishing Survey (Henry and Lyle 2003) identified fishing as an invaluable component of cultural lifestyle for indigenous people, with importance for food and nutrition, ceremonial occasions, and being connected to the responsibilities of land management and kinship. At a species, level the Murray cod, for example, plays a significant role in Aboriginal culture forming part of Dreamtime legend (Kearney and Kildea 2001) and has broader cultural importance as an icon freshwater fish. The translocation of native fish species for conservation purposes can help protect these values. Conservation of species was a primary factor in a number of the fish translocations documented during our surveys. Again, there are significant difficulties in assessing these values as no actual market exists. Non-market valuation methods described above can be useful for valuing this aspect of fish resources. In particular, choice experiments have gained popularity recently as they can overcome the issues with budget constraints that can be associated with willingness-to-pay surveys.

Van Bueren and Bennett (2004) provide a significant study of value estimates for environmental goods. The research was undertaken through a choice model where respondents are asked to choose their preferred option from several alternatives. A total sample of over 10,000 people was drawn for the study with a response rate of 16%. The assessed value of a species protected was $0.67 cents per household. On this basis, the value of each species protected is approximately $4.8 million per year based on a household population of 7.2 million people. This value does not take into account inflation since the study was undertaken and should only be considered an order of magnitude assessment at best due to the difficulties in transferring estimates from one study to another. When transferring economic valuation assessments from one study to another (known as ‘benefits transfer’) care must be taken to ensure that the studies are comparable and, in this case, that the species involved in the transferred study are likely to be valued in a similar way to translocated species. Other considerations also include whether the species are of national or regional significance and the extent to which the translocation has in itself protected the species from becoming endangered or extinct.

Overall it may be difficult to put a precise figure on the social value of any or all species translocated for conservation purposes. However, the study outlined above provides evidence at least that the community is willing to pay something to protect certain native species for conservation purposes.

5.6 Impacts of management actions

From the above data, some information is available which would allow the quantification of impacts if restrictions were imposed to stop or prevent translocations of native species. Some of the benefits of translocated native species include:

Aquaculture: there are significant aquaculture industries based on native species with barramundi the most significant species with production value of over $17 million in 2005-06 with an estimated total value relating to translocated species of $40 million. To the extent that management actions prevent or inhibit the aquaculture industries, this value would be reduced.

Recreational fishing: recreational fishing has a high social value in Australia. While there are significant numbers of native translocated species caught by recreational fishers, it is unclear what proportion of the catch derives from waterways receiving translocated species, making it difficult to estimate the impact that a ban on the translocation of native species would have. For there to be a significant impact on the value of recreational fishing, management actions would need to demonstrate a clear link between a particular species and the recreational fishing industry. In addition, there would need to be no adequate substitute for any species that is no longer available for fishing. That is, for there to be a cost, the inability to fish a particular species would need to significantly change the fishing experience in an area. For example through the imposition of harsher limits on overall catches.

5.7 Multiplier effects

The above information details only the direct impacts. The flow-on impacts to other areas of the economy have not been included. For example, when recreational fishers travel to a particular fishing spot they may consume a range of goods and services (e.g. accommodation, fishing equipment, fuel and food). This additional expenditure will then flow on through the economy as a multiplier effect which can impact the final demand for goods and services as well as total employment. These multipliers would be particularly important in assessing the consequences of the change in recreational fishing impacts due to management actions and the impacts associated with aquaculture industries. However, without the availability of specific regional data, particularly for recreational fishing, the use of multipliers to estimate total values may ultimately be misleading.

The multiplier approach however does not compare these impacts to the benefits of reducing fish translocations. A cost-benefit analysis could be used to assess the overall impact to the community by comparing all the costs and benefits (including social and environmental) in a consistent unit of measurement (usually dollars). This approach could be used to explore the change to consumer and producer welfare (eg, reduced ability to fish or continue with the aquaculture enterprise) and compare it with benefits of translocations (eg, environmental or ecosystem improvements, biodiversity loss etc). This approach usually excludes the multiplier impacts.

5.8 Knowledge gaps

- **The key knowledge gap is the ability to disaggregate available data to just translocated species.**

The main gap is the extent to which existing information can be disaggregated to only translocated native species. The exception to this is the commercial value of aquaculture industries where ABARE in conjunction with the ABS and industry provide species by species information. However, the more intangible valuations, such as recreational fishing value or conservation value, are not generally available. In the case of recreational fishing, species data is available, however it is not sufficiently detailed to gain an understanding of the importance of the translocated species alone compared with wild fish. Likewise, the conservation value of just the translocated species must be inferred from broader studies, taking into account the circumstances of the studies. This is not to say that the studies used in this assessment are of a poor quality or suffer from methodological constraints, but rather are not specific to the data requirements of this task. The lack of this information makes it difficult to undertake more detailed analysis such as cost-benefit or input-output analyses.

6. Management of translocated native fish species

6.1 Techniques for capture

The following section reviews and evaluates the current tools, techniques and practices used in relation to the humane capture, handling or destruction of translocated native fish species. A suite of sampling techniques are available if it is deemed necessary to reduce or eradicate the translocated native fish species. The impacts on the target and non-target species vary with technique used. The technique to be applied to collecting any fish species will vary depending on the ultimate use of the fish collected. Non-destructive techniques must be used if fish are to be collected for the purposes of conservation. Conversely, destructive techniques can be used to eradicate a population of fish which occur in an area. In selecting a technique, assessment must be made of the financial cost of employing the option compared with the benefit to be gained. Further, consideration must be made of the social impact of using each technique particularly where collection is to occur in a public area. Using either technique discussed, complete eradication requires a significantly greater effort than a targeted reduction in population size, and there are few situations where eradication is realistically achievable. Removal of a small proportion of the population therefore is often a fraction of the cost of eradication. In many instances however it may be considered that eradication is not necessary and that a significant reduction in population size is adequate. Many methods of collecting fish are not species specific but can be adapted to catch broad size classes in order to assist in collecting a targeted species.

A summary of available techniques along with the potential impact of the technique is described in Table 6-1. The magnitude of these impacts has been identified through consultation with the project review panel. The impact of each technique has been ranked from low to high where low is unlikely to lead to any death of the fish; moderate impacts may lead to death of the fish collected 50% of the time; high impacts may lead to death of the fish the majority of the time.

▪ **Table 6-1: Techniques which may be used for the capture of translocated fish species.**

Sampling technique	Formal operating procedure	Potential impact to translocated species	Potential impact to by-catch
Dipnets	Nil	Low	Low
Electrofishing (bank/backpack/boat)	Australian code of electrofishing practice (NSW Fisheries 1997)	Moderate	Moderate
Fish poisoning	National Rotenone Permit	High	High
Seine nets	Nil	Moderate	Moderate
Gill nets	Nil	High	High
Fyke nets	Nil	Low	Low
Bait traps	Nil	Moderate	Moderate
Water level reduction: dry	Nil	High	High
Water level reduction: partial	Nil	Low-High depending on supplementary technique	Low-High depending on supplementary technique

6.1.1 Nets

Netting includes the use of nets that immobilise and capture fish (eg. gill nets) and those which enclose a population of fish (eg. seine nets). Gill nets will immobilise all fish and by-catch that encounter the net. It is then up to those individuals undertaking the fish survey to ensure that the catch (fish and by-catch) are removed from the nets prior to severe injury or death. Gill nets therefore pose a high potential impact to translocated native fish species and by-catch. Gill nets can target broad size classes of fish through the use of particular mesh sizes or set at certain water depths to target fish at various locations in the water column. Gill nets cannot however be used to collect particular species. Gill nets can be constructed from either multifilament or monofilament material, with monofilament nets being more difficult to release fish unharmed. The use of gill nets is labour intensive as it relies on regular checking of the equipment to minimise injury and some catches within the nets taking significant time and effort to untangle. It is also a passive technique, relying upon the movement of fish into the nets. Gill nets can be perceived negatively by the public as they can indiscriminately collect other animals such as birds, reptiles and platypus and therefore need to be monitored regularly if deemed a necessary technique.

Seine nets are another recognised technique for the collection of fish, however these have restricted applications. To be most effective at collecting a range of fish species, seine nets are best set such that the net forms a barrier from the water’s surface to the bottom of the waterbody as the net is moved around in an arc in a constant motion and then moved onto the shore. This is generally done in wadable habitat and is limited to areas of limited or no woody debris so as to prevent snagging the net (e.g. in wetlands or small dams). Due to the restrictions of this technique to shallow, smooth bottomed water bodies with gently sloping banks it is likely to be used infrequently for removal of translocated species. Where applied in suitable habitat it can be a cost effective technique for the removal of fish. The impacts to translocated native fish species and by-catch are likely to be moderate while the technique is likely to be perceived positively by the community.

6.1.2 Traps

Bait traps and fyke nets work by trapping the live fish in a small enclosure. Both of these techniques are considered non-destructive to fish species as they generally do not immobilise the fish *per se*, rather the fish are contained and can be removed alive. Fyke nets generally target moderate to large sized fish (depending on the mesh size) while bait traps are targeted at catching small fish or small individuals of large species. The recommended method of setting fyke nets is to ensure that the end of the trap (cod end) is exposed out of the water so that air-breathing by-catch (platypus, water rats, turtles, birds) can use this air space as refuge until released. Typically, this leads to this technique having a low impact on by-catch.

Bait traps however are fully immersed for their set period and therefore can be fatal to diving air breathing fauna. For example, water rats and diving birds may become trapped in the small entrance to the bait traps or move into the bait traps while immersed and not be able to escape. The likelihood of this is low even though the impact is great. Similarly, fish species can be predated upon by crustaceans or other small predatory species while enclosed in these traps leading to mass deaths and moderate impact on translocated fish species and by-catch. Similar to fyke nets, this is a passive technique which is not very cost effective for reducing the size of a fish population. However, set correctly, these techniques are often perceived well by members of the public.

6.1.3 Electrofishing

Electrofishing is an effective technique which has been used within Australia for nearly 40 years. The operation of electrofishing is governed in Australia by the Australian Code of Electrofishing Practice (NSW Fisheries 1997). This Code of Practice outlines the safe operation and certification of equipment required to prevent injury to operators, observers and animals.

Electrofishing can be divided into three recognised techniques that are commonly used in Australia – backpack, boat mounted and bank mounted. Backpack electrofishing is a very portable application of electrofishing whereby all equipment is confined to a backpack unit and pole. Back pack electrofishing is limited to water bodies with low to moderate salinity. This technique is widely used in small wadeable streams and creeks. Boat electrofishing is limited by boat access, can be used in moderate to high salinities and is an effective technique for sampling fish in large rivers and lakes. Bank mounted electrofishing is used in wadeable habitat, similar to backpack electrofishing but can be applied in moderate to high salinities as it often uses the same power source as boat mounted units.

Electrofishing is an active technique which can be used to catch large numbers of fish covering a wide size range. Applied effectively, electrofishing can have minimal impact on fauna, however there is a moderate chance of injury to fish and by-catch if used inappropriately through haemorrhaging, spinal dislocation (through severe muscle contraction) or electrocution. This technique is generally perceived well by the public as they continue to be intrigued by electrofishing.

6.1.4 Poisons

Rotenone is a piscicide which has been widely used by researchers and managers worldwide to kill fish. The concentration of rotenone applied can be varied to assist in targeting species within a particular type and size of waterbody. Rotenone has been used throughout Australia to control non-indigenous fish species and can just as easily be applied to control the distribution of native translocated fish species. This must be done under controlled conditions with means of resuscitation of by-catch in place. For example , rotenone can be neutralised by the application of potassium permanganate (Rayner and Creese 2006). Examples of its application include the control of *Gambusia holbrooki* in selected ponds in New South Wales and to eradicate redfin (*Perca fluviatilis*) from Brushy Lagoon in Tasmania. The application of this piscicide depends upon the degree of site enclosure, water quality conditions and flow, presence of aquatic refuges, susceptibility of target species, rotenone type and application methods (Rayner and Creese 2006). Where used to eradicate species, rotenone has been most successful in small, easily accessible, closed lentic systems that are shallow and sparsely vegetated (Rayner and Creese 2006; West *et al.* 2007).

Rotenone is one well known option to chemically control invasive fish species (and unwanted fish species) in Australian freshwater environments although antimycin has been identified as a potential alternative (Sanger and Koehn 1997; Hewitt *et al.* 2002; West *et al.*). Antimycin is yet to be approved for use in Australia but is has been used widely overseas including in the USA (Sanger and Koehn 1997). Antimycin is a selective piscicide so it affects some fish more than others. It does not persist following application so it is essential to ensure that adequate quantities are available to top up the initial application (Rose 2007). Furthermore, NSW Fisheries use hydrated lime to eradicate fish from small dams (M. Lintermans, University of Canberra, pers. comm.).

Either poison mentioned above may have significant impacts on target fish species and by-catch if not managed effectively. It is however a cost effective technique for the removal of large numbers of fish when used under suitable conditions. The cost effectiveness of this technique is likely to be outweighed by the community backlash of potentially poisoning large numbers of by-catch and concerns over the ongoing ecological effects of these poisons.

6.1.5 Water level reduction

Water level reduction can be an effective method of concentrating fish and reducing the area to be sampled. This method is limited to sites where the water level may be controlled effectively. Water level reduction can be applied on two levels: controlled reduction in water level to permit the use of a supplementary technique or complete drying of the target water body. The controlled reduction in water level will lead to the fish being concentrated in a smaller area and permit cost effective removal using a suitable fishing technique. The impact on the target fish species and by-catch will then be as per the respective technique to be applied. This approach may however impact on riparian and aquatic vegetation (habitat) if water level is reduced for extended periods.

The complete drying of a waterbody will lead to the death of fish and must only be applied where the fish community of the waterbody is known and it is desirable to kill all individuals. It is therefore more appropriate to apply this technique once it can be confirmed that only the target species remain. This can be a very labour intensive and dangerous technique as movement through soft substrate can be difficult or may lead to staff getting stuck. The impact of this technique on target fish species and by-catch is therefore high with a high proportion of fish present likely to be collected. The community perception is likely to be negative as it will take significant time before all fish are removed leading to possible odours.

Controlling the water level has been used unintentionally to remove fish from Upper Coliban Reservoir in Victoria in 2006. The Upper Coliban Reservoir was drawn down to a very low level to meet water supply commitments. As water supply was at critical levels in the area in late 2006, the decision was taken to minimise evaporative losses by transferring remaining water from Upper Coliban into the immediately adjoining Lauriston Reservoir. On transferring the water, a high abundance of carp was observed in the mud and subsequently physically removed (J. Sloan, Victorian DPI, pers. comm.). In addition, water level reduction has been used by La Trobe University to control the population of gambusia (*Gambusia holbrooki*). One pond within a closed system was dried to kill fish following on from previous effective applications of this same technique within the same facility (G. Paras, La Trobe University, pers. comm.).

6.2 Techniques for euthanizing

An effective and humane method of killing fish species is essential in order to minimise pain to fish. Numerous euthanizing techniques are employed by fisheries researchers throughout Australia. They involve a combination of humane and potentially inhumane techniques. Recent documentation of wildlife handling and euthanasia techniques have been outlined by Rose (2007) who has collated information for various fauna species from the euthanasia codes of practice developed by the Royal Society for the Prevention of Cruelty to Animals (RSPCA), the Australian and New Zealand Council for the Care of Animals in Research and Teaching (ANZCCART), and National Health and Medical Research Council (NHMRC).

The preferred method for the euthanasia of fish in Australia is an overdose of anaesthetic agent delivered in a bath with the fish kept in the bath for 10 minutes after respiration ceases. Fish may also be chemically restrained in a bath of anaesthetic agent and then barbiturates injected into the vein, the heart or coelomic cavity. The recommended anaesthetic agent is Aqui-S. Other less effective anaesthetics include MS222, isofluorane or halothane and benzocaine. Other acceptable methods such as cranial concussion, spinal transaction or exsanguinations can be applied. Where possible these physical techniques should proceed only following the application of one of the abovementioned anaesthetics. Unacceptable methods include, but are not limited to, cooling or placing fish in a freezer as ice crystal formation is slow and painful. Similarly, leaving a fish out of water is considered an unacceptable technique (Koehn 2004b).

6.3 Summary

Numerous techniques are frequently applied for the collection of fish species in freshwater ecosystem throughout Australia. These techniques however are often not species specific therefore can lead to unnecessary deaths or injury of by-catch. Furthermore, as these techniques are not species specific, significant time may also be required to sort fish following collection in order to return non-target species to the waterbody of collection. The applicability of techniques depends upon the habitat being sampled, fish community present at the site and target fish species. Electrofishing is regularly used throughout Australia as a sampling technique as it can encompass backpack, bank mounted and boat mounted electrofishing. These techniques combined can effectively be used effectively in a wide range of habitats and typically collect a wide range of species. This technique has potentially moderate impacts on the target species and by-catch while being relatively efficient in catching a sample of the fish community. The setup costs of electrofishing can be very high.

If the aim of the sampling is to collect a large proportion of the fish population present or even eradicate the fish species then a combination of sampling techniques should be used. It is important to recognise that complete eradication of a population is far more time consuming than population reduction. As one technique will not always collect all fish present a combination of suitable techniques should be applied. Electrofishing is often paired with netting, similarly water level reductions should be paired with other techniques to increase effectiveness.

The overall effectiveness of sampling techniques may vary with changes in site characteristics. If a targeted control or eradication program were to be set up a trial of the most appropriate sampling techniques is recommended. This would involve assessing the effectiveness of each applied technique to determine the most appropriate technique to meet the project objective. Further measures must also be put in place for any control or eradication program to limit the further spread of species being controlled.

7. Policies and regulations

Current national legislation, designed to conserve the integrity of indigenous native fish species, is predominantly concerned with the impacts of introduced exotic species (Koehn 2004b). The incorporation of translocated species into Commonwealth legislation was recently assessed. This occurred via the nomination for "The introduction of live fish into waters outside their natural range within a river catchment after 1770" to be recognised as a Key Threatening Process under the Commonwealth Environmental Protection and Biodiversity Conservation Act (EPBC)1999 (Jackson *et al.* 2004). This nomination was unsuccessful and could not be adequately assessed due to inadequate information on the definition and its process (Jackson *et al.* 2004). However, Victoria recognises the premise of this nomination under the Flora and Fauna Guarantee Act 1998 as a key threatening process (Jackson *et al.* 2004). NSW also recognises "the introduction of fish to freshwaters within a river catchment outside their natural range" as a key threatening process under the Fisheries Management Act 1994 (MCFFA 1999). In 2007 a new key threatening process was proposed under the EPBC Act, "The introduction of live native or non-native fish into Australian watercourses that are outside their natural geographic distribution". This is currently being assessed.

This section provides a brief summary of the national, and state and territory policies and regulations which exist for the translocation of live aquatic species with a view to considering the translocation of fish species.

7.1 National policies

- *National Policy for the Translocation of Live Aquatic Organisms – Issues, Principles and Guidelines for Implementation (MCFFA 1999)*

The objective of the above policy is to provide a consistent national framework to assess the potential risks associated with all proposals for the translocation of live aquatic organisms. This risk assessment-based process is intended to deal with proposals for deliberate translocations where approval is sought from the relevant jurisdiction.

The guiding principles for the national translocation policy are as follows:

1) Translocation of an aquatic species or non-indigenous stocks of such species may have a clear potential economic, social or conservation benefit, but it is recognised that translocation of aquatic organisms can involve serious risks for the receiving ecosystem (and human health).
2) Translocations into catchments or maritime regions that are under more than one jurisdiction, for example the Murray-Darling system, require the agreement of all the relevant jurisdictions.
3) All translocation proposals should undergo an adequate and balanced risk assessment process, particularly with regard to the pest potential, disease status, potential to introduce parasites and

diseases and possibilities of affecting biodiversity, in accordance with consistent risk assessment protocols aimed at minimising adverse impacts.

4) A decision to permit a translocation may include a protocol that may be used for similar translocations.
5) The risk assessment will include assessment of the likelihood and consequences of an introduction and the mechanism for risk management and minimisation. Where aquatic organisms are released into the wild, considerations of habitat preservation, threatened species status, and the genetic effects need to be evaluated.
6) Whenever disease and parasite considerations are adequately addressed, translocation of "threatened" species for the purpose of stock rehabilitation is supported with appropriate measures to ensure the genetic diversity and integrity of the species.
7) Monitoring programs will be used by implementing agencies to assess and improve the accuracy of predictions generated by risk assessments and the effectiveness of management strategies applied to translocations.

This national policy is the basis upon which all States and Territory fisheries agencies have developed translocation policies and guidelines specific to their jurisdictions. It clarifies issues surrounding translocation, sets out agreed national policy principles and describes guidelines for the development of translocation policies.

- *(Draft) ANZECC Policy for Translocations of Threatened Animals in Australia (Anon undated)*

This policy applies to the translocation within Australia of threatened animals for the purpose of nature conservation, usually for the purpose of decreasing the probability of a species becoming extinct. This policy applies to any animal species (not just aquatic species) listed as threatened according to Commonwealth or State legislation. This policy makes particular reference to *The IUCN Position Statement on Translocation of Living Organisms (1987).*

- *National Code of Practice for Recreational and Sport Fishing (RecFish Australia 2001)*

This code is a voluntary agreement among RecFish Australia's 11 national and state/territory fishing member associations. It addresses four levels of fishing responsibility, including protecting fisheries and the environment, treating fish humanely and respecting the rights of others. This code specifically states that exotic species should not be used as live bait and all captured live bait should be released only into the waters from which it was collected. Recfish Australia would like to impose a ban on the *ad hoc* stocking of exotic species on private property and states that fish stockers in private waters should be encouraged to utilise only native species within their range, sourced from genetically secure stock. Recfish Australia also propose that stocking on private property should only take place if sufficient preventative measures have been undertaken to ensure that there is no possibility of accidental release of introduced species that can potentially colonise local waterways.

7.2 State policies

7.2.1 New South Wales

- *Introduction and Translocation Policy (NSW Fisheries 2003)*

The NSW translocation policy provides for continued fish stockings, but limits what species can be stocked and where stocking can occur in an attempt to minimise any adverse effects of these stockings. It is supported by the following legislation:

> Section 216(1) of the Fisheries Management Act, 1994: 'A person must not release into any waters any live fish except under the authority of a permit issued by the Minister or an aquaculture permit'.

- *Hatchery Quality Assurance Program for Murray Cod, Golden Perch and Siler Perch (Rowland and Tully 2004)*

The Hatchery Quality Assurance Program (HQAP) provides a framework for best practice and accreditation within the industry, and will provide significant benefits for the conservation of native fishes, recreational fisheries and commercial aquaculture in NSW and other states. This HQAP could also be used as a guideline for the production and stocking of the endangered species trout cod (*Maccullochella macquariensis*) and eastern freshwater cod (*Maccullochella ikei*) in NSW, and the critically endangered Mary River cod (*Maccullochella peelii mariensis*) in Queensland. The HQAP provides a broad overview of the impacts of inappropriate stocking and the requirements under the Fisheries Management Act 1994 for a permit to be issued prior to legal stocking taking place.

7.2.2 Victoria

- *Policy statement – native fish stocking in public waters (State of Victoria 2003)*

This statement applies to the stocking of native fish in Victoria's inland waters for the purposes of conservation and recreation. This stocking applies only to public waters, with the exception of special management or research needs. The priority waters for stocking will be based on habitat suitability criteria, existing or potential population levels of the species, capacity to monitor the stocking results, and the needs of the angling public or conservation status of the species.

- *Guidelines for Assessing Translocations of Live Aquatic Organisms in Victoria* (DPI 2003)

These guidelines provide a risk assessment and administrative framework for proposals to deliberately translocate live aquatic organisms into and within Victorian waters, which require approval under the Victorian Fisheries Act 1995.

- *Protocols for the Translocation of Fish in Victorian Inland Public Waters* (DPI 2005b)

These protocols apply to the translocation of fish, for recreational fishing and conservation purposes. In accordance with the *Guidelines for Assessing Translocations of Live Aquatic*

Organisms in Victoria, where translocations are likely to be repeated and have similar characteristics in terms of species, transport, medium, source and destination location, preference will be given to the development of approved translocation protocols. The protocols aim to minimise the risks associated with translocation. Specific protocols are outlined for the translocation of native and salmonid species for recreation purposes, as well as the translocation of native fish for conservation purposes. Each protocol specifies the criteria under which common types of translocations will be approved without the requirement for a case-by-case risk assessment.

7.2.3 Australian Capital Territory

- *Fish Stocking Plan for the Australian Capital Territory 2001-2005 (Environment ACT 2000)*

The purpose of this plan is to keep the community informed on the directions and philosophy of fisheries management in the ACT. This plan provides the legislative framework for planning and management of water resources in the Australian Capital Territory (ACT). It briefly describes the stocking history of Lake Burley Griffin, Lake Ginninderra and the Googong reservoir. The fisheries management in the ACT is also described, including the responsible parties for urban lakes, natural streams and water supply reservoirs. The impact of carp and redfin on native fish populations is also described. Finally, guiding principles for fish stocking in the ACT and a proposed fish stocking plan are provided.

- *Fisheries Act 2000 (ACT Parliamentary Counsel 2007a)*

A key aim of the Fisheries Act is to conserve native fish species and their habitats. This Act outlines that it is offence to import or export live fish without authority but does not apply to fish bought from a registered fish dealer for human consumption. It is also an offence under this Act to release fish into waters from which they were not collected without written from the authority. Further, it is an offence to use live fin fish as bait or be in possession of live fin fish for use as bait in or beside public waters.

- *Nature Conservation Act 1980 (ACT Parliamentary Counsel 2007b)*

The Nature Conservation Act makes provision for the protection and conservation of native animals and native plants, and for the reservation of areas for those purposes. The Act outlines that it is an offence to release animals from captivity which threatens the survival, abundance or evolution of any species of native animals with a licence.

7.2.4 Tasmania

- *(Internal Draft) Policy for the Translocation of Freshwater Fish in Tasmania: Background Information, Management Issues and Policy Statements (IFC 2006)*

This policy recognises the ecological, recreational, commercial and economic risks associated with the translocation of fish into Tasmanian waters, and requires that all proposed fish translocations undergo a balanced risk assessment to assess their feasibility. The development of monitoring programs is also a priority. This policy recognises the importance of public education and promotion of the issues involved with fish translocation. All programs and proposals for fish translocation require the approval of the Director of Inland Fisheries Service.

7.2.5 South Australia

There is no specific translocation legislation in place at the date of preparing this document in South Australia, although the Aquaculture Act may address some of the issues regarding the translocation of marine and freshwater organisms. The Aquaculture Act provides a framework for ecologically sustainable development of the aquaculture industry.

- *Action plan for South Australian freshwater fishes 2007-2012 (NFA 2007a)*

The Draft Action Plan was released for public comment in December 2007. It provides a comprehensive overview of issues and actions to protect and restore populations of threatened species and ecological communities. It identifies inappropriate translocations and stockings as a potential threat to the genetics of freshwater fishes in South Australia. A key recommendation of this action plan is the formulation of a 'fish introduction, translocation and stocking strategy' in line with the *National Policy for the Translocation of Live Aquatic Organisms (1999)* to provide proactive measures to address the problem of existing and potential alien fish and disease.

7.2.6 Western Australia

- *Translocation policy* (Department of Fisheries 2005)

A risk assessment process is used to provide an appropriate level of protection of the environment while facilitating the environmentally sustainable development of commercial aquaculture and stock enhancement for recreational fishing. The translocation of fish species requires the prior written approval of the Director of the Department of Fisheries.

7.2.7 Queensland

- *Management Arrangements for Translocation of Live Aquatic Organisms (Transport Between Bioregions) for Aquaculture, Aquaculture Policy FAMOP015 (QLD Government 2006b)*

The objectives of this policy are to minimise the risks associated with translocation of non-indigenous species or when there is the potential to impact on the genetic diversity of wild populations. Other objectives are to minimise the risk of introducing disease and minimising the socio-economic impacts that may result from the risks mentioned above. This policy provides guidelines for evaluating, on a case by case basis, the risks involved in translocation-related activities and providing specific translocation protocols to minimise the risks.

- *Fisheries (Freshwater) Management Plan 1999(QLD Government 2006a)*

The objectives of this plan are to manage the taking of freshwater fish in a way that ensures their sustainability and maintains/improves their conservation status, as well as ensuring a fair division between commercial, recreation and Aboriginal and Torres Strait Islander fishers. Also, the objective is to manage the freshwater fishery to give optimal, but sustainable, community benefit and to minimise the risk of damage to freshwater fish and their dependant ecosystems from nonindigenous and noxious fisheries resources.

- *Translocation Policy (for fish stocking) (DPIF 2008)*

Freshwater stocking in fresh water, including marine species, is carried out in Queensland in accordance with the translocation principles outlined in this policy. This policy guides the decision making process for new applications for fish stocking. It also outlines the drainage basins in Queensland where translocations may not be permitted on the basis of protecting threatened native fish species and catchment condition.

7.2.8 Northern Territory

- *Translocation Policy for Aquaculture (Northern Territory Government 2004)*

The objectives of this policy are to provide a framework for risk assessment and guidelines for decision making when assessing applications for translocations of aquatic organisms into, and within, the Northern Territory for aquaculture purposes, and to regulate the movements of aquatic organisms into and within the Northern Territory for aquaculture to prevent the introduction or spread of aquatic pests and disease, and to protect the existing and potential industry, the environment and biodiversity.

7.3 Murray-Darling Basin

- *Managing Fish Translocation & Stocking in the Murray-Darling Basin (Phillips 2002)*

This document provides a summary of specific recommendations for translocation in the Murray-Darling Basin. It urges State/Territory Governments without translocation or stocking policies to prepare them, and ensure they are consistent and complementary to the *National Policy for the Translocation of Live Aquatic Organisms* (MCFFA 1999) and allow cooperation between the various jurisdictions to result in Basin-wide consistency. It also includes a basin-specific risk analysis protocol in line with the aforementioned National Policy and the recommendation for quality control and accreditation for hatcheries and aquaculture.

Current stocking programs to support recreational fishing have specific objectives and outcomes largely directed towards providing improved angler satisfaction. The recommendation is to conduct a more rigorous and sophisticated decision-making process incorporating the social, economic and environmental costs and benefits for the stocking of both native and exotic species for recreational purposes in the Murray-Darling Basin. Translocation and stocking programs are also recognised as important management tools for achieving native fish conservation outcomes and should be conducted in accordance with relevant State or territory authorities and national recovery plans for threatened species. The impacts of native fish stocking on existing native populations in the Murray-Darling Basin is being assessed as part of the MDBC Native Fish Strategy (MDBC 2002).

7.4 Recovery plans

Recovery plans have been developed for numerous species within Australia. These recovery plans have been developed to outline the threats and the recovery actions and objectives. The recovery plans for Mary River cod, Eastern cod (*Maccullochella ikei*) and Oxleyan pygmy perch (*Nannoperca oxleyana*) considers the translocation or introduction of fish to be a threat to the survival of the respective species (NSW Fisheries 2004; NSW DPI 2005; Simpson and Jackson 2007). Specifically, the introduction of closely related cod species into the existing range of Mary River cod, namely Murray cod and Eastern cod, is considered a key threat to this species due to the potential for hybridisation (Simpson and Jackson 2007). Eastern cod are also considered threatened by other closely related cod species. It is now illegal to stock Murray cod in the range of Eastern cod for this reason (NSW Fisheries 2004). Intentionally introducing other fish into areas outside their natural range may also have negative impacts on pygmy perch because the species have not coevolved (NSW DPI 2005). Conversely, the Tasmanian Galaxiidae Recovery Plan (Jackson 2004) outlines the translocation of galaxids to be beneficial for the conservation for this group of species.

7.5 Relationship with National policies

All States and Territories have adopted the *National Policy for the Translocation of Live Aquatic Organisms* and are either implementing consistent State-based policies or have adopted the national policy framework. There is a need to monitor and evaluate the implementation of the National Policy, ensuring that any Basin-wide stocking policies, procedures and guidelines are complementary.

Queensland and Western Australia have translocation policies that are consistent with the protocols of the *National Policy for the Translocation of Live Aquatic Organisms – Issues, Principles and Guidelines for Implementation* (MCFFA 1999). Queensland has a comprehensive draft procedural policy which includes key principles, decision making and disease risk assessment protocols. Western Australia has a similar approach, with a generic risk assessment approach that is used for the translocation of live non-endemic fish into and within Western Australia.

The *Guidelines for Assessing Translocations of Live Aquatic Organisms in Victoria* (DPI 2003) were developed to meet the specific requirements of the *National Policy for the Translocation of Live Aquatic Organisms.* The other States and Territories, except South Australia, have policies, plans and management arrangements based on the National Policy.

A guiding principle in the National Policy is that translocations into catchments that are under more than one jurisdiction require the agreement of all the relevant jurisdictions. The document *Managing Fish Translocation & Stocking in the Murray-Darling Basin* sets a basin-specific framework for agreement to occur in the Murray-Darling Basin.

7.6 International policies

- *IUCN Position Statement on Translocation of Living Organisms* (IUCN 1999)

This statement sets out the IUCN's position on translocation of living organisms. It provides definitions of translocation as related to an introduction of an organism, a re-introduction of an organism and a restocking of an organism. The statement describes the advantageous uses of translocations and the precautions needed to avoid the disastrous consequences of poorly planned translocations. It outlines an approach for governments to adopt in order to reduce the damaging impact of introductions on the balance of natural systems. Within this approach, guidelines are given for translocations to natural, semi-natural and man-made habitats. This statement also provides guidance on assessing suitability of translocations, controlling experimental, extensive and accidental introductions, as well as dealing with alien species and biological control.

This statement outlines international declarations and codes of practice relating to translocation and specifies that the movement of introduced species across international boundaries should be prevented with appropriate consultation with neighbouring states.

8. Summary

A total of 77 native fish species have been identified as having been translocated within Australia. This includes all translocations within and between all states and mainland territories of Australia with the majority of the species and locations of translocations having occurred throughout the eastern mainland states. The environmental and social impacts of these translocations are varied. Similarly, the policies which govern translocations within each state adhere to the principles of the national policy to varying degrees.

The impacts of translocation may give rise to predation, competition, habitat alterations, disease outbreaks and infections, and the loss of genetic integrity and the genetic structure of populations in receiving waterbodies. These impacts of translocation, as discussed, are generally in the negative. Poor stocking management, illegal stocking, and escapees from farm dams and aquaculture have had, and can have, adverse effects on native fish stocks. The use of molecular techniques to identify genetic distinctiveness and a better understanding of the environmental impacts of translocated species is needed if translocations are to take place in the future. The benefits of stocking include recreational fishing, species conservation and introduction as a means of control against exotic species.

The social and economic value of translocated native fish species is associated with commercial fishing; tourism; and species conservation. It is difficult to assign a value to the translocation of native fish species as the value of these three aspects is not solely related to translocated species. Commercial production of fish in Australia is a large industry. This includes seven species which are known to be translocated (barramundi, eel species, silver perch, golden perch, and Barcoo grunter, Murray cod), however the value of translocation/stocking compared to production for direct consumption cannot be distinguished. The greatest economic value is associated with barramundi production in Queensland. Accordingly, part of the employment associated with commercial production can be directly associated with production for translocation. The translocation of fish for purposes of recreational fishing also has significant national value with associated tourism dollars brought into a region where fishing has been improved via translocations. Therefore if translocation of fish species were to cease there are likely to be locally significant social and economic impacts.

Numerous techniques are frequently applied for the collection of fish species in freshwater ecosystems throughout Australia. However these techniques are often not species specific and can lead to unnecessary deaths or injury of by-catch. As these techniques are not species specific, significant time may also be required to sort fish following collection in order to return non-target species to the waterbody of collection. The applicability of techniques depends upon the habitat being sampled, fish community present at the site and the target fish species. If the aim of the sampling is to collect a large proportion of the fish population present or even eradicate the fish species then a combination of sampling techniques should be used. It is important to recognise that complete eradication of a population is far more time consuming than population reduction.

All States and Territories have adopted the *National Policy for the Translocation of Live Aquatic Organisms* and are either implementing consistent State-based policies or have adopted the national policy framework. There is a need to monitor and evaluate the implementation of the National Policy, ensuring that any Basin-wide stocking policies, procedures and guidelines are complementary. An international position statement is also set out by the IUCN on the translocation of living organisms.

8.1 Knowledge gaps

- **Ecological impacts of translocations:** these are very poorly understood and many may go unnoticed due to lack of monitoring or for want of sensitive monitoring methods.
- **Biological controls**: the applicability and potential impact of using translocated native fish species as a biological control against pest or weed species needs research.
- **Identification of genetic markers**: fish of the same species are generally considered to be suitable for stocking, however they may be genetically distinct and thus a risk to the resident population. Much more work is required to determine the degree of genetic differentiation within species to identify genetic markers so as to ensure that only like populations are to be stocked.
- **Use of chemical markers:** fish being translocated for stock enhancement can be marked with a chemical agent providing managers a way to separate natural and introduced stocks. However the most appropriate chemical marker for doing so is yet to be identified.
- **Ability to disaggregate available data to translocated species:** the main gap is the extent to which existing information can be disaggregated to only translocated native species. The exception to this is the commercial value of aquaculture industries where ABARE in conjunction with the ABS and industry provide species by species information. However the more intangible valuations, such as recreational fishing value or conservation value, are not generally available. In the case of recreational fishing, species data is available however is not sufficiently detailed to gain an understanding of just the translocated species. Likewise, conservation value of just the translocated species must be inferred from broader studies, taking into account the circumstances of the studies. This is not to say that the studies used in this assessment are of a poor quality or have methodological issues but rather are not specific to the data requirements of this task. The lack of this information makes it difficult to undertake more detailed analysis such a cost-benefit analysis or input-output analysis.

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9. References

ABARE (2007). Australian Fisheries Statistics 2006, Australian Bureau of Agricultural and Resource Economics, Canberrra.

ACT Parliamentary Counsel (2007a). Fisheries Act 2000. **Republication Number 11**.

ACT Parliamentary Counsel (2007b). Nature Conservation Act 1980. **Republication Number 18**.

Allen, G. R., Midgley, S. H. and Allen, M. (2002). Field guide to the freshwater fishes of Australia. Perth, Western Australia, Western Australian Museum.

Anon (undated). ANZECC policy for translocations of threatened animals in Australia.

Aprahamian, M. W., Martin Smith, K. M., McGinnity, P., McKelvey, S. and Taylor, J. (2003). "Restocking of salmonids - opportunities and limitations. ." Fisheries Research **62**: 211-227.

Arthington, A. H. (1991). "Ecological and genetic impacts of introduced and translocated freshwater fishes in Australia." Canadian Journal of Fisheries and Aquatic Sciences **48 (Suppl. 1)**: 33-43.

Arthington, A. H., Hamlet, S. and Bluhdorn, D. R. (1990). The role of habitat disturbance in the establishment of introduced warm-water fishes in Australia [Poster]. Introduced and translocated fishes and their ecological effects. D. A. Pollard, Bureau of Rural Resources. Australian Government Publishing Service, Canberra.**:** 61-66.

Arthington, A. H. and McKenzie, F. (1997). Review of impacts of displaced/introducted fauna associated with inland waters. . Australia: State of the Environment Technical Paper Series (Inland Waters), Canberra, Department of the Environment.

Austin, C. M. and Ryan, S. G. (2002). "Allozyme evidence for a new species of freshwater crayfish of the genus *Cherax* Erichson (Decapoda : Parastacidae) from the south-west of Western Australia." Invertebrate Systematics **16**: 357-367.

Barlow, C. G., Hogan, A. E. and Rodgers, L. J. (1987). "Implication of translocated fishes in the apparent extinction in the wild of the Lake Eacham Rainbowfish, *Melanotaenia eachamensis* " Australian Journal of Marine and Freshwater Research **38**: 897-902.

Barnham, C. (1991). Summary of Researched Available Records on Non-indigenous and Indigenous Fish Stockings into Victorian Public Waters. Fourth Edition: 1871 to 1990, Department of Conservation and Environment.

Brumley, A. R. (1987). "Past and present distributions of Golden Perch *Macquaria Ambigua* (Pisces: Percichthyidae) in Victoria, with reference to releases of hatchery-produced fry." Proceedings of the Royal Society of Victoria **99**(3): 111-116.

Burrows, D. W. (2002). Fish Stocking and the Distribution and Potential Impact of Translocated Fishes in Streams of the Wet Tropics Region, Northern Queensland. Report to the Wet Tropics Management Authority. ACTFR Report No. 02/04, Australian Centre for Tropical Freshwater Research. James Cook University.

Cadwallader, P. L. (1981). "Past and present distributions and translocations of Macquarie Perch *Macquaria australasica* (Pisces: Percichthyidae), with particular reference to Victoria." Proceedings of the Royal Society of Victoria **93**: 23-30.

Cadwallader, P. L. (1996). Overview of the Impacts of Introduced Salmonids on Australian Native Fauna. Canberra, Australia Nature Conservation Agency.

Cadwallader, P. L. and Backhouse, G. N. (1978). "Some causes of the decline in range and abundance of native fish in the Murray-Darling River system." Proceedings of the Royal Society of Victoria **90**: 211-224.

Cadwallader, P. L. and Backhouse, G. N. (1983). "A guide to the freshwater fish of Victoria. Victorian Government Printing Office, Melbourne."

Cadwallader, P. L. and Gooley, G. J. (1984). "Past and present distributions and translocations of Murray Cod *Maccullochella Peeli* and trout cod *M. Macquariensis* (Pisces: Percichthyidae) in Victoria." Proceedings of the Royal Society of Victoria **96**(1): 33-43.
Campbell, H. F. and Brown, R. P. C. (2003). Benefit-cost analysis : financial and economic appraisal using spreadsheets. New York, Cambridge University Press.
Clements, J. (1988). Salmon at the Antipodes: A history and review of trout, salmon and char and introduced coarse fish in Australasia.
Crook , D. and Sanger, A. C. (1997). "Recovery Plan for the Pedder, Swan, Clarence, Swamp and Saddled Galaxias." 2007, from file://I%3A%2FVWES%2FProjects%2FVW03862%2FTechnical%2FReferences%2F220_Crook_1997.html.
Crook, D. A., Robertson, A. I., King, A. J. and Humphries, P. (2001). "The influence of spatial scale and habitat arrangement on diel patterns of habitat use by two lowland river fishes. ." Oecologia **129**: 525-533.
Cross, T. F. (2000). "Genetic implications of translocation and stocking of fish species, with particular reference to Western Australia." Aquaculture Research **31**: 83-94.
DEH (2006). The introduction of live native or non-native fish into Australian watercourses that are outside their natural geographic distribution. D. o. t. E. a. Heritage.
Department of Fisheries (2004). The stocking of Black Bream into inland water bodies in Southern Western Australia, Department of Fisheries Western Australia. **2007**.
Department of Fisheries. (2005, April 2005). "Translocation policy." Retrieved 30 April 2007, 2006.
DNR (1999). Fish Stocking Database, Department of Natural Resrouces - Source Peter Kind (DPIF).
Douglas, J. W., Gooley, G. J. and Ingram, B. A. (1994). Trout cod, Maccullochella macquariensis (Cuvier) (Pisces: Percichthyidae): resource handbook and research and recovery plan. Melbourne, Department of Conservation and Natural Resources.
Doupe, R. G. and Lymbery, A. J. (1999). "Escape of cultured barramundi (*Lates calcarifer* Bloch) into impoundments of the Ord River system, Western Australia." Journal of the Royal Society of Western Australia **82**: 131-136.
DPI (2003). Guidelines for the translocation of live aquatic organisms in Victoria, Department of Primary Industries, Victoria.
DPI. (2005a). "Introduction and Translocation policy. DPI - NSW website www.fisheries.nsw.gov.au."
DPI (2005b). Protocols for the translocation of fish in Victorian inland public waters, Department of Primary Industries, Victoria.
DPI. (2007). "Native Fish Stocking - Information Notes." 2007, from http://www.dpi.vic.gov.au/DPI/nreninf.nsf/LinkView/9ED2C7F8E7207ABFCA256BC80006E51C.
DPIF (2007). Queensland Impoundment Stocking Database. Brisbane.
DPIF (2008). Translocation Policy (for fish stocking), Department of Primary industries and Fisheries (Fisheries Business Group).
Ebner, B. (2006). "Murray cod an apex predator in teh Murray River, Australia." Ecology of Freshwater Fish **15**: 510-520.
Environment ACT (2000). Fish stocking plan for the Australian Capital Territory, 2001–2005.
Fickling, S. (1995). The Influence of Fish Predators on the Local Distribution of Frogs and Tadpoles in Rainforest Streams of the Tully River, James Cook University, Townsville. **Honours Thesis**.

Fletcher, A. R. (1986). Effects of introduced fish in Australia. Limnology in Australia. P. DeDecker and W. D. Williams, CSIRO/Dr W. Junk**:** 231-238.

Gillanders, B., Elsdon, T. and Munro, A. (2006). Impacts of native fish stocking within Murray-Darling Basin. Adelaide, Murray Darling Basin Commission.

Glazebrook, J. S., Heasman, M. P. and Beer, S. W. (1990). "Picorna-like viral particles associated with mass rnortalities in larval barramundi, Lates calcarifer Bloch." Journal of Fish Diseases **13**: 245-249.

Go, J., Lancaster, M., Deece, K., Dhungyel, O. and Whittington, R. (2006). "The molecular epidemiology of iridovirus in Murray cod (Maccullochella peelii peelii) and dwarf gourami (Colisa lalia) from distant biogeographical regions suggests a link between trade in ornamental fish and emerging iridoviral diseases." Molecular and Cellular Probes **20**(3-4): 212-222.

Hammer, M. P., Adams, M., Unmack, P. J. and Walker, K. F. (2007). "A rethink on *Retropinna*: conservation implications of new taxa and significant genetic sub-structure in Australian smelts (Pisces: Retropinnidae)." Marine and Freshwater Research **58**: 327-341.

Hammer, M. P. and Walker, K. F. (2004). "A catalogue of South Australian freshwater fishes, including new records, range extensions and translocations." Transactions of the Royal Society of South Australia **128**(2): 85-97.

Hardie, S. A. (2003). Current status and ecology of the golden galaxias (Galaxias auratus), Rep. No. Rehabilitation of Lakes Sorell and Crescent Report Series No. 7/1. Hobart, Australia, Inland Fisheries Service.

Harris, J. (1997). Environmental rehabilitation and carp control. Controlling carp: exploring the options for Australia. Proceedings of a workshop 22-24 October 1996. Canberra, CSIRO and the Murray Darling Basin Commission, **:** 21-36.

Harris, J. (2003). Fish stocking and translocation in the Murray-Darling Basin: issues, benefits and problems. Managing fish translocation and stocking in the Murray-Darling Basin workshop: Statement, recommendations and supporting papers. B. Philips. Canberra, 25-26 September 2002, WWF-Australia.

Harris, J. H. and Battaglene, S. C. (1990). The introduction and translocation of native freshwater fishes in south-eastern Australia. Introduced and translocated fishes and their ecological effects, Proceedings of the Australian Society for Fish Biology Workshop No. 8. Magnetic Island, Townsville, Queensland 24-25 August 1989, Bureau of Rural Resources. Australian Government Publishing Service, Canberra.

Harris, J. H. and Dixon, P. I. (1986a). "Hybridization between trout cod and Murray cod." Isozyme Bulletin **19**: 39.

Harris, J. H. and Dixon, P. I. (1986b). "Hybridization between trout cod and Murray cod." Isozyme Bulletin **19**: 39.

Henry, G. and Lyle, J. (2003). The National Recreational and Indigenous Fishing Survey, Australian Government Department of Agriculture, Fisheries and Forestry.

Herbert, B. W., Peeters, J. A., Graham, P. A. and Hogan, A. E. (1995). Freshwater Fish and Aquatic Habitat Survey of Cape York Peninsula. Cape York Peninsula Land Use Strategy (CYPLUS) Natural Resources Assessment Program (NRAP). . Brisbane, Queensland Dept. Primary Industries, .. 376pp.

Hewitt, C. L., Martin, R. B., Sliwa, C., McEnnulty, F. R., Murphy, N. E., Jones, T. and Cooper, S. (2002). "National Introduced Marine Pest Information System. ."   Retrieved 14-Feb-2008, 2008, from http://crimp.marine.csiro.au/nimpis.

Hogan, A. E. (1995). A history of fish stocking in Queensland - where are we at? Fish stocking in Queensland: Getting it right! . P. Cadwallader and B. Kerby. Townsville, Queensland, Queensland Fisheries Management Authority**:** 8-24.
Hollaway, M. and Hamlyn, A. (2001). Freshwater Fishing in Queensland A Guide to Stocked Waters (2nd ed.). QDPI Information Series QI01034. Brisbane, Queensland Department of Primary Industries**:** 154pp.
Hortle, K. G. and Pearson, R. G. (1990). "Fauna of the Annan River system, far north Queensland, with reference to the impact of tin mining. I. fishes." Australian Journal of Marine and Freshwater Research **41**: 677-694.
Hurst, T., Ryan, P., Brown, M. and Kay, B. (2005). "Fishing for a mosquito control agent." Arbovirus Research In Australia **9**: 143-147.
IFC (2006). Policy for the translocation of freshwater fish in Tasmania: Background information, management issues and policy statements - Internal Draft, Inland Fisheries Commission.
IUCN (1999). The IUCN position statement on translocation of living organisms: Introductions, re-introductions and re-stocking (www.iucn.org/themes/ssc/pubs/policy/transe.htm).
IUCN (2000) "IUCN Guidelines For The Prevention Of Biodiversity Loss Caused By Alien Invasive Species." **Volume**, DOI:
Jackson, J. E. (2004). Tasmanian Galaxiidae Recovery Plan 2004-2008, Inland Fisheries Service, Hobart.
Jackson, J. E., Raadik, T. A., Lintermans, M. and Hammer, M. (2004). "Alien Salmonids in Australia: impediments to effective impact management, and future directions." New Zealand Journal of Marine and Freshwater Research **38**: 447-455.
Jackson, P. D., Koehn, J. D., Lintermans, M. and Sanger, A. C. (1996). Family Gadopsidae. Freshwater blackfishes. Freshwater fishes of south-eastern Australia. R. M. McDowall, Reed Books, Chatswood.**:** 186-190.
Kailola, P. J. (1990). Translocated and exotic fishes: towards a cooperative role for industry and government. Introduced and translocated fishes and their ecological effects, Proceedings of the Australian Society for Fish Biology Workshop No. 8. Magnetic Island, Townsville, Queensland 24-25 August 1989, Bureau of Rural Resources. Australian Government Publishing Service, Canberra.
Kearney, R. E. and Kildea, M. A. (2001). The Status of Murray Cod in the Murray-Darling Basin, Applied Ecology Research Group University of Canberra.
Keenan, C. and Salini, J. (1990). The genetic implications of mixing barramundi stocks in Australia. Introduced and translocated fishes and their ecological effects, Proceedings of the Australian Society for Fish Biology Workshop No. 8. Magnetic Island, Townsville, Queensland 24-25 August 1989, Bureau of Rural Resources. Australian Government Publishing Service, Canberra.
Koehn, J. (2004a). "Carp (Cyprinus carpio) as a powerful invader in Australian waterways." Freshwater Biology **49**: 882-894.
Koehn, J. (2004b). "Priority management actions for alien freshwater fish species in Australia." New Zealand Journal of Marine and Freshwater Research **38**: 457-472.
Langdon, J. S. (1988). Prevention and control of fish diseases in the Murray-Darling Basin. Workshop on Native Fish Management, Canberra, Murray-Darling Basin Commission.
Langdon, J. S. (1989). Disease risks of fish introductions and translocations. Introduced and translocated fishes and their ecological effects., Canberra, Bureau of Rural Resources. Australian Government Printing Office.
Langdon, J. S. (1990). Disease risks of fish introductions and translocations. Introduced and translocated fishes and their ecological effects, Proceedings of the Australian Society for

Fish Biology Workshop No. 8. Magnetic Island, Townsville, Queensland 24-25 August 1989, Bureau of Rural Resources. Australian Government Publishing Service, Canberra.

Leggett, R. and Merrick, J. R. (1997). "Australia's Lake Eacham rainbow fish: lessons and outloook." Aquarium Sciences and Conservation **1**: 37-43.

Lintermans, M. (1991). "The decline of indigenous fish in the Canberra region: The impacts of introduced species." Bogong **12**: 18–22.

Lintermans, M. (2004). "Human assisted dispersal of alien freshwater fish in Australia." New Zealand Journal of Marine and Freshwater Research **38**: 481-501.

Lintermans, M. (2006). The re-establishment of Macquarie perch Macquaria australasica in the Queanbeyan River, New South Wales, with an examination of dietary overlap with alien trout, Environment ACT and CRC for Freshwater Ecology.

Lintermans, M. (2007). Fishes of the Murray-Darling Basin: an introductory guide. Canberra, Murray-Darling Basin Commission.

MacKinnon, M. R. and Cooper, P. R. (1987). "Reservoir stocking of barramundi for enhancement of the recreational fishery." Australian Fisheries **46(1)**(1): 34-37.

McDowall, R. M. (2006). "Crying wolf, crying foul, or crying shame: alien salmonids and a biodiversity crisis in the southern cool-temperate galaxioid fishes?" Reviews in Fish Biology and Fisheries **16**: 233–422.

MCFFA (1999). National Policy for the Translocation of Live Aquatic Organisms - Issues, Principles and Guidelines for Implementation Canberra, Australian Government Bureau of Rural Sciences.

McKay, R. J. (1989). Exotic and translocated freshwater fishes in Australia. Exotic aquatic organisms in Asia. Proceedings of the workshop on introduction of aquatic organisms in Asia, Asian Fisheries Society Special Publication 3.

MDBC (2002). Native Fish Strategy for the Murray-Darling Basin 2002-2012. Canberra, Murray-Darling Basin Commission**:** 39.

Merrick, J. R. and Schmida, G. E. (1984). Australian freshwater fishes: biology and management. Adelaide, Griffen Press.

Miller, A. D., Waggy, G., Ryan, S. G. and Austin, C. M. (2004). "Mitochondrial 12S rRNA sequences support the existence of a third species of freshwater blackfish (Percicthyidae: Gadopsis) from south-eastern Australia." Memoirs of Museum Victoria **61**(2): 121–127.

Mills, M. D., Rader, R. B. and Belk, M. C. (2004). "Complex interactions between native and invasive fish: the simultaneous effects of multiple negative interactions." Oecologia **141**: 713-721.

Ministerial Council on Forestry Fisheries and Aquaculture (1999). National policy for the translocation of live aquatic organisms-issues, principles and guidelines for implementation. Canberra, Bureau of Rural Sciences.

Morgan, D. L., Gill, H. S., Maddern, M. G. and Beatty, S. J. (2004). "Distribution and impacts of introduced freshwater fishes in Western Australia." New Zealand Journal of Marine and Freshwater Research **2004**(38): 511-523.

Munday, B. L. (1994). "Occurrence of the picornia-like virus infecting barramundi." Austasia Aquaculture **8**: 52.

Musyl, M. K. and Keenan, C. P. (1992). "Population genetics and zoogeography of Australian freshwater golden perch, Macquaria ambigua (Richardson 1845) (Teleostei : Percichthyidae), and electrophoretic identification of a new species from the Lake Eyre basin." Australian Journal of Marine and Freshwater Research **43**(6): 1585-1601.

Musyl, M. K. and Keenan, C. P. (1996). "Evidence for Cryptic Speciation in Australian Freshwater Eel-Tailed Catfish, Tandanus tandanus (Teleostei: Plotosidae)." Copeia **1996**(3): 526-534.

SKM

Navrud, S. (2001). "Economic Valuation of Inland Recreational Fisheries: Empirical Studies and their Policy use in Norway." Fisheries Management and Ecology **8**(4-5): 369-382.

NFA (2007a). Action Plan for South Australian Freshwater Fishes 2007-2012, Native Fish Australia (SA) Inc.

NFA (2007b). Native Fish Australia - trout cod (http://www.nativefish.asn.au/troutcod.html) Date accessed 16 July 2008.

Northern Territory Government (2004). Translocation policy for Aquaculture. Department of Business Industry and Resource Development, Fisheries Group.

NSW DPI (2005). Oxleyan pygmy perch - Recovery Plan and Background paper. Nelsons Bay, NSW Department of Primary Industries.

NSW DPI (2007). Fish Stocking Database: accessed July 2007. Cronulla, NSW Department of Primary Industries.

NSW Fisheries (1997). Australian Code of Electrofishing Practice, NSW Fisheries.

NSW Fisheries (2003). Environmental impact statement - freshwater fish stocking in NSW. Cronulla, NSW Fisheries.

NSW Fisheries (2004). Eastern (Freshwater) Cod (Maccullochella ikei) Recovery Plan. Nelson Bay, NSW Fisheries.

NSW Fisheries (2007). Fish Stocking Database. Cronulla, NSW Department of Primary Industries.

Pearce, M. (2000). Post Stocking Survey Report Koombooloomba Dam Ravenshoe, Qld. Survey 1, 19 April 2000. QDPI Information Series QI00095. Brisbane, Queensland Fisheries Service, Queensland Department of Primary Industries.

Phillips, B. (2002). " Managing fish translocation and stocking in the Murray-Darling Basin: statement, recommendations and supporting papers " Canberra, WWF-Australia.

Pusey, B., Bird, J., Kennard, M. J. and Arthington, A. H. (1997). "Distribution of the Lake Eacham Rainbowfish in the Wet Tropics Region, North Queensland." Australian Journal of Zoology **45**: 75-84.

Pusey, B. J. (2002). Burdekin Catchment Water Resource Plan: Fishes, Queensland Department of Natural Resources and Mines.

Pusey, B. J. (2007). Current Environmental Conditions and Impacts of Existing Water Resource Development. Fish. Pioneer Valley Water Resource Plan, Appendix I, Queensland Government (Department of Natural Resources and Mines).

Pusey, B. J., Burrows, D., Arthington, A. H. and Kennard, M. J. (2006). "Translocation and spread of piscivorous fishes in the Burdekin River, north-eastern Australia." Biological Invasions **8**: 965-977.

QFMA (1996). Queensland Freshwater Fisheries: Discussion Paper No. 4. Brisbane, Queensland Fisheries Management Authority.

QLD Government (2006a). Fisheries (Freshwater) Management Plan 1999, This reprint was prepared by the Office of the Queensland Parliamentary Counsel.

QLD Government (2006b). Management arrangements for translocation of live aquatic organisms (transport between bioregions) for Aquaculture, Aquaculture Policy FAMOP015, Department of Primary Industries and Fisheries.

Rayner, T. and Creese, R. (2006). "A review of rotenone use for the control of non-indigenous fish in Australian fresh waters, and an attempted eradication of the noxious fish, Phalloceros caudimaculatus." New Zealand Journal of Marine and Freshwater Research **40**: 477-486.

RecFish Australia (2001). The National Code of Practice for Recreational and Sport Fishing 2001.

Rolfe, J. and Prayaga, P. (2007). "Estimating values for recreational fishing at freshwater dams in Queensland." The Australian Journal of Agricultural and Resource Economics **51**: 157-174.

Rose, K. (2007). Wildlife Health Investigation Manual. Sydney, Zoological Parks Board of New South Wales.

Rowland, S., Dirou, J. and Selosse, P. (1983). "Production and stocking of golden and silver perch in N.S.W. ." Australian Fisheries **42**(9): 24-28.

Rowland, S. J. (1985). Aspects of the biology and artificial breeding of the Murray cod, Maccullochella peeli, and the eastern freshwater cod M. ikei sp. nov (Psces: Percichthyidae). Sydney, Macquarie University. **PhD:** 253.

Rowland, S. J. (2001). "Record of the Banded Grunter *Amniataba percoides* (Teraponidae) from the Clarence River, New South Wales." Australian Zoologist **31**(4): 603-607.

Rowland, S. J. and Tully, P. (2004). Hatchery Quality Assurance Program for Murray Cod, Golden Perch and Silver Perch, NSW Department of Primary Industries.

Russell, D. J. (1987). "Aspects of the limnology of tropical lakes in Queensland - with notes on their suitability for recreational fisheries." Proceedings of the Royal Society of Queensland **98**: 83-91.

Russell, D. J. and Hales, P. W. (1997). Fish Resources and Stream Habitat of the Liverpool, Maria and Hull Catchments. QDPI Information Series QI97039. Brisbane, Queensland Dept. of Primary Industries.

Russell, D. J., Ryan, T. J., McDougall, A. J., Kistle, S. E. and Aland, G. (2003). "Species diversity and spatial variation in fish assemblage structure of streams in connected tropical catchments in northern Australia with reference to the occurrence of translocated and exotic species." Marine and Freshwater Reseach **54**: 813-824.

Ryan, S. G., Miller, A. D. and C.M, A. (2004). "Allozyme variation and Taxonomy of the river blackfish, *Gadopsis marmoratus* Richardson, in Western Victoria." Proceeding of the Royal Society of Victoria **116**(2): 191-199.

Sanger, A. C. (2001). Prospects and problems for the restoration of the pedder galaxias. Lake Pedder - values and restoration, Occasional Paper No. 27. C. Sharpels. Hobart, Centre for Environmental Studies, University of Tasmania**:** 125-130.

Sanger, A. C. and Koehn, J. D. (1997). Use of chemicals in carp control. Controlling carp: exploring the options for Australia. Proceedings of a workshop 22-24 October 1996. Canberra, CSIRO and the Murray Darling Basin Commission, **:** 37-55.

Sheppard, R. and Helmke, S. A. (1999). A Fisheries Resource Assessment of the Annan River, North Queensland. Information Series QI99043

Brisbane, Queensland Dept. of Primary Industries.

Shipway, B. (1947). "Freshwater fishes of the Barron River." North Queensland Naturalist **14**: 25-27.

Simpson, R. and Jackson, P. (2007). The Mary River Cod Recovery Plan, Queensland Department of Primary Industries, Fisheries Group.

State of Victoria (2003). Policy statement - native fish stocking in public waters. Fisheries Notes Department of Primary Industries,.

Threatened Species Section (2006). Recovery Plan: Tasmanian Galaxiidae 2006-2010. Hobart, Department of Primary Industries and Water.

van Bueren, M. and Bennett, J. (2004). "Towards the development of a transferable set of value estimates for environmental attributes." The Australian Journal of Agricultural and Resource Economics **48**(1): 1-32.

Wager, R. (1993). The Distribution and Conservation Status of Freshwater Fishes in Queensland. Information Series QI93001. Brisbane, Queensland Department of Primary Industries.

Wager, R. (1994). "Fish translocation and biodiversity of Queensland freshwater fishes." Australian Biologist **71**(1): 23-32.

SKM

Waters, J. M., Shirley, M. and Closs, G. P. (2002). "Hydro-electric development and translocation of *Galaxias brevipinnis*: a cloud at the end of the tunnel?" Canadian Journal of Fisheries and Aquatic Sciences **59**: 49-56.

Webb, A. C. (1996a). "Impacts of introduced non-native, and translocated native fishes in northern Queensland. ." Waves (Northern Regional Ripples) **3**(2): 4.

Webb, A. C. (1996b). "Translocation of native fish species in Queensland. ." Waves (Northern Regional Ripples) **3**(1): 8-9.

Webb, A. C., Hogan, A. E. and Graham, P. A. (1996). Survey to Determine the Distribution of the Mozambique Mouthbrooder (Tilapia) Oreochromis mossambicus, in the Upper Barron River Catchment With Recommendations for Management. Walkamin, Department of Primary Industries.

Werren, G. (1997). Barron Catchment Rehabilitation Plan. Cairns, NQ Joint Board.

West, P., Brown, A. and Hall, K. (2007). Review of alien fish monitoring techniques, indicators and protocols: Implications for national monitoring of Australia's inland river systems. Canberra, Report prepared for the National Land & Water Resources Audit.

Wheeler, S. and Damania, R. (2001). "Valuing New Zealand recreational fishing and an assessment of the validity of the contingent valuation estimates." The Australian Journal of Agricultural and Resource Economics **45**(4): 599-621.

White, K. V. (1991). Investigations into the Extinction in the Wild of the Lake Eacham Rainbowfish (Melanotaenia eachamensis Allen and Cross, 1982). Zoology Department. Townsville, James Cook University of North Queensland. **BSc Honours Thesis**.

Whittington, R. J. and Chong, R. (2007). "Global trade in ornamental fish from an Australian perspective: The case for revised import risk analysis and management strategies " Preventive Veterinary Medicine **In press**.

Zhu, D., Degnan, S. and Moritz, C. (1998). "Evolutionary distinctiveness and status of the Lake Eacham rainbowfish (Melanotaenia eachamensis)." Conservation Biology **12**: 80-93.

Appendix A Questionnaire

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Impacts of Translocated Native Fish Species in Austra

A project for the Department of the Environment and Heritage

Sinclair Knight Merz (SKM) have been engaged by Department of the Environment and Heritage to undertake **An Overview of the Impacts of Translocated Native Fish Species in Australia**. This project involves a core team of personnel from SKM as well as Dr Gerry Closs. A review panel has also been established for the project which comprises Professor Angela Arthington, Dr John Harris, Dr Peter Davies, and Mark Lintermans.

The project is a desktop approach to identify the **environmental**, **social** and **economic** impacts of translocated native fish species in Australia. In addition, the project will also identify the policies associated with the translocation of fish species throughout Australia. The list of translocated species to be used is based on that from Lintermans, M. (2004). "Human assisted dispersal of alien freshwater fish in Australia." *New Zealand Journal of Marine and Freshwater Research* **38**: 481-501. (see Attachment 1). Outputs from the project will include a report detailing the impacts of translocatiing native fish species in Australia as well as a GIS layer identifying the distribution of translocated species.

Your contribution to this key project by answering the attached questionnaire, and where possible providing data, by Friday 8 March 2007 is gratefully appreciated. Please do not hesitate to contact me if you have any queries.

Regards

Sam Hannon
Project Manager/ Aquatic Ecologist
Ph: 03 9248 3225
Fax: 03 9248 3400
shannon@skm.com.au

1) Your name and contact details (all contributions will be acknowledged if details are provided):

2) Do you, or can you provide details of other persons/agencies that do, have direct access to references or data relating to the translocation of fish species? If no, please go to question 7.
   Yes ☐ No ☐

3) Can you provide contact details of other parties who may be happy to assist in this data collection phase (from question 2 above)?

   Name and contact details:

4) Can you list any translocated native fish species in Australia in addition to those listed in **Attachment 1**?

5) Are you aware of any references that document the impacts (social, economic or environmental) of translocated fish species? If yes, please list below or provide as an attached file. (Although the project is focussing on specific native fish species, exotic or international examples are also welcome).

SINCLAIR KNIGHT MERZ

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6)	Are you able to supply any distributional data which may detail the distribution of any species listed in **Attachment 1** ie. Pre or post translocation events as well as translocations? If yes, please paste data into the attached **Excel file** adhering as close as possible to the format specified in the spreadsheet. Yes ☐ No ☐
7)	If you are unable to provide data, please specify by ticking appropriate box Do not have access to data ☐ Licensing agreement required ☐ Other: ☐ Please specify:

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Attachment 1 – Native species reported to have been translocated within Australia.
Source: Lintermans (2004).

Species	Common name	Purpose/mechanism of translocation
Maccullochella peelii peelii	Murray cod	Recreational fishing
Maccullochella macquariensis	Trout cod	Recreational fishing
Maccullochella peelii mariensis	Mary River cod	Recreational fishing
Macquaria ambigua	Golden perch	Recreational fishing
Macquaria sp.	Lake Eyre callop	Recreational fishing?
Macquaria australasica	Macquarie perch	Recreational fishing
Macquaria novemaculeata	Australian bass	Recreational fishing
Macquaria colonorum	Estuary perch	Biological control
Nannoperca australis	Southern pygmy perch	Conservation
Ambassis agassizi	Olive perchlet	Conservation
Ambassis sp.	Northwest glassfish	Conservation
Scortum barcoo	Barcoo grunter	Aquaculture/recreational fishing
Hephaestus fuliginosus	Sooty grunter	Recreational fishing
Bidyanus bidyanus	Silver perch	Recreational fishing, aquaculture
Leiopotherapon unicolor	Spangled perch	?
Amniataba percoides	Banded grunter	Aquaculture
Bidyanus welchi	Welch's grunter	Conservation
Tandanus tandanus	Freshwater catfish	Recreational fishing
Neosilurus hyrtlii	Hyrtl's tandan	Conservation
Neosiluroides cooperensis	Cooper Creek catfish	Conservation
Porochilus argenteus	Silver tandan	Conservation
Gadopsis marmoratus	River blackfish	Recreational fishing, conservation
Anguilla australis	Short-finned eel	Aquaculture
Hypseleotris klunzingeri	Western carp gudgeon	Accidental
Hypseleotris sp. 1	Midgley's carp gudgeon	Water transfer
Hypseleotris galii	Fire-tailed gudgeon	?
Mogurnda adspersa	Purple-spotted gudgeon	Conservation
Mogurnda clivicola	Flinders Ranges Mogurnda	Conservation
Oxyleotris lineolatus	Sleepy cod	?
Retropinna semoni	Australian smelt	Conservation
Lates calcarifer	Barramundi	Recreational fishing, aquaculture?
Scleropages leichardti	Saratoga	Recreational fishing?
Scleropages jardini	Gulf saratoga	Recreational fishing?
Neoceratodus forsteri	Queensland lungfish	?
Nematolosa erebi	Bony herring	?
Galaxias brevipinnis	Climbing galaxias	Water transfer
Galaxias maculatus	Common galaxias	Water transfer
Galaxias truttaceus	Spotted galaxias	Bait bucket?
Galaxias pedderensis	Pedder galaxias	Conservation
Galaxias fontanus	Swan galaxias	Conservation
Galaxias auratus	Golden galaxias	Conservation
Galaxiella pusilla	Dwarf galaxias	Conservation
Melanotaenia splendida australis	Western rainbowfish	?
Melanotaenia splendida tatei	Desert rainbowfish	Conservation
Melanotaenia fluviatilis	Murray rainbowfish	Aquaculture (aquarium)
Glossamia aprion	Mouth almighty	?
Strongylura krefftii	Freshwater longtom	?
Arrhamphus sclerolepis	Snub-nosed garfish	Recreational fishing, forage
Toxotes chatareus	Archerfish	?

Appendix B Consultation

State	Organisation	Contact person
ACT	MDBC	Mark Lintermans
ACT	CSIRO (Sustainable Ecosystems)	Mark Jekabsons
NSW	NSW Fisheries	Craig Watson
NSW	NSW Fisheries	Kerry Gillfeather
NSW	NSW Fisheries	Lee Baumgartner
NSW	NSW Fisheries	NSW Fisheries
NT	DPI Fisheries	Glenn Ship
NT	DPI Fisheries	Phil Hall
NZ	Department of Conservation	Natasha Grainger
QLD	Department of Primary Industry	Peter Kind
QLD	FFSAQ (Freshwater Fishing and Stocking Association of Queensland)	Les Kowitz
QLD	Griffith University	Dr. Steve (Harry) Balcombe
QLD	James Cook University	Damien Burrows
QLD	Griffith University	Mark Kennard
QLD	Queensland DPI	John Russell
SA	-	Bryan Pierce
SA	-	Mike Hammer
SA	Lloyd Environmental	Lance Lloyd
SA	PIRSA Fisheries	Alice Fistr
SA	Rural Solutions SA	Jason Higham
SA	SA Water	Paul McEvoy
SA	SARDI	Brenton Zampatti
SA	University of Adelaide	Scotte Wedderburn
SA	SARDI	Dale McNeil
SA	SARDI	Qifeng Ye
TAS	-	Jean Jackson
TAS	Department of Primary Industry and Water	Scott Hardie
TAS	Freshwater Systems	Peter Davies
TAS	Hydro Tasmania	David Ikedife
TAS	Inland Fisheries Service	Stuart Chilcott
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Appendix C Fish species distribution