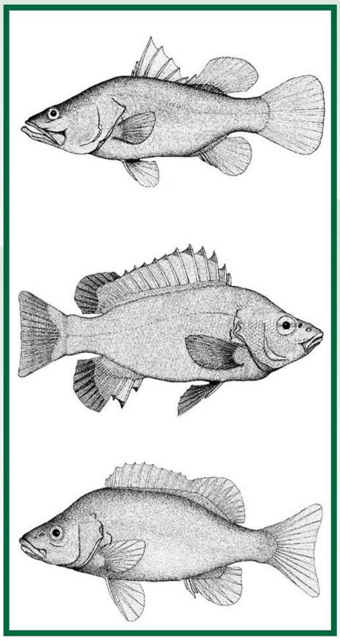
RESEARCH REPORT



Translocated Fishes in Streams of the Wet Tropics Region, North Queensland: Distribution and Potential Impact

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Cooperative Research Centre for Tropical Rainforest Ecology and Management

TRANSLOCATED FISHES IN STREAMS OF THE WET TROPICS REGION, NORTH QUEENSLAND

Distribution and Potential Impact

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WET TROPICS MANAGEMENT AUTHORITY

Rainforest CRC

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CONTENTS

EXECUTIVE SUMMARY

Native fishes do not occur throughout all river systems in Australia. Even within the one river, they may be restricted to certain sections. This is particularly so where barriers such as waterfalls limit the upstream distribution of fishes. Streams above waterfalls typically have a depauperate fish fauna. This is especially true for upland streams of the Wet Tropics. However, for a variety of reasons, but most commonly to create recreational fisheries in these streams, many native fish species have been moved (translocated) to above waterfalls in the Wet Tropics. The potential environmental impacts associated with translocation of native fishes have received very little attention, especially when compared to exotic species. However the two are analogous. Any fish, regardless of its origin, moved to a new stream where it does not naturally occur, may cause significant environmental changes.

Translocations have been occurring in the Wet Tropics for around 100 years, mostly done by private individuals and involving low numbers of fish. However, the Recreational Fishing Enhancement Program, a DPI initiative which began in 1986, and the development of mass-hatchery techniques in the last 20 years, has greatly increased the number of fishes stocked. Over 30 million fish have now been stocked in Queensland under this program, including 2 million into waters of the Wet Tropics. Fish that do not naturally occur in the Wet Tropics also enter streams here after escape from farm dams and aquaculture facilities where they are commonly stocked, or via release from aquaria. Evidence is found to suggest that up to 36 freshwater fish species plus red claw crayfish have been translocated into waters of the Wet Tropics. Many of these translocations have resulted in non-locally native species becoming established in the Wet Tropics World Heritage Area and a number of National Parks. These translocations are a combination of farm dam/aquaculture escapes; unofficial/illegal stockings by private individuals; and official stockings by government fisheries agencies. Addressing the issue of translocated fishes in the WTWHA will require a variety of management and planning methods.

Despite the extent of stockings that have occurred to date, and the important faunal components of Wet Tropics streams that are considered to be vulnerable to predation by novel fish predators, no environmental evaluations for fish stocking have been undertaken in the Wet Tropics. The distribution of translocated fishes within streams of the Wet Tropics is not adequately known, nor is the extent of overlap between translocated fishes and potentially vulnerable species such as frogs and crustaceans. Translocations of native fish (and other aquatic organisms) are not accounted for in the WTWHA Management Plan, but need to be included. Translocations of fishes (and other aquatic organisms), even where they are released outside of the WTWHA, may be cause for a trigger of the EPBC (1999).

Specific recommendations of this report are to:

1. Ensure translocations and stockings in the Wet Tropics are more thoroughly documented;
2. Determine the exact distribution of translocated and native freshwater fishes via further surveys targeting sites identified in this report;
3. Undertake environmental evaluations of existing, and some historical, stocking programs;
4. Investigate the role of farm dams and aquaculture facilities as sources of fish introductions;
5. WTMA to become more involved with the regulation and management of fish stocking;
6. WTMA to develop a fish stocking and translocation policy; and

7. Develop a public education program to reduce the incidence of translocations by private individuals.

1.0 INTRODUCTION

Fishing is a very popular activity in Queensland and generates considerable social and economic benefits. Certain fishes are preferentially desired by anglers (for food or sport) but these do not occur in all locations. Many streams lack any species desired by anglers. In response to this, fishes have been moved into these locations, often to create recreational and/or subsistence fisheries. Even where suitable species do occur, stocks are sometimes supplemented to boost catch rates. Exotic (non-Australian) fishes are not used in any stocking program in Queensland and issues associated with exotic species are not considered in this report. In contrast to the spread of exotic fishes which, spread predominantly as escapees from ornamental ponds, home aquaria and thoughtless people, most native fish translocations have been deliberate attempts to establish those fishes, often with the support of government agencies, for the purposes of establishing or enhancing recreational fisheries. For the purposes of this report, the moving of native fish species to streams where they do not naturally occur is termed a translocation (sometimes, this term is used to describe movement of fishes to areas within their natural range and of exotic fishes that are moved to new areas). Fish translocations also occur for a variety of other reasons such as release from aquaria and escape from farm dams and aquaculture facilities. Fish stocking and translocations are common in Queensland, but apart from a literature review of issues associated with fish stocking, this report, commissioned by the Wet Tropics Management Authority (WTMA), focuses on issues which have, or which may, affect the Wet Tropics World Heritage Area (WTWHA), or its values where these values occur outside of its formal boundaries.

There have been no environmental assessments of fish stocking in Queensland so there is no published, or even little collated, information to draw upon. Hogan (1995) provided a review of stockings occurring in northern Queensland up until 1995 but much has happened since then and additional stockings from pre-1995 are also documented here. This report has been as exhaustive as possible, though many stockings undoubtedly remain undocumented, as does the distribution of most translocated fishes. Common names are used for fishes mentioned in several places in this report. Scientific names for those fishes are given in Appendix A. Fishes mentioned only once are given their scientific names within the text.

1.1 HISTORY OF FISH STOCKING IN THE WET TROPICS

The Wet Tropics bioregion and the Wet Tropics World Heritage Area are located on the tropical NE coast of Australia and are drained by several major river catchments (Figure 1). People have been stocking fish into streams of the Wet Tropics for over 100 years. Early attempts often involved stocking exotic trout species into highland streams. Trout continued to be stocked into the 1960s (e.g. Pearce 2000), but no examples of their persistence are known. Early settlers also translocated native fishes to various streams. In some cases, the populations of fish in entire rivers are based on a small number of fish moved many years ago (e.g. sooty grunter in the Herbert River above Herbert River Falls and in Running River above Running River Falls – see sections 3.1 and 3.2). Many translocations that remain undocumented undoubtedly occurred during this time. These early stockings involved small numbers of fish and they did not always establish. In the 1980s and 1990s, there was a big push to stock farm dams. The species most commonly used were not locally native to the Wet Tropics (e.g. golden perch, silver perch). Escapes from these dams, and from aquaculture facilities using the same species, resulted in some translocations occurring. Most of these do not appear to have persisted (see golden perch in section 3.1 for an exception), though escapes continue to occur.

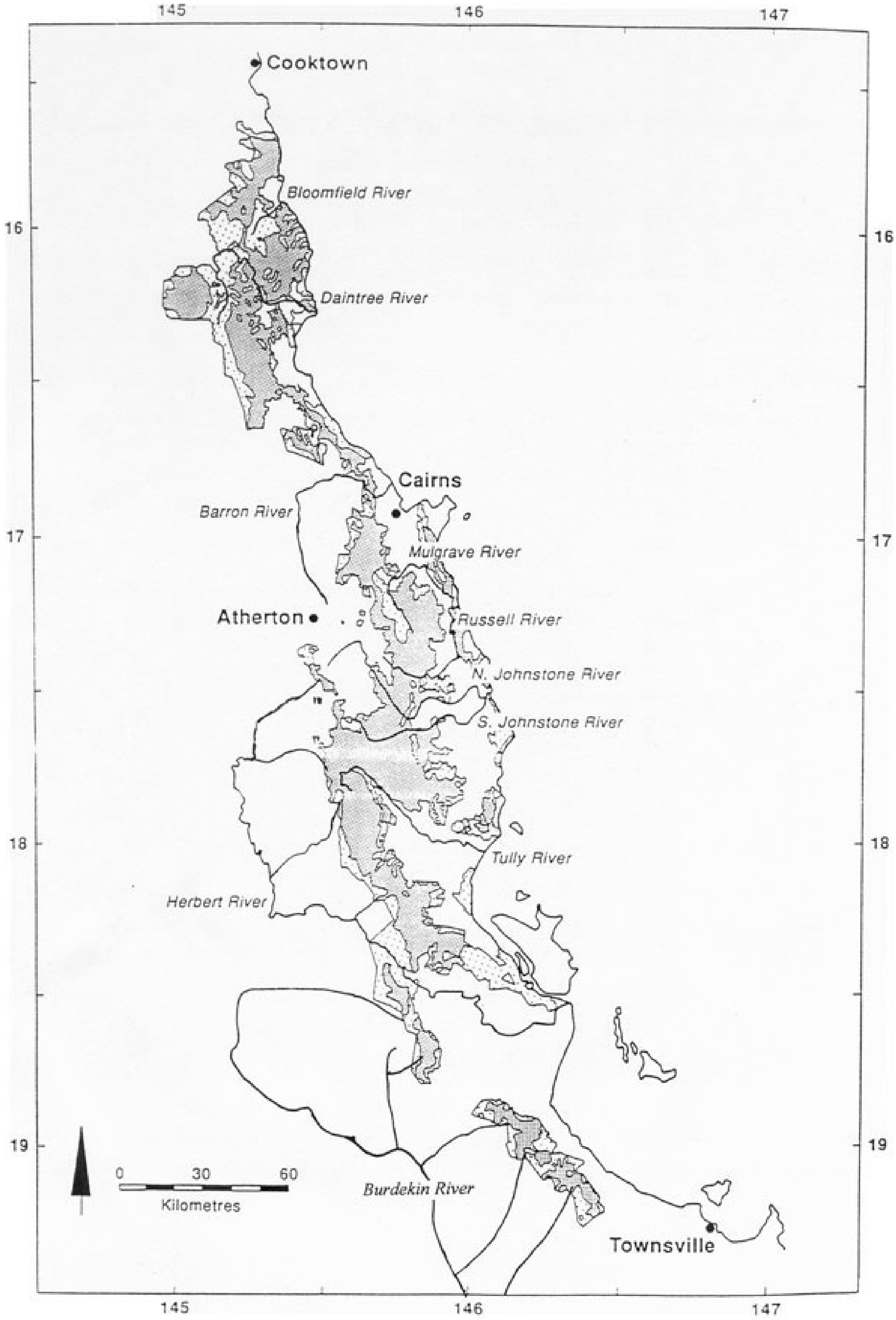

Figure 1: Map of the Wet Tropics World Heritage Area, including major river systems.

The development by the DPI of hatchery techniques for several fish species in the 1980s allowed for the mass stocking of fishes, initially into streams, but now mostly into impoundments (dams and weirs). During the 1980s, the fish being developed under these programs (sleepy cod, sooty grunter, silver perch and barramundi) were released into a number of impoundments and rivers in northern Queensland. With increasing participation in recreational fishing, and pressure on some stocks due to commercial fishing and habitat decline, there is increasing demand to augment a variety of fisheries. In response to this pressure, in partnership with recreational fishing groups, DPI began the Recreational Fishing Enhancement Program (RFEP) in 1986. This has been very successful in promoting and developing new recreational fisheries in estuarine and freshwaters. There is no doubt that fish stocking is a major recreational, social and economic activity (e.g. at Tinaroo Dam). There are now organised stocking groups in most catchments, supported by DPI extension officers. In the Wet Tropics, relevant stocking groups are:

- Twin Cities Fish Stocking Society – stock Ross River in Townsville and have also expressed interest in stocking Paluma Dam;
- Hinchinbrook Fish Care Group Inc. – stock lower Herbert River;
- Cardwell Shire Fish Restocking Association – stock lower Tully, Murray and Hull rivers;
- Ravenshoe and Koombooloomba Fish Stocking Committee – stock Koombooloomba Dam;
- Tablelands Fish Stocking Society – stock Tinaroo Dam;
- Johnstone Shire Fish Stocking Society – stock lower Johnstone rivers, Mourilyan Harbour, Liverpool Creek, Maria Creek;
- Mulgrave Shire Fish Stocking Committee – stock lower Barron River, Trinity Inlet and lower Russell-Mulgrave rivers;
- Cooktown Fish Restocking Association – stock lower Annan and Endeavour rivers; and
- Bloomfield – there is interest in starting a new stocking group here.

Since the introduction of the RFEP, nearly 30 million fish have been stocked in Queensland, including 2 million in the Wet Tropics (DPI-QFISH database), and the rate of stocking is rapidly increasing. Despite the level of effort that has been expended on this stocking program, there have been no assessments of potential environmental impacts and, until recently, no planning to protect conservation areas. There has also been little coordination with other relevant agencies such as the EPA, QPWS or WTMA, the agency responsible for management of the WTWHA. As fish stocking and translocations in waters of the Wet Tropics region have the potential to impact on the values of the WTWHA, they may trigger the EPBC Act (1999), although this has not been tested as yet and would only apply to actions occurring since 1999. Such stockings may act as a trigger even where the fish were originally released outside of the WTWHA. Several frog and fish species in the Wet Tropics are also listed under the EPBC (1999). Thus any waters where these species occur (even outside the WTWHA) that have fish resulting from stockings present, may also come under the EPBC.

Fish stocking did not require a permit until 1996, so there is patchy information available for what fish, where and how many were stocked. Anecdotal evidence indicates that numerous unauthorised or unrecorded stockings have occurred and, in most cases, these are only detected when fish sampling in the area produces fish that should not occur there. Many anecdotal reports remain unverified due to limited fish survey effort in key areas. In some cases, stocking occurred so long ago that it is not known whether the fishes are native or translocated.

1.2 EXOTIC VERSUS TRANSLOCATED FISHES

Most people now agree that the introduction and spread of exotic fishes into open waters should be actively prevented. There are legislative controls and education programs to inform the public about the environmental risks posed by exotic fishes, as well as several control and eradication programs. However, such concern does not extend to translocated native fishes even though the ecological basis for eradicating exotics whilst stocking translocated fishes into the same rivers is debatable. In the Barron River, there are great concerns about exotic fishes such as tilapia, yet little concern about the nearly 1.5 million large predatory native fishes that have been translocated there in the last 15 years, or the 23-36 native species that have been translocated into various parts of that catchment (see section 3.7). This argument does not diminish the importance of controlling tilapia in the Barron catchment and preventing its spread to the adjoining Mitchell catchment, but highlights the fact that, within the Barron catchment, exotic fishes are not the only potentially harmful, non-locally native fish species present. In a review of introduced and translocated fishes in Australia, Arthington (1991) concluded that translocating native fishes had the potential to be just as damaging as the introduction of exotic species and called for the translocation of native fish species to be subject to the same considerations of probable consequences as exotic fish species. Within Queensland, the number of translocated native species is several times greater than the number of exotic species present.

The designation of exotic is substantially based on political boundaries, not ecological boundaries. In Europe for instance, an exotic fish could be one from an adjoining catchment or even a different part of the same catchment. If Australia was as politically subdivided as other continents (e.g. as different countries, not states), then fish from elsewhere, such as from the Murray-Darling basin, would be considered exotic in northern Queensland and enjoy much less public and government support than they currently do. North Queensland fish faunas have more in common with Papua New Guinea (PNG) fishes than with southern Australian faunas. For instance, southern PNG shares only three freshwater fish species in common with northern PNG, but >30 freshwater fish species in common with Australia (Allen and Coates 1990, Unmack 2001, Hitchcock 2002). The Torres Strait and Arafura Seas that currently separate Australia from PNG have been less of a barrier to natural fish dispersal than have the PNG central highlands.

Under current government regulations, all exotic species are regulated, regardless of their potential environmental impact. In contrast, translocated fishes are minimally regulated, even though they may have a similarly great potential for environmental impact. An exception is in NSW, where the banded grunter, a northern Australian species, has been declared noxious – the same designation as exotics – following its accidental release with a batch of silver perch fingerlings into the Clarence River and its subsequent environmental impact (Rowland 2001). Through the same means of accidental introduction, banded grunter have also caused similar problems, such as decimation of crustacean stocks (Rowland 2001), in southern Queensland waters (e.g. Hinze Dam, Somerset Dam, Wivenhoe Dam), but this has prompted no action in Queensland. In the Wet Tropics, waterfalls act as effective barriers to fish dispersal, thus providing aquatic habitats that have, for millions of years, lacked large fish predators (except for eels). Such conditions are partly responsible for the diverse and unique assemblage of aquatic fauna present in those streams, many of which would not have good anti-predator mechanisms. Stocking native fish species above these waterfalls may put the resident aquatic species, and the ecological processes of these streams, at risk. Whether the stocked fish is a native that occurs in downstream sections of the same stream, or an exotic from the other side of the planet, does not matter as much as its specific ecology and behaviour. The ecology of the stocked species, in relation to the ecology of the location where it is to be stocked, is more important than its provenance, as stocked native species can have similar impacts as exotic species.

A classic example of the impact of translocating native fishes above waterfalls within the same waterway is the introduction of nile perch (*Lates niloticus*) into Lake Victoria (in the upper reaches of the Nile system) in 1960 which was followed by the extinction of numerous (potentially up to 200 – Baskin 1992, Lowe-McConnell 2002) native fish species and the decimation of the commercial and subsistence fisheries through predation by nile perch (Barel *et. al.* 1985, Barlow and Lisle 1987, Kaufman 1992). This represents one of the greatest vertebrate extinction events of modern times. These extinctions were brought about by a fish that is native to the Nile catchment, but historically excluded from the upstream reaches by a large waterfall. This draws parallels in the Wet Tropics of moving native fish above waterfalls to parts of the same catchment in which they do not occur. Barramundi, the most abundantly stocked fish in the Wet Tropics (and third most abundantly stocked in Qld – DPI-QFISH database) is related to nile perch, both being in the same genus – *Lates.* Queensland authorities considered introducing nile perch to develop recreational fisheries. This generated considerable debate over many years (Midgley 1968, 1981, Williams 1970, 1981, 1982), and although initial approval to import this species was given (Williams 1982), Queensland authorities abandoned the idea in 1986. If nile perch had been introduced into Queensland, Tinaroo Dam would almost certainly have been one of the first release sites. The ability to colonise non-target water bodies (unlike barramundi, nile perch breed in fresh water) and impacts on indigenous aquatic fauna were the main reasons why nile perch were not introduced to Queensland waters (Barlow and Lisle 1987), yet these same principles have not been applied to barramundi and other native fish species when they are translocated to new habitats.

1.3 RECOGNITION OF THE IMPORTANCE OF NATIVE FISH TRANSLOCATIONS

Concern over translocated native fishes has been recognised for some time. At the 1977 AGM of the Australian Society of Fish Biology, a resolution was passed on this topic and sent to all State and Commonwealth fisheries agencies. At their 1988 AGM, it was decided to again bring this same resolution to the attention of State and Commonwealth fisheries agencies and all relevant environmental and conservation agencies (Pollard 1990). The resolution reads:

> *"The Australian Society for Fish Biology recognizes that the distributions of Australian native freshwater fishes are imperfectly known, and are currently the subject of increasing interest and study. The Society is concerned that the artificial movement of these fishes from one drainage system to another can irreversibly change the natural distribution patterns and may affect other native species. Therefore the Society urges all fisheries authorities in Australia to do all in their power to restrict (or prevent) the artificial movement of Australian native freshwater fishes into drainage systems in which they are not known to occur naturally at the time of the proposed introduction."*

This resolution seems to have been poorly heeded by fisheries authorities and many fisheries and aquatic biologists.

Fish stocking is a widespread activity but with potentially far-reaching impacts on aquatic ecosystems. Despite much research into improving hatchery techniques, maximising growth and survivorship of stocked fish, and promoting fishing in stocked waters, not a single study has been commissioned on the environmental impacts of this statewide program. Until recent years, there was no planning to protect conservation areas, and current efforts in this regard, though improving, are still weak. Three possible reasons for the lack of environmental evaluation may be: 1) translocating natives has not been considered to be harmful; 2) there is relatively little information available to demonstrate impacts and the precautionary principle is not applied; 3) most stockings are into impoundments which, because they are artificial, are considered to be sacrificial. The potential impacts of translocated fishes are reviewed in this report to provide examples against the first two points. Stocked fish do not necessarily stay within the impoundment into which they are stocked as they may swim into upstream tributaries or go over the impoundment wall during floods. Most fish species show very strong natural instincts for migratory movements. Thus, stocking of impoundments on the basis that they are artificial often results in the stocking of natural streams. No official stockings have occurred directly within National Parks, or the WTWHA since its declaration, but many translocated fishes now occur in these designated conservation areas. Approval for stockings has to include consideration of the potential movements of the stocked fish. That the actual stockings occur outside of these conservation areas may explain the lack of consultation with the agencies responsible for their management, and their lack of response to such stockings. However, clearly, such agencies should be consulted for all stockings occurring in catchments where they have some management responsibility, a process that is only now being initiated in the Wet Tropics.

It is scientifically unarguable that that the introduction and long-term survival of tens of thousands of large predatory fish would not impact upon their receiving environments. The question is whether these impacts are significant or acceptable. No studies have been commissioned to determine the environmental impact of translocated fishes in Queensland, but information from other studies provides some indications. The extinction of the Lake Eacham rainbowfish in Lake Eacham was attributed to translocated native predatory fishes (Barlow *et. al.* 1987). For many years, it was thought that this fish was extinct in the wild, until new populations were fortuitously discovered elsewhere (see section 2.2 and 3.7.2). Pusey (in press) has documented declines of fish species associated with the spread of translocated sleepy cod throughout the upper Burdekin River. The fish fauna of Ross River in Townsville has been substantially altered since the stocking of barramundi there in 1992 (A. Webb *pers. comm.*). Neither of the latter two studies were designed to study the impacts of translocated fishes, but these fishes were released, or appeared at sampling sites, during the course of those studies. Banded grunter, a native species from northern Queensland, were accidentally released into several locations in south-eastern Queensland and northern New South Wales in a contaminated batch of silver perch fingerlings. They quickly devastated the local shrimp populations (Rowland 2001), thus altering entire food chains. Notably, banded grunter have been translocated into the Barron catchment and Lake Eacham (see section 3.7).

In the United States, where fish translocations are more common than in Australia, there are many more examples. Lakes that were formerly free of fish provided habitat for frog species. Since the translocation of native fishes there, the frogs have been eliminated (see section 4.4). Several of our native frog species, including those of high conservation value, are also intolerant of fish predation, only occurring above waterfalls that act as fish passage barriers (see section 4.4). Impacts on crustaceans (very vulnerable to predation – see section 4.5), waterbirds (through competition for food resources – see section 4.3) and other aquatic fauna are also possible. By virtue of their position as top aquatic predators, fish can alter entire food chains and instream ecological processes (see section 4.6). These issues are discussed in more detail later in this report.

1.4 IMPACTS OF TRANSLOCATED NATIVE FISHES

There is extensive scientific literature on the impact of introduced fishes. Most of this involves exotic species, though as already argued, the impacts of exotic and translocated fish are analogous. Still, the literature that specifically involves translocated native fishes is also extensive and some examples are provided here.

In the United States, as in Australia, many translocations of native fishes have been intentional releases to establish or enhance recreational and/or commercial fisheries, though predominantly the former. Translocation of native fish species has been widespread in the United States for over one hundred years, resulting in the establishment of at least 178 native fish species outside of their natural range (Courtenay 1990). This has caused dramatic changes in the ecology of many waterways. In some major river systems, such as the Colorado River drainage, introduced exotic and translocated native species dominate the fish fauna and many locally native fish are listed as threatened or endangered (Moyle 1986). Ono *et. al.* (1983) reviewed 151 fish species considered endangered or threatened in North America. They found that 37% were threatened by introduced fishes, both exotic and translocated natives. Introduced species have been associated with 68% of the 40 North American fish extinctions recorded in the last century (Miller *et. al.* 1989). Moyle (1986) described how the fish communities in the more speciose eastern drainages of the United States were less impacted by fish introductions than the less speciose western drainages. Even fish species related to and/or with a similar ecology to introduced fishes, can be replaced by those fishes. In two creeks of the Sierra Nevada ranges in California, the native cutthroat trout was replaced by three introduced trout species, two of which are translocated natives (Moyle 1986). In the upper Burdekin River, the fish most affected by the spread of translocated sleepy cod are purple-spotted gudgeon, which are in the same family as sleepy cod and have a similar ecology (Pusey, in press).

The example of the nile perch translocated to Lake Victoria has already been discussed (section 1.2). Another spectacular example is the Great Lakes of North America. Native fish populations in these lakes crashed following the introductions of rainbow smelt in 1923, sea lamprey in 1936 and alewife in 1949 (Moyle 1986) which entered these lakes from the St. Lawrence River via shipping canals (Smith 1972). The sea lamprey in particular, decimated populations of several large fish species and the changes in the fish communities went down the food chain to also affect the composition of the zooplankton communities (Moyle 1986). Key factors in the rapid and devastating impacts of the introduced fishes were the large populations of suitable prey which had no defenses for the particular style of predation of the translocated fishes, the absence of predators of the translocated fishes, and the suitable breeding conditions. All three of these conditions could be met by many streams in the Wet Tropics. In particular, many of the native resident species (fish and non-fish species) have never encountered large aggressive predators such as those introduced by stocking, and the translocated fish are placed in large numbers into an environment in which they have no predators to control their populations.

Knapp *et. al.* (2001) studied the effects of introduced trout on the aquatic fauna (including frogs, macroinvertebrates and zooplankton) of 533 alpine lakes in the Sierra Nevada Ranges of California. Nearly all of these lakes were naturally fishless but many have been stocked with various trout species (both native and exotic species) over the last 100 years to support recreational fisheries. They found that the faunal assemblages in the study lakes had low resistance to fish introductions, including dramatic reductions in macroinvertebrate and large zooplankton species, and local extinction of one frog species. Similarly, translocation of native fishes into fishless lakes in Scandanavia has had profound effects on those lakes, including localised extinction of invertebrate species (Nilsson 1972).

In Europe, significant movements of fishes within countries, and across countries, have occurred over a long time frame. Documented deleterious effects of these movements are not uncommon. Bianco and Ketmaier (2001) considered that translocations of several native Italian fish were responsible for declines in native fish populations, including one that may lead to extinction. They also found that introduction of fishes from neighboring countries (an exotic in their context but equivalent to a translocation on our spatial scale) had deleterious impacts on native fish populations. Pike is native to most areas of Europe but not Spain. Since its introduction to Spain, it has been recorded to have negative effects on native fish faunas in several river basins and National Parks (Elvira and Almodovar 2001). Even within parts of its native range in Europe, it has been translocated to mountain streams where it has depressed trout populations (Vooren 1972). In the United States, translocated native pike have also caused environmental problems and considerable expense is now being invested in removal campaigns. The expansion of pike perch from eastern to western Europe has caused declines in numbers of pike (Vooren 1972). European perch is native to Europe but, even within its native countries, when released into waters where it does not naturally occur, it has been recorded to adversely affect other species, to the point of local extinction (Vooren 1972). Following introductions of various European predatory fishes to Spain, a number of stocked streams also had to be stocked with forage fishes to support the stocked fish due to collapse of natural forage species (Elvira and Almodovar 2001).

The construction of the Lake Pedder impoundment in Tasmania in the 1970s established an artificial connection with the adjacent Gordon River system. This enabled exotic brown trout and the native *Galaxias brevipinnis* to invade Lake Pedder. The introduction of these fish, and not the impoundment of the lake (galaxids do well in impounded waters), are largely responsible for the decline of the endemic *Galaxias pedderensis* which is considered the most endangered freshwater fish in Australia (Crook and Sanger 1997, Waters *et. al.* 2002). Further examples of impacts of translocated native fishes in Australia are discussed throughout this report.

Despite a number of examples of the impact of translocated native fishes, these have received little attention in Australia. There is potentially a belief that native fishes are not harmful, even when translocated to new locations. This view does not reflect scientific findings. The prevalence of fish stocking and fish movements, often supported by government agencies, and its lack of regulation and publicity, has probably allowed this ambivalent attitude to develop. Even amongst scientists, this issue has been often ignored. This is evidenced by the lack of study of translocated fishes by aquatic biologists. Of the numerous reports in recent years that have discussed threats to aquatic communities, rarely are translocated fish mentioned. Many fisheries reports that detect translocated fishes do bring this fact to the readers attention, but rarely discuss any potential environmental consequences of those findings. Most publications concerning declining frog populations in the Wet Tropics have considered a range of possible contributory factors such as temperature changes, drought, habitat disturbance but have mostly ignored the potential role of fish translocations (see section 4.4). During the debate over the Tully-Millstream hydroelectricity scheme, considerable scientific debate centred on the potential impacts of flow regulation on aquatic invertebrates and ecosystem processes. However, I can find no reference to the potential impacts of translocated sooty grunter in those debates, despite these fish having been established there several years previous. Declining water quality, habitat degradation and flow regulation have probably been considered to be the major threats to upland Wet Tropics streams in recent years. However, inappropriate fish translocations may cause significant changes to faunal communities and ecosystem processes in pristine streams unaffected by any of these factors. The relevance of these modifications was recognised by Pusey (in DNR 1999) and Pusey (in press) in the respective fisheries reports for the Water Resource Plans for the Barron and Burdekin catchments. He pointed out that the population sizes and distribution of translocated fishes in those catchments was such that the impacts of altered flow regime may not be distinguishable from that of the translocated fishes. This statement would also apply to other forms of habitat modification. Thus the issue of native fish translocations warrants a higher profile in environmental research and management.

1.5 MANAGEMENT OF FISH STOCKING IN QUEENSLAND

In Queensland, fish stocking under the RFEP was initially undertaken by DPI-Fisheries, whose staff also developed hatchery techniques for their mass-rearing. Management and regulation of fish stocking was through the Queensland Fisheries Management Authority (QFMA) which merged with DPI-Fisheries in 2001 to become the Queensland Fisheries Service (QFS). Since 1996, the Freshwater Management Advisory Committee (FMAC), an expert-based stakeholder committee has provided advice on fish stocking to the QFMA/QFS. In conjunction with DPI and QFMA, the FMAC produced the Freshwater (Fisheries) Management Plan (1999) which outlines all regulations for freshwater fishing in Queensland, including bag, size and gear restrictions. This also includes some restrictions on the species and locations that can be stocked. Fish stocking into public waters has only required a permit since 1996. The Freshwater Management Plan is revised every two to five years with a revision due to be released in late 2002. Requests for permits to stock fish are assessed by the QFS and the stocking sub-committee of FMAC.

1.6 COMMONLY STOCKED FISH

Numerous fish species have been stocked into waters of the Wet Tropics. The five species most desired in this region are discussed below. Sleepy cod were commonly stocked in the 1980s and early 1990s as the breeding technology was developed early. When large numbers of sooty grunter and barramundi became available in the late 1980s, these became the most popular fish for stocking. Sleepy cod have now fallen out of favour in preference for these two species which are preferred by anglers. Breeding technology for mangrove jack is just now reaching a level where significant stockings will soon occur. The DPI have recently initiated research into breeding technology for jungle perch.

Barramundi (*Lates calcarifer*) – Barramundi occur across northern Australia. They are a large predatory fish that commonly grow well over one metre long. They are enormously popular as a sport fish and the most commonly stocked fish in northern Queensland. They have been stocked into Tinaroo, Copperlode and Koombooloomba Dams in the Wet Tropics as well as numerous other rivers and impoundments in Queensland. They have also been extensively stocked into lowland streams and estuaries of the Wet Tropics to supplement natural populations there (see sections 3.12 and 3.13). They breed in estuaries, thus having to migrate between fresh and salt waters, so do not naturally occur above fish passage barriers such as waterfalls, and will not establish reproducing populations in impoundments. Barramundi are not easy to catch and some angling experience and knowledge is required. Thus many anglers are not particularly successful in catching them, even in impoundments.

Sooty grunter and khaki bream (*Hephaestus* species) – Sooty grunter (*H. fuliginosus*) naturally occur in the Gulf of Carpentaria catchments, along the east coast from the Burdekin north to the Russell-Mulgrave, and also in a few streams on the east coast of Cape York Peninsula. Sooty grunter from the Walsh River (part of the Gulf of Carpentaria catchments) were originally described as a separate species – *Therapon bancrofti* – which was later combined, using very limited material, with *H. fuliginosus* (Vari 1978). Pusey (unpub data) suggests that sooty grunter in the Gulf of Carpentaria differ substantially in morphology and genetic composition, from sooty grunter along the east coast of northern Queensland, such that they may, upon further review, be resurrected as a separate species. Sooty grunter (broodstock sourced from a variety of locations) have also been extensively translocated into streams around Mackay and Proserpine as well into the Fitzroy catchment and other streams near Gladstone and Bundaberg (Hogan 1995, Hollaway and Hamlyn 2001). Khaki bream (*H. tulliensis*) are endemic to the Wet Tropics, only occurring from the Tully-Murray catchment to the Daintree catchment (Allen and Pusey 1999). This species was originally described in 1884 as a separate species to sooty grunter, but, as for, *T. bancrofti*, Vari (1978) also synonymised this species under *H. fuliginosus*. It was recently resurrected as a valid species by Allen and Pusey (1999). Both species are medium-sized predators (up to 50cm long, but usually less) with broad diets that include fish, frogs, terrestrial and aquatic invertebrates, aquatic plants and even fruit from riparian trees. They are also aggressive fish. They breed in riffles and need significant lengths of flowing water to successfully reproduce, which may explain their absence from short coastal streams within their distribution, and in impoundments which lack tributary streams with this characteristic. As they appear to have colonised the Wet Tropics by moving northwards along the coast from the Burdekin River (Pusey in press), they do not naturally occur above any waterfalls in the Wet Tropics. Within the Wet Tropics, sooty grunter have been stocked in Tinaroo, Copperlode and Koombooloomba dams and the upper Barron River, Lake Eacham, upper North and South Johnstone rivers, the upper Herbert River, the upper Running River and the upper Annan River. They have formed successful breeding populations in most cases, except Tinaroo and Copperlode dams and Lake Eacham. Several stockings into lowland freshwater streams have also occurred (see section 3.12). Khaki bream have only been stocked into the North Johnstone River system and into the Barron River above Tinaroo Dam, but appear to be breeding in both locations (Hogan 1995). Sooty grunter normally grow to 2-4 kg in streams (Allen 1989a) but regularly grow to 7 kg in impoundments such as Tinaroo, Koombooloomba and Copperlode, at rates of up to 1kg per year (Hogan 1995).

Sleepy cod (*Oxyeleotris lineolatus*) – These are hardy, benthic predators that commonly grow to 40 cm long. They are native to most Gulf catchments and the Fitzroy catchment of eastern Australia, but have been widely stocked into many other streams. There is some question as to their status (i.e. native or translocated) in some other eastern flowing drainages in Queensland (Pusey in press). Several related species occur in northern Queensland but *O. lineolatus* has been used in most stockings. It was stocked extensively in the early days because it was easily carried between locations, was simple to breed and easy to establish in new locations. Although fine to eat, it is not a popular sport fish because of its poor fighting qualities, so most stockings have proved to be of little recreational benefit and it is now rarely stocked. However, this fish has readily established in most places were it has been stocked. Pusey (in press) documents the spread of this fish throughout the Burdekin catchment and some associated impacts on native fishes (see section 3.1).

Mangrove jack (*Lutjanus argentimaculatus*) – This species is a very aggressive and active predator. They are largely an estuarine and reef fish species, and though they cannot breed in freshwaters, they may also be found considerable distances upstream in large lowland rivers. Because of their fighting qualities, mangrove jack are a popular sport fish that are eagerly anticipated by stocking groups. They have been stocked in low numbers into Copperlode Dam, Tinaroo Dam and Awoonga Dam, near Gladstone. Greater numbers would already have been stocked had the experimental hatchery spawnings been more successful. At least six other stocking groups have already applied for permits to stock mangrove jack. Hatchery techniques are currently being refined. Up to 4,000 fingerlings have now been produced in a single batch (DPI press release December 2001). Mangrove jack can grow very large (>1.5m), have a large mouth, formidable dentition and a highly predatory nature. Apart from fish, they may also eat other animals such as frogs, water rats, turtles and potentially even platypus, which inhabit many Wet Tropics streams and marginal areas of Tinaroo Dam and Paluma Dam and their tributaries.

Jungle perch (*Kuhlia rupestris*) – Jungle perch occur in coastal streams from south-eastern Queensland to Cape York Peninsula. They breed in estuaries so do not occur above waterfalls and will not form breeding populations if stocked into impoundments. However, they are adept at swimming as far up coastal waterways as is possible. If stocked into impoundments, they are likely to swim considerable distances up the inflowing tributaries with potential impacts on the ecology of these streams. Research into hatchery techniques for mass rearing of this species are soon to begin. They are a very popular sport fish that will be highly desired for stocking. A small number were released into Tinaroo Dam by DPI staff a few years ago (A. Hogan *pers. comm.*), though no other stockings are known.

Other species mentioned in the text are listed and described in Appendix A.

2.0 FISH STOCKING ACTIVITIES IN THE WET TROPICS

2.1 AQUATIC VALUES OF THE WET TROPICS

The Wet Tropics bioregion is one of the highest fish diversity regions in Australia and holds many endemic species and species of high conservation value. More than 80 species are recognised for the region, including approximately 70% of the fish genera, and 45% of the fish species, in Australia (Pusey and Kennard 1994, 1996 plus unpub. data). It is also the region of highest aquatic invertebrate biodiversity in Australia (Pearson *et. al.* 1986) and one of the highest in the world (R. Pearson *pers. comm.*) Despite this, the aquatic values of the region and the WTWHA are less well known than the terrestrial values. In the 1990s, the first comprehensive fish surveys of the Wet Tropics collected several undescribed fish species and several other species not previously recorded in Australia (Pusey and Kennard 1994, 1996, Allen and Pusey 1999). Genetic studies beginning in the mid-late 1990s revealed the existence of significant genetic variation between populations of various small fish species (rainbowfish, hardyheads, blue-eyes, purple-spotted gudgeons) and crustaceans that occur in the upland streams of the Wet Tropics (Hughes *et. al.* 1996, Hurwood and Hughes 1998, Zhu *et. al.* 1998, McGuigan 2000, McGuigan *et. al.* 2000, McGlashan and Hughes 2000, McGlashan *et. al.* 2001, Hurwood and Hughes 2001, McGlashan and Hughes 2002). In particular, these studies highlight the degree of isolation of upland populations from their lowland counterparts. Although only a few kilometres apart, they are many thousands, or even millions, of years apart in evolutionary terms.

New discoveries in Wet Tropics streams are not limited to fish. Five new crustacean species (three shrimps and two large crayfish) have been described from streams of the WTWHA during the 1990s (Short 1993, Short and Davie 1993, Choy and Marshall 1997, Short unpub. data). Several other, as yet undescribed species, are also present (J. Short *pers. comm.*). Smaller aquatic invertebrates are particularly diverse, especially in upland streams. At least 23 undescribed mayfly species from just one family (Leptophlebiidae) are also known from the Wet Tropics (F. Christidis *pers. comm.*). Undoubtedly, hundreds more unrecognised aquatic species and distinct genetic stocks are also present. Much of the Wet Tropics occurs in upland areas above major waterfalls that have acted as fish passage barriers for millions of years. Thus despite the overall high fish diversity of the Wet Tropics region, many individual streams are relatively fish depauperate, and this has no doubt been a key factor in the development of distinctive aquatic communities. It is these fish depauperate streams that have received the most fish translocations, but the least effort from fisheries surveys and scientific investigations. The fish-depauperate upland streams of the Wet Tropics are likely to be more susceptible to impacts of fish translocations than the lowland streams, especially because many of the aquatic species in the upland streams are likely to have limited or no tolerance to predation from novel fishes.

2.2 LAKE EACHAM RAINBOWFISH – AN EXAMPLE OF THE IMPACT OF FISH TRANSLOCATIONS

One of the most widely publicised examples of the impact of translocated fishes is the loss of Lake Eacham rainbowfish (*M. eachamensis*) from its type locality (Lake Eacham). This species was only formally recognised in 1982 (Allen and Cross 1982). Until the late 1980s, Lake Eacham was the only known habitat of *M. eachamensis*. Barlow *et. al.* (1987) reported the loss in the wild of this fish species due to translocated native fish predators unofficially released into the lake during the 1980s. Thus, within a few years of its formal recognition, the Lake Eacham rainbowfish was regarded as the first freshwater fish in Australia to have become extinct in the wild (some remained in captivity) since European occupation. Fortunately, since that time, genetic analyses have determined it to be present in a number of new localities within the Wet Tropics. Despite these new findings, *M. eachamensis* remains on both the state and federal endangered species lists. Allen (1989b, 1995) considered *M. eachamensis* to also be present in Lake Euramoo (another volcanic lake near Lake Eacham) and Dirran Creek (a upland tributary of the North Johnstone River). Based on genetic analysis of mtDNA sequences, Zhu *et. al.* (1998) confirmed Allen's findings and concluded that both sites, and possibly Charappa Creek (an upland tributary of the South Johnstone River) contained pure strains of *M. eachamensis.* Zhu *et. al.* (1998) also found populations that contained a mixture of alleles from *M. eachamensis* and the related rainbowfish, *M. splendida splendida,* in other locations such as an irrigation channel off Tinaroo Dam, Streets Creek (upper Barron) and other tributaries of the North and South Johnstone Rivers such as Williams Creek and Ithaca Creek. The finding of fish with Lake Eacham rainbowfish alleles within an irrigation channel leading from Tinaroo Dam suggests that this represents a translocation itself. More recent genetic analysis has also revealed *M. eachamensis* to occur in Bromfield Swamp in the North Johnstone River headwaters (McGuigan 2000). Using an analysis of morphological and meristic characters, Pusey *et. al.* (1997) believed *M. eachamensis* to be even more widespread, occurring in many upland and several lowland tributaries and reaches of the North and South Johnstone rivers, in upland tributaries of the Herbert River near Koombooloomba Dam and tributaries of the Upper Tully River (including Koombooloomba Dam). Subsequent genetic work (Zhu *et. al.* 1998, McGuigan 2000, McGuigan *et. al.* 2000, Hurwood and Hughes 2001) suggested that at least some of these occurrences are not *M. eachamensis* but either unusual variants of *M. splendida splendida,* a new species – *M. utcheensis* – or populations displaying alleles of more than one species. Brad Pusey (*pers. comm.*) still believes *M. eachamensis* to occur in the upper Tully and upper Daintree rivers, both of which are very poorly represented in the genetic surveys.

Rainbowfish from Utchee Creek have long been considered to be a distinct rainbowfish and are marketed in the aquarium trade as Utchee Creek rainbowfish. McGuigan (2000) described them as a new species – *M. utcheensis* – with populations known from Utchee, Fisher, Rankin and Short creeks in the North and South Johnstone catchments. Rainbowfish from upstream sections of Running River and a nearby river – Fanning River – (both in the upper Burdekin catchment) are referred to as the zig-zag rainbowfish (the name refers to their original collection locality, not any distinctive pattern of markings). Pusey (unpub. data) has established that these populations are morphologically and meristically distinct, though they have no formally recognised status. Trenerry and Werren (1991) also point out the existence of other informally recognised forms of Wet Tropics rainbowfish such as Davies Creek rainbowfish and Kuranda reds. Rainbowfish are phenotypically highly variable and hybridisation does occur. In their text on rainbowfishes, Allen and Cross (1982) made mention of the peculiarities of each stream population.

Despite the work that has been completed to date, the specific status and distribution of rainbowfish in the Wet Tropics still remains unclear and a comprehensive genetic survey of Wet Tropics rainbowfish is required. Whilst it is fortunate that *M. eachamensis* is now known to occur in a number of streams, most of which are within protected areas, many of these streams are subject to translocated native fish predators. Nearly all of the prime habitats of *M. eachamensis* are naturally free of large fish predators, except eels. The degree of overlap between the distribution of *M. eachamensis* and translocated predators is uncertain but predators have already been translocated into known or likely habitats of the Lake Eacham rainbowfish – Lake Eacham, upper North Johnstone tributaries and the upper Tully River area near Koombooloomba Dam. Translocated sooty grunter occur in Dirran Creek (Pusey unpub. data), a system containing a pure line of *M. eachamensis*. Lake Euramoo has not been surveyed for fish since 1973 (Russell 1987) so this should be a high priority. Lake Barrine, another crater lake adjacent to Lake Eacham, also once contained an undetermined species of rainbowfish that may or may not still be present (see section 3.7.2) and should also be surveyed to confirm their status.

3.0 WET TROPICS CATCHMENTS AFFECTED BY FISH STOCKING

For many years, the fish-depauperate upland streams of the Wet Tropics have been subject to extensive fish translocations and introductions of exotics. Active acclimatisation groups stocked trout into the Barron River, Lake Eacham, Lake Barrine, North and South Johnstone rivers, and the Palmer River in the 1890's (Hogan 1995). These activities continued into the 1950s and 1960s, with further attempts to stock trout, including into Koombooloomba Dam (Pearce 2000) as well as translocating several natives (e.g. sleepy cod from the Mitchell River into the upper Barron River which established a breeding population – A. Hogan *pers. comm.*). In more recent years, the variety of species stocked has declined as has the number of locations stocked. However, with increased hatchery production, the numbers of fish stocked has risen dramatically. Nearly two million fish have been stocked into waters of the Wet Tropics in the last 20 years, with 60% of these being into Tinaroo Dam (DPI-QFISH database). Barramundi dominate the numbers of fish stocked but are unable to breed in fresh water. Nearly all of the major catchments of the WTWHA have been subject to fish stocking and most have had native fish translocated to new areas, predominantly in upstream reaches.

3.1 BURDEKIN CATCHMENT

Only a relatively small percentage of the Burdekin catchment is within the WTWHA (Figure 1). Nevertheless, the number of streams and amount of aquatic habitat is significant (Figure 2). This includes upstream reaches and tributaries of the Star River and Keelbottom Creek near Paluma, the upper Running River, and tributaries of Douglas Creek, near Mt. Fox. Sleepy cod have been stocked, usually in low numbers, into the Burdekin catchment on many occasions over many years. Early instances include 20 sleepy cod from a swamp at Mt. Garnet (?Wurruma Swamp) stocked into Reedybrook Creek in the 1960s (G. Harriman *pers. comm.*). Good catches of these fish were only noticed about 10 years later in a localised area near the original stocking location. The largest stocking event comprised 8,501 sleepy cod from Walsh River stocks via Tinaroo Dam (A. Hogan *pers. comm.*) stocked into the Valley of Lagoons with DPI assistance from 1980-1982. It appears that up until 1990, sleepy cod were only present in the Valley of Lagoons/Reedybrook area. During the 1990s however, various reports and fisheries surveys (Pusey *et. al.* 1998, Burrows and Tait 1999, Burrows 2001, Pusey in press) documented the rapid spread of sleepy cod down the Burdekin River and then up several of the major tributaries, including all of those listed above. Despite probably only entering the downstream reaches of the Star River and Keelbottom Creek in 1997-1998, the most recent survey in 1999 (Burrows and Tait 1999), found they had penetrated at least two-thirds the length of these streams. No sites within the WTWHA were surveyed though. Anecdotal reports from members of the Mt. Fox Landcare group indicate that sleepy cod are also in Michael Creek, an upstream tributary of Douglas Creek that drains the WTWHA, inland from Ingham. Sleepy cod are now in the lower Running River but cannot reach the WTWHA from there because of the Running River falls, more than 20km downstream from the WTWHA boundary. So far there are no reports of their having been translocated above these falls.

Sooty grunter are abundant in the upper Running River, above Running River Falls which are a historical waterfall/fish barrier. They do not naturally occur above those falls but were moved there by graziers from Hidden Valley, about 35 years ago (B. Furber and P. Jones *pers. comm.*). The fish were collected from below the falls and moved to waterholes near Hidden Valley township. Spangled perch are also unlikely to naturally occur above these falls but are common there now. Possibly, they were moved there with the sooty grunter. The headwaters of Running River are in the Paluma area within the WTWHA, and include streams known to have frog species of conservation value and a phenotypically distinct strain of eastern rainbowfish (known as the zig-zag rainbowfish). Fishermen report regularly catching sooty grunter in Running River just a short distance downstream from the WTWHA boundary. There are also reports from anglers of another related species – referred to as leathery grunter – being present in the same locations. This could be a reference to *Scortum hillii* or the small-headed grunter, *Scortum parviceps*. If either is true, this would also be an unrecorded translocation. The distribution of these fishes within the Paluma section of the WTWHA is unknown but should be a priority for further surveys.

Paluma Dam is entirely surrounded by WTWHA (Figure 2). The dam was constructed in 1959 and supplies water to the Townsville/Thuringowa area. Overflow from the dam enters the Burdekin system via Birthday Creek and then Running River. Water released for urban consumption is piped across to Crystal Creek, which flows east into Halifax Bay (ie, an interbasin water transfer). The dam is built on the very upper reaches of a number of small rainforest creeks and may have been naturally devoid of all fish, except maybe for eels. In the creek below the dam spillway, only long-finned eels, purple-spotted gudgeons and rainbowfish are found naturally, though none of these have been confirmed in the dam itself (Webb 1995). Spangled perch were unofficially stocked into Paluma Dam, suggested by Webb (1996b) to be in the early 1980s but J. Tait (*pers. comm.*) recalls catching them there in 1977. They are now found in streams below the dam (R. Hunt *pers. comm.*). There are reports of their occurrence in Puzzle Creek (R. Mackay *pers. comm.*), another upstream tributary of Running River. Their exact distribution is unknown, because apart from the brief fish survey of Paluma Dam by Webb (1995) which found only spangled perch, there have never been any fish surveys of the upper Running River system. Fish stocked into Paluma Dam can also escape, via the water pipeline, into Crystal Creek, whose upstream reaches are also within the WTWHA.

Webb (1995) reported spangled perch in Paluma Dam to be in low numbers and of small body size, suggesting poor conditions for them. However, R. Hunt (*pers. comm.*) has found large spangled perch immediately below the dam spillway to be in good condition. Spangled perch are a major predator and can swim upstream or go over dam walls and establish in streams below dams. The habitat values of the tributary streams of Paluma Dam are unknown. The creek from the dam spillway drains into Birthday Creek, below Birthday Creek Falls. Birthday Creek is known habitat for two frog species (the waterfall frog, *Litoria nannotis* and the Australian lace-lid, *Nyctimystes dayi*) listed as 'Endangered' under the EPBC Act (1999). These frog populations have been monitored above Birthday Creek Falls since 1987 (R. Alford unpub data). The creek below the falls is likely to be viable habitat for the same frog species but has not been surveyed (R. Alford *pers. comm.*). The creeks above and below Paluma Dam should be surveyed for both fish and frogs.

The Twin Cities Fish Stocking Group, based in Townsville, have expressed interest in stocking Paluma Dam with recreationally desirable sport species (presumably barramundi and sooty grunter). Paluma Dam has few aquatic macrophytes, is anoxic at depth and only has a narrow productive margin to provide habitat (Webb 1995, ACTFR unpub. data). Webb (1995) suggested that the population of spangled perch was low and consisted of smaller individuals and the dam may not be productive enough to support a recreational fishery, although this is uncertain as others have reported catching larger healthier fish (J. Tait and R. Hunt *pers. comm.*) and some impoundments are surprisingly productive when stocked with large fishes. Given the lack of forage fish in Paluma Dam (Webb 1995), these would also need to be introduced to support a fishery. Red claw crayfish have recently been caught in Paluma Dam, the result of unauthorised translocations (R. Hunt *pers. comm.*). There are also reports of red claw crayfish being present in farm dams immediately west of Paluma township (R. Mackay *pers. comm.*). There are no current records of red claw crayfish in any of the local streams, though, except for Birthday Creek above Birthday Creek Falls, they have never been surveyed.

There have been several additional translocations into the Burdekin system that may be of relevance to the WTWHA. In the mid-1960s, a total of 12 golden perch from the upper reaches of the Thomson River catchment near Prairie, were liberated into a dam on a flood path of the upper Burdekin River at the Valley of Lagoons (A. Atkinson *pers. comm.*). Fingerlings of both golden perch and silver perch from NSW were also released into the Valley of Lagoons in the 1970s, as were murray cod fingerlings sometime later (A. Atkinson *pers. comm.*). Golden perch from the Murray-Darling catchment in NSW and the Lake Eyre catchments (including the Thomson River) are now considered to be separate species (Musyl and Keenan 1992), thus both species were stocked into the Valley of Lagoons. In addition, five golden perch caught in Burdekin Falls Dam in 2001 were all genetically identified as belonging to the Fitzroy River subspecies of golden perch (M. Pearce *pers. comm.*) *M. ambigua oriens* (Musyl and Keenan 1992). In 1976, 100 eel-tailed catfish and 100 golden perch from Narrendera Fisheries Research Station in New South Wales were released into the Valley of Lagoons in the upper Burdekin River (Midgley 1977). The upper Burdekin catchment already contains good populations of other catfish species, including the endemic soft-spined catfish, *Neosiluroides mollespiculum,* and two other species (*Neosilurus ater* and *N. hyrtlii*) of edible size. Following a large flood event associated with Cyclone Joy in January 1991, large numbers of golden perch, silver perch and murray cod escaped from an aquaculture facility upstream of Charters Towers Weir on the Burdekin River (Clayton 1994, Webb 1996b). During the 1980s and 1990s, the DPI encouraged the stocking of sleepy cod, silver perch and golden perch in farm dams, though many landholders also placed fingerlings directly into waterholes within streams. Fingerlings were readily available for this purpose and fish were stocked in a number of locations in the catchment, resulting in numerous escapes.

Silver perch and murray cod do not appear to have established in the Burdekin catchment. Eel-tailed catfish and golden perch have established (Burrows 2001, Pusey in press). The former is in low numbers but the latter has become increasingly abundant and more widely distributed throughout the catchment in recent years. Graziers from the upper Burdekin reported occasional catches of golden perch in the early-mid 1970s (A. Atkinson *pers. comm.*), though they were not collected in fisheries surveys there in 1976 (Midgley 1977), from 1989-1992 (Pusey *et. al.* 1998) or in tributary streams sampled in early 1999 (Burrows and Tait 1999). Since 1998 however, they have been collected in fisheries surveys near Charters Towers in 1998 (Hogan and Vallance 1998), the Belyando River in 1999 (Burrows *et. al.* 1999), Burdekin Falls Dam in 2001 (M. Pearce *pers. comm.*) and the Cape-Campaspe catchment in 2001 (Burrows 2001). They are also commonly reported in recreational catches from above and below Charters Towers weir (M. Pearce *pers. comm.*), above and below Burdekin Falls Dam (Hogan and Vallance 1998) and in local fishing media from below Burdekin Falls Dam (e.g. Townsville Bulletin 17 August 2000). Whether just one, or more than one, of the golden perch species have established is unknown. Neither golden perch nor the eel-tailed catfish have yet been recorded near the WTWHA, but this is a possibility, especially if they swim up the north-eastern tributaries or are translocated into upstream reaches of Running River.

3.2 HERBERT CATCHMENT

Parts of the Herbert River and several of its tributaries occur in the WTWHA (e.g. Herbert Gorge, the Kirrama Range and streams near Koombooloomba and near Ravenshoe). These regions are known for their significant fish and crustacean values and given the very limited exploration there, undoubtedly harbour many other unexplored environmental values. At least two frog species listed as 'Endangered' under the EPBC (1999) are known from streams of the Kirrama Range (Richards *et. al.* 1993). Tributary streams near Koombooloomba (e.g. Blunder Creek and Cameron Creek) have been little surveyed for frogs but there is a good chance that they too harbour, or formerly harboured, frog species listed under the EPBC (1999) and possibly Lake Eacham rainbowfish (also listed as 'Endangered' under the EPBC (1999)) as this species potentially occurs in the area (Pusey *et. al.* 1997). There has also been limited sampling of the aquatic faunas of the upper Herbert catchment, thus greatly limiting knowledge of this system.

Sooty grunter do not naturally occur above the Herbert River Falls but were hand-carried there from the Herbert River gorge below the falls by local graziers in the early 1930s (A. Atkinson *pers. comm.*). A total of 32 sooty grunter were liberated and within eight years, good catches were being noted (A. Atkinson *pers. comm.*). They are now well established throughout much of the upper Herbert catchment. Sooty grunter from the Walsh River were also apparently introduced to the upper reaches of the Herbert River about the same time after being carried there in barrels on horse drays (B. Herbert *pers. comm.*). In the early 1960s, local graziers translocated sooty grunter and possibly spangled perch, from Cameron Creek, a tributary of the upper Herbert where sooty grunter had become common, to Blencoe Creek above Blencoe Falls, as this creek had no suitable angling species apart from eels (A. Atkinson *pers. comm.*). Sleepy cod were also stocked into the upper Herbert many years ago. Local graziers stocked sleepy cod collected from the Copperfield River at Lyndhurst Station (part of the Gulf of Carpentaria catchments) into Kirrama Creek in the 1920s-1930s but these apparently did not establish (A. Atkinson *pers. comm.*). The Queensland Museum holds a specimen of sleepy cod collected from Blunder Creek in 1959 (Wager 1993). These hardy fish have been widely translocated and establish readily in new locations throughout Queensland. They are also adept at moving into upper reaches of streams, though not above waterfalls. These stockings impact on parts of the WTWHA and the Herbert River Falls National Park.

The upstream limit of the sooty grunter stocked in the Millstream, a major tributary of the Herbert River, would have been blocked by Millstream Falls. However, in 1981, DPI stocked sooty grunter above Millstream Falls so they could occur in the very upper reaches of this stream, some of which is within the WTWHA. Hogan (1995) considered that they had established a new population but recent reports suggest that they may not have persisted to the current time (A. Hogan *pers. comm.*). Wager (1993) lists Wild River, another major tributary of the upper Herbert River, as having been stocked with sooty grunter but provides no further details. The distribution of stocked fish in the upper Herbert catchment is unknown. Although of high environmental value, most of the upper Herbert catchment within the Wild River and Millstream sub-catchments is not within the WTWHA so may not rank as highly for further work from the perspective of the WTMA.

Spangled perch are also common throughout the upper Herbert catchment. They too may have been translocated into this system many years ago, although there is no specific information to confirm this. They were definitely not native to Blencoe Creek above Blencoe but were probably moved there with sooty grunter from Cameron Creek in the early 1960s (A. Atkinson *pers. comm.*). Webb (1996a) suggested that silver perch and golden perch had been stocked into the upper Herbert River but provided no further information. As occurred in other catchments, golden perch and silver perch were probably stocked into farm dams in the catchment. Silver perch are known to have escaped into the Herbert River system from ornamental ponds at the Ravenshoe racecourse (A. Hogan *pers. comm.*). Commercially purchased fingerlings of silver perch and golden perch (probably from NSW) were stocked into a dam at the Mt. Garnet racecourse in the early 1970s (A. Atkinson *pers. comm.*). Lack of survey effort in the upper Herbert catchment makes the status of these species uncertain. Golden perch have established throughout large lengths of the Burdekin River (see section 3.1) so might persist here too. Silver perch have not persisted anywhere in northern Queensland where they have been stocked or to which they have escaped, so it is unlikely that they remain present. A golden perch was caught in the lower Herbert River near Abergowrie about 1996/1997 (R. Hunt *pers. comm.*). The source of this fish is undetermined.

Most of the major waterfalls of the middle Herbert River (ie, Herbert gorge area) occur within the WTWHA or have their upstream reaches within the WTWHA, but these streams have never been surveyed for their fish fauna. The fish fauna above these waterfalls would be naturally depauperate of fish. Aquatic invertebrates have been intensively studied in Yuccabine Creek, a tributary of the Herbert River emanating from the Kirrama Range, which was found to have the highest diversity of aquatic invertebrates reported in Australia (Pearson *et. al.* 1986). Similarly high diversity is almost certainly typical of many Wet Tropic streams (R. Pearson *pers. comm.*). Sooty grunter have not been observed above the other waterfalls on Herkes Creek, Sword Creek, Yamanie Creek, Garrawalt Creek, or Stony Creek (Wallaman Falls) (F. Thuller *pers. comm.*) within the WTWHA, though no surveys have been undertaken. Stony Creek and Garrawalt Creek may provide suitable habitat for sooty grunter whereas the others have smaller catchment areas above their major waterfalls that are probably insufficient to support a sooty grunter population. Sooty grunter have been caught in Blencoe Creek above Blencoe Falls by R. Pearson (*pers. comm.*). Wager (1993) provides records of sooty grunter and spangled perch from Blencoe Creek above the falls from 1973 and also a 1973 record for spangled perch in Kirrama Creek, an upstream tributary of Blencoe Creek. Blencoe Creek has a significant length of its upstream reaches within the WTWHA. The source and timing of these translocations are unknown, but they are clearly >30 years old. Along with Blencoe Creek, the upper reaches of all major creeks of the Herbert Gorge, especially Stony Creek and Garrawalt Creek, should be surveyed for the presence of sooty grunter or other translocated species.

Other Herbert River tributaries such as Cameron Creek and Blunder Creek have their upper reaches within the WTWHA near Koombooloomba Dam (Figure 3). These streams share faunal elements with the streams of the upper Tully River and frog species of high conservation concern probably occur here. A single specimen from an unknown species of *Euastacus* (a large spiny crayfish) has been collected from Cameron Creek (J. Short *pers. comm.*). These creeks have not been adequately surveyed for their frog or fish fauna, and are likely to contain species of recognised conservation concern. Wager (1993) lists records of sooty grunter and sleepy cod from Blunder Creek but provides no further details. The Queensland Museum also holds a 1976 record for spangled perch from Glen Ruth station on Cameron Creek. Cameron Creek and Blunder Creek rank highly as candidates for further survey work.

3.3 ATTIE CREEK

Attie Creek is a tributary of Meunga Creek, a small coastal catchment, just north of Cardwell. The upstream reaches of Meunga Creek and several of its tributaries, are within the WTWHA. Sooty grunter were stocked into Attie Creek (Hogan 1995), probably in the 1980s. It is not known if this population still persists but the small coastal streams around Cardwell do not support sooty grunter naturally and may be too small for their long-term persistence.

3.4 TULLY CATCHMENT

The freshwater fauna of the upper Tully River is separated from that of the lower Tully River by the Tully Falls, a very large waterfall. The upper Tully River has been impounded since 1961 by Koombooloomba Dam, which is located 11 km upstream of Tully Falls and is used for hydroelectricity generation. The entire area surrounding the dam is part of the WTWHA (Figure 3). The streams of the upper Tully River and the adjacent streams of the upper Herbert River, are very important biogeographically, containing numerous freshwater species of significant conservation value. At least three frog species presumed extinct or listed as 'Endangered' under the EPBC (1999), are known from these streams (Richards *et. al.* 1993). Five new crustacean species from four genera were described from these streams in the

1990s (Short 1993, Short and Davie 1993, Choy and Marshall 1997, Short unpub. data), three of which are so far only known from a few streams in the Koombooloomba area. These are *Cherax parvus*, *Euastacus yigara* (Short and Davie 1993) and a soon-to-be described *Macrobrachium* species (J. Short *pers. comm.*). It is likely that these three species are endemic to the area (J. Short *pers. comm.*). *Euastacus yigara* is only known from two specimens collected in O'Leary Creek, though a third specimen from nearby Cameron Creek (upper Herbert tributary) may be the same species (J. Short *pers. comm.*). There is an additional *Cherax* species found in Nitchaga Creek, a tributary which enters the Tully River below the dam but above the falls. It is of uncertain identification though similar to *Cherax wasselli* (J. Short *pers. comm.*). Genetically distinct black and white colour morphs of *Caridina zebra* shrimps (Hughes *et. al.* 1996, J. Short *pers. comm.*) and genetically distinct strains of purple-spotted gudgeons (Hurwood and Hughes 1998) are known to occur here, as may Lake Eacham rainbowfish (Pusey *et. al.* 1997). A number of undescribed mayfly species have recently been discovered here (F. Chrisitidis *pers. comm.*). As the area is largely inaccessible and thus very poorly studied, many other significant aquatic species undoubtedly await discovery.

Apart from eels, the catchment area above Tully Falls lacks large fish predators because of the Tully Falls. The native fish fauna consists only of eels, purple-spotted gudgeons and rainbowfish (*Melanotaenia splendida splendida* and maybe *M. eachamensis*) (Russell 1987, Pusey and Kennard 1994, 1996, Pusey *et. al.* 1997, McGuigan *et. al.* 2000). This situation could be one of the factors that has enabled the development of a distinctive non-fish aquatic fauna. Attempts to stock a variety of species in Koombooloomba Dam are reputed to have occurred, including "mountain spotted trout" (it is presumed, but not confirmed, that this actually refers to rainbow trout - *Oncorhynchus mykiss*) in the 1960s (Pearce 2000), though these have not persisted. Local people carried sooty grunter from below Tully Falls to Koombooloomba Dam during the 1960s and 1970s (A. Hogan *pers. comm.*) and people recall catching them in the Tully River below the dam (but above the falls) during that time (B. Schneider *pers. comm.*). These fish did not appear to establish or were in low numbers as they were not recorded by Russell (1987) who surveyed Koombooloomba Dam in 1973. Russell (1987) suggested that because of its small catchment area and low productivity, Koombooloomba Dam would have a limited potential as an inland fishery, compared to other impoundments. Under the QDPI's Recreational Fishing Enhancement Program, Koombooloomba Dam was stocked with 3,000 barramundi in 1988-1989 then a further 76,566 from 1996-2001 (Pearce 2000, M. Pearce *pers. comm.*). Barramundi remain in relatively low abundance compared to densities of stocked fish in other impoundments in Queensland (Pearce 2000), though whether this is due to low productivity or lesser stocking effort, is unclear. The Ravenshoe Koombooloomba Fish Stocking Committee currently hold a 5-year permit (1999-2004) to stock 150,000 barramundi fingerlings per year (Pearce 2000).

A total of 8,238 sooty grunter from the Walkamin mixed stock (see section 4.7) were stocked into Koombooloomba Dam in 1985-1986, but none since (Pearce 2000). These have now formed a reproducing population. Sooty grunter only breed in flowing streams, so they must penetrate considerable distances up one or more of the tributary streams to spawn (ie, penetrate the WTWHA). It is not known if the barramundi move up any of the tributary streams. In the only fish survey of the tributary streams, Pusey and Kennard (1994) failed to find any sooty grunter or barramundi. However, they only sampled three sites on one occasion. Spangled perch are caught in Koombooloomba Dam (Hollaway and Hamlyn 2001, Pearce 2000), and have established a breeding population, though they do not appear to reach the large sizes typical of other impoundments such as Tinaroo (M. Pearce *pers. comm.*). However, given its upland location, it is highly unlikely that they occur there naturally and appear to be an unauthorised translocation. This species has been unofficially translocated to a number of other streams in northern Queensland. The date of the translocation to Koombooloomba Dam is unknown, but none were found in the dam by Russell (1987 – based on surveys in 1973-1974) or in tributary streams by Pusey and

Kennard (1994 – based on a 1993 survey). Provisional approval was granted to stock sleepy cod into the dam in 1996 and archerfish in 1999, but no permits were ultimately issued. Anecdotal reports from recreational fishers suggest that saratoga (probably northern saratoga), murray cod and archerfish have been caught in Koombooloomba Dam (A. Hogan *pers. comm.*). If true, these would be the result of unauthorised stockings and have either not persisted, or remain in very low numbers at present.

Red claw crayfish were officially recorded from Koombooloomba Dam for the first time in 2000 (Pearce 2000) though they appear to have been there for some years (Hogan 1995). These crayfish are the result of an unauthorised translocation/s and could have serious consequences for the existing *Cherax* and other crustacean species within the area, especially if they invade the upstream tributaries.

The Tully River below Koombooloomba Dam, but above Tully Falls, also holds many of the aquatic values of the dams' tributaries. Several significant creeks such as Nitchaga Creek join the river in this section (Figure 3). Fishes, including barramundi, sooty grunter and spangled perch, are washed over the dam wall during large flow events. Though the dam wall is 40m high, some fish may survive. Thus the streams below the dam may also contain these translocated fishes and should also be included in any future surveys or environmental evaluation.

Silver perch have been stocked into the lower reaches of the Tully River (Hogan 1995) and have escaped from aquaculture ponds during floods, along with Australian bass that escaped from farm dams (A. Hogan *pers. comm.*). However, neither species has been collected in any of the fish surveys conducted in the Tully River system to date.

Given the very high environmental values of the area, the extensive stream length within the WTWHA and the ongoing stocking program involving large numbers of fish, streams upstream and immediately downstream of Koombooloomba Dam should be surveyed as a matter of high priority. The stocking program in this dam requires a comprehensive environmental evaluation. It constitutes the most significant threat to the aquatic values of these otherwise pristine and near-pristine streams.

3.5 LIVERPOOL CREEK AND MARIA CREEK CATCHMENTS

These small coastal catchments have a large proportion of their area within National Park and/or the WTWHA, but as they are lowland streams without significant stream length above waterfalls, they less likely targets for fish translocations. Russell and Hales (1997) found a northern saratoga in Maria Creek during a survey in the mid-1990s. They attributed their presence to escape from a tourist park during a flood in 1990. Their breeding status is unknown but saratoga have a low reproductive rate and are unlikely to establish a large population. Hogan (1995) listed red claw crayfish as having been unsuccessfully stocked into Liverpool Creek but Russell and Hales (1997) found red claw in both creek systems during their surveys. Either the original stocking has persisted or there have been additional unofficial stockings and/or escapes from red claw crayfish aquaculture facilities which do (or did) occur in these catchments (Russell and Hales 1997).

3.6 JOHNSTONE CATCHMENT

This catchment consists of two main sub-catchments – the North Johnstone and the South Johnstone rivers – that join at Innisfail. Large parts of both catchments are on the Atherton Tablelands above a series of waterfalls. Sooty grunter did not historically occur above these waterfalls but have been stocked in various locations on the tablelands, enabling this fish to spread throughout the upper catchment and throughout the WTWHA and National Parks on the escarpment. It is not known how much of the upper catchment has been infiltrated thus far. The potentially impacted areas of the Johnstone River are habitat to populations of Lake Eacham rainbowfish (listed as 'Endangered' under the EPBC (1999)), the recently described rainbowfish, *M. utcheensis*, other strains of rainbowfish, a new, but as-yet-undescribed, species of hardyhead (Pusey *pers. comm.*) and at least five frog species presumed extinct or listed as "Endangered' under the EPBC (1999) (Richards *et. al.* 1993).

Over the last 50 years, sleepy cod, sooty grunter, khaki bream, silver perch and eel-tailed catfish have all been stocked above waterfalls on the upper North Johnstone River or its tributaries, with only silver perch not reported to be breeding successfully (Hogan 1995). Additionally, spangled perch and mouth almighty occur in the North Johnstone River between Glen Allyn and Malanda (B. Pusey *pers. comm.*), and represent unrecorded translocations. Most of these stockings were by private individuals (e.g. sooty grunter into the North Johnstone River above Malanda Falls in the 1950s – B. Schneider *pers. comm.*), though the DPI also stocked sooty grunter from the Russell-Mulgrave catchment into the North Johnstone system near Millaa Millaa, beginning in 1979, and Malanda, in the 1990s (Hogan 1995). Silver perch and sooty grunter have also been stocked above waterfalls in the upper South Johnstone River with the latter, but not the former, breeding successfully (Hogan 1995). Exotic brown trout (*Salmo trutta*) were also stocked in the upper South Johnstone River over 100 years ago but did not establish (Hogan 1995). The extent of the distributions of the stocked fish that have established in the upper sections of the North and South Johnstone rivers is not well known. The numerous waterfalls present on both systems are likely to have created truncated distributions on a number of streams. The fish can disperse downstream over waterfalls from their initial stocking locations but not upstream. Thus fish originally stocked higher in the catchment would be expected to have wider distributions than those stocked at more downstream locations.

There are many farm dams in the upper reaches of the North and South Johnstone Rivers that have been stocked with various fish plus red claw crayfish. Escapes to the river systems do occur. For example, rainbow trout escaped into the Beatrice River from an aquaculture venture a number of years ago, but have not persisted (A. Hogan *pers. comm.*). Australian bass have escaped from farm dams into the upper reaches of this catchment (A. Hogan *pers. comm.*). In the lower North Johnstone River, a professional fishing guide caught an Australian bass in 2000. This fish occurs in coastal rivers in northern New South Wales and south-eastern Queensland. The status of this species in the Johnstone catchment remain unknown, but they are not likely to have established a self-sustaining population. As they breed in estuaries, they could not sustain a population in the upper catchment.

The middle reaches of both the North and South Johnstone rivers are within the WTWHA. Because the upper reaches of both rivers have been farmed and developed, fish stocked into those reaches may disperse to the lower reaches on the escarpment within the WTWHA. Thus the streams on the escarpment, many of them also within National Parks, should be a high priority for further survey effort.

3.7 BARRON CATCHMENT

As most of the Barron catchment is above the Barron Falls, the natural fish fauna is depauperate, with only six species certain to be native to that area and up to seven others that may be native (Table 1). Translocations have been occurring within the Barron catchment for so long that the natural fish fauna of the upper reaches is not known with confidence. For instance, there are some suggestions (DNR 1999) that banded grunter and spangled perch may not be native to the upper Barron, despite having been reported by Shipway (1948a, 1948b) over 50 years ago. Some translocations had already occurred before this time. Spangled perch do not normally occur above waterfalls but may have entered the Barron system via overland routes from the Mitchell River, which is very close to the Barron River near Mareeba, and may coalesce with it during very large flood events. Spangled perch are known for their ability to move along shallow flow paths. Banded grunter are not known for these abilities, but in any case, they have been translocated to Lake Eacham (see section 3.7.2), making them a translocation within the catchment. Spangled perch also appear to have been translocated to Lake Barrine (see section 3.7.2), thus qualifying them as a translocation as well. Various catfish species may also have moved across this flood path between the Mitchell and Barron rivers but several catfish species are also known to have been translocated into the catchment, thus confusing their status.

Within the upland section of the Barron River, Tinaroo Falls (now the site of Tinaroo Dam – Figure 4) may have acted as a further fish passage barrier. Thus the Barron River may have naturally consisted of three distinct fish faunas (below Barron Falls, between Barron Falls and Tinaroo Falls, and above Tinaroo Falls). The translocations listed in Table 1 may have occurred to one or both of the upland reaches. The low-lying divide between the Mitchell and Barron rivers occurs within the reach between the Barron Falls and Tinaroo Falls. Thus fish such as spangled perch, banded grunter and various catfish may be native to the Barron River between Barron Falls and Tinaroo Falls, after crossing over the headwaters of the Mitchell River, but not necessarily to reaches where they currently occur above Tinaroo Falls. The 1948 records of Shipway (1948a, 1948b) were from just above Barron Falls. Spangled perch are found throughout many streams in the upper Barron catchment and their status (native or translocated) is important as this species has similar ecology and habits to sooty grunter, which has been translocated into the catchment in large numbers. Many of the potential ecological interactions that may be caused by translocated sooty grunter may already be occurring with spangled perch. Werren (1997), Cogle *et. al.* (1998) and DNR (1999) all provided lists of the fish fauna considered native and translocated to the Barron catchment. There is disagreement between these lists on the status of several species. Table 1 attempts to account for these uncertainties, plus allowing for the fact that some species do occur naturally in some parts of the catchment above Barron Falls, but have also been translocated to other sections of the upper catchment (e.g. eastern rainbowfish into Lake Eacham). The number of native Australian fish species translocated into, or within, the Barron catchment above Barron Falls, is here estimated to be 26-34 (plus red claw crayfish), though not all have established (Table 1). This makes the fish fauna of the upper Barron River one of the most modified in Australia, if not the most modified. Many of the stocked fish have come from the Mitchell River, thus giving fish from the Gulf catchments access to other east coast streams.

Notable stocking attempts in the catchment include rainbow trout (a North American species) brown trout (a European species) (Hogan 1995) and nearly 137,910 silver perch (a species from the Murray-Darling catchment). The DPI-QFISH database indicates that since the introduction of the RFEP, over 1.3 million fish have been stocked into Tinaroo Dam - the highest in northern Queensland and the fifth highest in the state after Somerset, Wivenhoe (both on the Brisbane River), Bjelke Peterson (Burnett catchment) and Leslie (Condamine River) dams. Over 90% of the fish stocked in Tinaroo Dam to date are sooty grunter or barramundi. The QFISH database records that as of 30 June 2001, 594,230 sooty grunter and 573,414 barramundi had been released there, with the former beginning in 1982 and the latter in 1985. More barramundi are currently being stocked than sooty grunter. Sooty grunter had also been introduced to the upper Barron catchment in the 1930s from the Walsh River after being carried over in barrels by horse drays (B. Herbert *pers. comm.*). Despite this being one of the largest and best known artificial fisheries in Australia, and its location adjacent to the WTWHA, no environmental assessment of the translocation and stocking program has been undertaken.

3.7.1 Tinaroo Dam

Barramundi were first stocked in Tinaroo Dam in December 1985 using fingerlings obtained from broodstock collected at Weipa (MacKinnon and Cooper 1987). Since then most of the barramundi have come from the appropriate mid-east coast genetic stock but some have also come from the Burrum River (DNR 1999). Though some barramundi apparently survive the drop over the Tinaroo Dam wall, it is highly doubtful they would survive going over the Barron Falls, which would be required for them to breed in the estuarine waters. Russell *et. al.* (2000) surveyed several tributaries of Tinaroo Dam but found no barramundi. Most tributaries may be too small for significant movements, and the main tributary, the Barron River, has a small waterfall at Picnic Crossing, 2km upstream from the impoundment which apparently blocks their upstream movement (Russell *et. al.* 2000). Barramundi have been stocked above this waterfall in the past, but A. Hogan (*pers. comm.*) suggests they moved down to the impoundment soon after.

Table 1: Translocated and Locally Native Fish Fauna of the Barron River Above Barron Falls.

Common Name	Species Name	Source of Stock	Establishment[1]	References
Locally native and not known to be translocated anywhere in the catchment				
Chequered Rainbowfish	*Melanotaenia inornata*			Werren 1997
Long-finned Eel	*Anguilla reinhardtii*			Werren 1997, DNR 1999
Pacific Eel	*Anguilla obscura*			DNR 1999
Purple-spotted Gudgeon	*Mogurnda adspersa*			Werren 1997, DNR 1999
Present in parts of the upper catchment but native or translocated status uncertain				
Utchee Rainbowfish	*Melanataenia utcheensis*	Johnstone?	Est.	DNR 1999
Empire Gudgeon	*Hypseleotris compressa*	?	Est.	Reported from upper Barron (Shipway 1948c), DNR 1999
Flathead Goby	*Glossogobius giurus*	Mitchell?	Est.	Werren 1997, DNR 1999, Russell *et. al.* 2000
Cf. Fly-specked Hardyhead	*C. aff s. stercusmuscarum sp. nov.*	North Johnstone?	Est.	McGlashin and Hughes 29000, DNR 1999
Native to parts of the Upper Barron Catchment but translocated to other parts				
Eastern Rainbowfish[3]	*Melanotaenia splendida splendida*			Werren 1997, DNR 1999
Lake Eacham Rainbowfish[3]	*Melanotaenia eachamensis*			Werren 1997, DNR 1999
May be native to parts of the Upper Barron Catchment but translocated to other parts				
Spangled Perch[3]	*Leiopotherapon unicolor*	Mitchell?	Est.	Reported in upper Barron (Shipway 1948b), Werren 1997, DNR 1999, Wager 1993
Banded Grunter[3]	*Amniataba percoides*	Mitchell?	Est.	Shipway 1948a, Hogan 1995, Werren 1997, DNR 1999, Russell *et. al.* 2000
Hyrtl's Tandan	*Neosilurus hyrtlii*	Mitchell?	Est.	Wager 1993, Recorded above Barron Falls by Shipway 1947; DNR 1999

Common Name	Species Name	Source of Stock	Establishment[1]	References
Probably translocated into the Upper Barron Catchment				
Macleay's Glassfish	*Ambassis macleayii*	?	Est.	Werren 1997, DNR 1999, Russell *et. al.* 2000
Fly-specked Hardyhead	*Craterocephalus stercusmuscarum stercusmuscarum*	?	Est.	Werren 1997, DNR 1999
Rendahl's Tandan	*Porochilus rendahli*	?[6]	Est.	DNR 1999, Russell *et. al.* 2000
Wet Tropics Tandan	*Tandanus sp. nov.*	Wet Tropics	Est.	DNR 1999
Translocated into the Upper Barron Catchment				
Muller's Glassfish	*Ambassis mulleri*	?	NE	DNR 1999
Fire-tailed Gudgeon	*Hypseleotris galii*	?	Est.	Wager 1993, Werren 1997, DNR 1999
Gertrud's Blue-eye	*Pseudomugil gertrudae*	?	Est.	Werren 1997, DNR 1999, Russell *et. al.* 2000
Black Catfish	*Neosilurus ater*	Tully?	Est.	DNR 1999
Eel-tailed Catfish	*Tandanus tandanus*	NSW, via Enoggera Dam	Est.	Hogan 1995, Werren 1997, DNR 1999
Shovel-nosed Catfish	*Arius midgeleyi*	Mitchell	NE	Hogan 1995, DNR 1999
Barramundi	*Lates calcarifer*	Cairns, Weipa, Burrum River	NE[2]	Mackinnon and Cooper 1987, Hogan 1995, DNR 1999
Northern Saratoga[8]	*Scleropages jardinii*	?	Prob. not	Hogan 1995, QFMA 1996
Southern Saratoga[8]	*Scleropages leichhardtii*	?	NE	QFMA 1996, Webb *et. al.* 1996
Mangrove Jack	*Lutjanus argentimaculatus*	Mulgrave	NE	DNR 1999, Hogan *pers. comm.*
Pikey Bream	*Acanthopagrus berda*	?	NE	Hollaway and Hamlyn 2001
Jungle Perch	*Kuhlia ruprestris*	?	NE	Hogan 1995, DNR 1999
Sooty Grunter	*Hephaestus fuliginosus*	Various catchments	Est.[2]	Hogan 1995, Werren 1997, Cogle *et. al.* 1998, DNR 1999
Khaki Bream	*Hephaestus tulliensis*	Tully	Est.	Hogan 1995, Werren 1997, Cogle *et. al.* 1998, DNR 1999, Allen and Pusey 1999

Common Name	Species Name	Source of Stock	Establishment[1]	References
Sleepy Cod	*Oxyeleotris lineolatus*	Mitchell	Est.	Hogan 1995, Werren 1997, DNR 1999, Russell *et. al.* 2000
Striped sleepy cod	*Oxyeleotris selheimi*	Mitchell?	Est.	DNR 1999, Russell *et. al.* 2000
Bony Bream	*Nematalosa erebi*	Mitchell[5]	Est.	Werren 1997, DNR 1999, Russell *et. al.* 2000
Silver Perch	*Bidyanus bidyanus*	Murray-Darling	NE[4]	Hogan 1995, Werren 1997, DNR 1999, QFMA 1996, Webb *et. al.* 1996
Golden Perch	*Macquaria ambigua*	Murray-Darling, Fitzroy?	NE	DNR 1999, QFMA 1996, Webb *et. al.* 1996
Australian Bass	*Macquaria novemaculeata*	? farm dams	NE	A. Hogan *pers. comm.*
Mouth Almighty	*Glossamia aprion*	Mitchell[5]	Est.	Wager 1993, Werren 1997, DNR 1999
Archerfish	*Toxotes chatareus*	Mitchell[7]	Est.	Wager 1993, Werren 1997, DNR 1999, Russell *et. al.* 2000
Freshwater Sole	*Brachiurus selheimi*	Mitchell?	NE	DNR 1999
Snub-nosed Garfish	*Arrhamphus sclerolepis*	?	Est.	DNR 1999
Long Tom	*Strongylura kreftii*	?	NE	DNR 1999
Other				
Red Claw Crayfish	*Cherax quadricarinatus*	Gulf catchments	Est.	Hogan 1995, Russell *et. al.* 2000
Exotic Species[9]				
Guppy	*Poecilia reticulata*	?	Est.	Webb *et. al.* 1996, Werren 1997, DNR 1999, Russell *et. al.* 2000
Rainbow trout	*Salmo gairdnerii*	North America	NE	Hogan 1995
Brown Trout	*Salmo trutta*	Europe	NE	Hogan 1995, DNR 1999
Black Tilapia	*Tilapia mariae*	Africa	Est.	Webb *et. al.* 1996, Werren 1997, DNR 1999
Mozambique mouthbrooder (Tilapia)	*Oreochromis mossambicus*	Africa	Est.	Webb *et. al.* 1996, Werren 1997, DNR 1999, Russell *et. al.* 2000

[1] NE = not established, Est. = established a breeding population.

[2] Are restocked under permit.

[3] Eastern rainbowfish, spangled perch and banded grunter all translocated to Lake Eacham. Unusual and truncated distribution of Lake Eacham rainbowfish (e.g. in Tinaroo irrigation channel) suggests that translocation has occurred.

[4] Individuals may be present but do not appear to have established.

[5] Present since at least 1974 (Wager 1993) but probably much longer.

[6] Present since at least 1988 (Wager 1993) but probably much longer.

[7] Translocated from Mitchell catchment in early 1900's (M. McKinnon *pers. comm.*) in Wager (1993). Also collected in Barron catchment in 1977 and 1980 (Wager 1993) and in Lake Eacham in 1987 (Barlow *et. al.* (1987).

[8] QFMA (1996) also includes southern saratoga as having been translocated to the Barron but this may be confused with northern saratoga.

[9] In addition, exotic swordtails, *Xiphophorus helleri*, have established in reaches of the Barron catchment below Barron Falls (Werren 1997, Russell *et. al.* 2000) and there are unconfirmed reports of their presence above the falls.

Juvenile sooty grunter have been observed in the Barron River above Tinaroo Dam (B. Pusey *pers. comm.*) but are not recorded to have established a breeding population or to make extensive movements upstream in any other tributary of Tinaroo Dam (A. Hogan *pers. comm.*). The related khaki bream have established a breeding population in the Barron River above Tinaroo Dam since their translocation there from the Tully River by the Tableland Anglers and Acclimatisation Society in the 1950s (Hogan 1995).

Numerous other fish species have been stocked into Tinaroo Dam or its tributaries (Table 1). Webb *et. al.* (1996) surveyed several tributary streams of the Barron River above Tinaroo Dam searching for tilapia, but also found a variety of translocated fishes such as mouth almighty, bony bream, sleepy cod, eel-tailed catfish and spangled perch (this last one possibly native – Table 1). Russell *et. al.* (2000) reported bony bream, rendahl's catfish and sleepy cod as occurring in tributaries of Tinaroo Dam. The WTWHA is close to, or directly abutts, Tinaroo Dam, in a number of places. The streams in these areas are of high environmental value. For instance, several tributaries, such as Wright Creek (within Lake Eacham National Park) and those of Danbulla State Forest (also within the WTWHA) are, or were, habitats for six frog species presumed extinct, or listed as 'Endangered', under the EPBC Act (1999) (Richards *et. al.* 1993). Despite the work of Webb *et. al.* (1996) and Russell *et. al.* (2000), most tributary streams of Tinaroo Dam have not been surveyed. The occurrence, and in particular, the upstream limit, of any translocated fish species within these streams should be documented in detail. Some of these streams may have been surveyed in the late 1990s as part of searches for tilapia (A. Hogan *pers. comm.*) but any records for fish species collected at individual sites during those surveys were not able to be located by this author.

In 2000, the then QFMA (now QFS) issued a permit to stock 300,000 mangrove jack into Tinaroo Dam. Due to difficulties with hatchery spawning, only 4,478 were stocked from Feb.2000 - Nov.2001 (M. Pearce unpub. data). Six mangrove jack have been confirmed as being caught thus far, with one growing to 37cm in 2.1 years (M. Pearce unpub. data, DPI press release 2002). The silver perch and golden perch (both species from the Murray-Darling catchment) stocked into the dam did not establish and are no longer present or stocked. However, silver perch and golden perch, and also southern saratoga, were recorded as present in farms dams in the upper Barron catchment as recently as 1996 (Webb *et. al.* 1996), and at least golden perch are apparently still found in farm dams on the Atherton Tablelands from which they may escape into various systems, including the Barron and the North Johnstone.

The eel-tailed catfish, *Tandanus tandanus,* was stocked into the Barron catchment with specimens from NSW and these may now established a breeding population (Hogan 1995), including in tributaries of the upper Barron above Tinaroo Dam (Webb *et. al.* 1996). Musyl and Keenan (1996) found significant genetic differences between populations of *T. tandanus* in northern NSW and south-eastern Queensland that were closely-located but separated by mountain ranges. This resulted in the recognition of two new species, even though the morphological differences were minor. The eel-tailed catfishes found naturally within the Wet Tropics are usually attributed to *T. tandanus* but they have such substantial genetic differences from this species that they should be considered as a separate species (C. Keenan unpub. data). The *Tandanus* sp. occurring in the Wet Tropics may be endemic to the region and if they can interbreed with the translocated NSW species, then this will cause considerable genetic mixing and contamination of the Wet Tropics genetic stock. Alternatively, their substantial genetic differences may prevent interbreeding. In any case, with a similar ecology to the native Wet Tropics *Tandanus* sp., the introduced fish would be significant competitors. The genetic and specific status of the Wet Tropics eel-tailed catfish, and their distribution in relation to the translocated species (if still present), should be determined.

Red claw crayfish were stocked into Tinaroo Dam in the early 1980s and have continued to be stocked under the DPI-RFEP to form an important recreational fishery. In a catchment-wide survey, Russell *et. al.* (2000) found red claw to be present at 26 (49%) of the sites they sampled in various parts of the catchment. They were only present in larger streams and apparently not abundant.

3.7.2 Crater Lakes

Three volcanic lakes (Eacham, Barrine and Euramoo) occur within close proximity of each other on the Atherton Tablelands (Figure 4). Lake Euramoo and Lake Eacham have closed catchments, but Lake Barrine has flood-flow connections to Toohey Creek, an upper tributary of the Mulgrave River. Although technically within the Mulgrave catchment, Lake Barrine is discussed here with Lakes Eacham and Euramoo. The loss of the Lake Eacham rainbowfish from its type locality (Lake Eacham) provides an example of the potential impacts of translocated fishes on native fauna (see section 2.2). During a fish survey in 1973-4, Russell (1987) found the Lake Eacham fish fauna to consist of only Lake Eacham rainbowfish, hardyheads and northern trout gudgeons (these are actually purple-spotted gudgeons). Lake Eacham rainbowfish were abundant within the lake at that time, but during the 1980s, four native fish species (mouth almighty, banded grunter, archerfish and bony bream) were translocated into the lake and it was noticed that the rainbowfish were no longer present. In 1987, Barlow *et. al.* (1987) surveyed the lake and failed to locate any rainbowfish, though the four introduced species were plentiful. Apart from the complete absence of the Lake Eacham rainbowfish, Barlow *et. al.* (1987) also failed to locate any gudgeons or any specimens of the crayfish, *Cherax cairnsensis*, which had been very abundant in the lake in the early 1980s. Thus, two of the three fishes (a potentially a crayfish as well) naturally occurring in the lake disappeared within 10 years during the same period that four translocated native fishes established breeding populations there. In addition, White (1991) also observed a barramundi in the lake in 1990 and DPI staff collected a large barramundi there in 1991 (G. Werren *pers. comm.*). Sooty grunter have also been stocked there (Webb 1996b) and are still present (T. Vallance *pers. comm.*) though they would be unable to breed there due to the absence of flowing water. Ironically, eastern rainbowfish, which are more resistant to predation than Lake Eacham rainbowfish, have been translocated into the lake and are now present in large numbers, and another species, believed to be an exotic, has also been observed, though not yet collected (T. Vallance *pers. comm.*). All these eight fish species stocked into the lake have been put there unofficially, presumably by thoughtless individuals. Interestingly, Zhu *et. al.* (1998) confirm the presence of Lake Eacham rainbowfish in irrigation channels of Tinaroo Dam, which would itself probably represent a translocation of these species to new waters within the upper Barron catchment. The unusual distribution of Lake Eacham rainbowfish alleles demonstrated by Zhu *et. al.* (1998) may also suggest that this fish has been translocated to other locations, and raises the possibility that even the crater lakes themselves may not be their original habitat.

Barlow *et. al.* (1987) attributed the loss of the Lake Eacham rainbowfish to predation by mouth almighty and the predation experiments of White (1991) supported this. It was at one point suggested that barramundi be stocked into the lake to rid it of the introduced fish and then after the barramundi died out (they only breed in estuaries), to restock with captive-bred populations of Lake Eacham rainbowfish. Further investigations suggested this was unlikely to be successful (Hogan 1995) and since that time, further wild populations of the Lake Eacham rainbowfish have been located elsewhere (see section 2.2). In November 1989, 3,000 Lake Eacham rainbowfish bred from captive stocks were released into the lake but none could be located in surveys just three months later and throughout 1990 (White 1991). As this reintroduction attempt was unsuccessful, and with the discovery of new populations of Lake Eacham rainbowfish elsewhere and the establishment of eastern rainbowfish in Lake

Eacham, there have been no further attempts to restore the Lake Eacham rainbowfish to its type locality.

Lake Eacham also hosts a large population of red claw crayfish that have been present since the mid-1990s at least, and appear to have modified the aquatic macrophytes communities there (K. McDonald *pers. comm.*). The status of the native *Cherax cairnsensis* that was abundant in the lake in the early 1980s but not found by Barlow *et. al.* (1987), is unknown. Although a high profile National Park and part of the WTWHA, the unique aquatic community of Lake Eacham has been highly and tragically modified. It stands as testament to the need to educate the public about inappropriate translocations and for environmental management agencies to place greater emphasis on aquatic management.

Lake Eacham may be an atypical case in that it is a closed environment with little in the way of protective cover to provide refuge from predators, but it serves to demonstrate the potential impacts of translocated fishes. It is disturbing to note that in a 1973 survey, Russell (1987) found mouth almighty, the fish most implicated in the demise of the Lake Eacham rainbowfish, to be present in nearby Lake Barrine. These almost certainly represent a translocation. Operators of tourist boat cruises on Lake Barrine first noticed mouth almighty there in the early 1970s (J. Curry *pers. comm.*). Russell (1987) also found Lake Barrine to contain rainbowfish of uncertain identity, although these were listed as eastern rainbowfish at the time. The presence of rainbowfish there is confirmed by a former tour boat operator on Lake Barrine (J. Curry *pers. comm.*). In a brief (1-day) but intensive day and night survey of Lake Barrine, White (1991) found numerous mouth almighty but no rainbowfish. Rainbowfish from Lake Euramoo were analysed as part of the genetic studies of Lake Eacham Rainbowfish in the Atherton Tablelands during the 1990s (Zhu *et. al.* 1998, McGuigan *et. al.* 2000), but no specimens from Lake Barrine were included in the study as the researchers could not locate any there (K. McGuigan *pers. comm.*). The effort expended in Lake Barrine consisted of three traps baited with dried cat food, left for one hour, near the main car park (K. McGuigan *pers. comm.*). Phone calls to the current and formers tour boat drivers on Lake Barrine yielded equivocal answers as to the current status of rainbowfish in Lake Barrine. As Lake Barrine has a connection to the upper Mulgrave River via Toohey Creek, the rainbowfish in Lake Barrine (if still present) may be/have been the common eastern rainbowfish or if the waterfalls in the upper Mulgrave and Toohey Creek prevented colonisation by eastern rainbowfish, they may be/have been Lake Eacham rainbowfish. Eastern rainbowfish are able to coexist with fish predators, including mouth almighty, in numerous other locations. White (1991) demonstrated experimentally that eastern rainbowfish are better able to avoid predation than Lake Eacham rainbowfish, hence their ability to thrive among the current fish fauna of Lake Eacham. The current status of rainbowfish in Lake Barrine is unclear but if rainbowfish are no longer present there, this would tend to favour the idea that they were Lake Eacham rainbowfish. The inability of two surveys to locate rainbowfish in Lake Barrine just a few years after they disappeared in the adjacent Lake Eacham, should have been investigated by authorities at the time. This is especially pertinent as both surveys that failed to locate rainbowfish in Lake Barrine were part of projects devoted to studying the recovery of Lake Eacham rainbowfish, a very high profile topic at that time. The absence of rainbowfish, but the abundance of mouth almighty in Lake Barrine, should have sounded warnings to both researchers and environmental management agencies, that a comprehensive survey of Lake Barrine was required. Ten years later, such a survey is now called for.

Bony bream have also been translocated into Lake Barrine and appear to be breeding (Werren 1997, T. Vallance *pers. comm.*) and may have been there 10-15 years (B. Bayn pers. comm). A barramundi was recently sighted there by tourist boat operators (B. Bayn *pers. comm.*). Eels are also known in Lake Barrine (B. Pusey *pers. comm.*) but these are a natural occurrence. Trout (exact species uncertain) were released into Lake Barrine in the 1920s and 1930s (J. Curry *pers. comm.*). An undetermined fish species was also released there in the 1930s and was apparently quite common until the early 1970s (J. Curry *pers. comm.*). This fish was locally referred as jungle perch but as it is also reported to breed in the lake (J. Curry *pers. comm.*), it could not have been jungle perch, as this species breeds in estuaries. It may have been spangled perch which have also been sighted in the lake by A. Hogan (*pers. comm.*) in 1980 or 1981, and would represent a translocation to the lake. Spangled perch should be able to establish a breeding population in Lake Barrine. A survey of Lake Barrine 2-3 years ago by QPWS staff using traps did not locate any red claw crayfish (T. Vallance *pers. comm.*), though the status of native *Cherax* reputed to occur there (J. Curry *pers. comm.*) is unclear. Interestingly, both Lake Eacham and Lake Barrine have freshwater crocodiles present (T. Vallance and B. Bayn *pers. comm.* respectively), both of which also represent translocations.

Another crater lake in the area, Lake Euramoo, is known to contain a pure strain of *M. eachamensis* (Zhu *et. al.* 1998). Russell (1987) reported only rainbowfish (species not specified) and northern trout gudgeons (these would actually be purple-spotted gudgeons) from Lake Euramoo. Lake Eacham rainbowfish and purple-spotted gudgeons, but no other fish, were located there by K. McGuigan (*pers. comm.*) in the 1990s as part of her genetic studies on rainbowfish. It is important that the Lake Euramoo population of *M. eachamensis* be protected from translocated fish. All three crater lakes should be surveyed as a matter of priority.

Both Lake Eacham and Lake Barrine National Parks also contain creeks that flow into Tinaroo Dam but are not associated with the lakes themselves. Both of these National Parks are very close to the impoundment area of Tinaroo Dam into which creeks (Wright Creek and Congoo Creek respectively) from these National Parks flow. It is possible that translocated fishes occur within these creeks. Three frog species listed as 'Endangered' under the EPBC Act (1999) have been recorded from Wright Creek (Richards *et. al.* 1993), although these authors failed to find any of them there during their surveys in 1992.

3.7.3 Barron River Between Barron Falls and Tinaroo Dam

Sleepy cod have been stocked into the Barron River between Kuranda Weir and Tinaroo Dam as have sooty grunter (n=5,500 – QFISH database) and both have established breeding populations there (Hogan 1995). Russell *et. al.* (2000) found sooty grunter to be present in several tributaries of this section of the Barron River, including Flaggy Creek and the Clohesy River. They also collected sleepy cod and striped sleepy cod in Flaggy Creek. Barramundi are sometimes caught in this section of river by recreational fishers though none have been collected in any fisheries surveys (e.g. Russell *et. al.* 2000). There are no official records of barramundi having been stocked in this section of the river though this may have occurred in Kuranda Weir (A. Hogan *pers. comm.*) or the caught barramundi may represent survivors of those washed over the Tinaroo dam wall. Numerous fish go over the dam wall when the river is in flood, and though most would be expected to perish, some clearly survive. A barrier net is now used to restrict loss of fishes over the dam wall. Many of the other translocated species listed in Table 1 occur in this section of the catchment (also see Russell *et. al.* 2000 for some records). This section of river also includes high value tributaries such as the Clohesy River, Davies Creek and Brindle Creek. The upper reaches of these creeks are known habitat for four frog species either presumed extinct or listed as 'Endangered' under the EPBC (1999) (e.g. *L. nannotis*, *L. rheocola*, *N. dayi*, and *T. acutirostris*) as well as significant crustacean species and a phenotypically distinct rainbowfish and hardyhead (Pusey *et. al.* 1999, C. Hoskins *pers. comm.*, G. Werren *pers. comm.*). The extent to which translocated fishes swim up these waterways is unknown.

3.8 FRESHWATER CREEK CATCHMENT

Copperlode Dam (also known as Lake Morris) in the upstream areas of Freshwater Creek, is entirely surrounded by WTWHA and fed by streams of high conservation value (Figure 4). These streams contain four frog species either presumed extinct or listed as 'Endangered' under the EPBC Act (1999) (*L. nannotis*, *L. rheocola*, *N. dayi*, and *T. acutirostris*). Being above a series of waterfalls on Freshwater Creek, the fish fauna of the Copperlode area is probably limited to rainbowfish, purple-spotted gudgeons and eels. However, Copperlode Dam has been stocked with bony bream, barramundi, sooty grunter, archerfish, sleepy cod, eel-tailed catfish and now mangrove jack. Webb (1996b) also listed jungle perch and northern saratoga as having been stocked into this impoundment, though Alf Hogan (*pers. comm.*), who monitors fish in this dam for DPI, denies this. As no fishing is allowed there, the dam is essentially used by DPI as a trial fish stocking pond. The sooty grunter were apparently first stocked there by a fisheries biologist in the late 1970s (A. Hogan *pers. comm.*). Archerfish, sleepy cod, bony bream and catfish were stocked by DPI staff in the early 1980s, and then more sooty grunter in the early 1990s and barramundi in 1997 (Anon 1982, A. Hogan *pers. comm.*). A total of 3,980 mangrove jack were stocked there in December 1998 and June 1999 by DPI staff as part of a trial to test their suitability for other freshwater impoundments (A. Hogan *pers. comm.*). During Cyclone Rona, large numbers of dead barramundi were found floating in Freshwater Creek below the dam, potentially posing an environmental and health risk. All of the above-mentioned species have established breeding populations with the exception of barramundi, mangrove jack and sooty grunter. Barramundi and mangrove jack cannot breed in freshwater and although sooty grunter can breed in freshwater they apparently do not spawn in the streams above this dam (Hogan 1995). Because of the small size and higher gradients of the tributary streams of this dam, the distance to which stocked fish penetrate them may be limited but this needs to be demonstrated. To date, no red claw crayfish have been found in Copperlode Dam (A. Hogan *pers. comm.*). This is probably because the dam is isolated in its own sub-catchment and because no recreational activities (including fishing) are allowed there.

3.9 MITCHELL CATCHMENT

Exotic rainbow trout have been stocked above the falls on Picaninny Creek on the Palmer River but are no longer present (Hogan 1995). Sooty grunter occur naturally throughout this catchment, but their populations have been augmented by stocking into the Walsh River at Dimbulah and the Mitchell River at Julatten (Hogan 1995). Sleepy cod have also been stocked into the upper Walsh River to augment the natural population there. The Walsh River was the original source for sleepy cod stocked into the Barron River in 1949 (A. Hogan *pers. comm.*). Fish used for the sleepy cod breeding program at the DPI Walkamin research station came from Tinaroo Dam (ie, Walsh River stock) (A. Hogan *pers. comm.*) and were used in many stockings throughout northern Queensland. Only a small section of the Mitchell River above Julatten is within the WTWHA so these stockings are not considered to be a major issue for the WTMA.

3.10 BLOOMFIELD CATCHMENT

The recently described Bloomfield cod, *Guyu wujalwujalensis*, occurs only in a section of the Bloomfield River above the Bloomfield Falls and below Roaring Meg Falls (Pusey and Kennard 2001). It is thus a highly vulnerable species. Bloomfield cod have no close relatives in the region and probably represent a relict population from previous ages. Two frog species (*L. nannotis* and *L. lorica*) listed as "Endangered' under state and federal legislation also occur in the upper Bloomfield Catchment (Cunningham 2002). There is a recent (2001) anecdotal report of sooty grunter (also commonly known as black bream) being present in the same stream reach as Bloomfield cod. Government agencies, including

DPI, WTMA and EPA were alerted to this report and the DPI responded by organising fish surveys of the middle reaches of the Bloomfield River in January 2002. This only involved a few hours of backpack electrofishing and failed to find any sooty grunter, though Bloomfield cod were common. Sooty grunter have the same diet as Bloomfield cod when young but as they are very aggressive and grow much larger than Bloomfield cod, sooty grunter may move from being a competitor to being a predator of the cod as they grow larger (Pusey and Kennard 2001, Pusey *pers. comm.*). The very restricted distribution of the relict Bloomfield cod population may be at least partly due to the more recent arrival into the Wet Tropics of sooty grunter, which are believed to have migrated north from the Burdekin area via coastal streams – Pusey in press). Above the Bloomfield Falls provided a sooty grunter-free environment. Reassociation of these two species, or even khaki bream, a close relative of sooty grunter, could be disastrous, even posing a potential extinction threat (Pusey and Kennard 2001). If sooty grunter or khaki bream are found, the population is likely to be low and should be eradicated as a matter of priority. Further survey effort urgently needs to be conducted on this matter to confirm that sooty grunter do not occur here. A community education project highlighting the importance of protecting the Bloomfield cod and warning against translocating new fish species, should be organised. If fish such as sooty grunter are found in this reach, then a captive Bloomfield cod breeding program may also be required as a precaution. Although very restricted in their distribution, Bloomfield cod are actually quite common in the few stream reaches where they do occur (Pusey and Kennard 2001).

3.11 ANNAN CATCHMENT

The upper reaches of this river are within the WTWHA and include very high value tributaries that contain remnant populations of six frog species listed as ‘Endangered’ under the EPBC (1999) (Richards *et. al.* 1993). Notable sites for these frog species within the catchment include Big Tableland, Mount Misery, Mount Finnigan and Shiptons Flat. Sooty grunter do not naturally occur in this river, but 2,030 were stocked above Annan River Falls in May 1980 by the DPI. They were subsequently collected there in late 1982 (Hortle and Pearson 1990), in Annan River Weir in 1987 (Barlow *et. al.* 1987, Wager 1993), in Wallaby Creek, an upstream tributary, in 1993 (Herbert *et. al.* 1995) and in Annan River Weir in 1999 (McDougall and Pearce 1999). Sheppard and Helmke (1999) failed to locate any sooty grunter at six freshwater sites sampled by backpack electrofisher below the weir in June 1998. Herbert *et. al.* (1995) also reported good catches of sooty grunter by recreational fishers. Thus, they have established a self-sustaining population above the weir. The upper reaches of the Annan River and its tributaries hold several waterfalls that restrict the upstream distribution of sooty grunter. The sooty grunter may not be present in the same stream reaches as the endangered frog species but this should be investigated further.

3.12 LOWLAND FRESHWATER STREAMS

This review has thus far focused on upland streams because this is where most fish translocations have occurred. Lowland streams have greater fish diversity because there are no barriers such as waterfalls that restrict their spread there. Extensive floodplains and historically lower sea levels have allowed fishes to move between adjacent lowland streams, thus creating a more uniform lowland stream fauna (Pusey and Kennard 1996). In contrast, upland streams are isolated by waterfalls, and fish movements between such systems are generally reliant on geological processes (e.g. alteration of drainage patterns by uplift or volcanism). Also, many Australian fish move between the estuarine and freshwaters as part of their life cycle, so waterfalls restrict their upstream occurrence. This prevents several of the most prized recreational fish species such as barramundi, jungle perch and mangrove jack from occurring above waterfalls.

Sooty grunter breed in freshwater but their occurrence in the Wet Tropics is relatively recent compared to the age of waterfalls and their arrival is believed to be via northward coastal movement from the Burdekin River (Pusey in press), thus they also do not naturally occur above waterfalls. Sooty grunter require long lengths of flowing riffles to successfully reproduce, such that short coastal streams with limited lengths of such habitat do not support sooty grunter populations. Sooty grunter have also been translocated to coastal streams such as Attie Creek (tributary of Meunga Creek, near Cardwell) but it is not known if they have established. Sooty grunter from the DPI-Walkamin mixed stock (see section 4.7) were released into Hawkins creek, a tributary of the lower Herbert River (Hogan 1995), presumably in the late 1980s or early 1990s. Though sooty grunter occur naturally in the lower Herbert River, this represents the introduction of fish from different catchments which may have different genetic structure. Preliminary genetic data of sooty grunter collected from the Gulf and Burdekin catchments indicate significant genetic differences (Pusey unpub. data).

Because of their higher fish diversity and the presence of large, desirable sport species, stocking for recreational purposes is rare into lowland freshwater streams, with the above exceptions for sooty grunter and also for barramundi (see section 3.13 for more details on barramundi). The occurrence of translocated species in lowland freshwater streams largely comprise escapees from farm dam and aquaculture facilities (e.g. silver perch, golden perch, murray cod, australian bass and northern saratoga as previously mentioned in section 3.0). Though individual fish appear to survive, these species do not appear to have established new populations in most cases, or are currently too low in abundance to be detected. Silver perch have been stocked heavily throughout Queensland but have done poorly, and no examples of permanent establishment in northern Queensland are recorded. Golden perch have also been heavily stocked throughout Queensland and have established new populations in several cases, including the Burdekin catchment (see section 3.1), though none are known for the Wet Tropics as yet. Given the time required to establish a substantial population, and the lack of regular surveys in most catchments, it may be some years before translocated populations are officially noted. Also, the failure of fishes to establish in initial attempts is no guarantee that they will not establish on subsequent attempts. This has happened on several occasions in northern Queensland. Probably the only translocated native species known to have established in freshwater lowland streams of the Wet Tropics is the red claw crayfish. Though not always recorded in fisheries surveys, this crayfish appears to now have a wide distribution (see section 3.14).

3.13 ESTUARINE STOCKING

Estuaries comprise a diverse mix of marine and freshwater species as well as estuarine specialists. Because of their high diversity and productivity, intentional introductions of new fish species are generally not required, and are not common, though there are some exceptions. Half of the species collected in a Californian estuary by Moyle *et. al.* (1986) were introduced there, with the most abundant species being a translocated native – the striped bass. Translocated natives are not known from estuaries of the Wet Tropics. However, supplementing the numbers of existing species is a common practice.

Apart from pikey bream (*Acanthophagrus berda*) which have been stocked into estuaries of the Johnstone and Moresby Rivers to augment natural populations there (Hogan 1995), barramundi is the only other fish species officially stocked into estuaries of the Wet Tropics. Barramundi have been stocked because of their popularity and the perception that barramundi stocks have declined due to commercial and recreational fishing pressure and habitat loss and degradation. Supplementation of estuarine fish stocks is common in the United States, though there is considerable debate as to the value of such activities. In the United States, hatchery-based stock enhancement was the main estuarine fish enhancement technique in the late 1800's to early 1900's, but fell out of favour because of the lack of evidence of any increase in fishery yield (Blankenship and Leber 1995). In recent years, there has been a resurgence of interest in this activity though participants in the 2nd International Symposium on Stock Enhancement and Sea Ranching (Jan-Feb 2002, Kobe, Japan) were still divided on the actual benefits of stock enhancement (Yap 2002). Where wild fish stocks have declined because of fishing pressure, then stocking replaces the lost stocks of the target species being impacted. Where habitat loss or degradation has occurred, many species are affected, but stocking only reinstates the 1-2 species that anglers desire. This may cause a shift in community structure (e.g. unnaturally high proportion of barramundi). In cases where neither overfishing nor diminished habitat applies, the benefits of stocking would be highly questionable.

To date, over 600,000 barramundi fingerlings have been released into estuaries and lowland freshwater reaches of the Wet Tropics under the RFEP. The DPI QFISH database provides the following figures for lowland/estuarine augmentation stockings of barramundi up to 30 June 2001: Russell-Mulgrave River, 98,500; Johnstone River, 158,381; Barron River delta, 45,102; Trinity Inlet, 93,895; Herbert River, 48,000; Annan River, 49,336; Endeavour River, 28,837; Moresby River, 14,184; Tully River, 44,000; Murray River, 5,000; Hull River, 3,200; Liverpool Creek, 2,300; and Daintree River, 30,000. Russell *et. al.* (1998) provide the following figures for barramundi stocked from March 1994-November 1997, into the lowland/estuarine reaches of the following systems: Daintree River (61,000); Mossman River (3,500); Saltwater Creek (5,500); and Mowbray River (1,500). The data provided in Hollaway and Hamlyn (1998, 2001) indicate that nearly 300,000 barramundi have been stocked into the lower Johnstone catchment and 120,000 into the lower Russell-Mulgrave catchment – higher than the numbers from the QFISH database. Hogan (1995) records an additional stocking of barramundi into Meunga Creek, Cardwell.

Even though these activities do not represent translocations, stocking excessively large numbers of barramundi to artificially inflate the population of this large predator, may also be harmful, though less obviously so than for translocations. Stockings may also be displacing, rather than increasing, natural fish stocks. Concerns are sometimes expressed that stocking of the few desired fish species to satisfy anglers allows habitat loss and poor fisheries management to continue whilst disguising or neglecting the reasons for decline in the wild fisheries. Such effects are difficult to detect (in the early stages) until significant damage has already occurred. Thus cautious management and rigorous protocols are required. In the United States, there are examples where supplementation of wild salmon stocks with hatchery-reared fish masked habitat decline and overfishing. There are also examples where the stocked fish outcompeted their wild counterparts but had poor reproductive success, resulting in decline of the wild stocks and greater reliance on stocking to ensure continued recreational fishing opportunities. This appears to have resulted from the peculiarities of the salmon life-cycle, mixing of genetic stocks, behavioural differences between wild and hatchery-reared and the large number of stocked fish relative to the wild population. Similar examples have not occurred in the Wet Tropics, but the potential for such impacts cannot be ignored.

It is widely agreed that fish stocking programs are not a management substitute for diminished capacity of wild fish stocks. The state of barramundi stocks in the Wet Tropics is a contentious issue, especially between recreational and commercial fishers. There is no doubt that there has been significant wetland loss (up to 80% of freshwater wetlands) in the lowlands of the Wet Tropics (e.g. Tait 1994, Russell and Hales 1997, Russell *et. al.* 1998, 2000). Information that demonstrates overfishing is rare. Management initiatives such as seasonal closures, area closures, bag limits, size limits and commercial gear restrictions have improved the management and state of the barramundi fishery. Returns from commercial fishing data indicate stable catch per unit effort since 1991, and if anything, catch per unit effort has increased since 1997 (Williams 2002). Nevertheless, there is still a popular public opinion that barramundi stocks require enhancement in estuarine areas.

Russell (1995) and Russell and Rimmer (1997) describe an experiment where 68,770 tagged barramundi fingerlings were released at six sites in the lower Johnstone River catchment in1992/1993. The stocked fish reached legally catchable size (58cm) by 1996. They found that the stocked fish comprised 15% and 19% of the recreational and commercial catches, respectively. Critics could argue that because increases in catch per unit effort were not determined, this does not demonstrate any increase in the barramundi population (e.g. stocked fish may have simply displaced wild fish). However, it is likely that the stocking did indeed increase the barramundi population. Results such as these have encouraged further expansion of estuarine stocking programs. Because such programs involve stockings into diverse fish assemblages in open systems, their impact is very difficult to assess.

Probably the biggest issues for augmentation of estuarine and lowland freshwater barramundi stocks are justifying the need for stocking, determining the number of fish to be stocked, disease and genetic effects. The number to be stocked will depend on the amount of available habitat and the degree to which natural stocks have declined. No guidelines are currently available. Data on catch per unit effort and the proportional size of the barramundi population (relative to other fish in the habitat) are required to provide some guidelines on this. Discussions of genetics and disease issues occur elsewhere in this document (see sections 4.7 and 4.8). Overseas, stock enhancement through stocking has been used to bolster commercial catches and the stockings to date in Australia probably serve this function in a limited way as well. This may be become increasingly important in the future and if taken to its full extent, may even be considered by some as a form of extensive open-area aquaculture.

3.14 RED CLAW CRAYFISH – *CHERAX QUADRICARINATUS*

Redclaw crayfish are native to the Gulf of Carpentaria catchments, some Cape York catchments north of the Olive River, and parts of the Northern Territory and SE New Guinea (Cook 1998). They have been extensively stocked throughout the Wet Tropics and Queensland. They are a large, fast-growing species that is hardy and has wide environmental tolerances, including brackish water, drying and temperature extremes (Cook 1998). This has made them popular for use in farm dams, in aquaculture, for recreational fishing and in the aquarium trade. Farm dams and aquaculture facilities that contain red claw are found in upland and lowland areas of most Wet Tropics catchments. Within the Wet Tropics, Tinaroo Dam is the only location where they have been officially stocked as a recreational fishing resource. Here they have established a substantial population that is popular with recreational fishers, though, for reasons not established, the catch rates have significantly declined recently (A. Hogan *pers. comm.*). Most of the occurrences in streams of the Wet Tropics result from farm dam escapes and releases by individuals wanting to establish a supply of catchable crayfish. The use of red claw in farm dams was actively encouraged and supported by government agencies during the 1980s and 1990s. This, combined with their official stocking into impoundments, must have given the impression to the general public that the spread of this species was appropriate. The process of catching and carrying red claw to new locations is relatively easy as they do not need to be kept in water during transportation and the transfer of gravid females with eggs will enhance the chances of establishment. The rate at which red claw spread throughout Queensland is alarming and they are now well established in numerous catchments throughout the state as well as New South Wales (Cook 1998). Today, they are very popular in commercial aquaculture, also being used for this purpose throughout Australia and even overseas.

In recent years, red claw have been found in many Wet Tropics streams, including tributaries of the upper Burdekin (Burrows and Tait 1999), the Paluma area (section 3.1), Maria and Liverpool Creeks (Hogan 1995, Russell and Hales 1997), the upper Barron (Russell *et. al.* 2000), Lake Eacham (section 3.7.2), upper Johnstone and Koombooloomba Dam (Hogan

1995, Pearce 2000) and the lower Johnstone, especially Mena Creek (B. Pusey *pers. comm.*). Because of their broad environmental tolerances, it might be expected that they would have a good chance of establishment in new locations. However, anecdotal reports suggest that they are not abundant in many streams, though they are abundant in Lake Eacham (T. Vallance *pers. comm.*) and there has been no documentation of their distribution elsewhere except by Russell *et. al.* (2000) who found them in most major tributaries of the upper Barron River that they sampled, though only in higher order streams. It is believed that they are preyed upon by eels (Hogan 1995) and that platypus and water rats may be feeding upon them in Tinaroo Dam (A. Hogan *pers. comm.*). Eels occur in most streams, even small upland streams, though Cook (1998) felt that eels would not be able to control the establishment and spread of red claw. The potential impacts of red claw have not been studied but it is much larger, hardier and has wider habitat tolerances, than most WTWHA crustacean species. In laboratory studies, Cook (1998) found that red claw were behaviourally dominant over *Cherax depressus* and *Macrobrachium australiense* under most conditions. Sub-adults were particularly dominant over other crustaceans because of their aggressiveness, which enabled them to gain optimal resources during this vulnerable stage of their life-cycle. Adults were less aggressive but still dominant due to their large size. Red claw feed upon detritus, macroinvertebrates and a variety of aquatic macrophytes (Cook 1998). The feeding upon macrophytes may potentially be an important mechanism of ecosystem disturbance as it will affect other species and ecosystem processes. Reductions of macrophytes in Lake Eacham have been noted since red claw were translocated there (K. McDonald *pers. comm.*).

There is considerable research currently being conducted into selective breeding and cross-breeding of red claw from different locations to produce crayfish strains with superior growth rates and other traits desirable from an aquaculture point of view (Jones *et. al.* 2000). Escape of these enhanced-strain red claw from farm dams and aquaculture facilities pose increased threats to local faunas, especially in high conservation value waterways. The distribution of red claw within the Wet Tropics needs to be determined and its spread halted. While policy would be required to regulate the incidence of farm dam escapes, an education program highlighting the environmental impacts and legal controls on their movements is also required.

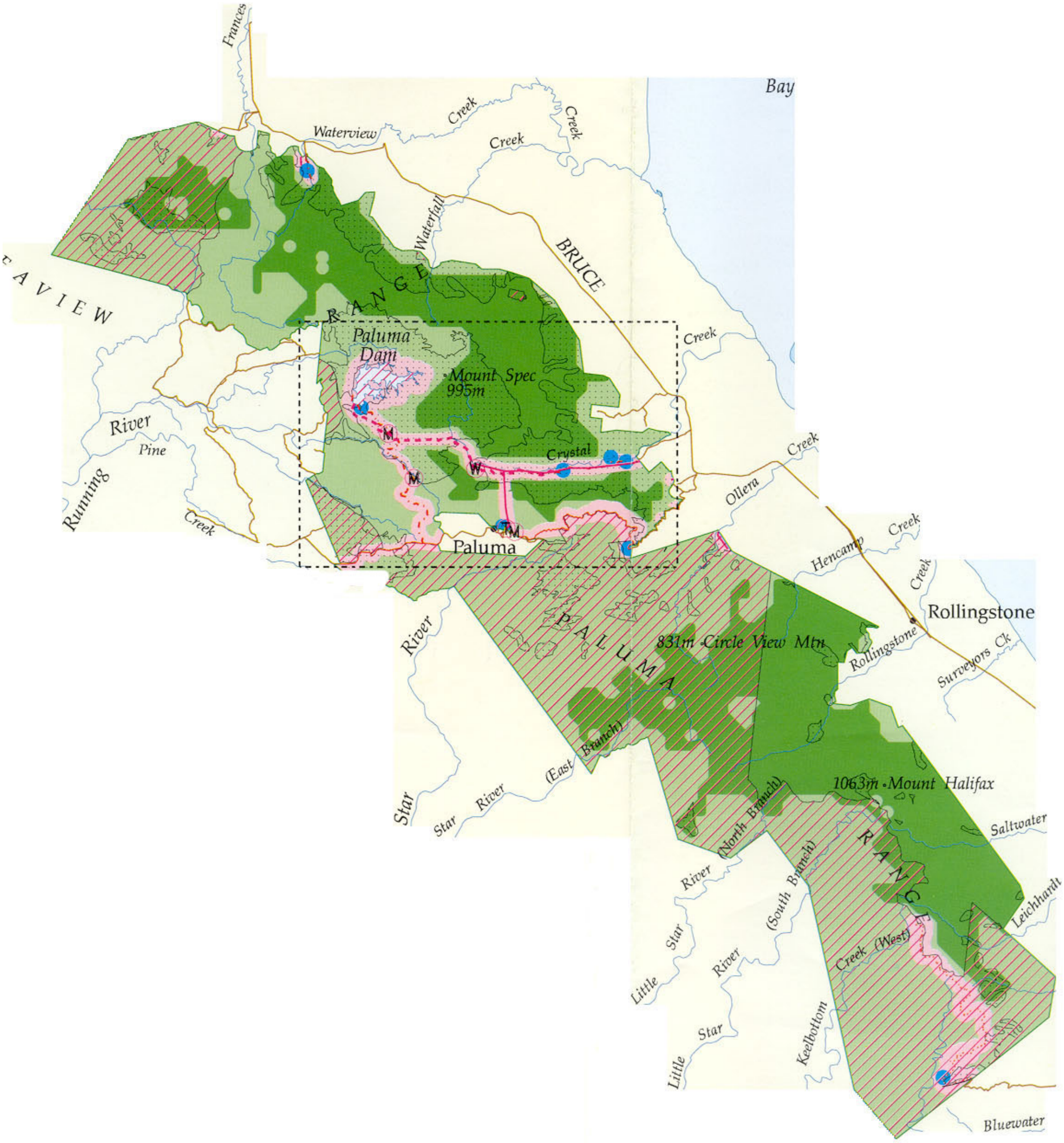

Figure 2: Map of Paluma Dam and north-eastern tributaries of the Burdekin Catchment.

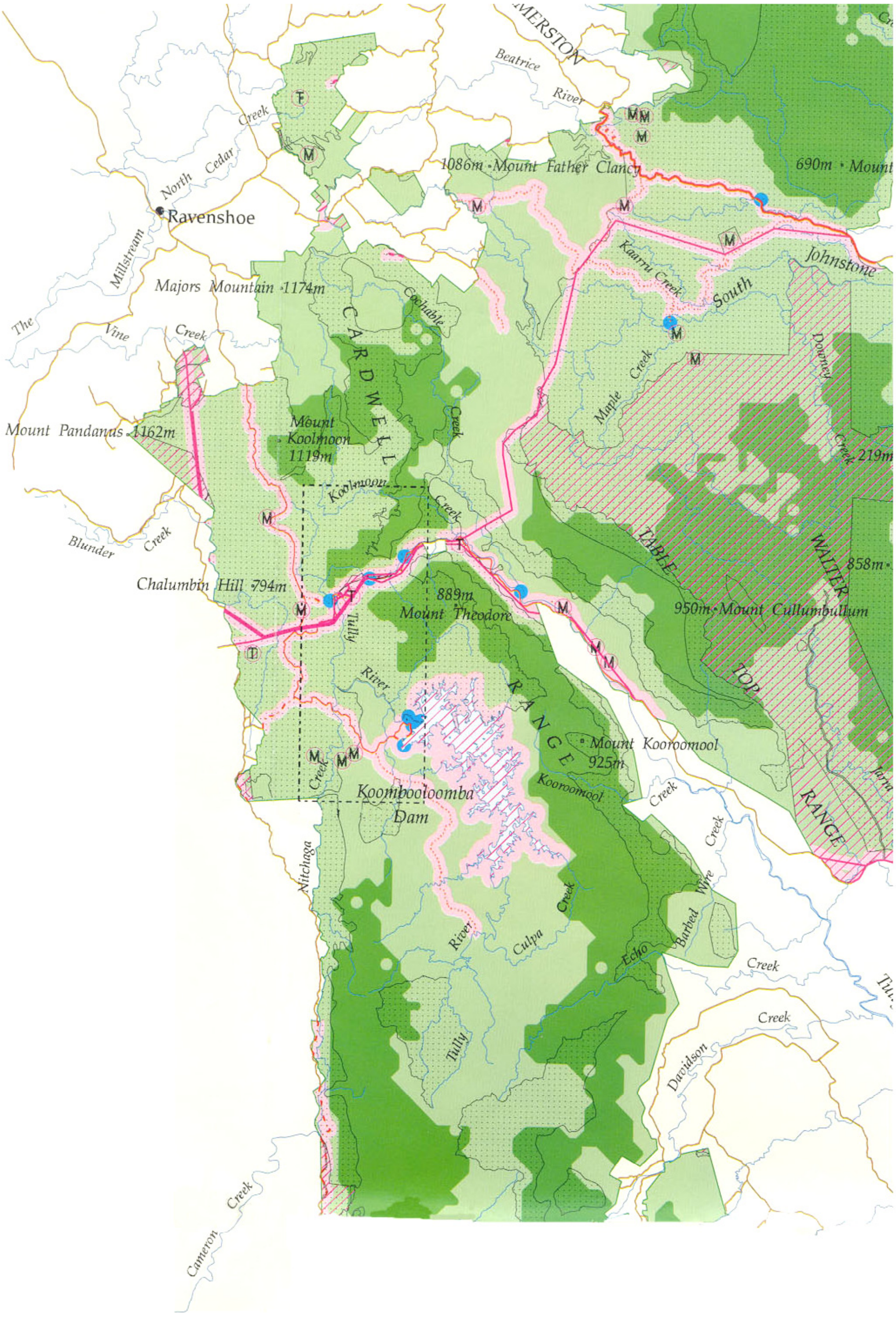

Figure 3: Map of Koombooloomba Dam and the upper Tully catchment. Includes portions of the South Johnstone and upper Herbert catchments.

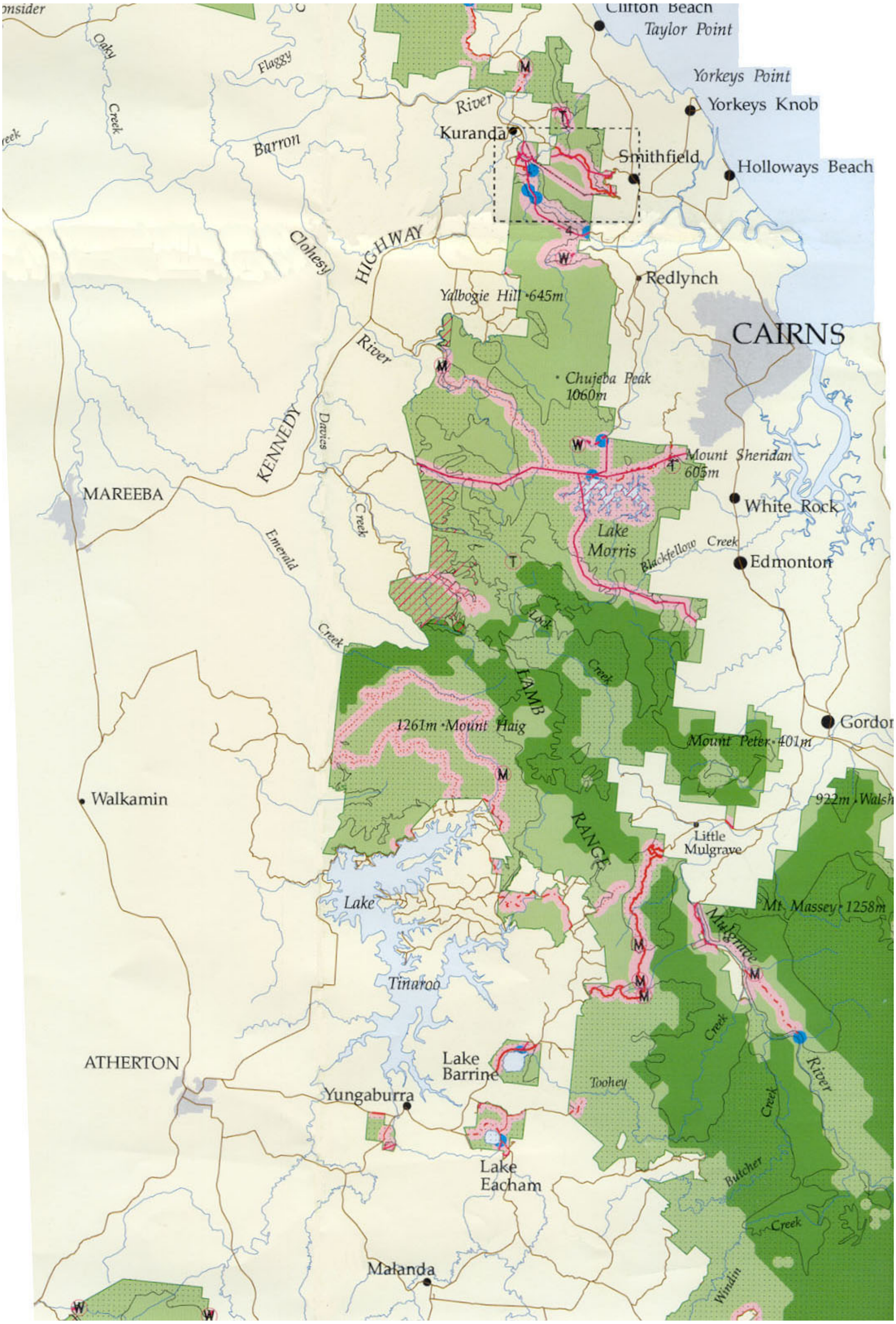

Figure 4: Map of Tinaroo Dam, Copperlode Dam (Lake Morris) and the upper Barron catchment.

4.0 OTHER STOCKING-RELATED ISSUES

4.1 NUMBERS OF FISH STOCKED

Even where the stocked fish species are naturally present within the waterway, there still remains the question of how many fish can be stocked without harm to other fauna. There has been no research into this question for fish that are stocked in Queensland. Food web interactions are very complex. Most decisions are based on general rules of thumb related to the surface area of the stocked waterbody. Environmental considerations do not feature. Stocking rates of 100 barramundi per hectare of surface area and up to 400 sooty grunter per hectare of surface area are recommended to stocking groups (Hogan 1995), though few groups can afford to purchase this many fingerlings. The ability of the numbers of fish stocked in any waterway or impoundment to survive is usually taken as evidence that there is available carrying capacity. However, the increase in fish biomass may come at the expense of some other component of the ecosystem (e.g. population sizes and biomass of prey species). For fish that move from impoundments into upstream tributaries, these stocking rates bear no relation to carrying capacity of those streams. The degree to which stocked fish move into tributary streams needs to be considered in decisions on stocking rates.

4.2 FARMS DAMS AND AQUACULTURE

These have already been mentioned in several parts of this report. Farm dams and ornamental ponds are common in both lowland and upland sections of the Wet Tropics, though escapes from the upland locations are more likely to create environmental problems. Exotic fish and aquatic weeds are also spread from these same sources (e.g. tilapia and cabomba in the upper Barron). The stocking of farm dams was widely promoted in the 1980s and 1990s. Species available for stocking at the time were silver perch, golden perch, murray cod, sleepy cod and red claw crayfish. Australian bass, saratoga and trout have also been used. Fishes that most likely originated from these sources occasionally appear in streams, but apart from sleepy cod and red claw crayfish, do not appear to have persisted in the Wet Tropics, at least not in any great numbers. The extent to which farm dams in sensitive catchments are stocked with non-locally native species is unknown, but the upper Barron catchment is most likely to be affected. Other vulnerable catchments are the upper Russell and Mulgrave, Bloomfield and upper Johnstone (north and south). The upper Daintree and upper Tully would also be sensitive but as their upper catchments are undeveloped, farm dams escapes are not envisaged. Under the Fisheries (Freshwater) Management Plan (1999), only barramundi and sooty grunter can be released into privately owned waters within some of the Wet Tropics catchments, without a permit. Such permits are unlikely to be issued except for commercial aquaculture ventures.

4.3 EFFECTS ON WATERBIRDS

Birds associated with wetlands in north east Queensland have endured considerable habitat loss since European occupation. Many of these birds feed on fish and aquatic invertebrates. Thus, they compete with predatory fish for resources. Fish stocking can alter the abundance, location and size structure of prey items, thus potentially affecting birds that compete for those same resources. Alternatively, some birds may take advantage of stocked fish as food. Anecdotal reports of greatly increased numbers of cormorants in Tinaroo Dam could be linked to the extensive stocking program there (R. Pearson *pers. comm.*). Bouffard and Hanson (1997) provide a review of interactions between fish and waterfowl. A major avenue for the effects of fish stocking on waterbirds is disturbance of waterbirds by boats. The shallow backwaters, drowned timber and macrophyte patches that are favoured by anglers are also sites frequented by waterbirds. Boats may disturb feeding and breeding behaviour and even force birds to move to other locations. Water skiing would have similar effects, although this activity is more likely to be confined to deeper open water areas away from impoundment margins.

4.4 EFFECTS ON FROGS

The direct and indirect effects of fish predation on frog tadpoles are recognised as one of the most important biotic factors influencing the composition of many frog communities. For example, in the central Amazon, Hero *et. al.* (1998, 2001) demonstrated that tadpole species richness and assemblage structure were explained by fish density and richness, not abiotic characteristics of the frog habitat. Many frog species cannot coexist with fishes that prey upon them and their distribution is mutually exclusive. Thus, tadpoles of many frog species are confined to habitats where such fishes do not occur (e.g. upland streams, above waterfalls, in temporary pools). Fickling (1995) found that in tributary streams of the Tully River, *Litoria nannotis* and *L. rheocola* (both listed as 'Endangered' under the EPBC Act 1999) were restricted to streams without predatory fish, even though suitable habitat was present in the streams that contained predatory fish (primarily sooty grunter). The barrier that defined the distributional disjuncture of the frogs and their fish predators, were waterfalls where the fish occurred in the stream reaches below the waterfall and the frogs in the stream reaches above the waterfall. Movement of fishes above those waterfalls would likely lead to the loss of *L. nannotis* and *L. rheocola* in those streams. Three other frog species were able to coexist with fish predators in the same habitats through either unpalatability to the fish and/or ability to utilise microhabitats (e.g. riffles) that reduced predation rates upon tadpoles.

Frog species that coexist with fish predators usually have coevolved adaptations such as unpalatable eggs and tadpoles (Hero *et. al.* 2001), predator avoidance behaviour or anti-predator defence. Because such survival strategies are coevolved, they tend to be predator-specific and are unlikely to be effective against all predators (Gillespie and Hero 1999). Thus, tadpoles which are unpalatable to the native fish predators with which they coexist may not be unpalatable to new or novel fish predators, or the tadpoles may not have the required anti-predator strategies suitable for coexisting with novel fish predators (Gillespie and Hero 1999). The introduction of novel fish predators (whether native or exotic) to the habitats of vulnerable frog species could result in the complete elimination of certain species from the stream reaches where the translocated fish occur. Frog diversity is high in the Wet Tropics, and many of the species present have high conservation values and restricted distributions, especially in upland streams. Because they are devoid of large fishes (except eels), upland streams have been the focus of most fish stocking activities. For at least seven frog species in the Wet Tropics, there have been significant documented declines in population size and distribution during the 1990s (Richards *et. al.* 1993, Trenerry *et. al.* 1993, McDonald and Alford 1999), with at least two species not seen for several years. The declines have occurred in some places where translocated fishes may be present but also in many areas where they are clearly not, thus other factors are clearly involved. However, surveys to determine the overlap in distribution of stocked fish species and frog species (or their former ranges) are urgently required. Possible locations of overlap include tributary streams of Koombooloomba, Tinaroo, Copperlode and Paluma dams, as well as the upper Annan River, upper Barron River, Blencoe Creek, upper Running River catchment and the upper Johnstone catchment.

There are many examples, especially in Europe and North America, of significant reductions and even localised extinction of frog populations after the introduction of novel fish predators, both exotic and translocated. About 60% of the approximately 3,000 naturally fishless high elevation lakes in the Sierra Nevada mountains in California are now stocked with various translocated native salmonid fishes (Bradford 1989). The frog *Rana muscosa,* is unable to persist under fish predation and has been eliminated from hundreds of lakes that it formerly occupied (Bradford 1989, Bradford *et. al.* 1993). Bradford *et. al.* (1993) demonstrated that because of greater distance between the remaining fishless lakes where populations of the frogs still exist, there is reduced movement between these populations, effectively isolating many of them. Thus, where some of the remaining populations in fishless lakes have declined or disappeared because of other reasons, there is limited or no, recolonisation from the remaining populations. Pilliod and Peterson (2001) found an identical result for the effects of stocked trout on spotted frogs and long-toed salamanders in North American mountain lakes. Other examples of frog declines as a result of novel fish predators, including examples from Australia, have been reviewed by Gillespie and Hero (1999). Gillespie (2001) demonstrates from field and experimental evidence that predation by introduced trout may be responsible for the significant decline of at least two frog species in south-east Australia, with one of those species being recognised as 'Endangered'.

Competitive effects may also occur. In some circumstances, these may even have a positive effect. Various aquatic invertebrates such as dragonfly larvae and some beetles also prey upon tadpoles but fishes may control the numbers of these predators. If the tadpoles can coexist with the fish, then the reduction in predation of the invertebrate predators may benefit the frog species. While examples of increased populations of certain frog species under this scenario are known (e.g. Werner and McPeek 1994), they are not common and the presence of any such interactions in the WTWHA is unknown and would require thorough investigation.

Apart from predation and competition, introduced fish predators can induce behavioural changes such as reduced activity, changes in feeding patterns and habit, and shifts in reproductive habits. In some frog species, the females are able to detect the presence of fish predators and preferentially lay their eggs in fishless waterbodies, even if they offer inferior habitat quality. Thus the mere presence of predatory fish may reduce reproductive success even without any direct contact between them. In an experiment in the USA consisting of eight ponds with predatory fish and eight without predatory fish, Binckley and Resitarits (2002) found that 95% of squirrel tree frog eggs were laid in the fish-free ponds. Bronmark and Edenham (1994) also found that the presence of fish affects the distribution and selection of egg-laying sites of tree frogs in Europe. Such anti-predator behaviours are not uncommon, even if they result in decreased growth rates and decreased survivorship and fecundity of offspring (Binckley and Resitarits 2002). More importantly, greatly reduced egg-laying into habitats containing fish restricts the amount of habitat available to these frogs.

In their review of the effects of introduced and translocated fish on Australian amphibians, Gillespie and Hero (1999) considered that the significant frog assemblages of the Wet Tropics would be at risk from introductions of novel fish species. They considered the stocking of high mountain streams to be of particular concern. Surveys within the Wet Tropics are required to determine the occurrence of various frog species in relation to the distribution of translocated fishes, and thereby identify which frog species are most vulnerable and which fish species may be impacting upon them. Such surveys will also prioritise which locations and which fish/frog combinations require more detailed investigation. As well as field work, predation experiments on tadpole survival strategies would evaluate the potential for coexistence.

4.5 EFFECTS ON AQUATIC INVERTEBRATES

There are numerous studies demonstrating that patterns of fish density and richness are major influences structuring assemblages of aquatic invertebrates, especially insects and crustaceans. For example, Leberer and Nelson (2001) found that adult atyid shrimps did not coexist with jungle perch (*Kuhlia rupestris*) on Guam, even though they were able to coexist with other predatory fish species. The adult shrimps found refuge from predation by ascending waterfalls whereas the smaller juveniles, which were able to bury themselves within the substrate to avoid predation, could coexist with jungle perch below the waterfalls. An experiment in which jungle perch were transplanted above waterfall barriers resulted in complete elimination of the atyid shrimps from the stocked pools whereas control pools showed no change in atyid density. Atyid shrimp density in the test pools returned to normal levels several months after removal of the jungle perch. This demonstrates how fishes, especially novel predators, can influence the geographic distribution, size distribution and behaviour of prey species, even though the prey species may currently coexist with other predatory fishes. In this case, only certain size classes (the adults) were unable to coexist with jungle perch. Similarly, Concepcion and Nelson (1999) found that the distribution and abundance of the prawn, *Macrobrachium lar* (a species also found in the Wet Tropics) in Guam, was also structured by the presence and density of jungle perch.

It is commonly observed that the behaviour of invertebrates changes dramatically in the presence of fish predators. Burrows and Tait (1999) observed that in a waterhole above Fanning River Falls (large fish predators absent), *Macrobrachium* prawns swam freely throughout the water column, including at the surface, but below the falls (several large fish species present), they always remained cryptically hidden amongst leaf litter and other benthic structure. Similar changes in behaviour, and increased abundance in the absence of large fishes, have been noted for *Macrobrachium* spp. on Hinchinbrook Island (Malcolm *et. al.* 1997) and in other Wet Tropics streams (R. Pearson and B. Pusey *pers. comm.*). Even where presence/absence observations show that invertebrates are able to coexist with fish predators, they clearly are forced to alter their patterns of microhabitat use. The amount of time that they spend in non-favoured or sub-optimal habitat avoiding predators may also be important to their long-term vitality. Exposure to novel fish predators can result in decreased abundance, or altered patterns of habitat use and productivity.

There is a voluminous literature, too large to be reviewed here, demonstrating the effects of fish predation on invertebrates. Though some exceptions are known (e.g. Pierce and Hinrichs 1997), fish are usually shown to negatively effect invertebrate populations, even where the fish predators are not novel to the invertebrates tested. Many invertebrates in upland Wet Tropics streams are not adapted to coexist with the translocated fishes to which they are now subjected.

4.6 EFFECTS ON ECOSYSTEM PROCESSES

Changes to invertebrates communities can have unexpected consequences for ecosystem processes and productivity. For example, in upland rainforest streams near Rio de Janiero, because of predation by fish predators, atyid shrimps are more abundant above waterfalls than below (Moulton 2001). The atyid shrimps feed upon benthic algae and detritus. Below the waterfalls, where the shrimps are less abundant, the rock substrate has a large amount of algae and sediment but above the waterfalls, where the shrimps are abundant and can forage in the open, the rocks are ‘clean’. Experimental exclusion of the atyid shrimps from sites above waterfalls resulted in the rapid coverage of the rocks with algae (Moulton 2001). This indicates that translocation of the fishes from below, to above, those waterfalls, could result in algae covering the currently ‘clean’ rocks. The presence or absence of herbivorous fishes can also affect growth and productivity of aquatic plants, especially algae (Pringle and Hamazaki 1997), and ecosystem responses to changes in nutrient supply (Flecker *et. al.* 2002).

Significant changes to water quality can also occur after fish stocking. Leavitt *et. al.* (1994) found large increases in algal production followed fish stocking of Canadian mountain lakes. Schindler *et. al.* (2001) found that stocked trout stimulated primary production and doubled phosphorus recycling rates in North American mountain lakes. Zimmer *et. al.* (2001) found that prairie wetlands containing fathead minnows had significantly increased turbidity and primary productivity compared to fishless prairie wetlands. On the other hand, Cogle *et. al.*

(1998) briefly examined the potential of harvesting fishes stocked into Lake Tinaroo as a means of removing nutrients from system and determined that they would store a significant proportion of the nutrients entering the lake from the surrounding catchment. However, they concluded that the situation was too complex for it to be a tenable idea without significant amounts of research being conducted first. Ongoing DPI research is examining the potential for stocked fish to harvest nutrients from small waterbodies (e.g. stocking mullet into a section of Sheep Station Creek in the lower Burdekin floodplain).

Leaf litter entering streams from terrestrial trees are important sources of external energy that significantly increase the productivity of rainforest streams (Wallace *et. al.* 1997). Invertebrates that shred these leaves (e.g. caddis-fly larvae) play a vital role in their breakdown and incorporation into instream food chains. This process has been shown to be important in rainforest streams of the Wet Tropics (Pearson and Tobin 1989, Pearson *et. al.* 1989, Nolen and Pearson 1993). Fish predators can reduce the abundance of invertebrate shredders and thus the rate of leaf litter breakdown, thereby affecting productivity of those streams (Short and Holomuzki 1992, Konishi *et. al.* 2001, Mancinelli *et. al.* 2002, Ruetz *et. al.* 2002). Similarly, fish consumption of aquatic macrophytes can drastically alter the occurrence of these important instream habitats and other organisms that depend on those plants.

Fish have the potential to alter aquatic ecosystem processes so much that in some situations, biomanipulation of large waterbodies via fish stocking, has been proposed to reduce the incidence and/or severity of blue-green algae outbreaks. This involves introducing large piscivorous fishes that prey upon smaller fishes that in turn prey upon zooplankton that eat blue-green algae. By using the large fishes to reduce the population of small fishes, the abundance of the algae-eating zooplankton community increases. Such interactions will only control blue-green algal outbreaks in limited situations as most fishes have very broad diets and can shift between various trophic levels and prey size classes. Fish also move between trophic levels and prey size classes as they grow. Food chains are not a simple model of cascading trophic levels and many species will feed at different levels. Algal outbreaks can also develop very quickly (days to weeks), before fish populations can respond. The opposite effect can also occur - the introduction of predatory fishes could actually work to decrease zooplankton populations, thus potentially increasing blue-green algal outbreaks. Declines in zooplankton abundance have been recorded in many impoundments following the introduction of new fishes (Nilsson 1972, Knapp *et. al.* 2001). Reviews of the potential for fish biomanipulation of blue-green algae by Boon *et. al.* (1994) and Gehrke and Harris (1994) suggest that trophic regulation by zooplankton and fish is unlikely to be particularly successful in Australian aquatic environments, although Matveev and Matveeva (1997) felt that the method still offered promise. This approach to biomanipulation has recently been scientifically trialled in Maroon and Moogerah dams in SE Queensland. Despite promising initial results, the researchers involved have concluded that overstocking of dams actually reduces water quality and increases the risk of blue-green algae outbreaks (CSIRO media release 28 June, 2002).

4.7 GENETIC AND HATCHERY EFFECTS

Most evidence of genetic impacts of stocking has come from the United States where this has been studied extensively, especially for trout and salmon. The return to natal spawning sites is so strong in various salmon species that they even return to the same reach of the same stream. This reproductive isolation has enabled the development of many distinct populations, even within the one catchment. Based on evolutionary theory, it is to be expected that each population is well-adapted to the particular conditions of each river system. However, fishery management has not always involved retention of such locally adapted traits. For instance, in California, early last century, people were employed to carry juvenile rainbow trout in packtrains along mountain ridgetops to seed each catchment, even though most already had unexploited populations of trout (Behnke 1979). Release of fish belonging to different genetic strains than that occurring in the release location. Such actions can lead to the destruction of genetically distinct forms of a species. Apart from the scientific and conservation importance of preserving all of the sub-species and genetic strains, members of the general public also desire their protection, because of their differences. Among other differences, each of the sub-species has different colouration and are sought after by keen sport fishers, increasing the awareness of these sub-species. Where they have been stocked into private fishing dams, they command a high price. Many of these stockings occurred in rivers that did not require them, but now programs to conserve these strains cost millions of dollars annually.

Evidence from the USA shows that hatchery-reared fish sometimes do poorly in the wild (Hilborn 1992) as hatchery-rearing can promote traits such as fast larval growth rate and the ability to compete for food in breeding ponds, that may not be optimal for survival in the wild or match the characteristics of the original population. For example, in their native environment, the Lahontan cutthroat trout grew to 30kg but the hatchery strains that have replaced them in the same streams, have shorter lifespans and only grow to 4kg (Behnke 1979). Some hatcheries in the USA are now trying to simulate wild river conditions to more appropriately select fish for stocking. Returns of hatchery-reared salmon are sometimes lower than for wild stocks and they may return at the wrong time, to the wrong stream, or occupy spawning grounds but fail to spawn (Pierce 1990) or spawn at different dates to their wild counterparts (Quinn *et. al.* 2002). Stocking programs that reduce the genetic diversity of the wild populations can render them more susceptible to disease (Allendorf *et. al.* 2001). Thus, despite the publicity generated by the well-known success stories, stocking has not always solved the problem of declining stocks, and because they have displaced better-adapted wild stocks, populations in some streams have now become even more dependent on stocking to maintain their populations for angling purposes, even taking on a 'conservation' role (Pierce 1990). For instance, Levin and Williams (2002) found that stocking of hatchery-reared steelhead salmon negatively affected survival of the wild steelhead salmon populations they were supposed to be enhancing. Similarly, Altukov and Salmenkova (1987) found that stocked Pacific salmon have a 50% less chance of surviving to adulthood than naturally occurring wild fish, even though the stocked fish came from the same catchment. In such situations, fish stocking is a poor long-term option for restoration of fish populations. Such effects are often overlooked in the statistics based on how many fish were stocked and catch returns for anglers. In some cases, where allowable fishing levels are based on the total population size, stocking may actually contribute to overfishing of wild stocks as the wild stocks suffer the same fishing pressure as the more abundant hatchery-reared stock that are simply replaced each year.

Erosion of the natural gene pool can occur rapidly in some situations, especially when broodstock from another location are used. In a Spanish stream, Garcia-Marin *et. al.* (1999) found that 5% of the native ancestry of brown trout was lost each year due to a stocking program that involved broodstock from another location. Also in Spain, Almodovar *et. al.* (2001) found that 25% of brown trout populations in one catchment showed introgression by hatchery genes of fish from other parts of Europe. Almodavar *et. al.* (2001) further found that genetic evidence of stocking disappeared within 10 years of cessation of stocking. This indicates that the stocked fish populations did not persist (reflecting their environmental inferiority) and had low levels of interbreeding with the wild fish populations. Though little work has been done to evaluate their occurrence, effects similar to those highlighted in the previous paragraphs are not known to have occurred in Queensland. However, these examples do highlight the potential problems that could arise, and the need for vigilance.

Even when fish collected as broodstock come from the same stream or location where the resulting fry will be released, there are still genetic issues to be considered. Most fish species produce exceedingly large number of gametes, and survival in hatcheries enables a single spawning to produce thousands of individuals for stocking. Low numbers of spawning broodstock can thus swamp natural populations with fish of restricted parentage (reducing genetic diversity through the equivalent of a founder effect and genetic drift). Dixon (1990) suggests that at least 100 individuals of each sex are required to prevent genetic drift and that selection of any kind should be avoided in the hatchery. Blankenship and Leber (1995) recommended the keeping of 125 broodstock with 25% of the broodstock being replaced by wild-caught fish each year. Allendorf and Ryman (1987) considered that 25 males and 25 females were the absolute minimum number of broodstock required. The number of broodstock required is likely to differ for different fish species. To safeguard against over-harvesting and to discourage the illegal sale of wild-caught fish, the collection and keeping of broodstock is a regulated activity in Queensland so hatcheries are limited in the number of broodstock they are allowed to have in their possession. Current Queensland guidelines limit barramundi to 40 broodstock and sooty grunter to 60 broodstock, though increased numbers are allowable under special circumstances. Typically, hatcheries in Queensland keep 20 broodstock or less (Keenan 1995). Not all are necessarily used in each spawning and some individuals may be used repeatedly. Apart from the numbers kept at any one time, the rate of replacement of broodstock is also important to maintaining genetic diversity. Thus a breeding plan that allows for contributions from as many of the broodstock as is realistically possible, and also regularly replaces broodstock, is important.

Genetic variation in barramundi populations has been investigated across northern Australia in several studies. A total of 16 genetically discrete stocks have been identified (Shaklee and Salini 1985, Salini and Shaklee 1988, Shaklee *et. al.* 1990, Keenan 1994). The Wet Tropics is represented by a single stock known as the north east coast stock. Initially, it was thought that the degree of genetic differences between the various stocks was sufficiently large that it is likely to produce important biological differences. Thus, it has been accepted as policy, and is represented in the Fisheries (Freshwater) Management Plan 1999, that barramundi stockings consist of fingerlings bred from the locally appropriate genetic stock. Similar policies are generally enforced for other fish species, even where no genetic information exists. Aquaculture farms do not always use the locally available stocks.

Recently, Keenan (2000) summarised the latest research based on more advanced genetic techniques and suggested that barramundi colonised the northern Australian coastline 350,000-320,000 years ago or less, resulting in only small genetic differences between the 16 populations that had previously been identified. He further identified that substantial migration between all populations has occurred in the 17,000 years since the last Ice Age. Keenan (2000) suggests that the 16 populations should be treated as management units within an evolutionary significant unit that includes the whole of northern Australia. He further suggests that there is no evidence for local adaptation and that translocation between the populations should not pose any ecological risks. While a well-argued case, as a precaution, unless it is not feasible or reasonable, broodstock for fish stocking should always be collected from the appropriate stock. Because they interbreed with wild stocks, genetic issues are even more important for barramundi stocked into lowland streams and estuaries where wild stocks occur.

Sooty grunter in northern Queensland have until recently, only been recognised as one species – *H. fuliginosus*. Based on this assumption, little attention has been paid to movement of these fish between catchments. For instance, sooty grunter translocated into the upper Barron have come from the Mitchell, Herbert, Burdekin, Mulgrave, Johnstone and Tully catchments (DNR 1999). Within the Wet Tropics, sooty grunter have now been formally recognised as comprising two separate species – sooty grunter and the khaki bream (*H. tulliensis*) (Allen and Pusey 1999). Both species may be found together in lowlands of the Tully-Murray, Johnstone and Russell-Mulgrave catchments. Only sooty grunter occurs in the Burdekin and Herbert catchments and only khaki bream is believed to naturally occur in the Daintree and Barron catchments (Allen and Pusey 1999). The Gulf stocks of sooty grunter may yet prove to be a different species (B. Pusey unpub. data). The QDPI Walkamin research station developed a mixed stock of sooty grunter during the 1980s based on fish collected from the upper Burdekin (at Valley of Lagoons), the upper Herbert and the upper Mitchell catchments, with more broodstock collected from the first two locations than the third (A. Hogan *pers. comm.*). The progeny from this mixed stock have since been widely dispersed throughout northern Queensland, including Koombooloomba Dam, Tinaroo Dam, Copperlode Dam, the upper Herbert River, Eungella Dam (Broken River in the Burdekin catchment), Peter Faust Dam (Proserpine) and the Pioneer River (Mackay). Thus the current gene pool is mixed to an unknown degree and the current genetic and specific status of these populations should be examined.

In upland streams of the Wet Tropics, populations of many aquatic animals are isolated, with mixing only occurring due to geological events (e.g. stream capture). Thus the probability of substantial genetic differentiation between species in the various catchments is high and many as yet undiscovered distinctive genetic units might be present. Hughes *et. al.* (1996) found significant genetic differences between populations of the recently described shrimp, *Caridina zebra,* in closely-located streams of the upper Tully and Herbert catchments in the WTWHA. Hurwood and Hughes (1998) demonstrated a similar pattern of differentiation between populations of purple-spotted gudgeons in the same streams. Both species also occur in other catchments of the Wet Tropics so additional genetically distinct populations are expected. Substantial genetic variation between, and also within, catchments in the Wet Tropics, have been found for pacific blue-eyes (McGlashan *et. al.* 2001, McGlashan and Hughes 2002) and hardyheads (McGlashan and Hughes (2000). Numerous genetically and phenotypically discrete populations of the eastern rainbowfish, and other rainbowfish species, occur naturally in the WTWHA (Trenerry and Werren 1991, Pusey *et. al.* 1997, Zhu *et. al.* 1998, Burrows and Tait 1999, McGuigan *et. al.* 2000), one of which has recently been raised to specific status (e.g. *M. utcheensis* – McGuigan 2000). These smaller fish species are commonly held in aquaria by hobbyists and often cross-breed. They are sometimes then released into local waterways. The genetic integrity of many streams is a significant component of the biodiversity in the Wet Tropics, and needs appropriate management. Already eastern rainbowfish have been translocated into Lake Eacham (see section 3.7.2) and Pusey (in DNR 1999) suggests that Utchee Creek rainbowfish and a new species of hardyhead from the North Johnstone catchment may have been translocated into the Barron catchment (see section 3.7.1). Lake Eacham rainbowfish mat also have been translocated within the Barron catchment (see section 3.7.2).

4.8 PATHOGENS AND PARASITES

Stocking and translocation of fishes pose disease risks, especially with large numbers of hatchery-reared fish. Because of their long isolation from other aquatic fauna, some upland areas of the Wet Tropics may be free of certain diseases that are present in lowland areas. Movement of fishes to these upland areas has the potential to spread some diseases to new areas. Introduction of new diseases across international borders is more common. However, movements over smaller spatial scales can still be a concern and this may also enable the spread of exotic pathogens after their introduction to Australia. Movements of frogs within Australia are a major concern for the spread of diseases implicated in the decline of frog populations across the country, and protocols are being developed to limit such movements (Speare 2000). There are many protocols on the movements of plants, especially agricultural plants, within Australia. Movements of fishes within Australia should come under similar consideration.

Nodaviruses are one of the more high profile diseases infecting fish. Nearly all marine fish have nodaviruses, but they have not been tested for in freshwater fish even though they have caused mortality of freshwater fish when injected experimentally (I. Anderson *pers. comm.*). Nodaviruses are believed to be passed from broodstock to offspring so the testing of broodstock should ensure hatchery stocks are free of nodaviruses (I. Anderson *pers. comm.*). Any larvae that are infected by nodaviruses will most likely die, so that the survivors that are stocked are free of the virus. Other patterns of disease are possible. Pusey (in press) records how an 'invasion front' of translocated sleepy cod that migrated down the upper Burdekin River in the 1990s from their initial release site, had a high incidence of epizootic-ulcerative syndrome (commonly known as 'red-spot' disease).

In recent years rapid declines in populations of frog species have been recorded across the world. One of the causative mechanisms being investigated is the spread of novel pathogens. Laurance *et. al.* (1996) suggested that a novel pathogen, introduced with exotic fish may be responsible for frog declines in Australia, though Hero and Gillespie (1997) and Alford and Richards (1997) did not support this claim. Nevertheless, several pathogens have been identified on frogs in Australia, including *Batrachochytrium dendrobatidis* (a chytrid fungus), which is known to cause frog mortality in wild populations in the Wet Tropics (Speare 2000). Pathogens may be transmitted between fish and amphibians. Thus the widespread movements of fish for recreational purposes and in farm dams may have implications for the spread of amphibian pathogens. Kiesecker *et. al.* (2001) studied the effects of the pathogen, *Saprolegnia ferax*, which is particularly common in hatchery-reared fish, on frogs in Oregon, USA. They found that native frog species suffered embryonic mortality when exposed not only to infected fish but also to soil that had been associated with infected fish. The chytrid fungus affecting frogs in the Wet Tropics is not known to utilise fish as hosts, though one of the recommendations of an international workshop on the issue in 2000 (Speare 2000) was to investigate possible non-amphibian reservoirs of chytridiomycosis.

Fish do carry some of the diseases, such as ranaviruses, that have been associated with declines of frog species (Daszak *et. al.* 1999). Ranaviruses also affect reptiles such as snakes and turtles (Hyatt and Cunningham 2000) and in recent years they have been detected over an increasing geographic range and number of species, including cane toads (*Bufo marinus*) in Queensland. Aquarium fish have most commonly been recorded as having infections, though Owens and Cullen (2000) were also able to experimentally infect fishes such as tilapia, barramundi, golden perch and silver perch. However, as cane toads are common vectors of this disease, it is likely to be present in most locations where cane toads are already present (L. Owens *pers. comm.*).

As well as diseases, the transfer of parasites is also an area of consideration. Parasites may be harmful to fish and translocation and stocking may bring novel parasites to sections of upland streams in the Wet Tropics. In some cases, parasites may be benign to some hosts but harmful to others, even when the hosts are closely related. *Myxosoma cerebralis*, an innocuous parasite of brown trout in Europe has devastated stocks of rainbow trout in the United States (Langdon 1990). Herbert (1987) found red claw crayfish to carry a variety of diseases, parasites and epibionts such as fungi, ciliates and platyhelminths and cautioned against translocations of crayfishes without strict regulations. As discussed in section 3.14, numerous unofficial translocations of red claw crayfish have occurred in the Wet Tropics.

The control of diseases is not just an issue for environmental managers, but also highly significant to hatcheries and aquaculturists. As such, DPI has research programs and hatchery/aquacultural monitoring and protocols in place to greatly reduce the risk of disease and parasite transfer.

5.0 INDIRECT EFFECTS OF ENHANCED FISHING EFFORT

Environmental management considerations of fish stocking initiatives involve more than just evaluating the dispersal and ecology of the stocked fish. Catching fish involves the use of boats and fishing equipment and potentially high levels of human visitation to sensitive or high conservation value environments, creating the potential for other environmental impacts.

5.1 WATER QUALITY

The effects of excessive fish stocking on water quality and blue-green algal levels, were discussed in section 4.6. Water quality can also be affected by recreational boating and human usage, particularly in regard to petroleum products and microbial contamination. On most dams in Australia that supply urban drinking water, boats are not allowed, or only electric-powered boats are allowed. On many dams used for drinking water (e.g. Copperlode Dam), no recreational access is allowed at all. Larson (2000) suggested that fish stocking and the resultant increase in visitors to Waldo Lake in Oregon, USA, were responsible for its polluted state and recommended that fish stocking cease. Similarly, Brancelj *et. al.* (2000) attribute changes in zooplankton community from fish stocking, and increased visitation following fish stocking, as a major cause of eutrophication of a lake in Slovenia.

There are other water quality issues to consider. After Cyclone Rona in 1999, hundreds of barramundi and other stocked fish were washed over the spillway of Copperlode Dam (G. Werren *pers. comm.*). The dead fish along the lower creek, a popular swimming area, produced a foul odour and must have created a water quality, and potentially a public health, risk. The installation of fish barrier nets in Tinaroo and Copperlode dams to reduce loss of fish over the spillway during flood events should reduce these occurrences. Preventing the loss of large numbers of stocked fish is also in the interests of the stocking groups.

5.2 SPREAD OF PEST MACROPHYTES AND ANIMALS

Boats and associated equipment (e.g. outboard motors, fishing gear and live wells) are major vectors of introduced pests. Since its introduction into North America in the mid-1980s, the freshwater zebra mussel (*Dreissena polymorpha*) has spread rapidly across a large part of the continent (Johnson and Carlton 1996). Within connected waterways, this has occurred via the planktonic larval phases or via adults attached to barges moving upstream (Johnson *et. al.* 2001). Recreational boating has been the main method of dispersal between isolated waterbodies (Johnson *et. al.* 2001). The initial invasions into isolated lakes in Winconsin were entirely into waterbodies used by boaters who also used other lakes infested by this pest (Padilla *et. al.* 1996). Boater education and boat cleaning programs have been implemented to reduce the rate of spread of this pest. Recreational boating activity has also been implicated in the spread of exotic zooplankton (Yan *et. al.* 1992, Havel *et. al.* 1995) and several species of aquatic macrophytes in the USA (Dove and Taylor 1982, Joyce 1982) and New Zealand (Johnstone *et. al.* 1985).

Johnson *et. al.* (2001) found that 33% of boats departing from three boat ramps in Lake St. Clair, Michigan, USA had entangled macrophytes and 16% of these had zebra mussels entangled within the macrophytes. Zebra mussels were also found on anchors, live wells, bait buckets, engine cooling water and bilge water. Johnstone *et. al.* (1985) found that the distributions of five species of introduced aquatic macrophytes in 88 lakes in New Zealand was significantly correlated with recreational boating and fishing activities. These five species are all native to Australia and two (*Hydrilla verticillata* and *Ceratophyllum demersum*) are found in the WTWHA. Fifty of the 61 lakes where boating and/or fishing were allowed, had established populations of at least one of the weeds. In contrast, all of the 27 lakes where boating and/or fishing did not occur were free of all five weed species. Entangled macrophytes were found on 27% of boats departing boat ramps. Boat inspections at 14 boat ramps found that 5.4% of boats that entered the water carried fragments of these aquatic weeds, and it was estimated that more than half of these were viable at the time of entry into the water. For four uninfested lakes in their study area, they estimated that a live fragment of *C. demersum* arrives every two weeks during the summer boating season. Boats leaving lakes usually only carried macrophyte fragments when the haul-out area was near weed beds. Thus removal of weed beds from near the haul-out area was deemed a priority management option for reducing the risk of boat-mediated dispersal of aquatic weeds.

Of the four major impoundments in the Wet Tropics region, three are open to recreational boating (including skiing). Invasions are more likely for popular waterbodies, especially those that are visited in conjunction with visitation to other waterbodies. A relevant example in the WTWHA could be movements of boats (fishing or skiing) and other equipment between Tinaroo and Koombooloomba dams on the same day, or the next day. Education programs at Tinaroo Dam have targeted the issue of aquatic weed transfer (A. Hogan *pers. comm.*). Tinaroo Dam contains a number of flora and fauna species that do not occur within Koombooloomba Dam, including salvinia (*Salvinia molesta*) and water hyacinth (*Eichhornnia crassipes*) (Russell *et. al.* 2000). Cabomba (*Cabomba caroliniana)* forms a dense growth over a large stream length in the Leslie Creek system of Tinaroo Dam (Webb 1995, Mackey 1996) and could spread to the dam itself. It apparently originated from the same source – an ornamental pond in the upper Leslie Creek – as the tilapia also found in that system (B. Herbert *pers. comm.*). The presence of gertrude's blue-eyes, a species not native to these streams (Table 1), in these same creeks (Cogle *et. al.* 1998, B. Herbert *pers. comm.*) indicates that they too may have originated from this source. If cabomba arrives in Koombooloomba Dam, it could infest many areas of the Tully River catchment downstream, where it is currently absent.

Although native to tropical and subtropical countries, cabomba is tolerant of cold temperatures. Using climate-modelling programs, Mackey (1996) found that it could successfully establish in Victoria and Tasmania. Cabomba also occurs in Canal Creek, near Babinda, Avondale Creek, north of Cairns, Goondi Creek, near Innisfail, Diggers Creek near El Arish and Maria Creek (Mackey 1996). Movements of boats between lowland rivers (where boats are more frequently used) and upstream areas such as Tinaroo and Koombooloomba are also possible. Paluma Dam is popular with water-skiers, many of whom would also ski on the Black Weir in Ross River in Townsville. This river has large populations of a number of macrophytes that do not occur in Paluma Dam, including cabomba and water hyacinth as well as many freshwater animal species that also do not occur in Paluma Dam. Despite the temperature differences, many of the lowland species from Ross River could survive in Paluma waters. Surveys for macrophytes in streams or impoundments used by boaters in the Wet Tropics are required.

6.0 CONCLUSIONS

Waterways of the WTWHA holds numerous significant aquatic values and also include some of the most pristine and biodiverse stream systems in Australia. Though their habitat remains intact, the ecology of many streams has been compromised by the translocation of native fish species. For some faunal elements, this can be just as destructive as habitat or water quality degradation. In contrast to the spread of exotic species, native fish translocations have largely escaped the attention of most people and environmental management agencies. This is perhaps not surprising as many translocations have been undertaken by private individuals and the exact distribution of native fishes, and important aspects of their ecology, genetics and life-history, are generally not well known. Thus the appearance of native fishes in new locations is not always recognised as a translocation. Even official government programs, which have contributed significantly to the further translocation of native fishes, have attracted little environmental interest and have thus not undergone appropriate environmental evaluations. It is important to note that translocated native fishes are in many ways, ecologically equivalent to exotic fishes in their new ranges. There is a significant literature demonstrating the impacts caused by translocated native fish. It is crucial that the notion that native fish do little harm when moved to new environments, be tempered with a more balanced and responsible view on the matter, in the attitudes of government agencies, environmental scientists and the general public.

Although some records may be uncertain, and not all have established permanent populations, as many as 36 native fish species (plus red claw) appear to have been translocated into waterways of the Wet Tropics (Table 2), affecting many WTWHA streams and even a number of National Parks. Significant numbers of translocated fishes occur in the upper Barron, upper North and South Johnstone, upper Tully, upper Herbert and upper Burdekin catchments. These occur within the WTHWA, though the extent of the transgressions is not known. The catchments north of Cairns (Mowbray, Mossman, Saltwater and Daintree) appear not to have been affected by fish translocations, though red claw may be present. There are red claw aquaculture facilities in the Daintree at least (Russell *et. al.* 1998), and possibly the other catchments. The Bloomfield system is currently believed to be free from translocations though an anecdotal report of sooty grunter there is still being investigated. The streams of the Russell-Mulgrave catchment, though supporting significant populations of exotic tilapia (G. Werren *pers. comm.*), appear to be translocation-free thus far, though Lake Barrine (technically within the Mulgrave catchment) has several translocated species present. Farm dams that are likely to be stocked with non-locally native species are present in the headwaters of both the Russell and Mulgrave rivers. The Moresby and Hull systems are also translocation-free, though red claw may be present. As these rivers are entirely lowland systems, they have a reduced likelihood of receiving translocations.

Given the number of species that have been translocated into the Wet Tropics and the number of streams affected, the potential extent of modification of the fauna of Wet Tropics waterways is significant. There has been insufficient survey and research effort to even document the distributional extent of the translocated species, let alone quantify any impacts, apart from obvious cases such as the loss of Lake Eacham rainbowfish from Lake Eacham. The lack of information readily available on this topic and the limited inter-agency co-ordination in the management of these activities, has hindered appropriate planning. For instance, in 1999, WTMA commissioned a report on the Conservation Values of Waterways in the WTWHA. Quite a few of the sub-catchments identified in that report as being of high conservation value and for which no development should occur, have been affected by stocking or translocations. This highlights the need to develop policy and strategies for fish stocking in order to ensure that intended planning actions (e.g. protection of certain streams) are successfully implemented. Many recreational activities are accounted for in the Wet

Tropics Plan, yet fish stocking, despite its high level of visibility in this area, is not. Planning and management actions will need to be guided by research into the specific impacts occurring within the Wet Tropics.

Although not often raised, the potential ecological impacts of stocking translocated native fishes above waterfalls within the WTWHA have previously been aired. In a report to WTMA, Webb (1995) expressed concerns about stocking in Tinaroo, Koombooloomba and Copperlode dams and stockings above major waterfalls in the Herbert and Johnstone Rivers. He also lamented the lack of impact assessment and administrative control over these stockings and strongly recommended that no further translocations of native fishes occur above such barriers in any catchment in the Wet Tropics. There does not appear to have been any response to this advice nor any further administrative actions to regulate or evaluate these activities.

The current priority issues for WTMA should include the distribution and impacts of translocated fish in the Koombooloomba and Paluma areas and the crater lakes, as well as the distribution and impact of translocated species in the upper North and South Johnstone rivers, upper Annan River, middle Herbert catchment and tributaries of Tinaroo Dam. Reports of sooty grunter translocation into Bloomfield cod habitat should also be followed up and this location monitored in case of future introductions there. In addition, WTMA needs to develop a policy or position to deal with future stocking requests, management of unofficial translocations, and implementing an education program on fish translocations similar to that for exotic fishes. The DPI did a preliminary investigation into reports of sooty grunter in the Bloomfield but the level of field survey was insufficient to determine if the report was correct. Even if that report is a false alarm, it is clear that vigilance is required as Bloomfield cod only occur in that single stream reach and new fish may be introduced there in the future. An education program highlighting the importance and vulnerability of Bloomfield cod and how translocated fishes may threaten its survival should receive a high priority. The local community should feel proud to have such a special fish in their local waterway. Bloomfield cod are currently quite common within their range but a captive breeding program may be warranted if any sooty grunter or other potentially damaging fish are translocated to their habitat.

Although numerous stockings have been documented in this report, of the upland catchments of the Wet Tropics, only Tinaroo Dam, Koombooloomba Dam, Copperlode Dam and the Barron River above Kuranda Weir have officially been stocked in recent years. There would seem little justification for further stocking of upland Wet Tropics streams because of (i) their high environmental values and sensitivity to introduction of novel fishes; (ii) the existence of productive impoundment fisheries in the area; and (iii) the fact that many upland streams already have established populations of translocated fishes suitable for recreational fishing. WTMA should discuss an environmental evaluation of stocking in Copperlode Dam with DPI, the sole user of stocked fish within this impoundment. The stocking programs of both Koombooloomba Dam and Tinaroo Dam also require environmental evaluation. Current information suggests that barramundi and sooty grunter do not swim up any tributaries of Tinaroo Dam (A. Hogan *pers. comm.*, Russell *et. al.* 2000) or Copperlode Dam, to any great degree (A. Hogan *pers. comm.*), although this needs to be unequivocally demonstrated. This, and the continued use of barrier nets on the dam walls, would greatly reduce the potential for impacts from the stocking program. Other fishes that display high levels of fidelity to the impoundment areas could also be considered for future stocking, subject to an environmental evaluation, monitoring and consideration of other factors such as increased visitation, weed management and disease transferral. As it is entirely surrounded by WTWHA, the stocking program at Koombooloomba Dam would have to adhere to more stringent environmental guidelines. These will require consultation with affected parties and inter-agency cooperation is required to achieve these objectives.

Table 2: Summary of translocations of native fish species in, or closely adjacent to, the Wet Tropics. Uncertain translocations are marked with an asterisk (*).

Fish Species	Location	Establishment	Reference
Barramundi	Barron River in Kuranda Weir	No	A. Hogan *pers. comm.*
	Tinaroo Dam	Regularly Stocked	MacKinnon and Cooper 1987, Hogan 1995
	Koombooloomba Dam	Regularly Stocked	Hogan 1995, Pearce 2000
	Lake Eacham	No	White 1991, G. Werren *pers. comm.*
	Lake Barrine	No	B. Bayn *pers. comm.*
	Copperlode Dam	Occasionally stocked	Hogan 1995
Sooty grunter	Annan River	Yes	Hortle and Pearson 1990, Wager 1993, Herbert *et. al.* 1995, Sheppard and Helmke 1999
	Attie Creek	Unknown, but doubtful	Hogan 1995
	Above Herbert Falls	Yes – widespread	Hogan 1995, Wager 1993
	Blencoe Creek, Kirrama Creek	Yes	Wager 1993, R. Pearson *pers. comm.*, A. Atkinson *pers. comm.*
	Above Millstream Falls	No recent records	Hogan 1995
	Hawkins Creek, lower Herbert	Probably	Hogan 1995
	Wild River	Unknown	Wager 1993
	Upper North Johnstone	Yes – widespread	Hogan 1995
	Upper South Johnstone	Yes	Hogan 1995
	Barron River above falls	Yes – also in tributaries	Hogan 1995
	Tinaroo Dam	Regularly stocked	Hogan 1995
	Lake Eacham	No	Webb 1996b, T. Vallance *pers. comm.*
	Koombooloomba Dam	Yes – uncertain distribution	Hogan 1995, Pearce 2000
	Upper Running River	Yes – uncertain distribution	Pers. obs., E. Riddle *pers. comm.*
	Copperlode Dam	No	Hogan 1995
	Bloomfield River[1]	Unconfirmed anecdote	Anecdotal angler report
Khaki bream	Barron River above Tinaroo Dam	Yes	Hogan 1995

Fish Species	Location	Establishment	Reference
Leathery Grunter[2]	Upper Running River[1]	Unconfirmed anecdote	E. Riddle *pers. comm.*
Sleepy Cod	Tinaroo Dam	Yes – widespread	Hogan 1995
	Barron River at Kuranda	Yes – widespread	Hogan 1995
	Copperlode Dam	Yes	Hogan 1995
	Upper North Johnstone River	Yes	Hogan 1995
	Upper Burdekin River	Yes – widespread	Pusey in press
	Upper Herbert River	Yes – widespread	Wager 1993
	Kirrama Creek	Uncertain	A. Atkinson *pers. comm.*
Striped Sleepy Cod	Upper Barron, below Tinaroo	Yes	DNR 1999
Silver Perch	Tinaroo Dam	No	McKay 1989, Hogan 1995
	Upper North Johnstone River	No	Hogan 1995
	Upper South Johnstone River	No	Hogan 1995
	Lower Tully River	No	Hogan 1995
	Upper Burdekin River	No	A. Atkinson *pers. comm.*, Pusey in press
	Upper Herbert River	No	A. Hogan *pers. comm.*, Webb 1996a, A. Atkinson *pers. comm.*
Golden Perch	Tinaroo Dam	No	Hogan 1995
	Upper Barron catchment	No	Prob. from farm dams
	Upper Herbert catchment	Doubtful	Webb 1996a, A. Atkinson *pers. comm.*
	Upper Burdekin River	Yes – widespread	A. Atkinson *pers. comm.*, Pusey in press
Spangled Perch	Paluma, upper Running River	Yes	Webb 1996b, Pusey in press
	Tinaroo Dam	Yes – also in tributaries	Webb *et. al.* 1996, DNR 1999
	Lake Barrine	Probably	A. Hogan *pers. comm.*
	Koombooloomba Dam	Yes	Pearce 2000, Hollaway and Hamlyn 2001
	Upper North Johnstone	Yes – widespread	B. Pusey *pers. comm.*
	Above Herbert River Falls	Yes – widespread	Wager 1993
	Blencoe Creek, Kirrama Creek	Yes	Wager 1993

Fish Species	Location	Establishment	Reference
Jungle Perch	Tinaroo Dam	No	Hogan 1995
Mouth Almighty	Lake Eacham	Yes	Barlow *et. al.* 1987
	Lake Barrine	Yes	Russell 1987
	Tinaroo Dam	Yes – also in tributaries	Webb *et. al.* 1996, DNR 1999
	Upper North Johnstone River	Yes – widespread	B. Pusey *pers. comm.*
Bony Bream	Tinaroo Dam	Yes – common	Anon 1982, Hogan 1995
	Copperlode Dam	Yes – common	Anon 1982, Hogan 1995
	Lake Eacham	Yes – common	Barlow *et. al.* 1987
	Lake Barrine	Yes - common	Werren 1997, T. Vallance *pers. comm.*
Mangrove Jack	Tinaroo Dam	No	DPI unpub. data
	Copperlode Dam	No	DPI unpub. data
Archerfish	Tinaroo Dam	Yes – widespread	Anon 1982, Hogan 1995
	Copperlode Dam	Yes	Anon 1982, Hogan 1995
	Lake Eacham	Yes	Barlow *et. al.* 1987
Black Catfish	Upper Barron catchment	Yes	Barron WAMP
	Tinaroo Dam	Yes	Hogan 1995, Barron WAMP
Rendahl's Tandan	Upper Barron catchment *	Yes – widespread	Barron WAMP
Hyrtl's Tandan	Upper Barron, below Tinaroo*	Yes but not common	Shipway 1947, Barron WAMP
Wet Tropics Tandan	Upper Barron catchment *	Probably	DNR 1999
Eel-tailed Catfish	Tinaroo Dam	Probably	Anon 1982, Hogan 1995
	Copperlode Dam	Yes	Anon 1982, Hogan 1995
	Beatrice River	Probably	Anon 1982
	Upper North Johnstone River	Yes	Hogan 1995
	Upper Burdekin River	Yes	Pusey in press
Shovel-nosed Catfish	Tinaroo Dam	No	Hogan 1995, DNR 1999
Australian Bass	Lower North Johnstone River	Probably not	T. Holman *pers. comm.*
	Upper Barron catchment	Probably not	? from farm dams
Fly-specked Hardyhead	Upper Barron catchment *	Yes	DNR 1999
Freshwater Sole	Upper Barron catchment	No	DNR 1999

Fish Species	Location	Establishment	Reference
Eastern Rainbowfish	Lake Eacham	Yes	T. Vallance *pers. comm.*
Lake Eacham Rainbowfish	Tinaroo irrigation channel*	Yes	Zhu *et. al.* 1998
Empire Gudgeon	Upper Barron catchment *	Yes	DNR 1999
Fire-tailed Gudgeon	Upper Barron catchment	Yes	DNR 1999
Macleay's Glassfish	Upper Barron catchment	Yes	DNR 1999
Mullers Glassfish	Upper Barron catchment	No	DNR 1999
Gertrude's Blue-eye	Upper Barron catchment	Yes	Webb *et. al.* 1996, Werren 1997, DNR 1999
Flathead Goby	Upper Barron catchment *	Yes	DNR 1999
Banded Grunter	Tinaroo Dam	Yes	Hogan 1995, DNR 1999
	Lake Eacham	Yes	Barlow *et. al.* 1987
Pikey Bream	Tinaroo Dam	No	Hollaway and Hamlyn 2001
Long-tom	Upper Barron catchment	No	DNR 1999
Snub-nosed Gar	Upper Barron catchment	Yes	DNR 1999
Northern Saratoga	Tinaroo Dam	Uncertain	Anon 1982, Hogan 1995
	Koombooloomba Dam[1]		A. Hogan *pers. comm.*
	Maria Creek	No, or in low numbers	Hogan 1995, Russell and Hales 1997
Southern Saratoga	Upper Barron catchment[2]	No	QFMA (1996)
Murray Cod	Koombooloomba Dam[1]	Unconfirmed anecdote	A. Hogan *pers. comm.*
	Upper Burdekin River	No	A. Atkinson *pers. comm.*
Red Claw Crayfish	Tinaroo Dam	Yes – common	Hogan 1995
	Upper Barron catchment	Yes – widespread	Russell *et. al.* 2000
	Liverpool Creek	Present	Hogan 1995, Russell and Hales 1997
	Koombooloomba Dam	Yes	Hogan 1995, Pearce 2000
	Johnstone catchment	Yes	B. Pusey *pers. comm.*
	Upper Burdekin catchment	Yes – widespread	Burrows and Tait 1999, Hogan and Vallance 1998

Fish Species	Location	Establishment	Reference
Red Claw Crayfish	Paluma Dam area	Yes	R. Hunt *pers. comm.*
	Lake Eacham	Yes – common	K. McDonald *pers. comm.*, T. Vallance *pers. comm.*

1 Anecdotal report only. Presence or identity of fish not confirmed.

2 This may actually be northern saratoga.

Clearly some inappropriate translocations have occurred. Where these have resulted in the establishment of a breeding population, eradication may have to be considered. However, this is a difficult and expensive undertaking. Meronek *et. al.* (1996) reported that 107 of 250 fish control projects they reviewed were successful, though this is probably an overestimate as failures are less likely to be reported. Eradication of trout, which have been strongly implicated in the decline of endangered spotted tree frog, *Litoria spenceri,* from some Victorian streams, is planned and budgeted in the recovery plan for this species (Gillespie and Robertson 1998). No recommendations for eradication or other forms of control are recommended here at this stage. Such actions should only be justified based on the results of more detailed environmental evaluation. An exception would be if sooty grunter or khaki bream are detected in the habitat of Bloomfield cod. These should be eradicated immediately upon detection.

Translocations to lowland streams would seem unnecessary, unless to assist in conservation goals. Augmentation of barramundi populations in lowland streams and estuaries has less environmental issues than stocking into upland streams. Stocking is not likely to be justified in a healthy system where overfishing is not occurring. Existing fishery regulations are available to limit the extent of overfishing. Stocking has been of most benefit in impoundments that have underutilised habitat, and where populations of fish suffer heavy commercial or recreational fishing pressure. Thus, in estuaries and lowland streams, reductions of fish populations should be demonstrated before stocking occurs. Additionally, the number of fish to be stocked should be appropriate to the population occurring there.

Apart from stockings that are for recreational benefit, many translocations also result from farm dam and aquacultural escapes. The extent of farm dam stocking is unknown. This has been widely encouraged over the last 20 years, though more recently, there have been moves to regulate the species that are used. Fish that are not native to the Wet Tropics, such as silver perch, golden perch and red claw cannot be used without a permit. Aquaculture is regulated by the DPI and further coordination with them on this matter is required.

The precautionary principle, which is government policy, needs to be more fully implemented. This principle would dictate that before stocking proceeds, proponents should demonstrate that the translocations will not harm the environment. This rarely occurs. In recent years, the inclusion of environmental considerations in stocking decisions has improved but they still remain under-represented. The number of streams within National Parks and the WTWHA that have translocated fishes present, and the number of habitats of endangered aquatic species which have been similarly infiltrated, is testament to the failure of environmental agencies and their protocols to protect these habitats and species from such invasions.

One of the current failings of existing regulations covering the movements of fish species is the reliance on whole catchments as management units. Because fish make extensive movements throughout stream systems, they are commonly managed on a whole catchment basis. In many situations, this is inappropriate. Even where no major barriers such as waterfalls exist, very few fish species are distributed throughout a whole catchment. Where waterfalls do occur, there are major differences between the fish communities above and below these barriers. For example, under current legislation (Fisheries Freshwater Management Plan 1999), fishes such as barramundi, mangrove jack, sooty grunter, jungle perch are considered to be native to the Barron, Johnstone, Tully and Burdekin catchments, even though they do not naturally occur in the extensive upland sections of those catchments. It is thus not illegal to release them into the upper parts of these catchments. For the few species that do occur both above and below such barriers (e.g. rainbowfish, purple-spotted gudgeons, hardyheads), recent genetic studies indicate they there is limited exchange between the upland and lowland populations and even limited exchange between populations with each section of a catchment. Stocking and the natural distribution of fishes, needs to be considered at within-catchment scales to take into account the effects of fish passage barriers that limit fish distributions.

Though this report has focused on the potential impacts of fish stocking and translocations, it is not intended to suggest that there is no place for fish stocking. Recreational fishing is an extremely popular activity, with significant economic and social benefits, especially for small, regional communities. Stocked impoundments such as Tinaroo and Koombooloomba provide recreational fishing opportunities where few or none would otherwise exist. Such programs can be compatible with maintaining desired environmental values, but only when the potential impacts are recognised and evaluated, and managed accordingly.

7.0 KEY RESEARCH AND MANAGEMENT RECOMMENDATIONS

The following actions are recommended for the WTMA.

1. Document the stockings and translocations that have occurred to date in the Wet Tropics region. This report has addressed this task, though it is recognised that it cannot be exhaustive. WTMA should request of DPI a comprehensive list of known stockings including dates, exact locations, number of fish stocked and their source, and WTMA should be consulted about any further stockings that may impinge on the WTWHA or its values.

2. Identify the distribution and abundance of stocked fishes within important streams. A critical step for management is knowing just how much of the WTWHA has been infiltrated by what species and in what locations. This report identifies stockings that have occurred but only field surveys can verify their current distribution in most cases. Existing fisheries surveys have focused most effort on larger, more diverse streams. Smaller headwater streams have rarely been sampled. The presence of many waterfalls and the degree to which small headwater streams are infiltrated by stocked fish means that their distribution will require mapping at a fine scale, rather than the catchment or sub-catchment scale more commonly applied to fish distribution reports. This requires field sampling in key areas. Sampling should include more than one period of the year as fishes may only be present during certain times of the year (e.g. during elevated wet season flows). A prioritised list of sites for sampling is provided in Table 3. This list applies mainly to streams of the WTWHA only. There are many streams that would otherwise have a high priority for survey but are wholly or largely outside the WTWHA. Some streams that are outside the WTWHA but hold values important to the WTWHA (e.g. potential frog habitat) are included. Some of the streams are not known to have any translocated fishes but as they have never been surveyed previously, are included in case that unreported translocations are present and in order to document their current fish fauna in the event of future translocations occurring.

3. Undertake an environmental evaluation of the existing, and some previous, stocking programs. To date, there has been no assessment of the impacts of stocked fishes on natural environments or locally native fauna. Such assessments should be undertaken for Koombooloomba Dam, Copperlode Dam and Tinaroo Dam, as these are ongoing stockings involving large numbers of fish. Previous stockings into the North Johnstone River, the Barron River between Barron Falls and Tinaroo Dam, the Annan River, tributaries of the middle Herbert River, and streams of the Paluma area, should also be considered for evaluation. This evaluation should include investigating impacts on native frogs and aquatic invertebrates as well as other fish. The evaluations should take account of the individual species involved, including new species such as mangrove jack and jungle perch, and the indirect impacts of stocking discussed in section 5.0. As the agency supporting several of these stockings, DPI-QFS should be supporting these tasks.

4. Investigate the role of farm dams and aquaculture facilities as sources of fish introductions. This report has mentioned escapes from farm dams and aquaculture facilities in several places. The contribution of such facilities to fish introductions is not known but potentially significant. An audit of farm dams and aquaculture facilities that hold fish or crustaceans is required. Inappropriate or illegal holdings should be removed. An education program is essential to reduce the incidence of inappropriate farm dam stockings.

5. Become more involved with the regulation and management of fish stocking. WTMA needs to be aware of fish stocking issues in advance of their approval and to have a say in whether or not they are approved. This requires more involvement in the fish stocking process in Queensland than is currently being exercised. This is best achieved through coordination with the FMAC and having input into all stocking requests for the Wet Tropics. Previously, WTMA have not been consulted about stockings occurring in the Wet Tropics. Recently, for the first time, stocking requests have been referred to WTMA. This is currently an informal process, but should be formalised to ensure its continuation. Also the Freshwater Management Plan that provides subordinate legislation for freshwater fishing issues in Queensland, is periodically reviewed. WTMA should have input into this process.

6. Develop a fish stocking policy and include fish stocking in the Wet Tropics Management Plan. If WTMA is to be involved in assessing fish stocking requests and liasing with other agencies on aspects of their policies relating to fish stocking, then it will need to develop a policy for dealing with fish stocking procedures and requests in a coordinated and consistent manner. Numerous environmentally relevant activities are included in the Wet Tropics Management Plan, but fish stocking and native fish translocation are not. Only exotic fish are covered. Translocated native fish should follow similar guidelines to exotics but still allow for the continuation of appropriate and properly monitored stocking programs. Development of policy, and alterations to the Wet Tropics Management Plan, will also need to take into account indirect effects of increased fishing activities (e.g. increased visitation, water quality, transfer of weeds) and should reinforce the precautionary principle.

7. Develop and implement an education program to reduce the incidence of translocations and stockings by private individuals. Most of the translocations in the Wet Tropics have been undertaken by private individuals, either intentionally, accidentally or naively. Similar education programs aimed at reducing the spread of exotic fish and weed species have proved very effective at changing public attitudes. This program would need to highlight the inherent values of the naturally low fish diversity of upland Wet Tropics streams, the potential impacts of translocating native fishes and the regulations and illegality of unauthorised stockings.

Table 3: Priority Survey Areas Within the Wet Tropics World Heritage Area. Low priority sites are not listed so all listed sites have a high priority. Rankings are from 1-5 with 1 being highest priority.

Catchment	Creek	Key Likely Targets	Priority
Burdekin Catchment			
Paluma Dam area	Upstream tributaries of Paluma Dam	Spangled perch, red claw, frogs	1
	Birthday Creek	Spangled perch, frogs	1
	Williams Creek	Spangled perch, frogs	1
	Upper Running River	Sooty grunter, spangled perch	2
	Hermit Creek	Spangled perch, frogs	5
Tully Catchment			
Upper Tully system	Tributaries of Koombooloomba Dam	Sooty grunter, spangled perch, red claw, frogs, crustaceans	1
	Nitchaga Creek	Sooty grunter, spangled perch, red claw, frogs, crustaceans	1
Herbert Catchment			
Middle Herbert	North Blencoe Creek, Kirrama Creek	Sooty grunter	2
	Stony Creek above Wallaman Falls	Sooty grunter	3
	Garrawalt Creek above falls	Sooty grunter	4
	Yamanie Creek, Herkes Creek, Sword Creek above falls	Sooty grunter	5
Upper Herbert	Cameron Creek	Sooty grunter, spangled perch	3
	Blunder Creek	Sooty grunter, spangled perch	3
Johnstone Catchment			
North Johnstone	Douglas Creek system	Sooty grunter, sleepy cod and others	1
	Beatrice River	Sooty grunter, sleepy cod and others	3
	Dirran Creek	Sooty grunter, sleepy cod and others	2
	Upstream reaches of North Johnstone River	Sooty grunter, sleepy cod and others	2
South Johnstone	Upper reaches of South Johnstone River and tributaries	Sooty grunter, sleepy cod and others	2
	Upstream reaches of Mena Creek	Sooty grunter	5
Russell-Mulgrave Catchment			
Upper Russell River	Kiandra Creek	Sooty grunter, sleepy cod	3

Catchment	Creek	Key Likely Targets	Priority
Upper Mulgrave River	Butcher Creek, Toohey Creek	Sooty grunter, sleepy cod	3
Barron Catchment			
Tinaroo catchment	Lake Eacham	Rainbowfish, red claw, exotics	3
	Lake Barrine	Rainbowfish, mouth almighty	1
	Lake Euramoo	Mouth almighty	1
	Upstream reaches of Barron River	Sooty grunter, barramundi and others	4
	Kauri Creek, Robson Creek	Sooty grunter and others	2
	Mobo Creek, Severin Creek	Sooty grunter and others	2
	Wright Creek, Congoo Creek	Sooty grunter and others	2
mid-Barron	Emerald Creek	Sooty grunter, sleepy cod	5
	Davies Creek	Sooty grunter, sleepy cod	2
	Bridle Creek	Sooty grunter, sleepy cod	1
	Upstream reaches of Clohesy River	Sooty grunter, sleepy cod	2
Freshwater Creek	Tributaries of Copperlode Dam	Sooty grunter, barramundi and others, plus frogs	2
Other Catchments			
Meunga Creek	Meunga Creek and tributaries	Sooty grunter	5
Mowbray River	Above Mowbray Falls	Unknown	5
Bloomfield River	Above Bloomfield Falls	Sooty grunter	1
Annan River	Upstream reaches	Sooty grunter	2

8.0 REFERENCES

Alford, R.A. and Richards, S.J. 1997. Lack of evidence for epidemic disease as an agent in the catastrophic decline of Australian rainforest frogs. Conservation Biology 11: 1026-1029.

Allen, G.R. 1989a. Freshwater Fishes of Australia. T.F.H. Publications Inc. USA. 240pp.

Allen, G.R. 1989b. Lake Eacham rainbowfish rediscovered? Fishes of Sahul 5: 217-219.

Allen, G.R. 1995. Rainbowfishes: In Nature and in the Aquarium. Tetra-Verlag, Melle.

Allen, G.R. and Coates, D. 1990. An ichthyological survey of the Sepik River, Papua New Guinea. Records of the West Australian Museum Supplement No. 34: 31-116.

Allen, G.R. and Cross, N.J. 1982. Rainbowfishes of Australia and Papua New Guinea. Angus and Robertson, Sydney.

Allen, G.R. and Pusey, B.J. 1999. *Hephaestus tulliensis* De Vis, a valid species of grunter (Terapontidae) from freshwaters of north-eastern Queensland, Australia. Aqua, Journal of Ichthyology and Aquatic Biology 3: 157-162.

Allendorf, F.W., Spruell, P. and Utter, F.M. 2001. Whirling disease and wild trout: Darwinian fisheries management. Fisheries 26: 27-29.

Almodovar, A., Suarez, J., Nicola, G.G. and Nuevo, M. 2001. Genetic introgression between wild and stocked brown trout in the Douro River basin, Spain. Journal of Fish Biology 59: Supp. A: 68-74.

Altukhov, Y.P. and Salmenkova, E.A. 1987. Stock transfer relative to natural organization, management and conservation of fish populations. Pages 333-344 In: Ryman, N. and Utter, F. (eds.). Population Genetics and Fishery Management. Washington Sea Grant Program, University of Washington Press, Seattle.

Anon. 1982. Northern fish hatchery expands production, steps up stocking. Australian Fisheries 41(9):18-20.

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

Bianco, P.G. and Ketmaier, V. 2001. Anthropogenic changes in the freshwater fauna of Italy, with reference to the central region and *Barbus graellsii*, a newly established alien species of Iberian origin. Journal of Fish Biology 59: Supplement A: 190-208.

Barel, C.D.N. and others. 1985. Destruction of fisheries in Africa's lakes. Nature 315: 19-20.

Barlow, C.G. and Lisle, A. 1987. Biology of the nile perch *Lates niloticus* (Pisces: Centropomidae) with reference to its proposed role as a sport fish in Australia. Biological Conservation 39: 269-289.

Barlow, C.G., Hogan, A.E. and Rogers, L.G. 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.

Baskin, Y. 1992. Africa's troubled waters – fish introductions and a changing physical profile muddy Lake Victoria's future. BioScience 42: 476-481.

Behnke, R.J. 1979. Monograph of the Native Trouts of the Genus *Salmo* of Western North America. Fish and Wildlife Service: Region 6, USA.

Binckley, C.A. and Resitarits, W.J.Jr. 2002. Reproductive decisions under threat of predation: squirrel treefrog (*Hyla squirella*) responses to banded sunfish (*Enneacanthus obesus*). Oecologia 130: 157-161.

Blankenship, H.L. and Leber, K.M. 1995. A responsible approach to marine stock enhancement. American Fisheries Society Symposium 15: 167-175; also reprinted as Pages 485-491 In: Hancock, D.A., Smith, D.C., Grant, A. and Beumer, J.P. (eds.). 1997. Developing and Sustaining World Fisheries Resources: The State of Science and Management. Proceedings of the 2nd World Fisheries Congress, Brisbane, Qld 1996. CSIRO Publishing, Canberra.

Boon, P.I., Bunn, S.E., Green, J.D. and Shield, R.J. 1994. Consumption of cyanobacteria by freshwater zooplankton: implications for the success of 'top-down' control of cyanobacterial blooms in Australia. Australian Journal of Marine and Freshwater Research 45: 875-887.

Bouffard, S.H. and Hanson, M.A. 1997. Fish in waterfowl marshes: waterfowl manager's perspective. Wildlife Society Bulletin 25: 146-157.

Bradford, D.F. 1989. Allopatric distribution of native frogs and introduced fishes in high Sierra Nevada lakes of California: implication of the negative effect of fish introductions. Copeia 3: 775-778.

Bradford, D.F., Tabatabai, F. and Graber, D.M. 1993. Isolation of remaining populations of the native frog, *Rana muscosa*, by introduced fishes in Sequoia and Kings Canyon National Parks, California. Conservation Biology 7: 882-888.

Brancelj, A, Milijan, S., Brancelj, I.R., Jeran, Z. and Jacimovic, R. 2000. Effects of land use and fish stocking on a mountain lake: evidence from the sediment. Periodicum Biologorum 102: 259-268.

Bronmark, C. and Edenhamn, P. 1994. Does the presence of fish affect the distribution of tree frogs (*Hyla arborea*)? Conservation Biology 8: 841-845.

Burrows, D.W. and Tait, J.P. 1999. Fish and Crustacean Survey of the Townsville Field Training Area (TFTA). Report No. 99/18 Australian Centre for Tropical Freshwater Research, James Cook University, Townsville.

Burrows, D., Faithful, J., Kutt, A., Tait, J. and Blunden, L. 1999. Environmental Study of a Proposed Dam at Mount Douglas on the Belyando River. Report No. 99/28 Australian Centre for Tropical Freshwater Research, James Cook University, Townsville.

Burrows, D.W. 2001. Monitoring of Riparian Environments With Respect to the Benefits of Fencing – Year 2 Report. Report No. 01/03 Australian Centre for Tropical Freshwater Research, James Cook University, Townsville.

Choy, S. and Marshall, J. 1997. Two new species of freshwater atyid shrimps (Crustacea: Decapoda: Atyidae) from northern Queensland and the distributional ecology of the *Caridina typus* species group in Australia. Memoirs of the Queensland Museum 41: 25-36.

Clayton, P.D. 1994. Charters Towers Weir EIS. Report No. 94/19 Australian Centre for Tropical Freshwater Research, James Cook University, Townsville.

Cogle, L., Gourley, J., Herbert, B. and Best, E. 1998. Nutrient Control Strategy for Tropical Catchments. Department of Natural Resources, Mareeba.

Concepcion, G.B. and Nelson, S.G. 1999. Effects of a dam and reservoir on the distributions and densities of macrofauna in tropical streams of Guam (Mariana Islands). Journal of Freshwater Ecology 14: 447-454.

Cook, B. 1998. The Ecological Role of the Redclaw Crayfish, *Cherax quadricarinatus*, and its Potential Impacts on Other Aquatic Macroinvertebrates. Freshwater Biological Monitoring Report No. 11, Department of Natural resources, Brisbane.

Courtenay, W.R.Jr. 1990. Fish conservation and the enigma of introduced species. Pages 11-20 In: Pollard, D.A (ed.). Introduced and Translocated Fishes and Their Ecological Effects. Proceedings of a Workshop by the Australian Society for Fish Biology held on Magnetic Island, Townsville, Queensland 24-25 August 1989. Australian Govt. Publishing Service, Canberra.

Crook, D. and Sanger, A. 1997. Recovery Plan for the Pedder, Swan, Clarence, Swan and Saddled Galaxias. Inland Fisheries Commission, Tasmania.

Cunningham, M. 2002. Identification and evolution of Australian torrent treefrogs (Anura: Hylidae: *Litoria nannotis* group). Memoirs of the Queensland Museum 48: 93-102.

Daszak, P. *et. al.* 1999. Emerging infectious diseases and amphibian population declines. Emerging Infectious Diseases 5: 735-747.

Department of Natural Resources. 1999. Barron Basin Water Allocation Management Plan. Queensland Department of Natural Resources, Brisbane.

Dixon, P. 1990. Hatchery releases – take care. Page 151 (abstract) In: Pollard, D.A (ed.). Introduced and Translocated Fishes and Their Ecological Effects. Proceedings of a Workshop by the Australian Society for Fish Biology held on Magnetic Island, Townsville, Queensland 24-25 August 1989. Australian Government Publishing Service, Canberra.

Dove, R. and Taylor, B. 1982. Studies on aquatic macrophytes, Part XXXVI: the 1981 Aquatic Plant Quarantine Project. Assessment and Planning Division Bulletin 18, Ministry of Environment (British Columbia), Victoria. British Columbia, Canada.

Elvira, B. and Almodovar, A. 2001. Freshwater fish introductions in Spain: facts and figures at the beginning of the 21st century. Journal of Fish Biology 59:Supplement A: 323-331.

EPBC. 1999. Environment Protection and Biodiversity Conservation Act. Environment Australia, Commonwealth of Australia, Canberra.

Fickling, S. 1995. The Influence of Fish Predators on the Local Distribution of Frogs and Tadpoles in Rainforest Streams of the Tully River. Honours Thesis, James Cook University, Townsville.

Fisheries (Freshwater) Management Plan 1999. SL No. 54 of 1999. Queensland Govt., Brisbane. 84pp.

Flecker, A.S. et. al. 2002. Interactions between herbivorous fishes and limiting nutrients in a tropical stream ecosystem. Ecology 83: 1831-1844.

Garcia-Marin, J.L., Sanz, N. and Pla, C. 1999. Erosion of the native genetic resources of brown trout in Spain. Ecology of Freshwater Fish 8: 151-158.

Gehrke, P.C. and Harris, J.H. 1994. The role of fish in cyanobacterial blooms in Australia. Australian Journal of Marine and Freshwater Research 45: 909-915.

Gillespie, G. and Robertson, P. 1998. Spotted Tree Frog 1998-2002 Recovery Plan. Report to Environment Australia, Canberra. Victorian Department of Natural Resources and Environment.

Gillespie, G. and Hero, J-M. 1999. Potential impacts of introduced fish and fish translocations on Australian amphibians. Pages 131-144 In: Campbell, A. (ed.). Declines and Disappearances of Australian Frogs. Environment Australia, Canberra.

Gillespie, G.R. 2001. The role of introduced trout in the decline of the spotted tree frog (*Litoria spenceri*) in south-eastern Australia. Biological Conservation 100: 187-198.

Havel, J.E., Mabee, W.R. and Jones, J.R. 1995. Invasion of the exotic cladoceran *Daphnia lumholtzi* into North American reservoirs. Canadian Journal of Aquatic and Fisheries Sciences 52: 151-160.

Herbert, B.W. 1987. Notes on the diseases and epibionts of *Cherax quadricarinatus* and *C. tenuimanus* (Decapoda: Parastacidae). Aquaculture 64: 165-173.

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). Queensland Dept. Primary Industries, Brisbane.376pp.

Hero, J-M. and Gillespie, G. 1997. Epidemic disease of amphibian declines in Australia. Conservation Biology 11: 1023-1025.

Hero, J-M, Gascon, C. and Magnusson, W.E. 1998. Direct and indirect effects of predation on tadpole community structure in the Amazon rainforest. Australian Journal of Ecology 23: 474-482.

Hero, J-M, Magnusson, W.E., Rocha, C.F.D. and Catterall, C.P. 2001. Antipredator defenses influence the distribution of amphibian prey species in the central Amazon rain forest. Biotropica 33: 131-141.

Hilborn R. 1992. Hatcheries and the future of salmon in the northwest. Fisheries 17: 5-8

Hitchcock, G. 2002. Fish fauna of the Bensbach River, southwest Papua New Guinea. Memoirs of the Queensland Museum 48: 119-122.

Hogan, A. 1995. A history of fish stocking in northern Queensland – where are we at?. Pages 8-24 In: Cadwallader, P. and Kerby, B. (eds.). Fish Stocking in Queensland Getting it Right! Proceedings of the Symposium held in Townsville, Queensland, 11 November 1995. Queensland Fisheries Management Authority, Brisbane. 96pp.

Hogan, A. and Vallance, T. 1998. Summary of Burdekin River Fisheries Reports (Draft Report). Queensland Department of Primary Industries, Walkamin.

Hollaway, M. and Hamlyn, A. 2001. Freshwater Fishing in Queensland A Guide to Stocked Waters (2nd ed.). QDPI Information Series QI01034. Queensland Department of Primary Industries, Brisbane.154pp. 1st edition =1998.

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.

Hughes, J.E., Bunn, S.E., Hurwood, D.A., Choy, S. and Pearson, R. 1996. Genetic differentiation among populations of *Caridina zebra* (Decapoda: Atyidae) in tropical rainforest streams, northern Australia. Freshwater Biology 36: 289-296.

Hurwood, D.A. and Hughes, J.M. 1998. Phylogeography of the freshwater fish, *Mogurnda adspersa*, in streams of northeastern Queensland, Australia: evidence for altered drainage patterns. Molecular Ecology 7: 1507-1517.

Hurwood, D.A. and Hughes, J.M. 2001. Historical interdrainage dispersal of eastern rainbowfish from the Atherton Tableland, north-eastern Australia. Journal of Fish Biology 58: 1125-1136.

Hyatt, A.D. and Cunningham, A.A. 2000. Ranaviruses; a threat to amphibians?. Abstract p.29 In: Getting the Jump on Amphibian Disease. Conference and Workshop Compendium. Rainforest CRC, James Cook University, Cairns.

Johnson, L.E. and Carlton, J.T. 1996. Post-establishment spread in large-scale invasions: dispersal mechanisms of the zebra mussel *Dreissena polymorpha.* Ecology 77: 1686-1690,

Johnson, L.E., Ricciardi, A. and Carlton, J.T. 2001. Overland dispersal of aquatic invasive species: a risk assessment of transient recreational boating. Ecological Applications 11: 1789-1799.

Johnstone, I.M., Coffey, B.T. and Howard-Williams, C. 1985. The role of recreational boat traffic in interlake dispersal of macrophytes: a New Zealand case study. Journal of Environmental Management 20: 263-279.

Jones, C.M., McPhee, C.P. and Ruscoe, I.M. 2000. A review of genetic improvement in growth rate in red claw crayfish *Cherax quadricarinatus* (von Martens) (Decapoda: Parastacidae) Aquaculture Research 31: 61-67.

Joyce, J.C. 1992. Impact of *Eichhornnia* and *Hydrilla* in the United States. International Council for Exploration of the Sea (ICES) Marine Science Symposium 20: 263-279.

Kaufman, L. 1992. Catastrophic change in species-rich freshwater ecosystems – the lessons of Lake Victoria. BioScience 42: 846-858.

Keenan, C.P. 1994. Recent evolution of population structure in Australian barramundi, *Lates calcarifer* Bloch): an example of isolation by distance in one dimension. Australian Journal of Marine and Freshwater Research 45: 1123-1148.

Kennan, C.P. 1995. Genetic implications of fish stocking. Pages 64-71 Pages 8-24 In: Cadwallader, P. and Kerby, B. (eds.). Fish Stocking in Queensland Getting it Right!

Proceedings of the Symposium held in Townsville, Queensland, 11 November 1995. Queensland Fisheries Management Authority, Brisbane. 96pp.

Keenan, C.P. 2000. Should we allow human-induced migration of the Indo-West Pacific fish, barramundi *Lates calcarifer* (Bloch) within Australia? Aquaculture Research 31: 121-131.

Kiesecker, J.M., Blaustein, A.R. and Miller, C.I. 2001. Transfer of a pathogen from fish to amphibians. Conservation Biology 15: 1064-1070.

Knapp, R.A., Matthews, K.R. and Sarnelle, O. 2001. Resistance and resilience of alpine lake fauna to fish introductions. Ecological Monographs 71: 401-423.

Konishi, M., Nakano, S. and Iwata, T. 2001. Trophic cascading effects of predatory fish of leaf litter processing in a Japanese stream. Ecological research 16: 415-422.

Langdon, J.S. 1990. Disease risks of fish introductions and translocations. Pages 98-107 In: Pollard, D.A (ed.). Introduced and Translocated Fishes and Their Ecological Effects. Proceedings of a Workshop by the Australian Society for Fish Biology held on Magnetic Island, Townsville, Queensland 24-25 August 1989. Australian Government Publishing Service, Canberra.

Larson, D.W. 2000. Waldo Lake, Oregon: eutrophication of a rare, ultraoligotrophic, high-mountain lake. Lake and Reservoir Management 16: 2-16.

Laurance, W.F., McDonald, K.R. and Speare, R. 1996. Epidemic disease and the catastrophic decline of Australian rainforest frogs. Conservation Biology 10: 406-413.

Leavitt, P.R., Schindler, D.E., Paul, A.J., Hardie, A.K. and Schindler, D.W. 1994. Fossil pigment records of phytoplankton in trout-stocked alpine lakes. Canadian Journal of Fisheries and Aquatic Sciences 51: 2411-2423.

Leberer, T. and Nelson, S.G. 2001. Factors affecting the distribution of atyid shrimps in two tropical insular rivers. Pacific Science 55: 389-398.

Levin, P.S. and Williams, J.G. 2002. Interspecific effects of artificially propagated fish: an additional conservation risk for salmon. Conservation Biology 16: 1581-1587.

Lowe-McConnell, R. 2002. Cichlids all! With an ecological view of African cichlids. Environmental Biology of Fishes 63: 459-463.

McDougall, A. and Pearce, M. 1999. Fish species sampled in the post-stocking survey of the Annan River Weir 1/10/99. Queensland Department of Primary Industries, Cairns.

Mackey, A.P. 1996. Cabomba in Queensland – Pest Status Review Series. Queensland Department of Natural Resources, Land Protection Branch, Brisbane. 35pp.

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

McDonald, K.R. and Alford, R.A. 1999. A review of declining frogs in northern Queensland. Pages 14-22 In: Campbell, A. (ed.). Declines and Disappearances of Australian Frogs. Environment Australia, Canberra. 234pp.

McDougall, A. and Pearce, M. 1999. Fish species sampled in the post-stocking survey of the Annan River Weir 1/10/99. Queensland Dept. of Primary Industries, Northern Fisheries Centre, Cairns.

McGlashan, D.J. and Hughes, J.M. 2000. Reconciling patterns of genetic variation with stream structure, earth history and biology in the Australian freshwater fish *Craterocephalus stercusmuscarum* (Atherinidae). Molecular Ecology 9: 1737-1751.

McGlashan, D.J. and Hughes, J.M. 2002. Extensive genetic divergence among populations of the Australian freshwater fish, *Pseudomugil signifer* (Pseudomugilidae), at different hierarchical scales. Marine and Freshwater Research 53: 897-907.

McGlashan, D.J., Hughes, J.K. and Bunn, S.E. 2001. Within-drainage population genetic structure of the freshwater fish *Pseudomugil signifer* (Pseudomugilidae) in northern Australia. Canadian Journal of Fisheries and Aquatic Sciences 58: 1842-1852.

McGuigan, K.L. 2000. An addition to the rainbowfish (Melanotaeniidae) fauna of north Queensland. Memoirs of the Queensland Museum 46: 647-655.

McGuigan, K.L., Zhu, D., Allen, G.R. and Moritz, C. 2000. Phylogenetic relationships and historical biogeography of melanotaeniid fishes in Australia and New Guinea. Marine and Freshwater Research 51: 713-723.

McKay, R.J. 1989. Exotic and translocated freshwater fishes in Australia. Pages 21-34 In: de Silva, S.S. (ed.). Exotic Aquatic Organisms in Asia. Proceedings of the Workshop on Introduction of Exotic Aquatic Organisms in Asia. Asian Fisheries Society Special Publication 3. Asian Fisheries Society, Phillippines. 154pp.

Malcolm, H., Graham, P., Burnham, M., Inglis, G. and Ford, M. 1997. Freshwater Fishes of Hinchinbrook Island. Unpublished Report. Department of Environment and Department of Primary Industries. 27pp.

Mancinelli, G., Costantini, M.L. and Rossi, L. 2002. Cascading effects of predatory fish exclusion on the detritus-based food web of a lake littoral zone (Lake Vico, central Italy). Oecologia 133: 402-411.

Matveev, V. and Matveeva, L. 1997. Grazer control and nutrient limitation of phytoplankton biomass in two Australian reservoirs. Freshwater Biology 38: 49-65.

Meronek, T,G, et. al. 1996. A review of fish control projects. North American Journal of Fisheries Management 16: 63-74.

Midgley, S.H. 1968. A study of the nile perch in Africa (and consideration for its suitability for Australian tropical inland waters). Winston Churchill Memorial Trust Fellowship Report No.3.

Midgley, S.H. 1977. Burdekin River Catchment Survey. Report to Queensland Fisheries Service, Brisbane.

Midgley, S.H. 1981. To introduce or not to introduce nile perch: The case for. SAFIC 5(4-5):6-8.

Miller, R.R., Williams, J.D. and Williams, J.E. 1989. Extinction of North American fishes during the past century. Fisheries 14: 22-38.

Moulton, T.P. 2001. Beyond monitoring – the understanding of biodiversity and ecosystem functioning in streams of the Atlantic rainforest, Brazil. Pages 441-445 In: Rutherford, I. *et. al.* (eds.). Proceedings of the Third Australian Stream Management Conference: The Value of Healthy Streams, 27-29 August 2001, Brisbane. CRC for Catchment Hydrology, Monash University, Victoria.

Moyle, P.B. 1986. Fish introductions into North America: patterns and ecological impact. Pages 27-43 In: Mooney, H.A. and Drake, J.A. (eds.). Ecology of Biological Invasions of North America and Hawaii. Spriger-Verlag. 321pp.

Moyle, P.B., Daniels, R.A., Herbold, J.C. and Baltz, D.M. 1986. Annual and long-term patterns in distribution and abundance of a noncoevolved assemblage of estuarine fishes in California. Fishery Bulletin 84: 105-117.

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: 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 3: 526-534.

Nilsson, N. 1972. Effects of introduced salmonids into barren lakes. Journal of the Fisheries Research Board of Canada 29: 693-697.

Nolen, J.A. and Pearson, R.G. 1993. Factors affecting litter processing by *Anisocentropus kirramus* (Trichoptera: Calamoceratidae) from an Australian tropical rainforest stream. Freshwater Biology 29: 469-479.

Ono, R,D,. Williams, J.D. and Wagner, A. 1983. Vanishing Fishes of North America. Stone Wall Press, Washington D.C. 257pp.

Owens, L. and Cullen, B. 2000. The potential role of pest fish in spreading systemic iridoviruses. Abstract p.33 In: Getting the Jump on Amphibian Disease. Conference and Workshop Compendium. Rainforest CRC, James Cook University, Cairns.

Padilla, D.K., Chotkowski, M.A. and Buchan, L.A.J. 1996. Predicting the spread of zebra mussels (*Dreissena polymorpha*) to inland watersheds: consequences of boater movement patterns. Global Ecology and Biogeography Letters 5: 353-359.

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

Pearson, R.G. and Tobin, R.K. 1989. Litter consumption by invertebrates from an Australian tropical rainforest stream. Arch. Hydrobiol. 116: 71-80.

Pearson, R.G., Benson, L.J. and Smith, R.E.W. 1986. Diversity and abundance of the fauna of Yuccabine Creek, a tropical rainforest stream. Limnology in Australia. Pages 329-342 In: de Dekker, P. and Williams, W.D.W. (eds.). Limnology in Australia, CSIRO, Melbourne.

Pearson, R.G., Tobin, R.K., Smith, R.E.W. and Benson, L.J. 1989. Standing crop and processing of rainforest litter in a tropical Australian stream. Arch. Hydrobiol. 115: 481-498.

Pierce, B.E. 1990. Biological impacts of translocations on North American salmonids, or how to use the latest U.S. fisheries management techniques to decimate otherwise useful fisheries. Pages 127-135 In: Pollard, D.A (ed.). Introduced and Translocated Fishes and Their Ecological Effects. Proceedings of a Workshop by the Australian Society for Fish Biology held on Magnetic Island, Townsville, Queensland 24-25 August 1989. Australian Govt. Publishing Service, Canberra.

Pierce, C.L. and Hinrichs, B.D. 1997. Response of littoral invertebrates to reduction of fish density: simultaneous experiments in ponds with different fish assemblages. Freshwater Biology 37: 397-408.

Pilliod, D.S. and Peterson, C.R. 2001. Local and landscape effects of introduced trout on amphibians in historically fishless watersheds. Ecosystems 4: 322-333.

Pollard, D.A. 1990. Introduction to the workshop. Pages 4-10 In: Pollard, D.A (ed.). Introduced and Translocated Fishes and Their Ecological Effects. Proceedings of a Workshop by the Australian Society for Fish Biology held on Magnetic Island, Townsville, Queensland 24-25 August 1989. Australian Government Publishing Service, Canberra.

Pringle, C.M. and Hamazaki, T. 1997. Effects of fishes on algal response to storms in a tropical stream. Ecology 78: 2432-2442.

Pusey, B.J. in press. Burdekin Catchment Water Resource Plan: Fishes. Queensland Department of Natural Resources and Mines.

Pusey, B.J. and Kennard, M.J. 1994. The Freshwater Fish Fauna of the Wet Tropics Region of Northern Queensland. Report to the Wet Tropics Management Authority.

Pusey, B.J. and Kennard, M.J. 1996. Species richness and geographical variation in assemblages structure of the freshwater fish fauna of the Wet Tropics region of northern Queensland. Marine and Freshwater Research 47: 563-573.

Pusey, B.J. and Kennard, M.J. 2001. *Guyu wujalwujalensis*, a new genus and species (Pisces: Percicthyidae) from north-eastern Queensland, Australia. Ichtyol. Explor. Freshwaters. 12: 17-28.

Pusey, B.J., Arthington, A.H. and Read, M.J. 1998. Freshwater fishes of the Burdekin River, Australia: biogeography, history and spatial variation in community structure. Environmental Biology of Fishes 53: 303-318.

Pusey, B.J., 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., Pearson, R., Werren, G. and Burrows, D. 1999. Conservation Values of Waterways in the Wet Tropics World Heritage Area. Report 99/10 Australian Centre for Tropical Freshwater Research, James Cook University, Townsville.

QFMA. 1996. Queensland Freshwater Fisheries. Discussion Paper No. 4. Queensland Fisheries Management Authority, Brisbane. 128pp.

Quinn, T.P., Peterson, J.A., Gallucci, V.F., Hershberger, W.K. and Brannon, E.L. 2002. Artificial selection and environmental change: countervailing factors affecting the timing of spawning by coho and chinook salmon. Transactions of the American Fisheries Society 131: 591-598.

Richards, S.J., McDonald, K.R. and Alford, R.A. 1993. Declines in populations of Australia's endemic rainforest frogs. Pacific Conservation Biology 1: 66-77.

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

Russell, D.J. 1995. Measuring the success of stock enhancement programs. Pages 72-78 In: Cadwallader, P. and Kerby, B. (eds.). Fish Stocking in Queensland Getting it Right! Proceedings of the Symposium held in Townsville, Queensland, 11 November 1995. Queensland Fisheries Management Authority, Brisbane. 96pp.

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. Queensland Dept. of Primary Industries, Brisbane. 68pp.

Russell, D.J. and Rimmer, M.A. 1997. Assessment of stock enhancement of barramundi Lates *calcarifer* (Bloch) in a coastal river system in far northern Queensland, Australia. Pages 498-503 In: Hancock, D.A., Smith, D.C., Grant, A. and Beumer, J.P. (eds.). 1997. Developing and Sustaining World Fisheries Resources: The State of Science and Management. Proceedings of the 2nd World Fisheries Congress, Brisbane, Qld 1996. CSIRO Publishing, Canberra.

Russell, D.J., McDougall, A.J. and Kistle, S.E. 1998. Fish Resources and Stream Habitat of the Daintree, Saltwater, Mossman and Mowbray Catchments. QDPI Information Series QI98062. Queensland Department of Primary Industries, Brisbane. 72pp.

Russell, D.J., McDougall, A.J., Ryan, T.J., Kistle, S.E., Aland, G., Cogle, A.L. and Langford, P.A. 2000. Natural Resources of the Barron River Catchment 1: Stream Habitat, Fisheries Resources and Biological Indicators. QDPI Information Series QI00032. Queensland Dept. of Primary Industries, Brisbane. 108pp.

Salini, J. and Shaklee, J.B. 1988. Genetic structure of barramundi, *Lates calcarifer* stocks from northern Australia. Australian Journal of Marine and Freshwater Research 39: 317-329.

Schindler, D.E., Knapp, R.A. and Leavitt, P.R. 2001. Alteration of nutrient cycles and algal production resulting from fish introductions into mountain lakes. Ecosystems 4: 308-321.

Shaklee, J.B. and Salini, J. 1985. Genetic variation and population subdivision in Australian barramundi, *Lates calcarifer* (Bloch). Australian Journal of Marine and Freshwater Research 36: 203-218.

Shaklee, J.B., Phelps, S.R. and Salini, J. 1990. Analysis of fish stock structure and mixed-stock fisheries by the electrophoretic characterization of allelic isozymes. In: Whitmore, D.H. (ed.). Applications of Electrophoresis and Isoelectric Focusing Techniques in Fisheries Management. CRC Press, Boca Raton, Florida.

Sheppard, R. and Helmke, S.A. 1999. A Fisheries Resource Assessment of the Annan River, North Queensland. Information Series QI99043. Queensland Dept. of Primary Industries, Brisbane.

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

Shipway, B. 1948a. Freshwater fishes of the Barron River. North Queensland Naturalist 15: 5-7.

Shipway, B. 1948b. Freshwater fishes of the Barron River. North Queensland Naturalist 15: 9-13.

Shipway, B. 1948c. Freshwater fishes of the Barron River. North Queensland Naturalist 15: 20-21.

Short, J.W. 1993. *Caridina zebra*, a new species of freshwater atyid shrimp (Crustacea: Decapoda) from northeastern Queensland rainforest. Memoirs of the Queensland Museum 34: 61-67.

Short, J.W. and Davie, P.J.F. 1993. Two new species of freshwater crayfish (Crustacea: Decapoda: Parastacidae) from northeastern Queensland rainforest. Memoirs of the Queensland Museum 34: 69-80.

Short, T.M. and Holomuzki, J.R. 1992. Indirect effects of fish on foraging behaviour and leaf processing by the isopod *Lirceus fontinalis*. Freshwater Biology 27: 91-97.

Smith, S.H. 1972. Factors of ecologic succession in oligotrophic fish communities of the Laurentian Great Lakes. Journal of the Fisheries Research Board of Canada 29: 717-730.

Speare, R. 2000. Developing Management Strategies to Control Amphibian Diseases: Decreasing the Risks Due to Communicable Diseases. Report to Environment Australia by the Steering Committee of Getting the Jump on Amphibian Disease. School of Public Health and Tropical Medicine, James Cook University, Townsville. 209pp.

Tait, J. 1994. Lowland Habitat Mapping and Management Recommendations Tully-Murray Catchments. Unpublished Report to Cardwell Shire Catchment Coordinating Committee.

Trenerry, M. and Werren, G. 1991. Fishes. Pages 104-107 In: Nix, H.A. and Switzer, M.A. (eds.). Rainforest Animals: Atlas of Vertebrates Endemic to Australia's Wet Tropics. Australian National Parks and Wildlife Service, Canberra. 112pp.

Trennery, M.J., Laurance, W.F. and McDonald, K.R. 1993. Further evidence for the precipitous decline of endemic rainforest frogs in tropical Australia. Pacific Conservation Biology 1: 150-153.

Yan, N.D. and others. 1992. *Bythotrephes cederstroemi* (Schoedler) in Muskoka Lakes: first records of the European invader in inland lakes in Canada. Canadian Journal of Aquatic and Fisheries Sciences 53: 134-140.

Yap. W.G. 2002. Kobe, Japan: “jury still out” on effectivity of stock enhancement. SEAFDEC Asian Aquaculture 24(1): 11.

Unmack, P.J. 2001. Biogeography of Australian freshwater fishes. Journal of Biogeography 28: 1053-1089.

Vari, R.P. 1978. The terapon perches (Percoidei, Teraponidae). A cladistic analysis and taxonomic revision. Bulletin of the American Museum of Natural History 159: 177-340.

Vooren, C.M. 1972. Ecological aspects of the introduction of fish species into natural habitats in Europe, with special reference to the Netherlands. Journal of Fish Biology 4: 565-583.

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

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

Webb, A.C. 1995. Impact of Translocated and Introduced Fish Species in Northern Queensland. Unpublished Postgraduate Research Report to the Wet Tropics Management Authority. 23pp.

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

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

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. Unpublished Report, Department of Primary Industries, Walkamin Research Station, Walkamin. 26pp.

Werner, E.E. and McPeek, M.A. 1994. Direct and indirect effects of predators of two anuran species along an environmental gradient. Ecology 75: 1368-1382.

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

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

Williams, L.E.(ed.). 2002. Queensland's Fisheries resources: Current Condition and Recent Trends 1988-2000. Information Series QI02012. Queensland Department of Primary Industries, Brisbane.

Williams, W.D. 1970. On the proposed introduction of *Lates niloticus* (L.) to Australia. Australian Society of Limnology Bulletin 3: 33-35.

Williams, W.D. 1981. To introduce or not to introduce nile perch: the case against. SAFIC 5(4-5):8-10

Williams,W.D. 1982. The argument against the introduction of the nile perch to northern Australian freshwaters. Search 13: 67-71.

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

Zimmer, K.D., Hanson, M.A. and Butler, M.G. 2001. Effects of fathead minnow colonization and removal on a prairie wetland ecosystem. Ecosystems 4: 346-357.

APPENDICES

APPENDIX A – FISH SPECIES MENTIONED ON SEVERAL OCCASIONS IN THE TEXT

(listed alphabetically by their common name)

The scientific names of species mentioned only once are listed within the text.

Archerfish – *Toxotes chatareus*

Australian Bass – *Macquaria novemaculeata*. Native to coastal streams of SE Qld and northern NSW

Banded grunter – *Amniataba percoides*

Barramundi – *Lates calcarifer*

Bony bream – *Nematalosa erebi*

Brown Trout – *Salmo trutta*. Exotic species from Europe

Eastern rainbowfish – *Melanotaenia splendida splendida*

Eels – *Anguilla* spp.

Eel-tailed catfish – *Tandanus tandanus*

Golden perch – *Macquaria ambigua* – also called yellowbelly. Native to the Murray-Darling system but with close relative/sub-species in the Lake Eyre and Fitzroy catchments.

Jungle perch – *Kuhlia rupestris*

Khaki bream – *Hephaestus tulliensis* – endemic to the Wet Tropics. Only described in 1999 (Allen and Pusey 1999)

Lake Eacham rainbowfish – *Melanotaenia eachamensis* – endemic to the Wet Tropics. Listed as ‘Endangered’ under the EPBC Act (1999)

Mangrove jack – *Lutjanus argentimaculatus*

Mouth almighty – *Glossamia aprion*

Murray cod – *Maccullochella peelii peelii* – native to the Murray-Darling system

Northern trout gudgeon – *Mogurnda mogurnda*

Purple-spotted gudgeon – *Mogurnda adspersa*

Rainbow trout – *Oncorhynchus mykiss*. Exotic species from North America

Red Claw Crayfish – *Cherax quadricarinutas*

Silver perch – *Bidyanus bidyanus* – native to the Murray-Darling system

Sleepy cod – *Oxyeleotris lineolatus*. Similar to striped sleepy cod

Sooty grunter – *Hephaestus fuliginosus*. Similar to Khaki bream

Spangled perch – *Leiopotherapon unicolor*. Related to sooty grunter

Striped sleepy cod – *Oxyeleotris selheimi*. Related to sleepy cod

Tilapia – *Oreochromis mossambicus*. Exotic species from Africa

Utchee Creek rainbowfish – *Melanotaenia utcheensis* – Endemic to the Wet Tropics. Only described in 2000 (McGuigan 2000)

APPENDIX B - LIST OF PERSONAL COMMUNICATIONS

Ian Andersen – Fish disease scientist, DPI, Townsville

Alan Atkinson – grazier, formerly of Valley of Lagoons and Cashmere stations, with a long family history in the upper Herbert and upper Burdekin

Bill Bayn – current co-operator of boat cruises on Lake Barrine

Faye Christidis – Aquatic invertebrate scientist, James Cook University, Townsville

Jim Curry – former operator of boat cruises on Lake Barrine

Bryan Furber – grazier at Hidden Valley station, with a long family history in the upper Running River catchment

George Harriman – grazier, Reedybrook Station, upper Burdekin catchment

Brett Herbert – Fisheries/aquaculture researcher – DPI, Walkamin

Alf Hogan – Freshwater fish scientist, DPI, Walkamin

Terry Holman – Professional fishing guide, Cairns

Conrad Hoskins – PhD Student (U. of Qld) researching rainforest frogs in the Wet Tropics

Rob Hunt – Ranger, Land and Water – NQ Water (operators of Paluma Dam), Townsville

Pat Jones – grazier at Ewan Hills station with a long history in the Running River catchment

Clive Keenan – Geneticist – formerly with DPI, Bribie Island

Keith McDonald – Frog/vertebrate researcher, EPA, Atherton

Roy Mackay – Naturalist, Paluma

Katrina McGuigan – Geneticist on freshwater fish, formerly at University of Queensland

Leigh Owens – Frog disease researcher, James Cook University, Townsville

Malcolm Pearce – Freshwater fish scientist, DPI, Cairns

Richard Pearson – Professor of Zoology, James Cook University, Townsville

Brad Pusey – Freshwater fish scientist, River Research Pty Ltd.

Eddie Riddle – Fishing writer/journalist, Townsville

John Russell – Fisheries scientist, DPI, Cairns

Fred Thuller – Queensland Parks and Wildlife Service, Ingham

Bill Schneider – traditional owner and lifelong fishermen, Atherton

John Short – Crustacean specialist, Queensland Museum, Brisbane

Tamara Vallance – Ranger, Queensland Parks and Wildlife Service, Lake Eacham Office

Alan Webb – Freshwater fish scientist, James Cook University, Townsville

Garry Werren – Ecologist, James Cook University, Cairns