Length and age composition of the commercial catch of blue moki (*Latridopsis ciliaris*) in MOK 1 during the 2004–05 and 2005–06 fishing years, including total and fishing mortality estimates

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New Zealand Fisheries Assessment Report 2010/34
October 2010

Published by Ministry of Fisheries
Wellington
2010

ISSN 1175-1584 (print)
ISSN 1179-5352 (online)

Manning, M.J.; Stevenson, M.L.; Dick, C.M. (2010).
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in MOK 1 during the 2004–05 and 2005–06 fishing years,
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.New Zealand Fisheries Assessment Report 2010/34.

This series continues the informal
New Zealand Fisheries Assessment Research Document series
which ceased at the end of 1999.

EXECUTIVE SUMMARY

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This report presents the results of a two-year market sampling programme on the blue moki catch in the target tarakihi bottom-trawl (BT-TAR) fishery and the target-moki setnet (SN-MOK) fishery operating off the east coast of the North Island during the 2004–05 and 2005–06 fishing years. This work was funded by the Ministry of Fisheries ("To monitor and assess the blue moki fishery in MOK 1"), Specific Objectives 1 ("To conduct sampling to determine the length and age structure of the commercial targeted setnet catch of blue moki in MOK 1"), 2 ("To conduct sampling to determine the length and age structure of blue moki caught by commercial trawlers targeting tarakihi in MOK 1"), and 3 ("To estimate fishing mortality of the adult MOK 1 stock"). Implementation of the sampling programme was subcontracted to the Area Two Inshore Finfish Management Company Ltd (ATIFMC).

The aim of the market sampling was to sample the age composition of both fisheries throughout both fishing years in order to produce suitable fishery catch-at-age distributions from which total and fishing mortality estimates could be calculated. The spatial extent of the sampling programme was restricted to that part of the MOK 1 fishstock on the east coast of the North Island (ECNI; New Zealand Fisheries Management Area 2 or "Central East" encompassing New Zealand fisheries statistical areas 011–019) as this matched the scope of earlier standardised catch-per-unit-effort analyses of both fisheries and the catch in the BT-TAR and SN-MOK fisheries in this area historically accounts for about half of the total MOK 1 catch per fishing year on average. Sampling effort was allocated to the three major ports on the ECNI (Gisborne, Napier, and Wellington) by month proportionally to historic trends in catch in the fishery by these factors. A so-called "direct-age" design was used, where sagittal otolith pairs from individual fish were sampled randomly from each fishery and scaled up to stratum totals in the analysis without using intermediate age-length keys. Variance targets of mean-weighted coefficients of variation of 30% were set for each fishery catch-at-age during each fishing year.

Targets of 50 sampled landings were set for both fishing years (BT-TAR: 30 landings; SN-MOK: 20 landings). Totals of 32 (2004–05) and 25 (2005–06) landings were sampled, with mean weighted c.v.s of 25–63% for the length frequencies and 23–60% for the age frequencies. Reasons for the failure by the ATIFMC to meet the sampling targets are discussed. However, the sampled catches accounted for 20% of the total combined catch of the BT-TAR and SN-MOK fisheries during 2004–05 and 10% during 2005–06. The sample data collected are thought to be generally representative of the fishing effort and catches in both fisheries during both fishing years, although some particular discrepancies are noted. The catches-at-age in both fisheries appear to consist of fish exceeding 40 years of age, but most fish present are between 4 and 12 years of age. There was some evidence of differential year-class success, with some evidence of abnormally strong 1984 and 1985 year classes persisting in the catch and a strong 1999 year class entering the catch. A revised natural mortality estimate of 0.10 y^{-1} was calculated.

Total mortality estimates were calculated separately for both fisheries during both fishing years assuming ages at full recruitment to each fishery of between 4 and 12 years. Fishing mortality estimates of 0.06 and 0.08 y^{-1} for the BT-TAR and SN-MOK fisheries respectively during 2004–05 and 0.03 y^{-1} for both fisheries, during 2005–06 assuming age at full vulnerability of 8 years were calculated from these results. A classical Beverton-Holt yield-per-recruit analysis was carried out to produce reference fishing mortality values to compare the observed fishing mortality estimates. With which comparison of the observed fishing mortality estimates with the yield-per-recruit reference values ($F_{0.1}$ and F_{max}) suggested that the stock that supports the BT-TAR and SN-MOK fisheries off the ECNI was not being overfished, regardless of the age at full vulnerability assumed in the reference point calculations and the age-at-full-recruitment assumed in the total mortality calculations and thus in the fishing mortality estimates. Theoretical shortcomings in the yield-per-recruit analysis and their implications for the conclusions drawn are discussed. Some recommendations for future blue moki market sampling are also discussed.

1. INTRODUCTION

Blue moki (*Latridopsis ciliaris*) is a moderate-sized demersal teleost distributed widely in the New Zealand region. It is found in depths from 10 m to about 200 m on the continental shelf around the North, South, and Chatham Islands (Anderson et al. 1998). It reaches lengths of about 80 cm from the tip of the snout to the caudal fork and about 8 kg in weight (Ministry of Fisheries Science Group 2007).

Commercial fisheries for blue moki in New Zealand waters are relatively small and are concentrated around the east coasts of the North and South Islands. Total annual reported commercial landings have ranged between 164 and 551 t and have averaged 427 t since the full implementation of the Quota Management System (QMS) at the start of the 1986–87 fishing year (1 October 1986 to 30 September 1987). Since then, blue moki in New Zealand waters have been managed as five separate Quota Management Areas (QMAs) or "Fishstocks": MOK 1, 3, 4, 5, and 10 (Figure 1). Fishstock catches and TACCs are given in Table 1, (Figure2). Fishstock MOK 1, which encompasses the east and west coasts of the North Island and west coast of the South Island, accounts for most (roughly 40% in any given fishing year) of the catch. Total annual reported commercial landings in MOK 1 have ranged between 109 t and 469 t and average 340 t.

1.1 Summary of available information

There is little information available on the biology and ecology of blue moki relevant to their fisheries management in New Zealand. Species identity was confirmed by Smith et al. (2001, 2003). Aspects of age and growth and sexual maturity of blue moki off the east coast of the South Island were investigated by Francis (1981a). Francis (1981b) found evidence of a spawning migration that begins off Kaikoura on the East Coast of the South Island in about May to June, travels north along the east coasts of the South and North Islands, reaches Gisborne to spawn off Gisborne and East Cape in about August to September, before passing Kaikoura again in about October. The spawning ground off Gisborne and East Cape is also the only known spawning ground in the New Zealand region. As well as the commercial fishery, recreational and customary fisheries also exist, and blue moki is of particular cultural importance to Cape Runaway Maori (Ministry of Fisheries Science Group 2007). However, the available recreational harvest estimates are thought to be biased and there are no quantitative estimates of the amount of customary catch available at this time (Ministry of Fisheries Science Group 2007).

Langley & Walker (2004) carried out a characterisation and catch-per-unit-effort (CPUE) standardisation analysis of the commercial fisheries in MOK 1. They found that most of the catch was caught in four main seasonal fisheries: the target tarakihi bottom-trawl fishery ("BT-TAR"); statistical areas 012–016; September–November and March–July), the target blue moki setnet fishery ("SN-MOK"; statistical areas 013–015; May–October), the target blue warehou setnet fishery ("SN-WAR"; statistical area 014; May–October), and the target tarakihi setnet fishery ("SN-TAR"; statistical area 018; April–June). They noted that there were no data on the size and age composition of fish in each of the four main fisheries and recommended that catch-sampling be undertaken to determine their composition. They also found that the setnet CPUE series, in particular the target blue moki component, were the most promising candidates for future monitoring of the fishery, but because of the poor quality of the data collected up to the end of the 2001–02 fishing year, suggested that the current trends were not thought to track abundance. Although the recently revised setnet catch and effort data form may provide data of sufficient quality to monitor relative abundance in the fishery in the future, the Ministry of Fisheries therefore currently has no information on the status of the stock, or whether current rates of exploitation will allow the stock biomass to move towards a level that can support the maximum sustainable yield.

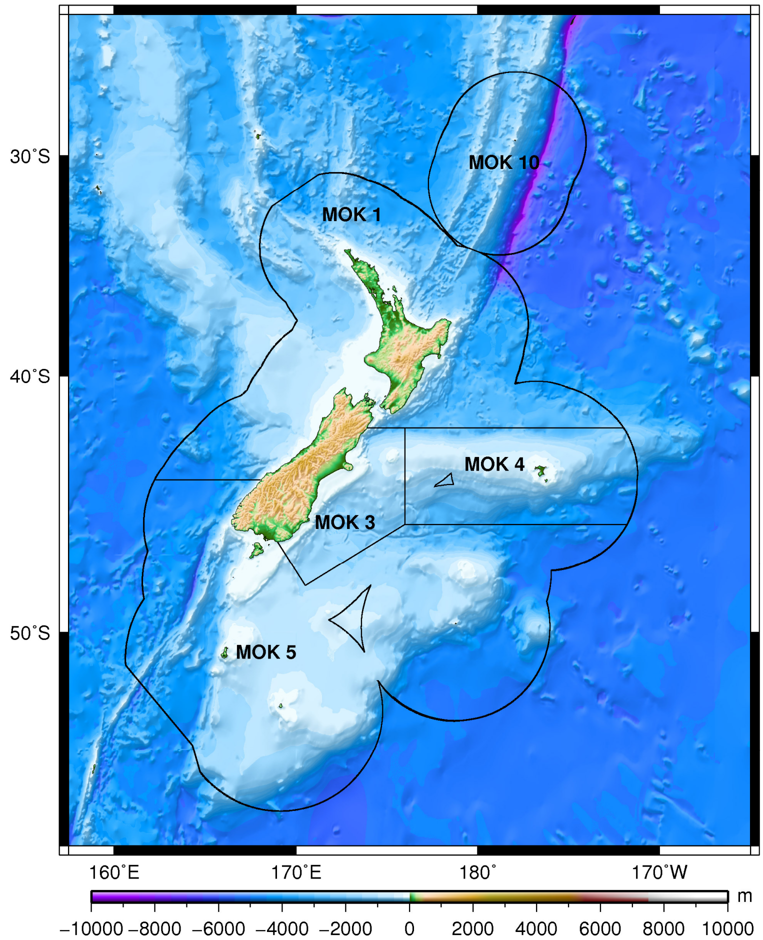


Figure 1: **Blue moki Quota Management Areas (QMAs). Blue moki in the New Zealand EEZ is managed as eight separate fishstocks. The QMAs do not necessarily contain individual biological stock units or populations.**

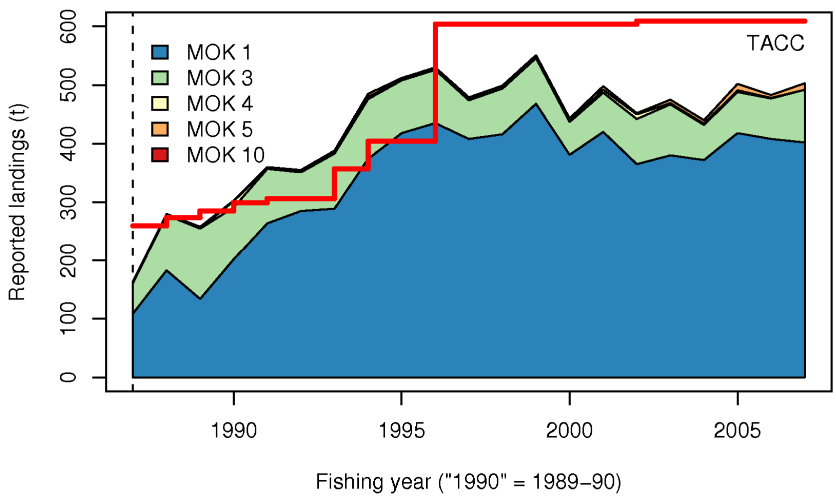


Figure 2: **The reported blue moki catch by fishstock and fishing year, 1986–87 to 2005–06 (Table 1). The MOK 1 catch dominates the total, with a smaller contribution from MOK 3. Catches in the other QMAs are negligible. The total TACC for all fishstocks is overlaid.**

Table 1: The total reported landed blue moki catch by fishing year and QMA (Ministry of Fisheries Science Group 2007). All data are New Zealand QMS data (1986–87 to 2006–07).

	MOK 1		MOK 3		MOK 4		MOK 5		MOK 10		All QMAs	
Fishing year	Catch	TACC	Catch	TACC	Catch	TACC	Catch	TACC	Catch	TACC	Catch	TACC
1986–87	109	130	52	60	–	20	3	40	–	10	164	260
1987–88	183	142	95	62	–	20	2	40	–	10	280	274
1988–89	134	151	121	64	–	20	3	40	–	10	258	285
1989–90	202	156	89	65	11	25	1	43	–	10	303	299
1990–91	264	157	93	71	1	25	2	43	–	10	360	306
1991–92	285	157	66	71	2	25	2	43	–	10	355	306
1992–93	289	157	94	122	1	25	4	43	–	10	388	358
1993–94	374	200	102	126	4	25	5	43	–	10	485	404
1994–95	418	200	90	126	<1	25	3	43	–	10	511	404
1995–96	435	400	91	126	1	25	3	43	–	10	530	604
1996–97	408	400	66	126	2	25	3	43	–	10	479	604
1997–98	416	400	78	126	3	25	2	43	–	10	500	604
1998–99	468	400	78	126	<1	25	4	43	–	10	551	604
1999–00	381	400	56	126	1	25	5	43	–	10	443	604
2000–01	420	400	67	126	5	25	6	43	–	10	499	604
2001–02	365	403	77	127	8	25	2	44	–	10	451	609
2002–03	380	403	87	127	2	25	6	44	–	10	475	609
2003–04	372	403	60	127	2	25	6	44	–	10	440	609
2004–05	418	403	70	127	3	25	11	44	–	10	502	609
2005–06	408	403	69	127	1	25	5	44	–	10	483	609
2006–07	402	403	90	127	<1	25	11	44	–	10	504	609

1.2 Aim of this study

This report presents the results of a two-year market sampling programme to begin to address the need for further information on the composition of the main fisheries in MOK 1. The aim of the programme was to sample catches in the target moki setnet (SN-MOK) and target tarakihi bottom trawl fisheries on the east coast of the North Island in MOK 1 during the 2004–05 and 2005–06 fishing years. A target mean-weighted coefficient of variation (c.v.) of 30% averaged over all age classes was set for the fishery catch-at-age distributions. Mortality estimates derived using catch-curve methods are also presented and are considered within the context of a deterministic per-recruit analysis. This work was funded by the New Zealand Ministry of Fisheries as research project MOK2003/01 ("Monitoring the blue moki fishery in MOK 1"). This report addresses Specific Objectives 1, 2, and 3 of that project.

2. METHODS

2.1 The spatial and temporal extent of the sampling programme

The spatial extent of the sampling programme was limited to that part of the MOK 1 fishstock on the east coast of the North Island (ECNI; New Zealand Fisheries Management Area 2 or "Central East) encompassing New Zealand fisheries statistical areas 011–019 and 201–206. Over 80% of the total MOK 1 catch is caught by setnet and bottom trawl vessels operating in this area. Catches in the BT-TAR and SN-MOK fisheries in this area in particular are well defined in both time and space.

Langley & Walker (2004) found that catches in the blue moki target setnet fishery (SN-MOK) on the ECNI accounted for about 25% of the total estimated blue moki catch in their dataset. Of this catch, they found that about 78% was caught in statistical areas 013–015, and that over 81% was caught in the six months from 1 May to 31 October. They also found that the catch in the tarakihi target setnet fishery (BT-TAR) off the ECNI accounted for about 22% of the total estimated catch in their dataset, with most of this catch (92%) caught in statistical areas 012–016, but that there were two seasonal peaks in this catch between March and July and between September and November.

We decided to further restrict our sampling effort to the BT-TAR and SN-MOK fisheries off the ECNI. By restricting sampling effort to these two fisheries, we expected to be able to sample a usefully large proportion of the total expected MOK 1 catch during the 2004–05 and 2005–06 fishing years, without needing to extend our sampling effort over the full spatial extent of this very large fishstock. A further advantage is that our sampling would also then be consistent with the definitions of the standardised CPUE indices developed by Langley & Walker (2004) for these two fisheries. Although the SN-MOK catch is highly seasonal, suggesting that our sampling effort could be restricted to some fraction of the fishing year, given the reduced seasonality in the BT-TAR fishery and that some Licensed Fish Receivers (LFRs) along the ECNI receive catch from both fisheries, suggested to us that sampling should be carried out throughout all 12 months of the 2004–05 and 2005–06 fishing years to allow optimal sampling designs for both fisheries to be developed that could be managed simultaneously.

We refer to that part of the MOK 1 fishstock on the ECNI as "MOK 1(E)" elsewhere in this report.

2.2 Sample design

2.2.1 Method

Proportions at age in New Zealand fisheries are usually estimated using one of three methods (Francis 2002):

(i) by collecting length-frequency data from the catch and using a modal separation program such as MIX to decompose the length-frequency distribution into an age-frequency distribution (the "indirect length-frequency" approach);

(ii) by collecting both a large sample of length-frequency data and a small sample of otoliths from the catch to generate an "age-length" key to transform the length-frequency distribution to an age-frequency distribution (the "indirect age-length key" approach); or

(iii) by collecting representative samples of otoliths and estimating the catch-at-age directly from the age-frequency distribution derived from the otoliths collected (the "direct-age estimation" approach).

The first is of little use for blue moki given their moderate longevity (at least 33 years) (Francis 1981a). The second is likely to be difficult to apply to the MOK 1(E) stock given the temporal distribution of the catch, fish growth, and probable migrations through the stock area within a given fishing year. Although there is a distinct seasonal peak in the SN-MOK catch over May to October, catch in the BT-TAR fishery is more spread out, with peaks in March to July and September to November. These fisheries are also exploiting the probable movement of fish northwards along the east coast of the South and North Islands to East Cape as part of the spawning migration identified by Francis (1981b).

The main advantage of method two is low cost: large numbers of fish can be measured relatively cheaply and the relatively more expensive age estimation component is restricted to relatively few fish. However, the cost advantage is reduced or lost when multiple age-length keys are needed. The number of age-length keys that would be required for MOK 1(E) is unclear, although it is probably at least four: separate spawning and non-spawning keys each for males and females along the east coast of the North Island. Each key needs to be derived from sufficient otoliths to define the length-at-age relationship with species with more than 30 year-classes in the catch, requiring considerable sampling effort. On balance, the third method, the direct-age estimation approach, appeared most appropriate for the MOK 1(E) fishstock and was selected.

2.2.2 Sampling effort allocation

To facilitate sampling effort allocation, all associated landing and fishing event records for all fishing trips from 1 October 1989 to 30 September 2004 where at least one non-zero landing event in MOK 1 was recorded were extracted from the MFish catch-effort and landings database *warehou* (Duckworth 2002). These data were then merged using the restratification and landed catch allocation algorithm described by Manning et al. (2004). Given the ablative nature of this procedure, the groomed and merged catch in each fishing year was rescaled to be equal to the corresponding QMR catch (Table 1).

The groomed and merged landed catch is plotted by fishery, month of landing, and fishing year in Figure 3. The catch is plotted by fishery, month, and reported place of landing in Figure 4. Trends similar to those identified by Langley & Walker (2004) in their analysis of estimated catch are apparent: the SN-MOK landed catch is highly seasonal and landed in relatively few places on the east coast of the North Island, namely Gisborne, Napier, and Ngawi, although Pourerere Beach and Wellington are also important. Catches in the BT-TAR fishery are less seasonal, with most of the catch in this fishery also landed in Gisborne, Napier, and Wellington; fish landed Ngawi and Pourerere Beach are probably transported to Wellington and Napier, respectively, for processing. Gisborne (30%), the Napier region (including Pourerere Beach; 24%), and the Wellington region (including Ngawi; 33%) account for 87% of the catch (Figure 5). Eighty-two percent of the MOK 1 catch is landed in the six months between 1 June and 30 November (Figure 3).

The catch is plotted by fishery, statistical area actually fished, and port of landing in Figure 6. There are some not unexpected associations between certain statistical areas fished and ports of landing although some overlap is also apparent. Catches unloaded in Gisborne are typically caught in statistical area 013, with a smaller contribution from statistical area 012. Catches unloaded in Napier are typically reported as caught in areas 013 and 014, but catches unloaded in Wellington (including those catches landed at Ngawi) are typically reported as caught in areas 015 and 016. These results suggest that port of landing may be a reasonably effective alias for the statistical areas actually fished during a given fishing trip (for these fisheries off the ECNI at least). Landings are also typically small, with most (97%) of all landings weighing 1 t or less (Figure 6). Further descriptions of the fishery are given in Section 3.

From these trends in catch, we decided to stratify our sampling effort by three-month divisions of the fishing year that seem to coincide reasonably well with the known peaks in catch in the SN-MOK and BT-TAR fisheries, and by the major ports of landing, north to south, along the ECNI. However, the optimal number of landings to sample and effort allocation scheme could not be evaluated quantitatively before this programme began. There are few available published data on the length and age composition of the MOK 1 catch, and what data are available, such as those presented by Francis (1981b), do not lend themselves to a quantitative evaluation of an optimal sampling design; the data have not been loaded to the *market* research database and are not in a form that would allow them to be easily processed and loaded to this or any other database (M. Francis, pers. comm.). But given that Blackwell & Gilbert (2002), using a direct-age sampling design, observed mean-weighted c.v.s of 27% and 25% for the snapper (*Pagrus auratus*) trawl fishery catch-at-age in SNA 7 during the 1999–2000 and 2000–01 fishing years after sampling 60 and 56 landings respectively, and given the crude similarities between this species and fishery and the BT-TAR and SN-MOK fisheries off the ECSNI, we decided to sample a similar number of landings. We set a target of 50 landings, 30 for the BT-TAR fishery and 20 for the SN-MOK fishery during each of the 2004–05 and 2005–06 fishing years, with the landings assigned to the season-port of landing sampling strata proportionally to the historic distribution of catch in these fisheries by these factors. Allocated sampling effort is given in Table 2.

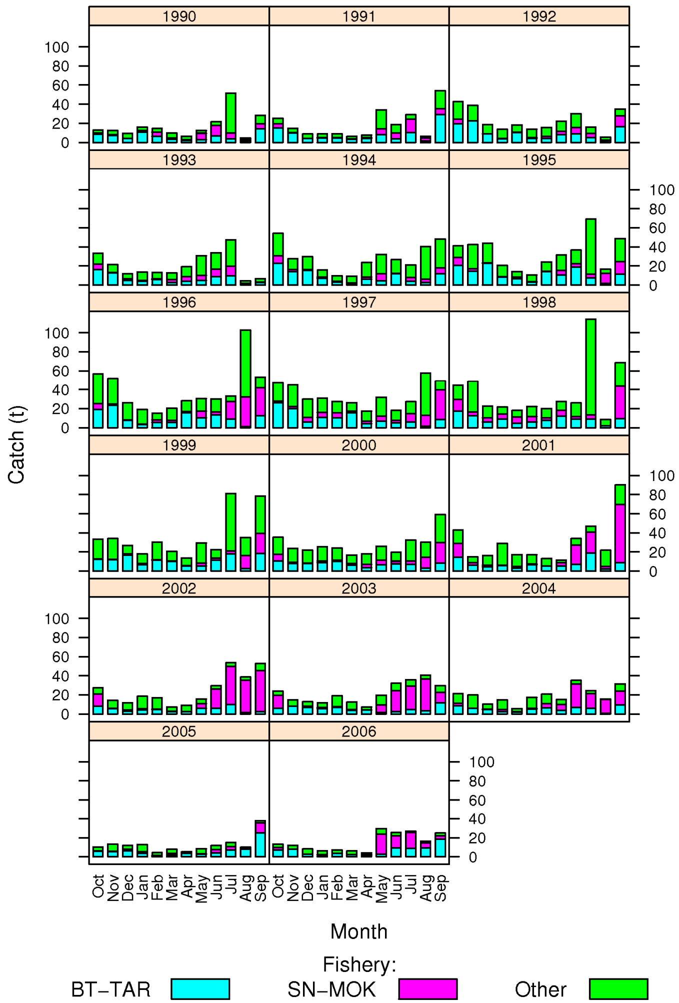


Figure 3: **The distribution of the catch in the groomed and merged catch-effort and landings dataset by month, fishing year, and fishery.**

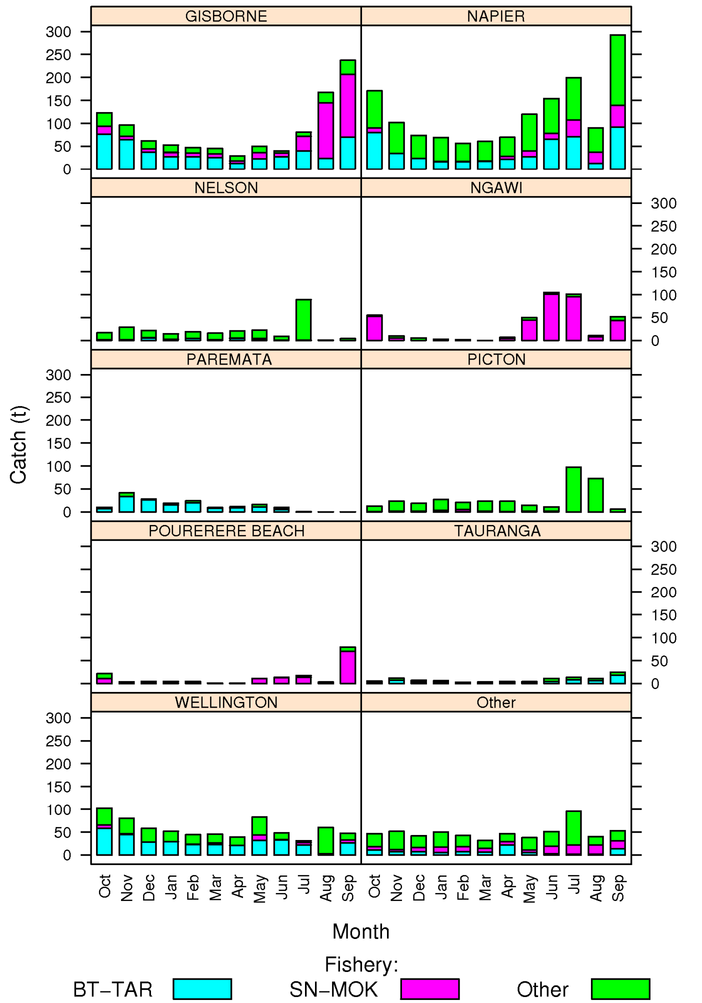


Figure 4: **The distribution of the catch in the groomed and merged catch-effort and landings dataset by month, port of landing, and fishery.**

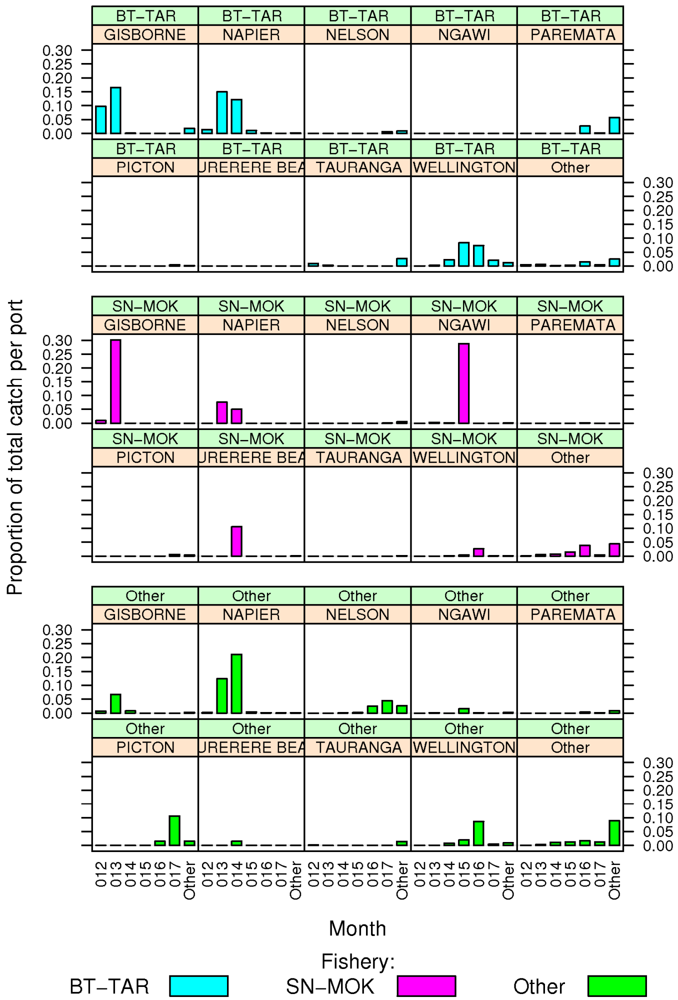


Figure 5: The distribution of the catch in the groomed and merged catch-effort and landings dataset by statistical area where caught, port of landing, and fishery. Catches are plotted as proportions of the total catch per fishery by these factors.

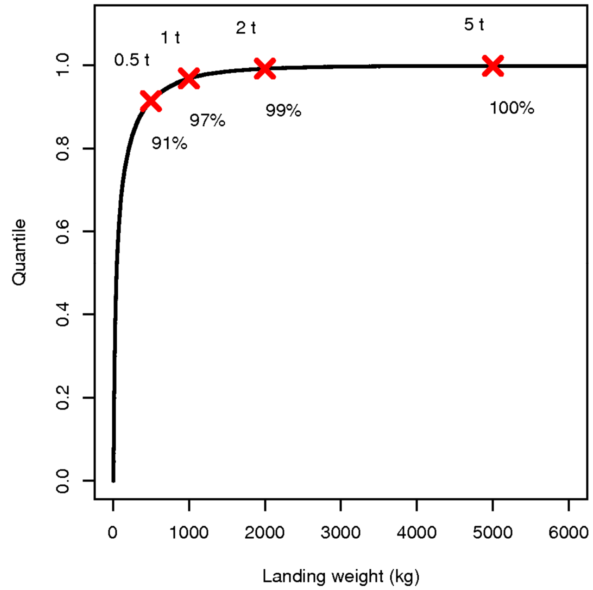


Figure 6: Empirical cumulative frequency function of the sum of greenweight (kg) by trip for all trips with at least one associated non-null, non-zero landing event where MOK 1 was specified (groomed but unmerged) during the fishing years 1989–90 to 2003–04. Interpolated quantiles at 500 kg, 1000 kg, 2000 kg, and 5000 kg landing weights are noted on the plot. The x axis is truncated to 6000 kg.

Table 2: Sample allocation by sampling stratum: (i) gives the distribution of all groomed landed catches from the 1989–90 to 2002–03 fishing years in the target blue moki setnet (SN–MOK) and target tarakihi fisheries (BT–TAR) by stratum; (ii) gives the catch by stratum as proportions-by-weight (t); and (iii) gives the provisional sample allocation by stratum.

(i) Groomed landed catch by stratum (t):

				Season	Total
Fishery	"Spring" (Oct-Nov-Dec)	"Summer" (Jan-Feb-Mar)	"Autumn" (Apr-May-Jun)	"Winter" (Jul-Aug-Sep)	
BT–TAR	719	340	349	443	1850
SN–MOK	163	77	259	670	1169
Total	882	417	608	1113	3020

(ii) Groomed landed catch by stratum (proportions):

				Season	Total
Fishery	"Spring" (Oct-Nov-Dec)	"Summer" (Jan-Feb-Mar)	"Autumn" (Apr-May-Jun)	"Winter" (Jul-Aug-Sep)	
BT–TAR	0.24	0.11	0.12	0.15	0.61
SN–MOK	0.05	0.03	0.09	0.22	0.39
Total	0.29	0.14	0.20	0.37	1.00

(iii) Sample allocation by stratum ("Napier" includes fish landed in Pourerere Beach and transported to Napier for processing; "Wellington" includes fish landed in Ngawi and Paremata and transported to Wellington for processing):

					Season	Total
Fishery	Port	"Spring" (Oct-Nov-Dec)	"Summer" (Jan-Feb-Mar)	"Autumn" (Apr-May-Jun)	"Winter" (Jul-Aug-Sep)	
BT-TAR	Gisborne	5	2	2	3	12
	Napier	3	1	1	2	7
	Wellington	4	2	2	3	11
	Total	12	5	5	8	30
SN-MOK	Gisborne	1	1	2	3	7
	Napier	1	1	1	3	6
	Wellington	1	1	2	3	7
	Total	3	3	5	9	20
Total	Total	15	8	10	17	50

A typical result in market sampling programmes is that there is usually (much) more variation in fish size and other quantities between rather than within landings. More precision in the observations of these quantities can usually be obtained by sampling fewer fish from many landings than by sampling many fish from a few landings. To account for this, we decided to sample a target of 50 landings, 25 per fishery, per fishing year. We proposed to randomly sample 25 sagittal otolith pairs from landings over 1000 kg or lighter and 50 sagittal otolith pairs from landings heavier than 1000 kg. As most MOK 1 landings are 1000 kg or less, we expected to collect somewhere around 1250 to 1500 otolith pairs across both fisheries per fishing year, of which we proposed to prepare and read 1000 individual otoliths per year. Collecting more otoliths than we proposed to prepare and read would give us the ability to post-stratify the otoliths collected to control sources of variation in the catch or other factors that were unknown when the sampling scheme was designed but may be shown later to be important.

2.2.3 Management of sampling operations

Implementation of the sampling programme was subcontracted by NIWA to the Area Two Inshore Finfish Management Ltd (ATIFMC). ATIFMC is the seafood industry stakeholder organisation that represents the interests of commercial fishers and quota owners in the Central East (FMA 2) fisheries management area. LFRs likely to receive large amounts of the MOK 1 catch during the 2004–05 and 2005–06 fishing years were identified using Quota Share Register reports (http://www.fishserve.co.nz) and their participation in the sampling programme was sought by ATIFMC. Once a list of participating LFRs had been compiled, the target landings per season, port, and fishery were then allocated evenly among these LFRs (Gisborne: Gisborne Fisheries Ltd and Moana Pacific Fisheries Ltd; Napier, Hawke Bay Seafood Ltd and Star Fish Supply Ltd; Wellington: Deep Blue Seafoods Ltd, John's Fish Market Ltd, and Pacific Catch Ltd). ATIFMC was then asked to assist each LFR to nominate suitable staff to carry out the sampling work from day to day. Sampling was then delegated to these staff. Nominated staff were given a comprehensive briefing and training session by NIWA and ATIFMC before beginning sampling at the start of the 2004–05 fishing year and all equipment and consumables (including suitable food-safe measuring board, tweezers, otolith envelopes, pencils, and a comprehensive set of notes prepared by NIWA) were provided. An ongoing data quality assurance programme involving regular contact with and debriefing of the nominated sampling staff was established by NIWA and ATIFMC to be managed by ATIFMC.

2.2.4 Sample data collection

Sampling staff were asked to sample landings on a "first come, first served" basis within the season-port sampling strata relevant to their fishery. Staff were asked not to sample landings less than 100 kg. Once a suitable landing had been selected (that is, a landing of the required weight, from the required fishery), staff were asked to collect simple random sample of unsorted fish of the required size (a total of 25 fish if the landing was 1000 kg or less in, 50 fish if more than 1000 kg) from the catch received for that landing. Staff were asked not to sample landings where they knew or suspected that the catch had been pre-sorted (by size etc.). Staff were asked to collect the fork length (to the nearest centimetre below actual fork length), sex, and sagittal otolith pair from each fish in the sample and the macroscopic gonad maturity stage of all female fish. The five-point NIWA-Ministry of Fisheries Observer Programme generalised gonad maturity scale was used (Sutton 2002).

2.3 Otolith preparation and analysis

All blue moki otoliths collected during the market sampling programme were retrieved from the Ministry of Fisheries otolith collection. All associated otolith inventory data were extracted from fisheries research database *age* (Mackay & George 2000) and all associated market sampling data were extracted from database *market* (Fisher & Mackay 2000).

A total of 2331 sagittal otolith pairs was collected from both fisheries over both fishing years, of which 1369 were collected during 2004–05, and 962 were collected during 2005–06. A random subsample of about 1000 otoliths was selected from the set of 1369 sagittal otolith pairs collected during 2004–05, with the sample inclusion probability for each otolith weighted to be roughly proportional to the landing weight, and a minimum of 10 otoliths was selected from each sampled landing. All of the 962 sagittal otolith pairs collected during the 2005–06 fishing year were selected, as fewer landings were sampled and otoliths were collected this year than was planned.

Francis (1981a) used a "break and burn" method derived from that of Christensen (1964) to prepare his blue moki otolith sections. This involved breaking each otolith by hand along its nuclear plane, then burning it in a naked Bunsen flame to improve the contrast between successive opaque and translucent growth zones. While this method can produce sections with good contrast between successive growth zones, it is time consuming, somewhat hit and miss, and not suited to the preparation of large numbers of otoliths, such as in this study. We therefore adapted the preparation and reading methods of Manning et al. (2008) for tarakihi, a closely related species with similar sized and shaped sagittal otoliths, instead. Manning et al. (2008) used a so-called "thick section" method, where relatively large numbers of otoliths are aligned in columns in a single mould and embedded in clear epoxy resin, then sectioned transversely along the nuclear plane. Large numbers of otoliths can be processed quickly using this method, especially if multiple layers of otoliths are embedded.

We used the right otolith from each pair of selected otoltihs. Where the right otolith had not been collected or was damaged, we used the left otolith instead. The otoliths were first baked in a ConTherm Series 5 scientific oven at 285 °C for 5 minutes until amber coloured. The baked otoliths were then embedded in layers in Araldite K142 clear epoxy resin. Once the resin blocks had cured, the embedded otoliths were sectioned transversely along the nuclear plane using a Struers Accutom-2 precision wafering saw turning a single Extec 12205 diamond-edged blade (blade thickness 0.3 mm). The cut surfaces of the resin blocks were then polished using Struers P1200 carborundum paper. Otoliths from tarakihi 25 cm or in fork length are usually read whole due to their small less size and fragility (Stevenson & Horn 2004, Manning et al. 2008), but as there were no otoliths from fish smaller than 40 cm in fork length in this study, all the blue moki otoliths in this study were embedded and sectioned.

The sectioned otoliths were read under reflected light using a Wild M400 binocular microscope at × 25 magnification: × 40 magnification was occasionally used to resolve the outer zones of otoliths from older fish. A thin layer of paraffin oil was applied to the cut surfaces of each section to improve clarity. Readings were generally made along an axis from the nucleus out towards the ventral margin to a point usually adjacent to the sulcus, but sometimes also on the dorsal margin or extended along the dorsoventral axis. Sometimes readings were started near the sulcus, but finished in some other area of the section; counts in the two areas were linked by tracing a clear zone across the section. All otoliths exhibited alternating light and dark regions under reflected light. Following Francis (1981a), we assumed that these light and dark regions were opaque and translucent zones (respectively) and that a single light (opaque) and a single dark (translucent) zone corresponds to a single year's growth (annulus). The number of fully formed translucent zones present, a five-point "readability" score, and a three-point "margin-state" score were recorded for each otolith (Table 3). All prepared (sectioned or whole) otoliths were read once by one reader (M. L. Stevenson). The reader had no knowledge of fish length or sex at the time of reading. Translucent zone counts were converted to decimalised age estimates using a simple algorithm (see below).

Otolith reading precision was quantified by carrying out within- and between-reader comparison tests after Campana et al. (1995). A subsample of 200 otoliths was randomly selected from the set of all otoliths prepared in this study. The subsampled otoliths were then re-read by the first reader and read by a second reader (P. L. Horn) and both sets of results compared with the first reader's first set of results. The Index of Average Percentage Error, IAPE (Beamish & Fournier 1981), and mean coefficient of variation (mean c.v.) (Chang 1982), were calculated for each test. Where X_{ij} is the ith count of the jth otolith, R is the number of times each otolith is read, and N is the number of otoliths read or re-read,

$$\mathrm{IAPE} = 100 \times \frac{1}{N} \sum_{j=1}^{N} \left[\frac{1}{R} \sum_{i=1}^{R} \frac{\left| X_{ij} - X_j \right|}{X_j} \right], \quad (1)$$

and

$$\text{mean c.v.} = 100 \times \frac{1}{N} \sum_{j=1}^{N} \left[\frac{\sqrt{\sum_{i=1}^{R} \frac{\left(X_{ij} - X_j\right)^2}{R-1}}}{X_j} \right]. \qquad (2)$$

2.3.1 Converting translucent-zone counts to age estimates

A simple algorithm was used to convert translucent zone counts to decimalised age estimates. The algorithm involves treating estimated fish age, $\hat{a}$, as the sum of three time components, namely,

$$\hat{a}_i = t_{i,1} + t_{i,2} + t_{i,3}, \qquad (3)$$

where $t_{i,1}$ is the elapsed time from spawning to the end of the first fully formed translucent zone present in the otolith, $t_{i,2}$ is the elapsed time from the end of the first fully formed translucent zone to the end of the outermost fully formed translucent zone for the *i*th fish, $t_{i,3}$ is the elapsed time from the end of the outermost fully formed translucent zone to the date when the *i*th fish was captured. Hence,

$$\begin{aligned} t_{i,1} &= t_{i,\text{ end first translucent zone}} - t_{i,\text{ spawning date}} \\ t_{i,2} &= (n_i + w) - 1 \qquad , \qquad (4) \\ t_{i,3} &= t_{i,\text{ capture}} - t_{i,\text{ end last translucent zone}} \end{aligned}$$

where n_i is the total number of translucent zones present for fish *i*, and *w* is an edge interpretation correction after Francis et al. (1992) applied to n_i: $w = 1$ if the recorded margin state = "wide" *and* fish *i* was collected *after* the date when translucent zones are assumed to be fully formed, $w = -1$ if the recorded margin state = "narrow" *and* fish *i* was collected *before* the date when translucent zones are assumed to be fully formed, otherwise $w = 0$.

Because of our current inability to precisely estimate spawning and translucent zone completion dates for individual blue moki, these dates were generalised for all fish. From Francis (1981b), we assumed an arbitrary spawning date of 1 October for all fish, and a date of 1 November for completion of all translucent (winter) growth zones (formation was assumed to begin on 1 May). The corresponding landing date was used as the capture date for each fish. Decimalised years were assumed for all time components. So, the estimated age for a fish captured on 30 November 2005 with a count of 21 completed translucent zones and a medium margin is $\hat{a} = t_1 + t_2 + t_3 = 0.08 + 20 + 0.08 = 20.16$ years (Figure 7).

Table 3: Readability and margin-state scores used in otolith readings.

Five-point readability score

Score	Description
1	Otolith very easy to read; excellent contrast between translucent and opaque zones; ± 0 between subsequent translucent-zone counts of this otolith
2	Otolith easy to read; good contrast between translucent and opaque zones, but not as marked as in "1"; ± 1 between subsequent translucent-zone counts of this otolith
3	Otolith readable; less contrast between translucent and opaque zones than in "2", but alternating zones still apparent; ± 2 between subsequent translucent zone counts of this otolith
4	Otolith readable with difficulty; poor contrast between translucent and opaque zones, deemed to be worse than in either "2" or "3"; ± 3 or more between subsequent counts of this otolith
5	Otolith unreadable

Three-point margin state score

Score	Description
Narrow	Last translucent zone present deemed to be fully formed; a very thin, hairline layer of opaque material is present outside the last translucent zone
Medium	Last translucent zone present deemed to be fully formed; a thicker layer of opaque material, not very thin or hairline in width, is present outside the last translucent zone; some new translucent material may be present outside the thicker layer of opaque material, but generally does not span the entire margin of the otolith
Wide	Last translucent zone present deemed not to be fully formed; a thick layer of opaque material is laid down on top of the last fully formed opaque zone, with new translucent material present outside the opaque layer, spanning the entire margin of the otolith

2.3.2 Calculating scaled length- and age-frequency distributions using `Catchatage`

Description

`Catchatage` (Bull & Dunn 2002) is a package of `R` functions (R Development Core Team 2005) developed and maintained by NIWA. It computes biomass estimates and scaled length-frequency distributions by sex and by stratum for trawl survey and market-sampling data using the calculations in Bull & Gilbert (2001) and Francis (1989). If passed a set of length-at-age data, it can construct an age-length key, which can then be applied to scaled length-frequency distributions to compute scaled age-frequency distributions, also by sex and stratum. A "direct-age" subroutine also exists, where individual age observations are weighted up to stratum catch totals using specified length-at-age and weight-at-length relationships. The coefficients of variation (c.v.) for each length and age-class and the overall mean-weighted c.v. for each length and age-frequency distribution are computed using a bootstrapping routine (Efron & Tibshirani 1993): fish length (or age) records are resampled within each station (or sample), stations (or samples) are resampled within each stratum, and the length-at-age data used to construct an age-length key are simply resampled, all with replacement. The bootstrap length- and age-frequency distributions are computed from each resample and the c.v.s for each length- and age-class and mean-weighted c.v.s for each length and age distribution computed from the bootstrap distributions.

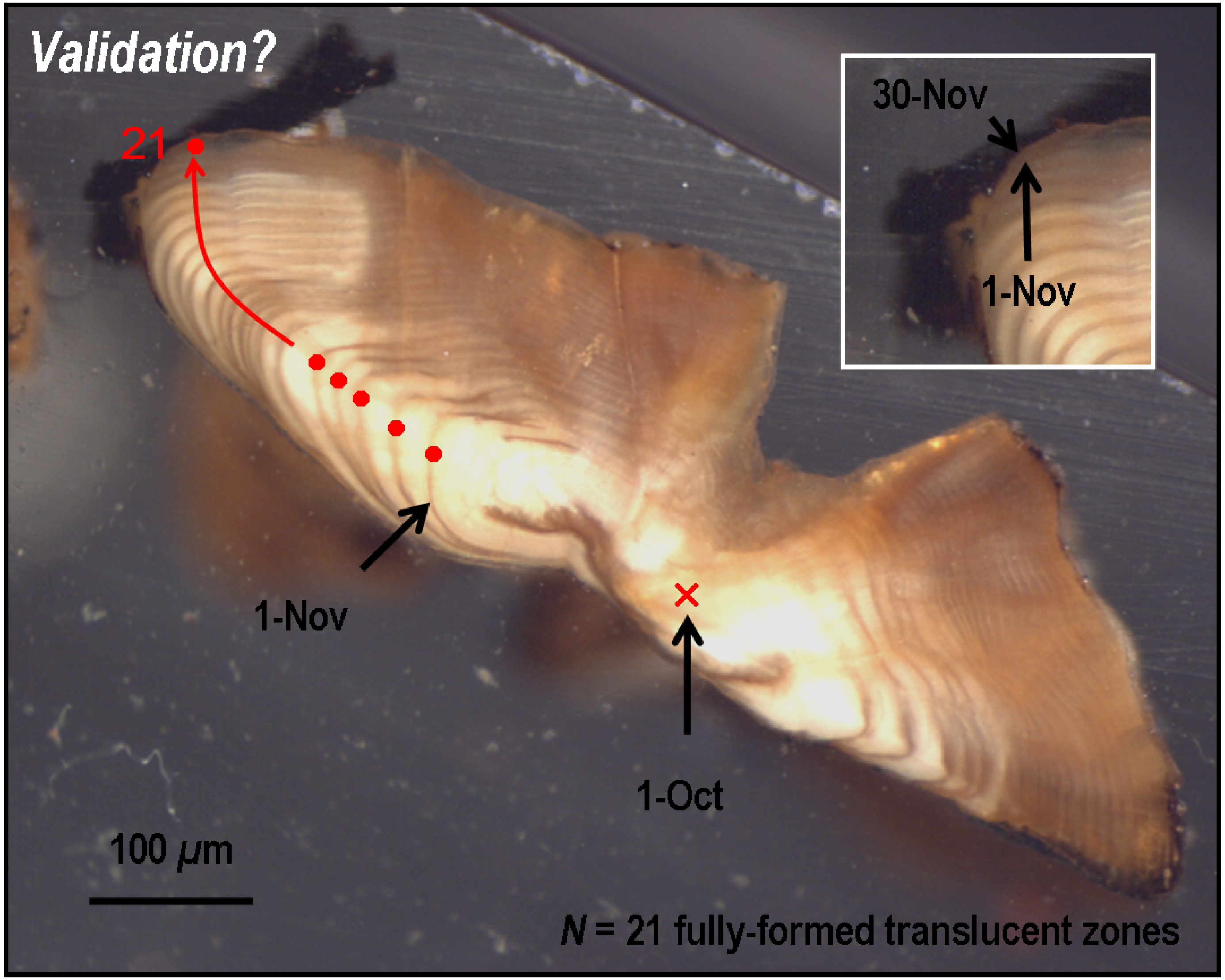


Figure 7: Typical prepared blue moki sagittal otolith from a 62 cm FL female landed on 30 November 2005 in Napier. The nucleus is marked with a cross. Fully formed translucent growth zones are marked with dots. Twenty-one fully formed translucent growth zones are present, leading to an estimated age for this fish of 20.16 years.

Analyses performed

`Catchatage` was used to calculate scaled length- and age-frequency distributions for the catch in both fisheries. Bootstrapped c.v.s and mean-weighted c.v.s were computed for each length and age class and length- and age-frequency distribution from 1000 iterations of the resampling algorithm. The weight-at-length relationship used to scale the length observations was parameterised using the results of a geometric mean regression of fish weight (in kilograms) on length (fork length in centimetres) for both sexes combined presented by Francis (1979). An unpublished length-at-age relationship for both sexes combined (M. Francis, pers. comm.) referred to in the May 2006 stock assessment Plenary Report (Ministry of Fisheries Science Group 2006) was used in the scaled age-frequency calculations. These relationships are given in Table 4.

Table 4: Blue moki biological parameters used in the scaled length and age frequency calculations.

Relationship	Parameter	All fish	Source
Weight-at-length	a	0.055×10^{-5}	Francis (1979).
	b	2.713	
Length-at-age	$L_{\infty,s}$	66.95	M. Francis (pers. comm.)
	k_s	0.208	
	$t_{0,s}$	-0.029	

Data matching

Catch-effort and landings data stored in the *warehou* database for the 2004–05 and 2005–06 fishing years were matched to each sampled landing to allow sampling representativeness to be investigated. Landings were matched to particular *warehou* trip keys using the concatenation of vessel name and landing date.

2.4 Mortality estimates

Total mortality estimates were derived from the fishery catch-at-age curves using the Chapman-Robson estimator. The Chapman-Robson estimator of total instantaneous mortality is

$$\hat{Z} = -\log_e \hat{s} \tag{5}$$

where $\hat{s}$, the estimated survival rate, is

$$\hat{s} = \frac{\sum_{i=1}^{N} y_i}{N + \sum_{i=1}^{N} y_i - 1} \tag{6}$$

where y_i is the true age of the ith fish in terms of years after recruitment, and N is the total size of the recruited population. The number of individuals that survive to exactly age y is unknown, so the approximations

$$N = \sum_{x=0}^{k} N_x \tag{7}$$

and

$$\sum_{i=1}^{N} y_i = \sum_{x=1}^{k} x N_x \qquad (8)$$

were used, where N_x is the number of individuals in the population or catch between age x and age $x+1$, and k is the number of age groups in the recruited population minus one (Jensen 1985). The Chapman-Robson estimator assumes that the population sampled has a stable age structure, i.e., that recruitment and mortality are constant, that fish greater than the age at full recruitment are equally vulnerable to sampling, and that there are no age-estimation errors (Ricker 1975). Given an instantaneous natural mortality estimate, $\hat{M}$, an instantaneous fishing mortality estimate, $\hat{F}$, can be derived from $\hat{Z}$ where $Z = M + F$ as $\hat{F} = \hat{Z} - \hat{M}$.

Manning & Sutton (2004) gave an expression for an analytical confidence interval for the Chapman-Robson estimator, but also calculated confidence intervals using a bootstrap approach. Their bootstrap approach involved calculating $\hat{Z}$ for different assumed ages at full recruitment for each of the resampled age distributions produced by `Catchatage` for the scaled age-frequency calculations, then taking appropriate percentiles of the bootstrapped distributions to yield the desired confidence interval. We have used this approach in this study.

2.5 Per-recruit analysis

Per-recruit analysis is a deterministic model of how fish growth and natural and fishing mortality interact to determine the optimum size (or age) at harvest and the optimum fishing mortality to apply to maximise yield or other quantities such as spawning biomass of a cohort of fish. The classical yield-per-recruit model developed by Beverton Holt (1957) gives the total yield available from a cohort of fish when: (i) the instantaneous rates of natural and fishing mortality and are assumed to be constant and independent of age; (ii) all fish recruited to the fishery are assumed to be fully and equally vulnerable to the fishing gear at some age ("knife-edge" selectivity); and (iii) that growth can be represented by the von Bertalanffy length-at-age curve (i.e., $L_t = L_\infty \left[1 - e^{-\kappa(t-t_0)}\right]$). The model can be written as

$$Y(t) = F N_r e^{-M(t_c - t_r)} W_\infty \sum_{n=0}^{3} \frac{U_n}{Z + n\kappa} e^{-n\kappa(t_c - t_0)} \left[1 - e^{-(Z+n\kappa)(t-t_c)}\right] \qquad (9)$$

where $Y(t)$ is the yield per recruit at age t , F is instantaneous fishing mortality, N_r is the number of recruits, M is instantaneous natural mortality, t_c is the age at which fish are (fully and equally) vulnerable to the fishery (fishing gear), t_r is the age at recruitment, W_∞ is the mean asymptotic weight at age parameter from the relationship $W(t) = W_\infty \left[1 - e^{-\kappa(t-t_0)}\right]^3$, $U_n = +1, -3, +3, -1$ for $n = 0,1,2,3$ from the result of a cubic expansion of $W(t)$, κ is the rate parameter from $W(t)$, Z is total instantaneous mortality and is defined as $Z = M + F$, and t_0 is the theoretical age at which a fish is of zero weight from $W(t)$. If Y is evaluated at the maximum age, t_∞ , then the result, $Y(t_\infty)$, is the total yield over the fishable life span of the cohort. Under this model, maximum yield-per-recruit occurs by applying infinite fishing mortality at critical age $t_* = t_0 + (1/\kappa) \times \ln(1 + 3/m)$, where $m = M/\kappa$.

A convenient, dimensionless reparameterisation of the classical yield-per-recruit model was given by Beverton & Holt (1964). This is

$$y = E\sum_{n=0}^{3} \frac{U_n (1-c)^{n+m}}{1+n(1-E)/m}, \tag{10}$$

where y is the lifetime yield from a cohort as a *proportion* of the maximum possible weight the cohort would reach if no mortality occurred after reference age t_0, E is the exploitation rate, defined as $E = F/Z = F/(M+F)$, C is L_c / L_∞, the length at which fish are fully and equally vulnerable to the fishing gear as a fraction of their mean asymptotic maximum length, and m is M/κ, natural mortality as a fraction of growth rate. It is also possible to transform the result from y back to the original yield-per-recruit scale using the expression $Y = ye^{M(t_r - t_0)}W_\infty$. Equivalent expressions can be derived for other quantities per recruit, such as spawning stock biomass.

Although simplistic, in that the spawner-recruit relationship and other important population dynamic processes usually considered in modern cohort-dynamic or statistical catch-at-age models are ignored, per-recruit analysis does allow fishing mortality estimates observed for a stock to be (quickly) compared with reference fishing mortality values. Two common reference points are $F_{\max}$, the fishing mortality that maximises yield-per-recruit for a given age at first capture, and $F_{0.1}$, the fishing mortality where the slope of the yield-per-recruit curve is 10% (0.1) that of the slope of the curve at the origin where zero fishing mortality is applied. The equivalent reference points defined in terms of exploitation rate rather than fishing mortality are $E_{\max}$ and $E_{0.1}$. Note that the latter is *not* that exploitation rate where the slope of the yield per recruit curve is 10% that of the slope of the curve at the origin, rather it is the result of transforming $F_{0.1}$ using the expression $E = F/Z$. Where $\partial y/\partial F$ is the derivative of the yield-per-recruit model given in equation (9), $F_{0.1}$ is found by finding a value of F that satisfies the expression

$$\left.\frac{\partial y}{\partial F}\right|_{F=F_{0.1}} = (0.1)\left.\frac{\partial y}{\partial F}\right|_{F=0} \tag{11}$$

and $E_{0.1}$ is found equivalently by solving the expression

$$\left.\frac{\partial y}{\partial E}\right|_{E=E_{0.1}} = \frac{0.1}{(1-E_{0.1})^2}\left.\frac{\partial y}{\partial E}\right|_{E=0} \tag{12}$$

where

$$\frac{\partial y}{\partial E} = \sum_{n=0}^{3} \frac{U_n (1-c)^{n+m}}{\left[1+n(1-E)/m\right]^2}\left(1+\frac{n}{m}\right) \tag{13}$$

$F_{\max}$ is found by solving the expression

$$0 = \frac{\partial y}{\partial F} \tag{14}$$

for F, and equivalently, $E_{\max}$ is found by solving the expression

$$0 = \frac{\partial y}{\partial E} = \sum_{n=0}^{3} \frac{U_n (1-c)^{n+m}}{\left[1+n(1-E)/m\right]^2}\left(1+\frac{n}{m}\right) \tag{15}$$

for E .

The per-recruit analysis literature is extensive: of important discussions of aspects of the theory were discussed by Beverton & Holt (1957, 1964) (model derivation), Deriso (1987), and Fletcher (1987) (reference points) among many others. Generalisation of the per-recruit model to include age-specific mortality (e.g., incorporation of age-specific rather than knife-edge selectivity) and other functional descriptions of length- and weight-at-age is trivial and was discussed in some depth by Quinn & Deriso (1999). The results of a per-recruit analysis can be misleading when the assumptions made have not been met. However, in this analysis, in the absence of a more robust quantitative stock assessment model for the ECNI blue moki fisheries, we have used classical per-recruit analysis to provide a measuring stick for the fishing mortality estimates that we calculated from the observed catches-at-age in these fisheries. We compare the observed values with the $E_{0.1}$ and $E_{\max}$ references points calculated assuming the quantities specified in Table 4 and derived in Section 3 below. We also discuss the limitations of this method for the ECNI blue moki fisheries (Section 4).

3. RESULTS

3.1 A brief description of the fisheries

Langley & Walker (2004) presented the last description of the MOK 1 fisheries spanning the 1989–90 to 2001–02 fishing years. We update their summary with an extra five years of data to the end of the 2006–07 fishing year. As noted above, the groomed and merged catch is plotted by fishery, month, and fishing year in Figure 3, by fishery, month, and port of landing in Figure 4, and by fishery, statistical area fished, and port of landing in Figure 6. Here the catch is plotted by month and fishing year, by statistical area and fishing year, by fishing method and fishing year, and by target species and fishing year in Figure 8. The annual groomed and merged catch is plotted by statistical area, target species, and fishing method in Figure 9. The distributions of selected catch and effort variables, including nominal log catch-per-unit-effort (CPUE), are plotted by fishing year for each of the BT-TAR and SN-MOK fisheries in Figure 10. Nominal log CPUE is defined as the natural logarithm of the catch divided by the total hours fished per effort stratum for the BT-TAR fishery and as the natural logarithm of the total catch divided by the total amount of net set per effort stratum for the SN-MOK fishery. Cross-tabulations of the data are given in Appendix A. Some important features of the fisheries are immediately apparent from these plots.

- Catches by the BT-TAR and SN-MOK fisheries continue to dominate the catch. Catches by the BT-TAR fishery in MOK 1(E) (i.e., vessels catching moki when targeting tarakihi using bottom trawls in statistical areas on the ECNI) now account for 33% of the total MOK 1 catch in the time series and ranging between 26 and 47% of the total catch in any given fishing year. Catches by the SN-MOK fishery in MOK 1(E) (i.e., vessels targeting blue moki using setnets in statistical areas on the ECNI) now account for 43% of the total catch, ranging between 17 and 61% of the total catch in any given fishing year. Both the total catch and nominal catch-per-unit-effort in the SN-MOK fishery appear to have increased over the last five fishing years (2001–02 to 2005–06). Total catch and nominal log catch-per-unit-effort in the BT-TAR fishery, however, appear to be static or slightly declining over this period.

- Catches by fisheries other than the BT-TAR and SN-MOK fishery are relatively unimportant. Of the other fisheries, the moki catch by setnet vessels targeting blue warehou on the ECNI is the only minor component of any note, accounting for 11% of the total catch in the dataset. However, this fishery appears to be becoming less and less important, accounting for 3–4% of the total catch in recent years (2001–02 to 2005–06). In the past, this fishery has accounted for as much as 25% of the total catch (1999–2000). There is some blue moki catch

Table 5: Achieved sampling effort (numbers of landings sampled and otolith pairs collected) in the BT-TAR and SN-MOK fisheries in MOK 1(E) during the 2004–05 and 2005–06 fishing years. 2005, 2004–05 fishing year; 2006, 2005–06 fishing year. Yearly subtotals are shaded.

Numbers of landings sampled

			Season				
Year	Fishery	Port	"Spring" (Oct-Nov-Dec)	"Summer" (Jan-Feb-Mar)	"Autumn" (Apr-May-Jun)	"Winter" (Jul-Aug-Sep)	Total
2005	BT-TAR	Gisborne	–	–	–	1	1
		Napier	1	2	–	5	8
		Wellington	1	–	1	–	2
	SN-MOK	Gisborne	1	–	–	10	11
		Napier	1	1	2	–	4
		Wellington	2	–	2	2	6
	All	All	6	3	5	18	32
2006	BT-TAR	Gisborne	–	–	–	1	1
		Napier	1	1	2	–	4
		Wellington	2	–	2	2	6
	SN-MOK	Gisborne	–	–	–	–	0
		Napier	–	–	–	2	2
		Wellington	–	–	4	8	12
	All	All	3	1	8	13	25
Total	All	All	9	4	13	31	57

Numbers of otolith pairs collected

			Season				
Year	Fishery	Port	"Spring" (Oct-Nov-Dec)	"Summer" (Jan-Feb-Mar)	"Autumn" (Apr-May-Jun)	"Winter" (Jul-Aug-Sep)	Total
2005	BT-TAR	Gisborne	–	–	–	50	50
		Napier	25	49	–	237	311
		Wellington	25	–	49	–	74
	SN-MOK	Gisborne	25	–	–	400	425
		Napier	–	–	–	50	50
		Wellington	–	47	–	366	413
	All	All	75	96	49	1103	1323
2006	BT-TAR	Gisborne	–	–	–	23	23
		Napier	50	25	100		175
		Wellington	55	–	100	75	230
	SN-MOK	Gisborne	–	–	–	–	0
		Napier	–	–	–	77	77
		Wellington	–	–	202	301	503
	All	All	105	25	402	476	1008
Total	All	All	180	121	451	1579	2331

Table 6: Summary of fishing and sampling activity during the 2004–05 fishing year. The numbers of landings and reported greenweight catch (t) by all vessels that reported a MOK 1 landing during the 2004–05 fishing year ("All"), by all vessels in the BT-TAR and SN-MOK fleets in MOK 1(E) ("Fleet"), and by all sampled vessels ("Samp.") by month. P_{SF}, the sampled catch as a percentage of the fleet catch by numbers or weight. Note that one landing of the 32 sampled during 2004–05 could not be matched to the catch-effort and landings dataset supplied by MFish.

		Landed catch (kg)				Number of landings			
Year	Month	All	Fleet	Samp.	P_{SF}	All	Fleet	Samp.	P_{SF}
2004	10	23 590	17 942	2 801	16	211	78	3	4
2004	11	23 731	10 430	–	–	265	72	–	–
2004	12	19 845	13 139	–	–	224	70	–	–
2005	1	21 110	10 999	812	7	262	74	1	1
2005	2	14 909	8 574	213	2	192	62	1	2
2005	3	16 613	9 683	117	1	171	74	1	1
2005	4	8 820	6 330	–	–	139	61	–	–
2005	5	28 279	18 397	2 239	12	209	79	1	1
2005	6	40 680	34 529	–	–	189	85	–	–
2005	7	51 025	45 174	5 388	12	209	115	2	2
2005	8	43 110	38 634	13 948	36	228	101	5	5
2005	9	165 423	159 708	47 357	30	264	141	17	12
	Total	457 135	373 540	72 874	20	2 563	1 012	31	3

Table 7: Summary of fishing and sampling activity during the 2005–06 fishing year. The numbers of landings and reported greenweight catch (t) by all vessels that reported a MOK 1 landing during the 2005–06 fishing year ("All"), by all vessels in the BT-TAR and SN-MOK fleets in MOK 1(E) ("Fleet"), and by all sampled vessels ("Sampled") by month. P_{SF}, the sampled catch as a percentage of the fleet catch by numbers or weight. All landings sampled during 2005–06 could be matched to the catch-effort and landings dataset supplied by MFish.

		Landed catch (kg)				Number of landings			
Year	Month	All	Fleet	Samp.	P_{SF}	All	Fleet	Samp.	P_{SF}
2004	10	24 668	17 877	616	3	225	79	1	1
2004	11	19 952	11 263	–	–	216	77	–	–
2004	12	22 349	14 698	2 132	15	227	69	2	3
2005	1	11 242	6 097	–	–	155	52	–	–
2005	2	10 534	4 351	–	–	144	64	–	–
2005	3	10 926	5 739	182	3	162	73	1	1
2005	4	9 594	6 351	–	–	169	55	–	–
2005	5	45 245	38 658	2 376	6	210	99	2	2
2005	6	56 895	52 994	11 418	22	191	99	6	6
2005	7	67 881	64 480	7 691	12	189	111	5	5
2005	8	33 103	29 281	456	2	196	102	1	1
2005	9	126 685	106 622	10 808	10	235	119	7	6
	Total	439 074	358 410	35 679	10	2 319	999	25	3

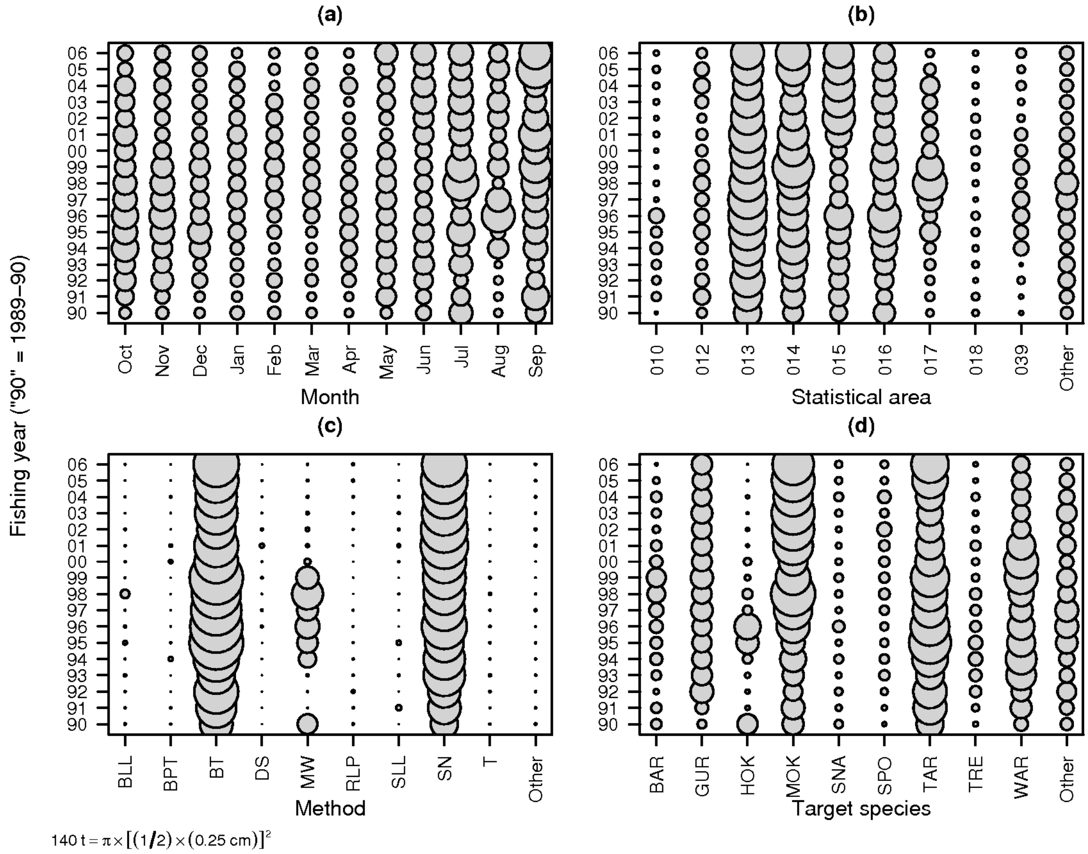


Figure 8: The groomed and merged MOK 1 catch by: (a) month and fishing year; (b) statistical area and fishing year; (c) method and fishing year; and (d) target species and fishing year. Circle areas are proportional to the amount of catch in each factor level and fishing year combination. The area of a circle 0.25 cm in diameter is 120 t.

by bottom trawl vessels targeting red gurnard in statistical areas 013 to 016, but this is of minor importance. Blue moki catches by midwater trawl vessels reportedly targeting either blue moki or hoki in statistical area 016 are almost certainly data entry or processing errors associated with the Cook Strait hoki fishery, where the catch and target species is presumably hoki, and the landed catch should have been recorded as "HOK 1" not "MOK 1".

- The catch continues to be highly seasonal. Two-thirds (66%) of the catch is caught in the six months from May to October over all factors in the dataset (all methods, areas, target species, etc.). Seasonality in the SN-MOK fishery remains particularly marked, with 91% of the total catch in this fishery caught during this time. There continues to be somewhat less seasonality in the BT-TAR fishery, with 62% of the total catch in this fishery caught during May–October across all years in the data.

- Contributions to the total MOK 1 catch from areas outside the ECNI were negligible. The catch outside MOK 1(E) by all fisheries (i.e., all areas, methods, target species) accounts for only 6% of the total MOK 1 catch in the data. Within the ECNI, most of the catch continues to be caught in statistical areas 013 to 016, with lesser contributions from 010, 012, and 018. Relatively more of the blue moki catch in the BT-TAR fishery comes out of 016 than in the SN-MOK fishery. Outside the ECNI, statistical area 039 is the only statistical area of any importance.

- There is some evidence of a recent change in the composition of the fleet in the SN-MOK fishery. Median vessel experience per effort stratum per fishing year in the BT-TAR fishery (where vessel experience per effort stratum is defined as the number of years each vessel is recorded in the dataset, beginning at zero, and incremented by one for each fishing year in the dataset where associated effort strata exist) is increasing throughout the dataset, indicating an ageing fleet, although new vessels continue to enter and become active in the fishery. However, median vessel experience per effort stratum per fishing year for records associated with the SN-MOK fishery increases steadily throughout the early to middle part of the time series, but drops suddenly after 1999–2000, indicating a pulse of new vessels entering the fishery (or at least this dataset).

- There is a corresponding change in the median length of the associated fishing vessel per effort stratum in the SN-MOK fishery at this time, with median vessel length per effort stratum per fishing year in this fishery increasing from about 7 m to about 13 m after 1999–2000.This probably does not indicate a large change in the relationship between catch and effort in this fishery as the catching power of a setnet vessel is not thought to be as closely related to the size of the vessel or of its engine as in a trawl vessel. Median vessel length per effort stratum per fishing year in the BT-TAR fishery has remained constant at about 18 m over the time series. Median vessel engine power per effort stratum per fishing year in the BT-TAR fishery may have increased slightly in the early 1990s, but has remained constant thereafter.

3.2 Market sampling results

A total of 57 landings was sampled and 2331 sagittal otolith pairs were collected from the blue moki catch in the BT-TAR and SN-MOK fisheries in MOK 1(E) over the 2004–05 and 2005–06 fishing years (Table 5), well short of the target sampling effort of 100 landings to be sampled over these fisheries and fishing years. The true reasons for the difference between the allocated and achieved sampling effort are unknown, but some contributing factors were identified in discussions with ATIFMC (to whom sampling had been contracted). These included: (i) resignations of designated sampling staff following training; (ii) restructuring of the Moana Pacific Fisheries processing factory in Gisborne during 2005–06; and (iii) the simple failure of some participating LFRs to deliver on their undertaken responsibilities. An attempt was made to mitigate this by transferring some sampling effort from Napier and Gisborne to Wellington in early 2007, where several important LFRs receiving catch from the BT-TAR and SN-MOK fisheries in these areas are based and where trained and experienced (NIWA) staff were available to carry out the sampling.

The sampled catch during 2004–05 accounted for 20% of the combined catch for both the BT-TAR and SN-MOK fisheries in MOK 1(E) during this year (Table 6). During 2005–06, the sampled catch accounted for 10% of the combined BT-TAR and SN-MOK fleet catch in MOK 1(E) (Table 7). An attempt to evaluate the representativeness (or otherwise) of the sample data was made as follows. The sampled landings were first matched to the groomed but unmerged catch-effort and landings dataset. All sampled landings could be matched. A summary of fishing and sampling effort (weight of landed catch, numbers of landings) is provided from the matched data for the 2004–05 fishing year in Figure 11. The catch by the sampled and entire BT-TAR fleet in MOK 1(E) by statistical area and target species during 2004–05 is compared in Figure 12. The catch by the sampled and whole SN-MOK fleet in 2004–05 by these factors is compared in Figure 13. Fishing and sampling effort during 2005–06 are summarised in Figure 14. The sampled and whole BT-TAR fleet catch during 2005–06 by statistical area and target species are compared in Figure 15 and the SN-MOK catch during 2005–06 is shown in Figure 16. Vessels were defined as being active in either fishery in MOK 1(E) during a given fishing trip if they had one or more associated fishing event records matching the fishing gear, target species, and statistical areas defined for each fishery.

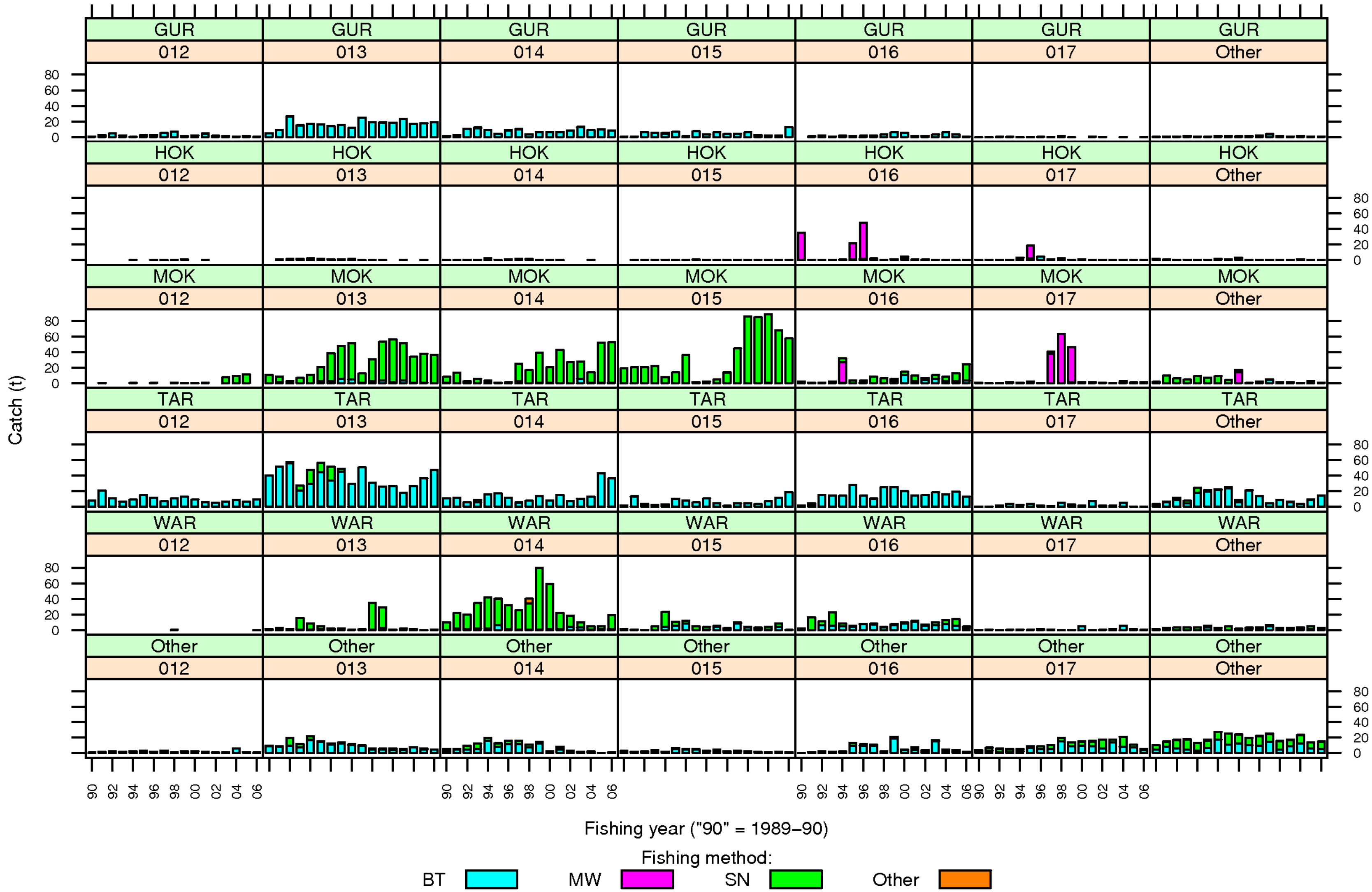


Figure 9: The groomed and merged MOK 1 catch by fishing year (1989–90 to 2005–06), target species (GUR, red gurnard; HOK, hoki; MOK, blue moki; TAR, tarakihi; WAR, blue warehou; Other, all other target species), statistical area, and fishing method (BT, bottom trawl; MW, midwater trawl; SN, setnet; Other, all other fishing methods)

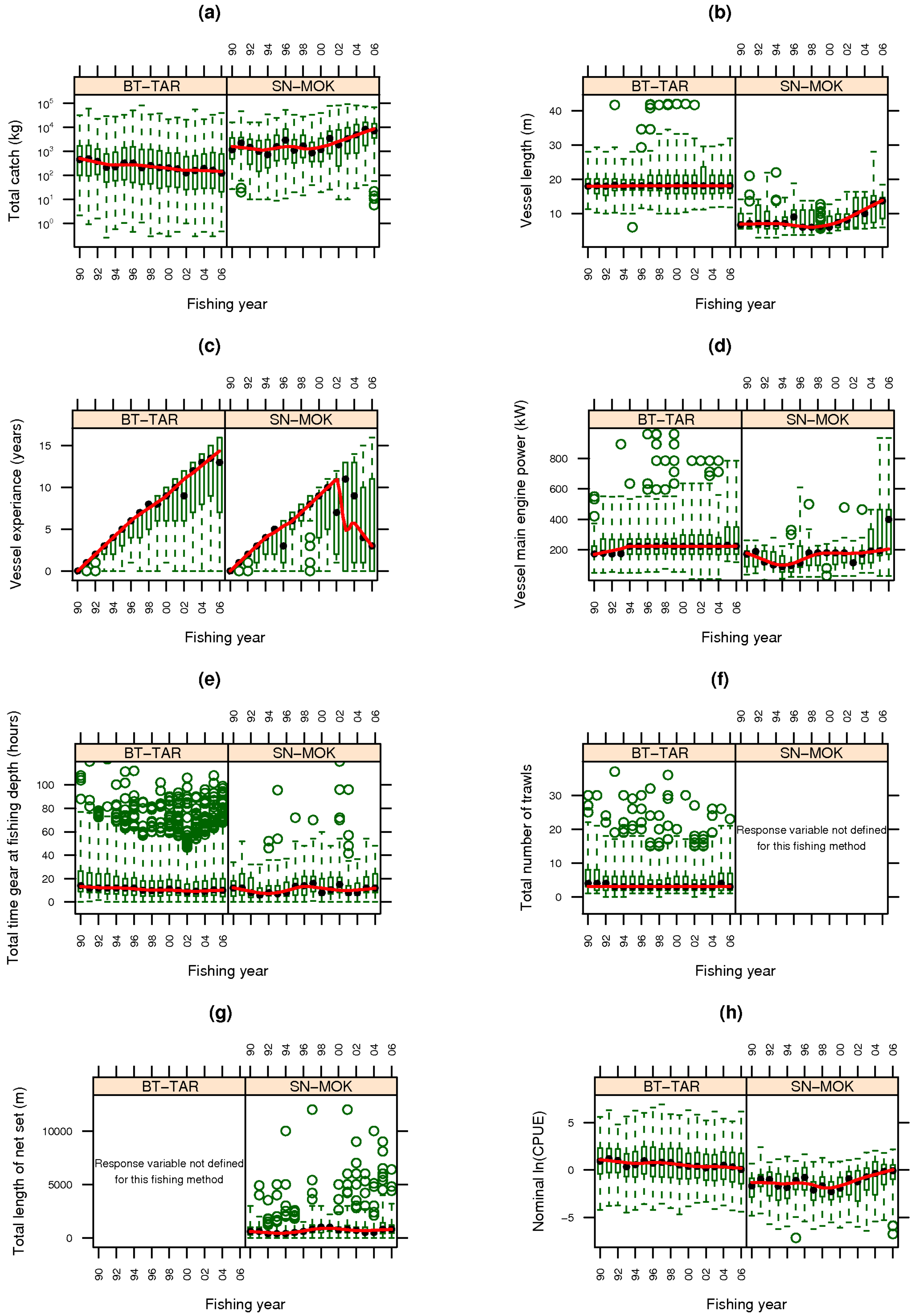


Figure 10: Box and whisker plots of selected variables in the groomed and merged dataset per effort stratum by fishing year fishery for the BT-TAR and SN-MOK fisheries: (a) total catch; (b) vessel length; (c) vessel experience; (d) vessel main engine power; (e) total fishing duration; (f) total number of trawls; (g) total amount of net set; and (h) nominal log catch-per-unit effort (catch per hour fished for BT-TAR and catch per metre net set for SN-MOK). Box hinges are drawn at the first and third quantiles. The whiskers extend three times the interquartile range above and below the first and third quantiles. Nominal outliers are plotted singly.

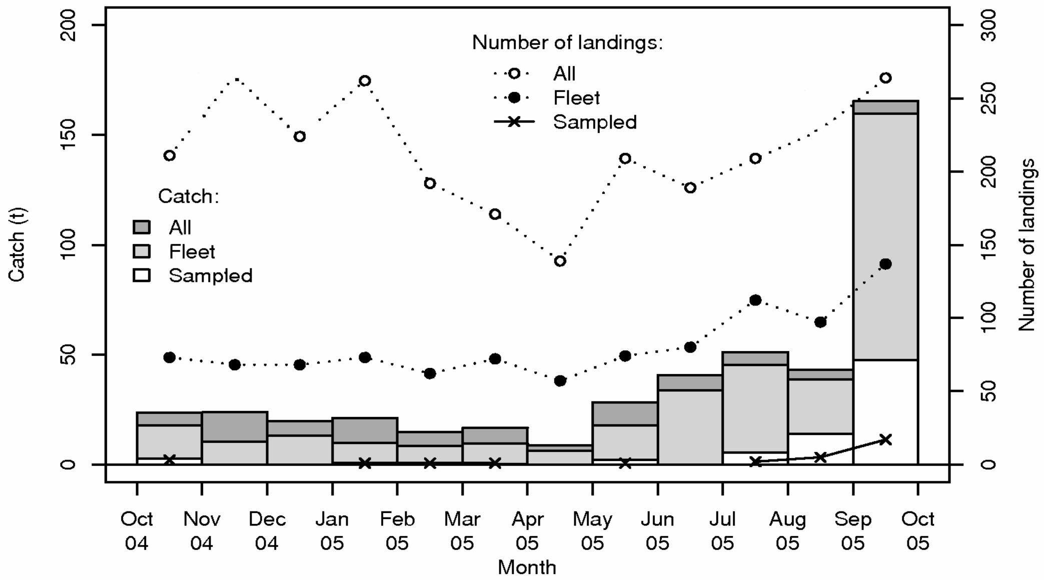
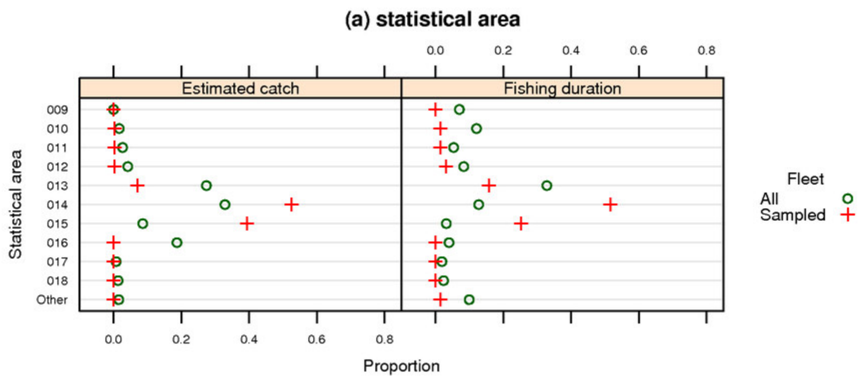


Figure 11: Summaries of fishing and sampling activity in MOK 1(E) during the 2004–05 fishing year. Histograms of the total landed catch (dark-grey bars) by all vessels, by all vessels in the BT-TAR and SN-MOK fisheries (light-grey bars), and by all sampled vessels (white bars) are overlaid. Numbers of landings by each fleet sector are also overlaid.



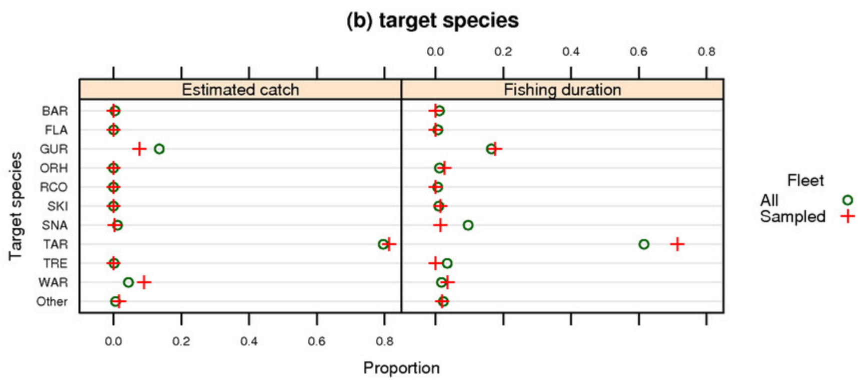


Figure 12: Comparing the sampled and BT-TAR fleet catch and effort during the 2004–05 fishing year by two covariates. Proportions of the estimated blue moki catch and of the number of trawl shots by (a) statistical area and (b) target species for all vessels in the BT-TAR fishery in MOK 1(E) are compared with those for the sampled fleet.

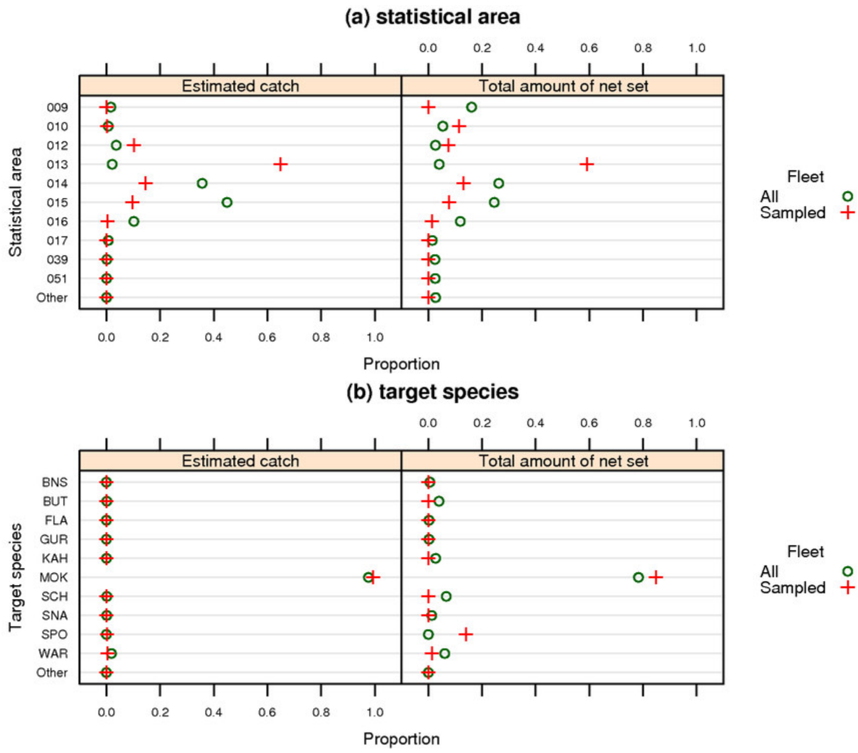


Figure 13: Comparing the sampled and SN-MOK fleet catch and effort during the 2004–05 fishing year by two covariates. Proportions of the estimated blue moki catch and of the total amount of net set by (a) statistical area and (b) target species for all vessels in the SN-MOK fishery in MOK 1(E) are compared with those for the sampled fleet.

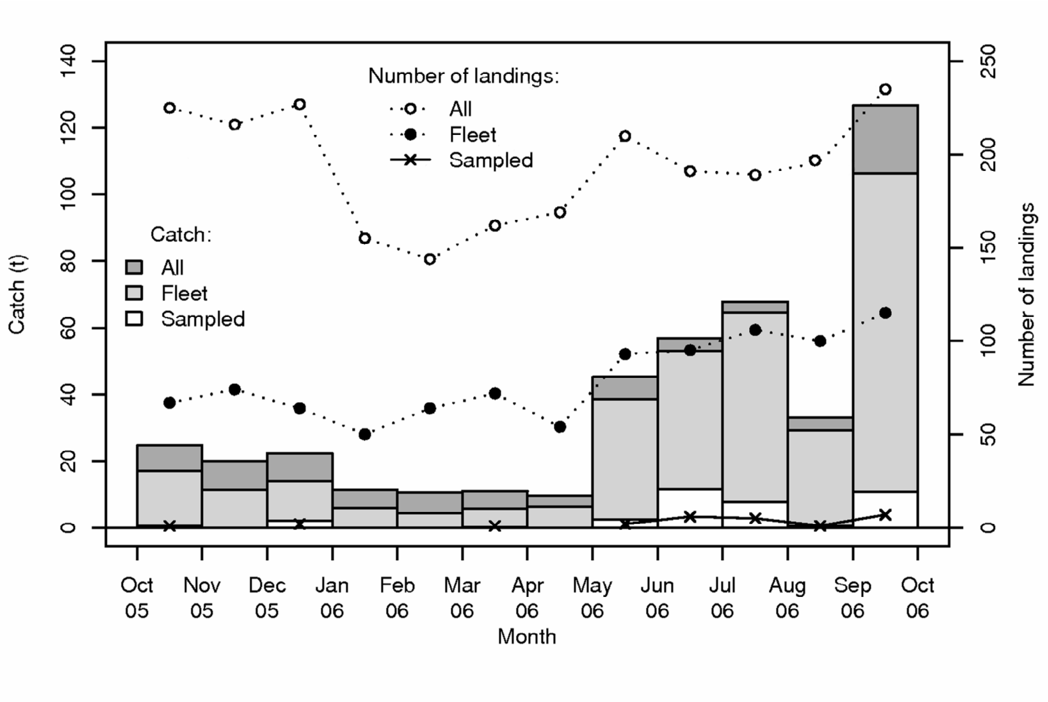


Figure 14: Summaries of fishing and sampling activity in MOK 1(E) during the 2005–06 fishing year. Histograms of the total landed catch (dark-grey bars) by all vessels, by all vessels in the BT-TAR and SN-MOK fisheries (light-grey bars), and by all sampled vessels (white bars) are overlaid. Numbers of landings by each fleet sector are also overlaid.

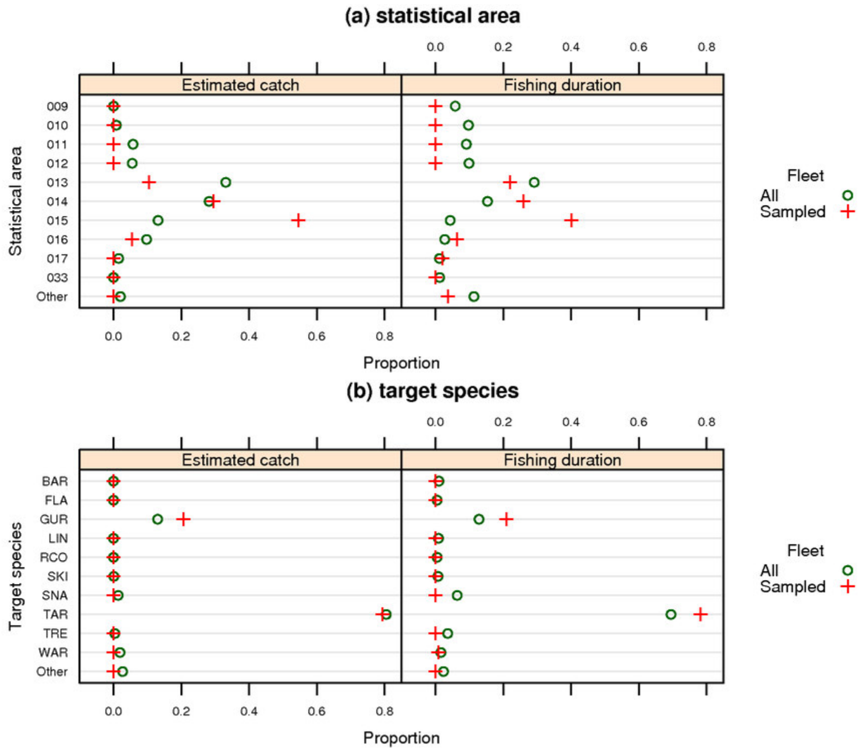


Figure 15: Comparing the sampled and BT-TAR fleet catch and effort during the 2005–06 fishing year by two covariates. Proportions of the estimated blue moki catch and of the number of trawl shots by (a) statistical area and (b) target species for all vessels in the BT-TAR fishery in MOK 1(E) are compared with those for the sampled fleet.

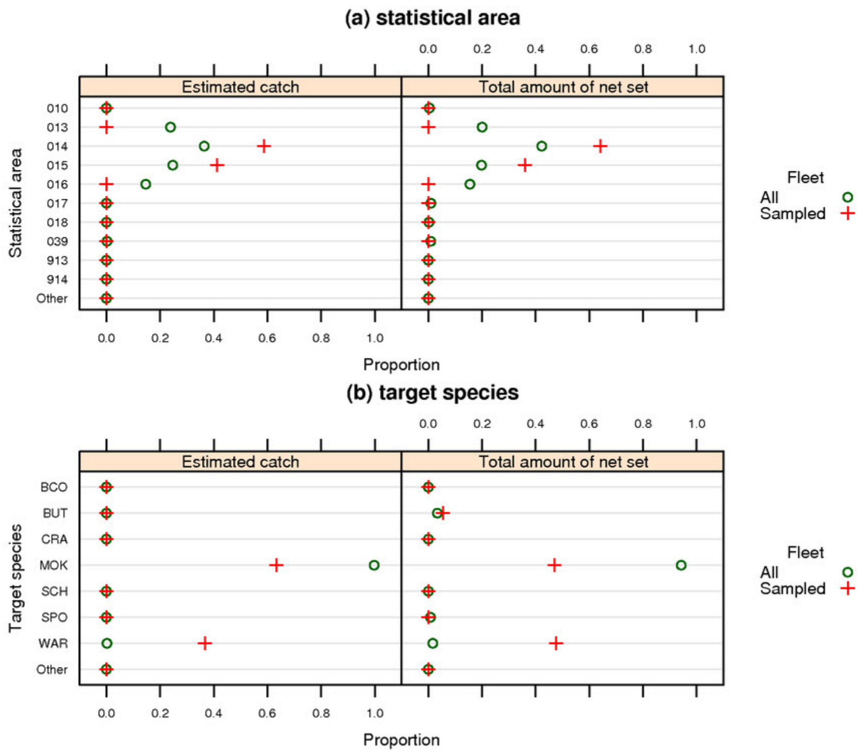


Figure 16: Comparing the sampled and SN-MOK fleet catch and effort during the 200506 fishing year by two covariates. Proportions of the estimated blue moki catch and of the total amount of net set by (a) statistical area and (b) target species for all vessels in the SN-MOK fishery in MOK 1(E) are compared with those for the sampled fleet.

Some differences between the sampled and entire catch for these fleets by the levels of these factors during both fishing years are noted. Generally, however, these differences are small to moderate, suggesting that the sampled catch is generally representative of the entire fleet catch, but some particular discrepancies are noted. Statistical areas 013 and 016 are under-represented and areas 014 and 015 are over-represented in both 2004–05 and 2005–06 for the BT-TAR fleet, although the catch and trawl effort by target species for the sampled fleet are comparable to those for the fleet as a whole, suggesting that the sampled fleet was fishing in a similar manner to the fleet as a whole, even though there may be some minor to moderate spatial differences in their catch and effort. Statistical area 013 is over-represented in the SN-MOK catch during 2004–05, but the catch and net effort by target species for the sampled and entire fleet during this year are comparable, again suggesting no gross discrepancies in fishing patterns. However, the SN-MOK fleet sample during 2005–06 has far more blue moki catch and effort associated with targeting blue warehou (WAR) than the fleet as a whole. If target species truly indexes different fishing patterns, then the sampled SN-MOK catch during 2005–06 may not be representative of the fishery.

3.3 Otolith readings and analysis

Despite the different method used, as was the case in Francis's (1981a) earlier study, alternating light (opaque) and dark (translucent) regions were visible in all prepared otolith sections. Translucent zone counts could be produced for virtually all of the prepared otoliths. Only 5 out of 1927 prepared otoliths were deemed to be unreadable. The age estimates produced ranged from 2.6 to 43.8 years. Results of the between-reader comparison test for the prepared otoliths collected during both the 2004–05 and 2005–06 fishing years are plotted in Figure 17. The relative symmetry of the histograms in panel (a), the position of the error bars about the one-to-one line in panel (b), and the relatively even distribution of plotted points about the zero line in panel (c) all suggest that no systematic bias exists between readers. A between-reader mean c.v. of 9.42% was obtained, equivalent to a between reader IAPE of 6.66%.

The smallest fish in the dataset compiled from the otolith readings was a 40 cm FL immature female, 2.9 years of age, that was caught in September 2006 by a setnet vessel targeting blue moki and butterfish (*Odax pullus*; MFish species code BUT) in statistical area 015 off the southeastern tip of the North Island. The largest fish present was an 83 cm FL female, 32.0 years old with spent ovaries, that was caught in October 2005 by a trawl vessel targeting tarakihi and red gurnard in statistical areas 013 and 014. The youngest fish present was a 2.7 year old immature male, 55 cm in fork length, that was caught in June 2006 by a trawl vessel targeting tarakihi in statistical areas 014 and 015. The oldest fish was a 43.8 year old female, 68 cm in fork length, that was caught in July 2006 by a trawl vessel that was also targeting tarakihi and red gurnard in statistical areas 014 and 015.

Length- and weight-at-age models fitted to the length- and weight-at-age data are plotted in Figure 18 (length) and Figure 19 (weight). Parameter estimates are tabulated in Table 8 (length) and Table 9 (weight). Length- and weight-at-age models were first fit assuming a single set of length- and weight-at-age function parameters for all fish in the dataset and normal errors parameterised with a constant variance, log-normal errors, and normal errors parameterised with a constant coefficient of variation. Comparing the model AIC and BIC statistics suggested the log-normal models had the greatest support from the data and these were refitted assuming separate length- and weight-at-age function parameters for males and females.

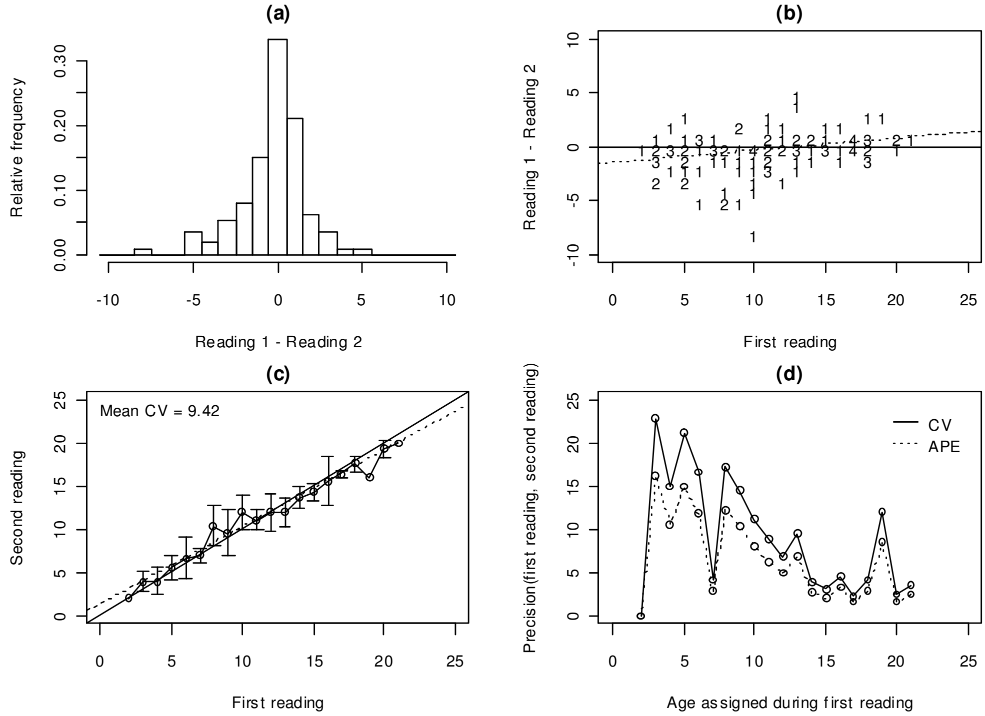


Figure 17: Results of the between-reader comparison test: (a) histogram of differences between the ages estimated during each reading of the same otolith; (b) differences between ages estimated during the second reading relative to the result of the first reading; (c) bias plot; and (d) c.v. and Index of Average Percentage Error (APE) profiles (precision) for a given age produced during the first reading. The expected one-to-one (solid line) and actual relationship (dashed line) between the ages estimated during the first and second readings of the same otolith are overlaid on (b) and (c). The numbers on (b) are the numbers of readings at each point. The error bars on (c) are 95% confidence intervals about the mean age produced during the second set of readings for a given age produced during the first set.

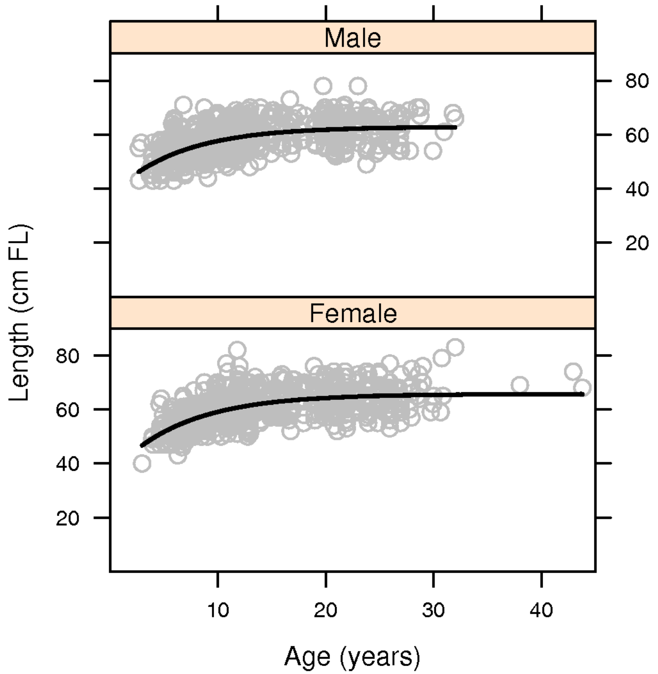


Figure 18: **Blue moki length-at-age by sex with fitted Schnute growth curves from the two-sex lognormal model overlaid. Von Bertalanffy parameters $L_{\infty,x}$ and $t_{0,x}$ were obtained for sex x for all fitted Schnute models using the expressions in Schnute (1981). See Table 11 for these values.**

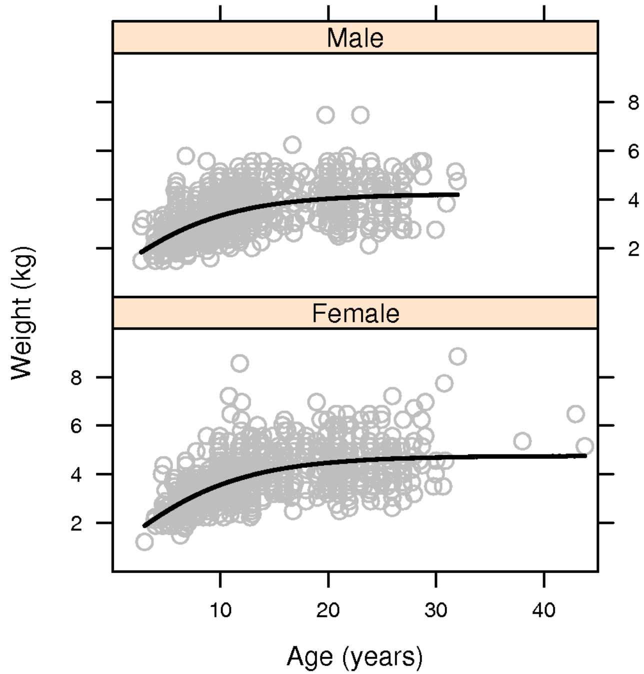


Figure 19: **Blue moki weight-at-age by sex with fitted Schnute growth curves from the two-sex lognormal model overlaid.**

Table 8: **Results of the three Schnute length-at-age models fitted assuming the same model parameters for all fish and either normal (constant σ^2), log-normal, or normal (constant c) errors. p, number of parameters and the two-sex log-normal model; AIC, Akaike Information Criterion; BIC Bayesian Information Criterion.**

Model	Error structure	p	AIC	BIC	Parameter	Estimate	Confidence interval
1	Normal (constant σ^2)	4	10965.5	10987.66	$L_{1,\text{All}}$	49.29	(48.49, 50.09)
					$L_{2,\text{All}}$	63.99	(63.53, 64.45)
					κ_{All}	0.15	(0.13, 0.17)
					σ^2	19.53	(18.29, 20.78)
2	Log-normal	4	10904.07	10926.24	$L_{1,\text{All}}$	49.21	(48.52, 49.91)
					$L_{2,\text{All}}$	63.79	(63.31, 64.28)
					κ_{All}	0.15	(0.13, 0.17)
					σ^2	0.01	(0.01, 0.01)
3	Normal (constant c)	4	10934.28	10956.45	$L_{1,\text{All}}$	49.49	(48.81, 50.17)
					$L_{2,\text{All}}$	64.14	(63.65, 64.63)
					κ_{All}	0.14	(0.12, 0.16)
					c	0.07	(0.07, 0.08)
4	Log-normal	7	10842.90	10881.07	$L_{1,\text{M}}$	49.23	(48.40, 50.06)
					$L_{2,\text{M}}$	62.29	(61.60, 62.97)
					κ_{M}	0.16	(0.13, 0.19)
					$L_{1,\text{F}}$	49.25	(48.01, 50.49)
					$L_{2,\text{F}}$	64.87	(64.22, 65.52)
					κ_{F}	0.15	(0.12, 0.18)
					σ^2	0.01	(0.01, 0.01)

Table 9: **Results of the three Schnute weight-at-age models fitted assuming the same model parameters for all fish and either normal (constant σ^2), log-normal, or normal (constant c) errors. p, number of parameters and the two-sex log-normal model;**

Model	Error structure	p	AIC	BIC	Parameter	Estimate	Confidence interval
1	Normal (constant σ^2)	4	4286.00	4308.17	$W_{\infty,\text{All}}$	4.55	(4.43, 4.68)
					k_{All}	0.15	(0.13, 0.17)
					$t_{0,\text{All}}$	-6.01	(-7.67, -4.35)
					σ^2	0.57	(0.53, 0.60)
2	Log-normal	4	3968.25	3990.42	$W_{\infty,\text{All}}$	4.45	(4.32, 4.59)
					k_{All}	0.15	(0.13, 0.17)
					$t_{0,\text{All}}$	-6.19	(-7.56, -4.82)
					σ^2	0.04	(0.04, 0.04)
3	Normal (constant c)	4	4137.23	4159.40	$W_{\infty,\text{All}}$	4.69	(4.53, 4.86)
					k_{All}	0.13	(0.11, 0.15)
					$t_{0,\text{All}}$	-7.6	(-9.13, -6.08)
					c	0.21	(0.20, 0.21)
4	Log-normal	7	3907.10	3945.90	$W_{\infty,\text{M}}$	4.15	(3.98, 4.31)
					k_{M}	0.16	(0.13, 0.19)
					$t_{0,\text{M}}$	-6.22	(-8.08, -4.36)
					$W_{\infty,\text{F}}$	4.66	(4.47, 4.85)
					k_{F}	0.15	(0.12, 0.18)
					$t_{0,\text{F}}$	-5.75	(-7.77, -3.73)
					σ^2	0.04	(0.04, 0.04)

3.4 The length- and age-composition of the BT-TAR and SN-MOK fisheries

Scaled length- and age-frequency distributions were computed from the data collected during 2004–05 and 2005–06. Unfortunately, the shortfall in landings sampled over both fishing years meant that the scope of the analysis originally planned needed to be revised. Originally, we had intended to scale the data from each fishery to the catch in separate north and south and in- and out-season strata during each fishing year (where 2 spatial divisions × 2 temporal divisions = 4 strata in total per fishing year); but the under-sampling meant that most strata would have been poorly populated.

Because of this, the data were scaled to separate temporal in- and out-season strata for each fishery and fishing year (where "in-season" was defined to be October and the months from June to September within a given fishing year and "out-season" the remaining months). There was thus no spatial component to the revised analysis. The analyses for both fishing years were carried out separately. The distribution of sampled landings by the fishing year, fishery, and season factors are shown in Table 10. Given that there were fewer than three sampled landings in the SN-MOK out-season strata, these strata (and data) were dropped from the analysis. There were thus three strata in the final analysis: (i) BT-TAR in-season; (ii) BT-TAR out-season; and (iii) SN-MOK in-season by fishing year. The total catch for each stratum was calculated from the groomed and merged catch-effort and landings dataset and rescaled to be proportional to the total recorded annual MOK 1 catches given in Table 1.

Table 10: Numbers of landings by stratum assigned during each fishing year. Separate analyses were carried out during each fishing year. Strata were defined as the interaction between the fisheries and whether the landings were in Season (October and June to September, inclusive) or out of season (November to May, inclusive) within each fishing year. The total catches for all strata calculated from the groomed and merged dataset are also provided. The SN-MOK out-season strata with fewer than three sampled landings (indicated by "*") were dropped from the analysis. N, number of landings

Fishing year	Fishery	Season	*N*	Total catch (t)
2004–05	BT-TAR	In	8	88
		Out	3	38
	SN-MOK	In	20	167
		Out	1*	15
2005–06	BT-TAR	In	7	99
		Out	4	39
	SN-MOK	In	13	134
		Out	1*	33

The scaled-frequency distributions of the fishery catch are plotted separately by sex and by the strata assumed in the analysis in Figure 20. Corresponding age-frequency distributions are plotted in Figure 21. Coefficients of variation for each length- and age-class are overlaid on each panel in Figures 17 and 21. Mean-weighted c.v.s for each length- and age-frequency distribution for each fishing year are given in Table 11, with values between 25 and 63% for the length frequencies and 23 and 60% for the age frequencies. Cumulative-frequency polygons for the age distributions for the 2004–05 and 2005–06 fishing year are plotted in Figure 22. Sex ratios from the catch-at-age are shown by year and stratum in Table 12.

Table 11: Mean-weighted coefficients of variation (%) for the length- and age-frequency distributions in the BT-TAR and SN-MOK fisheries sampled during the 2004–05 and 2005–06 fishing years by stratum and sex. Those computed for all strata pooled each year are shaded.

			Sex			
Distribution	Fishing year	Stratum	Males	Females	Unsexed	All fish
Length	2004–05	BT-TAR (in season)	57.3	54.2	–	41.9
		BT-TAR (out season)	91.7	75.8	–	63.3
		SN-MOK (in season)	39.7	51.5	–	32.0
		Pooled	32.7	37.3	–	24.9
	2005–06	BT-TAR (in season)	59.7	65.8	–	48.0
		BT-TAR (out season)	74.1	75.5	–	56.0
		SN-MOK (in season)	49.2	44.6	–	34.6
		Pooled	37.3	36.5	–	27.6
Age	2004–05	BT-TAR (in season)	51.4	54.2	–	39.3
		BT-TAR (out season)	92.4	64.1	–	55.7
		SN-MOK (in season)	37.4	47.8	–	30.0
		Pooled	30.3	34.3	–	23.1
	2005–06	BT-TAR (in season)	58.7	59.2	–	44.9
		BT-TAR (out season)	67.7	81.9	–	59.6
		SN-MOK (in season)	44.0	42.8	–	32.0
		Pooled	35.8	35.2	–	26.1

Table 12: Sex ratios in the catch-at-age by fishing year and stratum assumed in the analysis. Sex ratios are given relative to the number of males in each sex and stratum group in each analysis.

Fishing		Stratum		
year	Sex	SN-MOK (in-season)	BT-TAR (in-season)	BT-TAR (out-season)
2004–05	Male	1.0000	1.0000	1.0000
	Female	2.0095	0.9389	0.5731
	All fish	0.6677	0.4842	0.3643
2005–06	Male	1.0000	1.0000	1.0000
	Female	0.9106	1.3528	1.2430
	All fish	0.4766	0.5750	0.5542

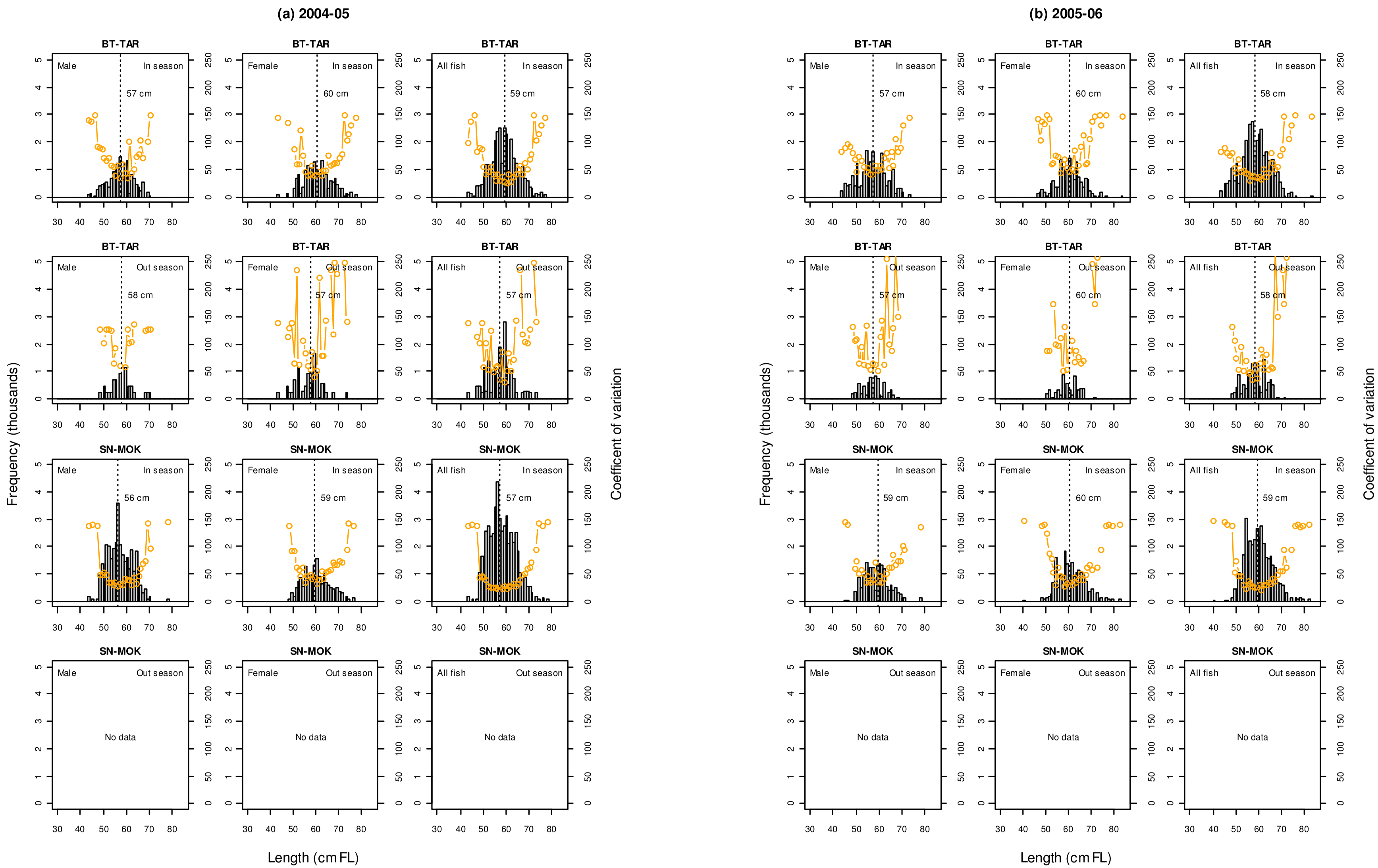


Figure 20: The length composition of the BT-TAR and SN-MOK catches during (a) the 2004–05 and (b) 2005–06 fishing years. The length-frequency distributions are plotted by sex and the strata assumed during the analysis. Bootstrapped coefficients of variation for each length class are overlaid (orange lines). Median lengths are noted on each panel (dotted lines).

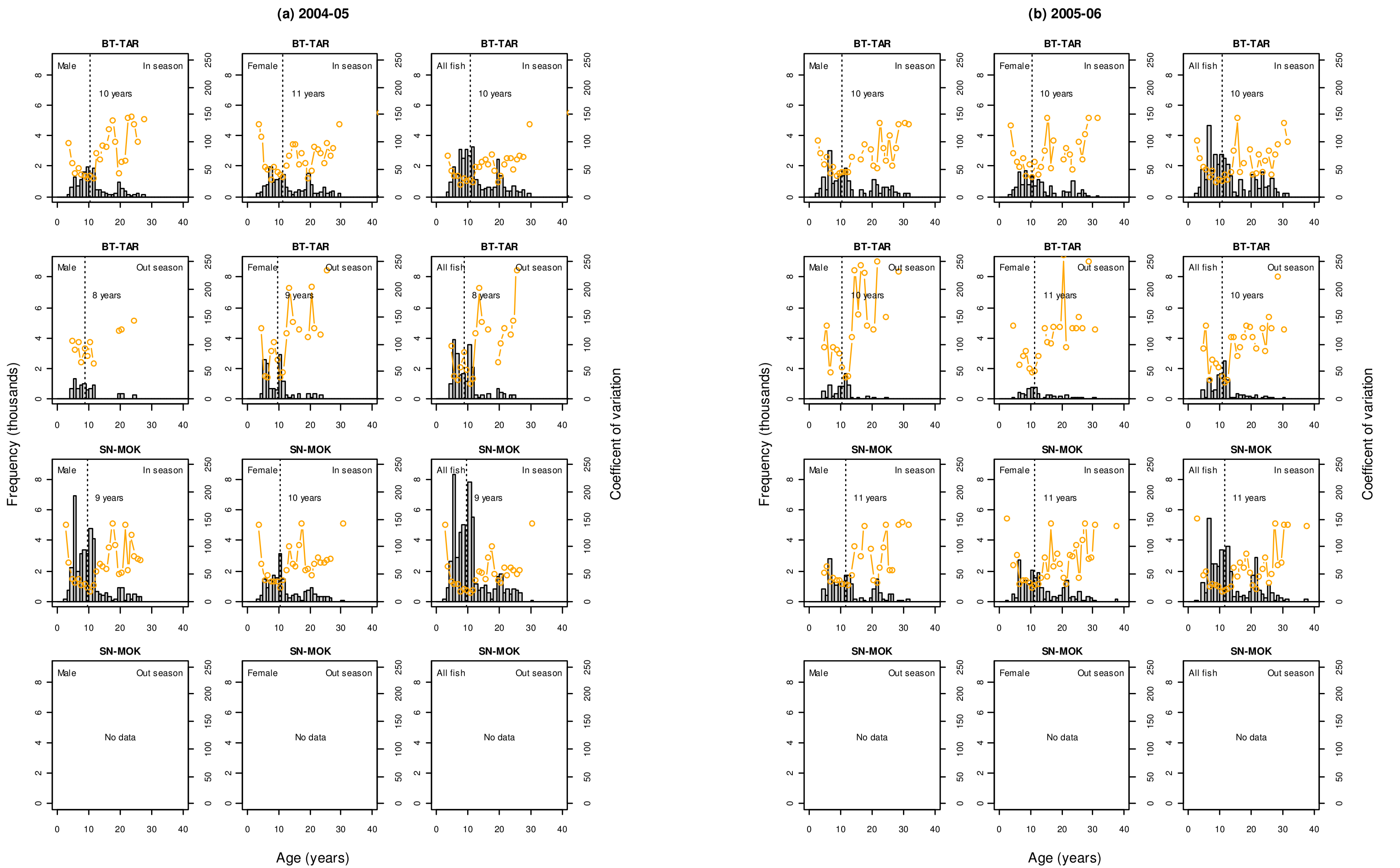


Figure 21: The age composition of the BT-TAR and SN-MOK catches during (a) the 2004–05 and (b) 2005–06 fishing years. The age-frequency distributions are plotted by sex and the strata assumed during the analysis. Bootstrapped coefficients of variation for each age class are overlaid (orange lines). Median ages are noted on each panel (dotted lines).

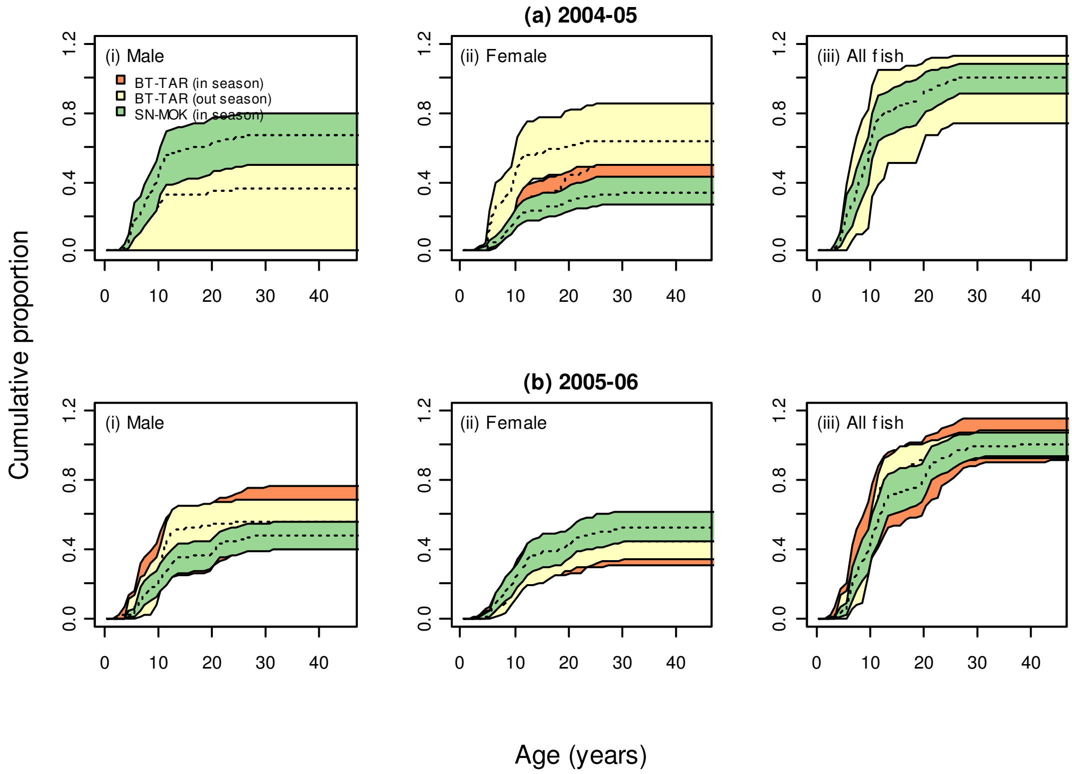


Figure 22: Cumulative proportions at age for (a) the 2004–05 and (b) the 2005–06 fishing years by stratum assumed in the scaled age-frequency calculations. The dotted lines are the cumulative proportions-at-age. The surrounding regions are bootstrapped 95% confidence intervals about the cumulative proportions at age. The proportions at age for all fish in each stratum have been scaled to sum to one.

Most fish in the sampled catch were between 50 and 70 cm in fork length (FL), although, as noted, fish as small as 40 cm FL and as large as 83 cm were observed. The scaled length-frequency distributions for the setnet and trawl catches sampled are generally unimodal in both fishing years. There is more apparent "structure" in those strata with fewer associated sampled landings (e.g., the out-season BT-TAR catch sampled in both 2004–05 and 2005–06), but this is a function of the fewer available data associated with these strata. There are no large differences apparent in either the maximum, minimum, or median length between the strata.

There is more structure apparent in the corresponding catches-at-age. Most fish are between 4 and 12 years old, but there is a long tail, with fish as old as 43 years present in the sampled catches. The age distribution tails do not follow a strict exponential decline, with a pulse of fish around 19–20 years of age present in the 2004–05 catch for all sexes and strata assumed in the analysis. The pulse appears at around 20–21 years in 2005–06 and corresponds to the 1984 and 1985 year classes and may correspond to a previous period of successful recruitment that produced year classes that have persisted and are moving through the catch. A strong 5 year old age class apparent in the 2004–05 catch, in particular in the in-season setnet catch, appears as a strong 6 year old age class in 2005–06, corresponding to the 1999 year class. There may be some differences in the age composition of the setnet and trawl catches, but this is not clear. There seems to have been proportionally more younger female fish in the in- and out season trawl catches than in the set-net catch in 2004–05, and for male fish in 2005–06, but the 95% confidence regions typically overlap the cumulative proportion for the in-season setnet catch, suggesting that these differences are not statistically significant. There are no obvious, consistent trends in sex ratios between strata or fishing years.

3.5 Mortality estimates

The results of applying the Chapman-Robson total mortality estimator to the 2004–05 and 2005–06 catches-at-age assuming ages at full recruitment (AFR) of 4 to 12 years are plotted by AFR, fish sex, and the strata assumed in the catch-at-age calculations (in- and out-season trawl strata pooled) in Figure 23. Median values and 95% confidence intervals calculated from the bootstrap distributions are given in Appendix C. Estimates range from 0.1141 to 0.2358 for males, from 0.1073 to 0.1730 for females, and from 0.1103 to 0.2039 for all fish combined over both fishing years. Assuming an age at full recruitment of 8 years, total mortality estimates are 0.1644 (95% confidence interval: 0.1392 to 0.1951) and 0.1894 (95% confidence interval: 0.1595 to 0.2279) respectively for all fish in the BT-TAR and SN-MOK fisheries sampled during 2004–05 and are 0.1396 (95% confidence interval: 0.1165, to 0.1812) and 0.1358 (95% confidence interval: 0.1189 to 0.1583) for all fish in these fisheries during 2005–06.

The current best estimate for blue moki natural mortality is 0.14 (Ministry of Fisheries Science Group 2008). This value was derived by passing the observed maximum age in Francis (1981a) into the equation $\hat{M} = \ln 100 / t_{\max}$, where $t_{\max}$ is the maximum age attained by the oldest 1% of an unexploited stock. Given that fish as old as 43 years were observed in this study and that the MOK 1(E) stock can hardly be described as unexploited, assuming $t_{\max} = 43$ may be more reasonable, leading to a single sex- and time-variant natural mortality estimate for MOK 1(E) of 0.11. Assuming $M = 0.11$ y^{-1} in $Z = M + F$, given the total mortality estimates for the BT and SN-MOK fisheries above and assuming an age at full recruitment of 8 years, leads to fishing mortality, $\hat{F}$, estimates of 0.06 y^{-1} and 0.08y^{-1} for the BT-TAR and SN-MOK fisheries respectively during 2004–05 and 0.03 for both fisheries during 2005–06. Reparameterising these values as exploitation rates produces exploitation rate estimates of 0.392 and 0.472 for the BT-TAR and SN-MOK fisheries during 2004–05 and 0.284 for both fisheries during 2005–06.

3.6 Per-recruit analysis

A yield-per-recruit analysis was carried out using the model described in Section 2.5 assuming the weight-at-length relationship given in Table 4 and the results of fitting the two-sex log-normal length- and weight-at-age models given in Tables 8 and 9 (derived parameters, including mean asymptotic maximum length or L_∞, for the length-at-age model fits are given in Table 13). Blue moki abundance (numbers or fish), fish weight, and total age-class biomass are plotted as functions of age under these assumptions in Figure 24. Six different yield-per-recruit curves are plotted separately as a function of fishing mortality and exploitation fraction given two different assumed natural mortality values (the revised value of M = 0.10 y^{-1} and the value of M = 0.14 y^{-1} specified in the 2008 Plenary Report) and three different assumed ages at full recruitment to the fisheries (4, 8, and 12 years) in Figure 25. Reference fishing mortality values $F_{\max}$, the fishing mortality that maximises yield-per-recruit for a given age at first capture, and $F_{0.1}$, the fishing mortality where the slope of the yield-per-recruit curve is 10% (0.1) that of the slope of the curve at the origin where zero fishing mortality is applied, along with the corresponding values reparameterised as exploitation rates using the equation $E = F / Z$, that is, $E_{\max}$ and $E_{0.1}$, are given in Table 14. Yield-per-recruit isopleths are plotted as a function of different exploitation rate and ages at full vulnerability to the fishery in Figure 26. Observed exploitation rates from the BT-TAR and SN-MOK fisheries during 2004–05 and 2005–06 fishing years assuming ages at full vulnerability of 4, 6, 8, 10, and 12 years are overlaid on the isopleth plot. These are well to the left of the lines of both eumetric and cacometric fishing as defined by Clark (1985) for both fisheries and fishing years regardless of the age of full vulnerability assumed.

Table 13: Derived parameters for the three Schnute length-at-age models fitted assuming the same model parameters for all fish and either normal (constant σ^2), log-normal, or normal (constant c) errors. p, number of parameters and the two-sex log-normal model.

Model	Error structure	Group (i)	$L_{\infty,i}$	$t_{0,i}$
1	Normal (constant σ^2)	All	64.65	-5.62
2	Log-normal	All	64.46	-5.69
3	Normal (constant c)	All	64.94	-6.19
4	Log-normal	Male	62.79	-5.74
		Female	65.57	-5.25

Table 14: Selected reference fishing mortality and exploitation fraction values (E_{max}, F_{max}, $E_{0.1}$, and $F_{0.1}$) for different assumed ages at full vulnerability (1–12 years) under the other assumptions (length-at-age, weight-at-age, natural mortality = 0.10 y^{-1}) made in the per-recruit analysis. Inf., infinite.

Age at full vulnerability	E_{max}	F_{max}	$E_{0.1}$	$F_{0.1}$
1	0.7552	0.3084	0.5324	0.1139
2	0.8083	0.4215	0.5537	0.1241
3	0.8609	0.6187	0.5725	0.1339
4	0.9127	1.0449	0.5888	0.1432
5	0.9635	2.6422	0.6028	0.1517
6	1	Inf.	0.6147	0.1595
7	1	Inf.	0.6249	0.1666
8	1	Inf.	0.6335	0.1729
9	1	Inf.	0.6409	0.1785
10	1	Inf.	0.6471	0.1834
11	1	Inf.	0.6524	0.1877
12	1	Inf.	0.6569	0.1915

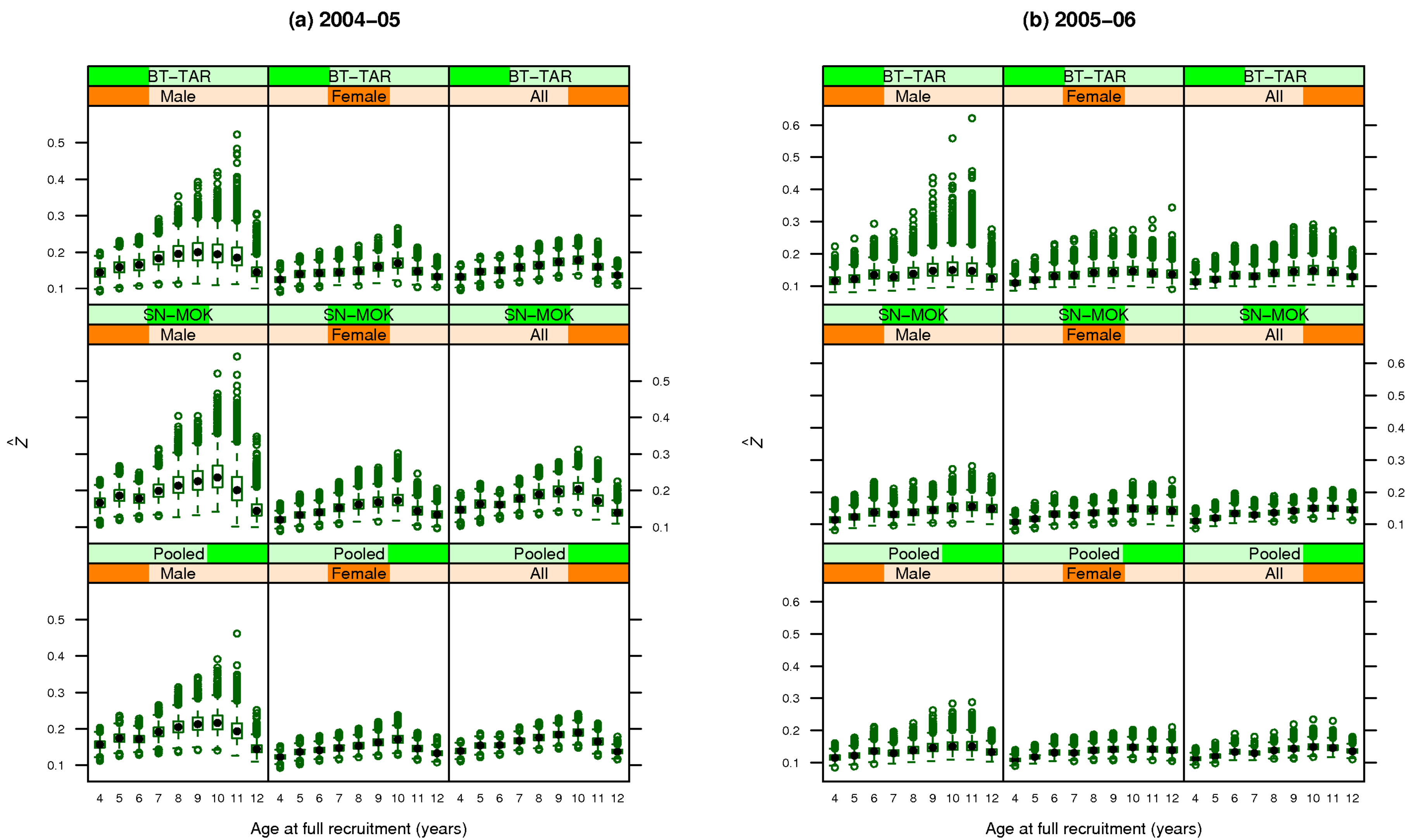


Figure 23: Results of applying the Chapman-Robson total mortality estimator to the bootstrapped age-frequency distributions for (a) the 2004–05 and (b) 2005–06 fishing years assuming ages at full recruitment of 8 to 12. Estimates are plotted by fish sex and the stratum assumed in the age-frequency calculations and the assumed age at full recruitment.

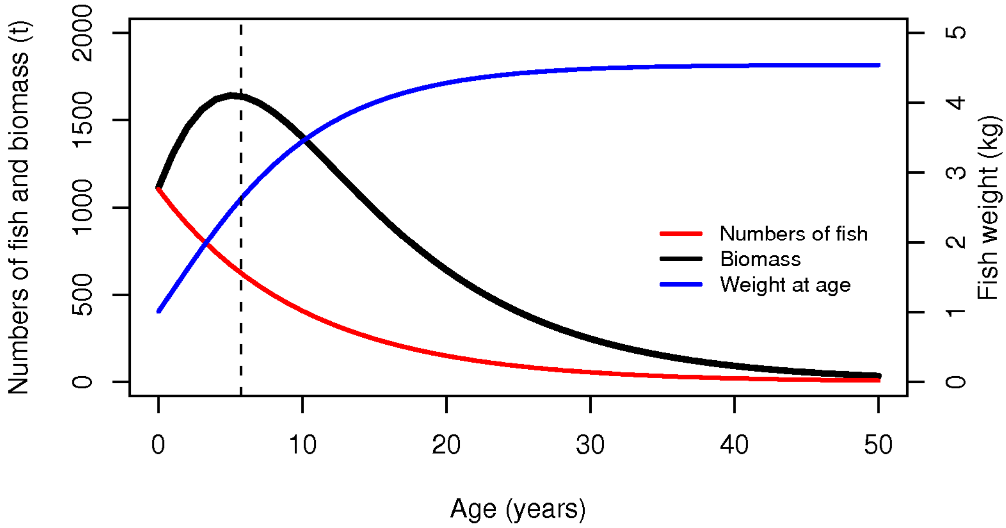


Figure 24: Blue moki abundance (numbers of fish), weight, and biomass assumed in the yield-per-recruit analysis as function of age. Maximum yield-per-recruit is obtained by applying infinite instantaneous fishing mortality at "critical" age $t_* = 5.72$ years, indicated by the dashed vertical line.

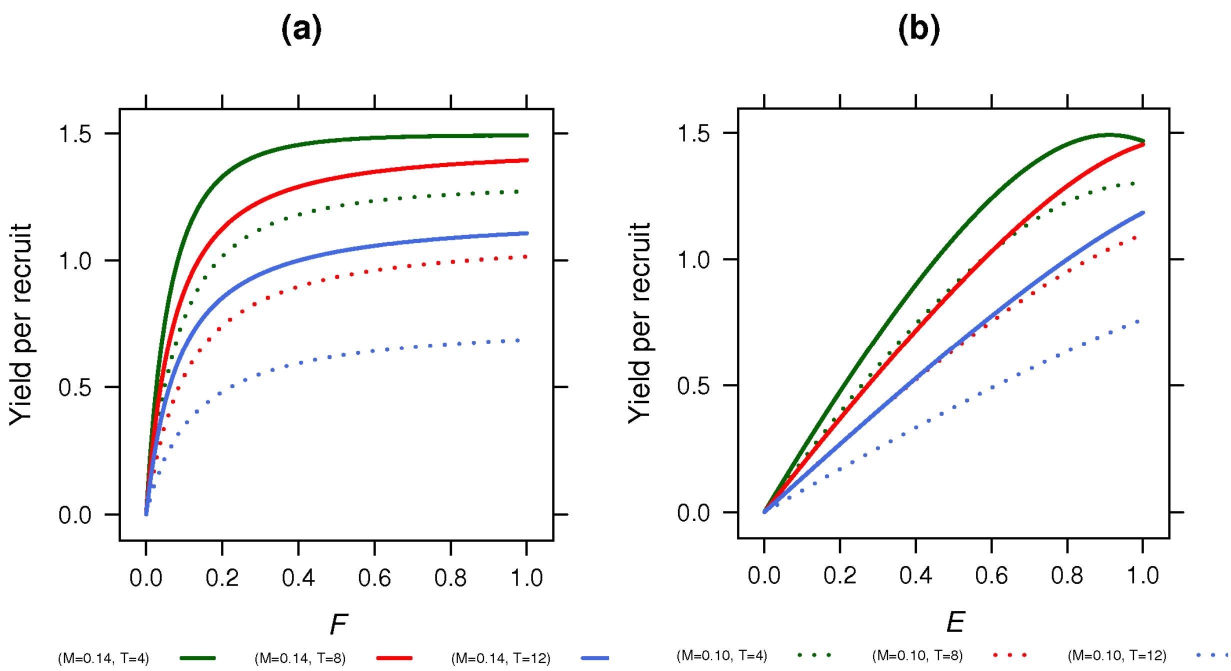


Figure 25: Yield-per-recruit curves for blue moki plotted as a function of fishing mortality (a) and exploitation fraction (b) for two different assumed natural mortalities (*M* = 0.10 and *M* = 0.14) and ages at full recruitment to the fisheries (4, 8, & 12 years).

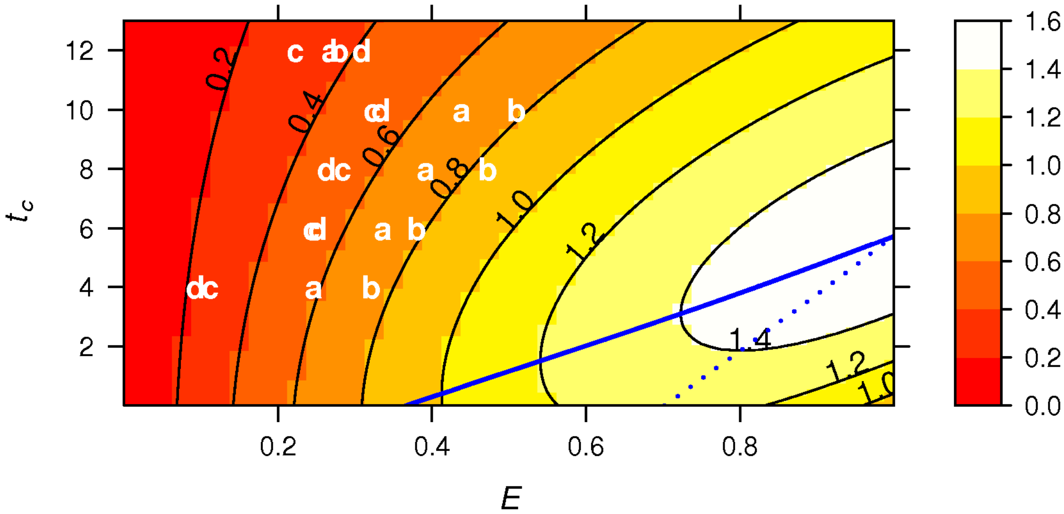


Figure 26: Blue moki yield-per-recruit isopleths (black lines) for different exploitation rates, *E*, and assumed ages at full fishery vulnerability, t_c, assuming the fitted values for length- and weight-at-age calculated in this study and assuming *M* = 0.10. The lines of so-called "eumetric" (blue solid line) and "cacometric" fishing (blue dotted line) after Clark (1985) are overlaid for comparison. Observed exploitation rates for both the BT-TAR and SN-MOK fisheries during the 2004–05 and 2005–06 fishing years assuming ages at full recruitment of 4, 6, 8, 10, & 12 years are also overlaid (white text: "a", BT-TAR fishery in 2004–05; "b", SN-MOK fishery in 2004–05"; "c", BT-TAR fishery in 2004–05; and "d", SN-MOK fishery in 2005–06).

4. DISCUSSION

4.1 The length and age composition of the catch

The length and age structure of the BT-TAR and SN-MOK catches sampled during this study are generally similar to the catches-at-length. The age range of the blue moki length and age data collected by Francis (1979, 1981a, 1981b) from around the east coasts of the North and South Islands in the 1970s. The (unscaled) length-frequency distributions presented by Francis (1981a) for the Kaikoura and Gisborne catches in 1977–78 were also unimodal, with fish as small as 40 cm and as large as 80 cm in fork length present in his samples, but with most fish between about 50 cm to 70 cm in fork length. No obvious discrete modes of young, small fish corresponding to successful year classes entering the catch were observed either by Francis or in this study. However, this probably reflects lower catchability of younger, smaller (i.e., less than 50 cm fork length) blue moki by the commercial net and trawl gear sampled in this study and by the sampling gear used by Francis in the 1970s rather than recruitment failure then and now. Young blue moki are known to occur intertidally and subtidally over rocky reefs (Duffy 1988), with adults found in deeper water further offshore on the continental shelf (Anderson et al. 1998), suggesting reduced areal and vertical availability of younger, smaller fish to commercial trawl and setnet gear. Presumably, this pattern is caused by some kind of ontogenic shift in habitat preference and distribution, but the dynamics are poorly understood at this time.

Francis (1981a) did not present age-frequency distributions, but did comment that the fish sampled in his study seemed to be fully recruited to the fisheries he sampled by about 60 cm in fork length, and from the length-at-age data he collected, at about 8 to 10 years of age. These results are consistent with the catches-at-length and catches-at-age calculated in this study, although the sampling gear and the spatial and temporal extent of sampling effort in this study are somewhat different from the gear and sampling scheme used by Francis (he did not sample trawl catches, for example). However, in any case, it appears that both the BT-TAR and SN-MOK commercial catches sampled in this study are based on a number of successful year classes with some evidence of particularly strong year classes entering and persisting in the catch. Our ability to identify and track year-classes in the catch-at-age is of course confounded by reader error, which in this study was moderate. Somewhat surprisingly, there do not appear to be any strong differences between the SN-MOK and BT-TAR (in- and out-season) catches-at-age for either of the fishing years sampled during this study. Observed age-frequency distributions are of course affected by the selectivity of the sampling gear. The shapes of the commercial setnet and trawl selectivity ogives for blue moki are unknown, but as gill- or setnets are quite selective (e.g., Hickford & Schiel 1995, Hickford & Schiel 1996, Millar & Holst 1997, Dunn & Paul 2000, Walker et al. 2005), typically capturing only some middle subset by length or by age of fish that encounter the gear, more marked differences were expected. However, if the commercial trawl gear is also efficient at retaining only a middle subset of fish, i.e., if very small and very large fish available to the trawl gear are not retained by the gear, perhaps because small (young) blue moki are too small to be retained by the codend mesh and large (old) blue moki are strong enough to out swim a typical trawl when towed at a typical fishing speed, as is the case for snapper (*Pagrus auratus*) in New Zealand (e.g., Gilbert et al. 2000, Harley et al. 2000, Maunder & Starr 2000, Bentley et al. 2004), then the gear selectivities might be similar and similar catches-at-age might be expected. However, teasing this out is confounded by different spatial fishing patterns (at the level of statistical areas at least and presumably on finer spatial scales) between the fisheries, suggesting potentially different catchabilities between the fisheries.

The oldest blue moki reported by Francis was 33 years, compared with 43 years in this study, representing an increase in maximum observed longevity of some 10 years or 30% from his study to this. The natural mortality estimate given in the 2007 Plenary Report (Ministry of Fisheries Science Group 2007), 0.14, is a function of the current best longevity estimate, and the increase in blue moki longevity reported in this study suggests that this should be revised to 0.10 accordingly. Both the Plenary Report estimate (0.14) and the revised estimate (0.10) were considered in the per-recruit analysis presented above, although the reference points and per-recruit isopleths were calculated assuming the revised value. The Plenary Report also states that blue moki stocks in New Zealand have a long catch history and are considered to have been seriously depleted by 1975. Although the average catch post-QMS (426 t, all QMAs, 1986–87 to 2006–07; Table 1), is less than half of the 1979 peak of 960 t, it is unlikely that the stock age-frequency distributions have returned to an unexploited or lightly exploited (i.e., an approximately equilibrium) state. Therefore, it is possible that the revised longevity (43 years) and natural mortality (0.10) estimates presented in this report may still underestimate true blue moki longevity and natural mortality.

4.2 Future market-sampling

The market-sampling programme carried out as part of this study was implemented in response to an information need identified by Langley & Walker (2004) in their descriptive and standardised catch-per-unit-effort analysis of the ECNI moki fisheries. From the insights gained on the composition of the catch and the apparent status of the stock in this study and the synergy of these results and the results of the previous catch-rate analysis, we recommend that catch- or market-sampling of the blue moki fisheries should continue in the future. An assessment of the optimum frequency and design of future blue moki sampling programmes is beyond the scope of this report, but we do recommend that future sampling programmes should be carried out for three not two years. This is because chance occurrence of anomalous patterns in fish distribution, fishing patterns, or in sampling effort in any given fishing year during a three-year sampling programme will affect a smaller fraction of the total results, increasing the chances of overall success. Three years also offers a better opportunity to develop and maintain a pool of suitable sampling staff, whether administrative and implementation responsibilities are assigned to a single, vertically integrated research service provider or not. We also note that the harvest level and thus the revenue that can be extracted from the fishery limits the scope and frequency with which future sampling programmes can be implemented, but once per decade, perhaps dependent on a trigger from a future standardised catch-rate analysis, seems sensible in advance of a proper consideration of optimum sampling frequency and design.

4.3 Implications of observed mortality estimates

Total mortality estimates were produced for the BT-TAR and SN-MOK fisheries off the ECNI for the 2004–05 and 2005–06 fishing years from which fishing mortality estimates for these fishing years were derived (0.06 and 0.08 for the BT-TAR and SN-MO`K fisheries respectively during 2004–05 and 0.03 for both fisheries during 2005–06 assuming age at full vulnerability of 8 years) in this study. However, fishing mortality estimates are of little value without reference fishing mortality values with which to compare the observed values. Given that no quantitative stock assessment model exists for blue moki off the ECNI at this time, a classical per-recruit analysis was carried out to produce reference fishing mortality values for comparison with the observed fishing mortality estimates.

Reference points F_{max}, the fishing mortality that maximises yield-per-recruit for a given age at full vulnerability, and $F_{0.1}$, the fishing mortality for a given assumed age at full vulnerability where the slope of the yield-per-recruit curve as a function of fishing mortality is 10% (0.1) of the slope of the curve at the origin, were calculated. Under the assumptions made in the per-recruit analysis, maximum yield-per-recruit is obtained by applying infinite fishing mortality at a "critical" age of 5.72 ages, and thus the tabulated F_{max} values calculated for assumed ages at full vulnerability of 6 years or more are infinite. However, fishing mortality at a level of F_{max} or greater corresponds to economic and growth overfishing, as the yield-per-recruit can be increased by decreasing fishing mortality, and can usefully be thought of as a level of fishing mortality to avoid, if possible ("cacometric" or "poorly measured" fishing, Clark (1985). The derivation and use of $F_{0.1}$ as a reference point was reviewed in some detail by Deriso (1987). The choice of the 0.1 factor is arbitrary, but $F_{0.1}$ is considered, at least theoretically, an economically efficient, risk-averse alternative to F_{max} ("eumetric" or "well measured" fishing, Clark (1985). It corresponds to a point on a given yield-per-recruit curve where the relative gain in yield-per-recruit as a function of fishing mortality is decreasing rapidly as F_{max} is approached. By definition, $F_{0.1}$ will always produce a lower yield-per-recruit than F_{max}, but due to the decreasing relative gain in yield-per-recruit as fishing mortality increases, a disproportionally large increase in fishing mortality is required to move from $F_{0.1}$ to F_{max}, requiring a disproportionally large increase in fishing effort in the real world, and thus in cost.

Having said all this, the observed fishing mortalities, regardless of the age at full vulnerability assumed, are all less than the corresponding $F_{0.1}$ estimates and are well to the left of the eumetric fishing line plotted on the yield-per-recruit isopleth surface. This appears to suggest, everything else being equal, that the blue moki stock supporting the BT-TAR and SN-MOK fisheries off the ECNI is not being over-fished and that yield could be increased by increasing fishing mortality further. Is this really the case? We should consider that per-recruit analysis can produce invalid results, leading to the calculation of invalid reference points, and thus leading to inappropriate management decisions if the assumptions made in the analysis have not been met. The classical per-recruit model presented by Beverton & Holt (1957) and used in this analysis is a deterministic model that does not consider uncertainty in the model parameters (in its original form it is not a statistical model), does not consider the stock-recruit relationship, and assumes knife-edge maturity and selectivity ogives, which, are over-simplifications of reality that may not address the full range of real population responses of ECNI blue moki to harvesting. The extent to which the lack of data from younger, smaller fish from which the length-at-age relationship assumed in the analysis was calculated has affected the results is unknown. It may be useful to collect otoliths from young, small blue moki and to update the length-at-age relationship presented and to test the sensitivity of the per-recruit analysis results to the revised length-at-age relationship.

Deriso (1987) goes on to discuss how $F_{0.1}$ can approximate F_{MSY}, the level of fishing mortality that supports the maximum sustainable yield (MSY), when recruitment is adequately described by a Ricker stock-recruitment function. No attempt has been made to derive a stock-recruitment relationship for the ECNI blue moki stock, or to explore the degree of stochasticity inherent in the relationship, but given that the observed fishing mortality estimates are all well to the left of the eumetric fishing line calculated in the per-recruit analysis given the assumptions made, it seems reasonable to assume, given these results, that current (2005–06) biomass is likely to be above the level that supports MSY. However, given the caveats discussed above, it would be premature to suggest a revised harvest limit without carrying out a quantitative stock assessment where current and historical biomass and yields are estimated and the full range of likely population responses of ECNI blue moki are explored. In the interim, it may be useful to generalise the selectivity, maturity, and other assumptions in the per-recruit analysis carried out and to explore the stochasticity in the results using Monte Carlo methods.

5. ACKNOWLEDGMENTS

We thank John and Pat Reid of the Area 2 Inshore Finfish Company Ltd and all staff of fishing companies who provided access to fish, landings data, or who were directly involved with data collection for their help with implementing the sampling programme. In particular, we thank Dion and John Muollo (Deep Blue Seafoods Ltd), Steve Keeves (Pacific Catch Ltd), and Vana, Mark, George, and John (John's Fish Market Ltd) and their staff for their help, without which the data gathered would be considerably more sparse. This project was funded by Ministry of Fisheries under project code MOK2003/01.

A small number of minor revisions and edits to a draft of the body of this report were made by Alistair Dunn before publication, following the death of Michael Manning (1973-2009).

6. REFERENCES

Anderson, O.F.; Bagley, N.W.; Hurst, J.; Francis, M.P.; Clark, M.R.; McMillan, P.J. (1998). Atlas of New Zealand fish and squid distributions from research bottom trawls. *NIWA Technical Report 42*. 303 p.

Beamish, R.J.; Fournier, D.A. (1981). A method for comparing the precision of a set of age determinations. *Canadian Journal of Fisheries and Aquatic Sciences 38*: 982–983.

Bentley, N.; Davies, N.M.; McNeill, S.E. (2004). A spatially-explicit model of the snapper (*Pagrus auratus*) fishery in SNA 1. *New Zealand Fisheries Assessment Report 2004/26*. 64 p.

Beverton, R.J.H.; Holt, S.J. (1957). On the dynamics of exploited fish populations. Fishery Investigations, Series II, Sea Fisheries, Volume 19. 533 p.

Beverton, R.J.H.; Holt, S.J. (1964). Tables of yield functions for fishery assessment. *FAO Fisheries Technical Paper 38*. 49 p.

Blackwell, R.G.; Gilbert, D.J. (2002). Age composition of commercial snapper landings in Tasman/Golden Bay (SNA 7), 2000–01. *New Zealand Fisheries Assessment Report 2002/49*. 17 p.

Bull, B.; Dunn, A. (2002). Catch-at-age user manual v1.06.2002/09/12. NIWA Internal Report 114. 23 p. (Unpublished report held by the NIWA Library, Wellington.)

Bull, B.; Gilbert, D.J. (2001). Catch-at-age sampling. *New Zealand Fisheries Assessment Report 2001/53*. 19 p.

Campana, S.E.; Annand, M.C.; McMillan, J.I. (1995). Graphical and statistical methods for determining the consistency of age determinations. *Transactions of the American Fisheries Society 124*: 131–138.

Chang, W.Y.B. (1982). A statistical method for evaluating the reproducibility of age determination. *Canadian Journal of Fisheries and Aquatic Sciences 39*: 1208–1210.

Christensen, J.M. (1964). Burning of otoliths, a technique for age determination of soles and other fish. *Journal Conseil Permanent International pour l'Exploration de la Mer 29*: 73–81.

Clark, C.W. (1985). Bioeconomic modelling and fisheries management. Wiley-Interscience, New York. 304 p.

Deriso, R.B. (1987). Optimal $F_{0.1}$ criteria and their relationship to maximum sustainable yield. *Canadian Journal of Fisheries and Aquatic Sciences 44*: 339–348.

Duckworth, K. (2002). Catch-effort reference library. Version 1.0. CD–ROM available from Ministry of Fisheries, Feltex House, 156–158 Victoria Street, Wellington.

Duffy, C.A.J. (1988). The fish fauna of subtidally fringing macroalgae sampled at Wairepo Flats, Kaikoura: species composition, distribution, and abundance. 136 p. (Unpublished MSc thesis held by the University of Canterbury library, Christchurch.)

Dunn, A.; Paul, L.J. (2000). Estimates of butterfish (*Odax pullus*) setnet selectivity. *New Zealand Fisheries Assessment Report 2000/2*. 22 p.

Efron, B.; Tibshirani, R. (1993). An introduction to the bootstrap. Chapman & Hall, New York. 436 p.

Fisher, D.O.; Mackay, K.A. (2000). Database documentation: market. NIWA Internal Report 93. 37 p. (Unpublished report held by the NIWA Library, Wellington.)

Fletcher, R.I. (1987). Three optimization problems of year-class analysis. *Conseil Permanent International pour l'Exploration Mer. 43*: 169–176.

Francis, M.P. (1979). A biological basis for the management of New Zealand blue moki (*Latridopsis ciliaris*) and smoothhound (*Mustelus lenticulatus*) fisheries. 208 p. (Unpublished MSc thesis, Joint Centre for Enivornmental Sciences, Lincoln University and University of Canterbury, Christchurch.)

Francis, M.P. (1981a). Age and growth of moki, *Latridopsis ciliaris* (Teleostei: Latridae). *New Zealand Journal of Marine and Freshwater Research 15*: 47–49.

Francis, M.P. (1981b). Spawning migration of moki (*Latridopsis ciliaris*) off eastern New Zealand. *New Zealand Journal of Marine and Freshwater Research 15*: 267–273.

Francis, R.I.C.C. (1989). A standard approach to biomass estimation from bottom trawl surveys. New Zealand Fisheries Assessment Research Document 89/3. 4 p. (Unpublished report held by the NIWA Library, Wellington.)

Francis, R.I.C.C. (2002). Estimating catch at age in the Chatham Rise hoki fishery. *New Zealand Fisheries Assessment Report 2002/9*. 22 p.

Francis, R.I.C.C.; Paul, L.J.; Mulligan, K.P. (1992). Ageing of adult snapper (*Pagrus auratus*) from otolith annual ring counts: validation by tagging and oxytetracycline injection. *Australian Journal of Marine and Freshwater Research 43*: 1069–1089.

Gilbert, D.J.; McKenzie, J.R.; Davies, N.M.; Field, K.D. (2000). Assessment of the SNA 1 stocks for the 1999-2000 fishing year. *New Zealand Fisheries Assessment Report 2000/38*. 52 p.

Harley, S.J.; Millar, R.B.; McArdle, B.H. (2000). Estimating unaccounted fishing mortality using selectivity data: an application in the Hauraki Gulf snapper (*Pagrus auratus*) fishery in New Zealand. *Fisheries Research 45*: 167 en 178.

Hickford, M.J.H.; Schiel, D.R. (1995). Catch vrs count: effects of gill-netting on reef fish populations in southern New Zealand. *Journal of Experimental Marine Biology and Ecology 188*: 215–232.

Hickford, M.J.H.; Schiel, D.R. (1996). Gillnetting in southern New Zealand: duration effects of sets and entanglement modes of fish. *Fishery Bulletin 94*: 669–677.

Jensen, A.L. (1985). Comparison of catch-curve methods for estimation of mortality. *Transactions of the American Fisheries Society 114*: 743–747.

Langley, A.D.; Walker, N. (2004). Characterisation of the blue moki (*Latridopsis ciliaris*) fishery and recommendations for future monitoring of the MOK 1 fishstock. *New Zealand Fisheries Assessment Report 2004/33*. 77 p.

Mackay, K.A.; George, K. (2000). Database documentation: *age*. NIWA Internal Report 68. 35 p. (Unpublished report held by the NIWA Library, Wellington.)

Manning, M.J.; Hanchet, S.M.; Stevenson, M.L. (2004). A description and analysis of New Zealand's spiny dogfish (*Squalus acanthias*) fisheries and recommendations on appropriate methods to monitor the status of the stocks. *New Zealand Fisheries Assessment Report 2004/61*. 135 p.

Manning, M.J.; Stevenson, M.L.; Horn, P.L. (2008). The composition of the commercial and research tarakihi (*Nemadactylus macropterus*) catch off the west coast of the South Island (TAR 7) during the 2004-05 fishing year. *New Zealand Fisheries Assessment Report 2008/17*. 65 p.

Manning, M.J.; Sutton, C.P. (2004). Age and growth of giant stargazer, *Kathetostoma giganteum*, from the west coast of the South Island (STA 7). *New Zealand Fisheries Assessment Report 2004/17*. 60 p.

Maunder, M.; Starr, P.J. (2000). Bayesian assessment of the SNA 1 snapper (*Pagrus auratus*) stock on the north-east coast of New Zealand. *New Zealand Journal of Marine and Freshwater Research 35*: 87–110.

Millar, R.B.; Holst, R. (1997). Estimation of gillnet and hook selectivity using log-linear models. *ICES Journal of Marine Science 54*: 471–477.

Ministry of Fisheries Science Group (2006). Report from the Fishery Assessment Plenary, May 2006: stock assessments and yield estimates. 875 p. (Unpublished report held by the Ministry of Fisheries, Wellington.)

Ministry of Fisheries Science Group (2007). Report from the Fishery Assessment Plenary, May 2007: stock assessments and yield estimates. 875 p. (Unpublished report held by the Ministry of Fisheries, Wellington.)

Ministry of Fisheries Science Group (2008). Report from the Fishery Assessment Plenary, May 2008: stock assessments and yield estimates. 990 p. (Unpublished report held by the Ministry of Fisheries, Wellington.)

Quinn II, T.J.; Deriso, R.B. (1999). Quantitative fish dynamics. Oxford University Press, New York, NY, 542 p.

R Development Core Team (2005). R: A language and environment for statistical computing. Version R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org.

Ricker, W.E. (1975). Computation and interpretation of biological statistics of fish populations. *Bulletin of the Fisheries Research Board of Canada 191*: 29–73.

Schnute, J. (1981). A versatile growth model with statistically stable parameters. *Canadian Journal of Fisheries and Aquatic Sciences 38*: 1128–1140.

Smith, P.J.; Gaffney, P.M.; Roberts, C.D. (2003). Phylogenetic relationships of the silver trumpeter *Latris pacifica* (Teleostei, Percomorpha, Latridae) based on allozymes and mitochondrial cytochrome b sequences. *Journal of the Royal Society of New Zealand 33*: 755–767.

Smith, P.J.; Roberts, C.D.; Benson, P.G. (2001). Biochemical-genetic and meristic evidence that blue and copper moki (Teleostei: Latridae: *Latridopsis*) are discrete species. *New Zealand Journal of Marine and Freshwater Research 35*: 387–395.

Stevenson, M.L.; Horn, P. (2004). Growth and age structure of tarakihi (*Nemadactylus macropterus*) off the west coast of the South Island. *New Zealand Fisheries Assessment Report 2004/11*. 23 p.

Sutton, C.P. (ed.) (2002). Biological data collection manual for Ministry of Fisheries observers. Unpublished technical manual held by Ministry of Fisheries, Wellington, 476 p.

Walker, T.I.; Hudson, R.J.; Gason, A.S. (2005). Catch evaluation of target, by-product and by-catch species taken by gillnets and longlines in the shark fishery of South-eastern Australia. *Journal of Northwest Atlantic Fisheries Science 35*: 505–530.

APPENDIX A: CROSS TABULATIONS OF THE GROOMED AND MERGED LANDED CATCH

Table A1: Distribution of catch (kg) by fishery (BT-TAR, SN-MOK, Other; see Section 2.2 for definitions), fishing year (1989–90 to 2005–06; "1990" = 1989–90), and month of the fishing year (October to September). Catches are calculated from the groomed and merged landed catch rescaled to the QMS values given in Table 1.

BT-TAR fishery

Fishing													Month
year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1990	3 300	3 423	2 083	3 672	2 661	736	253	966	2 903	2 023	1 359	9 249	32 627
1991	8 182	6 228	1 797	2 151	1 782	1 039	1 517	4 306	2 218	5 033	721	18 017	52 992
1992	8 636	9 922	4 529	1 881	3 091	1 635	1 488	3 241	3 899	2 420	1 060	6 287	48 090
1993	5 928	7 153	2 813	1 686	320	883	611	1 816	2 703	3 685	144	788	28 528
1994	10 116	6 636	4 736	585	799	426	1 041	2 170	4 073	2 168	1 114	4 896	38 760
1995	13 265	8 696	8 423	3 792	3 532	1 149	4 507	4 376	4 868	3 253	1 622	5 494	62 978
1996	9 332	8 828	2 141	1 437	1 596	995	2 110	2 166	4 485	3 613	1 274	5 878	43 853
1997	9 335	7 011	1 272	1 422	1 531	4 084	794	2 261	2 738	2 550	1 029	4 561	38 588
1998	7 219	6 529	3 118	4 460	2 708	1 717	4 175	3 980	3 139	2 759	1 811	3 969	45 584
1999	6 264	7 023	6 052	3 739	1 901	1 673	1 812	1 991	4 471	5 380	3 653	13 752	57 711
2000	5 950	4 144	5 155	2 364	2 352	2 683	1 009	2 143	4 300	3 626	1 290	2 730	37 746
2001	6 757	3 641	2 222	2 398	2 721	2 202	1 375	1 817	2 001	7 782	1 133	3 888	37 938
2002	3 414	1 295	2 196	3 293	3 201	2 085	2 093	3 590	3 466	5 966	783	2 552	33 936
2003	3 517	3 836	3 510	2 249	1 437	1 417	783	1 095	1 352	3 505	1 977	6 588	31 266
2004	5 468	2 282	1 732	1 589	742	2 401	3 474	2 462	4 435	4 867	944	9 907	40 302
2005	4 908	3 299	4 391	2 959	1 977	2 143	1 256	2 904	4 404	7 283	5 855	21 414	62 793
2006	5 118	5 916	4 304	1 386	834	1 600	1 036	4 559	9 681	9 253	7 792	17 485	68 962
Total	118 142	97 455	60 495	41 277	33 278	28 608	29 831	45 739	64 742	73 457	32 892	134 315	760 232

SN-MOK fishery

Fishing													Month
year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1990	610	285	24	897	2 108	525	399	3 076	5 110	3 052	1 016	2 860	19 962
1991	2 246	190	117	207	88	131	570	3 585	3 707	7 794	1 480	5 337	25 453
1992	2 269	121	90	266	193	357	1 303	2 055	3 166	2 289	757	3 081	15 947
1993	3 799	418	767	520	441	1 236	2 075	2 476	3 778	4 755	530	190	20 985
1994	4 551	993	421	594	350	359	1 040	1 514	182	1 801	1 594	2 987	16 387
1995	4 035	1 232	144	326	865	110	138	2 198	1 583	1 621	4 534	5 807	22 593
1996	2 464	390	163	146	917	755	453	2 892	1 403	7 644	13 017	12 082	42 325
1997	927	926	1 895	2 243	2 229	845	1 099	3 750	2 184	3 973	5 065	14 751	39 887
1998	5 896	1 597	1 854	1 933	1 497	1 930	516	2 845	1 663	2 217	100	13 848	35 897
1999	703	280	664	424	237	288	90	2 084	1 662	2 972	6 598	12 647	28 649
2000	4 023	753	310	768	644	146	1 834	2 503	2 469	1 963	5 930	11 846	33 191
2001	7 340	1 405	861	251	1 532	931	39	1 762	10 797	11 047	1 412	35 391	72 769
2002	7 415	177	681	720	572	1 277	347	2 498	12 648	20 244	16 391	22 236	85 205
2003	8 841	162	494	506	666	498	57	7 224	21 984	21 784	16 649	5 742	84 608
2004	6 464	–	59	1 137	319	518	2 157	7 010	19 024	20 016	8 887	10 119	75 710
2005	1 469	305	688	845	1 183	907	–	3 348	9 538	12 817	14 934	44 552	90 585
2006	2 930	–	–	107	30	68	635	15 493	15 579	17 517	6 510	24 304	83 174
Total	9 538	9 506	12 101	14 170	11 071	12 562	64 608	110 461	137 494	103 249	222 379	772 048	151 677

Table A1: (continued).

Other fisheries

Fishing												Month	
year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1990	2 123	3 033	2 641	3 331	2 180	3 352	2 539	1 907	2 040	19 664	635	4 967	48 411
1991	4 516	3 257	3 184	2 684	3 200	2 539	1 753	10 697	4 723	3 274	1 303	12 425	53 556
1992	10 516	12 419	6 060	5 392	6 807	5 031	5 796	6 632	8 975	4 003	1 640	5 193	78 463
1993	8 172	6 523	3 239	4 975	5 718	4 085	7 155	12 849	13 689	16 185	1 821	10 574	94 987
1994	17 768	10 159	13 139	6 382	3 840	3 922	9 612	13 030	10 730	8 541	16 517	18 212	131 853
1995	8 705	14 267	15 129	7 846	3 143	3 912	7 635	9 334	10 893	26 586	2 400	13 579	123 429
1996	16 295	18 597	10 156	7 761	4 839	7 371	9 729	8 676	7 609	3 425	29 410	7 454	131 322
1997	13 794	15 339	10 467	11 280	9 809	7 897	6 449	10 344	5 407	7 299	20 035	7 404	125 525
1998	8 238	14 726	6 453	3 850	5 572	6 590	5 658	7 580	7 222	43 310	2 997	14 324	126 519
1999	11 923	13 909	10 811	7 087	13 670	8 459	5 560	11 419	6 018	31 542	8 968	18 273	147 640
2000	10 170	9 267	8 375	11 946	10 546	7 627	7 415	9 204	5 617	11 599	8 048	19 749	119 564
2001	12 117	4 485	7 038	13 741	7 374	7 396	6 219	3 395	6 545	7 425	8 855	14 702	99 293
2002	4 675	9 041	5 436	7 426	7 784	4 316	3 931	3 309	3 229	4 076	2 932	7 205	63 359
2003	4 633	7 390	5 915	5 643	10 283	6 555	3 360	6 017	5 580	4 932	3 933	9 887	74 127
2004	8 292	10 829	6 293	7 920	3 460	8 090	8 127	3 580	3 726	2 612	683	6 376	69 989
2005	3 735	8 065	4 410	7 867	2 964	3 333	3 451	5 774	4 069	4 099	2 747	5 106	55 622
2006	3 798	4 919	4 956	3 666	4 231	4 537	2 533	4 955	3 479	3 047	1 722	10 020	51 863
Total	169 785	125 443	118 022	105 082	95 180	97 911	129 972	110 735	210 254	119 596	185 566	1 619 220	169 785

Table A2: Distribution of catch (kg) by statistical area and fishing year (1989–90 to 2005–06; "1990" = 1989–90). Catches are calculated from the groomed and merged landed catch rescaled to the QMS values given in Table 1. –, no catch recorded.

Fishing	Statistical area												
year	001	002	003	004	005	006	007	008	009	010	011	012	013
1990	415	303	6	–	84	24	73	73	394	325	1 369	4 547	33 395
1991	469	154	4	3	66	9	28	1 101	971	4 135	2 862	12 676	40 748
1992	2 059	969	75	–	53	25	273	574	2 654	3 448	990	8 777	54 431
1993	730	307	96	1	9	4	79	924	3 083	4 012	1 140	5 152	39 109
1994	230	553	71	3	26	11	0	675	1 191	6 306	1 360	6 190	53 716
1995	154	441	97	17	103	4	19	751	2 044	5 053	3 109	10 168	57 745
1996	116	110	85	46	17	3	158	493	4 128	8 867	1 098	8 013	59 617
1997	104	1 002	120	402	10	12	357	993	4 059	862	1 900	7 742	64 493
1998	80	523	57	1	28	3	124	83	3 800	1 207	1 957	9 856	52 794
1999	16	59	101	8	3	0	111	18	1 692	560	2 535	8 832	49 526
2000	13	100	129	1	4	2	47	124	1 052	851	2 241	6 417	60 718
2001	96	362	105	836	16	2	1	1 128	1 570	1 648	1 209	6 092	66 289
2002	–	334	171	7	4	1	2	52	1 550	994	706	3 918	53 847
2003	57	51	115	451	2	1	79	30	1 174	1 626	1 236	8 029	49 506
2004	43	260	104	1	203	30	0	713	1 818	2 091	1 207	12 437	43 184
2005	11	343	35	7	10	4	3	58	1 991	2 575	1 933	9 876	49 017
2006	–	353	69	0	11	5	44	34	748	1 304	5 471	5 166	53 711
Total	4 560	6 280	1 430	1 740	641	138	1 453	7 816	34 820	46 787	32 109	133 635	881 175

Fishing	Statistical area												
year	014	015	016	017	018	019	033	034	035	036	037	038	039
1990	17 932	12 385	20 876	2 543	1 948	106	94	273	209	59	128	46	1 507
1991	27 448	18 038	11 846	4 063	2 928	49	2	240	49	64	99	92	556
1992	24 051	16 357	15 598	3 902	993	469	–	133	73	86	247	28	361
1993	36 796	19 271	21 008	5 484	2 020	–	8	538	42	17	61	45	576
1994	45 954	20 645	29 513	5 881	1 787	8	–	108	88	39	93	119	619
1995	37 693	24 200	36 496	16 470	2 658	2	114	190	46	10	67	47	969
1996	35 165	31 681	43 088	8 011	2 681	118	4	17	77	46	148	75	861
1997	41 360	12 555	20 843	26 712	859	22	34	240	229	48	314	363	2 287
1998	40 037	11 619	20 126	45 692	1 442	111	22	50	7 258	11	88	208	4 752
1999	76 323	12 363	32 903	31 640	2 504	2	64	33	57	16	48	316	932
2000	48 108	11 682	29 746	12 042	3 874	1	358	738	63	33	215	756	1 968
2001	47 273	33 146	22 224	12 540	3 663	0	53	160	62	172	64	387	1 423
2002	31 979	51 412	16 816	9 884	3 868	0	43	249	84	24	124	438	532
2003	30 976	48 030	29 051	10 115	1 664	0	31	499	91	15	177	279	2 440
2004	21 378	51 490	23 633	17 498	1 815	101	1	50	69	24	89	268	620
2005	54 972	45 996	26 955	6 665	1 708	2	3	42	25	97	114	318	617
2006	58 370	45 066	22 038	3 356	1 370	0	14	112	66	53	151	296	505
Total	674 157	454 011	425 459	229 723	37 402	1 005	833	3 590	9 718	793	2 219	3 972	22 120

Fishing	Statistical area														
year	040	041	042	043	044	045	046	047	048	101-107	201-206	701-706	801	Other	Total
1990	825	175	9	–	–	105	3	10	–	–	0	–	–	0	101 000
1991	1 641	649	28	–	–	3	3	2	–	25	28	–	–	0	132 000
1992	1 894	1 358	50	–	1	1	1	4	–	–	0	–	–	0	142 500
1993	2 323	1 100	53	–	–	18	2	50	6	–	0	0	–	0	144 500
1994	1 789	299	8	–	–	40	2	22	–	0	6	12	–	0	187 000
1995	1 437	598	20	0	18	13	2	38	75	4	21	–	–	0	209 000
1996	2 034	489	8	23	–	8	6	64	–	65	24	2	0	0	217 500
1997	3 024	632	35	–	–	5	11	846	–	232	114	–	–	0	204 000
1998	1 061	225	7	2	0	8	2	155	5	17	13	–	0	0	208 000
1999	2 169	245	15	–	–	3	2	184	–	1	22	–	–	0	234 000
2000	2 034	104	12	1	0	12	23	98	–	127	4	–	1	0	190 500
2001	1 801	28	13	–	0	58	17	97	–	15	37	–	–	0	210 000
2002	2 496	83	9	–	25	5	6	33	–	84	0	–	–	0	182 500
2003	1 655	161	5	–	–	158	14	33	–	119	61	–	–	0	190 000
2004	2 326	45	8	–	–	11	3	13	–	2	17	12	0	0	186 000
2005	1 965	493	16	–	–	19	5	10	–	15	50	–	1	0	209 000
2006	875	117	9	1	–	8	6	92	17	26	2	1	1	0	204 000
Total	31 188	6 873	303	31	44	464	106	1 831	108	735	403	26	4	0	3 151 500

Table A3: Distribution of catch (kg) by fishing method and fishing year (1989–90 to 2005–06; "1990" = 1989–90). Catches are calculated from the groomed and merged landed catch rescaled to the QMS values given in Table 1.

Fishing											Fishing method
year	BLL	BPT	BT	DS	MW	RLP	SLL	SN	T	Other	Total
1990	116	40	49 172	–	17 637	118	–	33 701	62	154	101 000
1991	64	62	78 979	–	20	90	0	52 671	30	84	132 000
1992	56	6	92 396	–	45	415	–	49 420	101	60	142 500
1993	258	3	63 659	–	214	76	121	79 862	231	77	144 500
1994	30	753	93 845	7	13 438	62	–	78 745	57	65	187 000
1995	601	53	124 400	2	18 329	38	777	64 681	70	47	209 000
1996	161	7	110 928	127	23 579	9	–	82 593	85	11	217 500
1997	28	5	110 156	85	19 387	23	–	74 095	55	167	204 000
1998	3 089	4	96 246	2	38 706	1	25	69 667	220	41	208 000
1999	31	1	128 422	107	22 675	3	–	82 620	132	9	234 000
2000	109	695	94 089	39	1 999	3	64	93 466	18	19	190 500
2001	79	281	96 150	867	429	16	420	111 518	63	178	210 000
2002	133	–	72 794	206	606	47	160	108 358	19	176	182 500
2003	6	11	89 790	11	299	81	202	99 543	2	55	190 000
2004	28	110	87 976	22	201	116	97	97 338	2	110	186 000
2005	9	4	99 576	33	126	220	–	108 913	12	107	209 000
2006	48	4	103 031	4	63	177	–	100 548	12	114	204 000
Total	5 371	1 978	1 594 832	1 463	171 106	1 439	1 869	1 370 782	1 220	1 440	3 151 500

Table A4: Distribution of catch (kg) by fishing method and fishing year (1989–90 to 2005–06; "1990" = 1989–90). Catches are calculated from the groomed and merged landed catch rescaled to the QMS values given in Table 1.

Fishing												Target species
year	BAR	BUT	GUR	HOK	MOK	SNA	SPO	TAR	TRE	WAR	Other	Total
1990	4 917	909	3 630	18 503	20 688	3 173	730	33 190	1 137	8 343	5 780	101 000
1991	5 300	1 281	8 060	940	26 206	1 922	1 261	54 361	2 594	22 159	7 915	132 000
1992	1 322	1 716	25 292	820	16 066	2 757	2 324	53 300	6 166	17 924	14 812	142 500
1993	4 313	1 488	18 716	1 281	21 253	1 547	4 889	35 545	6 648	40 586	8 235	144 500
1994	6 640	1 659	17 041	4 079	31 489	3 675	4 105	58 048	8 205	43 116	8 943	187 000
1995	5 838	1 653	15 795	21 514	23 753	1 626	2 857	75 868	7 802	33 650	18 644	209 000
1996	6 846	2 698	14 730	27 922	43 916	5 316	2 679	60 783	4 741	28 899	18 970	217 500
1997	8 763	3 162	20 786	3 746	62 868	1 607	3 660	51 712	4 714	23 033	19 949	204 000
1998	12 557	1 747	15 134	4 197	78 313	2 052	4 775	48 649	5 046	25 599	9 931	208 000
1999	16 042	2 617	22 708	1 370	53 631	3 212	4 664	65 629	2 526	48 248	13 353	234 000
2000	7 736	2 037	19 182	2 929	41 176	2 223	5 373	42 509	2 754	57 554	7 027	190 500
2001	5 584	3 228	19 532	366	78 440	1 611	5 671	38 950	4 994	39 608	12 016	210 000
2002	2 647	1 205	18 523	499	88 538	1 542	9 633	34 390	2 082	16 413	7 028	182 500
2003	3 905	1 520	21 752	141	91 688	2 509	3 609	32 128	1 418	14 156	17 175	190 000
2004	5 708	1 939	17 808	468	78 499	4 016	7 999	40 420	3 103	16 253	9 786	186 000
2005	2 209	2 300	17 471	94	92 702	2 542	2 674	63 502	1 006	16 669	7 832	209 000
2006	307	1 664	20 486	35	85 671	2 551	2 885	69 652	909	13 671	6 169	204 000
Total	103 118	32 879	294 491	95 667	921 132	44 014	68 837	860 928	67 065	467 363	196 007	3 151 500

Table A5: Distribution of catch (kg) by fishing method (BT, MW, SN, Other), fishing year (1989–90 to 2005–06; "1990" = 1989–90), target species (GUR, HOK, MOK, TAR, WAR, Other) and QMA subregion (inside or outside ECNI). Catches are calculated from the groomed and merged landed catch rescaled to the QMS values given in Table 1.

Fishing	Fishing	ECNI						Other					
method	year	GUR	HOK	MOK	TAR	WAR	Other	GUR	HOK	MOK	TAR	WAR	Other
BT	1990	7 183	396	1 381	65 254	1 648	19 970	6	1 336	–	239	1	931
	1991	15 862	1 856	1 050	105 983	5 890	25 658	25	–	–	815	50	770
	1992	49 734	1 117	157	96 180	8 932	23 885	49	1	–	4 065	2	671
	1993	35 709	2 129	497	57 057	8 424	21 418	61	24	–	341	2	1 656
	1994	32 172	7 922	1 230	77 520	11 922	41 490	155	28	–	13 737	11	1 503
	1995	30 811	6 440	2 298	125 956	16 577	49 907	171	0	–	11 331	3 263	2 046
	1996	28 375	8 339	3 171	87 706	20 272	53 716	151	20	–	14 163	39	5 904
	1997	40 298	6 515	8 041	77 176	10 390	50 754	701	15	–	20 905	22	5 494
	1998	29 383	8 295	5 391	91 168	5 726	40 024	444	12	–	3 147	36	8 865
	1999	44 149	2 618	4 705	115 421	11 373	57 583	448	49	–	14 877	443	5 179
	2000	37 354	2 004	14 487	75 491	17 092	28 734	699	1	–	9 298	307	2 709
	2001	36 808	534	6 977	75 876	26 374	32 769	344	17	3 702	1 904	1 181	5 812
	2002	35 755	157	6 193	67 871	13 317	18 879	611	0	355	844	30	1 577
	2003	42 435	175	13 857	62 531	13 391	39 857	347	1	–	1 162	226	5 597
	2004	34 166	788	5 578	80 603	15 289	29 813	978	9	–	132	1 155	7 440
	2005	34 255	79	3 370	125 586	12 314	16 818	643	2	724	1 094	1 178	3 089
	2006	40 723	40	4 815	137 925	4 151	11 985	224	7	144	1 307	1 886	2 856
	Total	570 933	52 701	81 700	1 520 464	201 942	573 359	5 947	1 552	4 596	103 868	9 665	62 937

Fishing	Fishing	ECNI						Other					
method	year	GUR	HOK	MOK	TAR	WAR	Other	GUR	HOK	MOK	TAR	WAR	Other
MW	1990	–	35 274	–	–	–	0	–	–	–	–	–	–
	1991	–	24	–	–	–	17	–	–	–	–	–	–
	1992	–	46	–	–	–	45	–	–	–	–	–	–
	1993	–	356	–	–	5	66	–	–	–	–	–	–
	1994	–	208	26 576	–	–	92	–	–	–	–	–	–
	1995	–	36 567	–	42	–	48	–	–	–	–	–	1
	1996	–	46 998	–	–	–	160	–	1	–	–	–	–
	1997	–	750	37 876	–	–	149	–	0	–	–	–	–
	1998	–	86	62 928	–	–	53	–	0	14 345	–	–	–
	1999	–	73	44 959	–	–	318	–	0	0	–	–	–
	2000	–	3 850	–	3	–	143	–	3	–	–	–	0
	2001	–	178	–	0	–	678	–	2	–	–	–	–
	2002	–	841	–	–	0	371	–	–	–	–	–	–
	2003	–	104	–	0	–	492	–	1	–	–	–	0
	2004	–	135	–	–	0	257	–	2	–	–	–	6
	2005	–	105	–	–	–	145	–	1	–	–	0	1
	2006	–	23	–	–	–	102	–	1	–	–	–	0
	Total	0	135 747	186 774	48	5	3 044	0	10	16 575	0	0	8

Fishing	Fishing	ECNI						Other					
method	year	GUR	HOK	MOK	TAR	WAR	Other	GUR	HOK	MOK	TAR	WAR	Other
SN	1990	54	–	39 923	821	14 099	7 047	14	–	71	–	939	4 435
	1991	180	–	50 905	1 849	36 113	9 469	26	–	458	7	2 265	4 069
	1992	678	476	31 894	6 351	24 418	26 250	117	–	82	4	2 497	6 074
	1993	1 603	52	41 969	13 688	70 339	23 965	52	–	26	4	2 402	5 623
	1994	238	–	32 774	24 809	71 873	17 566	51	–	2 398	–	2 426	5 355
	1995	502	21	45 186	14 378	45 036	17 700	103	–	15	24	1 693	4 703
	1996	308	486	84 651	19 698	35 332	17 243	241	–	11	–	2 154	5 061
	1997	308	211	79 774	5 319	32 839	18 056	80	–	0	13	2 814	8 776
	1998	287	–	71 794	2 878	38 135	16 272	152	–	2 168	104	1 213	6 329
	1999	411	–	57 298	916	82 729	15 361	196	–	301	45	1 679	6 304
	2000	125	–	66 381	216	95 814	11 095	80	–	1 481	–	1 857	9 882
	2001	155	–	145 538	80	49 733	17 176	57	–	663	–	1 898	7 736
	2002	259	–	170 410	64	16 934	18 702	18	–	51	–	2 539	7 739
	2003	692	–	169 215	562	13 027	7 918	9	–	304	–	1 665	5 694
	2004	410	–	151 419	92	14 437	22 548	4	–	–	–	1 623	4 142
	2005	24	–	181 170	257	17 130	12 933	10	–	135	2	2 715	3 450
	2006	–	–	166 348	73	20 341	7 473	6	–	31	–	964	5 860
	Total	6 267	1 323	1 544 097	96 959	681 770	267 167	1 281	0	8 380	223	33 169	100 930

Table A5: (continued)

Fishing method	Fishing year						ECNI						Other
		GUR	HOK	MOK	TAR	WAR	Other	GUR	HOK	MOK	TAR	WAR	Other
Other	1990	–	–	–	–	–	543	4	–	–	65	–	366
	1991	2	–	–	0	–	442	24	–	–	68	–	124
	1992	2	–	–	–	–	1,228	4	–	–	0	–	42
	1993	–	–	13	–	–	1,162	6	–	–	0	–	350
	1994	1,463	–	–	29	–	372	2	–	–	0	–	77
	1995	0	–	6	4	731	2,277	2	–	–	0	–	160
	1996	373	–	–	–	–	289	12	–	–	–	–	126
	1997	172	–	45	0	–	408	14	–	–	11	–	74
	1998	0	–	–	–	6,087	629	–	–	–	0	–	46
	1999	214	–	–	0	259	53	–	–	–	–	13	28
	2000	77	–	3	1	38	1,658	28	–	–	8	–	78
	2001	1,660	–	–	40	21	1,877	40	–	–	0	8	159
	2002	402	–	67	1	–	872	0	–	–	0	6	135
	2003	21	–	–	1	–	257	0	–	–	0	3	455
	2004	4	–	0	14	–	487	54	–	–	0	3	411
	2005	2	–	4	64	–	167	9	–	–	1	1	522
	2006	5	–	4	–	–	275	14	–	–	–	–	417
	Total	4,352	0	142	144	8,145	12,938	203	0	0	150	32	3,454

APPENDIX B: ESTIMATED SCALED NUMBERS AT LENGTH AND AT AGE DURING THE 2004–05 AND 2005–06 FISHING YEARS

Table B1: Blue moki scaled numbers at length in the BT-TAR and SN-MOK fisheries in MOK 1(E) by sex and stratum (BT-TAR-IN, BT-TAR-OUT, SN-MOK-OUT, pooled across all strata) assumed during the 2004–05 fishing year.

	BT-TAR-IN						SN-MOK-IN					
	Male		Female		Total		Male		Female		Total	
Length	*N*	c.v.	*N*	c.v.	*N*	c.v.	*N*	c.v.	*N*	c.v.	*N*	c.v.
≤ 40	0	–	0	–	0	–	0	–	0	–	0	–
41	0	–	0	–	0	–	0	–	0	–	0	–
42	0	–	0	–	0	–	0	–	0	–	0	–
43	78	1.418	66	1.418	144	0.984	157	1.412	0	–	157	1.412
44	135	1.400	0	–	135	1.400	0	–	0	–	0	–
45	0	–	0	–	0	–	66	1.464	0	–	66	1.464
46	19	1.474	0	–	19	1.474	0	–	0	–	0	–
47	274	0.932	138	1.336	412	0.833	98	1.375	0	–	98	1.375
48	406	0.916	0	–	406	0.916	961	0.505	72	1.393	1033	0.460
49	418	0.905	0	–	418	0.905	1354	0.477	309	0.952	1664	0.467
50	490	0.717	308	0.863	798	0.561	732	0.538	186	0.903	919	0.441
51	516	0.673	677	0.599	1193	0.407	2039	0.497	509	0.620	2548	0.407
52	360	0.724	821	0.584	1181	0.458	2033	0.370	712	0.578	2745	0.293
53	677	0.589	102	1.211	779	0.554	1548	0.336	852	0.454	2400	0.265
54	910	0.540	339	0.773	1250	0.413	1932	0.301	534	0.607	2466	0.257
55	1118	0.376	936	0.448	2054	0.295	2162	0.357	1289	0.338	3451	0.256
56	1232	0.600	1127	0.413	2358	0.429	3594	0.270	770	0.466	4364	0.230
57	1444	0.345	1057	0.396	2502	0.290	2054	0.322	960	0.469	3014	0.252
58	606	0.594	595	0.560	1201	0.335	1714	0.302	857	0.407	2572	0.226
59	1239	0.424	1256	0.398	2495	0.273	1463	0.428	1304	0.436	2767	0.284
60	1312	0.346	977	0.421	2289	0.237	1589	0.387	1537	0.318	3126	0.224
61	115	1.023	832	0.455	948	0.421	1198	0.387	894	0.399	2092	0.271
62	800	0.434	1288	0.394	2089	0.283	1878	0.291	650	0.530	2527	0.258
63	672	0.488	746	0.488	1418	0.350	1072	0.431	1065	0.399	2137	0.312
64	418	0.704	811	0.475	1230	0.391	1840	0.322	660	0.533	2500	0.275
65	329	0.823	312	0.739	642	0.517	1238	0.449	585	0.549	1823	0.310
66	201	1.015	587	0.574	788	0.566	572	0.570	497	0.566	1069	0.393
67	520	0.693	544	0.572	1064	0.385	294	0.678	453	0.700	747	0.482
68	0	–	661	0.580	661	0.580	463	0.712	420	0.664	883	0.488
69	161	0.975	425	0.607	586	0.490	66	1.415	481	0.650	547	0.586
70	19	1.472	306	0.694	325	0.661	164	0.984	356	0.725	519	0.618
71	0	–	289	0.764	289	0.764	0	–	318	0.710	318	0.710
72	0	–	19	1.488	19	1.488	0	–	0	–	0	–
73	0	–	103	0.965	103	0.965	0	–	192	0.931	192	0.931
74	0	–	57	1.107	57	1.107	0	–	72	1.420	72	1.420
75	0	–	170	1.303	170	1.303	0	–	0	–	0	–
76	0	–	0	–	0	–	0	–	130	1.346	130	1.346
77	0	–	66	1.432	66	1.432	0	–	0	–	0	–
78	0	–	0	–	0	–	68	1.404	0	–	68	1.404
79	0	–	0	–	0	–	0	–	0	–	0	–
80	0	–	0	–	0	–	0	–	0	–	0	–
81	0	–	0	–	0	–	0	–	0	–	0	–
82	0	–	0	–	0	–	0	–	0	–	0	–
83	0	–	0	–	0	–	0	–	0	–	0	–
84	0	–	0	–	0	–	0	–	0	–	0	–
≥ 85	0	–	0	–	0	–	0	–	0	–	0	–

Table B1: (continued)

	BT-TAR-OUT						Pooled					
	Male		Female		Total		Male		Female		Total	
Length	*N*	c.v.	*N*	c.v.	*N*	c.v.	*N*	c.v.	*N*	c.v.	*N*	c.v.
≤ 40	0	–	0	–	0	–	0	–	0	–	0	–
41	0	–	0	–	0	–	0	–	0	–	0	–
42	0	–	0	–	0	–	0	–	0	–	0	–
43	0	–	222	1.403	222	1.403	235	1.069	288	1.156	522	0.803
44	0	–	0	–	0	–	135	1.400	0	–	135	1.400
45	0	–	0	–	0	–	66	1.464	0	–	66	1.464
46	0	–	0	–	0	–	19	1.474	0	–	19	1.474
47	0	–	444	1.199	444	1.199	371	0.773	583	0.999	954	0.711
48	235	1.249	235	1.253	470	1.013	1602	0.420	306	0.985	1909	0.392
49	0	–	222	1.377	222	1.377	1773	0.422	531	0.830	2304	0.401
50	470	1.024	692	0.647	1162	0.580	1692	0.407	1187	0.461	2879	0.306
51	235	1.259	28	2.331	263	1.009	2790	0.397	1214	0.419	4004	0.291
52	235	1.247	1136	0.649	1371	0.544	2628	0.323	2669	0.371	5297	0.232
53	235	1.246	0	–	235	1.246	2460	0.289	954	0.426	3414	0.239
54	692	0.653	290	1.018	982	0.502	3534	0.249	1163	0.442	4698	0.202
55	705	0.915	457	0.832	1162	0.581	3984	0.269	2682	0.263	6666	0.189
56	0	–	927	0.597	927	0.597	4826	0.252	2823	0.283	7649	0.200
57	927	0.590	970	0.540	1896	0.359	4425	0.219	2987	0.269	7412	0.168
58	0	–	553	0.815	553	0.815	2320	0.270	2005	0.324	4325	0.191
59	1162	0.573	1661	0.393	2823	0.298	3864	0.273	4222	0.239	8085	0.168
60	235	1.285	955	0.519	1189	0.515	3136	0.259	3468	0.232	6604	0.161
61	470	1.018	55	2.214	525	0.817	1783	0.363	1782	0.320	3565	0.229
62	470	1.003	540	0.747	1010	0.495	3148	0.248	2478	0.303	5626	0.181
63	222	1.389	540	0.743	762	0.691	1966	0.337	2351	0.301	4317	0.232
64	0	–	222	1.385	222	1.385	2259	0.295	1693	0.368	3952	0.228
65	0	–	0	–	0	–	1568	0.392	897	0.439	2464	0.265
66	0	–	28	2.340	28	2.340	773	0.497	1112	0.406	1885	0.331
67	0	–	250	1.170	250	1.170	814	0.507	1247	0.434	2061	0.303
68	235	1.250	28	2.340	263	1.003	698	0.621	1109	0.440	1807	0.354
69	235	1.271	28	2.310	263	1.023	462	0.722	933	0.444	1396	0.364
70	235	1.259	0	–	235	1.259	417	0.768	662	0.507	1079	0.439
71	0	–	0	–	0	–	0	–	607	0.512	607	0.512
72	0	–	28	2.400	28	2.400	0	–	46	1.795	46	1.795
73	0	–	222	1.352	222	1.352	0	–	517	0.733	517	0.733
74	0	–	0	–	0	–	0	–	128	0.910	128	0.910
75	0	–	0	–	0	–	0	–	170	1.303	170	1.303
76	0	–	0	–	0	–	0	–	130	1.346	130	1.346
77	0	–	0	–	0	–	0	–	66	1.432	66	1.432
78	0	–	0	–	0	–	68	1.404	0	–	68	1.404
79	0	–	0	–	0	–	0	–	0	–	0	–
80	0	–	0	–	0	–	0	–	0	–	0	–
81	0	–	0	–	0	–	0	–	0	–	0	–
82	0	–	0	–	0	–	0	–	0	–	0	–
83	0	–	0	–	0	–	0	–	0	–	0	–
84	0	–	0	–	0	–	0	–	0	–	0	–
≥ 85	0	–	0	–	0	–	0	–	0	–	0	–

Table B2: Blue moki scaled numbers at length in the BT-TAR and SN-MOK fisheries in MOK 1(E) by sex and stratum (BT-TAR-IN, BT-TAR-OUT, SN-MOK-OUT, pooled across all strata) assumed during the 2005–06 fishing year.

	BT-TAR-IN						SN-MOK-IN					
	Male		Female		Total		Male		Female		Total	
Length	*N*	c.v.	*N*	c.v.	*N*	c.v.	*N*	c.v.	*N*	c.v.	*N*	c.v.
≤ 40	0	–	0	–	0	–	0	–	23	1.469	23	1.469
41	0	–	0	–	0	–	0	–	0	–	0	–
42	0	–	0	–	0	–	0	–	0	–	0	–
43	215	0.859	0	–	215	0.859	0	–	0	–	0	–
44	0	–	0	–	0	–	0	–	0	–	0	–
45	486	0.893	0	–	486	0.893	44	1.430	0	–	44	1.430
46	389	1.002	108	1.369	496	0.809	49	1.386	0	–	49	1.386
47	418	0.925	148	1.056	566	0.768	0	–	0	–	0	–
48	778	0.861	271	1.377	1048	0.868	0	–	113	1.373	113	1.373
49	387	0.658	179	1.331	566	0.528	358	0.581	93	1.402	451	0.536
50	1199	0.466	40	1.462	1239	0.449	311	0.735	119	1.232	430	0.749
51	367	0.715	108	1.390	474	0.688	864	0.498	163	0.835	1026	0.446
52	393	0.652	499	0.588	892	0.450	477	0.568	262	0.782	739	0.463
53	890	0.575	562	0.612	1452	0.499	967	0.485	703	0.500	1670	0.278
54	1701	0.425	353	0.719	2054	0.403	1400	0.336	1607	0.296	3007	0.239
55	865	0.526	346	0.716	1211	0.438	960	0.459	516	0.618	1475	0.365
56	1280	0.412	1360	0.456	2640	0.329	1231	0.360	961	0.467	2192	0.330
57	1644	0.423	1073	0.615	2717	0.416	1223	0.390	852	0.421	2075	0.280
58	897	0.575	583	0.658	1480	0.347	419	0.718	1833	0.270	2252	0.247
59	1054	0.484	991	0.512	2045	0.340	1316	0.348	1353	0.329	2669	0.251
60	872	0.574	1389	0.447	2261	0.361	1368	0.460	972	0.333	2340	0.298
61	1604	0.526	872	0.470	2476	0.335	1333	0.332	1408	0.298	2740	0.211
62	864	0.695	616	0.848	1480	0.493	1192	0.423	910	0.459	2102	0.288
63	380	0.784	1266	0.451	1646	0.363	543	0.496	1039	0.354	1582	0.290
64	566	0.539	728	0.553	1294	0.416	405	0.617	1161	0.372	1566	0.334
65	344	0.820	540	0.920	883	0.799	600	0.612	1059	0.501	1659	0.332
66	982	0.559	357	1.104	1339	0.577	390	0.864	938	0.380	1329	0.394
67	107	1.049	650	0.566	757	0.486	492	0.692	748	0.470	1240	0.359
68	286	0.818	623	0.585	909	0.536	292	0.716	373	0.626	664	0.456
69	297	0.882	219	1.029	516	0.731	256	0.747	367	0.648	623	0.537
70	179	1.310	118	1.375	297	0.876	134	1.002	443	0.557	577	0.531
71	0	–	40	1.434	40	1.434	133	0.961	0	–	133	0.961
72	0	–	0	–	0	–	0	–	322	0.606	322	0.606
73	67	1.399	40	1.444	107	1.036	0	–	0	–	0	–
74	0	–	179	1.305	179	1.305	0	–	120	0.937	120	0.937
75	0	–	0	–	0	–	0	–	0	–	0	–
76	0	–	40	1.412	40	1.412	0	–	113	1.336	113	1.336
77	0	–	0	–	0	–	0	–	78	1.378	78	1.378
78	0	–	0	–	0	–	130	1.376	0	–	130	1.376
79	0	–	0	–	0	–	0	–	65	1.390	65	1.390
80	0	–	0	–	0	–	0	–	0	–	0	–
81	0	–	0	–	0	–	0	–	0	–	0	–
82	0	–	0	–	0	–	0	–	78	1.380	78	1.380
83	0	–	40	1.456	40	1.456	0	–	0	–	0	–
84	0	–	0	–	0	–	0	–	0	–	0	–
≥ 85	0	–	0	–	0	–	0	–	0	–	0	–

Table B2: (continued)

	BT-TAR-OUT						Pooled					
	Male		Female		Total		Male		Female		Total	
Length	*N*	c.v.	*N*	c.v.	*N*	c.v.	*N*	c.v.	*N*	c.v.	*N*	c.v.
≤ 40	0	–	0	–	0	–	0	–	23	1.469	23	1.469
41	0	–	0	–	0	–	0	–	0	–	0	–
42	0	–	0	–	0	–	0	–	0	–	0	–
43	0	–	0	–	0	–	215	0.859	0	–	215	0.859
44	0	–	0	–	0	–	0	–	0	–	0	–
45	0	–	0	–	0	–	530	0.823	0	–	530	0.823
46	0	–	0	–	0	–	438	0.898	108	1.369	545	0.745
47	0	–	0	–	0	–	418	0.925	148	1.056	566	0.768
48	202	1.314	0	–	202	1.314	979	0.733	384	1.067	1363	0.708
49	247	1.083	0	–	247	1.083	993	0.422	271	0.986	1264	0.369
50	247	1.082	183	0.896	430	0.771	1757	0.378	342	0.665	2099	0.346
51	573	0.639	326	0.835	899	0.525	1804	0.340	596	0.570	2399	0.303
52	173	0.962	0	–	173	0.962	1044	0.387	760	0.464	1804	0.303
53	469	0.628	49	1.726	518	0.533	2326	0.325	1314	0.374	3640	0.250
54	124	1.318	251	1.018	375	0.690	3225	0.269	2212	0.269	5436	0.204
55	583	0.605	330	0.949	913	0.440	2408	0.304	1192	0.433	3599	0.237
56	794	0.517	133	1.153	928	0.466	3306	0.245	2454	0.317	5760	0.210
57	434	0.626	879	0.526	1313	0.354	3301	0.269	2804	0.314	6105	0.222
58	821	0.622	124	1.291	944	0.626	2136	0.369	2540	0.251	4676	0.203
59	750	0.495	548	0.525	1297	0.352	3120	0.251	2891	0.254	6011	0.176
60	133	1.141	326	0.834	459	0.650	2373	0.349	2687	0.282	5061	0.224
61	108	1.353	143	1.068	251	0.849	3044	0.312	2423	0.254	5467	0.189
62	596	0.617	853	0.627	1449	0.493	2652	0.324	2380	0.353	5032	0.234
63	10	2.453	326	0.830	335	0.778	933	0.431	2630	0.277	3563	0.222
64	251	1.005	346	0.769	597	0.524	1222	0.385	2236	0.287	3457	0.233
65	310	0.853	394	0.621	704	0.549	1254	0.422	1993	0.382	3246	0.294
66	124	1.284	375	0.667	499	0.549	1495	0.449	1671	0.345	3166	0.310
67	10	2.437	0	–	10	2.437	609	0.576	1398	0.362	2007	0.286
68	59	1.502	0	–	59	1.502	636	0.509	996	0.427	1632	0.350
69	0	–	0	–	0	–	553	0.586	586	0.561	1138	0.444
70	10	2.333	10	2.225	19	2.109	322	0.800	571	0.513	893	0.446
71	0	–	49	1.697	49	1.697	133	0.961	89	1.183	223	0.761
72	0	–	10	2.255	10	2.255	0	–	331	0.585	331	0.585
73	0	–	0	–	0	–	67	1.399	40	1.444	107	1.036
74	0	–	0	–	0	–	0	–	298	0.859	298	0.859
75	0	–	0	–	0	–	0	–	0	–	0	–
76	0	–	0	–	0	–	0	–	154	1.029	154	1.029
77	0	–	0	–	0	–	0	–	78	1.378	78	1.378
78	0	–	0	–	0	–	130	1.376	0	–	130	1.376
79	0	–	0	–	0	–	0	–	65	1.390	65	1.390
80	0	–	0	–	0	–	0	–	0	–	0	–
81	0	–	0	–	0	–	0	–	0	–	0	–
82	0	–	0	–	0	–	0	–	78	1.380	78	1.380
83	0	–	0	–	0	–	0	–	40	1.456	40	1.456
84	0	–	0	–	0	–	0	–	0	–	0	–
≥ 85	0	–	0	–	0	–	0	–	0	–	0	–

Table B3: Blue moki scaled numbers at age in the BT-TAR and SN-MOK fisheries in MOK 1(E) by sex and stratum (BT-TAR-IN, BT-TAR-OUT, SN-MOK-OUT, pooled across all strata) assumed during the 2004–05 fishing year.

	BT-TAR-IN						SN-MOK-IN					
	Male		Female		Total		Male		Female		Total	
Age	*N*	c.v.	*N*	c.v.	*N*	c.v.	*N*	c.v.	*N*	c.v.	*N*	c.v.
0	0	–	0	–	0	–	0	–	0	–	0	–
1	0	–	0	–	0	–	0	–	0	–	0	–
2	0	–	0	–	0	–	107	1.400	0	–	107	1.400
3	160	0.969	172	1.325	332	0.744	730	0.700	161	1.396	891	0.649
4	612	0.620	318	1.082	930	0.470	2221	0.410	400	0.689	2621	0.362
5	1262	0.431	693	0.534	1955	0.374	6933	0.337	1446	0.388	8379	0.308
6	680	0.528	754	0.485	1433	0.381	1960	0.409	932	0.472	2892	0.311
7	1091	0.398	1980	0.321	3072	0.221	3142	0.290	1388	0.373	4530	0.190
8	1575	0.370	913	0.534	2488	0.331	3341	0.318	1689	0.353	5030	0.232
9	1924	0.344	1149	0.447	3073	0.293	3147	0.257	1565	0.359	4712	0.193
10	1511	0.377	1177	0.406	2688	0.302	4757	0.174	3120	0.256	7877	0.148
11	1852	0.340	1447	0.362	3299	0.273	4130	0.283	1437	0.388	5567	0.206
12	461	0.786	661	0.564	1122	0.544	676	0.542	454	0.573	1130	0.394
13	431	0.688	341	0.742	772	0.542	489	0.693	228	1.017	717	0.536
14	279	0.924	159	0.960	438	0.634	434	0.634	431	0.682	865	0.516
15	243	0.916	264	0.950	507	0.668	586	0.585	455	0.633	1042	0.399
16	150	1.231	490	0.588	640	0.583	315	0.974	285	1.020	600	0.803
17	130	1.386	343	0.784	473	0.761	87	1.420	76	1.421	164	1.012
18	176	0.994	438	0.612	614	0.463	142	1.019	661	0.567	803	0.496
19	966	0.429	1498	0.328	2464	0.259	908	0.502	705	0.603	1614	0.378
20	574	0.631	796	0.473	1370	0.385	882	0.515	881	0.469	1763	0.330
21	387	0.660	196	0.911	583	0.587	75	1.405	462	0.688	537	0.615
22	93	1.440	246	0.860	338	0.711	513	0.577	273	0.807	786	0.475
23	41	1.455	294	0.793	335	0.701	151	1.216	311	0.715	462	0.610
24	149	1.326	589	0.605	737	0.503	477	0.833	306	0.712	783	0.574
25	176	0.994	194	0.971	369	0.683	339	0.772	351	0.760	690	0.498
26	0	–	287	0.741	287	0.741	337	0.743	253	0.774	590	0.560
27	93	1.413	404	0.888	496	0.731	0	–	0	–	0	–
28	0	–	0	–	0	–	0	–	0	–	0	–
29	0	–	172	1.312	172	1.312	0	–	0	–	0	–
30	0	–	0	–	0	–	0	–	79	1.416	79	1.416
31	0	–	0	–	0	–	0	–	0	–	0	–
32	0	–	0	–	0	–	0	–	0	–	0	–
33	0	–	0	–	0	–	0	–	0	–	0	–
34	0	–	0	–	0	–	0	–	0	–	0	–
35	0	–	0	–	0	–	0	–	0	–	0	–
36	0	–	0	–	0	–	0	–	0	–	0	–
37	0	–	0	–	0	–	0	–	0	–	0	–
38	0	–	0	–	0	–	0	–	0	–	0	–
39	0	–	0	–	0	–	0	–	0	–	0	–
40	0	–	0	–	0	–	0	–	0	–	0	–
41	0	–	0	–	0	–	0	–	0	–	0	–
42	0	–	20	1.522	20	1.522	0	–	0	–	0	–
43	0	–	0	–	0	–	0	–	0	–	0	–
44	0	–	0	–	0	–	0	–	0	–	0	–
≥ 45	0	–	0	–	0	–	0	–	0	–	0	–

Table B3: (continued)

	BT-TAR-OUT						Pooled					
	Male		Female		Total		Male		Female		Total	
Age	*N*	c.v.	*N*	c.v.	*N*	c.v.	*N*	c.v.	*N*	c.v.	*N*	c.v.
0	0	–	0	–	0	–	0	–	0	–	0	–
1	0	–	0	–	0	–	0	–	0	–	0	–
2	0	–	0	–	0	–	107	1.400	0	–	107	1.400
3	0	–	0	–	0	–	890	0.597	332	0.958	1223	0.510
4	664	1.052	332	1.291	996	0.962	3497	0.334	1050	0.565	4547	0.297
5	1328	0.903	2594	0.424	3923	0.415	9524	0.280	4734	0.271	14257	0.222
6	664	1.035	2319	0.401	2983	0.347	3304	0.330	4005	0.274	7308	0.202
7	898	0.668	692	0.884	1590	0.569	5131	0.229	4061	0.249	9192	0.151
8	996	0.933	664	1.028	1661	0.851	5913	0.247	3266	0.300	9179	0.204
9	566	0.790	594	0.706	1159	0.526	5636	0.200	3308	0.263	8944	0.156
10	664	1.028	2899	0.396	3563	0.290	6932	0.171	7196	0.209	14128	0.125
11	898	0.654	1188	0.486	2085	0.367	6879	0.212	4072	0.233	10951	0.152
12	0	–	262	1.200	262	1.200	1137	0.452	1377	0.417	2513	0.331
13	0	–	85	2.018	85	2.018	920	0.487	654	0.687	1573	0.408
14	0	–	233	1.404	233	1.404	713	0.529	823	0.586	1536	0.414
15	0	–	0	–	0	–	829	0.498	720	0.526	1548	0.350
16	0	–	332	1.273	332	1.273	465	0.762	1107	0.501	1572	0.452
17	0	–	0	–	0	–	218	1.007	419	0.685	637	0.617
18	0	–	0	–	0	–	317	0.705	1100	0.421	1417	0.347
19	332	1.245	318	1.134	650	0.680	2207	0.324	2521	0.315	4728	0.210
20	332	1.279	85	2.044	417	1.005	1788	0.390	1762	0.362	3550	0.252
21	0	–	332	1.287	332	1.287	462	0.599	989	0.540	1452	0.422
22	0	–	0	–	0	–	605	0.536	519	0.581	1124	0.391
23	0	–	262	1.184	262	1.184	192	0.996	867	0.540	1059	0.476
24	233	1.430	0	–	233	1.430	860	0.663	895	0.466	1754	0.392
25	0	–	28	2.343	28	2.343	514	0.606	573	0.586	1088	0.397
26	0	–	0	–	0	–	337	0.743	540	0.536	877	0.448
27	0	–	0	–	0	–	93	1.413	404	0.888	496	0.731
28	0	–	0	–	0	–	0	–	0	–	0	–
29	0	–	0	–	0	–	0	–	172	1.312	172	1.312
30	0	–	0	–	0	–	0	–	79	1.416	79	1.416
31	0	–	0	–	0	–	0	–	0	–	0	–
32	0	–	0	–	0	–	0	–	0	–	0	–
33	0	–	0	–	0	–	0	–	0	–	0	–
34	0	–	0	–	0	–	0	–	0	–	0	–
35	0	–	0	–	0	–	0	–	0	–	0	–
36	0	–	0	–	0	–	0	–	0	–	0	–
37	0	–	0	–	0	–	0	–	0	–	0	–
38	0	–	0	–	0	–	0	–	0	–	0	–
39	0	–	0	–	0	–	0	–	0	–	0	–
40	0	–	0	–	0	–	0	–	0	–	0	–
41	0	–	0	–	0	–	0	–	0	–	0	–
42	0	–	0	–	0	–	0	–	20	1.522	20	1.522
43	0	–	0	–	0	–	0	–	0	–	0	–
44	0	–	0	–	0	–	0	–	0	–	0	–
≥ 45	0	–	0	–	0	–	0	–	0	–	0	–

Table B4: **Blue moki scaled numbers at age in the BT-TAR and SN-MOK fisheries in MOK 1(E) by sex and stratum (BT-TAR-IN, BT-TAR-OUT, SN-MOK-OUT, pooled across all strata) assumed during the 2005–06 fishing year.**

	BT-TAR-IN						SN-MOK-IN					
	Male		Female		Total		Male		Female		Total	
Age	*N*	c.v.	*N*	c.v.	*N*	c.v.	*N*	c.v.	*N*	c.v.	*N*	c.v.
0	0	–	0	–	0	–	0	–	0	–	0	–
1	0	–	0	–	0	–	0	–	0	–	0	–
2	193	1.019	0	–	193	1.019	0	–	26	1.513	26	1.513
3	542	0.791	100	1.302	642	0.709	0	–	0	–	0	–
4	1296	0.580	491	0.801	1787	0.532	787	0.524	447	0.663	1234	0.482
5	444	0.719	636	0.628	1080	0.492	359	0.646	204	0.836	564	0.554
6	3028	0.423	1651	0.546	4679	0.348	2778	0.369	2707	0.325	5486	0.270
7	884	0.539	810	0.691	1695	0.477	1183	0.428	1258	0.381	2441	0.311
8	1059	0.388	1724	0.380	2784	0.258	1090	0.388	1415	0.397	2504	0.293
9	1375	0.418	773	0.580	2148	0.316	1107	0.393	1159	0.332	2266	0.265
10	1398	0.448	1354	0.358	2751	0.296	1297	0.311	2057	0.240	3354	0.190
11	1824	0.454	675	0.624	2499	0.398	1690	0.315	1573	0.296	3263	0.196
12	1050	0.442	1084	0.408	2134	0.312	1747	0.299	1874	0.323	3621	0.216
13	442	0.715	945	0.547	1387	0.446	1135	0.478	862	0.426	1997	0.272
14	0	–	322	0.832	322	0.832	114	1.001	168	0.806	282	0.608
15	0	–	50	1.446	50	1.446	0	–	636	0.449	636	0.449
16	419	0.688	687	0.507	1106	0.440	267	0.831	69	1.411	336	0.700
17	211	0.950	232	1.017	442	0.621	45	1.385	312	0.632	356	0.623
18	0	–	0	–	0	–	0	–	208	0.876	208	0.876
19	344	0.861	0	–	344	0.861	230	0.953	375	0.684	605	0.518
20	1086	0.562	404	0.670	1490	0.414	818	0.396	867	0.441	1685	0.305
21	798	0.519	304	0.894	1102	0.426	1446	0.332	1396	0.324	2842	0.216
22	182	1.352	320	0.781	502	0.770	528	0.614	223	0.845	751	0.457
23	616	0.886	1027	0.493	1643	0.454	173	0.983	277	0.821	451	0.600
24	587	0.652	0	–	587	0.652	80	1.388	146	1.038	227	0.806
25	494	1.122	172	0.991	666	0.831	453	0.560	638	0.429	1092	0.343
26	743	0.555	427	0.676	1170	0.411	463	0.580	106	1.132	569	0.501
27	304	0.880	244	1.135	548	0.768	0	–	69	1.411	69	1.411
28	182	1.324	70	1.435	252	0.947	69	1.399	320	0.768	389	0.654
29	0	–	0	–	0	–	36	1.444	225	0.802	261	0.700
30	247	1.337	0	–	247	1.337	0	–	69	1.401	69	1.401
31	182	1.318	50	1.442	232	1.003	140	1.394	0	–	140	1.394
32	0	–	0	–	0	–	0	–	0	–	0	–
33	0	–	0	–	0	–	0	–	0	–	0	–
34	0	–	0	–	0	–	0	–	0	–	0	–
35	0	–	0	–	0	–	0	–	0	–	0	–
36	0	–	0	–	0	–	0	–	0	–	0	–
37	0	–	0	–	0	–	0	–	119	1.367	119	1.367
38	0	–	0	–	0	–	0	–	0	–	0	–
39	0	–	0	–	0	–	0	–	0	–	0	–
40	0	–	0	–	0	–	0	–	0	–	0	–
41	0	–	0	–	0	–	0	–	0	–	0	–
42	0	–	0	–	0	–	0	–	0	–	0	–
43	0	–	182	1.321	182	1.321	0	–	0	–	0	–
44	0	–	0	–	0	–	0	–	0	–	0	–
≥ 45	0	–	0	–	0	–	0	–	0	–	0	–

Table B4: (continued)

	BT-TAR-OUT						Pooled					
	Male		Female		Total		Male		Female		Total	
Age	*N*	c.v.	*N*	c.v.	*N*	c.v.	*N*	c.v.	*N*	c.v.	*N*	c.v.
0	0	–	0	–	0	–	0	–	0	–	0	–
1	0	–	0	–	0	–	0	–	0	–	0	–
2	0	–	0	–	0	–	193	1.019	26	1.513	218	0.911
3	0	–	0	–	0	–	542	0.791	100	1.302	642	0.709
4	498	0.945	124	1.328	622	0.916	2581	0.378	1063	0.492	3644	0.345
5	124	1.346	0	–	124	1.346	928	0.467	840	0.512	1768	0.363
6	920	0.493	438	0.628	1359	0.347	6727	0.254	4797	0.270	11524	0.196
7	176	0.957	351	0.787	527	0.713	2243	0.320	2420	0.329	4663	0.254
8	384	0.907	248	0.884	631	0.656	2532	0.269	3387	0.265	5919	0.188
9	866	0.842	702	0.544	1568	0.584	3348	0.303	2634	0.268	5982	0.212
10	881	0.582	764	0.479	1645	0.417	3576	0.254	4174	0.187	7750	0.161
11	1686	0.392	796	0.508	2482	0.302	5201	0.228	3044	0.246	8245	0.171
12	888	0.408	351	0.774	1240	0.348	3686	0.214	3309	0.240	6995	0.159
13	135	1.129	0	–	135	1.129	1712	0.379	1806	0.346	3518	0.236
14	10	2.338	124	1.285	135	1.122	124	0.920	614	0.553	739	0.477
15	62	1.533	249	1.049	310	0.775	62	1.533	934	0.412	996	0.379
16	10	2.432	252	1.004	263	0.949	696	0.522	1009	0.435	1705	0.349
17	21	2.302	201	1.318	222	1.128	276	0.768	745	0.532	1020	0.420
18	201	1.342	0	–	201	1.342	201	1.342	208	0.876	409	0.783
19	0	–	201	1.313	201	1.313	574	0.640	576	0.625	1150	0.433
20	124	1.279	10	2.626	135	1.119	2029	0.351	1281	0.366	3310	0.248
21	10	2.501	263	0.945	273	0.914	2254	0.280	1963	0.299	4216	0.192
22	0	–	0	–	0	–	710	0.561	543	0.570	1253	0.405
23	0	–	124	1.295	124	1.295	789	0.721	1429	0.401	2218	0.363
24	62	1.492	124	1.290	186	0.880	729	0.551	271	0.816	1000	0.449
25	0	–	103	1.492	103	1.492	947	0.648	913	0.407	1860	0.372
26	0	–	124	1.289	124	1.289	1206	0.408	657	0.535	1863	0.311
27	0	–	0	–	0	–	304	0.880	314	0.935	618	0.699
28	10	2.329	10	2.519	21	2.240	262	0.956	400	0.666	662	0.531
29	0	–	0	–	0	–	36	1.444	225	0.802	261	0.700
30	0	–	124	1.269	124	1.269	247	1.337	194	0.952	441	0.869
31	0	–	0	–	0	–	321	0.969	50	1.442	371	0.828
32	0	–	0	–	0	–	0	–	0	–	0	–
33	0	–	0	–	0	–	0	–	0	–	0	–
34	0	–	0	–	0	–	0	–	0	–	0	–
35	0	–	0	–	0	–	0	–	0	–	0	–
36	0	–	0	–	0	–	0	–	0	–	0	–
37	0	–	0	–	0	–	0	–	119	1.367	119	1.367
38	0	–	0	–	0	–	0	–	0	–	0	–
39	0	–	0	–	0	–	0	–	0	–	0	–
40	0	–	0	–	0	–	0	–	0	–	0	–
41	0	–	0	–	0	–	0	–	0	–	0	–
42	0	–	0	–	0	–	0	–	0	–	0	–
43	0	–	0	–	0	–	0	–	182	1.321	182	1.321
44	0	–	0	–	0	–	0	–	0	–	0	–
≥ 45	0	–	0	–	0	–	0	–	0	–	0	–

APPENDIX C: TOTAL MORTALITY ESTIMATES

Table C1: Chapman-Robson estimates of total mortality by fishing year, fishery (in- and out-season BT-TAR strata combined), sex, and assumed age at full recruitment. Estimates and bootstrapped 95% confidence intervals (parentheses) are provided

Year	Fishery	Sex	Assumed age at full recruitment (years)				
			4	5	6	7	8
2004–05	BT-TAR	Male	0.1444 (0.1110, 0.1779)	0.1589 (0.1186, 0.1999)	0.1652 (0.1254, 0.2088)	0.1835 (0.1364, 0.2387)	0.1955 (0.1410, 0.2659)
		Female	0.1251 (0.1015, 0.1471)	0.1400 (0.1118, 0.1653)	0.1427 (0.1191, 0.1718)	0.1446 (0.1217, 0.1748)	0.1482 (0.1236, 0.1806)
		All	0.1327 (0.1087, 0.1520)	0.1470 (0.1198, 0.1699)	0.1508 (0.1271, 0.1760)	0.1585 (0.1336, 0.1868)	0.1644 (0.1392, 0.1951)
	SN-MOK	Male	0.1664 (0.1332, 0.2016)	0.1859 (0.1471, 0.2314)	0.1780 (0.1461, 0.2145)	0.1991 (0.1575, 0.2547)	0.2134 (0.1617, 0.2933)
		Female	0.1198 (0.1028, 0.1409)	0.1331 (0.1127, 0.1593)	0.1400 (0.1184, 0.1664)	0.1527 (0.1273, 0.1869)	0.1619 (0.1331, 0.2044)
		All	0.1472 (0.1225, 0.1723)	0.1632 (0.1348, 0.1943)	0.1612 (0.1397, 0.1838)	0.1778 (0.1526, 0.2078)	0.1894 (0.1595, 0.2279)
	All pooled	Male	0.1570 (0.1329, 0.1817)	0.1744 (0.1457, 0.2051)	0.1722 (0.1477, 0.1995)	0.1915 (0.1600, 0.2296)	0.2051 (0.1662, 0.2565)
		Female	0.1227 (0.1070, 0.1381)	0.1368 (0.1177, 0.1554)	0.1414 (0.1237, 0.1613)	0.1474 (0.1296, 0.1698)	0.1532 (0.1339, 0.1790)
		All	0.1392 (0.1222, 0.1549)	0.1546 (0.1349, 0.1731)	0.1555 (0.1394, 0.1721)	0.1675 (0.1497, 0.1876)	0.1761 (0.1563, 0.1994)
2005–06	BT-TAR	Male	0.1156 (0.0929, 0.1578)	0.1214 (0.0982, 0.1659)	0.1346 (0.1072, 0.1907)	0.1281 (0.1013, 0.1839)	0.1385 (0.1065, 0.2100)
		Female	0.1094 (0.0935, 0.1361)	0.1188 (0.1007, 0.1497)	0.1303 (0.1078, 0.1730)	0.1327 (0.1093, 0.1753)	0.1415 (0.1150, 0.1898)
		All	0.1126 (0.0965, 0.1422)	0.1200 (0.1027, 0.1524)	0.1321 (0.1111, 0.1750)	0.1297 (0.1096, 0.1676)	0.1397 (0.1165, 0.1812)
	SN-MOK	Male	0.1141 (0.0949, 0.1425)	0.1231 (0.1018, 0.1560)	0.1371 (0.1104, 0.1799)	0.1310 (0.1105, 0.1622)	0.1371 (0.1131, 0.1721)
		Female	0.1073 (0.0925, 0.1255)	0.1172 (0.0998, 0.1402)	0.1313 (0.1102, 0.1602)	0.1286 (0.1099, 0.1522)	0.1355 (0.1150, 0.1606)
		All	0.1103 (0.0962, 0.1290)	0.1197 (0.1039, 0.1416)	0.1337 (0.1144, 0.1614)	0.1293 (0.1151, 0.1499)	0.1358 (0.1189, 0.1583)
	All pooled	Male	0.1152 (0.0985, 0.1406)	0.1221 (0.1045, 0.1501)	0.1359 (0.1146, 0.1706)	0.1292 (0.1099, 0.1603)	0.1379 (0.1150, 0.1752)
		Female	0.1085 (0.0970, 0.1229)	0.1182 (0.1049, 0.1356)	0.1310 (0.1144, 0.1538)	0.1305 (0.1149, 0.1517)	0.1382 (0.1211, 0.1621)
		All	0.1118 (0.1003, 0.1288)	0.1199 (0.1075, 0.1392)	0.1331 (0.1177, 0.1579)	0.1297 (0.1163, 0.1506)	0.1380 (0.1227, 0.1606)

Year	Fishery	Sex	Assumed age at full recruitment (years)			
			9	10	11	12
2004–05	BT-TAR	Male	0.1444 (0.1110, 0.1779)	0.1589 (0.1186, 0.1999)	0.1652 (0.1254, 0.2088)	0.1835 (0.1364, 0.2387)
		Female	0.1251 (0.1015, 0.1471)	0.1400 (0.1118, 0.1653)	0.1427 (0.1191, 0.1718)	0.1446 (0.1217, 0.1748)
		All	0.1327 (0.1087, 0.1520)	0.1470 (0.1198, 0.1699)	0.1508 (0.1271, 0.1760)	0.1585 (0.1336, 0.1868)
	SN-MOK	Male	0.1664 (0.1332, 0.2016)	0.1859 (0.1471, 0.2314)	0.1780 (0.1461, 0.2145)	0.1991 (0.1575, 0.2547)
		Female	0.1198 (0.1028, 0.1409)	0.1331 (0.1127, 0.1593)	0.1400 (0.1184, 0.1664)	0.1527 (0.1273, 0.1869)
		All	0.1472 (0.1225, 0.1723)	0.1632 (0.1348, 0.1943)	0.1612 (0.1397, 0.1838)	0.1778 (0.1526, 0.2078)
	All pooled	Male	0.1570 (0.1329, 0.1817)	0.1744 (0.1457, 0.2051)	0.1722 (0.1477, 0.1995)	0.1915 (0.1600, 0.2296)
		Female	0.1227 (0.1070, 0.1381)	0.1368 (0.1177, 0.1554)	0.1414 (0.1237, 0.1613)	0.1474 (0.1296, 0.1698)
		All	0.1392 (0.1222, 0.1549)	0.1546 (0.1349, 0.1731)	0.1555 (0.1394, 0.1721)	0.1675 (0.1497, 0.1876)
2005–06	BT-TAR	Male	0.1156 (0.0929, 0.1578)	0.1214 (0.0982, 0.1659)	0.1346 (0.1072, 0.1907)	0.1281 (0.1013, 0.1839)
		Female	0.1094 (0.0935, 0.1361)	0.1188 (0.1007, 0.1497)	0.1303 (0.1078, 0.1730)	0.1327 (0.1093, 0.1753)
		All	0.1126 (0.0965, 0.1422)	0.1200 (0.1027, 0.1524)	0.1321 (0.1111, 0.1750)	0.1297 (0.1096, 0.1676)
	SN-MOK	Male	0.1141 (0.0949, 0.1425)	0.1231 (0.1018, 0.1560)	0.1371 (0.1104, 0.1799)	0.1310 (0.1105, 0.1622)
		Female	0.1073 (0.0925, 0.1255)	0.1172 (0.0998, 0.1402)	0.1313 (0.1102, 0.1602)	0.1286 (0.1099, 0.1522)
		All	0.1103 (0.0962, 0.1290)	0.1197 (0.1039, 0.1416)	0.1337 (0.1144, 0.1614)	0.1293 (0.1151, 0.1499)
	All pooled	Male	0.1152 (0.0985, 0.1406)	0.1221 (0.1045, 0.1501)	0.1359 (0.1146, 0.1706)	0.1292 (0.1099, 0.1603)
		Female	0.1085 (0.0970, 0.1229)	0.1182 (0.1049, 0.1356)	0.1310 (0.1144, 0.1538)	0.1305 (0.1149, 0.1517)
		All	0.1118 (0.1003, 0.1288)	0.1199 (0.1075, 0.1392)	0.1331 (0.1177, 0.1579)	0.1297 (0.1163, 0.1506)