DEPARTMENT OF FISHERIES
DISCUSSION PAPER

THE TRANSLOCATION OF BROWN TROUT (*Salmo trutta*) AND RAINBOW TROUT (*Oncorhynchus mykiss*) INTO AND WITHIN WESTERN AUSTRALIA

June 2002

FISHERIES MANAGEMENT PAPER No. 156

OPPORTUNITY FOR PUBLIC COMMENT

This discussion paper has been prepared to assist in the assessment of the possible impact of the translocation of brown trout (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*), into and within Western Australia, for the purposes of recreational stock enhancement in public waters, non-commercial aquaculture on private properties and commercial aquaculture. In assessing the translocation of any aquatic species, economic and social benefits must be balanced with biological and environmental risks.

Comments about this discussion paper are sought from all stakeholders, including industry members, existing and potential trout farmers, relevant community interest groups, government agencies and interested members of the public.

In particular, the Department of Fisheries would appreciate your suggestions for the following:

- River catchments and drainage basins with high conservation value where trout stocking and aquaculture should be managed or prohibited, identifying the benefits of additional management or prohibitions.
- River catchments and drainage basins where trout stocking and aquaculture should be permitted and encouraged, and may already be taking place.

This discussion paper and your comments will be used to develop a draft policy on the translocation of brown and rainbow trout, which will designate areas within WA where stocking may or may not be permitted, the conditions under which stocking may occur and constraints on importing trout into or within the State.

To make your submission as effective as possible:

- keep it clear and concise;
- list your points according to the topic sections and page numbers in this paper;
- describe briefly each topic or issue you wish to discuss;
- say whether you agree or disagree with any or all of the information within each topic or just those of specific interest to you. Clearly state your reasons, particularly if you disagree, and give sources of information where possible; and
- suggest alternatives to address any issues that you disagree with.

To assist you with the above, an issues submission sheet has been compiled and may be found at the back of this document in Appendix Four.

The information provided in this paper should not be accepted to be conclusive and stakeholders are encouraged to consider additional information from other sources in providing the basis for comment.

Your comments would be appreciated by Friday, 30 August 2002 and should be marked to the attention of the Translocation Officer, Fish and Fish Habitat Protection Program, and addressed to:

Executive Director
Department of Fisheries
3rd Floor, SGIO Atrium
168 St George's Terrace
PERTH WA 6000

Should you not wish to comment, you may still register your interest in receiving the draft policy paper by notifying the Translocation Officer as above.

ACKNOWLEDGEMENTS

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- Dr Noel Morrissy
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- Mr Andrew Cribb, Mr Ben Davy, Mr Chris Dibden, Dr Greg Maguire, Mr Peter Millington, Dr Brett Molony, Ms Jacqueline Chappell, Ms Tina Thorne, Mr Colin Chalmers and Mr Craig Astbury (Department of Fisheries).

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NOTE:

The Department of Fisheries in Western Australia has undergone several name changes during the time covered by this paper. The agency has changed its name from the Department of Fisheries and Fauna to The Fisheries Department of WA to Fisheries WA and most recently to The Department of Fisheries. For simplicity, in the text the agency may simply be referred to as the 'Department of Fisheries'.

For the purposes of this paper, the South-West (capitalised) refers to the South-West Drainage Division - see Section 6. Otherwise the term refers to a general geographic direction or location.

1. INTRODUCTION

1.1 Background and Objectives

In Western Australia trout have been stocked into rivers and impoundments (farm dams and large government irrigation water supply dams which are open to public access) in the south-west, for recreational purposes, since the late 1870s. However, early attempts were relatively unsuccessful and it was not until the 1930s that trout stocking really advanced in WA. Since the 1970s stocking has been carried out by the Department of Fisheries in WA, with the Pemberton Trout Hatchery (now known as the South-West Freshwater Research and Aquaculture Centre [SWFRAC] and referred to as such throughout this report), providing the necessary stock. Few self-sustaining stocks of brown or rainbow trout have become established in WA and the recreational trout fishery relies on an annual stocking program.

The stocking of South-West waterways with introduced species has been the subject of debate within WA. The native freshwater fish in south-western WA provide no fish of interest to freshwater anglers with the exception of freshwater cobbler (*Tandanus bostocki*) which is also caught incidentally while fishing for trout in some rivers. The freshwater cobbler accounts for a very small proportion of the catch, so the introduction of trout has provided a valuable recreational fishery. However, the introduction of trout, which is a non-endemic predatory species, has the potential to:

- impact on the natural environment and biodiversity of native species;
- impact on the genetic diversity of native species;
- introduce disease and parasites.

During 1997, the Environmental Protection Authority (EPA) received a Section 38 referral under the *Environmental Protection Act 1986* concerning the release of trout fingerlings into south-west rivers. A Section 38 referral may be made by a decision making authority, a proponent, or any other person, if they consider a proposal appears likely to have a significant effect on the environment. Subsequently the EPA wrote to the Department of Fisheries requesting information on the environmental impact of the release of these fish. The Department of Fisheries responded to the request and also made a commitment to develop a policy on the translocation of trout.

The principal aim of this discussion paper is to identify and elaborate on issues associated with the translocation of brown and rainbow trout for recreational stock enhancement, commercial aquaculture and non-commercial aquaculture. The paper provides information about the biology and ecology of the species, past and current stocking practices, the current trout fishery, the trout aquaculture industry and the potential for trout to impact on the genetic diversity of native species, introduce disease and impact on the natural environment and biodiversity of native species.

This discussion paper and the public comments received, will be used to develop a draft policy, which will guide the translocation decision making process for trout species.

1.2 The Translocation of a Species

Translocation is the movement of organisms beyond their natural range and/or to areas within their natural range that have genetic stocks and/or populations that are distinct from those in the source area (Ministerial Council on Forestry, Fisheries and Aquaculture, 1999). Therefore, translocation includes species which are imported into a state or country and also species moved within a state or country, to regions in which they did not previously exist.

Several freshwater species currently found in Western Australia have been translocated. These include yabby (*Cherax albidus* [Australian range extended]), red-fin perch (*Perca fluviatilis* [introduced]), marron (*Cherax tenuimanus* [WA range extended]), trout (*Oncorhynchus mykiss* and *Salmo trutta* [introduced]) and silver perch (*Bidyanus bidyanus* [Australian range extended]). It should be noted that this is not a comprehensive list of the introduced species in WA, simply an indication.

In 1996 the Standing Committee on Fisheries and Aquaculture acknowledged the need for a common approach to the translocation of aquatic organisms. As a result, the Environment and Health Committee prepared a national policy on the matter. In 1999 the Ministerial Council on Forestry, Fisheries and Aquaculture released the *National Policy for the Translocation of Live Aquatic Organisms*.

The translocation of non-endemic species into or within WA requires the prior written approval or written authority of the Executive Director of the Department of Fisheries, in accordance with Regulation 176 of the *Fish Resources Management Regulations 1995*. The procedure used to assess applications for the translocation of non-endemic species for aquaculture and stock enhancement has been developed by way of a Memorandum of Understanding between the Department of Fisheries and the EPA. Applications to translocate non-endemic species for other purposes is considered on a case-by-case basis by the Department of Fisheries.

Issued pursuant to Section 246 of the *Fish Resources Management Act 1994*, Ministerial Policy Guideline No. 5, entitled *The aquaculture and recreational fishing stock enhancement of non-endemic species in Western Australia*, was developed to assist in the consideration of applications for the translocation of non-endemic species into and within WA for aquaculture and stock enhancement purposes. The policy guidelines may be summarised as follows:

i. Authorisation of the translocation of non-endemic species will be subject to a risk management assessment being carried out.
ii. The assessment will be undertaken by the Department of Fisheries within the context of an application and translocation synopsis provided by a proponent. Authorisation of the translocation will be conditional upon the assessment showing the translocation would present a low risk to the environment.
iii. The risk assessment must be based on the best scientific data available for the species and the environment into which it is to be introduced.
iv. The translocation application will be referred to relevant industry groups for consultation and public comment sought before any decisions are made.
v. The translocation decision should balance significant economic and social benefits with biological and environmental risks.

Species for which translocation policies have already been developed in WA are redclaw crayfish (*Cherax quadricarinatus*), silver perch (*Bidyanus bidyanus*) and silver-lip pearl oyster (*Pinctada maxima*). A policy on the translocation of barramundi is currently being finalised.

2. THE BIOLOGY OF TROUT

2.1 Taxonomy and Description

The suprageneric affinities of brown and rainbow trout are given below (Harvey Pough *et al*, 1990):

Family: Salmonidae
Subfamily: Salmoninae

Genus: *Oncorhynchus*	Genus: *Salmo*
Species: *mykiss* (Walbaum)[1]	Species: *trutta* L. (L. = Linnaeus)
(rainbow trout)	(brown trout)

Fish species of the order Salmoniformes are native to both the northern and southern hemispheres and inhabit cool, temperate, fresh and marine waters. Many of the species are diadromous[2], migrating between fresh and salt waters for breeding. Within this order is the family Salmonidae which contains the Atlantic salmon, trout and char.

Trout have the facultative adaptability to migrate to seawater as juveniles. At sea they undertake coastal or oceanic feeding migrations until maturity when they return to rivers for spawning, usually in the highland tributaries. Adult fish spawn in fresh water and eggs and early stage larvae require fresh water for survival. Few self-sustaining populations in Australia have established migratory stocks and therefore most populations are restricted to fresh water. However, trout which have been acclimatised to seawater between the ages of 6 months and 2 years, may be reared in marine conditions until maturity. The tolerance to such a range of salinities has positive implications for stock enhancement, commercial aquaculture and non-commercial aquaculture.

Both brown and rainbow trout are basically coldwater fish with a favourable range for growth and survival of 5 - 20°C. The lethal high temperature range starts at about 26 - 27°C (depending upon prior acclimation) with a resistance time to death of many hours, but at 30°C death occurs within minutes (Morrissy, 1973). However, populations in the south-west rivers have a higher temperature resistance, due to adaptation to Western Australian conditions (B. Molony, pers com).

Trout are also intolerant of low oxygen levels, requiring more than 3 mg/L for survival and 5 mg/L for feeding and growth. Lower oxygen levels are caused by summer conditions of heat, poor flow, stagnation, and other aspects of eutrophication.

Given a permanent, pure water resource, lake or river, trout are limited ecologically at high latitudes by winter mortality due to water freezing and at low latitudes by summer heat deaths. Although adapted to temperate climates where they have been widely translocated for sporting and aquaculture, trout have also been translocated to countries nearer to the equator, but only

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[1] The scientific name for rainbow trout prior to the mid- to late 1980s was *Salmo gairdneri* Richardson. However, in the 1980s this was superseded by the name *Oncorhynchus mykiss* (Walbaum).

[2] A diadromous species is one that migrates between fresh and brackish or sea water to complete its life cycle. Diadromous species may be either catadromous or anadromous. Catadromous species typically grow to maturity in fresh water and migrate to the brackish water of estuaries or to the sea to spawn. Anadromous species typically undergo much of their growth in the sea and then return to fresh water where they attain full sexual maturity and spawn.

at high altitudes. These equatorial countries include Kenya, southern India, Sri Lanka, Malaysia, the Hawaiian Islands and Papua New Guinea.

2.2 Natural Distribution

Brown trout are native to Iceland, the British Isles and all of Europe and western Asia, (extending northward from the Atlas Mountains in northern Africa to the Artic Circle in northern Scandinavia and north western Russia, and eastward to the Urals, Iran, and the Hindu Kush of Afghanistan) (Frost and Brown, 1967; MacCrimmon and Marshall, 1968; MacCrimmon et al, 1970; Elliott, 1994).

Rainbow trout are native to the northern Pacific basin, occurring in North America (from Alaska to Mexico, nearly always on the western slopes of the Rocky Mountains) and in north eastern Asia (in Russia on the Kamchatka Peninsula) (MacCrimmon, 1971, 1972; Stolz and Schnell, 1991).

2.3 Spawning and Early Life History

Rainbow trout are much easier to artificially spawn, feed, rear and catch than brown trout. In Western Australia rainbow trout are ready to breed at about two years of age and females can produce up to 2000 ova/kg of body weight (Morrissy, 1995a). Brown trout are ready to breed about a year later at three years of age and females produce a similar amount of eggs. Females commence ovarian egg production about six months before spawning, which occurs in early winter in WA for both species. Brown trout have the ability to reabsorb eggs if suitable spawning gravel is not available and a new batch of eggs are produced in the following year. Rainbow trout, however, do not have this ability.

Energy requirements for producing eggs and searching for spawning grounds decrease fish condition and slow their growth rate. Trout are artificially spawned in June in WA and the young fish are mainly stocked as feeding fry and then fingerlings in the springtime (September to November), before hot weather limits travel. However, the stocking of yearling trout (8 - 12 months old in April-May) has also increased in recent years.

For introduced trout to establish self-sustaining stocks, suitable spawning areas, or redds, must be present. These are usually found in the mountainous, upper reaches of rivers and tributaries to which trout migrate for spawning during the wet season. A spawning redd is the smooth water-rounded gravel and stones deposited at the wide tail of a pool or shallow run, where there is a well oxygenated sub surface water flow through the rocky substrate, unblocked by silt. The female trout digs a deep redd (trough) by flapping her tail, on her side, to dislodge gravel. She then releases eggs, which mix with milt (sperm) from a closely accompanying male and become lodged in the redd. The female then moves upstream of the redd and dislodges more gravel to fill in the redd. Trout produce large eggs, three to five millimetres in diameter, and have a very brief larval stage, the alevin. The alevin remains in the redd, absorbing the yolk sac and the young fish will emerge from the gravel within two months to feed.

2.4 Age and Growth

Growth rates of both brown and rainbow trout may be highly variable in different localities. The world record weights for angler-caught trout approach 20 kilograms. However, the Western Australian trout fishery is based upon young, fast growing fish, mostly 1+ year old fish of 0.5 to 1.0 kg. Rainbow trout are inherently short-lived compared to brown trout with the oldest being three to four years old and reaching five kilos (usually males or triploids). Larger brown trout are twice as old with four to five kilo fish approaching 10 years of age.

The growth rate of trout is variable and may be related to water temperature, nutrition and genetic factors. Consequently production of 200-gram fish from eyed eggs may take between 10 and 20 months (Bromage et al, 1990). In nutrition-rich dams in the south-west, trout have reached two kilos within two years and three kilos by three years of age. However, at the other extreme, in infertile or overstocked dams, fish growth may be stunted and trout may not reach the legal fishing size in two years (Morrissy, 1995a).

2.5 Diseases, Parasites and Predators

2.5.1 Diseases and Parasites

There are a number of diseases which affect salmonids worldwide, some of which result in significant mortalities while others reduce product quality and value. However, not all of these diseases are infectious to rainbow trout and/or brown trout. Both New Zealand and Australia have undertaken comprehensive reviews of the diseases and parasites of salmonids when undertaking Import Risk Analyses (Stone *et al*, 1997 and Australian Quarantine and Inspection Service, 1999). Australia is fortunate to have escaped the presence of a number of diseases which have had significant impacts on salmonids overseas.

Table 1 summarises the salmonid diseases currently present in Australia. The presence of fish diseases in Western Australia is predominantly based on disease testing of introduced fish kept under culture conditions. Wild fish are rarely submitted for disease testing and therefore the disease status of wild populations of native and introduced fish in WA is poorly known.

Table 1 *Summary of significant salmonid diseases present in Australia*

Disease	Presence in Australia	Presence in Western Australia	Brown Trout Susceptibility	Rainbow Trout Susceptibility
Bacteria				
Aeromonas salmonicida (Furunculosis/Goldfish Ulcer Disease) (notifiable disease)	'typical' strains not present; 'atypical' strains present	not isolated from WA fish since 1980s	very susceptible	susceptible but relatively resistant
Edwardsiella tarda (Edwardsiellosis)	present	never isolated	attempts at infection unsuccessful	susceptible
Flexibacter spp. (Bacterial Gill Disease and Fin Rot)	present	present	susceptible	susceptible
Mycobacterium marinum (Mycobacteriosis)	present	present	susceptible	susceptible
Nocardia spp. (Nocardiosis)	present	not isolated but probably present	probably susceptible	susceptible
Vibrio spp. (Vibriosis)	present	present	susceptible	susceptible
Yersinia ruckeri (Enteric Redmouth Disease)	present	never isolated	susceptible	main species susceptible
Parasites				
Chilodonella spp.	present	present	susceptible	susceptible
Ichthyophthirius multifiliis (White Spot Disease)	present	present	susceptible	susceptible
Trichodina spp.	present	present	susceptible	susceptible
Trichodinella sp.	present	present	susceptible	susceptible
Amoebic Gill Disease	present	no evidence of clinical disease, but amoeba probably present	no record of susceptibility	susceptible
Kudoa thyrsites	present	present, only in marine fish.	may be susceptible	susceptible
Viral				
Epizootic Haematopoetic Necrosis Virus (notifiable disease)	present	never isolated, no evidence of disease	no record of susceptibility	susceptible but relatively resistant
Infectious Pancreatic Necrosis Virus (notifiable disease)	may be present	never isolated, no evidence of disease	susceptible	susceptible
Tasmanian reovirus	present	unknown but may be present as a result of historical imports from Tasmania	unknown	unknown

(Bellet, 1965; Parisot *et al*, 1965; Halliday, 1976; Sano *et al*, 1977; Llewellyn, 1980; Wolf and Smith, 1981; Hill, 1982; McAllister, 1983; Morrison and Sprague, 1983; Boyce *et al*, 1985; Hedrick *et al*, 1986; Austin and Austin, 1987; Egidius, 1987; McVicar, 1987; Wolf, 1988; Nash et al, 1989; Eaves *et al*, 1990; Cvitanich *et al*, 1991; Hedrick *et al*, 1991; Langdon, 1991; Rodger *et al*, 1991; Kent, 1992; Austin and Austin, 1993; Freyer and Lannan, 1993; Furones *et al*, 1993; Hedrick *et al*, 1993; Kent *et al*, 1993; Anderson *et al*, 1994)

***Aeromonas salmonicida* (Furunculosis/Goldfish Ulcer Disease)**

Aeromonas salmonicida subsp. *salmonicida* are classed as 'typical' strains and cause classical furunculosis in salmonids and are also found in other non-salmonid fish. Other subspecies of *A. salmonicida* are classed as 'atypical' strains and cause disease in salmonids and non-salmonids. Typical strains have been reported from cultured salmonid populations almost everywhere, but not Australia (Austin and Austin, 1993; Anderson *et al*, 1994). A limited number of atypical strains have been found in non-salmonid species in Australia, including goldfish. However, there have been no reports of atypical strains associated with disease in salmonids. Groman *et al* (1992) describes symptoms of atypical furunculosis as acute respiratory distress within hours of death, random jumping, anorexia and raised scales.

***Edwardsiella tarda* (Edwardsiellosis)**

Edwardsiella tarda is a bacterium that causes disease in warm water species. Edwardsiellosis has been recorded from a diverse array of salmonid and non-salmonid species, including invertebrates, reptiles, amphibians, birds and mammals (Austin and Austin, 1987; Plumb, 1993). A single outbreak of *E. tarda* has been recorded in farmed rainbow trout from southern New South Wales and the bacteria was isolated from a native Australian eel. Although salmonids are susceptible to infection, natural infections are rare. The bacteria tend to be opportunistic pathogens and disease outbreaks appear to be stress related and influenced by poor environmental conditions (Austin and Austin, 1987).

***Flexibacter* sp. (Bacterial Gill Disease and Fin Rot)**

Bacterial gill disease and fin rot are infections of intensively reared salmon and other non-salmonid finfish caused by a variety of bacteria genera, of which *Flexibacter* is one. *Flexibacter psychrophis* has been found in Tasmanian Atlantic salmon where symptoms include inflammation, respiratory distress, swimming near the water surface and strands of mucous trailing from the gills.

***Mycobacterium marinum* (Mycobacteriosis)**

Mycobacteriosis is a common, widely distributed, chronic, progressive bacterial disease that affects more than 150 marine and freshwater fish species. Trout usually become infected when they are stressed by high temperatures and poor water quality and if infected will show symptoms such as lethargy, skin darkening, lesions in the kidneys, inflammation and ulceration of the skin. In general the disease has a long course and clinical disease is usually seen in animals older than two years. The bacteria which cause Mycobacteriosis are ubiquitous, remain viable for long periods of time and are practically impossible to eradicate from the environment. In Western Australia the species present is *Mycobacterium marinum*, which was first diagnosed in rainbow trout following mortalities at the South-West Freshwater Research and Aquaculture Centre in 1988. The origin of the bacterium is unknown, however, the disease may now be widespread in WA in trout and other freshwater fish species (B Jones, pers com). The South-West Freshwater Research and Aquaculture Centre controls the disease by cooling the water through water cooling towers during summer and through good management practices.

***Nocardia* spp. (Nocardiosis)**

Nocardiosis is another common bacterial disease which affects a wide range of marine and freshwater fish, particularly aquarium fish. While aquarium fish exhibit symptoms such as anorexia, popeye, skin discolouration, fin rot and ulcers, salmonids may show no external signs of disease. However, a post mortem will reveal internal lesions. Where the disease is detected destruction of infected stock and disinfection is usually recommended (Thorne, 1995).

***Vibrio* spp. (Vibriosis)**
Vibriosis is a term used for a group of marine fish diseases caused by bacteria of the genus *Vibrio*. It is the most economically important disease of marine fish culture (Egidius, 1987). Vibriosis affects all species of salmonids as well as non-salmonid finfish, bivalves and crustaceans. The disease has been found in Australian salmonids and other species, however, only a limited number of strains have been recognised. Vibriosis may result in 100 per cent fish mortality in 30 days and is typically associated with stress and poor water conditions (Hjeltnes and Roberts, 1993). Typical symptoms include darkening of the skin and lethargy. If the disease advances rapidly, symptoms will extend to exophthalmia, skin ulcers and frayed fins.

***Yersinia ruckeri* (Enteric Redmouth Disease)**
Enteric Redmouth Disease (ERD) is a disease of salmonids and non-salmonids caused by the bacterium *Yersinia ruckeri*. ERD is usually caused by the virulent 'Hagerman' type of *Y. ruckeri*, but many other types do occur. Strains of *Y. ruckeri* do exist in Australia and cause disease problems similar to those seen overseas. However, effective vaccines are available. Disease symptoms include reddening in the mouth and throat, inflammation and erosion of the jaws and palate, darkening of the skin and a tendency to sluggishness (Austin and Austin, 1987; Furones et al, 1993).

***Chilodonella* spp.**
Protozoan parasites belonging to the genus *Chilodonella* are commonly found on the gills and skin of Australian freshwater native and introduced fish, particularly in cold waters. Symptoms are similar to those for white spot disease.

***Ichthyophthirius multifiliis* (White Spot Disease)**
White spot disease is one of the most common freshwater fish diseases and is caused by the large motile ciliated protozoan *Ichthyophthirius multifiliis*. Severe outbreaks can be prevented if the white spots are treated quickly and symptoms include flashing, rubbing the gill cover and body against the tank, darkening of the skin, lethargy and breathing difficulties (Thorne, 1995).

***Trichodina* sp**.
When present in small numbers, parasites belonging to the genus *Trichodina* are harmless. However, in larger numbers they can cause serious problems in native fish fry and also in trout fry and fingerlings. Again the symptoms are similar to those for white spot disease and adults may develop a bluish slime which covers their bodies.

Trichodinella sp.
Parasites belonging to the genus *Trichodinella* also cause problems in native fish fry and trout fry and fingerlings and have symptoms similar to those for white spot disease.

Amoebic Gill Disease
Amoebic gill disease is caused by two species, *Paramoeba* sp. and *Thecamoeba hoffmani,* which parasitise the gills of salmonids. *Paramoeba* sp. causes significant disease problems in Atlantic salmon in sea cage culture in Tasmania where mortality results from respiratory impairment.

Kudoa thyrsites

Kudoa thyrsites is a myxosporean parasite that has been found in a number of non-salmonid finfish and rainbow trout in Australia (Langdon, 1991). *Kudoa thyrsites* does not cause significant disease problems in host fish with the symptoms being lethargy and paleness. However, its presence does reduce product quality and value by affecting the appearance and texture of the flesh, which may disintegrate on cooking.

Epizootic Haematopoetic Necrosis Virus

Epizootic haematopoetic necrosis is an iridovirus caused by the epizootic haematopoetic necrosis virus (EHNV)and its presence is restricted to mainland Australia (Langdon et al, 1986, 1988). Salmonid and non-salmonid finfish are susceptible to the disease which is transmitted through the movement of carrier fish. Symptoms of the disease include abdominal distension, pallor of skin and fins, a loss of equilibrium and flared opercula.

Infectious Pancreatic Necrosis Virus

Infectious pancreatic necrosis is an acute contagious disease of salmonids caused by a number of virus strains of the infectious pancreatic necrosis virus (IPNV) within the birnaviridae family (Dobos et al, 1979). The host range of IPNV and IPN-like viruses is extremely broad with isolates obtained from salmonids and non-salmonid finfish, marine shellfish and crustaceans (Hill, 1982; Wolf, 1988). However, it is not evident whether the hosts are actually infected with the disease or simply carriers. There is no evidence that many of the aquatic birnaviruses that are seriologically related to IPNV are pathogenic to salmonids and therefore they should not be referred to as IPN. To date IPNV has not been found in Australian salmonids. A recent finding of an IPN-Like aquatic birnavirus in Tasmania has been found to be non-pathogenic to salmonids. In salmonids, IPN is an acute disease causing high mortalities in fry and fingerlings with symptoms including darkening of the skin, abdominal distension, surface haemorrhages, lethargy and short periods of erratic swimming movements.

Tasmanian reovirus

A reovirus has recently been isolated from Tasmanian salmonids. However, the significance of the reovirus is unknown.

2.5.2 Disease Testing and Certification

The last importation of trout from the eastern states occurred in 1991. Prior to 1991 a number of shipments were imported into Western Australia, none of which were disease tested according to the strict disease testing requirements which are present today (B. Jones, pers com). To ensure that no new diseases are introduced, any future shipments of trout into WA would need to be disease tested according to present day requirements.

Following the discovery of mycobacteriosis in trout from the South-West Freshwater Research and Aquaculture Centre in 1988, the Fish Health Section of the Department of Fisheries regularly tested trout fingerlings for presence of the bacteria. In the years when this testing was carried out, no further evidence of the disease was found at the South-West Freshwater Research and Aquaculture Centre. However, the sensitivity of these tests is very low and testing for mycobacteriosis has been discontinued (B Jones, pers com).

For the past six years the Fish Health Section has been using an internationally accepted procedure to test for the presence of epizootic haematopoetic necrosis virus at the South-West Freshwater Research and Aquaculture Centre. The results of these tests have been negative and the South-West Freshwater Research and Aquaculture Centre is now recognised as being free of epizootic haematopoetic necrosis virus.

WA is fortunate in that a number of diseases affecting salmonids in other states are not present in local, hatchery-reared trout (Lawrence, 1993). The relatively disease-free status of trout in WA gives the industry a competitive advantage over other states within Australia (with the exception of Tasmania) and other countries which have a higher incidence of disease.

2.5.3 Predators

Being a large carnivorous fish in south-west freshwater rivers and impoundments, there are no higher order aquatic predators than adult trout. However, the survival of young trout is influenced by two factors. Firstly, if redfin perch are present they are liable to prey heavily on trout fry. Redfin are present in a number of waterways in the south-west where they have a tendency to multiply in number, eat out the food supply and stunt in size as a consequence. Secondly, cormorants and other fish eating birds can prey heavily on young fish if the waterway is bare of cover such as aquatic weeds, logs and rocks.

2.6 Stock Variations

The importation of trout from the eastern states ceased in 1991 and the current production of trout fingerlings is from existing domestic hatchery stock and also from stripping wild-caught fish and raising the young fish from eggs. The main breeding stock of rainbow trout at Pemberton has been a line of domesticated trout maintained since the mid-1940s. While rainbow trout were imported from Victoria and New South Wales in 1972 for comparative studies, these fish were not mixed with Western Australia stock.

In the early 1970s a study was conducted (Morrissy, 1973) which showed that the rainbow trout strain maintained at the South-West Freshwater Research and Aquaculture Centre has an increased ability to tolerate higher temperatures relative to the stock in eastern Australia at lower annual temperatures. Recent studies indicate that the hatchery strain of rainbow trout at the South-West Freshwater Research and Aquaculture Centre is much more heat tolerant and also grows faster than a wild strain (the Serpentine strain) of rainbow trout in WA (B Molony, pers com). This research indicates that the hatchery strain has been increasing in heat tolerance throughout its history at the South-West Freshwater Research and Aquaculture Centre. Further research undertaken in conjunction with CSIRO Marine Research has also demonstrated strong genetic differences between the hatchery stock and Serpentine strain (Ward et al, in prep).

As brown trout are more difficult to rear than rainbow trout, they have not been reared on a large scale. In the 1970s some large fish were kept for tourist show and mature fish were obtained from Lefroy Brook at spawning time to provide fry for the public fishery. By the early 1980s brown trout were proving increasingly difficult to artificially spawn and various attempts to trap wild fish were unreliable. Subsequent stocks were imported from Tasmania in 1985 and 1991 to satisfy demand. However, the Tasmanian stock performed poorly at the hatchery and a renewed effort was made to trap local fish. Successful trapping of wild brown trout in WA has since resulted in stock which are superior to the previous Tasmanian fish in breeding and summer survival.

3. TRANSLOCATION OF SALMONIDS

3.1 Introduction of Salmonids to Australia

3.1.1 History of Introduction

The introduction of salmonids commenced in the mid-1860s with at least seven species of salmonids being introduced to Australia from the northern hemisphere, of which five species are still extant in eastern Australia (Clement, 1988). These species are brown trout (*Salmo trutta*), rainbow trout (*Oncorhynchus mykiss*), Pacific salmon (*Oncorhynchus tshawytscha*), brook trout (*Salvelinus fontinalis*) and Atlantic salmon (*Salmo salar*). Brown and rainbow trout have established breeding populations in natural waterways in the eastern states. Pacific salmon, brook trout and Atlantic salmon stocks in the eastern states are maintained through hatchery breeding. However, there is one self-maintaining population of brook trout in New South Wales (McDowall, 1993). Brown trout have formed sea-run coastal, or at least estuarine, stocks in Tasmania. However, no migratory stocks of Atlantic salmon, Pacific salmon or rainbow trout have established, despite many translocation attempts. The last importations of salmonids from the northern hemisphere occurred in the 1960s.

Non-migratory brown trout from England (Hampshire, Itchen River) were first introduced to Tasmania in 1864, with a shipment of 3000 eggs (Walker, 1988). The shipment was a minor accompaniment to a large official shipment of Atlantic salmon. The newly fertilised eggs were susceptible to vibration on the sailing ship and less than 200 trout fry survived. Although there was a further shipment in 1866 of coastal brown trout, the original shipment from 1864 became the broodstock for successful breeding ventures. Progeny of this original shipment (six breeding pairs) were used to introduce brown trout to the rest of Tasmania and mainland Australia (Senior, 1880; Clements, 1988).

Rainbow trout of Californian origin were originally introduced to New South Wales from New Zealand in 1894. Later shipments to Victoria from New Zealand in 1898 probably founded the rainbow trout later supplied to Western Australia. Hatcheries in Australia continued to import New Zealand eyed ova until the introduction of more stringent Australian quarantine requirements and the discovery of whirling disease in New Zealand trout in the 1970s.

There is some debate surrounding the origin of the New Zealand stock which most probably resulted from migratory steelhead rainbow trout from Sonoma Creek in San Francisco Bay, but other Californian sea-run trout, river or lake strains and the giant heat-hardy Lahonton cutthroat trout from Lake Tahoe were also imported to New Zealand in small numbers (Scott et al, 1978).

3.1.2 Demand for Introduction

Various reasons have been documented outlining the demand by Australians for the translocation of salmonids. Some of these reasons have been summarised below.

- The original introductions of trout and salmon were part of wide-ranging introductions by European colonists of familiar, mainly domesticated, northern hemisphere animal and plant species for agriculture, hunting, gardens and pets.
- While many introductions were for practical reasons, such as the production of food by established methods on domesticated species, there was also a desire to 'Europeanise' the Australian landscape.
- The temperate highland rivers and lakes of the Southern Hemisphere continents generally lacked any large, native fish species suitable for sport fishing or which were of high food value. The introduction of salmonids provided recreational fishing opportunities.
- Introduced trout provided an important domestic food source in inland areas, because they are a large fish with a high protein value.
- The commercial and tourist value of sea-run populations of translocated Atlantic salmon would have been very high, if they could have been established in the Southern Hemisphere.
- Trout and Atlantic salmon are highly regarded freshwater angling species in the Western world, particularly in association with fly fishing.

3.2 Introduction of Trout to Western Australia

All trout translocated to Western Australia were sourced from eastern Australia, following the original introductions into Australia. The introduction of trout into WA commenced in the late 1870s with the introduction of brown trout. Table 2 summarises the early history of trout introduction and stocking in WA.

Table 2 *Summary of the early introduction of trout to Western Australia (1874 to 1905)*

Year	Details of shipment
1874	Suspected introduction of 800 brown trout eggs from Tasmanian records. Shipment not confirmed by Western Australian records.
1876	Shipment of brown trout ova from Ballarat Hatchery, Victoria to Albany. Eggs released into Maleys Stream at Albany.
1894	First shipment of brown trout ova to a new hatchery at Bunbury. Brown trout released from the hatchery at Preston River into the Preston River, Collie River, Murray River, Serpentine River and Harvey River.
1896	Shipment of 30,000 brown trout from Tasmania to Whitby Falls hatchery. Fry released into Murray River, Blackwood River, Serpentine River, Samson Brook and Gingin Brook.
1897	Shipment of 45,000 brown trout from Tasmania to Whitby Falls hatchery. Fry released into Murray River, Blackwood River, Serpentine River, Samson Brook and Gingin Brook.
1901	Further release of brown trout into Canning River, Blackwood River and Harvey River.
1902	Rainbow trout sought but records do not confirm successful import.
1905	Successful releases of brown trout and rainbow trout from Mundaring Weir hatchery into the weir.

(Coy, 1979; Clements 1988)

From observations and angling records, it must be concluded that these early releases of trout failed to establish self-sustaining stocks and no further attempts were made to import stock until 1930 at Pemberton. The lack of success is difficult to reconcile with later success in the 1930s in many of the same waters and the success in eastern Australia and South Australia from small releases. Reasons for the lack of success may have included inexperience with trout culture and stocking practice, lack of trout identification and angling experience, poor trout spawning conditions or a period of unfavourable climate. Table 3 summarises the later history of trout introduction and stocking in WA.

The importation of brown and rainbow trout from the eastern states ceased in 1991 and 1972 respectively and the current stock available in WA is progeny of earlier importations.

Table 3 *Summary of the later introduction of trout to Western Australia (1929 to 1991)*

Year	Details of shipment
1929	Attempted import of 6,000 rainbow trout ova from Victoria to Pemberton. All were dead upon arrival.
1931	Shipment of 20,000 brown trout eyed ova from South Traralgon hatchery, Latrobe Valley, Victoria to Pemberton. Fry were released into local streams in the Warren Catchment.
1936	Shipment of 50,000 rainbow trout and 50,000 brown trout eggs from Ballarat to Pemberton. 60,000 fry were released into streams between Albany and Gingin. Brown and rainbow trout fry were sent to Collie and Albany from Pemberton.
1937	Further shipment of 2,000 brown trout from Ballarat to Perth.
1937	Brown trout fry released in Drakesbrook River, Preston River and Harvey River.
1939	Shipment of 50,000 brown trout from Tasmania to Collie.
1940	Shipment of 20,000 brown trout from Tasmania to Collie.
1941	Shipment of 50,000 rainbow trout from Tasmania to Collie.
1963	Shipment of brown trout from Ballarat, Victoria.
1972	Shipments of 20,000 rainbow trout from Gaden, New South Wales and Snobs Creek, Victoria.
1985	Shipment of 50,000 brown trout from Tasmania.
1991	Shipment of 50,000 brown trout from Tasmania.

(Coy, 1979; Clements 1988)

3.3 Translocation of Trout within Western Australia

3.3.1 Stocking By Acclimatisation Societies

A number of societies and committees were formed to support and facilitate the introduction of trout into and within Western Australia. The first was the State Acclimatisation Committee which was formed in 1896 and continued until 1918. The Fish and Game Acclimatisation, Propagation and Protection Society of WA was formed in 1935 and had government patronage and funding. However, due to a lack of funds the Society was defunct by 1938 and a local trout society was formed at Pemberton to continue the work. The Pemberton Society was the forerunner of district trout acclimatisation societies, the first of which was registered in 1942. The societies were registered by an *Amendment Act 1940*, Part IIIA, Trout Acclimatisation Districts and Societies to the *Fisheries Act 1905* and were supported by

annual government grants. The various societies were, Pemberton-Warren (gazetted, 1942), Collie (gazetted, 1943), Murray-Dwellingup (gazetted, 1947), Serpentine-Jarrahdale (gazetted, 1948), Blackwood (gazetted, 1949), Harvey (gazetted, 1951), Gingin (gazetted, 1952) and Albany, Denmark and Plantagenet (gazetted, 1955). The registrations of the Collie and Gingin societies were cancelled in 1958 due to lack of interest, followed by Albany in 1964, and the trout acclimatisation part of the Act was repealed in 1965.

During 1948 a Trout Acclimatisation Council of WA was formed to coordinate the trout distribution activities of the societies and the South-West Freshwater Research and Aquaculture effort and finances. The last meeting of the council was in 1962. From 1962 the South-West Freshwater Research and Aquaculture Centre was run under government subsidy by the Pemberton Hatchery Board, comprised of the Director of the Department of Fisheries, a Department of Fisheries finance officer and representatives of the Pemberton Trout Acclimatisation Society. In 1967, the WA Trout and Freshwater Angling Association (WATFAA) was formed to represent inland anglers State-wide.

After imports in 1936 and 1937, the Pemberton Society endeavoured to obtain eggs from local breeding stock. Members of the society learnt to sex and strip fish and considerable effort was made to trap wild fish running up the streams to spawn in early winter floods. Trapping fish was a steep learning curve but by 1945 effective traps were operating on the Treen, East, Lefroy and Big Brooks. However, maintenance of the traps was difficult and a domesticated breeding stock of fish was sought from 1940. Initial attempts were unsuccessful with fish held and fed in ponds exhibiting egg infertility for several years due to diet (Nicholls, 1944). When this problem was overcome in 1946 the hatchery production of fish at Pemberton tended to a domestic pond stock of rainbow trout, rather than brown trout, or trout caught from traps. Demand for rainbow trout was high by 1949 with successful self-sustaining stocks of brown trout having established around Pemberton.

3.3.2 Stocking by the Department of Fisheries

When production of fish exceeded local demand near Pemberton in 1945, a more extensive annual distribution service was developed for the Acclimatisation Societies. By 1952 the production of over a million eggs, largely from domestic rainbow trout stock, greatly exceeded the needs of the Trout Acclimatisation Societies and sales promotion for the excess fish commenced with Department of Fisherie's staff taking over transport of fish from Pemberton to Perth, to the trout societies en route, and to wheatbelt 'bulk delivery distribution centres'.

During the 1950s a large quantity of fish were directed to a 'Fish for the Inland Scheme' which arose following reports of large trout in farm dams at Beverley, Pingelly, Katanning and one or two other dams in the western wheatbelt. However, after many sales extending far to the east (Salmon Gums), inland (Lake Grace) and north (Wittenoom), there were almost no reports of success. The Department of Fisheries investigated the scheme in 1958 and found that the lack of success was related to the type of dams used for stocking. The majority of dams were very small, muddy, excavated tank type dams which had unfavourable summer temperatures and low oxygen levels (Bowen 1961). However, some success was evident in a few dams which had been built on creek beds closer to the coast.

From 1962 a much-reduced rainbow trout supply was distributed annually by the Department of Fisherie's staff to the remaining trout society centres, with angling members carrying out the stocking. In 1971 the Department of Fisheries took over the South-West Freshwater

Research and Aquaculture Centre after a new main hatchery was built in 1970 to replace the old hatchery on the swimming pool brook. When the Department of Fisheries took over the hatchery, the supply stock were used entirely for public waters stocking and were all small fish. Subsequently, the sale of fish to farmers and WATFAA for stocking suitable gully farm dams was developed and then commercial trout farms were supplied. Some of the trout farms have since developed some breeding stock and the South-West Freshwater Research and Aquaculture Centre has looked more towards satisfying the large demand for stocking waters for recreational angling. Table 4 illustrates the supply of rainbow trout from the South-West Freshwater Research and Aquaculture Centre for public waters, private waters and trout farms, from 1970 to 1998.

Table 4 *Supply of rainbow trout eyed ova and fry from the South-West Freshwater Research and Aquaculture Centre to public waters (streams and government irrigation dams), private waters (farm dams) and trout farms in Western Australia.*

Year	Number Released		
	Public Waters	Private Waters	Trout Farms
1970	139 000		
1971	190 000		
1972	235 000		
1973	88 000	32 000	
1974	90 000	68 000	
1975	88 000	58 000	
1976	90 000	56 000	
1977	385 000	46 000	
1978	435 000	162 000	
1979	430 000	95 000	
1980	404 000	158 000	31 000
1981	138 000	165 000	83 000
1982	439 000	154 000	156 000
1983			123 000
1984	484 000	147 000	351 000
1985	256 000	125 000	595 750
1986	3 000	121 750	695 000
1987	100 000	63 650	706 750
1988			273 000
1989	108 000	214 750	100 000
1990	249 000	150 450	212 000
1991	132 000	117 650	395 000
1992	260 000	228 450	380 000
1993	358 000	197 500	263 750
1994	265 000	275 650	160 000
1995	296 500	119 900	70 000
1996	461 000	204 500	10 000
1997	426 000	143 000	132 000
1998	305 000	81 000	75 000
1999	549 500	232 400	17 500
2000	500 000		

In the early 1970s, a few private farm dams on the fertilised catchments of the beef cattle farms at Pemberton were experimentally stocked with rainbow trout. These dams produced some spectacular angling because of the rapid growth rates of the fish to large sizes. These

rapid growth rates were achieved due to the lack of competing species in the dams and the high nutrient input from the surrounding fertilised catchment, which made the dams highly productive. The dams provided more reliable and easier fishing than streams and anglers were encouraged to fish these dams. Access by property owners was readily granted and dams came to provide a backstop to stream fishing. WATFAA has since established agreements with some individual landowners for exclusive access to farm dams for annual stocking and fishing by members. The popularity and success of these dams continues to grow, with WATFAA catch records indicating that private dams provide over half the fish caught by members.

The large government irrigation dams which are open to public access have been a major part of the trout fishery in the Darling Ranges. In particular, the construction of new dams provided highly successful fisheries and trout were observed to have exceptional growth rates in this dams.

4. RECREATIONAL STOCK ENHANCEMENT

4.1 Stocking Practices

Before 1971, when the Department of Fisheries took over the South-West Freshwater Research and Aquaculture Centre, Department of Fisheries officers would deliver stock to various towns and the fish were released by nominated anglers. This practice was not ideal, as anglers could act to further their own personal interests and not the community interest, by stocking fish in areas other than the designated public access waters. Anglers may also not practice proper fish release techniques which would compromise fish survival. A marked improvement in catches was recorded in several public waters, such as the Murray River and Blackwood River, after the Department of Fisheries staff started carrying out the releases.

During the late 1960s, the list of waters for stocking fry in the springtime appears to have been drawn up based upon requests from the former Acclimatisation Society members who were centred at Bridgetown, Balingup, Harvey, Waroona and Dwellingup and who carried out the releases.

After the Department of Fisheries took over management in 1971, the annual trout stocking list was drawn up by the Department of Fisheries Freshwater Research Officer, following consultation with WATFAA. The annual stocking list for rainbow trout has been based upon popularity of the water (including fishing success, and accessibility), evidence of natural spawning, presence of brown trout, distribution difficulty and cost, biological information and experience. Until the community-chaired Recreational Fishing Advisory Committee (RFAC) was formed, WATFAA was taken as representing the interests of freshwater anglers. WATFAA participated in a trout research log book program for the Department of Fisheries in the late 1960s and these records along with research sampling, provided a basis for stocking lists into the 1970s (Morrissy, 1972). WATFAA also initiated a record card for entering fish in an annual competition with the return of the record card being a condition of membership. The return of this card became a log book system for more general catch recording and these long-term records provided a basis for arriving at the annual stocking list until the early 1990s (Anon, 1982; Piggot, 1985).

The annual trout stocking lists prepared by the Department of Fisheries were considered by the new RFAC at its meetings from September 1992 until April 1994, when it met to take control of stocking. Subsequently, the spring stocking list was prepared by a RFAC Trout Stocking Subcommittee (now called the Trout Stocking Committee). Attendees at the Trout Stocking Committee meetings include the Recreational Fishing Program Manager from the Department of Fisheries and representatives from the South-West Freshwater Research and Aquaculture Centre, Freshwater Fisheries Research, RFAC (including the Chairperson), community angling groups, the Western Australian Fish and Game Club, WATFAA and an Executive Officer.

The Trout Stocking Committee currently does not follow a formal process, nor has it established guidelines for use when preparing the annual trout stocking lists. The lists are developed at Committee meetings using an informal process and trout are only stocked in waters with a stocking history. The advice of committee members is invaluable in selecting waters which will be of greatest benefit to the public.

Table 5 illustrates the trends in recreational trout stocking in public waters in Western Australia. A comprehensive listing of the drainage basins of the south-west of WA is attached in Appendix 1 and details the history of trout stocking in WA.

Table 6 summarises trout stocking and catch in public waters in WA. The stocking figures have been calculated from the Department of Fisheries' historical records. The catch figures are based on WATFAA catch records and therefore should only be considered indicative of presence within the drainage basins.

Table 5 *Trends in recreational trout stocking in public waters in Western Australia.*

Year	Streams				Dams *			
	Fry		Yearlings		Fry		Yearlings	
	Rainbow	Brown	Rainbow	Brown	Rainbow	Brown	Rainbow	Brown
1970	114 000				25 000			
1971	116 000				74 000			
1972	175 000				60 000			
1973	78 000	50 000			10 000	30 000		
1974	60 000	60 000			30 000	40 000		
1975	43 000	74 000			45 000	20 000		
1976	35 000				55 000	10 000		
1977	280 000	56 000			115 000			
1978	262 000	44 000			173 000			
1979	290 000	30 000			140 000	4 000		
1980	289 000	37 000	3 600		115 000	7 000		
1981	93 000	24 000	3 000		45 000		5 900	
1982	295 000	42 000	12 000		125 000		7 000	
1983							5 000	
1984	264 000				220 000	4 000	10 000	200
1985	209 000		22 000		47 000	35 000	10 000	
1986	3 000		6 800				11 200	
1987	63 000		1 000	1 700	37 000		11 000	500
1988			4 000				7 000	
1989	83 000		4 000		25 000		7 000	
1990	174 000		2 000		75 000		11 000	
1991	112 000	9 000	1 400		48 000	45 000	9 600	
1992	160 000		3 000		100 000		5 000	
1993	188 000		13 000		50 000		12 000	
1994	205 000		15 000		60 000		11 000	
1995	244 000	2 400			41 000			
1996	355 000	6 000			100 000			
1997	337 000			3 000	77 000		11 000	3 000
1998	221 000	50 000		2 200	34 000		10 000	800
1999	475 000		9 000		60 000		13 000	
2000								

* Dams are large government irrigation dams, not private farm dams or government domestic water supply dams.

Table 6 *Figures refer to the number of years when a record of stocking or catch exists in Western Australia.*

Drainage Basin **		Number of years in each decade					
		1970s		1980s		1990s	
		stocking	catch	stocking	catch	stocking	catch
601	Esperance	0	0	0	0	0	0
602	Albany	5	6	7	7	5	7
603	Denmark	1	0	0	0	1	0
604	Kent	0	0	0	0	0	0
605	Frankland	1	0	0	0	0	0
606	Shannon	0	0	1	0	0	0
607	Warren	8	7	8	9	7	8
608	Donnelly	10	7	8	9	8	8
609	Blackwood	6	5	7	8	7	8
610	Busselton	0	0	0	0	1	0
611	Preston	7	1	8	6	8	8
612	Collie	5	6	7	9	8	8
613	Harvey	9	7	8	9	8	8
614	Murray	10	7	7	9	8	8
615	Avon	0	0	0	0	0	0
616	Swan Coastal	3	4	4	6	4	4
617	Moore-Hill	0	0	0	0	0	0
701	Greenough	0	0	0	0	0	0
Total no. years with records available		10	7	10	9	8	8

** Refer to Figures 1 and 2 in Appendix 1 which illustrate the locations of the drainage basins.

4.2 Stocking Technique

In Western Australia trout are artificially spawned in July and hatchery fish can be stocked as:

- eyed ova (in Vibert boxes);
- swim-up fry (before first feeding);
- feeding fry;
- fingerlings in springtime (most common);
- yearlings in autumn (approaching one year of age); and
- legal sized fish (usually ex-breeding stock).

Heat induced triploid trout have also been produced since the 1980s for stocking farm dams where trout cannot spawn. Female egg production normally detracts from growth and egg-bound female rainbow trout usually die as 2+ year olds in farm dams. Female triploid trout are sterile (no gonad development) and can grow to in excess of three kilograms in three to four years in farm dams. Male triploid trout undergo gonad development but are functionally impaired.

Brown and rainbow trout do not mix well in rivers and dams and should not be mixed when stocking. This is because brown trout tend to predominate in numbers by virtue of aggressive

behaviour, territorality, larger size, longevity, lower catchability and greater spawning success in rivers. In mixed stocks, rainbow trout need to be maintained by stocking, particularly against angling pressure, as they are far more catchable.

Table 7 illustrates the stocking of trout in Vibert boxes and as ex-breeding stock. Generally stocking of trout as eyed ova in Vibert boxes has been unsuccessful. However, stocking waters with ex-breeding stock has proved much more successful, particularly in Waroona Dam where ex-breeding stock have been released since 1991 (N Morrissy, pers com).

Table *7* *Trout stocked as eyed ova in Vibert boxes and as ex-breeding stock in Western Australia*

Year	Eyed Ova in Vibert boxes		Ex-breeding stock
	Rainbow	Brown	Rainbow
1985		35 000	
1990	25 000		
1991	28 000	54 000	500
1992	60 000		800
1993			2 300
1994			1 300

4.3 Success of Trout Stocking

An investigation of the trout fishery in Western Australia was carried out during the late 1960s and the trout fishery at the time was summarized by Morrissy (1972), as follows:

"Despite prolonged stocking activites lasting more than 36 years, when the present appraisal was commenced, in 1967, there was no clear information on whether trout acclimatisation could be judged a success or failure. In fact, informed opinion varied from the conclusion that the waters provided insufficient food for a successful trout fishery (Jenkins, 1952) to the view that fishing was comparable with the best in the eastern states (Francois, 1966)."

The inland distribution of trout in WA could ultimately be constrained by their inability to tolerate prolonged periods of low stream flow and high water temperatures in the headwater streams (Davies et al, 1988; Closs and Lake, 1996). Many of the streams where trout occur have been described as 'marginal' for these species, with distribution and abundance being restricted by low volumes of water and high water temperatures in summer and early autumn (Morrissy, 1972).

For introduced trout to provide worthwhile fisheries, water temperatures and quality, notably oxygen levels, must be suitable for survival over summer. Generally the south-west of WA is predisposed to limiting summer conditions for trout. Summer/autumn pools in the rivers of the south-west have water temperatures that often exceed the lethal temperatures for trout (26 to 27^{o}C) and also often have poor water quality. While the smaller perennial streams offer cooler, higher quality water, they often have a very low and unreliable summer flow, due to extraction demands. Storage dams and large river pools in the south-west become thermally stratified in summer. While the high surface water temperatures (>20^{o}C) are unsuitable for trout and the cold bottom water can become deoxygenated, the intermediate depth layers near

the thermocline provide very favourable conditions for trout (Morrissy and Cassells, 1985). Storage dams also offer little shelter to hide from aerial predators such as cormorants.

The major and minor south-western rivers of WA have an unusual reversed valley sequence with no headwaters in mountains or lakes on rivers (Morrissy, 1972, 1974, 1979). Unlike rivers in the actively eroding young mountains of New Zealand and eastern Australia, there is little suitable spawning gravel and stones. While some trout spawning substrate occurs as water-rounded quartz, the commoner stream rocks in the South-West are unsuitable laterite and coffee rock and most of the south-west river beds are sand, or bed rock. This lack of suitable spawning gravel makes it very difficult for wild trout to maintain self-reproducing populations. This is an advantage as it makes regulation of this fishery relatively easy, as reproduction in the field is negligble.

There is no evidence, from growth rates, to support the hypothesis that trout in the South-West are unsuccessful because of lack of food. The streams support abundant populations of crustacea (marron, gilgies, shrimps and amphipods) and small native fish, but the usual types of aquatic insects (mayflies, caddis-flies, stoneflies) which are found in other successful trout streams are not so prevalent. However, the best growth rates of trout in Australia and elswhere are attained on diets of crustacea and small fish, and not small insects.

Trout acclimatisation in WA can be judged generally as unsuccessful if the criterion which is used is the number of fish captured per unit of fishing effort. However, the excellent average size of fish which are captured appears to adequately compensate anglers for the sparsity of fish. Unfortunately, successfully stocked rivers are being slowly reduced in number and quality due to anthropogenic pressures such as construction of dams, clearing (and the resultant salinisation, soil erosion and siltation), diversion and training of rivers, and the invasion of waterways by other non-endemic species such as redfin perch.

4.4 Access to Stocked Waters

While some of the larger proclaimed streams and nearly all the major rivers have Crown Reserves along their banks, private fencing along rivers often physically prevents access. Until recently only a small number of anglers sought access through private properties and these individuals were usually well known to the property owners. However, with an increasing number of anglers requesting permission for access, consent from landowners is decreasing (N. Morrissy, pers com).

Government dams supply domestic water to Perth and many South-West country towns and irrigation water to the Perth Plain south of Waroona. All domestic (drinking water) dams and catchments supplying Perth are closed to public access above the dam wall. This policy was introduced as mandatory throughout Australia during WWII to prevent sabotage of water supplies. The policy has been maintained, although the reason for closure nowadays is not only to preserve the water quality, but also to preserve public safety. While many petitions have been made to the water agencies over the past three decades for a relaxation of this policy to allow angling, it is unlikely that the policy will ever be relaxed. Many of the small domestic dams serving country towns are also now closed to angling, although the access policy has been relaxed in the recent past in some instances. As there are no large, deep, natural, lakes on the South-West rivers, the open access irrigation dams from Waroona to Wellington and Glen Mervyn, which are open to the public, receive heavy recreational use.

Public access to most State Forests in the Darling Ranges is also prohibited for quarantine and/or water catchment reasons.

None of the public access problems apply to farm dams, which are not part of the public waters stocking program. Fish are purchased privately for stocking and access is either free with permission, or through pay-fishing. Put and take fisheries have developed since the 1980s and some tourist facilities advertise trout fishing as part of accommodation expenses.

Trout stocking has not been carried out by the Department of Fisheries in waters contained within National Parks and Wildlife Reserves. However, trout fishing is pursued by anglers where major rivers pass through some of these areas, deriving stock from other reaches where stocking does occur.

4.5 Social and Economic Benefits

There is extensive historical literature on the value of trout as an angling species worldwide, particularly for fly fishing (Schwiebert, 1978) and they are probably the most scientifically studied group of fishes (Stolz and Schnell, 1991).

"Trout are widely valued as recreational fish because they are beautiful; because they are delicious; because they will eat artificial flies; because they are strong for their size, swift and vigorous; and because their usual habitat is regarded by most people as pleasant to beautiful." (Engstrom - Heg, 1981).

The number of trout anglers in Western Australia has been estimated from a previous Inland Fisherman's Licence (until 1986), the current Freshwater Fishing Licence (from 1992) and telephone surveys (table 8).

Table 8 *Economic Benefit of Trout Fishing in Western Australia*

Year	Number of Licensees	Revenue[3]	Cost of Licence[4]
1984-1985	4268	$ 19 883	$ 5
1992-1993	7554	$ 46 137	$ 10
1993-1994	8704	$ 52 630	$ 10
1994-1995	9015	$ 53 828	$ 10
1995-1996	7909	$ 69 222	$ 15
1996-1997	8184	$ 83 744	$ 15
1997-1998	9226	$ 70 788	$ 15
1998-1999	11 906	$ 137 440	$ 15
1999-2000	13 263	$ 169 566	$ 15
2000-2001	15 795	$ 203 163	$ 15

A telephone survey for 1992-1993 gave the following breakdown of licensees: 4,914 (65%) trout anglers, 2,093 (28%) perch anglers and 546 (7%) cobbler anglers (Morrissy, 1993).

[3] Combination of fees accrued as a proportion of the umbrella licence and from the South West Freshwater Angling licence.

[4] Cost of single South West Freshwater Angling licence

Tilzey (1982), both a trout angler and researcher, was one of the first to point out the neglected economic value of WA trout fisheries. However, while the magnitude and economic value of recreational fishing in WA has been estimated, the various fisheries are not identified (Lindner and McLeod, 1991). This and earlier surveys all indicated high participation rates in recreational fishing (the most popular sport in Australia) and that the sport contributes significantly to the WA economy.

Using the average values for direct costs (tackle etc), vehicle costs and expenditure generating community flow-on, the total value of $741 per fisher for 1989-1990 from Lindner and McLeod (1991) can be applied to 3,500 trout anglers, giving an economic value of about $3.3 million for trout angling in WA.

In direct contrast, Victoria (with a population more than three times that of WA) has an estimated 300,000 anglers interested in salmonids (using 1980s data) which are estimated as spending a total (excluding flow-ons) of $180 million, annually (Youngman, 1992). Participation rates for trout fishing in Tasmania, New South Wales, and Victoria were six to seven per cent, compared to only 0.4 per cent in WA. However, in Victoria the participation rate for all inland fishing is about 14 per cent, which compares markedly with a participation rate for south-western WA of just two per cent. The low participation rate for the south-west inland fishing reflects the very limited nature of the surface water resources by the end of summer, which may have limited the native fish in size and species (Morrissy, 1995b).

There are also a number of farm stays and other accommodation facilities in the South-West which have privately owned dams stocked with trout. These facilities either offer free access to guests, or alternatively charge a fee.

4.6 Tourism Value

Trout angling was first associated with tourism by Mr A.R. Kelly, at Pemberton, under the slogan ‘Trout in the Karri Country’, more than 60 years ago (Anon, 1949).

As well as trout angling in public access waters, the community has private farm dam fishing, access via clubs to stocked private dams, entry to put-and-take commercial trout fishing ponds, pay-fishing lakes and gourmet country restaurants serving locally farmed trout. These developments represent considerable tourism expansion for trout fishing, as these facilities were not available three decades ago. There are also professional guides who specialise in guiding and instructing tourists in fly fishing for trout.

Although the Western Australian trout fishery is small in comparison to fisheries overseas and in the eastern states, WA does have an annual State Fly Fishing Championship event at Pemberton, which provides national representatives for the annual World Fly Fishing Championship. A commercially sponsored annual trout fishing competition was also held on the public waters around Nannup, but this event has been discontinued. A new event, known as the Forest Fishing Festival, is now held on an annual basis within the Blackwood, Donnelly and Warren Rivers.

5. TROUT AQUACULTURE

5.1 Synopsis of the Commercial Aquaculture Industry

During the 1970s, there were many enquiries to the Department of Fisheries for advice on trout farming in Western Australia. At the time, commercial aquaculture of trout in other states and overseas was undertaken in small ponds at very high densities and high rates of daily feeding. These culture conditions required regular exchanges of pond water throughout the day to maintain water quality. Based on these basic requirements, trout farming in WA was obviously risky and limited by the supply of cool water during summer. The Department of Fisheries was therefore hesitant about encouraging ventures. However, in 1980 an informal market survey in Perth showed that about 30 tonnes of trout was being imported from eastern states trout farms and the supply to WA was often unreliable and fish quality was poor.

Consequently, commercial aquaculture trials were carried out at the South-West Freshwater Research and Aquaculture Centre. The first trial commenced in 1979 and used imported pelleted trout feed from New South Wales. However, all the fish developed skeletal deformities due to a vitamin deficiency in the feed and for the next trial in 1980 a local pelleted feed was produced. This trial was very successful and a report and subsequent trout farming guide were made available to prospective trout farmers (Morrissy, 1981; Morrissy and Cassells, 1985). In the late 1980s rainbow trout sea cage culture was tried by private entrepreneurs, briefly but successfully, at Albany.

A small number of trout farmers have since produced up to 50 tonnes annually (Lawrence, 1995) and Pemberton trout are now available as fresh and smoked product and live fish have been exported to Asia. The South-West Freshwater Research and Aquaculture Centre supported all these farms with stocks of young trout and the stock demands often exceeded supply (Table 4).

5.2 Aquaculture Production Systems

5.2.1 Farm Dams

The stocking of large (greater than one hectare) gully dams with trout is undertaken by farmers operating pay-fishing opportunities where you pay for access to the dams. These facilities are not designed to reliably produce trout in large quantities and of a size and quality suitable for the restaurant and retail fish market. These dams are designed for recreational fishing opportunities.

Farm dams may yield up to 100 kilograms of trout per hectare of water surface annually, compared to 50,000 kg/ha/yr from an intensive pond culture operation. Careful management of the dams is required to ensure a continual supply of good-sized fish for recreational fishing.

5.2.2 Put-and-Take Ponds

These facilities also provide pay-fishing for visitors but differ from farms dams by guaranteeing a catch. The cost is based on your catch with the price calculated on the weight of the fish caught. Trout are stocked in a small, semi-natural earthen or concrete ponds (0.05 to 0.1 ha in size), are hand-fed and stocked at high densities. These facilities are generally located close to a conventional trout farm to ensure a continuous supply of fish for the ponds.

5.2.3 Earthen Pond Culture

Earthen ponds are generally used for holding breeding fish at low stocking densities and therefore require less water exchange than intensive ponds. They are also used for holding graded stock which are fed at a lower rate in earthen ponds and then moved into concrete ponds where they are fed at higher rates and grow rapidly.

Ponds are designed with steep floors leading to a deep central sump along the long axis for long term accumulation of wastes. The disadvantage of earthen ponds is that they are not durable enough to withstand frequent cleaning. Furthermore, water circulation is poorer than in properly designed concrete ponds and water temperatures are difficult to maintain. These factors together with oxygen depletion and the accumulation of noxious wastes makes their use unreliable during Western Australian summers.

5.2.4 Intensive Raceway Culture

Straight raceways are a long narrow concrete pond with a water inlet and outlet at opposite ends. The water inlet should be designed so that water flows into the raceway along the whole width of the narrow pond. The floor of the pond should grade steeply into the inlet area and then slope gently (grade of 1 in 50), downwards towards the outlet. A sump for waste accumulation and fish harvesting is also constructed in front of the outlet. Where raceways are constructed in series to reuse water, re-oxygenation of the water between ponds must be enhanced by providing an appreciable drop in water level between raceways. However, raceways in series tend to facilitate the spread of disease from one pond to the other.

Not all raceways are long and narrow, with some raceways being rectangular and circulating water through two side water inlets. Spiral raceways are also used whereby the water inlet is located at the top of a circular tank and the water spirals down to an outlet at the bottom of the tank.

5.2.5 Intensive Concrete Circular Pond Culture

Circular ponds differ from raceways by providing near uniform water quality and flow conditions over the whole pond, so that fish are usually distributed quite uniformly at high densities. They have a central outlet hole and the floor of the pond should slope (1 in 20) towards this outlet. The inlet pipe spans the diameter of the pond and rests on the outlet screen. The water then discharges along the length of the pipe through a number of jet holes inclined slightly from the vertical. While management and access to circular ponds is better than for raceways, they require more floor space.

Fish stocked in intensive pond culture systems are kept at high densities with a high rate of feeding. The high feeding rates result in the build-up of wastes so the ponds require regular cleaning.

5.3 Trout Feeding and Grow-out

Trout spawn only once a year, during early winter and are artificially spawned (manually stripped of eggs and milt) at the South-West Freshwater Research and Aquaculture Centre. The fry obtained are best reared indoors to about 5 to 10 grams in the springtime, before being placed in large outside ponds. Pelleted, specially formulated trout feed is available from feed milling companies.

5.3.1 Economic Benefits of Commercial Aquaculture

Salmonids are a remarkably adaptable species as shown by their extensive translocation throughout the world (Donaldson and Joyner, 1983; Hershberger, 1992). With the exception of carp, salmonids are probably the oldest cultured fish that have been artificially bred in captivity.

There are currently 24 licensed commercial trout aquaculturalists in Western Australia (table 9). The purposes of these farms included food production, sale of juveniles, put-and-take fishing and pay-fishing. Tourist localities which solely provide ponds or dams for pay-fishing or put and take fishing are currently unlicensed.

Table 9 *Licensed trout aquaculturalists currently operating in Western Australia*

Farm Name	Locality	Operating Since
King Trout Farm	Pemberton	1990
Arcadia Farm	Wellington Mills	1986
WH and HM Love	Pemberton	1991
PJ & PL Thomsett	Manjimup	1991
Celtic Nominees Pty Ltd	Northcliffe	1993
Wood Nominees	Denbarker	1996
NH & HA Nancarrow	Coolup	1998
Hoop Pty Ltd	Serpentine	1998
Bruce Malcolm Nairn	Dwarda Downs	2000
Brian Leslie Gisborne	Bridgetown	2000
SJ & KP Mathwin	KoJonup	2000
J & M Currie	Yallingup	2000
Golden Ponds Marron Farm	Irwin	1998
RM Archdall & RW McClymont	Nannup	1999
KG Lawrence	Pemberton	1995
AJ & MC Davis	Waroona	1994
SN Smith	Esperence	1994
MA Hancock	Pemberton	1996
Wolfgang Lanzberg	Baldivis	1998
GL & EJ Houston	Jerramungup	1998
C J & K D Brown	Nowergup	1999
G D Chatfield	Tammin	2000
SF Peedle, RG & PL Longwood	Parkwood	2000
CS & PB Williams	Cunderdin	2000

As illustrated in Table 10, the annual food production of trout in WA during the past three financial years has ranged from approximately 24 tonnes to 28 tonnes. While records prior to 1996/1997 are not available, anectodal evidence suggests that production has been as high as 48 tonnes. While the market value for trout in WA is around $7/kg, some fish are also exported live or sold smoked at much higher prices. Fish caught from put and take fishing ponds are charged for at a premium rate, usually about $12 to 15/kg and pay-fishing dams are fished at $30 to $50 per day per angler.

Table 10 *Commercial trout production in Western Australia*

Year	Production (tonnes)	Number of Farms	Value ($)
1996/1997	28.338	4	219 520
1997/1998	24.284	6	196 038
1998/1999	25.000	5	205 000

5.4 Non-commercial Aquaculture

For the purpose of this discussion paper, non-commercial aquaculture is defined as the stocking of trout in water bodies on private land, for non-commercial purposes:

- in dams which have been constructed off streams,
- in dams which have been constructed along streams, also referred to as gully dams, and
- in artificial ponds or tanks.

While the translocation of trout for non-commercial aquaculture may require the movement of a smaller quantity of animals, the practice presents the same risks as the translocation of trout for stock enhancement and commercial aquaculture. Gully dams in particular present a significant risk as they are built along natural waterways and may overflow during winter.

5.5 Rainbow Trout in Inland Salt Water

In 1998, the Department of Fisheries and Agriculture WA, in collaboration with over 100 individual landholders throughout the agricultural areas of WA, developed a project aimed at promoting a new inland saline water aquaculture industry (Trendall and Pitman, 1998). The Outback Ocean Program was initially testing the grow-out of rainbow trout in shallow ponds and dams which are filled with saline groundwater.

In Western Australia, the current production of trout is entirely from fresh water. However, a number of studies have indicated that growth and/or survival of trout in warmer waters is improved at higher salinities (Tatum, 1976; Teskeredzic *et al*, 1989). During 1999 a selected number of properties throughout the WA wheatbelt, from Kendenup to Mukinbudin were used to undertake preliminary trials on the grow-out of rainbow trout in saline groundwater. These trials found that fish stocked at 50g at the break of season (April/May) grew to at least 500 g (suitable for the fresh, plate size market) by the end of winter.

Interest in the production of trout in inland saline waters has increased over the last few years and has lead to the formation of the Western Inland Fisheries Cooperative and the Saltwater Trout Alliance. These organisations are being assisted by the Government to investigate the feasibility of the establishment of an industry. Results produced to date over a small number of farms look promising although further trials and more detailed information is required before the commercial potential of saltwater trout can be confirmed.

If investigations conducted over the next 12 months prove successful, the production of rainbow trout in inland salt water presents a unique opportunity for farm diversification. Although the benefits to any individual farmer may be small, the collective production of the overall number of participants could result in significant economic returns for regional Western Australia.

6. SOUTH-WESTERN AUSTRALIA ENVIRONMENTAL FEATURES

The only habitat suitable for trout in Western Australia is in the south-west of the State where there is cool, high quality, well oxygenated, abundant water. South-western Australia is defined, for the purposes of this discussion paper, as the South West Drainage Division and is illustrated in Figures 1 and 2 (see Appendix One). Generally, this division is the area bordered by Geraldton in the north-west and Esperance in the south-east.

6.1 Topography

The South West Drainage Division covers an area of 314,000 square kilometres (Western Australian Water Resources Council (WAWRC), 1992). The rivers and streams that drain this area have widely differing characteristics depending on the topography, rainfall, vegetation and land use. Most of the Division lies on the south-western corner of the Australian Shield, an extensive plateau (the Yilgarn plateau) covering most of the State. The inland boundary of the Division separates it from the inland drainage of the Western Plateau. From this divide the land slopes gradually to the sea. Towards the south the slope is essentially uniform and unbroken, except for the Stirling, Porongurup and South Coast Ranges and hills formed by Proterozoic granites. In the west the Shield ends abruptly in the Darling Escarpment which is the major topographic feature of the region, some 200 metres in height. At the foot of the escarpment is a gently undulating sandy plain extending 25 to 30 kilometres to the Coast between Perth and Bunbury, widening to form the Dandaragan Plateau in the north and the Blackwood Plateau in the south (WAWRC, 1992).

6.2 Climate and Water Resources

The South-West region has a typically Mediterranean climate, with cool, wet winters and warm to hot, dry summers. Annual rainfall falls mainly during winter and streams have only very small spring-fed flows through the dry season. Flows decline and often cease through summer, often until the first rains of the wet season, which may be delayed until mid-May. Rainfall in the South-West is more abundant than anywhere in the State, with the exception of the Kimberley Region. The highest and most reliable rainfall occurs in two areas: just inland from the Darling Scarp between Perth and Bunbury; and along the south coast from Irwin Inlet to Lake Jasper. The average rainfall in these two areas is more than 1200 mm per year. To the north and east of these areas the rainfall drops off to a minimum of approximately 250 mm (WAWRC, 1992).

The rivers in the South-West vary widely in length, flow volumes, landforms and natural vegetation. In the driest eastern extremity of the Division, the upper reaches of the Avon River catchment, the low rainfall makes the drainage pattern almost invisible and there is only a network of shallow basins containing salt lakes. Following heavy rainfall these basins fill, overflow and join together as rivers. Further towards the coast the drainage patterns become better defined as rainfall increases. Westward flowing rivers descend the Darling Scarp from the Yilgarn Plateau, river gradients increase and the valleys become steeply incised. Pools are formed between rocky rapids, with the occasional waterfall. Once on the coastal plain, gradients are again slight with the rivers draining slowly into the sea via estuaries or inlets.

6.3 Freshwater Environment of South-West Australia

The aquatic habitats of south-eastern Australia can be characterised by predictable climatic conditions, a highly seasonal litter fall and synchronised life histories of the resident fauna (Bunn and Davies, 1990). Furthermore, species richness in south-eastern Australia is comparable to Northern Hemisphere habitats. In comparison, although south-west Australia shares a common Gondwanan origin with the rest of southern Australia and also has predictable climatic conditions, it has a much-reduced stream faunal diversity. South-western Australia supports only 63 per cent and 49 per cent of the invertebrate families and species (respectively), of those recorded for the south-east. The aquatic fauna present in the south-east, which is lacking in South-West of Australia, can be categorised as cold stenotherms, slow-growing species with long life cycles, species that attain a large size, algal grazers and invaders from northern Australia (Bunn and Davies, 1990).

South-western Australia is effectively isolated by ocean and desert, and streams flow through an island of temperate forest, thereby reducing immigration (Bunn and Davies, 1990). The low diversity of aquatic fauna also reflects the reduced range of resources offered by smaller areas, and the higher tendency for chance extinctions (Bunn and Davies, 1990). The highly endemic nature of the south-western fauna and flora as a result of such long isolation has led to the region being listed as one of the world's most important biological hotspots.

A period of extreme aridity, 18, 000 years before the present, probably caused exceptionally low stream flows, thereby selecting against larger species and those species with long larval stages (DeDeckker, 1986; Bunn and Davies, 1990). Many species in the perennial south-western streams today also colonise aquatic habitats with intermittent flow regimes (Bunn and Davies, 1990). Although climatic predicability has been shown to cause spatial and temporal niche diversification (thereby resulting in speciation and higher diversity) in the temperate forest streams of the Northern Hemisphere and aquatic habitats of northern Australia, this has not occurred in the South-West, presumably due to the low productivity of habitats within the South-West (Bunn and Davies, 1990).

Streams within south-western Australia have a low net primary productivity, at least two orders of magnitude less than that of streams in the Northern Hemisphere (Bunn and Davies, 1990). The lateritic[5] soils of the South-West's catchments are known to be extremely infertile and the allochthonous[6] input of energy into the streams, in the form of forest litter, is poor in quality (Bunn, 1988; Bunn and Davies, 1990). The low availability of primary food resources from autochthonous[7] and allochthonous sources may also place limits on the absolute size attained by aquatic species. This is particularly true for those species that are limited by a single year's growth, given that most lotic[8] species in south-western Australia are small compared to congeneric species in the south-east (Bunn and Davies, 1990). Secondary production in streams is therefore also thought to be low.

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5 Lateritic soils are derived from clays formed by the weathering of rocks and are composed chiefly of iron and aluminium hydroxides.

6 Allochthonous input originates from outside the system, such as the leaves of terrestrial plants that fall into a stream.

7 Autochthonous input originates from within a system, such as organic matter in a stream resulting from photosynthesis by aquatic plants.

8 Lotic species are those that live in actively moving water.

The rivers in the South-West have been subject to degradation pressures associated with the colonisation and expansion of the population in WA and these have had a devastating effect upon many of the rivers (WAWRC 1992). Clearing for agriculture took away the rivers vegetation and habitat and in some instances reduced rivers to little more than drains. This clearing in turn caused stream salinisation, soil erosion and river siltation. Then, as the population grew, rivers were dammed to supply towns with water and to irrigate crops and pasture. Land clearing resulted in increased flooding, which in turn lead to the diversion and training of rivers to protect existing developed land. These pressures have left few rivers in a pristine state, with the majority being significantly modified.

6.4 Introduced Species

Some 38 species of exotic freshwater fish have been recorded in Australian waters (Allen, 1989; Fletcher, 1986; Arthington, 1991; Kailola *et al*, in prep.). In comparison, 16 species of introduced fish have been recorded in WA waters, with 14 species currently present within the south-western corner (table 11).

Redfin perch (*Perca fluviatilis*) was first introduced to WA in 1892, and have subsequently been released into a large number of public waterbodies in the South-West (Coy, 1979). The ornamental koi carp (*Cyprinus carpio*) and the common goldfish (*Carassius auratus*) have both been found in a number of water bodies along the Swan Coastal plain, particularly around the Perth and Mandurah regions (D Morgan, pers com).

Three species of poeciliid are currently established in WA, these being the mosquito fish (*Gambusia holbrooki*) (by far the State's most prolific and widespread freshwater fish species), the one-spot livebearer (*Phalloceros caudimaculatus*) (recorded below Wungong Dam and in Lesmurdie Brook), and the swordtail (*Xiphophorus helleri*) (first recorded in the Irwin River in December 1998 (Morgan and Gill, in press)). The effects of the mostly deliberate introductions of *Gambusia* on the south-western Australian native fish fauna are only now coming to light, with the species showing aggressive territorial behaviour toward, and possibly competition for food resources with, similar sized native fishes (such as *Galaxias occidentalis, Bostockia porosa* and *Edelia vittata*) in slow-flowing and lentic[9] water bodies (Hambleton et al, 1996; Gill et al, 1999).

At least four fish species native to eastern Australia have been translocated into Western Australia, and these include short-finned eels (*Anguilla australis*), Murray cod (*Maccullochella peeli*), Golden perch (*Macquaria ambigua*) and silver perch (*Bidyanus bidyanus*) (Lawrence, 1993; Thorne and Brayford, 1997).

[9] Lentic species are those that live in still water.

Table 11 *Freshwater fish species introduced to Western Australia*

Scientific Name	Common Name	Literature References
Anguillidae		
Anguilla australis	Short finned eel, Victorian silver eel	Coy, 1979; Lawrence, 1993.
Cyprinidae		
Carassius auratus *	Common goldfish	Coy, 1979; Allen, 1982; Records of the WA Museum, 1999.
Cyprinus carpio *	Koi carp	Coy, 1979; Allen, 1982; Lawrence, 1993; Records of the WA Museum, 1999.
Tinca tinca	Tench	Coy, 1979
Salmonidae		
Salmo trutta *	Brown trout	Morrissy, 1972; Coy, 1979; Allen, 1982, 1989; Morgan *et al*, 1998; Records of the WA Museum, 1999.
Oncorhynchus mykiss *	Rainbow trout	Morrissy, 1972; Coy, 1979; Allen, 1982, 1989; Morgan *et al*, 1998; Records of the WA Museum, 1999.
Poeciliidae		
Phalloceros caudimaculatus *	One-spot livebearer	Lawrence, 1993; D Morgan, pers com.
Gambusia holbrooki *	*Gambusia*	Mees, 1977; Coy, 1979; Allen, 1982; Pen and Potter, 1991c; Lawrence, 1993; Morgan *et al*, 1998; Records of the WA Museum, 1999.
Xiphophorus helleri *	Swordtail	Morgan and Gill, in press
Percichthyidae		
Maccullochella peeli *	Murray cod	Morrissy, 1970; Coy, 1979; Lawrence, 1993; Sarre, pers. comm.
Macquaria ambigua *	Golden perch	Coy, 1979; Lawrence, 1993.
Terapontidae		
Bidyanus bidyanus *	Silver perch	Coy, 1979; Lawrence, 1993; Thorne and Brayford, 1997; Sarre, pers. comm.
Percidae		
Perca fluviatilis *	Redfin (Eurasian) perch	Coy, 1979; Allen, 1982; Pen and Potter, 1992; Lawrence, 1993; Morgan *et al*, 1998; Records of the WA Museum, 1999.
Cichlidae		
Tilapia zillii *	Zilles cichlid	Records of the WA Museum, 1999; Morgan pers. comm.
Oreochromis mossambicus	Mossambique cichlid	Arthington, 1991; Lawrence, 1993; Records of the WA Museum, 1999.
Tilapia mariae	Black mangrove cichlid	Arthington, 1991; Lawrence, 1993.

* Species that currently occur within the south-western corner of Australia

6.5 Success of Introductions

Fish which are introduced into areas outside their natural ranges, either deliberately or otherwise, and which subsequently produce self-maintaining populations, are considered to be 'successful' introductions. Many authors (Taylor et al, 1984; Arthington and Mitchell, 1986; Ehrlich, 1989; Arthington, 1991) believe that successfully introduced fish possess a number of characteristics that enable them to become established in new locations. Such attributes typical of 'successful' fish include:

- preadaptations to survive and reproduce in disturbed habitats, particularly those adaptations which confer resistance to pollution, nutrient enrichment, or extremes of pH,
- wide tolerances to environmental variables such as temperature, salinity, oxygen levels, and turbidity,
- a broad diet (omnivory),
- high fecundity and/or specialised reproductive strategies such as oviparity and mouth brooding,
- fast growth rates,
- high genetic variability within the introduced population,
- freedom from host-specific parasites, disease, and natural predators, and
- association with humans (for example, as food or sport fishes).

Based on the above characteristics, introduced fish within south-western Australia can be broadly grouped into two categories. The first category includes those species that display the majority of characteristics listed above and are represented by members of the families Cyprinidae, Poeciliidae, Cichlidae and Percidae (Table 11). The second group owes its success mainly to humans, and as such, often requires few of the above characteristics in order to become 'successful'. Such fish include trout, whose success in south-western Australia can be largely attributed to an ongoing stocking program. Generally, the trout present in Australia have very low genetic variability, can only exist at the top of the food chain as the dominant predator, exhibit very low tolerance to high water temperatures and have limited natural breeding success, yet have persisted in the wild for over 100 years (Tilzey, 1977; Lawrence, 1993). Tilzey (1977) suggested that in addition to the virtual absence of parasites and disease, there are three factors that have contributed to the establishment and success of trout in Australia; the physiochemical and biological similarities between Australian trout habitats and those of ancestral stocks, the minimal competition from indigenous fauna, and the abundance and availability of certain native prey species.

6.6 Native Species

The south-western drainage division contains a total of 14 native fish species, (Table 12). There are ten principal species, comprising one species of the Plotosidae, the sole representative of the Lepidogalaxiidae, five species of the Galaxiidae, the only member of the Percichthyidae in Western Australia and two species of the Nannopercidae. All but two of the gallaxiid species are endemic to south-western Australia. With the exception of the freshwater catfish, none of these eight endemic species typically exceed 140 mm in total length and five of these species have maximum total lengths of less than 90 mm (Allen 1989, Morgan *et al*, 1995). Four of these species are typically confined to the high rainfall region in the extreme lower south-western corner of WA, whereas the other six species are much more widely distributed.

The freshwater waterways in this region also contain the pouched lamprey, the sole representative of the Geotriidae, one endemic species of the Atherinidae and two species of the Gobiidae, one of which is endemic (Morgan et al, 1998).
There are nearly 100 species of native freshwater crayfish species in Australia, however only a few of these are found in the streams and dams of south-western WA. The crayfish most commonly caught there are marron (*Cherax tenuimanus*), koonacs (*Cherax plebejus* and *Cherax glaber*), gilgies (*Cherax quinquecarinatus* and *Cherax crassimansu*) and yabbies (*Cherax albidus*). Yabbies are an introduced species from south-east Australia which have been stocked in many dams throughout the South-West. Marron is a very popular recreational species and has been stocked in rivers and dams outside its original range. Consequently the distribution of marron is now much wider than it was originally. Two other species commonly found in the South-West include a freshwater shrimp (*Paratya* spp.) and three species of burrowing decorated crayfish (*Engaewa* spp.).

Marron reach sizes over 38 cm (total length) and any crayfish over 20 cm (total length) is almost certainly a marron. They inhabit sandy bottoms of permanent rivers, lakes, streams and gully dams which remain cool and well oxygenated in summer. Koonacs may reach 20 cm (total length) in length and inhabit inland rivers and swamps. These inland waterways dry up seasonally and koonacs burrow to escape these droughts.

Gilgies are the smallest of the four crayfish reaching a maximum size of 13 cm (total length), but they are typically much smaller. They inhabit small semi-permanent streams and swamps and also burrow to escape drought. Yabbies are an introduced species which reach a size of 13 cm (total length) and are farmed in dams throughout south-western WA. However, they have escaped or been deliberately introduced into rivers within the South-West.

Table 12 *Native fish of south-western Australia*

Family	Scientific Name	Common Name	Conservation Status *	Endemic to south-western WA
Plotosidae	*Tandanus bostocki*	Freshwater cobbler	inclusion not warranted	yes
Lepidogalaxiidae	*Lepidogalaxias salamandroides*	Salamanderfish	restricted	yes
Galaxiidae	*Galaxias maculatus*	Spotted minnow	unknown	no
	Galaxias truttaceus	Trout minnow	most restricted distribution in SW Australia	no
	Galaxias occidentalis	Western minnow	inclusion not warranted	yes
	Galaxiella nigrostriata	Black-stripe minnow	restricted	yes
	Galaxiella munda	Western mud minnow	restricted	yes
Percichthyidae	*Bostockia porosa*	Nightfish	inclusion not warranted	yes
Nannopercidae	*Edelia vittata*	Western pygmy perch	inclusion not warranted	yes
	Nannatherina balstoni	Balston's pygmy perch	vulnerable	yes
Geotriidae	*Geotria australis*	Pouched lamprey	inclusion not warranted	no
Atherinidae	*Leptatherina wallacei*	Swan River hardyhead	inclusion not warranted	yes
Gobiidae	*Pseudogobius olorum*	Swan River goby	inclusion not warranted	no
	Afurcagobius suppositus	Big headed goby	inclusion not warranted	yes

* Conservation Status in the Australian Society for Fish Biology's List of Australian Threatened Species (Morgan *et al*, 1998)

7. ENVIRONMENTAL ISSUES

7.1 Impact on the Environment and Native Species

Salmonids are opportunistic predators and usually select the largest and most readily accessible prey (Tilzey, 1977). They are known piscivores (fish eaters) and preliminary results from the dietary analysis of brown and rainbow trout taken from water bodies in south-western Australia suggest that they take a diversity of prey, including fish (Western minnow, *Gambusia*, Western pygmy perch and redfin perch), amphibians, aquatic snails, aquatic insects, terrestrial insects and decapod crustaceans (such as marron, koonacs and gilgies) (Jenkins, 1952; Pusey and Morrison, 1989; Hambleton *et al*, unpublished data).

The effect of introducing large predatory fishes, such as trout, into freshwater habitats that have been historically devoid of such top order predators, may not only have an impact on a particular species but may also affect the overall functioning of stream communities. Preliminary examination of the stomach contents of trout taken from Lefroy Brook, Pemberton, show that large numbers of grazing invertebrates (gastropods and decapods) are ingested, which may in turn result in a reduction in the local abundance of grazers/scavengers and a concomitant increase in algal biomass (Hambleton *et al*, unpublished data).

7.1.1 Competition with and/or Predation on Native Fishes

The main impact an introduced fish will have on native fishes is to create competition for limited resources, mediated by interference and aggression (Arthington, 1991). The demand of two species, existing at the same trophic level, for a resource that is actually or potentially limiting (such as available food/habitat), is accepted as evidence for competition. A large overlap often occurs in the diets of the introduced fish and the native fish in a given system, and the extent to which the species are able to coexist depends on both the extent to which resource partitioning can occur, and the availability of resources in that system (Arthington, 1991). To date, there is a growing body of evidence suggesting that trout have had an impact on the native freshwater fish fauna of Australia and New Zealand (Table 13).

The main interactions between trout and native fishes are those of predation (by adult fish) and competition (between juvenile trout and native fish). Small native fusiform fishes, such as galaxiids and minnows, appear to be at the greatest risk of both predation by and competition with introduced trout, with around 90 per cent of the studies listed in table 13 reporting a decline in numbers, or reduction in range of these small fusiform species. This may, in part, be related to the similar habitat preferences of trout and these small fusiform fishes.

Four of the five species of native galaxiids of south-western Australia may be at risk of predation and/or competition from trout. These are the Western minnow, trout minnow, spotted minnow and Western mud minnow. The threat to the Western minnow is thought be low, due to the widespread range of this species, however there is a high risk of losing localised populations to trout. Genetically distinct populations of Western minnow have been identified from adjacent drainage divisions (Watts *et al*, 1995) and the loss of localised populations may have implications for the conservation of the genetic diversity of this species.

Table 13 *Australian and New Zealand case studies where salmonids have impacted on native fish species*

Observation	Case Studies supporting Observation	Species affected in each study	Location of study
Predation by salmonids resulting in the fragmentation and/or decline in range, or reduced abundance, of a native species.	1. Cadwallader and Eden, 1982	*1. Oncorhynchus mykiss* and *Galaxias maculatus*	1. Lake Purrumbete, Vic.
	2. Townsend and Crowl, 1991	2. *Salmo trutta* and *Galaxias vulgaris*	2. Taieri River, N.Z.
	3. McIntosh *et al*, 1994	3. *S. trutta* and *G. vulgaris*	3. Shag River, N.Z.
Competition by salmonids resulting in the fragmentation and/or decline in range, or reduced abundance, of a native species.	4. Cadwallader, 1975	*4. S. trutta*, *G. vulgaris, Gobiomorphus breviceps* and *Anguilla dieffenbachii*	4. Glentui River, N.Z.
	5. Tilzey, 1976	*5. S. trutta*, *S. gairdneri*, *Galaxias coxii* and *Galaxias olidus*	5. Lake Eucumbene catchment, N.S.W.
	6. Jackson, 1978	*6. S. trutta* and *Gadopsis marmoratus*	6. Aberfeldy River, Vic.
	7. McIntosh *et al*, 1992	*7. S trutta* and *G. vulgaris*	7. Shag River , N.Z.
	8. McIntosh *et al,* 1994	*8. S. trutta* and *G. vulgaris*	8. Shag River, N.Z.
	9. McIntosh and Townsend, 1995	*9. S. trutta* and *G. vulgaris*	9. Taieri River, N.Z.
Fragmentation and/or decline in range of a native species by salmonids but with no mechanism suggested	10. Cadwallader, 1979	*10. S. trutta* and *G. olidus*	10. Seven Creeks River system, Vic.
	11. Ault and White, 1994	11. *S. trutta* and *G. truttaceus*	11. Tasmania
	12. Jackson and Williams, 1980	12. *S. trutta, G. olidus* and *Galaxias brevipinnis*	12. Yarra River and Otway Ranges, Vic.

Trout minnows are most common in the streams and lakes comprising the Moates Lake catchment of the Two People's Bay Nature Reserve (Morgan *et al*, 1998), where trout have previously been found but have not been recorded for at least three years (Coy, 1979; Morgan and Gill, in press). The presence of trout in the reserve is surprising as trout have not been stocked in this area by the Department of Fisheries as part of any recreational stock enhancement program since the 1960s (N. Morrissy, pers com). Due to the extremely low numbers of trout minnows in WA, stocking of trout into waterways inhabited by this species would be likely to threaten the small populations. The spotted minnow is common between Two People's Bay and Israelite Bay (D. Morgan, unpublished data). The remaining species of minnow, the Western mud minnow, is thought to be at the highest risk of extinction by trout due to the small adult size that this species attains, the similarity in habitat preference between the two species, and the relatively restricted distribution of this species within the South-West. The fifth species of native galaxiid, the black-stripe minnow, is unlikely to be threatened by

trout as it occurs predominantly in the ephemeral tannin-stained waters of the southern acid peat flats, where trout are currently not present and, due to the unsuitability of this habitat, would probably not be introduced.

Research indicates that there has been a decline in the abundance of Western mud minnow, Western pygmy perch and nightfish, in a stream located in the South-West, where brown and rainbow trout also occur (see Pen *et al*, 1991a; Morgan and Gill, 1996; Morgan *et al*, 1998). Extensive sampling by Murdoch University suggests that the Western mud minnow may now have been lost from this system. However, it is difficult to prove conclusively whether this is due to the presence of trout, the presence of redfin perch, the hydrological changes imposed by the creation of a dam on this system, or a combination of these and other factors.

Research indicates that trout are able to coexist with native species, without having an impact, through sometimes subtle differences in habitat preferences and/or feeding times. A short-term (24-hour) experiment in the riffle zone of a lake-inlet stream of the Ryton River, New Zealand found that differences in the pattern of diet feeding and micro-habitat use may lessen the interaction between a galaxiid and two salmonid fish species (Glova and Sagar, 1991). These authors demonstrated that *G. brevipinnis* feeds almost exclusively at night on the benthos and frequently inhabit faster-flowing areas (water velocity 0.8 to 1.1 m/s), whereas both brown and rainbow trout feed mostly during the day, on drifting and benthic prey, and inhabit areas of lower flow (water velocity 0.4 to 0.7 m/s) (Glova and Sagar, 1991).

Some fishes native to eastern Australia (eg *Anguilla australis, Galaxias brevipinnis* and *Gadopsis marmoratus*) appear to be able to coexist with brown trout, probably due to both differences in habitat use (Jackson and Williams, 1980; Glova and Sagar, 1991) and the large size attained by the species. Brown trout are also apparently able to coexist with the smaller spotted minnow and trout minnow in streams where trout are in small numbers, as a consequence of limiting conditions (Jackson and Williams, 1980).

Table 14 summarises the threat that brown and rainbow trout pose to the native fish of south-west Western Australia.

Table 14 *Summary of the threats trout pose to south-west Western Australia's native fish fauna*

Native Species	Distribution, habitat and abundance	Coexist with trout	Potential threat from trout
Geotria australis (Pouched lamprey)	Widely distributed throughout the South-West.	Yes	Low, due to burrowing lifestyle of ammocetes and large adult size. However, an ammocete has been recorded in a trout stomach.
Tandanus bostocki (Freshwater cobbler)	Widely distributed. Most abundant in larger permanent water bodies.	Yes	Low, due to large size attained, presence of large venomous spines and no documented evidence of predation.
Lepidogalaxias salamandroides (Salamanderfish)	Restricted to lower south coast in some acidic, tannin-stained, ephemeral water bodies of the region.	Never recorded	Low, as trout would be unlikely to persist in its habitat. [Restricted]
Galaxias occidentalis (Western minnow)	Abundant and widely distributed throughout streams and lakes of the South-West.	Yes	Low, but may cause localised extinctions as trout predate heavily on this species.
Galaxias truttaceus (Trout minnow)	Distributed across southern Australia but only apparently abundant in one small drainage basin in the South-West (Two People's Bay).	Never recorded, although trout were once introduced into its habitat.	High-risk species due to its limited range in WA and occupying a similar niche.
Galaxias maculatus (Spotted minnow)	Distributed across southern Australia and occurs between Albany and Esperance in WA.	Never recorded, although trout were once introduced into its range.	High-risk species should trout be introduced into its range.
Galaxiella nigrostriata (Black-stripe minnow)	Restricted to pools of the lower south coast but with two disjunct populations at Bunbury and Ellen Brook.	Never recorded	Low, as trout would be unlikely to persist in its habitat. [Restricted]
Galaxiella munda (Western mud minnow)	Restricted to small streams from Margaret River to the lower south coast but with a disjunct population near Gingin.	Yes	High risk, due to small adult size and similar habitat preferences to trout. [Restricted]
Bostockia porosa (Nightfish)	Widely distributed throughout the south-west. However, not usually found in large numbers.	Yes	Low, due to cryptic lifestyle. May cause a localised decline in abundance.
Edelia vittata (Western pygmy perch)	Widely distributed throughout the south-west. Often very abundant.	Yes	Low, but may cause a localised decline in abundance as has been found in trout stomach contents.

Nannatherina balstoni (Balston's pygmy perch)	Restricted to pools and streams of the lower south coast but with disjunct populations at Bunbury and Gingin. Rare.	Yes	Moderate, as few populations occur in habitats suitable for trout. [Vulnerable]
Leptatherina wallacei (Swan River hardyhead)	Widely distributed throughout the south-west. Most abundant in lower reaches of river systems.	Yes	Low, due to the super-abundance of this species when found.
Pseudogobius olorum (Swan River goby)	Widely distributed throughout the South-West.	Yes	Low, but may cause a localised decline in abundance.
Afurcagobius suppositus (Big headed goby)	Widely distributed throughout the South-West.	Yes	Low, due to crypto-benthic lifestyle.

7.1.2 Competition with and/or predation on Native Invertebrates

The impact of trout on south-western Australia's freshwater crayfish, and in particular their effect on the marron fishery has never been quantified. Historically, studies have focused on the impact salmonids have on native fish, as opposed to determining the effect they have on the invertebrate fauna. The rationale for this is two-fold. Firstly, a decrease in native fish numbers gives the most immediate and obvious indication of an effect, due to the low density of these organisms relative to that of the invertebrate component. Secondly, a significant reduction in the invertebrate fauna by trout could also facilitate a concomitant decrease in the abundance of other high trophic level organisms (such as native fish) due to food webs being irrevocably linked.

Several studies have shown that decapod crustaceans can be a large component of salmonid diets (Jenkins, 1952; Pidgeon, 1981; Shave *et al*, 1994), and salmonids are held responsible for the local extinction of one of New Zealand's two freshwater crayfish species, *Paranephrops planifrons* from Lake Waingata in the North Island (Shave *et al*, 1994). The other freshwater crayfish *Paranephrops zealandicus* is also thought to have declined in both numbers and distribution on the South Island of New Zealand, due to predation by brown trout.

With respect to the regions invertebrate fauna, trout pose the greatest threat to those locally endemic species that are naturally rare or in danger of extinction. Of the 156 species of freshwater invertebrates identified from the Warren Bioregion (the coastal region between Cape Naturaliste and Albany) around 40 per cent of these are listed as endemic to this region (Trayler *et al*, 1996). Two of these locally endemic species are decapod crustaceans (*Engaewa subcoerulea* and *Engaewa similis*) that may be at risk of predation should their swampland habitat near Margaret River become flooded (through the construction of impoundments) and subsequently stocked with trout.

Given the long history of trout introductions into the South-West, any significant reduction in aquatic invertebrates by these fish should be evident from a comparison of similar streams in which trout are present and those in which there have been little or no introduction. Unfortunately, no aquatic invertebrate faunal study of the South-West to date has made a distinction between these two systems. Furthermore, in order to attribute any significant reduction in a component of the aquatic fauna to the presence of trout, it must be shown that these fish are selecting food items that are different to those consumed by the resident native fish fauna. Although there has been considerable analysis of the diets of native fish (including Pen and Potter, 1990, 1991a, 1991b; Pen *et al*, 1991b, 1992, 1993; Hewitt, 1992; Pusey and Bradshaw, 1996; Morgan *et al*, 1995, 1998), the only available literature pertaining to trout diets within the South-West are those by Jenkins (1952) and Pusey and Morrison (1989).

7.2 Genetic Diversity

The potential impact on genetic diversity is pertinent when there is an existing endemic population that differs genetically from the species being introduced. Genetic diversity may be decreased through inter- and intra-specific hybridisation or the mixing of genetically discrete strains (Lawrence, 1993). As trout are an introduced species and there are no endemic populations of the species, their impact on genetic diversity is unlikely to be an issue. Due to the high degree of endemism of Australia's freshwater fish fauna it is unlikely that hybridisations between introduced and native species will occur (Fletcher, 1986; Arthington, 1991). However, the introduction of new stock from the eastern states has the potential to impact on the genetic diversity of existing trout stocks which have established in WA.

7.3 Introduction of Diseases and Parasites

The introduction of salmonids to Australia during the past century, as eggs from wild fish, has prevented the introduction of many of the severe salmonid viral and bacterial diseases present in the Northern Hemisphere. However, there are several viral and bacterial diseases which have been acquired by Australian stocks. The origin of these diseases may be from the introduction and translocation of aquarium fish such as goldfish, other aquaculture species such as redfin perch and perhaps the 1960s imports of salmonids (Langdon et al, 1986, 1988).

The introduction of exotic parasites and diseases is always an associated risk with the translocation of fish. Western Australia is fortunate in that a number of diseases affecting salmonids in other states are not present in local, hatchery-reared trout (Lawrence, 1993). The relatively disease free status of trout in WA gives the industry a competitive advantage over other states within Australia (with the exception of Tasmania) and other countries which have a higher incidence of disease. Currently the most significant disease present in WA trout is the bacterium *Mycobacterium marinum*. While Mycobacteriosis is a significant disease in trout, its presence in WA is being controlled through culling of infected fish and reducing water temperatures at the South-West Freshwater Research and Aquaculture Centre, so that trout are less susceptible to infection. However, these conditions cannot be maintained once fish are stocked in natural waterways where disease outbreaks may occur and endemic species may be infected. Mycobacteriosis is also found in aquarium fish, including *Gambusia*, which if released to natural waterways may transmit the disease to endemic species.

While generally diseases from cultured organisms are unlikely to threaten wild stocks, transmission has occurred. For instance, Epizootic Haematopoietic Necrosis Virus was first described in redfin perch in Victoria in 1986 and has since spread to brown and rainbow trout, mountain galaxias, Macquarie perch and silver perch (Langdon, 1989). In comparison to wild fish, cultured fish are crowded and under stress and therefore more likely to be affected by disease.

There are a number of the diseases present in other states which pose a significant risk to trout in WA. The susceptibility of non-salmonid species to these diseases is of particular concern when considering recreational stock enhancement where cultured stock will come in contact with native species.

7.4 Conclusions

The translocation of any species must balance the economic and social benefits with the biological and environmental risks. This discussion paper has been prepared to assist in the determination of an appropriate management framework for the translocation of brown and rainbow trout, into and within Western Australia, for the purposes of recreational stock enhancement, commercial aquaculture and non-commercial aquaculture. The following conclusions are drawn in relation to the information provided about the environmental, disease and genetic risks.

Impact on the environment and native species

Trout are amongst the largest freshwater species in south-western WA, rivalled only by the native Freshwater cobbler and the introduced red-fin perch and koi carp. There is a considerable body of work devoted to the impact salmonids have on freshwater fish and only a small amount on their impact on freshwater invertebrates.

From a review of the available literature it would appear that the main deleterious effects of trout arise from predation on native fish and crayfish, and competition between juvenile trout and similar sized natives. In south-western Australia, trout are likely to have the greatest impact on native fusiform fish, such as the minnows and galaxiids, through predation and/or resource competition (Table 14). From the limited amount on information available, it is evident that trout do feed on a range of invertebrates. However, trout have co-existed with marron and other freshwater crayfish and invertebrates in the South-West for over 50 years. Further work into the impact trout are having on the freshwater invertebrates of the south-west is required to critically assess the impact.

Wager and Jackson (1993) nominated either salmonids or *Gambusia* as the main threat to 42 per cent of the eight per cent of Australian native freshwater fish species listed as endangered. For the remaining 58 per cent of endangered fishes, they nominated human processes as being the causative agent. Indeed, it is generally recognised that destruction of freshwater habitats from land and water management practices is the single largest threat to Australia's native fish fauna, greater than competition with introduced fish or fishing pressures (Weatherley and Lake, 1967; Cadwallader, 1978; Harris, 1984; Merrick and Schmida, 1984; Welcomme, 1984; Michaelis, 1989; Moberly, 1993; Wager and Jackson, 1993).

The presence of trout in south-western waterways is generally maintained through annual stocking, as few areas provide suitable spawning gravel. While this may be considered a feature that could minimise the impact to the natural environment and native species, it would only be apparent when continuous stocking ceased. Impacts arise from the presence of trout in natural waterways and continued restocking serves to maintain this presence in the absence of successful spawning.

The lack of reproductive success may be considered a benefit in areas where trout are stocked in dams or ponds from which trout may escape to natural waterways. In these instances escapees will only persist for a few years before they disappear.

Impact on genetic diversity

Being an introduced species there are no endemic populations of trout in the South-West of WA. Furthermore, it is highly unlikely that trout would interbreed with any native freshwater fish. Therefore, the translocation of trout is unlikely to have an impact on the genetic diversity of native species.

Introduction of diseases

There are a number of diseases present in other states that affect brown and rainbow trout, which are currently not found in WA. If these diseases are introduced to the trout aquaculture industry in WA, the impacts could be significant. Furthermore, many of these diseases are infectious to native Australian species and if released to natural waterways, may infect native fish.

Appropriate controls on the importation of trout from interstate, will minimise the risk of introducing new diseases and prevent the transfer of diseases to wild populations of native fish.

Impacts in context

Both brown and rainbow trout are predatory fishes. When co-existing in the same water body, brown trout will tend to consume benthic prey (such as crayfishes) while rainbow trout tend to consume mid-water prey, particularly insect fauna (Tilzey, 1976). However, both brown and rainbow tout, like most species of predatory fishes, are opportunistic and will prey on a wide variety of food sources, particularly in prey-limited environments. In WA, both brown and rainbow trout will impact on endemic fauna (endemic fishes, crustaceans and other species) due to the predatory nature of both trout species.

Although trout will have a negative impact on aquatic species, the level of impact that trout have relative to other factors must be considered. Throughout the South-West where trout have been stocked, land clearing, water extraction, salinisation and other anthropogenic impacts have all resulted in major changes to the freshwater environment. All of these factors have also had a negative impact on the distribution and abundance of native fishes and crayfishes. The real question in relation to trout translocation is; what is the impact of trout on endemic aquatic fauna in relation to other impacts (such as land clearing)?

Unfortunately, due to the long history of changes in land and water management (in excess of 150 years) and the long history of trout stocking in WA (approximately 100 years), being able to quantify the impact of each factor, including trout, is virtually impossible. However, there is good anecdotal evidence available from WA that indicates that changes in land practices have a far greater negative impact on aquatic fauna than the predatory effects of trout. For instance, only a small proportion of the Swan-Coastal catchment (watershed 616, where the Perth metropolitan area is located) was ever stocked with trout in relatively small numbers and most waters have been unstocked since at least 1970 (see Appendix 1). However, many of the species of native fishes that were originally present in the Swan-Coastal catchment have disappeared. This is most likely due to a combination of anthropogenic factors, including clearing and land development, flood mitigation and the introduction of exotic species capable of breeding and dominating the remnant aquatic areas (such as the mosquito fish, *Gambusia*). As a result, the ranges of many species of South-West native fishes have contracted significantly within this catchment (Morgan *et al*. 1998)

Although an extreme example, changes in land and water management in the other south-west catchments are also likely to have major impacts on the endemic aquatic fauna. Relative to these impacts, the impacts of trout are likely to be minor, especially considering the relatively low numbers of trout and limited number of stocking locations ($n < 20$). Further, there is anecdotal and research evidence to indicate that the most dominant species of fishes in the South-West are the predatory red-fin perch (*Perca fluviatilis*), which dominates the predatory fish fauna even when trout are present and the mosquito fish *Gambusia*, which is the most abundant species of fish in the South-West and very antagonistic to endemic fishes (Morgan *et al*. 1998). Nonetheless, as the examination of fish gut-contents is routine, there is a great deal of evidence of the impact of trout, and red-fin, on native fauna. Unfortunately, techniques to quantify other effects (for example, water diversion) are not as readily available as gut-content analyses. While reading the proceeding sections, the reader must bear in mind the likely impacts of trout relative to other, major changes in the South-West, including land clearing, water diversion, salinisation and the effects of other introduced species.

7.5 Future Policy on the Translocation of Brown and Rainbow Trout

A draft policy on the translocation of brown and rainbow trout for aquaculture and recreational fishing stock enhancement will be developed following the release of this discussion paper and a review of all the comments received.

The draft policy will be developed through the application of a risk assessment process to identify areas of significant impacts. A following cost-benefit analysis will establish the conditions under which the translocation of brown and rainbow trout may occur. These conditions will provide the framework from which to develop the draft policy.

The draft policy is likely to consider

1. the areas within Western Australia where stocking of brown and rainbow trout may or may not be permitted, for the purpose of recreational stock enhancement, non-commercial aquaculture and commercial aquaculture,
2. the suitability of properties within WA to culture or domestically stock trout, and
3. the constraints on importing live trout into WA.

Following the receipt of comments on the draft policy, the Department of Fisheries will prepare and distribute a final policy to all interested stakeholders.

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9. APPENDIX ONE

Listing and description of individual trout waters in South-West catchments.
(Morrissy 1972, Olsen and Skitmore 1991, WAWA 1989 and 1990, WAWRC 1984, 1985 and 1992).

Key:

A - Access for public angling
- 1 State Forest with access
- 2 Irrigation dam with access
- 3 Domestic city or town supply dam with no access
- 4 Private property
- 5 National Park or Wildlife Reserve

E - Catchment and Stream Environment
- 1 Stream, low salinity and nutrients
- 2 Stream, salinised and eutrophic
- 3 Stream on developed private property, farm dams, water extraction and eroded banks
- 4 Stream below dam with large summer tailwater release
- 5 Stream below dam with no or intermittent and/or small summer tailwater release

S - Trout spawning - stocking
- 1 1 Natural spawning
- 2 Hatchery stocking

T - Trout species present
- 1 1 Rainbow trout fishery
- 2 Brown trout fishery
- 3 Previous fishery/stocking attempts

P - Angling popularity
- 0 - 3 rating

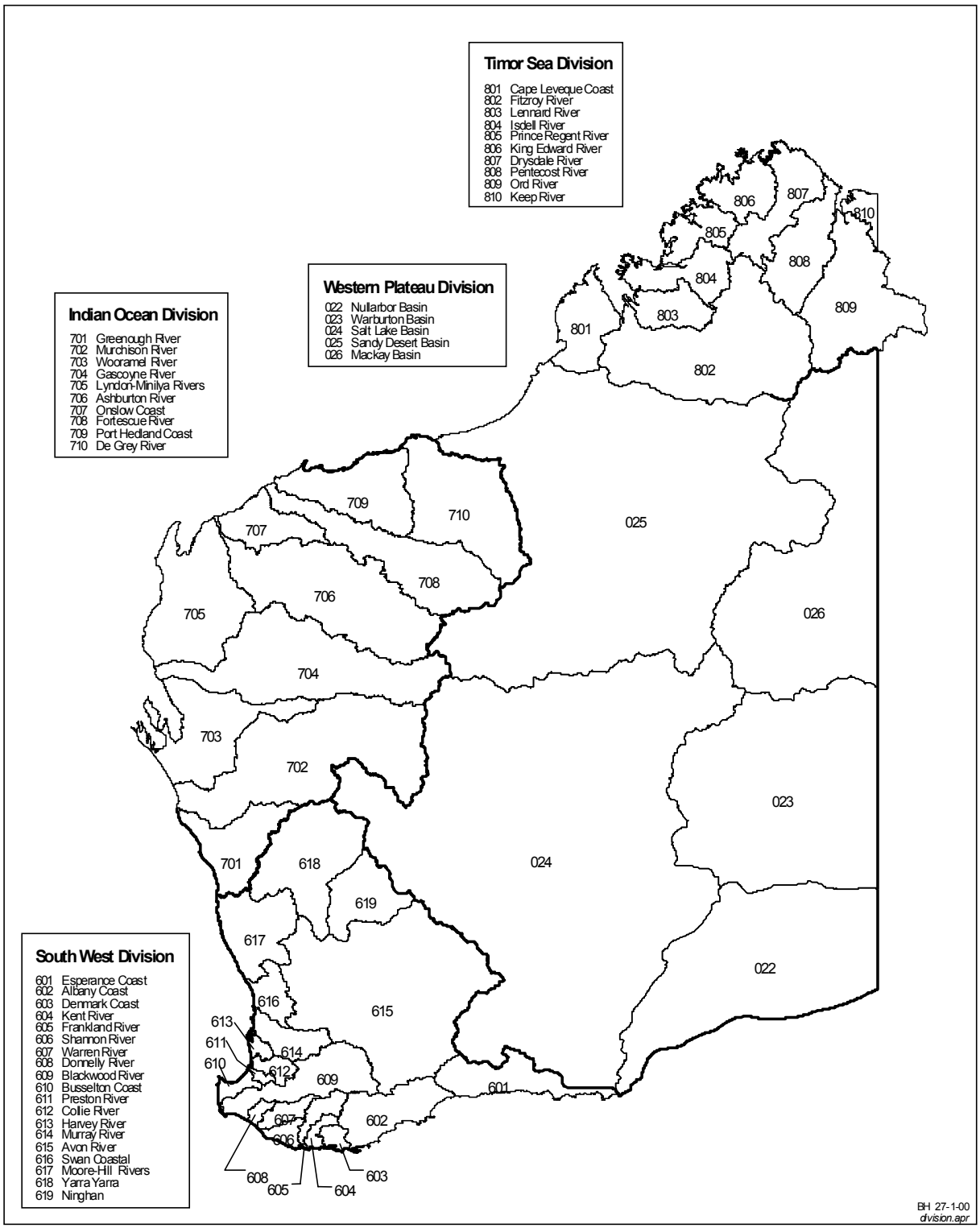

Figure 1 Drainage Basins of Western Australia

Figure 2 Drainage Basins of South-West Western Australia

601 Esperance Coast

Description

This region extends along the south coast, eastwards of Hopetoun. The rainfall falls off markedly to the east and inland, with several separate catchments to the coast to Esperance and then, east of Esperance, the flat drainage lines become indeterminate. The small coastal rivers are salinised and eutrophic because of headwater clearing and farming.

Stocking

Trout were sold from Pemberton in the 1950s for a 'Fish for the Inland' scheme involving stocking of farm dams, as far east as Salmon Gums. Trout were reared in ponds on a licensed fish farm adjacent to Lake Warden, Esperance, in the early 1990s. No public water stocking from Pemberton is known for the few streams between Hopetoun and Esperance and there are no records of trout angling or stocks in natural waters.

602 Albany Coast

Description

This region extends from Albany to the coastal Fitzgerald National Park and Hopetoun, and includes large rivers to the far inland Yilgarn Plateau (for example, the Pallinup River) and very small coastal streams(eg King Creek) which have steep gorges and separate estuaries at the coast.

The rainfall at Albany is on the border of the critical 760 mm level for salinity problems from inland clearing and rainfall declines to the east and inland. Only the smallest catchments closest to the coast and Albany remain unsalinised. There are many shallow coastal dune lakes (such as Moates Lagoon) and inland lakes, with clearing producing new lakes ('water logging') and salinising previous fresh lakes. The streams to the west of Many Peaks (Goodga, Kalgan, King Rivers) show the typically tannin-stained waters of the south coast catchments, extending around to the Warren River, Scott River and small streams near Augusta.

Almost the entire population of *Galaxias truttaceus* becomes trapped below the Goodga River weir during spawning and is therefore extremely vulnerable to predation by larger fish. Many of the rivers in this drainage basin provide an extremely important refuge for a number of rare species (including *Nannatherina balstoni*, *Galaxias truttaceus*, and *Galaxiella munda*). Fishing is prohibited in the Two People's Bay Nature Reserve.

Stocking

Waychinicup River	A4	E1	S2	T2	P1
King Creek	A4	E1	S2	T1, 2	P2
Angrove Creek	A5		S1	T3	
Goodga River	A5		S1	T3	
Kalgan River	A4	E2	S2	T1	P1
Gelgiup Brook	A4	E1, 3	S2	T1	P1
Napier Brook	A4	E2	S2	T1	P1
King River	A4	E2	S1, 2	T1, 2	P2
Malley's Stream				T3	
Limeburner's Creek				T3	
Lake Seppings				T3	

The small waters close to Albany have been stocked with trout since the 1950s and streams with post-1970 records of stocking and catches have been Waychinicup Creek, King Creek, Kalgan River (tributaries) and King River. King Creek was a productive trout stream in the late 1960s but the upland was cleared for farming after 1970 and public access was denied from the mid-1980s.

A licensed trout farm (Stockwell) was located near the lower end of the Two People's Bay Road during the 1980s. WATFAA's first successful farm dam fishery (ie privately stocked by the association) in the South-West was 'Dixon's dam' near Many Peaks, with the first angler catch recorded in the 1973 to 1974 season.

603 Denmark Coast

Stocking

Marbellup Creek	A4	E3	S2	T1	P0
Denmark River	A1, 4	E2		T3	

The Sleeman, Hay and Denmark Rivers have a common estuary, Wilson's Inlet. The Denmark River was stocked with trout prior to 1970 and some angling occurred in the town water supply dam. However, no river stocking and angler catch are recorded in the late 1960s or post-1970. There are many large farm dams (gully type) which are suitable for trout stocking, particularly on the headwaters of the Hay and Denmark Rivers and in the valley of Scottsdale Brook. Some of these dams have been stocked privately with rainbow trout.

A - Access for public angling
1 State Forest with access 2 Irrigation dam with access 3 Domestic city or town supply dam with no access
4 Private property 5 National Park or Wildlife Reserve
E - Catchment and Stream Environment
1 Stream, low salinity and nutrients 2 Stream, salinised and eutrophic 3 Stream on developed private property, farm dams, water extraction and eroded banks 4 Stream below dam with large summer tailwater release 5 Stream below dam with no or intermittent and/or small summer tailwater release
S - Trout spawning - stocking
1 natural spawning 2 hatchery stocking
T - Trout species present
1 Rainbow trout fishery 2 Brown trout fishery 3 Previous fishery/stocking attempts
P - Angling popularity
0 - 3 rating

604 Kent River

Stocking

No stocking and angler catch are recorded in these waters pre- or post-1970. There are many large farm dams (gully type) which are suitable for trout stocking, on the headwaters of the highly salinised Kent River. Some of these dams have been stocked privately with rainbow trout.

The Kent River is the original eastern limit to the natural distribution of marron along the south coast (Morrissy, 1978). However, marron have been extensively translocated to the catchments farther to the east.

605 Frankland River

Stocking

Frankland River	A1, 4, 5	E2		T3	

The Frankland River was stocked with trout prior to 1970. There are many large farm dams (gully type) which are suitable for trout stocking, on the headwaters of the Frankland River Some of these dams have been stocked privately with rainbow trout.

606 Shannon River

Description

The Shannon River is the only medium-sized catchment remaining on the south coast with no private (cleared) land. The upper catchment is regrowth former State Forest, now the Shannon National Park, and the lower catchment is the D'Entrecasteaux National Park, with no development around the Broke Inlet. Though the Shannon River is a small river with low or intermitent flow in summer, it provides representative native marron.

Stocking

Shannon River	A5	E1		T3	
Shannon Mill Dam			S2	T2	P0
Gardner River	A4, 5	E1, 3			P1

A - Access for public angling
1 State Forest with access 2 Irrigation dam with access 3 Domestic city or town supply dam with no access
4 Private property 5 National Park or Wildlife Reserve
E - Catchment and Stream Environment
1 Stream, low salinity and nutrients 2 Stream, salinised and eutrophic 3 Stream on developed private property, farm dams, water extraction and eroded banks 4 Stream below dam with large summer tailwater release 5 Stream below dam with no or intermittent and/or small summer tailwater release
S - Trout spawning - stocking
1 natural spawning 2 hatchery stocking
T - Trout species present
1 Rainbow trout fishery 2 Brown trout fishery 3 Previous fishery/stocking attempts
P - Angling popularity
0 - 3 rating

The only record of Pemberton stocking in any of these waters was 2000 brown trout fry stocked in the Shannon Mill Dam in 1980. Shannon Mill was a timber mill town, but it is now completely abandoned and the whole of the Shannon River is now in the Shannon and D'Entrecasteaux National Parks. Large rainbow trout are occasionally captured in the Gardner River and must have escaped from the many private farm dams in the Northcliffe area.

607 Warren River

Description

Much of the lower Warren catchment is State Forest and the D'Entrecasteaux National Park. There are several small National Parks and forest reserves near Pemberton: Warren, Lefroy, Brockman, Treen. However, in terms of water quality, the Warren River system is similar to the other major rivers of the South-West with a reversed series of valley forms. They arise as old flat valleys far inland in the now cleared and extensively salinised and eutrophic headwater upper catchments in the Wheatbelt (Morrissy 1978). The perennial, low salinity tributaries near the coast have V-shaped valleys and gorges and have maintained a lower salinity and nutrient status in the lower river by summer flushing. However, the ecological health and remaining trout and marron stocks of the lower Warren River and the other long rivers of the South-West, are being severely compromised by the enormous extent of private damming of these tributaries and massive summer water extraction.

Stocking

Warren River	A1, 4,5	E2, 3	S2	T1,2	P3
Deadmans Lake	A5	E1		T3	P0
Dombakup Brook	A1, 5	E1		T2	P1
Treen Brook	A1, 4,5	E1, 3	S1	T2	P2
King Trout Treen Lake	A4	E1, 3	S2	T1	P3
Lefroy Brook	A1, 4,5	E1, 3	S1,2	T1,2	P3
Big Brook	A1.5	E1, 4		T1,2	P3
Big Brook Dam (1986)	A2	E1	S2	T1,2	P3
Four and Five Mile Brooks	A1, 4	E1, 3	S1,2	T2	P1
East Brook	A1, 4	E1, 3	S1	T2	P2
Smith Brook	A4			T3	P0
Big Hill Brook	A1	E1	S2	T1, 2	P0

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E - Catchment and Stream Environment
1 Stream, low salinity and nutrients 2 Stream, salinised and eutrophic 3 Stream on developed private property, farm dams, water extraction and eroded banks 4 Stream below dam with large summer tailwater release 5 Stream below dam with no or intermittent and/or small summer tailwater release
S - Trout spawning - stocking
1 natural spawning 2 hatchery stocking
T - Trout species present
1 Rainbow trout fishery 2 Brown trout fishery 3 Previous fishery/stocking attempts
P - Angling popularity
0 - 3 rating

The Warren River and its perennial tributaries in the Pemberton area are the most popular and long established trout fishing waters in the south-west, dating back to the successful introduction of brown trout at Pemberton in 1931. The primary trout species in streams has been brown trout, which established naturally by spawning in several of the tributaries in the 1930s. The Warren River, Lefroy, Treen and East Brooks provided stock densities and angler catches of brown trout of a size comparable with recognised fisheries elsewhere (Morrissy, 1972), until the 1990s. While these streams continue to be recorded by anglers, the angler records also show that private farm dams with rainbow trout now provide most of the fishing in this catchment. The rainbow trout, easier to culture and easier to catch, has numerically dominated stocking and is increasingly dominating angler catch in the Warren stream system, farm dams, Big Brook Dam and commercial trout farm lakes.

Much of the Lefroy, Treen, East and Smiths Brook catchments are intensively developed agriculturally, with very large numbers of gully dams for summer water storage (WAWA, 1990; Olsen and Skitmore, 1991). The recreational angling clubs, WATFAA and Western Fly Fishers have privately stocked many dams in the Pemberton area for their members and maintain angler accommodation facilities. These large deep, clear water dams, with current, or former, fertilised beef cattle pasture catchments are very productive compared to waters with native forested catchments. There are many coastal dune lakes in the south coast National Park (Deadmans Lake) which were stocked in the 1950s.

608 Donnelly River

Description

The Donnelly River is a medium-length river and although the headwaters are developed, salinity is low because the source is in a high rainfall area near the South-West Highway, north of Manjimup. The main course of this river has not been subject to major damming for private or public water supply, either for domestic or irrigation water, because of isolation.

Stocking

Donnelly River	A1,4,5	E1, 3	S1, 2	T1, 2	P3
Fly Brook	A1		S1	T1	P2
Carey Brook	A1		S1	T1	P2
Karri Valley Dam	A4	E4	S2	T1	P3
Barlee Brook	A1	E1	S2	T1	P3
Lake Jasper	A5			T3	

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E - Catchment and Stream Environment
1 Stream, low salinity and nutrients 2 Stream, salinised and eutrophic 3 Stream on developed private property, farm dams, water extraction and eroded banks 4 Stream below dam with large summer tailwater release 5 Stream below dam with no or intermittent and/or small summer tailwater release
S - Trout spawning - stocking
1 natural spawning 2 hatchery stocking
T - Trout species present
1 Rainbow trout fishery 2 Brown trout fishery 3 Previous fishery/stocking attempts
P - Angling popularity
0 - 3 rating

The Donnelly River has been a very popular rainbow trout fishery for many years with the rainbow trout comparable in condition and angling quality to the best stocks elsewhere in the world. There is also a small stock of very hard-to-catch brown trout which has persisted in the lower river by natural spawning in tributaries since the 1940s. Some excellent spawning gravel substrate exists in the lower tributaries (such as Carey and Fly Brooks) and the upper river is stocked with rainbow trout in the tributaries near Manjimup. There is also a large number of private dams on the developed upper reaches of all major tributaries. Some of these dams, which overflow in winter, are stocked privately by the angling clubs and other private individuals.

The large Karri Valley tourist resort, associated with Beedelup National Park, has a licensed trout farm which stocks the fishing lake, tourist put and take pond and supplies the resort restaurant. Beedelup Brook, above the National Park falls, has headwaters in cleared farmland with farm dams stocked with rainbow trout by the angling clubs.

There are many large and small coastal dune lakes along the south coast in the D'Entrecasteaux National Park, of which the rather inaccessible Lake Jasper is the largest. Lake Jasper drains from the coast to Barlee Brook, a tributary of the Donnelly River. While there are records of trout stocking in the lake by the Acclimatisation Society and a local angling club, there are no records or anecdotes of angler catches from the lake.

609 Blackwood River

Description

The Blackwood River extends 500 km into the far wheatbelt and has the atypical reversed longitudinal valley form of the long south-western WA rivers (Morrissy, 1974). As a consequence of clearing and farming inland, there is a very high input of highly salinised and eutrophic water down the river in the wet season. Large amounts of foam caused by dissolved organic matter from the wheatbelt can be seen during winter The perennial tributaries at Bridgetown are low in salinity and nutrients. However, most of these tributaries are being increasingly developed and degraded by development of farms and dams. The ecological health of the Blackwood increases towards the estuary and most of the flow is through State Forest.

Stocking

Blackwood River	A1, 4,5	E2, 3	S2	T1	P3
Milyeannup Brook	A1	E1	S2	T1	
Red Gully Brook	A1, 4	E1	S2	T1	
St John Brook	A1, 4	E1, 3	S2	T1	P2
Nannup Brook	A1, 4	E1, 3	S1	T1	P2
Carlotta Brook	A4	E1, 3	S1	T1	P1
Tanjanerup Dam		E1	S2	T1, 2	P2
Ellis Brook	A1	E1	S1	T1	
Gregory Brook	A1, 4			T3	
Maranup Brook	A1, 4			T3	
Mokadillip Brook	A1, 4			T3	
Balingup Brook	A4	E1, 3	S2	T1, 3	P1
Cowan Dam	A4	E1	S2	T1	P1
Norilup Dam	A4	E1	S2	T1	P1
Hester Brook	A4	E2	S2	T1	P2
Geegelup Brook	A4	E3	S2	T3	P0
Shepherds Brook	A4	E3	S2	T3	P0

The catchment of the short, tannin-stained Scott River is mostly privately owned (Olsen and Skitmore 1991), with part of the catchment contained within National Park. There are no records of public water trout stocking or angler catch, but there was a large private development in the 1980s on the northern (inland) side of the catchment which involved trout dam development.

Trout stocking and angling in the Blackwood catchment was largely in the higher altitude tributaries near Bridgetown and Balingup until 1970. Residents enjoyed very good fishing, with brown trout spawning naturally. Following worthwhile rainbow trout angling in the 1970s by hatchery stocking in the Murray River, many of the Blackwood tributaries were regularly stocked with rainbow trout by South-West Freshwater Research and Aquaculture Centre staff. Recognition of the excellent rainbow trout fishery which eventuated in the productive main river down to Nannup and to the estuary was slow, but the publicity from the annual Nannup fishing competition in the 1990s has opened up these extensive waters to non-resident anglers.

The Blackwood valley has seen the development of many chalet-style holiday venues and trout and marron fishing is often mentioned as an attraction in publicity text.

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1 Rainbow trout fishery 2 Brown trout fishery 3 Previous fishery/stocking attempts
P - Angling popularity
0 - 3 rating

A successful commercial marron hatchery was operated by the mining company at Greenbushes during the 1970s and into the 1980s as part of rehabilitation of mining areas (restocking with marron and fish, including trout). These mine waters proved to be very unproductive. In 1993 two large ex-mining dams on Norilup Brook (part of the Gwalia-Greenbushes tin mining rehabilitation area) were opened to public fishing and stocked, but they gave poor fishing results.

610 Busselton Coast

Stocking

Margaret River	A1,4	E1	S2	T1	P1
Vasse River				T3	
Capel River				T3	
Millyannup Brook				T3	

Margaret River is the original source location of marron described as *Cherax tenuimanus* by Smith in 1912. These Margaret River marron are sufficiently physically different from marron elsewhere for their preservation to be of scientific and possibly eventual commercial value. Margaret River also contains populations of the restricted fish species *Nannatherina balstoni* and *Galaxiella munda*. Trout fishing was known prior to 1970 and recent fishing has been described by Burking (1995). From 1970, when South-West Freshwater Research and Aquaculture Centre staff took over public water stocking of trout, until 1995, there had been no stocking of this River.

The short Vasse River was heavily stocked with trout for several years after 1956, but no catches were recorded and no trout fishing is known these days with the sluggish lower river now heavily eutrophic.

None of these waters are recorded in stocking and angling occurrences between 1970 and the present day, except for recent stocking of the Margaret River.

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S - Trout spawning - stocking
1 natural spawning 2 hatchery stocking
T - Trout species present
1 Rainbow trout fishery 2 Brown trout fishery 3 Previous fishery/stocking attempts
P - Angling popularity
0 - 3 rating

611 Preston River

Stocking

Preston River	A4	E3,4		T3	
Joshua Brook				T3	
Glen Mervyn Dam (1969)	A2	E1	S2	T1,2	P3
Ferguson River	A4	E3		T3	

There are some early records of trout stocking in the Preston River, prior to 1970, with sightings of spawning fish in Joshua Brook. However, by the late 1960s the sluggish Preston River was heavily compromised by pesticides and eutrophication. During summer, algal blooms formed and the marron stock suffered heavy losses. The subsequent health of the river and marron benefited from the summer irrigation flows from Glen Mervyn Dam, built in 1969 on a northern tributary at Mumballup. However, no tailwater trout fishery has eventuated. Glen Mervyn dam has been a popular trout and marron fishing venue, particularly in the 1980s, but in recent years has become affected by near draining in one or two dry years and very large numbers of cormorants and redfin perch preying on newly stocked fish.

612 Collie River

Description

The Collie River is a medium-length river only partly affected by inland clearing. However, salinity increase in Wellington Dam by the 1980s was sufficient to see the Harris River dam (built in 1988) replace Wellington Dam as the domestic water supply, with water piped to inland wheatbelt areas (WAWA, 1985). The upper Collie Catchment is also influenced by acidic tailwaters pumped from deep coal mines and surface mine lakes that are also very low in nutrients (such as the 'Stockton open-cut').

Stocking

Butler's Gorge	A1	E1	S2	T1,2	P3
Wellington Dam (1933)	A2			T3	
Upper Collie Rivers	A1,4			T3	
Brunswick Rivers	A1,4	E1	S2	T1,2	P3

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S - Trout spawning - stocking
1 natural spawning 2 hatchery stocking
T - Trout species present
1 Rainbow trout fishery 2 Brown trout fishery 3 Previous fishery/stocking attempts
P - Angling popularity
0 - 3 rating

A Collie Trout Acclimatisation Society, registered in 1943, was very active in trout stocking for a few years with hatchery and rearing facilities at Collie, but without any encouraging angling results. Stocking efforts appear to have been directed at the upper Collie branches and Wellington Dam. No trout stocking or angling was recorded in the late 1960s in the Collie or neighbouring Brunswick River. However, after 1970 South-West Freshwater Research and Aquaculture Centre staff commenced stocking in the Collie River, below Wellington dam (Butlers Gorge), which has a large, cold, summer tailwater flow to the plains irrigation takeoff. This tailwater soon provided a popular fishery.

The Brunswick River joins the Collie River on the plain near Leschenault Inlet. From the mid 1970s, regular stocking created a consistent and worthwhile fishery. The upper branches of the Brunswick are located in a large area of bauxite strip-mining and tailings ponds.

613 Harvey River

Description

The Harvey River historically flowed naturally to the Peel-Harvey Inlet but now drains directly to the sea at Myalup. The other streams north of the Harvey are plains tributaries. The Harvey River and its tributaries are all short streams with catchments in the high rainfall State Forest of the Darling Ranges and consequently, are low salinity and low nutrient waters.

The dams in this basin predominantly provide summer irrigation for dairy farming on the Perth Plain and there is an extensive system of gravity feed water channels from Waroona-Drakesbrook south (to Wellington Dam and Burekup). The present Harvey Weir provides drinking water to the township of Harvey and currently, several options are being examined to increase the storage of the Harvey-Stirling system. At present, there is considerable concern amongst anglers and property owners over the control of the tailwater flow between Stirling and Harvey dams, as releases vary daily from extremely high flows that provide the State white water canoeing course, to almost no flow.

Stocking

Lower Harvey River	A1, 4	E1		T1, 2	P1
Harvey Weir (1961)	A2	E1		T1, 2	P2
Middle Harvey River	A4	E1, 4	S1, 2	T1, 2	P3
Stirling Dam (1948)	A1, 3	E1		T2	P1
Upper Harvey River	A1	E1	S1	T2	P2
Clarke Brook	A1, 4	E1, 3	S1	T2	P1
Logue Brook Dam (1963)	A1, 2	E1, 3	S2	T1	P3
Logue Brook	A1, 4	E1,3,5		T1	P1
Bancell Brook	A1,3,4	E1, 3	S2	T1	P1
Wokalup Brook	A1, 4	E1,3,5	S2	T1	P1
Mornington Dam	A4			T3	
Samson Dam (1941)	A1, 2	E1	S2	T1	P2
Lower Samson Brook)	A1, 4	E1,4	S2	T1	P2
McKnoe Brook	A1, 4	E1,3	S2	T1, 2	P2
Waroona Dam (1966)	A1, 2	E1	S2	T1, 2	P3
Upper Drakesbrook Brook	A1, 4	E1, 2	S1	T1, 2	

The Harvey Trout Acclimatisation Society was registered in 1951 and remained active in receiving and stocking trout delivered annually from Pemberton until the late 1960s. The Waroona area was stocked by Murray-Dwellingup Society members in later years when Logue Brook and Waroona Dams were built in the 1960s.

The upper Harvey River, which has spawning gravel, flows into Stirling Dam. The middle Harvey River (between Stirling Dam and Harvey Weir) has been a popular brown trout fishery and is also stocked with rainbow trout. The high summer flows of tailwater into the middle Harvey River, has been particularly attractive to fly fishers.

There are a number of other very small trout streams in this catchment which descend from State Forest, through private property, to the Perth Plain. However, the major waters for public angling have been the large irrigation dams.

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P - Angling popularity
0 - 3 rating

Logue Brook Dam was filled and stocked with rainbow trout in 1963. For a brief period, the decomposer food chains of the new dam supported prodigious rainbow trout growth rates, in common with most other new dams. These large fish were referred to by Francois (1966) in his review of the trout fishery. However, by the time of research sampling in the late 1960s the rainbow trout were plentiful but much slower growing and of small average size. This popular rainbow trout fishery has continued unchanged to the present day, maintained by annual stocking.

Waroona Dam was first filled and stocked in 1966 and by late 1967 there were reports of many, very large fish. Subsequently, research sampling (netting) confirmed this dam as a premier trout fishery and it rapidly became extremely popular with Perth anglers, particularly fly fishers, because of high catch rates. While trout average sizes had declined by the end of the 1960s, Waroona Dam continued to be more productive than Logue Brook Dam through the 1970s. The bed of Waroona Dam had been mostly a cleared fertilised cattle farm, while the bed of the less productive Logue Brook Dam was cleared low nutrient State Forest. The deliberate introduction of redfin perch to Waroona Dam in the early 1980s caused the abrupt decline of the trout fishery.

One small commercial trout farm was licensed to operate during the 1990s on the tailwater between Waroona and Drakesbrook Dams.

614 Murray River

Description

The Murray River is one of the longer South-West rivers which is highly salinised and eutrophic, with major headwater tributaries (Hotham and Williams Rivers) extending into the wheatbelt. However, the main river has a long reach, northwards to Dwellingup and then westwards to the Darling Scarp, in high rainfall State Forest. The many very low salinity tributaries in the forest are mostly perennial and the summer flows have maintained the health of the lower River. However, the bottom waters in the many long, deep river pools upstream from Dwellingup remain saline and anoxic through summer (Morrissy 1979).

The Murray River receives several minor (Marrinup Brook and Oakley Brook) and major tributaries (Dandalup River) on the Perth Plain, before flowing into the Peel-Harvey Inlet, alongside the Serpentine River. All of these other streams arise in the high rainfall region of the Ranges, are of very low salinity and except for Marrinup Brook, Little Dandalup (with a pipehead), Dirk Brook, and Gooralong Brook, have been progressively dammed since Serpentine Dam in 1961, for major water storage for domestic water supply.

Stocking

Murray River	A1, 4	E2	S1, 2	T1	P3
Marrinup Brook	A1, 4	E1	S1, 2	T1, 2	P2
Oakley Dam	A1	E1	S1, 2	T1	P2
Little Dandalup River	A1, 4	E1	S1	T1	P1
Lower Serpentine River	A1, 4	E1,5	S2	T1, 2	P1
Dirk Brook	A1, 4	E1	S2	T1	P3
Cooralong Brook	A1, 4	E1	S1, 2	T1, 2	P2

Trout were stocked regularly in the Murray River from 1936. The Society received and stocked fish delivered in springtime from Pemberton until the late 1960s.

The Murray River apparently held a large stock of rainbow trout and some brown trout at the end of the 1960s, but it was not a popular angling river. However, when the South-West Freshwater Research and Aquaculture Centre staff commenced stocking fry in the tributaries from 1970, rather than delivering fish to be stocked by local anglers, an extremely popular rainbow trout fishery rapidly developed, particularly for fly fishing, which had not been practiced previously. While there is some natural spawning gravel present in the Murray tributaries, the fishery was developed and maintained by regular stocking of fry against high fishing pressure through the 1970s and into the 1980s. The Murray trout fishery was notable for the fast growth of the fish in the productive, main river and the holding of large, very well conditioned fish.

Redfin perch is long established in the wheatbelt reaches of the major rivers and downstream invasion in the Murray River coincided with the disappearance of native fish and the demise of the popular trout fishery along the main river. A smaller fishery remains in the scarp reach (Blanksby 1991).

Prior to 1970, there were rainbow trout fisheries in the Dandalup rivers, which were most notable for large sizes of individual fish, rather than many fish. The larger South Dandalup River was dammed in 1973, and there is no tailwater. The smaller North Dandalup River was pipeheaded soon after and then a major dam was built by 1994. There is an assured release from this dam during summer, believed to be the first such commitment in Western Australia. Trout continue to flourish in North Dandalup Dam, which unlike South Dandalup Dam, has good spawning tributaries.

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S - Trout spawning - stocking
1 natural spawning 2 hatchery stocking
T - Trout species present
1 Rainbow trout fishery 2 Brown trout fishery 3 Previous fishery/stocking attempts
P - Angling popularity
0 - 3 rating

The Serpentine-Jarrahdale Trout Acclimatisation Society was registered in 1948 and operated very actively until 1957 when work commenced on the Serpentine Dam. The Society first stocked Serpentine River, Dirk Brook and Neerigen Brook in August 1947, with rainbow trout fry from Pemberton. Prior to the dam, the Serpentine River is recorded as providing high quality trout fishing close to Perth. Today, the Serpentine Dam rarely overflows and the lower river is much reduced. WATFAA gained permission for access to this part of the river in the late 1980s and stocked the river privately, but with poor catch results. Prior to 1970, Gooralong Brook, a perennial tributary to the lower river, with good spawning gravel, held a large stock of brown and rainbow trout. This fishery deteriorated through the 1970s, despite some stocking in the late 1970s and early 1980s.

Serpentine Dam has a self-sustaining stock of rainbow trout, although the fish are slow growing in the low nutrient dam water. Some dam stock were artificially spawned in 1996 by the Department of Fisheries, in cooperation with the then Water Authority, for the South-West Freshwater Research and Aquaculture Centre. Access to the dam for fishing is now prohibited.

Dirk Brook is a very small, short and as yet, undammed scarp stream which has had a long history of a very good self-sustaining stock of rainbow trout, because of spawning gravel. However, most of the stream is on private property and access to the best water upstream from the South-West Highway has long been denied to the general public. Some limited access has been permitted downstream on private property, but this water has rarely been stocked (1979 and 1986), being naturally stocked by recruitment from upstream.

There are many private gully dams in this catchment, particularly between the eastern edge of the forest and the Albany Highway. The large pay-fishing dam on 'Windermere' farm near Williams is an extremely popular trout fishing venue of very high productivity, which has operated since the early 1980s.

615 Avon River

Stocking

Dale River	A4	E2, 3		T3	

A Beverley branch of the Serpentine-Jarrahdale Trout Acclimatisation Society was active from 1953 to 1959 in stocking rainbow trout from Pemberton, in both farm dams and the Dale River. Although the Dale River branches arise on the eastern fringe of the forested high rainfall region, the flow is to the north-east, to the Avon

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1 Stream, low salinity and nutrients 2 Stream, salinised and eutrophic 3 Stream on developed private property, farm dams, water extraction and eroded banks 4 Stream below dam with large summer tailwater release 5 Stream below dam with no or intermittent and/or small summer tailwater release
S - Trout spawning - stocking
1 natural spawning 2 hatchery stocking
T - Trout species present
1 Rainbow trout fishery 2 Brown trout fishery 3 Previous fishery/stocking attempts
P - Angling popularity
0 - 3 rating

River There are records of moderate angling success in the 1950s, after which there are no records of stocking and catches in the River.

On a wider scale, many inland farm dams on the large wheatbelt catchment of the Avon were stocked through the 1950s. Most of these dams were muddy excavated tank dams, unsuitable for trout (Bowen 1961). More suitable clearwater gully dams are now privately stocked on the western, higher rainfall part of the catchment, in some cases, near Brookton and Toodyay, for tourist pay-fishing.

616 Swan Coastal

Stocking

Lower Canning River	A4	E5		T3	
Lower Wungong Brook	A4	E5		T3	
Wungong Dam (1979)	A3			T3	
Neerigen Brook	A4	E1, 3	S2	T1	P1
Bickley Reservoir	A1			T3	
Churchman Brook Dam (1929)	A3			T3	
Victoria Reservoir (1891)	A3			T3	
Mundaring Weir (1902)	A3			T3	
Helena River	A4	E1, 5		T3	
Jane Brook	A4, 5	E1, 3	S1,2	T1	P2
Wooroloo Brook	A1, 4	E2, 3		T3	
Lake Leschenaultia	A4	E1		T3	

The highly salinised and eutrophic Swan River is the least degraded remaining freshwater reach in the Darling Scarp gorge (Wilyunga National Park). Since 1970 the river has not been stocked with trout directly. However, catchment side waters, Lake Leschenaultia and Wooroloo Brook were stocked. Also, trout stocking has occurred privately in large farm dams on side streams in the scarp gorge of the Swan.

Canning Dam is reputed to contain self-reproducing stocks of trout. The Canning River in the scarp gorge below the large metropolitan water supply dam (which does not normally overflow) receives only small, intermittent 'riparian releases'. The lower river was last stocked, with brown trout fry, in 1974 and one catch was recorded in 1975. A property owner in the valley reared privately purchased rainbow trout in a spring pool alongside the river during the 1970s and other landowners have stocked trout privately in the river pools.

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1 Rainbow trout fishery 2 Brown trout fishery 3 Previous fishery/stocking attempts
P - Angling popularity
0 - 3 rating

The Wungong River in the Ranges was a very worthwhile rainbow trout stream before damming for domestic water supply in 1979 and a self-maintaining stock did persist in the closed dam (Pusey and Morrison, 1989). Both the Canning Dam and Wungong Dam are now closed to fishing.

Neerigen Brook, which flows alongside the Albany Highway, through private property and down through Armadale, has been privately stocked with trout in the many ornamental private pools built on the creek, including the sump lake opposite the Council Chambers, for public fishing.

A similar description to lower Canning River applies to the Helena River with the old Mundaring Weir stocked with trout well before the Pemberton era (Coy 1979), but no fishing was apparently allowed.

Jane Brook flows through numerous small private properties in the ranges and then through the John Forrest National Park on the Darling Scarp, where the summer flow has always been intermittent. This small stream contained a healthy stock of rainbow trout in the late 1960s and produced consistent WATFAA catches of rainbow trout through the 1980s and into the early 1990s, although it was rarely recorded as stocked (1981 and 1985). However, dam construction and extraction has seen this stream dry up in recent summers.

Lake Leschenaultia was originally constructed to supply water to steam trains ascending the Swan-Avon valley and is controlled now by the Mundaring Shire, as a recreation reserve. The lake was first stocked with fry in the 1970s by the Department of Fisheries, at the request of the Ranger at the lake. Fry were unsuccessful, but yearlings stocked in autumn produced many takeable fish by late spring. The Shire did not charge for fishing, only car entry to the lake reserve, which became very popular with local hills residents. Illegal fishing activities became too prevalent by 1994 and the Department of Fisheries was asked to cease stocking.

WATFAA has endeavoured for many years to acquire access to private gully dams near Perth to provide fishing for members, particularly as public access fisheries opportunities have diminished due to damming and invasion by redfin perch. Angler records during the 1990s show an increasing proportion of the annual catch is taken from several dams near Perth, approaching their Pemberton dams in share. In 1998, the private dam catch was 32 per cent of the total with 11 per cent from Perth dams, and the rest from Windamere near Williams and Pemberton.

617 Moore-Hill Rivers

Stocking

Moore River	A4	E2, 3		T3	

The State Gardens Board (precursor to National Parks) trialed trout in ponds at Yanchep in 1947, with the fish dying over summer. There may have been other direct stockings of the lake with trout, prior to 1970, by Perth anglers. The Department of Fisheries WA was requested to stock the lake in 1968, but refused because of the National Park status. The other, mainly shallow, coastal lakes on the Perth Coastal Plain down to Bunbury are too hot for trout during summer.

The Gingin Trout Acclimatisation Society was registered from 1952 to 1958 and stocked the Moore River, Gingin Brook and Lennards Brook. Some fish were caught, but the Society soon ceased activities. Rainbow trout are captured occasionally during springtime in the lower Moore River, presumably escapees from winter overflow of private farm dams in the hills.

618 Greenough River

The Greenough River has many permanent pools in a substantial gorge which reaches far inland, despite its insignificant appearance near the coast. The fish fauna in the Greenough shows a change to more northern species.

A spring-fed marron farm (Thomas) at Moonyoonooka, east of Geraldton, has reared small numbers of rainbow trout in undercover tanks.

A - Access for public angling
1 State Forest with access 2 Irrigation dam with access 3 Domestic city or town supply dam with no access
4 Private property 5 National Park or Wildlife Reserve
E - Catchment and Stream Environment
1 Stream, low salinity and nutrients 2 Stream, salinised and eutrophic 3 Stream on developed private property, farm dams, water extraction and eroded banks 4 Stream below dam with large summer tailwater release 5 Stream below dam with no or intermittent and/or small summer tailwater release
S - Trout spawning - stocking
1 natural spawning 2 hatchery stocking
T - Trout species present
1 Rainbow trout fishery 2 Brown trout fishery 3 Previous fishery/stocking attempts
P - Angling popularity
0 - 3 rating

10. APPENDIX TWO

Environmental values in relation to the identified drainage basin.

Drainage Basin		Environmental Values
601	Esperance Coast	• Jerdacuttup River - high conservation value with a large lake system at the base
607	Warren River	• much of the lower Warren catchment is State Forest and D'Entrecasteaux National Park • contains several small National Parks and CALM reserves, particularly around Pemberton - Warren, Lefroy, Brockman and Treen • contains populations of restricted fish species (*Galaxiella munda*, *Lepidogalaxias salamandroides*, *Galaxiella nigrostriata*)
608	Donnelly River	• contains National Parks and CALM reserves • contains significant coastal dune lakes within D'Entrecasteaux National Park • contains populations of restricted fish species (*G. munda*, *L. salamandroides*, *G. nigrostriata*) and a vulnerable fish species (*Nannatherina balstoni*)
609	Blackwood River	• Donnelly River - contains a number of high conservation value streams • Scott Coastal Plain and D'Entrecasteaux National Park - important fish habitat, high conservation value • Blackwood River below Nannup - high quality tributaries
610	Busselton Coast	• Margaret River - significant marron population and populations of *N. balstoni* and *G. munda* • Ludlow and Sabina Rivers - headwaters of these rivers have high conservation value • Collie River, above Harris River Dam and Wellington Dam - high quality streams
612	Collie River	• Collie River above the Harris River Dam and Wellington Dam - high quality streams associated with wetland habitats
613	Harvey River	• Harvey River above Drakes Brook - high quality streams • Samson Brook and Logue Brook - high quality streams • above Stirling Dams - high quality streams
614	Murray River	• North and South Dandalup Rivers above dams - high quality streams • Serpentine River, above Serpentine Dam - high quality streams

616	Swan Coastal	• Canning River above Canning Dam - high quality streams • Helena River and Beracking Brook, above Mundaring Weir - high conservation value
617	Moore-Hill Rivers	• Gingin Brook - restricted fish and high quality streams • Moore River - residual populations of *N. balstoni* and *G. munda* • north of Moore River National Park are high conservation value short tributaries • Nambung River - connects to high conservation value wetlands • Mingulo Brook and Mullering Brook, lower reaches - high conservation value • Hill River, lower reaches below Brand Highway - high conservation value • Cockleshell Gully - pristine system which connects to coastal wetlands

11. APPENDIX THREE

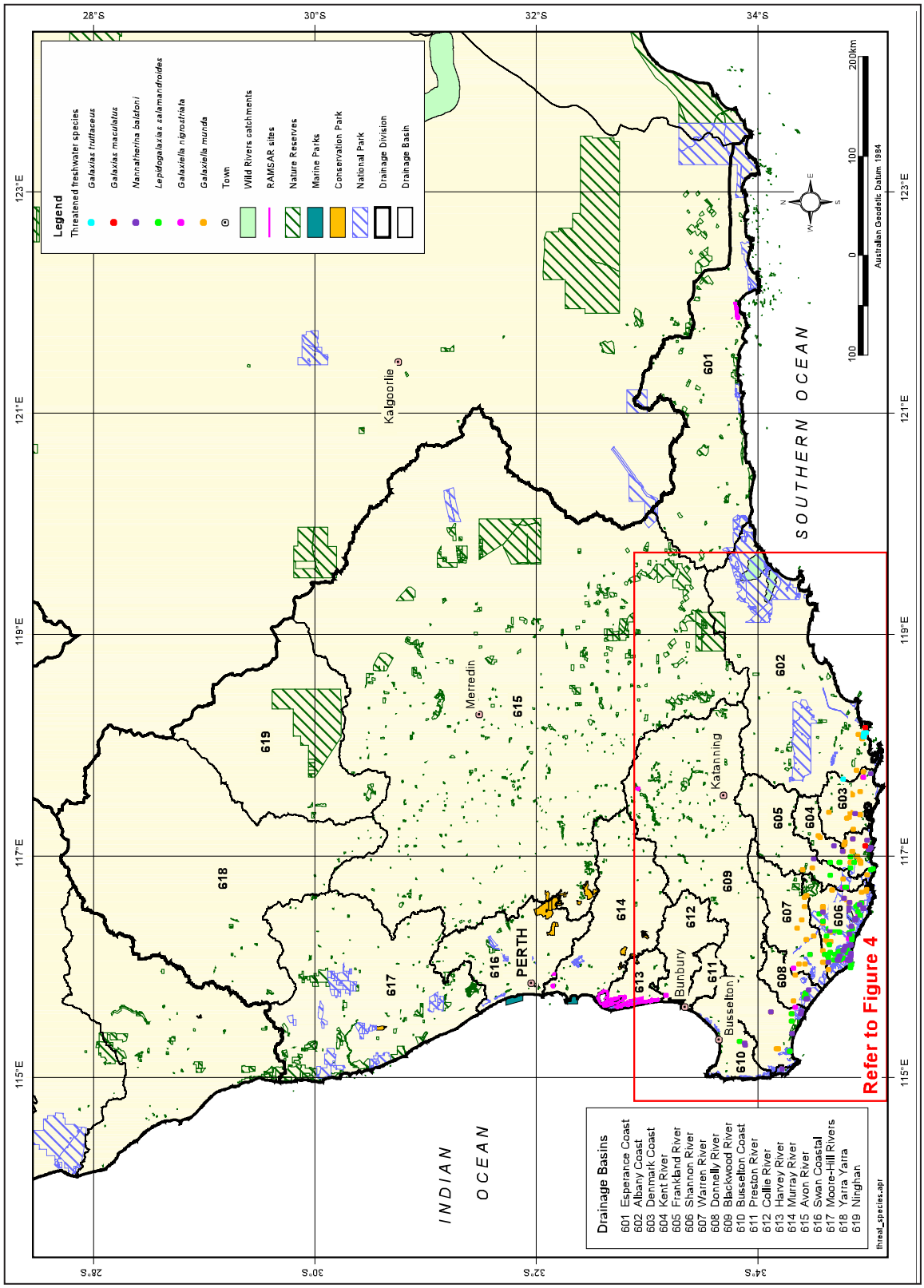

Figure 3 Threatened Freshwater Species of Southern Western Australia

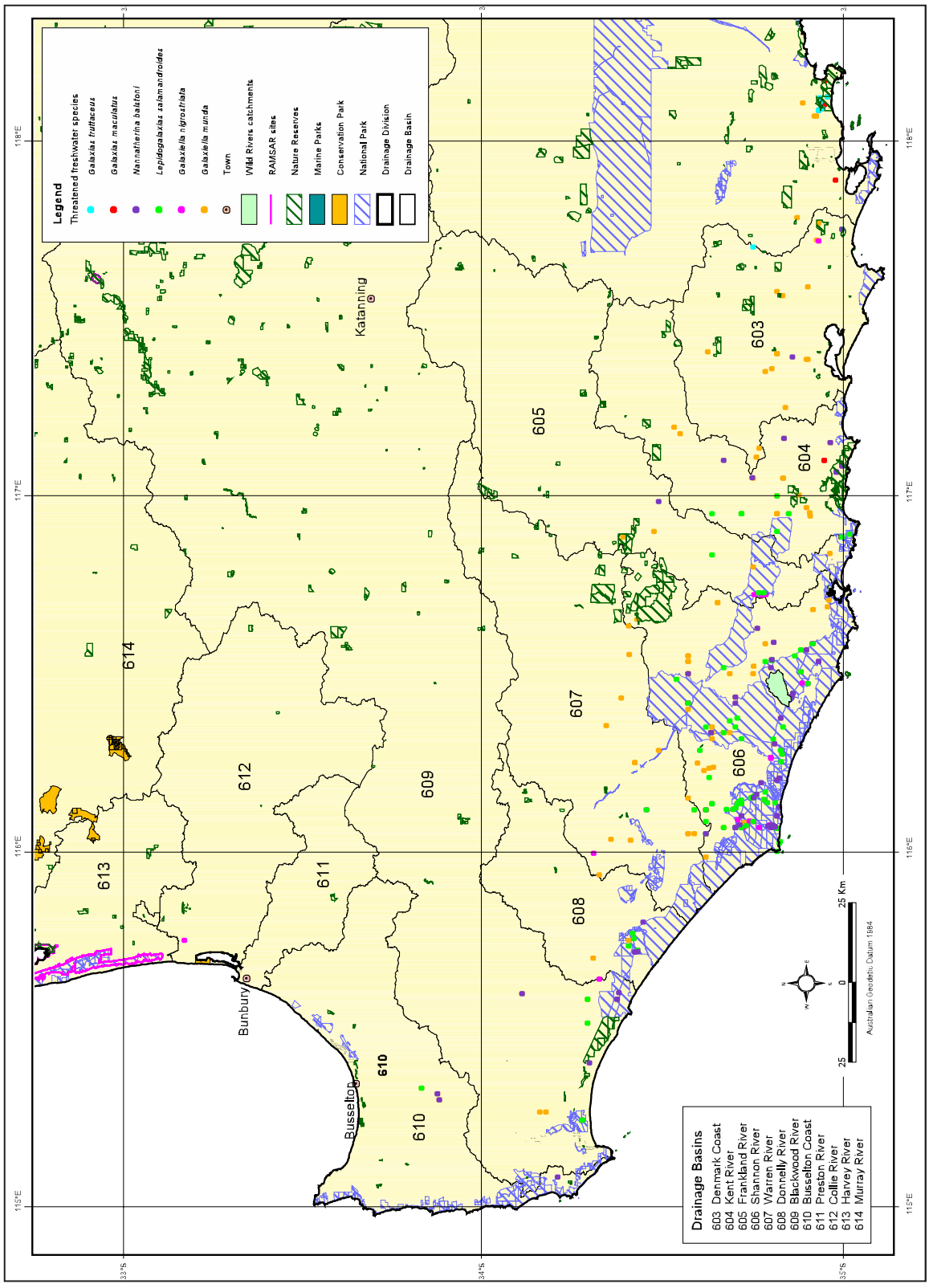

Figure 4 Threatened Freshwater Species of South-West Western Australia

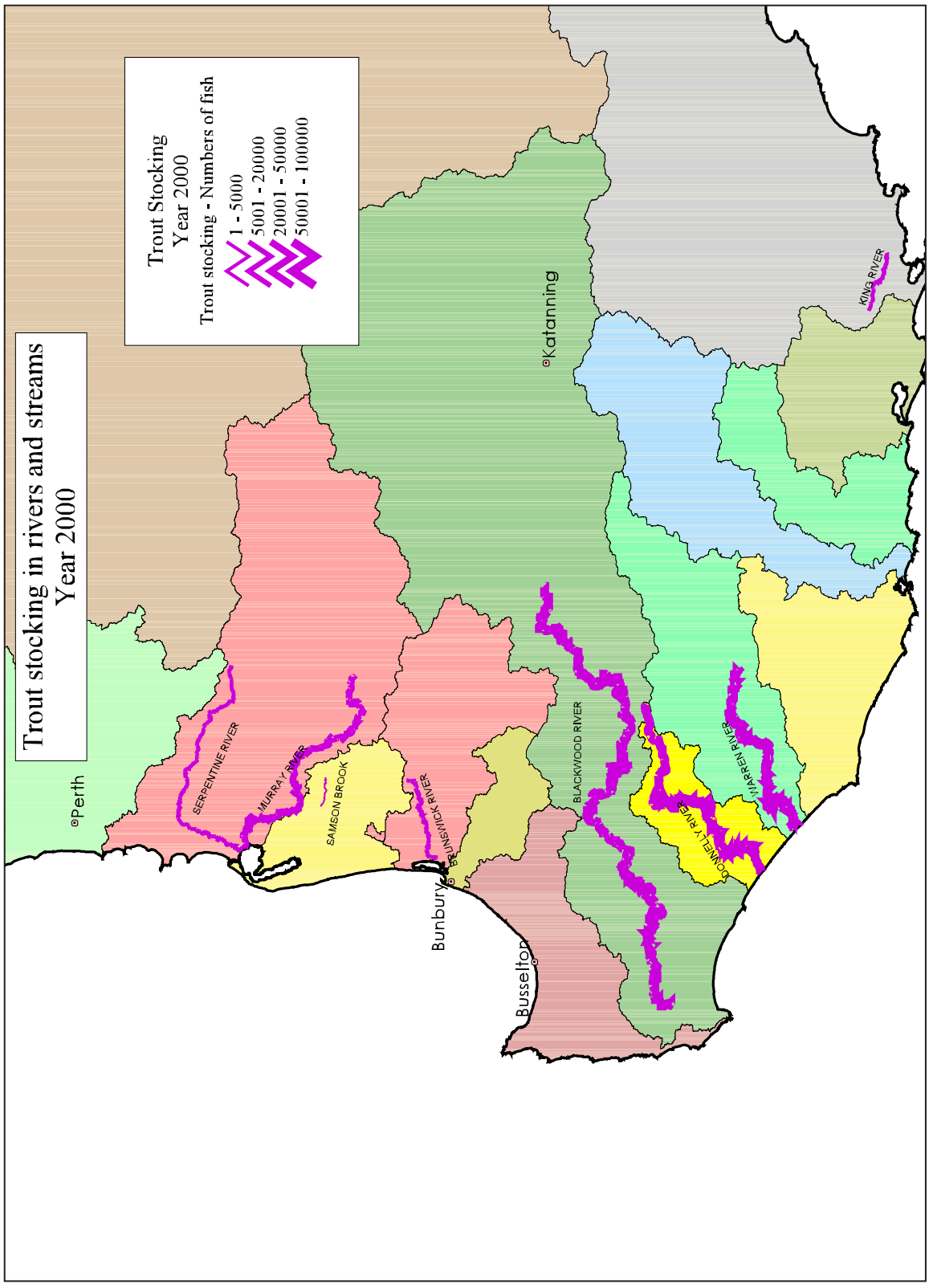

Figure 5 Trout Stocking in Rivers and Streams and Drainage Divisions Year 2000

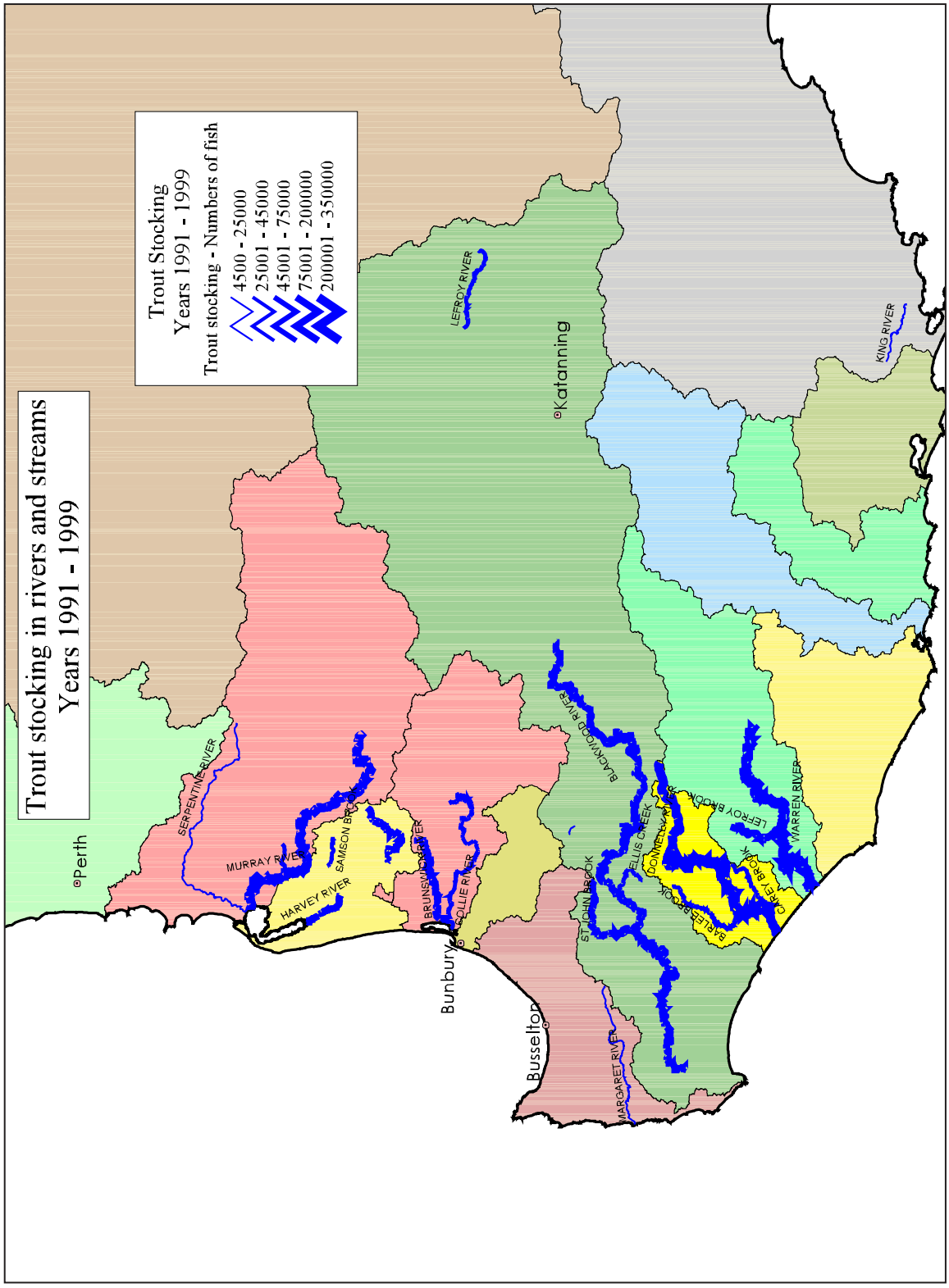

Figure 6 Trout Stocking in Rivers and Streams and Drainage Divisions Year 1991-1999

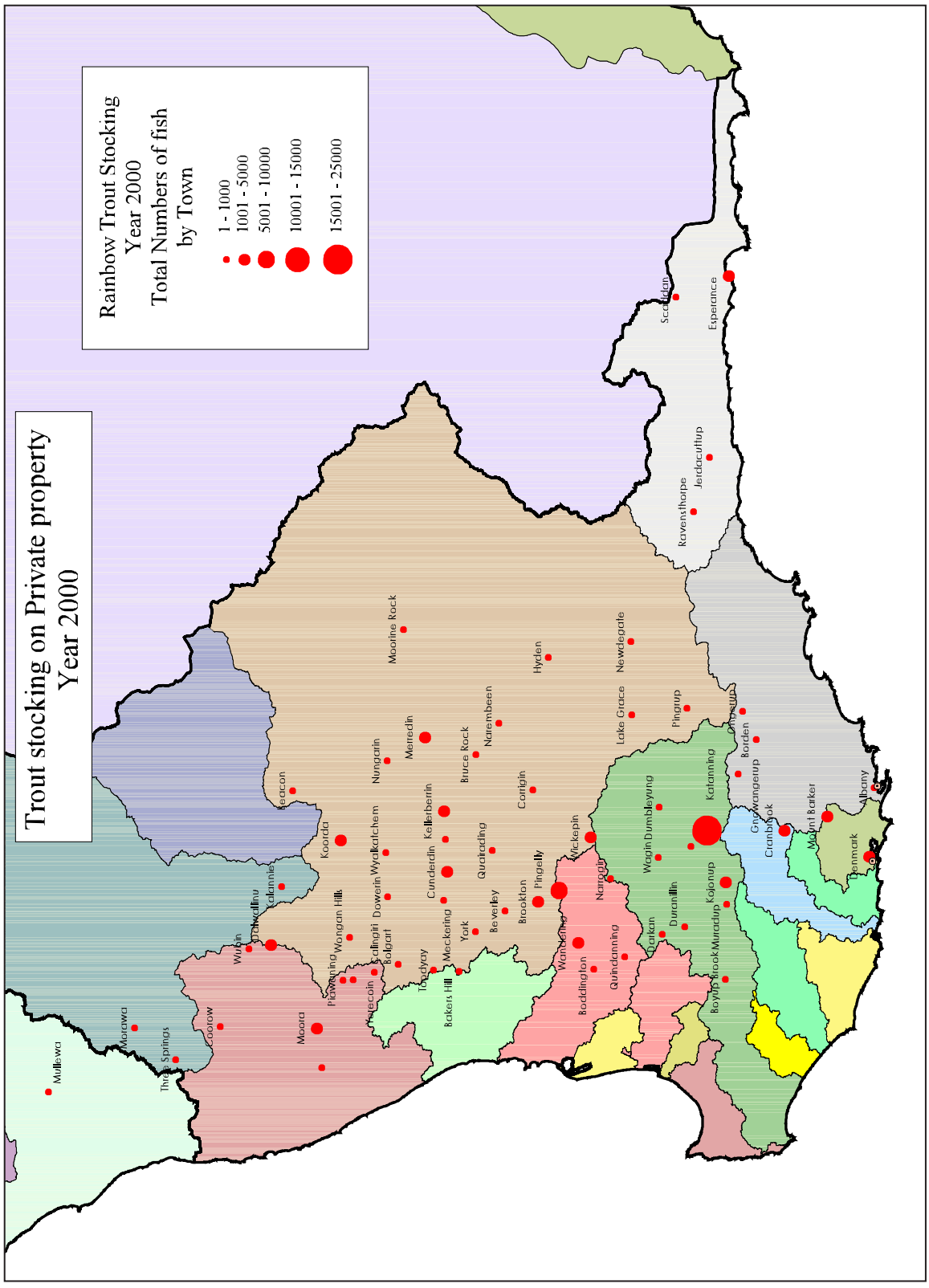

Figure 7 Trout Stocking in Private Property and Drainage Divisions Year 2000

12. APPENDIX FOUR

Issues Submission Sheet

Issue	**Comment/Strategy**
Introduction of trout to Western Australia	
Translocation of trout within Western Australia	
Recreational stock enhancement	
Access to stocked waters	
Social and economic benefits	
Tourism value	
Impact on the environment and native species	
Competition with and/or predation on native species	
Genetic diversity	
Introduction of diseases and parasites	
Future policy on the translocation of brown and rainbow trout	

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