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Catch-at-age of yellowtail kingfish (*Seriola lalandi*) caught by recreational fishers in KIN 1, New Zealand

New Zealand Fisheries Assessment Report 2013/3.

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Yellowtail kingfish are large semi-pelagic predators found mainly around rocky headlands, offshore islands and reef systems. They can grow to over 50 kg and 1.8 m long and are highly valued by recreational, customary and commercial fishers. Commercial landings of kingfish are reported largely as bycatch of inshore set net, trawl and bottom longline fisheries. From 1991 to late 2003 targeting of kingfish (at the time a non-QMS species) was prohibited unless the species was authorised on a fisher's permit. A few permit holders were authorised to target kingfish, and most of their catch was taken using set nets. Reported commercial catch in KIN 1 peaked at 378 t in 1992–93 and declined steadily to 49 t in 2003–04.

Kingfish are targeted by recreational fishers as a challenging species to catch on rod and reel, especially the larger fish. Harvest surveys of recreational catch have estimated between 380 t and 800 t of kingfish are taken in KIN 1 (North Cape to Cape Runaway). There is some uncertainty about these diary surveys estimates but in all three surveys kingfish was the third largest harvest in Quota Management Area 1, behind snapper and kahawai.

Kingfish were introduced to the Quota Management System in 2003 with an allowance of 459 t for recreational fishers, 76 t for customary fishers, and a Total Allowable Commercial Catch of 91 t in KIN 1. This project estimates the age structure of the KIN 1 population by sampling recreational catch as this is the largest fishery and main target method in the area.

The sampling design was based on data captured from New Zealand Sport Fishing Council club records and the Gamefish Tagging Programme. The main season was January to June and the KIN 1 area was split into two sub-regions: Bay of Plenty, and East Northland and Hauraki Gulf combined.

A total of 2091 kingfish were measured in this survey. Of these, 1287 (62%) were released, 711 (34%) without being tagged. The target sample size of 1000 lengths and 250 heads from East Northland and the Hauraki Gulf was exceeded (1198 lengths and 285 otolith sets) between February and July. Anglers and skippers from Bay of Plenty collected 905 lengths and 175 otolith sets between February and November in 2010. Since this was below target, the collection period was extended from July to November to boost numbers. The distribution of sample collections across all fishery statistical areas was adequate.

Many fishing clubs have a voluntary minimum size of 100 cm for kingfish. In the Bay of Plenty the survey length distribution matched the club and tagging data length distribution well. The survey sample from East Northland had a higher proportion of fish between 100 and 106 cm and fewer large fish over 120 cm than the club and tagging records.

Kingfish otolith samples were collected as a subsample of all kingfish measured and used to create age-length keys by sex and sub-region. Otoliths were aged using thin sections with emphasis on accurately identifying the first annulus. Levels of between-reader agreement for initial readings appeared moderate at 55% and 65% for East Northland/Hauraki Gulf and Bay of Plenty otolith samples respectively, with estimates of IAPE of 3.6% and 3.0%. Levels of agreement between each reader and the final agreed age estimates were higher and ranged from 80–87% for reader 1 and 73–77% for reader 2.

Most kingfish sampled from recreational catch in East Northland/Hauraki Gulf and Bay of Plenty during 2010 were less than 120 cm in length. Young kingfish grew rapidly and started to recruit to the

fishery (the minimum legal size of 75 cm) as three year olds, and were fully recruited at 4 or 5 years. The East Northland sample was dominated by young fish less than 8 years old, with few fish older than 12 years. The oldest and largest fish sampled in East Northland was a 156 cm fish (41.6 kg) caught in Bream Bay aged at 22 years.

Spatial differences in age composition were evident within the Bay of Plenty samples; with fish older than 15 years poorly represented in inshore areas when compared to White Island. The age structure of the Bay of Plenty inshore samples was nevertheless broader than those from East Northland. The oldest fish sampled in Bay of Plenty was a 170 cm fish caught at White Island aged at 24 years.

Chapman and Robson estimates of total mortality (Z) differ between the two KIN 1 sub-regions; fewer older fish in East Northland implies a higher level of fishing mortality than for the Bay of Plenty. Assuming full recruitment as 5 year olds in East Northland produces a total mortality estimate of 0.77 and assuming 5 or 6 years in the Bay of Plenty produces a total mortality estimate of 0.34–0.42. Estimates of Z for offshore (i.e., White Island) and inshore Bay of Plenty samples were 0.3 and 0.38, respectively; assuming an age of full recruitment of 5 years.

Natural mortality for kingfish based on a maximum age of 23 years is about 0.20. This could mean that the Bay of Plenty stock is at about full utilisation while East Northland is overfished. However, there may be explanations, other than fishing mortality, for the lack of older fish in our sample. For example older fish may migrate offshore; as observed for White Island in the Bay of Plenty.

Equilibrium fishing mortalities were derived from a per recruit analysis using growth estimates for female kingfish, natural mortality of 0.2, and age at maturity of 6 years old. The total mortality corresponding to 40% SSB/R for females equates approximately to 0.3, a value within the likely range of estimates for the Bay of Plenty.

Including historic catch in the qualitative analysis and extending the sampling area to include the Three Kings Islands and Ranfurly Bank in future programmes may help resolve uncertainty regarding the degree to which the age composition of the catch reflected that of the whole kingfish population in each region.

1. INTRODUCTION

1.1 Overview

Southern yellowtail kingfish (*Seriola lalandi lalandi*) have been recorded from latitude 29° to 46° S (Kermadec Islands to Foveaux Strait), but are predominantly found around the North Island and also occur at the top of the South Island in summer. Juveniles are often associated with rafts of floating debris or seaweed. Adult kingfish are large predatory fish that can exceed one and a half metres in length. They usually occur in schools ranging from a few fish to well over one hundred individuals. Adult kingfish tend to occupy a semi-pelagic existence and occur mainly in open coastal waters, preferring areas adjacent to rocky outcrops, reefs and pinnacles, particularly around off-shore islands. However, kingfish are not restricted to these habitats and are sometimes caught or observed in open sandy bottom areas and within shallow enclosed bays and harbours.

The biology and fisheries for kingfish in New Zealand were summarised in 2003 (Walsh et al. 2003). Further work was conducted on age, growth, maturity and natural mortality (McKenzie et al. 2005). Current biological parameters are summarised in the kingfish plenary report (Ministry of Fisheries 2011). This report notes that kingfish is a high value species for all stakeholders. Estimates of current and reference biomass are not available. It is not known if recent combined commercial and recreational catch levels are sustainable or if they are at levels that will allow the stocks to move towards a size that will support MSY.

While a formal stock assessment (based on a stock assessment model) is not proposed for kingfish at this time, age composition of the catch has been shown by previous studies to provide information on stock status and the sustainability of current removals. It is, however, critical in the case of kingfish that accurate information on the size (and age) composition of released fish is collected.

Age structure provides a tool with which exploitation rate can be measured, allowing for both temporal and spatial comparisons. Monitoring age structure also provides a means to better evaluate the response of a population to changes in regulations.

This report presents results from investigations undertaken pursuant to Ministry contract KIN2009/01. The contracted research study had two objectives:

1. To characterise the fisheries in order to inform the sampling design development and to investigate the use of Charter Boat CPUE as a monitoring tool for KIN 1.

2. To conduct representative sampling to determine the length, sex, and age composition of the recreational charter boat landings of kingfish in KIN 1 for the 2010–11 fishing year to monitor the KIN 1 stock.

Objective 2 had three specific analytical sub-components:

- Estimate the age structure of the KIN 1 population/s;
- Estimate total fishing mortality (Z) using a suitable catch curve approach allowing for uncertainty in key parameters (i.e. age at full recruitment and sample selectivity issues);
- Provide an estimate of F_{MSY} based on spawner biomass per recruit analyses (e.g. $F_{40\%SBR}$).

This project contributes to the overall objective ‘to monitor the status of kingfish (*Seriola lalandi*) stocks in KIN 1.

1.2 Description of the fishery

Recreational Fishery

The yellowtail kingfish is New Zealand's premier small gamefish species. New Zealand has a reputation for the largest yellowtail in the world, and 21 of 22 world records are held by New Zealand anglers (the woman's 1 kg line class record was caught in Australia) (IGFA 2012). The all-tackle record is shared by two Bay of Plenty anglers who caught 52 kg specimens in 1984 and 1987. New Zealand records are held by anglers from Gisborne to the Middlesex Bank.

Most of the recorded recreational catch is taken between January and June. This pattern tends to reflect general fishing effort, although the peaks in February and June coincide with an increase in targeting during specific fishing competitions (Figure 1).

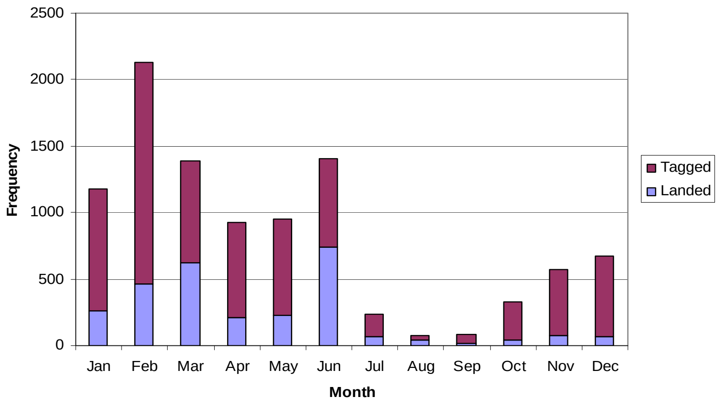

Figure 1: Recreational kingfish catch, landed and tagged, by month 1999 to 2009 in all areas.

Kingfish catches reported in sport fishing club records show seasonal peaks in different geographic locations that reflect in part the availability of other, larger species. Thus, in Northland the peak season tends to be autumn and winter, when the migratory species have largely deserted coastal waters. In Cook Strait, yellowtail are encountered mainly in summer. From East Cape to Hawke Bay, most fishing also occurs in summer (Holdsworth et al. 2007).

National recreational harvest is estimated to be several hundred tonnes with most catch reported from KIN 1 (Table 1). The Ministry note that the harvest estimates from the diary surveys should be used only with the following qualifications: a) they may be very inaccurate; b) the 1996 and earlier surveys contain a methodological error; and c) the 2000 and 2001 estimates are implausibly high for many important fisheries.

Table1: Recreational harvest estimates for KIN 1 (Ministry of Fisheries 2011).

Survey Year	Survey Method	Number	c.v. (%)	Range	Estimated Harvest (t)
1994	Telephone/diary	180 000	9	-	228
1996	Telephone/diary	194 000	7	215–255	234
2000	Telephone/diary	701 000	13	590.9–764	677
2001	Telephone/diary	449 000	19	-	434

The introduction of the higher MLS of 75 cm on 15 January 2004, which applies to recreational kingfish only, will have reduced the number of fish harvested. The recreational allowance in KIN 1 is 459 t and is significantly higher than in other fishery management areas (Table 2).

In 2004–05 a recreational harvest estimate for KIN 1 was requested as part of the combined aerial / boat ramp survey targeted primarily at snapper (*Pagrus auratus*) and kahawai (*Arripis trutta*). The pelagic fisheries assessment working group indicated that this estimate (106 tonnes) should be considered with considerable caution due to the limited overlap between this method's sampling frame and the fisheries for kingfish, e.g., the target fisheries for kingfish are usually in off-shore areas from launches which were not sampled by the boat ramp survey (Ministry of Fisheries 2011). Boat ramp intercept surveys are not suitable for estimating length and age structure of the population because of the low numbers encountered, even in KIN 1.

Many fishing clubs and some charter boat associations have adopted personal and boat limits that are more restrictive than the national bag and size limits. Charter vessels working the White Island area impose a bag limit of one retained yellowtail per day on their customers, and many clubs have a minimum size of one metre rather than the minimum legal size of 75cm. The Bay of Islands Swordfish Club allows anglers fishing in its International Tournament a personal limit of two fish per day and a boat limit of six, as opposed to the national bag limit of three per person.

Customary fishery

Kingfish is an important traditional food for Mäori, but no quantitative information about customary catch is currently available. The extent of the traditional fisheries for kingfish is described in the Muriwhenua Fishing Report. Given the coastal distribution of the species and its inclination to strike lures, it is likely that Mäori caught considerable numbers.

Regulations provide for Tangata tiaki/kaitiaki (once appointed) to report customary catch that they have authorised. Tangata tiaki/kaitiaki appointments currently cover only parts of the fishery and therefore traditional customary harvest authorised by them, while recorded, will be incomplete for the fishery as a whole. The customary allowance in KIN 1 is 76 t (Table 2).

Commercial fishery

Commercial landings of kingfish are reported largely as bycatch of in-shore set net, trawl and bottom longline fisheries. From 1991 to late 2003 targeting of kingfish (at the time a non-QMS species) was prohibited unless the species was authorised on a fisher's permit. A few permit holders were authorised to target kingfish, and most of their catch was taken using set nets. A MLS of 65 cm has been in place since October 1993 for all methods except trawl. The trawl exemption with respect to MLS was removed in December 2000. A minimum net mesh size of 100 mm applies to both commercial and non-commercial set netting for kingfish.

The main commercial fishing areas for kingfish are the east (QMAs 1 and 2) and west coast (QMA 8) of the North Island. The largest commercial catches generally come from QMA 1. Reported commercial catch in KIN 1 peaked at 378 t in 1992–93 and declined steadily to 49 t in 2003–04and has remained 50 to 60 t since then. Kingfish were introduced to the quota management system in 2003 and the TACC in KIN 1 is 91t.

Table 2: Recreational and customary non-commercial allowances, TACCs and TACs by Fishstock (Ministry of Fisheries 2011).

Fishstock	Recreational Allowance	Customary non-commercial Allowance	Other sources of fishing related mortality	TACC	TAC
KIN 1	459	76	47	91	673
KIN 2	65	18	24	63	170
KIN 3	1	1	0	1	3
KIN 4	1	1	0	1	3
KIN 7	10	2	2	7	21
KIN 8	31	9	7	36	83
KIN 10	1	0	0	1	2

1.3 Movement of tagged fish

Around 18 000 kingfish have been tagged and released in the New Zealand gamefish tagging programme for over 1300 recaptures (Holdsworth & Saul 2011). Most of these fish have been tagged off the north and east coasts of the North Island. While yellowtail kingfish are capable of extensive movements (five trans-Tasman trips have been recorded) more than 80% of recaptures are made in the same statistical area as release. Releases and recaptures can be summarised by General Statistical Area on the North and east coasts (Table 3). There is movement between statistical areas 002 and 003 in East Northland and movement to and from 003 and the Hauraki Gulf. In the Bay of Plenty there is some movement between 009 and 010 but less from 008. A reasonable proportion of recaptures from 008 have been made in East Northland and Hauraki Gulf and a few have travelled north and south out of the BOP from 009 and 010. It is unknown if there are differences in growth rates between the main kingfish fishing areas in East Northland and Bay of Plenty. There is some evidence of large fish being caught at remote off-shore locations but this may be due to low exploitation rates and a degree of residency.

Table 3: Release and recapture statistical areas for recaptured kingfish since 1994, East Northland and Hauraki Gulf areas (areas 2–7) and Bay of Plenty areas (areas 8–10).

Recapture statistical areas	Release statistical areas													
Stat.	47	48	2	3	5	6	7	8	9	10	11	12	13	Total
47	29	2		1										32
48	2	18												20
2		1	66	8				1		1				77
3	1		12	134	2	1	1	1	1	3			1	157
5	1		1	5	6	1		1		2				17
6				1		3	4	1	1					10
7				3	1	5	14							23
8				2				12	2	3		1		20
9				1				1	107	22	1	1		133
10		1							10	543	1	2	1	558
11										3	11	4		18
12										1	1	13		15
13								1	1	4	1	6	5	18
Total	33	22	79	155	9	10	19	18	122	582	15	27	7	1098

1.4 Sexual dimorphism

Stratified sampling of yellowtail kingfish landed by commercial fishers in NSW was conducted between 1998 and August 2000 (Stewart et al. 2004). The coast of NSW (latitude 29° S to 37.3° S) was divided into three regions. Forty seven tonnes of kingfish, representing 16% of total landings, were measured during the study. The results showed that the fishery was dominated by fish smaller than 65 cm fork length. Estimates of kingfish ages were made by counting annual marks in otoliths. Estimated ages ranged up to 21 years, however the fishery was dominated by 2 and 3 year old fish. There were no differences in the growth rates of kingfish from the three regions along the NSW coast, from Lord Howe Island, or between males and females (Stewart et al. 2004).

Thompson et al. (1999) found no differences in the growth rates of males and females for the closely related *Seriola dumerili* from the Gulf of Mexico, but did report sex related differences in their maximum sizes. Males were rarely found to be older than 7 years, whereas females were found up to 15 years. This is hypothesized to be the result of age related differential mortality, with males dying at younger ages than females. No evidence of this was found in the Australian study but the authors caution that few large fish were sampled (Stewart et al. 2004).

McKenzie et al. (2005) reported that despite the von Bertalanffy fits to the projected age datasets suggesting that growth rates of female kingfish are faster than males this hypothesis was not supported by the Kimura (1980) likelihood ratio tests. These tests failed to show that separately fitted male and female fitted von Bertalanffy parameters were significantly different from the sex combined values. Again this could be due to the small number of older fish sampled (more than 13 years) (McKenzie et al. 2005).

1.5 Charter boat logbooks

The Ministry has instigated a compulsory charter boat logbook which will require activity reports and records of catch for some species. Over 300 vessels have registered and started reporting activity, including fishing effort, during the 2010–11 fishing year. The numbers of kingfish retained will also be collected for charter trips in KIN 1 and KIN2 from 1 October 2011. A time series of kingfish catch per unit effort will be collected using these logbooks. Data on catch rates from the Ministry logbooks were not available during the time frame of this project.

1.6 Stock monitoring

An MFish funded project (KIN2004/01) investigated the feasibility of establishing a stock monitoring project for kingfish. Some of the conclusions of the draft report (McKenzie et al. 2006) were that:

- implementation of a 3–5 year charter boat based monitoring programme would be highly feasible in KIN 1;
- information on spatial recreational effort is missing. In future this information could be collected as part of a charter boat logbook programme;
- a method that catches a wide range of adult kingfish age classes is preferable for stock monitoring purposes;
- the simulations indicate that MWcv scores of 0.2 could be achieved from age collections of between 400 and 450 otoliths and length samples of between 150 and 200 trips;
- a charter boat based monitoring programme would require the supplementation of age data from the commercial fishery.

2. METHODS

2.1 Sampling Design

Existing data sources were used to characterise the recreational kingfish fishery and to investigate its spatial and temporal character. These included the gamefish tagging release (n = 11 700) and recapture data (n = 670) since 1994 and catch records for individual fish from gamefish club records.

The sampling design was intended to spread sampling effort across the sub-areas of East Northland, Hauraki Gulf and Bay of Plenty in Quota Management Area KIN 1. We did not attempt to characterise the age composition of the “actual” KIN 1 recreational catch. Following consultation with the Ministry of Fisheries the project focused on collecting lengths and hard parts in two areas of KIN 1 for one year.

The key elements of sampling design presented to and approved by the Northern Inshore Working group were:

– The two areas to be sampled are Bay of Plenty, and East Northland and Hauraki Gulf combined;

– Vessel trip is the sampling unit. There will be a spread of trips across the main statistical areas;
– Sampling will cover the main season from late January to end of July;
– Avid kingfish fishers will be recruited to measure all their kingfish catch and to retain heads;
– A large proportion of fish are caught and released so sampling at sea will be required;
– The well-established practice of measuring kingfish prior to tag and release will be encouraged;
– Sampling kits will be provided and fishers trained to measure to the nearest millimetre to encourage accurate measurements.

There are difficulties in determining the appropriate distribution of sampling effort because the annual kingfish catch by recreational fishers is not available. To provide an indication of recreational kingfish catch, fishing club and tagging programme records were combined and summarised by statistical area.

A large proportion of mature kingfish are released by recreational fishers - a direct result of kingfish bag limits and a range of additional voluntary conservation limits which are in place in various regions of KIN 1. Therefore, most of the kingfish length data was sourced via voluntary sampling at sea.

Kingfish measuring boards were designed and built to ensure the consistent measurement of kingfish across a range of different data collectors, and to be resilient to a range of weather and fishing boat conditions. Each board was cut to a length of 1200 mm from 400 mm diameter pipe to provide a curved surface to ‘cup’ and secure live kingfish when placed on the board.

Charter boat operators and avid private fishers were initially recruited using telephone and email. This was followed with a one-on-one meeting for each fisher who indicated a keen interest in the programme. During this meeting, fishers were introduced to the project objectives and the requirements of their time and effort to produce successful data. A detailed training session was provided to each fisher on the required methods of measuring and sexing kingfish, and how to remove and freezer store the heads of retained kingfish. Specifically, fishers were asked:

1. To record the date, general locality of capture, fishing method and fish length of each kingfish encountered for the duration of the programme.
2. To accurately measure all landed kingfish using the measuring board provided, including length measurements of all kingfish that are released back to the sea.
3. For each retained kingfish - to assess and record the gender (where possible), to remove and label the head using the waterproof head-tags provided in the sampling kit, and to freeze store the kingfish head until collection by Blue Water Marine Research staff.

Fishers were regularly and routinely contacted by telephone, email, in person and through a monthly newsletter service. This enabled any questions or problems with the programme to be readily identified and resolved; regular communication maintained higher levels of fisher interest in the programme; and it also allowed for frozen kingfish heads to be regularly retrieved from frozen storage.

Kingfish heads were collected from fishers via either direct pick-up by Blue Water Marine Research staff or courier delivery service. Kingfish heads were slowly defrosted at the ambient outside temperature prior to removal of otoliths. Data listed on each head-tag was double checked with the associated length/gender data sheet retrieved from the fisher.

For otolith removal, each kingfish head was mounted on a spike protruding from a timber board. A sharpened knife was driven along the top of the skull using a rubber mallet to expose the brain cavity. Two saggitae otoliths were gently extracted from the semicircular canals beneath the brain using dissection forceps. Otoliths were rinsed in freshwater to remove associated tissue and placed in plastic vials and then stored in labelled envelopes.

2.2 Otolith collections, preparation and ageing of kingfish

Kingfish otolith samples were collected as a subsample of all kingfish sampled for length frequency, predominantly from recreational fishers, with a few supplementary samples from commercial landings, between February and November 2010, and used to create age-length keys (refer Davies & Walsh 1995).

Kingfish otolith preparation and ageing, using the thin section technique, generally followed that previously described by McKenzie et al. (2005). Two readers initially spent time familiarising themselves with images of clear and easily interpretable thin section preparations from the previous research collection from 2002–03 with an aim of improving accuracy and precision in age estimates in the current collection. Opaque zones, which appear dark in thin section preparations under transmitted light, were counted from the core to the otolith edge, the primary axis being the dorsal sulcus region, as the ventral sulcus was often unclear. The formation of an opaque zone signified one fully deposited opaque and translucent zone had been previously laid down, indicative of a full year of growth. An opaque zone was usually present on the otolith edge around December, but this varied with age, indicating the translucent zone had probably been fully laid down 2–3 months earlier. The readability of each otolith was scored on a scale of 1 (excellent) to 5 (very uncertain) and a three-point margin state (Line, Narrow, Wide) was implemented.

Although previous research on ageing kingfish sampled from Bay of Plenty in 2002–03 showed good reader precision for a single reader, between reader differences were more obvious with bias predominantly related to different interpretations of the first annulus (McKenzie et al. 2005). Walsh & McKenzie (2009) determined similar inconsistencies in ageing trevally, and adopted a rigorous approach with an aim to improve reader accuracy and increase between-reader agreement. In summary, this modified protocol focused mainly on three main facets: the interpretation and location of the first annulus; forcing an expected margin on the reader relative to the otolith collection date; and allowing the readers access to a variety of otolith images from previous collections in the hope of improving reader accuracy and precision, especially in preparations that were not easily interpretable. Therefore, an approach similar to that for trevally was followed for ageing kingfish in 2010. Firstly, two readers read the entire sets independently to determine an unbiased reading estimate. Where agreement was reached, it was deemed to be the final agreed reading. If no agreement was attained, then the otolith was reviewed again with a third experienced reader present (via remote log-ons and teleconference technology) to reach agreement, or discarded from the set as unreadable. It was envisaged that discarding a random uninterpretable otolith from the age-length key should have minimal effect on the sample collections and is likely to improve the precision in estimates of catch-at-age. Other techniques developed from ageing inshore species such as trevally and tarakihi were also utilised. These included determining a distance range from the core to first opaque zone for adult kingfish, by comparing the size of otoliths from juvenile (0+) kingfish collected from FADs between February and August 2002. The first opaque zone is generally unclear in adult kingfish thin sections, and unlike the second zone, was found to be problematic in previous kingfish ageing (McKenzie et al. 2005). Dimpling on the distal otolith surface and sulcul groove also provided useful checks for the first annulus and subsequent annual zone deposition. Age was defined as a rounded whole year from a nominal birth date of 1 January.

Otolith reader precision was quantified by carrying out between-reader comparison tests on initial readings and calculating the Index of Average Percentage Error, IAPE (Campana et al. 1995). Age bias plots were used to detect bias in readings (Campana et al. 1995) by plotting each reader’s age estimate, derived from initial readings, against the final agreed age estimates (Davies et al. 2003). Initial age estimates for each of the two readers were plotted as a mean with a 95% confidence interval for each age class. Bias in initial ages occurs when the mean of the initial age estimates is clearly higher or lower than the final agreed age estimate for that age class, relative to the 95% confidence interval.

2.3 Catch at age estimation

An age-length key approach (Davies et al. 2003) was used to derive age composition estimates for the East Northland/Hauraki Gulf and Bay of Plenty KIN 1 sub regions. No fish were collected prior to 1 January 2010 so no adjustment for fish collected prior to that time, the nominal birth date, was necessary.

As it was not essential that otolith samples used to derive the age-length keys came solely from the recreational fishery, the age length keys were supplemented with commercially caught fish. All length samples, however, came entirely from recreational catches, pursuant to a spatial and temporally stratified sampling design.

Estimated scaled numbers-at-age were calculated using NIWA Catch-at-length and age software in R. Age and length frequency distributions were estimated by sex. The mean-weighted coefficients of variation (MWCV) were estimated by sex and overall using a bootstrapping routine (1000 bootstraps).

2.4 Growth parameter estimates

A von Bertalanffy growth model was fitted to the length-age data, by sex, using the model:

$$L_t = L_\infty\,(1 - \exp^{-K[t - t0]})$$

Where L_t was the length (cm) at age t, L_∞ the asymptotic mean maximum length, K was a constant (growth rate coefficient), and t_0 was the hypothetical age (in years) that the fish has zero length.

2.5 Mortality estimates

Total mortality (Z) was estimated from catch-curve analysis using the Chapman-Robson estimator (CR, Chapman & Robson 1960). The CR method has been shown to be less biased than the simple regression catch curve analysis (Dunn et al. 2002). Catch curve analysis assumes that the catch of fully recruited age classes declines exponentially with age and that the slope is equivalent to equilibrium total mortality experienced by the population, the sum of natural and fishing mortality, Z = (M + F). Implicit in this analysis are the assumptions that recruitment and mortality are constant, that all fully recruited fish are equally vulnerable to capture, and that there are no age estimation errors.

2.6 YPR and SSBR estimation

Spawning per recruit calculations were carried out using CASAL (Bull et al. 2008). Fishing mortality rate estimated from the catch curve were expressed as $F_{\%SPR}$.

3. RESULTS

3.1 2010 fishery profile

Catches of kingfish in 2010 by recreational fishers were relatively high compared to previous seasons. Charter skippers recorded good catches of kingfish particularly in the Bay of Islands and Alderman Pins area. The proportion by length of fish larger than 100 cm in the gamefish tagging data and club records was compared for the periods 1999 to 2009 and 2010 (i.e. the sampling year). Where lengths were not available a length-weight conversion was used. In East Northland and Bay of Plenty in 2010 there were higher proportions of kingfish between 100 and 105 cm than in the 1999–2009 period (Figure 2). Note that not all kingfish catch by club members is recorded in sport fishing club records or the tagging database.

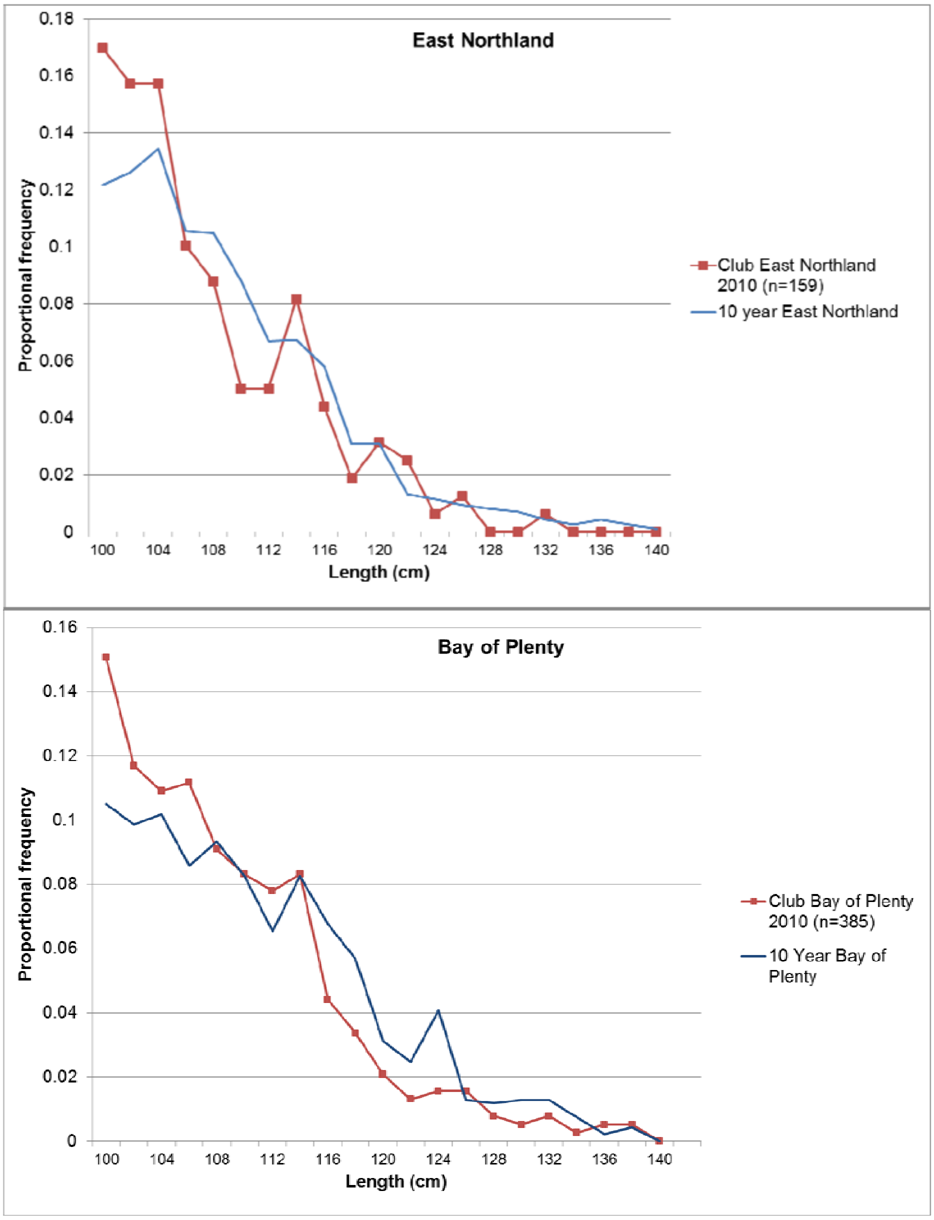

Figure 2: Proportion of kingfish by length (2 cm size bins) from gamefish tagging data and club records for the 10 years 1999–2009 compared to data from the same source in 2010 for East Northland (top) and Bay of Plenty (bottom).

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3.2 2010 kingfish sample

A total of 2091 kingfish were measured in this survey. Of these 1287 (62%) were released, with 576 tagged and 711 released without being tagged. Overall, 38% of measure kingfish were retained. The target sample size of 1000 lengths and 250 heads from East Northland and the Hauraki Gulf was exceeded (1198 lengths and 285 otolith sets) between February and July (Table 4). Distribution across the sub areas (General Statistical Areas) was adequate. Many of the fish caught in the Hauraki Gulf were below the 75 cm length used as the minimum for the age-length key.

Anglers and skippers from Bay of Plenty collected 905 lengths and 175 otolith sets between February and November 2010. This was below the target so the collection period was extended from July to November to boost numbers. Also 12 fish were sampled by Sanford staff from trawl caught fish landed in Tauranga to add to the sample of aged fish (Table 4). Sample distribution across the sub areas was not as expected with more in the western Bay of Plenty than recorded in historical data. This was mainly because fewer boats than expected fished at White Island.

Club catch records and length in the tagging database are not a complete record of catch and may be biased toward larger fish. A comparison of the proportion at length of kingfish from that source and the survey sample shows that a higher proportion of small fish and fewer larger fish over 120 cm were collected in the survey in East Northland (Figure 3 top). The length distributions from the two sources are very similar in the Bay of Plenty, although the proportion of fish over 130 cm is lower in the survey fish (Figure 3 bottom).

Table 4: Target survey length and otolith numbers and actual sample sizes achieved by statistical area.

	Northland/Hauraki Gulf			Bay of Plenty			Commercial
Statistical area	002	003	HG	008	009	010	009
Target number of lengths	200	600	200	200	200	600	
Lengths for area			1000			1000	
Target otoliths			250			250	
Lengths collected	314	793	91	426	94	373	12
Total lengths			1198			905	
Otoliths collected			285			175	11

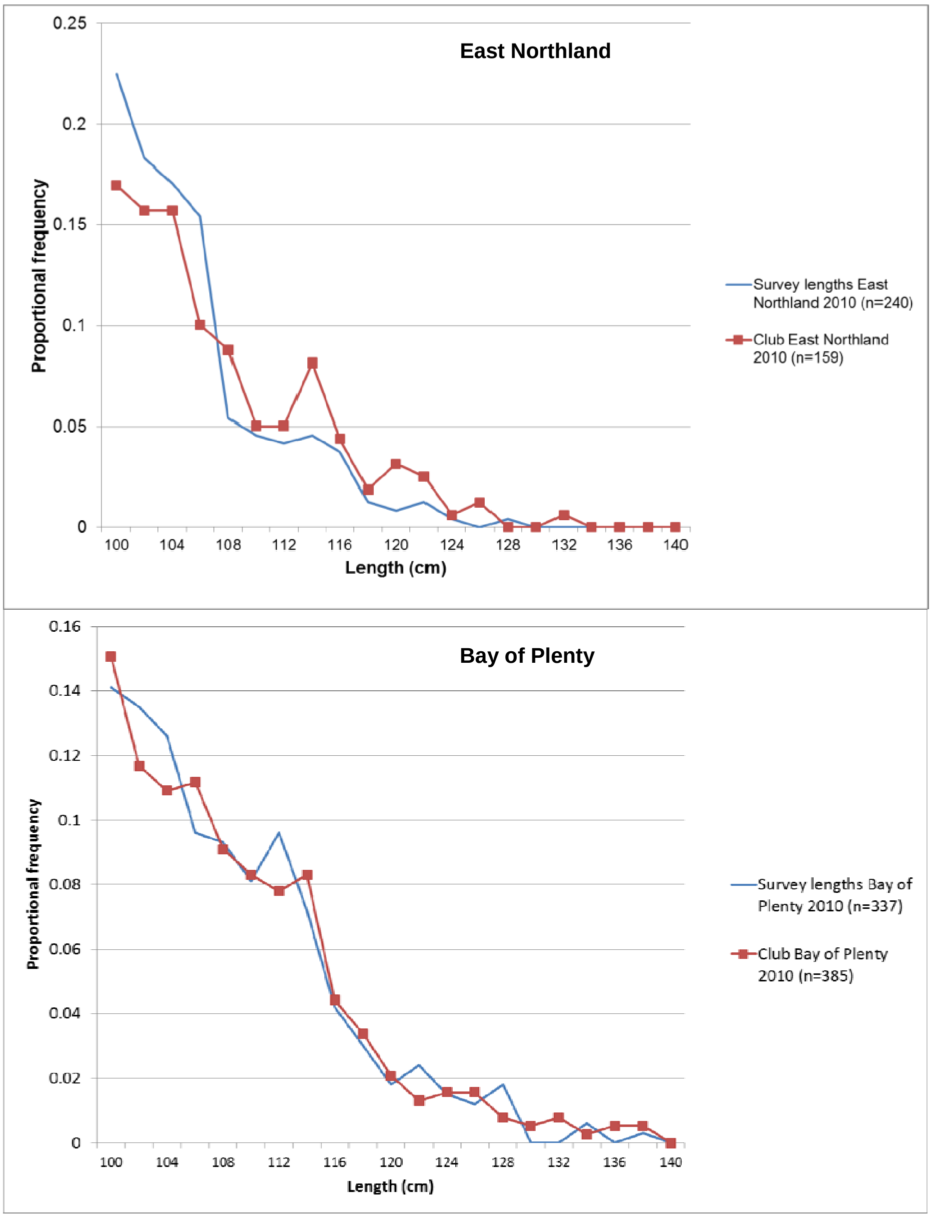


Figure 3: Proportion of kingfish by length (2 cm size bins) from gamefish tagging data and club records for 2010 compared with the proportion at length collected in the survey sample for East Northland (top) and Bay of Plenty (bottom).

Sampling effort in this project was spread over a wide range of habitats from in-shore to off-shore within KIN 1 and across all Ministry statistical areas (002 to 010) from North Cape to the eastern Bay of Plenty (Figure 4). One of the most active fisheries in East Northland was in the Bay of Islands (003) where fishing is mainly around headlands and in-shore reefs. There were few kingfish larger than 75 cm caught in the inner Hauraki Gulf (006 and 007). Length samples were obtained from in-shore and deeper reefs in the Western Bay of Plenty (008 and 009) and a reasonable sample of fish from the off-shore location of White Island and its associated reef systems (010) (Figure 4).

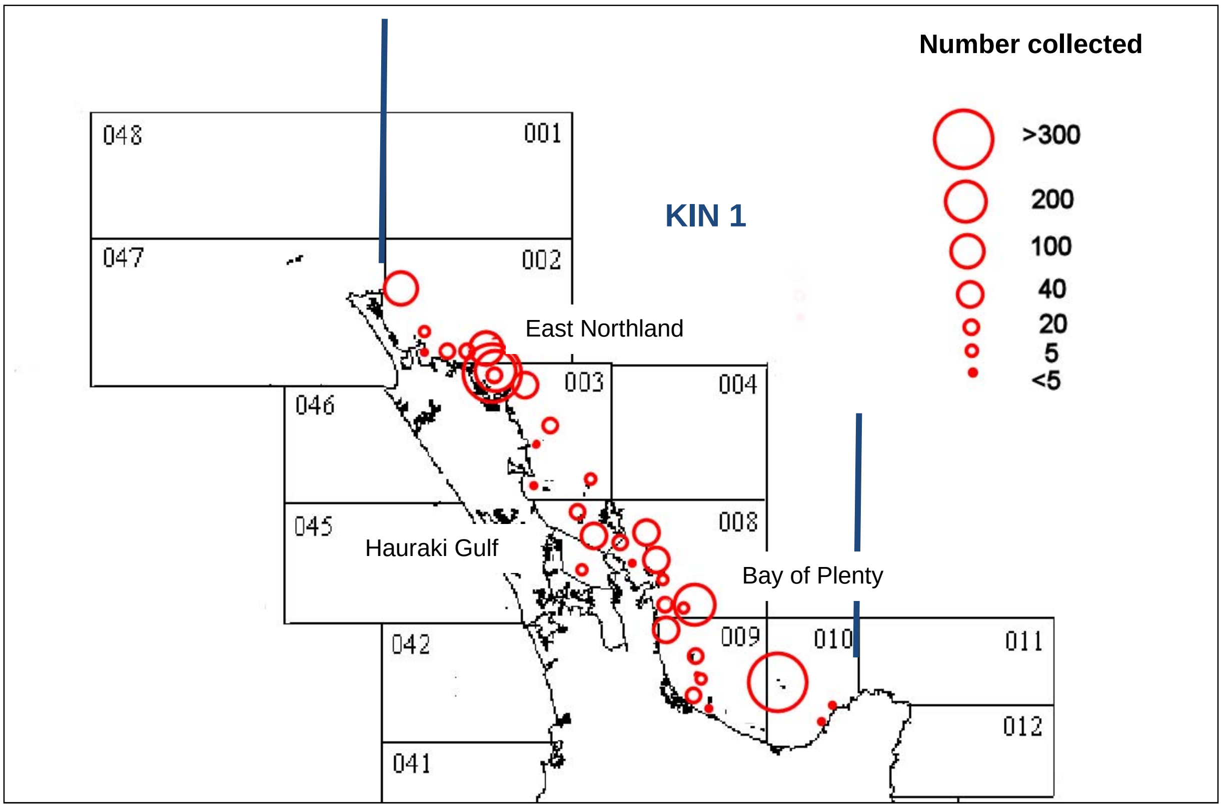


Figure 4: Distribution of the number of kingfish lengths collected in KIN 1 (bold lines) by location across General Statistical Areas.

The majority of kingfish were caught on livebait or jigs in both areas. There are slight differences in the average length caught on lures, jigs and livebait (Table 5). There is obviously better selectivity for large fish when using a speargun. Fish sourced from commercial trawl catch in the Bay of Plenty (statistical area 009) were smaller on average that those supplied by recreational fishers (Table 5).

Table 5: The proportion of catch and mean length of survey kingfish by method and region.

					Method
Region	Lure or Jig	Live bait	Bait	Speargun	Trawl
East Northland/Hauraki Gulf					
Proportion	0.28	0.71	0.004	0.01	
Average Length	91.5	89.8	82.2	103.7	
SD	11.08	10.27	6.31	6.53	
Bay of Plenty					
Proportion	0.51	0.42	0.06		0.01
Mean Length	98.0	92.7	98.6		80.1
SD	13.81	11.18	18.93		10.51

Otoliths were collected from a broad distribution of length classes in East Northland (Figure 5) while some smaller length classes were not well represented in otolith samples from the Bay of Plenty (Figure 6).

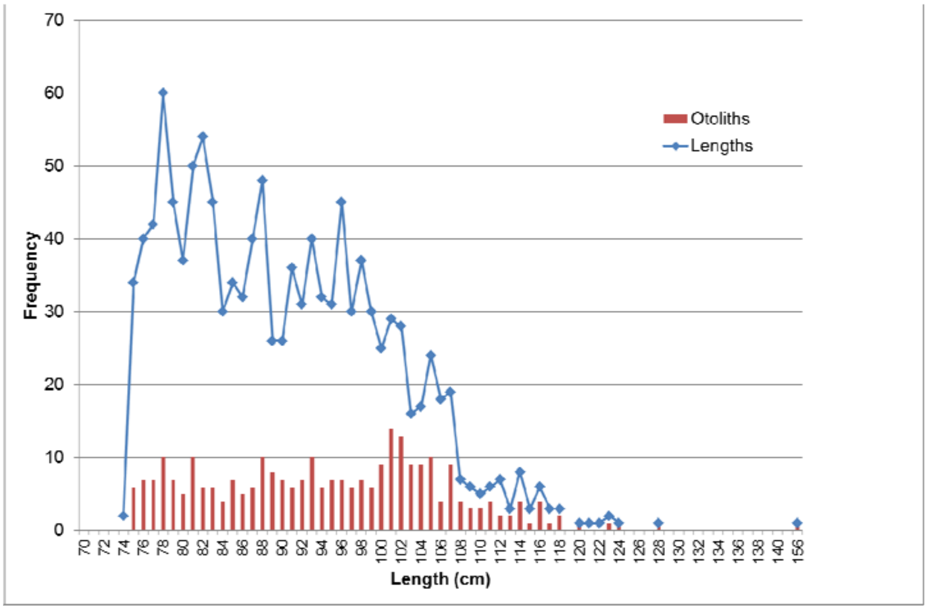


Figure 5: Number of otoliths collected in East Northland/Hauraki Gulf by 1 cm size bin (n=285).

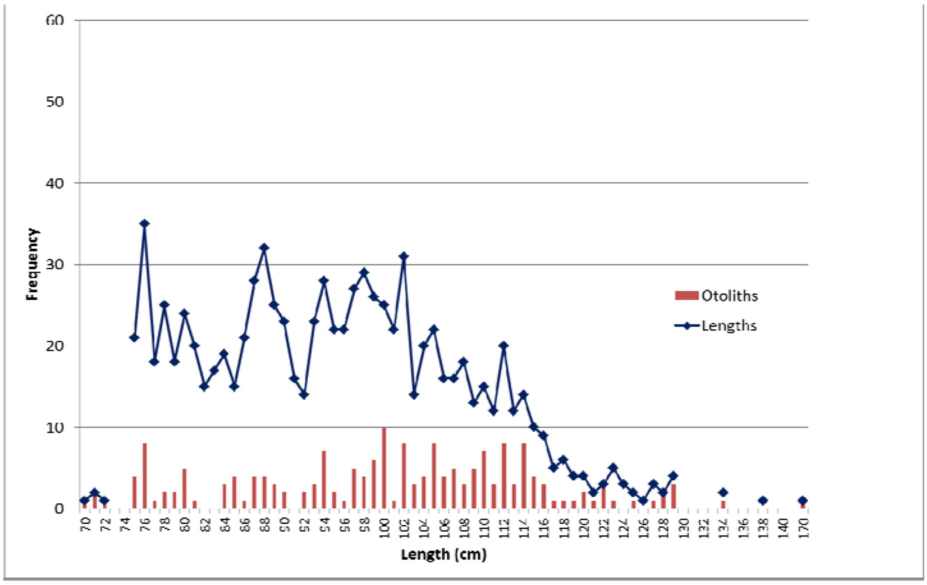


Figure 6: Number of otoliths collected in Bay of Plenty by 1 cm size bin (n=175).

Differences in length frequency were seen between areas and between males and females. There were more males 80 cm to 90 cm in East Northland (Figure 7). In the Bay of Plenty a high proportion of fish 78 cm to 87 cm were male while there were more females between 88 cm and 100 cm (Figure 8). Most of the fish larger than 120 cm were female in both regions.

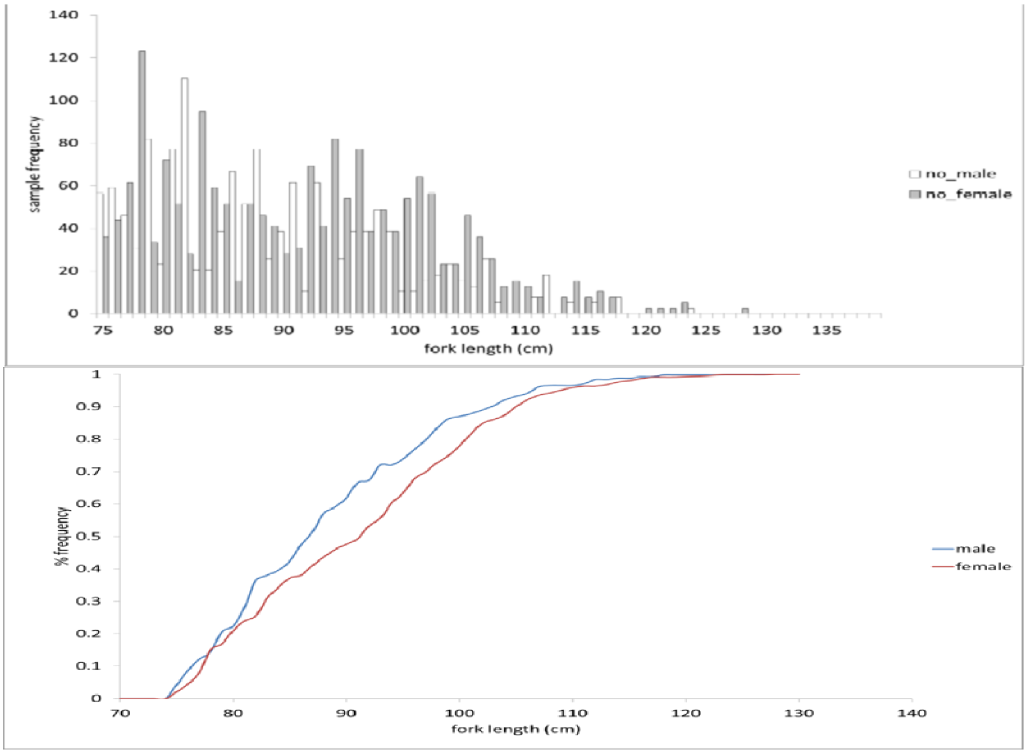


Figure 7: East Northland/Hauraki Gulf a) length frequency of kingfish sampled by sex and b) cumulative proportion of frequency by sex.

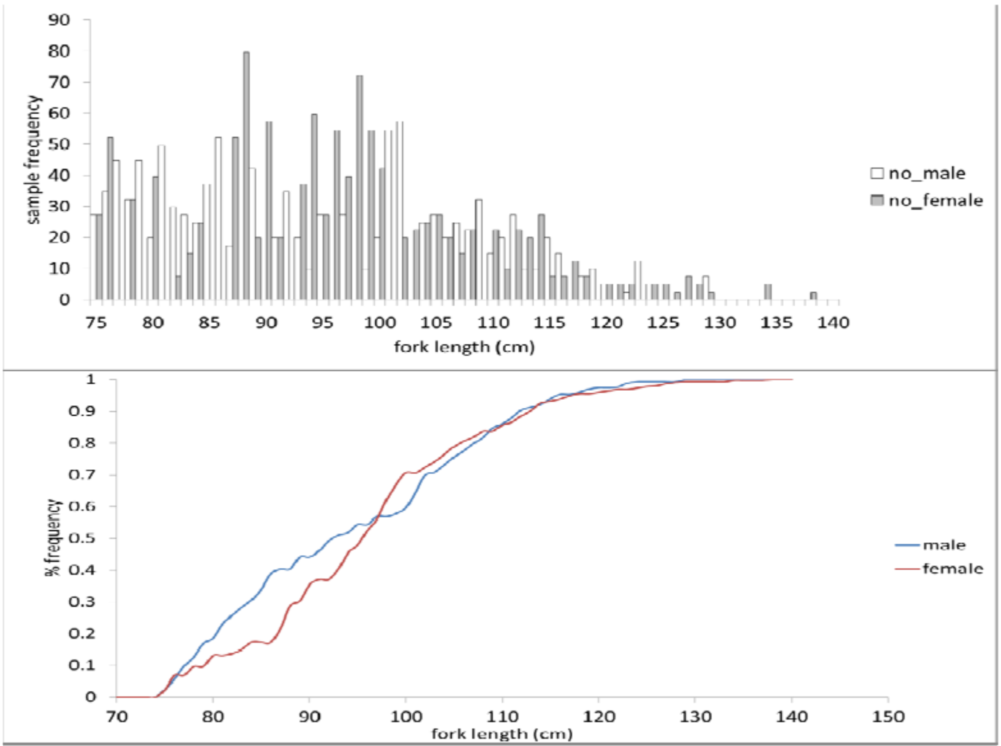


Figure 8: Bay of Plenty a) length frequency of kingfish sampled by sex and b) cumulative proportion of frequency by sex.

3.3 Reader error in estimating ages of kingfish

Total sample sizes of 283 and 184 otoliths were aged from the East Northland and Bay of Plenty 2010 kingfish collections respectively, encompassing a length range of 69 to 170 cm, with representation in consecutive centimetre size classes 75–117 cm, which made up 93% of the total. Only 7 otoliths were rejected as being unreadable from the East Northland collection and 3 from the Bay of Plenty.

Kingfish otolith preparation and ageing, using the thin section technique, generally followed that previously described by McKenzie et al. (2005). Opaque zones, which appear dark in thin section preparations under transmitted light, were counted from the core to the otolith edge, the primary axis being the dorsal sulcus region, as the ventral sulcus was often unclear (Figure 9). The formation of an opaque zone signified that one fully deposited opaque and translucent zone had been previously laid down, indicative of a full year of growth (Figure 10).

Levels of between-reader agreement for initial readings appeared moderate at 55% and 65% for East Northland and Bay of Plenty otolith samples, respectively; with estimates of IAPE of 3.6% and 3.0%. Levels of agreement between each reader and the final agreed age estimates were higher and ranged from 80–87% for reader 1 and 73–77% for reader 2 (Figure 11). There were some minor differences in symmetry and clustering of points about the zero-line between the each reader's age and the final agreed age estimates, suggesting that reader 1 was slightly more consistent in ageing kingfish otoliths than reader 2 (see Figure 11).

Individual reader bias is shown in age-bias plots (Figure 12). Reader 1 had slightly higher levels of precision than reader 2 for both the East Northland and Bay of Plenty otolith samples. Reader 1 appeared to display slightly more bias in ageing fish in the older age classes for collections from both areas, and reader 2 more bias and imprecision in ageing the young age classes from the Bay of Plenty collection, over estimating age mainly in fish collected from the latter part of the year. Reader 1 mainly displayed negative bias especially in the East Northland collection, consistently underestimating age in the older age classes compared to reader 2, who displayed both positive and negative bias (see Figure 12).

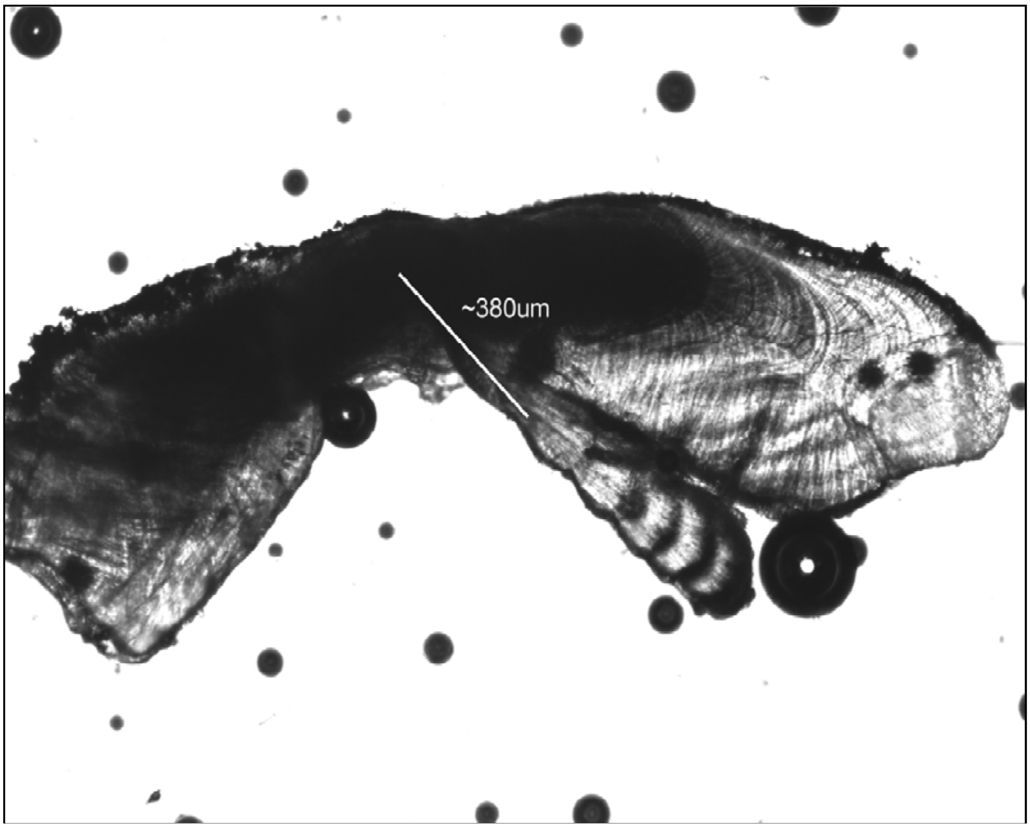


Figure 9: Thin transverse section of a sagittal otolith from a 99 cm kingfish captured in the Bay of Plenty, 26 March 2010 (otolith 11-2, age 6N, 40x).

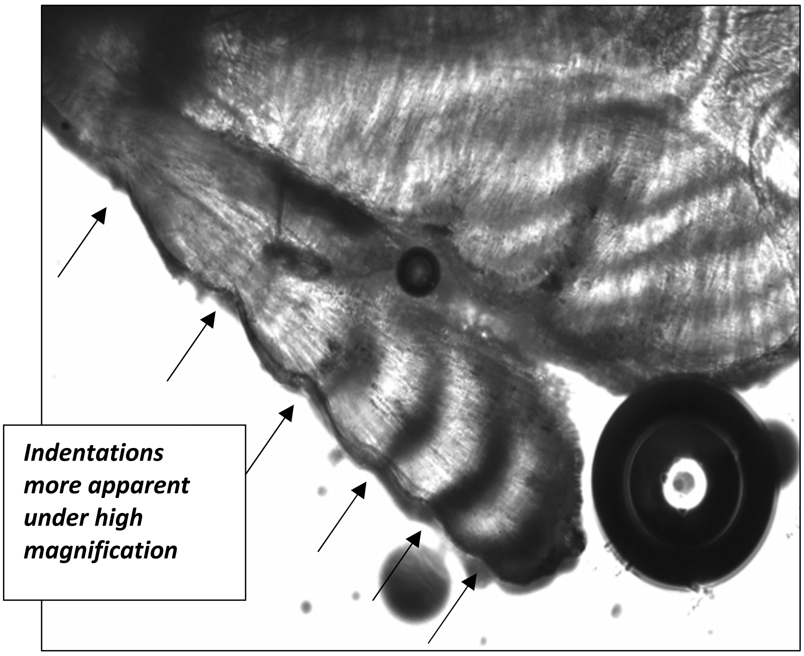
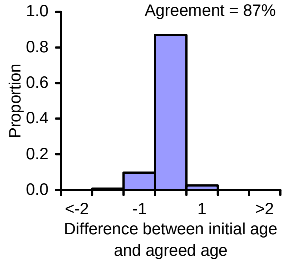


Figure 10: High magnification view of dorsal side (otolith 11-2, age 6N, 100x).

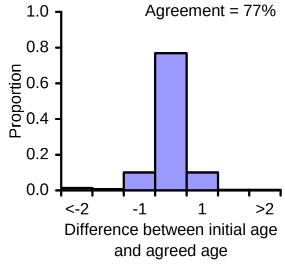
Reader 1 (East Northland) — Age class

Difference	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	>19	Total
<-2																			0
-2					1		1												2
-1		3	6	7	5	1		1	3	1									27
0	27	46	73	61	14	10	3	4		1								1	240
1		2	2	1	1	1													7
2																			0
>2																			0
Total	27	51	81	69	21	12	4	5	3	2	0	0	0	0	0	0	0	1	276
% agreement	100	90	90	88	67	83	75	80	0	50	0	0	0	0	0	0	0	100	87



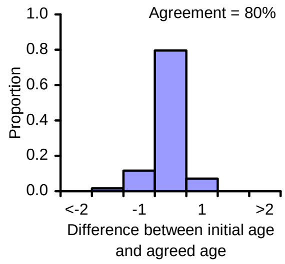
Reader 2 (East Northland) — Age class

Difference	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	>19	Total
<-2		1		2		1													4
-2					1					1									2
-1		4	6	9	3	3	2			1									28
0	25	40	72	45	16	6	2	4	2										212
1	2	5	3	13	1	2		1	1										28
2		1																	1
>2																		1	1
Total	27	51	81	69	21	12	4	5	3	2	0	0	0	0	0	0	0	1	276
% agreement	93	78	89	65	76	50	50	80	67	0	0	0	0	0	0	0	0	0	77



Reader 1 (Bay of Plenty) — Age class

Difference	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	>19	Total
<-2																			0
-2								1		1								1	3
-1		5		3	1	2			3	1	4			1	1				21
0	7	18	15	41	15	13	6	9	8	6	2	2						2	144
1		1	1	1	5				1	2			1					1	13
2																			0
>2																			0
Total	7	24	16	45	21	15	6	10	12	10	6	2	1	1	1	0	0	4	181
% agreement	100	75	94	91	71	87	100	90	67	60	33	100	0	0	0	0	0	50	80



Reader 2 (Bay of Plenty) — Age class

Difference	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	>19	Total
<-2			1						1										2
-2																			0
-1			1	2		1	2		5	1								2	14
0	4	15	11	35	20	12	4	8	4	8	6	1	1	1	1			2	133
1	3	7	4	7	1	2		1	1	1		1							28
2									1										1
>2		1		1				1											3
Total	7	23	17	45	21	15	6	10	12	10	6	2	1	1	1	0	0	4	181
% agreement	57	65	65	78	95	80	67	80	33	80	100	50	100	100	100	0	0	50	73

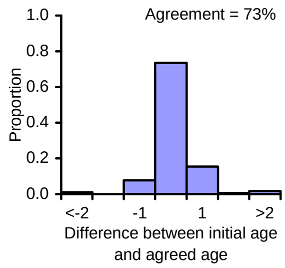


Figure 11: Reader comparisons between initial and agreed age estimates for kingfish collected from the East Northland and Bay of Plenty stocks in 2010.

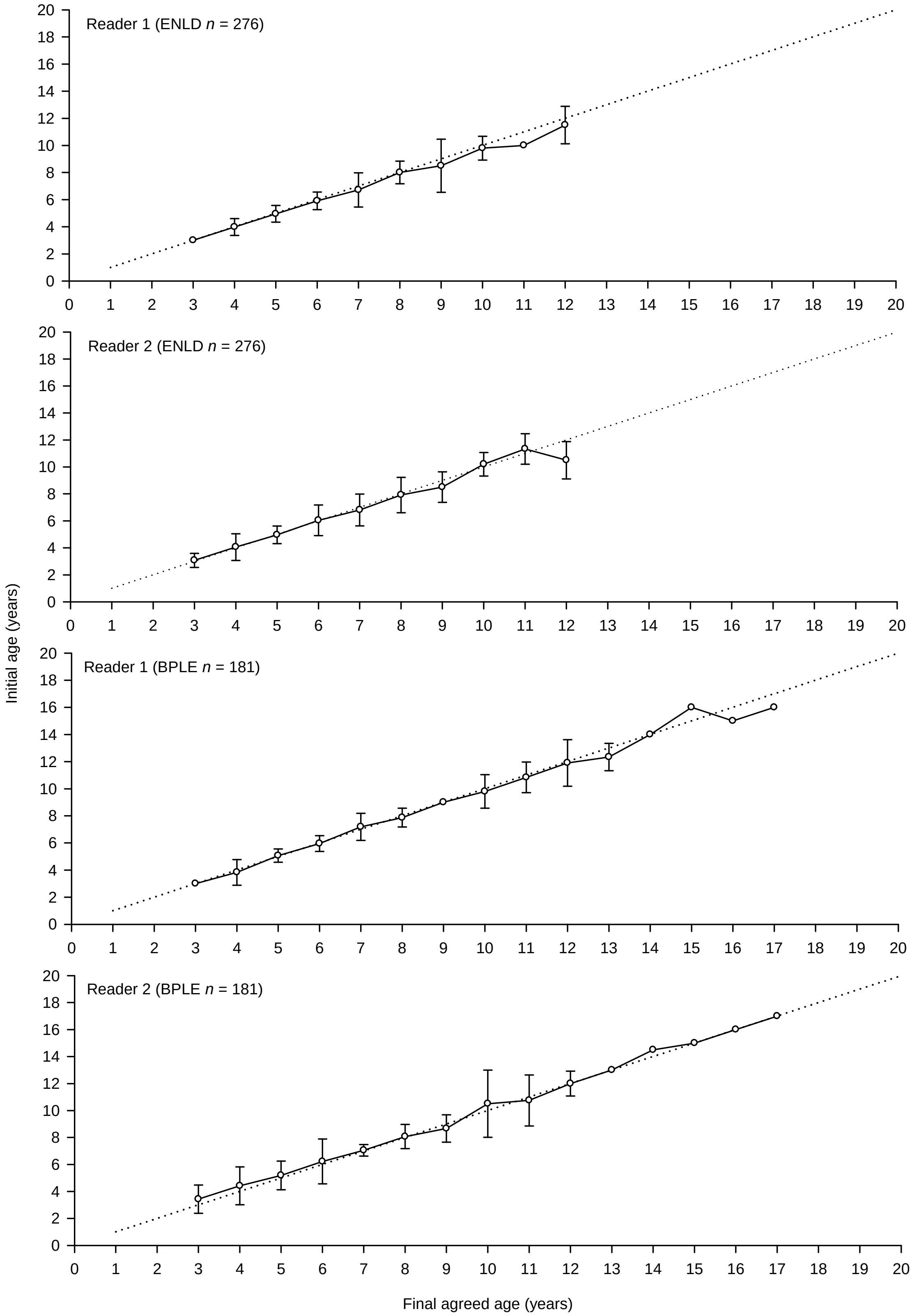


Figure 12: Age-bias plots for kingfish otolith data collected from the East Northland and Bay of Plenty fisheries in 2010. Dotted line denotes final agreed age (one-to-one line); error bars denote 95% confidence intervals of readers' initial age estimates.

3.4 Catch-at-age and length

Most kingfish sampled from recreational catch in East Northland and Bay of Plenty during 2010 were less than 120 cm in length (Figure 13).

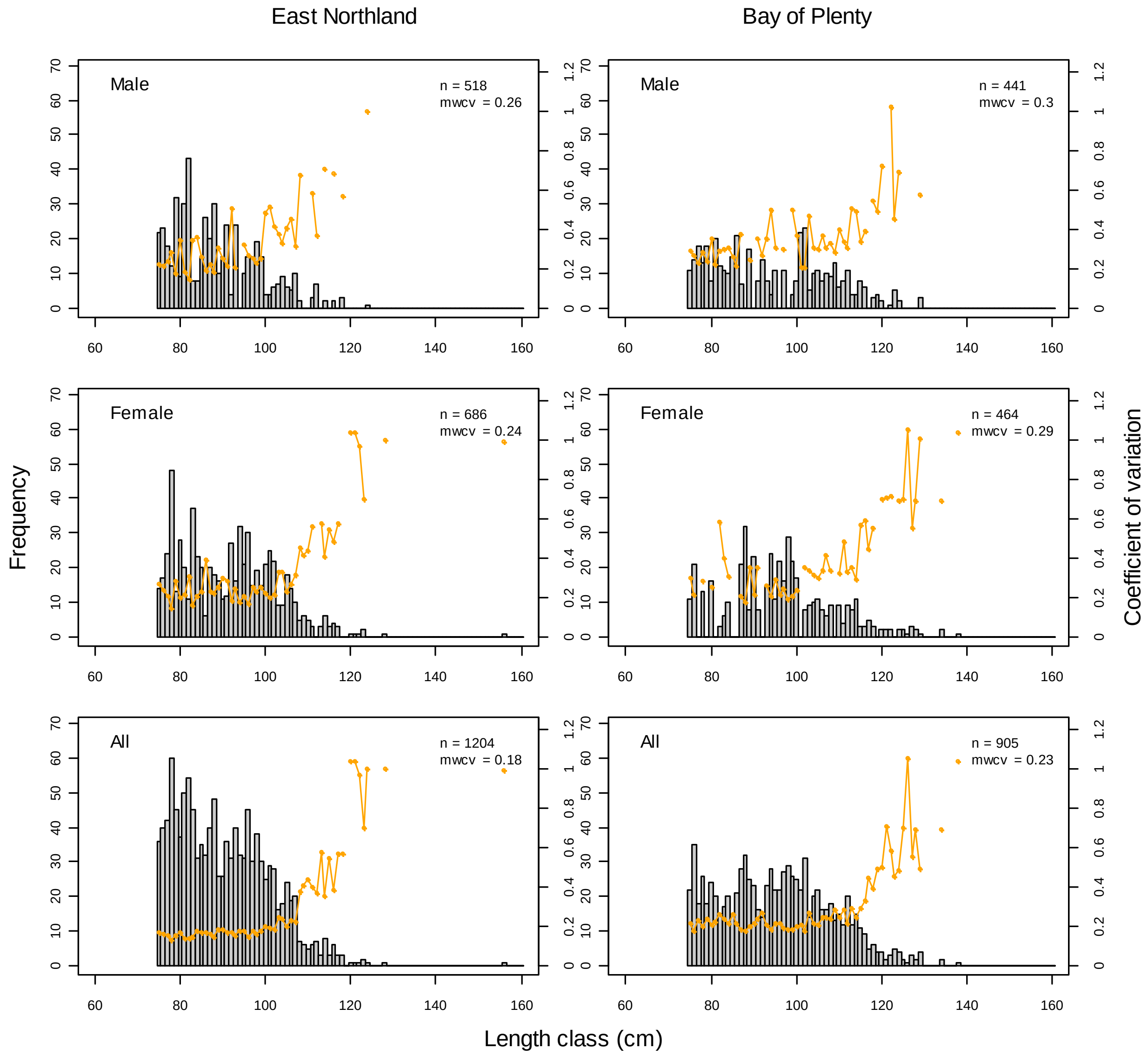


Figure 13: Length frequency of kingfish caught in the recreational fishery, sampled in 2010 separated by sex and region. The line represents the c.v. for each age.

The East Northland sample was dominated by young fish less than 8 years old with few fish older than 12 years. The mean weighed c.v. was low (0.18) due to the relatively tight age distribution. A broader range in age composition is seen in the Bay of Plenty recreational catches with an overall mean weighted c.v. of 0.23 (Figure 14). Young kingfish grew rapidly and started to recruit to the fishery (minimum legal size of 75 cm) as three year olds and were fully recruited at 4 or 5 years. The oldest fish sampled in East Northland was a 156 cm fish (41.6 kg) caught in Bream Bay aged at 22 years. The oldest fish sampled in Bay of Plenty was a 170 cm fish caught at White Island aged at 24 years.

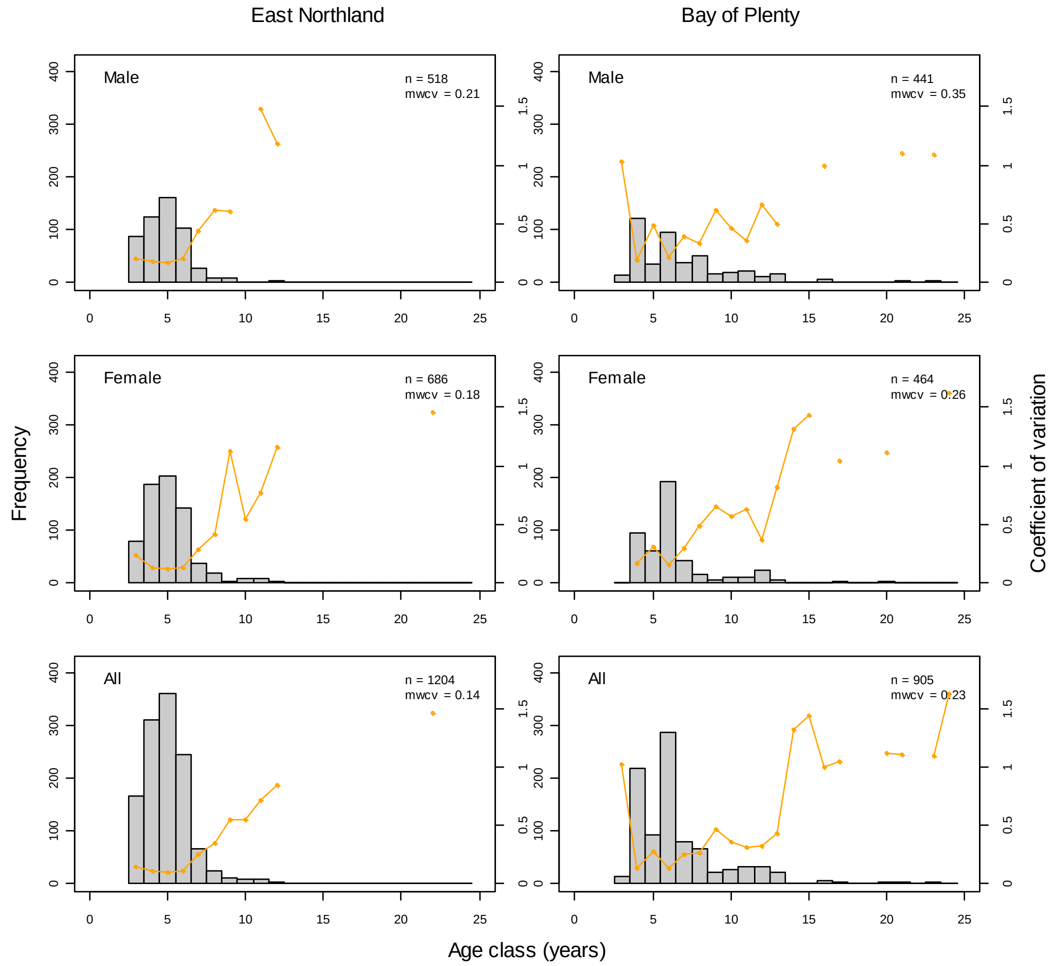


Figure 14: Scaled age frequency distributions of kingfish caught in the recreational fishery, sampled in 2010 separated by sex and region. The line represents the c.v. for each age.

Spatial differences in age composition were evident within the Bay of Plenty samples; fish older than 15 years were relatively absent from the in-shore areas, when compared to catches from White Island (Figure 15). Despite the lack of fish older than 15 years, the Bay of Plenty in-shore distributions were still broader than those observed in East Northland (Figure 14).

3.5 Mortality estimates

Chapman and Robson estimates of total mortality (Z) differ between the two KIN 1 subregions; fewer older fish in East Northland implies a higher level of fishing mortality than for the Bay of Plenty (Table 6). The age at full recruitment is usually estimated from the age class with peak abundance. Assuming full recruitment as 5 year olds in East Northland gives a total mortality of 0.77 (0.07); and assuming an age of full recruitment of 5 or 6 years old in the Bay of Plenty gives a total mortality of 0.34–0.42 (Table 6). Assuming an age at recruitment of 5 years, estimates of Z for offshore (i.e., White Island) and inshore Bay of Plenty samples were 0.3 (0.09) and 0.38 (0.09), respectively; and were not significantly different.

Total mortality is made up of fishing mortality and natural mortality. If fishing mortality is less than natural mortality, fishing is often regarded as being at sustainable levels. Natural mortality for kingfish based on a maximum age of 23 is about 0.20 (Ministry of Fisheries 2011). This could mean that the Bay of Plenty stock is fully/optimally utilised, while East Northland is overfished. However, there may be explanations, other than fishing mortality, for the lack of older fish in our sample.

Table 6: KIN 1 total mortality estimates (Chapman and Robson) derived from recreational catch-at-age by various assumed full recruitment ages with bootstrap MWCVs in brackets.

	Age (years)			
Region	3	4	5	6
East Northland	0.41 (0.03)	0.57 (0.04)	0.77 (0.07)	0.87 (0.12)
Bay of Plenty	0.25 (0.04)	0.32 (0.05)	0.34 (0.06)	0.42 (0.09)
White Is	0.22 (0.06)	0.26 (0.08)	0.30 (0.09)	0.30 (0.14)
In-shore	0.27 (0.05)	0.35 (0.07)	0.38 (0.09)	0.50 (0.14)
KIN 1 (East coast)	0.33 (0.02)	0.43 (0.04)	0.50 (0.05)	0.53 (0.08)

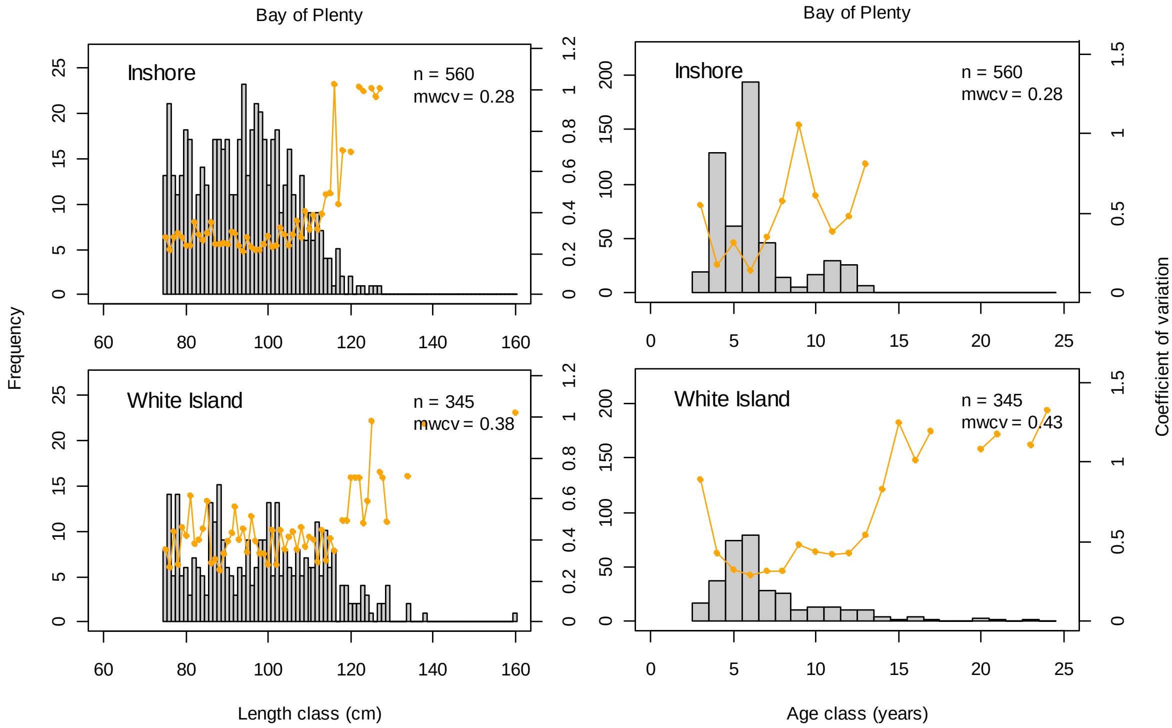


Figure 15: Age and length composition of in-shore and off-shore (White Island) Bay of Plenty catches 2010–11.

3.6 Growth estimates

Growth estimates (von Bertalanffy growth curves) were derived from age samples collected in 2010 with the addition of juvenile fish caught under FADs in 2002 to inform the shape of the left-hand side of the curve. In East Northland and Bay of Plenty the maximum size for male kingfish is smaller than for females (Figure 16). Male growth rates in East Northland were slightly lower than in the Bay of Plenty, whereas female growth in the two areas was similar (Figure 17); however data is sparse for older fish in East Northland.

Two tagged kingfish recaptured in the Bay of Plenty were measured and aged. Both had been at liberty for long periods so can provide information on growth. A 20 year old female kingfish caught at White Island in March 2010 measuring 134.5 cm had been at liberty for 8 years 2 months. Therefore it was 12 years of age when tagged at 125 cm. A 21 year old male kingfish re-caught at White Island in November 2010 was measured 129 cm after 10 years 10 months at liberty. It was tagged at Rangitira Knoll and should have been 11 years old when it was measured at 83 cm. This fish was in good condition on recapture and grew fast while at liberty. The back calculated age (11 years) falls outside the range of other fish around that size (83 cm) in this study. It is possible that this is a particularly slow growing fish as it is on the edge of the range of growth rates observed in the 2002 study (McKenzie et al. 2005). A larger sample of older fish would be needed to describe the full variability in kingfish growth.

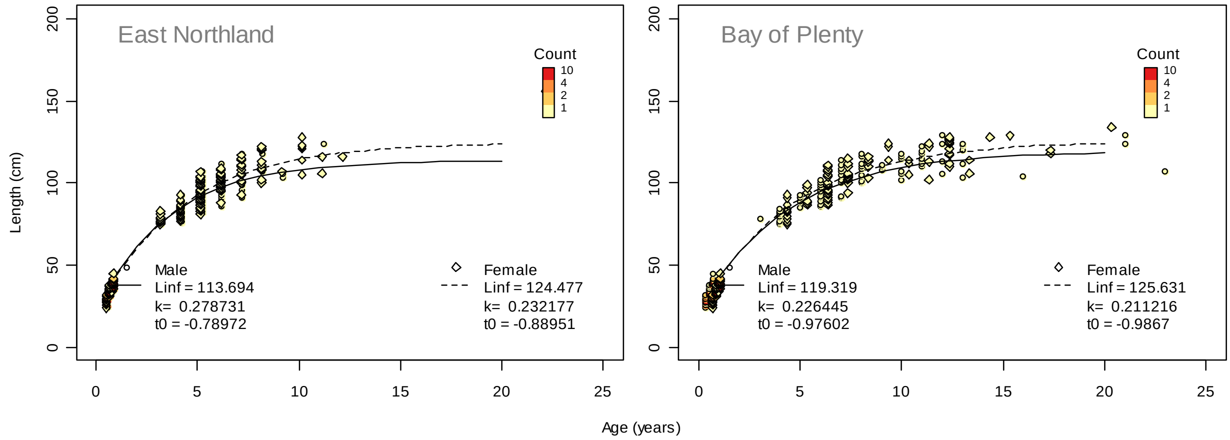


Figure 16: Length-at-age observations for male and female kingfish (points) and the von Bertalanffy growth model fits (lines) by subregion. Fish older than three years are from 2010 samples. One year old fish from samples collected from East Northland fish aggregation devices in 2002.

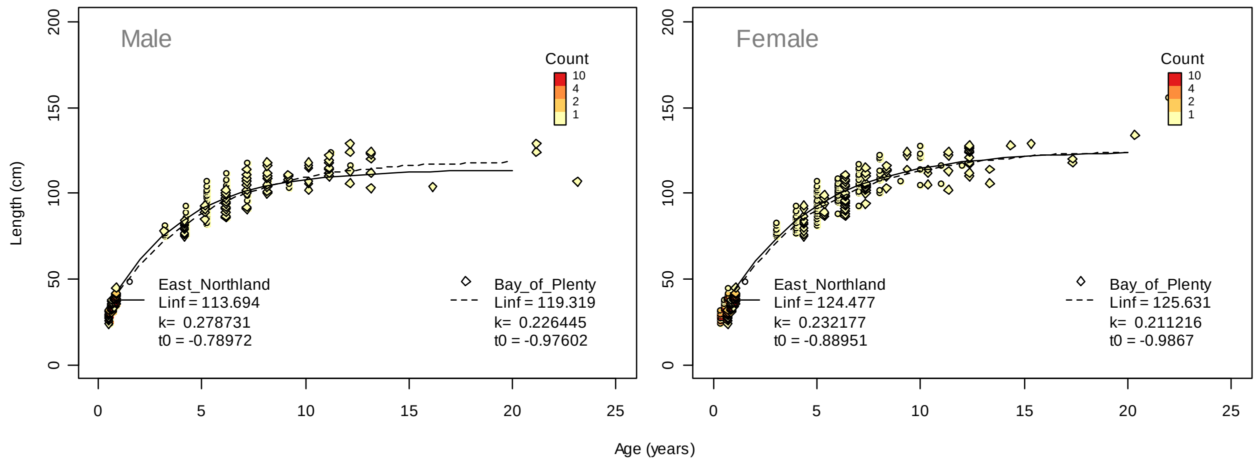


Figure 17: Length-at-age observations for East Northland and Bay of Plenty (points) and the von Bertalanffy growth model fits (lines) by sex. Fish older than three years are from 2010 samples. One year old fish from samples collected from an East Northland fish aggregation device in 2002.

3.7 $F_{\%SSB/R}$

Equilibrium fishing mortalities derived from a per recruit analysis using growth estimates for female kingfish, natural mortality of 0.2, and age at maturity of 6 years old (Appendix 1) are given in Table 7. The total mortality corresponding to 40% SSB/R for females equates to approximately 0.3, a value within the likely range of mortality estimates for the Bay of Plenty (Table 6).

Following the Harvest Strategy Standard operational guidelines for a species with kingfish growth and natural mortality parameters, the default categorisation would be medium productivity and a recommended target biomass of 35% virgin biomass and an $F_{\%SPR}$ of $F_{\%40}$.

Table 7: Reference fishing mortalities derived from the per recruit analysis pursuant to the growth dynamics given in Appendix 1.

	F	SSB/R (%)
$F_{SSB/R}$	0.11	40%
$F_{0.1}$	0.22	18%

4. DISCUSSION

There are indications that recreational and commercial kingfish catch was declining prior to the 2003–04 fishing year. Boat ramp surveys of recreational catch from 1991 to 2004 show a declining trend in the intercept rate of kingfish encountered per interview day (McKenzie et al. 2006). Commercial catch also declined in KIN 1 from 362 t in 1991–92 to 49 t in 2003–04. Most, but not all of the reduction, was from the decline in setnet catch which peaked in KIN 1 at 200 t per year in 1991–92 (McKenzie et al. 2006).

A study in 2002 measured and aged kingfish from recreational catch. Of the 1352 fish measured 68% came from White Island, 24% from Ranfurly Bank and 8 % from in-shore areas. None of the in-shore fish in 2002 were larger than 102 cm and they were dropped from the analysis as they were unlikely to be representative of the full adult population. While there is a broad distribution of lengths at off-shore locations there is consistently a higher proportion of large fish caught using the same recreational fishing gear as in-shore. In 2002, 5% of the kingfish measured from White Island were larger than 120cm. In the 2010 study, 7% of fish from White Island were larger than that, but just 1% of fish sampled from coastal Bay of Plenty and 1% of East Northland/Hauraki Gulf fish were larger than 120 cm.

There are a number of possible explanations for this:

- Large fish hooked in relatively shallow water can be harder to stop getting to the bottom and wrapping the line in weed or rock and busting off. So rod and reel fishing may catch fewer of the very large fish hooked in-shore.
- The combined fishing pressure on kingfish from all sectors may be a lot higher in in-shore waters than remote off-shore locations. If the in-shore population is resident and of limited size, fishing mortality may be high.
- Large kingfish may prefer off-shore habitats and become resident when they get there. A very high proportion of kingfish tagged at White Island are recaptured in that area. If they are recaptured elsewhere it tends be on other off-shore reef systems rather than in-shore (Holdsworth & Saul 2011). Kingfish tagged inshore are recaptured at offshore locations but it is not a common occurrence.

Indications from Club and tagging records in 2010 indicate a higher proportion of fish in the 100 to 105cm size classes. There are also anecdotal information and contest records to support an increase in these medium size kingfish in the last two years.

To address the uncertainty in the distribution of kingfish by size, recruitment of fishers for this project was spread across ports within KIN 1 and across all Ministry statistical areas. All length information supplied by these fishers was used in this analysis. As is often the case with voluntary logbook data, a few dedicated fishers do a very good job and supply the majority of the data. Consequently some areas are overrepresented in the data, although the spread across statistical areas was close to the proportions targeted in the design. Future work on monitoring the age structure of the kingfish stock should consider a more structured design that spreads sampling effort more evenly within statistical areas and across a wide range of habitats from in-shore to off-shore. Starting the sampling in October would help sample collection as fishing effort is directed at kingfish in the Bay of Plenty at that time.

A revised ageing protocol for kingfish was implemented in this current study, and it adopted a more rigorous approach with an aim of improving accuracy and precision in age estimates. Using two readers to read the entire otolith collections independently, and reviewing all disagreements collaboratively with a third experienced reader, also contributed to this achievement.

Considerable emphasis was placed on accurately identifying the first annulus in recruited kingfish, normally unclear in thin sections, and found to be problematic in other kingfish ageing studies (Stewart et al. 2004; McKenzie et al. 2006). A core to first opaque zone distance range was determined for adult kingfish from clear preparations by using dimpling evident on the distal and sulcul surfaces of the otolith, and by comparing the size of otoliths from juvenile (0+) kingfish collected over an 8 month period. Secondly, forcing an expected margin relative to the otolith collection date was also expected to improve reader agreement and accuracy in age estimation, especially as samples were collected over a 10 month period.

Although between-reader agreement in the current study was relatively low at 55% (with a c.v. of 3%) for East Northland/Hauraki Gulf, this increased to 65% (c.v. of 4%) for the Bay of Plenty, and may be related to readers familiarising themselves as they read more otoliths, reading the second collection better than the first, especially given that the Bay of Plenty comprised the wider age range of kingfish, and that one reader, although experienced in ageing, had never aged kingfish before. Overall our results were a slight improvement on those determined by Gillanders et al. (1999) who reported within-reader agreement as 54% in ageing whole otoliths (with a c.v. of 12%), but considerably less than Stewart et al. (2004) who achieved 86% (c.v. of 3%) ageing thin sections, although both studies used replicate counts from the same reader. McKenzie et al. 2006 reported within-reader agreement for thin section otoliths at 54% but between-reader agreement at only 3% because of a bias arising from different interpretations of the position of the first annulus, and had both readers used the same criteria, agreement would have increased to 76%.

What seemed most apparent during the review of all kingfish age disagreements for the 2010 collections, with the presence of a third experienced reader, was that both other readers could regularly see the mistakes they had made, and were likely to learn from the experience. Despite this, individual reader agreement comparisons with the final agreed age were relatively high at 73–87%. The Ministry of Fisheries has compiled a guideline for New Zealand fish ageing protocols (June 2011), and this should ensure that in future ageing is conducted in a manner that derives as precise and accurate estimates of fish age as can be expected for fish species of varying difficulties. Lastly, between-reader agreement and c.v. estimates derived here relate to initial readings only. For the remaining disagreements, agreed ages are determined collaboratively and are almost certainly more robust than those determined from initial estimates alone or by using a single reader.

No attempt was made in the current study to validate the annual deposition of otolith zones in kingfish. Comparisons were made between the otolith sizes from juvenile (0+) kingfish collected during 2002 and otoliths from adult fish in 2010. The relative size of sectioned otolith of 0+ fish overlayed on adult sections indicated that the location of the first annual opaque zone in the adult fish was outside the overlay. Our interpretation that the 2002 juveniles were 0+ individuals was supported by a number of factors:

- kingfish are report to spawn in October–January (Poortenaar et al. 2001) so the actual age of 0 + fish in 2002 would range from 2 to 11 months rather than 14 to 23 months for 1+ fish;
- the growth rate observed in 2002 over successive months would be slightly less than growth rates achieved for kingfish in aquaculture (NIWA unpublished data);
- the absence of an opaque zone signifying that the fish was entering their second year;
- that sectioned 0+ otolith dimensions usually fell within the first opaque zone of adult kingfish.

It would be helpful if the full age range of the population, especially those below the MLS (75 cm) (1–4 year olds), was collected in future catch sampling to help establish mean length at age for young fish.

The age composition of kingfish seen in the 2010 Bay of Plenty sampling was broad with fish older than 20 years present in the samples. The broadest range in age was observed in the White Island (off-shore) samples, with the in-shore samples lacking fish older than 15 years. Despite there being higher proportions of older fish in the off-shore White Island samples, the total mortality estimates for off-shore and on-shore samples were similar (approximately 0.3–0.36). For the region taken as a whole; there is no strong or compelling reason to believe that the 2010 programme did not sample the underlying population age structure of kingfish in the Bay of Plenty. Yield per recruit based on Bay of Plenty female growth rates suggests a total mortality of 0.31 consistent with the current recommended harvest soft-limit of 40% SSB/R. A catch curve analysis using the 2010 age data suggests that total mortality is consistent with the YPR optimum.

In contrast to the Bay of Plenty samples there was a lack of older fish in East Northland/Hauraki Gulf. Total mortality estimates were significantly higher than the Bay of Plenty (approximately 0.6–0.8), which the Northern Inshore Working Group felt were implausibly high given the likely low level of fishing mortality the stock has been subject to in recent years. It was not clear whether the lack of older fish in the East Northland samples was due to the movement of older fish (perhaps to Three Kings Islands) or to high fishing pressure. Including historic catch in the qualitative analysis and sampling of Three Kings Islands and Ranfurly Bank catches in future programmes would help resolve this uncertainty. The working group concluded that the sampling programme had done a good job of sampling the recreational fishery, but there is uncertainty regarding the degree to which the age composition of the catch reflected that of the kingfish population in each region.

The Bay of Islands Yellowtail Tournament has been running for 42 years and has always attracted anglers from around New Zealand and Australia. Ninety kingfish were measured at this tournament in June 2010 and they had a similar size and age distribution to other fish sampled in East Northland with a mode in length between 95 and 108 cm. The opportunity to measure 136 kingfish at the tournament in the following year (June 2011) was taken. Although no resources were available to age the fish from 2011, there was evidence of a shift in the length distribution to the right with the mode now measuring between 98 cm and 110 cm, indicative of growth and of fish residing within the Bay of Islands area. While there were few 7 year olds in the age distribution in 2010 the implication is that good numbers of 6 and 7 year olds were present in the Bay of Islands area in 2011. They had not all moved off-shore. A high proportion of 5 and 6 year olds in the 2010 catch-at age sample could indicate strong year classes from 2004 and 2005. Recreational fishers should be encouraged to continue to measure and record kingfish lengths at major fishing tournaments.

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7 APPENDICES

Appendix 1: Female kingfish growth and selectivity parameters used in the calculation of yield per recruit.

VB parameters		
	K	0.21
	Linf	125
	t0	-1..0
Length (cm) weight (kg) relationship		
	a	0.0000365
	b	2.762
Age at maturity (100%)		6
Age at selection (100%)		4
Natural mortality (M)		0.2

Appendix 2: KIN 1 estimated proportion at age by sex and subregion 2009-10.

	East Northland					
Age	Male		Female		All	
(years)	Proportion	c.v.	Proportion	c.v.	Proportion	c.v.
3	0.0720	0.19	0.0664	0.24	0.1384	0.15
4	0.1025	0.19	0.1546	0.13	0.2571	0.11
5	0.1321	0.16	0.1681	0.12	0.3002	0.10
6	0.0855	0.20	0.1172	0.14	0.2026	0.12
7	0.0224	0.44	0.0315	0.29	0.0539	0.25
8	0.0062	0.59	0.0145	0.40	0.0207	0.34
9	0.0071	0.59	0.0021	1.11	0.0091	0.52
10	0.0000	0.00	0.0075	0.52	0.0075	0.52
11	0.0008	1.47	0.0055	0.80	0.0064	0.73
12	0.0017	1.17	0.0017	1.10	0.0033	0.78
13	0.0000	0.00	0.0000	0.00	0.0000	0.00
14	0.0000	0.00	0.0000	0.00	0.0000	0.00
15	0.0000	0.00	0.0000	0.00	0.0000	0.00
16	0.0000	0.00	0.0000	0.00	0.0000	0.00
17	0.0000	0.00	0.0000	0.00	0.0000	0.00
18	0.0000	0.00	0.0000	0.00	0.0000	0.00
19	0.0000	0.00	0.0000	0.00	0.0000	0.00
20	0.0000	0.00	0.0000	0.00	0.0000	0.00
21	0.0000	0.00	0.0000	0.00	0.0000	0.00
22	0.0000	0.00	0.0008	1.37	0.0008	1.37
23	0.0000	0.00	0.0000	0.00	0.0000	0.00
24	0.0000	0.00	0.0000	0.00	0.0000	0.00
n	518		686		1204	

Age	Bay of Plenty					
	Male		Female		All	
(years)	Proportion	c.v.	Proportion	c.v.	Proportion	c.v.
3	0.0144	1.01	0.0000	0.00	0.0144	1.01
4	0.1348	0.18	0.1059	0.18	0.2407	0.13
5	0.0363	0.49	0.0656	0.31	0.1019	0.27
6	0.1055	0.23	0.2123	0.15	0.3178	0.12
7	0.0414	0.40	0.0452	0.30	0.0866	0.25
8	0.0552	0.34	0.0172	0.50	0.0724	0.28
9	0.0166	0.58	0.0055	0.65	0.0221	0.44
10	0.0192	0.47	0.0104	0.58	0.0296	0.37
11	0.0241	0.37	0.0103	0.61	0.0344	0.32
12	0.0107	0.62	0.0250	0.37	0.0356	0.32
13	0.0181	0.50	0.0064	0.82	0.0246	0.42
14	0.0000	0.00	0.0011	1.39	0.0011	1.39
15	0.0000	0.00	0.0011	1.54	0.0011	1.54
16	0.0055	1.01	0.0000	0.00	0.0055	1.01
17	0.0000	0.00	0.0033	1.03	0.0033	1.03
18	0.0000	0.00	0.0000	0.00	0.0000	0.00
19	0.0000	0.00	0.0000	0.00	0.0000	0.00
20	0.0000	0.00	0.0031	1.10	0.0031	1.10
21	0.0018	1.16	0.0000	0.00	0.0018	1.16
22	0.0000	0.00	0.0000	0.00	0.0000	0.00
23	0.0037	1.07	0.0000	0.00	0.0037	1.07
24	0.0000	0.00	0.0002	1.57	0.0002	1.57
n	441		464		905	

Age	KIN 1 (East coast)					
	Male		Female		All	
(years)	Proportion	c.v.	Proportion	c.v.	Proportion	c.v.
3	0.0543	0.21	0.0398	0.26	0.0941	0.16
4	0.1063	0.14	0.1339	0.12	0.2402	0.09
5	0.1057	0.16	0.1337	0.12	0.2395	0.10
6	0.0904	0.15	0.1457	0.10	0.2361	0.08
7	0.0301	0.28	0.0387	0.20	0.0688	0.17
8	0.0246	0.29	0.0163	0.27	0.0409	0.20
9	0.0092	0.46	0.0038	0.54	0.0130	0.36
10	0.0077	0.48	0.0088	0.39	0.0164	0.31
11	0.0111	0.36	0.0066	0.50	0.0177	0.29
12	0.0059	0.58	0.0112	0.36	0.0171	0.30
13	0.0059	0.53	0.0030	0.85	0.0089	0.45
14	0.0000	0.00	0.0005	1.25	0.0005	1.25
15	0.0000	0.00	0.0005	1.35	0.0005	1.35
16	0.0015	1.07	0.0000	0.00	0.0015	1.07
17	0.0000	0.00	0.0009	1.17	0.0009	1.17
18	0.0000	0.00	0.0000	0.00	0.0000	0.00
19	0.0000	0.00	0.0000	0.00	0.0000	0.00
20	0.0000	0.00	0.0013	1.13	0.0013	1.13
21	0.0007	1.18	0.0000	0.00	0.0007	1.18
22	0.0000	0.00	0.0006	1.21	0.0006	1.21
23	0.0014	1.06	0.0000	0.00	0.0014	1.06
24	0.0000	0.00	0.0000	2.43	0.0000	2.43
n	959		1150		2109	

Age	Bay of Plenty			
	In-shore		White Island	
(years)	Proportion	c.v.	Proportion	c.v.
3	0.0346	0.53	0.0487	0.90
4	0.2336	0.15	0.1106	0.41
5	0.1119	0.32	0.2171	0.30
6	0.3509	0.14	0.2344	0.29
7	0.0848	0.34	0.0830	0.32
8	0.0264	0.61	0.0756	0.32
9	0.0109	1.01	0.0306	0.50
10	0.0319	0.59	0.0407	0.44
11	0.0546	0.41	0.0385	0.44
12	0.0474	0.51	0.0310	0.44
13	0.0131	0.82	0.0318	0.53
14	0.0000	0.00	0.0147	0.80
15	0.0000	0.00	0.0039	1.26
16	0.0000	0.00	0.0118	1.00
17	0.0000	0.00	0.0059	1.14
18	0.0000	0.00	0.0000	0.00
19	0.0000	0.00	0.0000	0.00
20	0.0000	0.00	0.0084	1.11
21	0.0000	0.00	0.0039	1.20
22	0.0000	0.00	0.0000	0.00
23	0.0000	0.00	0.0059	1.10
24	0.0000	0.00	0.0034	1.30
n	560		345	