Methodology to survey and monitor New Zealand mudfish species

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Abstract

Standard methods to survey and monitor NZ mudfish species involve Gee minnow traps for adults and hand nets for earlier life stages, although a range of methods have been used. A basic assessment of fish abundance can be gained from one night of trapping, however, estimates of fish density and sub-population size require repeated identical sampling events. In developing a study the objective needs to be well considered in order that the information collected addresses the particular research question. Study design and sampling effort are usually individualised to the type of habitat being sampled and resources available. Catching fish and measuring their length and weight is straightforward and uses relatively simple equipment. More detailed examination and marking of fish may be required in some studies. From information collected in the field a range of further calculations and analyses are usually done to assess the state of health of the sub-population. Capture data should be submitted to the NZ Freshwater Fish Database and habitat assessed using the Handbook for Monitoring Wetland Condition. The Department of Conservation Mudfish Recovery Group plans to regularly collate survey and monitoring information.

Key words: Galaxiidae, *Neochanna,* mudfish, monitoring, survey, methodology, management.

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1 Introduction

New Zealand's five mudfish (*Neochanna* spp.) are cryptic, primarily nocturnal fish that tend to live in wetland habitats, and hence are rarely encountered in the course of general fish surveys of lakes and flowing waters. Considered difficult to capture (Eldon 1992), a range of techniques have been used in New Zealand over the last few decades in an attempt to survey and, in some instances monitor, mudfish populations. Most of this work has been undertaken on Canterbury mudfish (*Neochanna burrowsius*), brown mudfish (*Neochanna apoda*) and black mudfish *(Neochanna diversus*). Recent survey work has also been undertaken on the newly described Northland mudfish (*Neochanna heleios*) and the Chatham Island mudfish (*Neochanna rekohua*).

Although there are standard capture methods for other New Zealand non-migratory galaxiids (Allibone 2000), the survey and monitoring of mudfish species poses its own unique challenges. Wetlands can be difficult to move through and sample adequately, with dense vegetation, varying water depth and a variety of flowing and still water areas. Many habitats also dry up completely or partially, which restricts the timing of surveys and monitoring. Currently, survey and monitoring work for mudfish is undertaken in the absence of a recommended methodology specifically for mudfish. However, the need to develop a monitoring and survey methodology for mudfish is acknowledged (Rowe 1993). This need was included as an action in the Department of Conservation (DOC) mudfish recovery plan (Department of Conservation 2003, action 2.1).

There are a range of objectives that may guide plans to survey and monitor populations. In the context of these guidelines, surveying involves fishing at sites that are already known to contain mudfish or prospecting at new sites in an attempt to expand the known distribution of each species. Monitoring involves a more detailed habitat and mudfish sub-population assessment at known mudfish sites and may involve measuring attributes such as sub-population size and density, annual recruitment, fish condition and sub-population sex/size structure, and trends in each sub-population over time in response to impacts from local changes in hydrology, habitat and adjacent land use. Surveying for new mudfish sub-populations and monitoring trends in key mudfish sub-populations are important actions in the mudfish recovery plan (Department of Conservation 2003, actions 2.2 and 3.1 respectively). Surveying can be considered a first step towards long-term monitoring of a sub-population and many of the same techniques apply to both. Surveying potential habitat for new mudfish sub-populations is aimed at extending the known species distributions, particularly for the rarer species where few sub-populations are known. Surveying is also used to assess mudfish in different habitats or areas throughout a habitat. Resurveying sites previously known to contain mudfish is necessary to understand changes in the extent of mudfish distribution and abundance. Survey methods usually involve sampling a greater number of sites with less effort, compared to that of any subsequent monitoring. The aim of monitoring key mudfish sub-populations is to determine their persistence and assess changes in abundance or condition that may occur through time. Regular monitoring can also highlight changes in habitat associated with climatic or hydrological changes, nutrient enrichment, and / or the invasion of exotic plants and animals that may be detrimental to mudfish. The Department of Conservation aims to review the status of all threatened species every 3 years (Townsend et al. 2008), and survey and monitoring information is crucial to help inform this process by evaluating changes in the distribution and condition of mudfish populations.

The authors anticipate that this report will be useful to a range of people including: DOC staff, community groups, iwi, and researchers. There is still much to learn about mudfish, including the testing and fine-tuning of the methods described in this report.

2 Background

2.1 Known mudfish species and their habitats

The following is a brief introduction to each of the mudfish species of New Zealand, and the habitats where they are found. It is not intended to be a comprehensive guide to their biology. For further information on the biology of each species refer to McDowall 1990, 2000, Ling 2001, O'Brien & Dunn 2007.

2.1.1 Northland mudfish (*Neochanna heleios*)

The Northland mudfish is also sometimes referred to as the burgundy mudfish or the spotted mudfish. It is limited to a few wetlands in central Northland from west of Kaikohe to the Kerikeri coast. Almost all known habitats are ephemeral acidic peaty wetlands, but some remnant sub-populations remain in wetlands that have suffered some eutrophication due to the development of adjacent land.

2.1.2 Black mudfish (*Neochanna diversus*)

The black mudfish occurs throughout the northern half of the North Island, from southern Waikato to the Aupouri Peninsula in the Far North. It is almost exclusively found in acidic peaty wetlands dominated by sedges such as *Baumea* spp. The largest sub-populations are found in the Whangamarino and Kopouatai wetlands in the Waikato, and in the large wetlands north of Kaitaia (Kaimaumau and Waiparera), but many smaller sub-populations exist in remnants of once extensive wetlands throughout its range. It is also occasionally found in forest floor pools and swampy streams and drains.

2.1.3 Brown mudfish (*Neochanna apoda*)

The brown mudfish is the most widely distributed species and occurs throughout the southern North Island lowlands of Taranaki, Manawatu, and Wairarapa, as well as on the west coast of the South Island from south of Whanganui Inlet to Okarito. It may be found in a wide range of habitats, from small streams to muddy raupo wetlands, acidic peat bogs and shallow forest pools.

2.1.4 Canterbury mudfish (*Neochanna burrowsius*)

The Canterbury mudfish is confined to the Canterbury Plains from the Waitaki River in the south to north of the Ashley River. Most of its original habitat has been drained and vegetation removed, and what remains has been extensively modified. The majority habitats receive groundwater as springs sourced from hillsides, nearby rivers or deeper aquifer systems. It is more likely to occur in slowly flowing waters than other mudfish species and also persists in farm ponds and channalised streams, drains, and races.

2.1.5 Chatham Islands mudfish (*Neochanna rekohua*)

This species is known from three lakes on the Chatham Islands (McDowall 2004). Little is known about the biology of the species except that it seems to occur only in lakes rather than associated wetlands.

2.2 Life stages of mudfish

New Zealand's mudfish species have four distinct life history stages—eggs, larvae, juvenile and adult. The last three stages are those likely to be encountered during surveys. Breeding periods can only be approximated, as they depend on environmental cues such as water levels and temperature. Spawning in brown and black mudfish generally occurs from late autumn to late winter, usually when water returns to summer-dry habitat, whereas spawning occurs during late winter and spring for the Canterbury mudfish. Eggs are 2-3 mm in diameter, transparent, adhesive and are scattered on aquatic vegetation, usually near the water surface for most species. Larvae (Figure 1) hatch from the eggs 2–4 weeks after spawning and undergo metamorphosis, which is usually compete once they reach c. 20 mm. Larvae and small juveniles are active during the day and are commonly called fry. After hatching at around 5–9 mm total length[1] (T.L.) fry tend to occupy open-water habitats and can be

[1] Total length is the length from the tip of the snout to the tip of the tail.

readily observed. By the time they reach c. 30 mm T.L. they tend become nocturnal and display the cryptic behaviour of adults. This change in behaviour, called an ontogenic shift, has implications for sampling, with different methods needed for different life stages. Juveniles usually become sexually mature in their first or sometimes second year. Growth is initially quite rapid with most species reaching maturity at around 70–100 mm T.L. within 12 months (McDowall 1990). Whilst growth rates vary both inter and intra-specifically, mudfish can be arbitrarily classified into: fry (5–30 mm T.L.), juveniles (30–50 mm T.L.), and adults (> 50 mm T.L)[2].

3 Defining Mudfish Management Units

3.1 A hierarchical classification of management units

To co-ordinate the recovery of New Zealand mudfish species it is important that management units be defined at a range of scales. These definitions will help determine an appropriate level of distinctiveness to monitor and manage mudfish species, eg., populations, sub-populations, or evolutionarily significant units (ESU's). They will also provide a logical framework under which to collect and store data in a logical and consistent manner.

Considerations

When developing a system of management units there are a number of considerations that need to be kept in mind.

1. They must be compatible with Department of Conservation classifications to contribute to projects such as the Species Optimisation Project and triennial reclassifications of the threat status of native fish.
2. They must retain some flexibility at the lower levels where survey and monitoring occurs. There is huge variation in the types of places where

[2] Barrier & Hicks 1994 set the length for adults as > 70mm T.L., but 50–7-mm-long sexually-mature fish have been found. For the purpose of this standardisation, it is recommended that fish > 50mm T.L. are classified as adults.

mudfish are found. If definitions are too prescriptive then inevitably many survey sites will not fit within the system.

3. They should be intuitive. Mudfish work is not always undertaken by DOC staff or scientists so should be easy for non-technical people to grasp. The names used to describe units are particularly important in this respect.

POPULATION

It makes sense to adopt the DOC definition from the New Zealand Threat Classification manual (Townsend et al. 2007);

“Total number of individuals that are resident or that breed in New Zealand. For functional reasons, primarily owing to differences between life-forms, population numbers are expressed as numbers of mature individuals only.”

EVOLUTIONARILY SIGNIFICANT UNIT

There are several definitions around and DOC hasn’t adopted one of its own but we suggest sticking to this broad definition adapted from Allendorf & Luikart (2007) for now;

“A SUB-POPULATION or group of SUB-POPULATIONs that merit separate management because of high distinctiveness (both genetic & ecological)”

SUB-POPULATION

Again we suggest adopting the DOC definition from the New Zealand Threat Classification manual;

“Groups of individuals that have resulted from past or ongoing fragmentation (natural or human induced) between which there is now little genetic exchange. Sub-populations must have a demonstrable reproductive capability. Re-introduced wild populations must be self-sustaining before they are included as a sub-population. Populations held in captive institutions or grown in nurseries or gardens are not considered to be within the definition of sub-populations, unless they are the only remaining individuals of the taxon"

In most instances for non-migratory mudfish the maximum size for a SUB-POPULATION would be delineated by catchments that end at the sea. There is unlikely to be much gene flow going on between these catchments under current conditions. For example, black mudfish in the Mokau and Waikato River catchments are in the same ESU but there is very little likelihood of any gene flow between them. However, barriers (natural and man-made) may in many instances split up catchments into one or more SUB-POPULATIONs.

WETLAND

The following definition from the Resource Management Act is as good as any:

"… includes permanently or intermittently wet areas, shallow water and land water margins that support a natural ecosystem of plants and animals that are adapted to wet conditions"

For our purposes a WETLAND will be made up of one or more connected HABITAT's and so would include anything from a seep to a large wetland complex. There will be some unavoidable subjectivity around how "connected" habitats must be to become a single WETLAND. It is best to think in terms of connections that allow movement by mudfish for significant periods of the year.

This would be the unit used to spatially define "Key Sites" because this is the scale at which management is most likely to be co-ordinated.

HABITAT

These would be areas of a wetland with similar hydrology and vegetation type. For instance, a very large wetland such as the Whangamarino wetland will include several types of habitat such as oligotrophic peat bog, ponds of open water, mineralised margins of rivers dominated by willow canopy, etc. HABITAT's would be roughly analogous to the structural class level used in the

NZ wetland classification (Johnson & Gerbeaux 2004).

HABITATs don't fit precisely within the hierarchical system because LOCATIONS & SURVEY SITES may potentially straddle several HABITATs. Ideally, however, they shouldn't, particularly for annual monitoring programmes because sampling across different HABITATS will increase sample variability. HABITAT is best considered as a unit to use when evaluating where mudfish are found or to be managed in a wetland and to put SITES and LOCATIONS into context.

LOCATION

This is the trickiest and most subjective unit to come to terms with.

A LOCATION is basically a small area of a wetland which is surveyed using one or more SURVEY SITES.

We need this unit for those larger WETLANDS where SURVEY SITES are nested together. As mentioned above, LOCATIONS should ideally be contained within one HABITAT but it may sometimes be necessary to set sites across a number of different HABITATs, for example, when undertaking exploratory surveys.

Small wetlands are likely to only have one LOCATION and for the purposes of data recording the WETLAND and LOCATION would have the same name.

SURVEY SITE

This is an area within a LOCATION where a transect or nest of traps are set during mudfish surveys. A LOCATION may contain several SURVEY SITEs.

4 Survey and monitoring objectives

The first step towards long-term species management and conservation involves answering questions like:

Where is a species present?

How abundant is that species?

What factors threaten the long-term viability of individual sub-populations and the species as a whole?

FIGURE 1. BLACK MUDFISH (*NEOCHANNA DIVERSUS*) LARVAE, APPROXIMATELY 5 MM LONG AND A FEW HOURS OLD.

Various levels of complexity and effort can be applied to mudfish survey and monitoring programmes. The amount of effort expended will depend on what the objectives are (i.e. what level of sophistication in the data is required). For example, setting a few traps will provide presence / absence data and some idea of relative abundance; but to estimate sub-population size and to provide accurate measures of relative catch, then a much greater level of effort is required. Without measuring and weighing the fish, it will not be possible to determine sub-population size structure or fish condition. However, weighing and measuring fish is a much more complex and time-consuming operation than just counting them and requires a greater level of expertise and more equipment. The objectives of the study will determine the complexity of sampling required and the following examples illustrate this.

4.1 Are there unknown habitat remnants with mudfish?

Given their cryptic habits, juvenile and adult mudfish can sometimes be quite difficult to locate. Despite the extensive effort and success in locating new sub-populations of mudfish over the last decade it is likely that many other remnant areas of habitat are yet to be discovered. Sampling for fry is a quick and easy way of sampling a large number of locations with minimal effort if conducted during the right time of year. There are also often more fry than adults present and hence small sub-populations may be easier to detect. Otherwise, placing a few traps at a wide range of possible locations may indicate where they are present in reasonable numbers. However, to confidently establish the presence or absence of mudfish, potential mudfish habitat should be surveyed using a reasonable number of traps and could even involve several visits at different times of the year.

Remember: absence of mudfish evidence is not evidence of mudfish absence!

4.2 Are mudfish still present at a particular location?

Repeated surveying of known mudfish sites is carried out to determine whether sites still contain mudfish and if the overall range is expanding or contracting. Information needed for this level of monitoring is presence / absence data obtained by surveying known sites (by sampling for adults or fry) at least once every 5 years. Sometimes repeat sampling fails to catch any fish. In some locations mudfish abundance appears to fluctuate widely and some areas of habitat may only be occupied in wet years. Survey work may need to be carried out yearly or over a wider area to assess if local extinction has occurred or the distribution has contracted. Several trapping occasions and a fry survey may be required. Surveys should occur more frequently for those species or sub-populations most at risk (possibly annually) whereas more secure sub-populations may be surveyed less frequently (every 5 years).

4.3 What is the distributional extent of habitat used?

Often mudfish are trapped in a location within a habitat that was easily accessible during survey work. It is then a question of "how widely distributed are the mudfish" within upstream, downstream, and other areas of surrounding habitat. It will also be important to identify the extent of habitat used by all life stages as early life stages require subtly different habitat and food resources. The distribution of fry is usually greater than that of adults and a large area of habitat may be required when fry are abundant. Fry are also easily washed downstream into marginal habitat by flows and floods. Widespread trapping for observations of adults and fry would answer these questions and presence or absence data collection would be sufficient. However, if extensive sampling is required then great care should be taken to avoid excessive habitat damage caused by trampling vegetation to gain access to sampling sites or to set traps, especially in peat bogs where tracks may provide access routes for exotic fish and weeds and may take years for the vegetation to recover.

4.4 Are individuals in good condition?

If a habitat appears degraded or modified, any mudfish present may need to be assessed to see if they are below an expected weight or have a high incidence of infection. This would require fish to be measured and weighed using specialised rulers and scales. A close examination is also generally required to assess parasite load or infection. This study would require fish to be sedated with an anaesthetic during handling.

4.5 Is the sub-population reproducing?

A habitat may be very small with only a few fish captured and there may be doubts over whether it is a reproducing sub-population. Or, more likely, sub-population size structure information may indicate that few young adult fish are present or there may be missing size cohorts. In both cases it may be important to determine whether males and females are present. Also are eggs being spawned, are larvae hatching, and do they survive to recruit into adulthood. How variable is recruitment from year to year and why? A study into reproduction could involve multiple in-depth sampling of all life stages throughout the breeding season, or may be inferred from routine monitoring information. If a sub-population does not appear to have reproduced for several years it will be important to determine why and which life stage is most vulnerable. There may be a genuine reason for a failure of recruitment or it may just be that there is a high density of large healthy adult fish that restrict recruitment by cannibalism of juveniles or competition for food.

4.6 How significant is a particular habitat?

It may be that the significance of a particular habitat is of interest. This often happens when a habitat is threatened with destruction but also when selecting areas that are important to protect, possibly because they are a source of recruits for other areas. This question can be answered by trapping a variety of locations within a habitat or the general locality and comparing the number and length of mudfish caught. Information from a particular location can be compared with past records by analysis of the New Zealand Freshwater Fish Database (NZFFD) administered by the National Institute of Water and Atmospheric Research (NIWA). The minimum information required for such a comparison is the length of the largest fish and the average number of fish caught using multiple traps. However, complete size structure information, fish condition, presence of other fish species, and an understanding of relevant habitat characteristics and hydrology, may also be important in assessing habitat significance. Further, widespread fry sampling could be appropriate to determine areas used for spawning or with high fry abundance and food resources.

4.7 Are restoration and management initiatives working?

In many cases, and because mudfish occur in lowland agricultural areas, some form of habitat or hydrological management may be desirable. This could be intended as an enhancement or restoration activity, but it may also be incidental or intended as mitigation. New habitat may also be created and mudfish translocated from other areas. Accompanying any interventional activity, baseline survey work needs to be comprehensive and a monitoring program designed to adequately answer any management questions and gauge long term trends.

Surveying may be designed to compare mudfish in restored areas with untouched control areas, or assess before and after habitat changes. The distributional extent, size structure, condition and health of mudfish may also be determined from a monitoring programme. Monitoring may range from simple fry observations to ensure that mudfish reproduce each year and that a particular drought or land management action has not lead to local extinction, or examine a wide range of attributes of the habitat and mudfish present. In some cases, regularly calculating sub-population size and growth rates using mark-recapture methods may be appropriate.

4.8 How secure is a particular habitat long term?

Annual monitoring of individual mudfish sites will provide data on how 'secure' a sub-population is:

Is abundance remaining stable, increasing or decreasing?

Are threat pressures such as changes in surrounding land use, changes in hydrology, introduction of pest fish, etc., increasing?

Obtaining this information requires not only measurements of the mudfish sub-population, but also measurements and observations of changes in the habitat. A complete annual site monitoring programme would need to obtain data on:

- Habitat changes
- Changes in mudfish sub-population structure (i.e. using fish length data).
- Changes in mudfish health (condition factor and health inspection).
- Changes in mudfish abundance (from trapping and counting).

4.9 What is the threat status of every mudfish species in New Zealand?

The objective of the DOCs national mudfish monitoring programme is to evaluate the threat status of each mudfish species. The threat status of threatened species is re-evaluated every three years. It is based on the following information:

- An estimate of the total population size
- An estimate of the total area occupied by each species
- The number and size of sub-populations (geographically distinct groups in the population)
- The number of mature individuals in the largest known sub-population
- Trends in the total population
- Predicted decline in the total population in the next 10 years.
- The cause of any change in total population, area occupied or number of sub-populations.
- Age structure of the population.

Some of the information gathered in regular monitoring of individual mudfish sites will be able to contribute to the re-evaluation of threat status (such as trends in abundance), whereas there are other aspects (such as the population size, amount of habitat) that will require separate information gathering. A key piece of information to gather will be the spatial extent of mudfish habitat.

5 Overview of sampling methods

A variety of methods have been used to capture mudfish. The applicability of a particular method requires several considerations including capture efficiency, effort, operator safety and degree of habitat disturbance. Additionally, there are logistical limits to the extent of habitat that can be surveyed. Trapping methods are often constrained by the amount of sampling gear available, whereas, electrofishing and dip netting are usually limited to wadeable waters. Below are some of the more commonly used methods. However, on the basis of experience certain methods are most effective, these being dip nets for surveying fry and Gee-minnow traps for juveniles and adults.

FIGURE 2 FISHING FOR MUDFISH FRY IN A WETLAND MARGIN. A KITCHEN SIEVE SCREWED OR TAPED TO THE END OF A LENGTH OF DOWEL IS PUSHED RAPIDLY THROUGH THE WATER IN 0.5-1M-LONG SCOOPS. FRY, INVERTEBRATES AND OTHER DEBRIS ARE KNOCKED INTO THE BUCKET WHERE THEY CAN BE SORTED.

5.1 Dip- or hand-netting

Hand-held nets have been used to capture mudfish. Andrews (1991) found dip-netting for adult Tasmanian mudfish, while disturbing the sediment, to be more successful than baited wire cages. Push nets quickly passed through surface vegetation has also been effective for Canterbury mudfish (A. Meredith Environment Canterbury, personal communication). However, such methods can be very energetically demanding.

Dip netting is a quick and easy technique enabling rapid sampling of large areas of wetland, swampy streams or drains for the presence of mudfish fry and also *Gambusia*. Fry are readily captured with a fine-meshed (1 mm) scoop net because of their free-swimming open-water behaviour.

5.2 Electric fishing

This technique has variable success, depending upon the fish species and habitat type being sampled. Although most often used for capturing Canterbury mudfish it has also been used to capture brown mudfish. In typically muddy wetland habitat, the technique may give poor results, as mudfish appear to be able to protect themselves from the electrical current by hiding within mud and vegetation and stunned fish may not be observed in turbid water (Eldon 1992). However, electrofishing caught a greater proportion of Canterbury mudfish than trapping in habitats that also contained eels (O'Brien 2005).

Eldon (1992) found electric fishing in combination with spotlighting at night to be more effective than electric fishing alone during the day, and some habitats may be quite amenable to night-time spotlight surveying.

5.3 Fyke nets

Fine-mesh fyke nets may also be suitable for trapping mudfish in locations where greater water depth may make minnow traps less efficient and, possibly, for the lake / pond habitat of the Chatham Island mudfish.

5.4 Gee-minnow traps

Gee-minnow trapping (mesh size: 3 mm or 1/8 inch) is the most universally reliable technique for capturing juvenile and adult mudfish of all species (Figure 3). Steel mesh minnow traps with a 3-mm mesh size can be imported into New Zealand (see Appendix 1).

FIGURE 3 FINE-MESH (3 MM) STEEL GEE-MINNOW TRAP.

Mesh size influences the effectiveness of Gee-minnow traps in capturing mudfish (Dean 1995; Francis 2000; O'Brien 2005). In a comparison of effectiveness, 6 mm (1/4 inch) mesh traps were less likely to catch mudfish and caught significantly fewer than traps with smaller mesh (O'Brien 2005). Use of 3-mm-mesh size is recommended over 6 mm (1/4 inch) mesh, as small juveniles often escape through this larger mesh size and larger juveniles can become caught by the gills in escape attempts.

6 Mudfish sampling

6.1 Sampling mudfish fry

6.1.1 Species causing confusion

Although the larvae of non-migratory galaxiids appear very similar it is only in the case of surveying for Canterbury mudfish that the fry of other non-migratory species are likely to be encountered. Identification of Canterbury mudfish fry is possible, especially once metamorphosis has occurred, as the tail of Canterbury mudfish fry is not forked like that of other Galaxiids. If there is uncertainty regarding the species present, adult sampling and identification is required. The fry of brown, black and Northland mudfish are easily distinguished from those of other galaxiids because they lack pelvic fins.

6.1.2 When and where to sample for fry

Free-swimming mudfish fry (5–30 mm T.L.) can be locally abundant in waterways adjacent to adult habitat at certain times of the year, particularly from mid- to late-winter and as late as summer for Canterbury mudfish. Fry can be located in a variety of places; backwaters and pools, on the fringe of more permanent waterways, some distance from adult habitat, drift feeding in areas of gentle flow, and the inundated margins of wetlands. There appears to be subtle differences in the areas fry are found between species, with fry usually found among vegetation for black mudfish, but out in open water for Canterbury mudfish

To determine the presence of fry, multiple surveys may be required throughout the breeding season. Since the timing of spawning may be closely linked to wetland water levels, which can vary depending on rainfall or a number of other environmental factors, fry may be most abundant at different times from year to year.

6.1.3 How to sample fry

Sampling for fry is a quick and easy way to assess presence or absence of mudfish and it is not constrained by a limited number of expensive traps.

If water clarity allows, simply ‘spotting’ fry without catching them can be an adequate method of assessing abundance. Through observation, coded abundance estimates can be made from quick visual counts within a small area. Coded abundance ranks are usually ‘sparse’ for a count of 1 to 5, ‘common’ (5 to 20), ‘abundant’ (20 to 100) and ‘very adundant’ (>100). This method is valuable when juveniles are larger and difficult to catch.

If visibility is poor then pushing a dip net quickly through areas of likely habitat will usually capture mudfish fry if they are present. Have a white plastic tray or bucket on hand, into which to knock or wash the contents of the dip net. Debris and other material can then be separated from the fry. The fry are extremely delicate and should not be handled. If a constant amount of effort is used and a standard area is sampled, this would provide a simple relative measure of fry abundance. However, the reliability of quantitative sampling for fry is uncertain because it is difficult to keep effort constant. This is compounded by the patchiness of the habitat and the distribution of fry within microhabitats. A further consideration is that fry and juvenile numbers may not reflect adult population and in many cases abundances of fry and adults are negatively associated.

6.2 Sampling juvenile and adult mudfish

Minnow trapping is the preferred technique for both juveniles and adults and can be used both **qualitatively** to assess the presence / absence of mudfish, and **quantitatively** to assess relative abundance and population demographics of different sub-populations.

6.2.1 When and where to sample

Assessment of areas for potential mudfish habitat is largely dependent on prior knowledge of specific mudfish habitat requirements. However, mudfish can be found in, and some may persist in, some unlikely places. These include streams, roadside drains and culvert pools, quite dry areas and modified habitat. From the onset of heavy winter rains through till late spring is usually the only period suitable for sampling mudfish juveniles and adults using minnow traps. Sampling is impossible during the summer months when many habitats become dry. Late winter (early September through to mid-November) is the optimal period for the autumn-spawning species because young of the year fish are more likely to be encountered and this will give a relative estimate of annual recruitment. In the case of Canterbury mudfish, sampling should be conducted in autumn as this provides information on survival over summer and avoids sampling during the spawning period in spring.

6.2.2 How to set traps

Minnow traps should always be set only partially submerged (Figure 4) to ensure that any captured mudfish have access to an airspace within the trap. Mudfish wetland habitat is often oxygen depleted and the fish need to gulp air at the surface to augment their oxygen supplies. In anoxic water conditions, fish can drown in fully submerged traps.

Figure 4 Traps are set for mudfish with the entrance cones just below the water surface.

Partially submerging the traps also maximises the capture of mudfish feeding nocturnally at the water surface. Fish are more likely to be directed into the entrance cones of the trap if the widest diameter of the cone is just below the water surface. In shallow water, traps can usually rest on the substrate, but in deep water they must be suspended from overhanging vegetation or a stake driven into the ground. Mudfish can occupy extremely shallow wetland habitat, so scraping a depression in the substrate (using a boot or spade) in which to set the trap may be necessary for the trap entrance to be submerged.

Traps should be set overnight and collected the following day. They should not be left for longer than 24 h because fish can damage their skin and fins by continuously trying to escape from the trap and because predators such as eels or *Gambusia* may also have been trapped.

6.2.3 Limitations and influences on trap efficiency

It is important to recognise that trap do not give an absolute measure of fish abundance, nor is the area they have sampled from clearly quantified. Traps only catch a proportion of the fish present and their efficiency varies with factors such as the depth of water, the depth of the trap, and trap position relative to local features such as clumps of vegetation, logs, etc. Topography and trap-setting techniques are important influences on trap-capture rates. Techniques like using bait and covering traps with mud and foliage may increase catch rate for some species (D. Caskey, pers. comm.) although most mudfish trapping does not require baiting traps. When surveying for presence / absence of mudfish, the likelihood of capture can be maximised by using local features, such as logs, sedge bushes or raised mounds, to guide mudfish into the trap's entrance-ways. However, when undertaking quantitative sampling, it is important to try to set traps randomly to reduce between-site bias caused by placing traps next to small topographical features likely to aid capture.

There are many factors that have been suggested or shown to bias trapping by increasing or decreasing the proportion of fish caught. These sources of bias are usually assumed to be constant over the sampling area or period, but need to be considered when comparing the number of mudfish caught. It is important, but sometimes futile, to control for as many sources of bias and variation as possible. Failing that, factors likely to influence catch efficiency should be identified. These may include the overnight weather for the area. Barrier et al (1996) commented that more mudfish were caught on rainy nights. The presence of eels also appears to reduce the capture of mudfish in Gee-minnow traps (O'Brien 2005). It is therefore important to ascertain whether eels are also present when using Gee-minnow traps. Other biotic interactions, including the availability of prey species, may likewise influence the proportion of fish caught.

Habitat characteristics are important. For instance, the efficiency of minnow trapping will vary considerably depending on the habitat sampled. If the habitat is dominated by wetland sedges, and free water is limited to small shallow pools and furrows, then minnow traps set in these wet areas may catch many of the fish present. In contrast, the catch rate appears to decrease greatly when traps are used in areas of very thick vegetation or extensive open water and where the water is deep.

A common approach is to use unbaited traps or to bait them with yeast extract (e.g. Marmite). The ability of bait to increase trapping rates in still-water environments has not yet been formally investigated. However, captive trials of marmite baited vs. unbaited traps have shown no difference in capture rates (L. O'Brien, unpubl. data). Fish appear to be captured in minnow traps during the course of night-time foraging, rather than through attraction to bait, unless water flow exists within the habitat being sampled. This seems to suggest that mudfish either enter traps 'accidentally' during night-time foraging or 'colonise' the traps in response to the disturbance associated with them being set.

It is unlikely that the presence of mudfish in a trap would deter more mudfish from entering the trap although, obviously, there is an upper limit to the number of fish that can fit in a trap. Some high catch rates recorded include 64 black mudfish/trap on one occasion in a drain in the Waikato (N. Ling, unpubl. data) and 41 Northland mudfish/trap on one occasion in an Omapere wetland where all the fish were concentrated into residual pools (McGlynn, unpubl. data).

6.2.4 Trap security

A final but very important consideration in the use of minnow traps is the visibility of the traps. This has implications for trap relocation and for theft. It is extremely important that traps are carefully counted out prior to setting them and counted again following recovery to ensure that no traps are left behind. Abandoned traps can continue to capture fish, which then have no chance of escape and will die by starvation (or from desiccation when the wetland dries up in summer). Minnow traps, lost or abandoned in wetlands, have been found to contain the bodies of several skinks, so the potential threat posed by lost traps is not limited to fish.

Fishing equipment is extremely attractive to thieves and many minnow traps have been stolen, either from vehicles or from fishing sites. Traps should be sufficiently visible to ensure that they can be relocated, but not so visible that they are likely to be seen by the general public. Fine-mesh minnow traps are expensive and not locally available, so the costs and delays in replacing stolen traps can cause unfortunate interruptions in monitoring programmes.

6.2.5 Avoiding habitat damage

Habitat damage is mainly an issue in relatively pristine habitats. In such environments, access tracks to monitoring sites remain for a long period of time after the site has been visited, and often transform into water-filled depressions. While such depressions can benefit mudfish by providing small pools, care must be taken not to form too many of them. Sticking to one access track and not randomly wandering around the wetland during each visit will help keep such impacts to a minimum. Where shovel excavation is required to set minnow traps, such as in Westland pakihi bogs, material should be carefully re-instated after trap removal.

Avoiding the introduction of weeds such as crack willow (*Salix fragilis*), red water fern (*Azolla pinnata*) and duckweed (*Spirodela punctata*) to monitoring sites must be emphasised. Traps, waders and other sampling equipment should be thoroughly cleaned and/or sterilised before visiting sites, to avoid the transfer of weeds, pest fish eggs, or fish diseases. Minnow traps can be cleaned of debris using a high power water jet (fire hose or water blaster) and should be checked for cleanliness before redeployment. Sterilisation procedures should follow the recommendations of Biosecurity NZ (MAF 2008).

Fires can also be very damaging to wetlands, and while they can play a role in natural wetland ecology (e.g. black mudfish have been observed living in old burn holes in the Kopouatai Peat Dome), people have tended to dramatically increase the frequency of such fires, often deliberately, to facilitate activities such as hunting deer. Normal precautions against fires should be undertaken when visiting wetlands, particularly during strong winds, in summer, and in raised-bog-type wetlands.

6.2.6 Fish handling and use of anaesthetics

Mudfish should always be handled with wet hands and fish kept moist: if care is taken, they are relatively easy to handle, however, handling should be kept to a minimum. Meredith (1985) and Dean (1995) have commented that the lack of protective scales means that removal of skin mucus during handling can increase an individual’s susceptibility to infection.

After handling, fish should be placed into an aerated container filled with habitat water and allowed to recover before release. Although not always essential, it is ethically preferable to sedate wild animals before intensive handling. Sedating fish will also assist in making accurate measurements of fish length and weight, and is essential for the purposes of marking or tagging. Fish anaesthesia should not be attempted without suitable training. In the authors’ experience the best anaesthetics to use are benzocaine and 2-phenoxyethanol. Antacids, which release carbon dioxide, can also be used (R. Allibone, pers.

comm.). However, this procedure acts to asphyxiate fish, and during summer, when oxygen levels in water are often low, it has the potential to cause high handling mortality. Clove oil should not be used as there is little latitude in safe concentration (it is easy to overdose fish) and recovery from clove-oil-induced anaesthesia is slow.

6.2.7 How to measure and weigh fish

Mudfish can be weighed using battery-powered electronic scales or spring scales, and weights should be recorded at least to the nearest 0.1 g. Electronic scales are more accurate but also more expensive than spring scales. Spring scales also have the limitation of being available only in fixed weight ranges, and a number of spring scales may be required to cover the full range of mudfish weights.

Fish weight can vary from around 1 g for 50-mm T.L. sub-adults to more than 20 g for the largest individuals. The accuracy of weights measured for small individuals is compromised by water adhering to the body. This can be reduced by allow drips to fall before placing on scales or measuring the fish three times and recording an average. Don’t attempt to measure the weights of fish less than 50 mm T.L. as it tends to be inaccurate and fish are more sensitive to handling at this size.

Total length (from the tip of the snout to the tip of the tail) is the most appropriate measure for mudfish. Fish length can be measured in one of three ways: total length (T.L.), fork length (F.L.) or standard length (S.L.). Fork length (tip of the snout to the fork of the tail) is not used because mudfish don’t have forked tails. Standard length (tip of snout to end of backbone) relies on it being possible to easily determine the position of the end of the backbone, which is difficult in mudfish because of the fleshy base of the caudal fin. Fish should be measured to the nearest millimetre using a constructed measuring board, such as a plastic ruler with perspex sides attached. Details on how to construct one of these measuring boards are given in Appendix 4.

6.2.8 Examination of fish

During handling, if fish are sedated they can be inspected carefully and the incidence of deformity, external parasites and infection recorded. Comparisons of the prevalence of common parasites (e.g. whitespot *Ichthyophthirius multifiliis*) and infections (e.g. skin fungus and finrot) may indicate that fish are ‘stressed’ and more susceptible to infection. Deformities may indicate genetic problems from in-breeding or the presence of adverse conditions during embryonic development. High levels of apparent injury may indicate regular predatory attacks by fish or birds.

On close examination it is sometimes possible to determine the sex of mature fish by observing the colour of the gonads through the translucent body wall. Female gonad is light yellow / orange in colour, whereas male gonad is white. Differences in genital papilla size and shape may also be observed prior to breeding in Canterbury mudfish: a microscope, hand-held monocular or magnifiying glass would help. Fish are unlikely to express milt or eggs unless they are ‘running ripe’ and the application of considerable abdominal pressure is to be avoided as it may damage internal organs. Determination of fish sex is important in some studies but is not essential for general population monitoring work.

6.2.9 How to mark fish

The simplest way to mark fish is fin clipping, but this method does not enable the identification of individual fish. A small section of the caudal fin, usually the top or bottom margin, can be cut with a sharp pair of scissors. This cut causes the least damage to the fish and is unlikely to interfere with swimming. Avoid cutting too close to the base of the fin but ensure that the cut is sufficiently large and visible so that it cannot be confused with general raggedness or damage that may be caused to the fin during subsequent recapture in traps. Fin healing and regrowth is rapid as long as infection doesn’t occur.

More permanent makers can be made using implants under the skin allowing identification of individual fish. Choosing a suitable place for inserting a mark or tag will depend on how pigmented the mudfish species is and what sequence of marks will be used. Many places have been marked in galaxiid fishes, such as the belly and back, near the eye, fleshy fins and fin bases. Careful examination of potential tag locations on several sedated mudfish and a small mark retention study in an aquarium would be recommended before any new study.

Paint or elastomer tags can be used in combinations of body position and colour that allow a reasonable number of fish to be individually indentified, also for batch-tagging groups of fish or different sampling occasions. If a large number of fish are to be tagged simultaneously, then fluorescent silicon elastomer implants can be used. This material must be mixed with a curing agent and will then set within a limited time span. The rate of curing can be reduced by keeping the mixed preparation in the freezer; this may delay curing for up to a day. The material is expensive and a minimum quantity needs to be prepared so this is only useful if a significant number of fish are to be tagged. Non-toxic acrylic hobby paint can also be used as a cheaper but less effective alternative.

One way to individually identify a large number of fish is to use visible implant tags. These are individually numbered silicon wafers that must be implanted under the skin using a special injector. This is a skilled procedure that should not be attempted without prior instruction. A number of factors may reduce the readability of tags in recaptured fish, including the depth of original placement of the tag and reactions of the skin which produces pigment over the tag. Visible implant tags are expensive (around NZ$3 per tag), so tagging a significant number of fish will be a costly undertaking.

Because the injection of silicon elastomer and the use of visible implant tagging requires surgical manipulation of the fish (both to insert the tag and to remove it if it is not subsequently readable), approval by an animal ethics committee is required.

6.3 Study design

6.3.1 Sampling effort

Constant sampling effort is the key to successful mudfish trapping. There are two key aspects to effort: trap density and the total number of traps set. Because each minnow trap is identical in size and shape, setting traps overnight and retrieving them the next day provides a constant trapping effort if, at each site, the same number of traps are set, and a similar area of habitat is sampled. However, there are many situations where this may be difficult to achieve, such as if the site consists of a collection of small, scattered or highly patchy habitat zones, such as pools, islands, large woody debris, different vegetation types.

In most cases it is important to keep the general density of traps similar at sampling sites. Keep in mind that placing traps too close together means that one trap may reduce the number caught in another and then does not constitute a statistically independent replicate. As a general practice, traps are placed at least 2-4 meters apart in the case of contiguous habitat. Maintaining trap density may mean that fewer traps are placed in a small pool or habitat patch compared with a much larger one. An extreme example is trapping for mudfish in the small holes created in wetlands by Kauri gum digging. These holes can often only contain one trap and this trap would be a truly independent sample of fish abundance.

There is no simple formula for calculating the number of traps needed in a particular area or study, although there are complex statistical models that can predict trapping effort based on fish abundance and catch variability. Traps can be regarded as independent replicates used to obtain an average catch rate (fish per trap per night) and as with all estimates of an average, the greater the sample size (number of traps) the more reliable the average will be. However, the number of traps used is often constrained by time and trap availability. The number of traps may also depend on the type of study design used (section 6.3.2). To calculate the average number of fish caught in an area at least two traps are required, but the number of traps required to provide a useful measure of relative fish density is much greater and inversely dependent on fish abundance. Statistical modelling has indicated that ten traps at each site is the minimum required to confidently estimate abundance, especially if long term population trends are of interest (Ling unpublished data). Any lesser effort is really only likely to provide evidence of presence/absence although this also depends on mudfish abundance. If mudfish numbers are low then a much greater number of traps will need to be set to reliably catch them, whereas few traps need to be set at sites where mudfish are abundant.

6.3.2 Study Design

When designing a survey or monitoring study, the scale of the study is important to consider. This will depend on resource constraints and the question being asked or able to be answered. For example, if the question is "What was the average abundance of mudfish in a wetland", it is statistically preferable to spread traps randomly throughout the entire wetland. However, logistics often limit the ability to do this. In the Whangamarino Wetland monitoring study, ten traps were placed at each of eight locations along an access road within the wetland; these locations were annually sampled. This design means that the results are, statistically, only able to be generalised to explain trends occurring at each of those eight locations rather than in the Whangamarino Wetland as a whole. However, the existing road provided easy access through the wetland to a variety of different habitat zones and sampling in the centre of a 5,500 ha peat bog is practically impossible without constructing access tracks that may act as conduits for the introduction of weeds and be visible for years to come.

There are also many statistical ideals in how sampling should be conducted. For example, for sampling to be unbiased, all potential habitat has to have an equal chance of being sampled. In continuous habitat a numbered grid can be overlaid on a map of the sampling area. Random northings and eastings can then be used to generate random coordinates. Discard any point that lands outside the sampling area, or within 2 m of a previously selected point. However, how a habitat appears on a map and then on the ground can be quite different, and habitat complexity, problems with access, and the inability to set traps in very deep or shallow habitat, can all render such intentions unfeasible. During monitoring, traps should ideally be placed randomly throughout the site each time, however, consideration needs to be given to ongoing habitat disturbance. Having a fixed accessible sampling location by setting traps in the same place each year may be a less destructive option. Moreover, if fish density or sub-population size is being estimated then having traps placed in an identical way is necessary. The important thing is to clearly record what was done and the reasons behind the placement of traps.

Taking such issues into consideration and designing a study before trapping begins can avoid problems when doing comparisons and statistical analyses later. It may be wise to refer to statistical textbooks, look at other studies and seek expert statistical advice, if available. Common study designs used for trapping mudfish are random, stratified random, and transects. Simple random studies may involve setting many individual traps throughout the whole habitat. Stratified random involves dividing habitat into different types or selecting locations and placing multiple traps randomly within each type or location. The above example at Whangamarino Wetland is stratified by location. This design may limit the generalisation that can be made but does allow comparisons to be made within a habitat. At Whangamarino Wetland interesting interactions between mudfish and *Gambusia*, in relation to patterns of drying, are being monitored. Transects involve placing traps at regular or random distances "along a line". Transects are a convenient way of ensuring traps are not lost or are placed in the same spot on each sampling period. Transects are also a good way of investigating mudfish abundance in relation to gradients in environmental variables, such as changing from dry land, wetland, pool edge, through into a pool. With transects, however, comparisons between habitat types along a transect may not be possible unless there is sufficient replication of traps within each habitat zone. Thus, they might not provide information needed to answer management questions.

7 Mudfish survey and monitoring results

It is important to collect certain types of information while in the field, which will depend on the study type and the question being asked. From the information collected during fish sampling, a range of calculations and graphic analyses can be done to aid comparisons, monitoring, and statistical analysis of sub-populations.

7.1 How to estimate fish abundance (CPUE)

The standard method of trapping adults overnight provides the average number of fish *caught*, not the average number of fish *present*. This is important to recognise. It is usually a fair assumption that the greater the number of fish present, the higher the density, and therefore the greater the number of fish caught in traps and vice versa. Nonetheless, any possible departures from this assumption need to be identified and considered (section 6.2.3).

Catch per unit effort (CPUE) should not be used to estimate fish density (the number of fish per area) or sub-population size, as there is no way of knowing what proportion of the fish present where actually caught in traps, at least not without further sampling (see sections 7.4 & 7.5). Catch per unit effort can be used to make comparisons between areas and CPUE usually indicates likely abundance and so can be used to rank locations as having high, medium, or low numbers of mudfish present (section 7.6). If it can be assumed that any factors biasing CPUE at a particular site are constant, then trends in abundance can be detected over time through monitoring.

Catch per unit effort is calculated as;

CPUE = F / T*N

where F = number of fish, T = number of traps and N = the number of nights trapping occurred.

If trapping occurs over several nights and uses the same traps each night then the number of traps used is multiplied by the number of nights that trapping occurred.

For example, Fred had 5 traps. He set them overnight and the next morning found 10, 1, 7, 8, and 12 fish in each of his traps, respectively. He then set the traps overnight somewhere else in his wetland and caught 11, 7, 8, 6, and 10 mudfish. He calculated a CPUE for each sampling location of 7.6 and 8.4 and an overall CPUE for his wetland of 8. In this case the average CPUE for both wetland locations was similar and one could reasonably assume that mudfish density was also reasonably uniform. However, a large wetland may include areas of tree canopy, sedge peat bog, mineralised nutrient-rich raupo and open water, and to investigate the relative abundance of mudfish in each of these habitat zones requires comparable (and repeated) trapping effort in each area.

It is important to remember how many traps are set, and where, and also to treat each trap as a replicate, that is, record the number of fish (and possibly other species) caught in each trap. This can be easily done in the field by counting fish taken out of each trap as they are placed into a communal bucket, and recording the number immediately. If the numbers of fish caught in each individual trap are recorded separately it may possibly provide an indication of variation across the traps (i.e. allowing the addition of error bars to mean values).

7.2 How to assess mudfish size structure

Length-frequency, or the number of individuals in each size class (commonly 5 mm groups) provides a good indication of overall recruitment, growth, and longevity. This information is usually graphed as a histogram. In the field, it is important to measure as many fish as possible if size structure is to be assessed and to select fish randomly if all fish caught cannot be measured. Practises such as measuring a few of a common size or measuring only certain sizes leads to meaningless size frequency information. More than 50 fish are needed to give any useful analysis of sub-population size structure and the more fish the better. Length information can be appropriately pooled, either over time or over all locations in a habitat to provide an adequate sample size. Given that length measurements are usually grouped into 5 mm size ranges, exact fish measurement is not required and a measuring board may be ruled into 5 mm divisions to speed measurements.

It is hoped that a full size range of fish are present, and an abundance of large fish suggests low mortality and high growth rates typical of optimal habitat. The presence of numerous small fish, yet no large adults, could indicate the sub-population is recovering from disturbance, or some other factor causing high adult mortality, or that the habitat does not support adults, but there is suitable habitat nearby that is the source of fish caught. When interpreting length frequency patterns it is often important to know the habitat and the likely factors leading to the absence of certain sized fish. Size structure are indicative only and further study would be required to confidently determine the cause of any suggested limiting factor.

It is important to recognise that cohorts cannot be discerned from length frequency graphs alone. It is impossible to confidently tell the age of a mudfish just from its length. It is also difficult, and requires dissection, to age an individual from counting rings on its otoliths (fish ear bones). This is a highly specialised technique and is potentially problematic for mudfish given that more than one growth check may occur each year due to summer aestivation and low winter temperatures. Recording the growth from marked and recaptured fish may allow an estimate of age to be calculated, if enough data are obtained. However, this age estimate could only be applied to individuals in that particular habitat. Growth patterns differ seasonally and can be affected by patterns in abiotic factors, such as drought, and biotic factors, such as other species present. Furthermore, once reproductively mature the sexes appear to grow at different rates. Two peaks in size frequency may not indicate different cohorts, but rather different sexes.

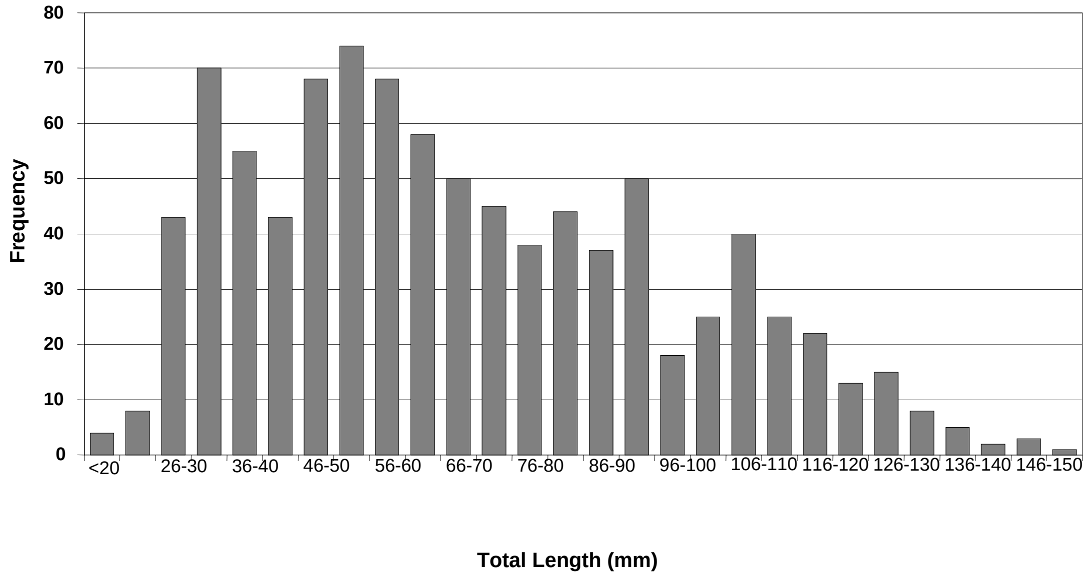


FIGURE 5 LENGTH-FREQUENCY DISTRIBUTION OF 932 BLACK MUDFISH SAMPLED WITH GEE-MINNOW TRAPS FROM THE WHANGAMARINO WETLAND FROM 1993 TO 2003. NOTE THAT FISHING WAS ALWAYS CONDUCTED IN LATE WINTER (MID SEPTEMBER TO EARLY NOVEMBER). MAXIMUM RECORDED LENGTH FOR BLACK MUDFISH IS 157 MM.

Figure 5 demonstrates the length frequency graph for a sub-population that would be considered to be ‘healthy’ as it has a large number of small recruits as well as a reasonable frequency of large fish.

7.3 How to calculate a condition factor

To assess average mudfish condition, the weights of individual fish need to be recorded in addition to their lengths. This enables condition factor or an average relationship between length and weight to be calculated. Condition can be useful for assessing chronic impacts of stressors between different sites or situations. For example, effects of introduced Gambusia, competing with mudfish for food, could be assessed by measuring condition factors at mudfish sites with and without Gambusia, in similar habitats.

When making comparisons using condition it is important to consider when sampling occurred and the reproductive stage of fish caught. Fish in prime condition or which are sexually mature and ready to spawn should have a greater weight for their size than fish which are starved or not in peak sexual condition. Condition should improve in the lead up to spawning and immediately decline following spawning due to the loss of eggs and milt. Thus, condition factors can be highly variable and care needs to be taken when interpreting them.

The following are condition factors determined for mudfish species based on large sample sizes of fish from measurements taken over multiple years and sites (Figure 6). Fish smaller than 65 mm T.L. have not been included in the calculation of these condition factors, since weight measurements of small fish taken in the field are usually inaccurate. Currently, there are no condition factor equations available for the Chatham Island mudfish.

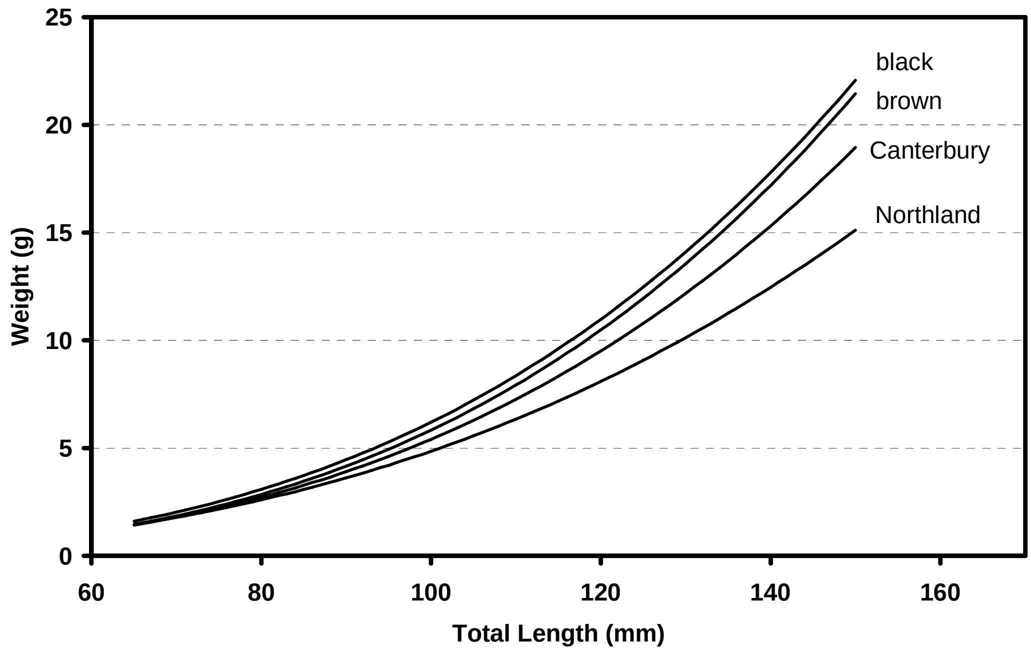


FIGURE 6 LENGTH–WEIGHT RELATIONSHIPS FOR FOUR MUDFISH SPECIES. IT IS CLEAR THAT THE 'FATNESS' OF FISH VARIES WITH SPECIES. BLACK AND BROWN MUDFISH ARE FATTEST FOR THEIR SIZE WHILE NORTHLAND MUDFISH ARE FINER-BODIED FISH.

Canterbury mudfish (*Neochanna burrowsius*)—based on 938 fish (> 65 mm T.L.) from 4 sites in Canterbury (1999–2001).

$$K = \frac{280{,}000m}{l^{3.09}}$$

Black mudfish (*Neochanna diversus*)—based on 283 fish (> 65 mm T.L.) from 8 sites in the Whangamarino Wetland (1993–2000).

$$K = \frac{293{,}000m}{l^{3.13}}$$

Brown mudfish (*Neochanna apoda*)—based on 274 fish (> 65 mm T.L.) from 9 sites in the North and South Islands.

$$K = \frac{451{,}000m}{l^{3.21}}$$

Northland mudfish (*Neochanna heleios*)—based on 106 fish (> 65 mm T.L.) from Ngawha Springs (1996 & 1997) and Lake Omapere (2001).

$$K = \frac{82{,}000m}{l^{2.80}}$$

where *m* = mass in grams and *l* = total length in mm

7.4 How to estimate fish density (based on local sub-population size)

To estimate absolute fish density, removal methods need to be conducted. That is, netting off the sampling location and repeatedly fishing until a significant reduction in catch is obtained. During each sampling event it is important to maintain the same effort and method as closely as possible. The number of fish present in the area of habitat sampled is estimated (see Box 1) either by graphing the result and extrapolating a total sub-population estimate (Hayne 1949) or by direct calculation using algorithmic methods such as that of Zippin (1958).

Although removal methods are commonly used when electrofishing stream fish they have not been routinely carried out for mudfish species. This is likely due to the non-linear character of most mudfish habitats and the extra time and effort involved. Dean (1995) found that successive nights of Gee-minnow sampling, with removal of fish, did not reduce the number of mudfish captured each night, however, she did not net off the area being trapped. The result suggests that either fish were moving into the area in response to decreasing local density or that only a small fraction of the mudfish were captured each night. O'Brien (2005) netted off a section of stream habitat and trapped and then electrofished and found that trapping only captured c. 50 % of the fish subsequently estimated by sequential removal to be present (Figure 7).

A similar method of multiple passes, is also needed when trying to remove mudfish before a habitat is destroyed. It is very difficult to remove all individuals. By sampling and removing at least three successive times the percentage of fish removed in relation to that estimated to be present can be determined. It might be acceptable to aim for the salvage of 80 – 90 % of fish estimated to be present.

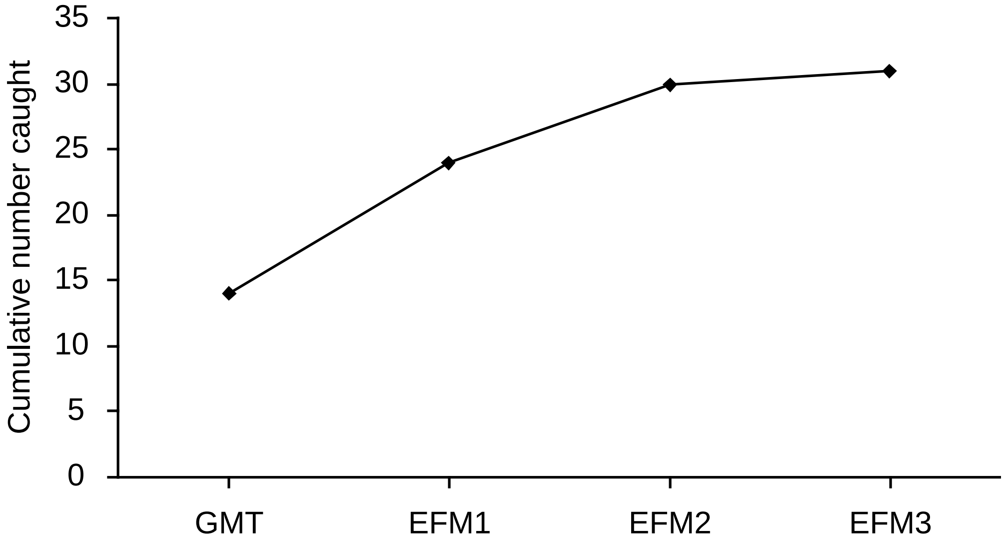


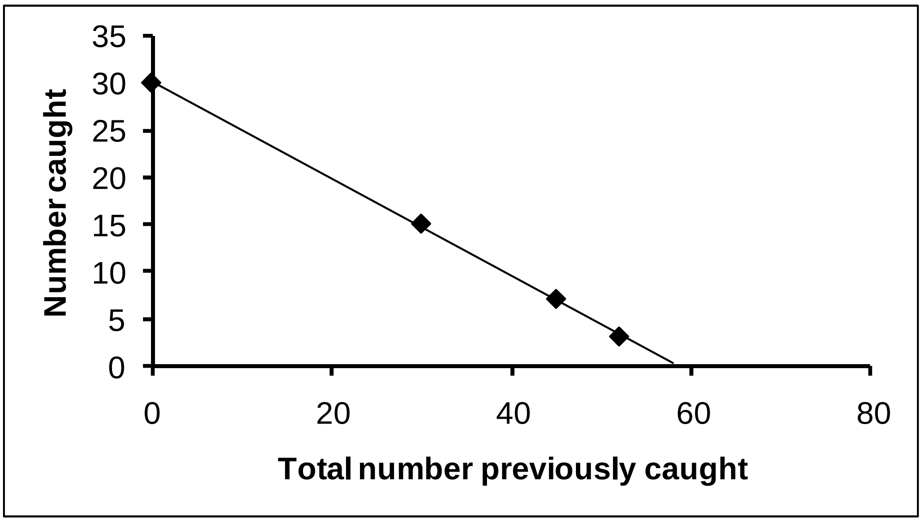
FIGURE 7. CUMULATIVE NUMBER OF *N. BURROWSIUS* CAUGHT IN A STOP-NETTED 50 M REACH AT TE ROTO REPO O TAWERA USING SIX GEE MINNOW TRAPS (GMT) PLACED OVERNIGHT, FOLLOWED BY 3-PASS ELECTROFISHING (EFM 1 – 3) THE NEXT DAY.

Box1: Estimating local population size by sequential removal

Removal estimates require at least 2 removals (2 periods of sampling) and in each case the sampling effort must be the same. If animals are released after capture they must be marked in some way so that they are not recounted if captured again. Suppose that a wetland was sampled with 10 minnow traps on 4 consecutive nights and the following data were obtained:

Night 1 – 30 fish, night 2 – 15 fish, night 3 – 7 fish, night 4 – 3 fish

Hayne's (1949) regression method: the results are plotted as follows and a regression line through the data is extrapolated to the x-axis giving a total population estimate of 59 fish.



Zippin's (1958) removal algorithm:

This method requires 2 removals and the total population is estimated from the following equation:

$$N = \frac{n_1^2}{(n_1 - n_2)}$$

Where n_1 and n_2 are the first and second removals, respectively, and N is the total population estimate. Applying this equation to the data above gives a population estimate of 60 fish.

Mark-recapture studies are also widely used to estimate sub-population size. However, such studies can be difficult, and largely inappropriate in many mudfish habitats. Recapture rates of marked fish may be quite low, meaning that a large number of fish may need to be marked in order to provide useful information. The resulting estimates may also have very wide confidence intervals meaning there is considerable uncertainty as to the number present. Furthermore, the methods used to calculate these estimates rely on assumptions that are often not valid, such as the requirement that the sub-population is 'closed' or confined, and there is no movement, recruitment or mortality during the study. Nonetheless, mark-recapture studies have been conducted on several species (Eldon et al 1979, Perrie 2004, O'Brien 2005).

Measurements of sub-population size using the simplest Petersen mark-recapture method, involving one mark and recover event are made using the following formula:

$$N = \frac{M\,(C+1)}{(R+1)}$$

where N = estimate of sub-population size, M = number of marked fish at liberty in the sub-population, C = number of fish caught, R = number of marked fish caught.

7.5 How to estimate total sub-population size

A rough estimate of population size can be gained by calculating local fish density (Section 7.4) at several sites to get an average fish density for the habitat and, after determining the extent of area occupied by mudfish, multiply the two to obtain a total sub-population estimate.

7.6 How to make comparisons using basic information

It is often necessary to determine the importance of a habitat for mudfish after only basic information has been collected. CPUE information in the New Zealand freshwater fish database provides a means to transparently compare catch rates at a location with those recorded more widely for that species. This allows sub-populations to be quickly ranked without relying on observer experience, and takes into account species specific characteristics. For example, a sub-population of brown mudfish with a CPUE greater than two would be considered to have high abundance, whereas for Canterbury mudfish, a sub-population in the top 25% of records would be expected to have a CPUE greater than five fish/trap/night. Table 1 sets out the CPUE ranges for each rank as currently calculated for four of the mudfish species.

Table 1 Expected catch per unit effort (CPUE; fish per trap night) for Canterbury, black, Northland and brown mudfish species

	High abundance	**Moderate abundance**	**Low abundance**
Species	CPUE in top 25% of records	CPUE range for upper 50% of records	CPUE in lower 50% of records
Canterbury	>4	2-4	<2
Black	>2	1-2	<1
Northland	>3	1-3	<1
Brown	>2	1-2	<1

Information in this table is determined from percentage cumulative histogram graphs of CPUE results for each species (see O'Brien & Dunn 2007). On-going improvements in standardisation and regular up-dates of information mean that comparisons and rankings need to be re-evaluated on an annual basis. This would involve analysis of the entire dataset to check the thresholds for each rank.

7.7 How to monitor changes in habitat quality

It is important to provide accurate details of where fish were captured within a wetland. For example, a simple grid reference for a site located in a lake edge fringe wetland, could lead subsequent researchers to conclude that fish were captured within the lake itself rather than in its associated peripheral wetland, if no description of capture location was given in the record. When re-sampling a known habitat, points placed on an aerial map are helpful and details may also include hand drawn or surveyed maps of the area.

New Zealand Freshwater Fish Database forms (Appendix 2) should be used to record habitat information from mudfish monitoring sites. The habitat descriptors provided should be used. The presence of any aquatic weeds or pest fish should also be recorded on the forms. If suitable equipment is available, then other habitat variables such as water pH, temperature, dissolved oxygen, turbidity (water clarity) and conductivity can also be measured to provide further information about habitat preferences of mudfish species.

The spatial area of possible mudfish habitat at each key site (and ultimately for all known mudfish habitat) should be determined where possible using Geographic Information System (GIS) techniques. The level of detail recorded for each site in terms of habitat quality will depend on resources available. The Handbook for Monitoring Wetland Condition[3] (Clarkson et al 2003) provides the standard for wetland monitoring. This approach relies on the use of changes in vegetation to indicate long-term changes in the habitat, such as eutrophication, that may be difficult to measure by other means. All key mudfish sites should be assessed using this scheme in order to monitor long-term changes in wetland condition. Refer to Appendix 3 for a wetland monitoring form.

It may be that initially some variables are collected more frequently until a clear picture of the situation is determined. After which the monitoring level can be reduced. For instance, to fully understand the hydrological fluctuations of habitat, it may not be sufficient to visit a site once a year. For key sites, and

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[3] http://www.landcareresearch.co.nz/research/biodiversity/landscapesprog/handbook2003.pdf

potential translocation and restoration sites, monthly visits and water depth measurements may be required to piece together a picture of the hydrological situation influencing a sub-population. Alternatively, installation of water level data loggers may be a cost-effective means of obtaining this information. Wetland water levels are an integral part of mudfish life history, so it is important to determine the pattern of wetting and drying at the site. During sampling it is also worth recording information such as time from last major rainfall event, if it is known, and whether the area is known to dry during the summer months. The annual drying of mudfish habitats is important for excluding competing or predatory fish species.

In addition to the information recorded on the Freshwater Fish Database forms and the Wetland Monitoring forms, annual photographs of each site should be taken and simple diagrams included that illustrate the general vegetation, the presence of drains or other structures, etc.

7.8 How to monitor trends in mudfish abundance

A performance measure in the mudfish recovery plan is that at least three key mudfish sub-populations within each evolutionarily significant unit (ESU) will be annually monitored by 2006 using a standardised approach (Department of Conservation 2003). To achieve this, based on the number of ESUs[4], the minimum number of habitats which must be included in a national monitoring programme are: 3 key Northland mudfish sub-populations, 6 key black mudfish sub-populations, 6 key brown mudfish sub-populations, 3 key Canterbury sub-populations and two Chatham island sub-populations.

As one of the key purposes of monitoring should be to identity gradual decline in abundance and distribution shrinkage, simply monitoring sub-populations which are secure and well managed may not allow identification of decline. Therefore, populations on the edge of each species' distribution and those with a high level of fluctuation should also be included in monitoring programmes.

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[4] As at May 2007

At each habitat at least two monitoring sites should be selected, taking into account access, avoidance of habitat disturbance, representativeness and the ability to provide a clear view for a photo point. Furthermore, when monitoring sites are selected, it is important to include some with high and low mudfish abundance to allow assessment of sub-population increments or declines. In large habitats, more monitoring sites will be required—at least one per major habitat zone.

8 Data management for survey and monitoring work

Capture data from each mudfish site should be submitted to the NZ Freshwater Fish Database and each mudfish habitat should be assessed using the Handbook for Monitoring Wetland Condition (Clarkson et al. 2003). The data collection and management requirements of a mudfish survey will depend on whether the survey is part of a monitoring programme or not (Table 2).

TABLE 2 MANDATORY AND DESIRABLE DATA COLLECTION AND MANAGEMENT REQUIREMENTS WHEN UNDERTAKING SURVEY AND MONITORING OF NEW ZEALAND MUDFISH SPECIES.

Data requirement	Survey	Monitoring
Fill out Freshwater Fish Database card	Mandatory	Mandatory
Record data using mudfish data entry template	Mandatory	Mandatory
Create/update key site database form	Mandatory for key sites	Mandatory
Complete Monitoring Wetland Condition sheets		Desirable
Water level monitoring		Desirable

8.1 Freshwater Fish Database

The results of survey work must always be submitted to the Freshwater Fish Database (FWFDB), either in hardcopy or electronically via the database assistant program (http://fwdb.niwa.cri.nz). Note: electronic forms get a higher priority for processing. **Even if no fish are captured, it is still important to fill out a database card**. Photocopy the FWFDB form (Appendix 2) onto waterproof paper for use in the field.

8.2 Mudfish data entry template

The standard FWFDB form does not allow for recording of information on individual lengths and weights of fish, tag information, etc., so these data may need to be recorded separately. To store length/weight in a form amenable to statistical analysis and comparisons between sub-populations, create a separate Excel spreadsheet using the mudfish data entry template. (A copy of this template can be accessed via DOCDM-211464, The Mudfish Recovery Group home page, —in DOC's internal electronic document management system).

A copy of this spreadsheet should be forwarded to the convener of the mudfish recovery group so that a central record can be kept of all mudfish work and so that research such as tag-recapture programs can be coordinated.

8.3 Other data

All other relevant information collected during mudfish surveys, including wetland condition and water level datasets, should be stored electronically on a computer server with a secure back-up facility. This would be best achieved by storing them on DOC's electronic document management system.

8.4 Key Site database form

For monitoring key mudfish sites (i.e. those identified in the mudfish recovery plan as being 'key sites'), enter site descriptions and other relevant site data onto a mudfish key site database form (Appendix 5) (also available to DOC staff via DOCDM-211464, The Mudfish Recovery Group home page,—in DOC's electronic document management system). Thus, each key site will have its own dedicated word file that includes information on habitat, land status, monitoring data. A copy of this form should be kept up to date and made available to the mudfish recovery group via DOC's electronic document management system.

9 Health and safety

Standard procedures for field work should always be followed when conducting surveys or monitoring for mudfish. Safety issues specifically related to mudfish survey relate to working in wetlands. Wetlands may contain deep mud-filled holes formed naturally or by human activities (such as gum digging) and getting out of such holes, once one has fallen in, may sometimes be difficult without assistance. There is also a high possibility of vehicles becoming stuck on access routes in and out of major wetland sites.

One final consideration is that many wetlands are used for illegal activities because they are rarely visited by the general public. Common sense and care about personal safety should be exercised to minimise the hazards of wetland work.

10 Glossary

Adult :	Sexually mature, usually in first or second year
Aestivation:	A period of summer or dry season dormancy
Cryptic:	Having coloration and behavior that allows individuals to avoid being seen
Diurnal:	Active during the day in the morning and afternoon
Fry:	Pelagic period of early life, includes larval and juvenile stages
Habitat:	An area usually defined by vegetation or water features that could possibly contain mudfish, such as a lake shore, a wetland, a valley bottom, an area of upwelling springs, even a stream or a tributary.
Juvenile:	After metamorphosis but before sexually mature
Larvae:	Before metamorphosis, does not have fully developed fins and adult morphology
Metamorphosis:	Process of change from larvae to juvenile
Nocturnal:	Active during the night
Pelagic:	Swimming in the water column in open water
Population:	The total number of individuals of the taxon that are resident, or that breed in New Zealand.
Sampling location:	Marked transect points, spot where traps are placed.
Site:	Usually associated with access points and is the area covering all sampling locations
Sub-population:	Geographically or otherwise distinct groups in the population between which there is little exchange.

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Appendix 1 - Equipment suppliers

Gee minnow traps

Steel mesh Gee minnow traps are made by:

Cuba Specialty Manufacturing

P.O. Box 195

Fillmore, NY 14735

U.S.A.

Tel: 001 585 567 4176

Fax: 001 585 567 2366

http://cubaspecialty.com

Note that to order fine-meshed (1/8 inch, 3 mm) traps, you need to ask for non-standard G-408M traps. Cuba Specialty do not sell directly to the public and have a minimum order quantity. The company has a complete list of USA and Canadian retailers of their products on their website.

Another overseas contact for minnow traps can be located at http://memphisnet.net under ‘commercial fishing catalogue’ > ‘fish traps’ > ‘wire crawfish/minnow traps’. This retailer also stocks 1/8-inch (3-mm) steel-meshed minnow traps, and lists them as ‘exotic fish traps, G48m’.This site also has a price list—the traps sell for approximately $25 US each, with reductions for bulk orders. The Cuba site is likely to be far more cost-effective, as they are a wholesale only company. Note that DOC has specific processes for importing goods; DOC staff should investigate these before setting out to import traps or other items themselves.

Visible implant tagging equipment and consumables

Visible implant elastomer material (VIE) and visible implant alphanumeric tags (VI Alpha) are manufactured by:

Northwest Marine Technology, Inc.

PO Box 427, Ben Nevis Loop Road

Shaw Island, WA 98286, USA
Tel: 001 360 468 - 3375
Fax: 001 360 468 - 3844
office@nmt.us
http://www.nmt-inc.com

Both of these materials are used for marking other species of fish. DOC already possesses some of the equipment and spare consumables for tagging fish, so DOC staff should check with appropriate R,D&I or Conservancy Freshwater Technical Support staff before purchasing new supplies.

Balances or spring scales

A large number of manufacturers produce small-capacity electronic scales and the price of these has reduced considerably in the last few years. For precise weighing, it is best to get scales that weigh to the nearest 0.01 g. These will cost considerably more than those that only weigh to the nearest 0.1 g. Good-quality spring scales are made by:

Pesola AG
Rebmattli 19
CH-6340 Baar
Switzerland
Tel: 0041 41 769 6040
Fax: 0041 41 769 6042

Their products can be ordered online from:
http://www.pesola.ch/

These spring scales are commonly used by other field researchers and may already be available within DOC conservancies.

Appendix 2 - Freshwater fish database (FWFDB) form

NZ FRESHWATER FISH DATABASE FORM	PLEASE RETURN TO:	FRESHWATER FISH DATABASE NIWA PO BOX 11-115, HAMILTON	
Date	Catchment system		Catchment number
Time	Sampling locality		
Observer	Access notes		Altitude (m)
Organisation	NZMS260 map	Coordinates	Inland distance (km)
Fishing method	Area fished (m^2) or Number of nets used	Number of electric fishing passes	Tidal yes/no/unknown

HABITAT DATA

Water	Colour blue/green/tea/uncoloured/other:			Clarity clear/milky/dirty		Temp.	pH
	Average width (m)		Average depth (m)	Maximum depth (m)		Conductivity (ms/m)	
Habitat type (%)	Still	Backwater	Pool	Run	Riffle	Rapid	Cascade
Substrate type (%)	Mud	Sand	Fine gravel	Coarse gravel	Cobble	Boulder	Bedrock
Fish cover (yes/no)	Weed Algae	Instream debris	Undercut banks	Bank vegetation			
Catchment vegetation (%)	Native forest	Exotic forest	Farming	Urban area	Scrub	Swamp land	Other
Riparian vegetation (%)	Native forest	Exotic forest	Grass Tussock	Exposed bed	Scrub Willow	Raupo Flax	Other

Type of river/stream/lake		
Water level low/normal/high/unknown	Downstream blockage yes/no/unknown	Pollution nil/low/moderate/high
Large invertebrate fauna	Koura abundant/common/occasional/rare/nil/unknown or numbers observed	
	Paratya shrimp abundant/common/occasional/rare/nil/unknown	Freshwater mussels nil/present/unknown
Small benthic invertebrate fauna low/moderate/high/unknown	Predominant species mayflies/caddis/snails/combination/other	Permanent water yes/no/unknown
Purpose of work		

FISH DATA

Species and life stage	Abundance*	Length data	Habitat/comments

Comments

*Use numbers observed or abundant/common/occasional/rare

Appendix 3 - Wetland monitoring sheets (Clarkson et al. 2003)

Table 2: Wetland Record Sheet

Wetland name:
Region:
Altitude:

Date:
GPS/Grid Ref.:
No. of plots sampled:

Classification: I System	IA Subsystem	II Wetland Class	IIA Wetland Form

Field team:

Indicator	Indicator components	Specify and Comment	Score 0– 5[1]	Mean score
Change in hydrological integrity	Impact of manmade structures			
	Water table depth			
	Dryland plant invasion			
Change in physico-chemical parameters	Fire damage			
	Degree of sedimentation/erosion			
	Nutrient levels			
	von Post index			
Change in ecosystem intactness	Loss in area of original wetland			
	Connectivity barriers			
Change in browsing, predation and harvesting regimes	Damage by domestic or feral animals			
	Introduced predator impacts on wildlife			
	Harvesting levels			
Change in dominance of native plants	Introduced plant canopy cover			
	Introduced plant understorey cover			
Total wetland condition index /25				

[1]Assign degree of modification thus: 5=v. low/ none, 4=low, 3=medium, 2=high, 1=v. high, 0=extreme

Main vegetation types:

Native fauna:

Other comments:

Pressure	Rating[2]	Specify and Comment
Modifications to catchment hydrology		
Water quality within the catchment		
Animal access		
Key undesirable species		
% catchment in introduced vegetation		
Other pressures		
Total wetland pressure index /30		

[2]Assign pressure scores as follows: 5=very high, 4=high, 3=medium, 2=low, 1=very low, 0=none

Table 3: Wetland Plot Sheet

Wetland name: **Date:** **Plot no:**
Plot size (2m x 2m default): **Altitude:** **GPS/GR:**
Field leader: **Structure:** **Composition:**

Canopy (bird's eye view)			**Subcanopy**			**Groundcover**		
Species[1] (or Substrate)	**%**	**H**	**Species**	**%**	**H**	**Species**	**%**	**H**

[1] % = % cover: total canopy % cover = 100%; H = maximum height in m; indicate introduced species by *

Additional species in vicinity in same vegetation type:

Comments:

Indicator (use plot data only)	**%**	**Score 0–5**[2]	**Specify & Comment**
Canopy: % cover introduced species			
Understorey: % cover introduced spp[3]			
Total species: % number introduced spp			
Total species: overall stress/dieback	NA		
Total plot condition index /20	NA		

[2]5=0%: none, 4=1–24%: very low, 3=25–49%; low, 2=50–75%: medium, 1=76–99%: high, 0=100%; very high
[3]Add subcanopy and groundcover % cover for introduced species

Field measurements:

Water table cm		Water conductivity uS (if present)	
Water pH (if present)		von Post peat decomposition index	

Soil core laboratory analysis (2 soil core subsamples):

Water content % dry weight		Total C %	
Bulk Density T/m³		Total N %	
pH		Total P mg/kg	
Conductivity uS			

Foliage laboratory analysis (leaf/culm sample of dominant canopy species):

Species		%N		%P	

Appendix 4 - How to measure mudfish length

To make a measuring board:

Take a clear plastic ruler—150 mm is usually adequate, as very few fish will be longer than this. Cut the end off to the zero mark. Cut 3 mm clear acrylic sheet (Perspex) into four suitably sized strips. One should be the exact size of the ruler and be glued to the back of the ruler to act as a firm base. The other three strips should be around 1.5 cm wide and glued to the edges of the base to form the three sides of the measuring board.

To measure fish length:

Fish are measured by placing them in the measuring board with the snout against the end wall. They are measured to the tip of the tail (Total Length or TL).

If you have a problem with fish jumping or wriggling out of the measuring board, then they can be restrained by a hinged lid made by cutting another piece of Perspex the same size as the base and taping it to one side of the measuring board with duct tape.

Appendix 5 - Mudfish key site database form

Site Information	
Species: (Scientific or common name)	
Site Name: (from NZMS 260 series map)	
Conservancy and Area Office	
Contact Staff member and VPN	
Map Reference:	
Land Status:	
Owners	
Contact details for landowners.	
Iwi and Iwi contact details.	
Regional and District Councils	
Photo/sketch	

Dates visited	**No of traps set**	**No. of mudfish captured**	**Other species**	**NZFFD card No.** (recommended but not required for all visits)

Other information available (e.g., theses, other NZFFD records)

Habitat and Management Information	
Habitat description	
Threats	
DoC management actions to date	
Future recommendations	

Appendix 6 - Equipment required.

Survey and monitoring of mudfish fry

Essential equipment

1. 200-mm-diameter kitchen sieve tied, screwed or otherwise attached to a broom handle.

2. White plastic bucket or deep tray for sorting fish and debris.

3. Thigh or chest waders.

Survey and monitoring of juveniles and adults

Essential equipment

1. Fine-mesh (3 mm or 1/8 inch) steel minnow traps. Traps need to have suitable clips to hold them together and strings to suspend them from vegetation or stakes.

2. 1.8-m wooden or plastic stakes for sites with deep water and without overhanging

vegetation.

3. White plastic buckets for sorting and holding fish

4. A measuring board suitable for small fish (see Appendix 4)

5. A 1 m rule or similar for measuring water depth

6. Freshwater Fish Database sheets (Appendix 2) or a waterproof notebook for recording information

7. Thigh or chest waders

Optional equipment

1. Battery-operated scales (cost approx. $350 to $2000 for ± 0.01 g precision) or spring scales (cost approx. $100 per scale) suitable for weighing in the range < 1 g to > 20 g with at least ±0.1 g accuracy.

2. A battery-operated air pump (cost approx. $20) is useful for keeping buckets of fish aerated, especially if a large number of fish have been caught.

3. Fish anaesthetic—although not essential, anaesthetising fish will assist in accurately making measurements of fish length and weight, and is essential for the purposes of marking or tagging.

4. Post-handling treatments – anti-fungal and anti-bacterial treatments suitable for fish ensure that injury to skin mucus and the close proximity of fish during handling does not result in subsequent high rates of infection.

4. Meters for measuring water pH, dissolved oxygen, conductivity and temperature. With the exception of temperature, measuring these parameters requires specialist training in the units of measurement and the calibration and maintenance of the meters. The costs for meters will vary from a few hundred dollars for reliable field pH meters to a few thousand dollars for good quality dissolved-oxygen and water conductivity meters.