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Design for a catch sampling programme to estimate the age structure of New Zealand hāpuku (*Polyprion oxygeneios*)

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EXECUTIVE SUMMARY

Maggs, J.Q.[1]; Parsons, D. (2023). Design for a catch sampling programme to estimate the age structure of New Zealand hāpuku (*Polyprion oxygeneios*).

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Hāpuku *Polyprion oxygeneios* is a teleost species found in New Zealand waters and has been managed together with the closely related bass *Polyprion americanus* under the combined stock referred to as groper (HPB). Fishers have historically been permitted to provide catch and landing records without having to differentiate between the two species. Only recently (1 December 2021) were the reporting requirements changed so that it is now mandatory for fishers to use the species-specific code, HAP (hāpuku) or BAS (bass), when reporting their catch of hāpuku or bass.

Groper stocks are managed as 'low knowledge' stocks due to the lack of reliable biomass or yield estimates. A fishery-independent longline survey to estimate the relative abundance of hāpuku was considered unfeasible by previous investigations due to high costs and potential for hyperstable catch rates. A catch-at-age sampling approach using otolith age information was recommended as an alternative to monitor changes in hāpuku total mortality (Z) rates. This report aimed to design a bottom longline survey to determine the age structure of New Zealand hāpuku through sampling commercial catches.

Two extracts of statutory commercial catch and effort data were obtained from Fisheries New Zealand's Enterprise Data Warehouse. The first extract included data prior to changes in reporting requirements (1 December 2021) and was used to broadly characterise the groper fishery (including any species-specific hāpuku records). The second extract included data after the change in reporting requirements (1 December 2021) and was used to focus on hāpuku-specific fisheries, and then to design and evaluate the feasibility of a hāpuku-specific catch sampling project. A subset of vessels, reporting the highest landings, were selected as potential catch sampling candidates. These fishers were interviewed by phone to gain a finer-scale level of detail about the fishery and to evaluate their suitability and willingness for inclusion in a catch sampling project. Licensed Fish Receivers (LFRs) were also contacted to determine their willingness to facilitate sampling within their factories and any cost that would be incurred with extracting otoliths from fish. Hāpuku age data were extracted from the Fisheries New Zealand *age* database to estimate the optimum sample size that would be required to obtain a reasonably precise estimate of total mortality.

Bottom longlining was the primary fishing method used to catch groper, followed by bottom trawling and set netting, which were primarily used in HPB 3. Other methods accounted for a small proportion of the catch. The catch by primary fishing methods did not show a strong seasonal pattern but was spatially concentrated in a limited number of statistical areas. Only four core regions were considered to have enough catch volume to support a hāpuku catch sampling project. These areas were defined as the Three Kings (within HPB 1), East Cape (within HPB 2), the Chatham Islands (within HPB 4), and Fiordland (within HPB 5).

Age data for 810 hāpuku otoliths were extracted from the *age* database. The collection dates of these otoliths ranged from 1982 to 2007 and the otoliths were collected primarily through the Scientific Observer Programme. A bootstrap resampling approach indicated that at least 250 otoliths were needed to achieve a 20% level of precision (coefficient of variation) on an estimate of Z for a given area and year.

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Six potential operators for a catch sampling programme were contacted and interviewed to assess feasibility. Fishers were generally cooperative but preferred that otolith extraction be done at LFR premises and not at sea. Devaluation rates for extracting otoliths from the fish varied from 25% to 100% of the port price per kilogram. The feasibility of a hāpuku catch sampling project was considered highest in the HAP 5 Quota Management Area (QMA) and lowest in the HAP 1 QMA, with HAP 2 and HAP 4 QMAs having medium feasibility. However, in most cases, sampling would likely incur high costs and would require close cooperation with fishers as well as a high degree of willingness. A pilot study was proposed for trialling the proposed design in just one QMA. However, a study of this type may be limited in its applicability to other QMAs. Careful consideration should be given to the various assumptions made in the feasibility analysis if the design is to be implemented.

1. INTRODUCTION

Hāpuku *Polyprion oxygeneios* is widely distributed around New Zealand, generally occurring over rough ground in depths ranging from 100 to 300 m. The species occurs sympatrically with the closely related bass *Polyprion americanus*. Because of similarities in appearance between the two species, distinguishing between them can be difficult. Fishers historically have therefore been permitted to provide catch and landing records without having to differentiate between the two species. Instead of having to use the species-specific codes HAP (hāpuku) or BAS (bass), the combined code HPB (groper) has been permissible and has been favoured by fishers. Consequently, the two species have been managed as a combined stock under the code HPB (Fisheries New Zealand 2022). The Total Allowable Catch (TAC) quota has also been set annually for the combined species code and not for the individual species. Only recently, from 1 December 2021, the reporting requirements were changed so that it is now mandatory for fishers to use the species-specific code, HAP, when reporting their catch of hāpuku and BAS if the catch is bass.

Groper stocks in New Zealand are considered 'low knowledge' stocks due to the lack of reliable biomass and yield estimates. It is also not known whether current catches or the total allowable commercial catch (TACC) limits are set at sustainable levels (Fisheries New Zealand 2022). Groper stocks are currently monitored using trends in catch, which have shown a decline in some Quota Management Areas (QMAs) in recent years. This has led to reductions in the total allowable catch (TAC) for HPB 1 and HPB 2 since October 2021 and for HPB 7 and HPB 8 since October 2022. However, due to the combined species codes, a hāpuku -specific catch trend has not been possible (Paul 2002).

An investigation into the feasibility of conducting a fishery-independent longline survey to estimate the relative abundance of hāpuku was carried out by Hartill et al. (2020). They concluded that a dedicated longline abundance survey was unfeasible for two reasons: (1) the high cost of chartering vessels (chartered vessels are required because any design would require directed fishing at specific locations); and (2) because the hāpuku longline fishery is associated with topographic features, survey abundance indices are likely to be hyperstable due to aggregation.

Hartill et al. (2020) recommended a catch-at-age sampling approach to monitor changes in hāpuku total mortality (Z) rates through the age composition of the population, as an alternative to a fishery-independent longline survey. Parker et al. (2011) came to a similar conclusion, from a previous characterisation and assessment of existing groper age information and recommended a cooperative industry sampling programme. The ageing of hāpuku otoliths has been validated, and hāpuku are known to live to 60 years of age (Francis et al. 1999, Parker et al. 2011).

Age information can provide an estimate of total mortality through a process known as catch curve analysis, which is often used in fisheries stock assessments where limited data about the population are available (e.g., Nelson 2019). Under this process, total mortality is estimated from the slope of the descending limb (i.e., the relative abundance of the older age classes that are fully selected by a fishing method) from the age composition data. However, the catch curve approach requires that the otoliths be collected by a fishing method having appropriate size and age selectivity.

The hāpuku fishery is concentrated on topographic features, and the biomass and size structure are known to vary between these features as hāpuku are mobile, undertaking annual spawning migrations (Beentjes & Francis 1999, Paul 2005). Consequently, the number of otoliths collected at a location should be weighted by the biomass (catch rate) at that location. Therefore, fine-scale spatial catch information is required for each set of the fishing gear where the hāpuku catch is destined for otolith extraction.

The objective of this project was to design a bottom longline survey to determine the age structure of New Zealand hāpuku, *Polyprion oxygeneios*. Due to the high cost of a dedicated survey, it was agreed that this project would provide a survey design for collecting hāpuku age information through catch sampling as suggested by Hartill et al. (2020). This report used statutory commercial catch and effort data to first characterise the groper/hāpuku fishery and then to design and evaluate the feasibility of a hāpuku catch sampling project. Selected fishers and Licensed Fish Receivers (LFRs) were also interviewed by phone to evaluate their willingness and suitability as participants in a potential catch sampling project.

2. METHODS

To achieve the objectives of this study, statutory commercial catch and effort data were used to characterise the HAP/HPB fishery over recent years. These data, along with telephone interviews with selected fishers, were used to design, and evaluate the feasibility of, a catch sampling project for hāpuku (HAP).

2.1 Study area

This study considered all HPB Quota Management Areas (QMAs) around New Zealand, except HPB 10 (Figure 1).

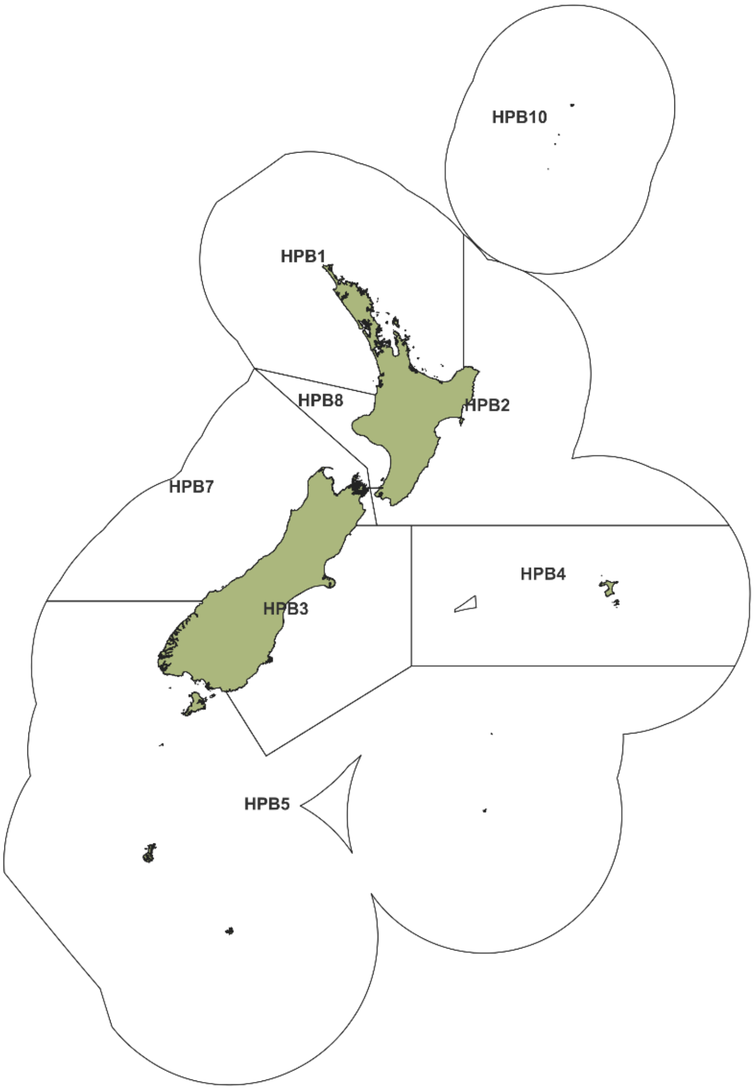

Figure 1: New Zealand Quota Management Areas for HPB, which is the combined species code for hāpuku and bass.

2.2 Data collection

Commercial catch and effort

Statutory commercial catch and effort data were requested from the Enterprise Data Warehouse, which is managed by Fisheries New Zealand, a business unit of the Ministry for Primary Industries. This included two separate extract requests.

The first extract request was for all available effort, estimated catch, and landings data from any trip where HPB, HAP, BAS, or BNS were specified as being targeted, caught, or landed. Bluenose (BNS) was included since hāpuku and bluenose are frequently caught together. The date range on this extract was 1 October 2016 to 30 September 2021. This extract was received on 23 March 2022 (Fisheries New Zealand replog 14251).

A second extract request was made later during the project. This was in response to a change in the reporting requirements for hāpuku and bass. Until 30 November 2021, fishers were not required to make a distinction between hāpuku (HAP) and bass (BAS) when reporting catches. Therefore, the code HPB, combining HAP and BAS, was used frequently. Use of the HPB combined code made it impossible to separate catch records for these two species when doing analyses. From 1 December 2021, fishers were required to report catches of hāpuku under the code HAP, which explicitly identifies the species as *Polyprion oxygeneios*, the subject of this investigation. The second request was therefore made to obtain new data that contained hāpuku-specific catch records and was in response to a recommendation made by the Inshore Working Group (8 December 2022). This data request was therefore the same as the first, but the date range was extended to include an extra year (i.e., 1 October 2016 to 30 September 2022). This extract was received on 15 November 2022 (Fisheries New Zealand replog 14715).

The data requests were irrespective of form type; however, this report covers a transition period from paper forms to the new Electronic Reporting System (ERS).

Telephone interviews

At the outset of each interview, it was established with the fisher that hāpuku was the focus of the interview because these fishers were likely to be catching both hāpuku and bass. A subset off these fishers were considered as potentially suitable for a HAP catch sampling project. After receiving the second data extract with HAP-specific catch records, the selected subset of potentially suitable fishers was interviewed a second time to obtain more focused information on their fishing activity and to discuss alternative catch sampling protocols in the light of the high-resolution data that had become available.

Lastly, Licensed Fish Receivers (LFRs) were also contacted to determine their willingness to facilitate sampling within their factories and any cost that would be incurred with extracting otoliths from fish.

Hāpuku age data

All available hāpuku age data were extracted from the Fisheries New Zealand *age* database (Mackay & George 2017) for use in a sample-size optimisation procedure. These otoliths were collected from around New Zealand primarily by the Scientific Observer Programme, with some also collected during historical catch sampling programmes and trawl surveys.

2.3 Data analysis

Data extracts, consisting of multiple data tables were received from Fisheries New Zealand and groomed following established protocols (Starr 2007, Starr & Kendrick 2016). Three separate tables of data were combined to produce a single composite dataset for further analyses. The first table contained the fishing effort, with each record representing a single fishing event. The second table contained records of species-specific estimated catch specified at the fishing event level. The third table contained records of stock-specific landings and landed weights specified at the trip level. First, the species-specific estimated catch per fishing event was matched to associated effort variables, such as fishing location, fishing method, target species, and tow speed to produce an intermediate dataset. Next, the intermediate dataset was matched to trip-level landed catch weights. Last, the trip-level landed catch weight for each species was prorated across events, using event-level estimated catch weight proportions. The link between the event-level estimated effort and trip-level landed catch weight tables was a common trip number field (trip_key).

The groomed datasets were used to produce fishery characterisation plots of annual catch by fishing method, month, target species, and statistical area. This was done in line with the "Guidelines to the design, implementation and reporting of catch sampling" (Ministry of Fisheries 2008). First, a broadscale characterisation of the fishery was undertaken using the data from the first extract, including all available fishing years (2016–17 to 2020–21). This characterisation could not differentiate hāpuku from bass as most records referred to the combined HPB code and the few HAP records were simply treated as HPB catch. The broadscale characterisation evaluated catch according to the standard HPB QMA delineations but showed that HPB catch was spatially concentrated in a few statistical areas. These areas were used to define core areas. For example, Statistical Areas 047 and 048 in HPB 1 were collectively defined as the Three Kings.

After establishing core areas, a subset of vessels, reporting the highest HPB landings, were selected as potential catch sampling candidates. The contact details of the operators of these vessels were obtained from Fisheries New Zealand so that telephone interviews could be conducted. In this report, the identification of the vessels and their operators have been anonymised for confidentiality reasons. A single uppercase character was assigned to each operator as their identifier and a numeric suffix was used to differentiate between multiple vessels owned by a single operator.

A more focused characterisation was undertaken using the data from the second extract. This characterisation focused specifically on HAP catches in the last available fishing year (2021–22), when it was mandatory to use the HAP species code.

Historical hāpuku age data were analysed using a bootstrapping approach to determine the minimum number of otoliths required to produce an estimate of total mortality with a reasonable degree of precision (i.e., coefficient of variation ≤ 20%). Firstly, the age data were plotted as the natural log of numbers at age versus age to determine the inflection point of the catch curve a_{max}, also known as the start of the descending limb or dome. Although one value of a_{max} would be appropriate, four alternative a_{max} values were evaluated. Next, 1000 bootstrap samples were drawn with replacement from the original age data. Bootstrap sample sizes from 20 up to 500, in increments of 20, were evaluated. A regression model was fitted to the descending limb of each of the 1000 samples to estimate the slope and hence the total mortality Z. Lastly, a coefficient of variation (CV) was determined for the 1000 estimates of Z.

Two sampling strategies were explored to assess the feasibility of a catch sampling programme. The evaluation of these approaches considered the need to obtain sufficient fish to collect at least 250 otoliths and to reduce the burden on the fisher as far as possible. The first approach included sampling either every seventh fish or every third fish that was caught based on the catch reported for the 2021–22 fishing year. The second strategy was to sample every fish captured on a longline set, but to limit the number of sets that were sampled (e.g., only sets having at least 20 hāpuku on the line).

Although this investigation was to design a bottom longline catch sampling programme, setnet catches in HPB 3 were briefly explored as a possible alternative for catch sampling in this QMA because bottom longline catches were considered too low to collect a representative sample.

Fishing years straddle calendar years, beginning on 1 October and ending on 30 September in the following year. For simplicity, fishing years are presented here as the final calendar year of the sequence. For example, the 2016–17 fishing year is presented as 2017. All analyses were performed using R v4.0.2 (R Core Team 2020). Maps were produced using QGIS 3.22.16.

3. RESULTS

3.1 Fishery characterisation (2017–2021 fishing years)

The fishery characterisation from 2017 to 2021 covers the period when catches were landed as HAP, BAS, or HPB. The total allowable commercial catch (TACC) for HPB remained stable at 2182 tonnes from the 2017 to the 2021 fishing years (Figure 2). During this period, the TACC for HPB covered landings of both hāpuku and bass, regardless of whether the catch was landed under HAP, BAS, or HPB. Landings against the codes HAP and HPB also remained relatively stable from 2017 (1267 t) to 2021 (1156 t) but have been consistently well below the TACC. Although not the subject of this report, landings reported against the BAS code were low and insufficient to account for the shortfall between the landings and the TACC.

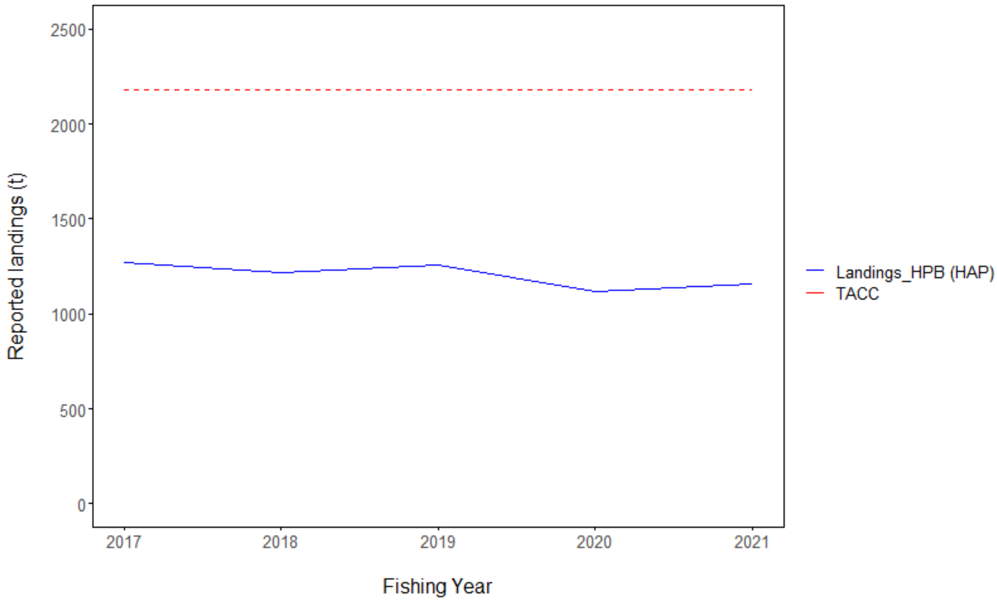

Figure 2: Total reported landings in tonnes, including all destination codes, for HPB (including hāpuku records). Total Allowable Commercial Catch (TACC) in tonnes for the combined groper species (HPB) also shown. Includes data for all fishing methods and for all New Zealand for the 2017 to 2021 fishing years.

Landed catch of HAP/HPB was taken primarily by bottom longline (BLL) in all years and in all quota management areas except HPB 3 (Figure 3). Bottom trawl (BT) also accounted for an appreciable amount of the catch, primarily in HPB 3, where bottom trawl and setnet catches (SN) exceeded that of bottom longline. Other methods, including dahn line (DL), Danish seine (DS), midwater trawl (MW), and precision bottom trawl (PRB), accounted for a small proportion of the catch in all QMAs.

The landed catch by the primary fishing methods (BLL, BT, SN, DL, DS, MW, PRB) did not show any strong overall seasonal patterns (Figure 4). In HPB 1, landings were generally higher from August to April. Conversely, landings in HPB 3 were generally highest from February to August.

The catch by the primary fishing methods was spatially concentrated by statistical area with the following areas providing the bulk of the catch: Statistical Area 047, 048, etc. (Figure 5). Heat maps of bottom longline, bottom trawl, and setnet catch, aggregated for all years (2017–2022), provided a higher spatial resolution of catch concentration (Figure 6).

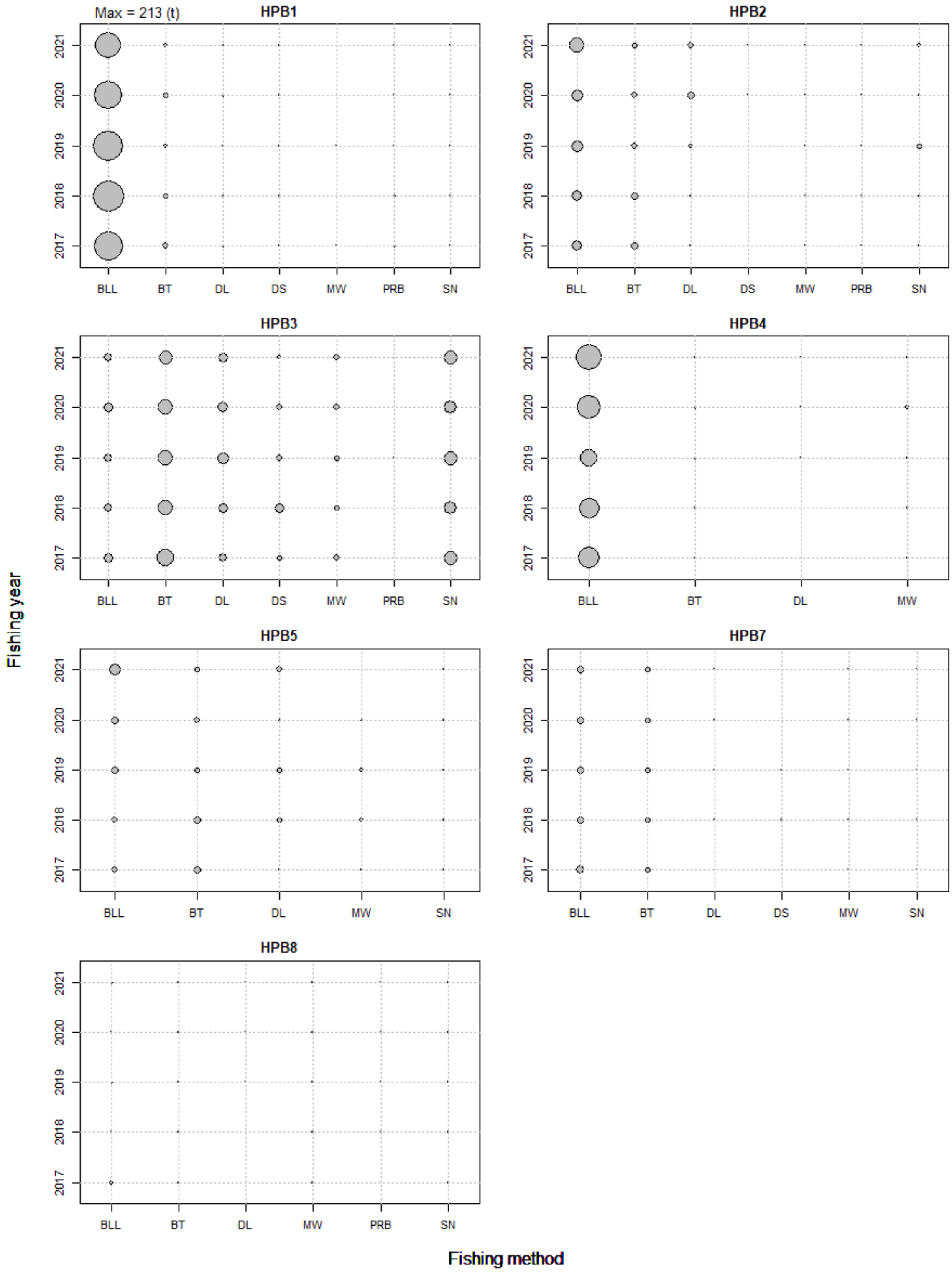

Figure 3: The distribution of the combined groper species (HPB, including hāpuku records) landed weight in tonnes by fishing method, fishing year, and quota management area. BLL = bottom longline, BT = bottom trawl, DL= dahn line, DS = Danish seine, MW = midwater trawl, PRB = precision bottom trawl, SN = setnet. Includes data for selected fishing methods for the 2017 to 2021 fishing years.

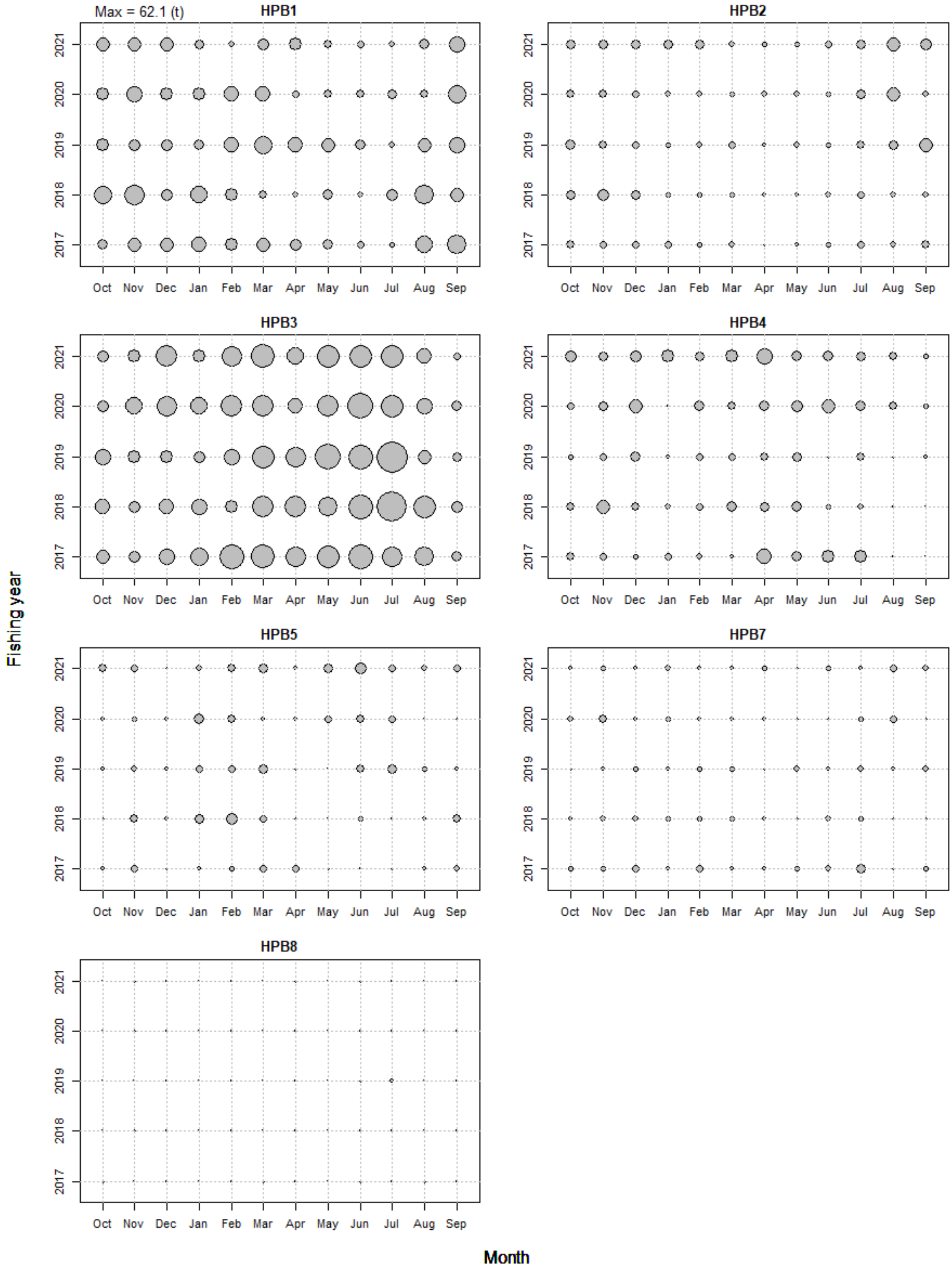

Figure 4: The distribution of the combined groper species (HPB, including hāpuku records) landed weight in tonnes by month, fishing year, and quota management area. Includes data for bottom longline, bottom trawl, dahn line, Danish seine, midwater trawl, precision bottom trawl, and setnet for the 2017 to 2021 fishing years.

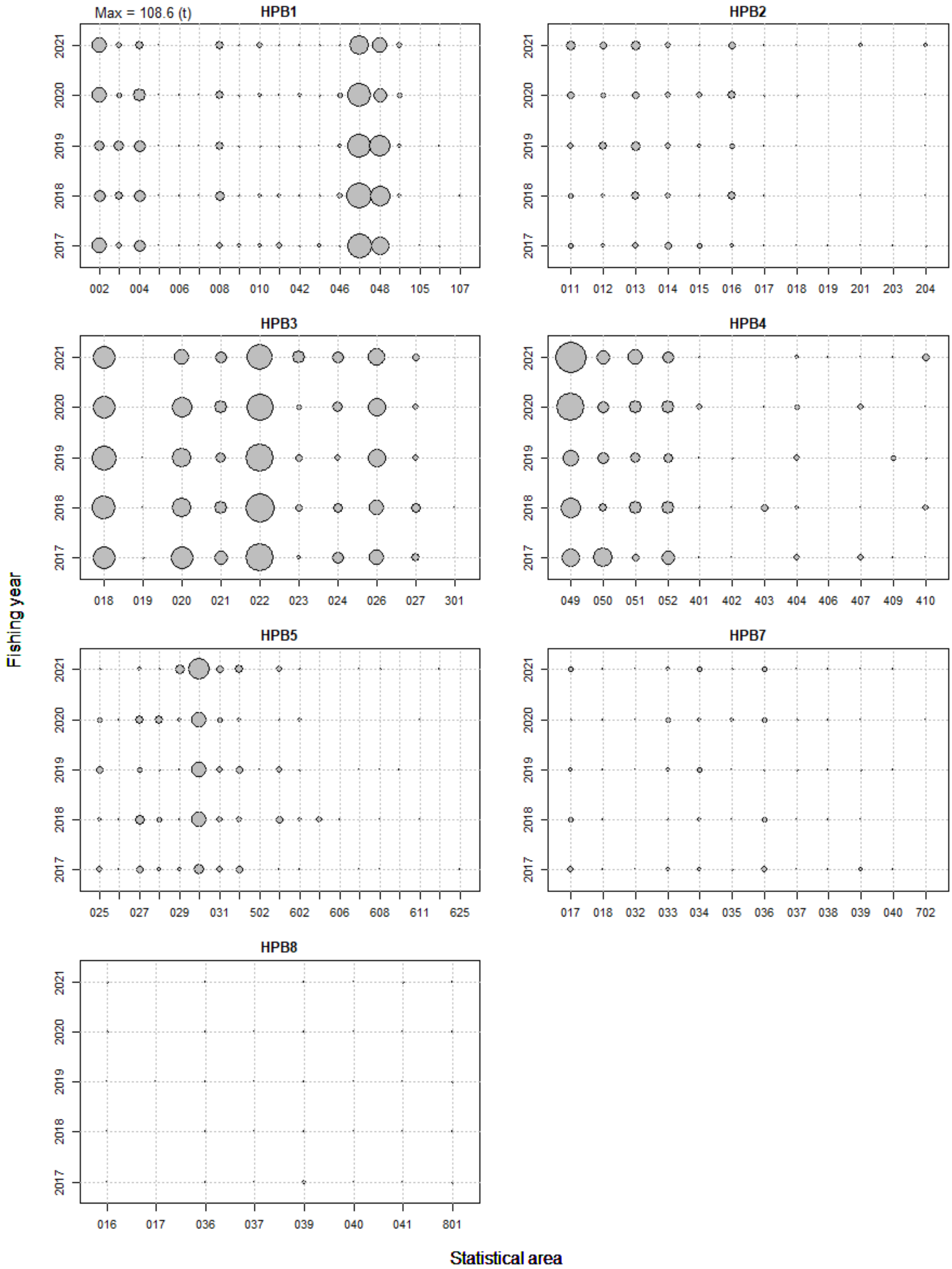

Figure 5: The distribution of the combined groper species (HPB, including hāpuku records) landed weight in tonnes by statistical area, fishing year, and quota management area. Includes data for bottom longline, bottom trawl, dahn line, Danish seine, midwater trawl, precision bottom trawl, and setnet for the 2017 to 2021 fishing years.

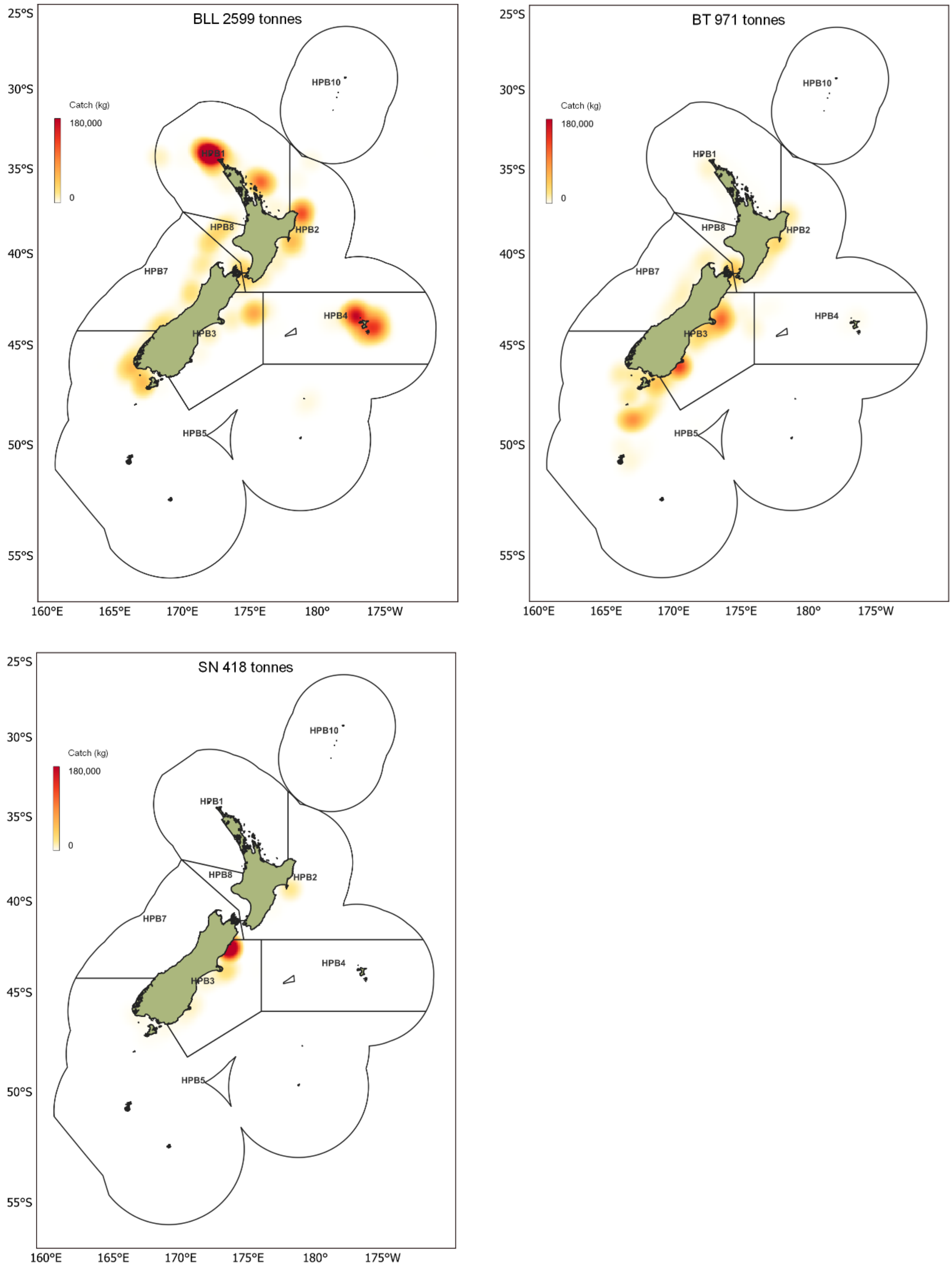

Figure 6: Spatial distribution of estimated green weight in kilograms for the combined groper species (HPB, including hāpuku records) taken by bottom longline (top left), bottom trawl (top right), and setnet (bottom left) fisheries for the 2017 to 2021 fishing years. Map data generated using Kernel Density Estimation (quartic kernel shape) with a 100 km radius and 10 km pixel size.

Overall, 73% of the catch came from a limited number of statistical areas included within ten core areas (Table 1). An evaluation of the overall bottom longline catch in the core areas for 2017– 2021 showed that only four core areas had potentially enough (>150 tonnes for 2017–2021) groper catch volume to support a hāpuku catch sampling project. These areas were the Three Kings (HPB 1), East Cape (HPB 2), the Chatham Islands (HPB 4), and Fiordland (HPB 5).

Table 1: Estimated catch for the combined groper species (HPB, including hāpuku records) in tonnes taken by bottom longline in selected statistical areas as grouped into core areas of spatially concentrated catch volumes for the 2017 to 2021 fishing years. Estimated catch also given for setnet (SN) in the East Coast South Island region. The category 'Other statistical areas' refers to all other statistical areas not included in the other ten core areas.

Core area	Statistical Areas	2017	2018	2019	2020	2021	Total
Chatham Islands	049, 050, 051, 052	128	105	77	151	176	636
Cook Strait	016, 017, 018, 019, 037, 039	40	40	29	18	11	139
East Cape	011, 012	18	16	36	38	76	184
East Coast Sth Island	018, 019, 020, 021, 022, 023, 024	29	31	20	35	29	144
East Coast Sth Island (SN)	018, 019, 020, 021, 022, 023, 024	81	70	76	70	75	372
Fiordland	029, 030, 031, 032, 033	39	35	44	53	90	260
North Taranaki Bight	041, 801	27	7	18	9	18	79
Other statistical areas		122	165	127	138	141	693
Statistical Area 004	004	12	2	7	8	2	30
Statistical Area 034	034	2	2	6	4	3	17
Three Kings	047, 048	100	84	107	69	59	419
Total		517	488	471	522	603	2 601

Within the four selected core areas, several bottom longline vessels had reported HPB catch from 2017 to 2021 (Figure 7). Fourteen of these vessels were selected for evaluation, based on the volume of their annual catch. The East Coast South Island core area had more setnet landings than bottom longline landings and accordingly all but one of the setnet vessels were selected for evaluation (Figure 8).

Using Fisheries New Zealand data, these vessels were matched to 19 respective fishers (Table 2). To maintain anonymity, fishers were assigned a unique identifier (uppercase character A-S). In most cases, a fisher operated only one vessel. However, fisher K owned two vessels (K1 and K2) as did operator C (C1 and C2). Several other bottom longline vessels (grouped as NA) reported little or inconsistent HPB catch to be suitable for a catch sampling project. Nineteen fishers were contacted during August to October 2022. Three fishers were unreachable, and one refused to be interviewed.

Of the original 19, six fishers, from around New Zealand, were deemed suitable candidates for participation in a catch sampling programme. This included bottom longline fishers C, F, G, I, M, and O, who were planning to continue their fishing operation into the future, were willing to participate in a catch sampling programme, and reported by phone to have landed sufficient hāpuku for sampling (Table 2). From the telephone interviews of the two East Coast South Island setnet fishers, it was clear that the setnet mesh size would be too size selective (narrow size range) for deriving a representative age structure of HAP. Consequently, the setnet fishery was abandoned as a viable catch sampling alternative for HAP.

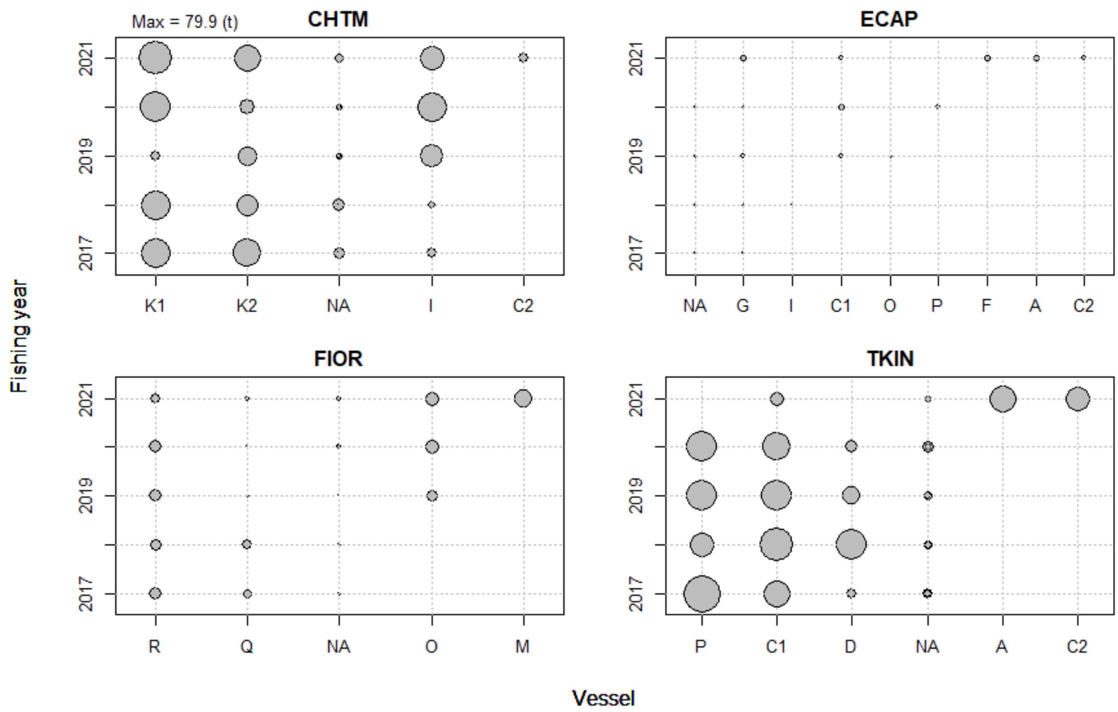

Figure 7: The distribution of the combined groper species (HPB, including hāpuku records) estimated green weight taken by individual bottom longline vessels (vessel identification recoded for confidentiality) in the Chatham Islands (CHTM), East Cape (ECAP), Fiordland (FIOR), and Three Kings (TKIN) regions for the 2017 to 2021 fishing years. In some cases, two vessels were owned by the same operator, and this is denoted by a numeric suffix (e.g., K1 and K2). Vessel NA refers to a grouping of vessels with very low catch volumes.

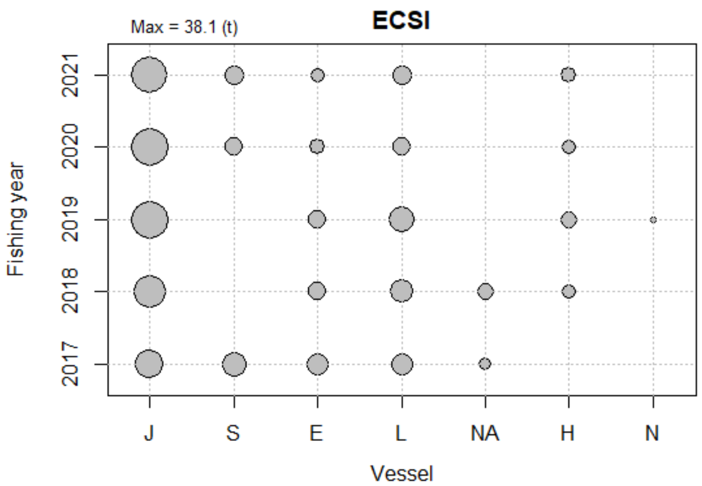

Figure 8: The distribution of the combined groper species (HPB, including hāpuku records) estimated green weight in tonnes taken by setnet in the East Coast South Island (ECSI) region for the period 2017 to 2021 fishing years. Vessel NA refers to a grouping of vessels with very low catch volumes.

Table 2: Overview of the responses from the first round of telephone interviews conducted in August–October 2022. Potential indicates potential catch sampling candidates. BLL = bottom longline, SN = setnet. HPB is the general combined code for reporting catches of hāpuku and bass. HAP is the specific code for hāpuku, BAS is the specific code for bass. FMA = Fishery Management Area. GRE = green, H&G = head and gutted, GUT = gutted. LFR = Licensed Fish Receiver. (Continued on next page)

Fisher	Fishing method	Area of operation	Continuation of fishing	Willing to work with us	HPB composition	Targeting features	Size range (kg)	Landing location	Landing state	Typical HAP landing size (kg)	Potential
A	BLL	Three Kings	No								No
B	BLL	Three Kings	*Referred us to Fisher A*								N/A
C	BLL	Three Kings	Yes	Yes	60–70% HAP	Yes	"full size structure"	Mangonui	GRE	500	Yes
D	BLL	Three Kings	Unlikely	?	75% BAS	Yes	10–15				No
E	SN	East Coast South Island	*Refused to be interviewed*								No
F	BLL	East Cape	Yes	Yes	90% HAP	Yes	5–20	Napier, Gisborne, Tauranga, Whangarei, Mangonui	GRE	Varies	Yes
G	BLL	FMA 2	Yes	Yes	85% HAP	Yes	6–8	Napier, Picton, occasionally Gisborne	GRE	100	Yes
H	SN	Kaikōura	Yes	Yes	100% HAP	No	6–9	Wharf at Kaikōura	H&G	200	No
I	BLL	Chatham Islands	Yes	Yes	95% HAP	?	8–10	Saltwater Seafoods (Hastings), Sanford (Auckland)	GUT	5 000–6 000	Yes
J	SN	East coast South Island	Yes	No							No
K	BLL	Chatham Islands	No								No

Fisher	Fishing method	Area of operation	Continuation of fishing	Willing to work with us	HPB composition	Targeting features	Size range (kg)	Landing location	Landing state	Typical HAP landing size (kg)	Potential
L	SN	East Coast South Island	*Unreachable*								?
M	BLL	Stewart Island / Fiordland	Yes	Yes	99% HAP	No	8–10	Bluff, picked up by contract LFR trucked to Dunedin	Small fish GRE (iki), big fish H&G	1 500–3 000	Yes
N	SN	East Coast South Island	*Unreachable*								?
O	BLL	Fiordland	Yes	Yes	99% HAP	Yes	6–15	Bluff	H&G	2 000–4 000	Yes
P	BLL	FMA 2	No								No
Q	BLL	FMA 3	New entrant to the fishery	Yes	95% HAP	?	Expecting 10–15	Lyttelton, Bluff, Greymouth	H&G	Expecting 5 000–7 000	No
R	BLL	Fiordland	Unlikely	No							No
S	SN	East Coast South Island	*Unreachable*								?

3.2 Fishery characterisation (2022 fishing year)

From 1 December 2021, it became mandatory to report hāpuku landings under the code HAP, which enabled an evaluation of hāpuku-specific catch for most of the 2022 fishing year (Figure 9). Although the use of the HAP code for hāpuku catch became mandatory, catches of HAP and BAS were still counted against the HPB quota. The total allowable commercial catch (TACC) for HPB was reduced from 2182 tonnes to 1655 tonnes for the 2022 fishing year. The total landings, including all landing destination codes and all fishing methods, reported against HPB and HAP codes combined in 2022 were 790 tonnes, down from 1156 tonnes in 2021. Total landings reported against just the HAP code in 2022 were 683 tonnes, indicating that 86% of the overall HPB/HAP catch was hāpuku in 2022.

Hāpuku catch in 2022 was highest around the Chatham Islands and in Statistical Area 030 in the Fiordland region (Figure 10, Figure 11).

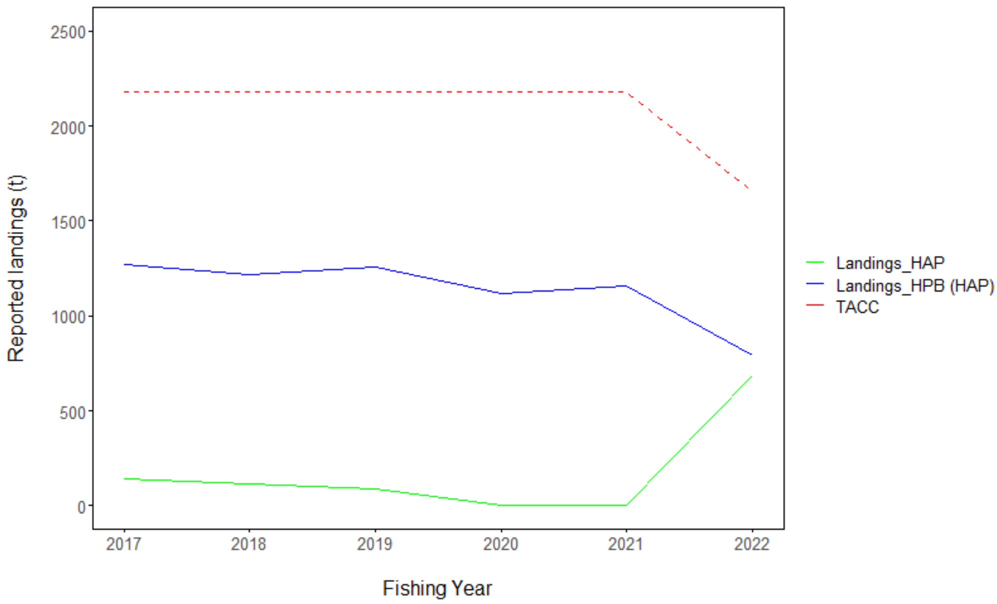

Figure 9: Total reported landings in tonnes, including all destination codes, for the combined groper species (HPB, including hāpuku records), and HAP. Total Allowable Commercial Catch (TACC) in tonnes for the combined groper species (HPB) also shown. Includes data for all fishing methods and for all New Zealand for the 2017 to 2022 fishing years. Note mandatory use of the HAP code for hāpuku catches from 2021-12-01 onwards.

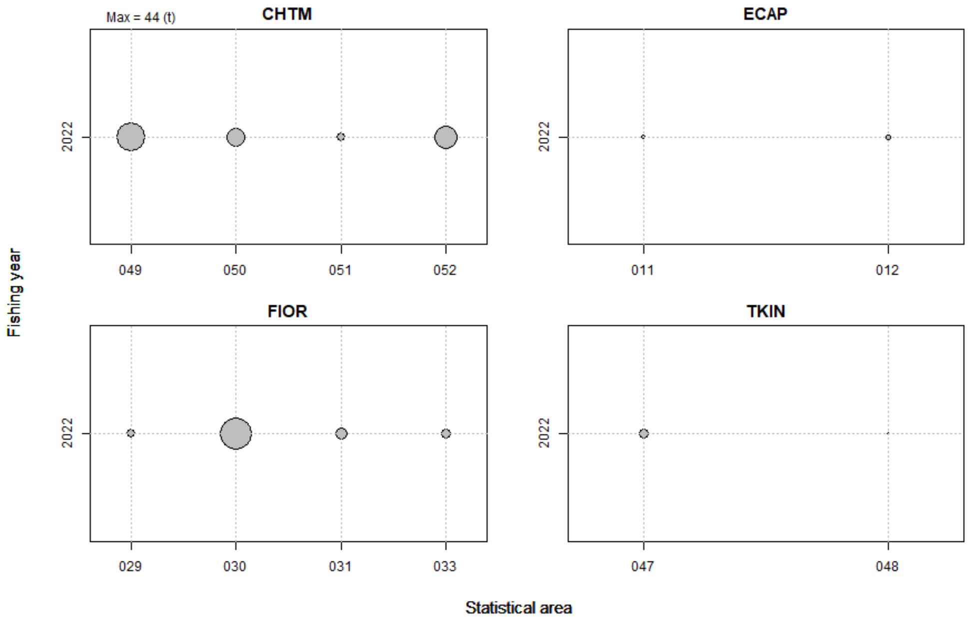

Figure 10: The distribution of hāpuku (HAP) landed weight in tonnes by statistical area within the four core hāpuku fishing regions. Includes data for bottom longline for most of the 2022 fishing year (2021-12-01 to 2022-09-30). CHTM = Chatham Islands, ECAP = East Cape, FIOR = Fiordland, TKIN = Three Kings.

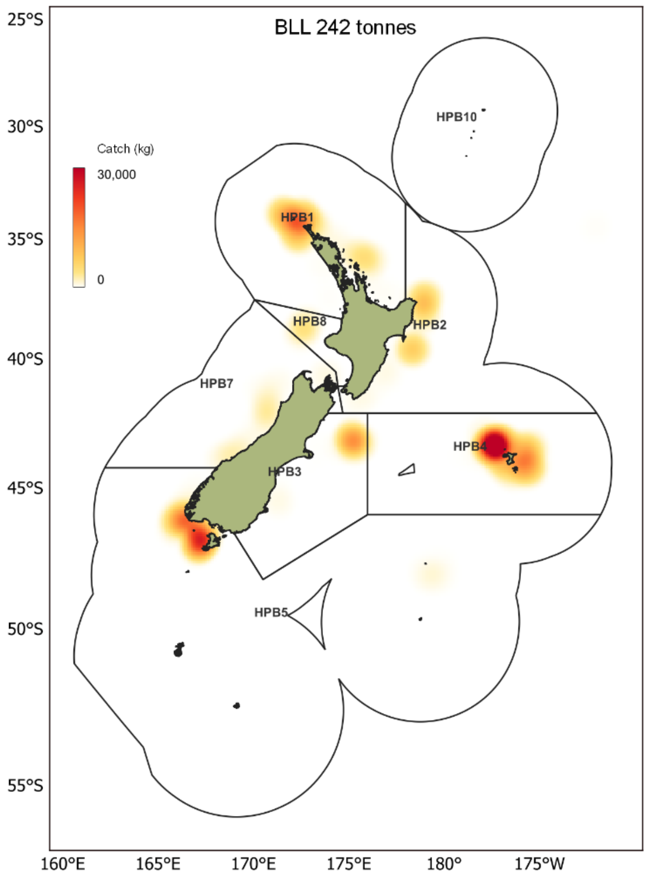

Figure 11: Spatial distribution of hāpuku (HAP) estimated green weight catch in kilograms taken by bottom longlining during the 2022 fishing year. Map data generated using Kernel Density Estimation (quartic kernel shape) with a 100 km radius and 10 km pixel size.

3.3 Simulation of optimal sample size

An extraction of all available age data from the Fisheries New Zealand *age* database yielded 810 records for HAP, including otoliths collected primarily from the Scientific Observer Programme, but also from historical catch sampling and trawl surveys (Figure 12, Figure 13). The collection dates for these otoliths ranged from 21 July 1982 to 9 May 2007. Although these 810 ages do not represent a population age structure in time or space, but are a summary of ages over a 25-year period throughout New Zealand waters, the plot of these data indicated peaks at three and eight years old. These data did not differentiate between sexes.

Using a bootstrapping simulation procedure, these age data were resampled to evaluate the expected precision for a given sample size and considered four alternative a_{max} values for the peak of the descending limb (Figure 14). To achieve an arbitrarily defined precision of 20% (CV) around Z, it was evident that at least 250 otoliths would be required for a given area and year.

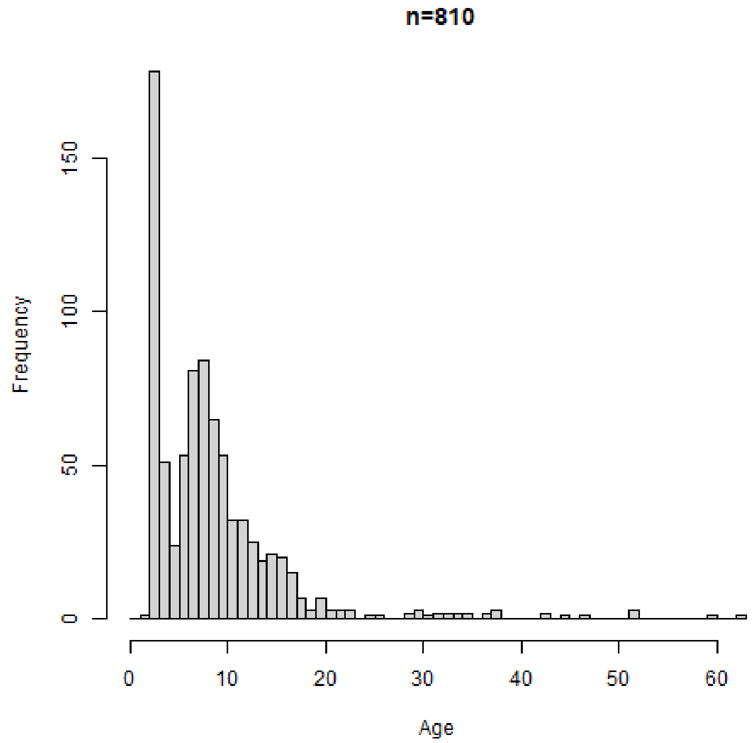

Figure 12: Age frequency distribution of hāpuku (HAP) based on all available data in the Fisheries New Zealand *age* database (21 July 1982 to 9 May 2007). Includes data from trawl surveys and catch sampling.

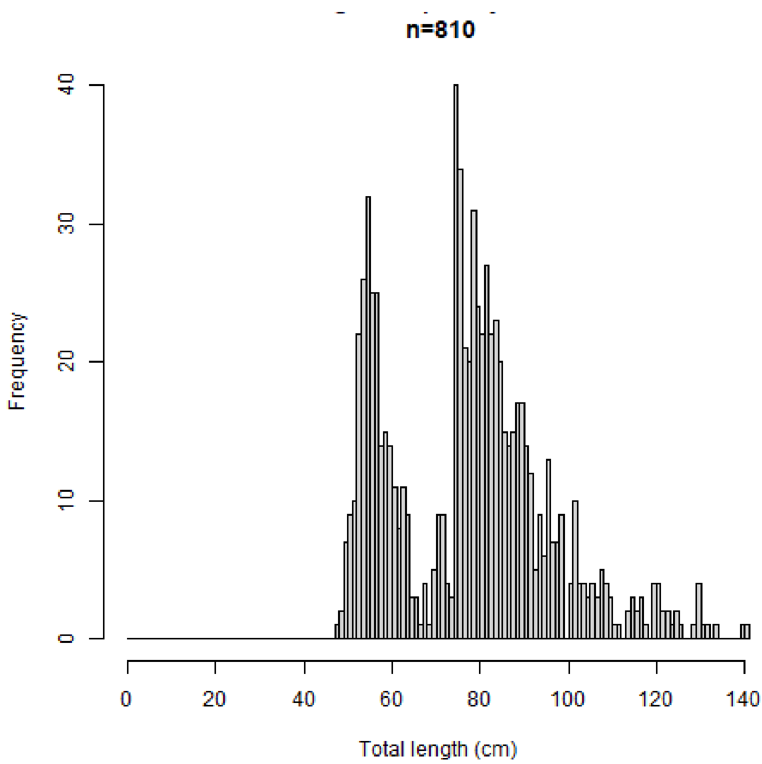

Figure 13: Length frequency distribution of hāpuku (HAP) based on all available data in the Fisheries New Zealand *age* database (21 July 1982 to 9 May 2007). Includes data from trawl surveys and catch sampling.

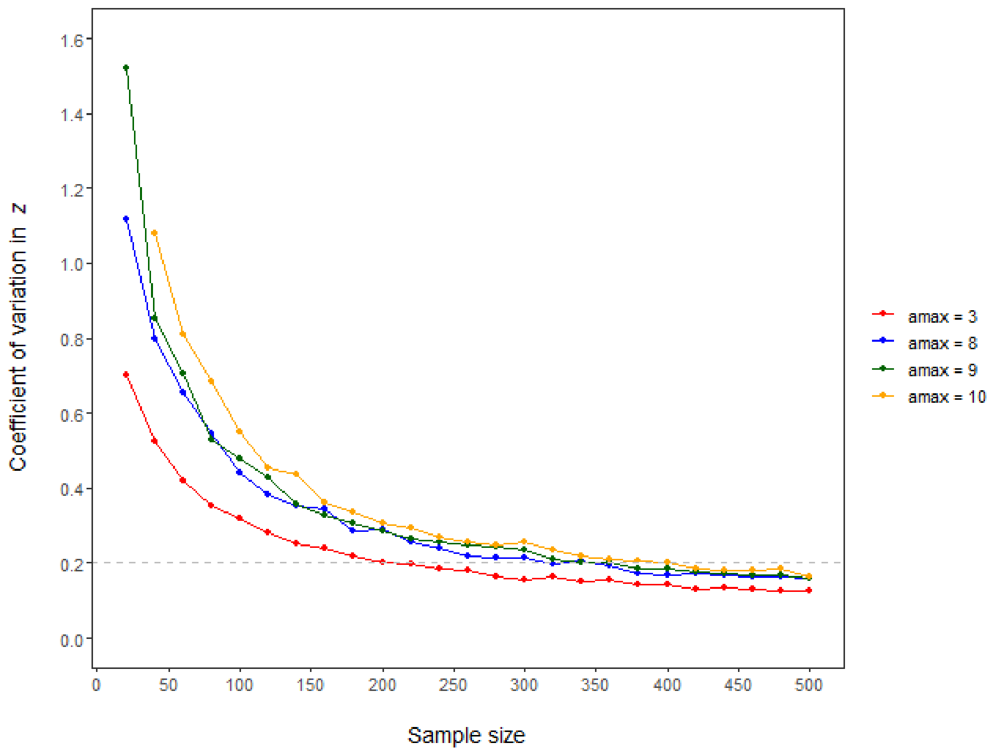

Figure 14: The expected coefficient of variation (CV) of 1000 total mortality estimates (*z*) for various sample sizes, assuming four different a_{max} (peak of the descending limb) values. Horizontal dotted line indicates an arbitrary 20% threshold for acceptable precision.

3.4 Feasibility analysis

The first sampling strategy, which considered every seventh, or every third, fish was tested on the 2022 data. However, this strategy was unlikely to produce 250 otoliths in most cases except for FIOR and only if every third fish was sampled in CHTM (Table 3). The Inshore Working Group (8 December 2022) suggested that an alternative strategy be evaluated and discussed with candidate fishers. An alternative strategy was proposed, where every (or as many as possible) hāpuku was to be collected on a longline set, but the number of sets to be sampled would be limited in some way (e.g., every second set or only sets with more than 20 hāpuku on the line) to reduce the burden on the fisher. The final strategy had to be flexible enough to suit the operations of the individual fishers.

Each of the six operators identified in the fishery characterisation as having potential for a catch sampling project were contacted again during December 2022 and January 2023 for a follow-up interview (Table 4). The feasibility of conducting a catch sampling project with these operators was assessed in the context of the 2022 HAP-specific landings and the revised sampling strategy. The potential sampling logistics varied between fishers, which was related to willingness, vessel size, hold storage capacity, and current workload on the vessel. Fishers were generally willing to tag individual HAP with spatial information, if sampling (i.e., otolith extraction) was done at the Licensed Fish Receiver (LFR) and not on the vessel. Consequently, several LFRs were contacted and interviewed to investigate the possibility of sampling at their premises and to discuss any devaluation rates that would be applicable for extracting otoliths from the fish. Devaluation rates ranged from 25% of the price per kilogram up to 100% of the price per kilogram (i.e., sampled fish would be purchased at full cost).

In the Three Kings region, Fisher C was the only operator considered feasible for catch sampling and reported to land hāpuku in a green state (GRE). The two sample size scenarios presented for Fisher C would provide between 250 and 400 otoliths, respectively, with an approximate cost between $10,875 and $65,400, depending on the number of otoliths collected and the devaluation rate required by the LFR. This included a cost of $3.50 per fish as compensation payable to the fisher for the additional workload of having to label individual fish with spatial information.

In the East Cape region, fishers F and G were the only two considered feasible for catch sampling and both fishers reported to land hāpuku in a green state. Only one scenario was presented for Fisher G due to the low volume of catch. Combining their efforts would provide between 250 and 350 otoliths with an approximate cost of between $12,000 and $57,000.

In the Chatham Islands region, Fisher I reported to operate two vessels, both of which were considered feasible for catch sampling and reported to land hāpuku in a green state. Combining the efforts of the two vessels would provide between 250 and 500 otoliths with an approximate cost of between $12,000 and $82,000.

In the Fiordland region, fishers M and O were the only two considered feasible for catch sampling. Both these fishers reported to land their hāpuku as headed and gutted (H&G) and that the heads are usually discarded. Both fishers were willing to retain a limited number of heads due to space constraints on the vessel. Combining their efforts would provide between 250 and 460 otoliths with an approximate cost of less than $2,000. The lower cost for fishers M and O is due to the low LFR costs associated with sampling heads, which would ordinarily be discarded.

Based on the proportion of available fish, the cooperation among fishers and LFRs as well as the cost, the overall feasibility of a hāpuku catch sampling project was considered highest in the HAP 5 QMA and lowest in the HAP 1 QMA (Table 5). The HAP 2 and HAP 4 QMAs were considered to have a medium feasibility.

Table 3: Sampling logistics associated with the initial proposed strategy for collecting hāpuku from participating fishers, based on catches reported in the 2022 fishing year. The minimum required landing weight was derived by assuming a mean individual fish weight of 8 kg and a minimum landings size of 20 fish for a viable sample. For example, 8 kg x 20 fish x 7 = 1120 kg. Upper case letters, C, F, G, I, M, and O are the anonymised fisher codes.

		TKIN (HAP1)			ECAP (HAP2)			CHTM (HAP4)	FIOR (HAP5)		
Strategy	Sampling logistics	C	C	Total	F	G	Total	I	M	O	Total
Sample every 7th fish	Minimum required landing weight (kg)	1 120	1 120		1 120	1 120		1 120	1 120	1 120	
	Actual number of landings	38	14	52	19	21	40	19	44	8	52
	Actual number of landings of 1120 kg or more (all targets)	0	4	4	0	0	0	8	13	6	19
	Landings to sample	0	4	4	0	0	0	8	9	4	13
	Total fish (otoliths) from all samples	0	80	80	0	0	0	160	180	80	260
Sample every 3rd fish	Minimum required landing weight (kg)	480	480		480	480		480	480	480	
	Actual number of landings	38	14	52	19	21	40	19	44	8	52
	Actual number of landings of 480 kg or more (all targets)	0	7	7	3	1	4	14	26	7	33
	Landings to sample	0	7	7	3	1	4	13	11	2	13
	Total fish (otoliths) from all samples	0	140	140	60	20	80	260	220	40	260

Table 4: Sampling logistics associated with a revised strategy for collecting hāpuku from participating fishers, based on catches reported in the 2022 fishing year. The potential sampling protocol considers the willingness of the fisher and the availability of fish with an attempt to limit the burden on the fisher. Fisher I had two vessels, which were evaluated independently. Two alternative sampling protocols are proposed for each fisher. Fisher cost was calculated at $3.50 per fish, except for Fisher G, who required $35 per bin. Average fish weight was taken from fisher interviews and Licensed Fish Receiver (LFR) price per kilogram was taken from LFR interviews. LFR cost was applied as a percentage of the LFR price per kilogram where whole fish are sampled (devaluation rate) and as a dollar cost per fish where headed fish are sampled. (Continued on next page)

Fisher	Landing state	Willingness to retain samples	Total HAP caught in 2022	Potential sampling protocol based on 2022 data	Number of fish to collect	Fisher cost ($)	Average fish weight (kg)	LFR price per kilogram ($)	LFR cost ($)	Total cost ($)
Fisher C	GRE/ GUT	Every fish on every set, but sampling must be at LFR.	1 319	Tag all fish on every second set having at least 20 HAP on the line (548 fish available).	400	1,400	8	20	1.00	65,400
							8	20	0.35	23,800
TKIN (HAP 1)							8	20	0.25	17,400
				As above but stop at 250 fish.	250	875	8	20	1.00	40,875
							8	20	0.35	14,875
							8	20	0.25	10,875
Fisher F	GRE	Every fish on every set, but sampling must be at LFR.	418	Tag all fish on every set having at least 20 HAP on the line (314 fish available).	300	1,050	8	20	1.00	49,050
							8	20	0.35	17,850
ECAP (HAP 2)							8	20	0.25	13,050
				As above but stop at 200 fish.	200	700	8	20	1.00	32,700
							8	20	0.35	11,900
							8	20	0.25	8,700
Fisher G	GRE	Tag bins (two fish to a bin) including all fish. Sampling must be at LFR and compensation required.	310	Bin all fish on every set having at least 20 HAP on the line. Tag bins (97 fish available).	50	875	8	20	1.00	8,875
							8	20	0.35	3,675
ECAP (HAP 2)							8	20	0.25	2,875
				Too few fish available for an alternative sampling protocol.	NA	NA				
Fisher I	GUT	Every fish on every second set, but sampling must	6 733	Tag all fish on every second set having at least 20 HAP on the line (2 833 fish available).	250	875	8	20	1.00	40,875
							8	20	0.35	14,875
							8	20	0.25	10,875

Fisher	Landing state	Willingness to retain samples	Total HAP caught in 2022	Potential sampling protocol based on 2022 data	Number of fish to collect	Fisher cost ($)	Average fish weight (kg)	LFR price per kilogram ($)	LFR cost ($)	Total cost ($)
CHTM (HAP 4)		be at LFR and additional compensation would be appreciated.		As above but stop at 150 fish.	150	525	8	20	1	24,525
							8	20	0.35	8,925
							8	20	0.25	6,525
Fisher I	GUT	Every fish on every second set. Sampling must be at LFR and additional compensation would be appreciated.	2 419	Tag all fish on every second set having at least 20 HAP on the line (712 fish available).	250	875	8	20	1	40,875
							8	20	0.35	14,875
CHTM (HAP 4)							8	20	0.25	10,875
				As above but stop at 100 fish.	100	350	8	20	1	16,350
							8	20	0.35	5,950
							8	20	0.25	4,350
Fisher M	H&G (30%)	Can tag 25–30 fish heads per trip. Compensation required.	1 083 (H&G)	Tag 30 fish heads on one set towards end of trip (2022 = 19 trips).	250	875	NA	NA	0.5	1,000
									0.2	925
FIOR (HAP 5)									0	875
				As above but stop at 125 heads.	125	438	NA	NA	0.5	500
									0.2	463
									0	438
Fisher O	H&G	Yes, but limited space for 20–30 heads. Heads must be picked up when offloading.	2 538	Tag 30 fish heads on one set towards end of trip (2022 = 7 trips).	210	735	NA	NA	0.5	840
									0.2	777
FIOR (HAP 5)									0	735
				As above but stop at 125 heads.	125	438	NA	NA	0.5	500
									0.2	463
									0	438

Table 5: Overall feasibility of a catch sampling project in each of the hāpuku (HAP) Quota Management Areas. Proportion of available fish is the target number of fish as a proportion of the estimated total number of fish landed in the 2022 fishing year.

Area	Target number of fish	Proportion of available fish	Fisher Cooperation	LFR Cooperation	Cost ($)	Feasibility
HAP1	250	0.46	High	Low-Med	11,000–41, 000	Low
HAP2	250	0.61	High	Low-High	12,000–42,000	Med
HAP4	250	0.07	Med	Low	11,000–41,000	Med
HAP5	250	0.32	High	High	1,000	High

4. DISCUSSION

This study developed a spatially limited survey design for collecting hāpuku age information through catch sampling. It was intended that a dedicated longline survey would be designed for all New Zealand, but due to the costs associated with a dedicated survey, a catch sampling survey design was investigated instead, as suggested previously (Parker et al. 2011, Hartill et al. 2020). It was also evident from the results of the current study that a hāpuku catch sampling project would not be feasible in all QMAs due to the current state of the fishery (i.e., low catches) and low number of remaining participants. Although hāpuku was the primary subject of this study, this species has been reported on, and managed under, a combined species code (HPB – groper) along with bass. This feasibility study design does not include bass in a future catch sampling programme.

The broadscale fishery characterisation (2017–2021 before use of the HAP code) showed that groper (HPB) were caught primarily by bottom longline in all QMAs except in HPB 3. Bottom longline is the preferred fishing method for a hāpuku catch sample programme because it has lower size selectivity than other methods (i.e., catches a broad range of sizes). It also supports a target fishery, which reduces the associated sampling cost. In HPB 3, catches by bottom trawl and setnet exceeded those of bottom longline and presented a potential alternative for collecting hāpuku. However, bottom trawl and setnet were deemed too size-selective for deriving a representative age-structure of the population and were thus excluded as possible alternatives.

There was only weak seasonality evident in the catches making it difficult to focus sampling effort temporally. Fishers also provided variable responses to questions about spawning seasons. Therefore, focusing sampling effort seasonally, especially considering the relatively low availability of hāpuku, may not be a productive approach.

There were, however, noticeable spatial concentrations in the catch. Although not possible to distinguish hāpuku in the annual trends before December 2021, telephone interviews with key fishers provided qualitative information on the proportion of hāpuku in the catch for each of the QMAs. Most fishers reported targeting spatially discrete undersea topographic features, confirming the need to obtain fine-scale spatial position data for each sampled hāpuku. In most cases, fishers reported landing their hāpuku catch whole (green) and bulk packed the hāpuku in the vessel hold. Fishers were also not keen to have sampling take place on their vessel, but rather at the LFR. Therefore, it would be necessary that individual hāpuku be 'tagged' with spatial information and depth at the time of capture. This would enable individual otoliths to be matched to spatial location at the LFRs when sampling took place.

For those fishers who reported landing their hāpuku headed and gutted, spatial information as well as total fish length, ideally, would need to be attached to each head. Retaining these heads would require additional cooperation by the fisher, especially since heads are usually discarded overboard due to limited space in the vessel's hold. Consequently, fishers were only willing to retain a limited number of heads per trip.

The commercial catch and effort obtained for part of the 2022 fishing year (from 1 December) enabled an evaluation of the hāpuku-specific fishery for the first time. The apparent large increase in hāpuku landings for 2022 reflect the abrupt change in the reporting requirements, with hāpuku catches in previous years having been reported predominantly under the HPB code. The decline in the overall HPB (including hāpuku records) landings, and that most of these records were hāpuku (HAP) in 2022, suggests that the hāpuku fishery is in decline. However, this assumes that the composition of the HPB landings (HAP to BAS) has remained stable over recent years, which may not be the case. The sentiment among the interviewed fishers suggested that a decline in the hāpuku abundance was supported.

It was evident from the interviews that some bottom longline fishers have exited the fishery in recent years and are not being replaced by new fishers. Considering the current state of the fishery and the low number of remaining participants, it is likely that a catch sampling programme for hāpuku may, at best, only be feasible in HPB 1, HPB 2, HPB 4, and HPB 5. However, in those QMAs catch sampling for hāpuku would require close cooperation with fishers to achieve the target number of otoliths. As mentioned, fishers would be required to record spatial information at the time of capture and attach this information to individual fish or to bins of fish from the same longline set. This requires a high degree of willingness and some financial compensation. There would also be a particularly high financial cost in HPB 1, HPB 2, and HPB 4, where hāpuku is sold whole as a premium product. Otolith removal devalues the product and would therefore require weight-based compensation payable to the LFR.

The use of the HPB code up until the 30 November 2021 complicated the 2017–2021 analyses because the patterns observed in the broadscale characterisation could not be reliably attributed to hāpuku. However, the focused characterisation in 2022 provided the necessary insight to validate the broadscale characterisation and properly assess the feasibility of a nationwide hāpuku catch sampling project.

If this design is to be implemented, careful consideration should be given to the various assumptions made in the feasibility analysis, some of which may not be valid in future years. The feasibility was assessed based on current catch volumes in relation to the minimum required number of otoliths determined from the simulations. However, the fishery appears to be in decline in multiple QMAs potentially reducing the availability of fish in the coming years. Also, the required minimum number of otoliths to achieve a precision of 20% around Z for both sexes combined, derived from the sample-size optimisation procedure, did not consider sex-specific age structuring in the hāpuku population as pointed out by the Inshore Working Group (8 December 2022). If age structure is related to sex and some other factors, such as location, the minimum number of otoliths required could be higher than anticipated.

It was evident that a high degree of fisher involvement would be required to get the necessary samples. However, the state of the fishery, adjustments to the TACC, and the prospect of having cameras on vessels have already affected the morale of some participants. Their willingness to participate in a catch sampling project may deteriorate in time. The costs associated with the collection of otoliths were based on conversations with fishers and LFRs, but ultimately relied on current market conditions. There is no guarantee that these will remain consistent over time.

This study confirmed that bottom longline is likely the only appropriate fishing method for hāpuku catch sampling in certain QMAs. Most of the catch was limited to a few statistical areas and was taken by a few remaining participants in the fishery. Of the remaining participants, there was a general willingness to participate in a catch sampling project, but some were planning to leave the fishery for a variety of reasons, leaving few options for catch sampling. Any potential catch sampling project would require highly targeted sampling and a high degree of cooperation with fishers. In contrast, there was a relatively lower degree of willingness among the interviewed LFRs. Based on the minimum required number of otoliths, current catches, and market conditions, there may be some potential for a catch sampling project in HPB 1, HPB 2, HPB 4, and HPB 5, but this would generally incur a high cost. The feasibility of a catch sampling project for hāpuku depends heavily on several assumptions made in this study.

5. POTENTIAL RESEARCH

A pilot study was proposed by the Fisheries New Zealand Inshore Working Group (9 February 2023) as a cost-effective means of trialling the design presented here for just one QMA. This could follow an age-length-key approach, which would require fewer otoliths. However, a pilot study would need to be conducted throughout the fishing year to account for potential movement.

While a pilot study may be useful to guide future sampling in the same QMA, the results may not necessarily be applicable to other QMAs. For example, HPB 5 (FIOR) was proposed as a good candidate for a pilot study, as the cost for catch sampling in HPB 5 was the lowest overall and there appears to be a higher availability of hāpuku landings. However, both fishers identified for catch sampling in HPB 5 landed their catch headed and gutted. The sampling protocol and costs would thus not be comparable with any of the other QMAs where hāpuku is landed in a whole state and where availability of hāpuku is lower.

6. ACKNOWLEDGEMENTS

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APPENDIX 1 - Hāpuku (HAP) fisher questionnaire

Interviewee:		Date/time:	
Vessel code:		Vessel name:	
Gear type:	BLL/SN		

Preamble: We are conducting a fisheries research project for Fisheries New Zealand. This project involves designing a survey to estimate the age structure of New Zealand hāpuku. Based on a preliminary analysis of commercial fishing data, we have identified you as a key participant in the fishery. To get a better understanding of this fishery, specifically relating to the logistics involved in sampling, we would like to ask you some questions about your fishing operation. If you agree to this, your answers would be captured in a Word document and be used in a fisheries assessment report. However, your responses would be anonymised.

Would you like to proceed, and do we have your permission to record your answers and present them in a report?

Fishing

1. Are you still operating?
2. Where are you operating (ET/QMA/stat)?
3. What fishing method are you using when catching HAP?
4. Any changes in the last two years, including changes in gear?
5. When (month) do you catch most HAP and when do you catch the least?
6. When is HAP spawning activity?
7. What species are you targeting when catching most HAP?
8. In what bottom depth are you catching HAP (bottom/off the bottom)?
9. In what habitat are you catching HAP?
10. Do you target certain bottom features when targeting HAP?
11. How many features would you target on a given trip?
12. What size HAP are you typically catching and is this feature or statistical area specific?
13. How long are your trips and does this vary according to statistical area?

Catch sampling

14. Where do you land the HAP?
15. What state do you land HAP in?
16. What time of day do you typically land your fish?
17. What is the composition of your HAP / BAS landing?
18. What tonnage of HAP do you typically land from a trip and does this vary according to statistical area?
19. Would you be willing to work with us to obtain head/otolith samples (*this would involve identifying hāpuku from individual features within the statistical areas of interest)?*

20. If targeting discrete bottom features, do you typically put fish from each feature in a separate portion of your hold, or would it be possible for you to do this so we can figure out from which feature individual fish were caught?
21. If you are landing headed and gutted, would you be able to retain and tag the heads for us from pre-identified trips (*willingness here is important and there are some complications, if it is not practical for them to retain and tag all of the heads from a trip, then we might have to get them to select some heads for retention, which gets tricky as we will need a system to eliminate bias. So I would establish what is practical for them and what they are willing to do. We could also look at compensating them for this if they are unwilling. This isn't for this project, but if a sampling project actually took place. I would only introduce that thought if it sounded like it might allow us to get samples – we would probably need to figure out a rate (per fish head) if that was the case, so we can budget for it in our feasibility analysis*)?
22. Where do your fish get unloaded to (i.e., a factory)?
23. Are the HAP from one landing size-graded in any way or mixed with other landings? (*these questions are getting at how we might send a sampler to get the samples. If they are landing into remote areas, then understanding how we get to the samples will be important – we might need to employ a local to get to the fish heads and ship them for us, or maybe they go to a factory in a location closer to where we have samplers. As such, understanding what happens to the fish from point of landing to the factory will be important – do the fish get size graded, mixed with other landings… anything that would affect us from sampling the fish at a factory. Especially important for Chathams and Fiordland I suspect*).

Other comments

APPENDIX 2 - Hāpuku (HAP) fisher questionnaire – part 2

Interviewee:		Date/time:	
Vessel code:		Vessel name:	
Gear type:	BLL		

Preamble: Based on your initial response, we would like to gather more detail on the feasibility of gathering HAP heads from your fishing activity. We have estimated that we would need at least 250 otoliths from one fishing year from your area.

1. How are your HAP stored after being caught - green or headed: to confirm previous interviews response.
2. If green, then…
    a. Would you be willing to tag every HAP with capture location (from every second set)? If yes, then go to question 4, if no then 2b.
    b. If unwilling or unable, are you bulk packing the catch or separating sets into bins? If bulk packing, then go to question 4, else go to 2c.
    c. If separating sets into bins, would you be willing to tag every HAP bin with capture location? If yes or no, then explore question 4.
3. If stored headed…
    a. Would you be willing to retain the HAP heads on board? If yes, then go to 3b, if no then 4.
    b. If willing to retain heads, would you be able to tag every HAP head with a capture location and a fork length (every second set)? If yes, then 4, if no then go to 3c.
    c. If not able to tag every head, could you keep heads from a particular set in a separate bin and tag the bin with capture location (every second set)? If yes, then go to 4.
4. What compensation would you require for this additional workload?
5. Would you be able and willing to have an observer on board to take care of the HAP otolith extraction?