Freshwater fish: passive nets—gill and trammel nets

Version 1.1

This specification was prepared by Michael Lake in 2013.

Contents

Department of Conservation
Te Papa Atawhai

Synopsis

In this method gill netting refers to the passive deployment of nets to intercept, capture and hold freshwater fish. Gill nets typically consist of a single sheet of net material deployed vertically in the water column and anchored at each end. Gill nets are designed to capture fish by allowing them to either wedge or 'gill' themselves in the mesh opening or entangle themselves in the mesh material (Hubert 1996).

Trammel nets consist of three layers of netting, with a finer mesh net sandwiched between two layers of coarser mesh net. Trammel nets work slightly differently from gill nets in that they are designed to capture and hold fish in pockets that form when the fish push a section of fine netting through an opening in the coarse netting mesh. Fish mortality tends to be less for fish caught in trammel nets compared with those caught in gill nets (Hubert 1996). Trammel nets are also thought to be more effective at capturing cautious species such as koi carp (*Cyprinus carpio*). For the purposes of readability in this method trammel netting will be considered a form of gill netting.

Mortality rates for fish captured using gill nets are normally very high but gill nets are one of the best methods for catching mobile fish species in deep open-water habitats. It is therefore envisaged that the most likely application of the gill net method by DOC will be for use in pest fish surveys and monitoring. It will not normally be used for native fish inventory and monitoring.

The capture efficiency of gill nets is strongly influenced by the characteristics of the net used, such as mesh size, mesh material and filament diameter. The type of nets used in a survey should be selected based on the survey objectives; there is no standard gill net type used in New Zealand freshwaters. Standardisation of sampling gear within a survey or monitoring programme is particularly important for obtaining relative abundance data that can be compared spatially and temporally.

Data collected using gill nets can be used to estimate taxa richness or presence/absence of fish species from a location as part of inventory type surveys. Gill netting tends to have strong species and fish size biases and so should be used in combination with other sampling methods when conducting inventory surveys. The species and habitat decision trees in the 'Introduction to monitoring freshwater fish' (docdm-1008026) should be used to identify whether gill netting is the appropriate method for sampling your species or communities of interest.

Gill nets can also be used to collect relative abundance data based on calculations of catch per unit effort (CPUE). Gill net CPUE, as with other passive netting methods, is usually expressed as number of fish caught per net per unit of time (e.g. hours or nights). The accuracy of CPUE as an index of abundance is primarily determined by whether catch efficiency, or 'catchability', remains constant and unaffected by other factors (Hubert & Fabrizio 2007). Unvarying catch efficiency is one of the key assumptions made when assessing differences in relative abundance. In reality, however, a wide range of factors can influence catch efficiency when using gill nets. It is important to take a cautious approach and consider potential differences in catch efficiency when comparing relative abundance data over time and space. Standardising net types and sampling protocols is critical for obtaining reliable relative abundance data (Hubert 1996).

Assumptions

Where the data are used to determine presence/absence:

- *Methodology is standardised to account for variation in detection probability.* It is important to use a consistent and legitimate spatial sampling framework. That is, that the number of nets used is large enough to capture the range of fish that are present in the area that is represented by the sample.
- *Species of interest are truly absent from the sample area when none are detected*. This assumption will be violated when species are present but are inactive or occur at densities that are undetectable by gill netting methods. For example, many introduced cyprinids are known to be much less active at lower water temperatures and are less likely to encounter and therefore be captured by gill nets. Similarly, at very low densities fish may fail to encounter any gill nets during the sampling period and therefore evade capture and detection. Because gill nets are species-selective, only those species known to be susceptible to capture should be considered as being sampled using gill nets.

Where the data are used to compare relative abundances:

- *The relationship between number of individuals collected (index) and number of individuals present (abundance) is linear*. This is unlikely to be the case in many instances with passive netting techniques because of their dependence on fish behaviour, which can be highly variable, and the effects of gear saturation (Hubert & Fabrizio 2007). Non-linear and even inverse relationships have been found for fish density and CPUE using gill nets (Borgstrøm 1992; Linløkken & Haugen 2006).
- *Capture efficiency is independent of environmental conditions, operator proficiency, and fish species and population structure*. These assumptions should be carefully considered when making temporal or spatial comparisons in relative abundance using CPUE data, as many of these factors are known to strongly influence catch efficiency. It is recommended that the reader refer to Hubert & Fabrizio (2007) for a full description of the assumptions inherent in CPUE data.
- *There is no movement into or out of the sample area during sampling (i.e. the population is demographically closed)*. This assumption is less likely to hold if the sampling period is extended, or if the area of the body of water being sampled greatly exceeds the area in which nets are deployed. This particularly applies to highly mobile species, which are often targeted by this sampling method.

Advantages

Gill and trammel nets:

- Are one of the best methods for sampling medium- to large-bodied fish species in deep open-water habitats.

- Can be set at different depths to sample fish from different depths in the water column. This is advantageous in deep lakes especially where thermoclines may restrict fish distribution (e.g. trout during summer conditions).
- Can be set over a wide range of substrate types. However, capture efficiency will be reduced when set over very uneven or steeply sloping substrates (Portt et al. 2006).

Advantages of passive netting in general:

- Sampling is relatively unaffected by turbidity or electrical conductivity which can limit the use of methods like spotlighting or electrofishing.
- Samples are taken continuously over a long time period. This has the advantage of dampening the effects of any diurnal variations in fish behaviour (Hayes 1989).
- It allows sampling in habitats that are not wadeable because water depth or sediment depth is too great.
- Does not require a high level of technical expertise or specialist training (although the experience of field staff will influence catch efficiency).
- It causes less disturbance in shallow habitats than some active methods, such as seining or electrofishing.

Disadvantages

Disadvantages of gill and trammel netting:

- They are strongly species selective. Gill nets are most effective on medium- to large-bodied fish species and generally not considered as effective on small fish (Hayes 1989; Hubert 1996). Gill nets are not recommended for sampling fish less than about 150 mm in length although this will vary depending on the girth of target fish, with wider fish easier to catch. Eels are rarely captured in gill nets.
- There are strong biases for fish length (Hubert 1996; Portt et al. 2006). This bias is dependent on the mesh size being used and the girth and therefore length of fish being sampled. Even if standardised mesh sizes are used in a study, catch efficiency may vary with fish condition or gravidity (Portt et al. 2006). Trammel nets are considered less size selective (Hubert 1996). Gill nets are therefore not recommended for collecting data on population structure in situations where other methods can be used instead.
- Catch efficiency decreases as more fish become captured and nets become saturated. This can result in the violation of the assumption that there is a positive linear relationship between density and CPUE (see 'Assumptions' section).
- Catch efficiency can be affected by net length (Minns & Hurley 1988 in Portt et al. 2006). A 50-m net may not be as effective as two 25-m nets.
- Catch efficiency can be affected by visibility of nets underwater (Portt et al. 2006).
- There is a very high rate of mortality and injury for fish caught in gill nets. This varies depending on species but can approach 100%. Rates of mortality and injury are less when using trammel nets (Hubert 1996). Eel predation can also be a significant issue by consuming and/or injuring

other fish caught in the nets. This may influence recorded catch rates and prevent the collection of accurate length and weight data and tissue samples. Mortality, injury and eel predation rates can be reduced if gill nets are set for very short periods of time and care is taken with handling animals. Eel predation can also be reduced by avoiding the setting of gill nets overnight, using nets with separation grills or deploying light sticks at the mouth of the net.

- The inadvertent capture of water birds can also be an issue. If the birds are captured at the surface they may be able to survive but diving species are often drowned. Shags, dabchicks and scaup are birds known to have been caught in gill nets in New Zealand.
- They are difficult to set effectively in flowing habitats because of their propensity to clog up with debris, which can result in the loss or damage of nets and reduced capture efficiency. If set in streams they should be set parallel to any flow. Gill nets are not frequently used as a method for sampling wadeable habitats in New Zealand (Joy et al. 2013).
- While gill nets are used to sample large rivers overseas their use in New Zealand rivers has been limited.
- They are more difficult to set amongst complex habitat (e.g. dense weed beds or coarse woody debris) compared with other passive netting methods such as minnow traps. This can be overcome to an extent by setting nets adjacent to complex habitat and relying on resident fish to move out at some point during the sampling period. Many fish species will move out of complex habitat and into open water at night when the risk of predation is less. Eel predation on fish caught in nets at night may then become an issue, however.

Disadvantages of passive netting in general:

- There is a very high rate of mortality and injury for fish caught in gill nets.
- It provides a less accurately defined unit of effort compared with active techniques because no spatial measure is included (Hayes, Ferreri & Taylor 1996).
- It is biased towards more active fish species. The more active a fish is the more likely it is to encounter the net.
- Catch rates and taxa richness can vary with time of day depending on diurnal patterns of fish behaviour (Portt et al. 2006) and eel predation. This can be overcome by setting gear over a 24-hr period.
- It requires a return trip to retrieve gear, which may increase the level of resources required to collect data, particularly for remote sites.

Suitability for inventory

It is appropriate to use this method in the following situations for inventory:

- Where other less destructive sampling techniques cannot be used or when target organism mortality is of low concern (e.g. pest fish surveys).
- When combined with other sampling methods to target large-bodied pelagic species that may be present within the fish community. Gill netting is too species-selective to be used as an inventory tool on its own.

Suitability for monitoring

It is appropriate to use this method in the following situations for monitoring:

- Where other less destructive sampling techniques cannot be used or when target organism mortality is of low concern (e.g. pest fish surveys).
- Where the target species are susceptible to capture using gill nets. This would typically restrict the use of gill nets to medium- to large-bodied species in relatively deep, open water habitats.

Skills

Field operations:

- The setting of gill nets does not require any specialist skills or training; however, it is highly recommended that at least one team member has some prior experience with setting gill nets. In most instances a boat will be required to set gill nets. Appropriate training and certification in the operation of boats will therefore be required (refer to the standard operating procedure: 'Boat competency SOP'—docdm-346005).
- The survey team should contain at least one person able to identify freshwater fish to species level and who has experience in handling fish to minimise any unnecessary injury or mortality.

Design and analysis:

- Staff involved in the development of survey programmes should be familiar with basic principles of good sampling design. 'A guideline to monitoring populations' (docdm-870579) will assist with understanding these principles. It is important that input from statisticians is obtained during both the design and analysis stages to ensure that the data collected are scientifically robust. Good statistical design is especially critical when developing monitoring programmes as they tend to be complex and have high ongoing running costs. It is much harder to improve design after data collection has started or been underway for some time than it is to put time into the initial planning. Putting effort into designing a programme well at the outset ensures that the running costs are justified and will result in useful information that meets the monitoring objectives.
- The ability to use a spreadsheet software package such as Microsoft Excel is a minimum skill required for data entry, data checking and analyses. The ability to use statistical software packages is desirable but not mandatory provided support from statisticians is available. Staff involved in data analysis must be conscious of the underlying assumptions of gill netting when undertaking their analyses and cautious of the level of inference derived from any results.

Resources

- Survey team. A minimum of two team members will be required to safely set gill nets. In some instances it will be advisable to have larger teams, particularly if large numbers of fish are caught. Larger teams can speed up the clearing of nets and processing of fish.
- Gill nets.
- Personal flotation devices and any other boat safety equipment if a boat is being used.

- Dive knife or similar to cut nets and/or ropes in any emergency.
- Anchor weights, anchor ropes and floats. Long poles may be used as an alternative to anchors if nets are being set in shallow water.
- Clips, for quickly attaching and detaching anchors and floats.
- Fish bins. At least two bins are needed, one for deploying/retrieving nets and one for holding captured fish for processing.
- Net bags for storing nets.
- Aerator if captured fish are to be kept alive for long periods.
- Measuring board (if fish are to be measured).
- Voucher jars for fish samples / fin clips filled with 70% ethanol.
- GPS unit.
- Water quality field meter(s). As a minimum, water temperature should be recorded but dissolved oxygen is also a useful parameter to measure.
- Rain-proof data sheets with clipboard and pencils, including New Zealand Freshwater Fish Database forms.
- Freshwater fish identification book, e.g. *The Reed Field Guide to New Zealand Freshwater Fishes* (McDowall 2000).

Minimum attributes

Consistent measurement and recording of these attributes is critical for the implementation of the method. Other attributes may be optional depending on the objective. For more information refer to 'Full details of technique and best practice'.

DOC staff must complete a 'Standard inventory and monitoring project plan' (docdm-146272).

The minimum requirements for a fish survey will largely be determined by the objectives of the study or monitoring programme. Careful consideration of these objectives should be made prior to collecting data. However, for any study the following minimum attributes should be recorded:

- The name of the observers who collected the data.
- The date and time of sampling (including time set and time retrieved).
- The location of each net set using a GPS.
- Net length and depth.
- Depth of water the net was set at.
- Mesh size(s) of net.
- Mesh material and filament diameter.
- All fish collected should be identified to species level. If this cannot be done in the field then a voucher sample may be collected and preserved, or a series of detailed photographs taken for further assessment by a qualified expert. A fin clip preserved in ethanol may be taken for mitochondrial analysis.

- The number of each fish species captured.

Measurement of fish length is optional depending on whether information about population structure is part of the survey objectives. As discussed under 'Disadvantages' gill nets are known to be highly selective for fish lengths depending on the mesh size used.

It is important to collect habitat data to describe factors that may influence catch efficiency and therefore the key underlying assumptions of the method. Habitat data is also useful when it comes time to analyse data as many habitat variables will help explain why certain results were observed. The minimum habitat variables that need to be recorded are:

- Water depth
- Water temperature
- Water visibility—visual estimates (e.g. good, average or poor) as a minimum but preferably some form of measurement (e.g. Secchi depth)
- Habitat description, including presence of any macrophytes or other structure and type of substrate.

Data storage

Data should be recorded on rain-proof field data sheets to ensure that they remain intact and legible. Forward copies of completed survey sheets to the survey administrator, or enter data into an appropriate spreadsheet as soon as possible. Collate, consolidate and securely store survey information as soon as possible, and preferably immediately on return from the field. The key steps here are data entry, storage and maintenance for later analysis, followed by copying and data backup for security.

Summarise the results in a spreadsheet or equivalent. Arrange data as 'column variables'—i.e. arrange data from each field on the data sheet (date, time, location, net type, number caught, identity, etc.) in columns, with each row representing the occasion on which a given survey site was sampled. An example of a data entry template for fish data collected using passive netting methods is provided in 'Appendix B'.

If data storage is designed well at the outset, it will make the job of analysis and interpretation much easier. Before storing data, check for missing information and errors, and ensure metadata are recorded.

Summaries of all fish survey data should also be entered into the New Zealand Freshwater Fish Database (NZFFD) administered by the National Institute of Water and Atmospheric Research (NIWA). The NZFFD is an important national repository for presence/absence data and represents a valuable resource for a range of different applications including research, impact assessments and threatened species monitoring. As a minimum, site location, fishing method and species collected should be recorded in the database forms. Data can be entered electronically using the Freshwater Fish Database Assistant software, which is freely available from the NIWA website[1].

Storage tools can be either manual or electronic systems (or both, preferably). They will usually be summary sheets, other physical filing systems, or electronic spreadsheets and databases. Use appropriate file formats such as .xls, .txt, .dbf or specific analysis software formats. Copy and/or backup all data, whether electronic, data sheets, metadata or site access descriptions, preferably offline if the primary storage location is part of a networked system. Store the copy at a separate location for security purposes.

Analysis, interpretation and reporting

Seek statistical advice from a biometrician or suitably experienced person prior to undertaking any analysis. Statistical advice should preferably be sought during the design stage of any proposed monitoring programme.

There are several texts available to assist with the analysis of fisheries data. Murphy & Willis (1996) provides a useful introduction into most types of analyses but a more in-depth and up to date text is provided by Guy & Brown (2007).

Datasets obtained from gill netting can be used to provide estimates of species diversity and relative abundances. Species diversity can be easily expressed as the total number of species, or taxa richness, recorded at a site. Gill netting has a strong bias for medium- to large-bodied mobile species and so should be combined with other sampling methods when undertaking inventory surveys.

The key variable that will be used to assess relative abundances is catch per unit effort (CPUE), which provides an index of abundance rather than a measure of density. As with all passive netting methods effort is measured in terms of soak time—the time period over which nets are set. Catch per unit effort for gill nets is usually expressed as the number of fish caught per net per night. Sometimes CPUE is expressed based on the length of netting set rather than individual nets and other time periods can also be used, e.g. hours.

When calculating CPUE the catch obtained from each net should be recorded as individual sub-samples. The mean (or median) CPUE and associated variance can then be calculated for each sampling site. Catch per unit effort data tend not to be normally distributed so care should be taken with applying parametric tests (Hubert & Fabrizio 2007). Some researchers recommend using the median rather than the mean as a measure of central tendency for CPUE data (Hubert 1996; Hubert & Fabrizio 2007).

When calculating CPUE for passive capture gear it is important to be aware that soak time (the time period over which nets are set) is not a proportional measure of fishing effort. This is because catch efficiency is known to decline as more and more fish are caught in a net through a process called gear saturation. This means that setting a net over 48 hours is likely to produce a different catch

[1] http://www.niwa.co.nz/our-services/databases/freshwater-fish-database

rate to the same net set over two 24-hr periods. Direct comparisons of CPUE data obtained using different soak times are therefore not recommended unless the relationship between catch efficiency and soak time is well understood.

To use CPUE as an index of abundance it is assumed that there is a positive linear relationship between CPUE and density. This relationship is known to be different for different species and influenced by a wide range of factors including the length of net, mesh size, mesh material, season and time of day. All of these variables can influence the ability of CPUE to reflect the relative abundance of species present at a site. It is therefore critical that gill net sampling be standardised by using the same sampling design, sampling gear (e.g. net types) and deployment procedures across the sites and time periods of interest. However, even when standardised, gill net catches are notoriously variable and large numbers of net sets are often required to achieve statistical power (Portt et al. 2006).

When interpreting data obtained from gill net catches it is necessary to consider the method-specific biases outlined in the 'Disadvantages' section. When using CPUE data as an index of relative abundance the variables that can affect the relationship between CPUE and actual fish density should always be considered. For example, care should be taken when comparing the CPUE of two species caught at a site if one of those species is known to be more susceptible than the other to capture in gill nets. Ideally, the ability of CPUE to reflect actual fish density should be validated before reaching any firm conclusions about observed differences in CPUE. Validation would require fish density estimates to be made using mark-recapture or depletion model approaches. In practice this may be difficult to achieve because it requires a less destructive sampling technique than gill netting to be used. In many instances if such a sampling technique was an option it would have been used in preference to gill netting in the first place.

Depending on the objectives of the survey it may be useful to assess population structure using any fish length data that have been collected. Because of the strong size biases inherent in this method, care should be taken when interpreting length frequencies obtained using gill net data alone. Length data are typically used to generate length-frequency histograms, which allow the structure of a fish population to be assessed. Length-frequency histograms can provide an insight into factors that may be affecting fish population dynamics, such as high mortality or recruitment failure (Anderson & Neumann 1996). When interpreting length-frequency histograms it is important to consider potential size biases in sampling and whether sample size is adequate. Many statisticians now recommend density plots as an alternative to histograms because the selection of length category boundaries (i.e. minimum and maximum values) can have a large influence on the appearance of histograms.

Survey results should be reported on in a timely manner to ensure that they are available for future users. Extending the time between data collection and reporting increases the potential for useful information gathered during sampling to be forgotten and lost. A detailed description of the net types used should be included in the report so the survey can be replicated at a future date.

Case study A

Case study A: Rotopiko (Serpentine) lakes rudd survey

Synopsis

The Rotopiko (Serpentine) lakes are a complex of three small peat lakes located near Ōhaupō in the Waikato region. In response to the discovery of rudd (*Scardinius erythrophthalmus*) in the lakes in 2001, an intensive gill netting programme was initiated to protect the native-dominated submerged aquatic vegetation communities present in the lakes. Data collected during the netting programme were used to assess whether it was having any influence on the relative abundance of exotic fish in the lakes.

Objectives

- Measure changes in exotic fish abundances in the Rotopiko lakes in response to the removal of exotic fish using gill nets.

Sampling design and methods

Fine mesh gill nets (mist nets) were deployed in North, East and South lakes at varying densities. Three different mesh sizes were used: 18 mm, 25 mm and 38 mm square mesh. All nets were 15 m long and 1.8 m deep. Net densities varied between 5.4 and 15.2 nets per hectare.

Monitoring data were collected from netting carried out during each netting episode between 2001 and 2011. The netting design was standardised by using the same number of nets and net types for each sampling episode. Data collected in 2011 and between 2005 and 2011 were comparable because the same mesh size configurations were used. Data collected between 2002 and 2004 were less comparable because mesh size configurations varied. Data analysis was standardised by only comparing catch data collected from the first night of netting and from samples collected in spring.

Data collection

The number and species of fish caught in each net were recorded. The total fishing effort expended over each netting period was also recorded. Due to high levels of eel consumption of ensnared rudd and goldfish overnight many records of capture were just for species rather than length, weight or other attributes. Where more intact rudd and goldfish were required, shorter pre-post dawn sets were used to allow fish to be caught but not consumed by eels.

Results

Catch per unit effort data were calculated for each fish species as fish/net/night. Mean CPUE was then calculated for each lake and year. Only the results obtained from North Lake are presented here for the sake of brevity.

The mean CPUE for rudd was initially high in North Lake (4.90 fish/net/night) in 2001 when the netting programme began (Figure 1). In Spring 2002 the CPUE for rudd was substantially lower at 1.05 fish/net/night but then increased again in 2003 to 2.38 fish/net/night. Between 2003 and 2007 the mean CPUE for rudd was relatively stable but since that time the catch rates for rudd have fluctuated significantly. In 2009 rudd CPUE was 4.6 fish/net/night, which was comparable with that originally recorded in 2001. In 2011 a CPUE for rudd of 0.78 fish/net/night was calculated, which was the lowest CPUE recorded since the study began.

The CPUE for goldfish and catfish have generally been lower than that for rudd in North Lake (Figure 1). An increase in goldfish catch rates was initially observed after the initiation of the netting programme and peaked at a mean CPUE of 3.27 fish/net/night in 2003. Since that time the density of goldfish has decreased and has remained relatively low since 2006.

Catfish were initially caught in very low numbers from North Lake but the species now dominates gill net captures (Figure 1). Between 2004 and 2011 the mean CPUE for catfish increased from 0.10 fish/net/night to 2.76 fish/net/night.

The netting effort used in North Lake peaked at 1520 net nights in the year ending in Spring 2003 but has declined since (Figure 1). Between 2004 and 2007 netting effort remained relatively constant at around 500 net nights. There was a large decrease in effort from 2007 onwards when the objective of the netting programme shifted from removing fish to monitoring fish abundances. The peak in fishing effort does not correspond to any noticeable reductions in CPUE for any of the species and preceded the large increase in CPUE observed for rudd in 2009.

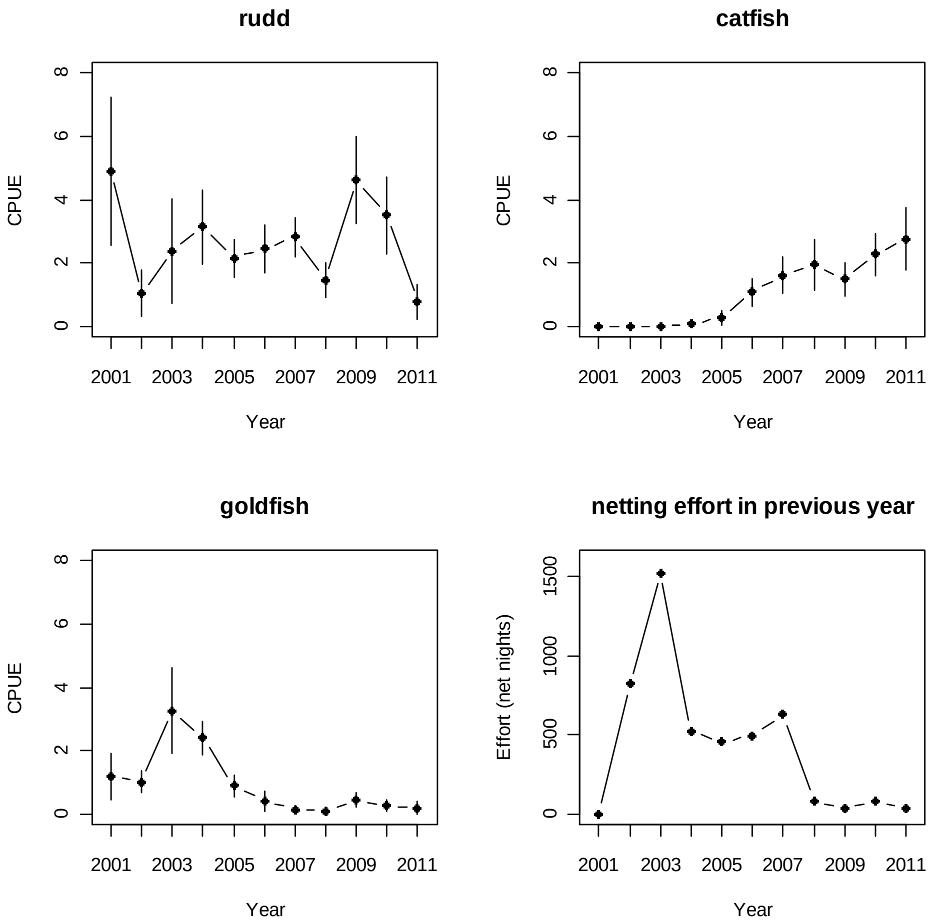

Figure 1. Catch per unit effort (CPUE) (fish/net/night) on the first night of netting for three exotic fish species and total netting effort expended in the preceding year for North Lake. Error bars denote 95% confidence intervals.

Limitations and points to consider

The netting removal programme carried out between 2001 and 2007 did not appear to have caused any sustained reduction in rudd numbers in North Lake. Catfish numbers increased over that same 2001–2007 time period and have continued to increase since netting effort was reduced in 2008.

These conclusions are based on the assumption that CPUE accurately reflects the relative abundance of rudd and catfish present in the lake. Validation of this assumption would allow more confident conclusions on changes in the relative abundances to be made.

Monitoring of exotic fish in the Rotopiko lakes using gill nets is likely to continue as a way of assessing other fish management options that were being planned at the time of writing.

Acknowledgement

Data were collected by staff from DOC Waikato Area Office and the Waikato Regional Council (formerly Environment Waikato).

Full details of technique and best practice

Net selection

A wide range of factors should be considered when selecting which gill nets should be used for a survey. Mesh material, filament diameter, mesh size and net length will all influence the species, numbers, and sizes of fish caught (Portt et al. 2006).

Mesh material refers to the material used to produce the net. Choose gill nets made from monofilament as it is the standard gill net material used in fisheries research and is the most efficient at capturing fish (Hubert 1996).

Filament diameter refers to the thickness of the filaments that are joined together to create the mesh. Generally, the thinner the filament diameter used in a gill net the more effective it is at capturing fish. This is particularly true for small mesh diameters where a fine filament is required to allow small fish to become wedged or gilled in the net. There is a trade-off with using fine filament diameters as the nets are more easily damaged and will need to be repaired or replaced more frequently.

The size of the openings in net mesh is referred to as mesh size and it can be measured in two ways. Square mesh or knot-to-knot measurements are taken as the distance between adjacent filament knots or joins. Stretched mesh measurements are taken as the widest distance between opposing knots or joins when the mesh is pulled taught.

It is important to use a range of mesh sizes to maximise the range of species and fish sizes that are effectively sampled. This can be achieved by using multi-panel (or variable mesh) gill nets that are made up of a series of panels, each with different mesh sizes. Alternatively, a range of different single-mesh gill nets could be used.

Gill nets used in research are typically less than 2 m in height and a net height of 1.8 m is the standard benthic gill net used in North America (Bonar et al. 2009). There is theoretically no limit to the length of gill net that can be used; however, very long nets will be difficult to set and retrieve and in the event that they become badly damaged, expensive to replace. The length of the ‘standard core mesh net’ used in North America is about 25 m (Bonar et al. 2009). Gill net lengths of between 15 and 30 m are recommended for most applications in New Zealand.

When using gill nets to gather relative abundance data it is critical that netting gear be standardised by ensuring that exactly the same type or types of nets will be deployed at all of the sites and time periods of interest. Select nets with characteristics that will best meet the survey or monitoring objectives and then continue to use those net types throughout the programme.

The location of nets can influence their catch efficiency and the potential risk to non-target species. Avoid setting nets over steep sloping stream or lake beds as these will compress and close the mesh openings (Bonar et al. 2009). If the habitat to be surveyed is likely to contain habitat for diving birds, such as dabchick (*Poliocephalus rufopectus*) or scaup (*Aythya novaeseelandiae*), follow the appropriate netting protocols (see ‘Set nets and diving birds: best practice guidance’—docdm-1470778).

Waterproof labels identifying that the nets are being used by DOC and providing a contact phone number should be attached to all nets. These will help prevent well-meaning people from removing nets during sampling.

Gill nets are best deployed from a boat using a team of at least two people. The main steps involved in setting gill or trammel nets are as follows:

1. Before deploying a net it is important to ensure that it is not tangled and does not contain any debris that may prevent it from hanging properly. Layering the net within a large fish bin while keeping the float and lead lines apart will help make deploying the net much easier. Some net makers (e.g. Lindeman) supply gill nets with a net hook which is another convenient way of deploying and retrieving fine mesh gill nets. Good net organisation prior to deployment is the key to safely and efficiently setting gill nets. Also ensure the water is of sufficient depth to allow the lead line and float lines to be sufficiently separated.
2. Attach a large float to the top of the anchor line and a weight to the bottom of the anchor line. Anchor ropes can be prepared in advance with loops tied at points corresponding to the required depths for the float and lead lines.
3. Drop the anchor over the side of the boat, quickly followed by the float line. Check that the net has not become twisted as it has descended. Long stakes or poles can also be used to anchor both ends of the net in shallow water.
4. The boat operator slowly backs the boat away from the first anchor and float. If possible avoid setting nets across the wind as this will make achieving an effective set difficult. Deploy the net slowly over the front of the boat while ensuring that the float lines and lead lines separate cleanly and do not become twisted. A dive knife or similar type of knife should be kept within arm’s reach at all times in case there is a need to sever nets or ropes in an emergency situation.
5. When the end of the net is reached, attach another anchor and float and drop overboard. Ensure there is adequate tension between the two anchor points and the float and lead lines. Gill nets will work best when allowed to ‘hang’ properly with the mesh openings maximised.
6. Record the location of nets using a GPS or draw up a map of the site showing net locations.
7. Leave the net in place over the duration of the required sampling period. Capture rates will be maximised by setting nets overnight to include both the dusk and dawn periods when fish movement is greatest (Portt et al. 2006). If survey objectives require the capture of live or whole fish then consider setting for shorter durations and/or avoid setting nets at night when the risk of eel predation is high.
8. Retrieve the net by pulling in one end of the net and removing the float and anchor. Slowly work your way up the length of the net pulling it overboard and placing it into an empty fish bin. Remove fish and any debris from the net as it is retrieved.
9. Process the fish as required. Return any native or sports fish and humanely euthanise any pest species. If fish species cannot be identified in the field, retain and preserve a sub-sample as a voucher collection for closer examination under a stereo microscope or by a qualified expert.

10. If information on population structure is required then measure fish using a measuring board. Record total length, which is the distance between the tip of the snout and the tip of the longest tail fin rays. If information on population structure is not required to meet the study objectives, consider only recording minimum and maximum lengths for each species to reduce processing time. If large numbers of fish are being captured and lengths need to be recorded, subsampling can be used as a way of reducing processing time. Another approach to reducing processing time would be to assign individual fish to length categories rather than actual lengths. Length categories for different species have been identified by Joy et al. (2013).
11. Measure and record all of the habitat parameters that are relevant to the survey. The minimum parameters that should be recorded are outlined in 'Minimum attributes'. More detailed descriptions of recommended parameters are outlined in the sections below.
12. Decontaminate all sampling gear to prevent the spread of pest species. Guidelines for net decontamination are provided in 'Freshwater fishing net decontamination protocol' (docdm-428359). Additional useful guidance can be found in 'Review of weed transfer risk associated with mudfish sampling and mitigation strategies' (docdm-645392), and on the Ministry for Primary Industries website[2].

Additional considerations when setting gill nets in lakes

- Consider the presence of any stratification when selecting net locations and depths. Fish may be concentrated in either the upper or lower layers depending on species present. Avoid setting nets within deoxygenated hypolimnion zones as catch rates will be lower in those areas and mortality rates are likely to increase.
- Catch rates will usually be greater in the littoral zones of lakes than in deep open water (pelagic) habitats. Most surveys will require that all available habitats are sampled but if the objective of the survey is to maximise the number of fish collected then concentrate nets in the littoral zone.
- Set gill nets perpendicular to the shore or contour lines to increase the potential to intercept moving fish.
- Habitat variables that should be recorded in conjunction with gill net catches in lakes include:
  - Water depth
  - Water temperature
  - Water clarity (Secchi depth)
  - Dissolved oxygen concentrations (preferably at surface and 1 m off bottom)
  - Habitat description including presence of any macrophytes or other structure and type of substrate nets were set on

Additional considerations when setting gill nets in wetlands

- The capacity to set nets in wetlands will generally be limited unless there are reasonably large areas of open water present. It may be possible to clear open areas in thick vegetation to allow the setting of nets but consideration should be given to the effects of such habitat modification, both in terms of experimental design and ecological impacts.

[2] http://www.biosecurity.govt.nz/pests/didymo/cleaning

- Habitat variables that should be recorded in conjunction with gill net catches in wetlands include
  - Water depth
  - Water temperature
  - Water clarity (Secchi depth)
  - Dissolved oxygen concentrations (preferably at surface and 1 m of bottom)
  - Habitat description including presence of any macrophytes or other structure and type of substrate

Additional considerations when setting gill nets in rivers and streams

- In most situations the accumulation of debris will be a significant issue that will limit the use of gill nets as a survey and monitoring tool in rivers or streams. This accumulation can be minimised by setting nets parallel to the flow and in habitats that experience little or no flow (e.g. pools and backwaters). Short soak times will also reduce debris accumulation. Capture efficiency may be increased by setting nets close to the bank, see 'Protocols for pest fish inventory and monitoring best practice guidance' (docdm-756153) for guidance.
- National protocols for assessing habitat in wadeable streams have been developed by Harding et al. (2009) and most regional councils will have appropriate standardised methods that could be adopted. Note that many of these methods won't be applicable to large non-wadeable streams and rivers. Habitat variables that should be recorded as part of gill net surveys in rivers and streams are:
  - Average stream width and depth
  - Substrate composition
  - Meso-habitat composition
  - Riparian cover and condition (a useful method has been developed by Collier, Kelly & Champion 2006)
  - Qualitative habitat assessments (e.g. P1 and P2d field sheets from Harding et al. 2009)

References and further reading

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Appendix A

The following Department of Conservation documents are referred to in this method:

docdm-346005	Boat competency SOP
docdm-428359	Freshwater fishing net decontamination protocol
docdm-870579	A guideline to monitoring populations
docdm-1008026	Introduction to monitoring freshwater fish
docdm-756153	Protocols for pest fish inventory and monitoring best practice guidance
docdm-1470778	Set nets and diving birds: best practice guidance
docdm-146272	Standard inventory and monitoring project plan

Appendix B

Data entry template for passive netting methods

This is an example of how to enter fish data collected using passive netting methods. This data entry template uses a 'long format' where individual records are entered in rows and variables are entered in columns. While this format can be more time consuming than other formats when entering data, it will save a lot of time and effort when it comes to data analysis. Multiple analyses can be quickly carried out using this one dataset thereby avoiding the need to re-enter the same data. This dataset format can be readily manipulated and summarised using filter, sort and pivot table tools found in Microsoft Excel. Most statistical software packages require that data be entered in 'long format'.

Net type	Net number	Species	Length (mm)	Number of fish	Comment
Type of net or trap used	Number assigned to each net/trap of a given type	Fish species caught. Important to record ‘No fish’ where none were caught in a net/trap.	Length measured for individual fish	Number of fish in this record. Note that this will always be 1 when the fish is measured.	Any comments regarding record (e.g. any injury or disease observed in fish)
Fyke net	1	*Anguilla australis*	600	1	
Fyke net	1	*Anguilla australis*	600	1	
Fyke net	1	*Anguilla australis*	570	1	
Fyke net	1	*Anguilla australis*	404	1	
Fyke net	1	*Anguilla australis*	506	1	
Fyke net	1	*Anguilla australis*	506	1	
Fyke net	1	*Anguilla australis*	606	1	
Fyke net	1	*Anguilla dieffenbachii*	407	1	
Fyke net	2	*Anguilla australis*	502	1	
Fyke net	2	*Anguilla australis*	505	1	
Fyke net	2	*Anguilla australis*	500	1	
Gee’s minnow trap	1	*Galaxias maculatus*	76	1	partially eaten
Gee’s minnow trap	2	*Galaxias maculatus*	68	1	partially eaten
Gee’s minnow trap	2	*Galaxias maculatus*	67	1	partially eaten
Gee’s minnow trap	2	*Galaxias maculatus*	88	1	
Gee’s minnow trap	2	*Galaxias maculatus*	79	1	
Gee’s minnow trap	2	*Galaxias maculatus*	92	1	
Gee’s minnow trap	2	*Galaxias maculatus*	76	1	
Gee’s minnow trap	2	*Galaxias maculatus*	74	1	
Gee’s minnow trap	2	*Galaxias maculatus*	79	1	
Gee’s minnow trap	2	*Galaxias maculatus*	88	1	
Gee’s minnow trap	2	*Galaxias maculatus*	63	1	
Gee’s minnow trap	2	*Galaxias maculatus*	69	1	
Gee’s minnow trap	2	*Gobiomorphus basalis*	60	1	gravid female
Gee’s minnow trap	3	*Galaxias maculatus*		14	
Gee’s minnow trap	4	No fish			
Gee’s minnow trap	5	No fish			