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Tini a Tangaroa

Trawl surveys of the Hauraki Gulf and Bay of Plenty in 2019 and 2020 to estimate the abundance of juvenile snapper

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This report presents the results of inshore trawl surveys of the Hauraki Gulf and Bay of Plenty using the R.V. *Kaharoa*. It has been 19 years (Hauraki Gulf) and 20 years (Bay of Plenty) since these trawl surveys were last conducted. Previous surveys were conducted between 1984 and 2000.

The recent surveys took place between 12 and 30 November 2019 (Hauraki Gulf) and 12 February and 1 March 2020 (Bay of Plenty) and used a stratified two-phase design optimised for pre-recruit snapper. The survey design involved removing deeper strata from the historic survey stratification to better target pre-recruit snapper. A total of 39 phase one and 5 phase two stations were completed for the Hauraki Gulf, and 42 phase one and 10 phase two stations were successfully completed in the Bay of Plenty. Phase two stations were conducted solely to reduce the coefficient of variation (CV) for pre-recruit snapper.

In the Hauraki Gulf, the estimated year class strength (YCS) of 1+ and 2+ snapper (the 2018 and 2017 year classes, respectively) was 5.4 (CV = 20.0%) and 7.4 (CV = 11.0%) million fish, respectively. These estimates are both well above the average YCS estimates for the entire Hauraki Gulf survey series (average YCS is 3.8 and 3.6 million for 1+ and 2+ snapper, respectively, in 12 previous surveys from 1984 to 2000), but well below the YCS predictions based on a previously established temperature-recruitment relationship. In the Bay of Plenty, the estimated YCS of 1+ and 2+ snapper (the 2019 and 2018 year classes, respectively) was 0.926 (CV = 27.4%) and 0.453 (CV = 23.3%) million fish, respectively. For 1+ snapper, the recent estimate is well above the average YCS for the Bay of Plenty survey series (the average 1+ YCS was 0.307 million fish). For 2+ snapper this estimate is very similar to the average YCS for the Bay of Plenty survey series (the average 2+ YCS since 1990 is 0.465 million fish). Future surveys in the Bay of Plenty should pay close attention to the spatial distribution of pre-recruit snapper, which was constrained to the eastern Bay of Plenty in the 2020 survey.

The recommencement of the Hauraki Gulf and Bay of Plenty trawl surveys series may also provide potential to monitor, with reasonable levels of precision, the relative abundance of year classes over 2 years (i.e., including recruited snapper). In the Hauraki Gulf, the estimated snapper biomass was 20 618 t (CV = 13.6%), whereas in the Bay of Plenty it was 2824 t (CV = 8.9%), representing increases of 139% and 87% since the last survey in each area, respectively. Other species that the Hauraki Gulf and Bay of Plenty surveys may have some potential to monitor include: red gurnard (Hauraki Gulf: 162 t, CV = 28.3%; Bay of Plenty: 181 t, CV = 14.6%), John dory (Hauraki Gulf: 188 t, CV = 14.7%; Bay of Plenty: 84 t, CV = 23.3%), and potentially leatherjacket (Hauraki Gulf: 338 t, CV = 30%; Bay of Plenty: 149 t, CV = 55.7%) and trevally (Hauraki Gulf: 107 t, CV = 34.7%; Bay of Plenty: 74 t, CV = 8.2%). For the Hauraki Gulf, the biomass of all these species was higher than that estimated by the previous survey. Conversely, in the Bay of Plenty, red gurnard, John dory, and trevally had all decreased (and leatherjacket had increased) relative to the previous survey estimates.

1. INTRODUCTION

The northern inshore trawl survey series was initiated in the early 1980s to monitor the status of snapper (SNA, *Chrysophrys auratus*), with secondary target species of John dory (JDO, *Zeus faber*) and red gurnard (GUR, *Chelidonichtys kumu*). These trawl surveys were conducted from the R.V. *Kaharoa* across separate SNA 1 sub-stocks in east Northland, the Hauraki Gulf, and the Bay of Plenty. Although only two east Northland surveys were conducted, due to large areas of untrawlable ground (Drury & Hartill 1994, Drury & McKenzie 1992a), six surveys were conducted in the Bay of Plenty (Drury & Hartill 1993, Drury & McKenzie 1992b, Morrison 1997, Morrison & Parkinson 2000), and twelve were conducted in the Hauraki Gulf (Drury & McKenzie 1992c, Langley 1994a, b, c, Morrison & Francis 1999, Morrison et al. 2001a).

In the Hauraki Gulf, the target of the survey was shifted in the mid-1980s to focus on 1+ SNA. Various other changes in target occurred to the other surveys as well, with snapper eventually being dropped as a target from the Bay of Plenty survey in 1999, with deeper strata added to better target tarakihi (NMP, *Nemadactylus macropterus*) (Langley 1994c, Morrison et al. 2013, Morrison et al. 2001a, Morrison & Parkinson 2000, Morrison et al. 2001b). The focus on juvenile snapper in the Hauraki Gulf was because SNA 1 recruitment has high inter-annual variation, which influences the yield available to commercial and recreational fisheries and could be effectively monitored by a trawl survey that estimated the abundance of recruiting year classes. The extensive survey series in the Hauraki Gulf proved capable of monitoring year-class strength for 1+ pre-recruit snapper. This time series was also used to establish a strong relationship between snapper recruitment strength and Sea Surface Temperature (SST) (Francis 1993, Francis et al. 1995).

The last East Coast North Island (ECNI) trawl surveys were carried out in 1999 and 2000, for the Bay of Plenty and Hauraki Gulf, respectively. At this time, it was decided that year class strength information could be more cost-effectively gathered by sampling commercial fish sheds for proportions at age in the catch. Although commercial catch sampling can provide a wider spatial-temporal coverage than trawl surveys, they have a critical disadvantage in that only fishery recruited cohorts can be monitored. The advantage of estimating year class strength from a trawl survey is that it provides advanced information about weak or strong year classes that are yet to recruit to the fishery. With the next SNA 1 assessment scheduled for 2020–22, the SNA 1 pre-recruit surveys presented here were timed to provide the most up to date information about the strength of year classes that will recruit to the SNA 1 fishery to assist with predicting SNA 1 yield out to 2025.

The present report details the Hauraki Gulf and Bay of Plenty surveys conducted in 2019 and 2020, respectively, and fulfils the final reporting requirements of Fisheries New Zealand project INT2018-03.

1.1 Specific objectives

1. To design updated R.V. *Kaharoa* Hauraki Gulf and Bay of Plenty trawl surveys focussed on estimating the abundance of 1+ and 2+ snapper over trawlable habitat less than 100 m for the purpose of estimating relative annual abundance (year class strength).

2. [Not relevant to these surveys.]

3. To determine the relative abundance and distribution of 1+ and 2+ snapper in the Hauraki Gulf spring-summer (October to November) period and the Bay of Plenty summer (January to February) period during the 2019–20 fishing year, by carrying out R.V. *Kaharoa* trawl surveys over the depth range of 10 to 100 m.

4. [Not relevant to these surveys.]

5. To collect the necessary data and determine the length frequency, length-weight relationship and reproductive condition of snapper, and other QMS species.

6. To collect otoliths from snapper from Hauraki Gulf and Bay of Plenty.

7. To collect the data to determine the catch weight of all species caught and the length frequencies and spawning condition of all other Quota Management System (QMS) species.

8. To collect data to underpin the development of assessment and monitoring capabilities for biodiversity and ecosystems.

2. METHODS

2.1 Survey areas and design

Two separate two-phase stratified random trawl surveys were conducted according to Francis (1984). Survey areas and stratification were based on those used in the historic surveys, using the stratification last used when snapper was a survey target. For the Hauraki Gulf this was the 2000 stratification, whereas for the Bay of Plenty this was the 1996 stratification. From this starting point, deeper strata were dropped to better target pre-recruit snapper (strataover 75 m and under 100 m were excluded from the Hauraki Gulf and Bay of Plenty survey areas, respectively). The resulting stratification was then evaluated relative to spatial patterns in the following three datasets: (1) catch rates of under 25 cm snapper from the most recent surveys (KAH9720 and KAH0012 for the Hauraki Gulf; and KAH9202, KAH9615, and KAH9902 for the Bay of Plenty); (2) catch rates of sub-legal snapper (SNX) from commercial fishing; and (3) catch rates of 0+ snapper from beam trawl surveys (Hauraki Gulf only) (M. Morrison, NIWA, unpub. data, Morrison et al. 2019). One stratum within each survey area was split to better account for within stratum variation in pre-recruit snapper abundance (for the Hauraki Gulf historic stratum 4492 was split into LITB and COLV, and for the Bay of Plenty historic stratum 7085 was split into 708N and 708S).

For the Hauraki Gulf the final stratification had eleven strata that encompassed 5004 km^2, depths of 10–75 m, and an area that included all the inner Hauraki Gulf and the outer gulf from Bream Bay in the northwest to the Mercury Islands in the southeast. For the Bay of Plenty, the final stratification had nine strata that encompassed 3989 km^2, depths of 10–100 m and an area that stretched from the Mercury Islands in the northwest to Cape Runaway in the east (Table 1, Figure 1). As for the historical surveys conducted in these areas, untrawlable ground was not included in the survey areas.

Station allocation for the surveys was determined using NIWA's R function *allocate* (see appendix 2 of Francis & Fu 2012) using the historic catch rate data for pre-recruit (under 25 cm) snapper (from the KAH9720 and KAH0012 surveys for the Hauraki Gulf; and from the KAH9202, KAH9615, and KAH9902 surveys for the Bay of Plenty). Specifying a minimum of three stations per stratum, the phase one allocation was calculated to achieve a target coefficient of variation (CV) of 20%. Some manual adjustments were then also made to this allocation to account for sampling logistics. The final allocation for both surveys is presented in Table 1. Overall, 39 phase one stations were planned for the Hauraki Gulf, and 42 for the Bay of Plenty.

Station positions were randomly generated using NIWA's custom software 'RandomStation'. The stations were required to be a minimum of 1.852 km (1 nautical mile, n. mile) apart. Non-trawlable ground was already excluded from the survey strata, so therefore was also excluded from the station allocation program.

2.2 Vessel, gear, and trawling procedure

R.V. *Kaharoa* is a 28-m stern trawler with a beam of 8.2 m, displacement of 302 t, and engine power of 522 kW and is capable of trawling to depths of 500 m. To be consistent with the historic trawl surveys both the Hauraki Gulf and Bay of Plenty surveys used the high opening bottom trawl (HOBT) net, with cut away lower wings and a nominal 40-mm codend. Depending on depth, the net should achieve doorspreads of 70–90 m, and a headline height of 5–6 m (Morrison et al. 2013).

Procedures followed those recommended by Stevenson & Hanchet (1999). All tows were undertaken in the daylight (between 0530 and 1700 hours NZST). For each tow the vessel steamed to the station position and, if necessary, the bottom was checked with the echosounder to determine whether it was suitable for bottom trawling. Once the station was considered trawlable, the gear was shot away so that the midpoint of the tow would coincide as closely as possible with the position generated by RandomStation. The direction of the tow was influenced by a combination of factors including weather conditions, tides, bottom contours, and the location of the next tow.

If the station was found to be in an area of untrawlable ground or if another vessel was at the station, an area within 5 km of the station was searched for a replacement tow path. If the search was unsuccessful, the station was abandoned and the next alternative station within the stratum was chosen from the random station list. Standard tows were 0.7 n. mile with a minimum valid tow length of 0.5 n. mile (i.e., tows were hauled early if large amounts of fish were observed going into the net). As such standard tows were about 14 minutes in duration at a speed over the ground of 3–3.5 knots. The tow was deemed to have started when the net monitor indicated that the net was on the bottom and was completed when hauling began. A warp length of 200 m was used for most tows in less than 50-m depth, although warp was shortened to 150 or sometimes 100 m for very shallow tows. At depths between 50 and 75 m a warp length of 250 m was used, and for tows in depths greater than 75 m a warp length of 275 m was used.

Headline height and doorspread were recorded from a Marport net monitor and Scanmar sensors, respectively. The surface and bottom temperatures and salinity at each station were recorded by a calibrated Seabird Microcat Conductivity Temperature Depth (CTD) unit. Surface temperatures were taken at a depth of 5 m below the surface. Bottom temperatures were taken at about 5 m above the sea floor because the CTD is attached to the headline. In addition to water temperature and salinity, water clarity (secchi depth), wind direction and speed, sea condition and colour, and swell height and direction were recorded for each trawl station. Acoustic data were also recorded during and between tows using the Simrad ES60 echosounder and hull-mounted 38 kHz transducer.

2.3 Catch and biological sampling

The catch from each tow was sorted into species on deck and weighed on electronic motion-compensating Marel scales to the nearest 0.1 kg. Organisms were identified to species where possible. Crustaceans, shellfish, and other invertebrate species not readily identified were frozen for later identification on shore. Unidentified specimens were placed in sealed plastic bags with a label noting the trip code and station number.

Length, to the nearest whole centimetre (cm) below the measured length, and sex (where possible) were recorded for all species managed under the Quota Management System (QMS) and a selection of non-QMS species. Either the whole catch or a randomly selected subsample of up to 100 fish per tow were measured. For snapper, John dory, red gurnard, tarakihi, and some other important species, more detailed biological examinations were carried out on a sub-sample of up to 20 fish per tow. This included individual fish weight (grams), length to the nearest millimetre, sex, and gonad stage (using the middle depths gonad stage definitions (Appendix 1)). Otoliths were collected from the (up to) 20 snapper that were biologically sampled at each station. As each voyage progressed, length frequency plots for snapper were used to identify length classes where additional otoliths were required (the aim was to obtain 10 snapper otoliths per centimetre length class, and for these otoliths to be representative of the spatial strata for each survey).

2.4 Otolith preparation and ageing

About 700 snapper otoliths were selected for ageing from each survey. For most one-centimetre length classes all otoliths collected were aged, but for the most common length classes (i.e., 20–35 cm) a sub-set of 20 otolith pairs per length class were randomly selected.

For the selected set of about 700 otolith pairs from each survey, preparation followed the break and burn technique (Chugunova 1963) and a standardised procedure for reading otoliths was followed, outlined in the age determination protocol for snapper (Walsh et al. 2014). Two readers were used, with each reader having no prior knowledge of the other's zone count obtained, or of the fish length. For otoliths where both readers agreed on the zone count, the age was determined from this count. When readers disagreed, the otolith was re-examined by both readers together to determine the likely source of disagreement and a final count agreed upon. The forced margin method was implemented to anticipate the otolith margin type (wide, line, narrow) *a priori* based on the month in which the fish was sampled to provide guidance in determining age. The theoretical birth date for ageing snapper is 1 January following Paul (1976), and, to be consistent with past trawl survey snapper ageing, otoliths were aged as age groups (i.e., 0+, 1+, etc.) from the collection date (November 2019 for the Hauraki Gulf and February 2020 for the Bay of Plenty). The resulting final ages were then used to form an Age Length Key (ALK) using NIWA's catch-at-length and -age analysis software tool CALA (Francis & Bian 2011).

Otolith reading precision was quantified by carrying out within- and between-reader comparison tests after Campana et al. (1995), including those between each reader and the final agreed age. The Index of Average Percentage Error, IAPE (Beamish & Fournier 1981), and mean CV (Chang 1982) were calculated for each test.

2.5 Historical survey time series

Data from the historical surveys of the Hauraki Gulf (12 surveys, 1984–2000) and Bay of Plenty (6 surveys, 1983–1999) were obtained from the Fisheries New Zealand *trawl* database. In a small number of instances data from these surveys contained some errors that were dealt with as follows:

1. Where length data were recorded but catch weight data were absent, a calculated catch weight using appropriate length-weight coefficients for that species was used (Appendix 2), by scaling up to the total weight caught using the percent sampled data for that species and station.
2. Where percent sampled was absent, the appropriate length-weight coefficients for that species (Appendix 2) and the available catch weight data were used to calculate percent sampled for that species and station.
3. Where the sum of the number of male and female fish measured was greater than the sum of all that was listed for that species, it was assumed that the sum of the number of male and female fish was the correct value.
4. Where there were multiple percent sampled values listed for a species at a station, it was assumed that separate sub-catches should have been denoted, and so, retrospectively, sub-catches were applied where appropriate.

The historic survey data were then re-stratified, using the latitude and longitude for each survey station to assign it to one of the strata used for the KAH1907 (Hauraki Gulf) and KAH2001 (Bay of Plenty) surveys (Table 1, Figure 1). Where a station was outside these strata, it was dropped. Where a station did not have a latitude and longitude listed, it was dropped. Where a stratum for a particular survey had less than three stations, that stratum was merged with an adjacent stratum so that the merged stratum had at least three stations. This resulted in 20 merged strata across 10 of the historic surveys for the Hauraki Gulf, and 10 merged strata across four historical surveys for the Bay of Plenty.

The Inshore Working Group noted that re-stratifying survey stations as described above could violate the assumptions of random station allocation. The stratum areas used throughout both the Hauraki Gulf and Bay of Plenty time series were subsequently investigated. Subsets of the original survey strata could be selected for each survey in the series, with the total area of these subsets being virtually identical to the survey areas of the Hauraki Gulf and Bay of Plenty surveys in 2019 and 2020, respectively. In future, species biomass and other outputs from historical surveys should be calculated using these subsets of original survey strata. Historic biomass and abundance estimates and length frequency distributions were not re-calculated after the Inshore Working Group, and the reader should therefore note that outputs for the historical survey series in the present report may contain some bias associated with the re-stratification process described above, but this bias is likely small. The analysis recommended by the Inshore Working Group (i.e., the use of original stratification for each survey) will be incorporated into the report associated with the next round of Hauraki Gulf and Bay of Plenty surveys (intended to be conducted in 2020 and 2021, respectively).

Age data for snapper from these historic surveys were obtained from the ALKs published in the survey reports (where available) and from Fisheries New Zealand *age* database. For the Hauraki Gulf, reports with ALKs were available for the six historic surveys conducted after 1990. For the six Hauraki Gulf surveys conducted in the 1980s, the age data from the database were inspected first. Because the Hauraki Gulf survey is conducted just prior to the theoretical birth date for ageing snapper (1 January), otolith readers sometimes record fish ages as being one year older than they actually were. In these instances (identified when the age data for a survey contained no fish in the 0+ age cohort), one year from all ages was subtracted before utilising these age data. CALA was then used to calculate ALKs for all the Hauraki Gulf surveys from the 1980s. For two surveys (KAH8517 and KAH8716) the ALKs produced were anomalous, with the length classes for some ages not matching the other ALKs (Appendix 3). Further, the ALKs produced for these surveys had considerable overlap for the young age cohorts (i.e., 1+ and 2+ fish) (Appendix 3). For these surveys, modal analysis of the scaled length frequency distributions was conducted to estimate the number of fish at age. This involved specifying a lower and upper size limit for the 1+ cohort for each survey where age data were not to be used, and then calculating the number of fish within this size range from the scaled length frequency distribution. Because only the 1+ cohort was clearly defined and largely separate from other cohorts, this modal analysis was conducted only for the 1+ cohort. For the Bay of Plenty, reports with ALKs were available for three of the four surveys conducted in the 1990s (KAH9004, KAH9202, KAH9601). For the remaining three Bay of Plenty surveys (KAH8303, KAH8506, KAH9902) otoliths were collected, but not aged. For these surveys. modal analysis was performed to estimate the number of fish in the 1+ cohort only.

2.6 Data analysis

Biomass estimates and their associated CVs were estimated by the area-swept method (Francis 1981, 1984) using the SurvCalc Program (Francis & Fu 2012). Biomass estimates were also re-calculated for all the historic survey data series. Only tows for which the gear performance was satisfactory (code 1 or 2) were incorporated into the scaled length frequency distributions, biomass estimates, and relative abundance estimates.

The following assumptions were made for calculating biomass estimates with the SurvCalc Program:

1. The area swept during each tow equalled the distance between the doors multiplied by the distance towed.
2. Vulnerability was 1.0. This assumes that all fish in the area swept were caught and there was no escapement.
3. Vertical availability was 1.0. This assumes that all fish in the water column were below the headline height and available to the net.
4. Areal availability was 1.0. This assumes that the fish stock being sampled was entirely within the survey area at the time of the survey.
5. Non-trawlable ground was excluded from the survey area.

It is unlikely that all these assumptions are correct, but they have been applied consistently to the entire trawl survey time series for both the Hauraki Gulf and the Bay of Plenty. Given that the assumptions are likely to be violated, the biomass estimates generated should be treated as relative indices of abundance.

Length frequencies were scaled by the percentage of catch sampled, area swept, and stratum area using CALA. The geometric mean functional relationship was used to calculate length-weight coefficients for species where sufficient length-weight data were collected. For other species, and often for the historic surveys where length-weight data were not as commonly recorded, coefficients were chosen from the *rdb* database and other published data sources (Appendix 2).

Sex ratios were calculated using scaled population numbers and are expressed as the ratio of males to females. Recruited lengths were determined from either minimum legal size, the size at which 50% of fish mature, or minimum lengths considered desirable for sale.

Relative recruitment indices of the number of 1+ (2018 year class for the Hauraki Gulf, 2019 for the Bay of Plenty) and 2+ (2017 year class for the Hauraki Gulf and 2018 for the Bay of Plenty) snapper were generated by either: (1) combining the final ALKs with the scaled length frequency distribution for the matching survey, or (2) conducting modal analysis of the scaled length frequency distribution for just the 1+ cohort for the historic surveys without useable age data. The process of estimating relative recruitment indices of the number of snapper was intended to be similar to that of Francis et al. (1995), and Morrison & Francis (1999), Morrison et al. (2001a), all of whom used the historic R.V. *Kaharoa* survey dataset to estimate the year class strength (YCS) of snapper, but just for the 1+ cohort, and just in the Hauraki Gulf. In addition, Francis et al. (1995), Morrison & Francis (1999), and Morrison et al. (2001a) also related these estimates to February-June SST measured at the Leigh Marine Laboratory. So that the relative recruitment estimates could be plotted in a way that was comparable to, and could extend, those of Francis et al. (1995), Morrison & Francis (1999), and Morrison et al. (2001a), similar adjustments were made, as follows:

1. From about 1988, alterations to the HOBT net (increases in the weight of the groundrope and flotation on the headline) resulted in reduced escapement of 1+ fish underneath the groundrope. Francis et al. (1995) compensated for this by multiplying the 1+ YCS estimates (in millions) for the first four Hauraki Gulf surveys by a correction factor of 1.822. The same correction factor was applied to our estimates of the number of 1+ and 2+ snapper prior to 1988 from the Hauraki Gulf and Bay of Plenty.
2. As mentioned above, Francis et al. (1995) divided the number of 1+ snapper in the Hauraki Gulf by 1 000 000. This convention was continued for 1+ and 2+ fish in the Hauraki Gulf; but for the Bay of Plenty, the number of 1+ and 2+ snapper was divided by 10 000 (the number of recruiting fish was sometimes less than 100 000 in the Bay of Plenty).
3. Recruitment data are usually log-normally distributed, so Francis et al. (1995) $\log_e$ transformed YCS estimates. To ensure the relative recruitment estimates could be plotted in a way that was comparable to that of Francis et al. (1995), the same $\log_e$ transformation was conducted on the estimates of the number of 1+ and 2+ snapper for both the Hauraki Gulf and the Bay of Plenty.
4. Francis et al. (1995) normalised YCS estimates to produce an index by dividing by the mean value. For 1+ snapper in the Hauraki Gulf the long-term predicted mean $\log_e$ YCS value was 1.2 (Francis et al. 1995). Therefore, for comparability with Francis et al. (1995), the Hauraki Gulf 1+ estimates and CVs were divided by 1.2, but all the other YCS indices were divided by their own means (1.18 for 2+ snapper in the Hauraki Gulf, and 0.99 and 1.56 for 1+ and 2+ snapper in the Bay of Plenty, respectively).
5. For the Hauraki Gulf, Francis et al. (1995) used February-June SST measured at the Leigh Marine Laboratory to generate a temperature-recruitment relationship (a predicted 1+ recruitment index). This relationship was then subsequently updated by Morrison & Francis (1999), using data from the KAH9720 survey. This was the last time the relationship was updated, because estimates of 1+ recruitment from the KAH0012 survey were much lower than expected. The Morrison & Francis (1999) relationship ($\log_e(\text{YCS}) = -16.99 + 0.9942\ \text{SST}$) to

Leigh Marine Laboratory SST data (the February-June monthly average for 1982 to 2019) (Shears & Bowen 2017) was applied to generate an updated predicted 1+ snapper index for the Hauraki Gulf. In the Bay of Plenty no temperature-recruitment relationship has been developed, so a visual comparison was made between the Leigh SST (again February-June monthly average) and the Bay of Plenty YCS index values.

6. To validate the re-stratification of the historic time series (see section 2.5), the re-stratified 1+ YCS index for the Hauraki Gulf was compared with the original 'Francis and Morrison' 1+ YCS index values (Francis et al. 1995, Morrison & Francis 1999, Morrison et al. 2001a).

3. RESULTS

3.1 Survey timing

For the Hauraki Gulf survey (KAH1907), R.V. *Kaharoa* departed Wellington on 12 November 2019 and arrived in Auckland on 15 November to load science crew, ice, and bins and then commenced trawling that day. Thirty-nine phase one stations were completed by 25 November, with unloads or repair work conducted in Auckland on 18, 19, 20, and 23 November. Five phase two stations were completed on 25–26 November before returning to Auckland on the evening of 26 November. *Kaharoa* departed Auckland on 27 November and returned to Wellington and demobilised on 30 November. A total of 39 phase one stations were completed, with five phase two stations completed across stratum 1268 (one station), stratum 1887 (one station), stratum 2229 (two stations), and stratum LITB (one station). At least three stations were carried out in all strata. Three other tows (stations 19, 22, and 39) were not used for biomass estimation because they were foul tows.

For the Bay of Plenty survey (KAH2001), R.V. *Kaharoa* departed Wellington on 12 February 2020 and arrived in Tauranga on 14 February. Science crew, ice, and bins were loaded on 15 February and trawling commenced that day. Forty-two phase one stations were completed by 21 February, with *Kaharoa* arriving in Tauranga that evening to unload fish the next day. Phase two trawling commenced on 23 February, with 10 stations completed by 24 February. Some science staff were offloaded in Tauranga on 24 February, camera tows (codend open) were conducted on 25–26 February, and, with the remainder of the science staff, the vessel departed on the 27th of February. The R.V. *Kaharoa* arrived in Wellington for demobilisation on March 1st. A total of 42 phase one stations were completed, with 10 phase two stations in total completed, consisting of three stations in stratum 1096, six stations in stratum 4085, and one station in stratum 6085. At least three stations were carried out in all strata. One other tow (station number 3) was not used for biomass estimation because it was a foul tow.

The survey areas, with stratum boundaries and station positions, are shown in Figure 1 and individual station data are given in Appendix 4.

A summary of gear and tow parameters by depth is shown in Table 2. Doorspread ranged from 50.7 to 85.3 in the Hauraki Gulf and from 66.0 to 85.8 m in the Bay of Plenty and headline height varied between 4.4 and 6.6 m in the Hauraki Gulf and was 4.5–5.5 m in the Bay of Plenty (Table 2, Appendix 4). Measurements of headline height and doorspread, and observations that the doors and trawl gear were polishing well, indicated that the gear was operating correctly. Overall, gear parameters were similar to those of previous years, indicating consistency between surveys.

3.2 Catch composition

Totals of about 32.5 and 8.6 t of fish and invertebrates were caught from the 44 and 52 valid biomass tows from the Hauraki Gulf (average 739 kg per tow) and Bay of Plenty (average 165 kg per tow) surveys, respectively. Of the fish catch, 10 chondrichthyan and 25 teleost species were recorded on the Hauraki Gulf survey, and 9 chondrichthyan and 30 teleost species were recorded on the Bay of Plenty survey. Species codes, common names, scientific names, and catch weights of all species identified during the survey are given in Appendix 5. Benthic macro-invertebrate species identified from the catch are given in Appendix 6.

The most abundant species by weight for both surveys was snapper, with 28.9 t (89% of the total catch) caught on the Hauraki Gulf survey and 5.7 t (66% of the total catch) caught on the Bay of Plenty survey. For the Hauraki Gulf survey, the next most abundant species was the yellowtail jack mackerel *Trachurus novaezelandiae* at 2.1 t (6.5% of the total catch). Other commonly caught species from the Hauraki Gulf survey included eagle ray (*Myliobatis tenuicaudatus*), leatherjacket (*Meuschenia scaber*), John dory (*Zeus faber*), short-tailed black ray (*Dasyatis brevicaudata*), porcupine fish (*Allomycterus jaculiferus*), red gurnard (*Chelidonichthys kumu*), and trevally (*Pseudocaranx georgianus*) (all less than 200 kg per species). For the Bay of Plenty survey, the most commonly caught species other than snapper accounted for a slightly higher percentage of the overall catch compared with the Hauraki Gulf, but were made up of a similar species. These common Bay of Plenty survey species included porcupine fish, yellowtail jack mackerel, kahawai (*Arripis trutta*), eagle ray, gurnard, trevally, and leatherjacket (all less than 570 kg per species).

Thirty-two and fifteen species or species groups of benthic macro-invertebrates were identified during the Hauraki Gulf and Bay of Plenty surveys, respectively (Appendix 6). The number of invertebrate species does not necessarily reflect biodiversity in the survey area because the gear is not designed to collect benthic macro-invertebrates. In addition, stations were intentionally positioned over soft or flat ground, which would strongly influence the incidence of some species groups.

3.3 Catch rates and species distribution

Catch rates for the most commonly caught QMS species are shown in Figures 2a–i (Hauraki Gulf: kahawai, gurnard, John dory, yellowtail jack mackerel, leatherjacket, snapper, rig, and trevally) and Figures 2j–u (Bay of Plenty: kahawai, frostfish, gurnard, John dory, yellowtail jack mackerel, kingfish, leatherjacket, tarakihi, snapper, rig, and trevally). Some of the species included here were not abundant in the 2019 Hauraki Gulf and 2020 Bay of Plenty surveys (e.g., kahawai, frostfish, kingfish, tarakihi, and rig), but have been included in Figures 2 and 3 (and the majority of subsequent tables and plots) due to their sometimes higher historical abundance. Catch rate maps for these species for the entire historical survey series (both Hauraki Gulf and Bay of Plenty) are presented in Figure 4 and discussed in section 3.6.

Catch rates of pre-recruit snapper (under 25 cm fork length, FL) were consistently high inside the line between Cape Rodney and Cape Colville (Figure 2f). The highest catch rates were achieved in the Firth of Thames, whereas low catch rates or zero catches occurred in the outer gulf. In the Bay of Plenty, pre-recruit snapper catch rates were lower than in the gulf and largely constrained to the inner eastern Bay, between the Rangitaiki and Motu river mouths (strata 4085 and 1096) (Figure 2r). Very low catch rates or zero catches were recorded from nearly all other stations in the Bay of Plenty.

Catch rates of recruited snapper (25 cm FL and larger) in the Hauraki Gulf were very similar to that of pre-recruit snapper, in that they were consistently high throughout the inner gulf and very low in the outer gulf (Figure 2g). Recruit-sized snapper were caught at every station in the Hauraki Gulf survey. In the Bay of Plenty, catch rates of recruited snapper were high, especially in the same area of the inner eastern bay where pre-recruit snapper were abundant (i.e., between the Rangitaiki and Motu river mouths) (strata 4085 and 1096) (Figure 2s). Recruit-sized snapper were caught at all stations throughout the bay, however, with some reasonable catches in the western bay (strata 2096 and 32NH), but low catches in deeper water.

Moderate gurnard catch rates were encountered at most stations throughout the Hauraki Gulf (gurnard were caught at 43 of 44 stations) (Figure 2b). In the Bay of Plenty, the highest gurnard catch rates were encountered in the eastern bay between the Tarawera and Motu river mouths (gurnard were caught at 46 of 52 stations) (Figure 2l).

John dory were caught at most stations in the Hauraki Gulf (35 of 44 stations), with catch rates highest in the mid-gulf, following an arc between the islands off Coromandel, across the north of Waiheke Island, and past Tiritiri Matangi Island into Kawau Bay (Figure 2c). Lower catch rates of John dory were achieved at most other sites throughout the gulf. In the Bay of Plenty, moderate John dory catch rates were achieved throughout the bay, both from west to east, and across the depth ranges that the survey covered (Figure 2m). However, 24 sites in the Bay of Plenty did not catch any John dory; more sites here had zero catch than in the gulf).

Yellowtail jack mackerel were also caught at most stations in the Hauraki Gulf (35 of 44 stations), with catch rates high in the eastern gulf, from the islands off Coromandel and down into the Firth of Thames (Figure 2d). Lower catch rates were recorded in the inner western gulf, and catch rates in the outer gulf were low or non-existent. In the Bay of Plenty, some high catch rates of yellowtail jack mackerel were recorded, but these were concentrated in an area in the inner eastern bay between the Rangitaiki River and Opape (mostly stratum 4085) (Figure 2n). At nearly all other sites in the Bay of Plenty, catches of yellowtail jack mackerel were low to non-existent.

Catches of leatherjacket in the Hauraki Gulf were almost exclusively constrained to the outer gulf (outside a line between Cape Rodney and Cape Colville, in strata 1449, LITB, and COLV) (Figure 2e). Outside this line, leatherjacket catches were consistently moderate at nearly all stations. In the Bay of Plenty, leatherjacket catches were constrained to the western bay, between Bowentown and Mercury Bay (Figure 2p). Some low catch rates of leatherjacket were achieved off Tauranga, and nearly all sites further east produced no leatherjacket.

Trevally were caught at about half of the stations in the Hauraki Gulf (21 of 44 stations), but catch rates were reasonably low and inconsistently distributed throughout the gulf, with many stations not catching any trevally regardless of location (Figure 2i). Mid gulf stations had the most consistent catches of trevally, although some trevally were caught in the inner and outer gulf. In the Bay of Plenty, trevally were consistently caught at nearly all shallow inner stations throughout the entire bay (strata 1096, 4085, 2096, and 32 NH) (Figure 2u). Deeper outer stations mostly had zero catches.

Rig catch rates in the Hauraki Gulf were also low (Figure 2h). Most stations had zero catches (rig were caught at 17 of 44 stations), with some low catch rates in the shallow inner gulf (Firth of Thames, Tamaki Strait, East Coast Bays, Kawau Bay). In the Bay of Plenty, rig were consistently caught in the shallow inner bay, mostly east of the Rangitaiki River mouth, but with some catches recorded from the inner western bay off Tauranga and Waihi (strata 4085, 1096, and 2096) (Figure 2t). Deeper stations north of Waihi did not catch any rig.

Kahawai catch rates were low throughout the Hauraki Gulf and Bay of Plenty (kahawai have been included here due to their historically higher catch rates, see section 3.6), other than a single large catch in the eastern Bay of Plenty in stratum 4085 (Figures 2a and 2j).

Frostfish, kingfish, and tarakihi (only presented for the Bay of Plenty) were only caught at a few stations in the Bay of Plenty (3, 4, and 4 of 52 stations, respectively). For frostfish, these stations were at the deeper extent (near 100 m) of the Bay of Plenty survey (Figure 2k). The stations kingfish were caught at were to the east of Whakatane and inshore (strata 4085 and 1096) (Figure 2o). The stations with tarakihi catches were off Whakatane in less than 50 m depth (stratum 4085) (Figure 2q).

Mean catch rates for the most abundant QMS species by stratum for the 2019 Hauraki Gulf and 2020 Bay of Plenty surveys are given in Table 3.

3.4 Biomass estimation

References to ‘biomass’ are to relative abundance estimates unless otherwise stated.

Biomass estimates for QMS species caught in all surveys in the Hauraki Gulf and Bay of Plenty trawl survey series are given in Table 4. Estimated biomass and CVs for the most common QMS species for the 2019 Hauraki Gulf survey were: snapper 20 617 t (14%); yellowtail jack mackerel 2131 t (29%); leatherjacket 338 t (30%); John dory 188 t (15%); gurnard 162 t (28%); trevally 107 t (35%); rig 29 t (25%); and kahawai 6.9 t (28%). Estimated biomass and CVs for the most common QMS species for the 2020 Bay of Plenty survey were: snapper 2824 t (9%); yellowtail jack mackerel 214 t (48%); gurnard 181 t (15%); leatherjacket 149 t (56%); kahawai 94.8 t (88%); John dory 84 t (23%); trevally 74 t (18%); rig 36 t (25%); frostfish 19 t (56%); kingfish 6 t (72%); and tarakihi 3 t (54%)

Biomass estimates based on length at recruitment for the most common QMS species are given in Table 5. For the 2019 Hauraki Gulf survey, gurnard, John dory, leatherjacket, snapper, and trevally all had estimates of recruited biomass that represented a high percentage of the total biomass (at least 75%). For the 2020 Bay of Plenty survey, kahawai, frostfish, gurnard, John dory, leatherjacket, tarakihi, snapper, and trevally all had estimates of recruited biomass that represented a high percentage of the total biomass (at least 71%).

The biomass estimates and CVs for the most common QMS species for both the 2019 Hauraki Gulf and 2020 Bay of Plenty surveys are given by stratum in Table 6.

Trends in biomass for selected species are shown in Figure 4 and are discussed in section 3.6.

3.5 Length frequency and biological data

The numbers of length frequency and biological samples taken during the survey are given in Table 7. Comparative population scaled length frequency distributions for the most common QMS species are shown in Figures 5a–5h and 6a–6k. Length frequency distributions are presented in alphabetical order by species code. Species codes are given in Appendix 5.

Using measurements from the 2019 Hauraki Gulf and 2020 Bay of Plenty surveys, length-weight coefficients (by area) were determined for gurnard, John dory, yellowtail jack mackerel, snapper, and trevally (just Bay of Plenty) (Appendix 2).

There were 970 and 1040 pairs of snapper otoliths collected from the Hauraki Gulf and Bay of Plenty surveys, respectively (Table 7). For each survey, 701 otoliths were prepared and aged. The between-reader CV and IAPE for the Hauraki Gulf otolith set were 3.24 and 2.29%. respectively. For the Bay of Plenty, the between-reader CV and IAPE were 5.24 and 3.7%, respectively. The age-length keys derived from these otolith readings can be found in Appendix 7.

Details of maturity stages for gurnard, John dory, tarakihi, snapper, and trevally are given in Table 8 and discussed in section 3.6; the gonad stages are defined in Appendix 1.

3.6 Trends in the most common QMS species

3.6.1 Snapper

In the Hauraki Gulf, snapper were caught at all 44 stations and between 6 and 69 m deep (Appendix 5). Higher catches of both pre-recruit and recruit snapper in 2019 were predominantly from the inner to mid gulf, which has been the trend throughout the survey series (Figures 2f and 2g and 3f and 3g). Although mid gulf strata made large contributions to the overall snapper biomass (e.g., 1219, 1268, 1386, 1887, and 2229 contributed 2471, 3397, 1157, 3215, and 5003 t respectively), the large outer gulf strata (LITB) also made a sizeable biomass contribution (2230 t) (Table 6). Overall snapper biomass in the gulf was variable, with a slight overall positive slope until the 2000 survey (8629.8 t), before increasing to a series high biomass of 20 618 t in 2019 (Figure 4 and Table 4). In 2019, a high proportion of the biomass estimate (15 559 t or 76 %) was recruited (25 cm and larger) fish (Table 5). The male to female sex ratio in 2019 was 1.09 to 1. Previous surveys where snapper were sexed have often also had a slightly male-biased sex ratio (Figure 5f). Most snapper caught on the 2019 survey were between 6 and 40 cm, with one distinct size mode between 6 and 13 cm (likely 1+ fish), and another merged age class mode between 14 and 40 cm (Figure 5f). Although the appearance of juvenile size modes varies between years according to the YCS of specific cohorts (see section 3.7), the size range of snapper in 2019 was broadly similar to that of previous surveys, although some of the surveys prior to 1990 had a higher proportion of fish 40 cm and larger (Figure 5f). There was little gonad development in snapper under 20 cm. Larger males were predominantly ripening but ranged between resting and running ripe. Larger females were also predominantly ripening but ranged between resting and partially spent (Table 8).

In the Bay of Plenty, snapper were caught at all 52 stations and between 13 and 96 m deep (Appendix 5). Highest catches of pre-recruit snapper in 2020 were predominantly from the inshore and eastern parts of the survey area, whereas catches of adult snapper were from inner parts of the entire survey area (Figure 2r and 2s). This spatial pattern of catches differs from previous surveys for pre-recruit snapper, which were formerly caught throughout the inner parts of the entire survey area (Figure 3r and 3s). The estimated biomass of snapper was dominated by the eastern strata (e.g., 1096, 4085, and 6085 contributed 745, 829, and 362 t respectively) (Table 6). Overall snapper biomass has increased, with some oscillation, throughout the survey series, with 2020 representing a series high of 2824 t (Figure 4 and Table 4). In 2020, 2602 t (92%) of the Bay of Plenty snapper biomass was recruited (25 cm and larger) fish (Table 5). The male to female sex ratio in 2020 was 0.94 to 1. Although only one previous Bay of Plenty survey sexed a large number of snapper, it too had a slightly female-biased sex ratio (Figure 6i). The majority of snapper caught in 2020 were between 6 and 40 cm length, with one distinct size mode between 6 and 13 cm (likely 1+ fish) (Figure 6i). This size range was broadly similar to that of previous surveys; but see section 3.7 for more specific detail about variation in snapper YCS in the Bay of Plenty. There was little gonad development in snapper under 20 cm. Larger males and females were predominantly resting, but ranged between resting and running ripe, with a few individuals that were spent (Table 8).

3.6.2 Red gurnard

In the Hauraki Gulf gurnard were caught at 43 stations between 6 and 69 m deep (Appendix 5). Gurnard were spread throughout the Hauraki Gulf survey area, but most were within the two outermost strata LITB (65 t) and COLV (21 t) (Table 6). The overall Hauraki Gulf gurnard biomass in 2019 was 162 t, an increase from the very low biomass at the previous survey in 2000 (28 t) (Table 4). Gurnard biomass in the Hauraki Gulf was much higher previously (e.g., 1494 t in 1987), but these historic biomass levels did fluctuate between surveys (Figure 4). In 2019, 120 t (74 %) of the Hauraki Gulf gurnard biomass was recruited (30 cm and larger) fish (Table 5). The male to female sex ratio in 2019 was 0.31 to 1. Although most historical surveys have also produced a female dominated sex ratio, 2019 was particularly female-biased (Figure 5b). The length of gurnard caught in 2019 was largely between 10 and 45 cm, with one distinct size mode between 10 and 17 cm (Figure 5b). The overall size range was generally similar to that of previous surveys, although there was a slightly higher proportion of large gurnard (30 cm and larger) in 2019 (Figure 5b). There was little gonad development in gurnard under 20 cm, but for larger fish there was a range of gonad stages with the majority of males resting or ripening and the majority of females ripening or ripe (Table 8).

In the Bay of Plenty, gurnard were caught at 46 stations between 13 and 96 m deep (Appendix 5). Although the highest catches of gurnard in 2020 were in the east of the survey area, the estimated biomass of gurnard was spread across all strata. Strata with larger areas, however, often contributed more to the overall biomass estimate (e.g., 4085, 6085, 708N, 708S contributed 23, 53, 23, and 39 t respectively) (Table 6). Apart from an anomalously low gurnard biomass estimate in 1985, gurnard biomass has steadily declined throughout the Bay of Plenty survey series (Figure 4). The overall gurnard biomass estimate in 2020 was 181 t, the lowest in the series apart from the anomalous 1985 estimate (Table 4). In 2020, 130 t (72%) of the Bay of Plenty gurnard biomass was recruited (30 cm and larger) fish (Table 5). The male to female sex ratio in 2020 was 0.67 to 1. As in the Hauraki Gulf, the bias towards females was stronger in 2020 than previously (Figure 6c). The length of gurnard caught in 2020 was largely between 10 and 45 cm, which is generally similar to that of previous surveys (Figure 6c). There was little gonad development in gurnard under 20 cm, but for larger fish there was a range of gonad stages with the majority of males and females resting, although a number of females were also partially spent or spent (Table 8).

3.6.3 John dory

In the Hauraki Gulf, John dory were caught at 35 stations between 12 and 69 m deep (Appendix 5). Highest catches of John dory in 2019 were predominantly from the mid gulf, which has been the trend throughout the survey series (Figures 2c and 3c). Although mid gulf strata made large contributions to the overall John dory biomass (e.g., 1219, 1268, and 2229 contributed 20, 22, and 42 t respectively), the large outer strata also made sizeable biomass contributions (LITB and COLV contributed 62 and 20 t, respectively) (Table 6). John dory biomass generally increased through the time series until the 2000 survey, when it decreased to 151 t (Table 4). In 2019, the overall Hauraki Gulf John dory biomass of 188 t was slightly higher than that in 2000 (Table 4). In 2019, nearly all (187 t or 99.5 %) of the Hauraki Gulf John dory biomass was recruited (25 cm and larger) fish (Table 5). The male to female sex ratio in 2019 was 0.79 to 1. Previous surveys also had female-dominated sex ratios (Figure 5c). The length of John dory caught in 2019 was largely between 15 and 50 cm, with one distinct size mode between 15 and 21 cm and another, likely merged age class, mode between 25 and 50 cm (Figure 5c). The overall length frequency distribution was broadly similar to that of previous surveys (Figure 5c). There was little gonad development in John dory under 20 cm, and for larger fish the majority of both males and females were ripening (Table 8).

In the Bay of Plenty, John dory were caught at 28 stations between 18 and 96 m deep (Appendix 5). Catches of John dory in 2020 occurred throughout the survey area, which is consistent with the historical distribution (Figures 2m and 3m). The estimated biomass of John dory was dominated by the larger and deeper strata (e.g., 6085, 708N, and 708S contributed 20, 28, and 25 t respectively) (Table 6). John dory biomass increased throughout the survey series until the early 1990s, before steadily decreasing (Figure 4). The overall John dory biomass estimate in 2020 continued this declining trend and was the lowest in the time series at 84 t (Table 4). In 2020, 81 t (96%) of the Bay of Plenty John dory biomass was recruited (25 cm and larger) fish (Table 5). The male to female sex ratio in 2020 was 1.42 to 1. Previous Bay of Plenty surveys generally have had a reasonably even sex ratio (Figure 6d). The length of John dory caught in 2020 was between 20 and 50 cm without distinct size modes, which is generally similar to that of previous surveys (Figure 6d). All but one of the John dory sampled were mature. The majority of both males and females were resting, although some females were ripening or ripe (Table 8).

3.6.4 Yellowtail jack mackerel

In the Hauraki Gulf, yellowtail jack mackerel were caught at 35 stations between 6 and 69 m deep (Appendix 5). Catches of yellowtail jack mackerel in 2019 were predominantly from the inner gulf, which has been the trend throughout the survey series (Figures 2d and 3d). Although inner gulf strata made large contributions to the overall yellowtail jack mackerel biomass (e.g., 1268 and 1887 contributed 340 and 630 t, respectively), larger mid and outer gulf strata also made sizeable biomass contributions (1219, 2229, and LITB contributed 487, 191, and 324 t, respectively) (Table 6). Yellowtail jack mackerel biomass has fluctuated, often with high associated variation, throughout the survey series (Figure 4). In 2019, the overall Hauraki Gulf yellowtail jack mackerel biomass was a series high 2131 t (Table 4). In 2019, little of the Hauraki Gulf yellowtail jack mackerel biomass (292 t or 14%) was recruited (25 cm and larger) fish (Table 5). Although a low proportion of yellowtail jack mackerel were sexed on the Hauraki Gulf survey in 2019, the male to female sex ratio of those sexed was 1.1 to 1. Most previous surveys have not sexed yellowtail jack mackerel, so trends in sex ratio are unknown (Figure 5d). The length of yellowtail jack mackerel caught in 2019 was largely between 10 and 25 cm, with distinct size modes between 10 and 17 cm, and another between 17 and 25 cm (Figure 5d). The length frequency distribution of yellowtail jack mackerel from previous surveys has varied, sometimes containing both smaller and larger fish (Figure 5d). The gonad stage of yellowtail jack mackerel caught on the 2019 Hauraki Gulf survey was not examined.

In the Bay of Plenty yellowtail jack mackerel were caught at 33 stations between 18 and 96 m deep (Appendix 5). Highest catches of yellowtail jack mackerel in 2020 predominantly occurred in the eastern part of the survey area, which is consistent with the historical distribution (Figures 2n and 3n) and two of the eastern strata dominated the biomass estimates (1096 and 4085 contributed 39 t and 173 t, respectively) (Table 6). Yellowtail jack mackerel biomass has remained relatively stable throughout the Bay of Plenty survey series, apart from a higher initial biomass estimate in 1983 (479 t) and two lower biomass estimates in 1990 (19 t) and 1992 (0 t) (Table 4). The overall yellowtail jack mackerel biomass estimate in 2020 was 214 t (Table 4). In 2020, only 0.8 t (0.4 %) of the Bay of Plenty yellowtail jack mackerel biomass was recruited (25 cm and larger) fish (Table 5). The male to female sex ratio in 2020 (or for any other survey years) is unknown because yellowtail jack mackerel were not sexed. The length of yellowtail jack mackerel caught in 2020 was between 5 and 20 cm, with a distinct size mode between 5 and 10 cm and another likely mixed age size mode between 10 and 20 cm (Figure 6e). The gonad stage of yellowtail jack mackerel caught on the 2020 Bay of Plenty survey was not examined.

3.6.5 Leatherjacket

In the Hauraki Gulf, leatherjacket were caught at 22 stations between 15 and 77 m deep (Appendix 5). Highest catches of leatherjacket in 2019 were predominantly from the outer gulf, which has been the trend throughout the survey series (Figures 2e and 3e). Accordingly, the outer gulf strata also dominated the biomass estimates for leatherjacket in 2020 (1219, 1449, LITB, and COLV contributed 50, 51, 171, and 62 t, respectively) (Table 6). Leatherjacket biomass has varied throughout the survey series, sometimes with a high CV around the estimated biomass values (Figure 4). In 2019, the overall estimated biomass of leatherjacket in the Hauraki Gulf was 338 t (Table 4). In 2019, nearly all (337 t or 99.8 %) of the Hauraki Gulf leatherjacket biomass was recruited (19 cm larger) fish (Table 5). The male to female sex ratio in 2019 (or for any previous surveys) is unknown because too few leatherjacket were sexed. The length of leatherjacket caught in 2019 was largely between 15 and 30 cm (Figure 5e) and was broadly similar to that of previous surveys, although some surveys in the 1980s had a higher proportion of smaller (10–20 cm) leatherjacket (Figure 5e). The gonad stage of leatherjacket caught on the 2019 Hauraki Gulf survey was not examined.

In the Bay of Plenty, leatherjacket were caught at 32 stations between 15 and 77 m deep (Appendix 5). Catches of leatherjacket in 2020 largely occurred in the western part of the survey area, which is consistent with the historical distribution (Figures 2p and 3p), and the western strata also dominated the estimated biomass of leatherjacket (5287, 708N, 708S contributed 25, 18, and 86 t, respectively) (Table 6). Leatherjacket biomass increased to a peak in 1992 (253 t), before a decline in the later 1990s (Figure 4). The overall leatherjacket biomass estimate in 2020 was 149 t (Table 4). In 2020, 146 t (99%) of the Bay of Plenty leatherjacket biomass was recruited (19 cm and larger) fish (Table 5). The male to female sex ratio in 2020 was 0.95 to 1. Previous trends in leatherjacket sex ratio are unknown because leatherjacket have not previously been sexed (Figure 6g). The length of leatherjacket caught in 2020 was generally between 15 and 20 cm, with two size modes between 15 and 23 cm and between 23 and 30 cm (Figure 6g). The overall size range of leatherjacket caught in 2020 was generally similar to that caught on previous surveys (Figure 6g). The gonad stage of leatherjacket caught on the 2020 Bay of Plenty survey was not examined.

3.6.6 Trevally

In the Hauraki Gulf, trevally were caught at 21 stations between 6 and 49 m deep (Appendix 5). Catches of trevally in 2019 were from throughout the survey area, whereas trevally catches in previous surveys were largely from shallow areas (both inner and outer gulf) (Figures 2i and 3i). Three strata contributed the majority of the overall biomass estimate for trevally (1219, 2229, and LITB contributed 39, 25, and 26 t, respectively) (Table 6). Trevally biomass remained relatively low throughout the survey series apart from two high biomass estimates in 1985 (140 t) and 1989 (129 t), which also had high CVs (Figure 4). In 2019, the estimated biomass of trevally was the third highest value in the series (107 t) (Table 4). Nearly all this biomass (106 t or 99%) was recruited (25 cm and larger) fish (Table 5). The male to female sex ratio in 2019 was 0.89 to 1. Previous surveys have not sexed enough trevally to provide any insight about trends in sex ratio (Figure 5h). The length of trevally caught in 2019 was mainly between 20 and 40 cm, although a small size mode between 17 and 20 cm was also present (Figure 5h). The size range of trevally from previous surveys has been variable, with size modes of trevally anywhere between 5 and 60 cm present depending on the particular survey (Figure 5h). There was no gonad development in trevally under 20 cm, whereas for larger male and female fish the gonad stage was anywhere from resting to running ripe (excluding one spent female) (Table 8).

In the Bay of Plenty, trevally were caught at 31 stations between 13 and 63 m deep (Appendix 5). Catches of trevally in 2020 were from throughout the survey area, which was similar to previous surveys (Figures 2u and 3u). The two shallowest strata contributed the majority of the estimated biomass of trevally in the Bay of Plenty (1096 and 2096 accounted for 38 and 15 t, respectively) (Table 6). Apart from a very low initial biomass estimate in 1983 (6 t) and a very high biomass estimate in 1999 (267 t), trevally biomass has generally declined (Figure 4). In 2020, the estimated biomass of trevally was 74 t. Nearly all this estimated biomass (70 t or 95%) was recruited (25 cm and larger) fish (Table 5). The male to female sex ratio in 2020 was 0.83 to 1. The 1999 Bay of Plenty survey (the only other survey where a number of trevally were sexed) had a similarly female-biased sex ratio (Figure 6k). The length of trevally caught in 2020 was mostly between 18 and 50 cm, with one size mode between 18 and 24 cm, and another (likely mixed age) size mode between 25 and 50 cm (Figure 6k). This size range captured in 2020 was generally similar to that of previous surveys (Figure 6k). There was little gonad development in trevally under 20 cm, whereas for larger male and female fish the gonad stage was anywhere from resting to running ripe (although female fish were predominantly resting and ripening) (Table 8).

3.6.7 Rig

In the Hauraki Gulf, rig were caught at 17 stations between 6 and 66 m deep (Appendix 5). Highest catches of rig in 2019 were predominantly from the inner gulf, which is consistent throughout the survey series (Figures 2h and 3h) and inner strata contributed most of the overall biomass estimate (1149, 1268, and 1887 contributed 7, 5, and 5 t, respectively) (Table 6). Rig biomass generally increased to a peak in 1988 (99 t), before declining to a low in 2000 (3 t) (Table 4). In 2019, the overall Hauraki Gulf rig biomass had increased to 29 t (Table 4). Only 4%, or 1 t, of this biomass was recruited (90 cm and larger) fish (Table 5). The male to female sex ratio in 2019 was 1.07 to 1. Previous surveys have also generally had a male-dominated sex ratio (Figure 5). The length of rig caught in 2019 was mainly between 40 and 80 cm, with one distinct size mode between 40 and 60 cm, and another size mode between 60 and 80 cm (Figure 5g). The overall size range in 2019 is broadly similar to that of previous surveys, although relatively few rig were measured (Figure 5g). The gonad stage of rig caught on the 2019 Hauraki Gulf survey was not examined.

In the Bay of Plenty, rig were caught at 19 stations between 17 and 66 m deep (Appendix 5). Catches of rig in 2020 predominantly occurred in the eastern parts of the survey area, with some catches also in shallow water off Tauranga (Figures 2t and 3t). This is broadly consistent with the historical distribution (Figures 2 and 3). One of the eastern strata dominated the estimated biomass of rig in the Bay of Plenty (stratum 4085 accounted for 21 t) (Table 6). Rig biomass has generally increased throughout the survey series (with some variation), with the estimated biomass in 2020 (36 t) the highest in the series (Figure 4). The CV for these biomass estimates, however, has often been high (Table 4). In 2020, 17 t (46%) of the Bay of Plenty rig biomass was recruited (90 cm and larger) fish (Table 5). The male to female sex ratio in 2020 was 0.41 to 1. Previous Bay of Plenty surveys have caught few rig and provide little insight into trends in the sex ratio of rig (Figure 6j). The length of rig caught in 2020 was mostly between 60 and 120 cm and without distinct size modes. This size range is generally similar to previous surveys although few rig were measured (Figure 6j). The gonad stage of rig caught on the 2020 Bay of Plenty survey was not examined.

3.6.8 Kahawai

In the Hauraki Gulf kahawai were caught at 13 stations between 6 and 32 m deep (Appendix 5). All captures of kahawai were from inner strata (strata 1386, 1284, 1149, 1887) (Table 6). Biomass in 2019 was low (6.9 t) and has been generally low throughout the Hauraki Gulf survey series (Figure 4a). The exception was a high biomass estimate for the 1986 survey (120 t), which also had a very high CV (93%) (Table 4) driven by a high catch in the Firth of Thames. In 2019, only 0.9 t (13%) of the biomass was recruited (40 cm and larger) fish (Table 5). The male to female sex ratio in 2019 was 0.42 to 1. Trends in sex ratio are unknown because sex was not determined for kahawai in most previous surveys.

The length of kahawai caught in 2019 was largely between 15 and 35 cm, which was similar to the size range in previous surveys (Figure 5a). In 2019, distinct length modes for kahawai of 17–24 cm and 25–31 cm were observed (Figure 5a). The gonad stage of kahawai caught on the 2019 Hauraki Gulf was not examined.

In the Bay of Plenty, kahawai were caught at 13 stations between 13 and 48 m deep (Appendix 5). The vast majority of kahawai biomass (88 t) was associated with stratum 4085, in the eastern part of the Bay of Plenty survey area (Table 6). The estimated kahawai biomass of 95 t in 2020 was the highest in the time series, but nearly all surveys have high CVs (Table 4, Figure 4). In 2020, 86 t (90%) of the kahawai biomass in the Bay of Plenty was recruited (40 cm and larger) fish (Table 5). The male to female sex ratio in 2020 was 1.02 to 1. Trends in sex ratio are unknown because sex was not determined for kahawai in most previous surveys. Kahawai caught in 2020 were mainly between 20 and 55 cm (Figure 6a). Although a similar size range was captured on previous Bay of Plenty surveys, the proportion of large kahawai between 40 and 50 cm was higher in 2020 than in any previous survey (Figure 6a). Distinct kahawai size modes were not obvious from the 2020 survey length frequency distribution plots (Figure 6a). There was little gonad development in kahawai under 30 cm, but for larger fish there was a range of gonad stages with the majority of males running ripe and the majority of females ripening (Table 8). No fish were spent or partially spent.

3.6.9 Tarakihi

Tarakihi were seldom caught on either the 2019 Hauraki Gulf or 2020 Bay of Plenty surveys but have previously been more frequently caught, particularly in the Bay of Plenty. The removal of the deeper strata from both of the present surveys may have contributed to the low tarakihi catches observed in 2019 and 2020. Detailed results are presented here for just the Bay of Plenty. In 2020, tarakihi were caught at 4 stations in the Bay of Plenty between 39 and 61 m deep (Appendix 5). The stations where tarakihi were caught in 2020 were all in the eastern part of the survey area, whereas historical catches have come from throughout the survey area (Figures 2q and 3q). In 2020, the estimated biomass of tarakihi was associated with two strata, 4085 (2 t) and 6085 (1 t) (Table 6). Tarakihi biomass has remained relatively low throughout the Bay of Plenty survey series apart from a high biomass estimate in 1992 (92.8 t) (Figure 4). The overall tarakihi biomass estimate in 2020 was a series low of 2.7 t (Table 4). In 2020, all the tarakihi biomass in the Bay of Plenty survey was recruited (25 cm and larger) fish (Table 5). The four tarakihi caught on the 2020 survey were between 30 and 40 cm (Figure 6h). Previous surveys sometimes have had a broader size distribution, likely due to the larger number of tarakihi captured (Figure 6h). All the tarakihi sampled were mature; all males were resting, and females were either resting or ripening (Table 8).

3.6.10 Kingfish

Kingfish were seldom caught on either the 2019 Hauraki Gulf or 2020 Bay of Plenty surveys but have been more frequently caught in previous Bay of Plenty surveys, so detailed results are presented here just for the Bay of Plenty. In 2020, kingfish were caught at 4 stations in the Bay of Plenty, all between 13 and 39 m deep (Appendix 5). These four stations were all in the eastern part of the survey area, but in previous surveys kingfish have occurred throughout the survey areas inner strata (Figures 2 and 3o). The 2020 biomass estimate of 6 t was the lowest in the series; the highest biomass (49.7 t) was in 1992 (Table 4). In 2020, none of the Bay of Plenty survey kingfish biomass was recruited (90 cm and larger) fish (Table 5). The male to female sex ratio and gonad stage in 2020 are unknown because all kingfish were returned to the sea alive. The length of kingfish caught in 2020 was between 35 and 80 cm, with too few fish caught to compare with the length frequency distributions of previous surveys (Figure 6f).

3.6.11 Frostfish

In 2019 and 2020, frostfish were caught only on the Bay of Plenty survey, where they were caught at three stations between 70 and 96 m depth in the 708N and 708S strata (Appendix 5, Table 6). Biomass of frostfish in 2020 was 18.6 t (Table 4). High levels of frostfish biomass were estimated for the 1996 and 1999 surveys (127.1 and 73.3 t, respectively), and all other surveys had lower biomass estimates (Table 4). In 2020, all the frostfish biomass in the Bay of Plenty was recruited (90 cm and larger) fish (Table 5). No males were caught in 2020, but the number of fish measured and sexed was low. Trends in sex ratio are unknown becausesex was not determined for frostfish in most previous surveys. The length of frostfish caught in 2020 was mainly between 100 and 125 cm, which is generally similar to previous Bay of Plenty surveys (other than the occasional small fish under 50 cm) (Figure 6b). Too few frostfish were captured to distinguish size modes from the 2020 survey length frequency distribution plots (Figure 6b). The gonad stage of frostfish caught on the 2020 Bay of Plenty survey was not examined.

3.7 Estimation of snapper year class strength

Proportion-at-age distributions for snapper caught on the 2019 Hauraki Gulf and 2020 Bay of Plenty surveys are presented in Figure 7.

For the Hauraki Gulf in 2019, the estimated YCS of 1+ and 2+ snapper (the 2018 and 2017 year classes) was 5.4 (CV = 20.0%) and 7.3 (CV = 11.0%) million fish, respectively (Table 9). These estimates are both above the average YCS estimates for the entire Hauraki Gulf survey series (average YCS is 3.8 and 3.6 million for 1+ and 2+ snapper, respectively). These raw numbers of the estimated abundance of 1+ and 2+ snapper in the Hauraki Gulf were used to recalculate the YCS index for 1+ snapper (see section 2.6). The resulting index matched the original ‘Francis and Morrison’ YCS values for previous surveys, giving confidence in the re-stratification process (Figure 8a). The YCS index values estimated by the 2019 Hauraki Gulf survey were well below the YCS predictions (16.0 and 12.2 million 1+ and 2+ snapper, respectively), based on the mean February-June Leigh SST temperature relationship (Figure 8b). Although the relative strength of year classes is difficult to interpret from proportion-at-age distributions alone, a strong 2015 year class in the Hauraki Gulf (4 year olds during the 2019 survey) was also evident.

For the Bay of Plenty in 2020, the estimated YCS of 1+ and 2+ snapper (the 2019 and 2018 year classes) was 0.926 (CV = 27.4%) and 0.453 (CV = 23.3%) million fish, respectively (Table 9). For 1+ snapper, this estimate is well above the average YCS for the Bay of Plenty survey series (the average 1+ YCS is 0.306 million fish). For 2+ snapper, this estimate is very similar to the average YCS for the Bay of Plenty survey series (the average 2+ YCS since 1990 is 0.465 million fish). A relationship between SST and YCS has not been previously investigated in the Bay of Plenty, but at first inspection there does not appear to be a strong relationship (Figure 8c). As in the Hauraki Gulf, the 2015 year class appears to be relatively strong in the Bay of Plenty (5 year olds during the 2020 survey).

4. CONCLUSIONS

The 2019 Hauraki Gulf and 2020 Bay of Plenty surveys were the 13th and 7th surveys in these series, resuming after gaps of 19 and 20 years, respectively. Estimates of YCS for pre-recruit snapper were produced with acceptable levels of variation. For the Hauraki Gulf, the 1+ and 2+ year classes observed in 2019 were both above average strength and likely represent reasonably strong year classes that will recruit to the Hauraki Gulf fishery over the next three to five years. In the Bay of Plenty, the 1+ year class observed in 2020 was well above average and the 2+ year-class was average. In the 2020 Bay of Plenty survey, the spatial distribution of pre-recruit snapper was constrained to the eastern Bay of Plenty, which was a more restricted distribution than in previous surveys. This may suggest that the value of the eastern Bay of Plenty to snapper recruitment has increased, or alternatively other areas have decreased in importance. The spatial distribution of snapper pre-recruits should be monitored in future surveys.

In the Hauraki Gulf, a strong snapper temperature-recruitment relationship was established (Francis et al. 1995). However, in 1999, the Hauraki Gulf survey estimate of 1+ snapper abundance was well below that predicted by this temperature-recruitment relationship (Morrison et al. 2001a). That 1999 year class did eventually turn out to be a very strong year class that dominated the Hauraki Gulf fishery for a number of years (Walsh et al. 2011). Relevant to the most recent Hauraki Gulf survey, the 2018 year class is again predicted by the temperature-recruitment relationship to be very strong. Although the Hauraki Gulf survey estimate of 1+ snapper abundance was above average, it is still well below that predicted by this temperature relationship. The strength of this 2018 year class will ultimately be verified when it recruits to the fishery in three to five years, but a second observation of this year class, as 2+ fish, will be made after the Hauraki Gulf trawl survey conducted in late 2020.

The recommencement of the northern trawl survey series also provides potential to monitor, with reasonable levels of variation, the relative abundance of snapper biomass overall (i.e., including recruited snapper) and associated species. In 2019 and 2020, snapper biomass increased relative to the previous survey for both the Hauraki Gulf (139%) and the Bay of Plenty (87%) surveys. Gurnard and John dory are also potentially well monitored by this survey series, whereas estimates with higher variance are obtained for leatherjacket and trevally. In the Hauraki Gulf, the biomass of these four species increased relative to the 2000 survey estimate (469% for gurnard, 24% for John dory, 179% for leatherjacket, and 316% for trevally). Conversely, in the Bay of Plenty the biomass of three of these species decreased relative to the 1999 survey estimate (decreases of 43% for gurnard and John dory, and 72% for trevally), whereas leatherjacket biomass was observed to increase by 79% over the same time period.

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7. TABLES AND FIGURES

Table 1: Stratum depth ranges, survey area, number of stations suggested by *allocate* as well as the number of phase one stations targeted (all were successfully completed), the number of phase two biomass stations successfully completed and station density. Non-trawlable area was excluded from survey strata so is not listed.

Hauraki Gulf

Stratum	Depth (m)	Area (km^2)	No. of stations suggested by *allocate*	No. of phase one stations targeted	No. of phase two stations	Station density (km^2 per station)
1149	10–25	64.1	3	3	0	21.4
1219	25–50	882.9	3	4	0	223.4
1268	25–45	310.2	3	4	1	64.6
1284	10–25	72.8	3	3	0	24.3
1386	10–25	67.4	3	3	0	22.5
1449	10–50	267.6	3	4	0	66.9
1887	10–25	268.5	3	4	1	53.7
2229	25–45	556.6	3	4	2	92.8
9292	10–25	66.2	3	3	0	22.1
COLV	15–75	843.7	3	3	0	281.2
LITB	45–75	1570.7	3	4	1	316.0
Total		5 003.7	33	39	5	108.1

Bay of Plenty

Stratum	Depth (m)	Area (km^2)	No. of stations suggested by *allocate*	No. of phase one stations targeted	No. of phase two stations	Station density (km^2 per station)
1096	10–25	296.2	3	3	3	49.4
2096	10–25	133.3	19	5	0	26.7
32NH	10–25	25.5	3	3	0	8.5
4085	25–50	482.7	14	7	6	37.1
5187	25–50	231.6	5	5	0	46.3
5287	25–50	393.3	6	6	0	65.5
6085	50–100	734.9	3	3	1	183.7
708N	50–100	834.5	11	6	0	139.1
708S	50–100	856.9	3	4	0	214.2
Total		3 988.8	67	42	10	85.6

Table 2: Gear parameters for valid biomass stations by depth range (*n*, number of stations; s.d., standard deviation).

Hauraki Gulf		*n*	Mean	s.d.	Range
All stations		44			
	Headline height (m)		5.5	0.50	4.4–6.6
	Doorspread (m)		72.6	6.90	50.7–85.3
	Distance (n. mile)		0.7	0.09	0.49–0.75
	Warp:depth ratio		13.0	15.22	3.8–100.0
0–25 m		20			
	Headline height (m)		5.6	0.53	5.0–6.6
	Doorspread (m)		67.8	6.53	50.7–77.0
	Distance (n. mile)		0.6	0.09	0.50–0.74
	Warp:depth ratio		21.6	19.47	10.0–100.0
25–50 m		17			
	Headline height (m)		5.5	0.39	4.8–6.4
	Doorspread (m)		75.2	3.03	69.5–79.8
	Distance (n. mile)		0.7	0.08	0.49–0.75
	Warp:depth ratio		6.5	1.48	4.3–9.5
50–75 m		7			
	Headline height (m)		5.1	0.49	4.4–5.9
	Doorspread (m)		79.8	4.99	69.2–85.3
	Distance (n. mile)		0.7	0.07	0.51–0.71
	Warp:depth ratio		4.2	0.55	3.8–5.3
Bay of Plenty					
All stations		52			
	Headline height (m)		5.1	0.23	4.5–5.5
	Doorspread (m)		76.7	4.62	66.0–85.8
	Distance (n. mile)		0.7	0.02	0.54–0.72
	Warp:depth ratio		6.4	2.87	2.8–15.4
0–25 m		14			
	Headline height (m)		5.2	0.18	4.9–5.5
	Doorspread (m)		72.2	3.41	66.0–76.8
	Distance (n. mile)		0.7	0.00	0.69–0.71
	Warp:depth ratio		10.4	2.30	7.7–15.4
25–50 m		24			
	Headline height (m)		5.0	0.20	4.7–5.4
	Doorspread (m)		76.8	2.29	70.8–80.1
	Distance (n. mile)		0.7	0.03	0.54–0.72
	Warp:depth ratio		5.5	0.89	4.3–7.7
50–75 m		11			
	Headline height (m)		5	0.25	4.5–5.3
	Doorspread (m)		82.2	2.91	76.6–85.8
	Distance (n. mile)		0.7	0.01	0.69–0.72
	Warp:depth ratio		4.1	0.41	3.6–4.9
75–100 m		3			
	Headline height (m)		5.2	0.26	5.0–5.5
	Doorspread (m)		76.6	7.59	67.8–81.1
	Distance (n. mile)		0.7	0.01	0.70–0.71
	Warp:depth ratio		3.1	0.28	2.8–3.3

Table 3: Mean catch rates (kg km^{-2}) by stratum for the most common QMS species in order of catch abundance for the 2019 Hauraki Gulf and 2020 Bay of Plenty surveys. Some species are included due to high historical abundance. Species codes are given in Appendix 5.

Hauraki Gulf

	Species code							
Stratum	SNA	JMN	JDO	LEA	GUR	TRE	SPO	ATT
1149	9 474	448	39	0	28	74	114	34
1219	2 799	551	23	56	13	44	4	0
1268	10 952	1 097	72	5	42	15	16	0
1284	11 109	344	19	0	98	16	56	10
1386	17 171	313	130	4	23	13	12	14
1449	1 119	0	16	190	32	9	0	0
1887	11 973	2 348	13	0	60	4	18	9
2229	8 988	344	76	5	27	46	6	0
9292	12 064	957	32	2	17	33	0	5
COLV	747	23	24	73	24	0	0	0
LITB	1 420	206	39	109	42	16	0	0

Bay of Plenty

	Species code										
Stratum	SNA	JMN	GUR	LEA	TRE	ATT	JDO	SPO	FRO	KIN	NMP
1096	2 514	130	61	0	127	18	7	8	0	14	0
2096	1 566	2	3	23	115	5	13	42	0	0	0
32NH	1 011	0	29	120	73	0	6	0	0	0	0
4085	1 717	357	48	1	16	182	5	44	0	4	4
5187	881	4	77	20	9	5	6	10	0	0	0
5287	148	0	16	64	14	0	8	0	0	0	0
6085	493	0	72	10	4	0	28	6	0	0	1
708N	308	0	27	22	0	0	34	0	14	0	0
708S	157	1	46	100	0	0	29	0	8	0	0

Table 4: Relative biomass estimates (t) and CVs by trip for each of the Hauraki Gulf and Bay of Plenty surveys for QMS species. Species codes are given in Appendix 5.

	KAH8421		KAH8517		KAH8613		KAH8716		KAH8810		KAH8917		KAH9016		KAH9212	
Species code	Biomass	CV	Biomass	CV	Biomass	CV	Biomass	CV	Biomass	CV	Biomass	CV	Biomass	CV	Biomass	CV
ATT	0.1	100.0	9.0	56.5	119.8	92.8	5.4	50.2	25.1	91.5	10.2	78.9	2.9	40.9	2.4	64.5
BAR	16.1	100.0	0.0	0.0	0.0	0.0	0.9	100.0	12.1	49.5	95.9	69.5	32.9	100.0	225.1	48.2
EMA	0.0	0.0	0.1	100.0	3.7	85.1	122.7	99.7	8.0	76.2	6.8	34.5	0.4	33.5	2.5	37.5
GUR	379.1	13.1	21.0	59.3	212.6	23.7	1 494.4	23.8	580.7	17.2	100.4	30.4	86.2	22.8	285.5	9.6
JDO	125.5	24.6	137.5	14.8	159.0	19.1	177.9	27.5	243.1	24.0	199.6	22.8	176.8	14.8	181.6	34.3
JMA	69.8	54.4	0.0	0.0	224.0	47.1	0.0	0.0	0.0	0.0	40.4	62.3	0.0	0.0	0.0	0.0
JMD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
JMM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
JMN	63.8	44.0	314.1	58.4	1 168.9	69.6	1 020.9	34.7	1 128.0	30.6	1 145.8	32.8	970.3	23.1	660.0	27.5
LEA	485.4	64.9	162.3	58.7	317.6	28.6	322.0	51.5	145.5	33.0	296.1	27.5	245.7	27.5	141.7	40.0
NMP	6.2	100.0	0.0	0.0	5.7	100.0	0.0	0.0	29.0	96.6	0.0	0.0	31.0	95.6	33.3	91.5
PAR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	50.8	0.0	0.0	2.4	45.7	1.6	61.3
PIL	0.0	0.0	0.0	0.0	0.4	100.0	0.0	0.0	5.0	64.9	0.0	100.0	0.6	98.9	22.7	89.8
RSK	24.3	82.0	0.0	0.0	14.6	80.7	0.0	0.0	175.5	43.1	0.0	0.0	0.0	0.0	0.0	0.0
SCH	0.0	0.0	0.3	100.0	0.0	0.0	10.3	100.0	12.3	64.4	0.4	100.0	0.0	0.0	2.5	90.7
SFL	12.7	73.5	0.5	100.0	2.3	58.2	8.9	95.2	49.8	26.2	7.1	38.8	1.3	68.7	75.0	29.7
SNA	4 061.5	26.2	2 182.5	23.4	2 538.8	30.9	7 181.0	22.7	3 352.8	17.1	8 064.9	20.0	9 379.6	22.9	2 639.6	14.9
SPO	29.3	43.7	12.3	69.9	61.9	43.6	82.8	50.3	98.5	25.2	59.4	64.5	72.6	71.3	40.7	23.2
SPZ	0.0	0.0	0.0	0.0	13.5	58.4	1.0	88.8	34.4	34.0	13.2	35.9	2.3	59.5	38.7	31.0
SSK	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TRE	25.3	96.1	139.8	66.2	18.1	42.6	29.3	48.9	10.8	56.3	128.6	74.1	38.3	44.6	5.4	68.9
YBF	0.0	0.0	0.3	100.0	1.6	55.0	1.3	75.0	13.2	36.7	2.3	44.5	0.7	57.4	18.5	26.8
YEM	0.0	0.0	0.0	0.0	19.7	99.3	0.0	0.0	8.3	92.7	1.1	36.0	3.5	47.7	8.3	81.7

Table 4— Hauraki Gulf continued.

Hauraki Gulf

	KAH9311		KAH9411		KAH9720		KAH0012		KAH1907	
Species code	Biomass	CV	Biomass	CV	Biomass	CV	Biomass	CV	Biomass	CV
ATT	15.0	61.2	28.7	91.3	1.3	71.6	4.4	57.4	6.9	27.9
BAR	22.7	37.3	68.6	38.5	122.1	40.0	157.8	68.3	0.9	70.7
EMA	181.4	47.8	2.6	41.7	6.4	40.1	3.9	66.1	2.3	64.6
GUR	149.1	22.7	189.7	19.3	213.0	15.1	28.4	47.3	161.7	28.3
JDO	325.2	26.0	255.3	12.7	329.7	18.5	151.4	20.8	188.3	14.7
JMA	0.0	0.0	28.7	100.0	0.0	0.0	0.0	0.0	0.0	0.0
JMD	0.0	0.0	2 379.9	63.9	30.0	67.5	6.2	100.0	0.0	0.0
JMM	0.0	0.0	0.0	0.0	0.0	0.0	1.0	100.0	0.0	0.0
JMN	1 954.4	15.9	1 705.4	20.9	797.6	19.5	736.1	18.3	2 130.6	29.1
LEA	492.2	22.0	232.3	15.5	483.8	26.4	120.9	42.3	337.5	30.0
NMP	25.9	68.1	103.6	96.5	49.4	48.9	778.0	100.0	11.9	41.6
PAR	3.3	41.8	3.5	55.9	1.0	82.3	0.9	100.0	0.2	100.0
PIL	6.0	71.5	152.7	99.3	15.9	98.5	3.8	51.0	0.8	68.2
RSK	29.1	36.5	0.3	100.0	0.0	0.0	0.0	0.0	27.2	61.7
SCH	6.1	77.0	2.4	69.7	1.3	100.0	0.4	100.0	39.9	67.6
SFL	84.2	25.9	193.2	20.7	5.7	57.6	0.0	0.0	0.6	40.8
SNA	6 933.1	15.7	3 755.7	12.2	7 165.8	25.1	8 629.8	29.1	20 617.7	13.6
SPO	28.3	41.6	3s3.7	44.6	29.2	27.8	3.2	55.9	28.9	24.8
SPZ	12.4	26.1	17.2	22.9	33.7	47.8	1.2	73.1	2.6	64.3
SSK	0.0	0.0	242.2	28.5	164.6	45.9	0.0	0.0	0.0	0.0
TRE	14.3	67.1	10.0	75.4	5.2	67.1	25.7	50.9	107.1	34.7
YBF	3.8	50.4	20.9	48.7	0.0	0.0	0.1	100.0	0.0	0.0
YEM	0.3	91.5	6.8	98.6	2.6	100.0	0.1	100.0	0.0	0.0

Table 4— Bay of Plenty (continued on next page).

Species	KAH8303		KAH8506		KAH9004		KAH9202		KAH9601		KAH9902		KAH2001	
code	Biomass	CV	Biomass	CV	Biomass	CV	Biomass	CV	Biomass	CV	Biomass	CV	Biomass	CV
ATT	18.6	40.5	86.3	37.7	61.4	53.6	39.1	50.5	9.8	40.9	46.5	24.7	94.8	88.1
BCO	3.7	79.6	0.0	0.0	1.3	96.4	1.5	74.4	0.4	94.9	0.0	0.0	0.0	0.0
BRI	3.1	55.0	0.0	0.0	0.3	61.8	0.4	61.9	0.0	0.0	0.0	0.0	0.0	0.0
FRO	6.3	71.0	0.0	0.0	24.4	47.5	7.5	56.7	127.1	81.1	73.3	36.2	18.6	55.7
GSH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GUR	382.2	21.1	33.7	14.5	398.9	11.8	261.9	9.4	273.9	12.6	318.7	14.1	181.3	14.6
HOK	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
JDO	107.6	23.0	89.2	14.8	133.0	16.9	214.8	12.6	188.3	43.1	146.5	15.1	84.2	23.3
JMA	101.1	75.7	50.5	42.7	50.8	61.3	92.5	26.1	3.3	96.1	0.0	0.0	0.0	0.0
JMD	8.9	90.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.1	32.1	2.6	28.4
JMM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
JMN	478.8	38.4	250.1	90.9	19.2	60.8	0.0	0.0	394.0	43.2	238.0	39.9	214.4	47.5
KIN	12.2	37.3	39.2	65.2	21.4	55.1	49.7	36.6	13.7	38.5	19.4	57.5	6.0	71.9
LDO	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LEA	79.7	27.4	46.7	34.3	147.7	16.8	253.1	18.8	118.5	22.4	83.1	22.7	148.7	55.7
LIN	1.3	58.5	0.0	0.0	0.0	0.0	0.0	0.0	4.2	100.0	0.0	0.0	0.0	0.0
LSO	7.9	42.9	0.0	0.0	1.1	31.8	0.1	84.9	1.2	53.7	3.1	23.8	1.6	48.4
NMP	6.1	45.7	3.0	55.2	13.2	65.6	92.8	31.4	16.1	86.2	9.4	65.2	2.7	54.2
RBT	0.0	0.0	0.0	0.0	0.0	0.0	0.2	100.0	0.2	100.0	0.0	0.0	0.0	0.0
RCO	2.9	61.2	0.0	0.0	0.6	71.4	0.0	0.0	5.1	100.0	16.5	66.7	0.0	0.0
RSK	41.8	37.7	0.0	0.0	0.0	0.0	0.0	0.0	46.2	47.9	41.0	32.7	8.5	74.8
SCH	0.0	0.0	0.0	0.0	13.8	75.1	0.8	69.5	0.0	100.0	0.0	0.0	0.0	0.0
SFL	6.2	33.5	0.0	0.0	20.1	53.4	2.5	32.8	8.0	26.8	6.5	65.1	0.3	100.0
SKI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	100.0
SNA	145.6	24.0	641.4	15.2	1 548.1	14.6	1 123.1	9.0	979.3	14.2	1 511.6	17.2	2 823.9	8.9
SPE	0.6	83.3	0.0	0.0	0.2	100.0	1.5	58.3	2.8	83.0	3.4	67.9	0.0	0.0
SPO	2.3	100.0	5.1	67.6	19.5	39.3	11.1	39.9	2.9	71.2	26.4	85.3	35.9	24.9
SPZ	6.0	46.0	0.1	100.0	8.3	19.3	6.6	28.3	8.3	20.3	1.0	57.9	2.9	62.2
SQU	23.8	53.0	0.0	0.0	0.4	72.0	4.8	53.4	2.9	37.2	1.0	52.6	1.7	100.0
SSK	0.0	0.0	0.0	0.0	74.8	47.7	0.0	0.0	0.0	0.0	10.7	84.2	0.0	0.0
STA	1.2	100.0	0.0	0.0	0.8	73.6	5.6	38.8	0.0	0.0	0.0	0.0	0.0	0.0
TRE	6.0	50.6	104.9	18.5	84.9	28.5	65.3	35.4	37.4	27.3	266.5	26.4	73.5	18.2
WAR	8.2	90.8	0.0	0.0	0.0	0.0	7.4	81.5	0.2	79.6	0.0	0.0	0.1	100.0

Table 5: Estimates of recruited biomass (fish length ≥ recruited length) for the most common QMS species (in alphabetical order by species code) for the 2019 Hauraki Gulf and 2020 Bay of Plenty surveys. Species codes are given in Appendix 5. The recruited biomass of kingfish in the Bay of Plenty is 0 because no kingfish greater than the recruited length were caught on the 2020 Bay of Plenty survey.

Hauraki Gulf

Species code	Recruited length (cm)	Biomass (t)	CV %	% of overall biomass ≥ recruited length
ATT	40	0.9	74.7	13.0
GUR	30	119.7	34.4	74.0
JDO	25	187.4	14.8	99.5
JMN	25	292.3	28.1	13.7
LEA	19	336.9	30.0	99.8
SNA	25	15 558.6	15.0	75.5
SPO	90	1.1	100.0	3.8
TRE	25	106.1	35.0	99.1

Bay of Plenty

Species code	Recruited length (cm)	Biomass (t)	CV %	% of overall biomass ≥ recruited length
ATT	40	86	92.1	90.7
FRO	90	18.6	55.7	100.0
GUR	30	130.2	14.5	71.8
JDO	25	80.9	24.1	96.1
JMN	25	0.8	57.2	0.4
KIN	90	0.0	0.0	0.0
LEA	19	145.9	55.0	98.1
NMP	25	2.7	54.2	100.0
SNA	25	2 601.7	9.3	92.1
SPO	90	16.6	35.4	46.2
TRE	25	69.5	17.2	94.6

Table 6: Estimated biomass (t) and CV (%) by stratum for the most common QMS species in order of catch abundance for both the 2019 Hauraki Gulf and 2020 Bay of Plenty surveys. Species codes are given in Appendix 5.

Hauraki Gulf

										Species code
Stratum	SNA all	SNA pre–recruit	SNA recruit	JMN	LEA	JDO	GUR	TRE	SPO	ATT
1149	608 (40)	131 (19)	477 (47)	29 (61)	0 (100)	3 (100)	2 (59)	5 (34)	7 (64)	2 (57)
1219	2 471 (35)	780 (28)	1 691 (45)	487 (100)	50 (36)	20 (38)	11 (44)	39 (60)	4 (100)	0 (0)
1268	3 397 (23)	819 (19)	2 578 (25)	340 (34)	2 (100)	22 (28)	13 (21)	5 (70)	5 (49)	0 (100)
1284	808 (25)	226 (5)	582 (33)	25 (38)	0 (0)	1 (95)	7 (23)	1 (100)	4 (43)	1 (63)
1386	1 157 (46)	85 (32)	1 072 (47)	21 (48)	0 (100)	9 (57)	2 (46)	1 (38)	1 (50)	1 (100)
1449	300 (64)	10 (58)	290 (64)	0 (0)	51 (34)	4 (36)	9 (7)	2 (100)	0 (0)	0 (0)
1887	3 215 (39)	973 (34)	2 241 (44)	630 (23)	0 (0)	4 (62)	16 (43)	1 (100)	5 (32)	3 (37)
2229	5 003 (29)	985 (14)	4 018 (35)	191 (45)	3 (60)	42 (19)	15 (28)	25 (47)	3 (64)	0 (0)
9292	799 (24)	201 (16)	598 (37)	63 (60)	0 (100)	2 (53)	1 (34)	2 (78)	0 (0)	0 (100)
COLV	630 (80)	161 (52)	469 (91)	19 (100)	62 (43)	20 (31)	21 (37)	0 (0)	0 (0)	0 (0)
LITB	2 230 (67)	687 (73)	1 543 (64)	324 (100)	171 (55)	62 (37)	65 (67)	26	0 (0)	0 (0)
Total	20 618 (14)	5 059 (13)	15 559 (15)	2 131 (29)	338 (30)	188 (15)	162 (28)	107	29 (25)	7 (28)

Bay of Plenty

													Species code
Stratum	SNA	SNA pre–recruit	SNA recruit	JMN	GUR	LEA	ATT	JDO	TRE	SPO	FRO	KIN	NMP
1096	745 (17)	46 (36)	698 (20)	39 (96)	18 (32)	0 (0)	5 (38)	2 (100)	38 (30)	2 (68)	0 (0)	4	0 (0)
2096	209 (27)	1 (55)	207 (27)	0 (32)	0 (64)	3 (47)	1 (63)	2 (64)	15 (33)	6 (63)	0 (0)	0 (0)	0 (0)
32NH	26 (41)	0 (0)	26 (41)	0 (0)	1 (34)	3 (54)	0 (0)	0 (100)	2 (22)	0 (0)	0 (0)	0 (0)	0 (0)
4085	829 (17)	92 (22)	737 (18)	173 (55)	23 (15)	1 (56)	88 (95)	3 (37)	8 (31)	21 (30)	0 (0)	2 (53)	2 (63)
5187	204 (49)	15 (60)	189 (49)	1 (72)	18 (64)	5 (41)	1 (100)	2 (100)	2 (61)	2 (100)	0 (0)	0 (0)	0 (0)
5287	58 (23)	1 (67)	58 (23)	0 (45)	6 (42)	25 (28)	0 (0)	3 (41)	6 (50)	0 (0)	0 (0)	0 (0)	0 (0)
6085	362 (17)	27 (41)	335 (16)	0 (100)	53 (36)	8 (31)	0 (0)	20 (45)	3 (100)	5 (100)	0 (0)	0 (0)	1
708N	257 (40)	35 (82)	222 (37)	0 (45)	23 (22)	18 (51)	0 (0)	28 (36)	0 (100)	0 (0)	12 (67)	0 (0)	0 (0)
708S	135 (21)	5 (96)	130 (19)	1 (76)	39 (30)	86 (96)	0 (0)	25 (56)	0 (0)	0 (0)	7 (100)	0 (0)	0 (0)
Total	2 824 (9)	222 (19)	2 602 (9)	214 (48)	181 (15)	149 (56)	95 (88)	84 (23)	74 (18)	36 (25)	19 (56)	6 (72)	3 (54)

Table 7: Number of biological and length frequency records. Measurement methods; 1, fork length (FL); 2, total length; 5, pelvic length. †, biological data includes one or more of the following: fish length, fish weight, gonad/maturity stage, otoliths. Species codes are given in Appendix 5. (Continued on next page)

Hauraki Gulf

		Length frequency data		Biological data (†)		
Species	Measurement method	No. of samples	No. of fish	No. of samples	No. of fish	No. of otoliths
ATT	1	13	81			
BAR	1	2	19	1	2	
BOA	1	1	5			
BRA	5	1	1			
EGR	5	6	11			
EMA	1	4	15			
ERA	5	1	1			
GUR	1	43	514	43	458	
JDO	2	35	138	35	138	
JMN	1	33	3 138	17	377	
KIN	1	1	1			
LEA	2	22	531	1	4	
LSO	2	1	1			
NMP	1	3	3	3	3	
PAR	1	1	1	1	1	
PIL	1	1	1			
POR	1	1	1			
RMU	1	1	1			
RSK	5	2	3			
SCH	2	4	5			
SFL	2	6	6			
SNA	1	44	7 105	44	974	967
SPO	2	17	56			
SPZ	2	2	2			
THR	2	1	1			
TRE	1	21	176	18	126	
Total		267	11 817	163	2 083	967

Bay of Plenty

		Length frequency data		Biological data (†)		
Species	Measurement method	No. of samples	No. of fish	No. of samples	No. of fish	No. of otoliths
ATT	1	13	111	8	43	
BAR	1	3	3			
BOA	1	4	8	1	3	
BRA	5	1	1			
EGR	5	11	19			
EMA	1	3	32			
ERA	5	1	1			
FRO	1	3	8			
GUR	1	46	743	46	533	
HHS	2	2	10			
JDO	2	28	92	28	92	
JMD	1	8	62			
JMN	1	31	1 096			
KIN	1	4	6			
LEA	2	32	478	3	63	
LFB	2	1	5			
LSO	2	4	4			
NMP	1	4	6	4	6	
PIL	1	1	3			
POR	1	1	8	1	8	
RSK	5	2	2			
SFL	2	1	2			
SKI	1	1	1			
SNA	1	52	4 918	52	1 073	1 040
SPO	2	19	30			
SPZ	2	3	6			
THR	2	1	2			
TRE	1	31	214	30	183	
TUR	2	1	1			
WAR	1	1	1			
WRA	5	1	1			
Total		314	7 874	173	2 004	1 040

Table 8: Number of individual fish at each reproductive stage for fish staged on the 2019 Hauraki Gulf and 2020 Bay of Plenty surveys (small fish of undetermined sex were not included). Gonad stages are defined in Appendix 1. (Continued on next page)

Hauraki Gulf

	Male gonad stages							Female gonad stages							
Length (cm)	1	2	3	4	5	6	7	1	2	3	4	5	6	7	Total
Gurnard															
11–20	1							1							2
21–30	19	19	19	2				11	14	77	28	1	5	1	196
31–40		7	5	1		1		3	4	94	38	6	13	5	177
41–50										5	4			1	10
Total	20	26	24	3	0	1	0	15	18	176	70	7	18	7	385
John dory															
11–20	6							5							11
21–30	4	4	2					3	1						14
31–40		2	15	6			1			13	1			1	39
41–50			1						2	60	1		2		66
51–60										7					7
Total	10	6	18	6	0	0	1	8	3	80	2	0	2	1	137
Tarakihi															
31–40			1						1						2
41–50									1						1
Total	0	0	1	0	0	0	0	0	1	0	0	0	0	0	2
Snapper															
11–20	20	4	2					37	3	1					67
21–30	8	28	175	36	18			20	34	116	88	5			528
31–40			56	35	26				2	44	33	7	2		205
41–50			9	6	11					1	8				35
51–60				3	3						1				7
61–70					1										1
71–80															0
81–90													1		1
Total	28	32	242	80	59	0	0	57	39	162	130	12	3	0	844
Trevally															
11–20	2							2							4
21–30	1	2	7	3	1				8	2					24
31–40			8	11	17				8	29	2	2		1	78
41–50					1						1				2
51–60										1					1
Total	3	2	15	14	19	0	0	2	16	32	3	2	0	1	109

Bay of Plenty

	Male gonad stages							Female gonad stages							
Length (cm)	1	2	3	4	5	6	7	1	2	3	4	5	6	7	Total
Kahawai															
21–30	5							2							7
31–40		4		1	3				2	1					11
41–50			1	2	7					7					17
51–60					3				1	2		1			7
Total	5	4	1	3	13	0	0	2	3	10	0	1	0	0	42
Gurnard															
11–20	3	6						2	1						12
21–30	6	107	7		1	7			36	60	1	2	24	16	267
31–40	1	21	3				3		13	129	10		23	12	215
41–50		2							2	17	3		1		25
Total	10	136	10	0	1	7	3	2	52	206	14	2	48	28	519
John dory															
21–30	1	19							19						39
31–40		20	3						1	3	2				29
41–50		1								9	9	1			20
Total	1	40	3	0	0	0	0	0	20	12	11	1	0	0	88
Tarakihi															
31–40		2							2	2					6
Total	0	2	0	0	0	0	0	0	2	2	0	0	0	0	6
Snapper															
11–20	17	1						41							59
21–30	19	105	31	1	3		1	8	122	58	2				350
31–40		101	34	9	13		7		150	57	5	2		7	385
41–50		22	2	2	2		2		23	7	2			3	65
51–60			3						6	3	3				15
Total	36	229	70	12	18	0	10	49	301	125	12	2	0	10	874
Trevally															
11–20		2						1							3
21–30	3	9		1	6			5	7	3					34
31–40		1	3	6	31				3	35	1	1			81
41–50			1	3	4				1	30					39
Total	3	12	4	10	41	0	0	6	11	68	1	1	0	0	157

Table 9: Estimated number and CV (%) of 1+ and 2+ snapper for the Hauraki Gulf and Bay of Plenty survey series. Numbers estimated for historic surveys recalculated using stratification for the 2019 Hauraki Gulf and 2020 Bay of Plenty surveys and either a combination of scaled length frequency distributions and age length keys of those historic surveys, or by conducting modal analysis of just the 1+ cohort where age data were either not available or were unreliable (indicated by an *). NA = not available.

Hauraki Gulf

Trip code	No. 1+ SNA	CV (%)	No. 2+ SNA	CV (%)
KAH8421	1 054 113	34.2	1 370 590	18.0
KAH8517	3 855 761*	16.9	NA	NA
KAH8613	2 762 671	36.8	2 615 497	12.2
KAH8716	4 616 758*	34.1	NA	NA
KAH8810	1 558 161	15.8	2 184 319	14.4
KAH8917	3 833 550	25.5	1 389 625	18.1
KAH9016	10 796 258	23.3	6 378 088	12.6
KAH9212	3 485 413	16.9	1 910 154	9.7
KAH9311	1 311 907	33.8	5 570 629	11.9
KAH9411	1 207 875	18.4	1 310 497	11.9
KAH9720	5 847 745	17.6	5 430 086	8.3
KAH0012	4 165 564	24.5	3 737 526	22.1
KAH1907	5 364 830	20.0	7 317 134	11.0

Bay of Plenty

Trip code	No. 1+ SNA	CV (%)	No. 2+ SNA	CV (%)
KAH8303	236 364*	48.4	NA	NA
KAH8506	17 899*	44.9	NA	NA
KAH9004	290 062	23.3	691 514	19.8
KAH9202	293 933	23.7	297 856	15.2
KAH9601	337 502	24.3	418 609	19.5
KAH9902	43 662*	51.2	NA	NA
KAH2001	926 167	27.4	452 979	23.3

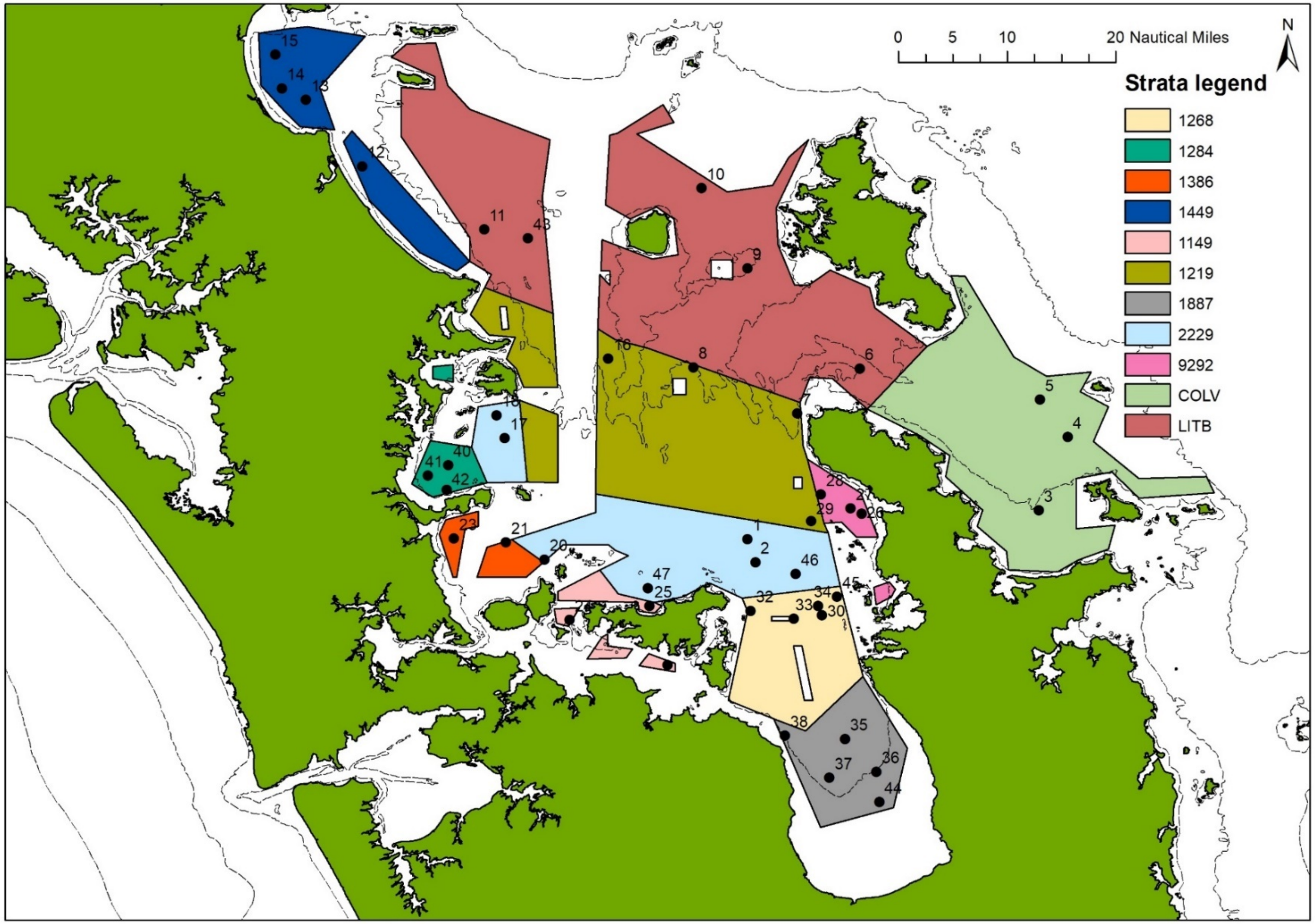


Figure 1: Survey area showing stratum boundaries and names (legend) for the Hauraki Gulf (a) and Bay of Plenty (b) surveys, with valid station positions (filled circles) and station numbers. Dashed lines represent the 10, 50, and 100 m depth contours. White areas were not within the survey areas (they were either outside the survey area or excluded due to foul ground). (Continued on next page)

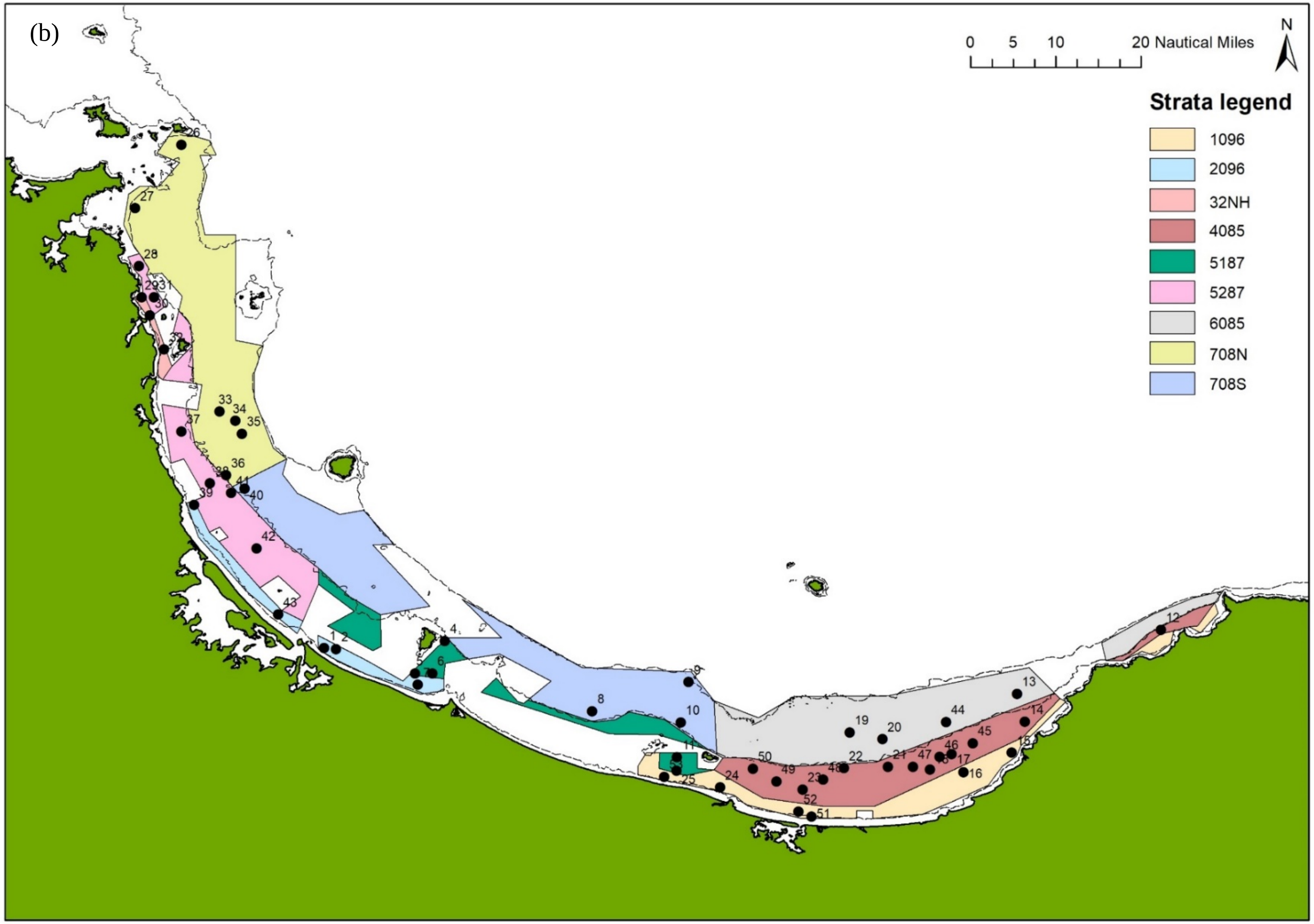
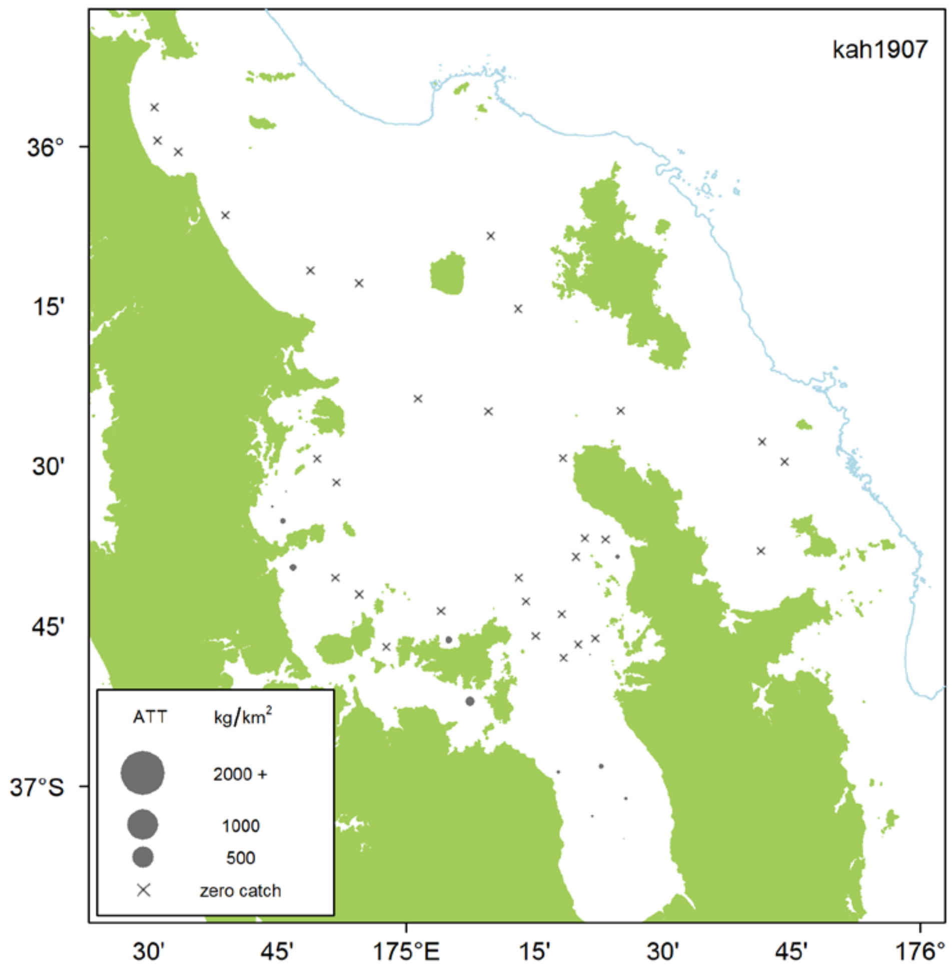
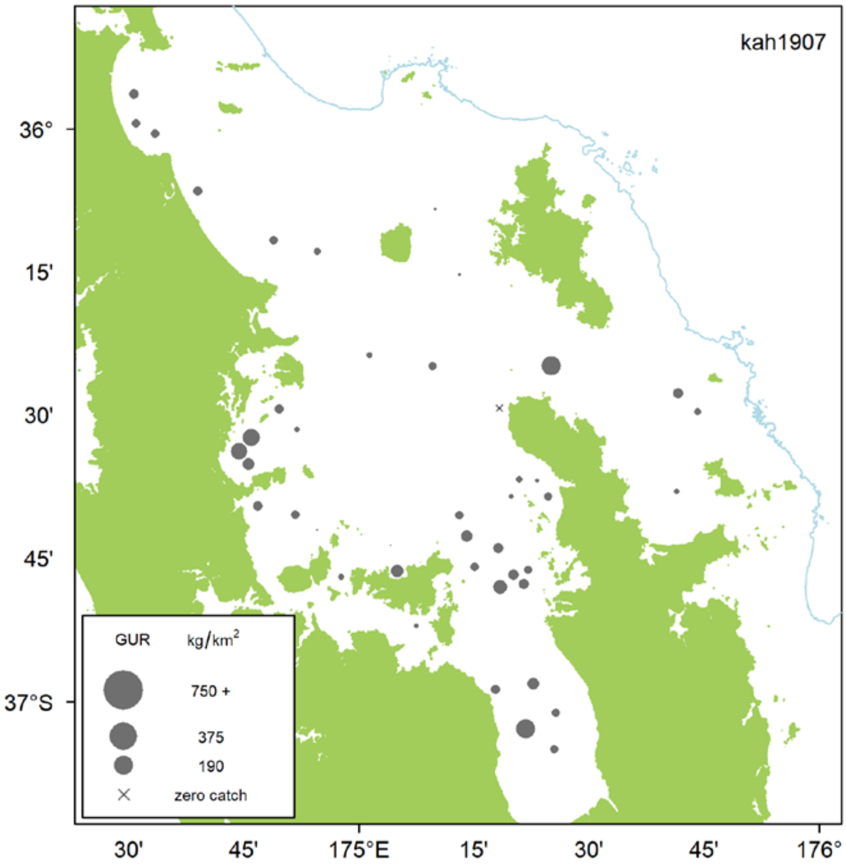


Figure 1: continued.

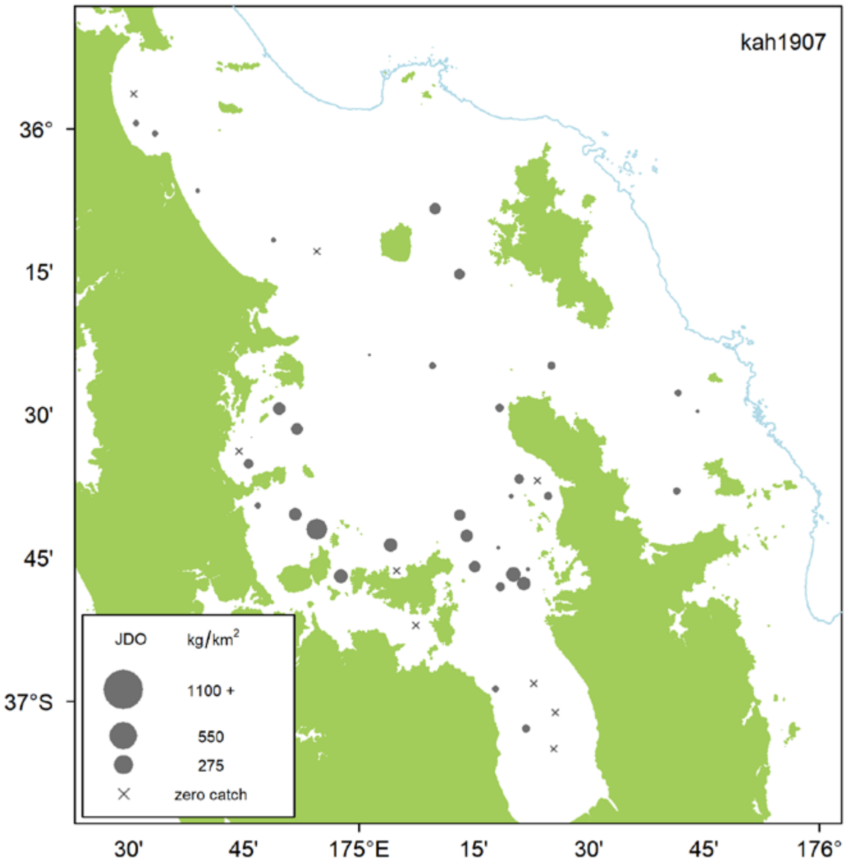


a: Kahawai (ATT), Hauraki Gulf.

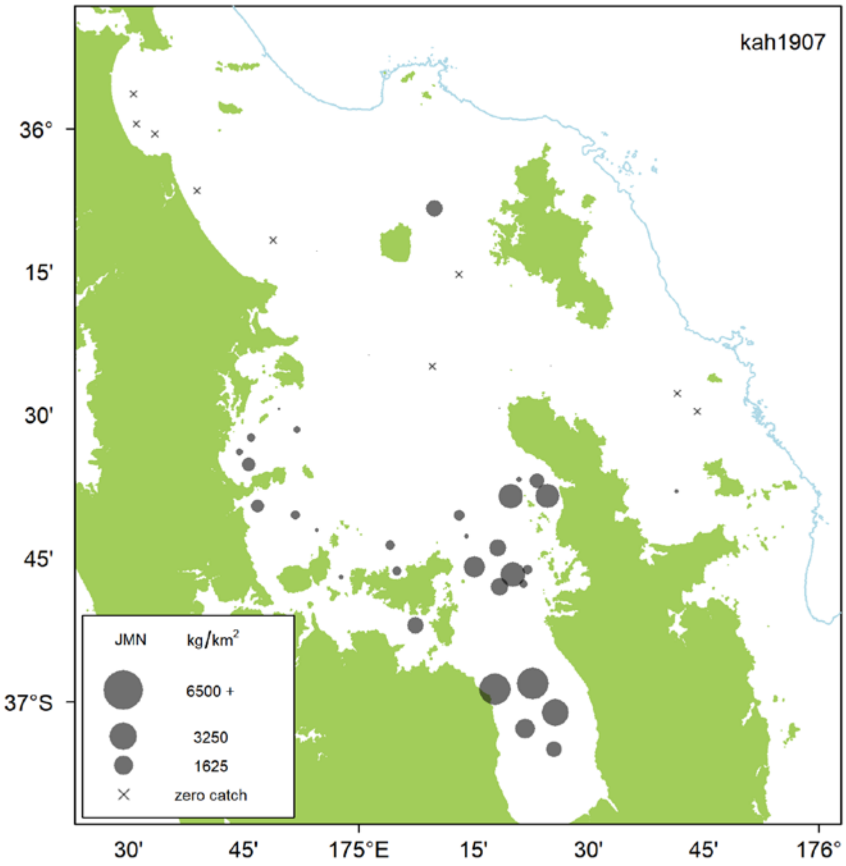
Figure 2: The spatial distribution of catch (kg km^{-2}) for the most common QMS species (in alphabetical order by species code) from the 2019 Hauraki Gulf and 2020 Bay of Plenty surveys. Some species are included due to high historical abundance. N.B. Catch rate scale varies between species. For consistency within a species, however, catch rates are scaled to the largest catch in the full historic time series (see Figure 3) for that species in either the Hauraki Gulf or Bay of Plenty surveys.



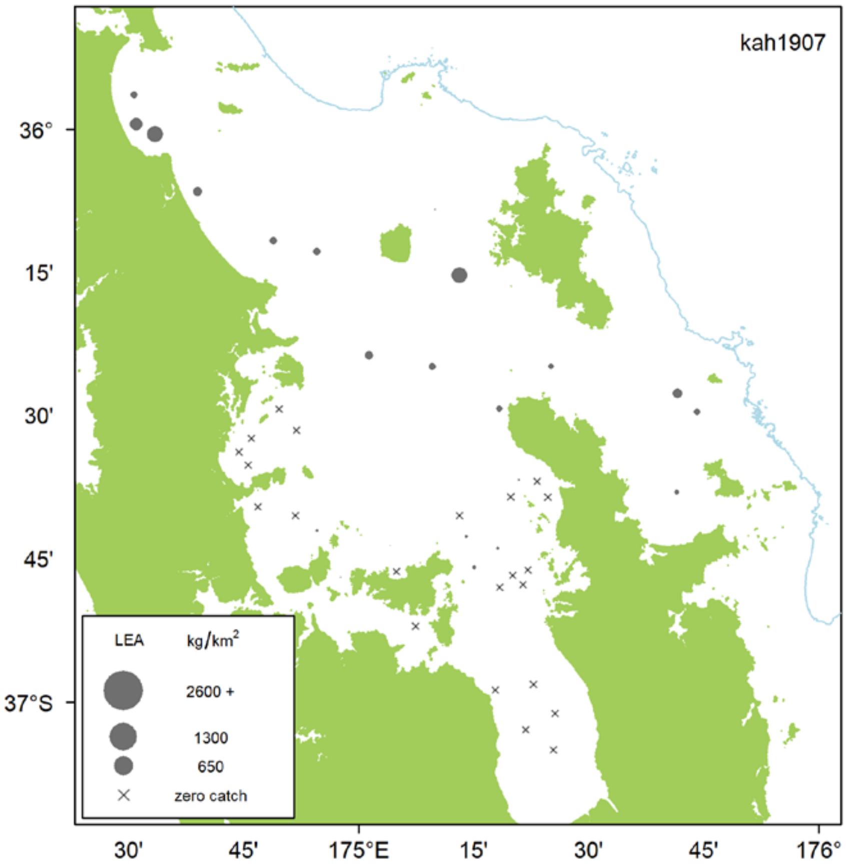
b: Gurnard (GUR), Hauraki Gulf.



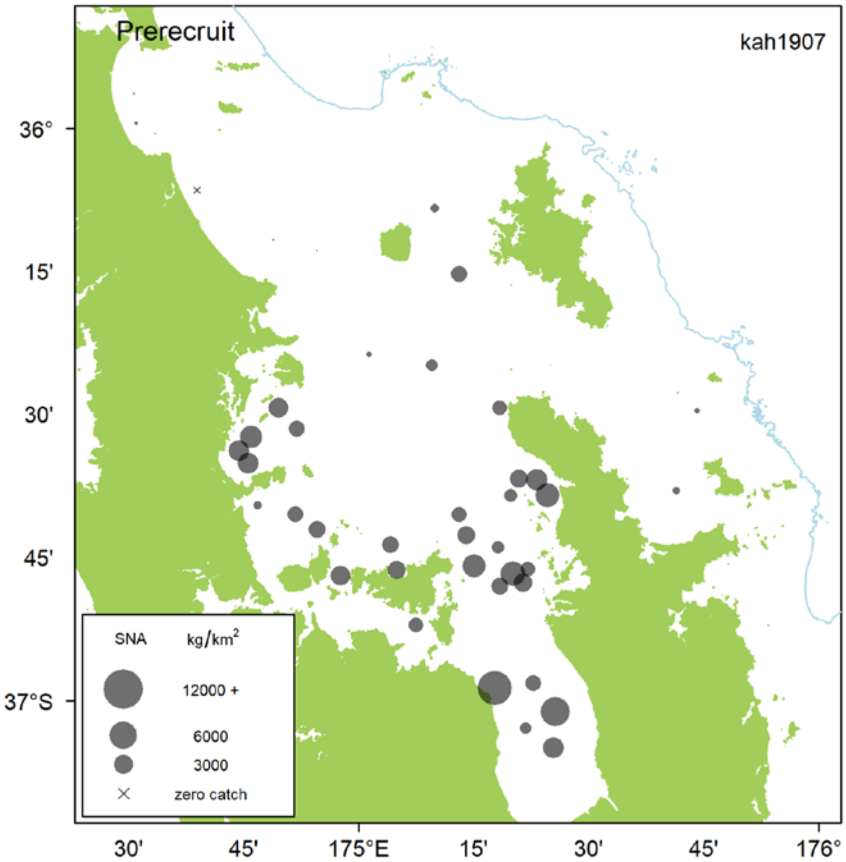
c: John dory (JDO), Hauraki Gulf.



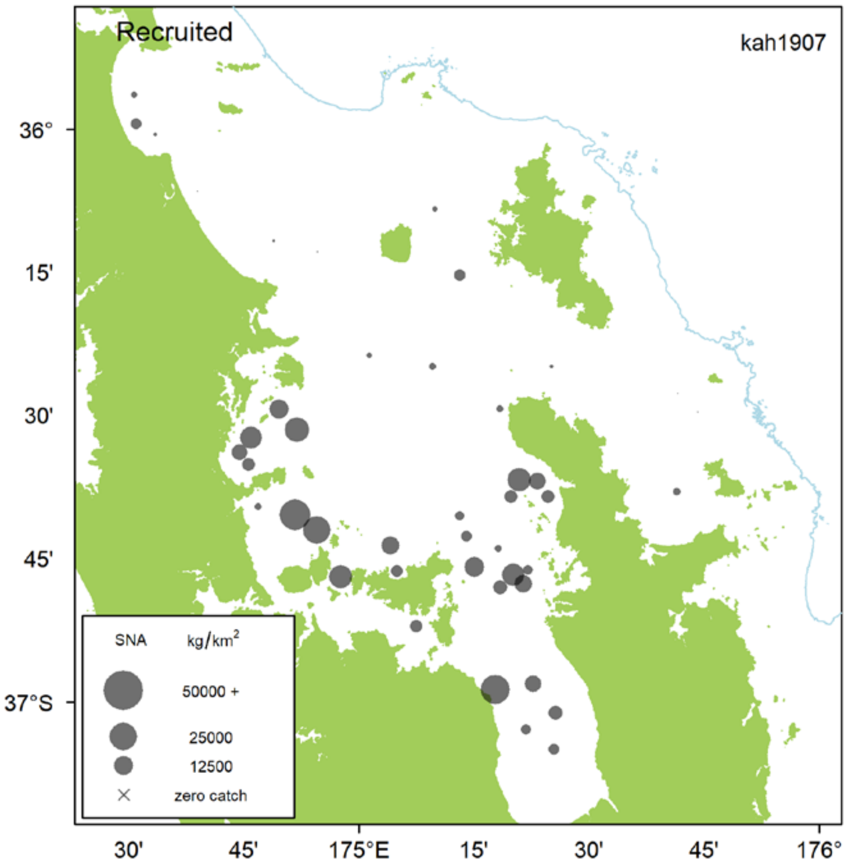
d: Yellowtail jack mackerel (JMN), Hauraki Gulf.



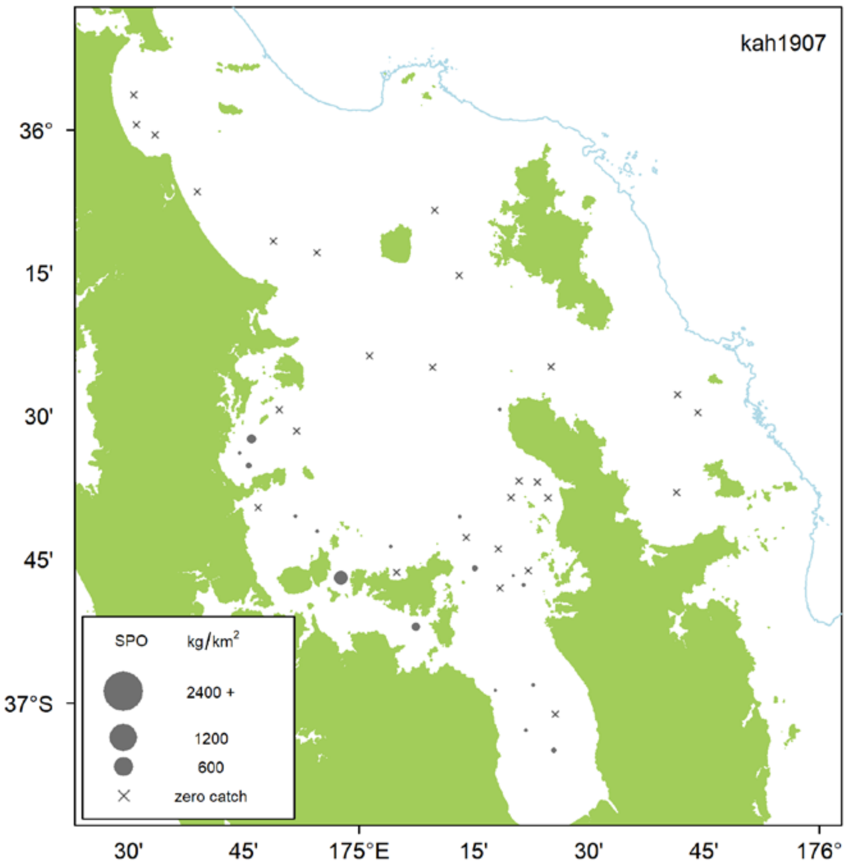
e: Leatherjacket (LEA), Hauraki Gulf.



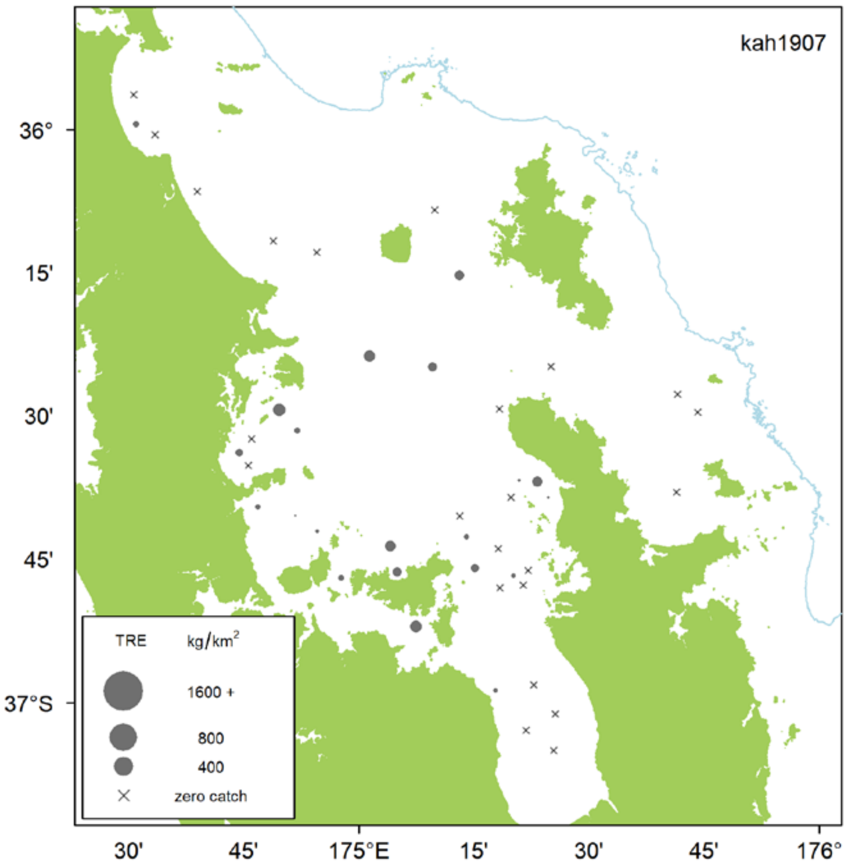
f: Pre–recruit snapper (SNA; <25 cm FL), Hauraki Gulf.



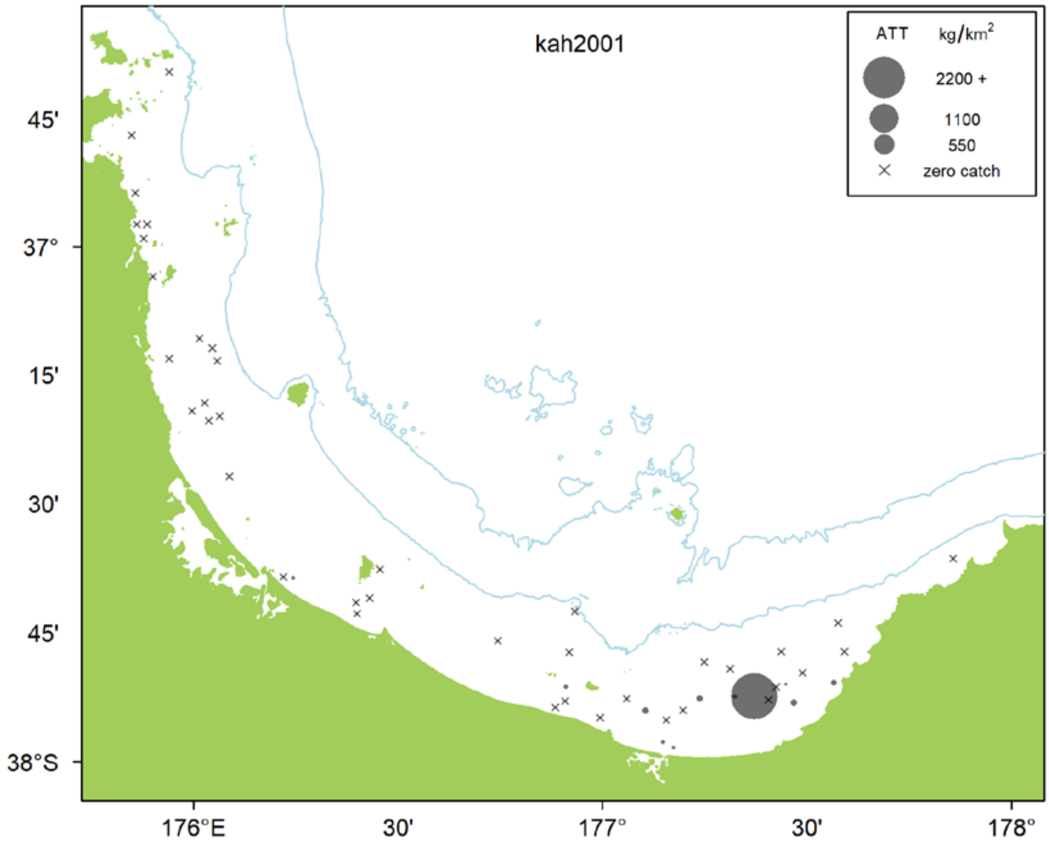
g: Recruited snapper (SNA; 25 cm and larger), Hauraki Gulf.



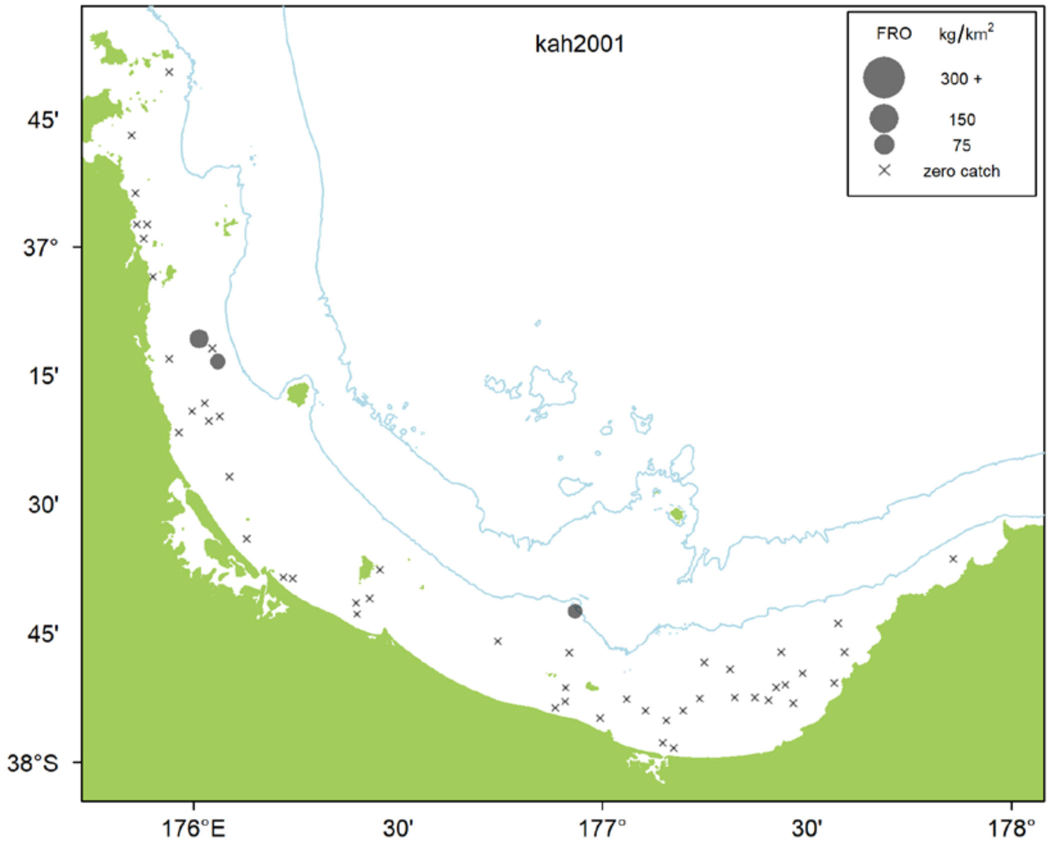
h: Rig (SPO), Hauraki Gulf.



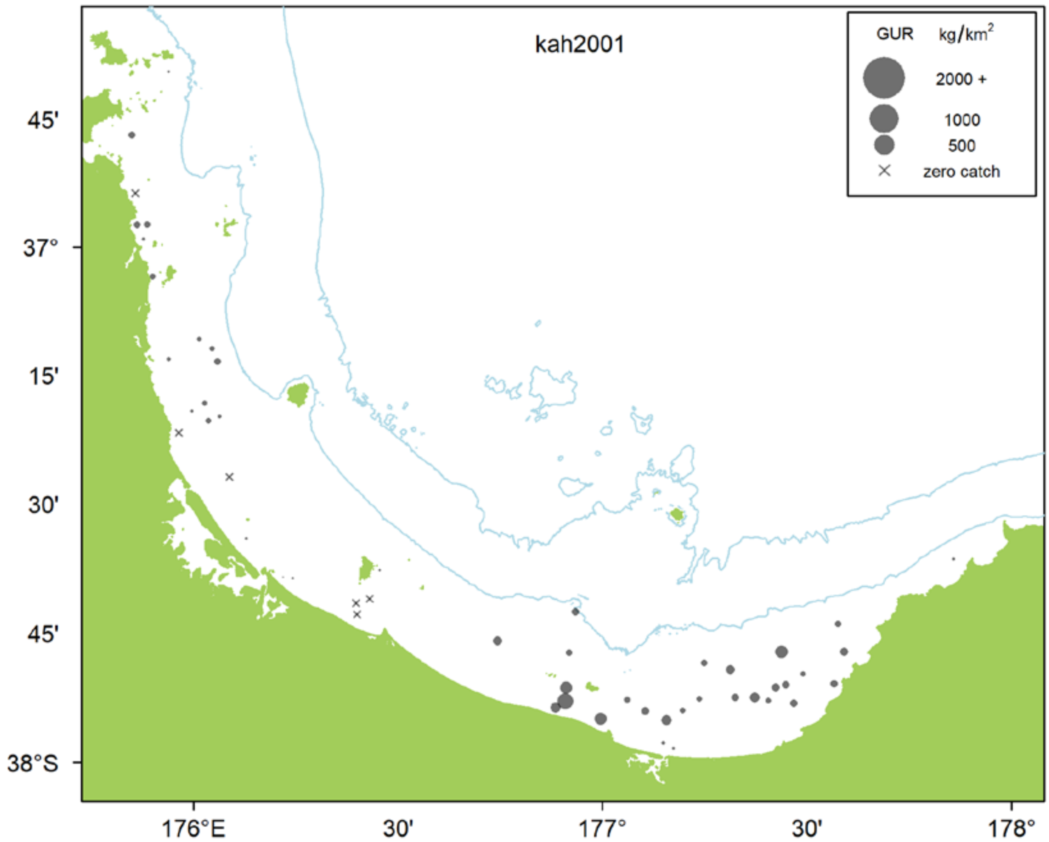
i: Trevally (TRE), Hauraki Gulf.



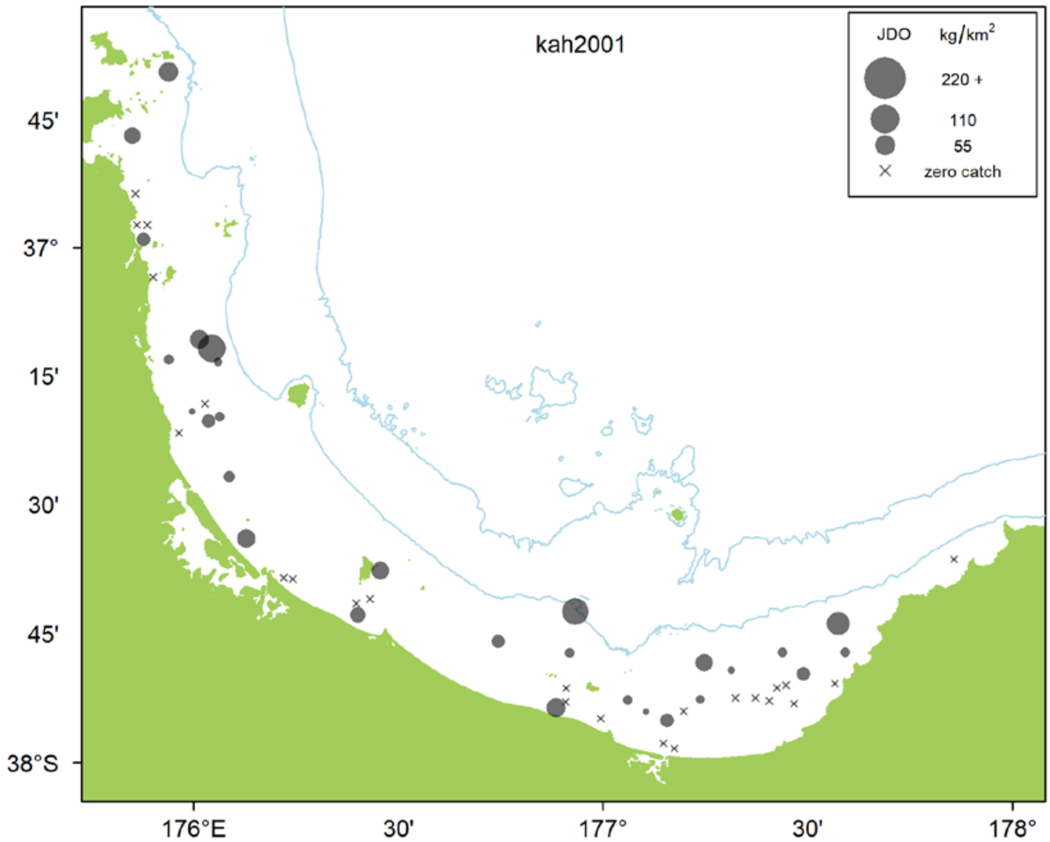
j: Kahawai (ATT), Bay of Plenty.



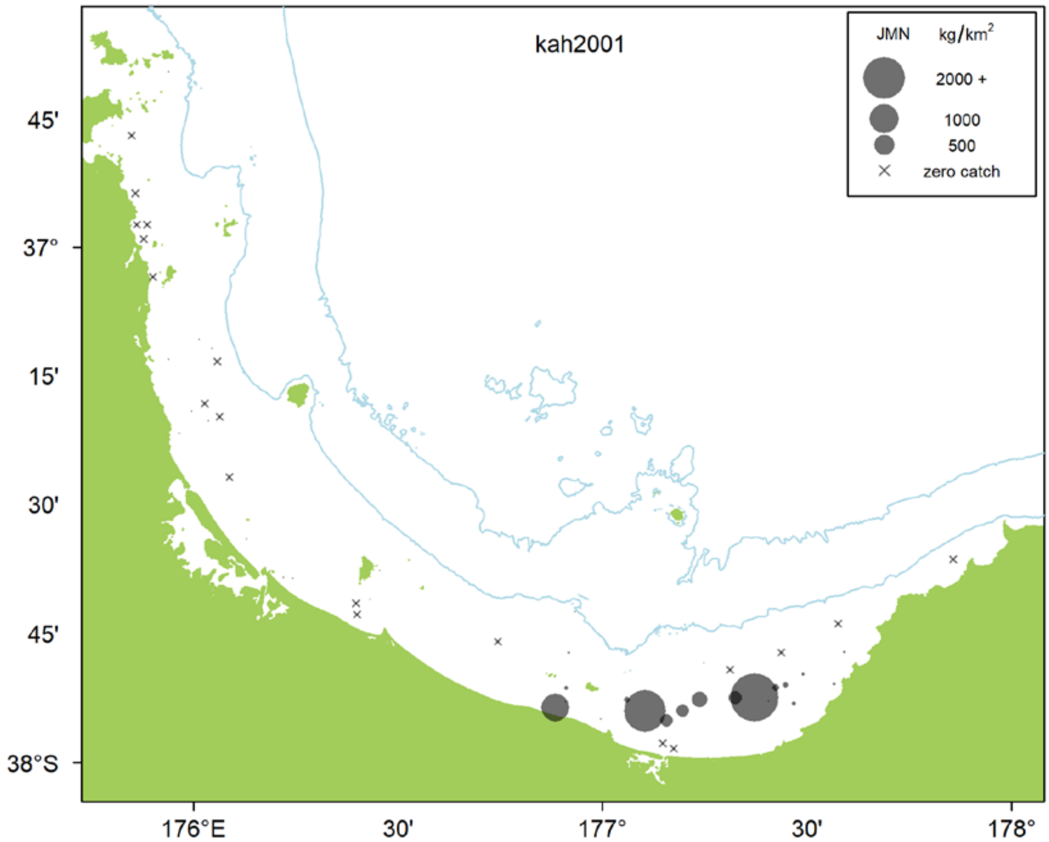
k: Frostfish (FRO), Bay of Plenty.



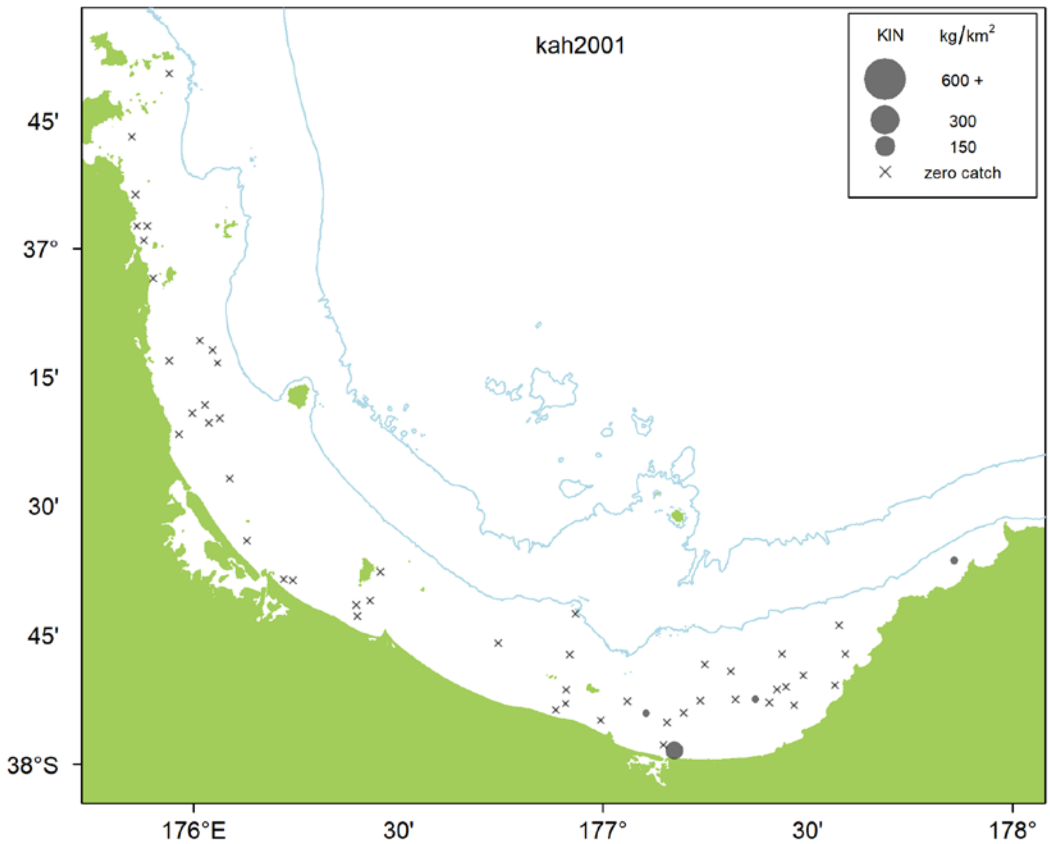
l: Gurnard (GUR), Bay of Plenty.



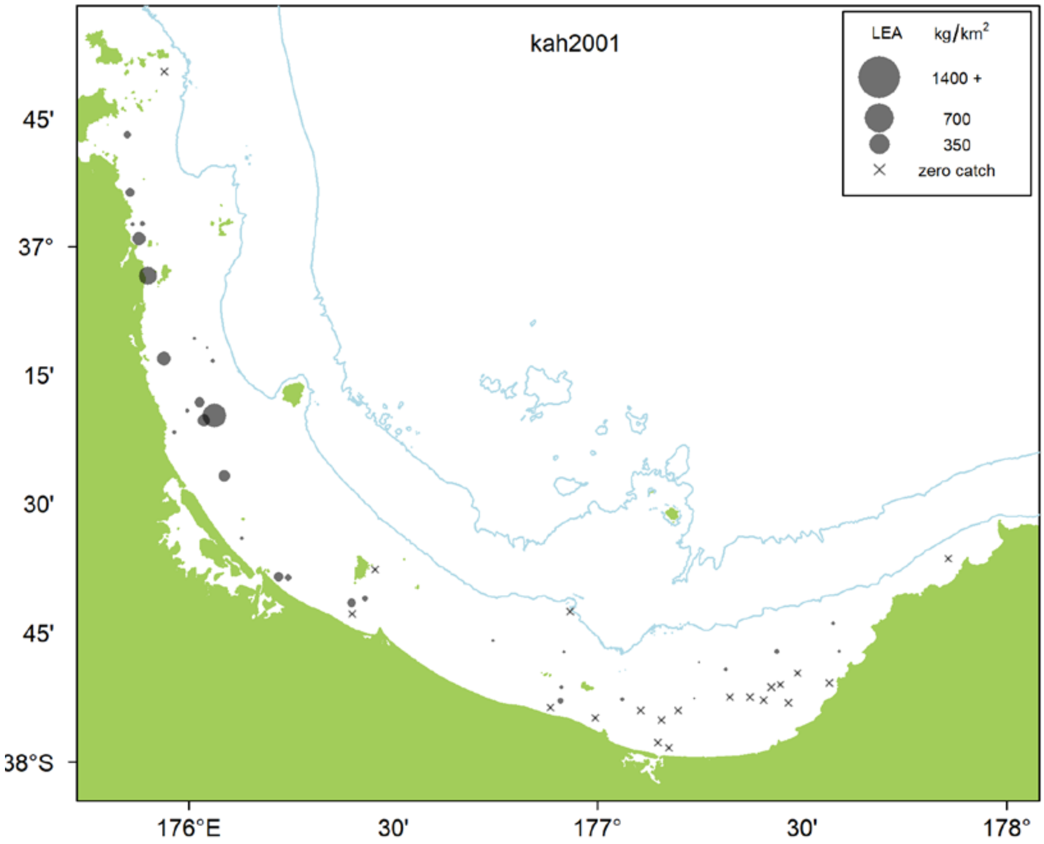
m: John dory (JDO), Bay of Plenty.



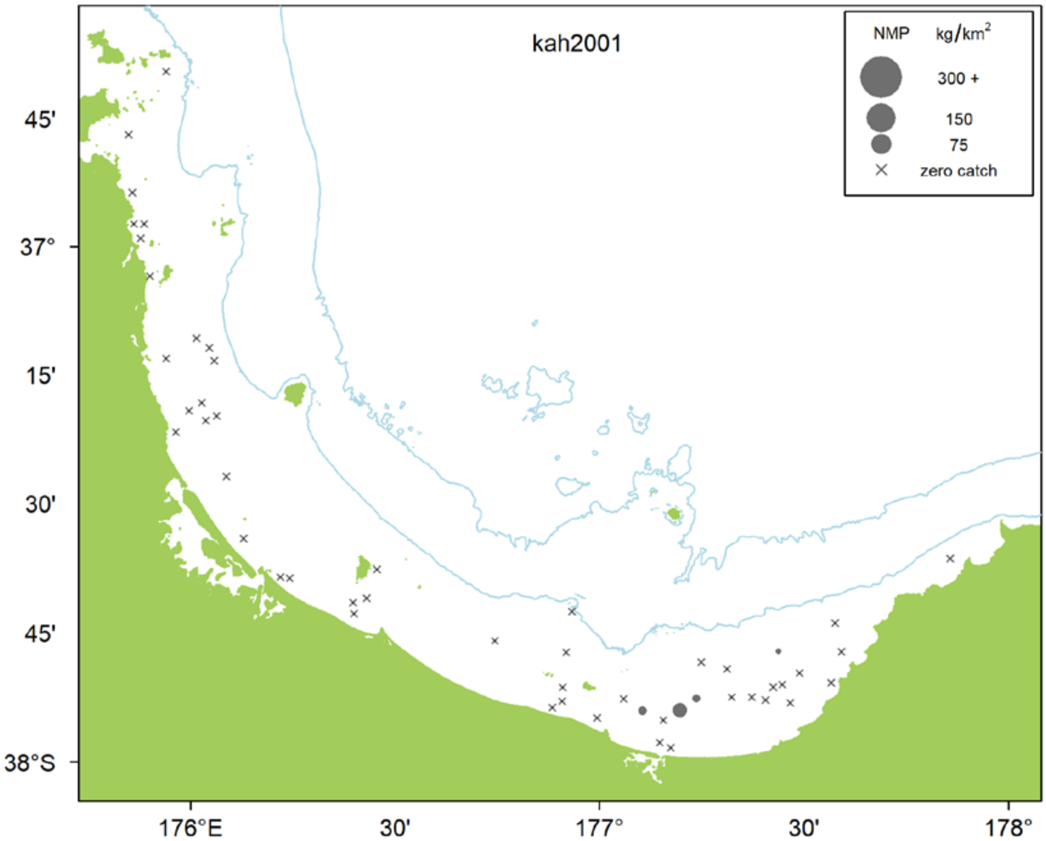
n: Yellowtail jack mackerel (JMN), Bay of Plenty.



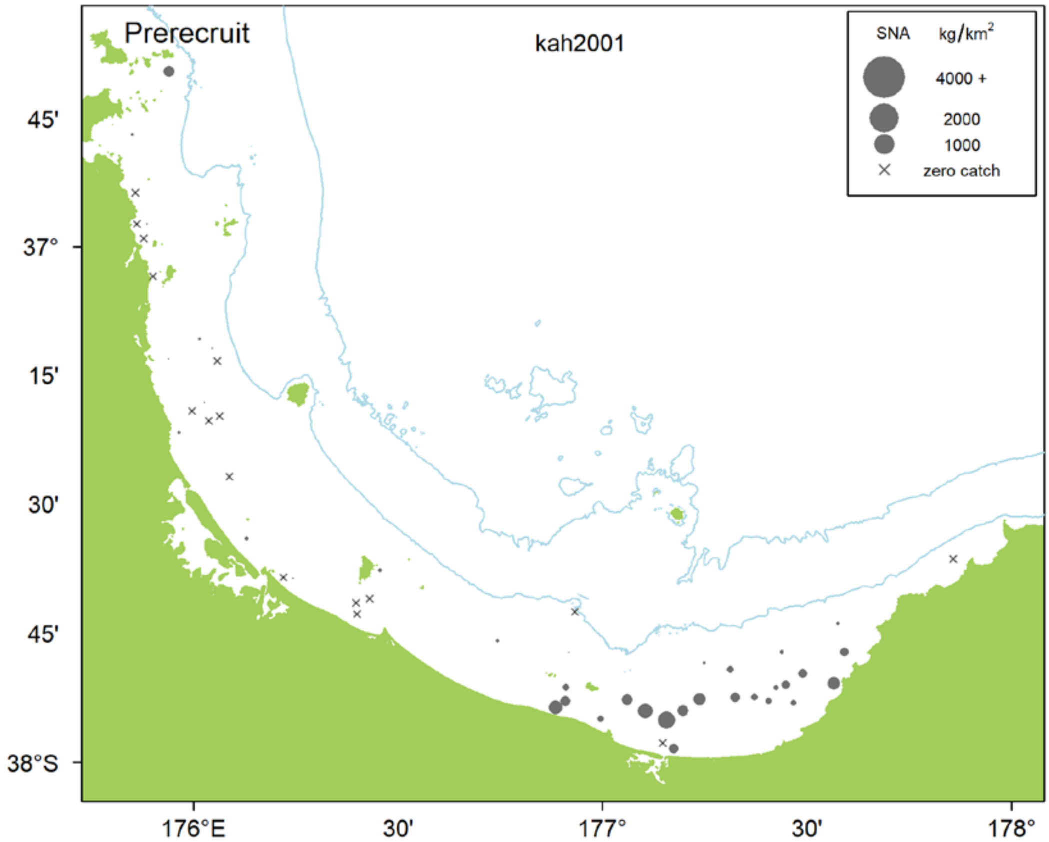
o: Kingfish (KIN), Bay of Plenty.



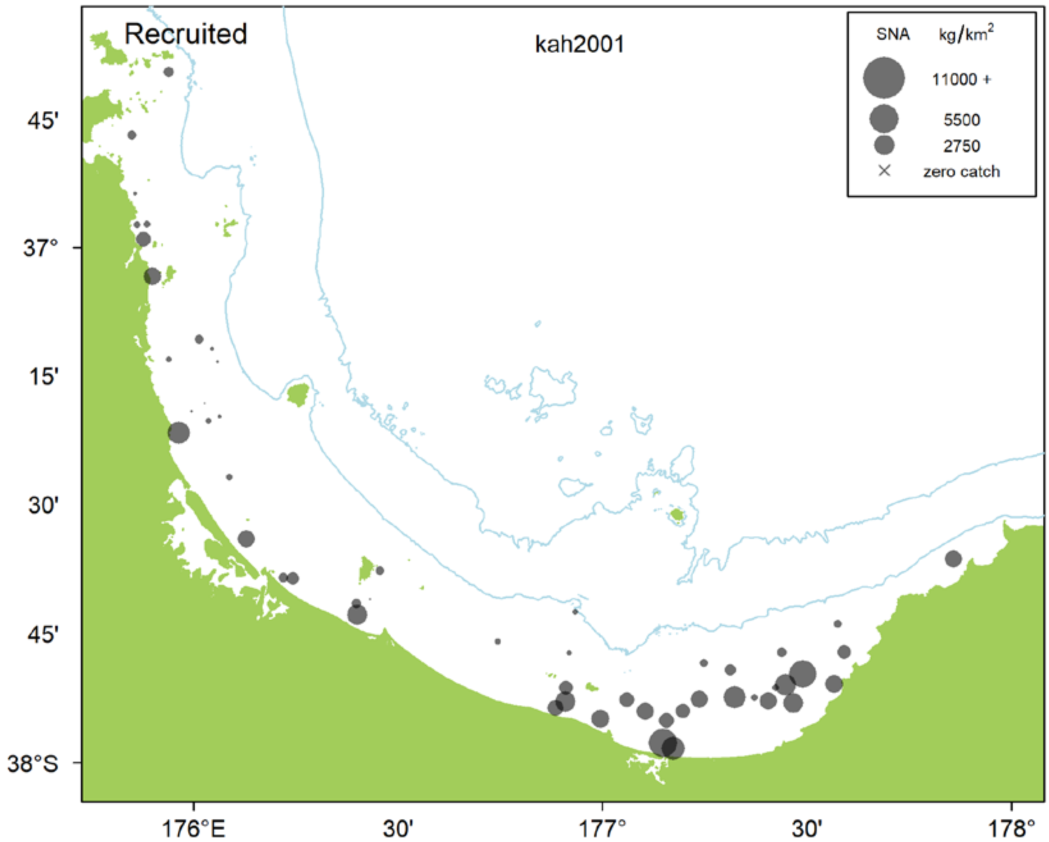
p: Leatherjacket (LEA), Bay of Plenty.



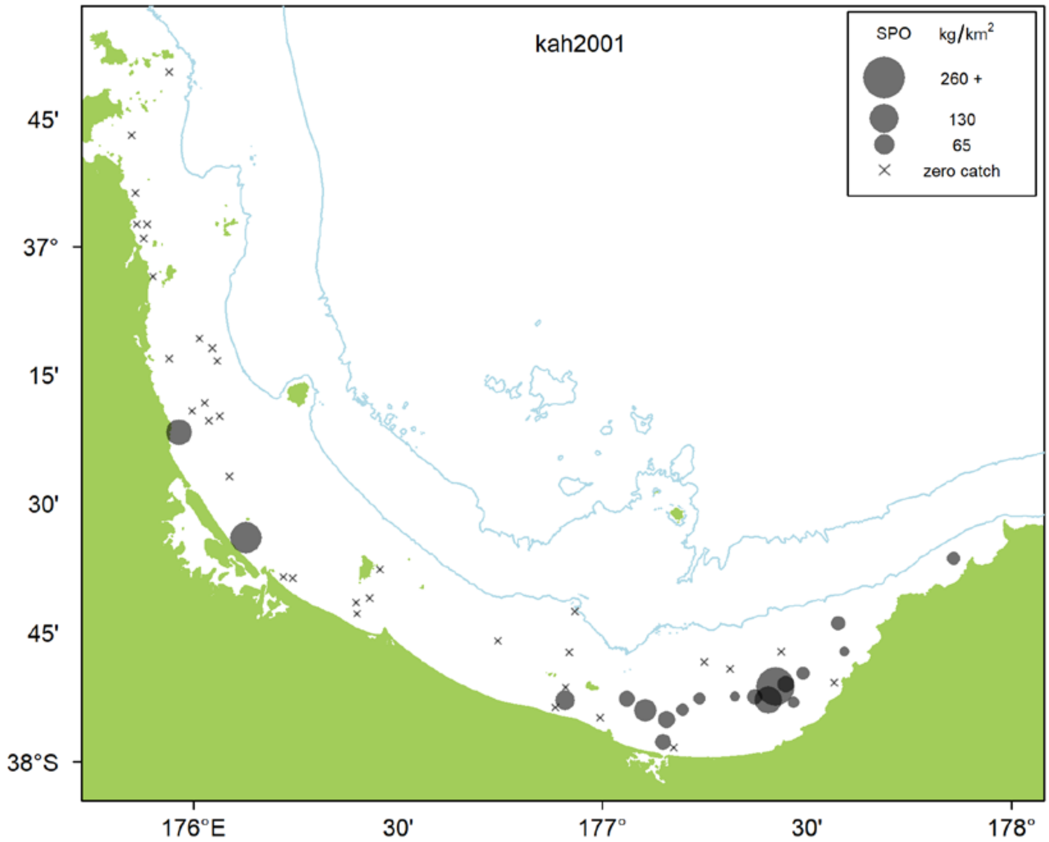
q: Tarakihi (NMP), Bay of Plenty.



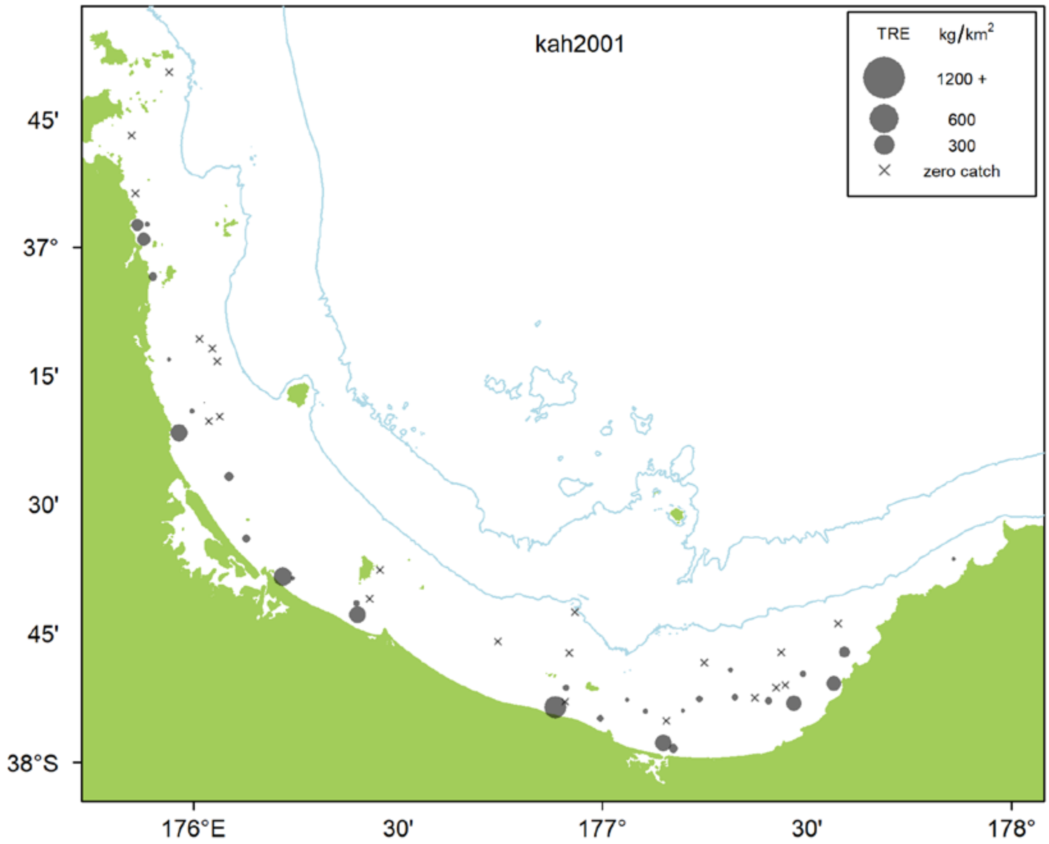
r: Pre–recruit snapper (SNA; <25 cm FL), Bay of Plenty.



s: Recruited snapper (SNA; 25 cm FL and larger), Bay of Plenty.



t: Rig (SPO), Bay of Plenty.



u: Trevally (TRE), Bay of Plenty.

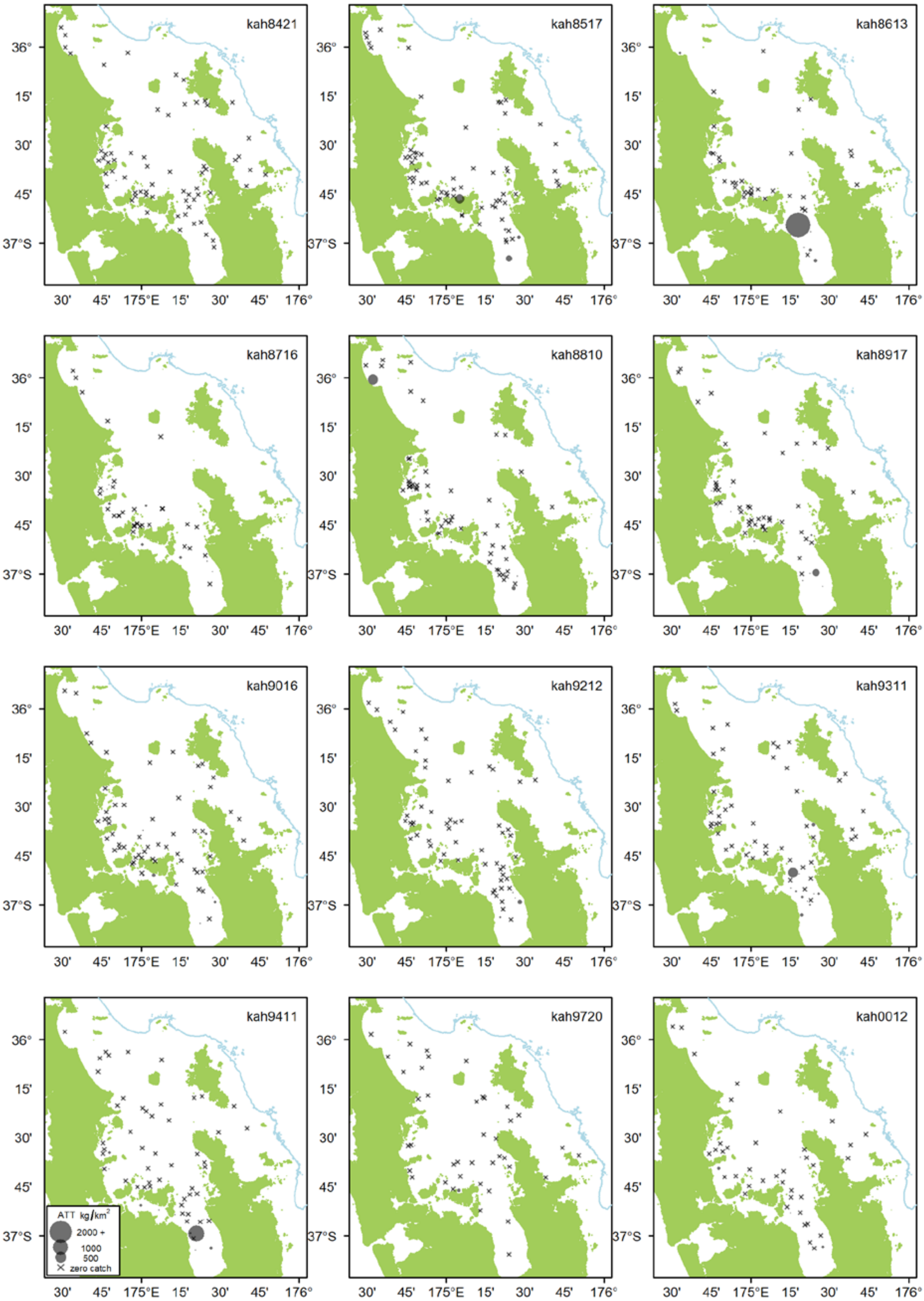
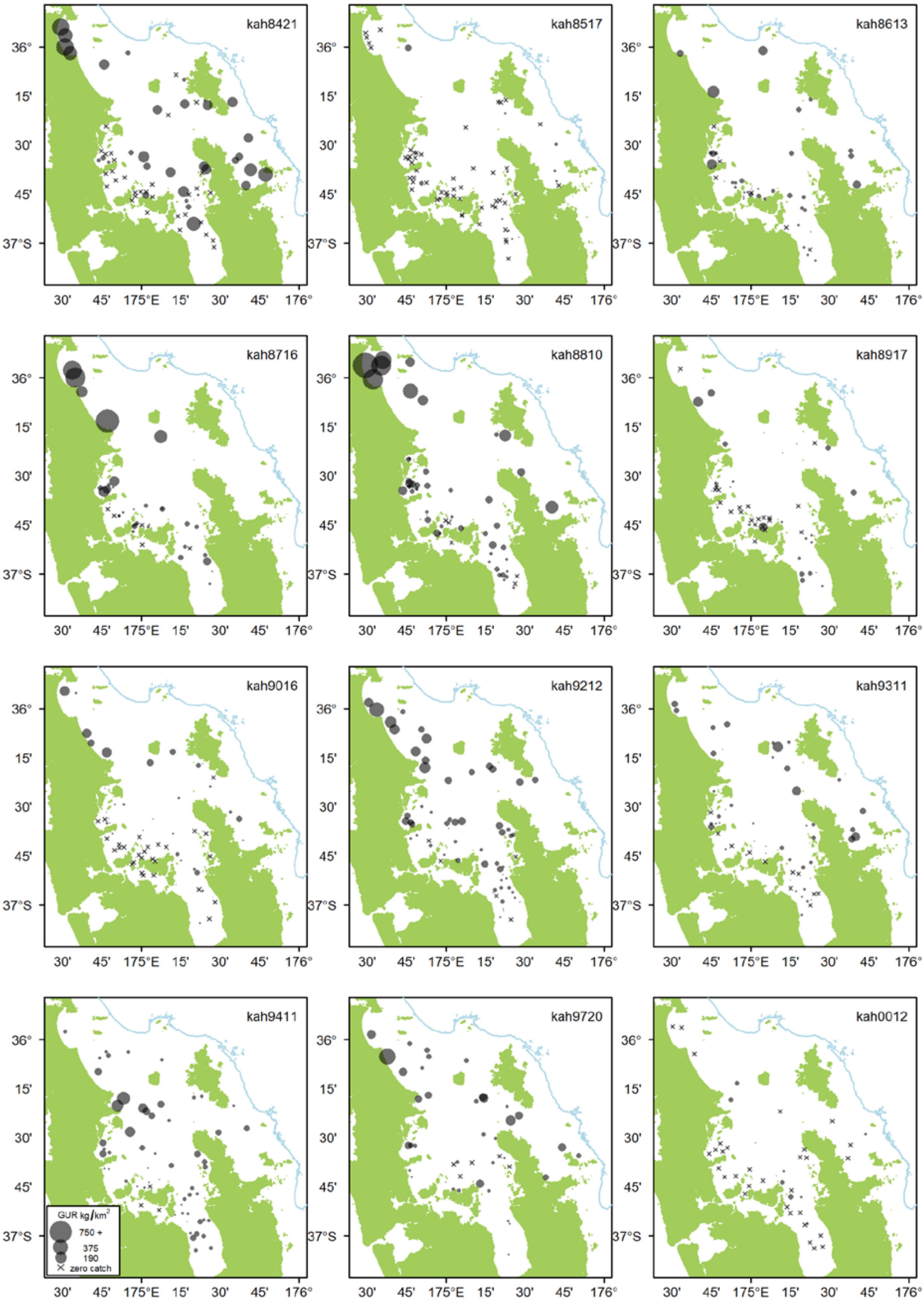
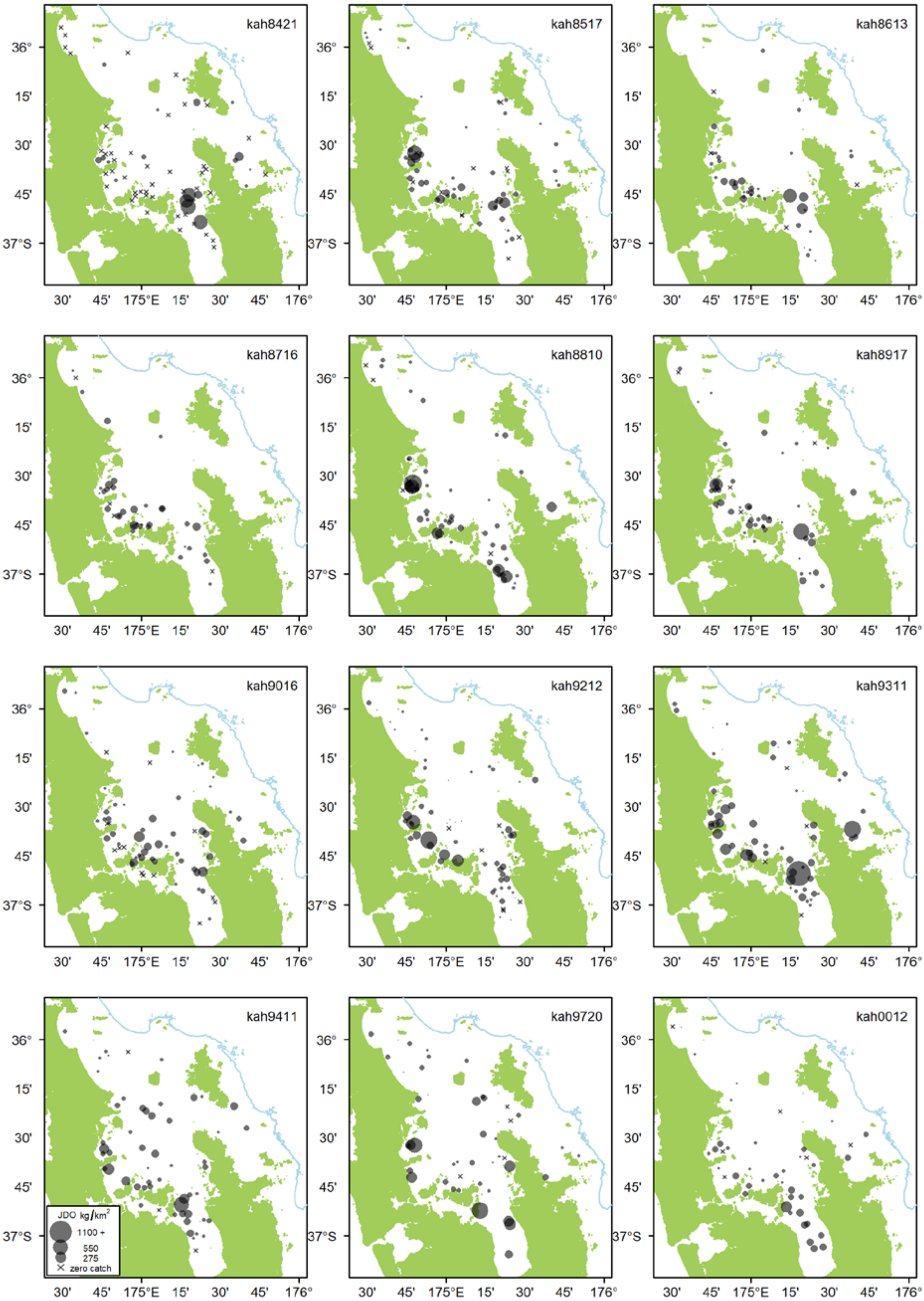


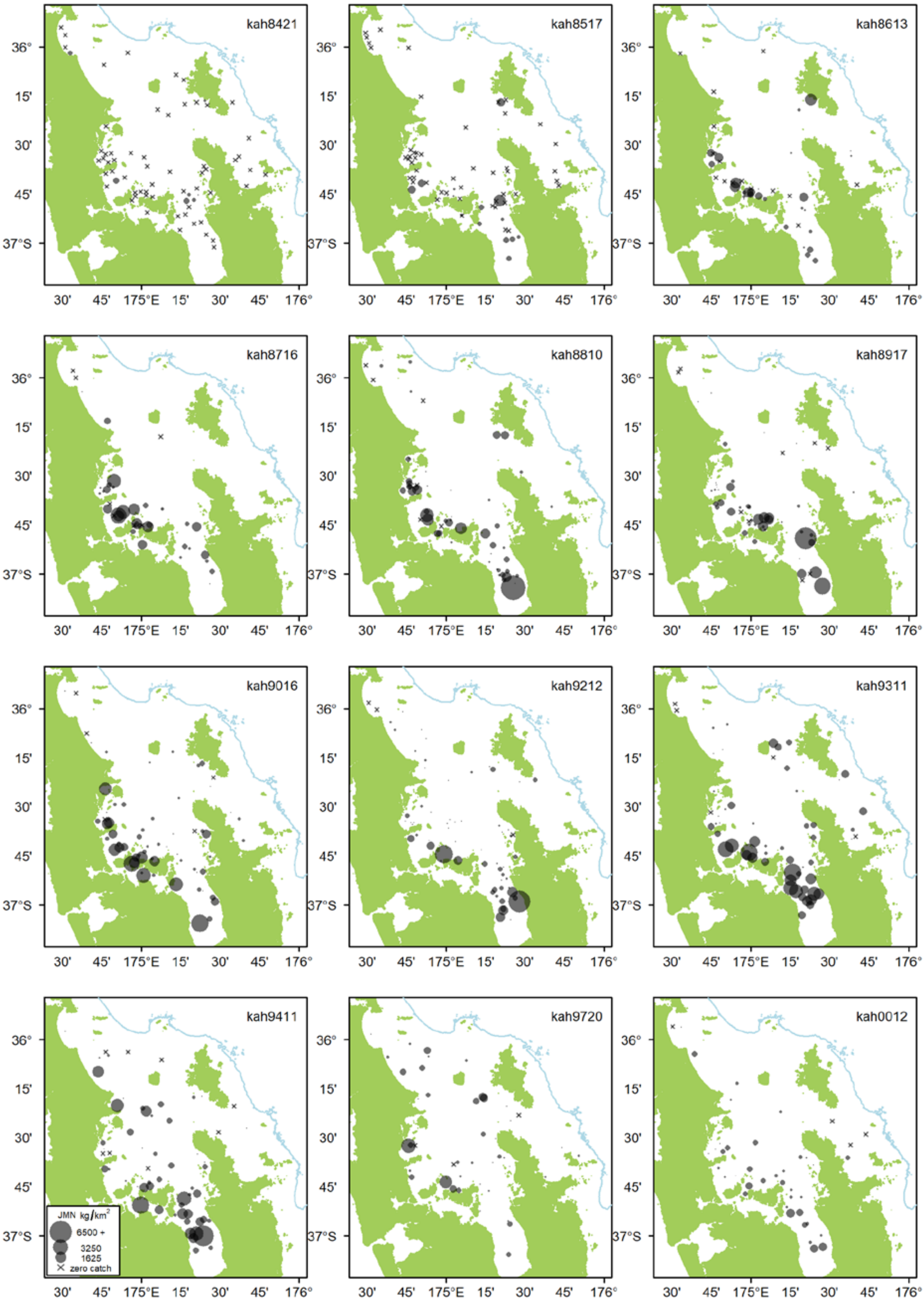
Figure 3: The spatial distribution of catch (kg km^{-2}) for the most common QMS species for the historical survey series in Hauraki Gulf and Bay of Plenty. N.B. Catch rate scale varies between species. a: Kahawai (ATT), Hauraki Gulf.



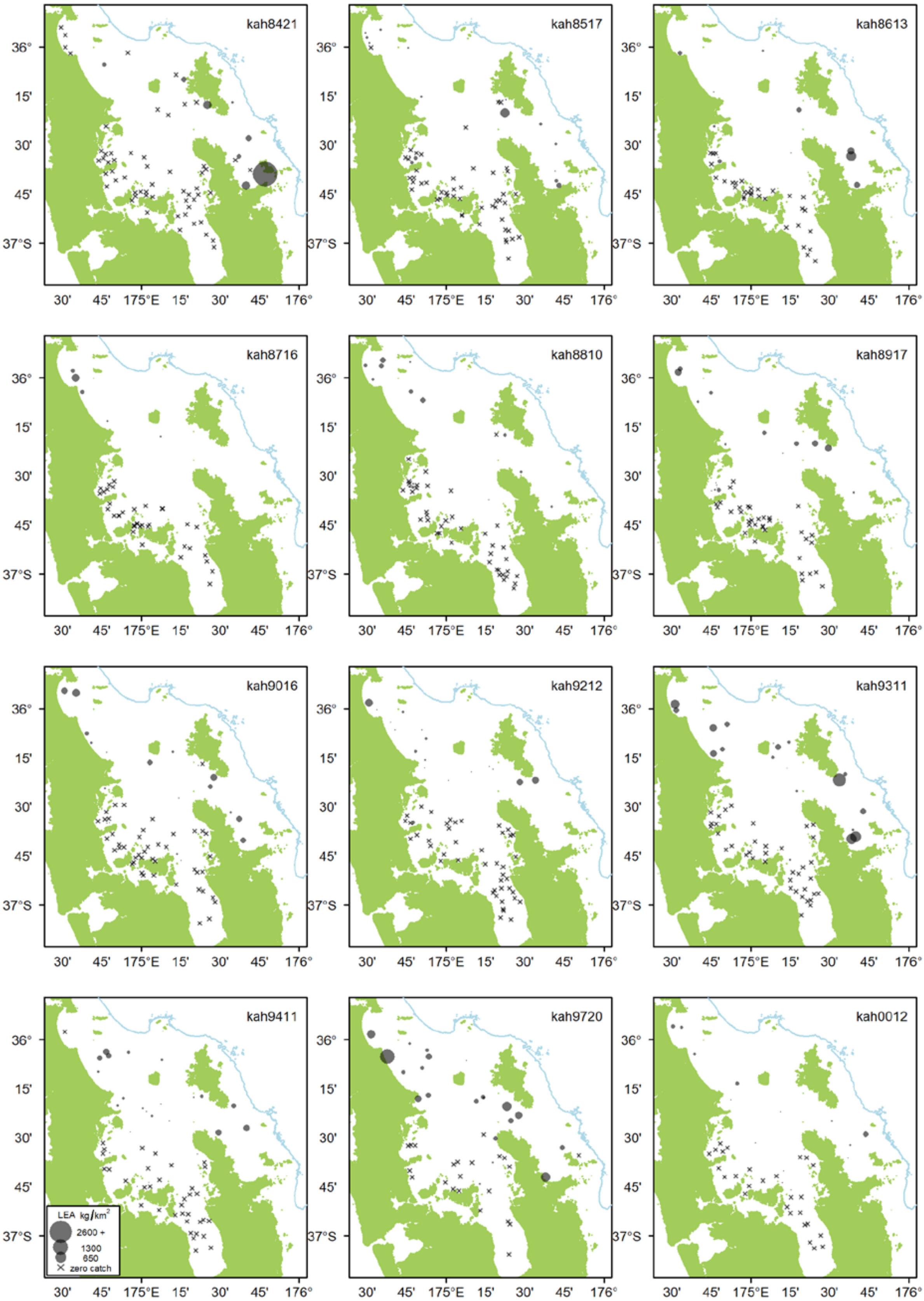
b: Gurnard (GUR), Hauraki Gulf.



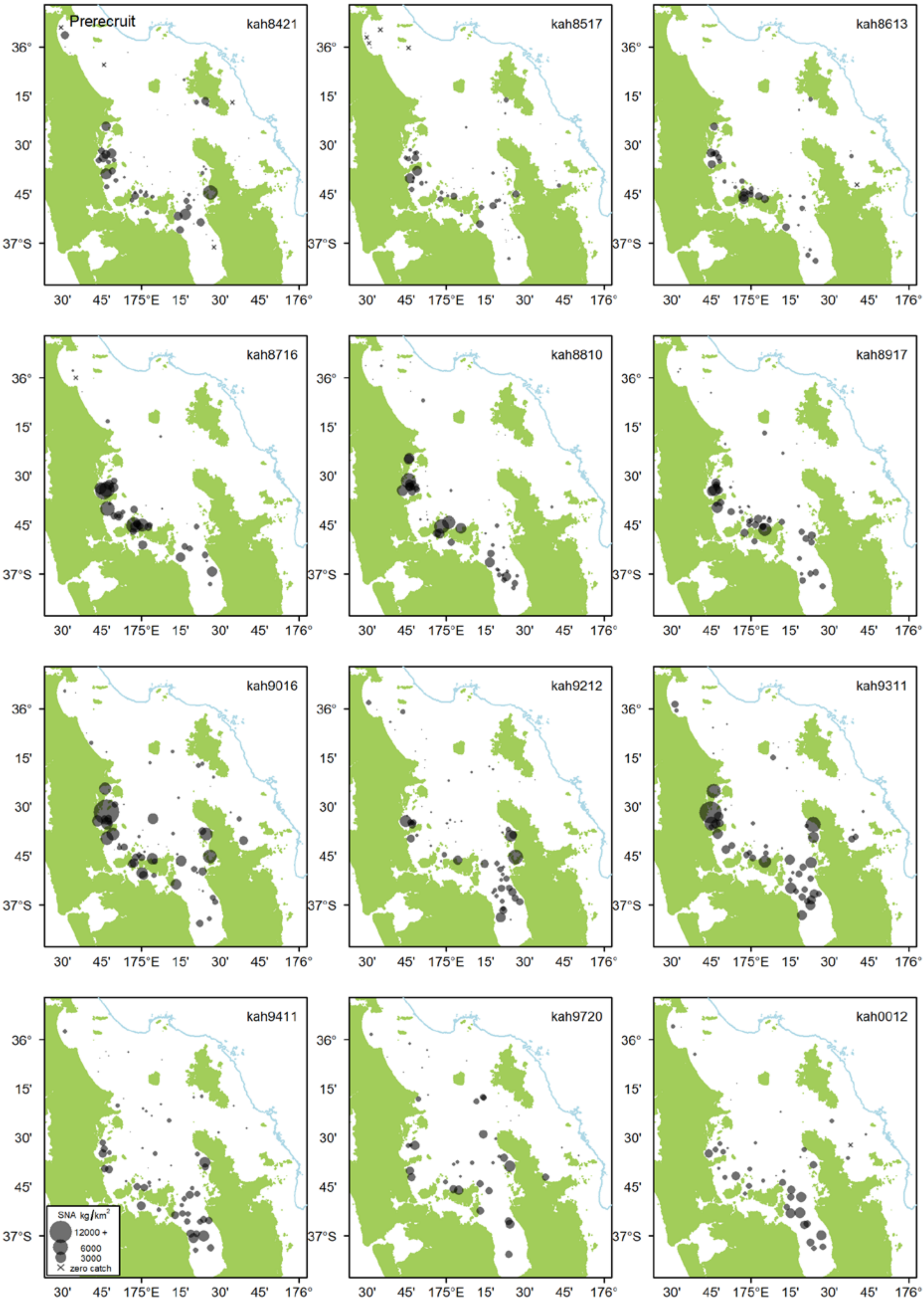
c: John dory (JDO), Hauraki Gulf.



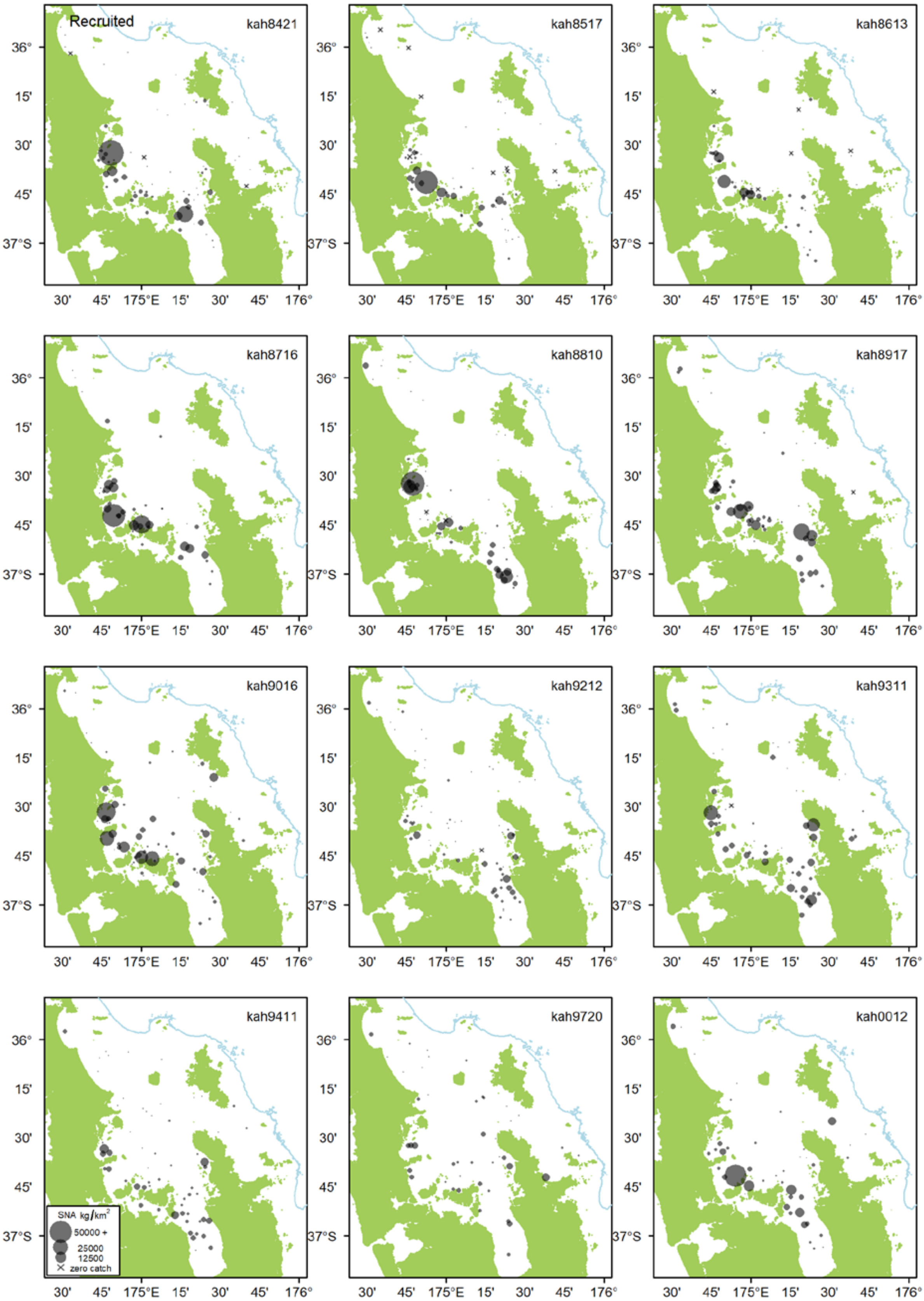
d: Yellowtail jack mackerel (JMN), Hauraki Gulf.



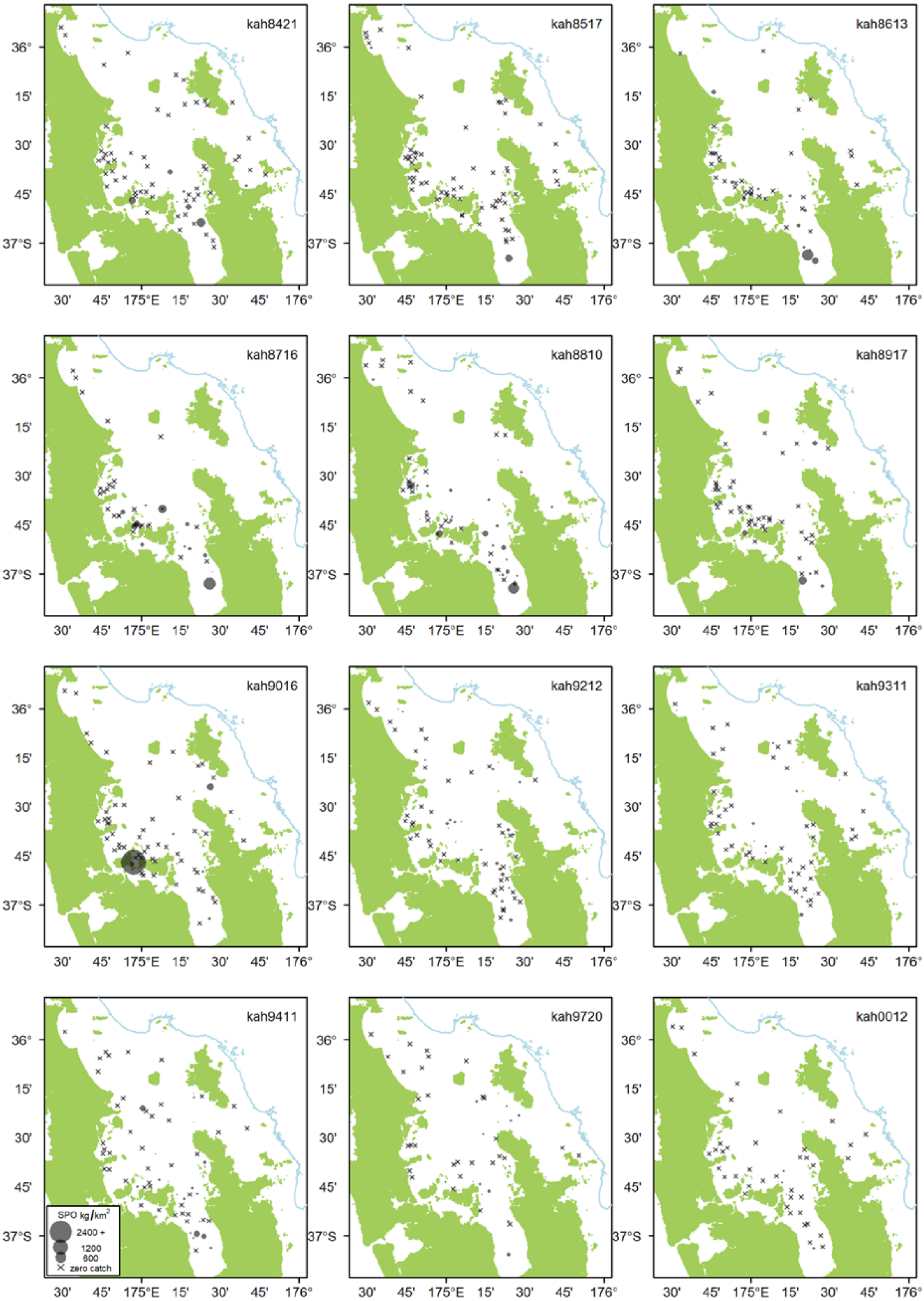
e: Leatherjacket (LEA), Hauraki Gulf.



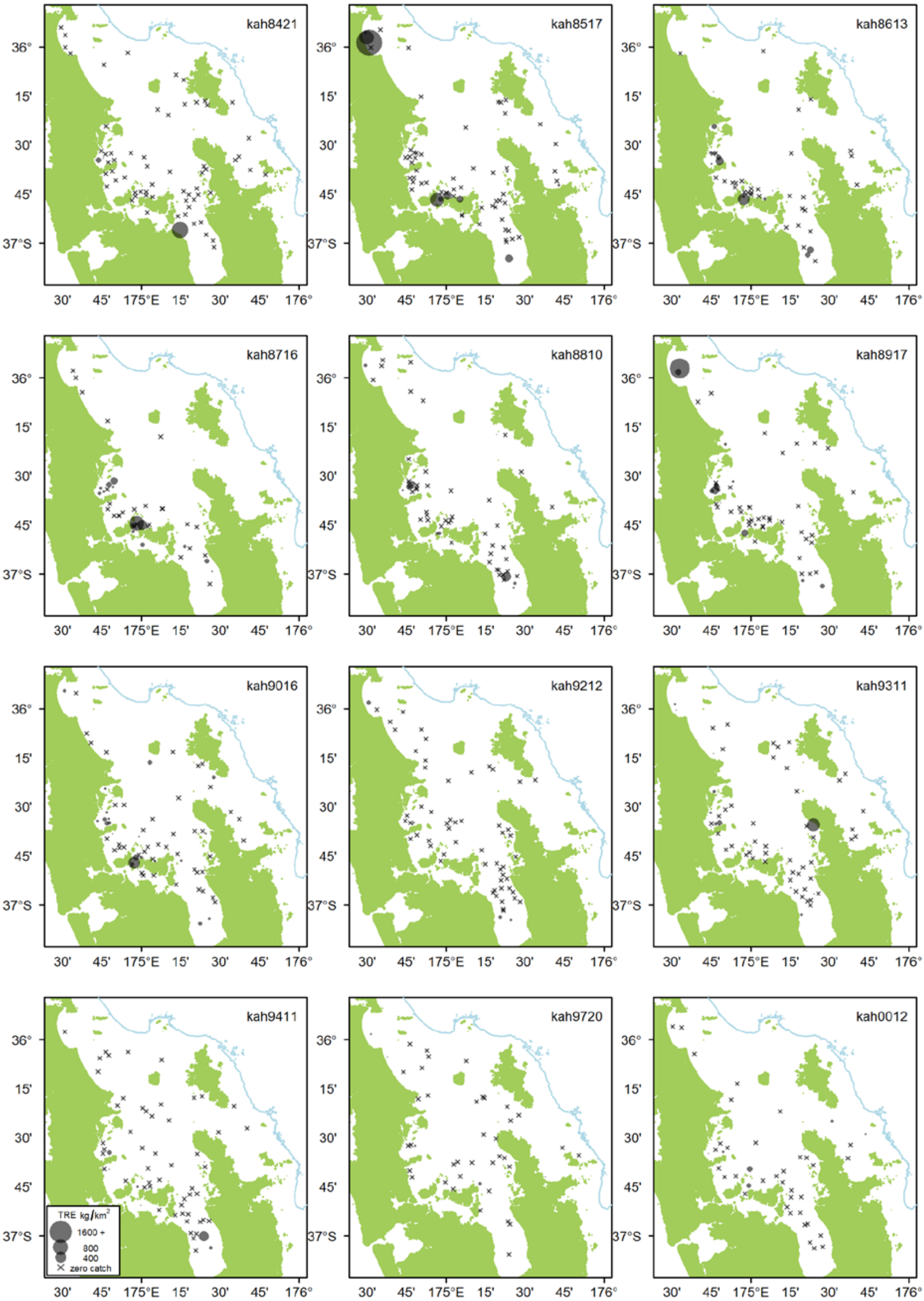
f: Pre-recruit snapper (SNA), Hauraki Gulf.



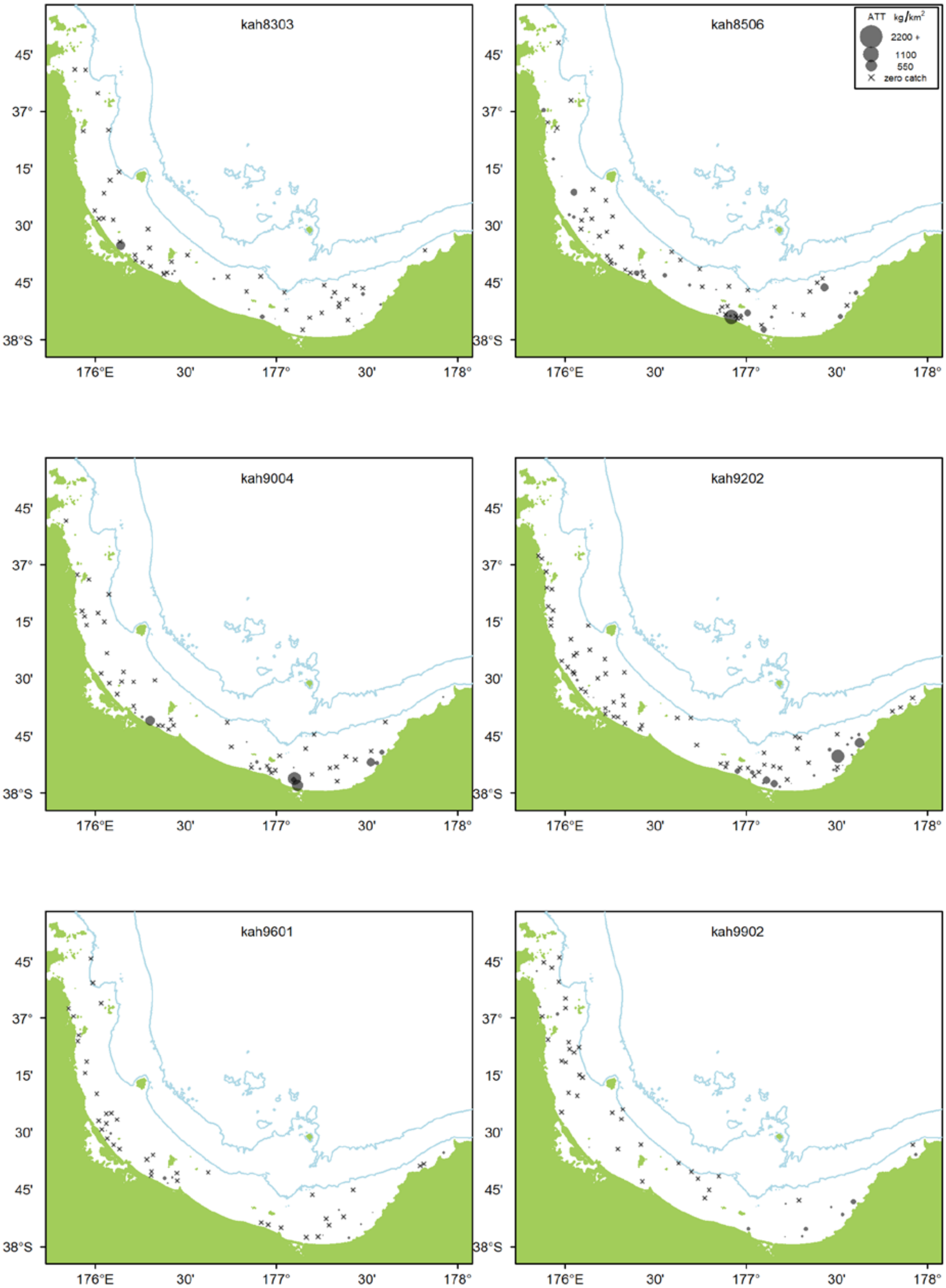
g: Recruited snapper (SNA), Hauraki Gulf.



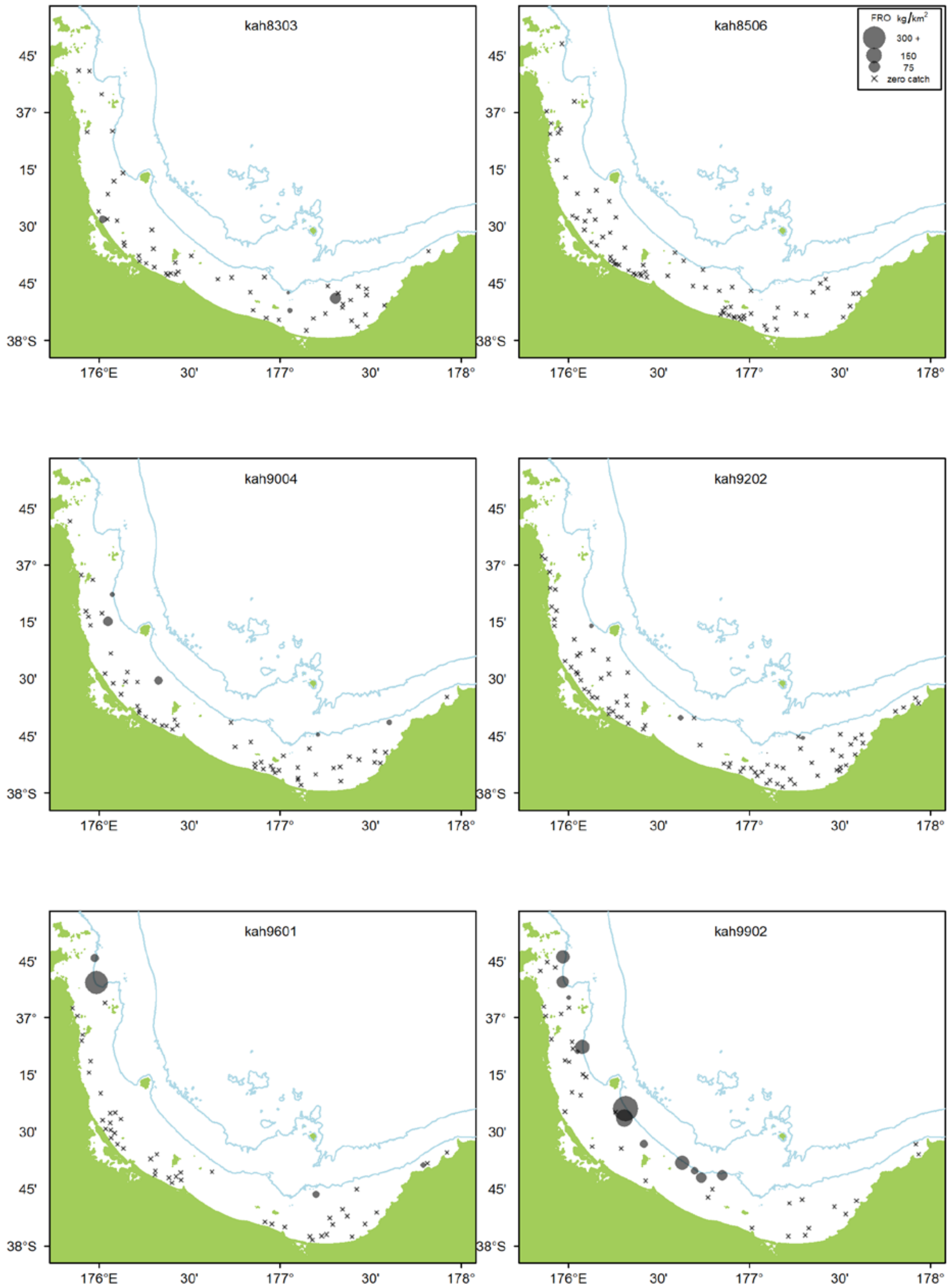
h: Rig (SPO), Hauraki Gulf.



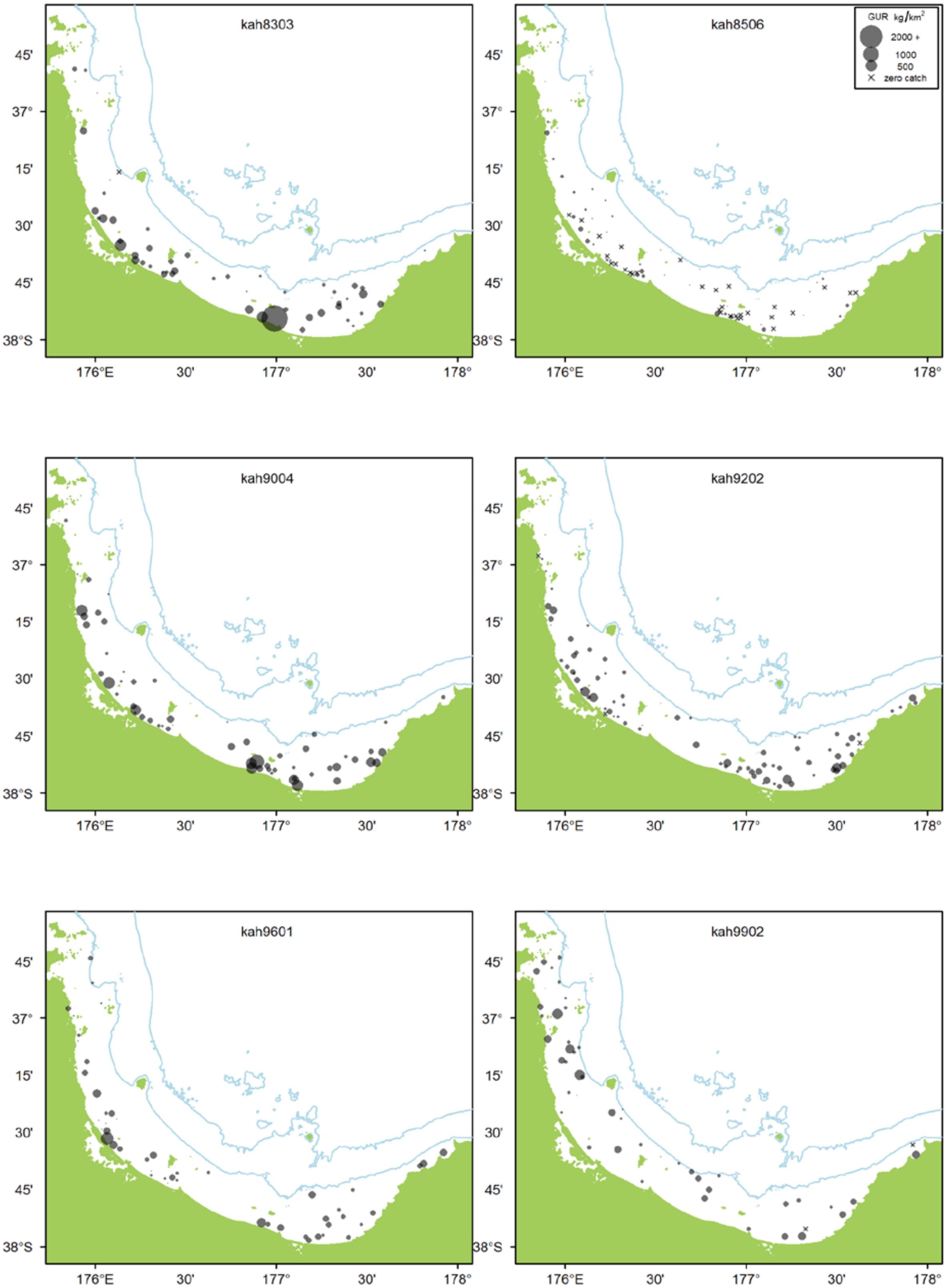
i: Trevally (TRE), Hauraki Gulf.



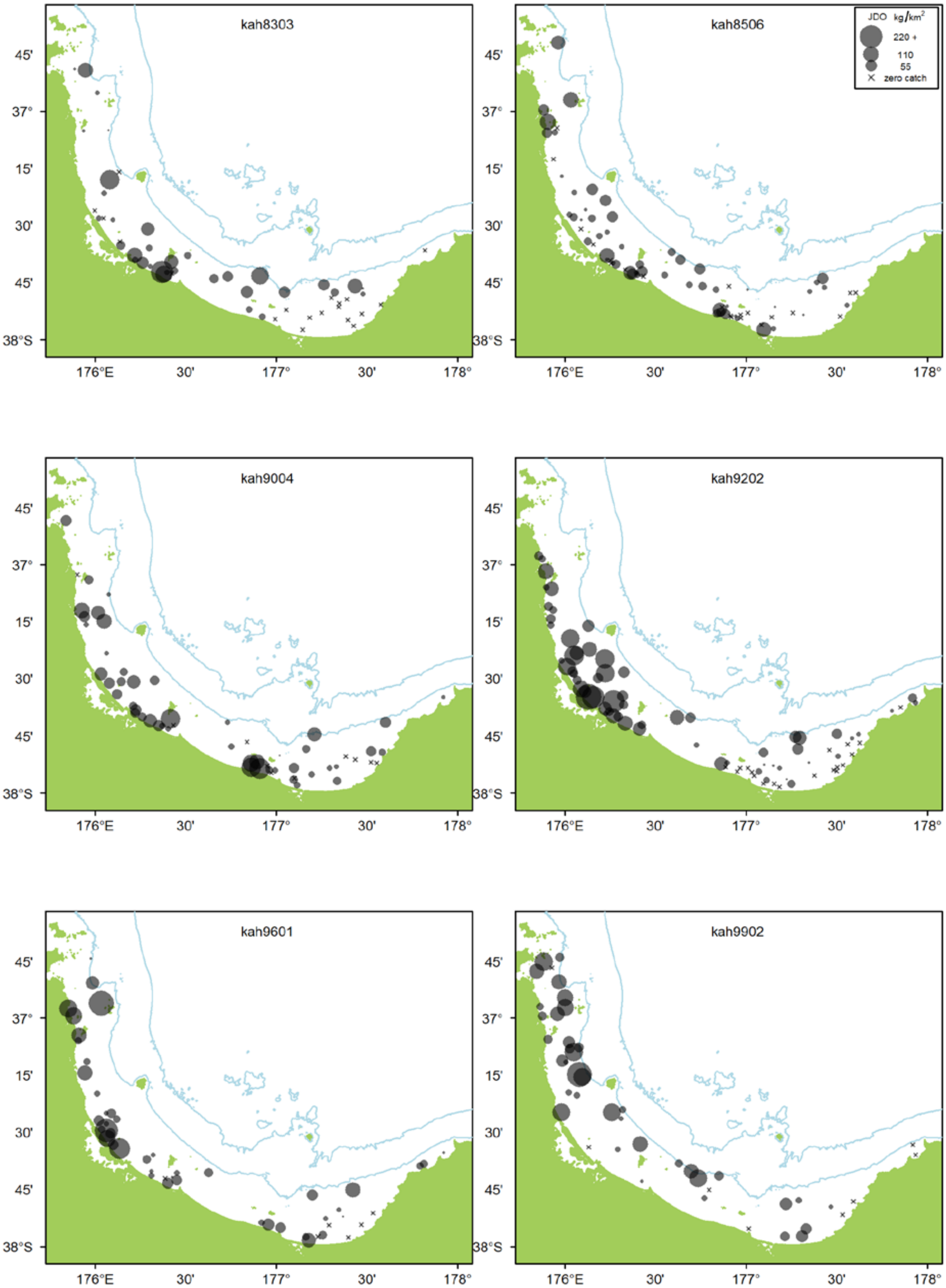
j: Kahawai (ATT), Bay of Plenty.



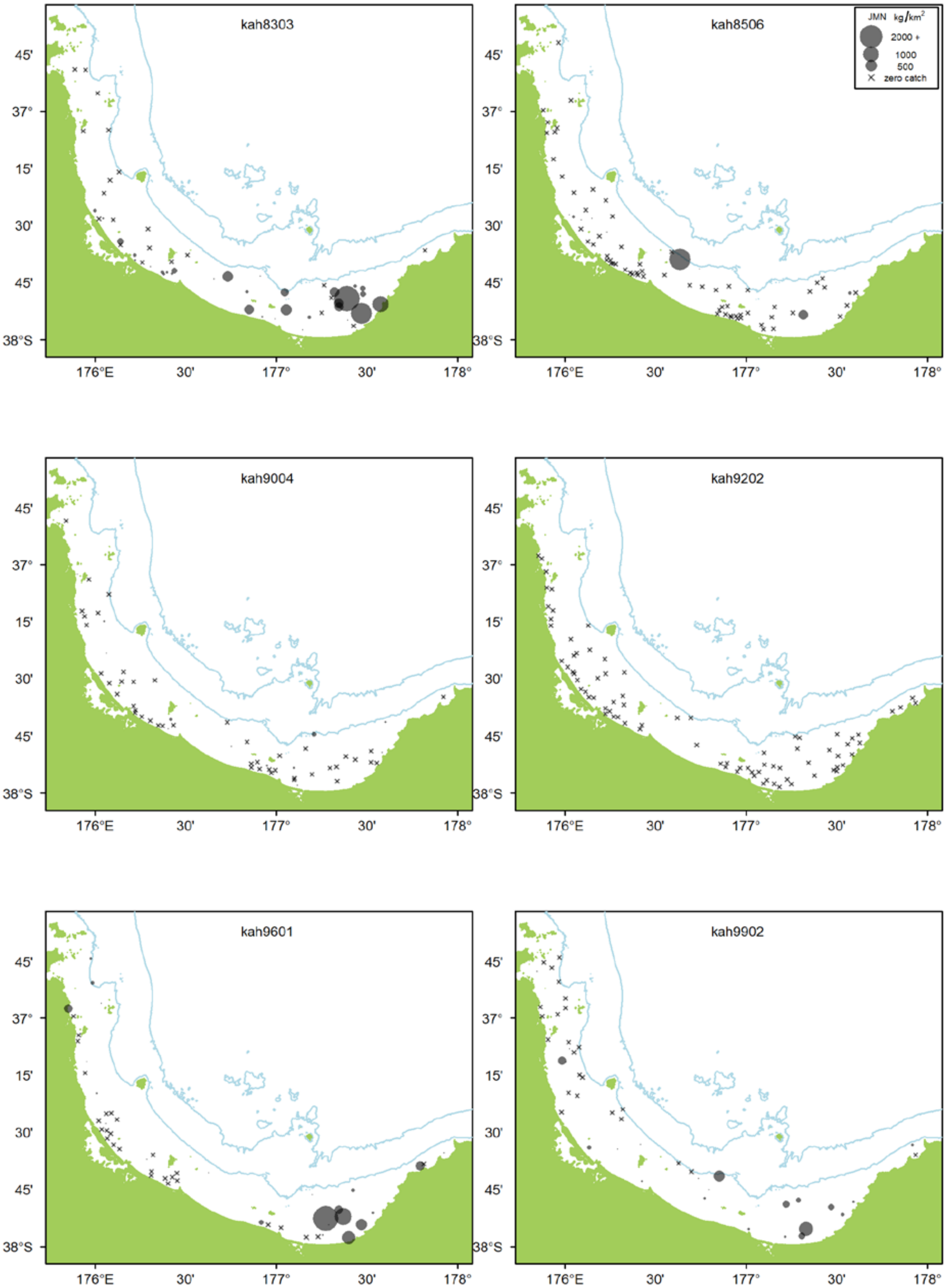
k: Frostfish (FRO), Bay of Plenty.



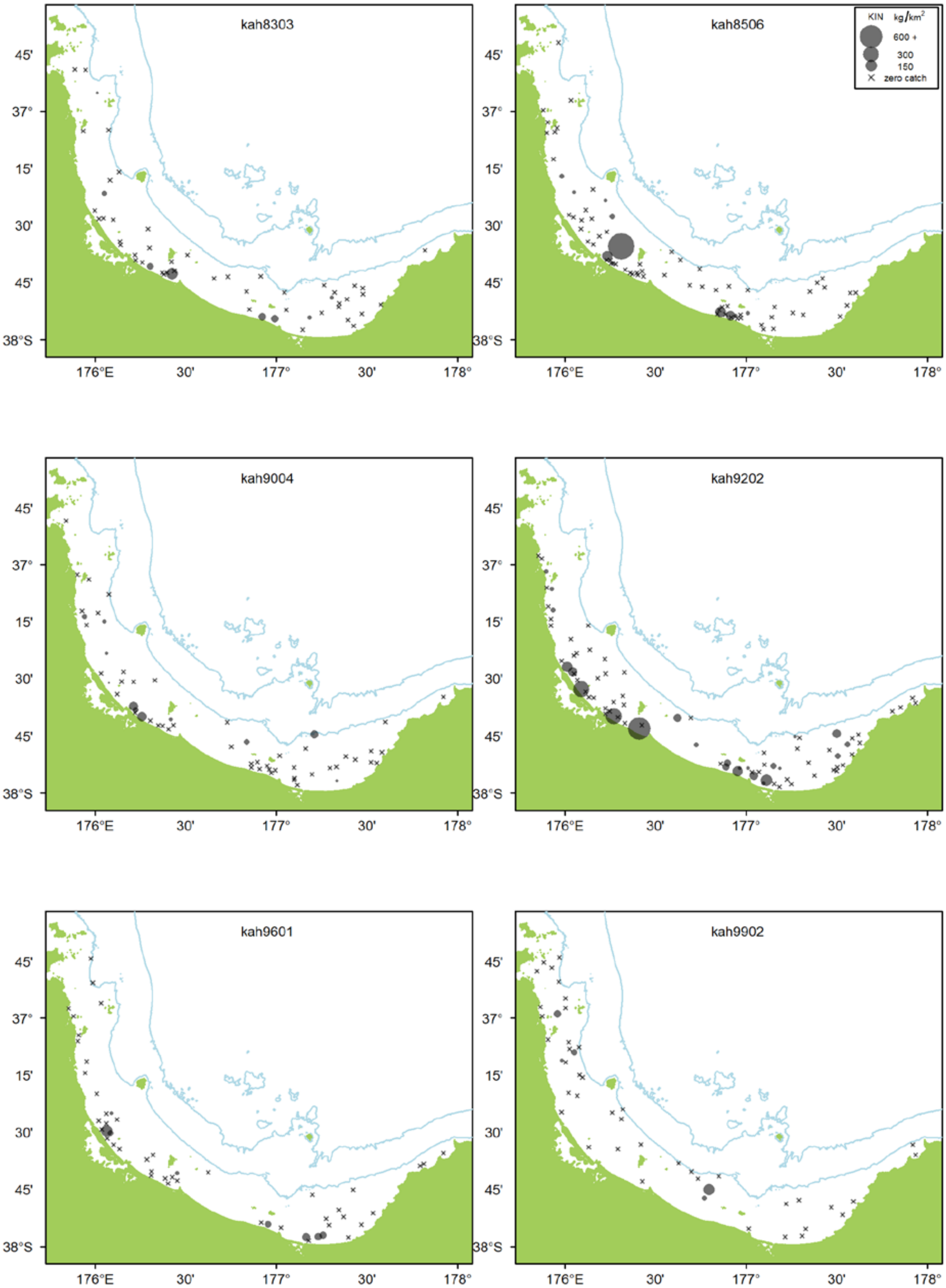
l: Gurnard (GUR), Bay of Plenty.



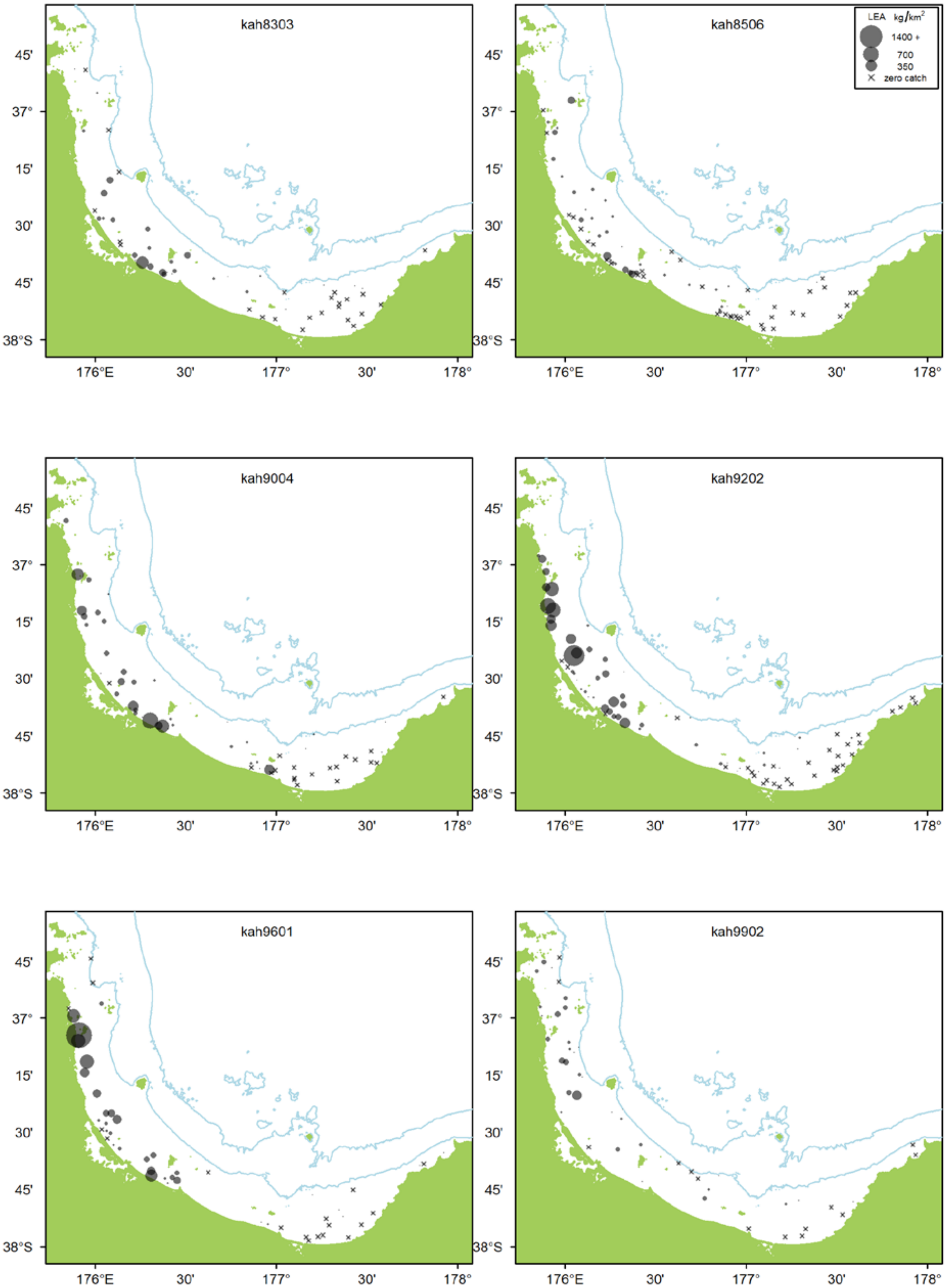
m: John dory (JDO), Bay of Plenty.



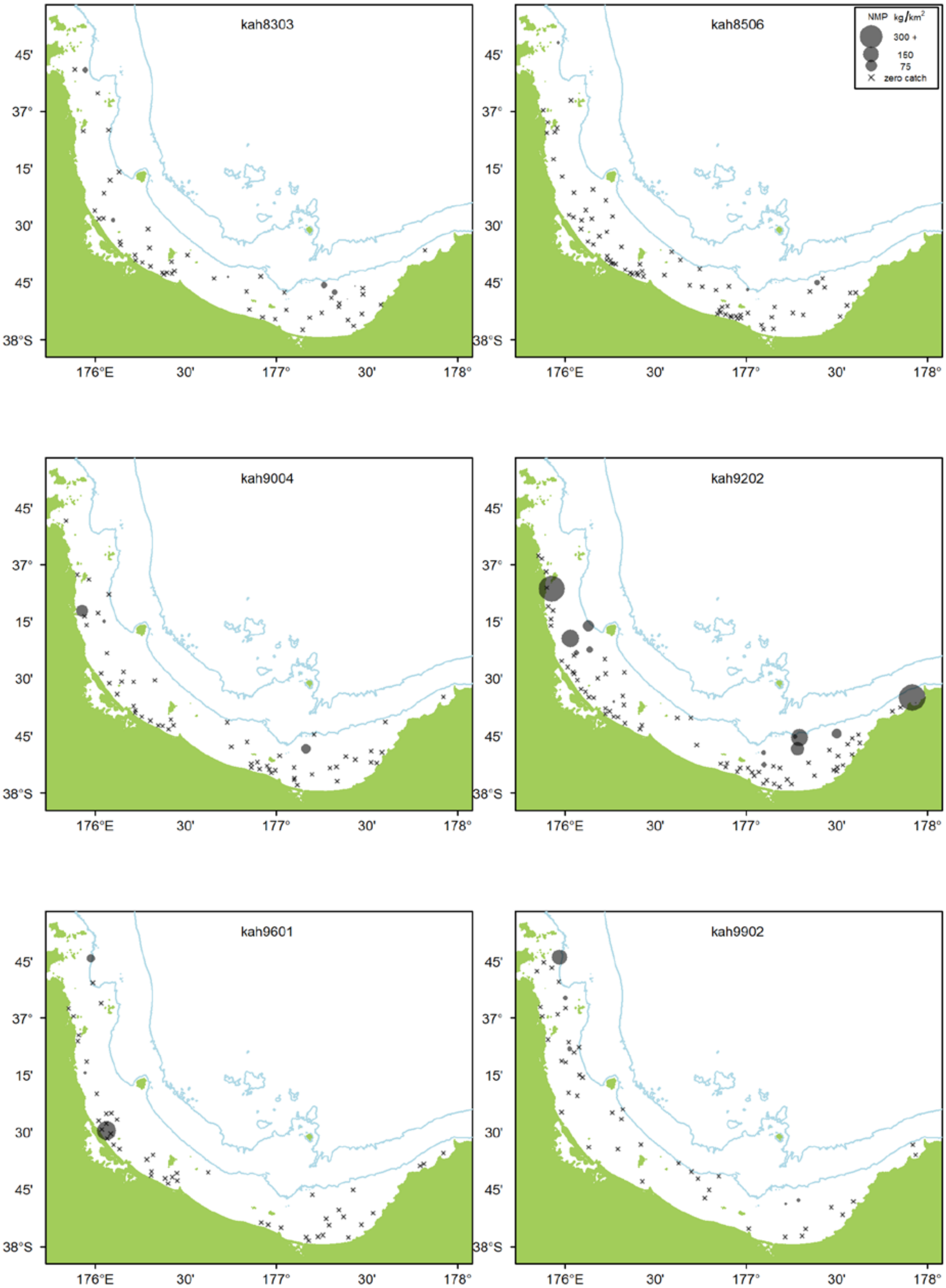
n: Yellowtail jack mackerel (JMN), Bay of Plenty.



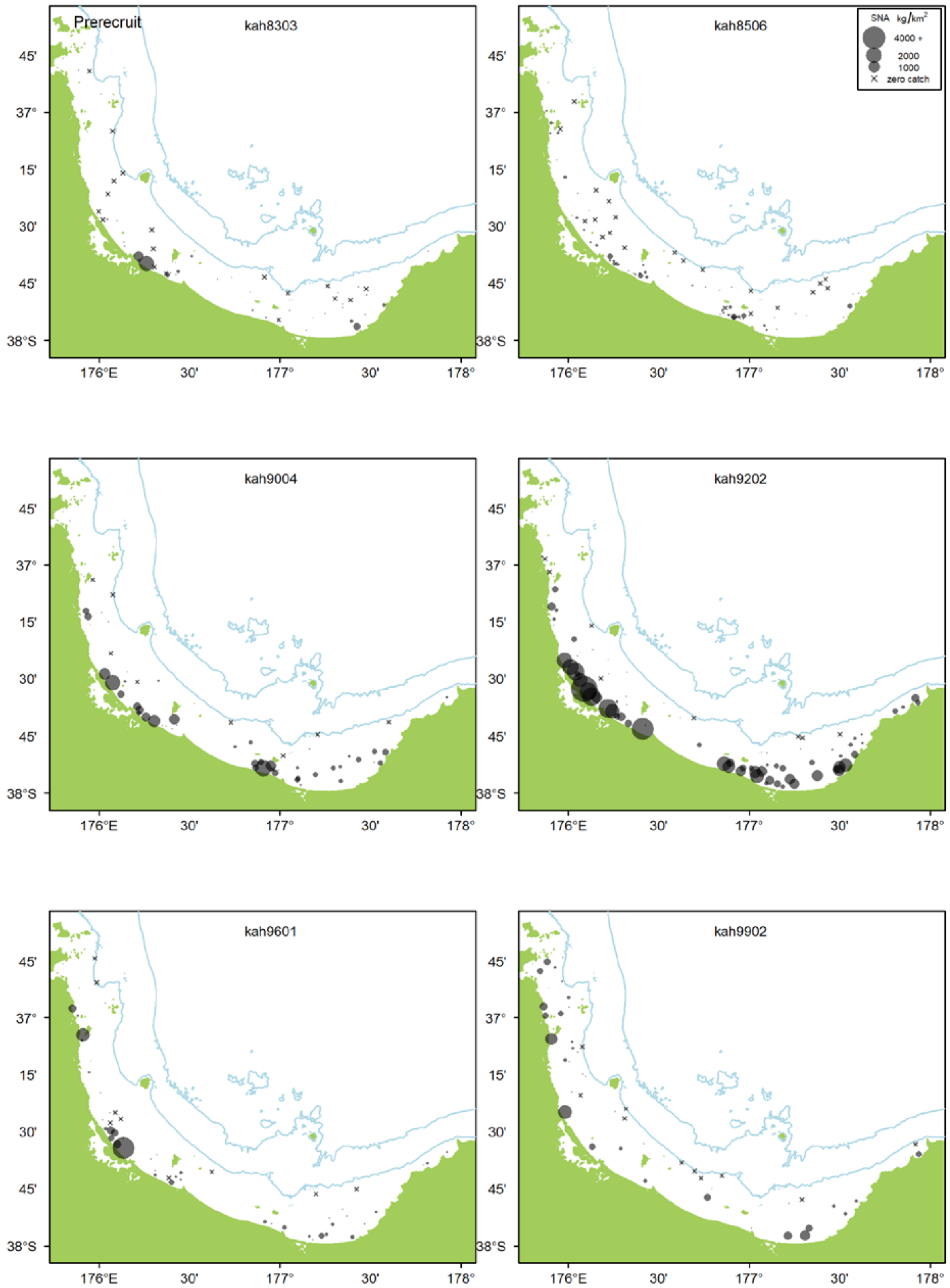
o: Kingfish (KIN), Bay of Plenty.



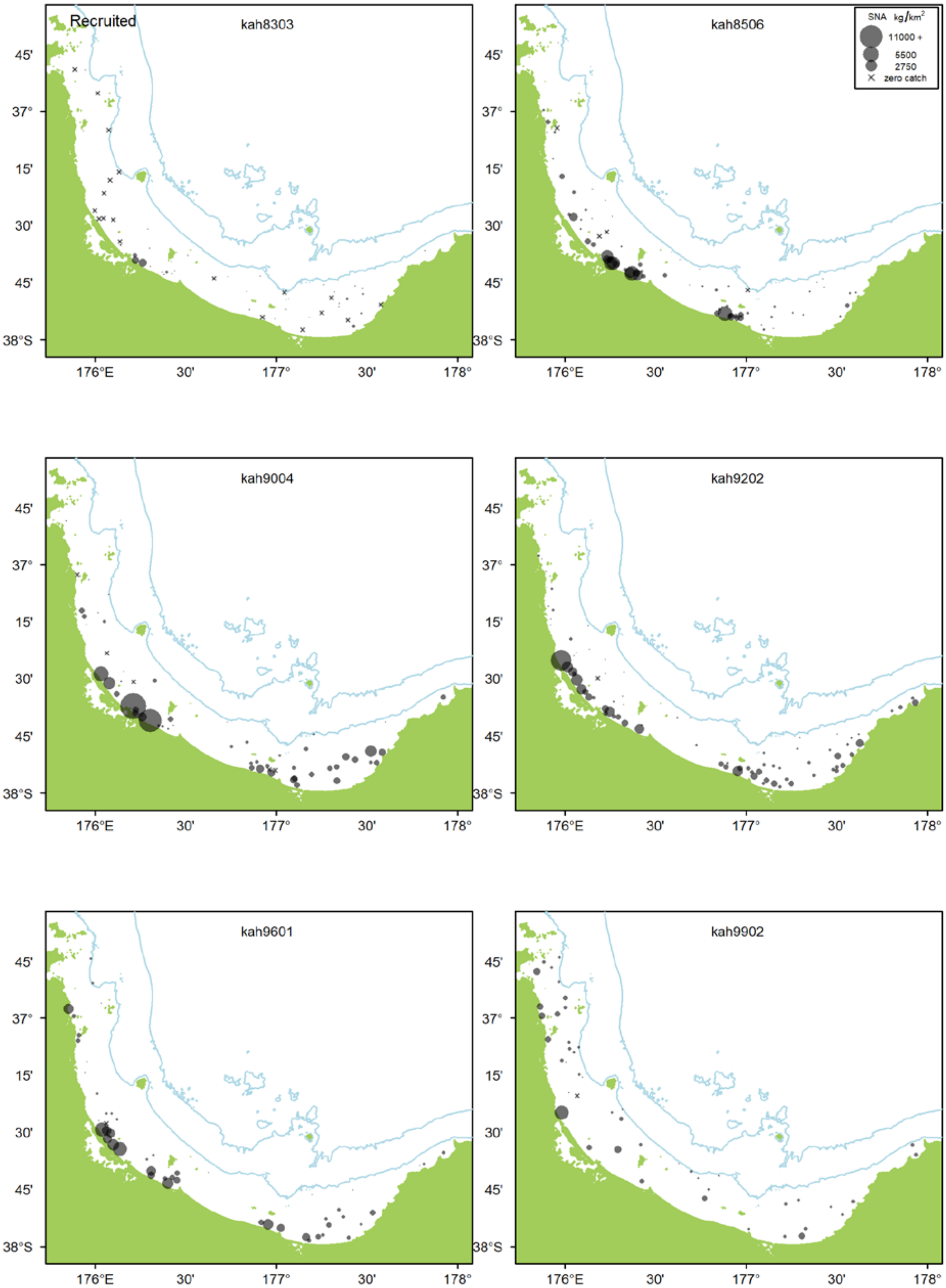
p: Leatherjacket (LEA), Bay of Plenty.



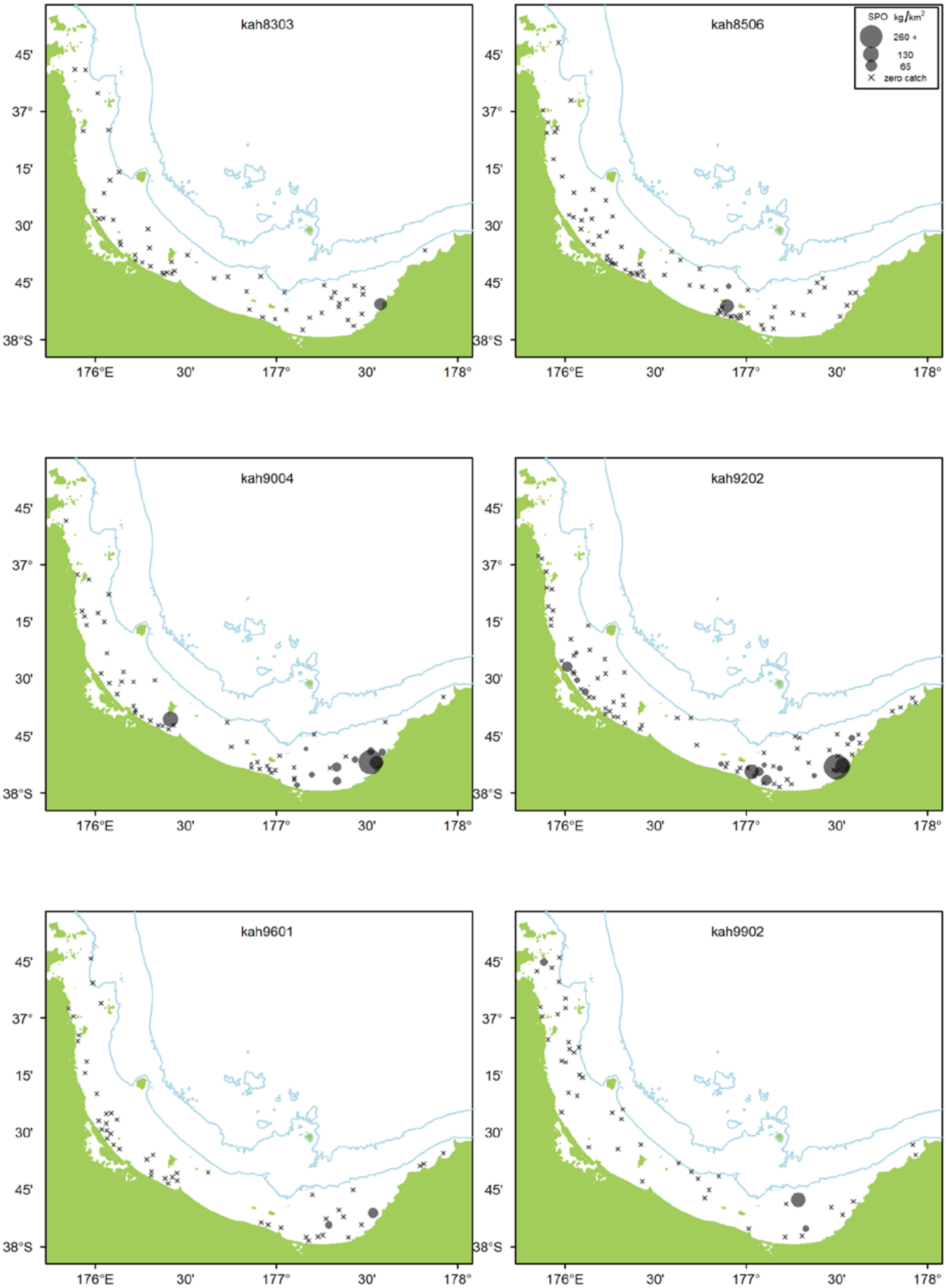
q: Tarakihi (NMP), Bay of Plenty.



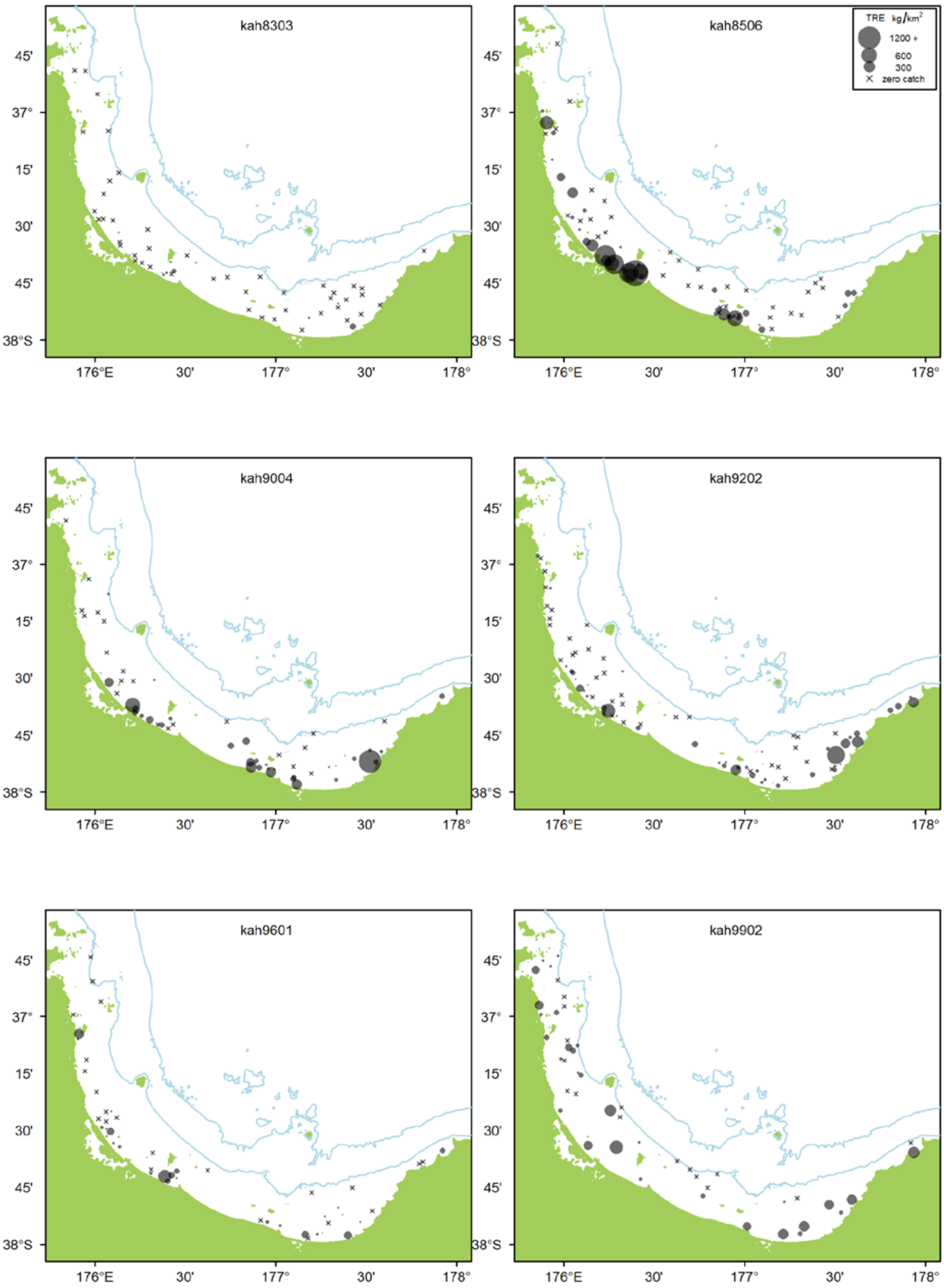
r: Pre-recruit snapper (SNA), Bay of Plenty.



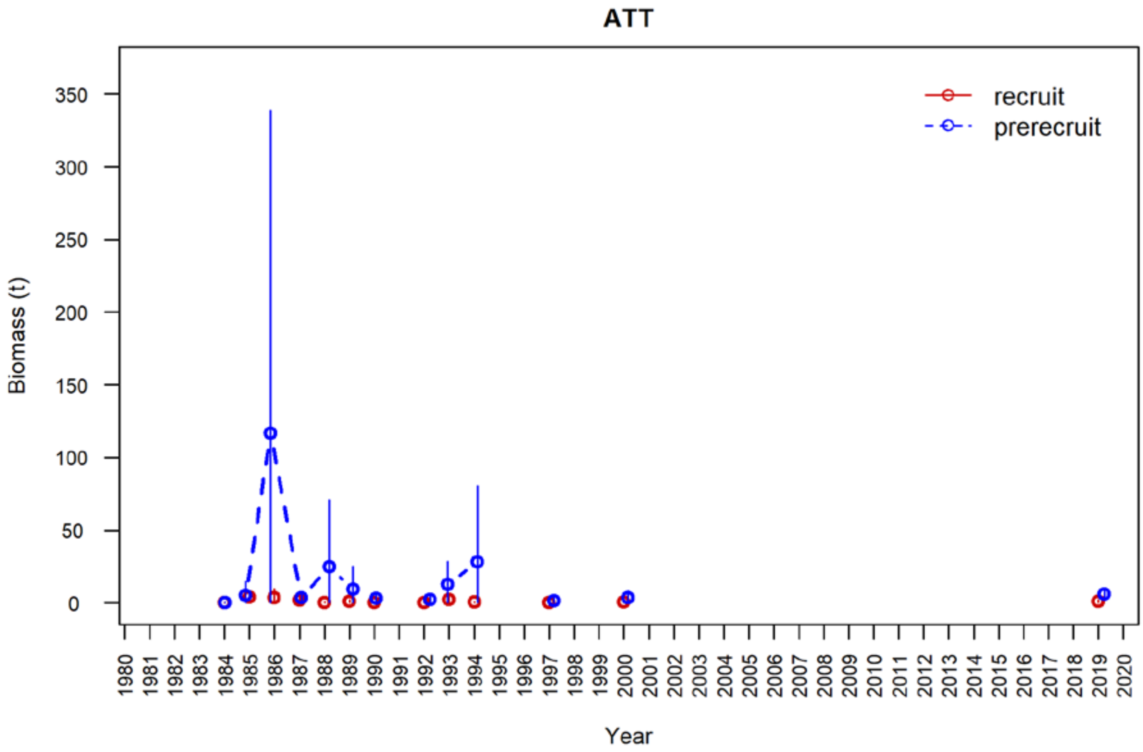
s: Recruited snapper (SNA), Bay of Plenty.

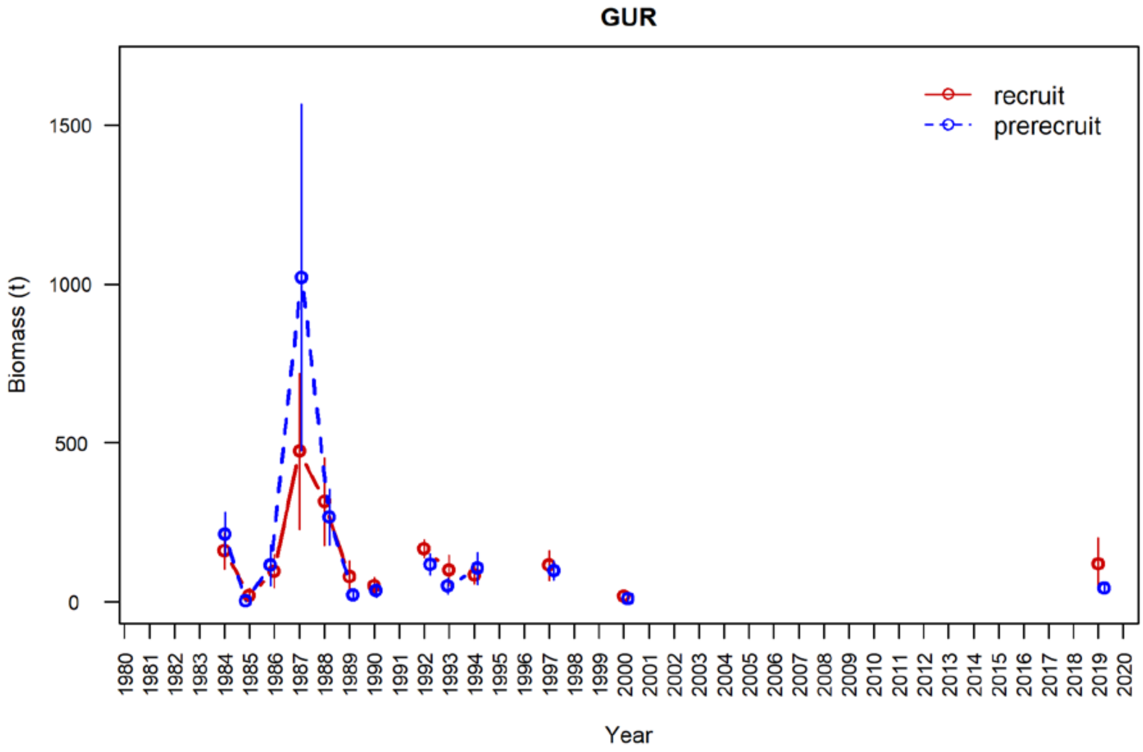


t: Rig (SPO), Bay of Plenty.



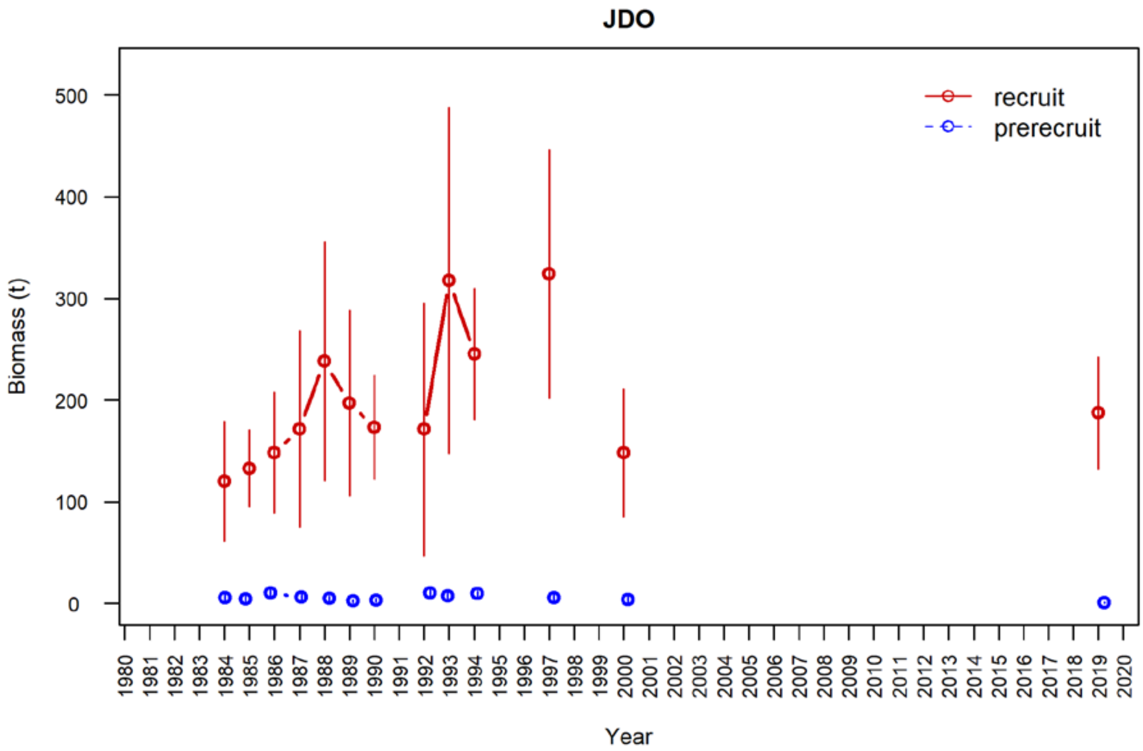
u: Trevally (TRE), Bay of Plenty.





a: Hauraki Gulf.

Figure 4: Biomass trends with 95% confidence intervals for pre-recruit (dashed blue line) and recruited (solid red line) fish for the most common QMS species (all sexes combined) for all Hauraki Gulf (a) and Bay of Plenty (b) surveys. For some species (JMN, LEA, and TRE in the Hauraki Gulf and FRO, JMN, and LEA in the Bay of Plenty) only overall biomass is presented (solid black line just for those plots) as historic length measurements were not available. Recruited lengths, see Table 5.



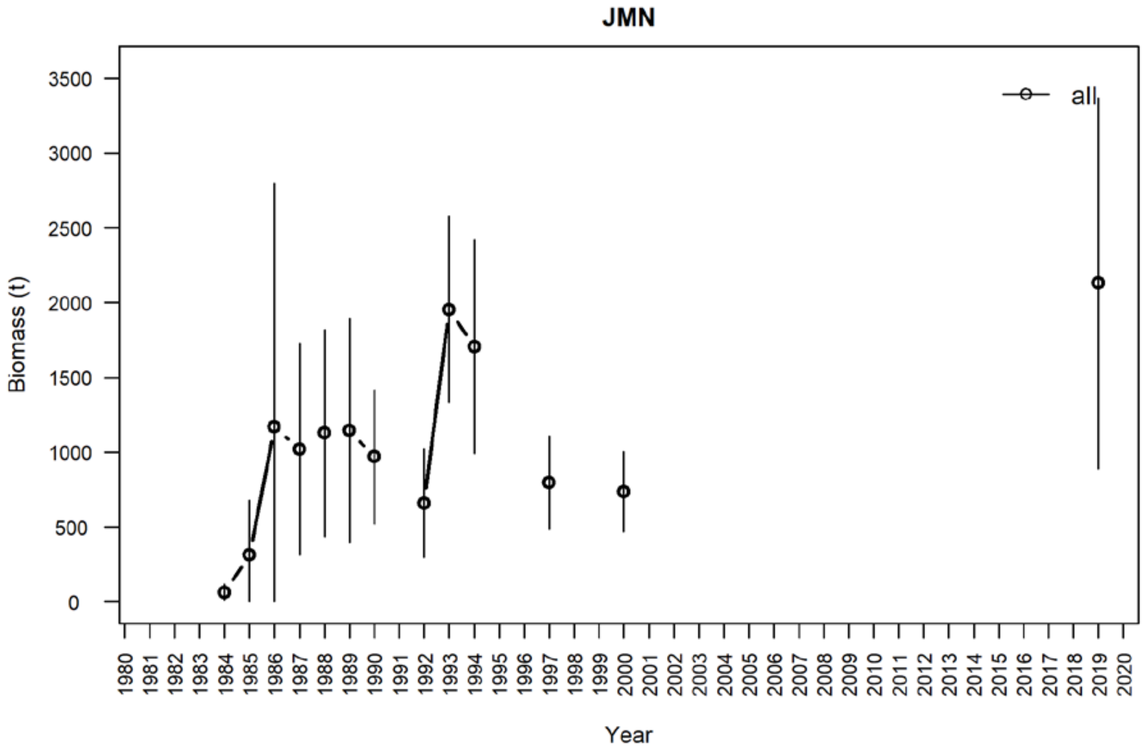
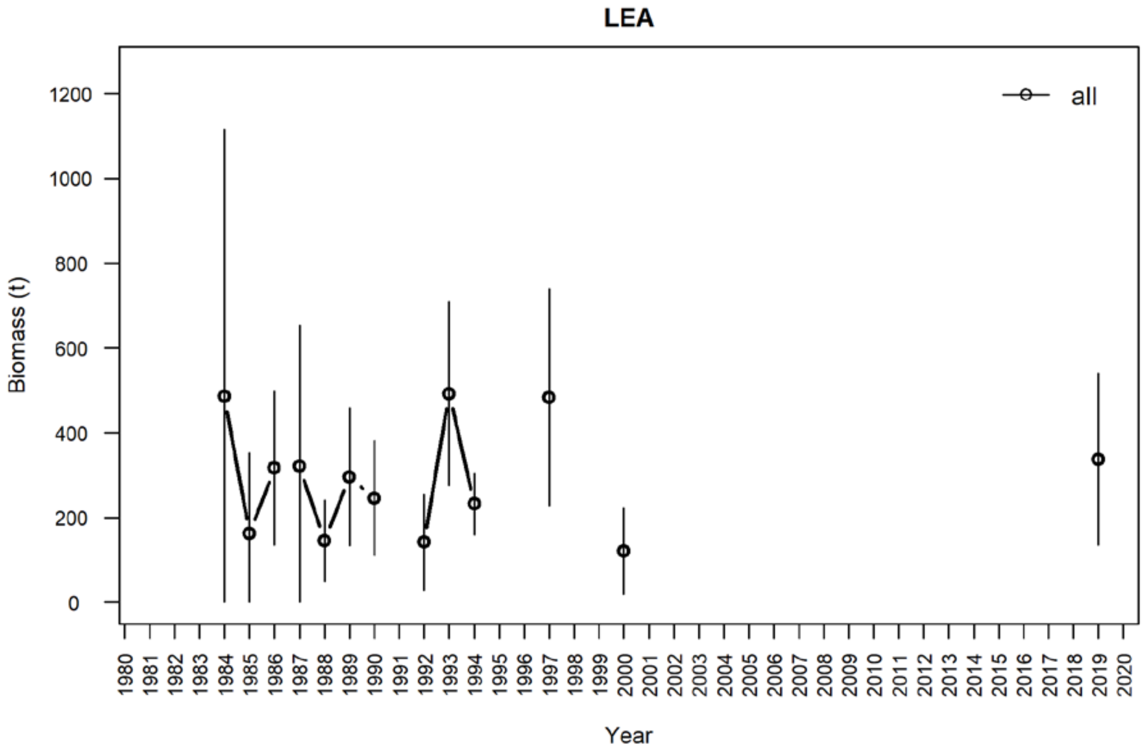


Figure 4a: Hauraki Gulf—continued.



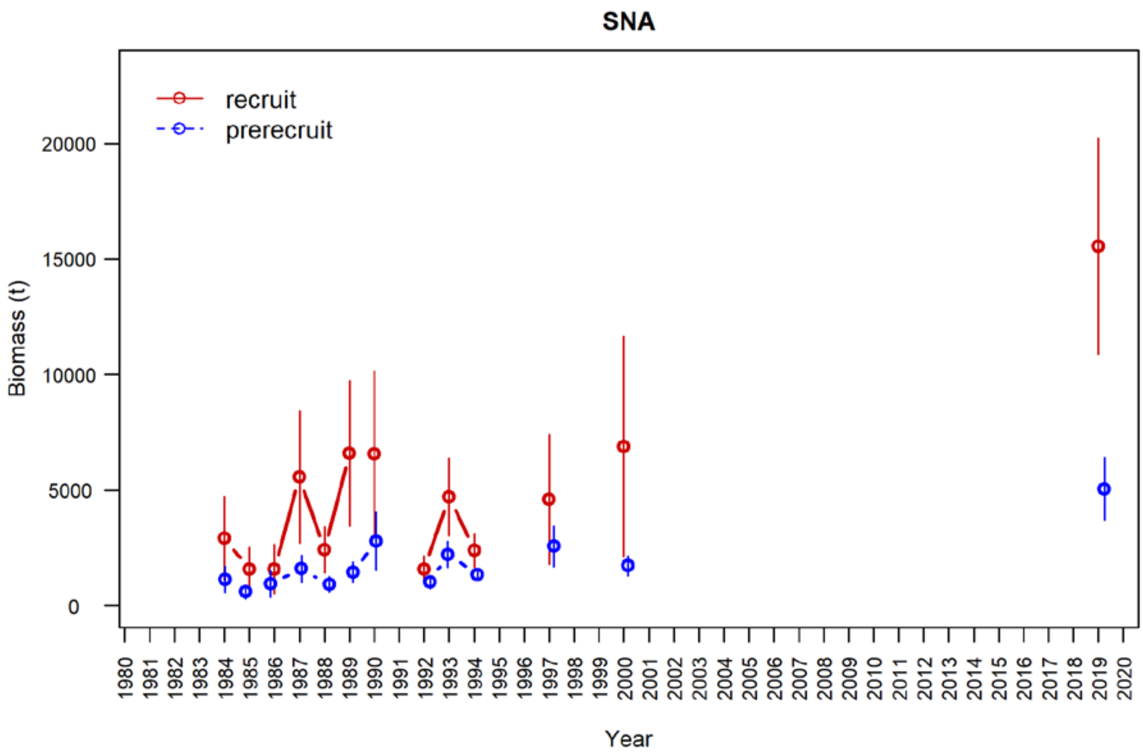
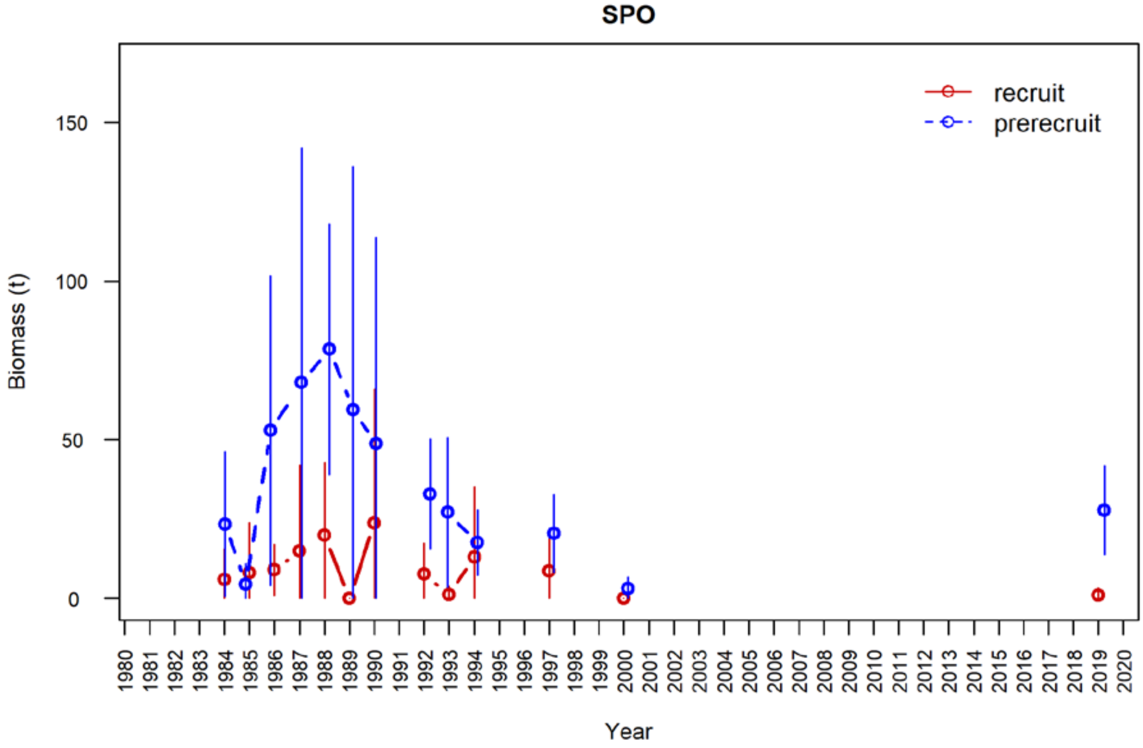


Figure 4a: Hauraki Gulf—continued.



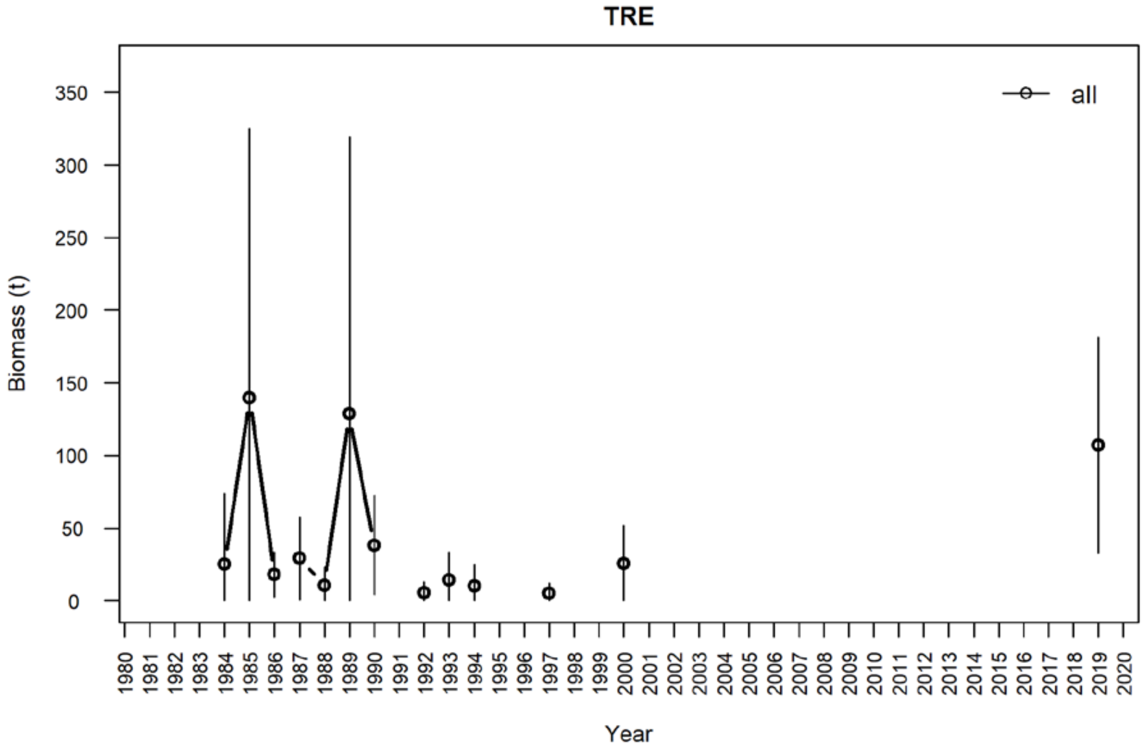
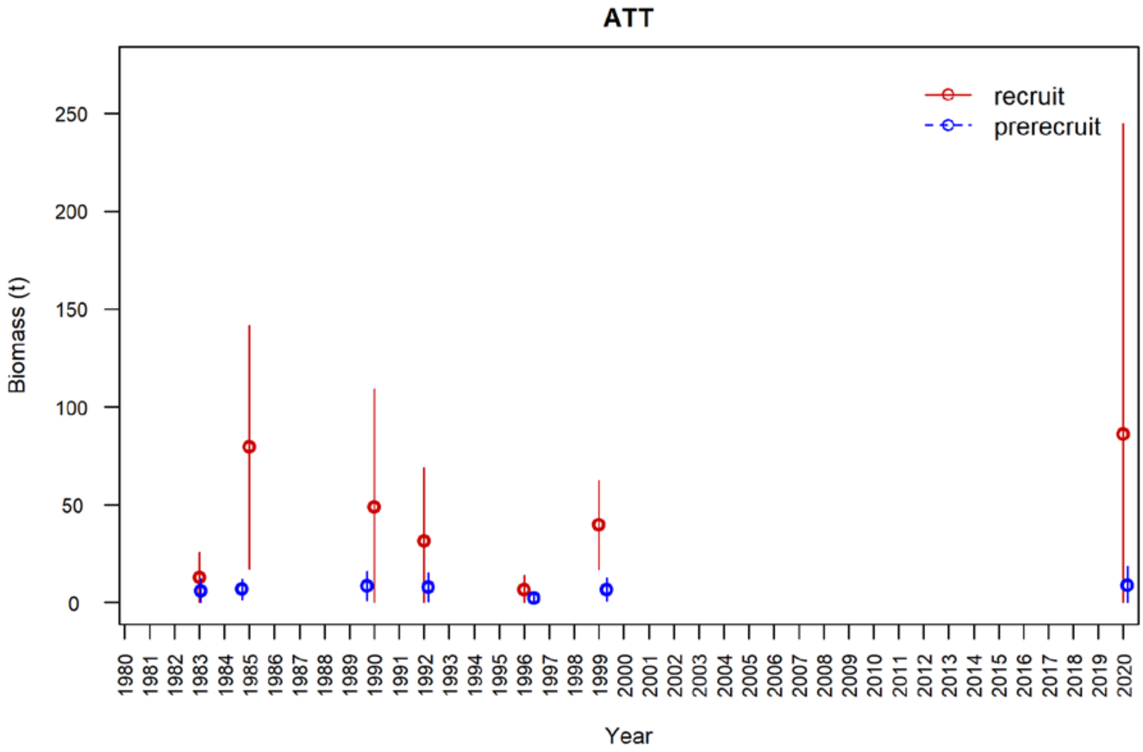


Figure 4a: Hauraki Gulf—continued.



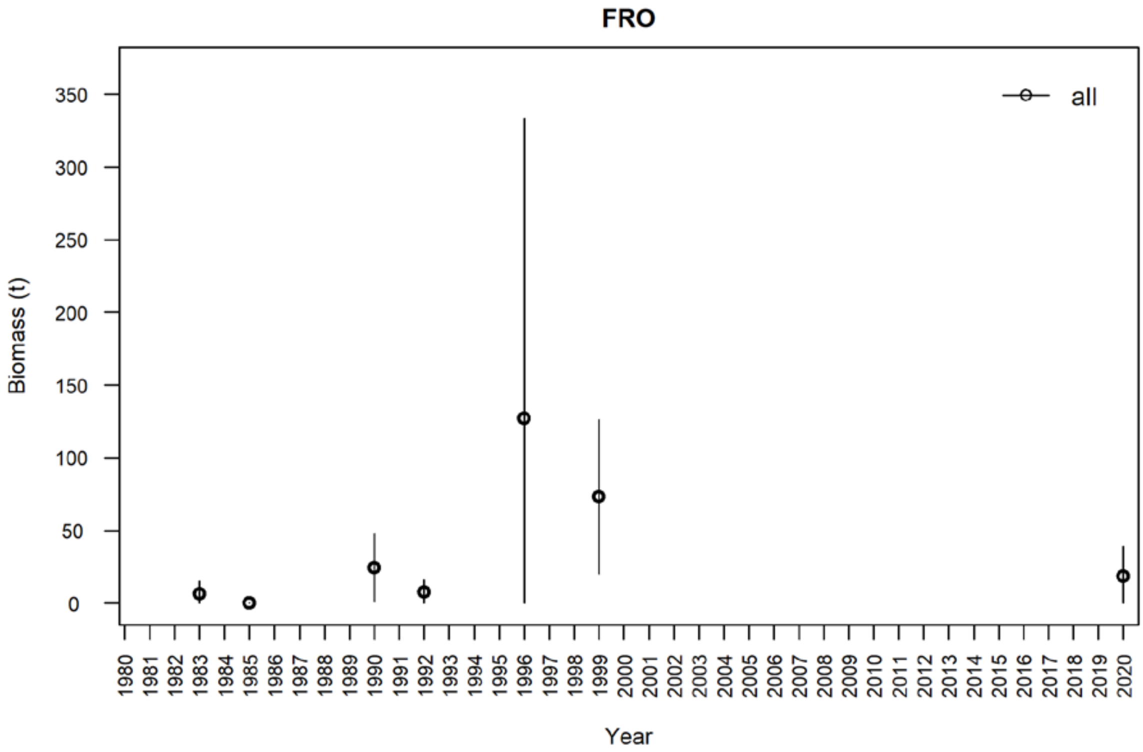
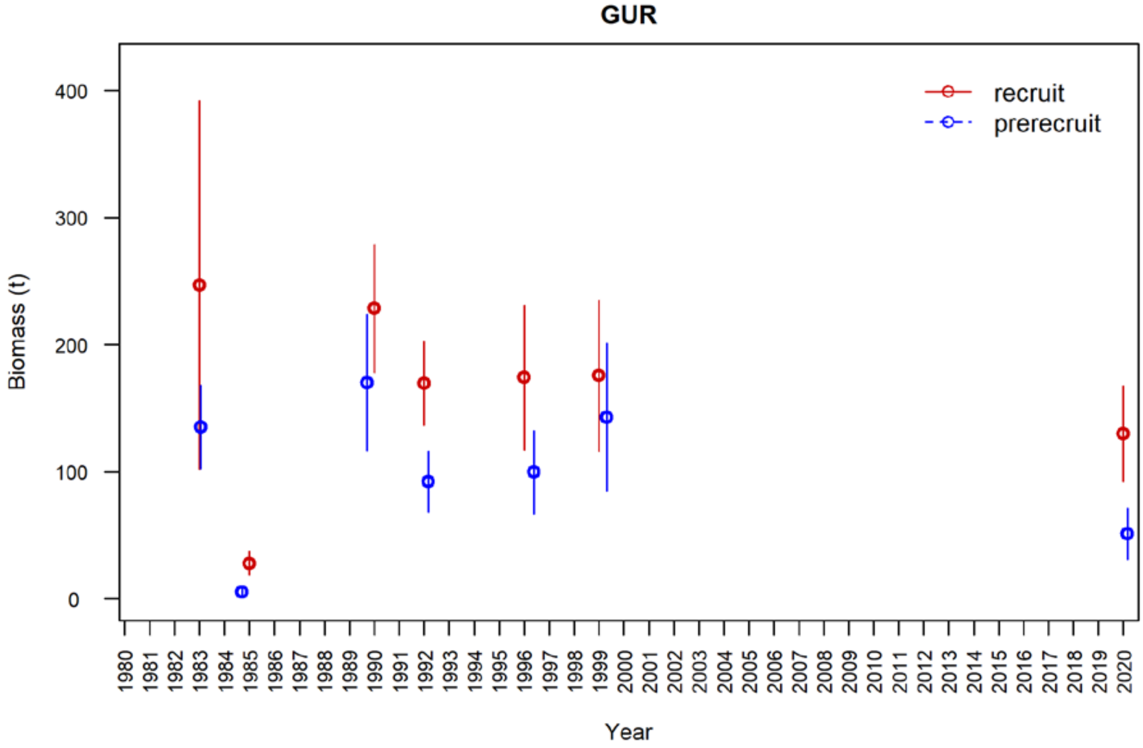


Figure 4b: Bay of Plenty.



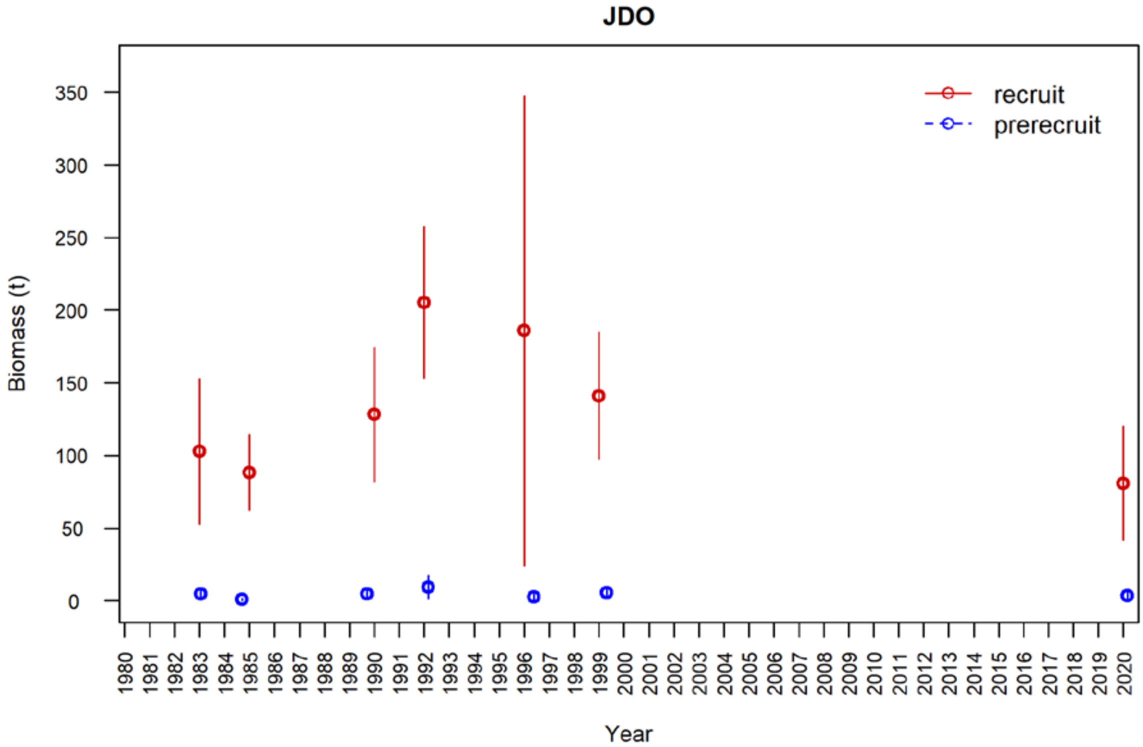


Figure 4b: Bay of Plenty—continued.

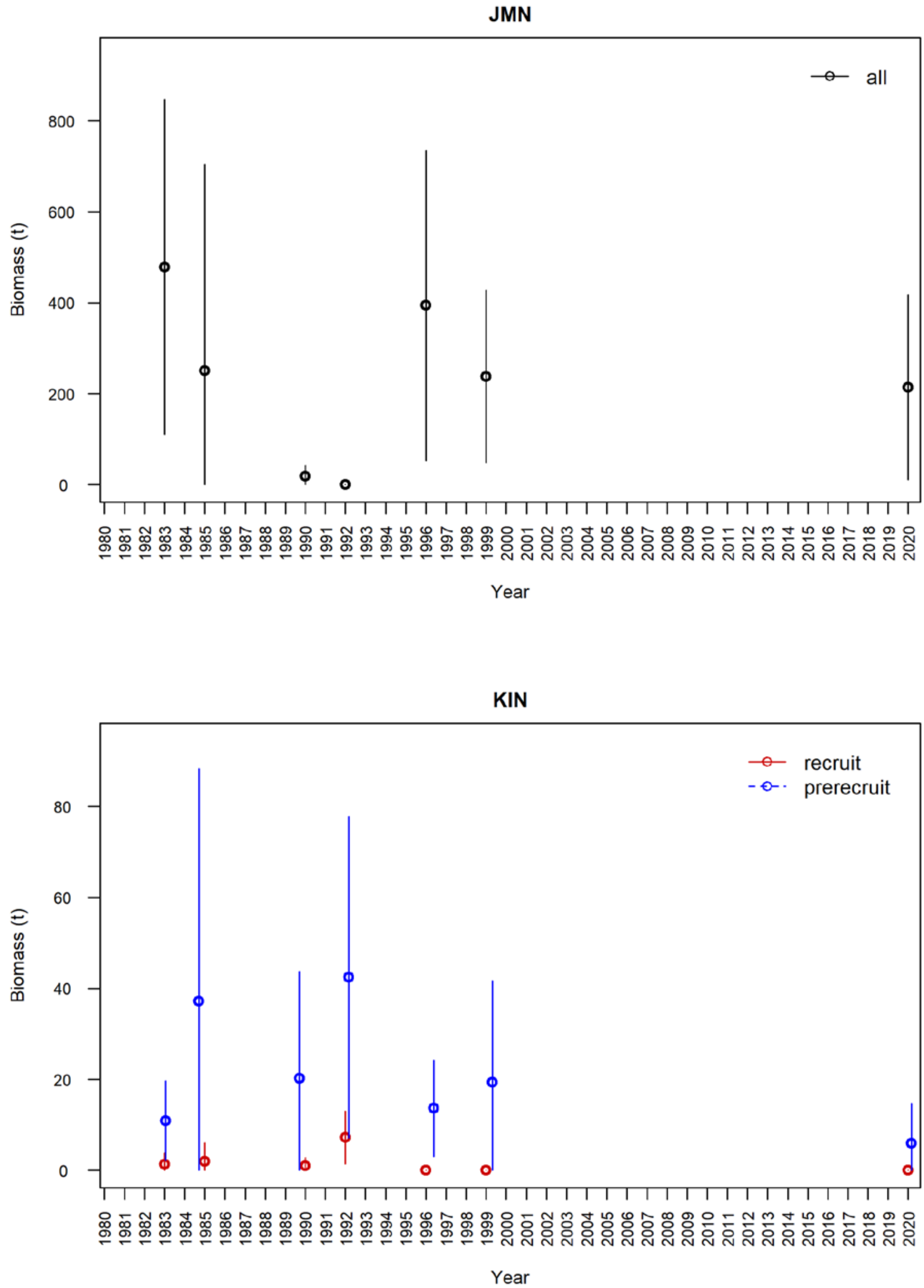
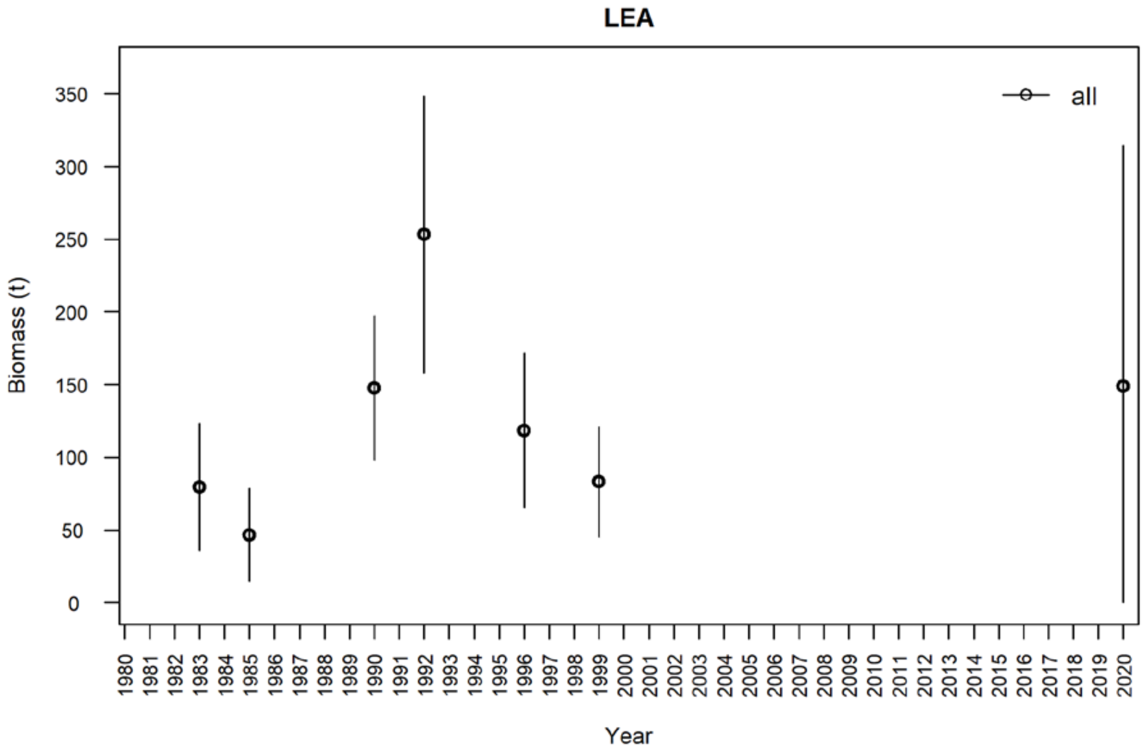


Figure 4b: Bay of Plenty—continued.



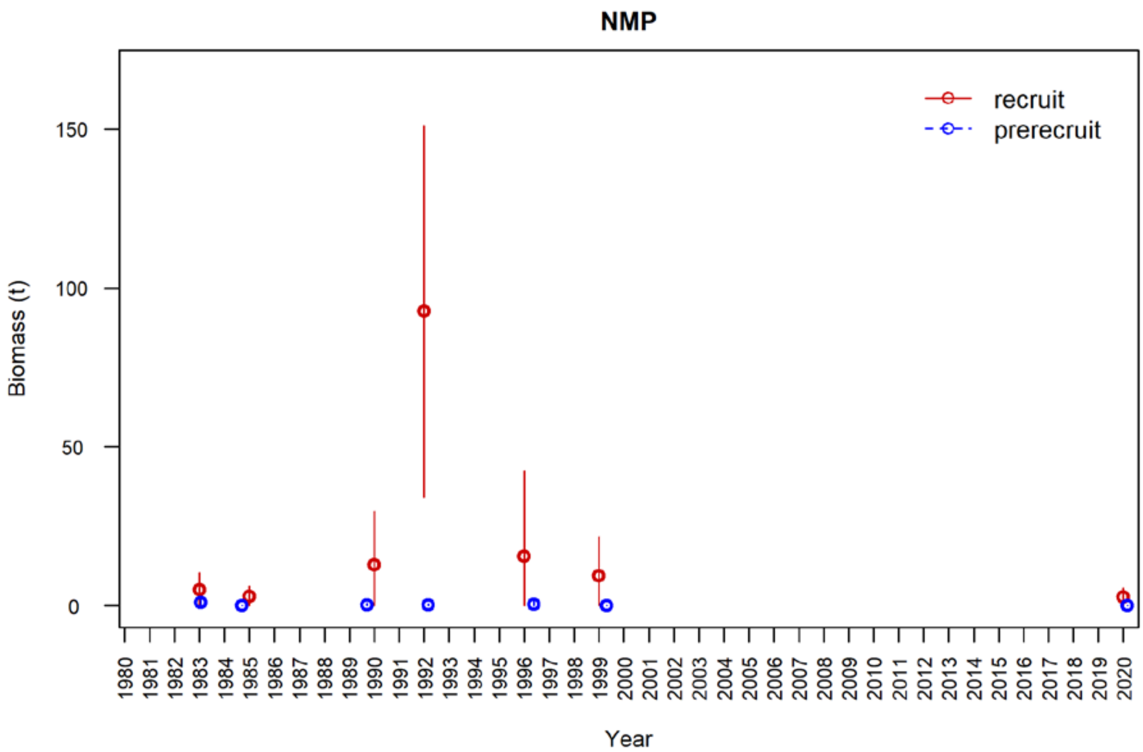
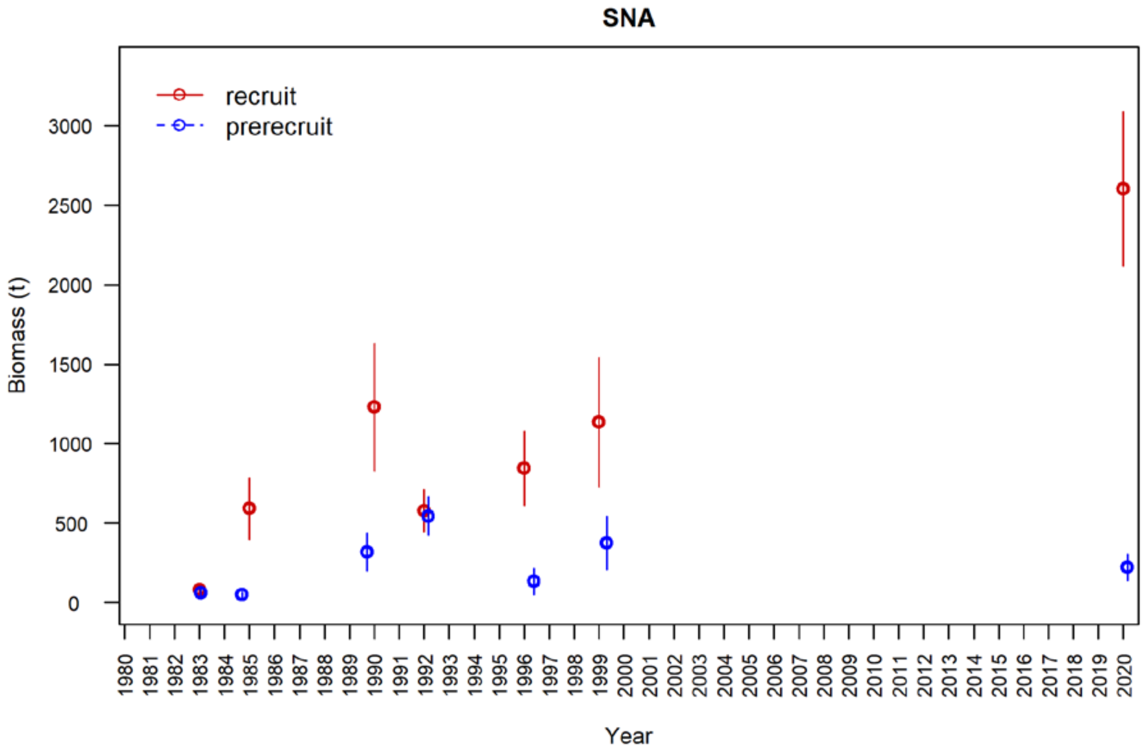


Figure 4b: Bay of Plenty—continued.



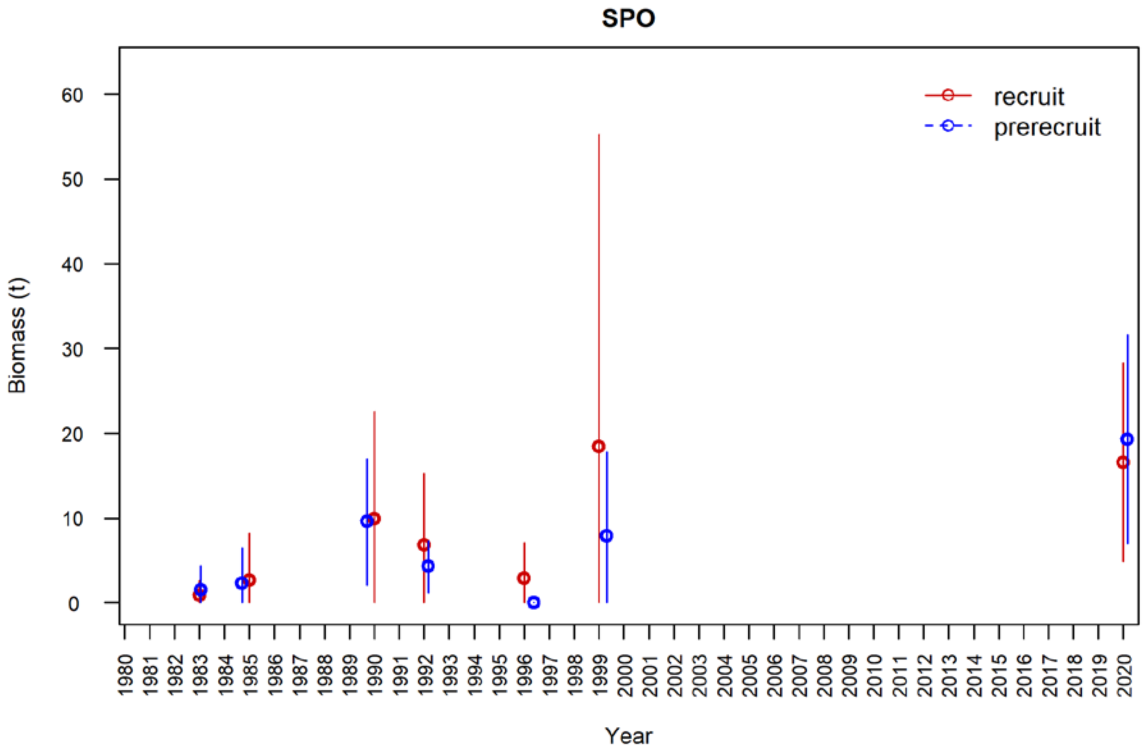


Figure 4b: Bay of Plenty—continued.

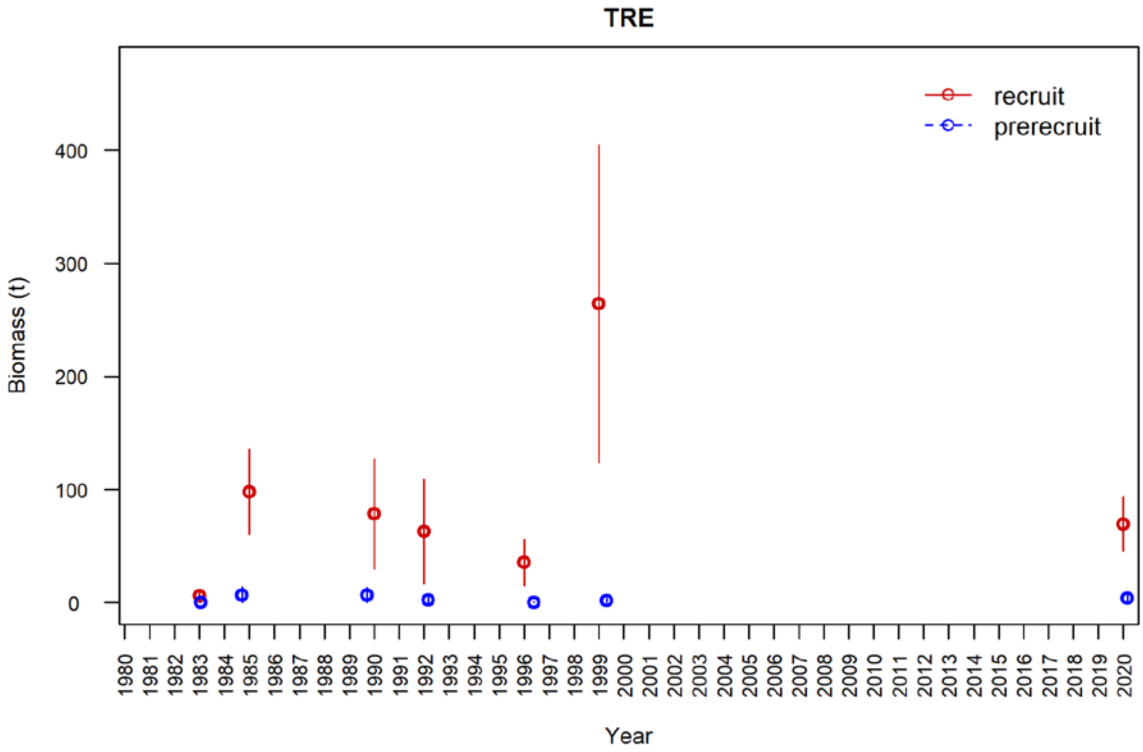
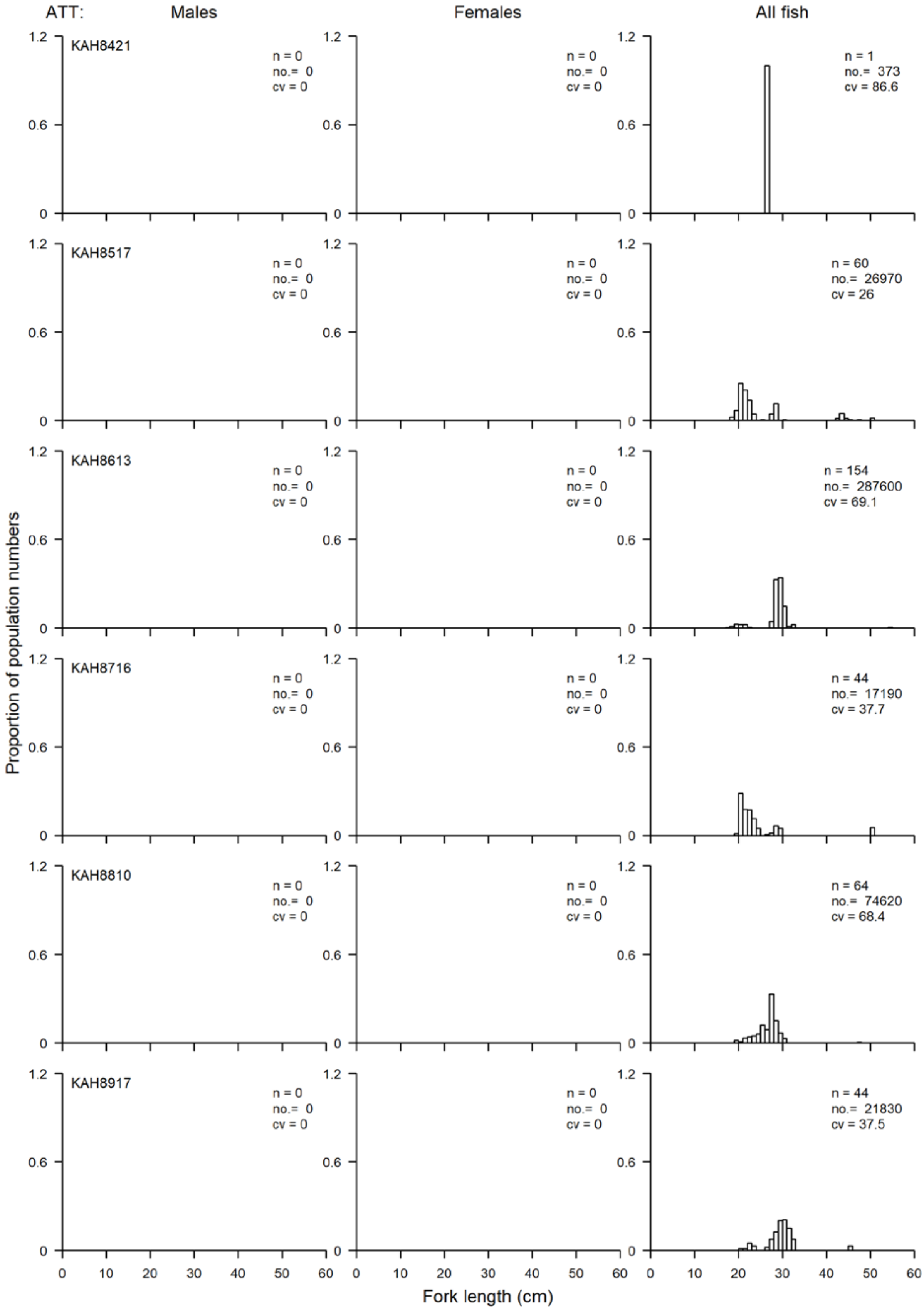


Figure 4b: Bay of Plenty—continued.



a) Kahawai.

Figure 5: Comparative scaled length frequency distributions for the most common QMS species in the Hauraki Gulf. n = number of fish measured, no. = scaled population number, cv = coefficient of variation. * = scaled population number inaccurate due to limited length sampling for that species and survey. 'All fish' includes any unsexed fish.

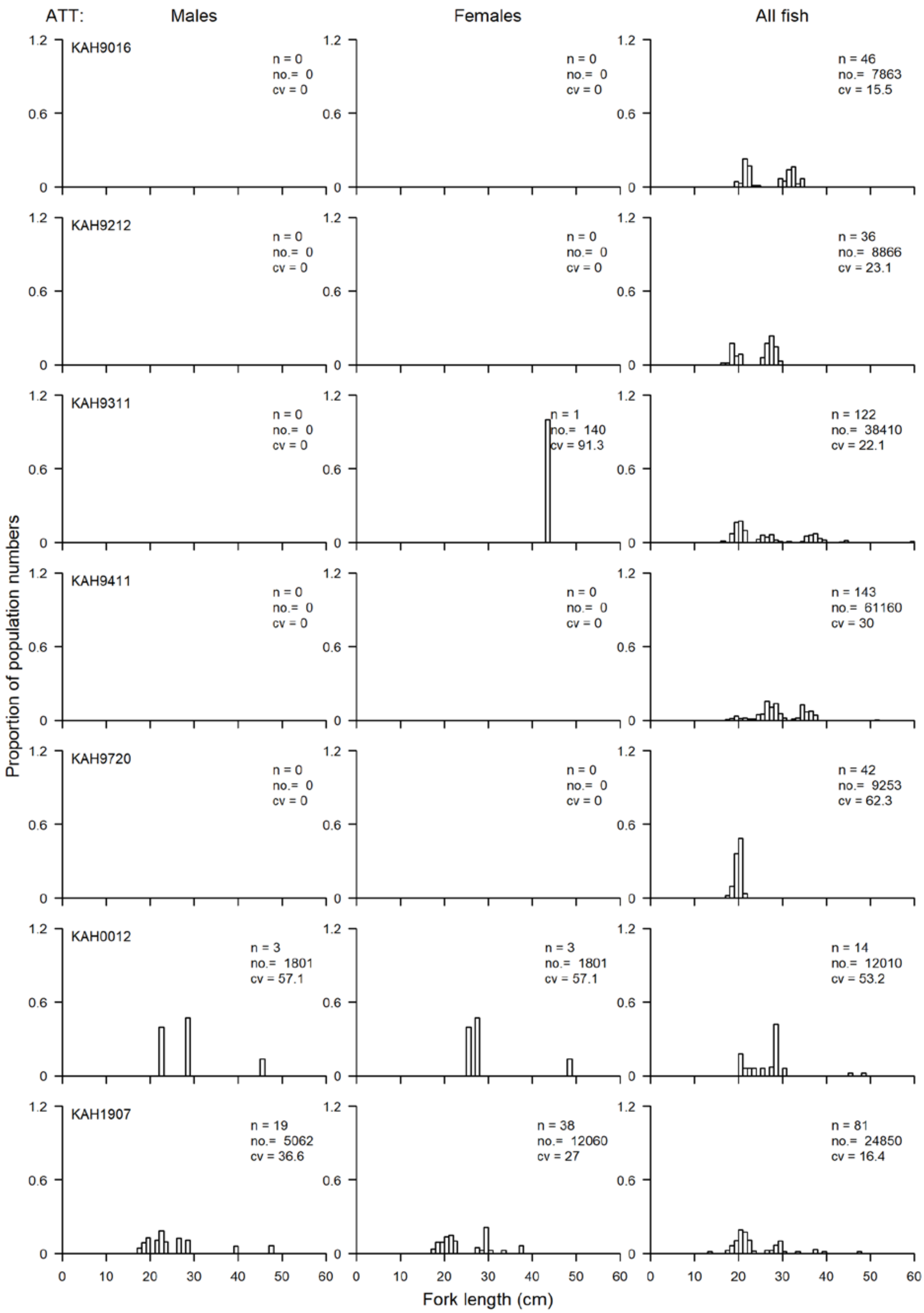


Figure 5a: – Kahawai continued.

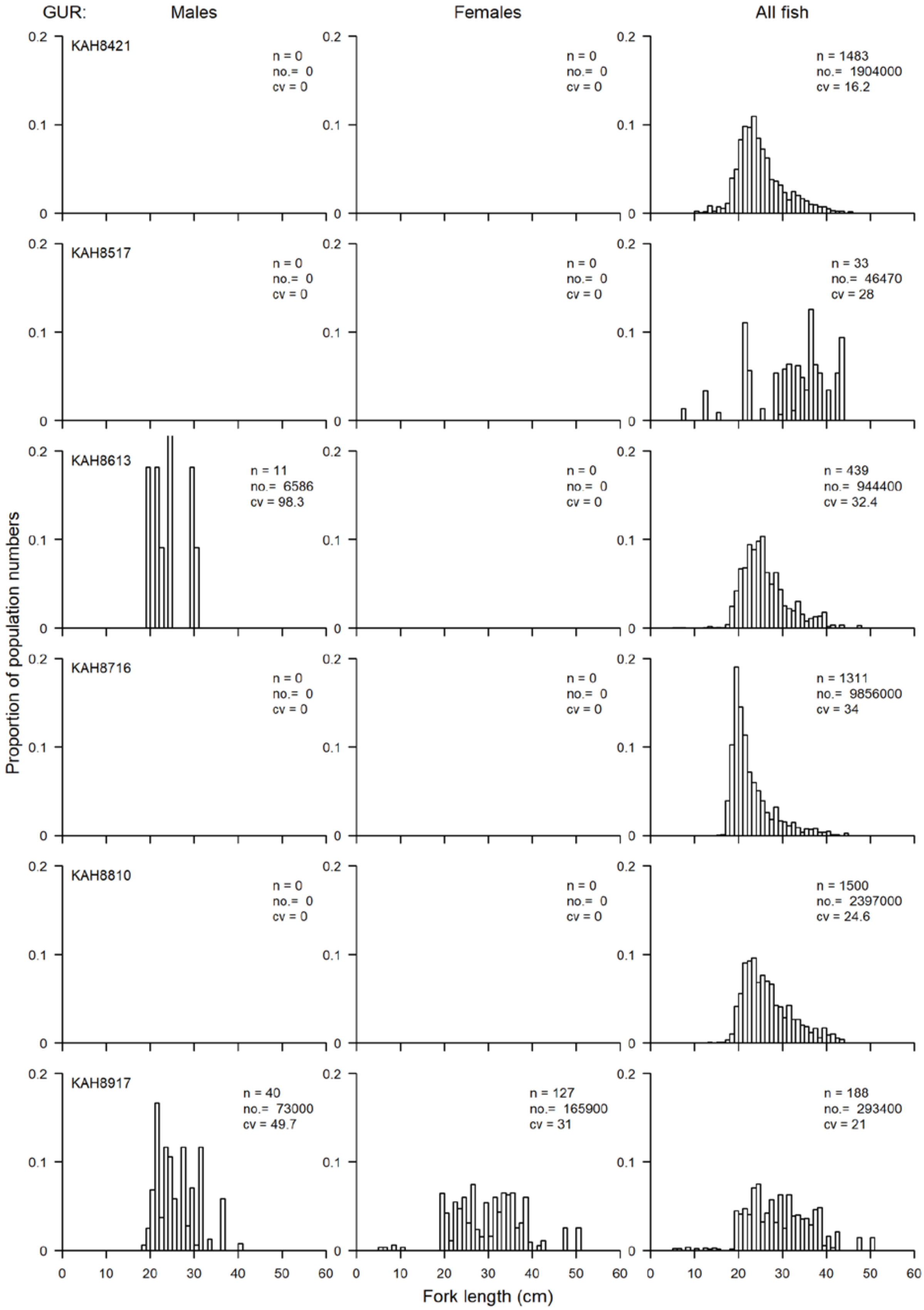


Figure 5b: Gurnard.

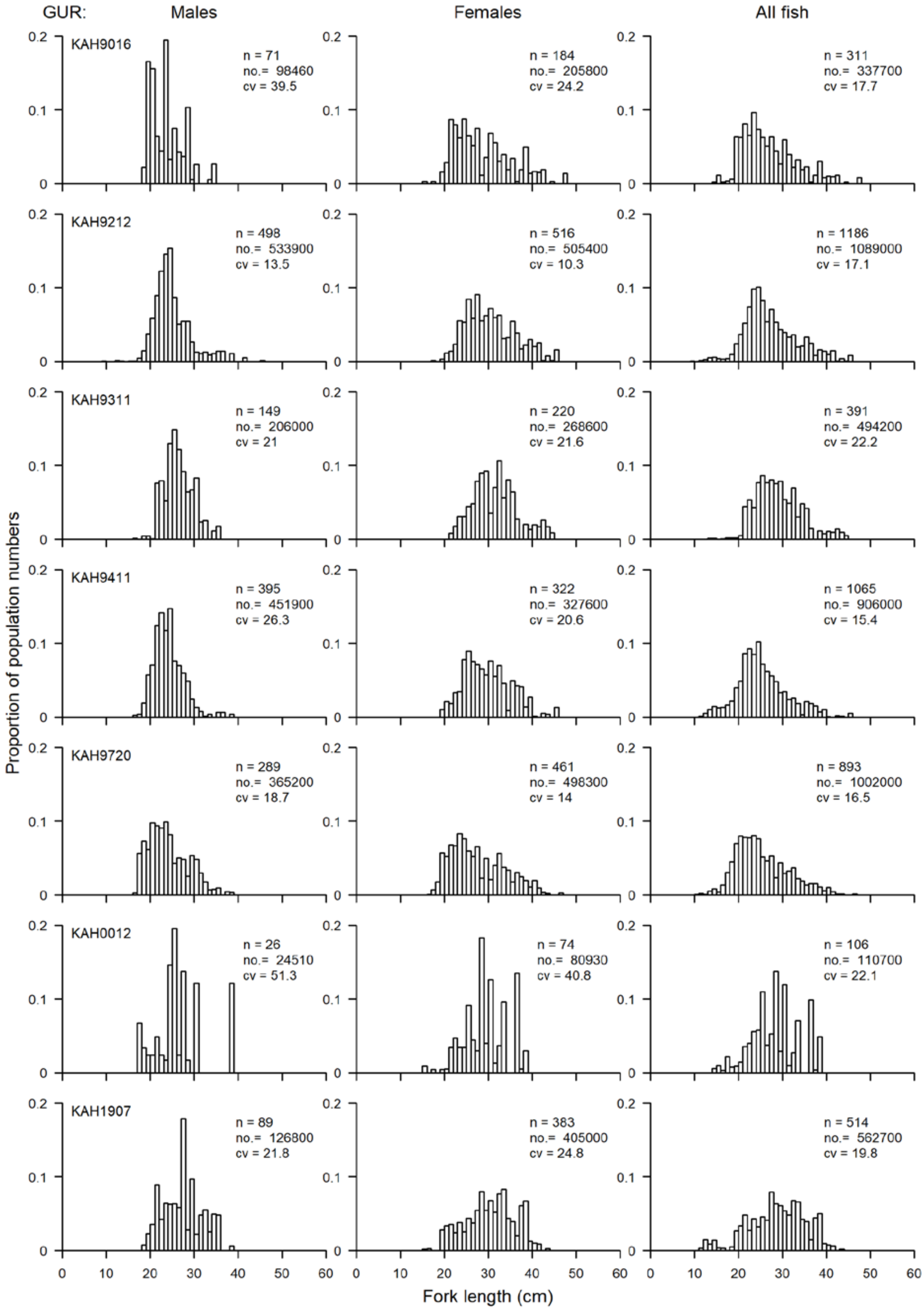


Figure 5b: – Gurnard continued.

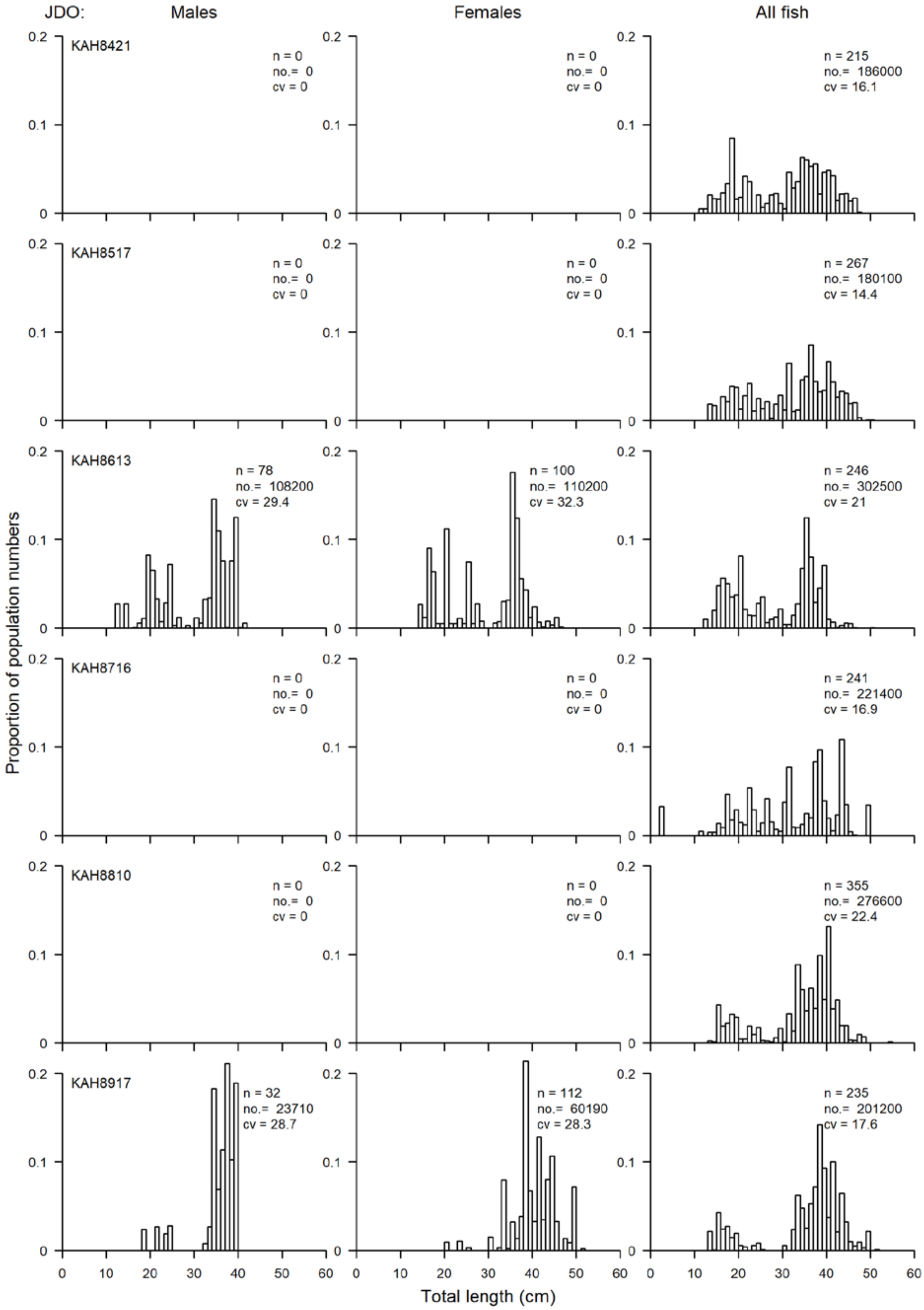


Figure 5c: John dory.

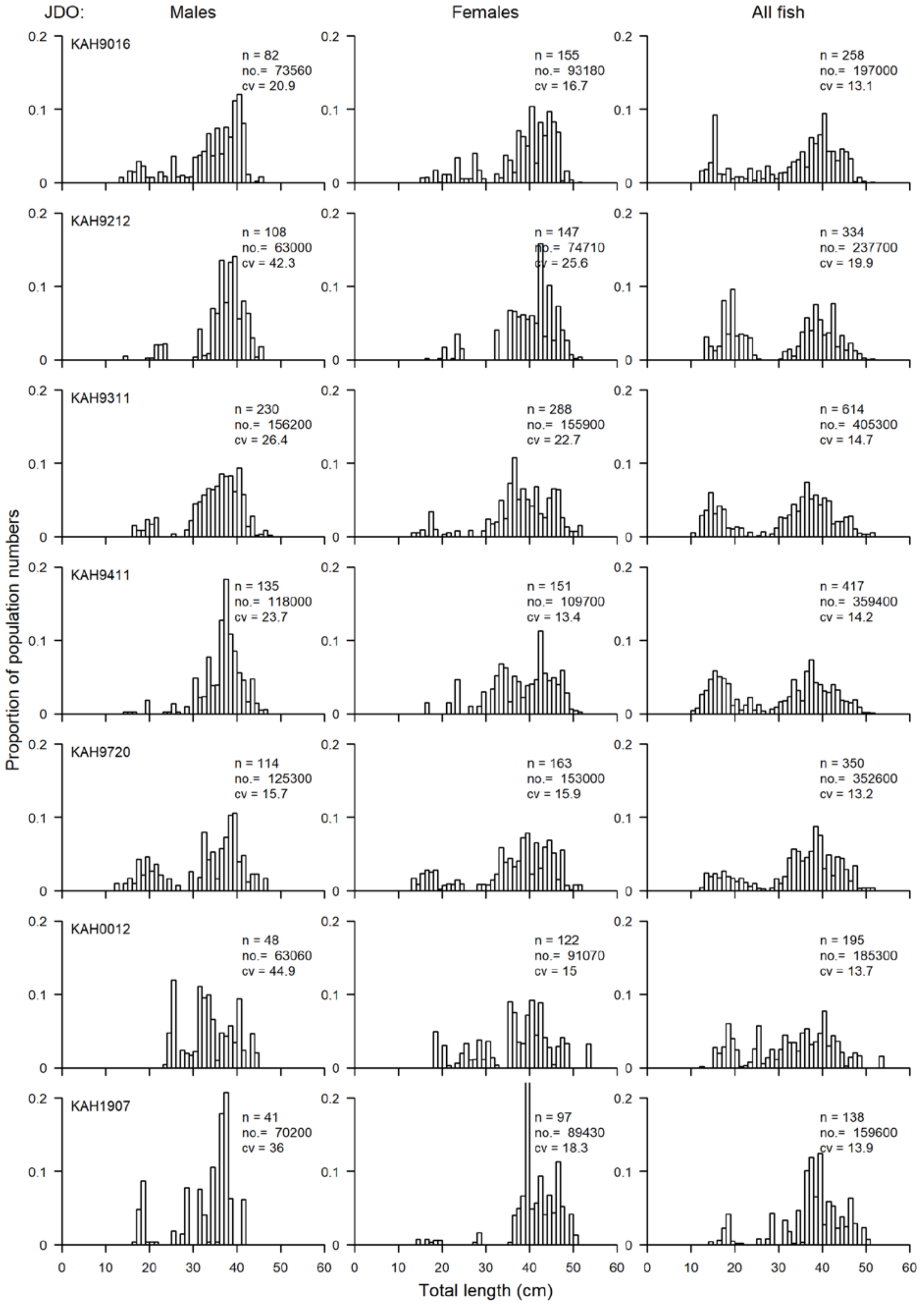


Figure 5c: – John dory continued.

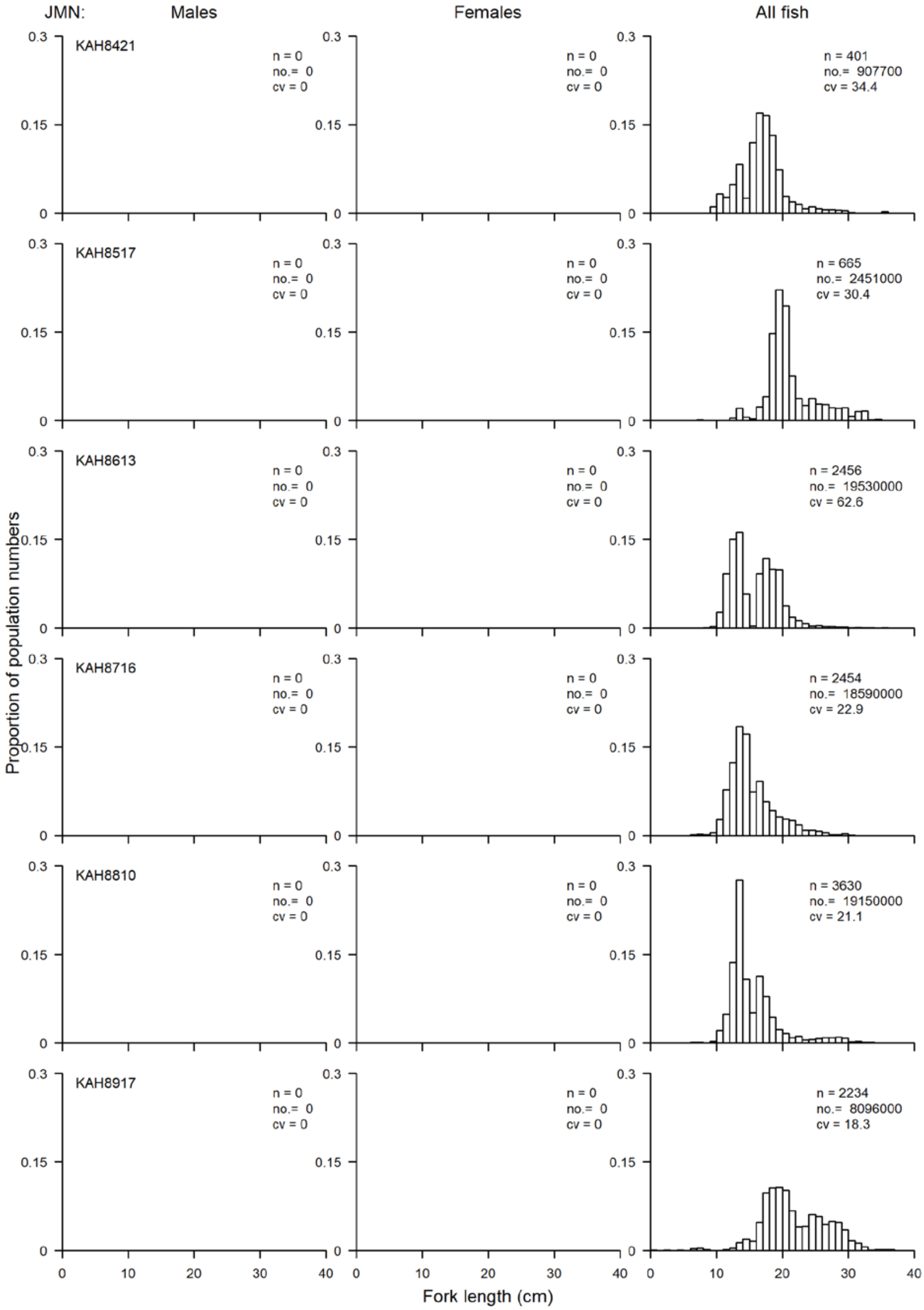


Figure 5d: Yellowtail jack mackerel.

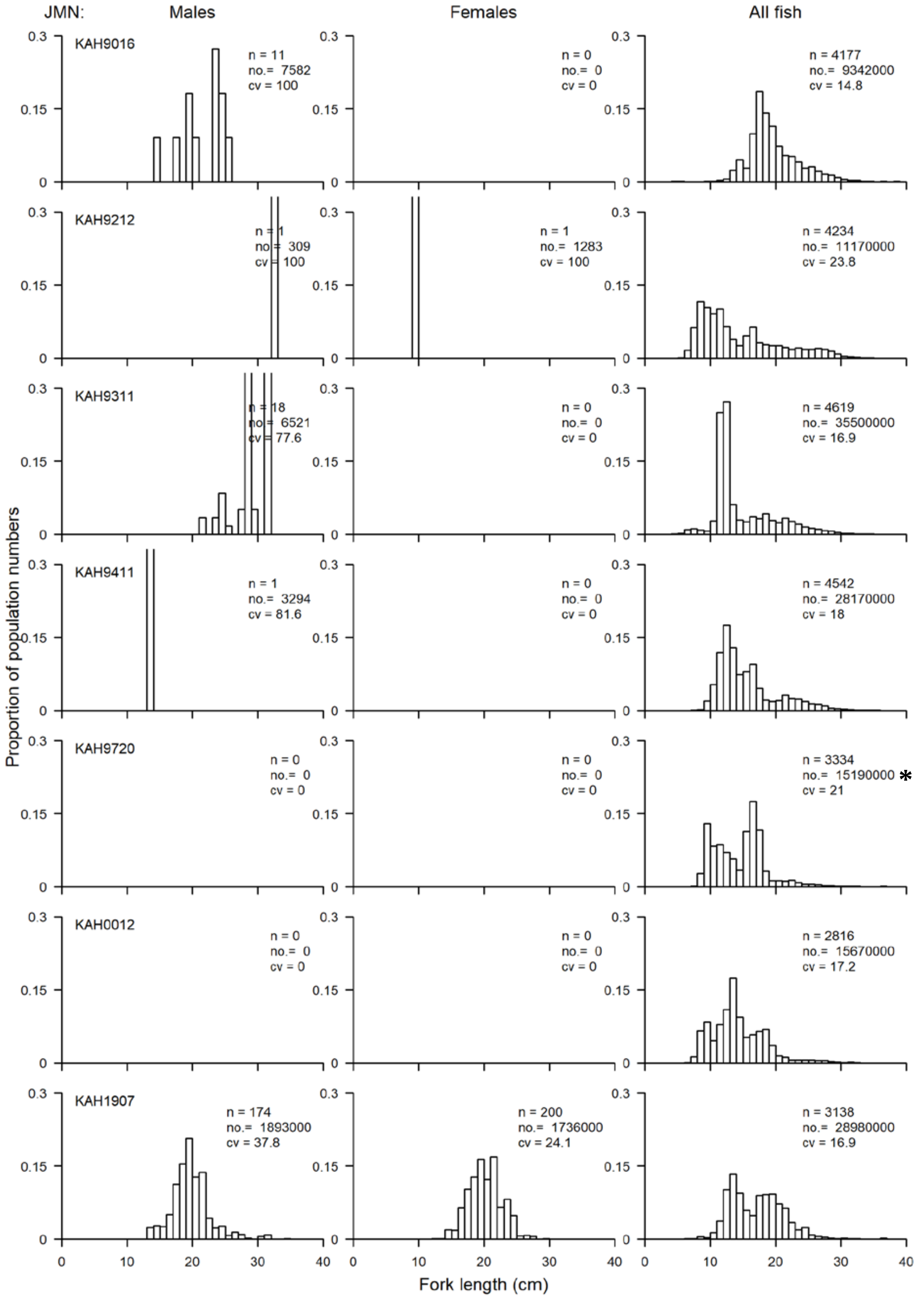


Figure 5d: – Yellowtail jack mackerel continued. * scaled population number inaccurate due to limited length sampling for the 1997 survey.

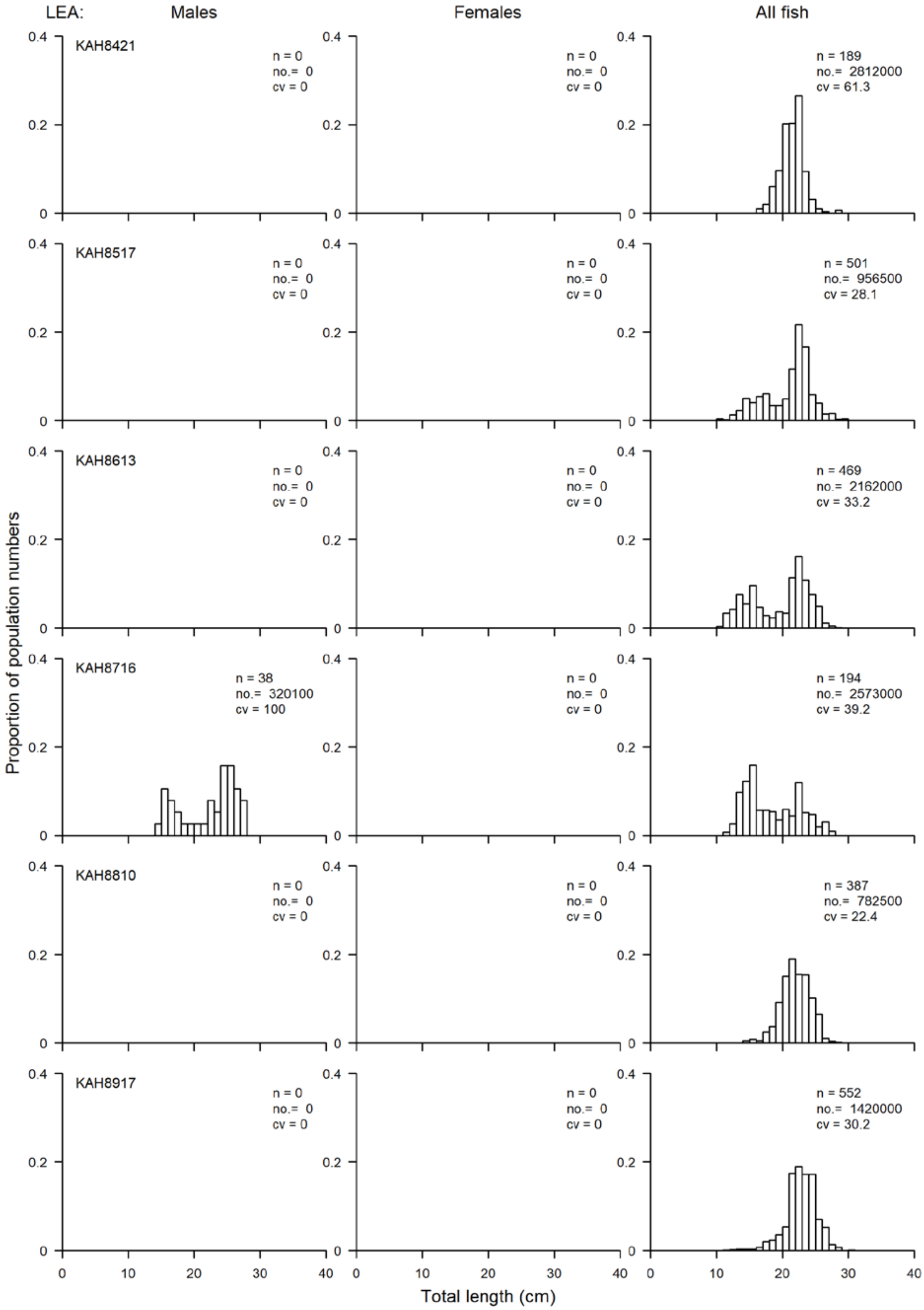


Figure 5e: Leatherjacket.

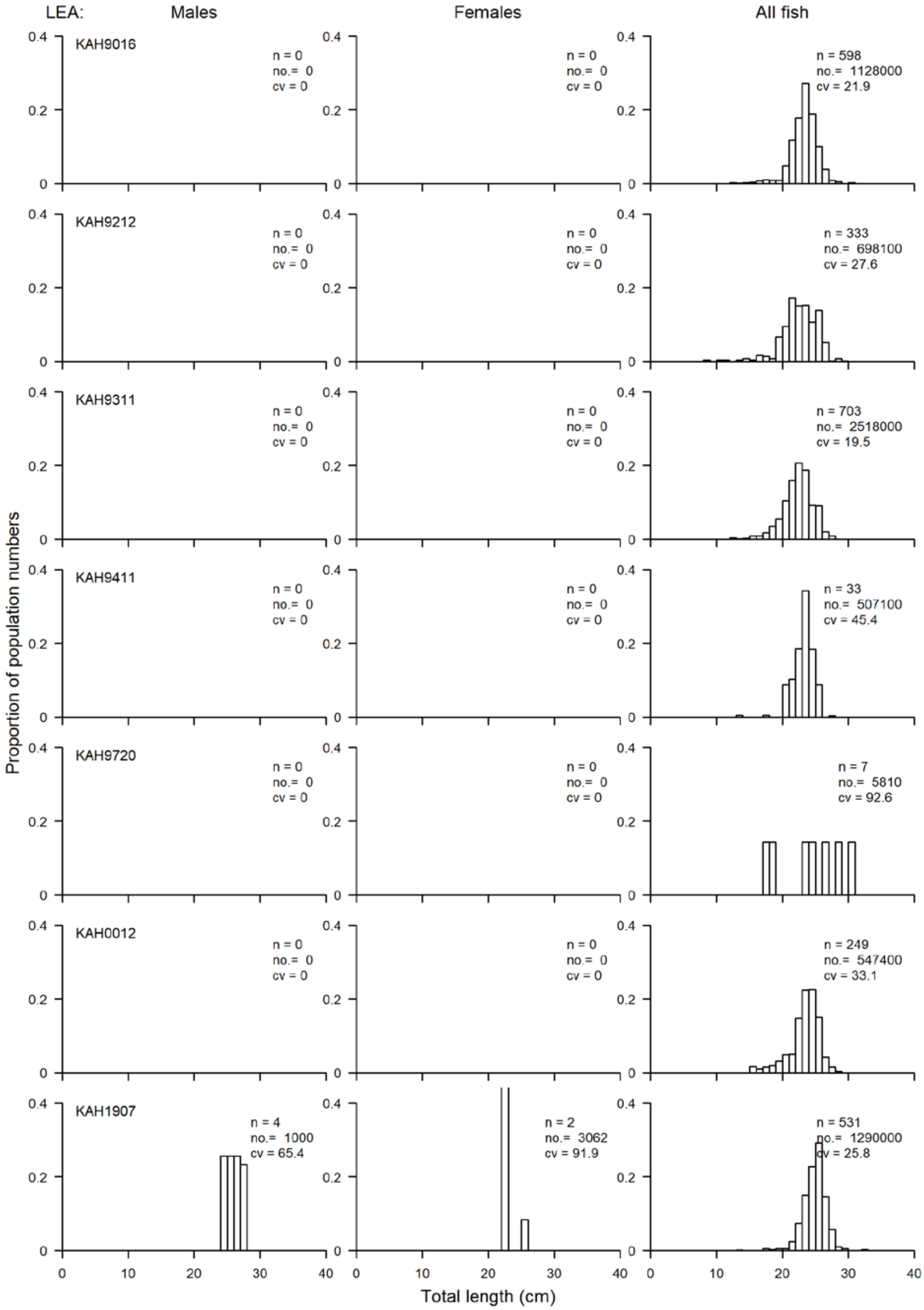


Figure 5e: – Leatherjacket continued.

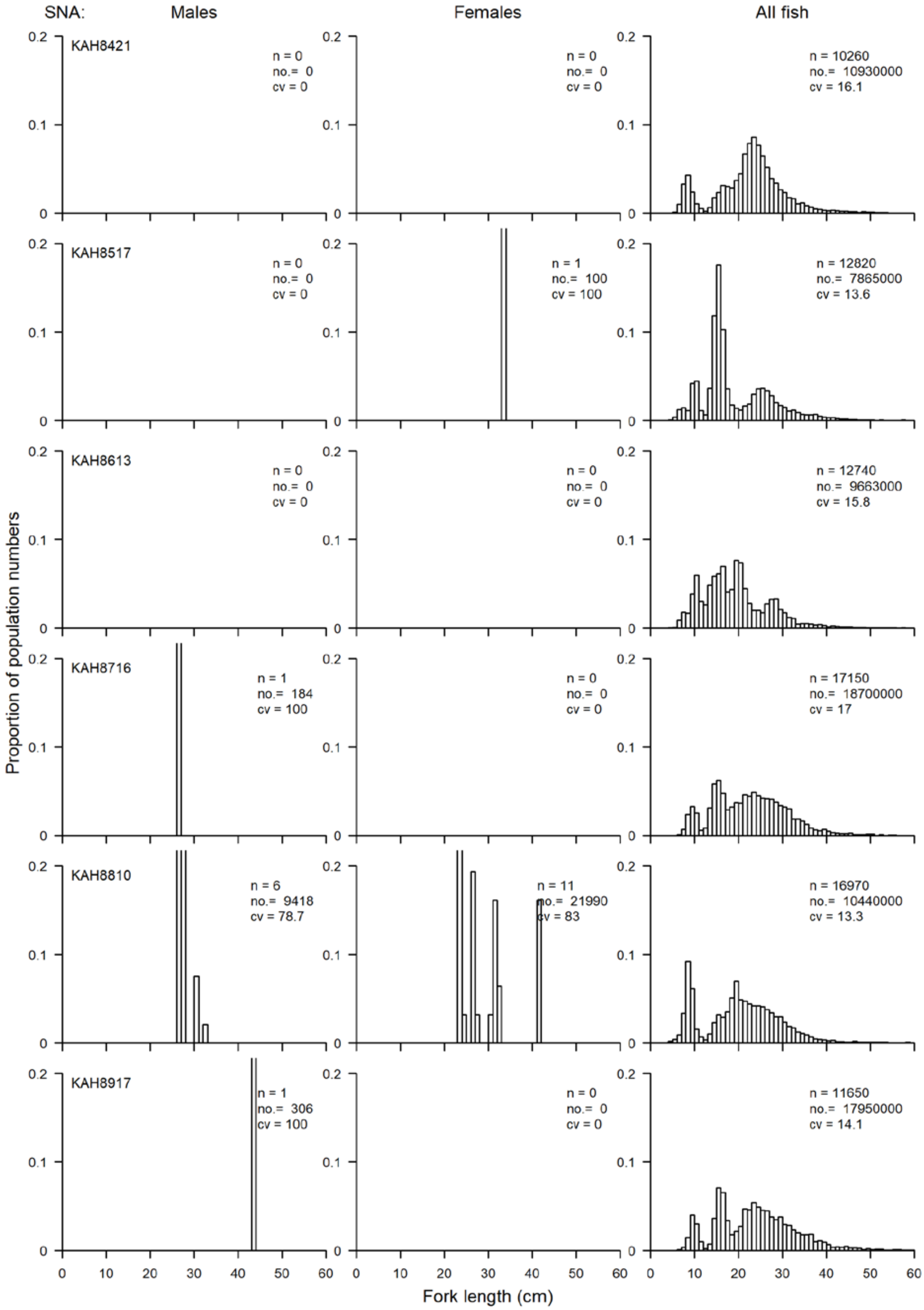


Figure 5f: Snapper.

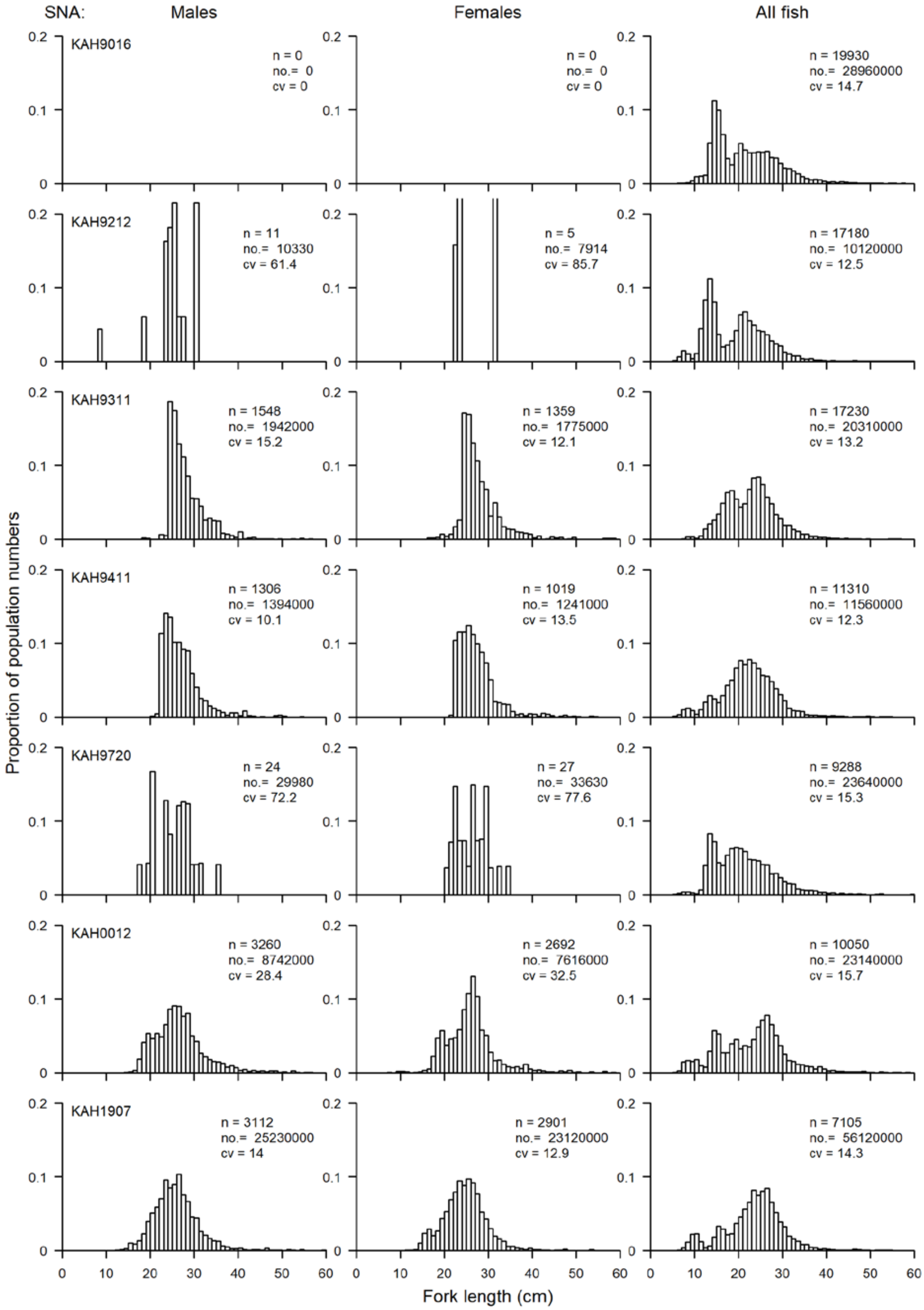


Figure 5f: – Snapper continued.

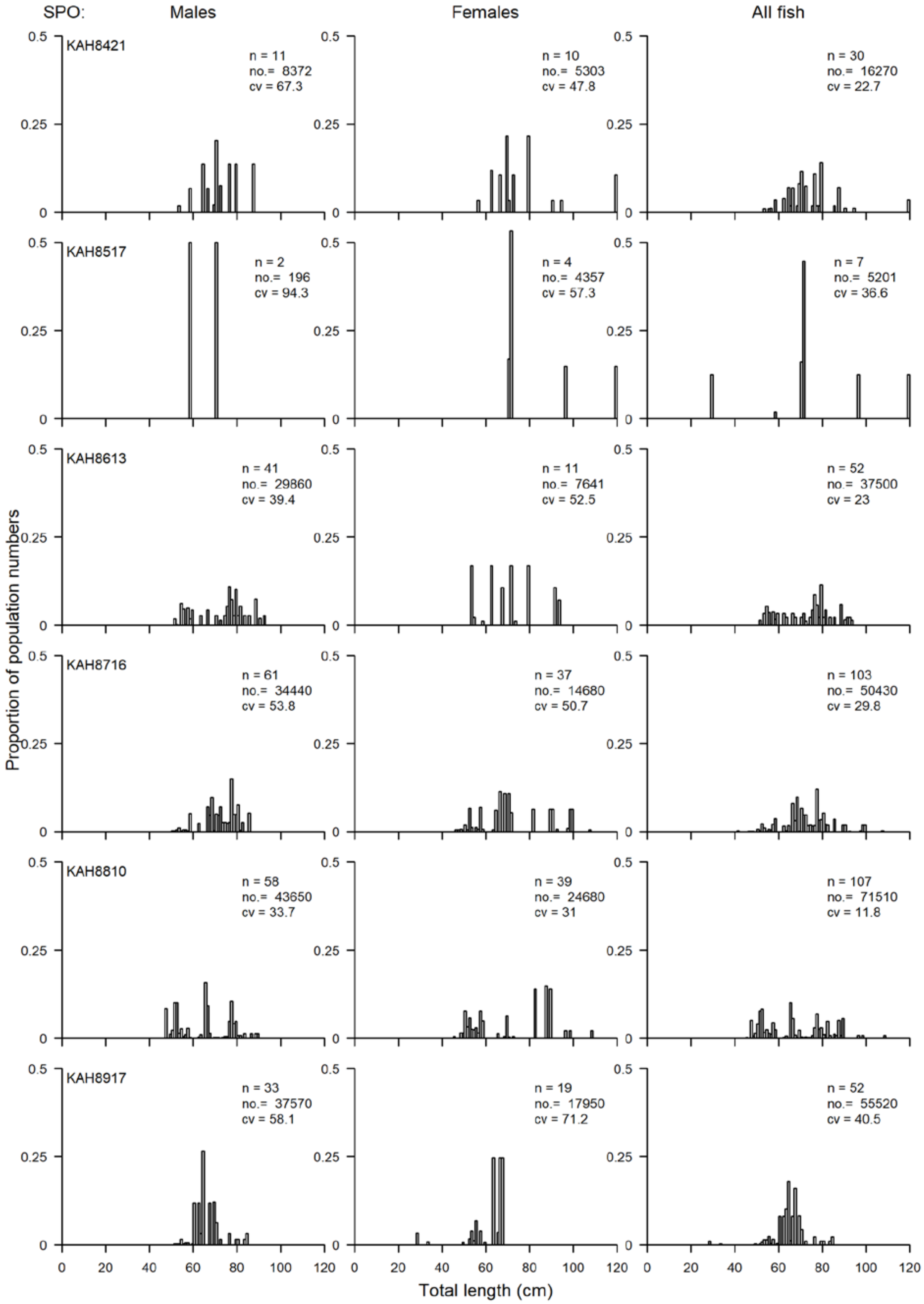


Figure 5g: Rig.

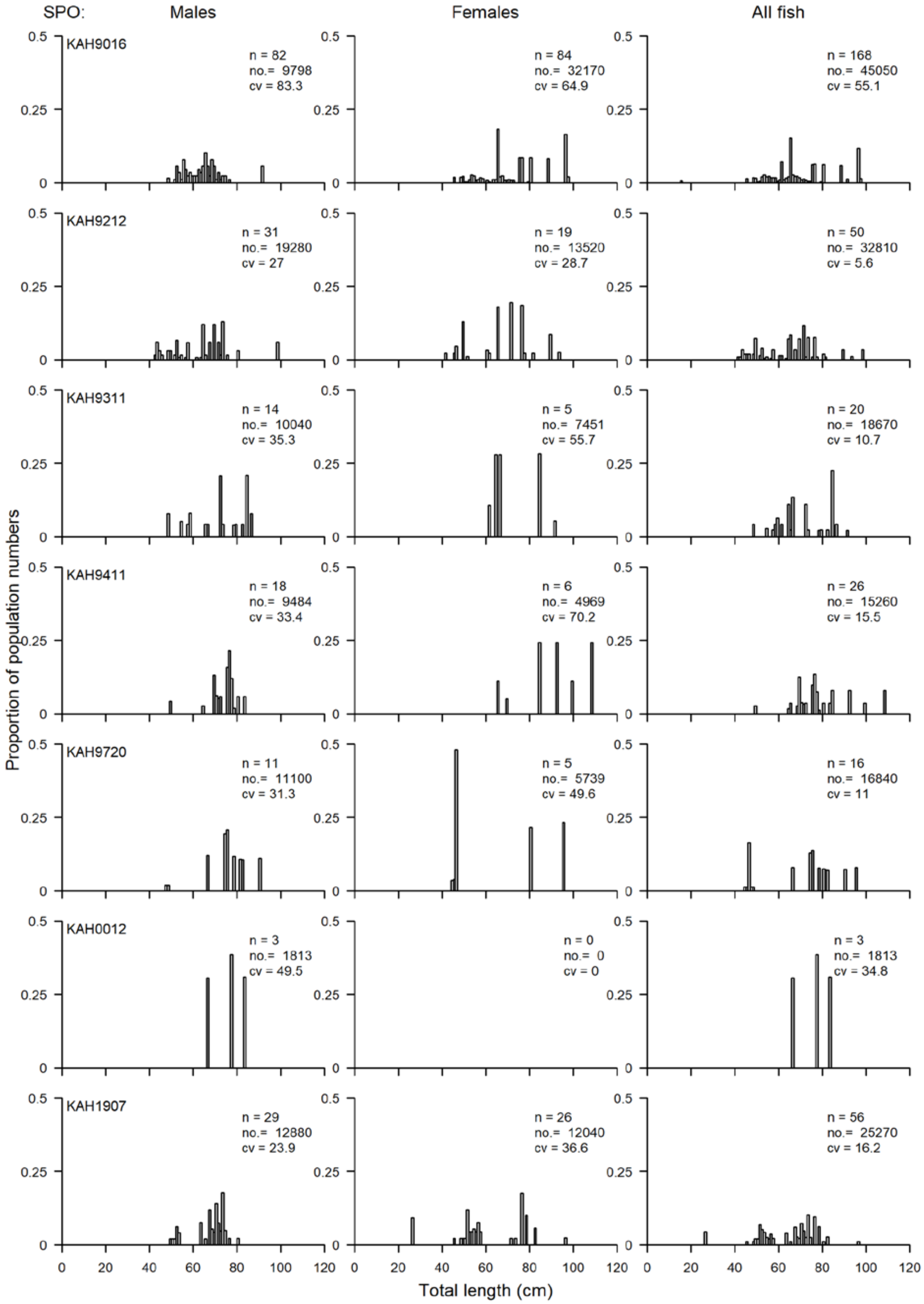


Figure 5g: – Rig continued.

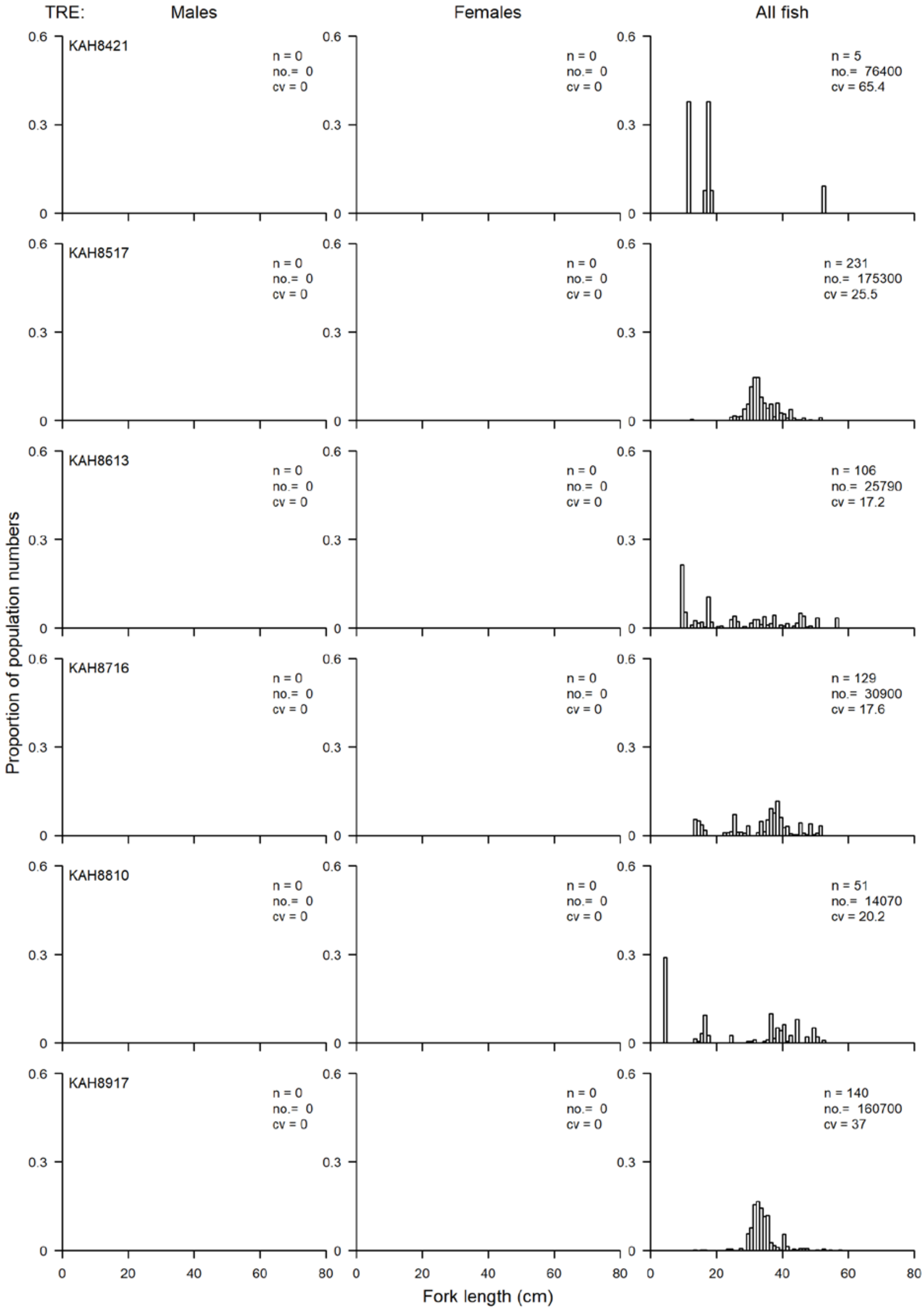


Figure 5h: Trevally.

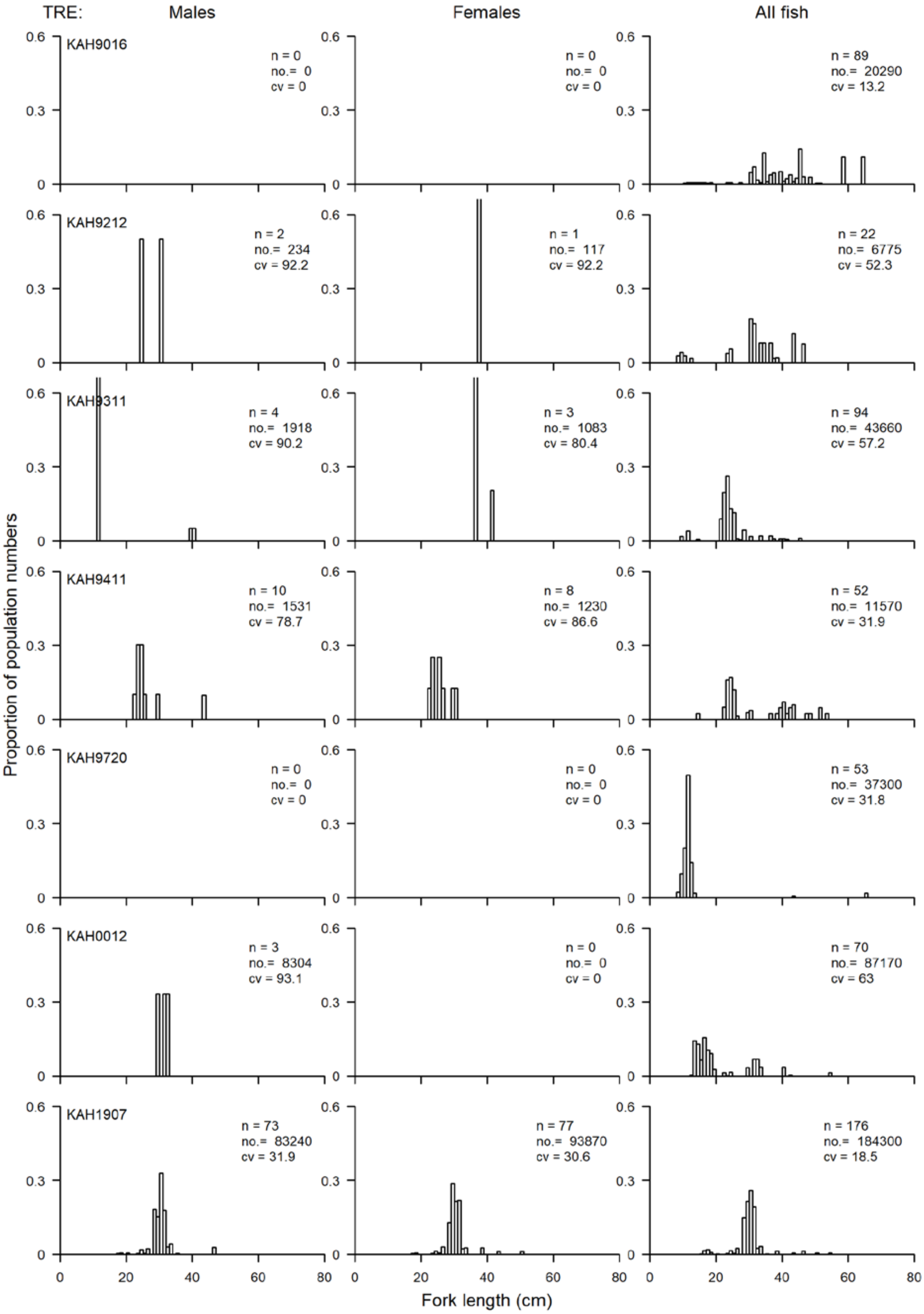
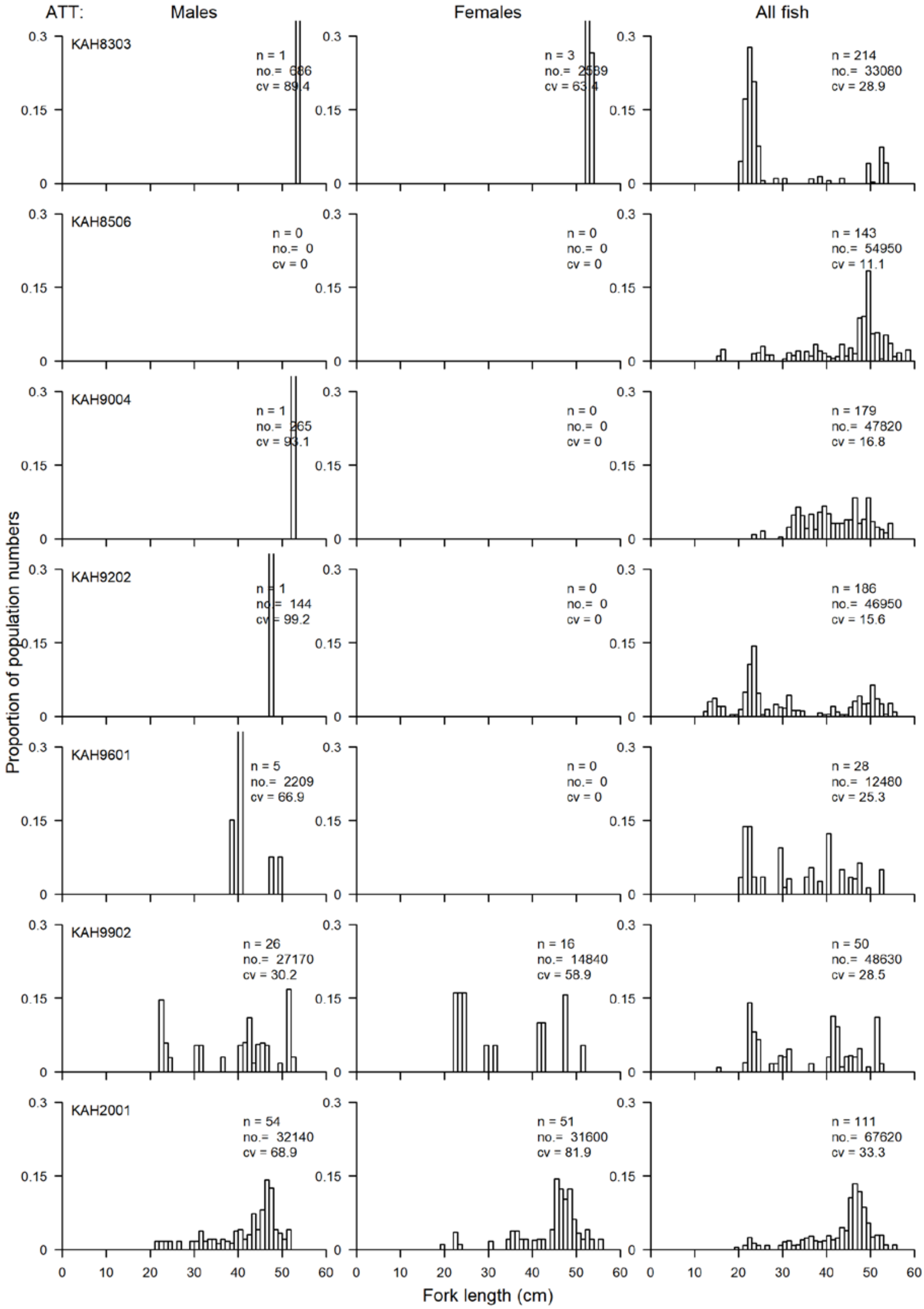


Figure 5h: – Trevally continued.



a) Kahawai.

Figure 6: Comparative scaled length frequency distributions for the most common QMS species in the Bay of Plenty. n = number of fish measured, no. = scaled population number, CV = coefficient of variation. * = scaled population number inaccurate due to limited length sampling for that species and survey. 'All fish' includes any unsexed fish.

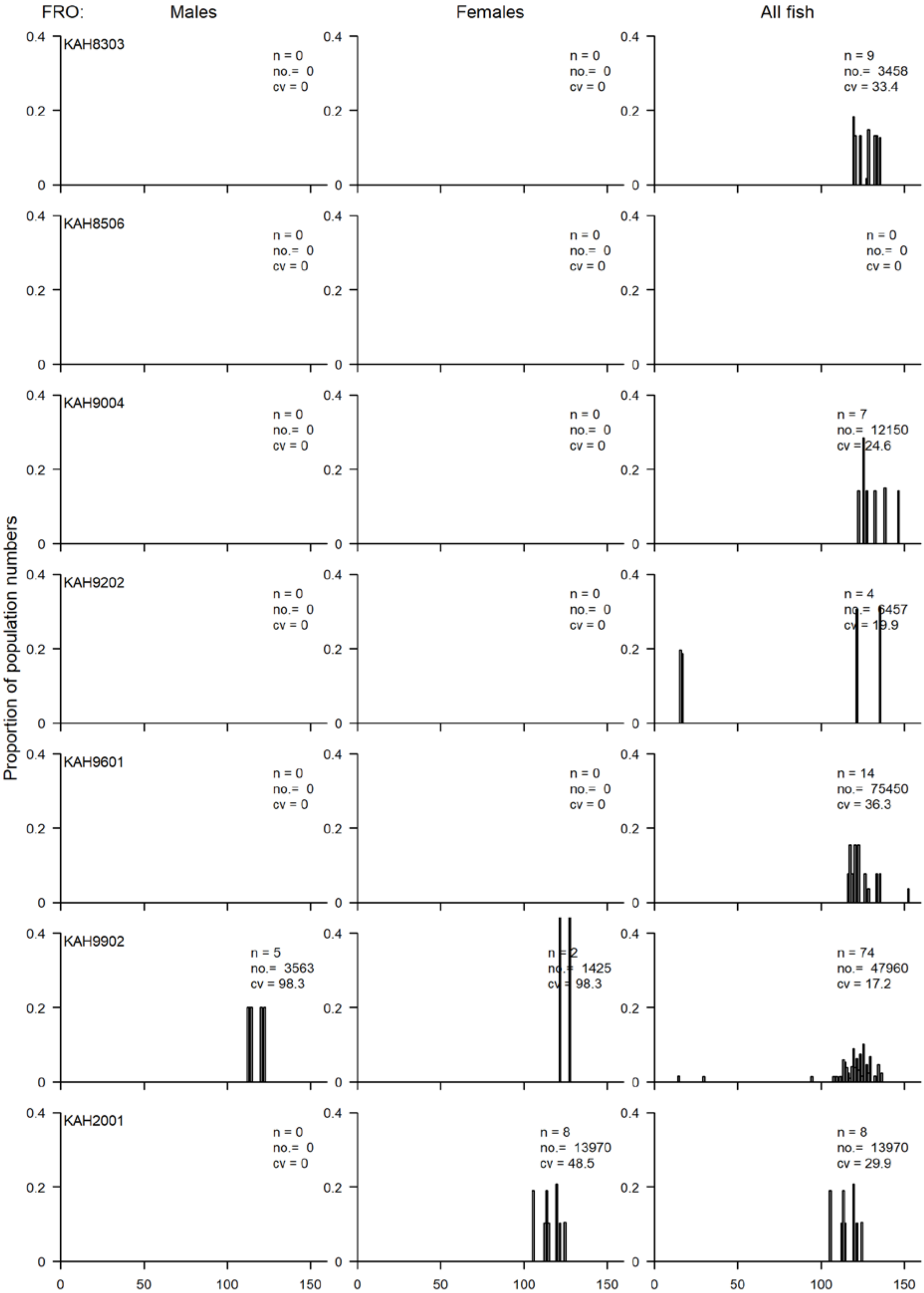


Figure 6b: Frostfish.

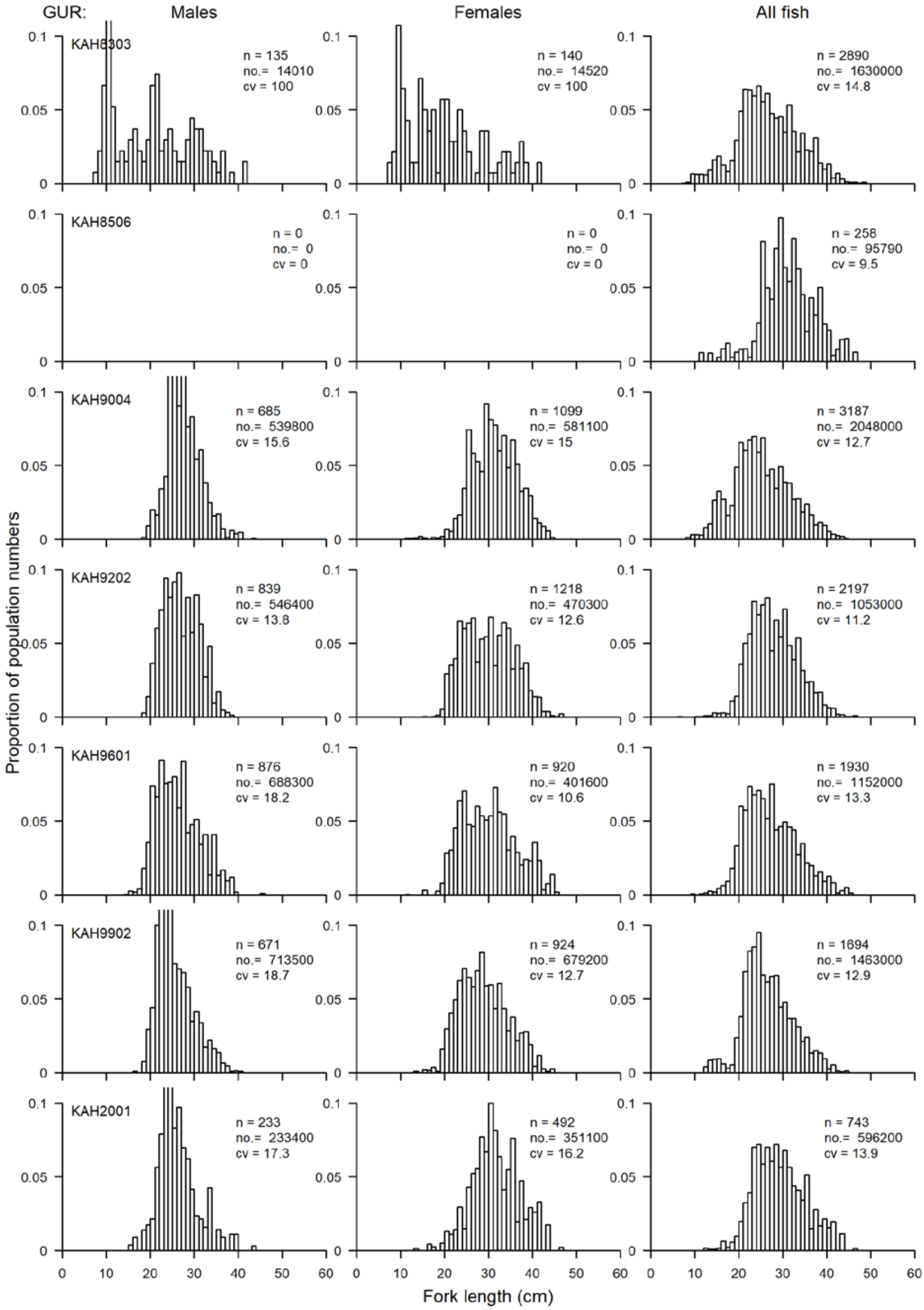


Figure 6c: Gurnard.

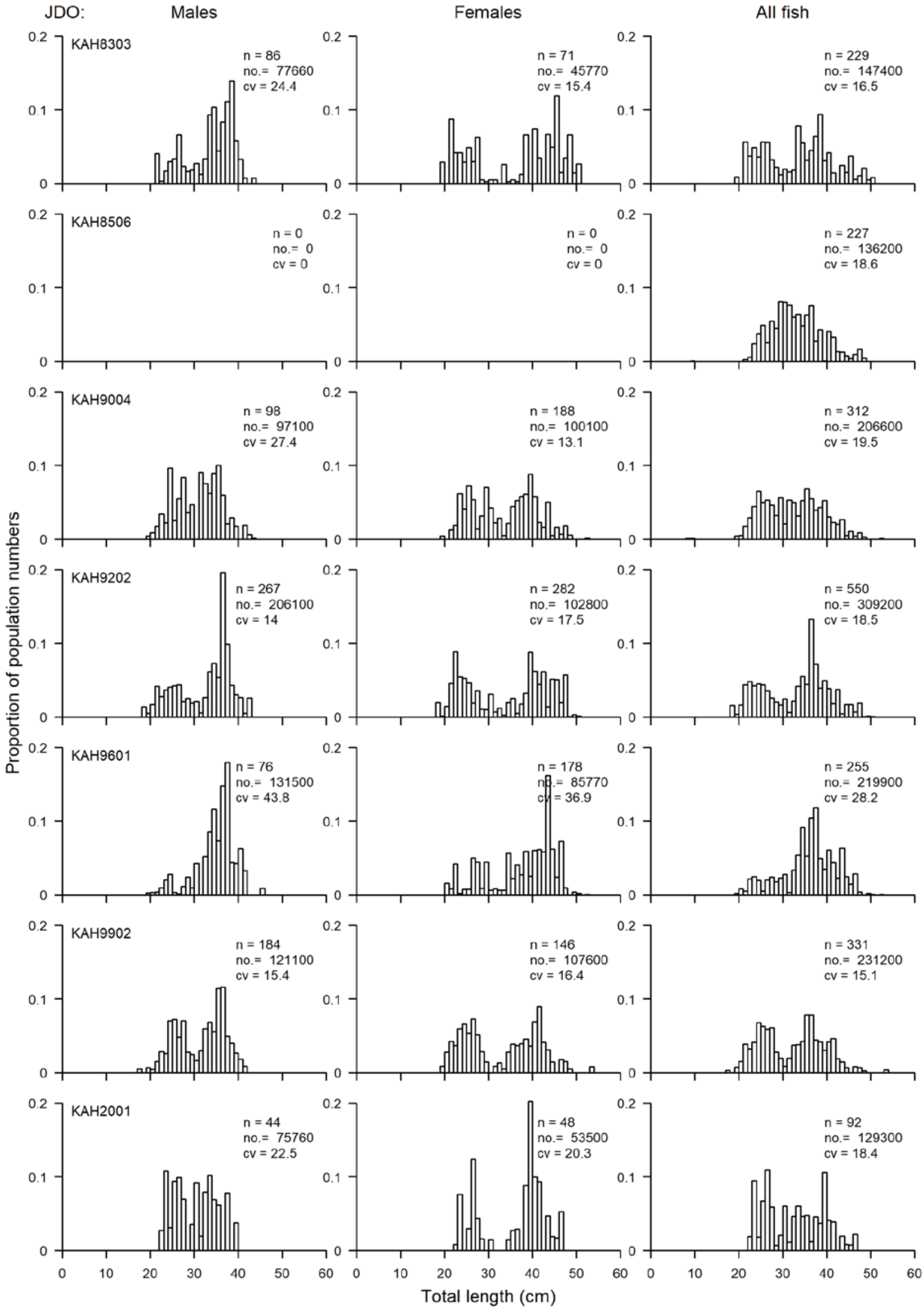


Figure 6d: John dory.

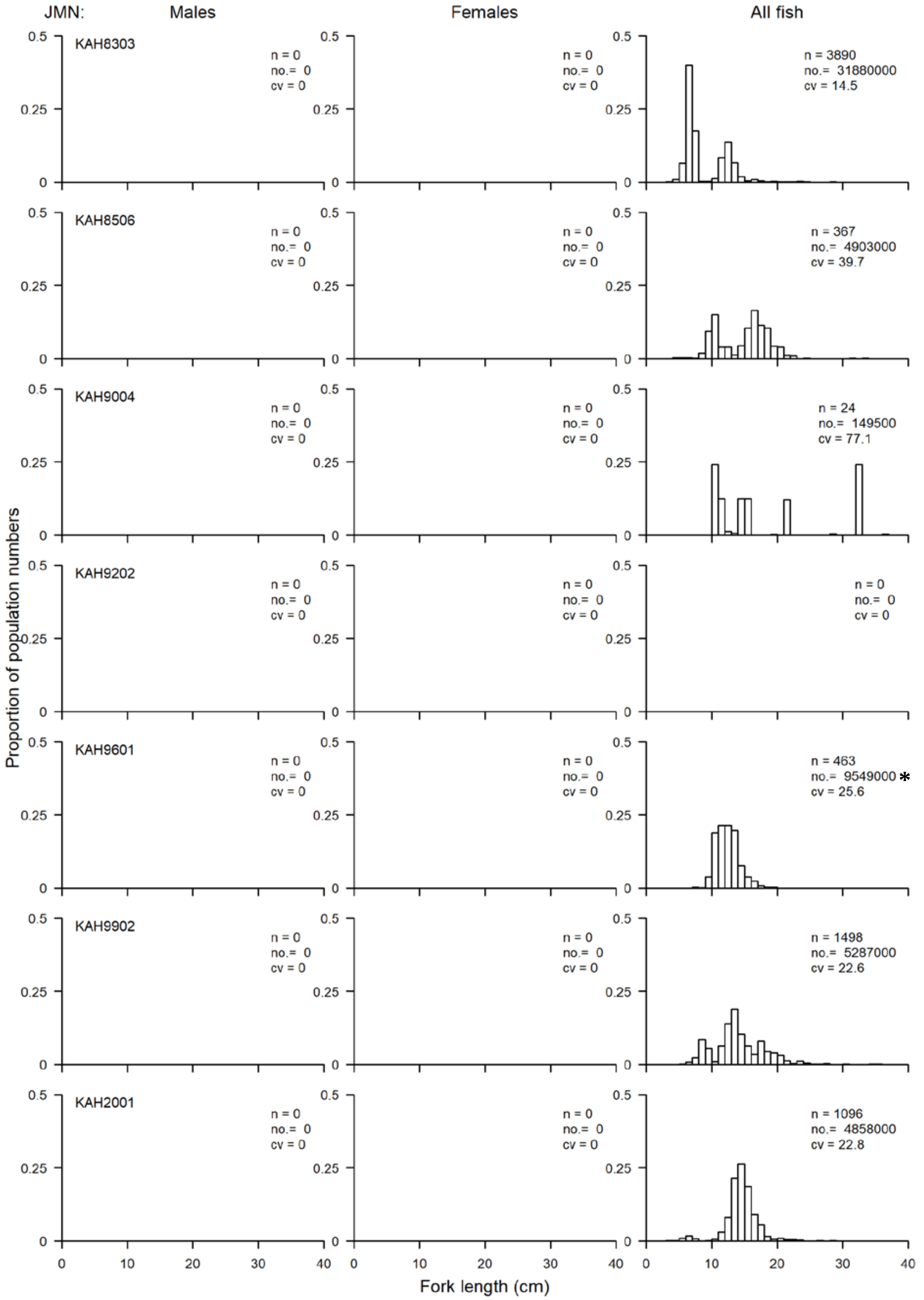


Figure 6e: Yellowtail jack mackerel. * = scaled population number inaccurate due to limited length sampling for the 1996 survey.

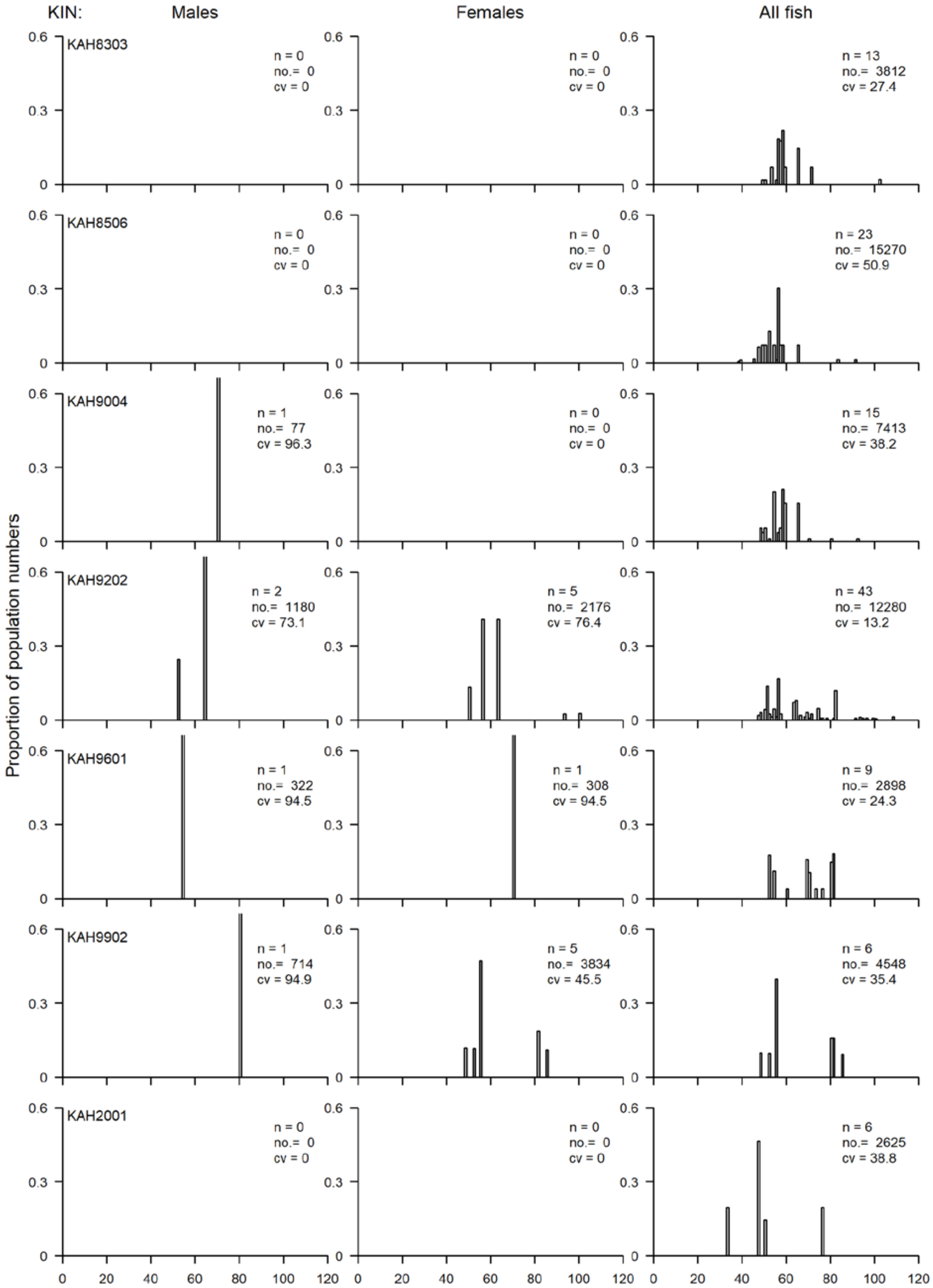


Figure 6f: Kingfish.

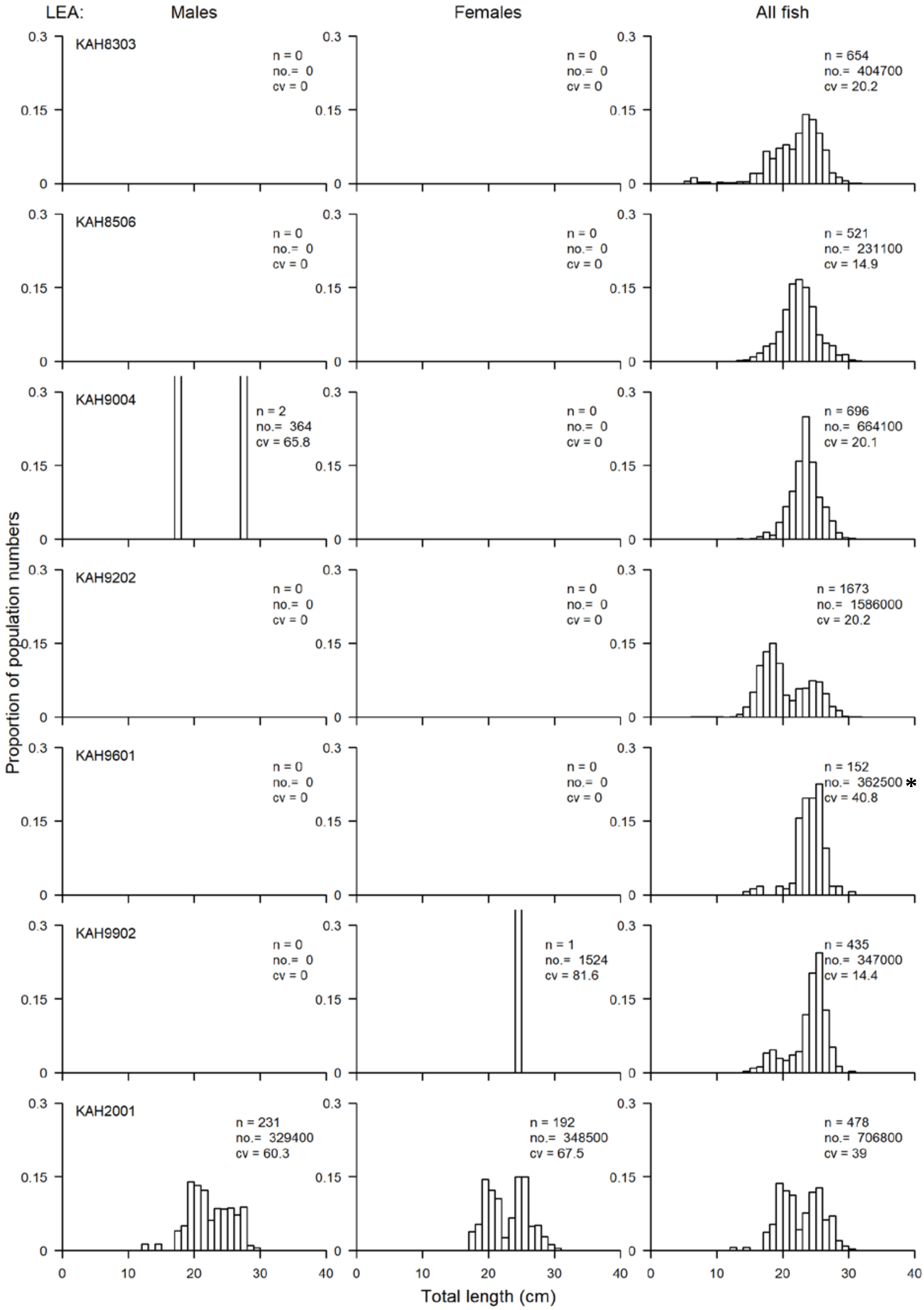


Figure 6g: Leatherjacket. * = scaled population number inaccurate due to limited length sampling for the 1996 survey.

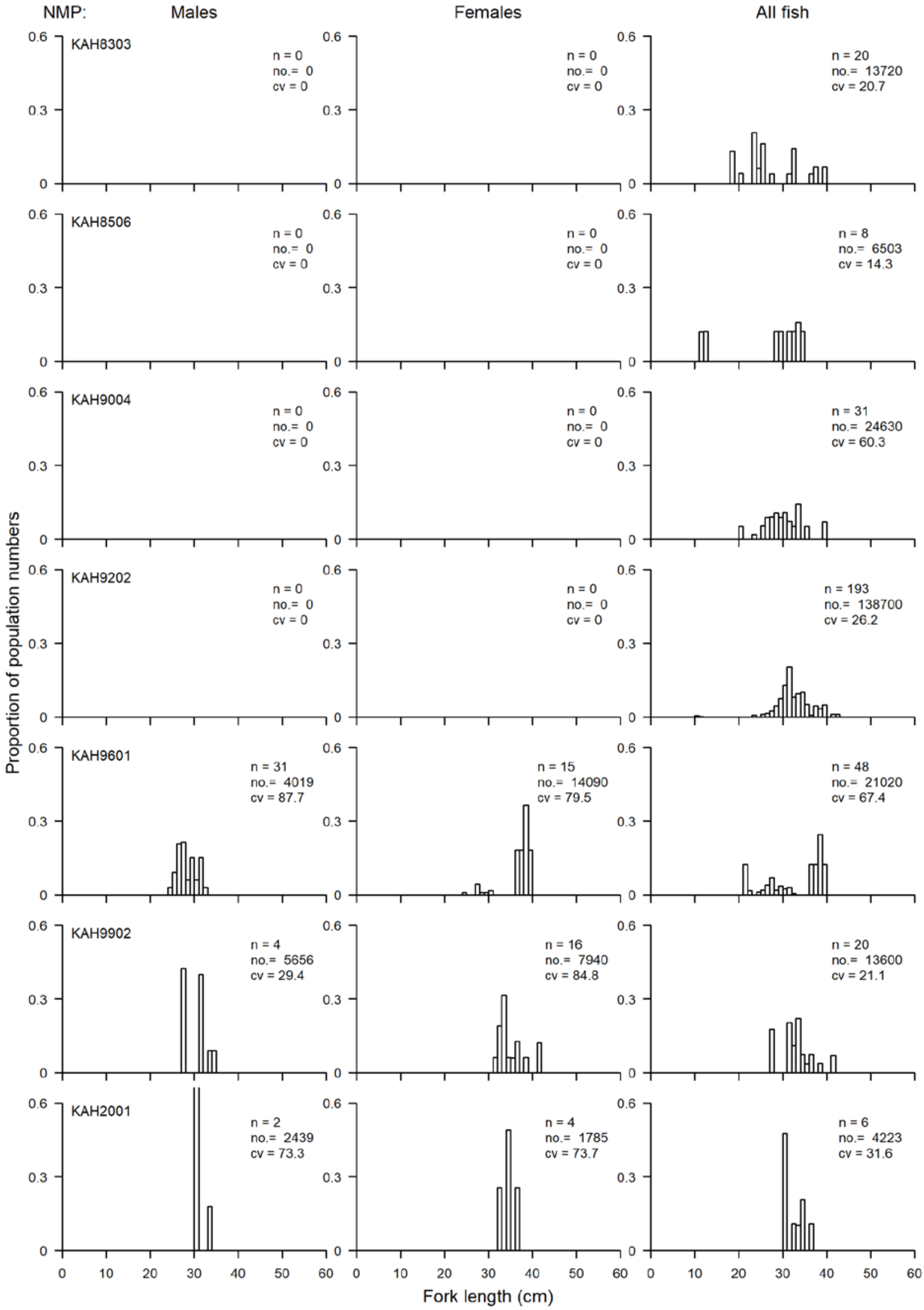


Figure 6h: Tarakihi.

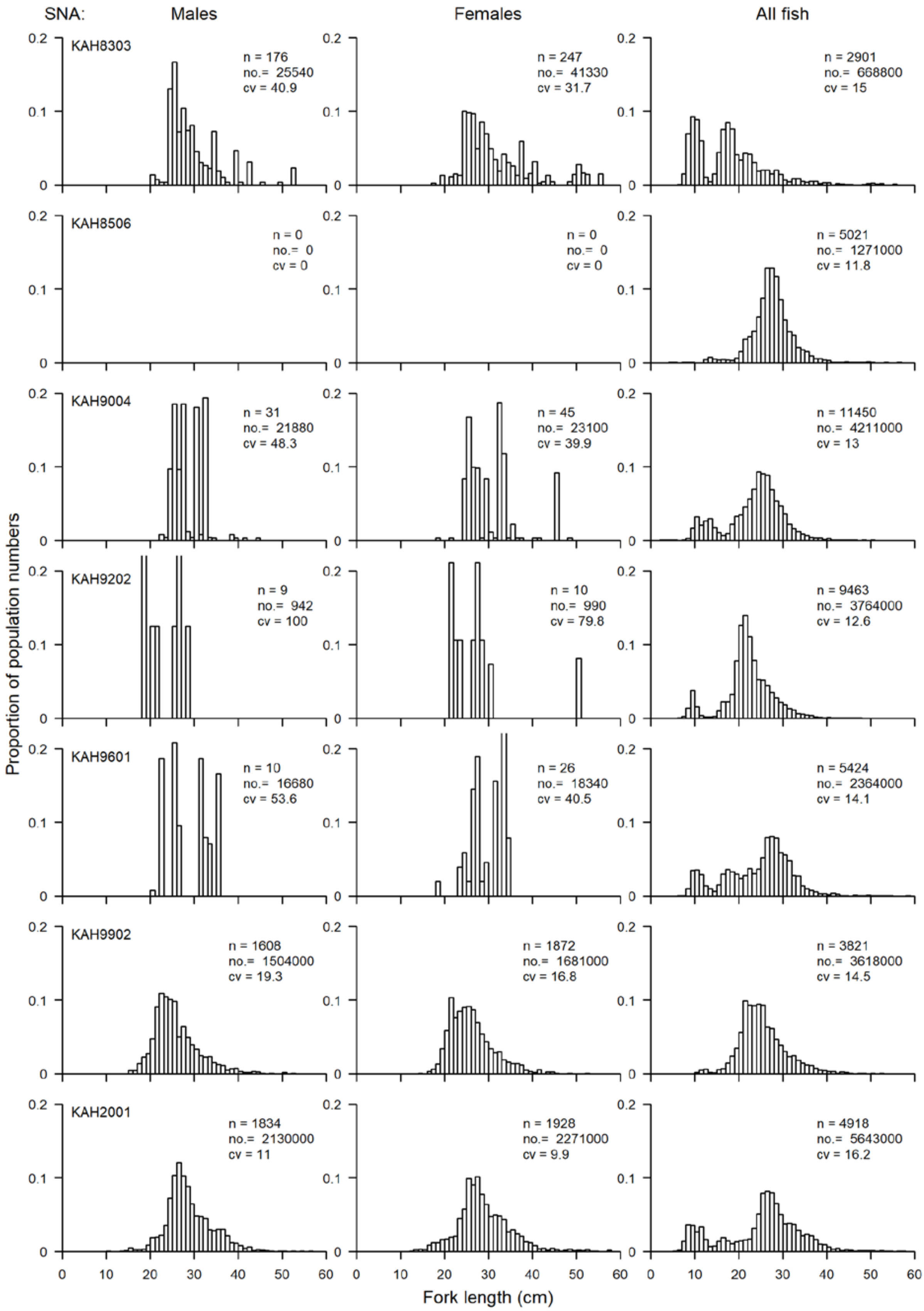


Figure 6i: Snapper.

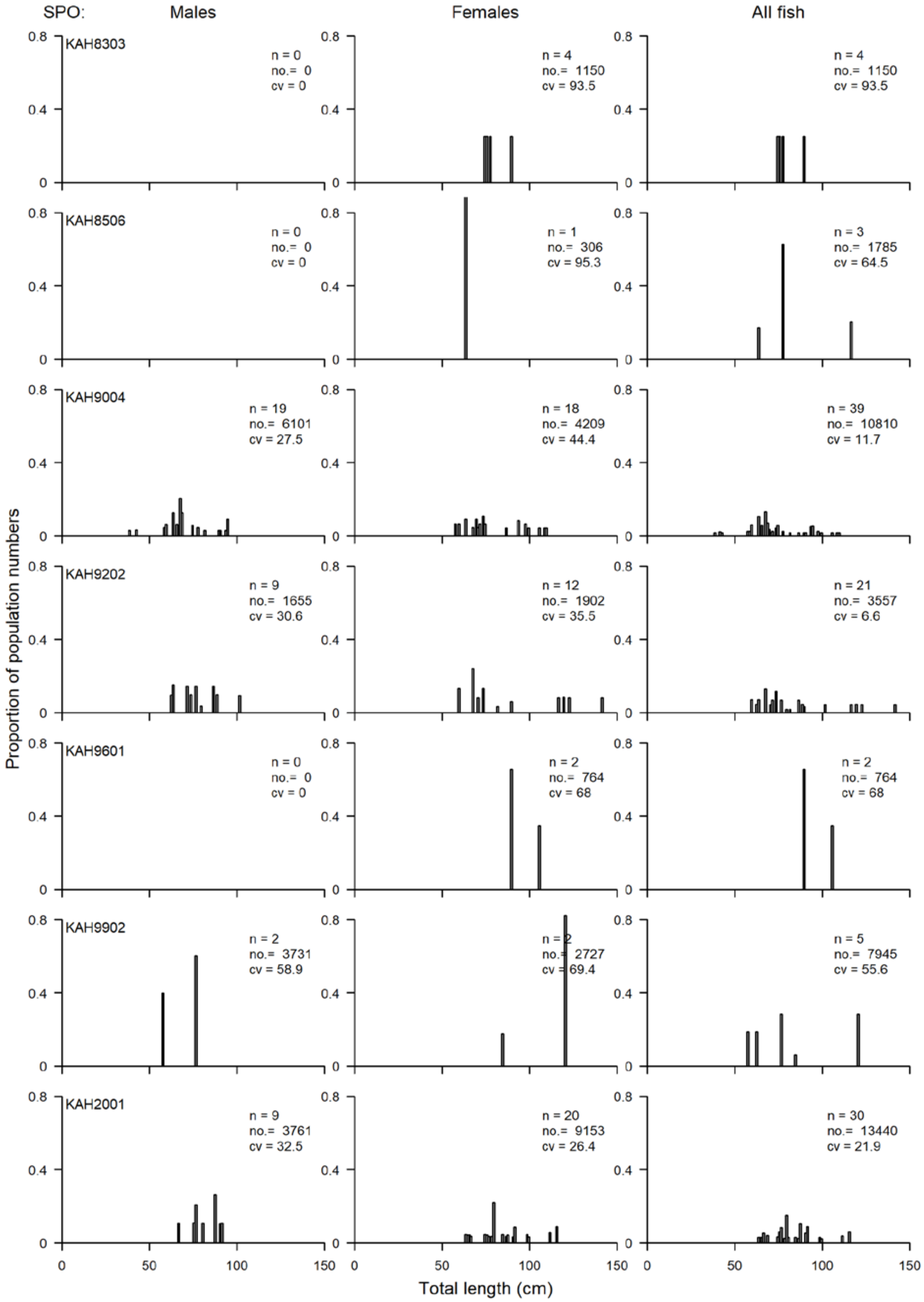


Figure 6j: Rig.

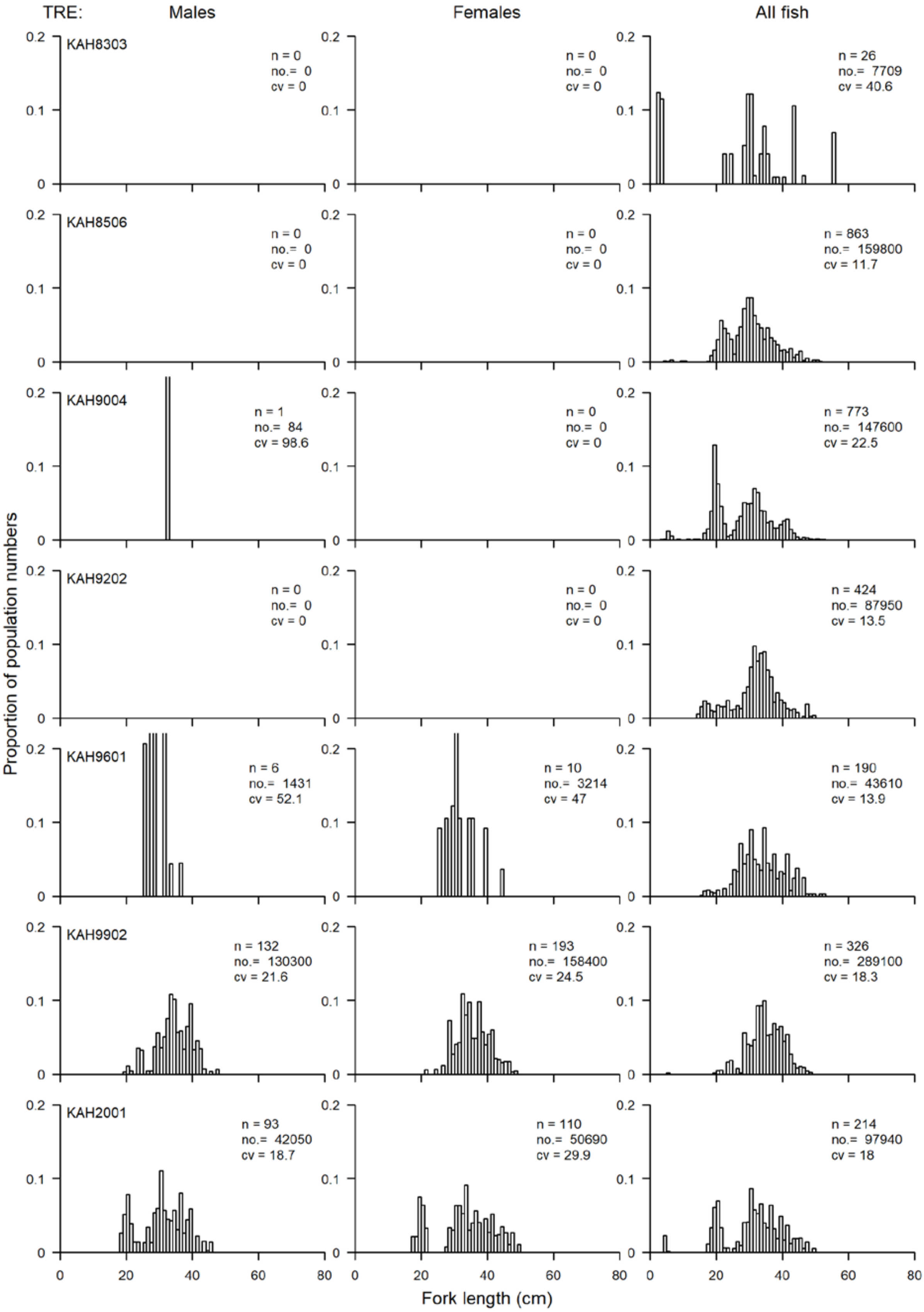


Figure 6k: Trevally.

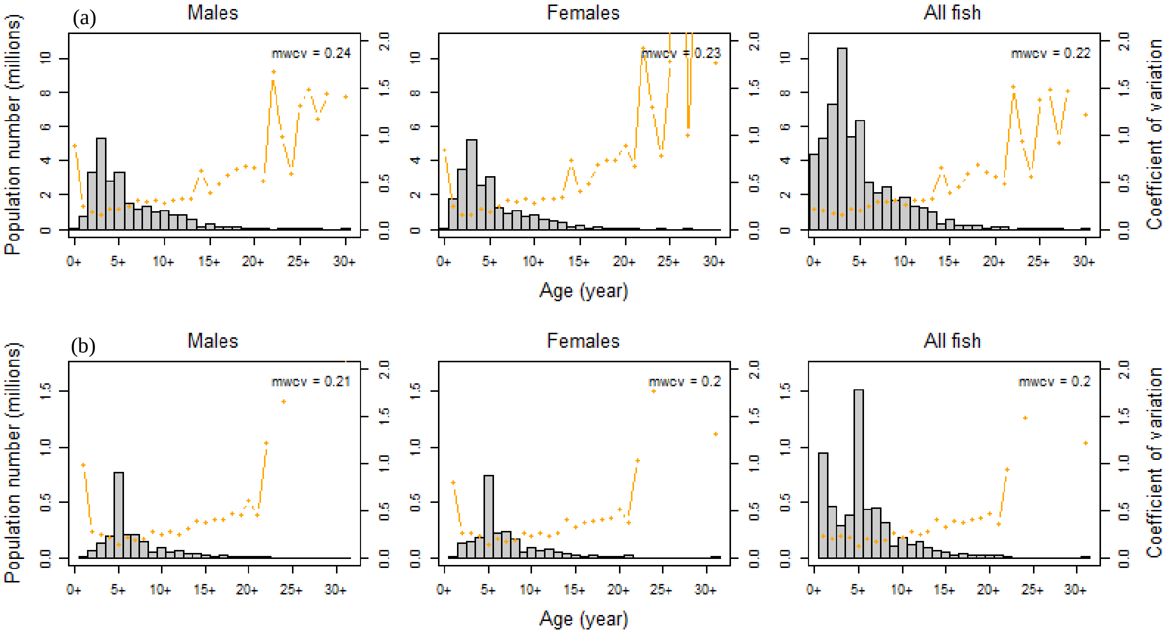


Figure 7: Proportion-at-age distributions (histogram) and CVs (line) determined from snapper caught on the (a) 2019 Hauraki Gulf and (b) 2020 Bay of Plenty surveys (mwcv = mean weighted coefficient of variation; n = sample size).

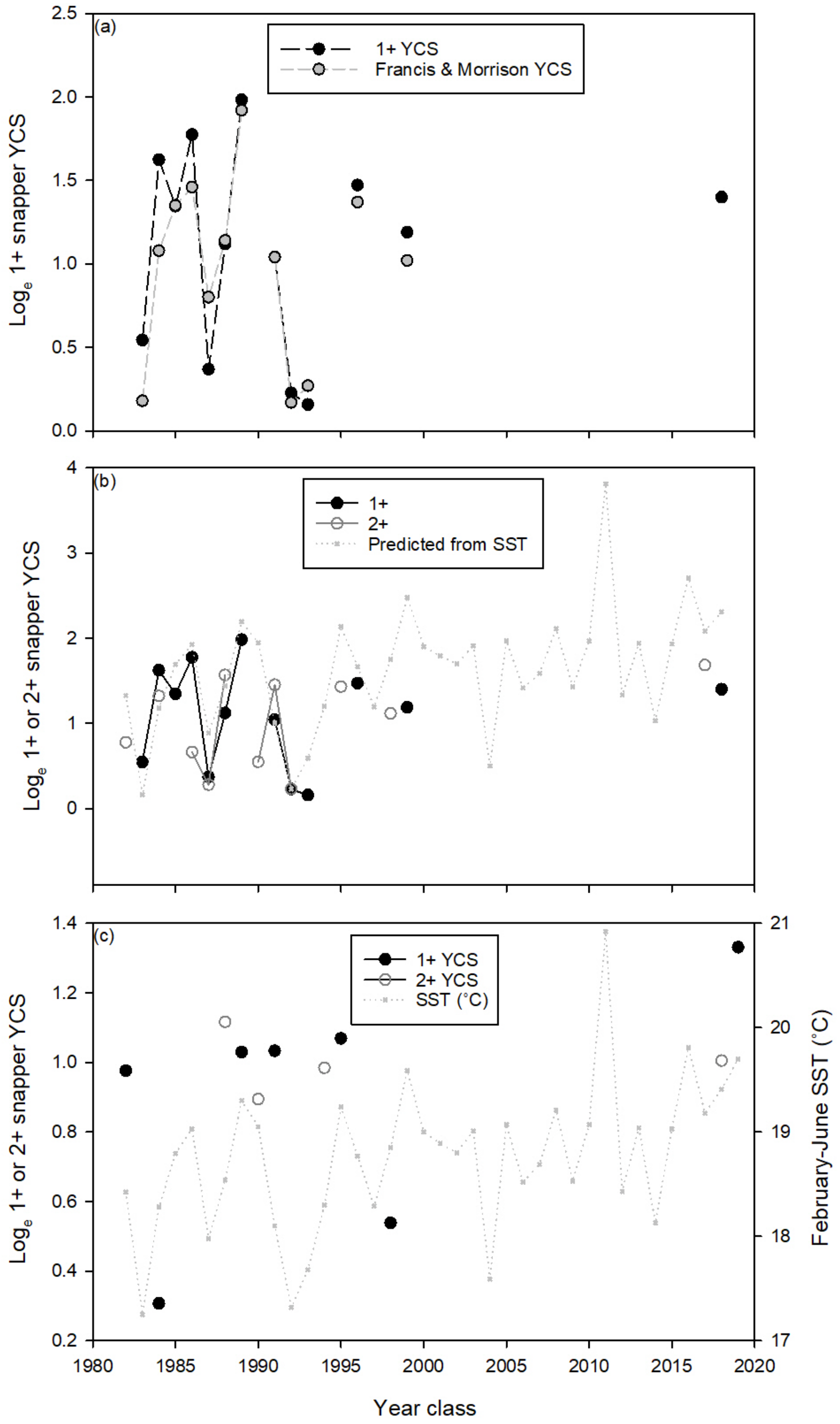


Figure 8: Trawl survey estimates of 1+ and 2+ snapper year class strength (YCS). (a) Represents a validation of the re-stratification process and compares the Hauraki Gulf 1+ YCS index with the original 1+ YCS estimates calculated by Francis et al. (1995) and Morrison et al. (2001a), (b) the Hauraki Gulf 1+ (again) and 2+ index, (c) the Bay of Plenty 1+ and 2+ YCS. For the Hauraki Gulf (b) a time series of predicted YCS based on Leigh sea surface temperature (SST) is also presented. For the Bay of Plenty (c) the average February-June Leigh SST is presented on a second axis.

Appendix 1: Description of gonad staging for teleosts (middle depths method)

Research gonad stage		Males	Females
1	Immature	Testes small and translucent, threadlike or narrow membranes.	Ovaries small and translucent. No developing oocytes.
2	Resting	Testes thin and flabby; white or transparent.	Ovaries are developed, but no developing eggs are visible.
3	Ripening	Testes firm and well developed, but no milt is present.	Ovaries contain visible developing eggs, but no hyaline eggs present.
4	Ripe	Testes large, well developed; milt is present and flows when testis is cut, but not when body is squeezed.	Some or all eggs are hyaline, but eggs are not extruded when body is squeezed.
5	Running-ripe	Testis is large, well formed; milt flows easily under pressure on the body.	Eggs flow freely from the ovary when it is cut or the body is pressed.
6	Partially spent	Testis somewhat flabby and may be slightly bloodshot, but milt still flows freely under pressure on the body.	Ovary partially deflated, often bloodshot. Some hyaline and ovulated eggs present and flowing from a cut ovary or when the body is squeezed.
7	Spent	Testis is flabby and bloodshot. No milt in most of testis, but there may be some remaining near the lumen. Milt not easily expressed even when present.	Ovary bloodshot; ovary wall may appear thick and white. Some residual ovulated eggs may still remain but will not flow when body is squeezed.

Appendix 2: Length-weight relationship parameters used to scale length frequencies and calculate length class biomass estimates

$W = aL^b$, where W is weight (g), and L is length (cm). *rdb* refers to Fisheries New Zealand research database for length-weight parameters; n = sample size. Species codes are given in Appendix 5.

Hauraki Gulf

Species	*a*	*b*	n	Min length (cm)	Max length (cm)	Surveys parameters applied to	Data source	Units	Area of source data
ATT	0.0236	2.8900	2 091	5.0	60.0	All surveys	Hartill & Walsh (2005)	g and cm	KAH 1 & 3
GUR	0.0099	2.9924	106	15.9	39.2	KAH0012	*rdb*, KAH0012	g and cm	Hauraki Gulf
GUR	0.0114	2.9622	418	12.5	44.5	KAH1907	KAH1907	g and cm	Hauraki Gulf
GUR	0.0075	3.1032	505	11.0	47.0	All surveys prior to KAH0012	*rdb*, KAH9720	g and cm	Hauraki Gulf
JDO	0.0021	3.5814	227	13.5	54.6	KAH0012	*rdb*, KAH0012	g and cm	Hauraki Gulf
JDO	0.0026	3.5431	138	15.5	51.4	KAH1907	KAH1907	g and cm	Hauraki Gulf
JDO	0.0024	3.5461	352	13.0	52.0	All surveys prior to KAH0012	*rdb*, KAH9720	g and cm	Hauraki Gulf
JMN	0.0200	2.8204	376	12.6	35.7	All surveys	KAH1907	g and cm	Hauraki Gulf
LEA	0.0216	2.9035	659	c. 60.0	c. 330.0	All surveys	Visconti et al. (2018)	g and cm	Hauraki Gulf
SNA	0.0412	2.8117	1 817	7.4	57.3	KAH0012	*rdb*, KAH0012	g and cm	Hauraki Gulf
SNA	0.0409	2.8084	972	7.1	82.6	KAH1907	KAH1907	g and cm	Hauraki Gulf
SNA	0.0341	2.8744	871	9.0	76.0	All surveys prior to KAH0012	*rdb*, KAH9720	g and cm	Hauraki Gulf
SPO	0.0005	3.4660	–	–	–	All surveys	Francis (1979)	g and cm	SPO 3
TRE	0.0201	2.9837	125	16.2	55.5	All surveys	*rdb*, KAH9720	g and cm	Hauraki Gulf

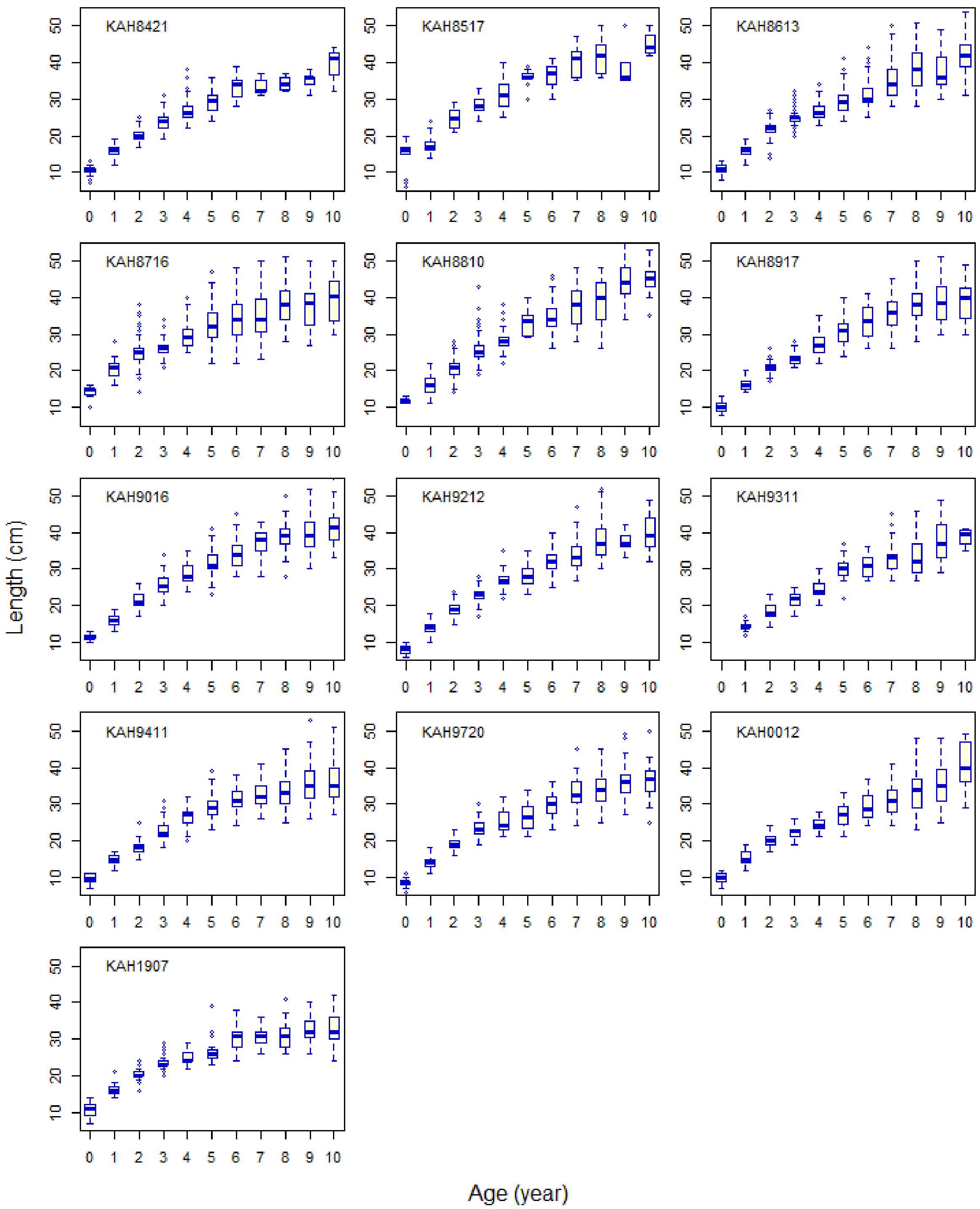
Bay of Plenty

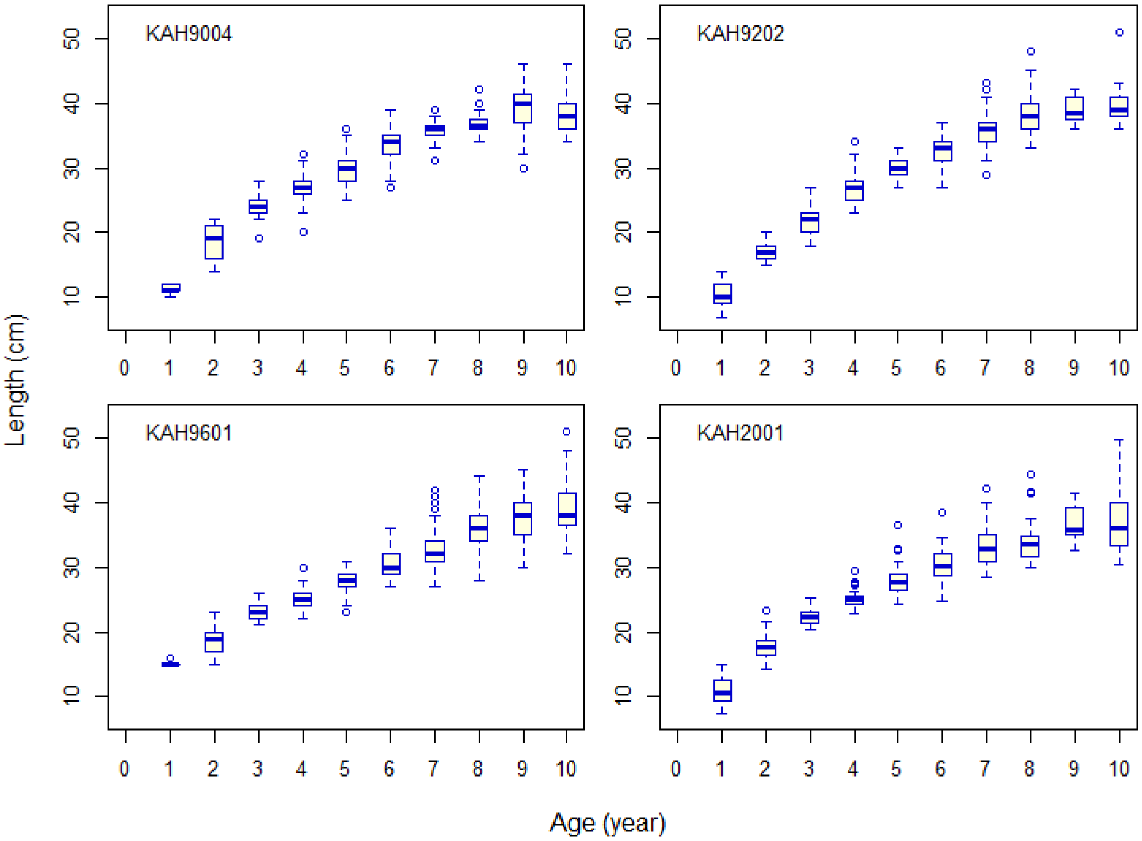
Species	*a*	*b*	n	Min length (cm)	Max length (cm)	Surveys parameters applied to	Data source	Units	Area of source data
ATT	0.0236	2.8900	2 091	5.0	60.0	All surveys	Hartill & Walsh (2005)	g and cm	KAH 1 & 3
FRO	0.0004	3.1550	965	10.0	164.0	All surveys	Horn (2013)	g and cm	WCSI
GUR	0.0043	3.2514	517	14.0	47.0	KAH2001	KAH2001	g and cm	BPLE
GUR	0.0038	3.2771	1 184	13.4	48.3	All surveys prior to KAH2001	*rdb*, KAH9902	g and cm	BPLE
JDO	0.0066	3.2455	352	18.4	54.3	All surveys	*rdb*, KAH9902	g and cm	BPLE
JMN	0.0200	2.8204	376	12.6	35.7	All surveys	KAH1907	g and cm	HAGU
KIN	0.0365	2.7620	489	34.0	159.0	All surveys	Walsh et al. (2003)	g and cm	KIN 1
LEA	0.0216	2.9035	659	c. 60.0	c. 330.0	All surveys	Visconti et al. (2018)	g and cm	Hauraki Gulf
NMP	0.0098	3.1666	155	19.2	48.0	All surveys	*rdb*, KAH9902	g and cm	BPLE
SNA	0.0449	2.7970	1 063	7.5	58.8	KAH2001	KAH2001	g and cm	BPLE
SNA	0.0445	2.7809	1 222	12.4	62	All surveys prior to KAH2001	*rdb*, KAH9902	g and cm	BPLE
SPO	0.0005	3.4660	–	–	–	All surveys	Francis (1979)	g and cm	SPO 3
TRE	0.0291	2.8861	180	5.4	48.8	All surveys	KAH2001	g and cm	BPLE

Appendix 3: Snapper age-length data for all Hauraki Gulf and Bay of Plenty surveys where age data were available

Box plots represent the distribution of fish lengths within an age class where the lower and upper lines of the box are the 25th and 75th percentiles respectively, and the middle line is the median. Whiskers represent a 95% confidence interval.

a) Hauraki Gulf





b: Bay of Plenty

Appendix 4: Station details

'#' = not suitable for biomass calculation.

Hauraki Gulf

				Start of tow		End of tow		Gear depth (m)							
Station	Stratum	Date	Time	° ' S	° ' E	° ' S	° ' E	Min.	Max.	Distance trawled (n. mile)	Headline height (m)	Doorspread (m)	Surface temp ˚C	Bottom temp ˚C	Warp length (m)
1	2229	15/11/2019	1411	36 40.53	175 13.16	36 40.20	175 14.00	36	42	0.75	5.3	77.3	17	15	200
2	2229	15/11/2019	1542	36 42.70	175 14.30	36 42.32	175 14.72	35	35	0.67	5.4	76.5	17.2	15.3	200
3	COLV	16/11/2019	0550	36 38.30	175 41.43	36 37.55	175 40.79	42	44	0.70	5.5	78.5	15.7	15.0	200
4	COLV	16/11/2019	0741	36 29.65	175 44.16	36 30.80	175 43.45	68	69	0.71	5.4	80.5	16.4	14.9	250
5	COLV	16/11/2019	0905	36 27.77	175 41.58	36 27.35	175 40.89	62	63	0.69	5.3	80.4	16.6	14.8	250
6	LITB	16/11/2019	1142	36 24.87	175 25.70	36 24.50	175 24.31	59	60	0.71	4.4	80.1	16.6	15.8	250
7	1219	16/11/2019	1335	36 29.32	175 18.36	36 28.63	175 18.57	56	70	0.71	5.9	85.3	17.2	15.6	250
8	1219	16/11/2019	1513	36 24.90	175 09.59	36 24.40	175 09.00	47	48	0.68	5.2	78.5	17.1	15.4	200
9	LITB	17/11/2019	0532	36 15.29	175 13.10	36 15.27	175 13.97	44	46	0.70	5.2	79.8	16.9	15.6	200
10	LITB	17/11/2019	0703	36 08.40	175 09.91	36 07.90	175 09.76	69	71	0.51	4.9	80.7	16.9	15.0	250
11	LITB	17/11/2019	0939	36 11.69	174 48.88	36 11.70	174 49.77	51	57	0.71	5.1	82.1	16.5	14.4	250
12	1449	17/11/2019	1126	36 06.49	174 38.98	36 05.89	174 38.53	38	39	0.70	5.5	71.8	16.4	14.3	200
13	1449	17/11/2019	1247	36 00.50	174 33.45	35 59.77	174 33.36	17	20	0.73	5.8	69.3	16.0	14.7	200
14	1449	17/11/2019	1349	35 59.42	174 31.10	35 58.71	174 31.15	16	17	0.71	5.4	68.0	16.3	14.8	200
15	1449	17/11/2019	1454	35 56.30	174 30.70	35 55.61	174 30.54	19	20	0.70	5.4	72.1	16.2	14.8	200
16	1219	18/11/2019	0605	36 23.73	175 01.39	36 23.60	175 01.16	50	50	0.69	4.9	77.8	16.9	15.0	200
17	2229	18/11/2019	0805	36 31.57	174 51.95	36 30.90	174 51.65	31	32	0.71	5.4	71.9	17.4	15.2	200
18	2229	18/11/2019	1104	36 29.37	174 49.64	36 28.80	174 50.90	26	27	0.69	5.9	69.5	17.3	15.5	200
19#	1386	19/11/2019	0915	36 43.33	174 52.44	36 43.80	174 52.76	18	21	0.35	5.7	64.5	17.3	16.2	200
20	1386	19/11/2019	1005	36 42.70	174 54.56	36 41.67	174 55.30	23	24	0.71	5.2	70.6	17.1	15.7	200
21	1386	19/11/2019	1256	36 40.50	174 51.77	36 40.17	174 52.56	24	26	0.71	6.0	68.2	17.4	15.8	200
22#	1386	21/11/2019	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	200

				Start of tow		End of tow		Gear depth (m)							
Station	Stratum	Date	Time	° ' S	° ' E	° ' S	° ' E	Min.	Max.	Distance trawled (n. mile)	Headline height (m)	Doorspread (m)	Surface temp ˚C	Bottom temp ˚C	Warp length (m)
23	1386	21/11/2019	1011	36 39.59	174 46.88	36 40.14	174 46.96	11	12	0.55	6.6	63.9	17.4	17.3	200
24	1149	21/11/2019	1201	36 46.97	174 57.70	36 47.64	174 57.63	21	23	0.67	6.1	70.4	17.5	17.1	200
25	1149	21/11/2019	1520	36 46.35	175 04.95	36 46.22	175 05.82	19	20	0.70	5.3	71.0	17.2	16.1	200
26	9292	22/11/2019	0601	36 38.56	175 24.67	36 37.87	175 24.48	12	13	0.70	6.3	67.5	17.2	16.8	200
27	9292	22/11/2019	0757	36 36.91	175 23.26	36 37.38	175 23.48	16	16	0.50	5.5	70.8	17.6	16.2	200
28	9292	22/11/2019	0918	36 36.79	175 20.89	36 36.10	175 20.73	23	24	0.70	5.0	77.0	NA	NA	200
29	1219	22/11/2019	1154	36 38.55	175 19.83	36 39.40	175 19.81	36	37	0.49	6.4	76.2	17.5	15.7	200
30	1268	22/11/2019	1336	36 47.71	175 21.45	36 47.19	175 20.85	32	33	0.70	4.8	75.6	17.9	15.4	200
31	1149	22/11/2019	1603	36 52.50	175 07.45	36 51.77	175 06.64	6	6	0.70	5.7	50.7	NA	NA	200
32	1268	23/11/2019	0536	36 45.95	175 15.14	36 46.80	175 14.27	31	31	0.70	5.6	75.5	17.6	15.5	200
33	1268	23/11/2019	0744	36 48.20	175 18.43	36 47.53	175 18.26	31	32	0.50	5.5	77.5	17.8	15.5	200
34	1268	23/11/2019	0905	36 46.75	175 20.12	36 46.34	175 20.49	29	32	0.50	5.9	74.0	17.5	15.4	200
35	1887	23/11/2019	1111	36 58.11	175 22.78	36 58.59	175 22.96	18	19	0.50	6.2	69.0	18.1	17.3	200
36	1887	23/11/2019	1227	37 01.12	175 25.64	37 01.61	175 25.84	9	10	0.51	6.6	63.6	18.3	18.0	200
37	1887	23/11/2019	1350	37 02.83	175 21.80	37 02.16	175 21.52	13	15	0.70	5.2	60.8	18.8	17.3	150
38	1887	23/11/2019	1504	36 58.68	175 17.83	36 58.28	175 17.44	13	14	0.50	5.2	68.3	18.8	18.5	200
39#	1284	24/11/2019	1514	36 34.22	174 47.88	NA	NA	19	19	NA	5.3	73.0	NA	NA	200
40	1284	25/11/2019	0548	36 32.43	174 46.10	36 33.40	174 46.45	18	20	0.70	5.0	74.2	18	17.7	200
41	1284	25/11/2019	0814	36 33.87	174 44.42	36 34.36	174 44.58	14	14	0.50	5.2	73.4	18.1	18.0	200
42	1284	25/11/2019	1000	36 35.20	174 45.63	36 35.65	174 46.31	13	14	0.70	5.1	73.1	18.0	17.7	200
43	LITB	25/11/2019	1503	36 12.86	174 54.55	36 12.51	174 53.79	53	53	0.70	4.7	69.2	17.7	14.7	200
44	1887	26/11/2019	0607	37 04.90	175 25.43	37 04.40	175 26.12	8	9	0.74	6.1	53.9	18.9	18.0	100
45	1268	26/11/2019	0842	36 46.20	175 22.80	36 45.50	175 22.22	37	38	0.70	5.9	72.7	17.6	15.7	200
46	2229	26/11/2019	1030	36 43.93	175 18.17	36 43.40	175 18.44	39	40	0.57	5.4	75.6	18.3	15.6	200
47	2229	26/11/2019	1230	36 43.65	175 04.12	36 44.70	175 04.81	25	28	0.69	5.5	70.5	17.8	15.6	200

Bay of Plenty

Station	Stratum	Date	Time	Start of tow ° ' S	Start of tow ° ' E	End of tow ° ' S	End of tow ° ' E	Gear depth (m) Min.	Gear depth (m) Max.	Distance trawled (n. mile)	Headline height (m)	Doorspread (m)	Surface temp ˚C	Bottom temp ˚C	Warp length (m)
1	2096	15/02/2020	1318	37 38.52	176 13.20	37 38.96	176 13.91	21	22	0.71	5.2	74.0	21.0	19.9	200
2	2096	15/02/2020	1456	37 38.66	176 14.58	37 39.13	176 15.24	21	26	0.70	5.4	72.8	21.0	19.8	200
3#	5187	15/02/2020	1626	37 37.46	176 17.98	37 37.68	176 18.40	NA	NA	NA	NA	NA	20.7	19.7	200
4	5187	16/02/2020	0546	37 37.71	176 27.37	37 38.26	176 26.81	39	46	0.70	5.0	76.5	20.7	18.1	200
5	5187	16/02/2020	0713	37 41.52	176 23.87	37 41.57	176 24.76	24	26	0.70	4.9	75.0	20.3	19.3	200
6	5187	16/02/2020	0831	37 41.50	176 25.89	37 41.16	176 26.77	30	31	0.70	5.4	74.5	20.3	19.1	200
7	2096	16/02/2020	0937	37 42.85	176 24.20	37 43.18	176 24.81	18	18	0.70	5.1	75.1	20.1	20.3	200
8	708S	16/02/2020	1206	37 45.94	176 44.66	37 46.70	176 45.54	57	58	0.70	4.6	83.4	21.3	18.6	250
9	708S	16/02/2020	1350	37 42.53	176 56.00	37 42.90	176 56.77	98	99	0.71	5.5	67.8	21.3	15.4	275
10	708S	16/02/2020	1502	37 47.26	176 55.10	37 47.67	176 55.84	55	56	0.71	4.5	84.4	21.5	18.5	250
11	5187	16/02/2020	1620	37 51.33	176 54.65	37 51.39	176 55.33	31	31	0.54	5.1	78.4	21.4	19.6	200
12	4085	17/02/2020	0548	37 36.39	177 51.47	37 36.87	177 50.80	31	33	0.71	4.8	73.3	21.1	19.3	200
13	6085	17/02/2020	0759	37 43.90	177 34.57	37 44.27	177 33.82	66	66	0.69	5.2	77.4	21.3	16.8	250
14	4085	17/02/2020	0912	37 47.20	177 35.50	37 47.76	177 34.93	37	38	0.71	4.8	80.1	21.4	19.5	200
15	1096	17/02/2020	1115	37 50.83	177 33.97	37 51.31	177 33.32	20	21	0.70	4.9	76.8	21.6	20.6	200
16	1096	17/02/2020	1236	37 53.12	177 28.30	37 53.59	177 27.35	26	26	0.71	5.0	77.5	21.8	21.6	200
17	4085	17/02/2020	1354	37 50.99	177 26.87	37 51.43	177 26.17	36	36	0.70	5.1	79.1	21.6	20.1	200
18	4085	17/02/2020	1531	37 52.82	177 24.35	37 53.18	177 23.56	33	33	0.71	5.3	76.8	21.7	20.7	200
19	6085	18/02/2020	0549	37 48.45	177 14.93	37 48.41	177 15.82	70	70	0.70	5.2	81.4	21.5	16.7	250
20	6085	18/02/2020	0703	37 49.24	177 18.76	37 49.60	177 19.63	63	64	0.71	5.0	85.8	21.6	17.1	250
21	4085	18/02/2020	0811	37 52.47	177 19.43	37 52.51	177 18.53	43	44	0.71	4.8	77.3	21.5	19.4	200
22	4085	18/02/2020	0942	37 52.62	177 14.26	37 52.63	177 13.36	46	47	0.71	4.7	78.0	21.8	19.1	200
23	4085	18/02/2020	1207	37 55.14	177 09.41	37 55.21	177 08.52	36	36	0.70	4.8	78.5	21.6	19.5	200
24	1096	18/02/2020	1339	37 54.89	176 59.70	37 54.77	176 58.83	19	20	0.69	5.3	75.3	21.6	21.3	200

Station	Stratum	Date	Time	Start of tow ° ' S	Start of tow ° ' E	End of tow ° ' S	End of tow ° ' E	Gear depth (m) Min.	Gear depth (m) Max.	Distance trawled (n. mile)	Headline height (m)	Doorspread (m)	Surface temp ˚C	Bottom temp ˚C	Warp length (m)
25	5187	18/02/2020	1458	37 52.94	176 54.57	37 52.71	176 53.73	27	28	0.70	5.2	75.4	21.2	19.8	200
26	708N	19/02/2020	0554	36 39.45	175 56.42	36 40.80	175 55.99	63	65	0.71	5.0	83.7	21.4	16.7	250
27	708N	19/02/2020	0748	36 46.90	175 50.96	36 46.19	175 51.16	51	52	0.72	4.9	83.6	21.0	17.2	250
28	5287	19/02/2020	0944	36 53.69	175 51.44	36 54.29	175 51.89	39	42	0.69	5.3	73.6	21.1	17.7	200
29	32NH	19/02/2020	1109	36 57.37	175 51.75	36 57.99	175 52.17	20	22	0.70	5.3	68.3	19.7	19.0	200
30	32NH	19/02/2020	1157	36 59.50	175 52.72	36 59.71	175 53.40	21	22	0.70	5.5	66.6	20.5	19.2	200
31	5287	19/02/2020	1331	36 57.34	175 53.19	36 57.89	175 53.75	35	35	0.70	4.9	70.8	21.3	18.4	200
32	32NH	19/02/2020	1512	37 03.48	175 54.40	37 02.78	175 53.99	13	15	0.70	5.3	66.0	21.1	19.8	200
33	708N	20/02/2020	0556	37 10.77	176 00.88	37 11.43	176 01.22	68	70	0.71	5.1	81.2	21.5	15.6	250
34	708N	20/02/2020	0713	37 11.86	176 02.74	37 12.50	176 03.11	76	77	0.70	5.1	81.1	21.7	15.3	250
35	708N	20/02/2020	0802	37 13.38	176 03.53	37 14.40	176 03.85	75	76	0.70	5.0	80.8	21.7	15.3	250
36	708N	20/02/2020	0950	37 18.25	176 01.66	37 17.80	176 02.34	48	52	0.70	5.0	76.6	21.4	16.8	200
37	5287	20/02/2020	1138	37 13.11	175 56.42	37 13.83	175 56.49	40	42	0.72	5.0	75.9	21.5	17.5	200
38	5287	20/02/2020	1254	37 19.19	175 59.79	37 19.82	176 00.21	37	37	0.71	5.2	76.5	21.4	18.3	200
39	2096	20/02/2020	1406	37 21.71	175 57.89	37 22.37	175 58.22	21	23	0.71	5.3	72.2	21.5	20.1	200
40	708S	21/02/2020	0557	37 19.80	176 03.84	37 20.32	176 04.45	51	53	0.71	4.8	82.1	21.6	17.0	240
41	5287	21/02/2020	0653	37 20.33	176 02.24	37 20.94	176 02.71	45	48	0.71	5.0	75.2	NA	NA	200
42	5287	21/02/2020	0814	37 26.84	176 05.26	37 27.31	176 05.93	33	33	0.70	5.3	76.0	21.1	18.3	200
43	2096	21/02/2020	0945	37 34.60	176 07.78	37 34.52	176 08.45	20	21	0.70	5.3	70.7	21.9	20.1	200
44	6085	23/02/2020	0600	37 47.21	177 26.25	37 47.46	177 25.41	63	64	0.70	5.3	84.5	22.1	15.9	250
45	4085	23/02/2020	0721	37 49.70	177 29.37	37 50.13	177 28.66	35	35	0.70	5.	77.8	22.1	18.7	200
46	4085	23/02/2020	0901	37 51.32	177 25.47	37 51.68	177 24.70	37	38	0.70	4.9	77.4	22.1	18.9	200
47	4085	23/02/2020	1110	37 52.47	177 22.35	37 52.80	177 21.56	38	38	0.70	5.0	78.9	22.2	19.2	200
48	4085	23/02/2020	1243	37 54.00	177 11.82	37 53.75	177 10.98	39	40	0.70	4.9	75.5	22.4	18.7	200
49	4085	23/02/2020	1348	37 54.20	177 06.31	37 54.20	177 05.40	38	39	0.71	4.7	79.8	22.5	19.0	200
50	4085	23/02/2020	1517	37 52.71	177 03.57	37 52.62	177 02.68	40	42	0.70	5.0	80.1	22.2	18.9	200

Station	Stratum	Date	Time	Start of tow ° ' S	Start of tow ° ' E	End of tow ° ' S	End of tow ° ' E	Gear depth (m) Min.	Gear depth (m) Max.	Distance trawled (n. mile)	Headline height (m)	Doorspread (m)	Surface temp ˚C	Bottom temp ˚C	Warp length (m)
51	1096	24/02/2020	0608	37 58.35	177 10.45	37 58.22	177 09.57	12	13	0.70	5.4	72.7	21.8	21.7	200
52	1096	24/02/2020	0741	37 57.72	177 08.91	37 57.71	177 08.20	16	18	0.70	5.2	70.0	21.9	21.4	200
53	1096	24/02/2020	0932	37 53.66	176 53.12	37 53.40	176 52.29	22	22	0.70	5.4	75.1	21.1	20.3	200
54	4085	25/02/2020	0715	37 55.32	177 20.16	37 54.76	177 21.21	30	30	1.01	5.1	77.4	NA	NA	200
55	1096	25/02/2020	0833	37 55.67	177 23.61	37 55.36	177 24.89	23	23	1.07	5.0	75.5	NA	NA	200
56	1096	25/02/2020	0958	37 56.31	177 26.45	37 55.92	177 27.72	18	19	1.08	5.2	75.3	NA	NA	200
57	1096	25/02/2020	1144	37 54.32	177 29.20	37 53.72	177 30.13	20	21	1.07	4.8	76.0	NA	NA	200
58	4085	25/02/2020	1417	37 56.16	177 10.29	37 56.10	177 09.14	30	30	0.92	4.9	83.0	NA	NA	200
59	4085	25/02/2020	1525	37 54.61	177 06.77	37 54.59	177 05.56	35	36	0.95	5.1	80.2	NA	NA	200
60	5287	26/02/2020	0721	37 15.96	175 57.35	37 17.76	175 58.36	35	37	2.02	5.2	74.0	NA	NA	200
61	5287	26/02/2020	0905	37 17.11	175 57.50	37 18.63	175 58.33	31	34	1.69	5.3	70.2	NA	NA	200
62	5287	26/02/2020	1035	37 17.22	175 58.34	37 19.90	175 59.20	33	36	2.04	5.3	75.7	NA	NA	200
63	5287	26/02/2020	1216	37 19.86	175 59.20	37 21.37	175 59.61	28	31	1.62	5.1	76.3	NA	NA	200
64	5287	26/02/2020	1359	37 21.25	175 59.49	37 19.16	175 58.48	25	28	2.28	5.2	75.3	NA	NA	200
65	5287	26/02/2020	1548	37 15.64	175 57.57	37 16.84	175 57.90	33	37	1.27	5.4	74.8	NA	NA	200

Appendix 5: Catch summary for the Hauraki Gulf and Bay of Plenty surveys in order by catch weight

* = less than 0.1% of total catch for that survey.

Hauraki Gulf

Species code	Common name	Scientific name	Catch weight (kg)	% of total catch	No. of stations	% occurrence	Min. depth (m)	Max depth (m)
SNA	Snapper	*Chrysophrys auratus*	28 945.3	89.0	44	100.0	6	69
JMN	Yellowtail jack mackerel	*Trachurus novaezelandiae*	2 129.6	6.5	35	79.5	6	69
EGR	Eagle ray	*Myliobatis tenuicaudatus*	197.5	0.6	16	36.4	6	66
LEA	Leatherjacket	*Meuschenia scaber*	178.1	0.5	22	50.0	16	69
JDO	John dory	*Zeus faber*	177.9	0.5	35	79.5	12	69
BRA	Short–tailed black ray	*Dasyatis brevicaudata*	145.5	0.4	8	18.2	13	44
POP	Porcupine fish	*Allomycterus jaculiferus*	143.7	0.4	15	34.1	16	68
GUR	Gurnard	*Chelidonichthys kumu*	142.1	0.4	43	97.7	6	69
TRE	Trevally	*Pseudocaranx georgianus*	91.9	0.3	21	47.7	6	49
SPO	Rig	*Mustelus lenticulatus*	65.6	0.2	17	38.6	6	66
DSO	Demosponges	Demospongiae	48.4	0.1	2	4.5	20	66
BWH	Bronze whaler shark	*Carcharhinus brachyurus*	45.0	0.1	1	2.3	18	18
SCH	School shark	*Galeorhinus galeus*	36.3	0.1	4	9.1	8	66
HHS	Hammerhead shark	*Sphyrna zygaena*	32.5	0.1	4	9.1	6	13
ATT	Kahawai	*Arripis trutta*	17.7	0.1	13	29.5	6	32
CRS	Airy finger sponge	*Callyspongia ramosa*	16.3	0.1	19	43.2	13	69
WOD	Wood	Wood	14.5	*	3	6.8	19	47
ONG	Sponges	Porifera	12.6	*	6	13.6	20	57
ERA	Electric ray	*Torpedo fairchildi*	8.5	*	2	4.5	14	63
RSK	Rough skate	*Zearaja nasuta*	8.1	*	2	4.5	51	69
ECK	*Ecklonia*	*Ecklonia*	7.3	*	2	4.5	19	20
THR	Thresher shark	*Alopias vulpinus*	6.6	*	1	2.3	13	13
SBL	Fanworms	Sabellidae	5.8	*	6	13.6	6	34
ASC	Sea squirt	Ascidiacea	5.4	*	1	2.3	19	19
SPZ	Spotted stargazer	*Genyagnus monopterygius*	4.5	*	3	6.8	12	39
EMA	Blue mackerel	*Scomber australasicus*	4.1	*	5	11.4	13	36
NMP	Tarakihi	*Nemadactylus macropterus*	3.5	*	3	6.8	51	69
POR	Porae	*Nemadactylus douglasii*	3.1	*	1	2.3	66	66
CON	Conger eel	*Conger* spp.	2.6	*	1	2.3	10	10
BOA	Sowfish	*Paristiopterus labiosus*	2.5	*	2	4.5	20	27
FLL	Fragments shell		2.1	*	1	2.3	20	20
KIN	Kingfish	*Seriola lalandi*	2.0	*	1	2.3	63	63
MUS	Mussels		2.0	*	1	2.3	19	19

Species code	Common name	Scientific name	Catch weight (kg)	% of total catch	No. of stations	% occurrence	Min. depth (m)	Max depth (m)
CAR	Carpet shark	*Cephaloscyllium isabellum*	1.6	*	1	2.3	69	69
BSQ	Broad squid	*Sepioteuthis australis*	1.5	*	3	6.8	6	19
SFL	Sand flounder	*Rhombosolea plebeia*	1.2	*	6	13.6	8	31
APC	*Astropecten* spp.	*Astropecten* spp.	1.1	*	8	18.2	13	69
ASR	Asteroid (starfish)		1.0	*	2	4.5	19	20
COZ	Bryozoan	Bryozoa	0.8	*	1	2.3	47	47
HOR	Horse mussel	*Atrina zelandica*	0.8	*	1	2.3	13	13
PAR	Parore	*Girella tricuspidata*	0.7	*	1	2.3	23	23
SUA	Fleshy club sponge	*Suberites affinis*	0.5	*	4	9.1	47	66
CCM	Eleven–arm seastar	*Coscinasterias muricata*	0.5	*	2	4.5	19	36
BAR	Barracouta	*Thyrsites atun*	0.4	*	3	6.8	38	68
STY	Spotty	*Notolabrus celidotus*	0.4	*	3	6.8	6	14
SQU	Arrow squid	*Nototodarus sloanii* & *N. gouldi*	0.3	*	3	6.8	36	66
PIL	Pilchard	*Sardinops sagax*	0.3	*	3	6.8	14	69
SCC	Sea cucumber	*Stichopus mollis*	0.3	*	2	4.5	13	20
LSO	Lemon sole	*Pelotretis flavilatus*	0.2	*	1	2.3	24	24
RMU	Red mullet	*Upeneichthys lineatus*	0.2	*	2	4.5	13	20
PTU	Sea pens	Pennatulacea	0.1	*	1	2.3	34	34
PYR	*Pyrosoma atlanticum*	*Pyrosoma atlanticum*	0.1	*	1	2.3	68	68
ACP	*Acentrogobius pflaumii*	*Acentrogobius pflaumii*	0.1	*	1	2.3	57	57
CEP	Red bandfish	*Cepola haastii*	0.1	*	1	2.3	57	57
OPA	Opalfish	*Hemerocoetes* spp.	0.1	*	1	2.3	57	57
ANT	Anemones	Anthozoa	0.1	*	1	2.3	31	31
SYC	Clubbed tunicate	*Styela clava*	0.1	*	1	2.3	20	20
WIT	Witch	*Arnoglossus scapha*	0.1	*	1	2.3	39	39

Bay of Plenty

Species code	Common name	Scientific name	Catch weight (kg)	% of total catch	No. of stations	% occurrence	Min. depth (m)	Max depth (m)
SNA	Snapper	*Chrysophrys auratus*	5 692.9	66.2	52	81.2	13	96
POP	Porcupine fish	*Allomycterus jaculiferus*	569.3	6.6	27	42.2	18	77
JMN	Yellowtail jack mackerel	*Trachurus novaezelandiae*	559.2	6.5	33	51.6	18	96
ATT	Kahawai	*Arripis trutta*	256.4	3.0	13	20.3	13	48
EGR	Eagle ray	*Myliobatis tenuicaudatus*	225.7	2.6	19	29.7	13	65
GUR	Red gurnard	*Chelidonichthys kumu*	220.2	2.6	46	71.9	13	96
TRE	Trevally	*Pseudocaranx georgianus*	184.7	2.1	31	48.4	13	63
LEA	Leatherjacket	*Meuschenia scaber*	153	1.8	32	50.0	15	77
SPO	Rig	*Mustelus lenticulatus*	89.3	1	19	29.7	17	66
SEO	Seaweed		80.1	0.9	4	6.2	15	60
JDO	John dory	*Zeus faber*	70.6	0.8	28	43.8	18	96
BRA	Short–tailed black ray	*Dasyatis brevicaudata*	66.5	0.8	3	4.7	15	30
ECK	*Ecklonia*	*Ecklonia*	62.5	0.7	8	12.5	18	60
ULV	Ulva	Ulva	51.0	0.6	2	3.1	21	23
WOD	Wood	Wood	47.9	0.6	4	6.2	21	70
STT	Starry toado	*Arothron firmamentum*	34.7	0.4	5	7.8	33	52
HHS	Hammerhead shark	*Sphyrna zygaena*	30.2	0.4	2	3.1	13	17
PYR	*Pyrosoma atlanticum*	*Pyrosoma atlanticum*	24.3	0.3	11	17.2	40	96
WRA	Longtailed stingray	*Dasyatis thetidis*	20.5	0.2	1	1.6	48	48
ERA	Electric ray	*Torpedo fairchildi*	19.8	0.2	4	6.2	28	77
BOA	Sowfish	*Paristiopterus labiosus*	17.4	0.2	4	6.2	17	40
THR	Thresher shark	*Alopias vulpinus*	15.8	0.2	2	3.1	21	21
KIN	Kingfish	*Seriola lalandi*	13.0	0.2	4	6.2	13	39
FRO	Frostfish	*Lepidopus caudatus*	11.9	0.1	3	4.7	70	96
RHO	Red seaweed	Rhodophyta	10.5	0.1	1	1.6	23	23
POR	Porae	*Nemadactylus douglasii*	7.3	0.1	1	1.6	40	40
SPZ	Spotted stargazer	*Genyagnus monopterygius*	7.1	0.1	5	7.8	18	23
OCT	Octopus	*Pinnoctopus cordiformis*	6.2	0.1	3	4.7	18	96
BSQ	Broad squid	*Sepioteuthis australis*	5.8	0.1	9	14.1	15	70
RSK	Rough skate	*Zearaja nasuta*	5.5	0.1	2	3.1	61	77
NMP	Tarakihi	*Nemadactylus macropterus*	5.2	0.1	4	6.2	39	61
BAR	Barracouta	*Thyrsites atun*	4.9	0.1	3	4.7	15	65
NOS	NZ southern arrow squid	*Nototodarus sloanii*	3.5	*	9	14.1	33	77
LFB	Longfinned boarfish	*Zanclistius elevatus*	2.7	*	1	1.6	65	65
JMD	Greenback jack mackerel	*Trachurus declivis*	2.2	*	8	12.5	38	77

Species code	Common name	Scientific name	Catch weight (kg)	% of total catch	No. of stations	% occurrence	Min. depth (m)	Max depth (m)
LSO	Lemon sole	*Pelotretis flavilatus*	2.2	*	6	9.4	23	77
ONG	Sponges	Porifera	1.9	*	5	7.8	18	53
CRM	Airy finger sponge	*Callyspongia cf ramosa*	1.5	*	4	6.2	25	53
EMA	Blue mackerel	*Scomber australasicus*	1.4	*	6	9.4	21	41
PHC	Packhorse rock lobster	*Jasus verreauxi*	1.3	*	1	1.6	18	18
SQU	Arrow squid	*Nototodarus sloanii* & *N. gouldi*	1.3	*	1	1.6	70	70
TUR	Turbot	*Colistium nudipinnis*	0.8	*	1	1.6	17	17
GAS	Gastropods	Gastropoda	0.7	*	2	3.1	38	41
LMC	Carpet star	*Luidia maculata*	0.7	*	2	3.1	39	40
PIL	Pilchard	*Sardinops sagax*	0.6	*	3	4.7	37	77
APC	*Astropecten* spp.	*Astropecten* spp.	0.6	*	2	3.1	21	60
SFL	Sand flounder	*Rhombosolea plebeia*	0.5	*	1	1.6	22	22
WIT	Witch	*Arnoglossus scapha*	0.4	*	3	4.7	21	70
STY	Spotty	*Notolabrus celidotus*	0.4	*	1	1.6	22	22
CCM	Eleven–arm seastar	*Coscinasterias muricata*	0.3	*	2	3.1	30	56
SCG	Scaly gurnard	*Lepidotrigla brachyoptera*	0.2	*	2	3.1	61	96
SKI	Gemfish	*Rexea* spp.	0.2	*	1	1.6	48	48
ANC	Anchovy	*Engraulis australis*	0.2	*	2	3.1	21	28
WAR	Common warehou	*Seriolella brama*	0.2	*	1	1.6	22	22
SCA	Scallop	*Pecten novaezelandiae*	0.1	*	1	1.6	25	25
SNI	Snipefish	*Macroramphosus scolopax*	0.1	*	1	1.6	70	70

Appendix 6: Benthic and pelagic macro–invertebrates taken as bycatch during the Hauraki Gulf and Bay of Plenty surveys

Hauraki Gulf

Species code	Common name	Scientific name	No. of stations
CRS	Airy finger sponge	*Callyspongia ramosa*	19
APC	*Astropecten* spp.	*Astropecten* spp.	8
ONG	Sponges	Porifera	6
SBL	Fanworms	Sabellidae	6
SUA	Fleshy club sponge	*Suberites affinis*	4
BSQ	Broad squid	*Sepioteuthis australis*	3
SQU	Arrow squid	*Nototodarus sloanii & N. gouldi*	3
DSO	Demosponges	Demospongiae	2
ASR	Asteroid (starfish)		2
CCM	Eleven–arm seastar	*Coscinasterias muricata*	2
SCC	Sea cucumber	*Stichopus mollis*	2
ASC	Sea squirt	Ascidiacea	1
MUS	Mussels		1
HOR	Horse mussel	*Atrina zelandica*	1
PTU	Sea pens	Pennatulacea	1
PYR	*Pyrosoma atlanticum*	*Pyrosoma atlanticum*	1
ACP	*Acentrogobius pflaumii*	*Acentrogobius pflaumii*	1
ANT	Anemones	Anthozoa	1
SYC	Clubbed tunicate	*Styela clava*	1
CKI	Pink conular sponge	*Chondropsis kirkii*	1
ONG	Sponge	*Iophon minor*	1
ONG	Sponge	*Cliona celata*	1
ONG	Sponge	*Dysidea* sp.	1
COZ	Bryozoan	*Arachnopusia* sp.	1
COZ	Bryozoan	*Bugula* sp.	1
COZ	Bryozoan	*Caberea zelandica*	1
COZ	Bryozoan	*Cellaria tenuirostris*	1
COZ	Bryozoan	*Cornuticella trapezoidea*	1
COZ	Bryozoan	*Diaperoecia purpurascens*	1
COZ	Bryozoan	Exidmonea	1
COZ	Bryozoan	*Galeopsis porcellanicus*	1
COZ	Bryozoan	*Gregarinidra* sp.	1

Bay of Plenty

Species code	Common name	Scientific name	No. of stations
PYR	*Pyrosoma atlanticum*	*Pyrosoma atlanticum*	11
BSQ	Broad squid	*Sepioteuthis australis*	9
NOS	NZ southern arrow squid	*Nototodarus sloanii*	9
ONG	Sponges	Porifera	5
CRM	Airy finger sponge	*Callyspongia cf ramosa*	4
OCT	Octopus	*Pinnoctopus cordiformis*	3
GAS	Gastropods	Gastropoda	2
APC	*Astropecten* spp.	*Astropecten* spp.	2
CCM	Eleven–arm seastar	*Coscinasterias muricata*	2
PHC	Packhorse rock lobster	*Jasus verreauxi*	1
SQU	Arrow squid	*Nototodarus sloanii* & *N. gouldi*	1
SCA	Scallop	*Pecten novaezelandiae*	1
ASC	Sea squirt	*Molgula* sp.	1
ONG	Sponge	*Tedania diversirhaphidiophora*	1
ONG	Sponge	*Ciocalypta* sp.	1

Appendix 7: Estimates of proportion of length-at-age for snapper sampled from (a) the 2019 Hauraki Gulf and (b) the 2020 Bay of Plenty surveys

(a) Hauraki Gulf

Length	Age (years)																	No.
(cm)	0+	1+	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+	12+	13+	14+	15+	>15+	aged
7	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4
8	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13
9	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15
10	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	22
11	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	25
12	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	24
13	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7
14	0.57	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7
15	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	18
16	0.00	0.95	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	22
17	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16
18	0.00	0.56	0.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9
19	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9
20	0.00	0.00	0.97	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	31
21	0.00	0.05	0.70	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20
22	0.00	0.00	0.41	0.56	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	34
23	0.00	0.00	0.08	0.76	0.14	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	51
24	0.00	0.00	0.02	0.40	0.32	0.14	0.10	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	50
25	0.00	0.00	0.00	0.45	0.10	0.40	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20
26	0.00	0.00	0.00	0.15	0.20	0.40	0.05	0.10	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20
27	0.00	0.00	0.00	0.05	0.25	0.30	0.00	0.10	0.15	0.05	0.05	0.00	0.05	0.00	0.00	0.00	0.00	20
28	0.00	0.00	0.00	0.15	0.15	0.15	0.15	0.05	0.15	0.05	0.00	0.10	0.00	0.00	0.05	0.00	0.00	20
29	0.00	0.00	0.00	0.05	0.10	0.00	0.15	0.10	0.05	0.10	0.15	0.05	0.05	0.10	0.00	0.05	0.05	20
30	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.15	0.15	0.05	0.20	0.10	0.05	0.15	0.00	0.00	0.05	20
31	0.00	0.00	0.00	0.00	0.00	0.03	0.15	0.06	0.09	0.15	0.15	0.06	0.09	0.03	0.03	0.15	0.00	33
32	0.00	0.00	0.00	0.00	0.00	0.11	0.14	0.11	0.08	0.05	0.16	0.14	0.05	0.05	0.00	0.05	0.05	37

Length (cm)	Age (years) 0+	1+	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+	12+	13+	14+	15+	>15+	No. aged
33	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.05	0.10	0.10	0.05	0.00	0.25	0.10	0.00	0.00	0.15	20
34	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.13	0.06	0.19	0.00	0.25	0.13	0.00	0.06	0.06	0.06	16
35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.09	0.00	0.00	0.27	0.36	0.09	0.00	0.00	0.09	11
36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.05	0.14	0.14	0.05	0.05	0.24	0.00	0.05	0.24	21
37	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.09	0.09	0.18	0.00	0.09	0.00	0.00	0.09	0.36	11
38	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.11	0.22	0.11	0.11	0.11	0.11	0.00	0.11	9
39	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.25	0.00	0.00	0.25	4
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.20	0.00	0.00	0.60	5
41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.63	8
42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.50	2
43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.67	3
44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.67	3
45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	4
46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1
47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.33	0.00	0.00	0.00	0.33	3
48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	4
49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1
50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1
51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0
52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	2
53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1
54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1
55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1
56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0
57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0
58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0
59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0
60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1
61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0

Length (cm)	Age (years) 0+	1+	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+	12+	13+	14+	15+	>15+	No. aged
62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0
63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0
64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0
65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0
66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1
Total																		701

(b) Bay of Plenty

Length (cm)	Age (years) 0+	1+	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+	12+	13+	14+	15+	16+	17+	18+	19+	>19+	No. aged
7	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1
8	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10
9	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	30
10	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15
11	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11
12	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16
13	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16
14	0.00	0.27	0.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11
15	0.00	0.11	0.89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9
16	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15
17	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	22
18	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	18
19	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9
20	0.00	0.00	0.50	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12
21	0.00	0.00	0.29	0.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14
22	0.00	0.00	0.00	0.83	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12
23	0.00	0.00	0.07	0.57	0.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14
24	0.00	0.00	0.00	0.19	0.50	0.25	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16
25	0.00	0.00	0.00	0.09	0.43	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	23
26	0.00	0.00	0.00	0.00	0.09	0.74	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	23
27	0.00	0.00	0.00	0.00	0.13	0.83	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	23
28	0.00	0.00	0.00	0.00	0.00	0.74	0.13	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	23
29	0.00	0.00	0.00	0.00	0.04	0.48	0.26	0.09	0.09	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	23
30	0.00	0.00	0.00	0.00	0.00	0.26	0.26	0.30	0.13	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	23
31	0.00	0.00	0.00	0.00	0.00	0.04	0.13	0.26	0.26	0.00	0.13	0.09	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	23
32	0.00	0.00	0.00	0.00	0.00	0.09	0.17	0.30	0.22	0.04	0.09	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	23
33	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.13	0.22	0.13	0.26	0.09	0.04	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	23

Length (cm)	Age (years) 0+	1+	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+	12+	13+	14+	15+	16+	17+	18+	19+	>19+	No. aged
34	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.30	0.39	0.04	0.04	0.09	0.04	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	23
35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.13	0.26	0.09	0.00	0.13	0.09	0.00	0.00	0.04	0.00	0.00	0.00	0.00	23
36	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.22	0.09	0.04	0.04	0.13	0.22	0.13	0.04	0.00	0.00	0.00	0.04	0.00	0.00	23
37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.04	0.00	0.17	0.13	0.13	0.09	0.09	0.22	0.00	0.00	0.00	0.04	0.00	23
38	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.07	0.07	0.03	0.21	0.28	0.07	0.03	0.03	0.10	0.00	0.03	0.03	29
39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.09	0.04	0.13	0.04	0.09	0.04	0.17	0.13	0.09	0.00	0.04	0.09	23
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.17	0.00	0.04	0.17	0.09	0.09	0.04	0.13	0.09	0.04	0.00	23
41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.14	0.00	0.14	0.14	0.00	0.00	0.00	0.14	0.07	0.14	0.00	0.07	14
42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.08	0.00	0.17	0.17	0.08	0.08	0.00	0.08	0.08	0.17	12
43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.14	0.00	0.00	0.14	0.00	0.00	0.00	0.14	0.29	0.14	7
44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	3
45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.30	0.00	0.00	0.30	0.00	0.10	0.00	0.00	0.20	10
46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.33	0.50	6
47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.67	3
48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.50	2
49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.33	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	3
50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	3
51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.50	2
52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1
53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.33	0.00	0.50	6
54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.17	0.00	0.75	0
55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1
56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0
57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1
58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	2
Total																						701