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2013 Independent review of the information available for monitoring trends and assessing the status of New Zealand freshwater eels

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Preface

The Ministry for Primary Industries and its predecessor, the Ministry of Fisheries, have conducted fully-independent expert reviews of stock assessments, research methodologies and research programmes since 1998. We also run specialist technical review workshops to further advance fisheries and other marine science methodologies and techniques. These fully-independent reviews and technical workshops are separate from, but complementary to, the annual Science Working Group processes that are used to ensure the objectivity and reliability of most of our scientific research and analyses.

A new publication series, Fisheries Science Reviews, has been initiated in 2015 to ensure that reports from these reviews are readily accessible. The series will include all recent and new fully-independent reviews and technical workshop reports, and will also incorporate as many historical reports as possible, as time allows. In order to avoid confusion about when the reviews were actually conducted, all titles will include the year of the review. They may also include appendices containing the Terms of Reference, a list of participants, and a bibliography of supporting documents, where these have not previously been incorporated. Other than this, there will be no changes made to the original reports composed by the independent experts or workshop participants.

Fisheries Science Reviews (FSRs) contain a wealth of information that demonstrates the utility of the processes the Ministry uses to continually improve the scientific basis for managing New Zealand's fisheries.

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Independent review of the information available for monitoring trends and assessing the status of New Zealand freshwater eels

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25 November 2013

1 Background

This section is taken from the Ministry for Primary Industries' Terms of Reference (ToR) for the review. The complete ToR is appended to the end of this report.

The New Zealand eel fishery is based on the two temperate species of freshwater eels occurring in New Zealand, the shortfin eel *Anguilla australis* and the longfin eel *A. dieffenbachii*. A third species of freshwater eel, the Australasian longfin (*A. reinhardtii*), identified in 1996, has been confirmed from North Island landings. The proportion of this species in landings is unknown but is thought to be small. New Zealand's native freshwater eels are taonga to Mäori, and are targeted by customary Mäori, amateur and commercial fishers.

Both longfin and shortfin eels are managed under New Zealand's Quota Management System (QMS). In the North Island, Quota Management Areas (QMAs) are designated separately for longfin under the code LFE and for shortfin under the code SFE. In the South Island, QMAs are specified for the two species combined under the code ANG, although commercial landings are usually reported by species.

The management objective for freshwater eels is to secure social, economic and cultural benefits from each eel species by maintaining adequate spawning biomass to provide for high levels of recruitment, and protecting, maintaining and enhancing eel habitats. Research contracted by the Ministry for Primary Industries (MPI) is focused on monitoring trends in the recruitment of elvers and in the abundance of larger exploited eels. This and other information is also used by the Department of Conservation (DOC) to fulfil various obligations such as assessing the threat status of New Zealand's native species, and by regional Councils and iwi and other groups to inform local area management. Habitat protection is addressed by developing peer networks with natural resource management agencies such as DOC, the Ministry for the Environment and Regional Councils, and by identifying habitats of particular significance to freshwater fisheries. Habitat degradation is a significant issue for freshwater eels.

The research planned on a routine basis to monitor the status of New Zealand shortfin and longfin eel stocks may be divided into three categories:

> **Standardised Catch per Unit Effort (CPUE):** Indices of abundance, based on standardised CPUE, are produced for the commercially targeted portions of eel populations within each QMA. The CPUE indices are updated on a 3 year cycle. Although the ANG QMAs of the South Island are composed of both shortfin and longfin eels, separate indices of abundance are produced for each species. CPUE analysis is done at the spatial resolution of Eel

Statistical Areas (ESAs). Each QMA consists of multiple ESAs and in most cases the ESA providing most of the catch is used to produce an index of abundance for the QMA. In some instances (e.g. ANG15) two indices of abundance are calculated as both support important fisheries, i.e. one for each ESA. MPI intends, where this is possible, to develop CPUE based management targets for each species within each QMA. Low numbers of active permit holders, inconsistent participation across years after the introduction of eels into the QMS, and generally low overall catch and effort activity resulted in unreliable/poor indices of abundance after 2001 for several South Island QMAs.

Elver Recruitment: Annual numbers of the elvers of each species passing hydro-electric power dams on several rivers are recorded by stakeholders, mostly (but not exclusively) as part of their resource (operating) consent conditions. Eels recruit into rivers as transparent glass eels in their first year of life and spend some time in estuarine reaches before moving upstream. Elvers, the next stage in the life-cycle, are 1-4 yr old and move upstream as they grow older. Elvers entering the traps at sampling sites therefore comprise more than one year class, with the number of year classes in the sample and average size/age increasing with the distance of the dam/site from the mouth of the river. Although field surveys targeting glass eels may provide a better indication of annual recruitment, the cost of monitoring multiple rivers would be prohibitive (New Zealand law currently does not allow the harvesting of glass eels). Elver catch indices at dams are nevertheless thought to provide a long term indication of recruitment trends, which in conjunction with CPUE and the size composition of the catch, contribute substantially to the overall understanding of abundance and stock status.

Size Composition: Proportions of the catch of each species falling into market-related size categories are provided by all major Licensed Fish Receivers (LFRs) that process eels. The data are provided annually at a sub-ESA spatial resolution related to catchment. Increasing rates of exploitation are expected to result in higher proportions of the catches of each species in smaller size categories. Given that there is sometimes less market demand for eels in the medium size category, with the result that eels in this category are often avoided or released, modelling relative abundance of the large size category (standardised CPUE) is being investigated.

In early 2013 the Parliamentary Commissioner for the Environment (PCE) completed a review of the stock status of longfin eels. One of the conclusions of the PCE's report was that the information used by MPI to monitor eels had limited value and that greater emphasis should be placed on the following alternative data:

New Zealand Freshwater Fish Database (NZFWFDB): This is a voluntary database containing a substantial quantity of research data, beginning in 1960, that could potentially be used to monitor eel abundance. It is mostly presence/absence data collected using electric fishing by a variety of organisations including NIWA, the Department of Conservation (DOC) and Regional Councils.

Electric Fishing Size Composition Data: Regional Councils and NIWA have a substantial quantity of length frequency data for both longfin and shortfin eels collected by electric fishing in wadeable streams.

The PCE’s report also recommended “the establishment of a fully-independent peer review panel to assess the full range of information available on the status of the longfin eel population”. The purpose of this review is therefore to review the utility of all sources of data and analytical methods that have potential for monitoring the abundance and informing the stock status of both species of New Zealand freshwater eels, with particular emphasis on longfin eels, and to draw conclusions on what this information reveals about the status and trends of freshwater eel populations.

2 Panel members

In order to be fully-independent, panel members must have no current or previous connection with the research, monitoring, assessment or management of New Zealand eels and must declare any actual or potential conflicts of interest that might affect their ability to come to an objective view of current or alternative methods for monitoring the abundance and status of New Zealand eels.

Alex Haro

Dr. Haro is a Research Ecologist with the S.O. Conte Anadromous Fish Research Laboratory (Ecosystems Mission Area, U.S. Geological Survey) at Turners Falls, Massachusetts, USA. He has previously consulted with Dr. Jacques Boubée (NIWA, Hamilton) on general aspects of fish passage, eel biology, and telemetry, but has no current or previous formal collaboration with research, monitoring, or assessment of New Zealand eels.

Willem Dekker

Dr. Dekker is a fisheries scientist from the Swedish University of Agricultural Research. He has been involved in national and European studies on the status of the European eel stock. He has not been involved in studies on New Zealand eels before.

Nokome Bentley

Mr Bentley is a fisheries scientist from New Zealand. He has no current or previous connection with research, monitoring, assessment or management of New Zealand eels. MPI is a major client of Mr Bentley's research company, Trophia Ltd. Trophia is both a competitor and collaborator of NIWA, a major provider of eel monitoring and research. Neither of these linkages affects Mr Bentley's ability to provide a scientifically objective view of eel monitoring or assessment.

3 Report organisation

The following five sections address each of the objectives in the Terms of Reference (ToR) for the review. We have reordered the topics from the ToR in what we consider to be a more logical flow. Sections 4 (Efficacy of current monitoring), 5 (Alternative monitoring) and 8 (Status and trends of eel populations) were listed in the ToR as primary objectives and sections 6 (Habitat based assessments) and 7 (Reference points), as secondary objectives. For each section, relevant excerpts from the ToR are provided in italics.

4 Efficacy of current monitoring

The primary objective for the expert panel is to provide advice to the Ministry for Primary Industries on the efficacy of current and alternative methods for monitoring the abundance, population trends and stock status of shortfin and longfin eels.

Although the above excerpt from the ToR mentions "current and alternative methods" we limit this section to an examination of current methods and discuss alternative methods in the following section (Section 5).

4.1 Elvers at dams

Specifically...the use of annual information on the numbers of elvers at dams to monitor trends in recruitment

It should be noted that there is currently some lack of definition of the term "elver" with respect to age; "elver" can be interpreted to mean either: (a) unpigmented "glass" eels recently transformed from leptocephali and entering freshwater for the first time, typically less than 12 months of age (i.e. age 0+); (b) 0+ glass eels that have developed some pigmentation; or (c) eels of older age classes (1+ and older) that have developed extensive pigmentation and begun to feed and grow. For the purpose of the Panel's discussion, and for clarification in this section, it was decided to refer to juvenile eels collected at dams as follows:

0+ eels: recently transformed leptocephali, first year in freshwater, both pigmented and unpigmented. Also referred to in other sections as **glass eels**.

1+ and older eels: eels of age 1+ and older

juvenile eels: 0+ and 1+ and older eels are referred to collectively

Juvenile eels (approximate age 0+ to 4+) are collected below hydropower dams at four sites on the North Island (Karapiro, Matahina, Waikaremoana, and Patea Dams) and three sites on the South Island (Arnold, Waitaki, and Roxburgh Dams). Data have been collected from different sites over the period from 1991 to present, but over varying time periods (8 to 19 years), with not all years sequentially sampled. Trapping is conducted during the migratory season; capture efficiencies of traps are unknown but are assumed to be relatively high due to the absence of accumulations of upstream migrants below the dams.

Species composition (by weight) is determined by separating each species from a subsample of at least 100 individuals (if present). Prior to the subsample being taken, the catch is well mixed to ensure that the subsample examined is representative of the catch. Each species fraction is then weighed and an average individual weight for each species calculated. Based on the total weight of each fraction an estimate catch weight of each species is obtained. The species-specific total numbers in the catch are derived from the estimated catch weight of each species and the respective average species weight. For days when subsamples of the catch are not examined, the nearest available records are used.

No significant trends in juvenile eel recruitment indices for either shortfin or longfin eels have been observed at any site except Waikaremoana (increasing, for both species), but the time series for most sites are relatively short, and improvements to several traps have been made within the first several years of operation that have resulted in increased trap efficiency that may bias trend data upward.

The Panel concluded that counts of juvenile eels at dams was an effective monitoring method for assessing general trends in recruitment of juvenile eels (of multiple age classes) to freshwater habitats. Absolute numbers of 0+ eels are difficult to measure directly in catches, due to large catch numbers. Sub-sampling and otolith ageing of a representative sample of the catch would allow for extrapolation of absolute numbers of 0+ eels (as well as 1+ and older eels) within a daily catch sample, but this technique can be extremely labour-intensive if applied to all daily catch samples. Ageing of a "snapshot" of catches on a less regular basis may allow representation of age class distribution of catches over a season for a particular site, but the frequency of sampling required to obtain a representative snapshot would need to be determined.

The Panel had concerns about dependency of performance of traps on hydrodam operations; i.e., alterations in dam operation or configuration might influence attractiveness of traps to juvenile eels, thus biasing counts either upward or downward. Therefore any changes in dam configuration/operation or modifications to trap design should be accounted for in future count data. To more comprehensively monitor new recruits to the eel populations, the Panel recommends increasing the number of sampled dam sites (close to tidal limit), especially in the South Island; a more comprehensive geographic representation nationwide is preferred. At existing sites, the Panel recommends continued monitoring to extend the time series under existing trap configurations, and documenting increases in trap efficiency when improvements are made to trap design or operation. Also, recruitment indices are based on total counts of all juvenile eels collected, which may represent several year classes, not exclusively 0+ eels. Age-specific counts data would provide more accurate estimates of recruitment of 0+ eels for a given year. The Panel therefore recommends development of a protocol for otolith ageing of juvenile eels in subsamples to provide age-specific recruitment data, or development of some other less labour-intensive technique (e.g., pigmentation, condition factor) to (at a minimum) accurately discriminate 0+ eels from the multi-year class catch without the need for otolith ageing (see also Section 4-*Alternative Monitoring*). Accurate ageing of the entire juvenile eel catch would also enable back-calculation of age-specific growth and possibly survival below dams.

4.2 Commercial catch size composition

Specifically...the utility of information on the size composition of the commercial eel catch

Monitoring of landed commercial eel catches has only been underway in New Zealand for a relatively short period (9 years for the North Island; 5 years for the South Island). Coverage has been complete for North Island subareas, but only complete for the South Island subareas for 2010- 11 and 2011-12. There is relative confidence in the accuracy of the more recent data. Landing weights for each species are currently recorded only for three distinct size grades (small, medium, and large).

For the North Island, catch is heavily concentrated within several subareas, but is relatively consistent within subareas between years, for both species. Most of the catch came from less than about six subareas. No trend was noted in North Island shortfin eel catch, size grade, or spatial distribution. Similar lack of trend was noted for North Island longfin eel, but there was some influence of quota availability and market demands on catch.

For the South Island, most of the shortfin eel catch came from three subareas, while dominant catches of longfin eel came from about ten subareas. Trends in South Island catch cannot be presently determined with only two years of complete coverage.

New initiatives to improve data resolution and reporting (trials in 2014) include:

- Greater resolution on location of catches (GPS-based), and identification of individual fishers
- Number and type of nets used (including baiting)
- Species targeted by fishers (shortfin or longfin)
- Number of >4 kg longfin eels released
- By-catch species caught
- Environmental data (e.g., river flow)
- Uploads of data to a centralized database

The Panel concluded that landings data, while still incomplete in terms of time series for the South Island, were a valuable asset in terms of information on spatial distribution and consistency in catch. Additional initiatives to increase spatial monitoring and resolution should prove beneficial for answering questions about catch within subareas, and possible market-driven trends in catch. The Panel recommends implementing proposed advancements in fine-scale catch data resolution and reporting.

Additionally, the Panel recommends implementing sampling of specific sizes within the three size grades to better resolve size selectivity.

4.3 Size composition from electric fishing surveys

Specifically...the utility of information on the size composition of eels in electric fishing surveys

Analysis of size class distribution in electrofishing samples is a potentially useful means of inferring year class strengths and informing estimates of growth and mortality. However, because observed size-frequencies are an accumulated result of several potentially confounding processes, care needs to be taken when making such inferences.

During the review, size-frequency distributions were presented by year for each of three NIWA electrofishing sites (D. Jellyman, NIWA). The size-frequencies were generally consistent within each site across years with consistent differences in size distribution among sites. This pattern suggests differences among sites in size-selectivity of the electrofishing method. The Panel acknowledged the potential for site-specific selectivity of electrofishing methods, where under some conditions smaller eels are more difficult to see and capture while electrofishing, or remain buried under sediments or bottom structure.

Site-specific selectivity of electrofishing can result in bias when these data are used to infer year class strengths. The modelling study of Graynoth et al. (2008) assumes the same size-selectivity in samples from at all sites. Given this, the estimates of recruitment strength from this study should be used with caution. The overall modelling approach is useful for reconstructing historical year class strengths. However it is important that additional data be collected, or analyses be done, to better determine any differences in selectivity among sites.

The Panel recommends that the potential for site-specific size selectivity of the electrofishing method be evaluated, quantified, and, if possible, a method for correction be developed. The Panel recommends that age data continue to be collected from electrofishing samples.

4.4 Commercial catch per unit effort

Specifically...the use of standardised CPUE to monitor the abundance of the vulnerable portion of the eel population

In our opinion the CPUE standardisations that have been conducted for New Zealand eels are comprehensive, use appropriate methods, are well documented and appear to have been thoroughly peer reviewed by the EWG. The Panel recommends that such CPUE analyses continue to be done regularly. However, CPUE indices need to be interpreted with caution and in the remainder of this section we outline potential issues and suggest some improvements that could be made to these analyses.

There are widely recognised problems with the use of fishery catch per unit of effort (CPUE) for monitoring fish populations. Despite this, because it is often one of the few indices available, CPUE is widely used to monitor fisheries around the world. Rather than ignore CPUE entirely, the general approach taken is to (a) as far as possible standardise for factors other than biomass that affect CPUE, and (b) be cognisant of potential biases when interpreting CPUE indices. This general approach appears to have been applied in the case of New Zealand eels. Below we briefly describe potential issues with eel CPUE and how, if at all, they have been addressed. We do not consider any of these problematic enough to warrant completely ignoring eel CPUE indices.

4.4.1 Unrepresentative of entire population

CPUE is a relative index of the biomass of eels that are vulnerable to fishing. It does not provide an index of the biomass of eels that are invulnerable to fishing including those that are (a) not allowed to be taken legally (e.g. large females that are released), (b) not selected by the fishing method (e.g. small eels that exit nets through escape tubes), (c) not in areas where fishing occurs (e.g. small, inaccessible streams). It appears that the authors of the CPUE analyses and the Eel Working Group are aware that CPUE is not an index of the entire eel population and interpret CPUE indices accordingly

4.4.2 Changes in effort characteristics

Standardisation of CPUE via Generalised Linear Models (GLM) is done to remove the confounding affects on CPUE of changes in factors such as the number of net lifts and months of fishing. For New Zealand eels, most of the GLMs included as standardising factors, at least fishing permit (to account for changes in the composition of the fishing ‘fleet’ e.g. the dropping out of less efficient fishers and retention of the most efficient fishers), lifts (to account for changes in the amount of effort used to take the catch), month (to account for changes in seasonality e.g. a shift towards only fishing in the best months).

However, in interpreting CPUE indices it should be remembered that there may be changes in fishing effort that are not recorded on catch-effort forms and thus which cannot be taken into account in the GLMs. These include subtle changes in fishing gear and behaviour. For example, over time there may have been improvements in fyke nets or in their deployment. There was some discussion during the review about the potential for such unquantified changes. The general consensus appeared to be that there had been little change in the methods used over the last two decades. A comment was made during the review that fishing had "gotten smarter" but we were not presented with any evidence of this.

It should also be acknowledged that there are changes in effort that may bias CPUE downwards. For example, if due to changes in TACs, fishers shift their targeting from species A towards species B then it may bias CPUE downwards for species A. It is possible this may have occurred in the North Island where there was a greater reduction in TACC for longfins than for shortfins.

4.4.3 Hyperstability

The relationship between CPUE and vulnerable biomass may not be strictly linear. Hyperstability describes the situation in which CPUE does not fall as rapidly as biomass. In the New Zealand eel fishery this may occur for two principal reasons. First, fishing effort may move serially, deplete biomass in a localised area and then move to an undepleted area. Second, eels may move from areas of less preferred habitat into areas of preferred habitat which fishers target thereby maintaining CPUE despite overall decline in biomass.

The review briefly discussed both serial depletion and eel movement as mechanisms for hyperstability. In the North Island, catch data are available at the level of subarea (in most cases a catchment) since 2004. This finer scale data does not show strong evidence of shifts in effort from one subarea to another. It is not possible to rule out that serial depletion may be occurring at finer spatial scales. In the South Island, the time series of subarea catch is only available for two years so no conclusions can be drawn on changes in the distribution of catch at that level. However, during the review it was noted that fishing effort in the South Island is more mobile than in the North Island and less restricted to "territorial patches".

4.4.4 Nonlinear relationships between catch and effort

During the review a concern was raised that catch may not be directly proportional to fishing effort. That is, as effort declines in a fishery the catch:effort ratio may increase simply because there a limited amount of catch being divided amongst fewer units of effort. The corollary of this is that as effort increases, the catch:effort ratio declines and the relationship between catch and effort plateaus. This phenomenon is likely to be more pronounced in a fishery where the gear is highly efficient and a single unit of effort is capable of taking a large proportion of the vulnerable population. It could be argued that, at least on small rivers or streams, this is the case for the eel fishery. However, at the larger statistical area scale, it is likely that exploitation rates would have to be very high before this phenomenon had a substantial bias on CPUE.

In addressing this concern it is important to note that the GLM models used to standardise CPUE use catch (not catch divided by effort) as the dependent variable and effort (i.e. lifts) as one of the dependent variables. Thus, at the scale of an individual fisher day (as recorded on catch effort forms), it is not assumed that catch is linear to effort. Indeed, the plots of estimated relationship between catch and effort (e.g. Figure J26 of Beentjes 2013a) indicate a plateau effect. Nonetheless we urge researchers to be mindful that non-linearities in the catch-effort relationship may exist at small spatial scales when considering the combined effort of all fishers.

4.4.5 Lack of target variable and treatment of zero catches

The CPUE standardisation is based on positive catches only. No attempt has been made to standardise the presence-absence information that is in the data in the form of zero catches of each species.

During the review it was noted that there were large reductions in the proportion of zero catches during the mid-2000s in many ESAs (e.g. Figure A4 of Beentjes 2013a). It was discovered that this was an artefact of the way that the data had been treated (the records which only recorded eels unidentified, code EEU, had be retained for the summary) and the plots were regenerated and provided to us (Figure 1 includes two examples).

The proportion of zero catches of each eel species is likely to be most affected by which species is being targeted. Longfin and shortfin generally live in quite different habitats and as a result fishers generally target, and catch, one or the other. Unfortunately, target species is not recorded on the more recent ECER forms and so this cannot be accounted for by the GLM. In some ESAs, the proportion of zero catches of each species mirror each other (Figure 1, top plot). This suggests that changes in target species are indeed a dominant factor. However, in most ESAs the proportion zeros for each species fluctuate independently suggesting that other factors, such as population occurrence, may be an influence (Figure 1, lower plot).

<u>The Panel recommends that future CPUE analyses attempt to reconstruct the target species in data from ECER forms</u>. There are several potential avenues for this. One is to reconstruct a target for each record based on the catch composition for that record. This could be done using simple catch percentage thresholds (e.g. 50%, 60% etc) above which a record is considered to be targeting one species or other. More advanced approaches include using multivariate modelling with target included as a “latent” variable (i.e. estimated variable for each record). This would be a far more sophisticated and resource intensive analysis but would have the additional advantage of allowing the records that only record species as EEU to be utilised.

<u>The Panel recommends that if and when target species has been reconstructed, that binomial models be considered for standardising the observed proportion of zero catches.</u>

4.5 Occurrence and relative abundance indices from surveys

Specifically...the utility of information on the frequency of occurrence of shortfin and longfin eels in electric fishing surveys stored on the NZFWFD

Surveys of freshwater fish, including eels, have been conducted by a number of groups including NIWA, regional councils, iwi and hapu, using booth electric fishing and fyke nets. Such fisheries independent data can be very useful for monitoring and assessing fish populations. As such, whilst noting that these surveys can be expensive, the Panel encourages their continuation.

Recent work to standardise sampling protocols (Joy et al. 2013) is an important step towards improving the reliability of survey data and we encourage further coordination among organisations in this regard. In particular, the protocols developed by Joy et al. (2013) for fyke net sampling could be useful for any further expansion of sampling by iwi and hapu.

Electro fishing surveys being conducted by the Waikato and Otago regional councils, amongst others, and fyke net surveys being conducted by iwi and hapu potentially provide indices of relative abundance. Whilst these surveys are currently of relatively short duration (3-5 years) as they continue they could be increasingly valuable datasets. The Panel recommends that electric fishing and fyke net survey data be analysed to assess their potential to provide indices of relative abundance.

Modifications to the NZFWFDB to include abundance data (in addition to presence/absence data) are encouraged. Having a single database for all eel survey data would be ideal and the NZFWFDB may be an appropriate repository for the various surveys undertaken, including fyke net surveys undertaken by iwi and hapu.

During the review presentations were made on recent analyses of occurrence data in the NZFWFDB. The work appears to be preliminary and we encourage further development. In particular, we suggest that annual indices be generated by,

- region (e.g. North Island/South Island, catchments or groups of catchments) to examine for spatial differences in trends
- habitat type (e.g. lower/upper catchments) to examine for range contractions

Most of the work presented used Generalised Linear Models (GLMs). Preliminary analyses using boosted regression trees (BRTs) were presented. Although BRTs are a potentially powerful tool for analysis of these data we suggest that the analysts focus first on the above, more detailed, analyses using GLMs, which are more familiar to Eel Working Group members and have been used for analysing CPUE.

During the review concerns were expressed about committing too many resources to this analysis of the NZFWFDB given that it only provides indices of occurrence. However, given the long duration of this dataset (more than 30 years) we consider it worthwhile to make the best possible use of the large volume of accumulated survey data. Although occurrence indices are less useful than abundance indices they still hold value for monitoring eel populations. The Panel recommends further analysis of occurrence data from the NZFWFDB.

The (potential) distribution of the longfin eel spans almost all aquatic habitats, from the larger rivers and estuaries to the upland streams and creeks. Anthropogenic impacts may affect the stock in all those habitats. Monitoring and assessment should ideally address the full distribution area and all anthropogenic impacts. The very small proportion of the stock in each small habitat unit and the sheer number of those units makes this an extremely challenging task (Dekker 2000). According to Graynoth et al. (2008), the part of the stock in the smaller, unexploited habitats can be up to half of the total stock biomass – which indicates that fisheries-dependent assessments focusing on the larger, exploitable habitats probably give a restricted view on the whole stock.

Data available for the smallest units often show a reduced level of detail; semi-quantitative data or even just presence/absence data commonly occur. This applies to electro-fishing surveys in the smaller creeks, fyke net surveys in small rivers, etc. Noting the high proportion of the eel stock residing in these smaller habitat units, a judicious choice must be made between coverage and data-detail. The Panel considers that even presence/absence data can be informative, when considering the effect of migration barriers and range contractions due to diminishing abundance. The current availability of less-quantitative data from general fish surveys in several regions enables exploring this. Additional information from customary users, when available and properly standardised, may also be utilised.

Aiming at a comprehensive assessment (fisheries and other anthropogenic impacts) using available information also from the smaller-scaled water-bodies, the type of assessment model may need to be considered. On the one hand, the panel took note of the derivation of reference points (section 8), using a conventional age-structured population dynamics model, focusing on dynamics (mortality), wherever the eel and the impacts may occur (non-spatially differentiated). On the other hand, there is the GIS-based approach (section 7), in which prime focus is on stock abundance (biomass) in relation to environmental characteristics of the scattered habitat, and less attention is paid to the dynamics resulting in the current abundance distribution. The Panel notes that each approach has its pros and cons, and notes that assessments of temperate eel stocks in the northern hemisphere struggle with the same dichotomy in methods. For the longfin assessment, the Panel recommends a more comprehensive approach than currently presented, in which classical and alternative data sources are used to the full, all anthropogenic impacts are considered, and the stock dynamics as well as the spatial differentiation is taken into account.

5 Alternative monitoring

Based on evaluation of these datasets and the analyses applied to them, the Panel should provide advice to MPI on information that should be routinely collected to monitor New Zealand shortfin and longfin eels, with recommendations on how such data collection programmes are best designed and analysed. The Panel will have the latitude to recommend alternative data collection programmes and analytical approaches.

The Panel identified several potential alternative methods of monitoring; these methods may also be considered supplemental to existing methods. Some consideration should be given to whether any alternative method can be effectively scaled up to the regional or national scale, in order to assess whether monitoring data can be applied to a larger scale.

Sampling of glass eels at mouths of rivers using nets, traps, etc. – This method is employed in Europe and North America as a monitoring technique to specifically target glass eels entering freshwater and thus estimate recruitment of the youngest available age classes. Sampling sites would be systematically selected throughout the geographic range (North and South Islands) where glass eels regularly congregate (e.g., head of tide). Typical gear would include elver nets (fine mesh fyke nets) or fixed traps (e.g. Dekker 2002), fished systematically with individual elver length, age, and fishing effort recorded. This method would also require a technique for discriminating age classes of juvenile eels within catches, as described in section 4.1, *Elvers at Dams*.

Monitoring escapement of migrants – No systematic program for monitoring of migrant eels exists in New Zealand, so spawning escapement of eels is unquantified. The Panel identified this as a deficiency in the monitoring program, as escapement is a critical component of survival to reproduction. Escapement of eels is notoriously difficult to measure directly, and usually has to be estimated via systematic sampling. Long-term monitoring of escapement may not be feasible, but initial estimation of baseline escapement would have great value. Potential methods for monitoring escapement include the following:

- *Trapping of migrants* – Downstream migrant eels can be intercepted by fyke nets or weirs set in smaller streams or rivers, or by downstream bypass samplers at hydrodams. These devices would need to be maintained and operated continuously throughout the downstream migratory season. However, it is often difficult to ensure that any downstream sampling device operates with 100% efficiency (e.g., high flows can compromise or destroy nets or weirs; downstream bypasses at dams are usually not 100% efficient), so estimates of escapement using these methods may have limited accuracy, or require correction (e.g. through mark-recapture studies; see below).

- *Telemetry* – Eels can be collected and tagged with telemetry tags (e.g., radio, acoustic, or passive integrated transponder [PIT] tags), and their passage at downstream sites can be monitored with autonomous data logging receivers. Radio or acoustic tags would allow monitoring of passage/escapement in larger rivers, but have limited transmit life, so only fish expected to emigrate within a short time period could be tagged. Cost of these tags also limits the number of fish tagged. PIT tags are lower cost, so more fish can be tagged, but detection ranges of PIT tags are limited, therefore only smaller rivers or bypasses or constriction points at dams could be monitored with PIT receivers. Because only a subset of potential migrants within a study catchment can be tagged, total escapement would need to be estimated from additional population sampling.

- *Mark-recapture* – Marking of migrant eels prior to the migration season, followed by additional sampling for marked fish after the migration season has ended could yield data on proportion of fish that emigrate (e.g., marked fish not recaptured). Additional data from mark-recapture studies include local immigration/emigration of eels into or out of various freshwater habitats, including immigration of eels into areas that are fished. However, mark-recapture methods are also subject to error incurred by mark retention, catchability of marked fish and natural mortality prior to emigration, which would also need to be estimated.

Mark-recapture of sub-adult, resident life stages – Data on age-specific mortality, growth, age validation, and other life history metrics of pre-migrant eels could be obtained by mark-recapture studies in various environments. Techniques for these studies vary widely depending on study objectives; commercial, customary commercial and customary non-commercial fisheries could be employed to facilitate these studies.

Assessment/monitoring of anthropogenic non-fishing mortality – The Panel identified significant gaps in knowledge regarding anthropogenic non-fishing mortality; i.e., mortality incurred by habitat loss, pollution, disease, passage of emigrating eels through turbines, spillways, water withdrawal structures, and other sources. Because all mortality in pre-migrant eels is pre-reproductive mortality (McCleave 2001), these effects are potentially significant for population sustainability in eels. The proportion of reproductive loss that each of these factors incurs, however, is unknown for most eel species. Nonetheless the Panel agreed that these components of total mortality would be important to assess and monitor, both locally and for the two populations as a whole.

<u>The Panel recommends consideration of these alternative/supplemental methods</u>. Many of these methods can be conducted with enhancement of existing work or implementation of new work by NIWA, regional councils, iwi and hapu.

6 Habitat based assessments

Graynoth et al. (2008) used a GIS approach to estimate the following: 1) the proportion of longfin eel habit that is not fished commercially; 2) proportions of the longfin eel population in unfished and fished areas; 3) spawning escapement (as a proportion of virgin levels); and4) commercial exploitation rates. The results of this study have been widely and uncritically used by various agencies, with little attention paid to the assumptions necessary to estimate the respective metrics. A secondary objective of the fully-independent expert review is therefore to review the Graynoth et al. (2008) methodology, providing advice on the assumptions and the reliability of results. Recommendations on data and analytical methods that would improve upon estimates made using this approach will also be useful. The Panel should also provide advice on the utility of closed areas in maintaining or rebuilding eel stocks.

The Panel notes that Graynoth et al. (2008) developed and implemented a novel approach, in which current and pristine eel biomass are estimated from a spatial model, which takes into account spatial differentiation in habitat characteristics and anthropogenic impacts. The French model, Eel Density Analysis (EDA), developed by Jouanin et al. (2012), has followed the same line of thinking, although these latter authors were not aware of the earlier development by Graynoth etal.(2008).

The longfin model is tuned on data from 212 quantitatively sampled sites, located in 5 Regions; the French model is tuned on data from 9 556 quantitatively sampled sites scattered all over the country. There is little doubt that the 212 longfin samples represent a restricted basis for the analysis, and the Panel points at the opportunity to use more data sets that can be made available relatively easily (regional, customary, etc.). Additional semi-quantitative data might contain less information, but the high number of available samples probably makes it worth exploring these too.

On the relationship between fishing pressure and abundance: The fishing pressure exerted is generally unknown; Graynoth et al. (2008) estimated it on the basis of the simulated relationship between fishing pressure and mean size, and the observed mean size. The mean size at sampling sites has been recorded, but details (tabular or graphical) have not been provided in the report. Of the 212 sampled sites, 69 are reported to have been exploited and the remaining 143 have not. A comparison of the mean size at the exploited and unexploited sites could have been used to at least partially indicate the adequacy of the simulated relationship. This information not being available, the Panel could not evaluate the adequacy and relevance of the effects of exploitation as assessed in this report. However, we note that the assumed relationship between mean length and exploitation rate is derived from a simulation model that is based on life history parameters from a single river and assumes deterministic recruitment and a constant exploitation rate.

The analysis focuses on the biomass of the standing stock in lakes, rivers and streams - which is a static, observable variable. The line of reasoning is that there is a relationship between location- specific environmental characteristics and eel abundance, which can only be true if the eel abundance is determined by those environmental conditions (i.e. not by a low number of eels recruiting to the location), which implies that eel abundance is at (or near) carrying capacity. Noting that fished locations are assumed to have a reduced abundance, this density dependence (carrying capacity) apparently affects the under-sized life stage. Evidence for the presence of density dependence in the under-sized stage and its absence in the exploited stage is not shown.

Graynoth et al. (2008) conclude that current spawner escapement is probably less than 20% of the pristine state, and discuss whether or not current recruitment is below the historical level, and whether that leads to a reduction in female escapement or is compensated by density dependent mechanisms. The Panel notes an inconsistency with respect to the assumption about the existence of density dependence.

The report analyses the longfin abundance at 212 sampled sites, and extrapolates that to the whole country. The impact of fishing is taken into account as is the effect of natural and man-made barriers to migration. Habitat loss (land drainage), however, has not been accounted for, because it cannot be quantified and habitats are unlikely to be restored. Consequently, the resulting estimate of "original" escapement effectively refers to the best possible escapement from current habitats only (B_{best}, in the terminology of ICES-WGEEL), and therefore does not represent the pristine state (B_0). Expressing current escapement as a percentage of "historical" escapement (i.e. pre- exploitation and pre-dating the major habitat loss) is therefore inadequate. Noting the many uncertainties in the relationships and parameter values in the current analysis, the Panel recommends exploring the pristine escapement using approximate estimates of habitat loss. Consideration of the potential effect of density dependent mortality operating in areas of habitat saturation will be required; density dependent natural re-distribution over available habitats has been shown in the European eel (Briand et al. 2005).

Noting that the assessment of the status and trends in the eel stock requires consideration of fisheries and non-fisheries anthropogenic impacts (including altered habitat characteristics and habitat loss), the Panel considers habitat/GIS-based approaches an important step forward. The currently available analysis applies a mix of a limited set of observations, empirically derived relationships, simulated relationships, and GIS-based extrapolation, ignoring habitat loss. The Panel considers that further development is required before the adequacy and relevance of the results for the management of the stock can be evaluated. Noting the capability of habitat-based assessments to include most non-fishery mortalities operating in smaller-scaled water-bodies, the Panel recommends further development of this line of research.

7 Reference points

MPI has recently commissioned the National Institute of Water and Atmospheric Research (NIWA) to develop selected reference points for the assessment and management of longfin eels. The reference points will include the biomass associated with maximum sustainable yield, B_{MSY} (as a percentage of the unfished level, B_0) and the fishing mortality rate associated with maximum sustainable yield, F_{MSY}. The sensitivity of these reference points to a range of stock-recruitment relationships and to growth rates (which may vary substantially amongst localities) is also to be investigated. A second secondary objective of the fully- independent expert review is therefore to review the reference point analysis.

The Panel was informed about the development of selected reference points for longfin eels by a presentation given by A. Dunn (NIWA, work in progress). Following a review of the available information on biological process parameters (natural mortality, recruitment variability, steepness of the stock-recruit relationship, weight-at-size, size-at-age, and maturation), a derivation of B_{MSY} and F_{MSY} was presented, including the sensitivity of these indicators to assumptions about natural mortality and the steepness of the stock-recruit relationship.

The Panel considered the derivation to be state-of-the-art. As concerns the adequacy of the analysis, it is noted that the application of a standard model (CASAL) narrows the analysis to the current fishery on resident yellow eel – other anthropogenic impacts (migration barriers, habitat loss, hydropower generation related mortality, catch & carry of immigrating and emigrating eels, and customary exploitation of emigrating silver eel) have remained out of scope. Even in a framework in which the biomass of the fishing yield is optimised, the other anthropogenic mortalities should be taken into account.

Estimates of B_{MSY} and F_{MSY} are sensitive to the length-selectivity of the anthropogenic impacts; it seems highly unlikely that non-fisheries anthropogenic impacts have the same length-selectivity as the fishery. Not knowing the magnitude and length-selectivity of the non-fisheries mortalities (in comparison to the fishing mortality), the Panel felt unable to judge the potential effect of the other anthropogenic mortalities on the derived reference points. Additionally, potential density dependence in the freshwater phase, might affect the results considerably.

The Panel notes that through the documents and presentations available, there seems to be a lack of consistency with respect to what anthropogenic impacts have been taken into account (fisheries and non-fisheries); what biological processes are assumed/proven to exist (in particular density dependence in the freshwater phase); and whether or not the stock is in (severe) decline (which would potentially rule out recent density dependence).

The stock-recruit relationship for eels is poorly understood, and available historical time series are too short to enable an empirical derivation. It is not known, if – and at what level – the spawning stock biomass is limiting the production of new recruits. In a world-wide perspective, however, a steep decline of northern temperate eel stocks (in Europe, America and Asia) has been observed, and concerns have been raised that this might be due to four potential factors:

1. A strong reduction in the quantity of maturing eels escaping from the continent to undertake spawning in oceanic locations (Dekker 2003). The quantitative reduction might

be caused by over-exploitation, habitat loss, migration barriers, hydropower generation related mortality, or other factors on the continent;

2. A depensatory stock-recruit relationship (Dekker 2004), in which the production of new recruits is severely hampered, even at intermediate spawning stock levels. When the spawning stock declines, depensation results in recruits declining faster than the adult stock – as observed in the European eel in recent decades;
3. A deteriorating quality of the emigrating silver eels, leading to a reduced likelihood of successful spawning and/or a reduced fecundity and/or a lowered viability of the offspring (Belpaire 2008). This may include the effect of chemical pollution on migratory capacity/fecundity/viability; the effect of introduced parasites (e.g. *Anguillicoloides*) on swimming behaviour; or unnatural early silvering and emigration due to altered environmental conditions on the continent;
4. Climate change in the ocean (Knights 2003). This may affect the adult migration towards and congregation at the spawning location, the larval growth and survival, or the transport of larvae towards the continent.

For the European eel, there is a growing number of studies addressing the potential causes of the observed decline – but at the bottom line, there is no hard evidence or shared view; scientific advice is based on the Precautionary Approach.

The presented study on potential reference points for the longfin eel addresses one (quantity) of the four potential mechanisms. The Panel notes that it is quite unlikely that the New Zealand longfin eel stock has already experienced a decline as dramatic as that in the northern temperate eel stocks. Consequently, the estimated reference points (B_{MSY} and F_{MSY}) are based on theoretical considerations, extrapolating from the current conditions and assumed functional relationships. The Panel feels unable to predict in detail what effect the other mechanisms might have on the reference points. However, if these mechanisms are considered, it seems likely that the risk criterion used (SSB > 20% of B_0, 90% of the time) is likely to become more important than the yield- maximisation objective. The Panel recommends considering what potential effect the other mechanisms (depensation, spawner quality, climate change) might have on the derivation of reference points, and to consider the potential effects of non-fisheries anthropogenic mortalities.

8 Status and trends of eel populations

Based on their analysis of these and other datasets, the Panel shall draw conclusions on the status and trends of the New Zealand longfin and shortfin eel populations, and indicate any aspects of particular concern (e.g. age structure, sex ratios and proportions of migrants).

It is important to state that our conclusions regarding the status and recent trends of New Zealand eel populations imply nothing regarding past or potential management actions.

8.1 Status

Here, we use the word *status* to refer to the current spawning biomass as a proportion of the average pristine spawning biomass (i.e. the mean spawning biomass prior to any human impact). Estimating the status of any fish population is fraught with difficulty. In most cases this is simply due to the lack of data from the period when the population was in a pristine state or during the initial depletion of the stock. This is certainly the case for New Zealand eel populations which have comparatively little data prior to the 1990s.

Given these difficulties, we consider it inappropriate for us to draw strong conclusions on the status of New Zealand eel populations. Collectively we have extensive experience in the assessment of fish populations and eel populations in particular. However, our experience with the New Zealand eel populations is almost entirely restricted to the term of this review. Therefore, in attempting to come to a conclusion regarding the status of New Zealand eel populations, we have, in the first instance, based our conclusions on those of experienced New Zealand eel scientists and then briefly comment on whether we find their conclusions to be consistent with the evidence presented during our review.

Longfin eels

Jellyman (2012) concluded that "there is no doubt that the longfin resource is seriously depleted". We agree that there is a high probability that the longfin eel population has been substantially reduced relative to pristine biomass. However we consider there to be a high level of uncertainty regarding the current stock status. Graynoth et al. (2008) estimated stock status at about 20% B_0. The EWG (2013) estimated that "the biomass of longfin eels above the minimum weight at migration is less than 20% of historical values". We have already stated our concerns with the methods used by Graynoth et al. (2008) to estimate longfin status. The estimate of the EWG is also highly uncertain. Nonetheless, we do not consider either of these estimates to be implausible given the biology of the species and the duration and extent of culling, habitat modification, damming and customary and commercial fishing.

Shortfin eels

There has been less focus on estimating the stock status of shortfin eels. The MPI EWG has expressed the general view that, compared to longfin eels, there is less concern regarding the status of shortfin eels. However, they also note that caution is required given the nature of their biology and the fact that they are harvested before spawning. We concur with both these views.

8.2 Trends

Here we use the word *trend* to refer to the general direction of recent changes in the biomass, or other attributes, of New Zealand eel populations. In comparison to the population status, it is far easier for us to come to conclusions on trends in eel populations simply because these conclusions can generally be drawn directly from the available data and analyses. In summarising the trends we have focussed on indices of relative biomass and abundance from CPUE and electric fishing surveys. To both facilitate and justify our conclusions, we have included figures of the indices that were made available to us.

In section 4.4 we listed, and briefly discussed, some potential issues with using CPUE as an index of eel population biomass. Nonetheless, as already stated, we do not believe that CPUE should be ignored when examining trends in eel populations. Figure 2 provides all current CPUE indices for longfin eels (from Beentjes and Dunn 2013a and Beentjes and Dunn 2013b). Figure 5 provides all current CPUE indices for shortfin eels (from Beentjes and Dunn 2013a and Beentjes and Dunn 2013b).

In section 4.5, we briefly described some potential limitations of electric fishing survey data but concluded that, because of the standardisation of fishery independent sampling protocols, they are a useful, fishery-independent method for monitoring eel population abundance. Indices of occurrence based on electric fishing surveys in the NZFWFDB are provided in Figure 3 (longfins) and Figure 6 (shortfins).

Indices of relative abundance based on data provided to us by NIWA, the Waikato Regional Council and the Otago Regional Council are provided in Figure 4 (longfins) and Figure 7 (shortfins). So that they could be compared on the same plot, we have scaled the annual abundance at each site by the geometric mean of annual abundance at each site. These surveys cover a limited time period but we examined them as a source of fisheries independent data to see if they confirmed, or not, trends seen in the other data. It should be noted that the Otago Regional Council's surveys used a different sampling methodology in 2007 and 2008 that may affect the relative indices in those years. It should also be noted that these indices differ from CPUE indices in that they include eels less than the minimum legal size and the sites are generally small streams not commercially fished.

We limit our conclusions regarding trends, to trends in sub-adult biomass or abundance. We have not considered trends in recruitment based on either (a) age or length structure from electric fishing surveys or from commercial fishing, or (b) elvers at dams. To do (a) requires inferences and assumptions to be made regarding, among other things, the size selectivity of surveys and we did not have sufficient time to make these with confidence. For (b), we consider there to be potential biases with the data collection (i.e. improvements in elver trap design) that may confound the trends at some sites (see Section 3.3).

Longfin eels

For longfin eels in the North Island there was a general decline in CPUE across eel statistical areas (ESAs) from the early 1990s until the late 2000s. There is some suggestion that since the late 2000s there has been a slowing, and perhaps even a halting, of these declines. For the South Island there are differences in trends among ESAs. However, the same general pattern is evident; the declines in CPUE observed during the 1990s have slowed, and perhaps even slightly reversed, in the most recent years (Figure 2).

We note that, in general, electric fishing surveys provide indices of occurrence or abundance that are similar to the trends in relative biomass seen from CPUE indices: a period of decline from the early 1990s to the late 2000s followed by relatively stable abundance (Figures 3 & 4).

Shortfin eels

For shortfin eels both the North and South Island CPUE indices show similar trends: a decline in CPUE during the 1990s followed by a quite sudden, and substantial, increase in CPUE starting in the mid 2000s.

The index of occurrence of shortfin from the NZFWFDB also exhibits an increase during the 2000s but shows a recent decline not seen in the CPUE indices (Figure 6). Indices of relative abundance from the electric fishing surveys conducted by the regional councils are not inconsistent with the CPUE indices with most survey sites exhibiting an increase during recent years (Figure 7).

8.3 Concerns

The panel was asked to indicate any aspects of particular concern. We have noted the concerns, expressed by the Eel Working Group and others, regarding the relative susceptibility of eel populations, and longfin eels in particular. These include the facts that eels are long lived and are affected by habitat modification and pollution. We do not have any further concerns over and above those that have already been expressed.

9 Wrapping up

To review the information used for monitoring eel populations in New Zealand, a fully- independent peer review panel was established, and it is this panel that reports its findings in this document. The overarching aim of the review was to examine the utility of the data and analytical methods used for monitoring the abundance and informing management for both species of New Zealand freshwater eels. In the preceding sections, we have discussed and evaluated a range of specific objectives regarding the utility of specific data sources, and we have commented on the quality and adequacy of the analyses made using these data.

The management objective for freshwater eels is ”to secure social, economic and cultural benefits from each eel species by maintaining adequate spawning biomass to provide for high levels of recruitment, and protecting, maintaining and enhancing eel habitats”. This requires consideration of a diversity of types of data. In the course of our review, we were presented extensive analyses of data sets collected routinely or on an ad-hoc basis. We have provided comments on each of these in the preceding sections, but our most striking observation is that most data sets have been collected and analysed in relative isolation. Depending on the data used and the approach taken, different conclusions have been reached.

On the one hand, there are the conventional data sources for fisheries management, including catch-per-unit-effort, recruit surveys, and commercial catch sampling – for which conventional reference points are being developed targeting an optimal level of fishing. On the other hand, there are the more typical fresh-water sampling programmes, including general fish stock monitoring in streams, presence/absence scoring, and habitat-based assessment of the inland stock – which (can) respond to typical fresh-water issues such as habitat loss/degradation.

What appears to be lacking is an integration of the different information sources, a comprehensive assessment addressing all potential impacts/threats to the eel – informing the managers on the status of the stock as well as its resilience to human impacts in inland habitats. Additionally, we have noted that several data sources have been identified, that have not yet been used to the fullest possible extent, while at the same time the shortage of adequate information is a recurring theme in discussions.

Finally, we note that the presentations and discussions during our review were co-operative and productive, and that all parties expressed their willingness to contribute to the data collection and assessment.

From our experience in the assessment of (northern) temperate eel stocks we know that eels are difficult to assess. This is not only because many of the eels’ biological characteristics are unknown or atypical amongst exploited fish species, but also because eels cut across governance structures, span environments as different as the open ocean and the mountain creek, are impacted by land, river and fisheries activities, and can be monitored and assessed using a range of diverse methodologies. Maintaining healthy eel stocks in productive habitats requires comprehensive assessment, integrating across these environments, impacts and methodologies.

From a northern temperate perspective, we note the ubiquity of New Zealand eels, the relative richness of information sources, and the high quality of the analyses that have been undertaken. In recent years, European countries have initiated comprehensive assessments of their respective parts of the eel stock, and American states have recently started that same process. In our view, current circumstances enable a similar development of comprehensive eel population assessments in New Zealand.

10 Acknowledgements

We are grateful for the insights and constructive inputs made by participants at the review meetings. We thank Pamela Mace and Marc Griffith (MPI) for their considerable efforts in organising and chairing the review. Thanks to Don Jellyman (NIWA), Bruno David (Waikato Regional Council) and Matthew Dale (Otago Regional Council) for providing us with abundance data from electric fishing surveys. Thanks also to Erica Williams (NIWA) for providing logistical support during our deliberations.

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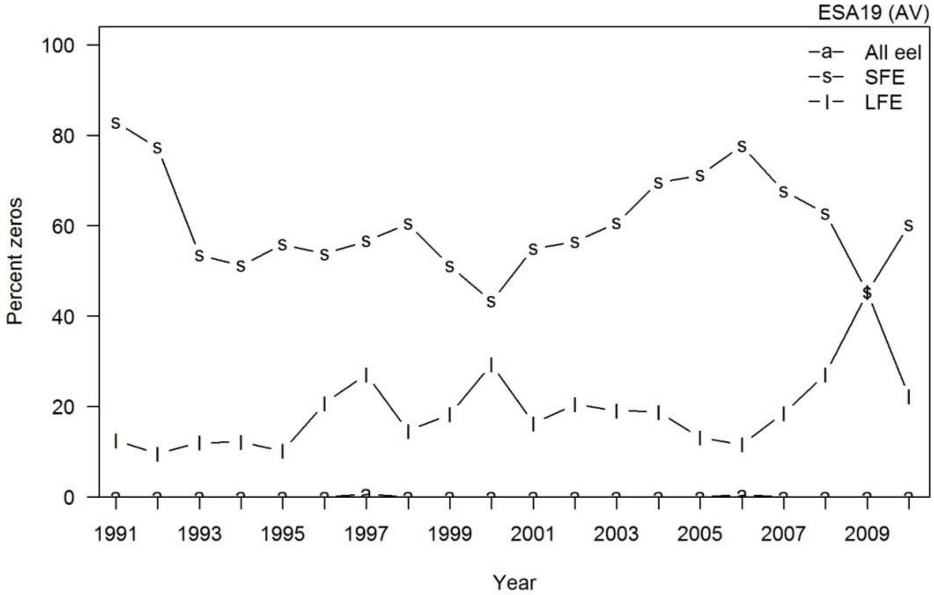


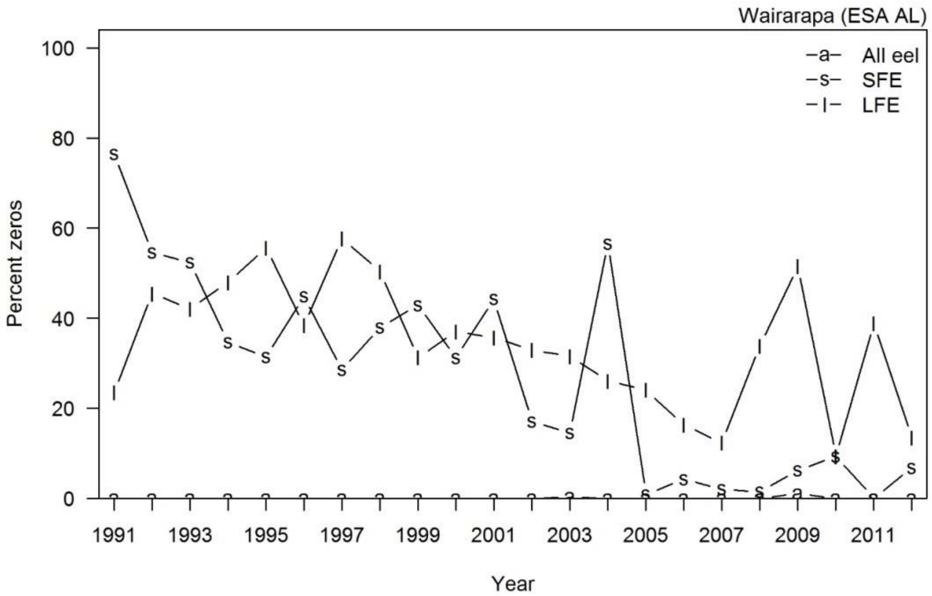


Figure 1: Percent of catch-effort records where the catch of one of the eel species was zero. Two example ESAs that exhibit contrasting patterns are shown. Figures provided by M. Beentjes (NIWA).

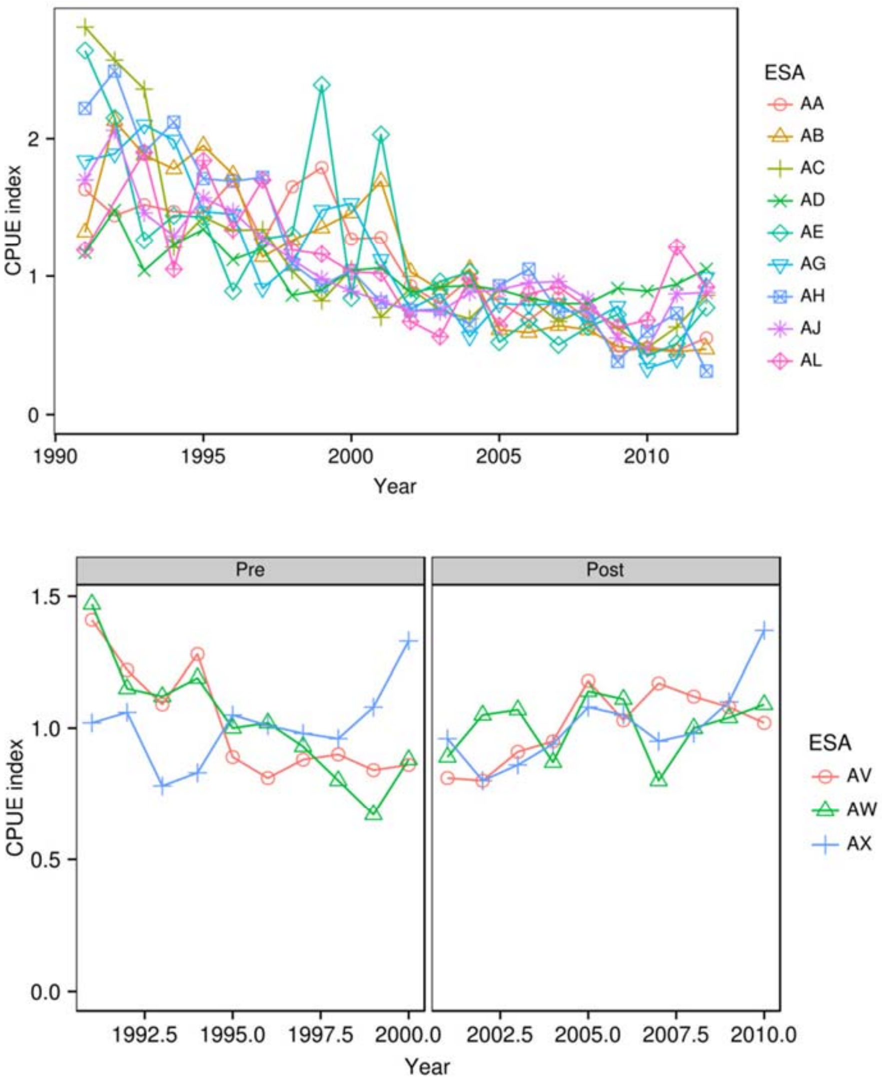


Figure 2: CPUE indices of relative biomass for longfin eel in the North Island (top) and South Island (bottom). From Beentjes and Dunn 2013a and Beentjes and Dunn 2013b. Two North Island ESAs with high c.v.s are excluded.

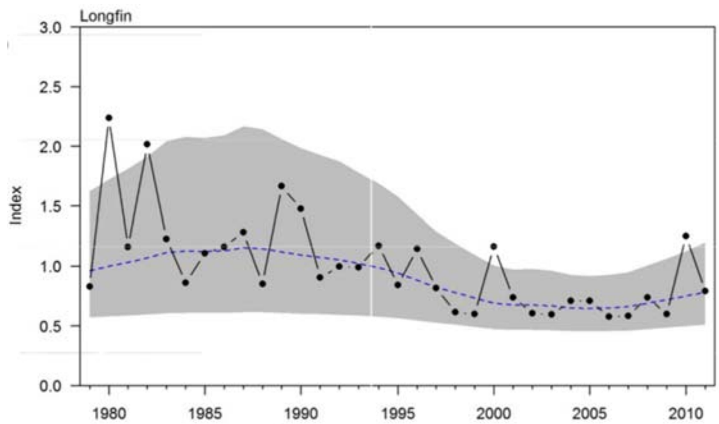
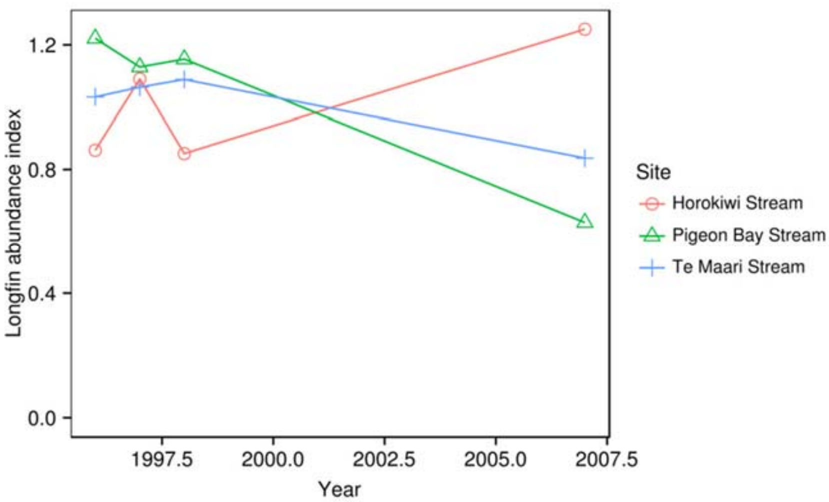


Figure 3: Standardised index of occurrence of longfin eels from electric fishing surveys in the NZFWFDB. From Crowe & Dunn presentation to the review.

A



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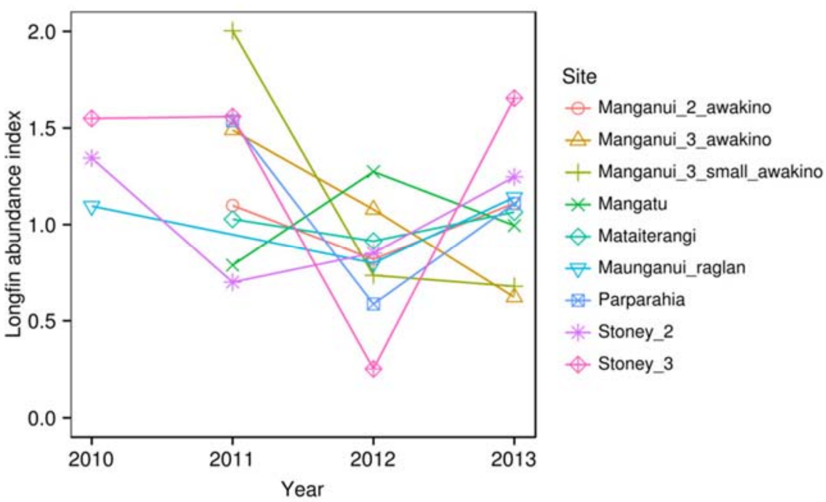

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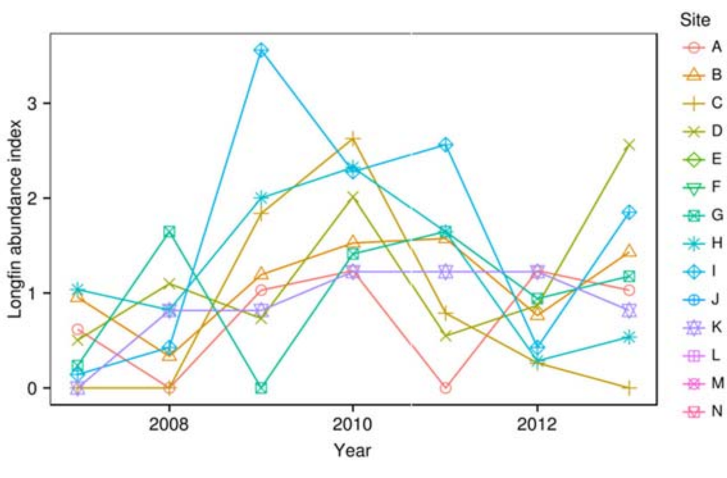


Figure 4: Indices of relative abundance for longfin eels from electric fishing surveys conducted by (A) NIWA, (B) Waikato Regional Council, and (C) Otago Regional Council.

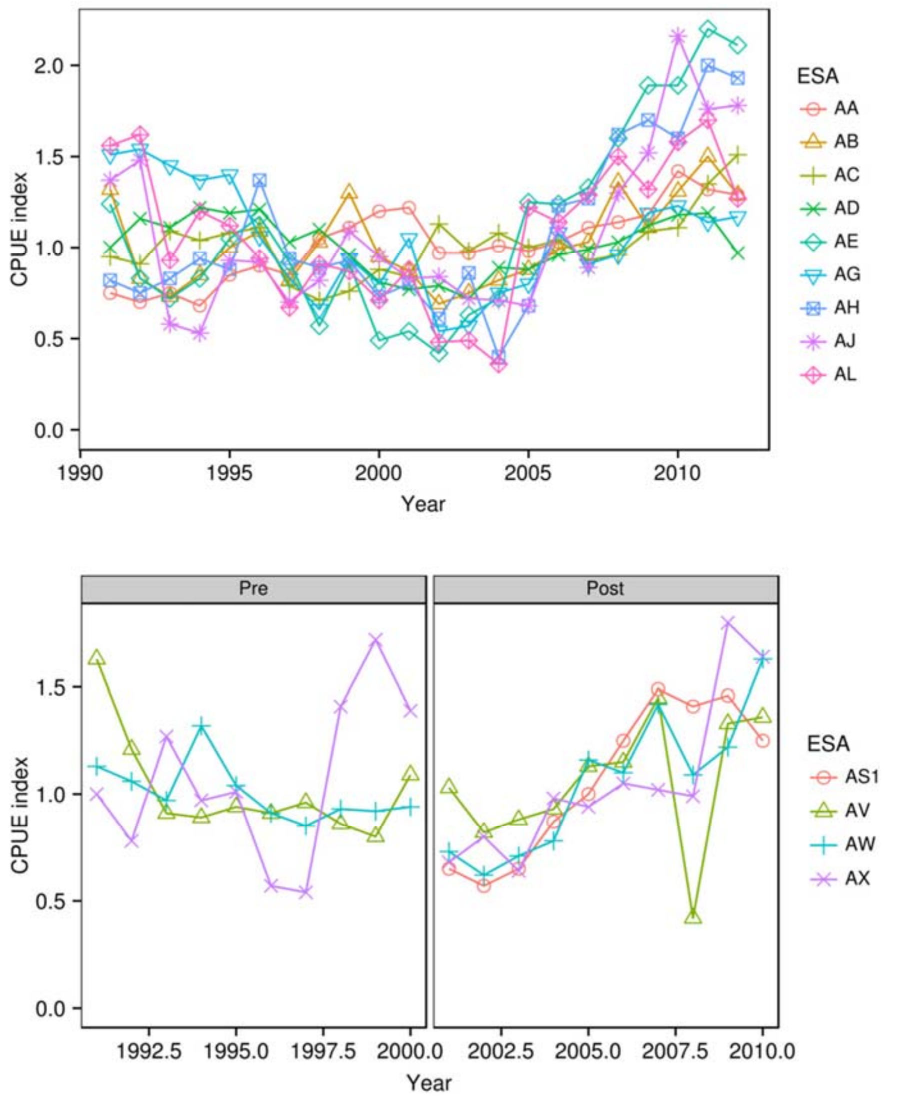


Figure 5: CPUE indices of relative biomass for shortfin eels in the North Island (top) and South Island (bottom). From Beentjes and Dunn 2013a and Beentjes and Dunn 2013b. Two North Island ESAs with high c.v.s are excluded.

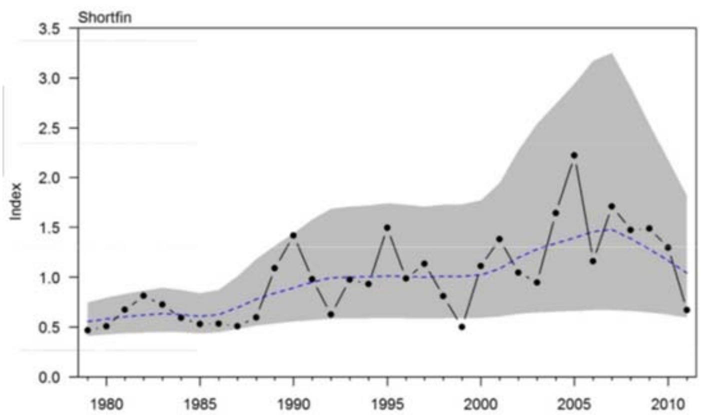
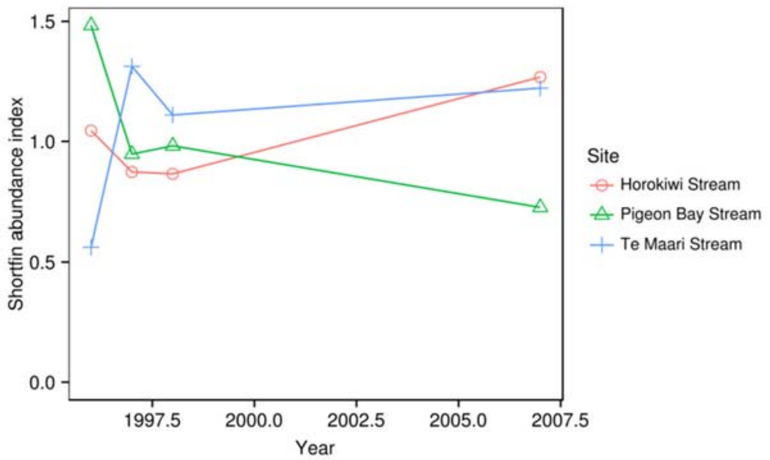


Figure 6: CPUE Standardised index of occurrence of shortfin eels from electric fishing surveys in the NZFWFDB. From Crowe & Dunn presentation to the review.



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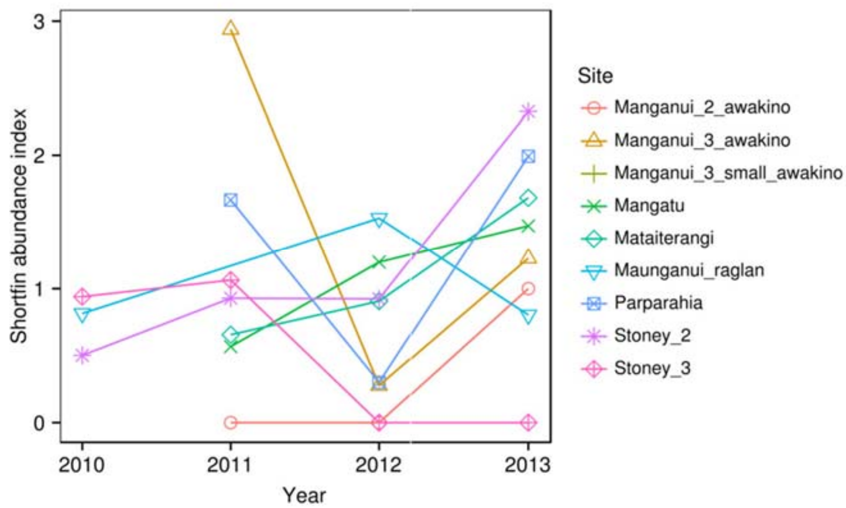

C

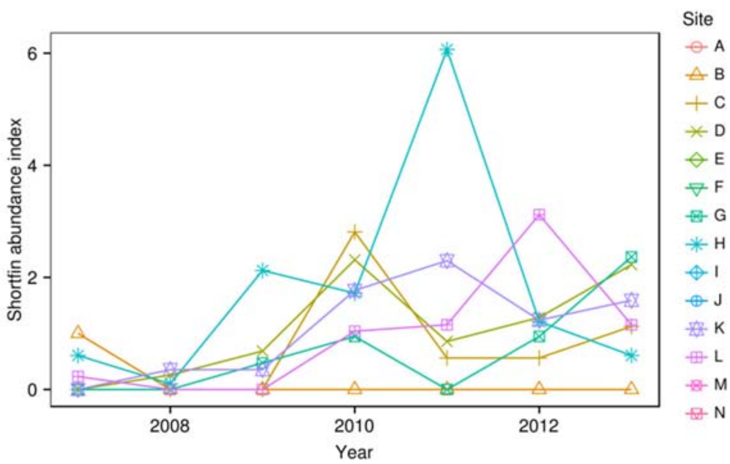

Figure 7: Indices of relative abundance for shortfin eels from electric fishing surveys conducted by (A) NIWA, (B) Waikato Regional Council, and (C) Otago Regional Council.

Ministry for Primary Industries Terms of Reference for an independent review of the information available for monitoring trends and assessing the status of New Zealand freshwater eels

1. Background

The New Zealand eel fishery is based on the two temperate species of freshwater eels occurring in New Zealand, the shortfin eel *Anguilla australis* and the longfin eel *A. dieffenbachii*. A third species of freshwater eel, the Australasian longfin (*A. reinhardtii*), identified in 1996, has been confirmed from North Island landings. The proportion of this species in landings is unknown but is thought to be small. New Zealand's native freshwater eels are taonga to Mäori, and are targeted by customary Mäori, amateur and commercial fishers.

Both longfin and shortfin eels are managed under New Zealand's Quota Management System (QMS). In the North Island, Quota Management Areas (QMAs) are designated separately for longfin under the code LFE and for shortfin under the code SFE. In the South Island, QMAs are specified for the two species combined under the code ANG, although commercial landings are usually reported by species.

The management objective for freshwater eels is to secure social, economic and cultural benefits from each eel species by maintaining adequate spawning biomass to provide for high levels of recruitment, and protecting, maintaining and enhancing eel habitats. Research contracted by the Ministry for Primary Industries (MPI) is focused on monitoring trends in the recruitment of elvers and in the abundance of larger exploited eels. This and other information is also used by the Department of Conservation (DOC) to fulfill various obligations such as assessing the threat status of New Zealand's native species, and by regional Councils and iwi and other groups to inform local area management. Habitat protection is addressed by developing peer networks with natural resource management agencies such as DOC, the Ministry for the Environment and Regional Councils, and by identifying habitats of particular significance to freshwater fisheries. Habitat degradation is a significant issue for freshwater eels.

The research planned on a routine basis to monitor the status of New Zealand shortfin and longfin eel stocks may be divided into three categories:

1. **Standardised Catch per Unit Effort (CPUE)**: Indices of abundance, based on standardised CPUE, are produced for the commercially targeted portions of eel populations within each QMA. The CPUE indices are updated on a 3 year cycle. Although the ANG QMAs of the South Island are composed of both shortfin and longfin eels, separate indices of abundance are produced for each species. CPUE analysis is done at the spatial resolution of Eel Statistical Areas (ESAs). Each QMA consists of multiple ESAs and in most cases the ESA providing most of the catch is used to produce an index of abundance for the QMA. In some instances (e.g. ANG15) two indices of abundance are calculated as both support important fisheries, i.e. one for each ESA. MPI intends, where this is possible, to develop CPUE based management targets for each species within each QMA. Low numbers of active permit holders, inconsistent participation across years after the introduction of eels into the QMS, and

generally low overall catch and effort activity resulted in unreliable/poor indices of abundance after 2001 for several South Island QMAs.

1. **Elver recruitment:** Annual numbers of the elvers of each species passing hydro-electric power dams on several rivers are recorded by stakeholders, mostly (but not exclusively) as part of their resource (operating) consent conditions. Eels recruit into rivers as transparent glass eels in their first year of life and spend some time in estuarine reaches before moving upstream. Elvers, the next stage in the life-cycle, are 1-4 yr old and move upstream as they grow older. Elvers entering the traps at sampling sites therefore comprise more than one year class, with the number of year classes in the sample and average size/age increasing with the distance of the dam/site from the mouth of the river. Although field surveys targeting glass eels may provide a better indication of annual recruitment, the cost of monitoring multiple rivers would be prohibitive (New Zealand law currently does not allow the harvesting of glass eels). Elver catch indices at dams are nevertheless thought to provide a long term indication of recruitment trends, which in conjunction with CPUE and the size composition of the catch, contribute substantially to the overall understanding of abundance and stock status.

2. **Size composition:** Proportions of the catch of each species falling into market-related size categories are provided by all major Licensed Fish Receivers (LFRs) that process eels. The data are provided annually at a sub-ESA spatial resolution related to catchment. Increasing rates of exploitation are expected to result in higher proportions of the catches of each species in smaller size categories. Given that there is sometimes less market demand for eels in the medium size category, with the result that eels in this category are often avoided or released, modelling relative abundance of the large size category (standardised CPUE) is being investigated.

In early 2013 the Parliamentary Commissioner for the Environment (PCE) completed a review of the stock status of longfin eels. One of the conclusions of the PCE's report was that the information used by MPI to monitor eels had limited value and that greater emphasis should be placed on the following alternative data:

1. New Zealand Freshwater Fish Database (NZFWFDB): This is a voluntary database containing a substantial quantity of research data, beginning in 1960, that could potentially be used to monitor eel abundance. It is mostly presence/absence data collected using electric fishing by a variety of organisation including NIWA, the Department of Conservation (DOC) and Regional Councils.

2. Electric fishing size composition data: Regional Councils and NIWA have a substantial quantity of length frequency data for both longfin and shortfin eels collected by electric fishing in wadeable streams.

The PCE's report also recommended "the establishment of a fully-independent peer review panel to assess the full range of information available on the status of the longfin eel population". The purpose of this review is therefore to review the utility of all sources of data and analytical methods that have potential for monitoring the abundance and informing the stock status of both species of New Zealand freshwater eels, with particular emphasis on longfin eels, and to draw conclusions on what this information reveals about the status and trends of freshwater eel populations.

2. Terms of Reference

- An independent panel comprising Dr Alex Haro (US Geological Survey, Massachusetts), Dr Willem Dekker (Freshwater Institute, Swedish Agricultural University) and Nokome Bentley (Trophia, New Zealand) will be convened. Collectively, the panel has scientific expertise in eel biology, freshwater sampling techniques, quantitative analysis and stock assessment.

- In order to be fully-independent, panel members must have no current or previous connection with the research, monitoring, assessment or management of New Zealand eels and must declare any actual or potential conflicts of interest that might affect their ability to come to an objective view of current or alternative methods for monitoring the abundance and status of New Zealand eels.

Primary Objectives

- The primary objective for the expert panel is to provide advice to the Ministry for Primary Industries on the efficacy of current and alternative methods for monitoring the abundance, population trends and stock status of shorfin and longfin eels. Specifically:
  - the use of standardised CPUE to monitor the abundance of the vulnerable portion of the eel population
  - the use of annual information on the numbers of elvers at dams to monitor trends in recruitment
  - the utility of information on the size composition of the commercial eel catch
  - the utility of information on the frequency of occurrence of shortfin and longfin eels in electric fishing surveys stored on the NZFWFDB
  - the utility of information on the size composition of eels in electric fishing surveys

- Based on their analysis of these and other datasets, the Panel shall draw conclusions on the status and trends of the New Zealand longfin and shortfin eel populations, and indicate any aspects of particular concern (e.g. age structure, sex ratios and proportions of migrants).

- Based on evaluation of these datasets and the analyses applied to them, the Panel should provide advice to MPI on information that should be routinely collected to monitor New Zealand shortfin and longfin eels, with recommendations on how such data collection programmes are best designed and analysed. The Panel will have the latitude to recommend alternative data collection programmes and analytical approaches.

Secondary Objectives

- Graynoth *et al*. (2008) used a GIS approach to estimate the following: 1) the proportion of longfin eel habit that is not fished commercially; 2) proportions of the longfin eel population in unfished and fished areas; 3) spawning escapement (as a proportion of virgin levels); and 4) commercial exploitation rates. The results of this study have been widely and uncritically used by various agencies, with little attention paid to the assumptions necessary to estimate the respective metrics. A secondary objective of the fully-independent expert review is therefore to review the Graynoth *et al*. (2008) methodology, providing advice on the assumptions and the reliability of results. Recommendations on data and analytical methods that would improve upon estimates made using this approach will also be useful. The Panel should also provide advice on the utility of closed areas in maintaining or rebuilding eel stocks.

- MPI has recently commissioned the National Institute of Water and Atmospheric Research (NIWA) to develop selected reference points for the assessment and management of longfin eels. The reference points will include the biomass associated with maximum sustainable yield, B_{MSY} (as a percentage of the unfished level, B_0) and the fishing mortality rate associated with maximum sustainable yield, F_{MSY}. The sensitivity of these reference points to a range of stock-recruitment relationships and to growth rates (which may vary substantially amongst localities) is also to be investigated. A second secondary objective of the fully-independent expert review is therefore to review the reference point analysis.

Out of scope

While the purpose of the data collection programmes that are the subject of this review is to underpin fisheries management decisions, DOC's threat classification system, and Regional Council and other local area initiatives, the mechanisms by which such systems operate are not in scope. That is, the following are out-of-scope for this review:

- the efficacy of past MPI eel fisheries management measures themselves, or the QMS in general
- the efficacy of local area eel management actions
- recommended future management actions
- the efficacy of the current threat classification system

Outcomes

- The expert panel will summarise their findings and any recommendations in a report to the Principal Advisor Fisheries Science, Ministry for Primary Industries. Where consensus cannot be reached by the external reviewers, any differences of opinion should be recorded.

3. Background documents

The following documents will be provided:

Primary documents

- The 2013 Plenary Report for freshwater eels
- Fishery Assessment Reports (FARs) describing the latest standardised CPUE analyses for the North and South Islands (FAR2013/62 and FAR2013/11)
- Elver recruitment project (FAR 2013/50)
- Size composition of the commercial catch (FAR 2013/47)
- Glass eel recruitment (presentation only)
- Electrofishing length frequencies (presentation only)
- NZFWFDB analysis (presentation only)
- Spawning escapement of female longfin eels (FAR 2008/07)
- Biomass of longfin eels in medium to large rivers (FAR 2009/44)
- Reference points for longfin eels (presentation only)
- Iwi/hapu data collection programmes (presentation only)

- Regional Council data collection programmes (presentation only)

(Presentations will be loaded onto the review website as soon as they become available).

Background references

- Parliamentary Commissioner for the Environment. 2013. On a pathway to extinction? An investigation into the status and management of the longfin eel.

(Note: Additional documents may be added to this list).

4. Format for review

The format for the review will be a workshop involving the independent external expert reviewers ("the Panel"), key players and other interested parties in Wellington, New Zealand to discuss the data, analyses and results in detail over a period of 5 days. The review will start with a number of presentations to ensure a common understanding of the work (about 2 days), and will be followed by a period of contemplation by the Panel, focused discussions with lead researchers or other parties (at the Panel's discretion), and drafting of a report containing the Panel's conclusions and recommendations (2–3 days). The Panel will present a draft version of their findings to interested parties on the last day to receive feedback and suggested corrections on matters of fact. The Panel may, at their discretion, reflect such feedback in their report. The aim is to have a near-final version of the Panel's report by the end of the week, although it could take 1-3 weeks or so until the final version is available. The final version will be made publically available but drafts will not be circulated.

5. Timetable

The workshop is set down for 11–15 November 2013 and will be held in the Main Conference Room, National Institute for Water and Atmospheric Research (NIWA), Greta Point, Wellington, New Zealand. Pamela Mace, Principal Advisor Fisheries Science, MPI, will chair the open sessions.

Monday 11 November	Presentations on current data sources and analytical methods used to monitor stock status	Open session
Tuesday 12 November	Presentations on alternative data sources and Graynoth analysis	Open session
Wednesday 13 November	Panel confers with individuals or works alone	Panel's discretion
Thursday 14 November	Panel works on review	Closed session
Friday 15 November a.m.	Panel presents draft findings	Open session
Friday 15 November p.m.	Panel concludes review	Closed session

It is anticipated that the review will be concluded by the afternoon of Friday 15 November, although final drafting of the report may take place over subsequent days or weeks.

A more detailed agenda is attached.

Ministry for Primary Industries Terms of Reference for an independent review of the information available for monitoring trends and assessing the status of New Zealand freshwater eels

Main Conference Centre, NIWA, Greta Point, Evans Bay Parade, Wellington

Chair (of open sessions 1–15, and 19): Pamela Mace, DDI (04) 819 4266, email Pamela.Mace@mpi.govt.nz

AGENDA

Monday 11 November 2013 (starting 09:30)
Morning coffee/tea/scones; lunch; and afternoon coffee/tea provided

1. Introductions and general arrangements for the review (Pamela Mace, Marc Griffiths) (10 minutes)

Presentations:

2. Jan Wright: Background to the report by the Parliamentary Commissioner for the Environment (20 minutes)

3. Marc Griffiths: A brief summary of the life history of New Zealand eels (10-15 minutes)

4. Dave West: Habitat impacts on longfin eel (20 minutes)

5. Mike Beentjes: Fishery characterization and CPUE analyses for South Island longfin and shorfin eels (60 minutes)

6. Mike Beentjes: Fishery characterization and CPUE analyses for North Island longfin and shorfin eels (40 minutes)

7. Jacques Boubee: Trends in the numbers of shortfin and longfin elvers arriving at New Zealand dams (80 minutes)

8. Mike Beentjes: Size composition of commercial landings of longfin and shortfin eels (60 minutes)

9. Don Jellyman: Existing data on glass eel recruitment (60 minutes)

Tuesday 12 November 2013 (starting 09:30 or earlier as agreed)
Morning coffee/tea/scones; lunch; and afternoon coffee/tea provided

Presentations continue:

10. Doug Jones and Mick Kearney: Monitoring of eels by iwi and hapu: examples (60 minutes)

11. Bruno David: Waikato Regional Council monitoring program (30 minutes)

12. Don Jellyman & Alistair Dunn: Using the size composition of electric fishing catches to infer recruitment strength (60 minutes)

13. Shannan Crowe & Alistair Dunn (NIWA): Analysis of presence/absence data for longfin eels on the New Zealand Freshwater Fish Database (60 minutes)

14. Eric Graynoth & Don Jellyman: A GIS approach to estimating the biomass of longfin eels in New Zealand Rivers (60 minutes)

15. Alistair Dunn & Shannon Crowe (NIWA): Biological Reference Points for longfin eels (60 minutes)

Panel in session

16. Panel discussions with presenters or others at their discretion

Wednesday 13 November 2013

Panel in session

17. Panel discussions with presenters or others at their discretion

Thursday 14 November 2013

Panel in session

18. Panel probably in closed session (but may have discussions with presenters or others at their discretion)

Friday 15 November 2013 (starting 09:30 or earlier as agreed)
Morning coffee/tea/scones provided

Conclusions and recommendations

19. Panel presents draft conclusions and recommendations to interested parties for general impressions and corrections on matters of fact (open session)

20. Panel concludes deliberations (closed session)

It is anticipated that the open session on Friday 15 November will be completed by 12:00 noon.

Attendees at open sessions, 11-12 & 15 November 2013

Independent Expert Review panel:

Alex Haro (Principal Investigator and Section Leader, S.O. Conte Anadromous Fish Research Center, U.S. Geological Survey, Massachusetts, USA)

Willem Dekker (Senior Scientist and Project Leader, Freshwater Institute, Swedish Agricultural University)

Nokome Bentley (Principal Investigator and Independent Consultant, Trophia, New Zealand)

Open session participants: Pamela Mace (Chair), Marc Griffiths, William Arlidge, Terry Lynch, Santiago Bermeo, Kevin Sullivan (MPI); Rosie Hurst, Don Jellyman, Alistair Dunn, Shannan Crowe, Mike Beentjes, Jacques Boubee; Eric Graynoth, Erica Williams (NIWA); Jan Wright (introductory sessions), Jan Wright, Grant Blackwell, Sky Davies, Karen Lavin, Sarah Clark (PCE's office); Bruno David (Waikato Regional Council); Matt Dale (Otago regional Council); David Middleton (Seafood New Zealand); Jane Goodman, Rosemary Miller, Dave West, Philippe Gerbeaux, James Griffiths (DOC); Bill Chisholm, Vic Thompson, Mike Holmes, John Jameson, Steve Allen, Paul Breen (Commercial fisheries); Travis Stull (Trustpower); Mark James (Meridian); Mick Kearney, Doug Jones, Kirsty Woods (TOKM).