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Estimates of the total wetted-area commercially fished for eels in the North Island (2020 to 2024), and the proportion of longfin habitat fished

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Contents

PLAIN LANGUAGE SUMMARY

The aim of this project was to estimate the extent of the spatial area that was commercially fished for longfin and shortfin eels in the North Island from 2020 to 2024. For longfin only, the area fished was compared with the total available habitat to update the proportion of longfin habitat that is commercially fished. This provides an indication of the spatial fishing pressure that both longfin and shortfin eel species have experienced, and can be used as a tool to assess the status or health of eel stocks.

From 2020 to 2024 there were 1690 North Island eel fishing events of approximately 20 fyke nets per event, from 24 fishers. Most events were in rivers (83%), followed by lakes (11%) and harbours (6%) with the latter targeting shortfin. More than three-quarters of fishing events were in just three regions (Northland, Waikato, Hauraki).

A total of 7156 unique river reaches (totalling approximately 6000 km) were fished over the five years. About half the river reaches were fished just once, but within the most intensively fished river systems, many experienced over 10 passes in the five years, with the highest intensity in the Waikato and Waipa Rivers where some stretches were fished from 60 to 100 times.

The total area commercially fished in the North Island was 33.7 km^2 for longfin and 65.7 km^2 for shortfin. Total current longfin habitat in North Island rivers, and in lakes accessible to longfin was estimated at 458.8 km^2, of which the current area fished equates to 7.3%. Compared to the previous 2016 estimate of the proportion of longfin habitat fished, the current estimate has declined by about two-thirds, reflecting a substantial drop in fishing effort in recent years.

EXECUTIVE SUMMARY

Beentjes, M.P.; Shankar, U. (2026). Estimates of the total wetted-area commercially fished for eels in the North Island (2020 to 2024), and the proportion of longfin habitat fished

New Zealand Fisheries Assessment Report 2026/31. **29 p.**

The longfin and shortfin eel spatial area commercially fished in the North Island over the five fishing years 2019–20 to 2023–24 (2020 to 2024) was estimated using fine scale reporting of effort (latitude and longitude) from the electronic reporting system (ERS). The longfin area fished was compared to the estimates of the total North Island current longfin habitat from a previous study in 2016, to provide an update of the proportion of longfin habitat that is currently fished. There are no current estimates for total shortfin habitat.

All recorded river eel fishing positions on the ERS in 2020 to 2024 were georeferenced to individual segments of the River Environment Classification (REC v2.4). Using information from the REC, the wetted area commercially fished in rivers was estimated for longfin and shortfin eels, separately (i.e., river segment length × mean width of segment at mean annual low flow). The wetted area fished in naturally formed lakes over 0.9 km^2 that have unimpeded access to longfin eels, was estimated as the length of shoreline fished/lake perimeter × longfin habitat area.

In 2016, the total longfin habitat area estimate in North Island rivers was derived from 'probability of capture' models within REC segments, a relatively small number of which were above hydro dams. Similarly, total longfin habitat was estimated for lakes over 0.9 km^2 that were naturally formed with unimpeded access to longfin eels. Both river and lake habitat were expressed as wetted area.

There were 1690 fishing events from 24 fishers (permits) in the data set and of these 11% were in lakes, 83% in rivers, and 6% in harbours. Most (94%) longfin catch was from rivers whereas 17% of the shortfin catch was from harbours and lakes. Vessels were used in most fishing events (82%) and nearly all (99%) land-based events were in rivers. Shortfin eels were the main target species (95% of fishing events). Virtually all fishing events used fyke nets, of which 65% were baited. More than three-quarters (80.1%) of valid longfin fishing events (targeting or catching longfin) and 75.0% of valid shortfin fishing (targeting or catching shortfin) were in just three Eel Statistical Areas (AA, Northland; AD, Waikato; AC, Hauraki). For valid-longfin fishing events there were 3510 unique river segments fished over the five years, equating to 2981 km of river fished. For valid shortfin events this was 7144 segments and 6049 km of river fished. Within the most intensively fished river systems, many segments experienced over 10 passes in the five years, with the highest intensity in the Waikato and Waipa Rivers where some stretches were fished from 60 to 100 times. The total wetted area fished for longfin in the North Island from 2020 to 2024 was 33.67 km^2 (28.17 km^2 for rivers and 5.50 km^2 for lakes), and for shortfin this was 65.74 km^2 (59.02 km^2 for rivers and 6.72 km^2 for lakes). Total current longfin habitat in North Island rivers, and in lakes accessible to longfin was estimated at 458.8 km^2 in 2016, of which the current 33.7 km^2 fished equates to 7.3%.

Compared to the original 2016 study (2010 to 2014), the number and length of unique North Island segments fished in the recent period (2020 to 2024) dropped by about 60%, and the river wetted area fished by 71%. The natural lake wetted area fished, however, increased by 26%. The corresponding estimate of the proportion of longfin habitat fished, declined by more than two-thirds from 22.5% to 7.3%. Similarly, the virgin habitat fished dropped by a similar degree from 20.9% to 6.8%. The maximum impacted abundance also dropped, but not to the same extent, from 29.0% to 14.4% The reduction in longfin habitat fished by two-thirds between 2010 to 2014 and 2020 and 2024 is consistent with an observed contraction in spatial effort with current effort concentrated on ten major North Island river systems.

1. INTRODUCTION

The commercial freshwater eel fishery in New Zealand developed in the late 1960s and landings consist of both the endemic longfin eel (*Anguilla dieffenbachii*), and the shortfin eel (*Anguilla australis*) which is also found in southeast Australia. Longfin eels are considered to be more at risk of overfishing than shortfin because they are endemic to New Zealand and both sexes migrate and spawn at a considerably older age (Fisheries New Zealand 2026). Further, because longfin females live much longer than males, they are considered more vulnerable to overfishing; sustainability therefore depends on sufficient numbers of females surviving to migrate and spawn each year (Jellyman et al. 2000, Hoyle & Jellyman 2002, Fu et al. 2012).

In the South Island, longfin eels are found further inland than shortfin eels, occupying high country lakes, some of which have had both longfin upstream and downstream passage blocked by hydro-electric dams, essentially removing this habitat from the total habitat available for longfins where they can contribute to spawning (Beentjes et al. 1997, Beentjes 2005). Graynoth et al. (2008) estimated that as much as 6000 t of longfin eels are contained in hydro reservoirs. There is, however, trap and transfer of migrating eels below some hydro dams (Fisheries New Zealand 2026). Trap and transfer of elvers above hydro dams occurs at most of the major New Zealand hydro-electric dams (Crow et al. 2023). In the North Island there is a much greater overlap of the distribution of the two species, although shortfin tends to be the dominant species in most areas.

For the successful management of any fishery, it is desirable to have some index of relative abundance for the fished portion of the population to monitor the effects of fishing on the population. Many conventional fisheries sampling and survey techniques for determining relative abundance indices cannot validly or practically be applied in the freshwater eel fishery, with the notable exception of catch-per-unit-effort (CPUE) analyses which are routinely carried out for the commercial eel fishery (Beentjes & McKenzie 2017, Beentjes 2021, 2025, 2026).

Before the 2019–20 fishing year (1 October to 30 September) commercial eel catches and associated effort were reported on Catch Effort Landing Returns (CELRs) and then on Eel Catch Effort Returns (ECER), and the finest spatial resolution of reporting was by Eel Statistical Area (ESA) which are broadly catchment-based, but can include multiple major river systems (Figure 1). With the introduction of the electronic reporting system (ERS) in 2019–20, eel catch and effort is recorded spatially by start and finish coordinates of fishing events (latitude and longitude).

A Fisheries New Zealand project in 2015 (EEL2014-01) collected fine scale spatial data during face-to-face interviews with fishers throughout New Zealand (Beentjes et al. 2016). During interviews, 53 fishers were asked where they had caught longfin eels within the five-year period (2009–10 to 2013–14 fishing years) and the extent of fishing was annotated on topographical maps which was analysed using GIS methods. This was compared with the extent of the modelled current total longfin habitat to provide a quantitative estimate of the proportion of the habitat that was fished at this time, and conversely the proportion that was unfished (Beentjes et al. 2016). The results gave longfin habitat fished estimates of 32.5% for the South Island, 22.5% for the North Island, and 27.2% for the whole of New Zealand. This was repeated for the South Island only for the period 2020 to 2023, this time using ERS fine scale reporting data, and comparing this with the results of the 2015 study. The estimate of the proportion of accessible longfin habitat fished in the South Island, had declined from 32.2% to 13.6% (Beentjes & Shankar 2025).

The objective of the current project (EEL2024-01) was to update the estimates of longfin habitat in the North Island fished over the period 2020 to 2024, using ERS data and similar methods to the South Island update, and to compare that with the results of the 2016 study to see if there has been any change in spatial effort and intensity.

1.1 Specific objectives

1. To characterise North Island commercial eel fisheries.

2. To analyse CPUE trends in the North Island commercial eel fisheries (LFE 20, LFE 21, LFE 22, LFE 23, SFE 20, SFE 21, SFE 22, SFE 23) using data up to the end of the fishing year 2023–24.
3. To estimate the proportion of longfin habitat commercially fished.
4. Broader Outcomes.
5. To characterise and analyse CPUE trends for Waikato-Tainui Fisheries Area[1].

Objectives 1, 2 and 5 are reported in Beentjes (2026).

2. METHODS

2.1 Fishing location data

The fishing effort data used in this report were extracted from the Fisheries New Zealand Enterprise Data Warehouse (EDW) and for each daily record (i.e., fishing event) from fishing years 2020 (2019–20) to 2024 (2023–24) (1 October to 30 September) for all North Island fishing events. All data were reported by fishers in the ERS with the following variables recorded:

- Event key
- Trip ID
- Client key
- Start date- date at start of nets lifted
- Start time – time at start of first net lift
- Start position – latitude and longitude of first net lift
- Finish date- date at finish of last net lift
- Finish time – time at finish of last net lift
- Finish position – latitude and longitude of last net lift
- Method (FN, fyke net; EFN, Ellesmere fyke net; EP, eel pot; FP, fish trap)
- Number of net lifts
- Estimated catch weight of shortfin (SFE)
- Estimated catch weight of longfin (LFE)
- Target species (SFE or LFE)
- Is vessel used – yes or no
- Are nets baited – yes or no
- Eel Statistical Area (derived from latitude and longitude)

Henceforth we refer to rivers as including rivers, streams and creeks. Commercial eel fishing can take place from a vessel or from land on the riverbank. A fishing event in the eel fishery is defined as when a series of fyke nets (usually about 10 to 30) are set a distance apart along a riverbank, or around a lake shore and left to fish, typically, for one or two nights before retrieval. The ERS records the position of the first and last net lifted.

2.2 Area fished in rivers (longfin and shortfin)

The ERS data start and finish positions were imported into ArcGIS Pro (v3.3) where they were plotted and inspected for veracity. Where possible, these were georeferenced and then assigned to River Environment Classification (REC v2.4) segments. They were subsequently checked for continuity from start to end point by using the ArcGIS Pro network analysis tracing tool. The most common errors were that the finish position was the same as the start position or that they were not in the river or lake. The

[1] Objective 5 was added under contract variation.

REC was created by the Ministry for the Environment and the National Institute of Water and Atmospheric Research (NIWA, now Earth Sciences New Zealand) (Snelder et al. 2004) and was updated to version 2.5 (Crow et al. 2014). We used version 2.4, however, to be consistent with that used by Beentjes et al. (2016) for the 2010 to 2014 analyses. Unlike LINZ topographic maps, the REC system is a synthetic river network derived from a digital elevation model. There are 593 466 REC segments with mean length of 696 m (range 15 to 32 627 m) with additional information about physical characteristics such as stream order, mean flow, catchment areas, distance inland, altitude, topography, geology and land cover etc. Shortfin fishing locations were also included in the current analyses for 2020 to 2024 fishing events, unlike the previous analyses from 2010 to 2014 which only dealt with longfin.

The fishing event data for the five fishing years (2020 to 2024) were then processed in the following way:

1. There were 6190 fishing events, and these were categorized as occurring in one of six habitat types (Table 1):
    a. Harbour = where fishing occurred in a harbour or estuary and was more than 500 m away from an REC segment (mostly Firth of Thames, Kaipara, Manukau, Waitemata, and Hokianga harbours). These fishing events were not used in estimation of wetted area fished (*N* = 384 Harbour fishing events). Of these, 30 events recorded set net and 354 fyke net as the fishing method, respectively.
    b. Lake-hydro = hydro-electric dam impoundments (impeded access to longfin).
    c. River-hydro = rivers above or between hydro impoundments (impeded access to longfin). e.g., Waikato River between Lakes Karapiro and Arapuni.
    d. Lake-natural = natural lakes over 0.9 km^2 in area (unimpeded access to longfin).
    e. Lake-small-natural = natural lakes less than 0.9 km^2 in area (unimpeded access to longfin);
    f. River-REC = REC river segments (unimpeded access to longfin), including those that were within 500 m of a fyke net harbour fishing event.
2. For each of the 5806 fishing events (excluding harbours), those with start and finish positions on the water in different places in the same river, stream or lake, were identified, and termed 'sensible' fishing events (*N* = 2489). This excluded events where finish positions were on land or were the same as the start positions – these were termed 'non-sensible' fishing events (*N* = 3317).
3. For the 'sensible' positions, the river was traced from the REC segment containing the start position to the REC segment containing the finish position, taking 50% of the start and finish segments and 100% of the intervening segments. This approach was used because it was not possible to estimate length from only part of a segment. Tracing was carried out using a bespoke Fortran program that processed all valid start and end points.
4. The mean length of river fished was then estimated for traced, sensible start–finish fishing events, separately for vessel-based and land-based fishing (mean = 6.12 km for vessel fishing, standard error = 0.12; mean = 3.73 km for land-based fishing, standard error = 0.16). To remove outliers, land-based fishing events were restricted to less than 6 km and vessel-based fishing events to less than 20 km.
5. For the 3317 non-sensible fishing events, the mean length of river fished from sensible fishing events was used as a proxy (6.12 km for vessel fishing and 3.73 km for land-based fishing), and the REC segments associated with the start position were identified.
6. For the full set of fishing events ('sensible' and corrected 'non-sensible', N = 5806) the following metrics were then calculated for the fished sections of rivers corresponding to the 'unique' river segments fished (N = 7156), regardless of the number of times fished over the five years:
    a. Mean stream order (Strahler system), in which source tributaries represent order one, and there can be as many as eight stream orders in some large catchments such as the Waikato River (where order eight represents the main stem Waikato River).
    b. Total length of rivers fished (m).

c. Number of REC segments.
d. Mean MALF (cumecs): Mean annual low flow in cubic metres per second.
e. Mean MALFwidth (m): River width at MALF. The statistics for MALF and river width at MALF for each segment were modelled from actual data recorded at 485 gauging stations throughout New Zealand (Booker & Wood 2014). If MALFwidth was less than 1 m then it was converted to 1 m, because it is not realistic to be able to set nets in a creek less than 1 m wide.
f. Wetted area fished (km^2): River habitat fished estimates were expressed as wetted area calculated from unique REC segment length (m) × mean segment width at MALF (m) /10^6. This assumes that the entire area of rivers is available to either species. Wetted area of unique segments was counted only once regardless of how many times it was fished from 2020 to 2024.

7. The metrics in step 6 were also calculated for fishing events where longfin was caught or recorded as targeted (valid-LFE), and those where shortfin was caught or recorded as targeted (valid-SFE).

Fishing intensity in rivers

Because waterways (i.e., REC segments) can be fished by one or more fishers, and multiple times a year by an individual fisher, an index of fishing intensity was calculated to distinguish among lightly and heavily fished areas. The number of times a unique segment (N = 7156) was fished over the five years (2020 to 2024) was summed and the proportion of these segments fished at frequencies of 0, 1, 2…10, and over 10 times was calculated for valid-SFE and valid-LFE fishing events separately. Fishing intensity of zero for valid-SFE occurred in unique REC segments where shortfin were not caught or targeted, and similarly for longfin where they were not caught or targeted. Values greater than one indicate that more than a single pass or fishing event has occurred over the five years. In this way it was possible to map the cumulative effort spatially on the REC. This was also carried out for individual years and for valid-SFE and valid-LFE fishing events separately.

2.3 Area fished in natural lakes

The REC is primarily a river system model and does not include lakes unless they were natural rivers that had been flooded for hydro power production or for other purposes. For these analyses, all lake fishing was considered outside the REC except for some small wetland areas less than 0.9 km^2 (i.e., Lake-small-natural) associated with rivers that were included in the REC (N = 23) (Table 1).

Only naturally formed lakes over 0.9 km^2 in area that were considered to currently have unimpeded access for longfin eels were included in the fished lake habitat estimates. For these, total longfin habitat (km^2) was estimated previously by Beentjes et al. (2016, Appendix 1), based on the euphotic, or littoral zone, where aquatic macrophyte plants extend. For the shallow and or coastal lakes, which are overwhelmingly dominated by shortfin eels, the habitat was prorated to 10% of the total lake area to reflect the low longfin densities.

The littoral area of lakes was not available in any New Zealand freshwater database but was estimated for 36 South Island lakes over 5.0 km^2 by Beentjes et al. (1997) based on the depth of the euphotic zone or the maximum depth to which macrophytes are found, and then estimated from bathymetric maps. Although longfin eels may reside in waters deeper than this, it was generally considered that most food exists in the littoral zone and this is where fishing tends to be concentrated. Littoral zone areas in North Island lakes were estimated using the same principle using data from the NIWA Aquatic Plants Database and NIWA unpublished data on lake bathymetry. In theory, if these natural lakes have unimpeded access to longfin, then they will have access to shortfin, although the more inland and higher altitude lakes are less suitable as shortfin habitat, at least in the South Island.

The only fished North Island natural lakes over 0.9 km^2 between 2020 and 2024 were Lakes Waahi, Waikare, and Whangape (Waikato), Lake Runanga (Hawke's Bay), and Lake Waiparera (Northland).

With the exception of Lakes Wairarapa and Waikare, these are relatively small, shallow lakes, and all are primarily shortfin fisheries, although longfin are still caught. Regardless, in these analyses, the longfin lake habitat fished was assumed to be the same as for shortfin. All fishing in these five natural lakes was by vessel along the lake shoreline. The 2020 to 2024 wetted area fished (i.e., habitat fished) in natural lakes was estimated as follows:

1. The wetted area for these five fished natural lakes was estimated as (from appendix 1 of Beentjes et al. 2016):

   length of shoreline fished (km)/lake perimeter (km) × longfin habitat (km^2)

   In this case, because the fished natural lakes are generally small and shallow, and often start and finish net lift positions were the same, i.e., at the boat ramp, we assumed that the entire perimeter of the lakes was fished, so the habitat fished was simply equal to total longfin lake habitat.

2. For all other natural water bodies under 0.9 km^2 the mean distance fished by vessel (6.1 km) was used. These were usually small wetland areas that feed into mainstem river segments and were identified by REC segments. For these events, all of which were vessel-based, the wetted area was calculated as for rivers.

For the original New Zealand wide analyses from 2010 to 2014, natural lakes accessible to longfin that had been fished were identified, and for these the area of habitat fished was simply the wetted area (km^2) of the entire lake, the littoral zone, or a prorated proportion of these areas (Beentjes et al. 2016, Appendix 1). For the South Island analyses from 2020 to 2023, we used either the total lake habitat area or an adjusted proportion of this area based on the length of shoreline fished, calculated using the average distance fished per vessel (Beentjes et al. 2016).

2.4 Estimates of total North Island longfin habitat

The total current longfin habitat in rivers and lakes throughout New Zealand was estimated as part of the New Zealand wide 2010 to 2014 fishing data analyses by Beentjes et al. (2016). These estimates of total longfin river habitat were not repeated in the updated analyses for the South Island (2020 to 2023) or in the current North Island update and were assumed not to have changed to any meaningful extent. Detailed methods on how these estimates were made are provided in Appendix A of this report, and briefly described below.

The total longfin river habitat was derived from the 'probability of capture' model developed by Leathwick et al. (2008) who used statistical models to describe the probabilities of capture for longfins and other freshwater species in all rivers and stream segments throughout New Zealand, including Stewart Island. Although the model sometimes included habitat above hydro dams, the bulk of the habitat was below dams. The probability of capture' model also includes Department of Conservation land, and areas closed to fishing by Fisheries New Zealand. For segments with probability of longfin capture of 0.5 or greater, total longfin habitat was estimated in the same way as longfin river habitat fished, described above, i.e., wetted area (km^2) = REC segment length (m) × mean segment width at MALF (m) /10^6.

Lake habitat was estimated for natural lakes over 0.9 km^2 accessible to longfin eels, or selected natural hydro lakes where longfin are known to be present, as the wetted area (km^2) of the entire lake, the littoral zone, or a prorated proportion of these areas (Appendix A).

2.5 Estimates of longfin habitat fished

2.5.1 Proportion of current longfin habitat fished

The formulae to estimate the proportions of total longfin habitat fished are the same as those for the previous analyses and are given below (Beentjes et al. 2016, Beentjes & Shankar 2025).

Rivers fished

The proportion of longfin habitat fished in rivers was determined from the empirical relationship between fished segments, and total segments where longfin are predicted to be present. Using wetted area (km^2) as a proxy for habitat, the proportion of current North Island (2020 to 2024) river habitat fished (PC_{river_fished}) is given by:

$$PC_{river\_fished} = \frac{A_{river\_fished}}{A_{river\_pred}} \qquad (1)$$

where:

A_{river_fished} is the wetted area (km^2) of the REC fished.

A_{river_pred} is the wetted area (km^2) of the REC at probability of longfin capture of 0.5 or higher. Relative abundance of longfin is assumed to be the same in all river segments

Lakes and rivers fished

The proportion of current combined North Island river and lake habitat fished ($PC_{river\_lake\_fished}$) is given by:

$$PC_{river\_lake\_fished} = \frac{A_{river\_fished}+A_{nat\_lake\_fished}}{A_{river\_pred}+A_{nat\_lake}} \qquad (2)$$

Where:

$A_{nat\_lake\_fished}$ is the wetted area (km^2) of accessible natural lakes over 0.9 km^2 that were fished.

A_{nat_lake} is the wetted area (km^2) of suitable longfin habitat in all accessible natural lakes., i.e., those over 0.9 km^2 in which longfin have unimpeded access to the sea.

Proportions of current longfin habitat fished (lakes and rivers combined) are provided for North Island as a whole, and also by Eel Statistical Area and Quota Management Area.

2.5.2 Proportion of virgin longfin habitat fished

The proportion of virgin unmodified habitat (i.e., longfin habitat present before human impacts) fished is determined in the same way as the proportion of current combined river and lake habitat fished ($PC_{river\_lake\_fished}$) except that habitat where longfin are present also includes natural hydro lakes where access is now impeded, river habitat lost by the creation of artificial and inaccessible impoundments or reservoirs, and habitat lost through degradation. The proportion of virgin habitat fished ($PV_{river\_lakes\_fished}$) is given by:

$$PV_{river\_lake\_fished} = \frac{A_{river\_fished}+A_{nat\_lake\_fished}}{A_{river\_pred}+A_{nat\_lake} + A1_{hydro\_lake\_nat}+A1_{river\_res} + A_{degrad}} \qquad (3)$$

Where:

$A1_{hydro\_lake\_nat}$ is the wetted area (km^2) of all natural lakes where hydro or other dams have resulted in 100% impeded access in and out the lakes.

$A1_{river\_res}$ is the wetted area (km^2) of the original river habitat replaced by artificial impoundments or reservoirs, and A_{degrad} is the wetted area (km^2) of habitat lost to non-specific habitat degradation, i.e., farms drains, farm pumping stations, culverts, drainage, river modification and channelling, willow clearing, and water quality etc. There are no quantitative data on habitat degradation but nominally, 5% of current river habitat was assumed to be lost through degradation.

Proportions of virgin longfin habitat fished are provided for North Island as a whole, and by Eel Statistical Area and Quota Management Area.

2.5.3 Proportion maximum impacted longfin abundance

To estimate the maximum anthropogenic impact on relative longfin abundance from commercial fishing and habitat loss we also need to consider the habitat loss in 1) natural hydro lakes where access is impeded, 2) the loss of previous river habitat by the creation of artificial and inaccessible hydro reservoirs or impoundments, and 3) any other losses due to habitat degradation. Hence, the impacted abundance ($A1_{anthropogenic}$) is expressed by the ratio between all habitat losses plus fished habitat (numerator), and all virgin habitat unaffected by anthropogenic activities (denominator), and is given by:

$$A1_{anthropogenic} = \frac{A_{river\_fished} + A_{nat\_lake\_fished} + A2_{hydro\_lake\_nat} + A2_{river\_res} + A_{degrad}}{A_{river\_pred} + A_{nat\_lake} + A1_{hydro\_lake\_nat} + A1_{river\_res}} \quad (4)$$

Where:

$A2_{hydro\_lake\_nat}$ is the wetted area (km^2) of all natural lakes where hydro or other dams have resulted in impeded access in and out the lakes, less any allowance for elver transfer and catch and transfer of migrating eels, i.e., 50% of the littoral wetted area for Lakes Te Anau and Manapouri and a nominal 5% for all other New Zealand natural hydro lakes combined.

$A2_{river\_res}$ is the wetted area (km^2) of the original river habitat replaced by artificial impoundments or reservoirs with impeded access, less any allowance for spawning contribution due to elver transfer and passive escapement of spawning eels over spillways and overtopping dams in periods of floods, combined with sporadic programmes of migrant catch and transfer, i.e., nominally, 5% of habitat from artificial impoundments or reservoirs throughout New Zealand.

Proportions of maximum impacted longfin abundance are provided for North Island as a whole and also by Eel Statistical Area and Quota Management Area.

No assumptions are made about fishing mortality.

2.6 Spatial distribution of effort

ERS 2020 to 2024 position data that shows the start and finish location of the sets plotted on a North Island map at high resolution (0.04-degree squares) were presented to the Eel Working Group on 15 October 2025. However, for publication Fisheries New Zealand data confidentiality rules only allow publication of these data so long as each spatial cell displayed contains data from at least three permit holders.

Restricting catch-location plots to cells containing data from at least three permit holders results in much of the dataset being excluded at any meaningful spatial resolution. In some areas, all data are suppressed. Plotting the catch location data adhering to data confidentiality guidelines is therefore of no value in understanding the spatial nature of the eel fishery, hence these maps are not presented. The spatial distribution is, however, broadly described in the results.

3. RESULTS

3.1 Fishing event metrics

The ERS analyses data set contained 6190 North Island fishing events between 2020 and 2024, with an average of 20 fyke nets per event, reported by 24 fishers or permits; all events included position data (latitude and longitude) (Table 1). Only one fisher reported set nets (30 events), and these were used only in harbours; all other fishing events used fyke nets. Most fishing events were in rivers (83%) with 11% in lakes and 6% in harbours. The latter figure is slightly higher than shown as some of the river events were near the junction of harbour and river/stream mouth. Of the total 6190 fishing events, 51% were valid longfin events (longfin caught or targeted) and 99.7% were valid shortfin events (shortfin caught or targeted) (Table 1). The distribution of valid longfin and valid shortfin events by habitat were similar, although for harbour fishing shortfin was caught or targeted more than longfin.

A total of 1132 t of eels were reported in the ERS as caught during 2020 to 2024, of which just under 20% were longfin and the remainder were shortfin (Table 2). Most longfin catch was from rivers (94%), whereas 17% of the shortfin catch was from harbours and lakes. Shortfin was caught in 15 lakes, five of which are natural lakes (over 0.9 km^2), and of the 10 hydro lakes most catch was from Lake Ohakuri where 15 tonnes were caught (Figure 2). Longfin was caught in the same 15 lakes except Lakes Runanga and Waiparera, but in much smaller amounts (Figure 2).

Vessels were used in most fishing events (82%) and of these, more than three quarters were in rivers (80%) (Table 3). Of the 18% of fishing events that were land-based, nearly all (99%) were in rivers. Shortfin eels were the main target species (95%) and for both species rivers were the main habitat type fished (Table 3). About two-thirds (65%) of fishing events reported using baited fyke nets, and this was mostly in rivers (Table 3). Of the target longfin events (N = 333) 63% used baited nets, and of the shortfin target events (N = 5857) 65% of nets were baited (Table 3).

3.2 Metrics for unique river segments fished

The total number of REC river segments in the North Island is 268 877 with total length of 181 934 km (Table 4), although a very small number of these may be small lakes or wetland areas. The numbers of fished unique river segments from 2020 to 2024, (where a unique segment is defined as one which is counted only once, regardless of whether it was fished by more than one fisher or multiple times), are shown in Table 4. For valid-LFE fishing events from 2020 to 2024, there were 3510 unique segments fished (1.3% of all North Island REC segments) and 2981 km of river fished (1.64% of the length of all North Island REC segments). Similarly, for valid-SFE fishing events, there were 7144 unique segments fished and 6049 km of river fished, equating to 2.7% and 3.32% of the REC segments respectively (Table 4).

For all fishing events in 2020 to 2024, regardless of target species or if eels were caught, 7156 unique North Island river segments were fished that covered a distance of 6056 km (Table 5). Other metrics included are mean stream order, MALF statistics, and river wetted area fished (Table 5).

3.3 Fishing intensity and spatial distribution of effort in rivers

Of all unique fished segments (N = 7156), about 40% did not qualify as valid-longfin fishing events with zero fishing intensity (longfin not targeted or caught); under a third of unique segments were fished only once, 16% were fished more than three times, and 4% were fished more than ten times, with a maximum fishing intensity of 59 times for one segment (Table 6, Figure 3). The total number of valid longfin unique segments fished each year from 2020 to 2024 showed no clear temporal trend in fishing intensity (Figure 3). Valid shortfin fishing intensity showed a similar pattern to valid-longfin but with very few unique segments that were not fished (0.6%), and there were proportionally more segments fished greater than ten times (Table 6, Figure 4).

Although spatial maps of fishing positions and fishing intensity cannot be provided for confidentiality reasons, the bulk of the North Island river-fishing effort between 2020 and 2024 was in ten main river systems and their tributaries: Wairoa and Wairua Rivers, Northland; Waikato and Waipa Rivers, Waikato; Piako and Waihou Rivers, Hauraki; Rangitaiki River, Bay of Plenty; Manawatu River, Manawatu; Ruamahanga River, Wairarapa; and Tukituki River, Hawke's Bay. There was little to no fishing in Taranaki, Central North Island and East Cape. Within nearly all these river systems, there were many stretches that had experienced moderately high fishing intensity (over 10 passes in the five years), with the highest intensity in the Waikato and Waipa Rivers where some stretches were fished from 60 to 100 times. The target species would have been shortfin for most of these fishing events as only 5% of fishing events targeted longfin (see Table 3).

The proportions of valid-LFE and valid-SFE fishing events for the five years (2020 and 2024) within the Eel Statistical Areas (ESA) are shown in Table 7. More than three-quarters (80.1%) of valid LFE fishing events were in just three ESAs (AA, Northland; AD, Waikato; AC, Hauraki). Similarly, 74.0% of valid SFE fishing events were in the same three ESAs (Table 7). For both species the Waikato has received the most valid fishing events.

3.4 Wetted area fished

The total wetted area fished for longfin in the North Island from 2020 to 2024 was 33.67 km^2 (28.17 km^2 for rivers and 5.50 km^2 for lakes), and for shortfin this was 65.74 km^2 (59.02 km^2 for rivers and 6.72 km^2 for lakes) (see Table 5). The total wetted area fished was about twice as large for shortfin than longfin, and was also larger in all ESAs (Figure 5). Overall, 88.3% of the longfin wetted area fished was in five ESAs (AA, AC, AD, AK, and AL) (Figure 5). Similarly, for shortfin, 81.2% of the wetted area fished was in five ESAs (AA, AC, AD, AG, and AK).

3.5 Longfin habitat fished

Estimates of total current longfin habitat (wetted area), along with longfin habitat fished (wetted area fished) in the North Island for fishing years 2020 to 2024 are shown in Table 8. As mentioned in the methods, the longfin habitat was not estimated as part of this study and was taken from the previous analyses (Beentjes et al 2016). Total North Island current longfin habitat in rivers, and in natural lakes over 0.9 km^2 accessible to longfin, was estimated at 458.8 km^2, and of this 33.7 km^2 (7.3%) was fished from 2020 to 2024 (equation 2) (Table 8). Of the 33.7 km^2 longfin habitat that was fished, most was in rivers with only 16% in natural accessible lakes.

The proportion of current longfin habitat fished by ESA ranged from 0% in AM (Wellington) to 29% in AC (Hauraki), and only five ESAs had more than 10% of current longfin habitat fished (AA, Northland; AB, Auckland; AC, Hauraki; AD, Waikato; AK, Manawatu) (Table 9b, Figure 6). A much higher proportion of the longfin habitat was fished in the two northern (LFE 20, LFE 21), compared to the two southern QMAs (LFE 22, LFE 23) (Table 10b).

The corresponding estimates for virgin habitat fished (equation 3) and maximum impacted abundance (equation 4) were 6.8% and 14.4%, respectively and are shown by ESAs and Quota Management Areas (QMA) (Tables 9b and 10b, respectively, Figure 7).

4. DISCUSSION

4.1 North Island fishing practices

Data from the ERS fishing events over the period 2020 to 2024 were analysed to estimate the wetted area in rivers and lakes that was fished in the North Island for longfin and shortfin individually. This follows on from a similar project before the introduction of the ERS, where for longfin only, wetted area fished was estimated for the period 2010 to 2014 based on information provided from face-to-face interviews with longfin eel fishers throughout New Zealand (Beentjes et al. 2016). Subsequently, the South Island wetted area fished was updated from ERS data (2020 to 2023), with the same methods adopted for the current North Island update (Beentjes & Shankar 2025). Both the South Island analyses and the current North Island updates estimated the full wetted area fished. This approach also incorporated shortfin eel habitat, which was not included in the original analyses that focused solely on longfin eels. Utilisation of the positional data available in the ERS has resulted in a more comprehensive and quantitatively accurate estimate of the areas that were fished for both species compared to those based on fisher interviews which were restricted to the main longfin eel fishers. In all three studies, the intensity or frequency of fishing within these discrete areas was also quantified, revealing those areas which were the most heavily and lightly fished.

The North Island eel fishery is a mixed fishery in many places, where both species are present and vulnerable to capture by fyke net. Shortfin catch has dominated in recent years as longfin Total Allowable Commercial Catches (TACC) were substantially reduced in 2006–07 and 2018–19, ACE (annual catch entitlement) has often been difficult to obtain by fishers, and markets are stronger for shortfin (Beentjes 2026, Fisheries New Zealand 2026). Hence, shortfin targeting was much more common than for longfin during fishing events, particularly in harbours (see Table 3). Further, there were about twice as many valid-shortfin than valid-longfin fishing events, with shortfin estimated catch more than four times greater than longfin (see Tables 1 and 2).

Vessels were used in more than 80% of fishing events across all habitats, as opposed to land-based fishing which was nearly all along riverbanks (see Table 3). Baiting of fyke nets was used in about two-thirds of fishing events in both lakes and rivers for both species, but seldom in harbours where fyke nets or sets nets are set in channels and eels (mostly shortfin) are caught while moving between streams and the harbour during incoming and outgoing tides.

The number and length of unique REC river segments where longfin was caught or targeted were about one-half of those for shortfin (see Table 4) and were distributed throughout the North Island coastally and well inland, with substantial overlap with shortfin distribution (not shown due to Fisheries New Zealand data confidentiality rules). This was consistent with the fishing intensity results where nearly half of the unique river segments (40%) were not fished at all for longfin, compared to less than 1% unfished for shortfin, i.e., not targeted or caught in the fishing event (see Table 6, see Figures 3 and 4). Further, a much higher proportion of the unique segments were fished more than ten times for shortfin (8%) compared to longfin (4%). The total wetted area fished for longfin in rivers and natural accessible lakes was 33.67 km^2, and for shortfin this was substantially more at 65.74 km^2 (see Table 5).

All of these features of the North Island eel fishery described above are consistent with a predominantly target shortfin fishery with longfin caught as by-catch, and is supported by the results of recent catch per unit effort analyses (Beentjes 2026). This contrasts with the South Island where, in rivers and inland lakes, longfin are predominantly the main target species, there were more valid longfin than valid shortfin fishing events, and the wetted area fished was much greater for longfin (Beentjes & Shankar 2025).

4.2 Spatial and temporal fishing effort

Although spatial effort data cannot be presented in this report for data confidentiality reasons, the breakdown of fishing events by ESAs shows that more than three quarters of the valid-longfin events were from Northland, Hauraki and Waikato ESAs, with the latter area having by far the most fishing effort for both species within the Waikato and Waipa Rivers and tributaries (see Table 7). There was little to no fishing, for either species in Taranaki, Central North Island and East Cape, in part due to declining fisher numbers, and avoidance of longfin where ACE is not available to cover the bycatch. Without longfin ACE, legal size eels must be returned to the water and recorded as destination X in the disposal report. Further, longfins over the maximum legal size[2] are also required to be returned to the

[2] Maximum legal size is 4 kg except in the Waikato Tainui Fisheries Area where it is 2 kg.

water and reported as destination G. Combined Destination X and G disposals were about twice the North Island landed longfin catch in the four years up to (Beentjes 2026) representing considerable logistical effort by fishers for no pecuniary return. Consequently, fishers tend to avoid fishing in these and other areas where longfin are abundant.

There was no temporal pattern in fishing intensity from 2020 to 2024 for either species (Figures 3 and 4), with some reaches of river fished more than 100 times in the five years. This demonstrates that fishers return to the same places within and between years, presumably because these are the most productive areas with the best habitat. In these intensively fished areas, eel size is likely to be small with catches comprised mostly of eels that have recently recruited to the fishery, i.e., eels that become too large to fit through the fyke net escape tubes.

4.3 Longfin habitat fished

Using previously estimated habitat within natural lakes over 0.9 km^2 accessible to longfin, and rivers at the >0.5 probability of capture model (Beentjes et al. 2016), the proportion of longfin habitat fished in the North Island for the period 2020 to 2024 was estimated at 7.3% (equation 2) (see Table 8), however, this may be slightly underestimated, as it includes river habitat above hydro dams that is not accessible to longfin. Similarly, the 2020 to 2024 estimate of the proportion of virgin longfin habitat fished (equation 3) was 6.8%. The maximum impacted abundance of longfin (equation 4), accounting for all potential losses of habitat and fishing activity, was 14.4% (see Table 9b, Figure 7).

The total longfin habitat in the North Island is an estimate only, based on the wetted area of rivers (i.e., segment length × MALF width) and the proportions of lake areas for which longfin eels were thought to inhabit and have unimpeded access and egress. This assumes that the entire wetted area of rivers is available as habitat for longfin eels; however, this is unlikely to be true for very large rivers where eels are more likely to occur close to river banks, or in river segments with suboptimal habitat. In addition, the estimates of total longfin habitat from the probability of capture models should be regarded with caution given that there were many segments where eels were caught yet the model predicted longfins were absent (Beentjes et al. 2016). Similarly, there is no way of knowing where eels are absent, despite the model predicting that eels are present.

There are currently no estimates of total shortfin habitat in New Zealand, and hence it is not possible to estimate the proportion of shortfin habitat that was fished. The Eel Working Group (7 April 2026) recommended that a predictive model of shortfin habitat be investigated and used to estimate the proportion of habitat fished.

4.4 Comparison between 2010 to 2014 and 2020 to 2024 fishing years

Different methods were used to estimate the area fished in the two studies (2010 to 2014, and 2020 to 2024), and hence the proportion of longfin habitat fished. Further, as mentioned, the latter study also provided estimates of the area fished for shortfin, absent from the 2010 to 2014 study which focused exclusively on the spatial distribution of longfin target effort. Despite the different methods, fundamentally the same outcomes were achieved and are broadly comparable. One key difference between methods is that the current study defined a longfin or shortfin fishing event by whether that species was targeted or caught, and on some occasions a single event could be categorised as both a valid shortfin and valid longfin fishing event. The earlier study disregarded shortfin, and fishers provided spatial effort data primarily on areas where they predominantly caught longfin. Consequently, the earlier study may have underestimated the proportion of longfin habitat fished compared with the current estimate.

Fishing intensity is not directly comparable between the two studies because of the different ways that it was estimated and compiled, but in broad terms the practice of fishing the same areas multiple times in a year, or over a number of years, has continued. The compiled fishing intensity on unique REC segments in the current study is quantitatively more accurate than the original study. The most productive areas, and those that are most accessible and economic to fish were likely to be fished most often. These intensively fished sections of river may, however, change depending on whether shortfin or longfin are the preferred catch, the marketable sizes required by processors, access to ACE, and avoidance of longfin.

The spatial distribution of longfin effort has changed markedly between the 2010 to 2014 and the 2020 to 2024 periods. The same key river systems were still intensively fished (i.e., Wairoa, Wairua, Waikato, Waipa, Piako, Waihou, Rangitaiki, Manawatu, Ruamahanga, and Tukituki), however many of the previously fished rivers and streams throughout the North Island were not fished in the last five years, including virtually all those in Taranaki, a region which historically was dominated by longfin. As explained above, the contraction in longfin effort is driven by a drop in fisher numbers, avoidance of longfin habitat, and economic viability of fishing more remote less productive areas, especially when much of the longfin catch is returned to the water under destination types G and X.

Compared to the original study (2010 to 2014), the number and length of North Island unique segments fished in the recent period (2020 to 2024) has dropped by about 60%, and the river wetted area fished by 71%. The natural lake wetted area fished, however, increased by 26%. The corresponding estimate of the proportion of longfin habitat fished, declined by more than two-thirds from 22.5% to 7.3% (see Table 8, Figure 7). Similarly, the virgin habitat fished dropped by a similar degree from 20.9% to 6.8%. The maximum impacted abundance also dropped, but not to the same extent, from 29.0% to 14.4% (see Tables 9a and b, Tables 10a and 10b, Figure 7). The reduction in longfin habitat fished by two-thirds between 2010 to 2014 and 2020 and 2024 is consistent with the observed contraction in spatial effort as a result of the factors described above.

In the South Island, longfin habitat fished declined by a half between 2010 to 2014 and 2020 to 2023 due to a slightly different set of circumstances including an ageing and declining fisher demographic, TACC cuts, market fluctuations, and the loss of processing capability (Beentjes & Shankar 2025).

5. FULFILMENT OF BROADER OUTCOMES

The following broader outcomes were delivered:

- A commitment to contributing positively to the social, economic, cultural, and environmental wellbeing of New Zealand.
- An innovative GIS project on the extent of longfin and shortfin eel habitat that is commercially fished which is largely unique from an international perspective and will benefit a range of stakeholders, including the general public, Māori, the commercial fishing industry, environmental NGOs, and the international eel research community.
- This project has advanced our understanding of the overlap of where longfin live, and what parts of this are currently commercially fished, providing an estimate of the proportion of available habitat that is fished. This is important for addressing the sustainability of the longfin eel fishery in the North Island.

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8. TABLES

Table 1: Fishing events by method and habitat type, overall and for valid longfin (LFE) and valid shortfin (SFE) fishing events for the North Island eel fishery for fishing years 2019–20 to 2023–24. A valid-LFE', fishing event is when longfin was caught or recorded as the target species, and a valid-SFE' fishing event is when shortfin was caught or recorded was target species. Harbour, estuary or harbour, Lake_hydro, hydro-electric dam lake (impeded access); River-hydro, rivers between hydro lakes (impeded access); Lake_natural, natural lake over 0.9 km^2 (unimpeded access to longfin); Lake_small_natural, Lake_natural, natural lake less than 0.9 km^2 (unimpeded access to longfin); River_REC, REC river segments (unimpeded access to longfin). *, total number of fishers across all methods and habitats.

			All Events		Valid LFE events		Valid SFE events	
Habitat	Method	Fishers	*N*	%	*N*	%	*N*	%
Harbour	Fyke	9	354	5.72	94	2.96	352	5.70
	set net	1	30	0.48	0	0.00	30	0.49
Lake_hydro	Fyke	5	358	5.78	212	6.69	358	5.80
Lake_ natural	Fyke	8	301	4.86	141	4.45	301	4.88
Lake_natural_small	Fyke	4	23	0.37	1	0.03	23	0.37
River_hydro	Fyke	2	36	0.58	34	1.07	36	0.58
River_REC	Fyke	24	5 088	82.20	2 689	84.80	5 073	82.18
Total		24*	6 190	100	3 171	100	6 173	100

Table 2: Estimated catch (t) by method and habitat type, overall and for longfin (LFE) and shortfin (SFE) for the North Island eel fishery for fishing years 2019–20 to 2023–24.

		Total eels		LFE		SFE	
Habitat	Method	Catch (t)	%	catch (t)	%	Catch (t)	%
Harbour	Fyke	78.0	6.9	4.76	2.2	73.3	8.0
	set net	5.1	0.5	0.00	0.0	5.1	0.6
Lake_hydro	Fyke	53.4	4.7	3.91	1.8	49.5	5.4
Lake_ natural	Fyke	30.8	2.7	1.96	0.9	28.9	3.1
Lake_natural_small	Fyke	5.4	0.5	0.02	0.0	5.3	0.6
River_hydro	Fyke	5.5	0.5	1.26	0.6	4.2	0.5
River_REC	Fyke	954.0	84.3	200.7	94.4	753.3	81.9
Total		1 132.3	100.0	212.6	100.0	919.7	100.0

Table 3: Metric variables for all North Island eel fishing events (N = 6190) for 2019–20 to 2023–24 fishing. Baited refers to the baiting of nets. Lake includes natural lakes (over 0.9 km^2), and hydro lakes. River includes river_ REC and small natural lakes (under 0.9 km^2). LFE, longfin eel; SFE, shortfin eel.

	Lake	River	Harbour		Lake	River	Harbour	ALL
Fishing Events	*N*	*N*	*N*	%	%	%	%	*N*
All fishing events	659	5 147	384	NA	10.6	83.2	6.2	6 190
Vessel events	658	4 061	381	82.4	12.9	79.6	7.5	5 100
Non-vessel events	1	1 086	3	17.6	0.1	99.6	0.3	1 090
Total				100				6 190
Target LFE events	30	301	2	5.4	9.0	90.4	0.6	333
Target SFE events	629	4 846	382	94.6	10.7	82.7	6.5	5 857
Total				100				6 190
Baited-net events	460	3 512	33	64.7	11.5	87.7	0.8	4 005
Unbaited-net events	180	1 539	321	33.0	8.8	75.4	15.7	2 040
Not recorded	19	96	30	2.3	13.1	66.2	20.7	145
Total				100				6 190
Baited-net events (LFE target)	11	199	0	63.1*	5.2	94.8	0.0	210
Baited-net events (SFE target)	449	3 313	33	64.8*	11.8	87.3	0.9	3 795
Not recorded	19	96	30	NA	13.1	66.2	20.7	145

*Percent of longfin target events (N=333), and percent of shortfin target events (N = 5857)

Table 4: Number and length of all unique REC segments in the North Island; and the number, length and proportion of these unique river segments fished. Data are shown for fishing periods 2010 to 2014 for longfin fishing only as identified by fishers; and 2020 to 2024 are from ERS data for valid-SFE and valid-LFE fishing events (i.e., where either longfin or shortfin were caught or targeted). LFE, longfin eel, SFE, shortfin eel. The 2010 to 2014 results are from Beentjes et al. (2016).

		Segment number			Segment length (km)		
Species	Period	REC	Fished	% fished	REC	Fished	% fished
LFE	2010 to 2014	268 877	9 144	3.4	181 934	6 746	3.7
LFE	2020 to 2024	268 877	3 510	1.3	181 934	2 981	1.64
SFE	2020 to 2024	268 877	7 144	2.7	181 934	6 049	3.32

Table 5: Metric variables for all fishing in unique North Island river REC segments. The 2010 to 2014 data include unique river segments identified by fishers where longfin was caught; the 2020 to 2024 data include unique river segments from valid longfin or valid shortfin fishing events (i.e., where either longfin or shortfin were caught or targeted) recorded in the ERS. Totals in 2020 to 2024 includes unique river segments fished, regardless of target species or whether eels were caught. Natural lake (over 0.9 km^2) wetted area fished is also shown. Fishing in Lake Wairarapa was not included in natural lakes fished because most fishing occurred in the tributaries of the lake. Cumecs, cubic metres per second; MALF, mean annual low flow; river total wetted area = length × mean stream width at MALF; lake wetted area = total habitat of natural lakes (over 0.9 km^2). The 2010 to 2014 results are from Beentjes et al. (2016).

		2010 to 2014			2020 to 2024
Variable	NI totals	LFE	Valid-LFE	Valid-SFE	Total
Segment number (N)	268 877	9 144	3 510	7 144	7 156
Segment length (km)	181 934	6 746	2 981	6 049	6 056
Wetted area lakes (km^2)	109.3	4.04	5.50	6.72	6.72
Wetted area rivers (km^2)	349.5	99.20	28.17	59.02	59.05
Total wetted area (km^2)	NA	103.24	33.67	65.74	65.77
Mean of MALF (cumecs)	NA	5.7	7.1	6.5	6.5
Mean of stream width at MALF (m)	NA	14.4	11.0	10.8	10.8
Mean stream order	NA	4.7	4.2	4.1	4.1

Table 6: Fishing intensity (times fished) frequency (number and percent) of unique North Island REC segments (N = 7 156) for 'valid longfin' and 'valid shortfin' fishing events for the 2020 to 2024 fishing years combined. Fishing intensity in segments ranged from zero to more than ten times. Fishing intensity of zero for valid-SFE occurred in 45 unique REC segments where no shortfin were caught or targeted; similarly for longfin there were 2834 unique REC segments where no longfin were caught or targeted. 'Valid longfin or shortfin' is where either species was caught or targeted on a fishing event. LFE, longfin eel; SFE, shortfin eel.

	Unique REC segments			
Fishing Intensity	Valid-LFE		Valid-SFE	
	N	%	*N*	%
0	2 834	39.6	45	0.6
1	2 197	30.7	3 969	55.5
2	651	9.1	1 106	15.5
3	342	4.8	469	6.6
4	248	3.5	308	4.3
5	169	2.4	195	2.7
6	151	2.1	162	2.3
7	90	1.3	116	1.6
8	62	0.9	103	1.4
9	68	1.0	50	0.7
10	57	0.8	57	0.8
>10	287	4.0	576	8.0
Totals	**7 156**	**100**	**7 156**	**100**

Table 7: Number and percent of ‘valid longfin’ fishing events, and ‘valid shortfin’ fishing events for 2020 to 2024 fishing years combined for each North Island Eel Statistical Area (ESA). ‘Valid-LFE is where longfin was caught or targeted on a fishing event. ‘Valid-SFE’ is where shortfin was caught or targeted on a fishing event. LFE, longfin eel; SFE, shortfin eel. See Figure 1 for location of Eel Statistical Areas.

	Valid-LFE		Valid-SFE	
ESA	(*N*)	%	(*N*)	%
AA	615	19.4	1 016	16.5
AB	148	4.7	398	6.4
AC	525	16.6	1 336	21.6
AD	1 401	44.2	2 214	35.9
AE	14	0.4	75	1.2
AF	0	0.0	20	0.3
AG	72	2.3	227	3.7
AH	31	1.0	193	3.1
AJ	20	0.6	63	1.0
AK	208	6.6	424	6.9
AL	137	4.3	207	3.4
Totals	3 171	100	6 173	100

Table 8: Estimates of total current longfin habitat (wetted area) from rivers, and in natural lakes accessible (over 0.9 km^2) to longfin, together with longfin habitat fished and percent of total available habitat fished, for fishing years 2010 to 2014, and 2020 to 2024 in the North Island. The longfin habitat estimates, and 2010 to 2014 fished habitat results are from Beentjes et al. (2016). Note that a small proportion of longfin habitat included in available river habitat, is above hydro dams, and not accessible to longfin.

	Longfin habitat available (km^2)			Longfin habitat fished (km^2)			
Period	Rivers	Natural lakes	Total	Rivers	Natural lakes	Total	% of total available
2010 to 2014	349.5	109.3	458.8	99.2	4.04	103.2	22.5
2020 to 2024	349.5	109.3	458.8	28.2	5.5	33.7	7.3

Table 9: Estimates of total current longfin habitat fished, virgin habitat fished, and maximum impacted abundance from all rivers and lakes by Eel Statistical Area, and overall for the North Island, for fishing years 2010 to 2014 (a); and 2020 to 2024 (b). See Figure 1 for Eel Statistical Area locations. The 2010 to 2014 results (a) are from Beentjes et al. (2016). LFE, longfin; Max, maximum.

a) 2010 to 2014

			Percent (%)
Eel Statistical Area	Current habitat fished	Virgin habitat fished	Max. impacted abundance
AA	36.1	34.7	40.2
AB	34.9	33.8	38.2
AC	50	47.6	55
AD	43.2	34.4	55.7
AE	17.4	16.2	23.9
AF	8.6	8.2	13.6
AG	17.3	16	24.7
AH	24.8	23.6	29.9
AJ	17	15.9	23.6
AK	36	34.5	40.6
AL	4.2	4.1	5
AM	2.4	2.2	7.4
All	22.5	20.9	29.0

b) 2020 to 2024

			Percent (%)
Eel Statistical Area	Current habitat fished	Virgin habitat fished	Max. impacted abundance
AA	11.4	10.9	15.4
AB	12.6	12.2	15.9
AC	29.2	27.8	34.2
AD	20.9	16.7	37.4
AE	1.4	1.3	8.3
AF	0.0	0.0	5.0
AG	3.2	2.9	11.1
AH	2.0	1.9	7.2
AJ	0.1	0.1	7.1
AK	10.0	9.6	14.6
AL	3.6	3.6	4.4
AM	0.0	0.0	5.0
All	7.3	6.8	14.4

Table 10: Estimates of total current longfin habitat fished, virgin habitat fished, and maximum impacted abundance from all rivers and lakes by Quota Management Area/Eel Statistical Area, and overall for the North Island, for fishing years 2010 to 2014 (a); and 2020 to 2024 (b). See Figure 1 for Eel Statistical Area locations. The 2010 to 2014 results (a) are from Beentjes et al. (2016). QMA, Quota Management Area; LFE, longfin;

a) 2010 to 2014

				Percent (%)
QMA	Eel Statistical Area	Current habitat fished	Virgin habitat fished	Max. impacted abundance
LFE 20	AA-AB	35.8	34.4	39.7
LFE 21	AC-AF	31.4	27.3	41.7
LFE 22	AG, AK-AM	13.2	12.7	16.5
LFE 23	AH, AJ	22.0	20.8	27.7
All	All	22.5	20.9	29.0

b) 2020 to 2024

				Percent (%)
QMA	Eel Statistical Area	Current habitat fished	Virgin habitat fished	Max. impacted abundance
LFE 20	AA-AB	11.6	11.1	15.5
LFE 21	AC-AF	13.5	11.7	25.5
LFE 22	AG, AK-AM	4.5	4.4	8.0
LFE 23	AH, AJ	1.4	1.3	7.2
All	All	7.3	6.8	14.4

9. FIGURES

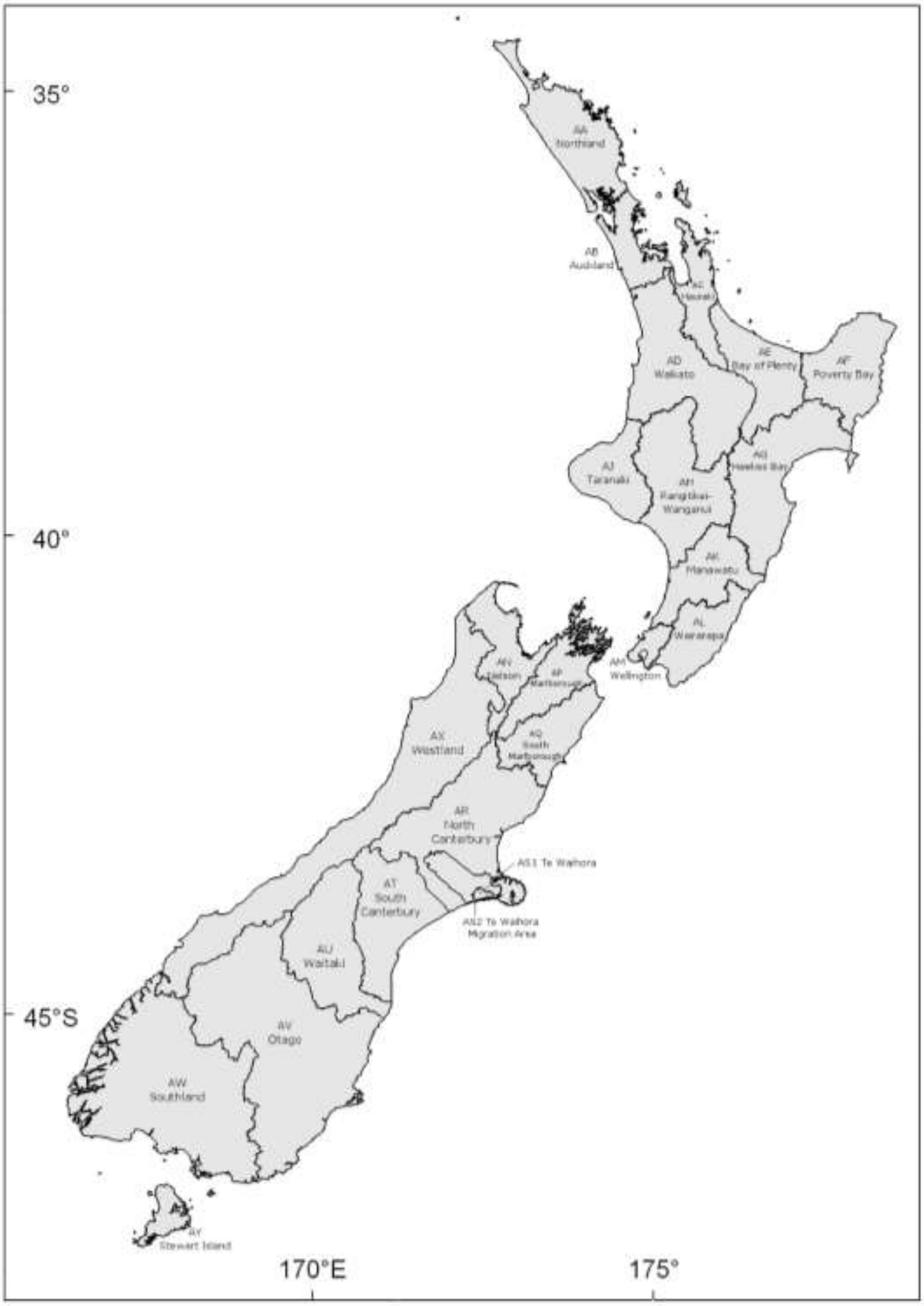


Figure 1: Eel Statistical Areas used for reporting location of catch from the commercial freshwater eel fishery before 2019–20, after which fishing events were reported by latitude and longitude.

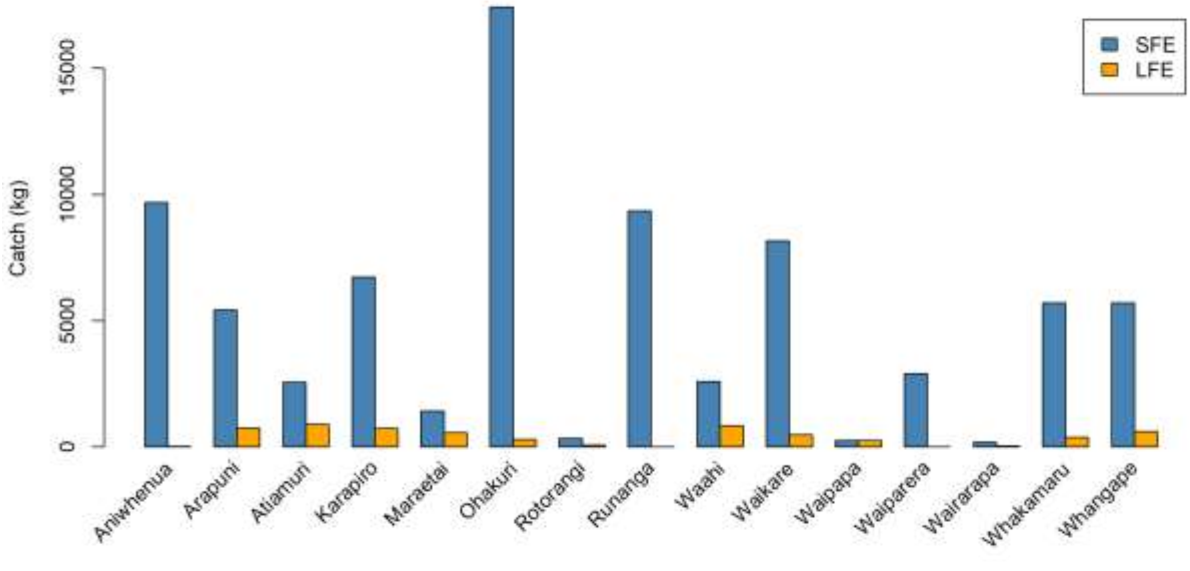
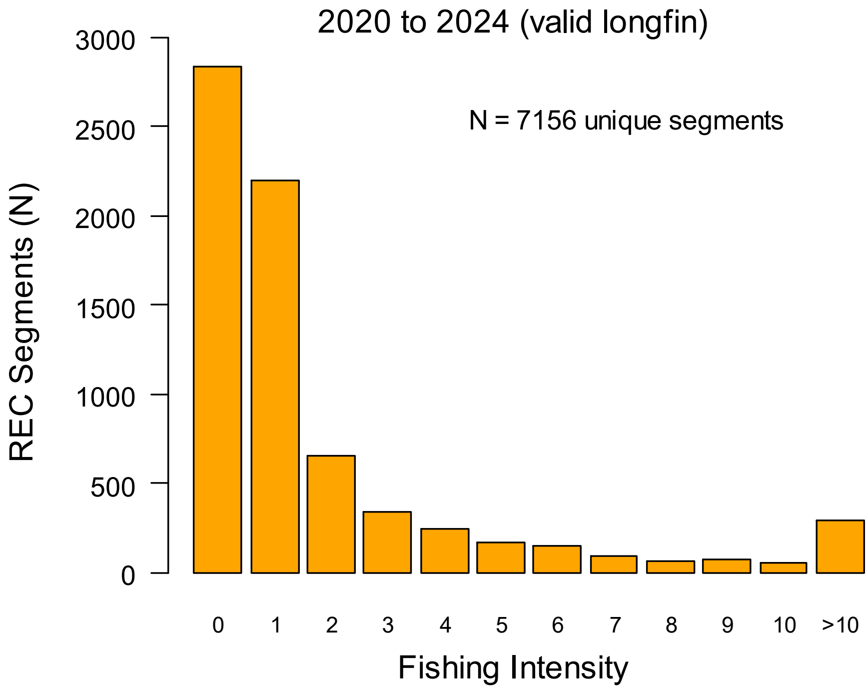


Figure 2: Catch of shortfin and longfin from North Island hydro and natural lakes (over 0.9 km^2) from 2020 to 2024. Lakes Runanga, Waahi, Waikare, Waiparera, and Whangape are natural lakes (over 0.9 km^2) with unimpeded access to eels, and others are hydro lakes with impeded access to eels.



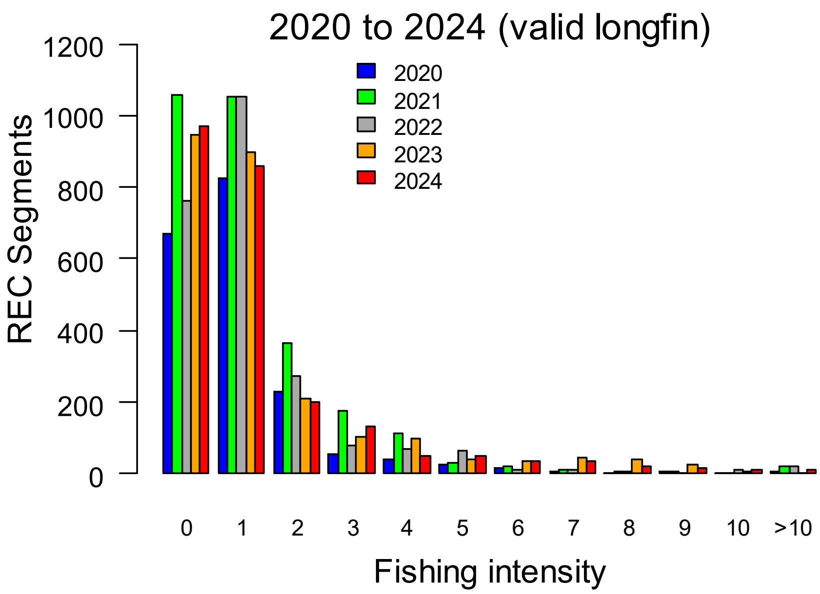


Figure 3: Histogram of the total number of unique North Island REC segments fished (N = 7156) for 'valid longfin' fishing events, and where no longfin were caught or targeted (= zero intensity) for 2020 to 2024 fishing years combined (top panel), and by fishing year (bottom panel). Intensity ranges from zero to more than ten times. Valid longfin is where longfin was caught or targeted on a fishing event.

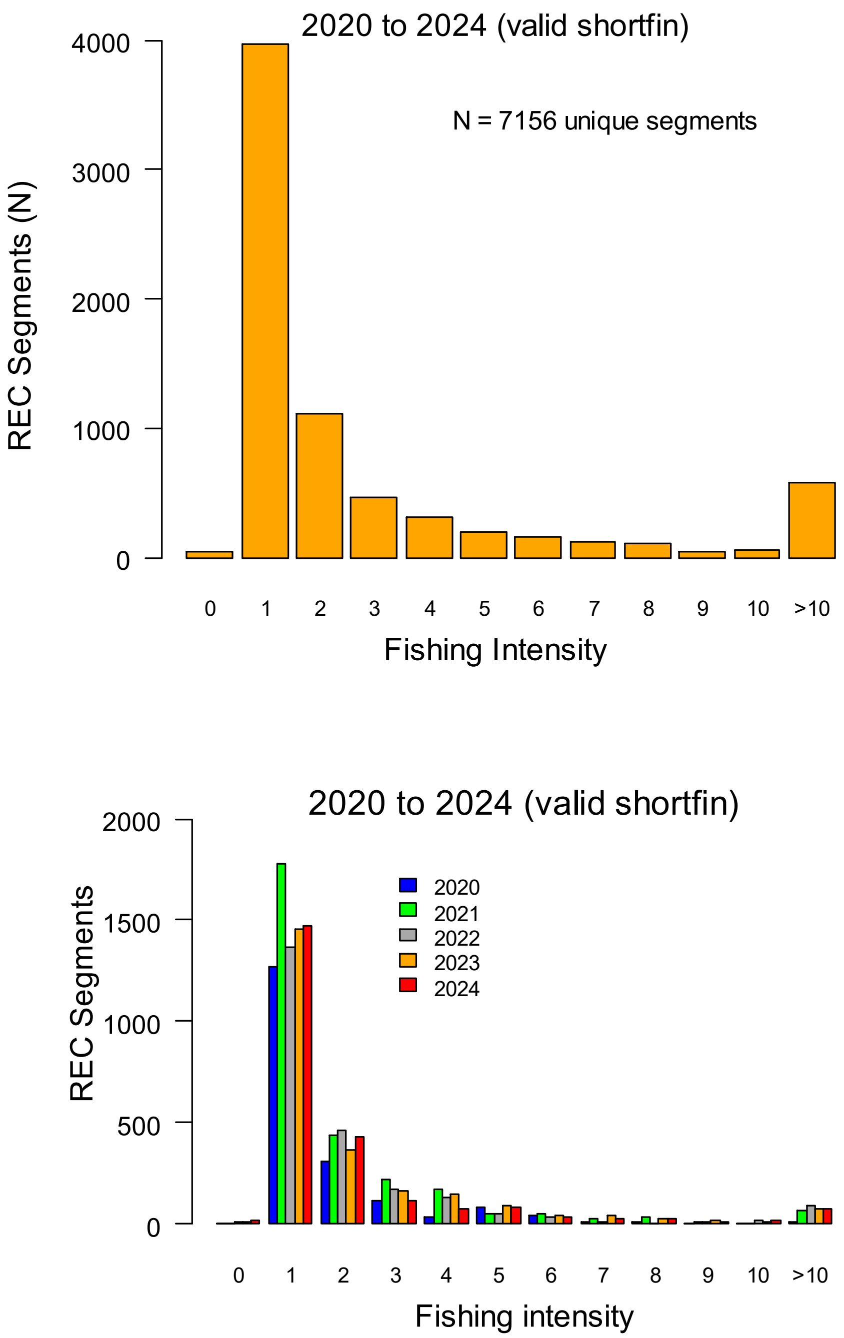


Figure 4: Histogram of the total number of unique North Island REC segments fished (*N* = 7156) for 'valid shortfin' fishing events, and where no shortfin were caught or targeted (= zero intensity) for 2020 to 2024 fishing years combined (top panel), and by fishing year (bottom panel). Intensity ranges from zero to more than ten times. Valid shortfin is where shortfin was caught or targeted on a fishing event.

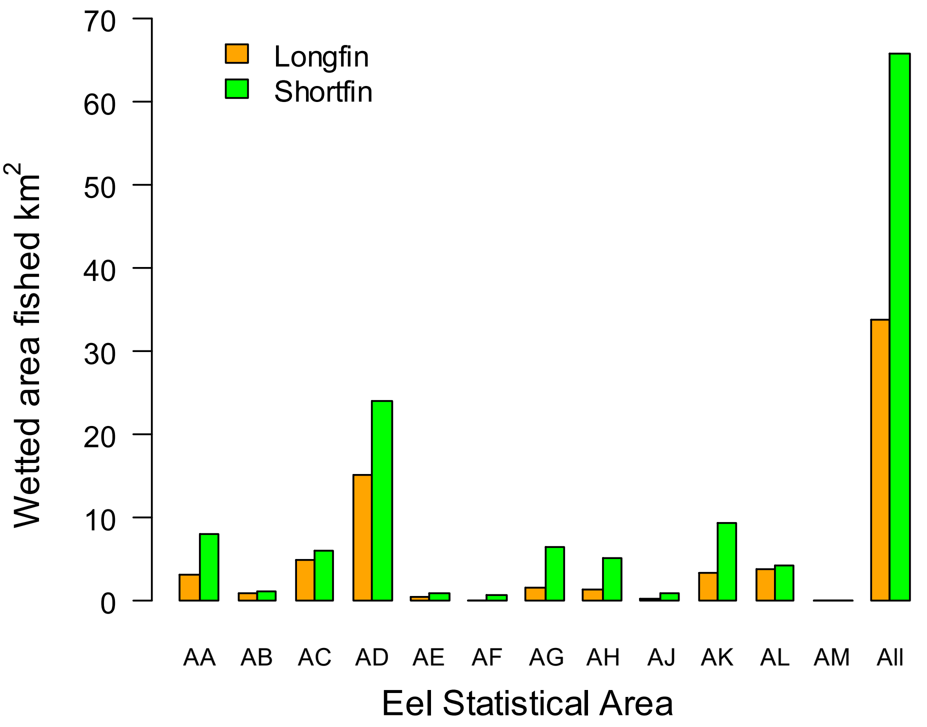


Figure 5: Total wetted area fished (km²) in unique river segments and accessible natural lakes (over 0.9 km²) in the North Island, by Eel Statistical Area, and all areas combined, over the period 2020 to 2024. Results are shown for valid-LFE and valid-SFE fishing events, i.e., where these species were caught or targeted. See Figure 1 for location of Eel Statistical Areas.

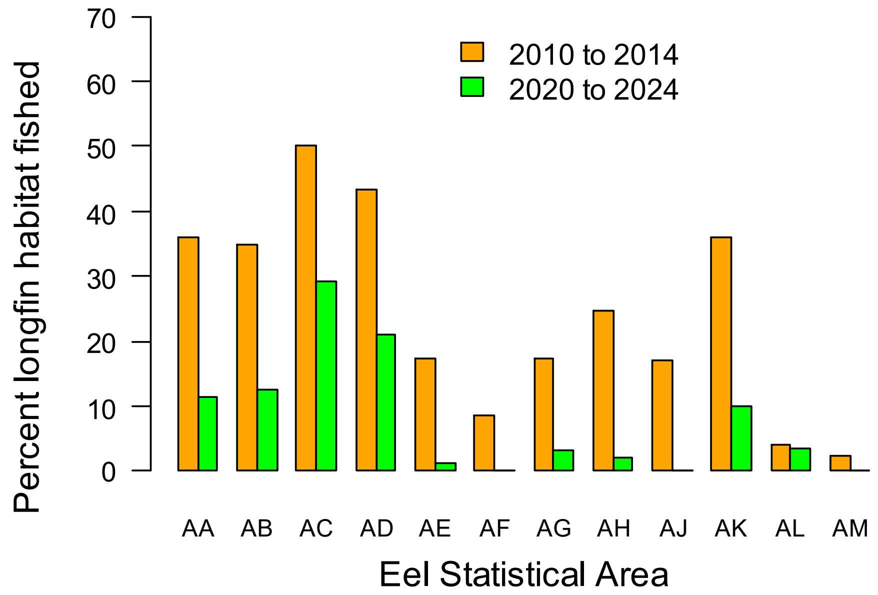


Figure 6: Percent longfin habitat fished (rivers and lakes combined, km²) by Eel Statistical Area for the periods 2010 to 2014 and 2020 to 2024 for the North Island. Results are shown for valid-LFE fishing events, i.e., longfin was caught or targeted. See Figure 1 for location of Eel Statistical Areas.

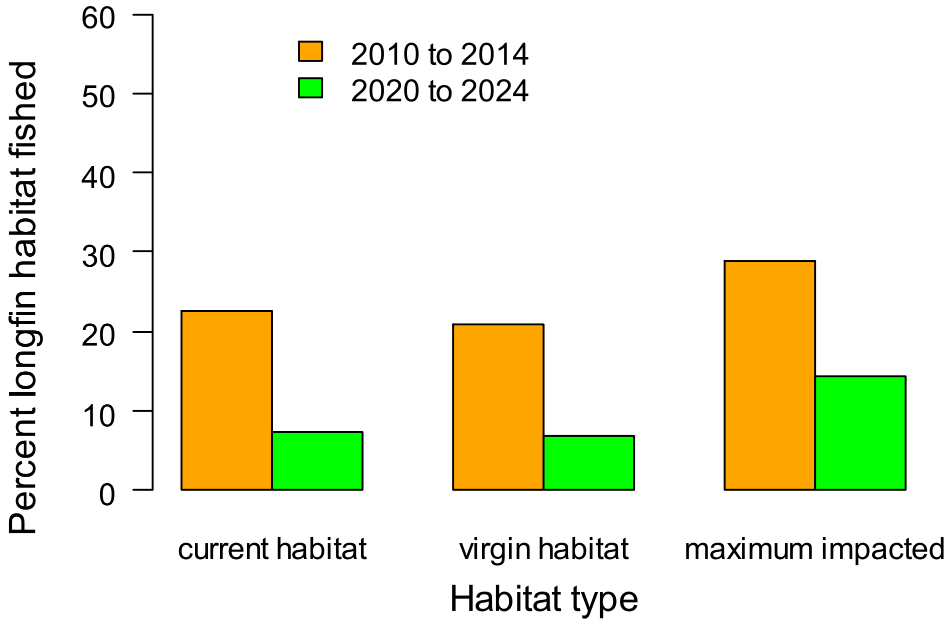


Figure 7: Estimates of percent of the current longfin habitat fished, virgin habitat fished, and maximum impacted abundance, from all rivers and lakes for the North Island, for fishing years 2010 to 2014, and 2020 to 2024. The 2010 to 2014 results are from Beentjes et al. (2016). Virgin habitat is all habitat where longfin were historically present including natural hydro lakes where access is now impeded, river habitat lost by the creation of artificial and inaccessible impoundments or reservoirs, and habitat lost through degradation (equation 3). Maximum impacted abundance includes all habitat losses plus fished habitat (equation 4).

10. APPENDIX

Appendix A. Methods used to estimate longfin habitat in rivers and lakes (from Beentjes et al. 2016)

River longfin habitat

The total current longfin habitat/distribution in New Zealand rivers was initially derived from the 'probability of capture' model developed by Leathwick et al. (2008) who used statistical models to describe the probabilities of capture for longfins and other freshwater species in all rivers and stream segments throughout New Zealand, including Stewart Island, but excluding the Chatham Islands. Their model was based on 22 500 fished sites recorded on the NIWA New Zealand Freshwater Fish Database (NZFFD), of which longfins were present in 6650 sites, and on the physical environment of discrete stream segments as recorded on the REC and elsewhere. Boosted regression trees (BRT) were used to model the relationships between fish occurrence and the physical environment.

The probability of longfin capture model is, in essence, a *de facto* longfin habitat suitability map, with the suitability of habitat related to probability of capture. Marginal habitat tends to be the high-altitude streams which may also be inaccessible due to waterfalls and the most suitable habitat is in moderately coastal locations extending considerable distances inland in lower gradient rivers. The model is influenced to some extent by sites that have recorded longfins in the NZFFD. For example, in some locations where longfin are known to be present, they are not always accurately represented by Leathwick's probability values.

Crow et al. (2014) subsequently updated the probability of capture model for the REC with the addition of new environmental variables and with new statistical analyses (Random Forest Analysis). The revised model and probability of longfin capture in REC segments has been used in the current analyses. Unlike Leathwick et al. (2008), Crow et al. estimated probability of capture separately for methods electric fishing, fyke net, and visual observations. Cohen's Kappa (Cohen 1960), a classification which maximises the agreement between two correct classification rates (i.e., true presence and true absence), was used to estimate the optimal probability of capture. The threshold chosen was where 90% of observations were correctly assigned, and the estimated probability thresholds of capture were 0.65 for electric fishing, 0.69 for fyke net fishing, and 0.3 for visual methods.

All three methods (electric fishing, fyke net, and visual) were combined by assuming that for each segment, if the probability of capture of one or more of the three methods indicated that longfin were present, then they were actually present and assigned a value of 'present'. Exploratory analyses of fishing effort (2010 to 2014 fishing data) and a probability threshold of Cohen's Kappa of 0.65 for electric fishing resulted in slightly more than one-third (37%) of fished segments being categorised as longfins absent, which seems intuitively too high and cast doubt on the efficacy of the model as a predictor of longfin habitat. The updated probability model remained sensitive to the density and distribution of observations within river systems, frequently indicating longfin eels as absent from rivers with few NZFFD records, even where they were abundant and heavily fished. Hence, the combined three method probability model, with probabilities of capture of values 0.2 and over, 0.4 and over, 0.5 and over, and 0.6 and over were compared with fished segments from our fisher interviews, as a 'ground truthing' test (Table A1).

Table A1: Probability model predictions for the 17 344 fished segments in 2010 to 2014. Of the fished segments, 98.1% overlapped with those where longfin were predicted to occur for a predictive threshold of 0.2 and over, and 52.4% for a threshold of 0.6 and over. (From Beentjes et al. 2016).

Probability threshold model	Longfin present (%)
>0.2	98.1
>0.4	84.6
>0.5	71.0
>0.6	52.4

While 0.2 appeared too lax to define longfin habitat adequately, 0.6 seemed too restrictive and so the probability of capture outputs for four probability thresholds were estimated. The information on spatial fishing effort obtained from commercial eel fishers should be representative of longfin habitat, although some habitat may be optimal and some marginal, but this was difficult to know without catch information associated with effort. Hence for segments where fishing was recorded (N= 17 344), the probability threshold models were 'tuned' by converting all values listed as 'absent' to 'present'. Without this procedure the habitat would be underestimated and the proportion of habitat that was fished would be overestimated, particularly for the higher thresholds. However, the 'tuning' process eliminates known under-counts, but there is no way of identifying the over-counts, i.e., segments for which the model indicates eels are present when they are not. The Fisheries New Zealand Eel Working Group (EELWG 2015/07b) recommended that the over 0.5 probability model was the most suitable and likely to be the best representation of longfin distributions within rivers (Figure A1).

River habitat for longfin eels was expressed as the wetted area (km^2) calculated from REC segment length (m) × mean segment width at mean annual low flow (MALF) (m) /10^6. This assumes that the entire area of rivers is available to longfin eels as habitat. A relatively small number of REC segments above hydro dams were included by the 0.5 probability model, and these were used in the total longfin habitat estimate.

Natural lakes longfin habitat

The total wetted area (km^2) of habitat available (=accessible) to longfins in natural lakes was estimated from the complete list of New Zealand lakes that were naturally formed, over 0.9 km^2, and considered to currently have unimpeded access to and egress to the sea for longfin eels (Beentjes et al 2016, appendix 1). This list includes all ten natural fished lakes accessible to longfin except Loch Katrine and Lake Mason in Canterbury, and Lake Rotokawau north of Kaipara Harbour which are all less than 0.9 km^2 – for these three lakes habitat was assumed to be the area of the entire lake. For New Zealand there were 95 candidate natural lakes of which 67 were considered to be accessible to longfin and for which habitat area was estimated (Beentjes et al 2016, appendix 1). The area of habitat was taken as the wetted area (km^2) of the entire lake, the littoral zone, or a prorated proportion of these areas. For some lakes, with little or no information on bathymetry or macrophytes, it was necessary to make a judgement call on the extent of the habitat and suitability of the habitat and this was often based on information for similar or nearby lakes (Beentjes et al 2016, appendix 1). South Island hydro-electric Lakes Manapouri and Te Anau were included in the natural lakes list at the recommendation of the Eel Working Group (EELWG-2015/07b) because there is an active elver transfer and migrant trap and release programme that has been running in these lakes since 2002 with nearly 7000 migrant eels transferred in 2014–15, of which about half were female (Unpublished data, Meridian Power Scheme, Mark James). For these two lakes, habitat was taken as 50% of the littoral area. Similarly, Lake Brunner was also included in the natural lakes because of the substantial fishery that exists in this lake, suggesting that elvers have access to the lake naturally and spawning migrants are thought to escape when the dam overtops during flood events. Lake Brunner habitat was taken as 50% of the littoral area to account for the dominance of shortfin in the lake and the compromised access. Te Waihora habitat was taken as 10% of the lake as it is dominated by shortfin.

Hydro lakes, impoundments and reservoir longfin habitat

All New Zealand lakes for which there is a hydro-electric dam or a barrier to upstream and downstream migration of longfins were extracted from the NIWA lakes database (Beentjes et al 2016, appendix 2). Although currently unavailable to longfin eels, the total wetted area (km^2) of dammed natural lakes such as Lakes Wanaka, Hawea and Wakatipu provided historic habitat for longfins. Man-made reservoirs or impoundment such as Lakes Dunstan, Waitaki, Karapiro and Matahina sit over relic reaches of rivers such as the Clutha, Waitaki, Waikato and Rangitaiki Rivers, respectively. A total of 51 hydro lakes were examined and of these 12 were deemed to have no eels because of features such as waterfalls or high altitude, leaving 39 lakes where habitat was estimated. Habitat was estimated for dammed natural lakes in the same way as described above for accessible natural lakes. Man-made impoundments and reservoirs, however, were first converted back to the original river segments and then within these the wetted area (km^2) was estimated as previously described, i.e., segment length (m) × mean segment width at MALF (m) / 10^6.

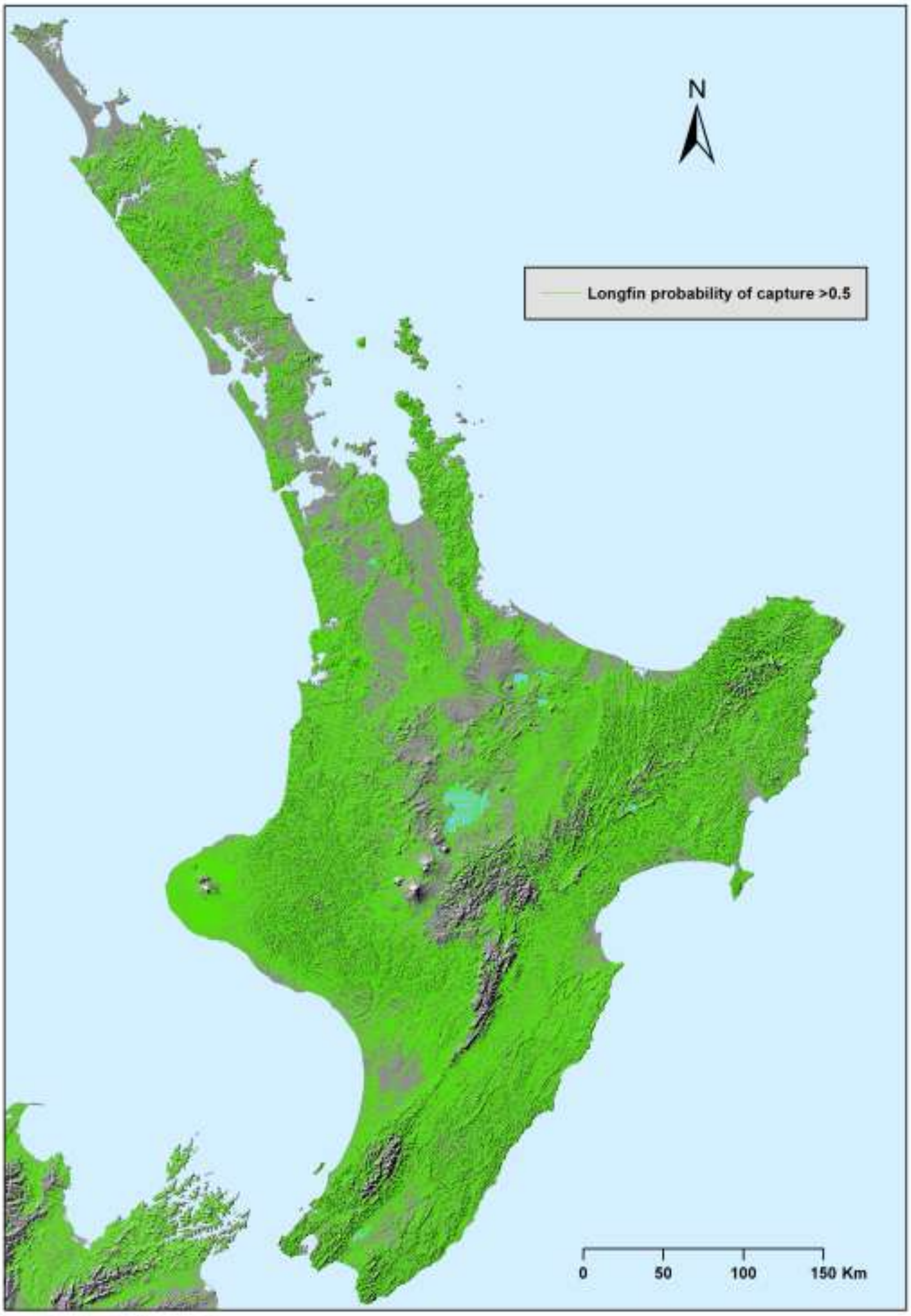


Figure A1: North Island probability of capture of over 0.5 for longfin eels, adjusted by fishing data where eels were caught. Based on Crow et al. (2014). Green represents REC segments where longfin were predicted to be present. From Beentjes et al. (2016).