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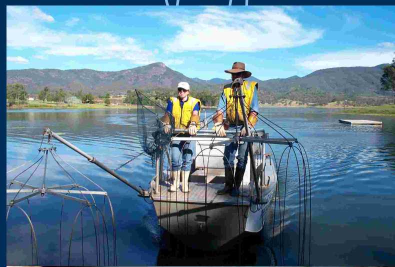

Fish stocking in impoundments

A best practice manual for eastern and northern Australia

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Queensland Government
Department of Primary Industries

Fisheries Research & Development Corporation

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Contents

Preface

This document has been compiled from a number of sources and, to the authors' knowledge, represents the best advice currently available regarding fish stocking in impoundments in northern and eastern Australia. Although the principles outlined in this document may apply to impoundment stocking in other parts of Australia, the examples and references provided relate specifically to Victoria, New South Wales, Queensland and the Northern Territory—the states where native fish stocking in public waters is currently carried out. Many of the examples and recommendations given are based on research carried out in south-eastern Queensland between 1998 and 2002[1]. Other data has been gleaned from individual researchers and research organisations throughout northern and eastern Australia and, in a few instances, from research carried out in other countries.

Although the information in this document is provided in good faith, it should be used as a guide only. It is not possible to make absolute statements or foolproof recommendations regarding fish stocking strategies that will apply equally to all impoundment scenarios. We have attempted to point out many of the factors that can lead to differing success rates among stocking programs, particularly in terms of the fish species being stocked, the manner in which these are stocked, the number and variety of fish and other flora and fauna already present in the impoundment, and the physical and chemical characteristics of the impoundment. However, given the almost infinite number of possible combinations and permutations of these factors that a particular impoundment might present, there can be no guarantee that strict adherence to the recommendations given in this document will always result in the best possible outcome.

We are, however, confident that a thoroughly planned fish stocking program that takes into account the principles and issues outlined in this document will stand a much greater chance of success than one which is hastily conceived without due regard for potential influencing factors.

[1] Fisheries Research and Development Corporation, Project no. 98/221, 'Impoundment Stocking Strategies for Eastern and Northern Australia.'

1. Introduction

Fish stocking is a valuable and widely used fisheries management tool. If managed well, a fish stocking program can improve the status of declining or threatened fish stocks, restore species diversity to a degraded waterway, and even create a fishery where there was none before. The positive image of thousands of small fish being released into a waterway ensures that fish stocking is equally popular among politicians, fisheries managers and the general community.

There are five main types of fish stocking activities carried out in eastern and northern Australia:

Put, grow and take fisheries—public impoundments
Most native sportfish do not breed in impoundments, and so must be stocked repeatedly if numbers are to be maintained. The primary purpose of impoundment stocking is to create or enhance recreational fisheries, and thereby contribute to local recreational opportunities and tourist-related income. The main species used in this sort of stocking are golden perch, silver perch, Australian bass, barramundi, sooty grunter and Murray cod.


Keith Chilcott

A fat sooty grunter from a central Queensland impoundment

Enhancement stocking—public impoundments
Enhancement stocking is sometimes carried out in an attempt to restore or improve species diversity in an otherwise impoverished system. An example is the stocking of garfish into impoundments in south-eastern Queensland. Garfish provide a food source for other stocked sportfish, and are an additional target for recreational anglers. Garfish will reproduce in impoundments, so ongoing stocking is usually not necessary once a population has become established.

Enhancement stocking—riverine areas
Many riverine areas have been stocked with endemic species because of a perceived depletion of fish stocks. Although, the main aim of this stocking has been to enhance recreational fishing opportunities, it may also help to restore the natural diversity of degraded riverine areas.


Keith Chilcott

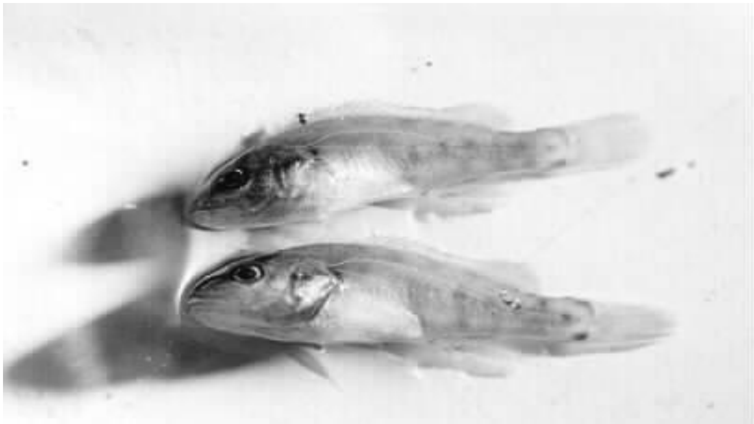
Snubnose garfish provide food for other stocked fish and sport for anglers

Farm dams

Farm dams are stocked with fish for a variety of reasons including recreation, food, aquaculture and conservation. Native sport/foodfish will breed only rarely, if ever, in a farm dam, so repeated stocking may be required to maintain populations.

Conservation

Conservation stocking is generally more specialised than other types of fish stocking, with close attention paid to the genetic diversity of stocked fingerlings. It is usually carried out by government agencies as part of a recovery program for endangered or threatened species. Recent examples include the stocking of Mary River cod in south-eastern Queensland, eastern freshwater cod in north-eastern New South Wales, and trout cod and Macquarie perch in southern New South Wales and Victoria.


Mark Dawson

Mary River cod fingerlings

The widespread use of fish stocking stems from the preconception that it will lead to increased yields from a fishery. However, this is only one possible outcome of a stocking program. There have been numerous examples from around the world of poorly conceived and under-planned stocking programs either failing to produce the desired results or, in some cases, even causing damage to other fauna or habitats.

Before any fish stocking program commences it should be thoroughly planned and appraised, with consideration given to:

- why the stocking is deemed necessary;
- what the program plans to achieve;
- factors that are likely to work for and against the success of the program;

- the costs of implementing the program;
- the availability of suitable fish species;
- how the results of stocking will be evaluated.

Only after these questions have been answered satisfactorily should the decision be made whether or not to proceed with stocking.

Much of the fish stocking that occurs in impoundments in eastern and northern Australia is undertaken to improve recreational fishing opportunities. However, large, static water bodies are not a common feature of the natural environment in Australia, and few of our native fish species are adapted to breeding in this sort of habitat. The commonly stocked species may survive well and grow quickly in impoundments, but they rarely, if ever, breed there. Most Australian impoundment fisheries based on native species are therefore ‘put, grow and take’ fisheries. They require an ongoing commitment to stocking to replace numbers that are lost to fishing pressure, other mortality and emigration.

Between 1995 and 2001, over 36 million native Australian sportfish from eight species were stocked into public waters of Queensland, New South Wales, Victoria, and the Northern Territory for recreational fishing enhancement alone. More than 60% of these were released into Queensland impoundments. Stocked fish have become a significant component of Queensland’s recreational fishery since intensive stocking commenced in 1986 under the Recreational Fishing Enhancement Program. Other stocking has been undertaken to help recover populations of endangered and threatened species, including the release of 200 000 Mary River cod in south-eastern Queensland between 1998 and 2001, and more than 600 000 trout cod in New South Wales and Victoria between 1995 and 2001.

Recreational fish stocking in northern and eastern Australia 1995/96–2000/01

Species	**1000s of fish stocked by state, 1995/6–2000/01**				
	Qld	**NSW**	**Vic**	**NT**	**Total**
Golden perch	10 749	6 397	1 436.2	0	**18 582.2**
Silver perch	3 665	1 906	43.5	0	**5 614.5**
Australian bass	3 313	1 186	22.7	0	**4 521.7**
Barramundi	4 295	0	0	63	**4 358.0**
Murray cod	181	981	706.5	0	**1 868.5**
Sooty grunter	1 330	0	0	0	**1 330.0**
Macquarie perch	0	9	85.6	0	**94.6**
Saratoga	3.6	0	0	0	**3.6**
Total	**23 536.6**	**10 937.7**	**2 448.7**	**63.0**	**36 373.1**

(Compiled from data provided by staff of state and territory fisheries agencies)

This manual provides guidelines to help plan and carry out fish stocking programs in northern and eastern Australian impoundments. It presents an introduction to the main biological and ecological concepts that determine the outcome of stocking programs, and provides community fish stocking groups with a protocol to help ensure the success of their stocking activities.

2. Why stock?

Key messages

- Stocking fish will not necessarily lead to a long-term increase in fish numbers.
- The aims of a stocking program should be clearly defined at the outset.

The answer to this question seems obvious—we stock so there will be more fish. More fish for anglers, and more fish for the environment. But is the equation really as simple as that, and is *more* necessarily *better* anyway? There are plenty of people who would respond with an unqualified 'yes' to both questions, but experiences from around the world suggest that we should be looking a little deeper. In fact, stocking does *not* always result in a long-term increase in fish numbers. If a waterway already supports large populations of fish, stocking may simply create additional competition for available food and space. And more is *not* necessarily better if fish become stunted due to overcrowding, or if other resident species are adversely affected by the sudden influx of stocked fingerlings. The question of why we want to stock fish should be considered carefully on a case-by-case basis.

The pressure to stock often comes about because of a perception among anglers or fishery managers that fish stocks have declined or are unable to naturally sustain their populations. It is sometimes very difficult to confirm if a fishery is in decline, or has declined, particularly when the only information available is anecdotal. For example, anglers who have regularly fished an area for many years may consider a drop in their catches to be proof of declining fish stocks, whereas factors such as increasing pressure from other anglers, or long-term, natural fluctuations in stock size may, in fact, be more to blame. Assessing the status of resident stock before new stocks are added and gathering evidence to confirm that a decline has actually occurred may seem like a lot of trouble, however, failure to do so makes planning, appraising and evaluating the stocking program very difficult. It is not possible to gauge the program's success without knowing what stocks were there initially.

If it can be confirmed that a fish stock has declined due to factors like disease, lack of food or habitat, poor water quality or poor breeding success due to altered stream conditions (e.g. regulated stream flows, dams), then simply releasing more fish without addressing the underlying problems will probably not help the situation. Either the factors limiting fish production should be mitigated, or it must be accepted that ongoing and regular stocking will be required to maintain fish stocks.

Another misconception regarding stocking is that no matter how good a fishery is, it can be made better by stocking more fish or different species. This idea contradicts the basic ecological theory of 'carrying capacity' (see section 3.6), which should be familiar to anyone who has ever been involved in livestock production, or simply kept a few fish in a tank. It is pointless to stock additional animals into an environment unless there is food and space available to support them. Every grazier is aware that overstocking a pasture will not increase production in the long term, but will surely damage the pasture and lower the average condition of the stock. Likewise, stocking a healthy waterway which is already at or near its carrying capacity will not magically increase local fish populations, but will increase competition for food and space.

In this situation, stocked fish will only become established in the wild population at the expense of those fish that were already present.

Andrew Berghuis

Weirs and dams restrict fish movements, and have contributed to the decline of some native species

In eastern and northern Australia, the reason for stocking impoundments is clear-cut. Native sportfish are generally unable to maintain viable stocks in impoundments through natural reproduction, so stocking is required to create and/or maintain the fishery. This stocking does not so much address a decline in stocks, as it does the inability of stocks to establish significant, sustainable populations. Both endemic and translocated fishes have been used in impoundment stockings to increase the variety of species available to anglers.

Keith Chilcott

Australian bass are a popular species for stocking in Queensland and New South Wales, but they will not breed in impoundments

3. Planning the stocking program

Key messages

- Before planning a stocking program, state or territory fisheries authorities should be contacted and ideas discussed.
- The genetic implications of fish stocking should be considered in any breeding and restocking program.
- Interactions with resident fauna (both fish and other animals) can have a major impact on the outcome of a fish stocking program.
- Care must be taken to avoid the transfer of unwanted species and diseases.
- Migratory fish species need special consideration.
- The suitability of the receiving environment (water quality, water temperature etc.) for the selected species should be considered before stocking.
- The 'carrying capacity' of an impoundment will determine how many stocked fish survive and grow.
- Pre- and post-stocking monitoring of impoundments will provide valuable information about the success of stocking programs.

Many factors interact to determine the success or otherwise of a fish stocking program. Some of these factors are beyond the control of those involved in the program, but still need to be considered when planning the stocking strategy and assessing the chances of the program achieving its aims.

3.1. Legal requirements

A good starting point when planning a fish stocking program is to find out what restrictions might be placed on stocking activities by the appropriate state fisheries agency. Each state and territory has a number of requirements that must be met before any stocking of fish is allowed, and it is essential to contact the relevant authority to discuss ideas before progressing too far. It would be a waste of time to plan which species to stock and where, only to find that a seemingly good idea fails to meet a basic regulatory requirement.

Very briefly, the following requirements apply:

New South Wales—permit required from NSW Fisheries for any fish stocking in New South Wales public waters. No permit is required to stock fish into private waters (e.g. farm dams) but there are restrictions on which species may be stocked in different areas.

Queensland—permit required from Queensland Fisheries Service (DPI) for any fish stocking in Queensland public waters. No permit is required to stock fish in private waters, but it is an offence to stock fish in contravention of the DPI Translocation Policy.

Victoria—permit required from Natural Resources and Environment for any fish stocking into public or private waters in Victoria.

Northern Territory—permit required from Primary Industries and Fisheries for any fish stocking into public or private waters in the Northern Territory.

In all cases, the state or territory fisheries authority can provide further details of the species that may be stocked, and additional information on recommended stocking densities and strategies (see Appendix I). Authorities in respective states also provide stocking guidelines in various forms as indicated in the references and further reading section (e.g. MacKinnon 1989, Fisheries Victoria 1998).

3.2 Genetic considerations

Genetic issues can vary depending on the reasons fish are being stocked. Very stringent guidelines are required for conservation stockings, however for put, grow and take fisheries genetic considerations, although still important, may be more relaxed.

There are two main genetic risks to be considered when stocking fish: inbreeding and outbreeding depression. Both of these effects can reduce the fitness of stocked fish to survive in the wild. Genetic considerations are important for impoundment stocking, as impoundment-stocked fish will commonly migrate to adjacent riverine areas upstream and downstream of the impoundment and mix with existing wild populations.

Inbreeding occurs when too few parent fish are used to produce a batch of fingerlings for stocking, or when closely related individuals are paired. In these situations, the genetic variability of subsequent generations is reduced, which lessens the ability of the population to respond to changing environmental conditions. It may also produce high levels of mutation in the offspring.

Outbreeding depression can occur when genetically different stocks of a species are crossed with each other. Different stocks of the same species (e.g. from different river systems) may exhibit genetic variation that is characterised by differences in growth potential, age at maturity, fecundity, and seasonality of behaviour. If non-local stock is less suited to the river or lake environment into which it is released, any fish that survive to reproduce may confer a reduced adaptation upon some or all of the offspring. A detailed genetic study of the species in question may show that there is little genetic difference between populations in different areas, in which case the likelihood of outbreeding depression occurring is low. In the absence of this sort of information, it is recommended that parent fish be collected from the area to be stocked, and not crossed with fish from other areas.

Many years of fish stocking in Australia may have had an effect on pre-existing wild riverine populations, the extent of which cannot be determined because the genetic make-up of wild populations has not been documented. Further breeding of the common stocking species and, more importantly, of new stocking species should only be undertaken after full consideration of the wider genetic implications. The extent of genetic differences between wild populations from different areas should be investigated before stocking proceeds.

3.3 Species interaction

Stocked fish may have adverse effects on resident fish, or vice versa, through predation and competition. This is most likely to occur when stocking involves a non-endemic species. An often quoted example occurred in Lake Victoria, Africa, when non-endemic and highly predatory Nile perch released into the lake led to the rapid decline and, in some cases, extinction of resident fish species upon which local people relied for food and trade.

Closer to home, survival of golden perch stocked in farm dams has been found to be much lower in dams already containing the introduced pest *Gambusia* (mosquito fish), than in dams where it is absent. The aggressive *Gambusia* has a habit of nipping pieces of fin from other, often much larger, fish, which can cause stress, disease, and death of the affected fish.

There is also circumstantial evidence that golden perch stocked in impoundments do better in the absence of Australian bass, and that bass stockings are less likely to be successful where there is an established population of barramundi. Barramundi prey on juvenile, and probably adult, bass and may alter bass feeding and schooling behaviour in impoundments, making them less catchable by anglers.

Rod Cheetham

Golden perch, a popular stocked species, may not perform well in some mixed species stockings

Mixed species fisheries might be a great idea in theory, but may be difficult or less cost-effective to maintain in reality. Concentrating on a smaller number of complementary species may, in many instances, be a more suitable approach for impoundments. This should be addressed in the development stages of a stocking program.

Species interactions may also involve fauna other than fish. Perhaps the most important of these in eastern and northern Australia is predation by birds, particularly cormorants. Cormorants may completely strip the fish from a small farm dam and, undoubtedly, also account for losses of significant numbers in large impoundments.

Several options are available to help control predation by cormorants:

- On smaller dams and water bodies, predator netting, or bird scare-wire can be installed. This is relatively expensive, and so is most often seen on commercial aquaculture ponds.
- Cormorant predation can be minimised by providing fish with abundant shelter or cover. In small dams, it may be appropriate to introduce pieces of timber or other structures, but in larger impoundments, it should be negotiated at the time of construction that standing timber and other structures not be removed.
- An abundance of alternative prey items, like yabbies or other small fishes, will help to reduce the pressure on recreational fish stocks.

It should be noted that cormorants and other aquatic birds are fully protected by law in all Australian states.

It may also be necessary to consider the impacts that fish stocking will have on fauna such as frogs and crustaceans, particularly if they are listed as endangered or threatened species. This will not usually be a major issue when stocking impoundments, which are already highly modified, artificial habitats, however, some migration of stocked fishes out of impoundments is to be expected, and the potential impacts of this should be considered. The potential for adverse impacts on resident fauna can be reduced by stocking only those species that are endemic to an area.

3.4 Stocking of associated species

There is a risk that unwanted species could be introduced along with the target stocking species. This may include species that are similar in appearance to the target species, or other fauna that is on or in the target species or in the transport medium. The recent proliferation of non-endemic banded grunter in several impoundments in south-eastern Queensland and in the Clarence River, New South Wales, probably occurred following the stocking of Australian bass fingerlings that were contaminated with banded grunter fingerlings.

Gunther Schmida

Banded grunter, *Amniataba percoides*

The best defence against this risk is vigilance. It is in the interests of fish hatcheries to thoroughly check batches of fish for unwanted contaminants or disease, as they may quickly lose customers if found to be supplying contaminated stock. NSW Fisheries is working with hatcheries from November 2002 to prevent stock contamination as part of a quality assurance project. This project will also include aspects such as disease and broodstock quality assurance. It is recommended that people organising the stocking carry out further checks at the stocking site. A suggested protocol for assessing fingerling health and contamination is included in section 5.3.

Fish are transported to release sites in water that may harbour other undesirable organisms. The risk of unwanted introductions can be reduced by careful management of the transport water at the hatchery (e.g. filtration or chemical treatment), and by thoroughly cleaning transport equipment (e.g. transport container, nets, buckets) before and after transporting fish.

3.5 Disease

Transfer of fish from one water body to another raises the risk of disease transmission. The main concern is that a pathogenic organism (bacteria, virus, or parasite) could be introduced into populations of fish that have no natural immunity or defence against the pathogen. This could quickly lead to mass mortality of a resident population. Some diseases of particular concern in Australia include *Nodavirus* in barramundi, goldfish ulcer disease in goldfish, and epizootic haematopoietic necrosis carried by the introduced redfin. This latter disease affects trout and has infected native species in laboratory trials. However, it has not yet been recorded in native species in the wild, despite outbreaks of the disease in wild redfin.

Policies on health certification requirements for fish stocking vary between states. In Queensland, it is recommended that any barramundi to be stocked be tested for *Nodavirus* at days 21 and 42 before they leave the hatchery. There are also strict policies on the transfer of fish between states—for example, any fish to be brought into Queensland must first be certified free of disease. As policies and guidelines regarding fish health certification are currently under review in Victoria, New South Wales and Queensland, the appropriate state fisheries authority should be contacted for up-to-date information.

Risks of disease transfer can be further minimised by employing adequate quarantine procedures at the hatchery, by careful inspection of fingerlings at the release site, and by appropriate management and treatment of transport water and equipment (see section 5.3).

3.6 Movement behaviour

Most native sportfish move long distances at certain times of the year, often as part of the breeding cycle. When stocked into an artificial impoundment, these riverine fish retain their instinctive movement patterns and may try to migrate upstream or downstream out of the impoundment.

Fish that move upstream may be considered lost (temporarily) to the impoundment fishery. However, if the movement takes them into riverine habitats that are suitable for breeding, the result may be natural replenishment of the impoundment fishery.
A much bigger problem occurs when fish move downstream. Fish may or may not survive the drop over a dam or weir wall, depending on the height of the structure and

the conditions below. Those that do survive will be unable to return to the impoundment unless an effective fishway (i.e. fish-ladder or fish-lock) has been constructed on the structure. In this way, a significant proportion of the stocked population can be lost from an impoundment fishery.

There have been several graphic examples of this problem in Queensland in recent years. Large numbers of adult barramundi stocked into Lake Tinaroo in north Queensland have died while trying to migrate downstream over the dam wall. A large barrier net has now been installed in the lake in an attempt to keep the barramundi away from the dam wall, and this appears to have been quite successful. Similarly, large numbers of adult Australian bass have been lost from Hinze Dam and other south-eastern Queensland impoundments during floods—this is a problem that will recur every year when adult bass try to migrate down to the estuary to spawn. So far, the problem has been dealt with by a combination of 'rescuing' fish from below the dam wall and returning them to the impoundment, and by maintaining annual stocking of the impoundments to supplement those fish that are lost.

Rod Cheetham

Adult Australian bass will try to migrate downstream to the estuary in autumn/winter to spawn

The message regarding migratory fish species *is not* that they should not be stocked, but that contingency plans should be put in place to deal with likely losses of fish. The 'barrier net' option appears to be a solution of sorts, but is very expensive to install, requires regular maintenance, and is not highly regarded by state water resources agencies that manage many of the larger impoundments. The 'rescue and transfer' approach can be difficult, time consuming and costly, causing physical damage and stress to the fish, but may be worthwhile depending on the numbers of fish that can be rescued. Despite the potential for these two options to reduce losses of migratory fish, ongoing stocking will still be required to replenish and maintain numbers.

3.7 Environmental considerations
For fish stocking to be successful, the receiving water body must provide all of the basic requirements for growth and survival of the stocked species. That includes good water quality with the appropriate range of temperatures for each species, adequate habitat for feeding and resting, and abundant food in the appropriate size ranges. Depending on the objectives of stocking, the water body should also be conducive to successful breeding and recruitment. In many Australian impoundments which are managed as put, grow and take fisheries, this latter point is less of a concern as most native sportfish do not breed in dams. However, suitable breeding conditions would be an essential prerequisite in any conservation stocking program where the aim is to establish a self sustaining population.

Many environmental considerations can be adequately addressed simply by stocking only those species that are endemic to the release area. The risk of failure is increased when the stocking represents a translocation. For example, moves to establish populations of barramundi in south-eastern Queensland impoundments must be considered to have a relatively low chance of success on the basis of winter water temperatures alone. While barramundi may survive that far south in most winters, their growth rates and angling season are likely to be much reduced compared to those in their natural, northern habitats.

An important concept to consider when planning a stocking program is the ‘carrying capacity’ of the receiving habitat. Every waterway has a limit as to how many fish (and other organisms) it can support—no more fish will survive than the available food and habitat will allow. If a waterway is stocked too heavily, there is likely to be increased mortality (due to predation, starvation and increased disease), reduced growth rates (stunting), and increased dispersion. The sometimes mooted idea of enhancing already healthy fisheries by stocking more or different fish is often doomed to failure from the outset.

The carrying capacity of a waterway is usually expressed as the biomass of fish (or other animals) it can support per unit area or volume. In relatively enclosed waterways like lakes and dams, a relationship exists between shoreline length, surface area, water depth, habitat availability and carrying capacity. The relationship may vary seasonally as food sources follow their annual patterns of boom and bust, and even adjacent dams may have quite different carrying capacities, but it at least gives managers a starting point to determine how many, if any, fish should be stocked. In open systems such as rivers, the relationship between physical habitat and carrying capacity is more complex, and expert opinion is usually relied upon to get an idea of the appropriate stocking density.

3.8 Monitoring and evaluation
An often overlooked aspect of fish stocking programs is pre- and post-stocking monitoring and evaluation. It is not uncommon for active involvement in stocking programs to cease once the fish have been released, but this is really only the start of the story. Stocking can only be considered successful if the objectives of the program have been met, whether they are to establish a new species, increase the average size of a species, increase abundance or increase social or economic values. There is no way of knowing if the objectives have been met without undertaking some form of

monitoring and evaluation. If, in fact, the stocking has failed to produce any positive results, it is important to know this so that the same mistakes aren't repeated, and more resources wasted.

Pre-stocking monitoring should be undertaken before any fish are released to get an idea of the numbers and variety of potential predators already present in the waterway. This information will be useful in deciding upon an appropriate stocking strategy (i.e. how many fish to release, at what size to release them, and where and when to release them). Pre-stocking surveys will also provide baseline information on the overall fish community present. This information can be compared to the results of later post-stocking surveys to get an idea of what impact stocking activities have had.

Post-stocking monitoring is vital in assessing the results of the stocking program, providing data on the survival and growth of the released fingerlings. These surveys will also indicate whether fish have been stocked at an appropriate density. If stocked fish are in poor condition, it is likely that they are not finding enough food, and it would be worth considering reducing the stocking rate in subsequent years.

Monitoring may rely solely on angler catch records, but should preferably be combined with standardised scientific surveys carried out by trained personnel who have access to nets, traps and electrofishing equipment. Ideally, stocked fish should be marked in some way for later identification (e.g. microwire tags, genetic markers, scale pattern checks), but it is rarely possible (logistically or economically) to mark all fish that are to be stocked. Biologists employ methods to extrapolate information about the whole stocked population from a small number of tagged individuals.

Keith Chilcott

Electrofishing and netting surveys are used to assess the success of stocking

4. Translocation

Key messages

- Translocation of fish into new habitats can be beneficial for anglers, but can also cause serious problems for resident species.
- Environmental and biodiversity issues need to be considered.
- It is best to use local species to stock impoundments, as they are adapted to local conditions and are less likely to cause problems for other fish and fauna.

'Translocation' is the introduction of organisms into habitats in which they do not naturally occur. Translocations may involve exotic species (e.g. the introduction of trout and salmon into Australia) or native species (e.g. the stocking of Murray-Darling golden perch in coastal catchments). Even the movement of a species into different parts of its natural range may be considered a translocation if that species is represented by genetically different populations in different areas (e.g. barramundi in Queensland). At a more local scale, the stocking of fish into parts of a river system to which they do not normally have access, such as upstream of a large waterfall, is an example of a translocation.

Many of Australia's inland fisheries have been created or enhanced as a result of the translocation of one or more species. In southern Australia, introductions of trout in the 1800s, and regular subsequent stockings, have led to the establishment of a valuable and world-renowned recreational trout fishery. Similarly, in south-eastern Queensland, the stocking of coastal impoundments with non-endemic golden perch saratoga and silver perch has helped to create new recreational fisheries that are important contributors to local economies.

While the potential benefits of translocation are clear, there have been enough examples of failures, and even environmental disasters, resulting from the introduction of non-endemic species, that governments now take a very cautious approach to the issue. Australia's experiences with species like rabbits, cane toads and European carp have demonstrated some of the perils of translocation, while potential new problems arrive each year via the hulls and bilge water of international ships, releases and escapes from aquarium and aquaculture facilities, and through the illegal importation of flora and fauna.

Translocations of fish into, and between, Australian waters have been carried out in attempts to enhance recreational fishing (e.g. trout, carp, golden perch, silver perch), to try and reduce mosquito problems (i.e. *Gambusia*), and as accidental or ill-conceived releases of aquarium species (e.g. tilapia, swordtails). Many of the exotic fish species involved have gone on to become pests of national significance. Whereas the translocation of native species is sometimes considered much less of a problem, problems can still arise. In northern Australia, translocation of the predatory mouth-almighty, banded grunter and archerfish into Lake Eacham is considered responsible for the localised extinction of the Lake Eacham rainbowfish. Any such translocation of predatory species can adversely affect resident species that are not adapted to deal with predation.

Because of the high potential for damage to local species and systems, a National Policy for the Translocation of Live Aquatic Organisms has been developed. Each state also has a specific policy or set of guidelines to control the movements of native and introduced species within its borders. These policies and guidelines take a precautionary approach to translocations, giving full consideration to the potential associated risks mentioned in the previous section.


Bob Simpson

European carp have become established in a number of Australian rivers and impoundments

Although it is virtually impossible to predict how a species will respond after it has been translocated, and what effects it might have on the receiving habitat and the resident flora and fauna, a full risk assessment should be carried out on all proposed new translocations to at least identify which risks are real, and whether the potential outcome warrants taking those risks. This is an important process, as it can be nearly impossible to eradicate a translocated organism once it has become established in its adopted home.

In relation to fish stocking, state translocation policies provide clear guidelines as to which species can be stocked in which locations. In general, the approach is to only allow stocking with species that are endemic to a given area, however, there are exceptions to this. For example, the Queensland Translocation Policy permits continued stocking of non-endemic golden perch and silver perch into selected coastal catchments, as their impacts on the receiving systems are considered minimal, and the likelihood of either species establishing self-sustaining populations is low. A cessation of this stocking should therefore lead to the eventual elimination of golden and silver perch from these systems. Some biologists have suggested that stocking of golden and silver perch outside their natural range should cease when coastal catchment endemic species such as jungle perch and mangrove jack become available to stocking programs.

Specific details of which species may be stocked in which areas can be obtained by contacting your state fisheries agency. The National Policy for the Translocation of Live Aquatic Organisms can be downloaded at www.affa.gov.au.

5. Transporting and releasing the fish

Key messages

- Handling and transport stresses fish, so they should be treated as carefully as possible and transported without delay.
- Fingerlings to be stocked should be checked carefully for contamination with other species and disease, and the entire batch rejected if necessary.
- Fish should be given time to acclimatise to their new surroundings before they are released.

Moving fish to their release site is a relatively simple process, but it does need to be done properly or the fish could become sick and die. Any handling can cause stress and physical damage to the fish, which can affect post-stocking survival. Therefore, the aim is to get the fish to their release sites as quickly as possible and with as little handling as possible.

There are a couple of standard procedures that the fish hatchery will carry out before the fish are collected for stocking. Most hatcheries rear their fish in outdoor ponds, so these must be harvested and the fish transferred to clean water (e.g. indoor tanks) for counting and inspection. The fish should then be 'purged' for 24–48 hours in clean water prior to transport so that they travel on an empty stomach. If this is not done, there is a good chance that their wastes will foul the transport water and kill some, or the entire, batch. The purge period also serves as a quarantine period, when the fish can be inspected for any signs of disease and parasites.

Once the fish have passed inspection, they are ready to be transported. This can be done in several ways, but regardless of the method, it is vital to maintain adequate oxygen in the transport water, to keep the temperature stable, and to get the fish where they are going as quickly as is legally possible. Depending on the number of fish, the hatchery may deliver them to the release location in an insulated transport container, or send them in plastic bags to which water and oxygen have been added.

5.1 Loading densities

The number of fingerlings that can be safely transported depends on the volume of the transport containers, efficiency of the aeration equipment, distance to be transported, water and air temperature, and size and condition of the fish. Generally, for a given volume of water, a lower weight of small fish can be transported than large fish. This is not normally something that the people undertaking stocking have to worry about, as hatchery staff will usually load the fish at the appropriate density, and often deliver them to the release location.

Maximum recommended densities of fish for transport

a. Plastic bags (45 cm x 80 cm)

	Duration of transport			
	1 hr	**12 hr**	**24 hr**	**48 hr**
Newly hatched larvae (grams/l)	120	80	40	10
2.5 cm fingerling (grams/l)	120	100	75	40
5 cm fingerling (grams/l)	120	105	90	40
7.5 cm fingerling (grams/l)	120	105	90	40
Larger fish (grams/l)	480	180	120	60

b. Large containers with diffused oxygen

	Duration of transport			
	1 hr	**6 hr**	**12 hr**	**24 hr**
Newly hatched larvae (grams/l)	NR*	NR	NR	NR
2.5 cm fingerling (grams/l)	120	60	30	30
5 cm fingerling (grams/l)	240	180	120	120
7.5 cm fingerling (grams/l)	360	240	120	120
Larger fish (grams/l)	480	480	360	240

*NR = not recommended

(Adapted from website of Auburn University, Alabama, USA)

5.2 Transport water

The water in which fish are transported should be kept cool and well-oxygenated. Avoid sudden changes in temperature of greater than 3°C; warm water holds less oxygen than cool water, so it is important that the temperature is kept below 25°C. Murray-Darling and other temperate zone species travel well at temperatures below 20°C. Insulated containers help in this regard, and plastic bags can be placed inside large polystyrene boxes for the same effect. Ice can be packed around plastic bags or other containers on very hot days. A wet towel wrapped around small transport containers will help to keep the temperature down through evaporative cooling. Ideally, fish should be moved during the coolest part of the day or at night and, if possible, in an air-conditioned cab. At the very least, transport containers should be kept well-shaded. When transporting tropical species like barramundi, sooty grunter and saratoga care should be taken not to allow the temperature to drop below about 18°C.

In larger transport containers aeration is usually achieved by compressed air and/or bottled oxygen delivered to the water via air-stones or other diffusers. Care should be taken not to overdo the flow of air as over-vigorous aeration can be detrimental. Smaller batches of fish will often be packed in sealed plastic bags with water and oxygen added. One bag is placed inside another to double the thickness and then approximately quarter-filled with water and fish. The remaining space is filled with oxygen and the bag sealed with a rubber band.

Various concoctions can be added to the transport water to try and make the ride less stressful for the fish. Perhaps the most widely used, and most highly recommended, of these is salt. A low concentration of salt in the water helps to reduce stress and prevent infection of any damaged parts, and can even improve post-stocking survival of fish. Coarse salt is added to transport water at a rate of 0.5-1.0 kg / 100 litres (0.5-1.0% NaCl solution). Some hatcheries use a mild anaesthetic to quieten the fish down so that they use less oxygen and are less likely to do any damage to themselves. However, because the sensitivity of fish to anaesthetics and other chemicals varies widely between species and under different prevailing conditions, expert advice should be sought before any such substances are added to water in which fish will be transported.


Glynn Aland

Fish transported in plastic bags are easily distributed around the stocking site

5.3 Checking fish for disease and unwanted species

In Victoria, New South Wales and Queensland, there is an onus on commercial fish hatcheries to comply with health guidelines that are designed to ensure that only healthy, disease-free fish are sold for stocking. Random, but infrequent, spot checks are made by fisheries officers to ensure that hatcheries meet their obligations. In Queensland, random checks of fingerlings are also made immediately prior to release to check for contamination with unwanted species and obvious signs of disease.

Despite these checks, it is in the interests of people undertaking fish stocking to become familiar with external symptoms of fish diseases, and to closely inspect their fingerlings before they are released. Many books have been written on this subject, and local libraries or state fisheries agencies should be able to provide advice on suitable reference material. A suggested procedure for checking a batch of fish prior to release is provided below. It is strongly recommended that, before these checks are carried out, people undertaking fish stocking contact an experienced fisheries officer to clarify the procedure and to ensure they are fully conversant with the safe and effective use of an appropriate fish anaesthetic such as Aqui-S.

Protocol for inspecting hatchery fish prior to release

- Do an overall inspection of entire consignment for dead fish. If mortality is high (>5%) reject batch immediately.

If mortality levels are lower:

- Check batches of 100 fingerlings at a time. Aim to check at least four to five batches of 100 fingerlings—more if possible.
- Samples of fish should be taken from all levels of the transport container, as different species or diseased individuals may occupy different levels in the water.
- Place 100 fish in a bucket of water with anaesthetic.
- Remove 10 anaesthetised fish at a time, check carefully for visible disease (e.g. fin rot), and check fish are of the required species.
- If unwanted species are present, or if disease is prominent, **do not stock**.
- Preserve a sample of any diseased fish, and/or any contaminants (i.e. non-target species), then contact the appropriate state or territory fisheries agency. Non-target species can be preserved in 70% ethanol or methylated spirits. Diseased samples should be kept alive or preserved in 10% formalin*.

If no apparent contamination or disease:

- Measure 10 fish from each 100 and record lengths.
- Allow the sampled fish to revive in a bucket of clean water before releasing.
- Forward the results of the inspection to the relevant fisheries authority.

This protocol relies on inspecting a representative sample of the fish to be stocked, and so provides no guarantee that the consignment is absolutely free of disease or contaminants. Although a small amount of physical damage or disease may normally be expected in a large batch of fish, it is appropriate to reject a batch of fingerlings that display unacceptable levels of mortality or signs of disease outbreak.

Unfortunately, there is no hard and fast rule as to what is unacceptable. It is not unusual for some fingerlings (<2%) to be damaged or die during transportation—these will often be the smallest fish in the batch and may show signs of physical damage. Low levels of infection may also be apparent in the form of frayed or rotted fins—this is not normally a problem as long as only a small proportion, say less than 2%, of the fish are affected. Such occurrences are normally related to the stress of transport.

In more serious cases, where a larger proportion of the fish are dying or showing symptoms of disease, or where the symptoms are more severe (e.g. entire fins rotted away, fish covered in white spots or cottonwool-like growth), then **do not stock**. The supplying hatchery should be notified of the problem, and the state fisheries agency contacted for advice. Further information on disease and how to preserve and submit diseased samples can be found on fishweb at www.dpi.qld.gov.au/fishweb. Follow the links to aquaculture, then health and disease of fish.

*Formalin is toxic. Follow health and safety guidelines when using this chemical.

5.4 Acclimatising the fish

Most fish are tolerant to a range of water temperatures and water chemistry, but they usually need some time to acclimatise to new conditions. If, upon arrival at the release location, the fish are immediately poured into their new environment, the stresses of coping with different water temperatures and chemistry on top of the stresses involved in transport, may render them prone to disease, or even cause immediate mortalities as a result of shock. The simple remedy to this problem is to acclimatise the fish to their new environment gradually.

To acclimatise fish effectively, empty around half of the transport water and slowly replace it with clean water from the release site. Repeat this process after 10 minutes, and wait a further 10 minutes before releasing the fish. If the transport water temperature differs from the stocking site water by more than 3°C, exchange a quarter of the water three or four times before releasing the fish. A soft net can be used to transfer fish from the transport container into a bucket for distribution and release. The acclimatisation process is similar for fish in plastic bags—float the plastic bags in the water for 5–10 minutes to allow the temperature to equilibrate, then open the bags and exchange some of the water as described above before releasing the fish.

It should be noted that once a plastic bag has been opened, the remaining oxygen will quickly be used up. Exchanging some of the water will introduce more oxygen, but fish should not be left to acclimatise in an opened plastic bag or bucket for more than about 10 minutes without water exchange. It is advisable to keep a close eye on the fish at this stage. At the first signs of oxygen stress (gasping at the surface, losing balance and rolling), they should be infused with new water or released as soon as possible.

Rod Cheetham

Fish need time to acclimatise to their new conditions before they are released

5.5 Methods of release

Once acclimatised, the fish should be allowed to swim out of the bags into their new surroundings. In general, it is best not to pour the fish out of the bags (or from buckets) from any height as they are easily injured. However, the fingerlings of some species including Murray cod and barramundi will sometimes amass into a tight ball when released into open water, making them particularly vulnerable to mass predation in the first 10–15 minutes after release. This behaviour can reportedly be avoided by pouring the fish from a height of 3–5 cm. Alternatively, release fingerlings in small batches close to cover if this problem is encountered.

There are three basic methods for releasing fish into a new environment: spot, scatter, and trickle release. Spot release, where fish are released in one location all at the same time (i.e. all of your eggs in one basket), is the simplest but least preferred method. With scatter release, the batch of fish is divided into several large groups, which are released at different locations around the stocking site. Trickle release involves releasing the fish at the same or different locations over a period of time (e.g. several weeks). Both scatter release and trickle release disperse the fish so they are less vulnerable to mass predation.

One situation where it may be unwise to use trickle releases is with the stocking of barramundi. These fish can grow very quickly, and the larger fish in a batch will commonly cannibalise smaller individuals. Barramundi released at 50 mm may attain 90 mm within two weeks if adequate food is available—if another batch of 50 mm fish was released at the same location two weeks after the first, there could be high losses to cannibalism.

Keith Chilcott

Allow fingerlings to swim out of the plastic bag when they are ready

5.6 Keeping records

It is important that records are kept of all fish stocking activities including the species stocked, the numbers, sizes and condition of the fingerlings, and exact locations in which they are released. This should be done for future reference, and it is also a requirement of the stocking permit that these details be forwarded to the state fisheries authority for storage on a database. A form for recording these details is provided by the fisheries authority when the permit is issued. A sample fish stocking record form, as currently used in Queensland, is included in Appendix II. There is also an example of a fin fish specimen advice form, which is submitted with diseased specimens by hatcheries in Queensland, but could be adapted for use by fish stocking groups.

6. Getting the best out of the stocked fish

Key messages

- The numbers of fish released in a given impoundment should be tailored to suit the prevailing conditions (i.e. size of impoundment, amount and quality of habitat, numbers of predatory, and other, species present).
- Fish released at a larger size generally are less vulnerable to predation and other stresses.
- Golden perch, silver perch, Australian bass and barramundi, generally survive best if stocked at 50 mm or larger.
- If possible, fish should be stocked early in the spring/summer growing period so that they have time to increase in size and condition before winter.
  - The presence of large populations of predators in an impoundment, particularly barramundi, can make it difficult for other stocked fish to become established.
- Releasing fish in large batches at three or four locations around a dam helps spread the risk of predation.

This section provides advice on how to achieve optimal results when stocking four of the most popular stocking species in northern and eastern Australia: golden perch, silver perch, Australian bass and barramundi. The guidelines presented here are based largely on research funded by the Fisheries Research and Development Corporation and carried out by DPI Fisheries in Queensland between 1998 and 2002. Many of the comments and underlying principles presented here will have application to stocking programs involving other fish species.

6.1 Choice of species

Golden perch are the most stocked native fish species in Australia, accounting for just over 50% of fish stockings for recreational purposes in northern and eastern Australia in recent years. They are a popular angling target in impoundments and rivers as they readily take artificial lures and baits and are considered good table fare.

Gunther Schmida

Golden perch, *Macquaria ambigua*

There are at least four distinct genetic stocks of golden perch in Australia, occurring in the Murray-Darling, the Fitzroy-Dawson, and the Bulloo-Bancannia river systems and in the Lake Eyre drainages. In keeping with translocation policies, care must be taken to ensure that golden perch from one river system are not used in stocking programs for another river system. Most golden perch that are stocked outside their natural range in coastal catchments are sourced from Murray-Darling stock. Golden perch are a riverine spawner, and are unable to reproduce successfully in impounded waters, including farm dams.

Growth rates may vary between locations, however, this species can reach the legal size of 300 mm in 15–18 months. Adult golden perch from the Murray-Darling River system commonly attain weights of 5–9 kg and lengths of 600–700 mm in impounded waters. Golden perch from other river systems tend to be smaller, rarely exceeding 5 kg and 500 mm.

Silver perch have been the second most commonly stocked species in eastern Australia since 1995. Recreational catches of this species from stocked impoundments have been variable—juveniles are commonly caught on lures or baits, but catchability often decreases as the fish age. It is thought that this is because larger fish become predominantly vegetarian. Experienced anglers take large silver perch with worm baits fished in the shallows.

Silver perch occur naturally in the Murray-Darling River system where they have become progressively rare, to the point that they are now considered threatened nationally. Growth rates can vary markedly, but the legal size of 300 mm may be attained in about 12 months under optimal conditions. Adult fish often reach 550 mm and 7 kg in impounded waters. Similar to golden perch, these fish are riverine spawners and do not normally breed in impounded waters.

Gunther Schmida

Silver perch, *Bidyanus bidyanus*

Australian bass have become the big success story of impoundment fish stocking in recent years, particularly in south-east Queensland and north-east New South Wales. They appear to have comparatively high survival rates under most conditions, are aggressive takers of artificial lures and baits throughout the year, and are excellent table fish. The biggest drawback is that their annual urge to seek estuarine spawning grounds may see large numbers migrate downstream over the weir or dam wall, particularly during autumn/winter floods.

Australian bass occur naturally in coastal streams from Fraser Island and the Mary River south to Gippsland in Victoria. Bass are relatively slow growing, commonly taking up to three years to reach the legal size of 300 mm. This can be reduced to two years in optimal conditions. They can eventually reach 600 mm and upwards of 4 kg in impoundments. Bass are salt-water spawners and are therefore unable to reproduce in freshwater impoundments.


Glynn Aland

Australian bass, *Macquaria novemaculeata*

Barramundi are one of Australia's fastest growing and best-known freshwater sport fish, and have been stocked mainly in the Northern Territory and Queensland north from Maryborough.

A number of distinct populations of barramundi have been identified using genetic techniques, including a Western Australian strain, a Northern Territory strain, and six management strains in Queensland (south-east Gulf of Carpentaria, north-west Cape York, east coast Cape York, mid north-east coast, central east coast, and south-east coast). In general, only barramundi from the appropriate strain are used to stock a given area, although some mixing of barramundi from adjacent populations has been allowed.

Spectacular growth rates can see stocked fish reach the minimum legal size of 58 cm twelve months after stocking in productive impoundments. One of the best known stocked impoundments, Lake Tinaroo in north Queensland, yields specimens up to 45 kg and 130 cm total length.


Gunther Schmida

Barramundi, *Lates calcarifer*

6.2 Stocking density

The appropriate stocking density for a given impoundment is usually determined based on the surface area, shoreline length and water depth. Other factors that should also be considered include the existing stock density and the expected survival of the fish to be stocked, both of which can be very difficult to quantify. Information on the existing stock density can be obtained from pre-stocking surveys and angler catch data. The survival of stocked fish is influenced by many factors, including the abundance of potential predators, the availability of appropriate food and habitat, the size at which the fish are stocked, and the location into which the fish are released (i.e. deep or shallow water, cover or open water). A degree of 'guesstimation', based on past experience and local knowledge, is usually required on the part of fisheries managers in determining appropriate stocking densities. The situation can be even more difficult in riverine areas, where there is no set surface area or length of shoreline within which the stocked fish will be constrained.

Some examples of stocking densities are shown below:

- In Queensland: 100–200 fish/ha (fish stocked at 50 mm)
- In Victoria: Australian bass, golden perch, silver perch—250 fish/ha; Murray cod—200 fish/ha (fish average 1 gram)
- In Texas (USA): 1.5"(38 mm) bass and 2" (50 mm) catfish—250 fish/ha (<830 ha storage); 125 fish/ha (830–4166 ha storage); 60 fish/ha (>4166 ha storage).

6.3 Size at stocking

In general, fish stocked as larvae or very small fingerlings have relatively low survival rates compared to fish stocked at a larger size. A major reason for this is that the smaller the fish, the more vulnerable it is to predation by larger fish and other aquatic animals. Very small fingerlings are also more likely to succumb to physical stress and starvation, so stocking groups can usually expect better returns by stocking bigger fish. However, the advantages of growing fish to a larger size before stocking may be offset by ongoing costs to the hatchery, and the increasing chances of 'hatchery-selection' occurring. Hatchery-selection is an undesirable consequence of raising fish in artificial ponds or tanks, whereby the artificial habitat favours the survival and growth of fish that may not be well suited to surviving in the wild.

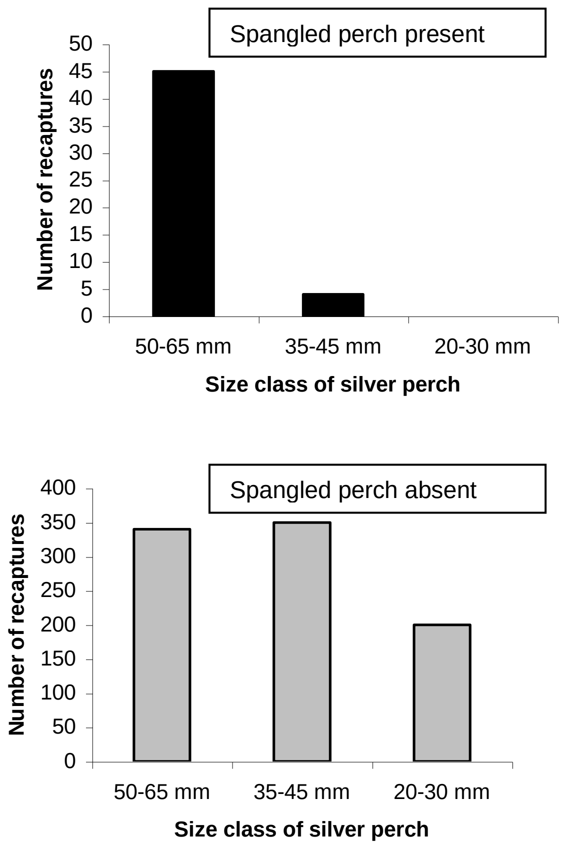
Research carried out in Queensland into the survival of golden perch, silver perch, Australian bass and barramundi stocked at different sizes supports the idea that bigger is better. In all four species, survival tended to be highest among fish stocked at a size of 50–65 mm compared to those stocked at lengths of less than 45 mm. There were, however, exceptions to this trend, where fish stocked at a smaller size appeared to survive as well as, or even better than, those stocked at a larger size. The researchers attributed these results to the presence of different combinations of predators present in the impoundments.

For example, it was found that where Australian bass were stocked in areas with established populations of barramundi or mouth almighty, only the largest size class of bass (50–65 mm) survived. However, if these predators were not present, bass stocked at 35–45 mm survived in comparable numbers to those stocked at 50–65 mm. Pre-existing populations of bass and spangled perch did not appear to have much effect on the survival of subsequent bass stockings.

Similarly, silver perch stocked in the presence of predators including barramundi, bass and spangled perch generally do not survive well. In these situations, the best results will be obtained by stocking 50+ mm silver perch, but even these are unlikely to do well where there is an established population of barramundi. When stocked in the absence of significant predator populations, 35–45 mm silver perch survived at least as well as 50–65 mm fish.

Generally, stocking of juvenile fish into impoundments containing established populations of barramundi yielded low returns. This was a consistent result across all size classes of Australian bass, golden perch and silver perch. Stocked barramundi fingerlings, particularly those 50 mm or larger, were less effected by pre-existing barramundi populations than the other species. Fork-tailed catfish and mouth almighty appear to be the main predators of barramundi fingerlings.

Survival of stocked silver perch



The above graphs present a comparison of silver perch survival between a dam with spangled perch present and a dam containing no spangled perch. With spangled perch present, silver perch stocked at 50 mm or greater survived far better than those stocked at less than 50 mm. In the absence of spangled perch, all of the size classes of silver perch survived relatively well. Note also that the overall survival of stocked silver perch was far greater when spangled perch were absent, as evidenced by the much higher number of recaptures in the second graph.

Keith Chilcott

Newly released barramundi fingerlings

6.4 Timing of stocking

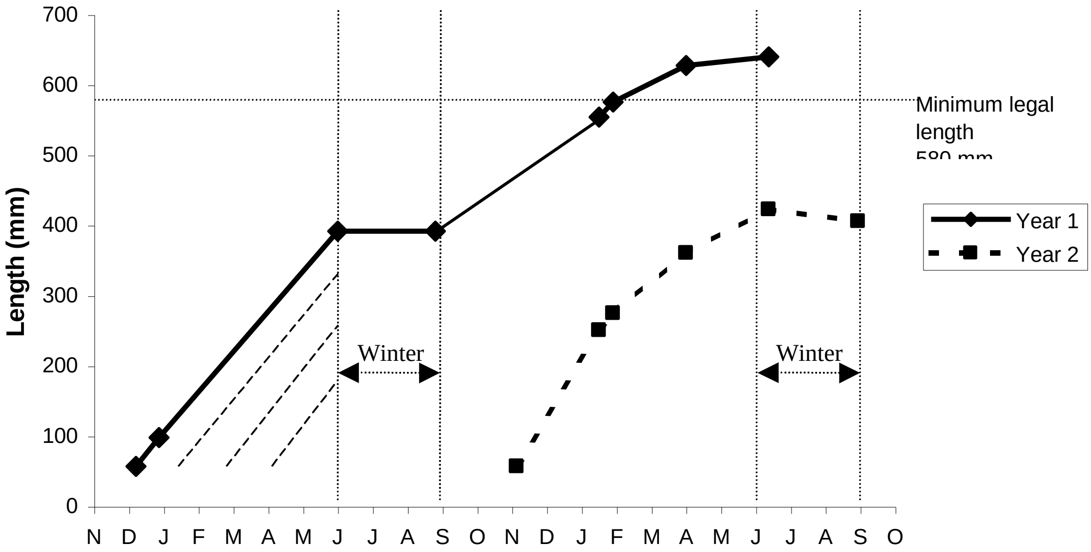
In the past, fish hatcheries have had little control over when fish spawned, and therefore when fingerlings were available for stocking. Broodstock in hatcheries generally followed the same patterns as fish in the wild, with the onset of spawning behaviour dictated by seasonal temperatures, day lengths and other natural phenomena. More recently, advances in biomanipulation of broodstock have led to much greater control over the breeding process, so that some species can now be produced year round.

Logic dictates that it is generally better to stock fingerlings as early in the spring/summer growing season as possible. This maximises the time available for growth before the onset of the next winter period. Fingerlings stocked late in the growing season will grow relatively little before cooler temperatures suppress the growth rate, leaving them at a size that is more vulnerable to predation over the winter period. For example, barramundi stocked by early November in productive impoundments may reach legal size (58 cm) by December of the following year. Fish stocked late in the growing season (e.g. March) may not reach legal size until April of the following year. An example of this has been observed in Awoonga Dam near Gladstone (Qld) where barramundi stocked at approximately 100 mm in April averaged little more than 100 mm by August.

Another example, this time from the United States, may also be relevant to Australian species and conditions. Rainbow trout have traditionally been stocked in spring to take advantage of zooplankton blooms. This system generally works well, except when populations of the predatory walleye are present. Walleye take a heavy toll on small rainbow trout, particularly in the warmer months when their feeding activity is at a peak. It was found that by stocking larger sized trout later in the season (i.e. autumn) when the feeding activity of walleye was declining, returns to trout anglers in subsequent seasons improved.

Similarly, in Australian impoundments, the presence of the predatory barramundi appears to have a marked negative effect on the stocking success of silver perch stocked in spring and summer. Feeding activity of barramundi decreases during the winter period, particularly in the cooler southern parts of the species range where silver perch are likely to be stocked (e.g. south of Gladstone). However, silver perch stocked in this area (which represents the northern end of their geographic range) are likely to continue to grow throughout winter, albeit at a reduced rate. It may, therefore, be prudent to stock larger-sized silver perch in autumn to coincide with decreasing activity levels of barramundi. Similar manipulations of the timing of stocking and size at release may have relevance for fish stocking throughout northern and eastern Australia, but research into this effect is required before it can be employed with any confidence in stocking programs.

Growth of stocked barramundi fingerlings



The above graph gives an example of growth rates of juvenile barramundi stocked into an impoundment near Bundaberg in Queensland. Fish stocked in December of Year 1 grew steadily until the onset of winter, whereupon further growth virtually ceased until spring. A similar pattern can be seen with the fish stocked in November of Year 2. The oblique dashed lines show hypothetical growth rates of barramundi stocked progressively later in Year 1—these suggest that fish stocked as late as April may remain at less than 200 mm throughout the winter period, and therefore remain highly susceptible to predation by fish and birds for a much longer period than fish stocked early in the season.

6.5 Suitable habitats for release

Stocked fish are at their most vulnerable to predation and other mortality in the hours and days immediately following their release. Survival can be improved by carefully selecting the type of habitat into which the fish are being released. Recent research in Queensland compared the long-term survival of fish released into shallow water, deep open water, and into artificial cover rafts anchored over deep water. The findings included:

- **Australian bass:** The best results were obtained by releasing bass into artificial cover rafts, although shallow water releases did nearly as well. Releases into deep open water yielded poor results and should be avoided for this species;
- **Barramundi:** There was little difference in survival of barramundi released into different habitats. The presence of cover may have conferred a marginal advantage, but shallow water releases appear to be sufficient in most cases. Results varied between impoundments and years and may have been more dependent on where predators were distributed at the time of release.
- **Golden perch:** Golden perch survived best when released into shallow water locations, although deep water releases performed nearly as well. Survival was much lower among fingerlings released into artificial cover.
- **Silver perch:** Survival of silver perch was similar irrespective of the release location or the presence of cover.

Shallow water or edge releases will suffice for all of the above species. Much of the variation that was found between years and impoundments is most likely due to the distribution patterns of predators within the impoundment at the time of stocking. It is therefore recommended to spread the risk by stocking large batches of fingerlings at as many suitable sites as practicable on the day of stocking. Splitting the consignment of fingerlings into three or four groups should suffice in most instances. Barramundi, silver perch and golden perch can be released into a combination of both deep and shallow areas. Bass should be released in a number of shallow areas. This spreads the risk and lessens the chance of dropping all the fingerlings onto a school of predators.

6.6 Pre-existing/Resident species

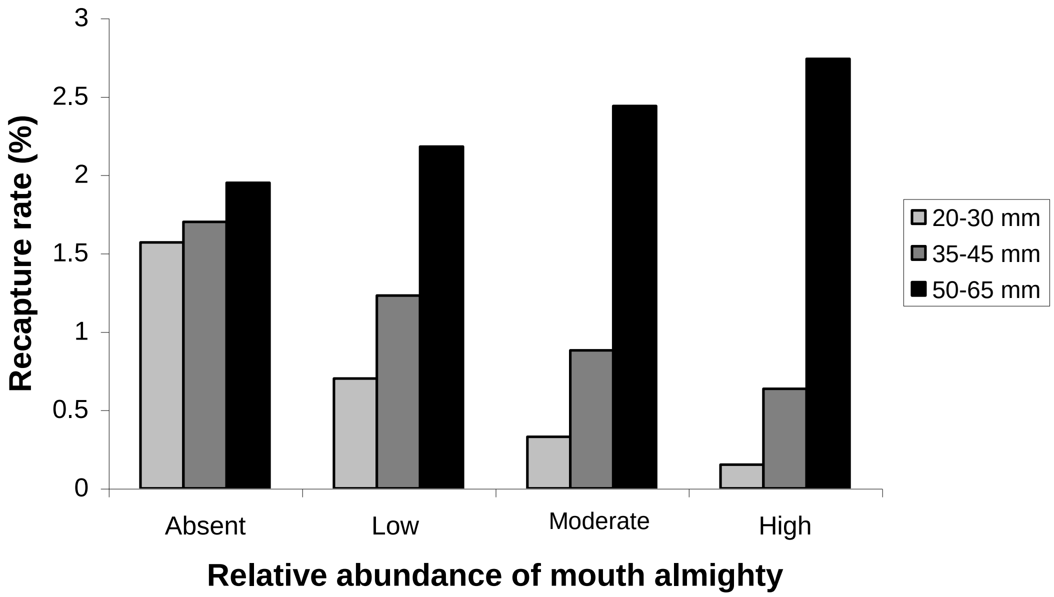
An important aspect to consider when planning to stock fish is the potential effect of pre-existing/resident species on fingerling survival. Predation by resident fishes such as mouth almighty, spangled perch or other previously stocked species is inevitable, and can drastically reduce fingerling survival. A list of resident predators, and some idea of their relative abundance, can be compiled from a combination of local knowledge and pre-stocking surveys using nets, traps and electrofishing.

A knowledge of the potential predators in an impoundment will help to determine the appropriate stocking density and release strategy for the fish to be stocked. For example, research in Queensland has found that stocking fish into dams where mouth almighty and/or forktailed catfish are present can yield very poor results. Survival of stocked fingerlings can be improved by releasing fish at greater than 50 mm but, even then, returns, particularly of golden and silver perch, may be very low. In New South Wales and Victoria it is likely that redfin perch may have a negative impact on stocked fingerlings, similar to that of mouth almighty or spangled perch. In dams with substantial populations of redfin perch it is probably best to stock fish larger than 50 mm.

It can be very difficult to establish populations of bass, golden perch or silver perch in dams dominated by barramundi. In these cases, fish-stocking groups may have to decide whether they want a barramundi fishery or a bass/perch fishery. If bass have been stocked several years before barramundi, large bass will persist, but subsequent stockings of bass are unlikely to succeed.

Stocking fingerlings in areas where predators occur in high densities, such as snags, drop-offs, rock bars and old creek or riverbeds, should be avoided if possible.

Predicted effects of mouth almighty on stocked barramundi.



This graph shows the predicted survival of barramundi fingerlings stocked at three sizes into a dam containing a population of mouth almighty. With mouth almighty absent, all three size-classes of barramundi survive reasonably well. As the abundance of mouth almighty increases, the smaller sizes of barramundi fingerling show progressively lower survival. The apparent increase in survival of 50–65 mm barramundi with increasing abundance of mouth almighty occurs because there is less competition from the two smaller size classes of barramundi—however, the overall number of barramundi across all size-classes decreases as mouth almighty become more abundant.

Gunther Schmida

Forktailed catfish and mouth almighty are voracious predators of stocked fingerlings in coastal Queensland impoundments

6.7 Low water levels
The survival of stocked fingerlings in impoundments is greatly reduced by low water levels. Predators become more concentrated and suitable habitat is restricted during periods of low storage capacity. All other factors being equal, survival of fingerlings tends to be best if they are stocked when water levels are high. Stocking is not recommended if a dam has been *rapidly* drawn down to less than 15% of its full supply volume, or less than 20% of its full supply surface area. If, however, a dam has been at a low storage level for an extended period (e.g. several years), a balance is likely to have been reached between the existing fish populations and the available food and habitat. In such a situation, stocking of fish at a density in proportion to the new storage surface area could proceed.

Glynn Aland

Low storage levels are not conducive to successful fish stocking

6.8 Cost-effective fish stocking
As previously indicated, survival rates of given sizes of fish are affected by a number of factors. The relative cost-effectiveness of stocking fingerlings at different sizes can be difficult to determine. To do so requires data on both the cost of the fish and the expected survival of the fish once stocked. Both of these factors can vary markedly, however, recent season's fingerling prices and data from research into fingerling survival in southern Queensland, will serve as a useful starting point. It should be kept in mind, however, that fingerling survival is dependent on many factors, and will vary between impoundments and seasons. Recommendations in this report are based on data from six impoundments studied between 1998 and 2002, and will not necessarily hold true under all circumstances. The data below has been adjusted for factors other than size. As a rule of thumb, the greater the density and diversity of predatory species in a dam, the less cost effective it becomes to stock smaller sizes (see 6.6).

In recent years, the going rate for barramundi and Australian bass has been one cent per millimetre average total body length (i.e. a 50 mm fish would cost 50 cents). Golden and silver perch, on the other hand, have been sold at a set price irrespective of size. The research upon which the following recommendations are based compared survival of three size-classes of fingerlings (20–30 mm, 35–45 mm and 50–65 mm) from four commonly stocked fish species (Australian bass, barramundi, golden perch and silver perch).

The tables presented below compare the relative survival ratio and relative cost ratio between size-classes for each stocked species. If the survival ratio is greater than the cost ratio, then the first of the two size-classes being compared is the most cost-effective to stock. For example, in the comparison between 50–65 mm Australian bass and 35–45 mm bass:

Survival ratio (S) = 1.16
Cost ratio (C) = 1.44
S<C, therefore it is more cost-effective to stock 35–45 mm bass.

The inverse relative survival ratio gives an indication of how cheap the less cost-effective size-class would have to be before it became more cost-effective to stock that size class. So for the above example:

Inverse survival ratio = 0.862,
Therefore, 35–45 mm bass would have to cost less than 86.2% of 50–65 mm bass before it would be more cost-effective to stock the smaller size.

Australian bass: In dams with mouth almighty or forktailed catfish present, stocking 50 mm bass or larger is recommended, regardless of price. Avoid stocking bass into dams dominated by barramundi as most won't survive.

Relative cost-effectiveness of stocking Australian bass at different sizes.

Size class comparison	Relative survival ratio	> or <	Cost ratio
50–65 mm: **35–45 mm**	1.16 (0.862)	<	1.44
50–65 mm: 20–30 mm	2.43 (0.411)	>	2.3
35–45 mm: 20–30 mm	2.10 (0.476)	>	1.6

Relative survival ratios of different size classes of Australian bass compared with relative cost ratios based on current hatchery prices. The most cost-effective size is in bold type for each paired comparison. An inverse relative survival ratio is shown in parentheses. Overall, 35–45 mm is the most cost-effective size to stock, and 20–30 mm the least cost-effective.

In other situations, 35–45 mm bass do almost as well as 50–65 mm fish. If 35–45 mm bass can be bought for less than 80% of the price of 50–65 mm bass, then stock the 35–45 mm fish. Avoid 20–30 mm bass unless they can be acquired at less than 40% of the price of 50–65 mm bass.

Barramundi: In most cases, it is most cost-effective to stock barramundi at 50 mm or larger. In dams with mouth almighty or forktailed catfish present, the cost-effectiveness of stocking these larger sized barramundi increases, as research has shown that few of the smaller sized fish will survive.

In dams with few predators, and where barramundi are not already abundant, 20–30 mm fingerlings can do almost as well as the larger sizes—they will quickly grow to a size where they are safe from most predators. This is the only situation where there might be a cost advantage in stocking the smaller sized barramundi.

Relative cost-effectiveness of stocking barramundi at different sizes

Size class comparison	Relative survival ratio	> or <	Cost ratio
50–65 mm: 35–45 mm	1.95 (0.514)	>	1.44
50–65 mm: 20–30 mm	2.38 (0.420)	>	2.3
35–45 mm: **20–30 mm**	1.22 (0.820)	<	1.6

Relative survival ratios of different size classes of barramundi compared with relative cost ratios based on current hatchery prices. The most cost-effective size is in bold type for each paired comparison. An inverse relative survival ratio is shown in parentheses. Overall, 50–65 mm is the most cost-effective size to stock, and 35–45 mm the least cost-effective.

Golden perch: Golden perch stockings often do not succeed in dams dominated by barramundi, regardless of the size of fingerlings stocked. There is also evidence that golden perch do better in the absence of bass. We recommend stocking only 50 mm or larger golden perch in dams with large populations of Australian bass or spangled perch. As long as the price of golden perch fingerlings remains fixed regardless of size, it will be most cost-effective to stock fish of 50 mm or larger.

Relative cost-effectiveness of stocking golden perch at different sizes

Size class comparison	Relative survival ratio	> or <	Cost ratio
50–65 mm: 35–45 mm	2.33 (0.430)	>	1
50–65 mm: 20–30 mm	8.11 (0.123)	>	1
35–45 mm: 20–30 mm	3.49 (0.287)	>	1

Relative survival ratios of different size classes of golden perch compared with relative cost ratios based on current hatchery prices. The most cost-effective size is in bold type for each paired comparison. An inverse relative survival ratio is shown in parentheses. Overall, 50–65 mm is the most cost-effective size to stock, and 20–30 mm the least cost-effective.

Silver perch: We recommend against stocking silver perch into dams dominated by barramundi, mouth almighty, banded grunter or forktailed catfish, as survival is often very low. In dams with Australian bass or spangled perch present, we recommend stocking 50 mm or larger silver perch. In other situations, 35–45 mm fish do as well as 50–65 mm fish, and are worth stocking if they are cheaper than the larger fingerlings.

Relative cost-effectiveness of stocking silver perch at different sizes

Size class comparison	Relative survival ratio	> or <	Cost ratio
50–65 mm: 35–45 mm	1.10 (0.911)	>	1
50–65 mm: 20–30 mm	1.96 (0.510)	>	1
35–45 mm: 20–30 mm	1.79 (0.560)	>	1

Adjusted mean relative survival ratios of different size classes of silver perch compared with relative cost ratios based on current hatchery prices. The most cost-effective size is in bold type for each paired comparison. An inverse relative survival ratio is shown in parentheses. Overall, 50–65 mm is the most cost-effective size to stock, and 20–30 mm the least cost-effective.

Alf Hogan

The end-result of a successful fish stocking program—a 40+kg barramundi from Lake Tinaroo in north Queensland*

* Exercise caution when holding large barramundi like the one pictured.. They are powerful fish and could inflict serious injury with their dorsal spines and opercular (gill cover) spines.

7. Frequently asked questions / do's and don'ts

Although fish stocking has been carried out in northern and eastern Australia for some years now, there are still many unknowns regarding the best methods and approaches required to provide optimum results for anglers and for the environment. This manual attempts to shed light on some of these unknowns, but given the highly variable conditions experienced in different regions and impoundments, and the complex interactions that occur between different combinations of fish species, there is a need to tailor stocking approaches to suit particular situations. Despite these difficulties, it is possible to provide some answers to the questions that are commonly asked by people and organisations involved in fish stocking.

Do I need a permit to stock fish?
A permit must be obtained from the relevant fisheries authority to stock fish into public waters in Victoria, New South Wales, Queensland and the Northern Territory. A permit is also required to stock private waters (e.g. farm dams) in Victoria and the Northern Territory—in the other states, private waters may be stocked without a permit, but there are restrictions on which species may be used. Further details can be obtained from the relevant fisheries authority (see Appendix I).

What is the best size to stock fingerlings?
Research in Queensland has identified that, overall, fingerlings survive best in impoundments when they are released at 50 mm or larger. This is particularly so when the impoundment being stocked contains established populations of predators such as barramundi, Australian bass and mouth almighty. In the absence of large populations of predators, stocking larger numbers of smaller silver perch, barramundi and Australian bass can be just as successful. (See section 6.3).

Where do I release the fingerlings?
The best place to release fingerlings in an impoundment varies between species. Overall, Australian bass appear to do best if released in shallow water, preferably with some cover; golden perch also do well if released in shallow water, while the presence of cover may slightly improve their survival; barramundi survive marginally better if released into cover, but water depth does not appear to be crucial; and silver perch appear to do equally well whether released into shallow or deep water, with or without cover. For all species, it is a good idea to scatter-release the batch of fingerlings in several large groups around the stocking site (see section 5.5), and to avoid releasing fingerlings where predators are likely to be most abundant (see section 6.5).

What sort of fish can I stock?
There are limitations to the species that can be stocked due to translocation policies and availability of fingerlings. In general, impoundments can be stocked with species that occur naturally in that area. For more details, contact the fisheries agency that has jurisdiction over the area to be stocked. (see section 6.1 and appendices).

When do I stock my fingerlings?
Fingerlings are best stocked as early in the spring/summer growing season as possible to maximise growth and minimise their vulnerability to predation over the subsequent

winter period. To limit fingerling stress, it is advisable to release fish during the cooler times of the day, i.e. early morning or late afternoon (see section 6.4).

How do I transport my fingerlings?
If fingerlings are to arrive at their stocking location in good condition, they must be transported under conditions that limit stress. That means ensuring they have an adequate oxygen supply, are not subject to temperature changes, and are not overcrowded. The hatchery that provides the fish or the local fisheries agency will be able to provide specific information to ensure a safe trip for the fingerlings. (see section 5).

How fast will my fingerlings grow?
Fingerling growth rates depend on many factors, including the amount of food available in the impoundment, the prevailing water temperature, the number of fish sharing available resources, the general environmental conditions of the impoundment, and of course, the species of fish that has been stocked. Growth rates can be maximised by tailoring the stocking based on all of these factors, and by ensuring that the fingerlings are transported carefully and released in an appropriate way and at a suitable location. Generally, bass are the slowest growing of the stocked species and may take up to three years to reach legal size in Queensland. Barramundi are the fastest growing of the stocked species and can reach legal size in a year if conditions are suitable. Golden and silver perch perch grow faster than bass, but slower than barramundi. (see section 6.1).

How many fish should I stock?
The appropriate stocking density for a given impoundment will depend on factors including the pre-existing stock density, the particular suite of species already present in the impoundment, food availability, and the size of the fish to be stocked. The hatchery that provides the fish or the local fisheries agency will assist in determining the appropriate number of fish to stock based on these factors and the size and depth of the impoundment. (see section 6.2).

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9. Glossary of Terms

Acclimatise	Adapt to new conditions.
Carrying capacity	The upper limit to how many fish and other living organisms a particular water body can support sustainably.
Endangered species	Species classified as being at high risk of extinction.
Endemic	Occurring naturally within a specific ecosystem or area.
Exotic fish	Fish which have been introduced (translocated) from another country.
Extrapolate	To infer what is not known from that which is known. (e.g. use data derived from a small number of tagged fish to make assumptions about the whole population or species).
Fecundity	The capacity for female fish (or other animals) to produce large numbers of offspring. A fish that produces thousands of eggs is said to be more fecund than one that produces only hundreds.
Fishway	A structure that allows fish to move up or downstream past an artificial barrier (i.e. dam or weir).
Genetic stock/strain	A population or group of populations of a species that differ in their genetic makeup from other populations of the same species. Different genetic stocks/strains are usually separated geographically (e.g. six management strains of barramundi exist in Queensland).
Hatchery selection	An undesirable consequence of raising fish in artificial ponds or tanks, whereby the artificial habitat favours the survival and growth of fish that may not be well suited to surviving in the wild.
Impoundment	A waterbody formed upstream of a dam or weir on a natural water course.
Pre-stocking survey	A survey of the number and variety of fish present in a waterway before stocking takes place. These surveys are undertaken to determine the number of predators present, and for comparison after fish have been stocked.
Post-stocking survey	A survey of the number and variety of fish present in a waterway after stocking has taken place. These surveys are commonly used to obtain information on the survival and growth of stocked fish.

Purge	To cleanse of waste products. Fish to be stocked are ‘purged’ by starving them for ~24 hours prior to transporting, so that any body wastes are expelled and thus cannot foul the transport water.
Riverine	Occurring in, or related to, a river (c.t. *lacustrine* = of or pertaining to a lake). Riverine fishes spend all or most of their life-cycle in a river.
Stock density	The number of fish present per unit area/volume of a waterway. (e.g. 1000 fish per hectare). This term can be applied to the density of fish present whether they have been stocked or occur naturally.
Stocking density	The number of fish being stocked per unit area/volume of a waterway.
Threatened species	Species considered at risk of becoming included in endangered species category.
Translocation	The introduction of a species outside its natural range.

10. References and further reading

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Appendix I

Contact details for fish stocking information current October 2002:

Queensland	Department of Primary Industries Phone 07-3404 6999 (if calling from interstate) 13 25 23 (if within Qld) www.dpi.qld.gov.au/fishweb/
New South Wales	NSW Fisheries Phone 02-9527 8576 www.fisheries.nsw.gov.au
Victoria	Natural Resources and Environment Phone 03-9412 5701 www.nre.vic.gov.au/fishing/
Northern Territory	Primary Industries and Fisheries Phone 08-8999 2372 www.nt.gov.au/dbird/

Appendix II

Example of a fish stocking record form (as used in Queensland)

STOCKING DETAILS FROM 2000/01 SEASON

(FROM 1 JULY 2000 TO 30 JUNE 2001)

In Table (1) below, please enter the stockings your group undertook this financial year. In the lower section of Table (2), please enter the stockings your group undertook with grant money provided by DPI (if applicable).

For your information, stockings by the Queensland Government are shown in Table (2) (if applicable).

STOCKING SITE: ....

Table (1) Your Management Group Stocking

DATE	SPECIES	NUMBER OF FINGERLINGS STOCKED	HATCHERY	COST PER FINGLERING	SIZE

Table (2) DPI Stockings

DATE	SPECIES	HATCHERY	NUMBER OF FINGERLINGS STOCKED
Stockings from Grant Money			

Appendix III

Example of a fish specimen advice sheet (as used in Queensland by hatcheries)

Finfish specimen advice sheet

FINFISH SPECIMEN ADVICE SHEET

Date:	
Name of sender:	
Postal address:	
Telephone:	( )
Facsimile:	( )
Purpose of submission: (Health test/translocation interstate/overseas sale/diseased/sick/health monitoring)	

DETAILS OF AFFECTED FISH SAMPLED

Pond/tank No.	Hatchery	No. fish sampled	Age	Length (mm)	Weight (g)	No. Deaths per day	Date of first signs of sickness

TOTAL NUMBER OF PONDS/TANKS AFFECTED ON FARM:

TOTAL NUMBER OF PONDS/TANKS SAMPLED & SENT TO LAB:

DETAILS OF SAMPLED PONDS/TANKS

Please fill out the table below for each pond/tank from which fish were sampled for the laboratory.

POND/TANK NUMBER			
Species:			
Origin:			
Date of Stocking:			
Date of onset of sickness:			
Number mortalities/day:			
List any previous disease problems in this pond			
List any previous treatments for this pond			