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SKI 1 and SKI 2 Fishery Characterisation and CPUE Report

New Zealand Fisheries Assessment Report 2016/63

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EXECUTIVE SUMMARY

Starr, P.J.; Kendrick, T.H. (2016). SKI 1 and SKI 2 Fishery Characterisation and CPUE Report.

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The fisheries taking gemfish (*Rexea solandri*) in SKI 1 and SKI 2, located on the northwest and east coasts of the New Zealand North Island from 1989–90 to 2012–13, are described using compulsory reported commercial catch and effort data held by the Ministry for Primary Industries (MPI). This species is almost exclusively captured by bottom trawl, accounting for over 88% of the accumulated landings over the 24 year period. A midwater trawl fishery largely directed at gemfish accounted for a further 7% of the landings. About 70% of the bottom trawl landings in SKI 1 and SKI 2 were targeted at gemfish, with the balance of the bottom trawl landings of gemfish targeted at tarakihi, hoki and scampi. The only other capture method of importance is bottom longline, which has taken about 3% of the total gemfish landings while mainly targeting bluenose, hapuku/bass and gemfish. Detailed characteristics of the landing data associated with SKI 1 and SKI 2, as well as the spatial, temporal, target species and depth distributions relative to the catch of gemfish in the bottom trawl fishery are presented.

Fine scale positional information from catch and effort records are available from the beginning of the data set in 1989–90 because of the high level of usage of event-level data in SKI 1 and SKI 2. These data show the large catches of gemfish that took place off the east and west sides of North Cape, where there were active fisheries on spawning aggregations up to the late 1990s. Fishing on spawning aggregations of gemfish also took place in the Bay of Plenty. The SKI 2 fishery on the east coast of the North Island is directed at a wider range of target species and extends from September/October to May, ceasing after the northward winter migration of gemfish to SKI 1. After experiencing successive drops in the SKI 1 and SKI 2 TACCs implemented for sustainability reasons, the East Northland and west coast trawl fisheries disappeared in response to the overall TACC dropping by about 80% between 1996–97 and 2001–02. Fine scale location information from the decade beginning in 2003–04 show the contraction of the fishery and the extent of recent landings on the east coast of the North Island.

Commercial Catch Per Unit Effort (CPUE) analyses based on SKI 1 bottom trawl catch and effort data were ruled out as indices of relative abundance in 2007 by the Northern Inshore Working Group (NINSWG) because of the severe contraction of that fishery, including the loss of the far north fisheries. While SKI 2 also experienced contraction, there were a wider range of available data and a large part of the remaining fishery takes place in SKI 2. This project investigated ten CPUE analyses for SKI 2 to see if there was potential for using the SKI 2 catch and effort data for monitoring the overall SKI 1 and SKI 2 stock. Five of the analyses were based on daily amalgamated records while the remaining five used event-level (tow-by-tow) records. The daily analyses were preferred because there were insufficient data before 1993–94 in the tow-by-tow data sets and it was in this early period that the gemfish CPUE dropped by about 70% between 1989–90 and 1991–92. However, the two types of analyses (daily and tow-by-tow) showed a high level of agreement in the overlapping years, as did an independent analysis based only on scampi target fishing.

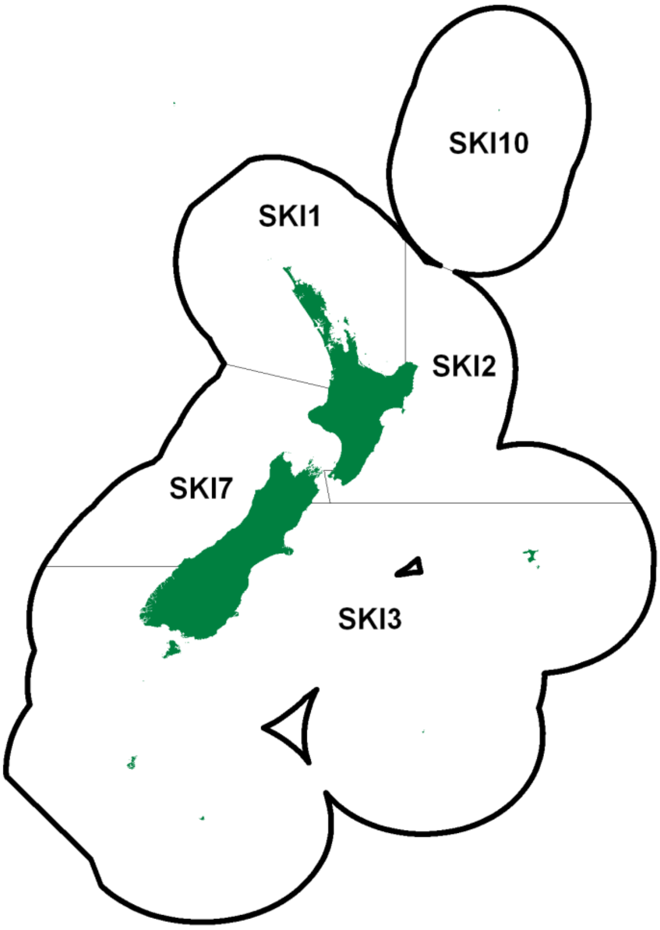

Figure 1: Map of SKI QMAs.

1. INTRODUCTION

This document describes work conducted under Objectives 1 and 2 of the Ministry for Primary Industries (MPI) contract SKI2013/01.

Overall Objective:

1. To characterise the gemfish (*Rexea solandri*) fishery in SKI 1 and SKI 2 and undertake a CPUE analysis in SKI 2.

Specific Objectives:

1. To characterise the SKI 1 and SKI 2 fisheries.
2. To analyse existing commercial catch and effort data to the end of the 2012–13 fishing year with the aim of developing a standardised CPUE index of abundance based on gemfish by-catch in the tarakihi bottom trawl fishery in SKI 2.

The following text table gives the references for the most recent SKI 1 and SKI 2 characterisations, by Fishstock (Figure 1), and the final fishing year in each analysis series:

Fishstock	**Reference**	**Last fishing year in analysis**
SKI 1	Fu et al (2008)	2005–06
SKI 2	Fu et al (2008)	2005–06

This report summarises fishery and landings characterisations for SKI 1 and SKI 2, as well as presenting CPUE standardisations derived from trawl data originating from SKI 2. This work is part of the MPI schedule for Group 3 inshore stocks: stocks which are monitored through periodic reviews of indices generated through accepted CPUE standardisations, rather than through full quantitative stock assessments.

Abbreviations and definitions of terms used in this report are presented in Appendix A. A map showing the gemfish MPI QMAs is presented in Figure 1. Appendix B presents the MPI FMAs in the context of the contributing finfish statistical reporting areas.

2. INFORMATION ABOUT THE STOCK/FISHERY

2.1 Catches

The TACC for gemfish in SKI 1 was set at 550 t when this Fishstock was first put into the QMS in 1986–87, but increased to 1152 t by 1989–90 (Table 1). The TACC remained at that level until 1996–97 when it was progressively reduced in three steps to 210 t by 2001–02 in response to a decline in abundance (Figure 2A; Table 1). The TACC has since remained at that level. Catches were below the TACC during the period of declining TACCs but have fluctuated around the level of the current TACC after 2001–02.

The TACC for gemfish in SKI 2 was set at 866 t when this Fishstock was first put into the QMS in 1986–87. It was increased to 1179 t in 1988–89, and then progressively increased to 1300 t by 1992–93 (Figure 2B; Table 1). Catch in SKI 2 only reached the TACC in 1991–92 and then followed the TACC as it was reduced in three steps in response to a decline in abundance, beginning in 1997–98 and reaching 240 t in 2001–02 (Figure 2B; Table 1). Catches have since varied around the current TACC of 240 t, although with more variation than in SKI 1 (Table 1).

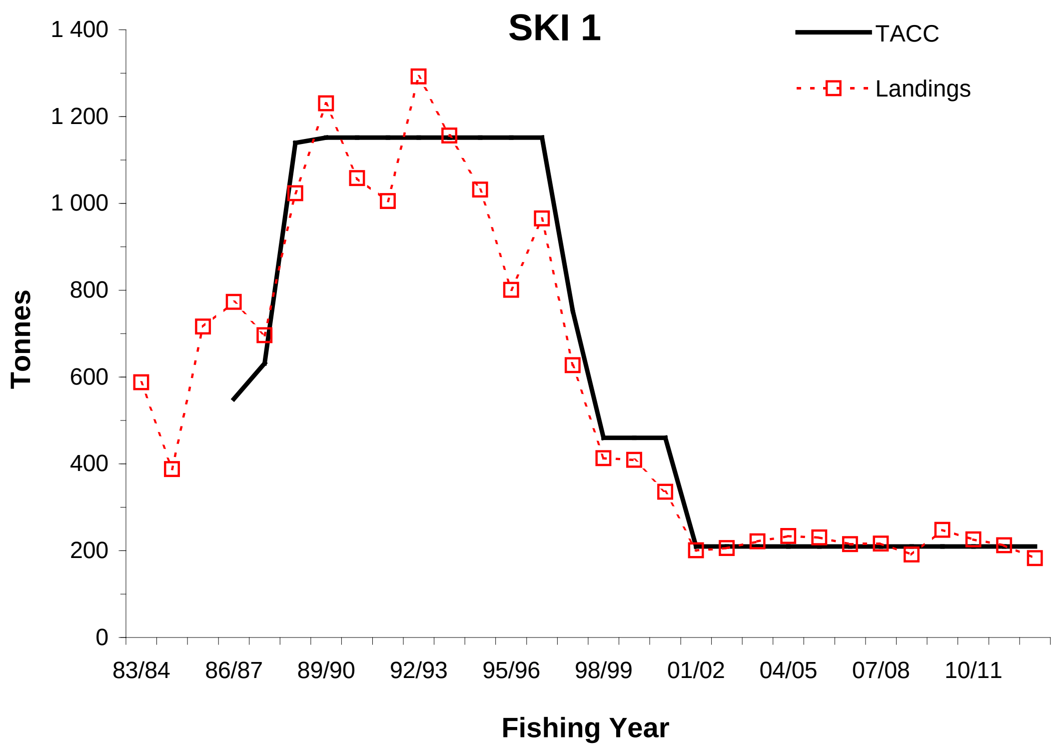

Figure 2A: Plot of SKI 1 landings and TACCs from 1983–84 to 2012–13 (see Table 1 for list of landings and TACCs by SKI QMA).

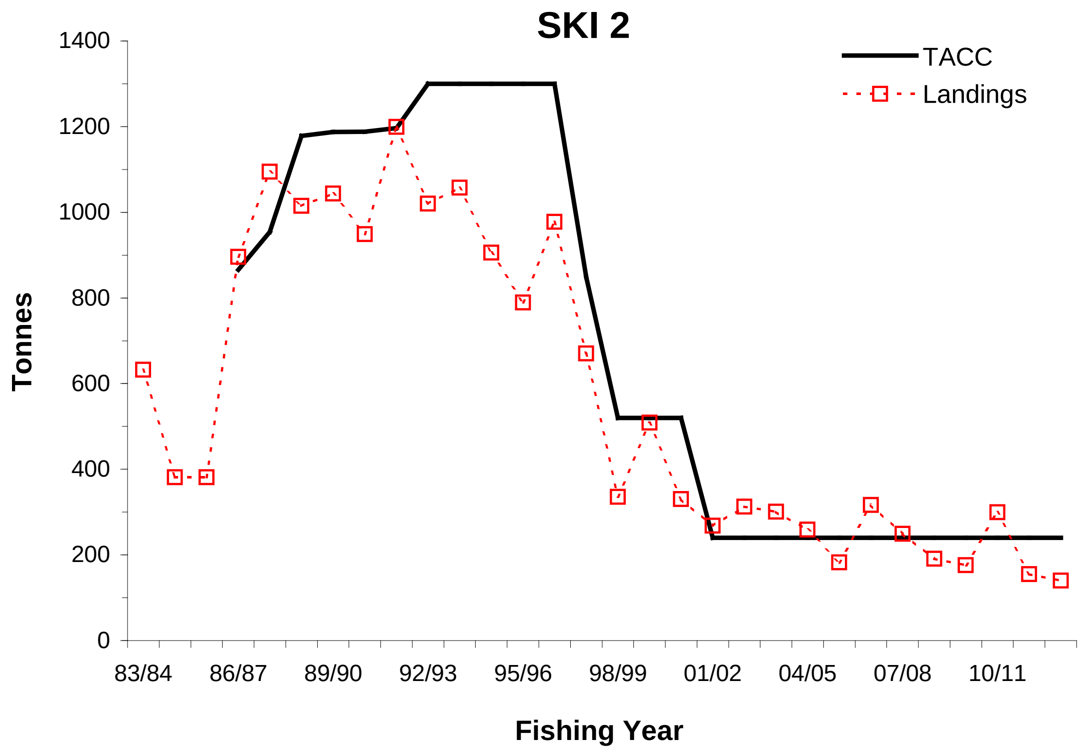

Figure 2B: Plots of SKI 2 landings and TACCs from 1983–84 to 2012–13 (see Table 1 for list of landings and TACCs by SKI QMA).

Table 1: Reported landings (t) and TACC (t) of gemfish in SKI 1 and SKI 2 from 1983–84 to 2012–13 (Data sources: FSU [1983–84 to 1985–86]; QMR [1986–87 to 2000–01]; MHR [2001–02 to 2012–13). '–': TACC not set from 1983–84 to 1985–86

Fishing	FSU/QMR/MHR			TACC		
Year	SKI 1	SKI 2	Total	SKI 1	SKI 2	Total
1983–84	588	632	1 220	–	–	–
1984–85	388	381	769	–	–	–
1985–86	716	381	1 097	–	–	–
1986–87	773	896	1 669	550	866	1 416
1987–88	696	1 095	1 790	632	954	1 586
1988–89	1 023	1 015	2 039	1 139	1 179	2 318
1989–90	1 230	1 043	2 274	1 152	1 188	2 339
1990–91	1 058	949	2 007	1 152	1 188	2 340
1991–92	1 005	1 199	2 205	1 152	1 197	2 348
1992–93	1 292	1 020	2 312	1 152	1 300	2 452
1993–94	1 156	1 058	2 213	1 152	1 300	2 452
1994–95	1 032	906	1 938	1 152	1 300	2 452
1995–96	801	789	1 590	1 152	1 300	2 452
1996–97	965	978	1 943	1 152	1 300	2 452
1997–98	627	671	1 297	752	849	1 601
1998–99	413	336	748	460	520	980
1999–00	409	509	918	460	520	980
2000–01	335	330	666	460	520	980
2001–02	201	268	469	210	240	450
2002–03	206	313	518	210	240	450
2003–04	221	301	522	210	240	450
2004–05	234	259	493	210	240	450
2005–06	230	182	413	210	240	450
2006–07	215	317	532	210	240	450
2007–08	216	249	465	210	240	450
2008–09	191	191	382	210	240	450
2009–10	247	176	424	210	240	450

Fishing	FSU/QMR/MHR			TACC		
Year	SKI 1	SKI 2	Total	SKI 1	SKI 2	Total
2010–11	226	300	525	210	240	450
2011–12	212	155	367	210	240	450
2012–13	182	140	322	210	240	450

2.1.1 Recreational catches

Recreational catches in New Zealand are generally poorly known, including for all gemfish QMAs (SKI 1, SKI 2, SKI 3, and SKI 7). A series of regional and national surveys, which combined phone interviews with detailed catch figures from randomly selected diarists, have been conducted since the early 1990s (Tierney et al. 1997, Bradford 1998, Boyd & Reilly 2005), but the results from these surveys are not considered to be reliable by most of the Fishery Assessment Working Groups. In particular, the Recreational Technical Working Group (RTWG) concluded that the framework used for the telephone interviews for the 1996 and previous surveys contained a methodological error, resulting in biased eligibility figures. Consequently the harvest estimates derived from these surveys are unreliable. This group also indicated concerns with some of the harvest estimates from the 2000–01 survey. The following summarises that group's views on the telephone /diary estimates:

> "*The RTWG recommends that the harvest estimates from the diary surveys should be used only with the following qualifications: a) they may be very inaccurate; b) the 1996 and earlier surveys contain a methodological error; and, c) the 2000 and 2001 harvest estimates are implausibly high for many important fisheries*." (quoted from Chapter 36, Kahawai, Ministry for Primary Industries 2016)

A large scale population-based diary/interview survey was conducted under contract for MPI from 1 October 2011–30 September 2012, with the intention of estimating FMA-specific annual catches for all major finfish and non-finfish species (Heinemann et al. 2015). This survey estimated the coastwide recreational gemfish catch to be on the order of 3000 fish (CV=0.39; Table 2). No estimate of catch weight was provided because there was no associated mean weight estimate. Catches were only recorded in FMA 1 (equivalent to SKI 1E), FMA 8 (top part of SKI 7) and FMA 9 (equivalent to SKI 1W), resulting in catches being estimated from only the east and west coasts of the North Island. The reliability of this survey with respect to gemfish is unknown.

Table 2: Summary catch information for gemfish from the Large Scale Marine Survey (LSMS: Wynne-Jones et al. 2014). The 'number fishers' and 'number events' categories are the survey sample size.

Summary values		FMA		Capture method		Capture platform	
Category	**Value**	**Category**	**Count**	**Category**	**Count**	**Category**	**Count**
Number fishers	12	1	2539	Rod/line	2854	Trailer boat	2033
Number events	17	2	0	Longline	35	Launch	856
Catch (numbers)	2889	3	0	Net	0	Yacht	0
CV (numbers)	0.39	5	0	Pot	0	Large yacht	0
MeanWgt (kg)[1]	–	7	0	Dredge	0	Kayak	0
Catch (t)[1]	–	8	137	Hand/shore	0	Shore	0
CV (catch)[1]	–	9	213	Diving	0	Other	0
				Spear	0		
				Other	0		
		Total	2889	Total	2889	Total	2889

[1] Not provided

2.2 Regulations Affecting the Fishery

Gemfish are generally landed whole (green), consequently there are no issues with respect to changing conversion factors. There are no known regulations that might affect the capture of this species beyond changing TACCs.

2.3 Analysis of SKI 1 and SKI 2 catch and effort data

2.3.1 Methods used for 2013 analysis of MPI catch and effort data

Two data extracts were obtained from the Ministry for Primary Industries (MPI) Warehou database (Ministry of Fisheries 2010). One extract consisted of the complete data (all fishing event information along with all gemfish landing information) from every trip which recorded landing gemfish in SKI 1 or SKI 2, starting from 1 October 1989 and extending to 30 September 2013). A second extract was obtained by identifying every trip that had a fishing event that had taken place in the statistical areas valid for SKI 1 or SKI 2 using the method BT (see Appendix A for abbreviation definitions and Appendix B for the location of the statistical areas). Once the list of trips was identified, all fishing event data and gemfish landing data from the entire trip, regardless of method of capture, were obtained. These data extracts (MPI replog 9303) were received 14 January 2014. The first data extract was used to characterise and understand the fisheries taking gemfish. These characterisations are reported in Sections 2.3.2 and 2.3.3. The second extract was used to calculate CPUE standardisations for SKI using the BT capture method (Section 3 and from Appendix F).

Data were prepared by linking the effort ("fishing event") section of each trip to the landing section, based on trip identification numbers supplied in the database. Effort and landing data were groomed to remove "out-of-range" outliers. The method used to groom the landings data is documented in Appendix C; the remaining procedures used to prepare these data are documented in Starr (2007) and below.

The original level of time stratification for a trip is either by tow or day of fishing, depending on the type of form used to report the trip information. The data used in the characterisation section of the report were amalgamated into a common level of stratification known as a "trip stratum" (see table of definitions: Appendix A). Depending on how frequently an operator changed areas, method of capture or target species, a trip could consist of one to several "trip strata". This amalgamation was required so that these data could be analysed at a common level of stratification across all reporting form types while maintaining the integrity of the QMA of capture. Gemfish landings by QMA within a trip were allocated to the "trip strata" in proportion to the estimated gemfish catches in each "trip stratum". In situations when trips recorded landings of gemfish without any associated estimates of catch in any of the "trip strata" (operators were only required to report the top five species in any fishing event), the gemfish landings were allocated proportionally to effort (tows for trawl data, sets for bottom longline data and length of net set for setnet data) in each "trip stratum". Some inshore statistical areas, particularly those around Cook Strait, are not unique among the gemfish QMAs. Trips which fished within an ambiguous statistical area and landed to multiple SKI QMAs were dropped entirely from the characterisation data set.

Data used for CPUE analysis were prepared using the "daily effort stratum" procedure proposed by Langley (2014). As noted above, catch/effort data must be summarised to a common level of stratification in order to construct a time series of CPUE indices that spans the change in reporting forms instituted the late 2000s. Although the "trip-stratum" procedure proposed by Starr (2007) addresses the nominal instructions provided to fishers using the daily-effort CELR forms, Langley (2014) showed that the actual realised stratification in the earlier form types was daily, with the fisher tending to report the "predominant" statistical area of capture and target species rather than explicitly following the instructions. He showed this by noting that the frequency of changes in statistical area of fishing or target species within a day of fishing was much higher for comparable tow-by-tow event-based forms than in the earlier daily forms. Consequently, we have adopted Langley's (2014) recommendation to use the "daily-effort-stratum" method for preparing data for CPUE analysis. The following steps were used to "rollup" the event-based tow-by-tow data in the TCER and TCEPR forms to a "daily-stratum":

1. discard trips that used more than one method in the trip (except for rock lobster potting, cod potting and fyke nets: these methods are dropped because they are deemed unlikely to capture gemfish) or that used more than one form type;
2. sum effort for each day of fishing in the trip;
3. sum estimated catch for each day of fishing in the trip[1];
4. calculate the modal statistical area and target species for each day of fishing, weighted by the number of fishing events: these are the values assigned to the effort and catch for that day of fishing;
5. distribute landings proportionately to each day of the trip based on the species estimated catch or to the daily effort when there is no species estimated catch, without maintaining QMA integrity.

Note that the above procedure was also applied to the original CELR forms to ensure that each of these trips was also reduced to "daily effort strata" if fishers report more than one statistical area or target species in a day of fishing.

Table 3. Comparison of the total adjusted QMR/MHR catch (t), reported by fishing year, with the sum of the corrected landed catch totals (bottom part of the MPI CELR form or MPI CLR forms), the total catch after matching effort with landing data ('Analysis' data set) and the sum of the estimated catches from the Analysis data set, all representing the combined SKI 1 and SKI 2 QMAs. Data source: MPI replog 9303: 1989–90 to 2012–13.

Fishing Year	QMR/MHR (t)	Total landed catch (t)[1]	% landed/ QMR/MHR	Total Analysis catch (t)	% Analysis /Landed	Total Estimated Catch (t)	% Estimated /Analysis
89/90	2 274	2 021	89	1 979	98	1 780	90
90/91	2 007	1 815	90	1 798	99	1 582	88
91/92	2 205	2 162	98	2 140	99	1 901	89
92/93	2 312	2 322	100	2 288	99	1 926	84
93/94	2 213	2 207	100	2 185	99	1 970	90
94/95	1 938	1 879	97	1 856	99	1 692	91
95/96	1 590	1 515	95	1 490	98	1 377	92
96/97	1 943	1 807	93	1 787	99	1 649	92
97/98	1 297	1 168	90	1 138	97	1 098	96
98/99	748	744	99	738	99	626	85
99/00	918	914	100	914	100	830	91
00/01	666	670	101	648	97	572	88
01/02	469	470	100	468	99	391	84
02/03	518	517	100	514	99	429	83
03/04	522	517	99	509	99	420	83
04/05	493	486	99	472	97	412	87
05/06	413	408	99	403	99	304	75
06/07	532	516	97	512	99	412	80
07/08	465	461	99	458	99	382	83
08/09	382	384	100	379	99	293	77
09/10	424	424	100	418	99	329	79
10/11	525	506	96	498	98	384	77
11/12	367	365	99	357	98	272	76
12/13	322	320	99	306	95	254	83
Total	25 541	24 600	96	24 257	99	21 283	88

[1] includes all SKI 1 and SKI 2 landings in replog 9303 except for 7 trips excluded for being "out of range" (Table C.1).

[1] ideally this would be done for every species reported on the trip on that day with the procedure only taking the top five species captured in the day; however, this level of information was not part of the data request so this step in the preparation routine was omitted;

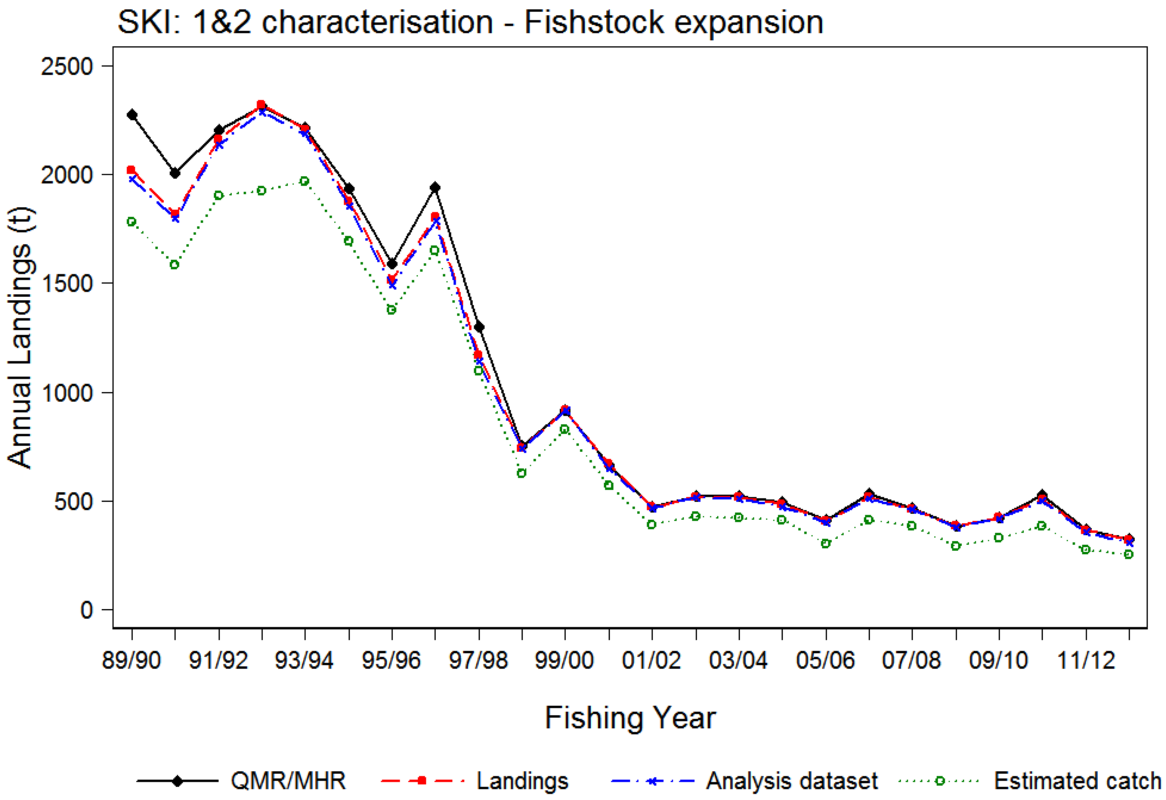

Figure 3: Plot of the combined SKI 1 and SKI 2 catch dataset for totals presented in Table 3.

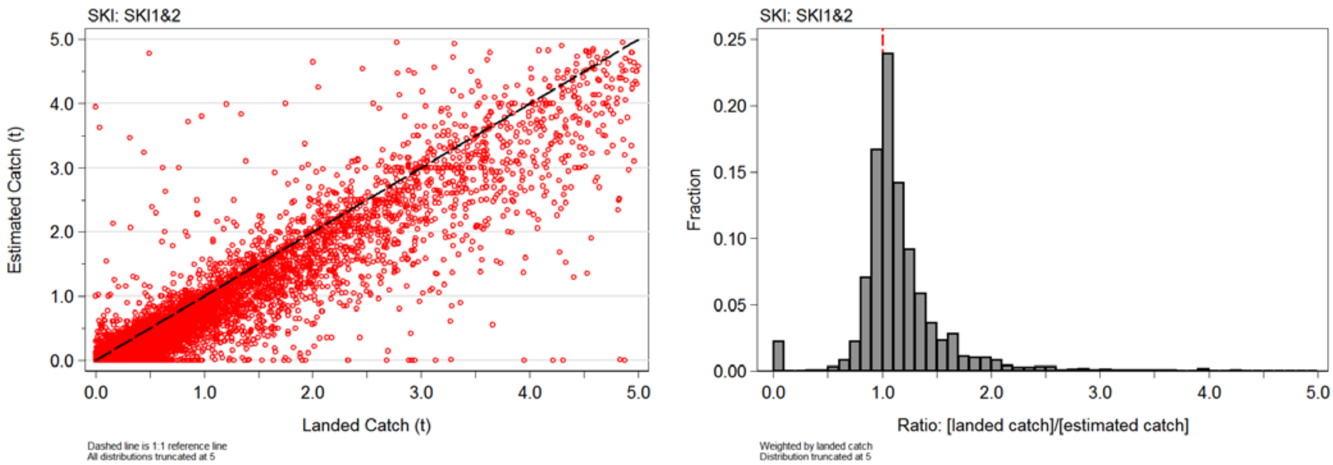

Figure 4: [left panel]: scatter plot of the sum of landed and estimated gemfish catch for each trip in the combined SKI 1 and SKI 2 analysis dataset. [right panel]: distribution (weighted by the landed catch) of the ratio of landed to estimated catch per trip. Trips where the estimated catch=0 have been assigned a ratio=0.

Catch totals in the fishery characterisation tables have been scaled to the QMR/MHR totals reported in Table 1 by calculating the ratio of these catches with the total annual landed catch in the analysis dataset and scaling all the landed catch observations (i) within a trip using this ratio:

Eq. 1 $$L'_{q,i,y} = L_{q,i,y} \frac{\mathbf{QMR}_{q,y}}{AL_{q,y}}$$

where $\mathbf{QMR}_{q,y}$ is the annual QMR/MHR landings in QMA q, $AL_{q,y}$ is the corresponding total annual landings from the analysis data set for QMA q and $L_{q,i,y}$ are the landings for record i in year y associated with QMA q.

The annual totals at different stages of the data preparation procedure are presented in Table 3 and Figure 3. Total landings in the data set are similar to the landings in the QMR/MHR system, except for 10 to 11% shortfalls in landings in the first two years of data (1989–90 and 1990–91: see Table 3). Landings by year in the subsequent fishing years vary from –4% to +1% relative to the QMR/MHR annual totals, except for 1997–98 which is –10% (Table 3). The shortfall between landed and estimated catch by trip varies from –25% to –4% by fishing year and has averaged at -15% (Table 3). A scatter plot of the estimated and landed catch by trip shows that relatively few trips overestimate the landing total for the trip, but the scatter tends to be fairly tight along the 1:1 axis (Figure 4 [left panel]). The distribution of the ratios of the landed relative to estimated catch shows a slightly skewed distribution with few ratios greater than 2.2 and with a mode slightly above 1.0 (Figure 4 [right panel]).

Table 4: Summary statistics pertaining to the reporting of estimated catch from the combined SKI 1, SKI 2, SKI 3, SKI 4, SKI 5, SKI 7 and SKI 8 analysis dataset.

	Trips with landed catch but which report no estimated catch			Statistics (excluding 0s) for the ratio of landed/estimated catch by trip			
Fishing year	Trips: % relative to total trips	Landings: % relative to total landings	Landings (t)	5% quantile	Median	Mean	95% quantile
89/90	29	5	103	0.77	1.06	1.33	2.51
90/91	27	2	33	0.70	1.08	1.36	2.71
91/92	28	2	50	0.61	1.09	1.80	2.80
92/93	31	1	31	0.67	1.11	3.52	3.28
93/94	34	1	26	0.60	1.12	1.67	3.50
94/95	41	2	35	0.62	1.16	1.60	3.99
95/96	33	2	36	0.58	1.16	1.46	3.38
96/97	31	2	37	0.60	1.14	1.48	3.30
97/98	37	2	20	0.55	1.12	1.48	3.35
98/99	37	2	16	0.52	1.20	1.73	3.45
99/00	40	2	17	0.55	1.30	1.58	3.40
00/01	40	3	17	0.60	1.22	1.67	3.53
01/02	40	4	18	0.64	1.30	1.75	3.90
02/03	41	3	16	0.63	1.31	1.88	4.00
03/04	40	3	16	0.60	1.37	1.81	4.20
04/05	38	3	14	0.58	1.30	1.99	4.15
05/06	41	4	18	0.56	1.42	1.95	4.47
06/07	39	3	17	0.62	1.32	1.88	4.62
07/08	32	2	9	0.50	1.20	2.02	4.23
08/09	30	3	10	0.56	1.30	1.96	4.80
09/10	31	2	9	0.54	1.32	2.38	5.15
10/11	27	2	9	0.58	1.36	1.99	5.71
11/12	29	2	7	0.57	1.28	1.80	4.40
12/13	27	3	9	0.53	1.26	1.80	4.80
Total	34	2	572	0.60	1.20	1.85	3.88

For the entire SKI dataset across all years, 34% of all trips which landed gemfish estimated no catch of gemfish but reported SKI in the landings (Table 4). This occurs because operators using the CELR form were only required to estimate the catch of the top five species in any single day (8 species by fishing event since the introduction of the TCER forms in 2007–08). These landings represented 2% of the total SKI landings over the period, for a total of 572 tonnes over all years (Table 4). The introduction of the new inshore forms (TCER for BT method), which record fishing activity at the level of a fishing event and report more species, had only a minor effect on the proportion of trips which estimated nil gemfish while landing this species (Table 4). This lack of sensitivity to the change in form type was probably due to the high level of event-level reporting in these two QMAs before 2007–08 (discussed below in Section 2.3.2.3).

Estimated catches tend to underestimate the eventual landings of gemfish, with the 5% to 95% quantiles for the ratio of landed to estimated catch (in the total SKI dataset excluding trips where there was no estimated catch) ranging from 0.60 to 3.88. The median and mean ratios have the landed catch at 20% and 85% higher respectively than the estimated catch (Table 4), with no trend in these statistics over time.

Plots and tables similar to Figure 3 and Table 3 are provided for SKI 1 and SKI 2 in Appendix D, showing the shortfall in landings by QMA in the analysis datasets relative to the QMR/MHR catches, which is small for both QMAs (Table D.1; Figure D.1, Figure D.2). Tables and figures equivalent to Table 4 and Figure 4 have been prepared for the two SKI QMAs (Table D.2; Figure D.3; Figure D.4). Both SKI QMAs show a tendency to underestimate landings, with the statistics very similar to those reported in Table 4. As well, the percentage of trips which report no gemfish is also very similar in the two QMAs (Table D.2).

2.3.2 Description of landing information for SKI 1 and SKI 2

2.3.2.1 Destination codes in the SKI landing data

Landing data for gemfish were provided for every trip which landed SKI 1 or SKI 2 at least once, with one record for every reported SKI landing from the trip. Each of these records contained a reported green weight (in kg), a code indicating the processed state of the landing, along with other auxiliary information such as the conversion factor used, the number of containers involved and the average weight of the containers. Every landing record also contained a "destination code" (Table 5), which indicated the category under which the landing occurred. The majority of the landings were made using destination code "L" (landed to a Licensed Fish Receiver; Table 5). However, other codes (e.g., A, C or W; Table 5) also potentially described valid landings and were included in this analysis but these are all minor compared to code "L". A number of other codes (notably Q and R; Table 5) were not included because it was felt that these landings would be reported at a later date under the "L" destination category. Two other codes (D and NULL) represented errors which could not be reconciled without making unwarranted assumptions and these were not included in the landing data set.

Table 5: Total landings (t) over the period 1989–90 to 2012–13 by destination codes in the unedited landing data for SKI 1 and SKI 2. The "how used" column indicates which destination codes were included in the characterisation analysis. "–": no landings in the QMA for the indicated destination code.

Destination code	SKI 1	SKI 2	Total	Description	How used
L	12 915.9	12 092.4	25 008.3	Landed in NZ (to LFR)	Keep
C	9.8	18.4	28.2	Disposed to Crown	Keep
F	6.3	0.5	6.7	Section 111 Recreational Catch	Keep
E	1.2	0.4	1.5	Eaten	Keep
U	0.7	0.2	0.8	Bait used on board	Keep
A	0.1	0.1	0.1	Accidental loss	Keep
W	–	0.1	0.1	Sold at wharf	Keep
S	0.1	–	0.1	Seized by Crown	Keep
R	26.0	19.3	45.3	Retained on board	Drop
NULL	0.3	4.0	4.2	Nothing	Drop
T	1.1	–	1.1	Transferred to another vessel	Drop
B	0.3	0.4	0.7	Bait stored for later use	Drop
Q	0.3	0.2	0.5	Holding receptacle on land	Drop
D	0.3	–	0.3	Discarded (non-ITQ)	Drop

Some of the destination codes (notably "P", "Q" and "R") represent intermediate holding states that have the potential to invalidate the method of Starr (2007), which assumes that the reported landings for a trip have been taken using the effort reported for the trip. However, because these intermediate landing destination codes are dropped (due to the potential for double counting), it is quite possible that "L" landings reported for a trip may have been taken by another trip where the landings were declared by an intermediate code. This issue cannot be resolved within the current MPI catch reporting system because it is not designed to maintain the integrity of catches among trips. Consequently, in these situations, the linking method of Starr (2007) may result in biased estimates of CPUE, with landings associated with an incorrect measure of effort. The use of intermediate landing destinations has been common in the rock lobster fishery, where catches have been left in holding pots (destination code "P") beginning in the early 2000s (Starr 2016). Kendrick & Bentley (2012) noted that this was a particular problem in the SPO 1 setnet fishery, where an increasing proportion of landings use the intermediate code "Q" because operators in this QMA hold landings in freezers for a period of time before taking them to a LFR, mostly likely due to economic reasons. For instance, the LFRs may limit the amount of landings permitted in a time period or the operators may wait for a more favourable beach price. Destination codes for the two SKI QMAs have been examined, concluding that there is little evidence that this type of behaviour is any component of SKI 1 or SKI 2. Only R landings even register in Table 5, at less than 0.1% of the total L landings, leading to the conclusion that this problem can be safely ignored for this species in these two QMAs.

Table 6: Total greenweight reported and number of events by state code in the landing file used to process the total SKI characterisation and CPUE data, arranged in descending landed weight (only for destination codes indicated as "Keep" in Table 5). These data summaries have been restricted to SKI 1 and SKI 2 from 1989–90 to 2012–13.

State code	Number Events	Total reported green weight (t)	Description
GRE	34 706	24 040.8	Green (or whole)
DRE	1 271	672.6	Dressed
HGU	2 013	232.6	Headed and gutted
Other	262	100.0	Other (misc)[1]

[1] includes (in descending order to 1.0 t): Headed, gutted, and tailed; Fillets: skin-on untrimmed; Gilled and gutted tail-on; Gutted; Fish meal; Fillets: skin-on.

2.3.2.2 State codes in the SKI landing data

Almost all (96%) of the valid landing data for SKI 1 and SKI 2 were reported using state code GRE, with the remaining landings (less than 4%) spread out primarily among DRE and HGU codes (Table 6). There have been virtually no changes to the conversion factors, given that GRE has a conversion factor of 1.0 and there was only a minor change in the DRE conversion factor (from 1.60 to 1.55) between 1990–91 and 1991–92 (Table 7).

Table 7: Median conversion factor for the six most important state codes reported in (in terms of total landed greenweight) and the total reported greenweight by fishing year in the edited file used to process SKI landing data. These data summaries are for the total SKI 1&2 landing data set over the period 1989–90 to 2012–13. '–': no observations.

					Landed State Code			
Fishing	Conversion factor by State Code				Total landed weight by State Code			
Year	GRE	DRE	HGU	Other	GRE	DRE	HGU	Other
89/90	1	–	1.5	1.6	2 080.2	–	55.2	116.7
90/91	1	1.60	1.5	1.6	1 831.5	66.2	48.2	19.1
91/92	1	1.55	1.5	1.1	2 179.6	73.5	21.1	0.3
92/93	1	1.55	1.5	1.1	2 455.0	81.3	10.0	0.8
93/94	1	1.55	1.5	1.1	2 205.4	74.8	8.6	0.1
94/95	1	1.55	1.5	1.1	1 898.5	31.9	47.8	3.4
95/96	1	1.55	1.5	1.1	1 514.5	37.0	6.6	15.8
96/97	1	1.55	1.5	2.15	1 825.2	23.4	12.5	18.4
97/98	1	1.55	1.5	5.6	1 151.7	18.4	5.4	0.3
98/99	1	1.55	1.5	3.875	718.3	27.2	4.6	4.9

Fishing Year	Conversion factor by State Code				Landed State Code Total landed weight by State Code			
	GRE	DRE	HGU	Other	GRE	DRE	HGU	Other
99/00	1	1.55	1.5	2.65	879.9	28.2	4.6	3.8
00/01	1	1.55	1.5	5.6	624.8	41.1	10.2	5.1
01/02	1	1.55	1.5	5.6	420.8	43.2	9.2	5.4
02/03	1	1.55	1.5	5.6	486.1	37.8	9.6	3.2
03/04	1	1.55	1.5	5.6	487.6	58.6	13.5	13.6
04/05	1	1.55	1.5	5.6	462.1	29.2	9.2	1.9
05/06	1	1.55	1.5	5.6	383.5	25.8	4.8	1.8
06/07	1	1.55	1.5	2.4	485.5	34.0	5.4	0.2
07/08	1	1.55	1.5	5.6	438.6	23.8	4.6	0.3
08/09	1	1.55	1.5	5.6	365.9	22.6	5.2	0.1
09/10	1	1.55	1.5	5.6	395.4	28.1	10.4	0.2
10/11	1	1.55	1.5	5.6	467.9	44.7	19.2	0.2
11/12	1	1.55	1.5	5.6	352.2	19.3	9.8	0.4
12/13	1	1.55	1.5	5.6	292.9	24.0	16.5	1.6
Total	–	–	–	–	24 402.8	894.2	352.2	217.6

Table 8: Distribution of total landings (t) by gemfish Fishstock and by fishing year for all trips that recorded SKI landings, regardless of QMA. Seven landing records with improbable greenweights have been dropped (see Appendix C).

Fishing year	Gemfish QMA SKI 1	SKI 2	SKI 3	SKI 7	Total
89/90	1 090.1	949.6	159.5	53.0	2 252.2
90/91	1 025.1	825.3	62.3	50.2	1 962.9
91/92	1 007.6	1 154.8	40.6	71.6	2 274.6
92/93	1 346.0	1 009.2	54.1	137.8	2 547.2
93/94	1 153.6	1 064.6	9.3	61.4	2 288.9
94/95	1 009.6	878.4	68.5	25.1	1 981.6
95/96	739.2	795.1	18.6	20.9	1 573.8
96/97	955.9	892.1	4.3	27.3	1 879.6
97/98	630.0	543.7	0.9	1.2	1 175.7
98/99	410.4	338.6	0.7	5.3	755.1
99/00	407.5	506.9	0.4	1.6	916.4
00/01	355.1	314.9	0.4	10.8	681.1
01/02	204.1	266.3	2.3	5.9	478.6
02/03	204.4	312.7	1.9	17.7	536.7
03/04	216.4	300.6	12.9	43.4	573.3
04/05	238.0	256.1	1.9	6.3	502.2
05/06	226.4	181.7	0.9	6.9	415.9
06/07	205.5	310.4	0.4	8.8	525.0
07/08	216.6	245.6	1.0	4.1	467.3
08/09	194.6	189.2	0.2	9.8	393.8
09/10	248.1	176.8	0.5	8.7	434.1
10/11	222.5	287.0	0.5	22.1	532.1
11/12	213.2	155.6	0.2	12.6	381.7
12/13	182.3	140.0	0.8	11.9	335.0
Total	12 702.4	12 095.1	442.9	624.4	25 864.8

Green weight landings $\left(G'_{i,y}\right)$ were adjusted in the CPUE analysis and for some parts of the characterisation analysis for state code DRE to a consistent conversion factor using the following equation:

Eq. 2 $$G'_{i,s,y} = G_{i,s,y} \, cf_{i,s,2012-13} \big/ cf_{i,s,y}$$

where

$G_{i,s,y}$ is the reported green weight for record *i* using landed state code *s* in year *y*;

$cf_{i,s,y}$ is the conversion factor for record i using landed state code s in year y;

$cf_{i,s,2012-13}$ is the conversion factor for record i using landed state code s in year 2012–13 (=1.55 for DRE)

Total landings available in the data set are primarily from SKI 1, SKI 2 with a minor amount in SKI 3 and SKI 7 which come from trips which also landed either SKI 1 or SKI 2 (Table 8).

2.3.2.3 Form types used in the SKI landing and effort data

Unlike many inshore species, landings from SKI 1 and SKI 2 have been predominantly by the CLR form rather than the CELR form (see three left columns in Table 9). This is because there was a commitment in the mid-1990s made by the two major fishing companies operating at the time in FMA 1, FMA 2 and FMA 9 to report on the tow-by-tow TCEPR form rather than the more usual daily CELR form used by most inshore fishermen. This shift can be seen in Table 9, with a switch in the mid-1990s away from the CELR form (expressed as a percentage of annual landings) to the CLR form, which is the form used to record landings from the TCEPR form. This shift occurred in both SKI 1 and SKI 2, with the shift delayed one or two years in SKI 2 compared to SKI 1 (Figure 5). Other operators continued to use the CELR form, but this accounted for between 9 and 28% of the landings, with an increasing trend in the mid-2000s (Table 9). Use of the CELR form dropped to below 5% after the introduction of the tow-by-tow TCER form, which was mandatory for all vessels greater than 6 m (Table 9).

Table 9: Distribution by form type for landed catch by weight for each fishing year in the SKI 1&2 landings dataset. Also provided are the number of days fishing and the associated distribution of days fishing by form type for the combined SKI 1&2 effort data. See Appendix A for definitions of abbreviations used in this table.

	Landings (%)[1]			Days Fishing (%)[2]				Days Fishing				
	CELR	CLR	NCELR	CELR	TCEPR	TCER	LTCER	CELR	TCEPR	TCER	LTCER	Total[3]
89/90	81	19	0	77	23	–	–	3 459	1 013	–	–	4 472
90/91	75	25	0	74	26	–	–	4 580	1 584	–	–	6 164
91/92	73	27	0	79	21	–	–	5 173	1 403	–	–	6 576
92/93	64	37	0	74	26	–	–	5 299	1 855	–	–	7 154
93/94	33	67	0	64	36	–	–	4 296	2 411	–	–	6 707
94/95	27	73	0	61	39	–	–	3 585	2 256	–	–	5 841
95/96	19	81	0	43	57	–	–	2 633	3 437	–	–	6 070
96/97	22	78	0	44	56	–	–	2 903	3 693	–	–	6 596
97/98	13	87	0	44	56	–	–	2 769	3 531	–	–	6 300
98/99	17	83	0	44	56	–	–	2 495	3 121	–	–	5 616
99/00	9	91	0	43	57	–	–	2 393	3 133	–	–	5 526
00/01	11	89	0	43	57	–	–	2 426	3 277	–	–	5 703
01/02	12	88	0	38	62	–	–	2 418	3 873	–	–	6 291
02/03	18	82	0	46	54	–	–	2 998	3 505	–	–	6 503
03/04	17	83	0	42	58	–	–	2 697	3 741	–	–	6 480
04/05	21	79	0	46	53	–	–	2 853	3 313	–	–	6 215
05/06	28	72	0	47	51	–	–	3 160	3 417	–	–	6 659
06/07	24	76	0.1	52	46	–	–	3 374	2 969	–	–	6 428
07/08	1	99	0.1	3	38	27	28	170	2 433	1 730	1 771	6 402
08/09	5	95	0.5	3	40	29	22	195	2 361	1 677	1 303	5 867
09/10	4	96	0.04	3	40	31	22	195	2 742	2 079	1 512	6 800
10/11	4	96	0.01	3	40	28	26	194	2 910	2 057	1 916	7 338
11/12	3	96	0.6	2	40	30	26	121	2 484	1 902	1 652	6 262
12/13	2	96	1.6	3	35	34	26	161	2 125	2 016	1 569	6 006
Total	38	62	0.04	40	44	8	6	60 547	66 587	11 461	9 723	149

[1] Percentages of landed greenweight
[2] Percentages of number of days fishing
[3] NCELR: 525 days fishing and LCER: 1133 days fishing omitted

The effort data (calculated as days fishing) show a considerable amount of effort reported using the event-level line fishing form after it became mandatory in 2007–08 (see nine left-most columns in Table 9). The explanation for this must be that many of the vessels that landed SKI 1 and SKI 2 also did some line fishing, given the wording of the characterisation data request. This effort would be associated with the CELR form before 2007–08, which would explain the high percentages in the effort part of Table 9 associated with that form before that year. There was a corresponding drop in the usage of the CELR form in the effort data after 2007–08 with the introduction of the mandatory LTCER form.

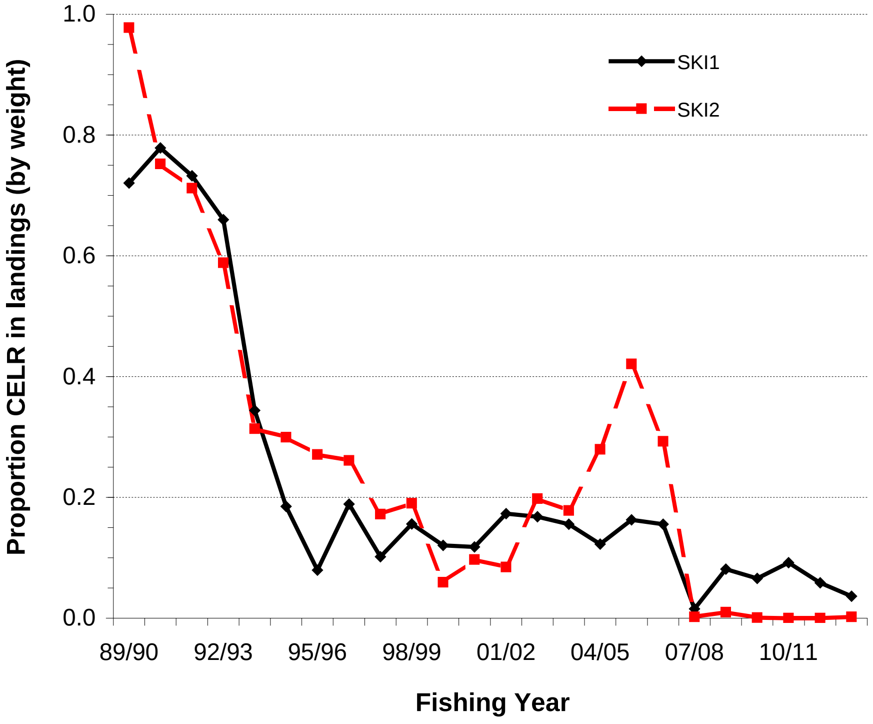

Figure 5: Time series of the proportion of landings (by weight) reported on the CELR form for SKI 1 and SKI 2.

2.3.3 Description of the SKI 1 and SKI 2 fisheries

2.3.3.1 Introduction

As discussed in Section 2.3.1, landings were matched with effort for every trip while maintaining the integrity of the QMA-specific information. This procedure worked well for both SKI QMAs because the shared statistical areas of Area 041 (with SKI 7 in the North Taranaki Bight, north of New Plymouth) and eastern Cook Strait, where Areas 016, 017 and 018 are shared with both SKI 3 and SKI 7, are not important locations for the capture of gemfish. Fortunately, the statistical area and QMA boundaries coincide between SKI 1 and SKI 2, at Cape Runaway in the eastern Bay of Plenty (Appendix B). The amount of lost landings due to dropping trips which fished in ambiguous statistical areas and landed multiple SKI QMAs amounted to about 2% of the total landings, which was considered acceptable for the purposes of characterising the fishery. The CPUE analysis data were selected on the basis of the statistical area fished rather than by the QMA.

The characterisation information in this section is presented by the following sub-regions within SKI 1 and SKI 2 (see Appendix B for the locations of the statistical areas):

Reported SKI region	Statistical Area definition
East Northland (EN)	SKI 1 & (001–007,105,106)
Bay of Plenty (BoP)	SKI 1 & (008–010,107)
SKI 2 North (SKI2N)	SKI 2 & (011–013,201–203)
SKI 2 South (SKI2S)	SKI 2 & (014–019,204–206)
SKI 1W	SKI 1 & (041–048, 101–104)

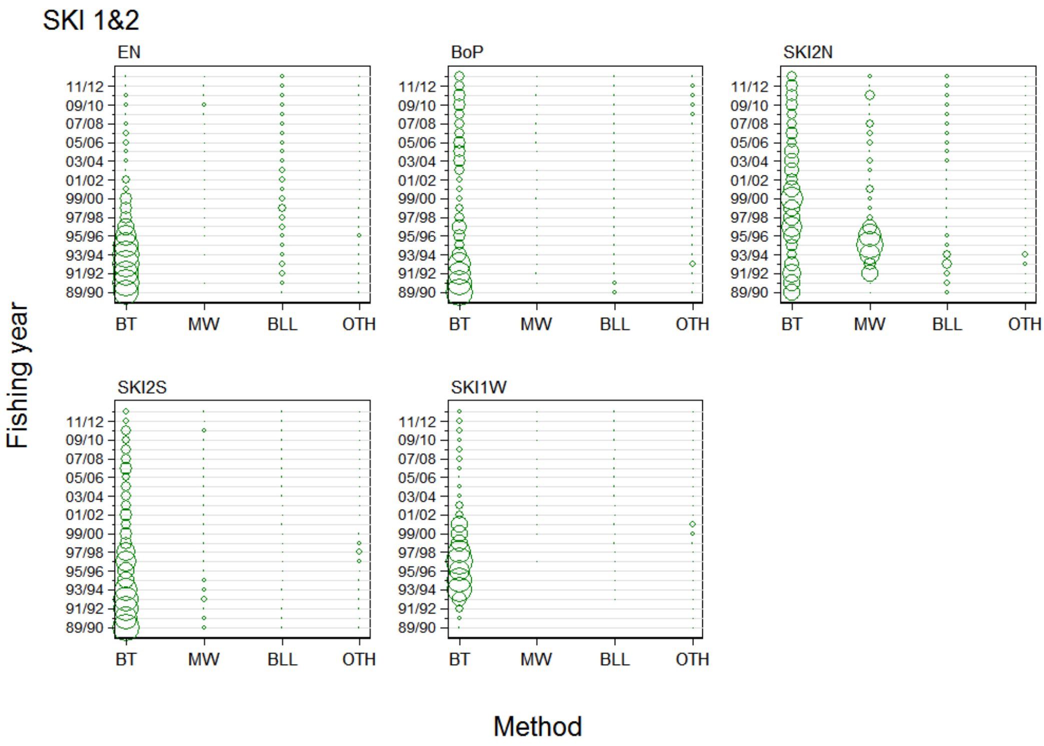

Figure 6: Distribution of gemfish landings in the SKI 1 and SKI 2 sub-regions for the major fishing methods by fishing year from 1989–90 to 2012–13. Circles are proportional to the catch totals by method and fishing year within each sub-graph: [EN]: largest circle= 391 t in 92/93 for BT; [BoP]: largest circle= 888 t in 89/90 for BT;[SKI2N]: largest circle= 410 t in 94/95 for MW; [SKI2S]: largest circle= 865 t in 89/90 for BT; [SKI1W]: largest circle= 592 t in 96/97 for BT. Data for these plots are presented in Table E.1.

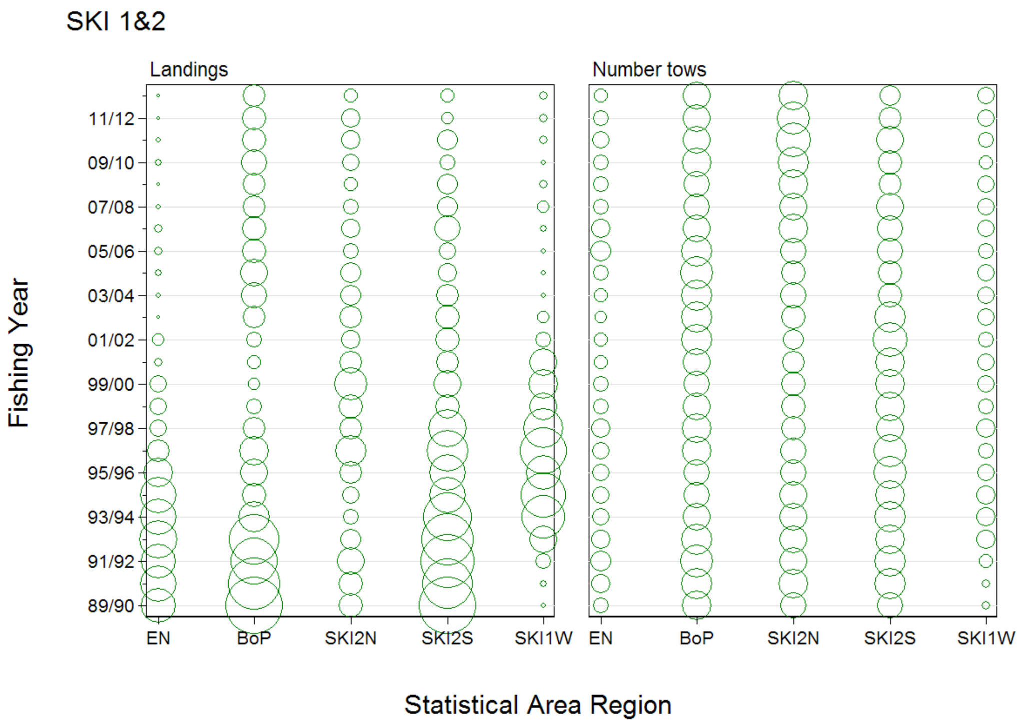

Figure 7: Distribution of gemfish bottom trawl landings and number tows in the SKI 1 and SKI 2 sub-regions by fishing year from 1989–90 to 2012–13. Circles are proportional to the catch totals by method and fishing year within each sub-graph: [Landings]: largest circle= 888 t in 89/90 for BoP; [Number tows]: largest circle= 4464 tows in 01/02 for SKI 2S.

Table 10: Total landings (t) and distribution of landings (%) for gemfish for important fishing methods in the SKI 1&2 sub-regions from trips which landed gemfish, summed from 1989–90 to 2012–13.

SKI 1&2 Region	BT	MW	BLL	Other	Total
	Method				
	Total landings (t)				
EN	2 892	19	310	28	3 250
BoP	5 845	36	173	172	6 226
SKI2N	2 963	1 570	302	28	4 863
SKI2S	7 099	193	66	125	7 483
SKI1W	3 583	1	30	53	3 667
Total	22 383	1 818	881	405	25 488
	Distribution of landings (%)				
EN	89.0	0.6	9.5	0.9	12.7
BoP	93.9	0.6	2.8	2.8	24.4
SKI2N	60.9	32.3	6.2	0.6	19.1
SKI2S	94.9	2.6	0.9	1.7	29.4
SKI1W	97.7	0.0	0.8	1.4	14.4
Total	87.8	7.1	3.5	1.6	100.0

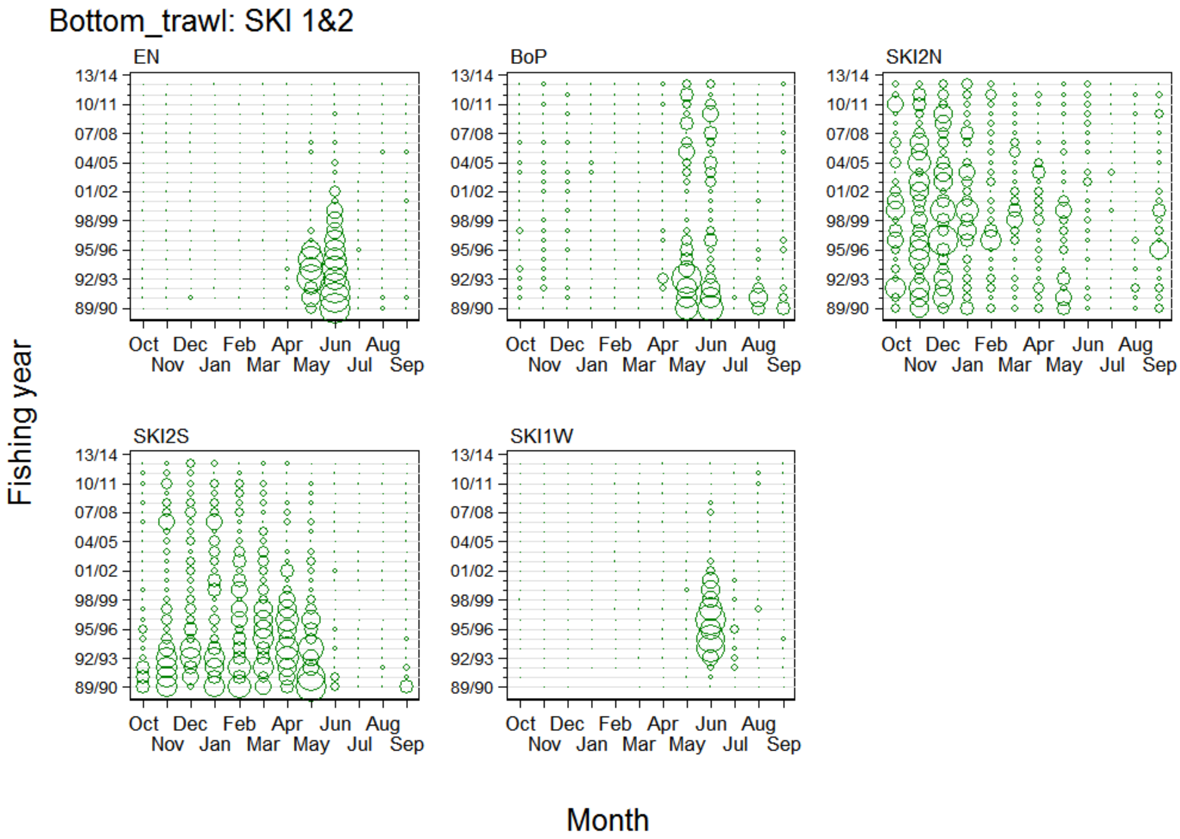

Figure 8: Distribution of bottom trawl landings by month and fishing year in the SKI 1&2 sub-regions based on trips which landed gemfish. Circle sizes are proportional within each panel: [EN]: largest circle= 263 t in 89/90 for Jun; [BoP]: largest circle= 481 t in 92/93 for May; [SKI2N]: largest circle= 101 t in 96/97 for Dec; [SKI2S]: largest circle= 239 t in 89/90 for May; [SKI1W]: largest circle= 586 t in 96/97 for Jun. Values for the plotted data are provided in Table E.2.

2.3.3.2 Distribution of landings and effort by method of capture and QMA

Gemfish in SKI 1 and SKI 2 are taken almost entirely by bottom trawl (88% BT over the 24 year period: Figure 6; Table 10; Table E.1). There is also a midwater trawl component in the northern statistical areas of SKI 2 (Table 10). As noted in Table 9, there is a component of bottom longline fishing for gemfish in SKI 1 and the northern part of SKI 2 (Table 10). A plot of bottom trawl landings and number of tows (Figure 7) shows how the gemfish fishery waned in the mid-1990s as the TACCs were reduced in response to reduced gemfish abundance. This occurred first in East Northland and the Bay of Plenty and then later on the west coast of the North Island. The Bay of Plenty fishery recovered in the early 2000s to a relatively constant but low level. The bottom trawl fishery north of Mahia has been relatively small compared to the larger Bay of Plenty/East Northland fisheries, but has been reasonably consistent in the face of the TACC reductions while the Hawke Bay/Wairarapa BT fishery has dropped considerably from its high levels in the early 1990s. The effort side of Figure 7 shows very little difference within each region across the years.

2.3.3.3 Seasonal distribution of landings

The seasonal aspect of the SKI 1 bottom trawl fishery for gemfish is shown in Figure 8, with the majority of the landings in East Northland and the Bay of Plenty taking place in May and June, which is when this species aggregates to spawn (Table E.2). The west coast North Island fishery (SKI 1W) is even more constrained in terms of timing, with the entire fishery occurring in June (Figure 8). That fishery began in the mid-1990s, later than in the Bay of Plenty and East Northland spawning fisheries, reflecting the later discovery of this spawning aggregation. The two SKI 2 east coast fisheries are more spread out in timing (Figure 8; Table E.2). This is because these two fisheries are directed at gemfish when they are more dispersed before they migrate north to spawn. This can be seen in the seasonal timing plots for SKI 2N and SKI 2S, with the virtual cessation of these two fisheries after May, only to resume again in September/October (Figure 8).

2.3.3.4 Distribution of landings by declared target species

The large majority of the bottom trawl fishery which catches gemfish is targeted at gemfish, regardless of the sub-region of capture (Figure 9; Table 11; Table E.3). Other species targeted by the bottom trawl fishery when it catches gemfish include tarakihi, hoki and scampi (the latter in the Bay of Plenty and SKI 2S). The midwater trawl fishery in SKI 2N is also primarily targeted at gemfish. The bottom longline fishery, when it catches gemfish, tends to target bluenose (Figure 9; Table 11), although the BLL fishery in EN and SKI 2N also targets gemfish.

Table 11: Total landings (t) and distribution of landings (%) for gemfish by target species and method of capture in the SKI 1&2 sub-regions from trips which landed gemfish, summed from 1989–90 to 2012–13. "–": no data for indicated sub-region/method/target species cell.

Target	Method of Capture (t)					Method of Capture				
species	BT	MW	BLL	Other	Total	BT	MW	BLL	Other	Total
East Northland										
SKI	2 678	0	54	1	2 733	82.4	0.0	1.7	0.0	84.1
BNS	0	0	184	3	187	0.0	0.0	5.7	0.1	5.8
TAR	103	0	1	6	109	3.2	0.0	0.0	0.2	3.4
HPB	1	–	64	4	69	0.0	–	2.0	0.1	2.1
SNA	22	–	2	1	26	0.7	–	0.1	0.0	0.8
SCI	21	–	–	–	21	0.6	–	–	–	0.6
HOK	21	0	–	–	21	0.6	0.0	–	–	0.6
RBY	2	19	–	–	20	0.0	0.6	–	–	0.6
OTH	46	0	4	13	64	1.4	0.0	0.1	0.4	2.0
Total	2 892	19	310	28	3 250	89.0	0.6	9.5	0.9	100.0

Target species	Method of Capture (t) BT	MW	BLL	Other	Total	Method of Capture BT	MW	BLL	Other	Total
Bay of Plenty										
SKI	4 611	9	2	23	4 644	74.1	0.1	0.0	0.4	74.6
TAR	422	–	0	102	525	6.8	–	0.0	1.6	8.4
HOK	328	0	–	10	338	5.3	0.0	–	0.2	5.4
SCI	267	–	–	–	267	4.3	–	–	–	4.3
BNS	0	3	136	13	153	0.0	0.1	2.2	0.2	2.5
RBY	40	23	–	1	64	0.6	0.4	–	0.0	1.0
LIN	50	–	13	0	64	0.8	–	0.2	0.0	1.0
HAK	39	–	–	0	39	0.6	–	–	0.0	0.6
OTH	89	1	22	23	134	1.4	0.0	0.3	0.4	2.2
Total	5 845	36	173	172	6 226	93.9	0.6	2.8	2.8	100.0
SKI 2N										
SKI	1 894	1 298	101	19	3 313	39.0	26.7	2.1	0.4	68.1
TAR	814	0	0	1	816	16.7	0.0	0.0	0.0	16.8
RBY	29	213	–	–	242	0.6	4.4	–	–	5.0
HOK	146	0	0	–	146	3.0	0.0	0.0	–	3.0
BNS	2	3	126	0	131	0.0	0.1	2.6	0.0	2.7
BYX	3	54	0	–	57	0.1	1.1	0.0	–	1.2
LIN	17	–	35	1	53	0.4	–	0.7	0.0	1.1
OTH	57	2	40	6	105	1.2	0.0	0.8	0.1	2.2
Total	2 963	1 570	302	28	4 863	60.9	32.3	6.2	0.6	100.0
SKI 2S										
SKI	5 273	25	1	20	5 320	70.5	0.3	0.0	0.3	71.1
HOK	527	26	–	6	559	7.0	0.3	–	0.1	7.5
TAR	487	0	0	0	487	6.5	0.0	0.0	0.0	6.5
SCI	465	–	–	–	465	6.2	–	–	–	6.2
BYX	155	85	1	–	241	2.1	1.1	0.0	–	3.2
WAR	40	0	0	87	127	0.5	0.0	0.0	1.2	1.7
BNS	37	32	53	2	125	0.5	0.4	0.7	0.0	1.7
OTH	114	24	11	10	159	1.5	0.3	0.2	0.1	2.1
Total	7 099	193	66	125	7 483	94.9	2.6	0.9	1.7	100.0
SKI 1W										
SKI	3 312	0	1	48	3 362	90.3	0.0	0.0	1.3	91.7
TAR	120	–	0	1	121	3.3	–	0.0	0.0	3.3
LIN	100	–	1	0	100	2.7	–	0.0	0.0	2.7
HPB	0	–	20	1	21	0.0	–	0.6	0.0	0.6
SNA	17	–	0	1	18	0.5	–	0.0	0.0	0.5
OTH	34	1	7	2	45	0.9	0.0	0.2	0.1	1.2
Total	3 583	1	30	53	3 667	97.7	0.0	0.8	1.4	100.0

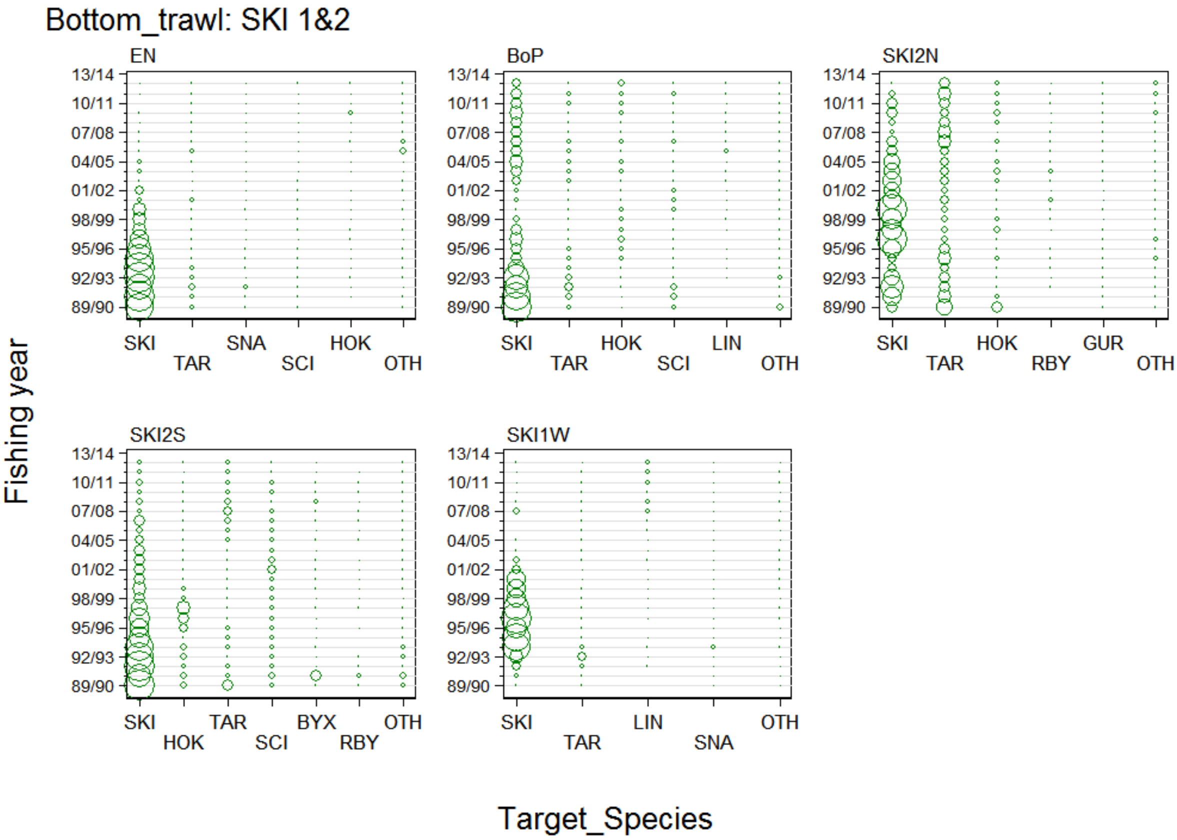

Figure 9: Distribution of bottom trawl landings by target species (ranked in terms of descending order of total landings) and fishing year in the SKI 1&2 sub-regions for trips which landed gemfish. Circle sizes are proportional within each panel: [EN]: largest circle= 375 t in 92/93 for SKI; [BoP]: largest circle= 793 t in 89/90 for SKI; [SKI2N]: largest circle= 260 t in 99/00 for SKI; [SKI2S]: largest circle= 707 t in 89/90 for SKI; [SKI1W]: largest circle= 588 t in 96/97 for SKI. Values for the plotted data are provided in Table E.3.

2.3.3.5 Preferred bottom trawl fishing depths for gemfish

Depth information is available from TCEPR and TCER forms which report bottom trawl catches pertaining to gemfish (either recording an estimated catch of gemfish or declaring gemfish as the target species). These data come either from the TCER forms introduced on 1 October 2007 or the longstanding TCEPR forms, which are primarily used by the larger offshore vessels with the exception of FMA 1, FMA 2 and FMA 9, where these forms have been in general use since the mid-1990s (see discussion in Section 2.3.2.3 above). The TCEPR forms have been in operation since the first year of data in this report (1989–90), with approximately 85% of the depth observations reported in Table 12 originating from the TCEPR forms, accumulated over the 24 years.

Reported depth observations, summarised by combining both form types beginning in 1989–90, show that target gemfish bottom trawl fishing tends to be a deep fishery in all five regions, with the lowest mean depth being 244 m in SKI 2S and the deepest mean depth being 341 m in SKI 1W (Table 12). There is very little difference between the mean and median depths. The depth distribution of tows which caught or targeted gemfish varies according to the remaining target fisheries in the five regions, with most being relatively deep fisheries like scampi, hoki, ling and alfonsino (Figure 10). In the context of capturing gemfish, tarakihi is a relatively shallow fishery, with mean depths that take gemfish being below 200 m. There are relatively few observations of gemfish capture by the even more shallow fisheries, such as red gurnard (Figure 10).

Table 12: Summary statistics in the SKI 1&2 sub-regions from distributions from all records (combined TCER and TCEPR formtypes) using the bottom trawl method for effort that targeted or caught gemfish by target species category. Data are summarised by sub-region from 1989–90 to 2012–13.

					Depth (m)
Target species	Number	Lower 5% of	Mean of	Median (50%) of	Upper 95% of
East Northland					
SKI	2 114	162	281	285	370
TAR	418	117	216	210	320
SCI	405	337	362	360	410
BYX	72	590	619	625	652
HOK	51	210	395	395	500
LIN	36	192	374	390	450
Other	50	84	280	303	550
Total	3 146	158	293	290	405
Bay of Plenty					
SCI	4 864	340	387	390	430
SKI	2 575	151	312	329	400
TAR	2 033	108	194	200	260
HOK	1 373	210	367	380	452
LIN	245	290	404	419	468
RBY	183	160	327	345	410
Other	167	80	270	270	450
Total	11 440	144	331	360	430
SKI 2N					
TAR	3 953	63	123	119	200
SKI	1 904	145	271	296	368
HOK	446	110	226	200	415
GUR	149	40	82	80	122
RBY	113	185	283	294	350
SCI	87	325	367	370	404
LIN	69	200	371	400	470
Other	176	80	268	200	599
Total	6 897	70	181	149	355
SKI 2S					
SCI	6 784	304	347	345	398
SKI	3 971	132	244	239	390
TAR	2 035	92	145	140	210
HOK	1 548	153	329	308	508
BYX	202	235	419	444	520
GUR	144	51	83	84	123
WAR	107	50	94	90	140
Other	299	90	292	300	520
Total	15 090	112	286	317	415
SKI 1W					
SKI	1 541	200	341	350	400
TAR	269	105	192	185	325
LIN	165	200	389	400	460
BYX	35	430	528	524	600
HOK	25	350	422	400	583
Other	75	110	300	320	405
Total	2 110	162	328	350	430

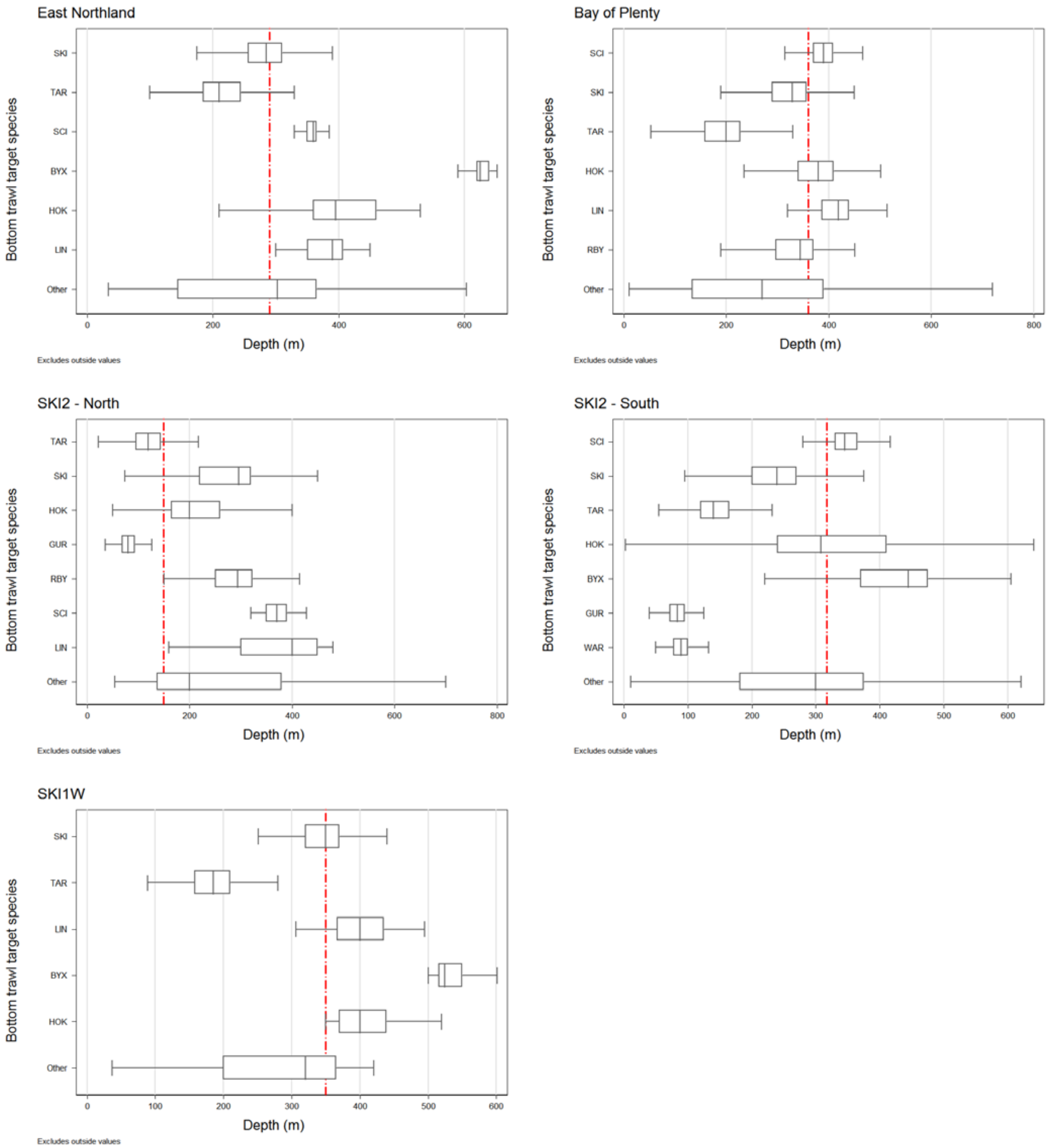

Figure 10: Box plot distributions of bottom depth from combined TCER and TCEPR formtypes using the bottom trawl method for effort that targeted or caught gemfish in the five SKI 1&2 sub-regions by target species category for the period 1989–90 to 2012–13. The vertical line in each panel indicates the median depth from all tows which caught or targeted gemfish.

2.3.3.6 Fine scale distribution of landings and CPUE for setnet and bottom trawl

Bottom trawl landings of gemfish occur on both coasts of the North Island in relatively localised areas of high catches. Two plots are provided, each showing the distribution of landings in two separate decades, 1989–90 to 1998–99 (Figure 11) and 2003–04 to 2012–13 (Figure 12). A second set of plots which shows the pattern of positive trawl CPUE (in kg/h) are provided, again with one showing the distribution of CPUE in the first ten years in the data set (1989–90 to 1998–99: Figure 13) and the other showing the CPUE in the final ten years in the data set (2003–04 to 2012–13: Figure 14). These pairs of plots demonstrate how the fishery for this species has changed as a result of the 80+% drop in the combined SKI 1&2 TACC from 2452 t in 1996–97 to 450 t by 2001–02 (see Table 1). These changes are particularly important given the seasonal nature of the gemfish fishery and the almost total disappearance of the early winter targeted fishery on gemfish spawning aggregations on both North Island coasts (see Figure 8). A comparison of Figure 11 with Figure 12 shows how landings in East Northland and the northwest coast have almost completely disappeared. There are still strong landings in the Bay of Plenty and off Hawke's Bay and the Wairarapa, but the scale of the landings has halved in the second plotted decade. The CPUE comparison is similar, with the highest CPUE in the first decade occurring in East Northland and the northwest North Island (Figure 13). CPUE in the final decade is highest in the Bay of Plenty, off of Gisborne and in various locations off the Wairarapa, but the scale of the CPUE in the second plot is about one-quarter of the high CPUEs observed in the first decade (Figure 14).

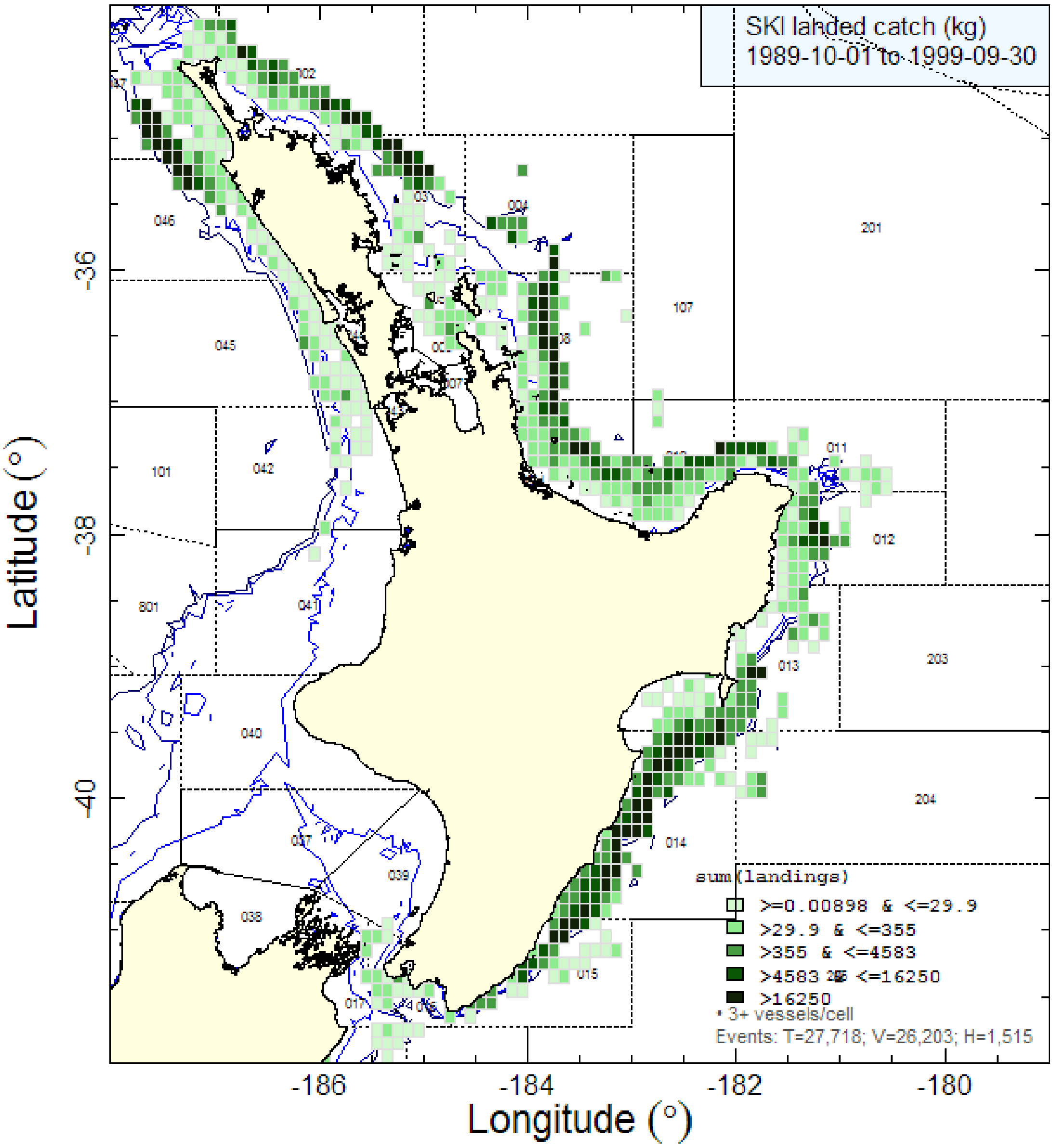

Figure 11: Total bottom trawl landings (t) for gemfish on the North Island, arranged in 0.1° × 0.1° grids, summed from 1989–90 to 1998–99. Legend colours divide the distribution of total landings into 25%, 50%, 75%, 90% and 95% quantiles. Only grids which have at least three reporting vessels are plotted. Boundaries are shown for the general statistical areas plotted in Appendix B and the bathymetry indicates the 100 m, 200 m and 400 m depth contours.

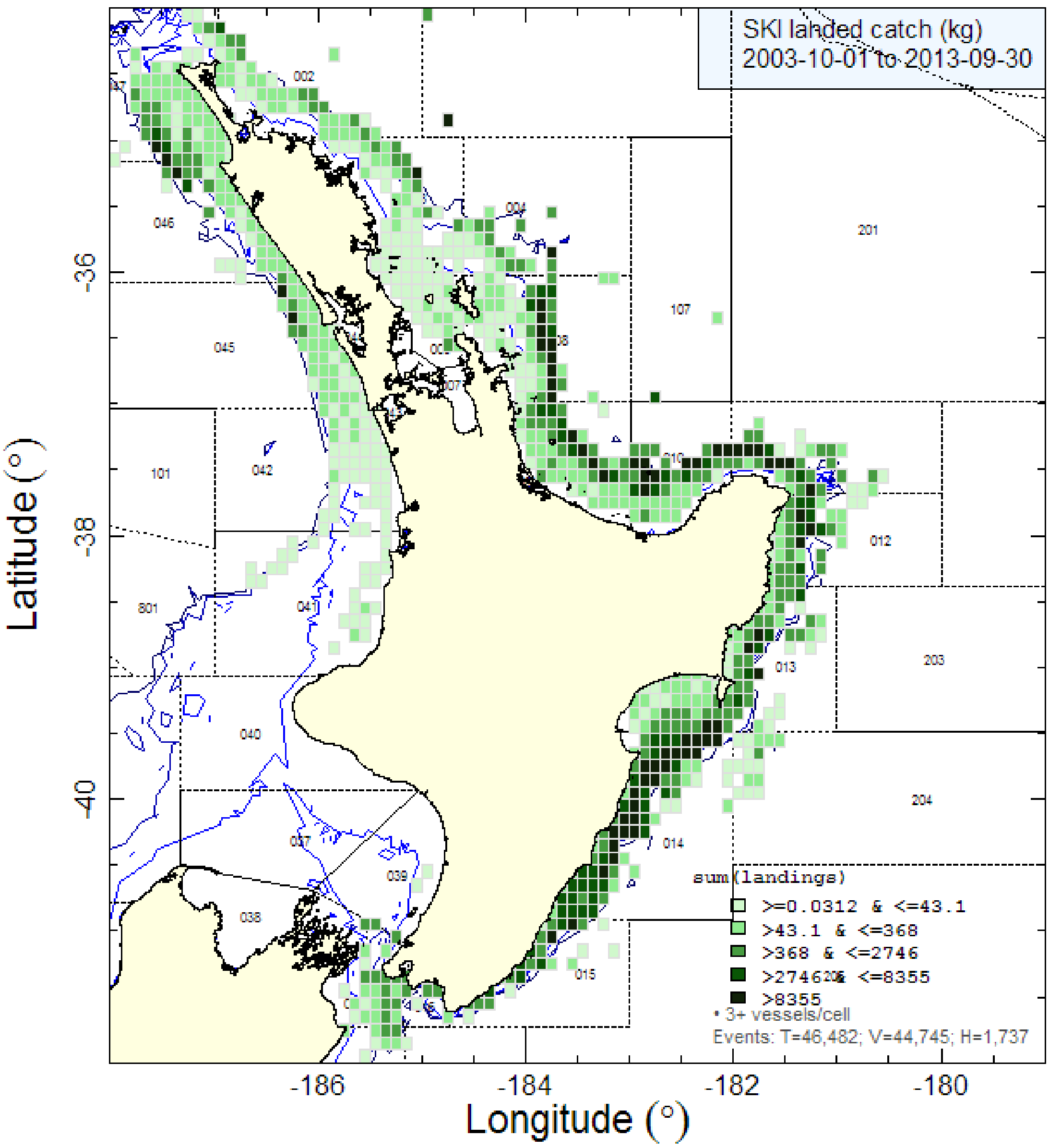

Figure 12: Total bottom trawl landings (t) for gemfish on the North Island, arranged in 0.1° × 0.1° grids, summed from 2003–04 to 2012–13. Legend colours divide the distribution of total landings into 25%, 50%, 75%, 90% and 95% quantiles. Only grids which have at least three reporting vessels are plotted. Boundaries are shown for the general statistical areas plotted in Appendix B and the bathymetry indicates the 100 m, 200 m and 400 m depth contours.

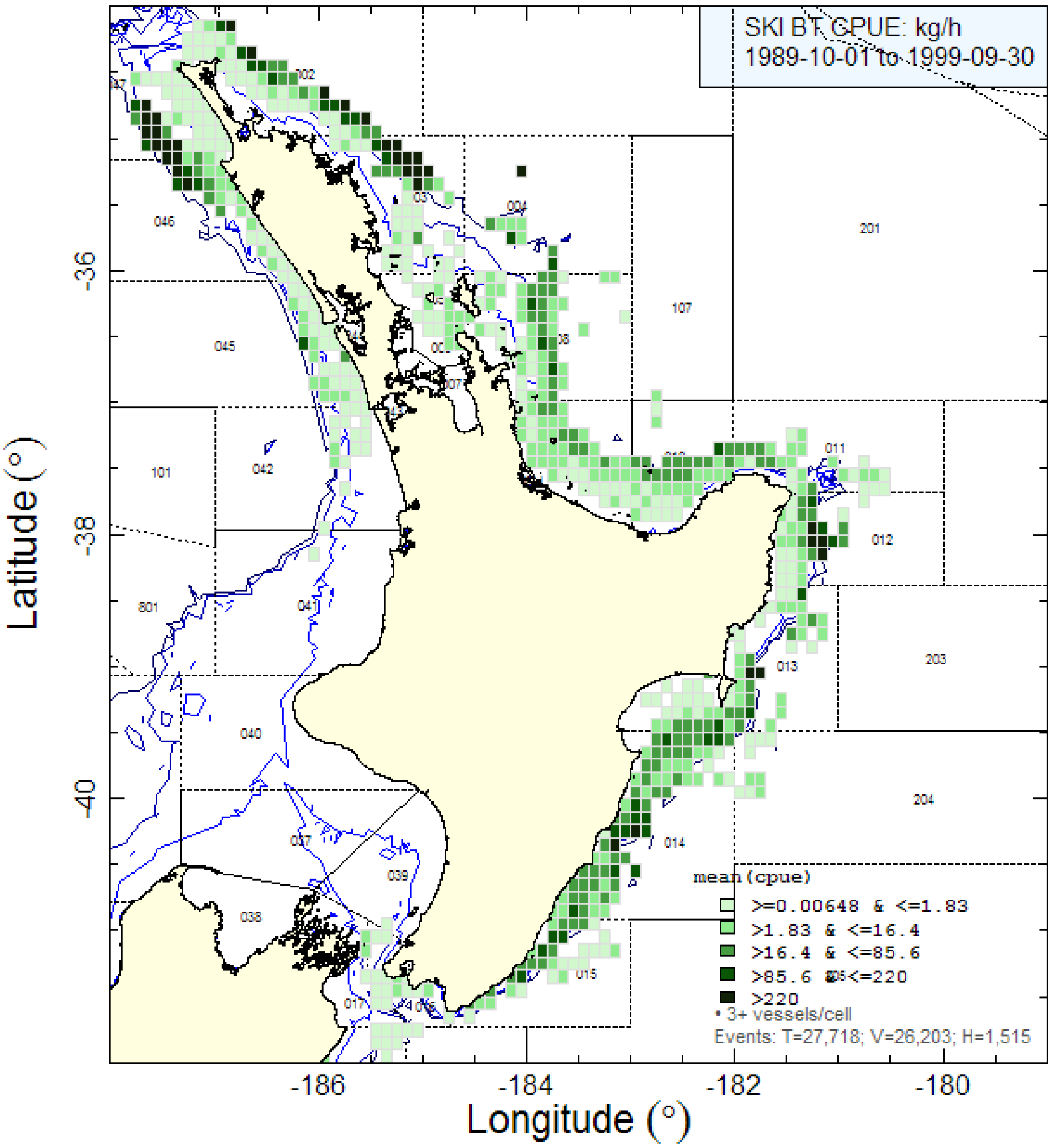

Figure 13: **Total bottom trawl CPUE (kg/h) for gemfish on the North Island, arranged in 0.1° × 0.1° grids, summed from 1989–90 to 1998–99. Legend colours divide the distribution of total landings into approximate 25%, 50%, 75%, 90% and 95% quantiles. Only grids which have at least three reporting vessels are plotted. Boundaries are shown for the general statistical areas plotted in Appendix B and the bathymetry indicates the 100 m, 200 m and 400 m depth contours.**

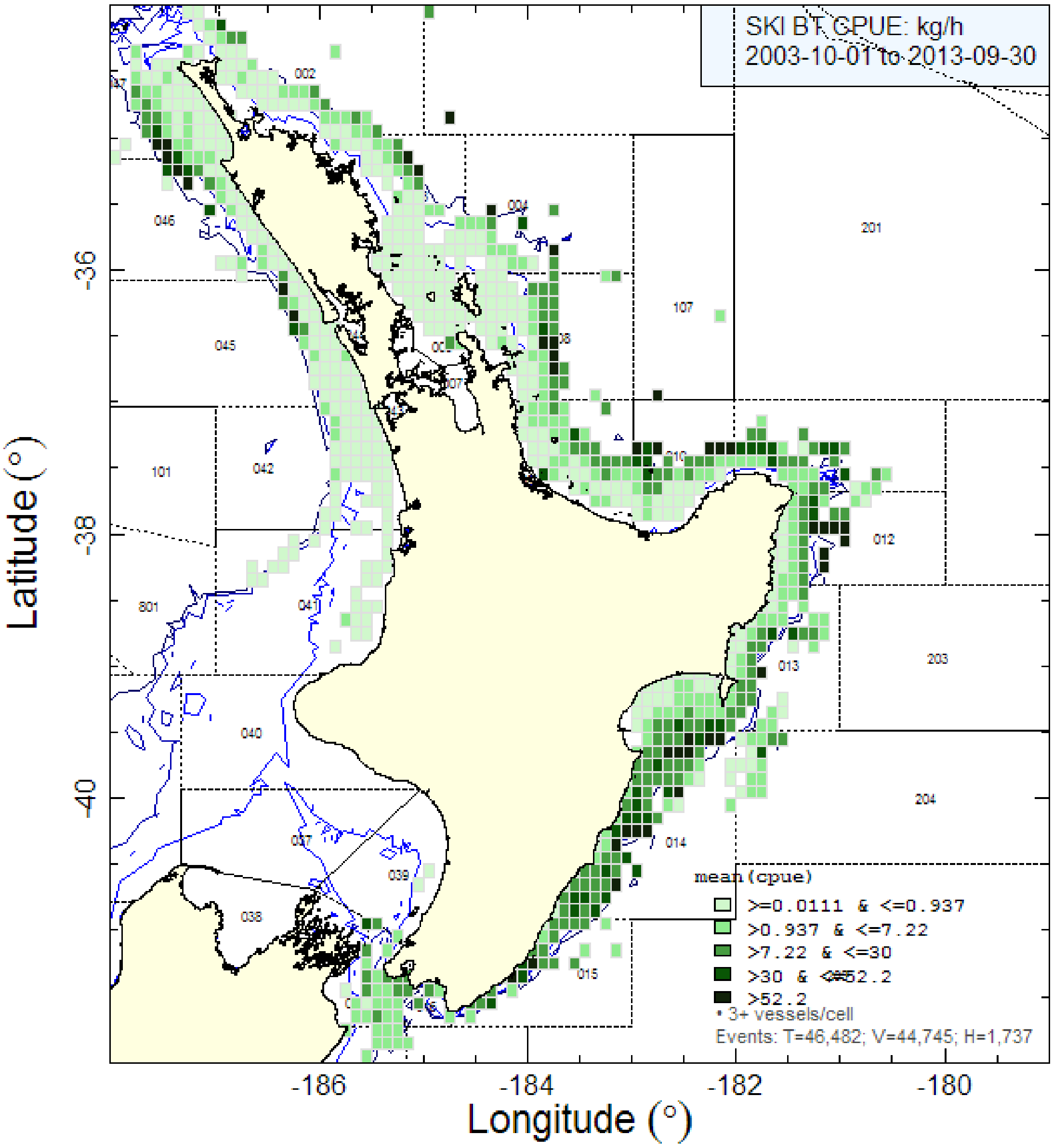

Figure 14: Total bottom trawl CPUE (kg/h) for gemfish on the North Island, arranged in 0.1° × 0.1° grids, summed from 2003–04 to 2012–13. Legend colours divide the distribution of total landings into approximate 25%, 50%, 75%, 90% and 95% quantiles. Only grids which have at least three reporting vessels are plotted. Boundaries are shown for the general statistical areas plotted in Appendix B and the bathymetry indicates the 100 m, 200 m and 400 m depth contours.

3. STANDARDISED CPUE ANALYSIS

CPUE analyses based on SKI 1 bottom trawl catch and effort data were ruled out as indices of relative abundance in 2007 by the NINSWG because of the severe contraction of that fishery, including the loss of the far north fisheries. While SKI 2 also experienced contraction, there exist a wider range of available data and a large part of the remaining fishery takes place in SKI 2. This project's objective was to use available catch and effort data for SKI 2 to develop CPUE analyses for monitoring the overall SKI 1 and SKI 2 stock.

Ten SKI 2 CPUE analyses were investigated, five of which were based on daily amalgamated records (see Section 2.3.1) while the remaining five used event-level (tow-by-tow) records. The daily analyses were preferred because there were insufficient data before 1993–94 in the tow-by-tow data sets to provide reliable indices and it was in this early period that the gemfish CPUE dropped precipitously. Table 13 lists the ten fishery CPUE models considered, showing the fishery definitions used for each model including the data preparation method, the form types used, the modelled year range, the statistical area definitions, the target species specifications, the core vessel rule and the selected best distribution:

Table 13: List of CPUE models considered as potential abundance monitoring indicators for SKI 2. Supporting diagnostics are reported in detail for the three fisheries highlighted in colour while a reduced set of diagnostics is provided for each of the remaining seven fisheries.

No.	Fishery	Data Prep Type	Forms	Year range	Statistical Areas	Target Species	Core Vessel Definition	Best distribution
1	SKI2_BT(MIX+SKI)	daily effort	CELR, TCEPR, TCER	1989–90 to 2012–13	011–019	GUR, SNA, TAR, LIN, BAR, HOK, SKI	5 trips/5 years	Lognormal
2	SKI2_BT(MIXnoSKI)	daily effort	CELR, TCEPR, TCER	1989–90 to 2012–13	011–019	GUR, SNA, TAR, LIN, BAR, HOK	5 trips/5 years	lognormal
3	SKI2_BT(SCI)	daily effort	CELR, TCEPR, TCER	1989–90 to 2012–13	014–015	SCI	3 trips/4 years	log.logistic
4	SKI2_BT(MIX+SKI)	tow-by-tow	TCEPR, TCER	1993–94 to 2012–13	011–019	GUR, SNA, TAR, LIN, BAR, HOK, SKI	5 trips/5 years	lognormal
5	SKI2_BT(MIXnoSKI)	tow-by-tow	TCEPR, TCER	1993–94 to 2012–13	011–019	GUR, SNA, TAR, LIN, BAR, HOK	5 trips/5 years	lognormal
6	SKI2_BT(SCI)	tow-by-tow	TCEPR, TCER	1993–94 to 2012–13	014–015	SCI	3 trips/4 years	log.logistic
7	SKI2_BT(MIX+SKI)	daily effort-	CELR, TCEPR, TCER	1989–90 to 2012–13	011–017	GUR, SNA, TAR, LIN, BAR, HOK, SKI	5 trips/5 years	lognormal
8	SKI2_BT(MIXnoSKI)	daily effort-	CELR, TCEPR, TCER	1989–90 to 2012–13	011–017	GUR, SNA, TAR, LIN, BAR, HOK	5 trips/5 years	lognormal
9	SKI2_BT(MIX+SKI)	tow-by-tow	TCEPR, TCER	1993–94 to 2012–13	011–017	GUR, SNA, TAR, LIN, BAR, HOK, SKI	5 trips/5 years	lognormal
10	SKI2_BT(MIXnoSKI)	tow-by-tow	TCEPR, TCER	1993–94 to 2012–13	011–017	GUR, SNA, TAR, LIN, BAR, HOK	5 trips/5 years	lognormal

Three (highlighted in colour in Table 13) of the above ten fisheries are reported in detail as Appendices which contain diagnostics, tabular output and plots for the selected model. These appendices are meant to serve as examples for the closely allied models, all of which contain a great deal of overlapping data with the example analyses, leading to similar diagnostics in each case (the Fishery Model Numbers below refer to first column in the above text table):

- Appendix G: SKI 2_BT(MIX+SKI)(daily) [Fishery Model No. 1 provides diagnostics as an example for allied fishery models 2, 7 and 8];
- Appendix H: SKI 2_BT(MIXnoSKI)(towbytow) [Fishery Model No. 5 provides diagnostics as an example for allied fishery models 4, 9 and 10];
- Appendix I: SKI 2_BT(SCI)(daily) [Fishery Model No.3 provides diagnostics as an example for allied fishery model 6];

Model selection tables, tables of CPUE indices and plots of the positive catch series and of the combined, binomial and positive catch series are provided in Appendix J for the seven CPUE series without detailed diagnostics.

3.1 SKI 2_BT(MIX+SKI)(daily):

The percentage of trips with zero SKI landings fluctuated between just over 40% to about 70% over the 24 year period [lower left panel] Figure G.2). The mean number of events per day of fishing jumped from 1.0 to nearly 1.3 from 2007–08 ([lower right panel]; Figure G.2), indicating that the daily-effort data preparation procedure did not completely adjust for the change from a daily to an event-based form type. The lognormal model explained 54% of the deviance (Table G.2), with target species, month, vessel and log(duration) entering the model after fishing year. There is a strong standardisation effect at the beginning of the series when the target species variable enters the model, adjusting for the shift away from targeting gemfish and switching to other species where the expected gemfish CPUE is much lower (Figure G.5, Figure G.7). The model fits the lognormal distribution well (Figure G.6), with the lognormal series showing a strong initial drop in the first two fishing years, followed by a long period with little or no trend (Figure G.4). The initial strong drop is seen in all the panels of the target×year implied residual plots, with the possible exception of LIN which has very little data (Figure G.11). The implied residual plots for area×year also match the strong initial decrease in all statistical areas, although the match is less obvious after the drop (Figure G.12). The combined series accentuates the strong initial decrease while the binomial series is nearly trendless (Figure G.13). The annual trend estimated by the SKI 2_BT(MIX+SKI)(daily) model is consistent with trends estimated by similar models by Fu et al. (2008) (Figure G.14). This analysis is supported by its diagnostics and can be used for monitoring the SKI 2 population that is vulnerable to this fishery.

3.2 SKI 2_BT(MIXnoSKI)(towbytow):

The percentage of trips with zero SKI landings decreased gradually from around 60% to near 40% over the 20 year period [lower left panel] Figure H.2). The mean number of events per record stayed at 1.0 because this is an event-based data set, but the mean effort (hours fished) dropped from about 3.6 to 2.2 hours/tow as the SKI target fishery waned into the late 1990s but the increased back to near 3.5 h/tow by the end of the series ([upper right panel] Figure H.2). The lognormal model explained 54% of the deviance (Table H.2), with month, area, bottom depth and vessel entering the model after fishing year. There is a strong standardisation effect in the middle and at the end of the series, when the area variable is added to the model because it compensates for high CPUE in this period due to a northward shift (predominantly off Gisborne) to statistical areas with high gemfish catch rates (Figure H.5; Figure H.8). The model fits the lognormal distribution well (Figure H.6), with the lognormal series showing a initial drop to a nadir in the early 2000s, followed by a gradually increasing trend to levels higher than the start of the series by 2012–13 (Figure H.4). The implied residual plots for area×year match the overall series trend in all statistical areas, as do the target species implied residuals, at least for those species with adequate amounts of data (Figure H.11, Figure H.12). The combined series looks very much like the lognormal series; with a slightly greater peak in 2011–12 than for the lognormal while the binomial series is nearly trendless (Figure H.13). The annual trend estimated by the SKI 2_BT(MIXnoSKI)(towbytow) model is reasonably consistent with the trend estimated by a similar model by Fu et al. (2008) (Figure H.14). This analysis is supported by its diagnostics and can be used for monitoring the SKI 2 population that is vulnerable to this fishery.

3.3 SKI 2_BT(SCI)(daily):

The percentage of trips with zero SKI landings is generally low, being less than 20% in most years [lower left panel] Figure I.2). The mean number of events per day of fishing declined gradually from around 3.0 to below 3.0 ([lower right panel] Figure I.2), indicating that the daily-effort data preparation procedure adjusted the change from a daily to an event-based form type reasonably well (or that it was not necessary due to the high level of event-based forms in use by this fishery). The mean duration per record increased gradually over the same period ([lower right panel] Figure I.2). The log-logistic model explained 37% of the deviance (Table I.2), with month, vessel and log(duration) entering the model after fishing year. There is a strong standardisation effect at the beginning of the series when the month variable enters the model, adjusting the year coefficients upward because of fishing during months when the expectation of catching gemfish is low (Figure I.5, Figure I.7). The model fits the log-logistic distribution only moderately (Figure I.6), with the positive log-logistic series showing a strong initial drop in the first three fishing years, followed by a long period with little or no trend, and a possible drop at the end of the series (Figure I.4). The implied residual plots for area x year are not very informative because there is really only a single area with adequate data to specify a series (Area 014; Figure I.10). The combined series accentuates the strong initial decrease and drops a bit more at the end of the series, giving an overall decline after the steep initial decline while the binomial series is nearly trendless (Figure I.11). While this SKI 2_BT(SCI)(daily) model was developed as a sensitivity model, given the relatively small number of vessels and records and the limited spatial extent of the fishery, the estimated annual trend shows good consistency with the SKI 2_BT(MIX+SKI)(daily) and the SKI 2_BT(MIXnoSKI)(daily) models (Figure I.12).

3.4 Investigation of possible leverage of Area 018 data on the estimated year indices:

Appendix K investigates the possible leverage associated with the large amount of data in Area 018 which may influence the series trend estimated by the various SKI 2 models. As well, Area 018 is administratively part of SKI 3, not SKI 2. Figure K.1 demonstrates that there is no difference between the year coefficients estimated by paired models with and without Area 018. Table K.1 demonstrates that the annual implied residual coefficients for each area correlate well with the annual model coefficients. As well, the correlation of the Area 018 annual implied residual coefficients with the overall model year coefficients is as strong as the more northerly areas.

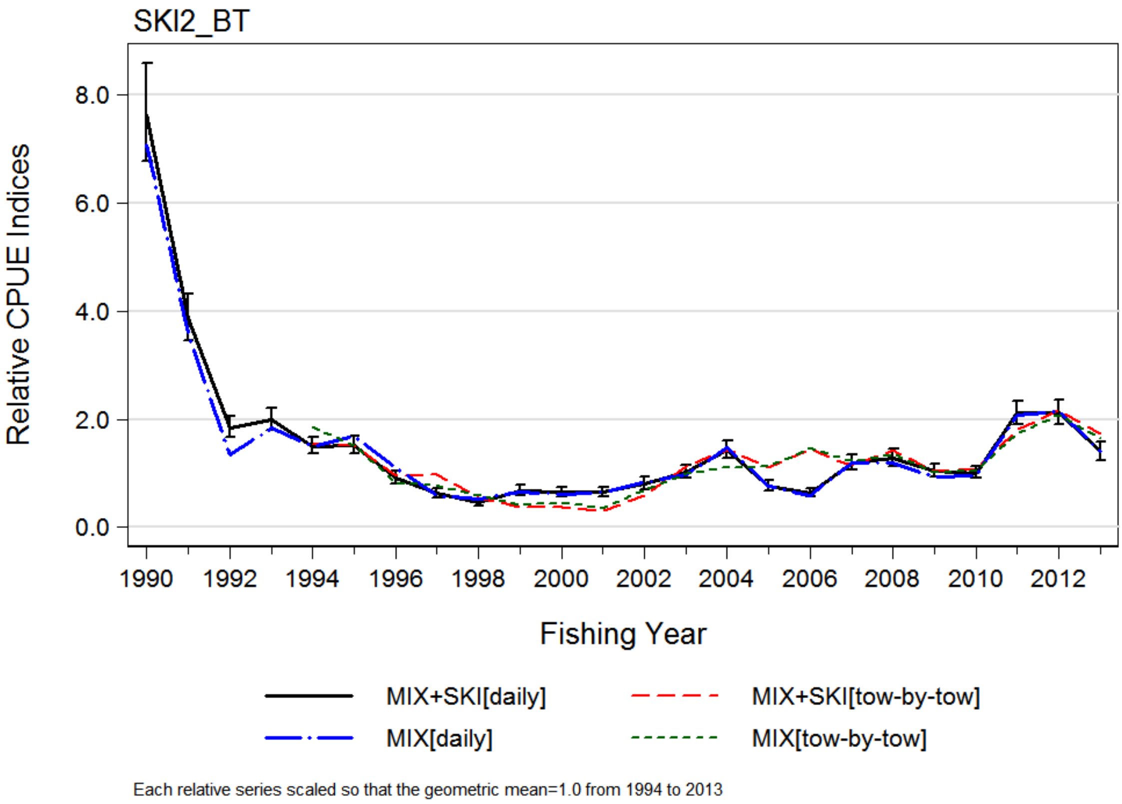

Figure 15: Comparison of the four main combined SKI 2 standardised CPUE series: a) SKI 2_BT(MIX+SKI)(daily); b) SKI 2_BT(MIXnoSKI)(daily); c) SKI 2_BT(MIXnoSKI)(towbytow); d) SKI 2_BT(MIX+SKI)(towbytow).

3.5 Conclusions

The two daily-effort series show a strong drop in the first two years, followed by an almost trendless series which is consistent among all four analyses (Figure 15). Although the series after 1991–92 appears nearly trendless because of the wide scale in the plot introduced by the strong drop between 1989–90 and 1991–92, a declining trend can be inferred that reaches a nadir in the late 1990s, around the time that the TACCs for SKI 1&2 were being reduced (Table 1). Since then, there is possible evidence that the indices have increased, although the increase has been modest compared to the initial decline (Figure 15).

The correspondence between the four main series (designated Fishery Models No. 1, 2, 4, 5 in Table 13) is excellent, with all four models in good agreement (Figure 15). This correspondence, as well as the corroboration from the independent analysis taken from gemfish bycatch in the SKI 2 scampi fishery (see Figure I.12), provide some confidence that these SKI 2 CPUE analyses appear to be tracking the underlying gemfish abundance in SKI 1 and SKI 2.

On reviewing the results of this study on 29 April 2014, the NINSWG made the following conclusions:

- Standardised CPUE for SKI was accepted as an index of abundance for the SKI 1+2 biological stock.

- The Mix+SKI daily analysis was accepted as the main index of abundance for this stock. The combined index (delta lognormal), with confidence intervals, were to be presented in the WG Report.
- Future CPUE analyses should include data from the Bay of Plenty, as the characterisation work revealed that sufficient catch and effort data are currently collected from this part of SKI 1 (especially from Statistical Area 008). The area:month residual implied coefficients may provide additional insight on the movement of gemfish.

4. ACKNOWLEDGEMENTS

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Appendix A. GLOSSARY OF ABBREVIATIONS, CODES, AND DEFINITIONS OF TERMS

Table A.1: Table of abbreviations and definitions of terms

Term/Abbreviation	Definition
AIC	Akaike Information Criterion: used to select between different models (lower is better)
AMP	Adaptive Management Programme
analysis dataset	data set available after completion of grooming procedure (Starr 2007)
arithmetic CPUE	Sum of catch/sum of effort, usually summed over a year within the stratum of interest
CDI plot	Coefficient-distribution-influence plot (see Figure G.7 for an example) (Bentley et al. 2012)
CELR	Catch/Effort Landing Return (Ministry of Fisheries 2010): active since July 1989 for all vessels less than 28 m. Fishing events are reported on a daily basis on this form
CLR	Catch Landing Return (Ministry of Fisheries 2010): active since July 1989 for all vessels not using the CELR or NCELR forms to report landings
CPUE	Catch Per Unit Effort
daily effort stratum	summarisation procedure which amalgamates catch and effort data to a day of fishing and assigns the predominant statistical area and target species to the associated data
destination code	code indicating how each landing was directed after leaving vessel (see Table 5)
EEZ	Exclusive Economic Zone: marine waters under control of New Zealand
estimated catch	an estimate made by the operator of the vessel of the weight of gemfish captured, which is then recorded as part of the "fishing event". Only the top 5 species are required for any fishing event in the CELR and TCEPR data (expanded to 8 for the TCER, LTCER and NCELR form types)
fishing event	a "fishing event" is a record of activity in trip. It is a day of fishing within a single statistical area, using one method of capture and one declared target species (CELR data) or a unit of fishing effort (usually a tow or a line set) for fishing methods using other reporting forms
fishing year	1 October – 30 September for gemfish
FMA	MPI Fishery Management Areas: 10 legal areas used by MPI to define large scale stock management units; QMAs consist of one or more of these regions
landing event	weight of gemfish off-loaded from a vessel at the end of a trip or otherwise disposed of as part of a transaction. Every landing has an associated destination code and there can be multiple landing events with the same or different destination codes for a trip
LCER	Lining Catch Effort Return (Ministry of Fisheries 2010): active since October 2003 for lining vessels larger than 28 m and reports set-by-set fishing events
LFR	Licensed Fish Receiver: processors legally allowed to receive commercially caught species
LTCER	Lining Trip Catch Effort Return (Ministry of Fisheries 2010): active since October 2007 for lining vessels between 6 and 28 m and reports individual set-by-set fishing events
MHR	Monthly Harvest Return: monthly returns used after 1 October 2001. Replaced QMRs but have same definition and utility
MPI	New Zealand Ministry for Primary Industries
NCELR	Netting Catch Effort Landing Return (Ministry of Fisheries 2010): active since October 2006 for inshore vessels using setnet gear between 6 and 28 m and reports individual fishing events
QMA	Quota Management Area: legally defined unit area used for gemfish management (Figure 1)
QMR	Quota Management Report: monthly harvest reports submitted by commercial fishermen to MPI. Considered to be best estimates of commercial harvest. In use from 1986 to 2001.
QMS	Quota Management System: name of the management system used in New Zealand to control commercial and non-commercial catches
replog	data extract identifier issued by MPI data unit
residual implied coefficient plots	plots which mimic interaction effects between the year coefficients and a categorical variable by adding the mean of the categorical variable residuals in each fishing year to the year coefficient, creating a plot of the "year effect" for each value of the categorical variable
rollup	a term describing the average number of records per "trip-stratum"
RTWG	MPI Recreational Technical Working Group
SINSWG	Southern Inshore Fisheries Assessment Working Group: MPI Working Group overseeing the work presented in this report

Term/Abbreviation	Definition
standardised CPUE	procedure used to remove the effects of explanatory variables such as vessel, statistical area and month of capture from a data set of catch/effort data for a species; annual abundance is usually modelled as an explanatory variable representing the year of capture and, after removing the effects of the other explanatory variables, the resulting year coefficients represent the relative change in species abundance
statistical area	sub-areas (Appendix B) within an FMA which are identified in catch/effort returns. The boundaries for these statistical areas do not always coincide with the QMA/FMA boundaries, leading to ambiguity in the assignment of effort to a QMA.
TACC	Total Allowable Commercial Catch: catch limit set by the Minister of Fisheries for a QMA that applies to commercial fishing
TCEPR	Trawl Catch Effort Processing Return (Ministry of Fisheries 2010): active since July 1989 for deepwater vessels larger than 28 m and reports tow-by-tow fishing events
TCER	Trawl Catch Effort Return (Ministry of Fisheries 2010): active since October 2007 for inshore vessels between 6 and 28 m and reports tow-by-tow fishing events
trip	a unit of fishing activity by a vessel consisting of “fishing events” and “landing events”, which are activities assigned to the trip. MPI generates a unique database code to identify each trip, using the trip start and end dates and the vessel code (Ministry of Fisheries 2010)
trip-stratum	summarisation within a trip by fishing method used, the statistical area of occupancy and the declared target species
unstandardised CPUE	geometric mean of all individual CPUE observations, usually summarised over a year within the stratum of interest

Table A.2: Code definitions used in the body of the main report and in Appendix E.

Code	Definition	Code	Description
BLL	Bottom longlining	BAR	Barracouta
BPT	Bottom trawl—pair	BNS	Bluenose
BS	Beach seine/drag nets	BUT	Butterfish
BT	Bottom trawl—single	ELE	Elephant Fish
CP	Cod potting	FLA	Flatfish (mixed species)
DL	Drop/dahn lines	GMU	Grey mullet
DS	Danish seining—single	GSH	Ghost shark
HL	Handlining	GUR	Red gurnard
MW	Midwater trawl—single	HOK	Hoki
RLP	Rock lobster potting	HPB	Hapuku & Bass
SLL	Surface longlining	JDO	John Dory
SN	Set netting (includes gill nets)	JMA	Jack mackerel
T	Trolling	KAH	Kahawai
TL	Trot lines	KIN	Kingfish
		LEA	Leatherjacket
SKI 1E	the part of SKI 1 in FMA 1	LIN	Ling
SKI 1W	the part of SKI 1 in FMA 9	MOK	Moki
		POR	Porae
		RCO	Red cod
		SKI	Gemfish
		SCI	Scampi
		SKI	Gemfish
		SNA	Snapper
		SPD	Spiny dogfish
		SPE	Sea perch
		SKI	Gemfish
		SQU	Arrow squid
		STA	Giant stargazer
		SWA	Silver warehou
		TAR	Tarakihi
		TRE	Trevally
		WAR	Blue warehou

Appendix B. MAP OF MPI STATISTICAL AND MANAGEMENT AREAS

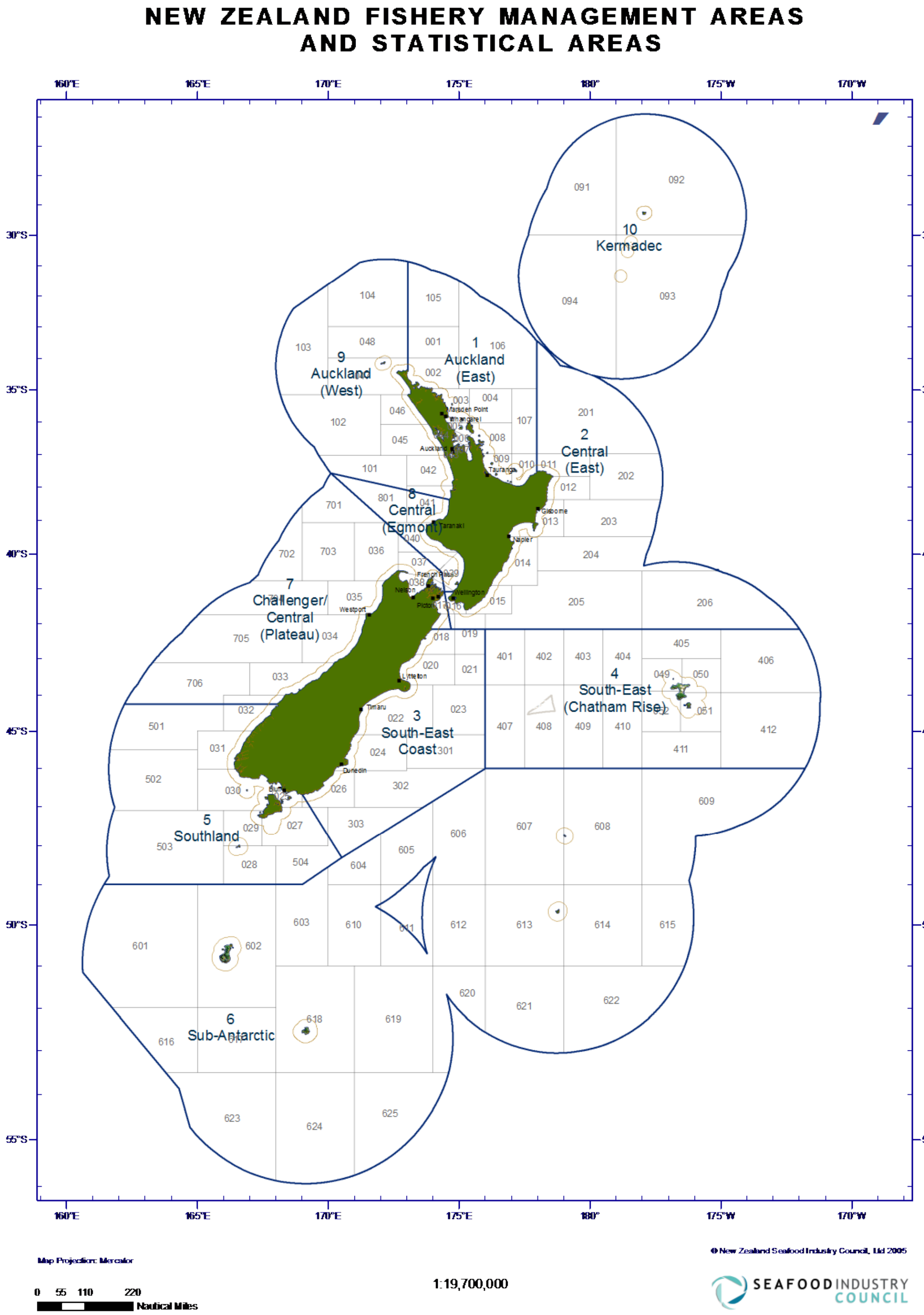

Figure B.1: Map of Ministry for Primary Industries statistical areas and Fishery Management Area (FMA) boundaries, showing locations where FMA boundaries are not contiguous with the statistical area boundaries.

Appendix C. METHOD USED TO EXCLUDE "OUT-OF-RANGE" LANDINGS

C.1 Introduction

The method previously used to identify "implausibly large" landings used arithmetic CPUE, with the presumption that trips with extremely large arithmetic CPUE values existed because the contributing landings were implausibly large. This method had two major problems: one was that the arithmetic CPUE for mixed-method trips could not be easily calculated and the other was that there was a lot of subjectivity in the process (how does one identify an "implausibly large" arithmetic CPUE?). Dropping "implausibly large" landings is often necessary because there are large landings which are due to data errors (possibly at the data entry step), with landings from single trips occasionally exceeding 100–300 t for some species (near to 160 t for SKI). These errors can result in substantial deviations from the accepted QMR/MHR catches and affect the credibility of the characterisation and CPUE analyses. The previous method transferred the problem of identifying "implausibly large" landings to identifying unreasonably large CPUE values. A further problem with the procedure was that the CPUE method was difficult to automate, requiring intermediate evaluations.

C.2 Methods

The method use for this procedure is less subjective and can be automated, evaluating trips with very large landings based on internal evidence within the trip that potentially corroborate the landings. The method proceeds in two steps:

Step 1 Trips with large landings above a specified threshold were selected using the empirical distribution of trip landing totals from all trips in the data set (for instance, all trips in the largest 1% quantile in terms of total trip landings);

Step 2 Internal evidence substantiating the landings within each trip was derived from summing the estimated catch for the species in question, as well as summing the "calculated green weight" (=*number_bins*avg_weight_bin*conversion_factor*) (Eq. C.1). The ratio of each these totals was taken with the declared green weight for the trip, with the minimum of the two ratios taken as the "best" validation (Eq. C.2). High values for this ratio (for instance, a value of 9 for this ratio implies that the declared green weight is 9 times larger than the "best" secondary total) are taken as evidence that the declared greenweight landing for the trip was not corroborated using the other available data, making the trip a candidate for dropping.

A two-way grid search was implemented for this procedure across a range of empirical quantiles (Step 1) and test ratio values (Step 2). The reason for stepping down through the quantiles was to minimise the number of trips removed by starting with trips that returned the largest catches. Similarly, the search started with the most extreme $rat_{t,s}$ values and stepped down from there. For each pair of values, the "fit" (SSq^z; Eq. C.3) of the annual sum of the landings was evaluated against the QMR/MHR totals, using a least-squares criterion. The pair of quantile and $rat_{t,s}$ values which gave the lowest SSq^z was used to select the set of candidate trips to drop because the resulting landings totals would be the closest overall to the QMR/MHR total catch.

The grid search was done independently for each SKI QMA because different ranges of quantile thresholds needed to be explored within each QMA in order to find a minimum.

C.3 Equations

For every trip, there exist three estimates of total greenweight catch for species *s*:

$$G^d_{t,s} = \sum_{i=1}^{n_t} gwt_{t,s,i}$$

Eq. C.1
$$G^c_{t,s} = \sum_{i=1}^{n_t} CF_s * W_{t,i} * B_{t,i}$$

$$G^e_{t,s} = \sum_{j=1}^{m_t} est_{t,s,j}$$

where $G^d_{t,s}$ = sum of declared greenweight (*gwt*) for trip *t* over all n_t landing records;

$G^c_{t,s}$ = sum of calculated greenweight for trip *t* over all n_t landing records, using conversion factor CF_s, weight of bin $W_{t,i}$ and number of bins $B_{t,i}$;

$G^e_{t,s}$ = sum of estimated catch (*est*) for trip *t* over all m_t effort records.

Assuming that $G^d_{t,s}$ is the best available estimate of the total landings of species *s* for trip *t*, calculate the following ratios:

Eq. C.2
$$r1_{t,s} = G^d_{t,s} \big/ G^c_{t,s}$$
$$r2_{t,s} = G^d_{t,s} \big/ G^e_{t,s}$$
$$rat_{t,s} = \min(r1_{t,s}, r2_{t,s})$$

where $G^d_{t,s}$, $G^c_{t,s}$ and $G^e_{t,s}$ are defined in Eq. C.1, and ignoring $r1_{t,s}$ or $r2_{t,s}$ if missing when calculating $rat_{t,s}$.

The ratio $rat_{t,s}$ can be considered the "best available information" to corroborate the landings declared in the total $G^d_{t,s}$, with ratios exceeding a threshold value (e.g. $rat_{t,s} > 9.0$) considered to be uncorroborated. This criterion can be applied to a set of trips selected using a quantile of the empirical distribution of total trip greenweights. The set of trips to drop was selected on the basis of the pair of criteria (quantile and ratio threshold) which gave the lowest SSq^z (Eq. C.3) relative to the annual QMR/MHR totals:

Eq. C.3
$$gg^z_y = \sum_{1}^{p^z_y} L^z_y$$
$$Ssq^z = \sum_{y=89/90}^{y=12/13} \left(gg^z_y - MHR_y \right)^2$$

where p^z_y is the number landing records in year *y* for iteration *z* (i.e.: a combination of a ratio threshold criterion with an empirical quantile cutoff criterion);

L^z_y is a landing record included in year *y* for iteration *z*.

MHR_y is the corresponding MHR/QMR landing total for SKI in the QMA in year *y*.

C.4 Results

This approach found a "minimum" fit to the SKI 1 and SKI 2 QMR/MHR annual landings (as defined by Eq. C.3), resulting in dropping 4 and 3 trips in each respective QMA (Table C.1). This resulted in dropping about 250 t from the landings data set, including one trip from 1989–90 which was responsible for nearly 160 t of SKI 1 (Table C.2). A plot of the annual QMR/MHR SKI 1 landings compared to the sum of the landings in the SKI 1 data set showed that the total unedited landings was closer to the early annual QMR totals than was the sum of landings after removing the 4 identified SKI 1 trips (Figure C.1). But the details of the trip totals showed that the ratios ($r1_{t,s}$ or $r2_{t,s}$, see Eq. C.2) ranged between 10 and 20 for these 4 trips, with one trip in 1989–90 reporting a total catch of 157 t of gemfish, a very large catch for an 8-day trip which only reported 14 t of estimated SKI catch

$\left(G_{t,s}^{e}\right)$ and calculated catch $\left(G_{t,s}^{c}\right)$ respectively. The remaining three trips reported landings in the order of 20–30 t. These large uncorroborated ratios were considered sufficient justification to drop these four trips in spite of the poorer fit to the early QMR annual catch totals (Figure C.1), with concern that they would bias estimates of CPUE in those early years with relatively less error checking in place. The effect of the dropped trips in SKI 2 was minimal as the total tonnage involved was less than 20 t (Figure C.1, Table C.2).

Table C.1: Statistics associated with the selected minimum in each QMA. MHR_y = **QMR/MHR landings in year *y*;** gg_y^0 = **unedited landings in year *y*;** gg_y = **edited landings at selected minimum in year *y*;** $rat_{t,s}$ **as defined in Eq. C.2.**

Fishstock	Quantile	$rat_{t,s}$	Number trips dropped	Total trips in data set	Sum landings dropped (t)	$\sum_{y=89/90}^{y=12/13} MHR_y$	$\sum_{y=89/90}^{y=12/13} gg_y^0$	$\sum_{y=89/90}^{y=12/13} gg_y$	$\sum_{y=89/90}^{y=12/13}\left(gg_y - MHR_y\right)$
SKI1	99.5	2	4	18 694	231.0	12 904	12 934	12 703	-201
SKI2	96	4	3	16 405	19.6	12 638	12 112	12 092	-545

Table C.2: Distribution of tonnage dropped by year for the seven trips identified in Table C.1.

Fishing	QMA		
Year	SKI 1	SKI 2	Total
89/90	157.2	–	157.2
90/91	25.7	–	25.7
91/92	26.7	–	26.7
93/94	21.5	–	21.5
95/96	–	6.5	6.5
04/05	–	8.0	8.0
05/06	–	5.1	5.1
Total	231.1	19.6	250.7

Table C.3: Number of trips dropped over a two parameter search: A) a threshold quantile cut-off which selected the set of large landings over which to search and B) the ratio $\left(rat_{t,s}\right)$ (Eq. C.2) which sets the maximum criterion for accepting a landing. The quantile/ratio pair with the lowest *Ssq*² (Eq. C.3) is coloured blue for each SKI QMA. Selected pairings (Table C.1) which differed from the actual minimum are marked in grey.

	SKI 1 Ratio					SKI 2 Ratio				
Quantile	2	4	6	8	10	2	4	6	8	10
95	7	5	5	5	4	5	3	2	2	1
96	5	5	5	5	4	5	3	2	2	1
97	5	5	5	5	4	4	2	2	2	1
98	4	4	4	4	3	3	1	1	1	0
99	4	4	4	4	3	1	0	0	0	0
99.5	4	4	4	4	3	0	0	0	0	0
99.9	1	1	1	1	1	0	0	0	0	0

Table C.4: Annual statistics associated with the selected minima in SKI 1 and SKI 2. MHR_y = QMR/MHR landings in year *y*; gg_y^0 = unedited landings in year *y*; gg_y = edited landings at selected minimum in year *y*. The final two columns are the annual result of applying Eq. C.3 to the unedited landings and to the selected QMA "minimum" defined in Table C.1.

	SKI 1					SKI 2				
Fishing year	MHR_y	gg_y^0	gg_y	$\left(gg_y^0-MHR_y\right)$	$\left(gg_y-MHR_y\right)$	MHR_y	gg_y^0	gg_y	$\left(gg_y^0-MHR_y\right)$	$\left(gg_y-MHR_y\right)$
89/90	1 230.1	1 247.3	1 090.1	294.8	19 613.7	1 043.5	949.6	949.6	8 812.0	8 812.0
90/91	1 057.8	1 051.9	1 026.1	34.4	999.2	949.0	826.0	826.0	15 140.1	15 140.1
91/92	1 005.4	1 034.2	1 007.5	825.7	4.2	1 199.2	1 154.8	1 154.8	1 974.0	1 974.0
92/93	1 292.0	1 345.9	1 345.9	2 910.6	2 910.6	1 020.1	1 009.2	1 009.2	119.1	119.1
93/94	1 155.8	1 174.6	1 153.2	352.9	7.1	1 057.6	1 064.6	1 064.6	49.3	49.3
94/95	1 031.7	1 009.6	1 009.6	485.4	485.4	905.9	878.4	878.4	757.1	757.1
95/96	800.6	739.2	739.2	3 759.2	3 759.2	789.3	798.2	791.7	80.8	6.0
96/97	965.2	955.9	955.9	85.5	85.5	977.8	892.1	892.1	7 350.5	7 350.5
97/98	626.9	630.0	630.0	10.0	10.0	670.5	543.7	543.7	16 093.1	16 093.1
98/99	412.7	410.4	410.4	5.2	5.2	335.6	338.6	338.6	9.0	9.0
99/00	409.1	407.5	407.5	2.3	2.3	508.6	506.9	506.9	2.9	2.9
00/01	335.4	355.1	355.1	385.1	385.1	330.5	314.9	314.9	243.5	243.5
01/02	200.9	204.1	204.1	9.9	9.9	268.1	266.3	266.3	3.1	3.1
02/03	205.5	204.4	204.4	1.4	1.4	312.8	312.7	312.7	0.0	0.0
03/04	221.1	216.4	216.4	21.3	21.3	300.7	300.6	300.6	0.0	0.0
04/05	233.7	238.0	238.0	18.6	18.6	259.3	264.1	256.1	23.7	9.9
05/06	230.1	226.4	226.4	14.0	14.0	182.4	186.8	181.7	18.9	0.5
06/07	214.9	205.5	205.5	87.8	87.8	316.6	310.4	310.4	39.1	39.1
07/08	216.0	216.6	216.6	0.4	0.4	248.9	245.6	245.6	11.1	11.1
08/09	191.0	194.6	194.6	13.1	13.1	191.0	189.2	189.2	3.2	3.2
09/10	247.4	248.1	248.1	0.5	0.5	176.1	176.8	176.8	0.5	0.5
10/11	225.8	222.5	222.5	10.8	10.8	299.6	287.0	287.0	158.2	158.2
11/12	212.2	213.2	213.2	0.9	0.9	154.7	155.6	155.6	0.9	0.9
12/13	182.3	182.3	182.3	0.0	0.0	140.0	140.0	140.0	0.0	0.0
Total	12 903.6	12 933.9	12 702.8	9 329.8	28 446.3	12 637.8	12 112.0	12 092.4	50 889.9	50 782.8

Table C.5: Trip threshold (t) associated with each quantile searched: every trip above the indicated threshold tonnage was evaluated for corroboration of declared greenweight catch.

	Fishstock	
Quantile	SKI 1	SKI 2
95	2.7	3.6
96	4.0	4.4
97	5.9	5.7
98	8.6	7.8
99	13.9	11.8
99.5	20.3	16.6
99.9	48.9	34.6

Table C.6: Total landings (t) dropped over the two parameter search defined in Table C.3. The quantile/ratio pair with the lowest Ssq^2 (Eq. C.3) is coloured blue for each SKI QMA. Selected pairings (Table C.1) which differed from the actual minimum are marked in grey.

	SKI 1 Ratio					SKI 2 Ratio				
Quantile	2	4	6	8	10	2	4	6	8	10
95	245.8	239.1	239.1	239.1	217.6	43.6	19.6	14.6	14.6	6.5
96	239.1	239.1	239.1	239.1	217.6	43.6	19.6	14.6	14.6	6.5
97	239.1	239.1	239.1	239.1	217.6	38.5	14.6	14.6	14.6	6.5
98	231.1	231.1	231.1	231.1	209.6	32.0	8.0	8.0	8.0	0
99	231.1	231.1	231.1	231.1	209.6	12.8	0	0	0	0
99.5	231.1	231.1	231.1	231.1	209.6	0	0	0	0	0
99.9	157.2	157.2	157.2	157.2	157.2	0	0	0	0	0

Table C.7: "Fit" (Ssq^2: Eq. C.3) over the two parameter search defined in Table C.3. The quantile/ratio pair with the lowest Ssq^2 is coloured blue for each SKI QMA. Selected pairings (Table C.1) which differed from the actual minimum are marked in grey.

	SKI 1 Ratio					SKI 2 Ratio				
Quantile	2	4	6	8	10	2	4	6	8	10
95	30 546	29 491	29 491	29 491	29 837	52 798	50 783	50 801	50 801	50 815
96	29 491	29 491	29 491	29 491	29 837	52 798	50 783	50 801	50 801	50 815
97	29 491	29 491	29 491	29 491	29 837	52 816	50 801	50 801	50 801	50 815
98	28 446	28 446	28 446	28 446	28 792	52 891	50 876	50 876	50 876	50 890
99	28 446	28 446	28 446	28 446	28 792	50 874	50 890	50 890	50 890	50 890
99.5	28 446	28 446	28 446	28 446	28 792	50 890	50 890	50 890	50 890	50 890
99.9	28 649	28 649	28 649	28 649	28 649	50 890	50 890	50 890	50 890	50 890

Table C.8: Differences between the edited total landings and the sum of the QMR/MHR landings $\left(\sum_{y=89/90}^{y=12/13}\left(gg_y - MHR_y\right)\right)$ over the two parameter search defined in Table C.3. The quantile/ratio pair with the lowest Ssq^2 is coloured blue for each SKI QMA. Selected pairings (Table C.1) which differed from the actual minimum are marked in grey.

	SKI 1 Ratio					SKI 2 Ratio				
Quantile	2	4	6	8	10	2	4	6	8	10
95	- 216	- 209	- 209	- 209	- 187	- 569	- 545	- 540	- 540	-532
96	- 209	- 209	- 209	- 209	- 187	- 569	- 545	- 540	- 540	-532
97	- 209	- 209	- 209	- 209	- 187	- 564	- 540	- 540	- 540	-532
98	- 201	- 201	- 201	- 201	- 179	- 558	- 534	- 534	- 534	-526
99	- 201	- 201	- 201	- 201	- 179	- 539	- 526	- 526	- 526	-526
99.5	- 201	- 201	- 201	- 201	- 179	- 526	- 526	- 526	- 526	-526
99.9	- 127	- 127	- 127	- 127	- 127	- 526	- 526	- 526	- 526	-526

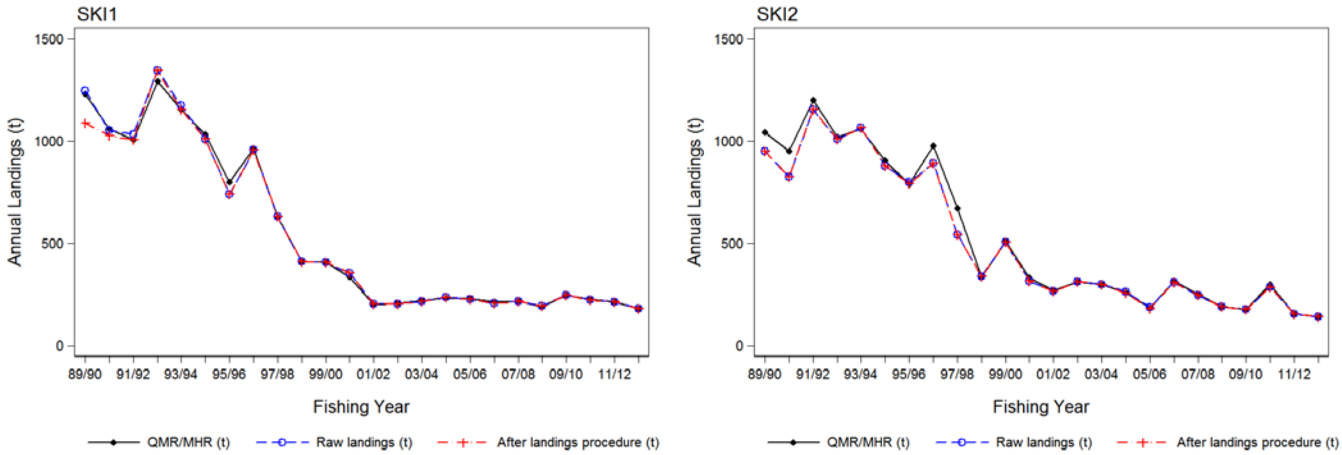

Figure C.1: Comparison of QMR/MHR annual total landings for SKI 1 and SKI 2 with two extracts: A: unedited or “raw” landings; and B: total landings after dropping the trips identified at the selected QMA “minimum” quantile/ratio pairing defined in Table C.1.

Appendix D. DATA PREPARATION INFORMATION BY QMA

Table D.1. Comparison of the total adjusted QMR/MHR catch (t) for SKI 1 and SKI 2, reported by fishing year, with the sum of the corrected landed catch totals (bottom part of the MPI CELR form or MPI CLR form), the total catch after matching effort with landing data (‘Analysis’ data set) and the sum of the estimated catches from the Analysis data set. Data source: MPI replog 9303: 1989–90 to 2012–13. Landings and QMR/MHR totals have been adjusted to consistent conversion factors across years.

	SKI 1							SKI 2						
Fishing Year	QMR/ MHR (t)	Total landed catch (t)[1]	% landed/ QMR/ MHR	Total Analysis catch (t)	% Analysis /Landed	Total Estimated Catch (t)	% Estimated /Analysis	QMR/ MHR (t)	Total landed catch (t)[1]	% landed/ QMR/ MHR	Total Analysis catch (t)	% Analysis /Landed	Total Estimated Catch (t)	% Estimated /Analysis
89/90	1 230	1 072	87	1 067	100	958	90	1 043	950	91	912	96	822	90
90/91	1 058	1 023	97	1 019	100	931	91	949	793	84	779	98	651	84
91/92	1 005	1 007	100	1 005	100	832	83	1 199	1 155	96	1 135	98	1 070	94
92/93	1 292	1 313	102	1 302	99	1 082	83	1 020	1 009	99	986	98	843	86
93/94	1 156	1 153	100	1 149	100	1 030	90	1 058	1 054	100	1 036	98	940	91
94/95	1 032	1 009	98	1 007	100	932	93	906	870	96	848	97	760	90
95/96	801	729	91	725	99	683	94	789	786	100	765	97	694	91
96/97	965	944	98	939	100	851	91	978	864	88	848	98	797	94
97/98	627	628	100	600	96	539	90	671	541	81	538	99	559	104
98/99	413	405	98	404	100	330	82	336	339	101	334	99	296	89
99/00	409	408	100	407	100	349	86	509	507	100	507	100	481	95
00/01	335	355	106	334	94	290	87	330	315	95	314	100	283	90
01/02	201	204	102	202	99	162	80	268	266	99	266	100	229	86
02/03	206	204	99	204	100	167	82	313	313	100	310	99	261	84
03/04	221	216	98	213	99	161	76	301	301	100	296	99	259	87
04/05	234	238	102	233	98	189	81	259	248	96	240	97	223	93
05/06	230	226	98	223	98	167	75	182	182	100	180	99	136	76
06/07	215	205	96	203	99	156	77	317	310	98	309	99	255	83
07/08	216	216	100	216	100	171	79	249	245	98	242	99	211	87
08/09	191	194	102	193	99	139	72	191	189	99	186	98	153	83
09/10	247	247	100	246	99	187	76	176	177	100	173	98	141	82
10/11	226	220	97	219	99	161	74	300	286	96	279	98	222	80
11/12	212	209	99	208	99	160	77	155	155	101	149	96	112	75
12/13	182	181	99	175	97	143	82	140	139	100	131	94	111	85
Total	12 904	12 607	98	12 494	99	10 771	86	12 638	11 992	95	11 764	98	10 512	89

[1] excludes 4 trips from SKI 1 and 3 trips from SKI 2 which were dropped for being “out of range” (see Table C.1).

Table D.2. Summary statistics pertaining to the reporting of estimated catch from the SKI 1 and SKI 2 analysis datasets.

	SKI 1							SKI 2						
	Trips with landed catch but which report no estimated catch			Statistics (excluding 0s) for the ratio of landed/estimated catch by trip				Trips with landed catch but which report no estimated catch			Statistics (excluding 0s) for the ratio of landed/estimated catch by trip			
Fishing year	Trips: % relative to total trips	Landings: % relative to total landings	Landings (t)	5% quantile	Median	Mean	95% quantile	Trips: % relative to total trips	Landings: % relative to total landings	Landings (t)	5% quantile	Median	Mean	95% quantile
89/90	28	6	70	0.67	1.08	1.39	2.78	29	3	33	0.80	1.04	1.29	2.23
90/91	26	1	12	0.56	1.10	1.32	2.59	27	2	23	0.80	1.06	1.40	2.86
91/92	21	4	38	0.58	1.11	2.17	2.88	33	1	11	0.65	1.07	1.36	2.70
92/93	27	1	19	0.67	1.09	1.53	2.94	34	1	12	0.66	1.13	5.83	3.44
93/94	38	1	12	0.54	1.11	1.37	3.00	31	1	15	0.66	1.13	1.90	4.08
94/95	42	1	14	0.53	1.15	1.49	3.50	39	3	25	0.70	1.16	1.70	4.44
95/96	30	3	20	0.62	1.18	1.45	3.09	36	2	16	0.46	1.12	1.47	3.76
96/97	30	1	9	0.55	1.14	1.47	3.23	33	1	9	0.68	1.13	1.50	3.31
97/98	35	2	10	0.58	1.12	1.51	3.50	41	1	10	0.50	1.12	1.41	3.03
98/99	34	2	10	0.50	1.22	1.55	3.44	43	2	6	0.56	1.17	2.01	3.45
99/00	36	2	10	0.50	1.33	1.57	3.36	45	2	8	0.57	1.20	1.61	3.95
00/01	34	2	7	0.60	1.25	1.65	3.28	50	4	13	0.60	1.21	1.67	3.90
01/02	35	5	11	0.60	1.34	1.79	3.65	48	3	7	0.70	1.25	1.69	3.98
02/03	36	4	7	0.63	1.34	1.69	3.75	47	3	9	0.62	1.26	2.07	4.11
03/04	36	4	9	0.56	1.40	1.83	4.00	46	2	6	0.67	1.30	1.72	4.45
04/05	38	3	7	0.70	1.34	2.07	3.68	39	3	7	0.43	1.19	1.86	4.67
05/06	37	4	10	0.51	1.50	2.04	4.69	46	4	8	0.53	1.35	1.77	4.12
06/07	34	4	8	0.60	1.33	1.95	4.95	42	3	9	0.60	1.30	1.77	4.60
07/08	36	2	5	0.50	1.26	1.72	4.43	27	2	6	0.46	1.17	2.28	4.47
08/09	32	4	7	0.46	1.32	2.16	5.50	27	1	3	0.60	1.28	1.91	5.32
09/10	33	2	5	0.63	1.38	2.54	5.43	28	2	4	0.50	1.25	2.30	6.00
10/11	31	3	6	0.60	1.51	2.20	6.50	23	1	3	0.56	1.26	1.90	5.00
11/12	33	2	5	0.52	1.38	1.89	5.00	24	2	3	0.55	1.22	1.86	4.00
12/13	27	2	3	0.60	1.38	1.93	4.70	26	4	6	0.45	1.16	1.70	5.00
Total	33	2	315	0.59	1.23	1.75	3.84	35	2	252	0.60	1.17	1.98	4.00

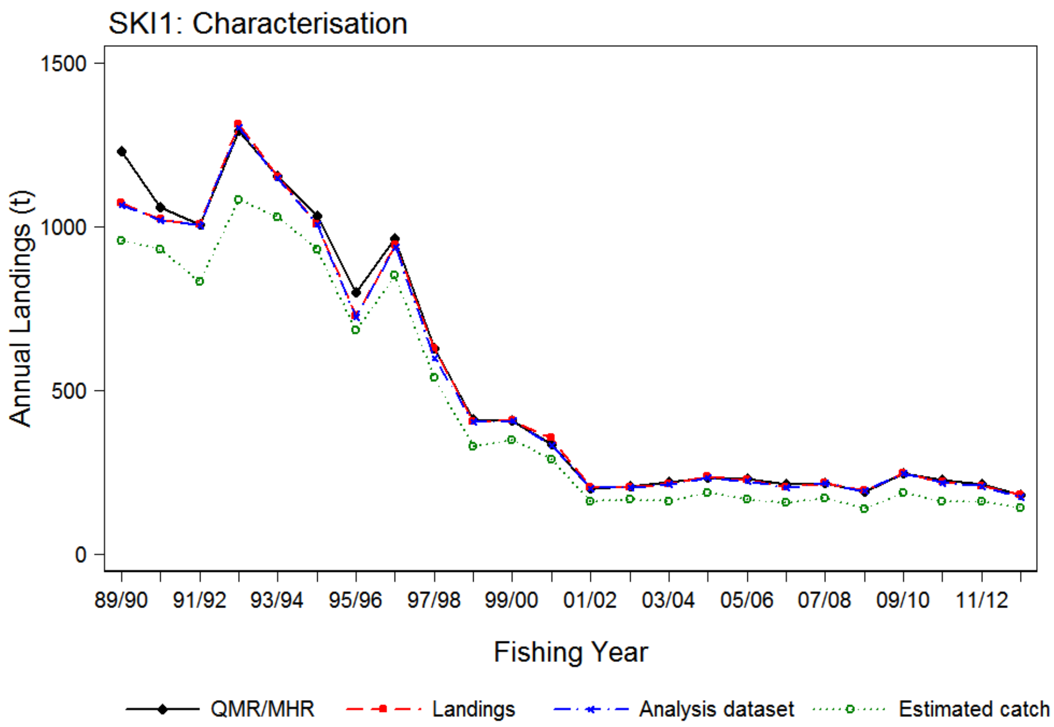

Figure D.1: Plots of the SKI 1 catch dataset using annual totals presented in Table D.1.

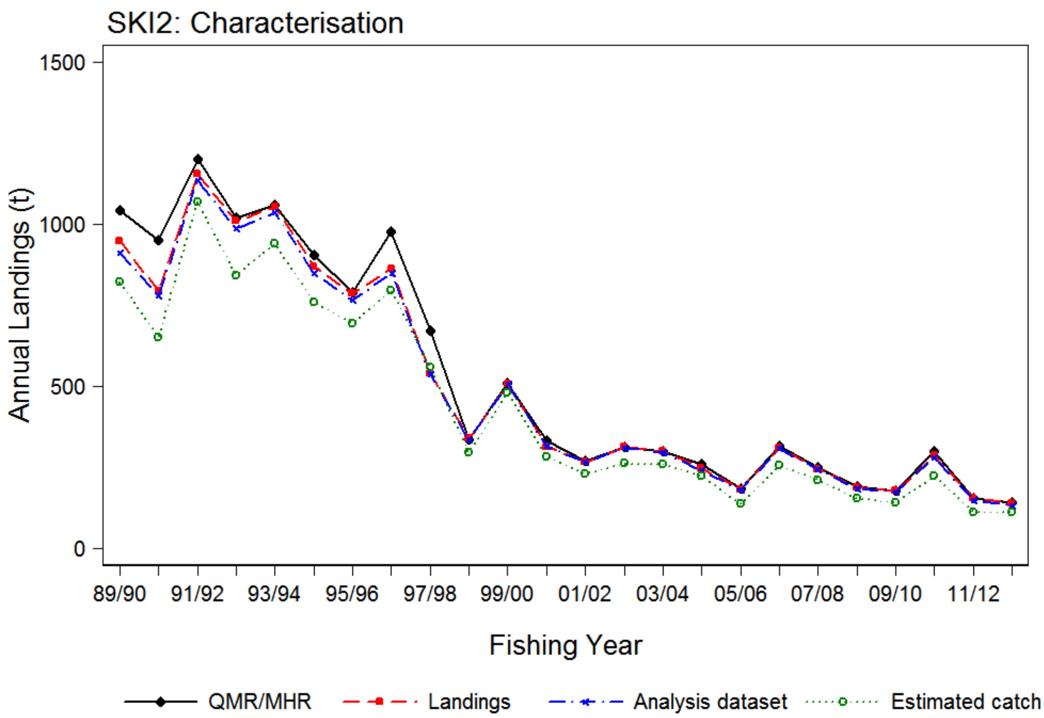

Figure D.2: Plot of the SKI 2\catch datasets using annual totals presented in Table D.1.

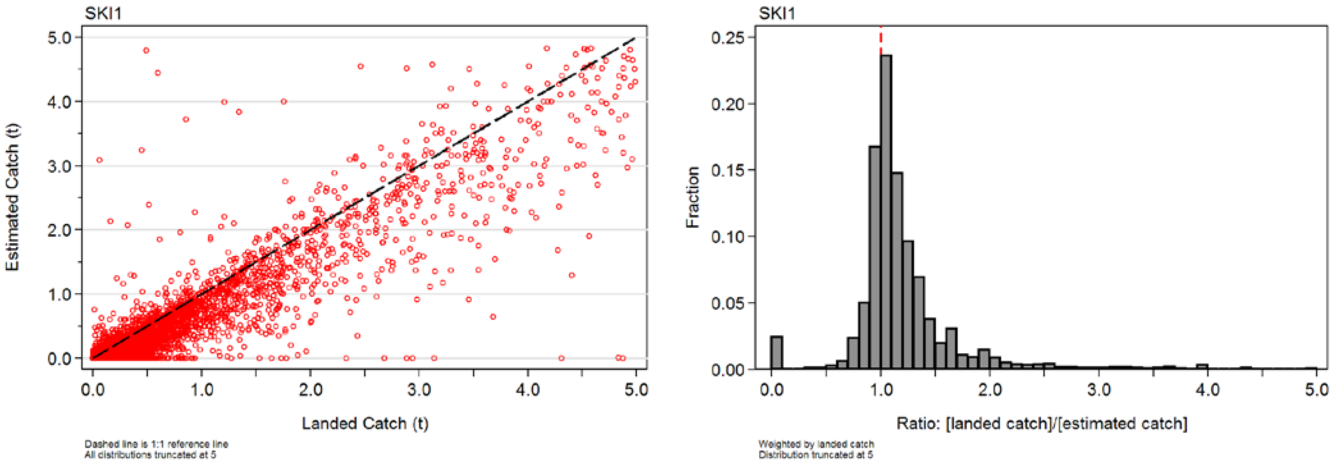

Figure D.3: [left panel]: scatter plot of the sum of landed and estimated gemfish catch for each trip in the SKI 1 analysis dataset. [right panel]: distribution (weighted by the landed catch) of the ratio of landed to estimated catch per trip. Trips where the estimated catch=0 have been assigned a ratio=0.

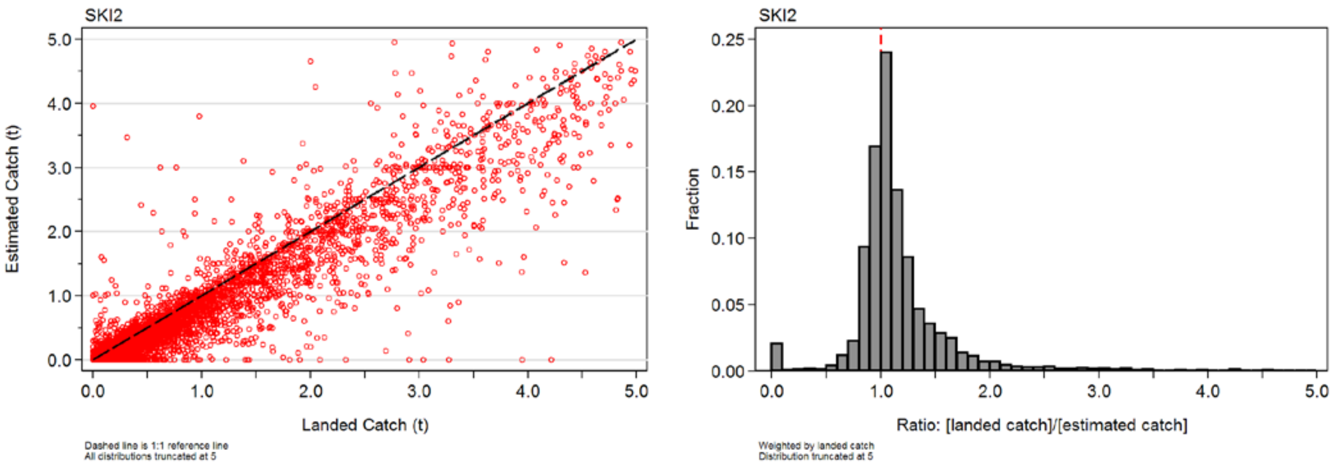

Figure D.4: [left panel]: scatter plot of the sum of landed and estimated gemfish catch for each trip in the SKI 2 analysis dataset. [right panel]: distribution (weighted by the landed catch) of the ratio of landed to estimated catch per trip. Trips where the estimated catch=0 have been assigned a ratio=0.

Appendix E. DATA SUMMARIES BY SUB-REGION: SKI 1 AND SKI 2

Table E.1A: Distribution of landings (%) by method of capture and fishing year for SKI 1 East Northland (EN) and Bay of Plenty (BoP) based on trips which landed gemfish. The final column gives the annual total landings for BT in each sub-region. These values are plotted in Figure 6.

Fishing	Distribution (t)					Distribution (%)				
year	BT	MW	BLL	Other	Total	BT	MW	BLL	Other	Total
EN										
89/90	315.2	–	1.8	0.6	317.5	99.2	–	0.6	0.2	9.8
90/91	372.3	0.0	11.3	1.0	384.5	96.8	0.0	2.9	0.3	11.8
91/92	317.8	–	23.2	0.8	341.7	93.0	–	6.8	0.2	10.5
92/93	391.2	–	20.9	1.4	413.5	94.6	–	5.1	0.3	12.7
93/94	365.9	0.0	12.0	1.5	379.4	96.4	0.0	3.2	0.4	11.7
94/95	346.3	–	12.3	2.9	361.5	95.8	–	3.4	0.8	11.1
95/96	221.6	0.0	6.3	9.5	237.3	93.4	0.0	2.7	4.0	7.3
96/97	143.3	0.0	17.8	0.6	161.8	88.6	0.0	11.0	0.4	5.0
97/98	88.0	0.0	18.3	2.1	108.4	81.2	0.0	16.9	1.9	3.3
98/99	82.7	0.0	28.9	1.0	112.7	73.4	0.0	25.7	0.9	3.5
99/00	84.8	0.0	16.9	0.2	102.0	83.2	0.0	16.6	0.2	3.1
00/01	19.5	0.0	12.8	0.4	32.7	59.7	0.0	39.0	1.3	1.0
01/02	44.9	0.0	15.5	0.1	60.5	74.2	0.0	25.6	0.2	1.9
02/03	4.6	0.0	15.0	0.2	19.9	23.2	0.0	75.6	1.1	0.6
03/04	7.4	0.0	9.5	0.1	17.0	43.4	0.0	55.8	0.7	0.5
04/05	11.6	0.0	10.3	0.0	21.9	52.8	0.0	47.1	0.1	0.7
05/06	23.8	0.1	13.4	0.2	37.5	63.6	0.3	35.7	0.4	1.2
06/07	19.4	0.3	12.3	0.3	32.2	60.1	0.9	38.1	0.9	1.0
07/08	6.4	0.0	9.6	0.2	16.3	39.5	0.2	59.2	1.0	0.5
08/09	2.9	2.9	8.7	0.2	14.8	19.9	19.8	58.9	1.4	0.5
09/10	10.2	8.1	6.1	0.3	24.7	41.2	32.6	24.9	1.3	0.8
10/11	5.4	2.5	10.6	2.9	21.4	25.1	11.8	49.7	13.5	0.7
11/12	2.6	4.5	6.6	1.5	15.3	17.2	29.6	43.3	9.9	0.5
12/13	4.5	0.2	9.9	0.5	15.1	30.1	1.2	65.7	3.0	0.5
Total	2 892.4	18.7	310.1	28.4	3 249.6	89.0	0.6	9.5	0.9	100.0
BoP										
89/90	888.1	–	12.1	3.0	903.2	98.3	–	1.3	0.3	14.5
90/91	726.2	0.2	14.2	1.1	741.6	97.9	0.0	1.9	0.1	11.9
91/92	607.4	5.0	9.6	4.5	626.4	97.0	0.8	1.5	0.7	10.1
92/93	660.7	0.0	7.2	36.6	704.4	93.8	0.0	1.0	5.2	11.3
93/94	256.5	0.0	5.1	10.4	272.0	94.3	0.0	1.9	3.8	4.4
94/95	155.7	0.0	4.2	3.3	163.3	95.4	0.0	2.5	2.0	2.6
95/96	201.1	0.8	6.4	7.9	216.2	93.0	0.4	3.0	3.7	3.5
96/97	241.5	0.8	6.2	7.4	255.9	94.4	0.3	2.4	2.9	4.1
97/98	143.6	0.0	5.6	9.2	158.4	90.6	0.0	3.5	5.8	2.5
98/99	64.9	0.3	4.1	7.2	76.6	84.8	0.5	5.3	9.4	1.2
99/00	44.6	4.4	3.7	0.7	53.4	83.5	8.2	7.0	1.3	0.9
00/01	51.2	0.1	9.8	0.2	61.3	83.5	0.2	16.0	0.3	1.0
01/02	62.2	0.3	8.5	0.5	71.6	86.9	0.4	11.9	0.8	1.1
02/03	131.3	0.0	8.2	0.4	139.9	93.9	0.0	5.8	0.3	2.2
03/04	172.7	–	11.9	3.2	187.9	91.9	–	6.3	1.7	3.0
04/05	196.8	0.2	11.2	0.6	208.9	94.2	0.1	5.4	0.3	3.4
05/06	166.3	6.9	10.4	0.3	183.8	90.5	3.7	5.6	0.1	3.0
06/07	155.3	4.2	6.2	0.3	166.1	93.5	2.5	3.8	0.2	2.7
07/08	146.8	8.0	6.3	1.5	162.7	90.3	4.9	3.9	0.9	2.6
08/09	137.5	0.5	2.7	15.1	155.7	88.3	0.3	1.7	9.7	2.5
09/10	189.6	0.6	7.2	16.0	213.4	88.8	0.3	3.4	7.5	3.4
10/11	159.9	2.3	4.9	18.5	185.6	86.2	1.3	2.6	9.9	3.0
11/12	155.5	0.2	4.8	13.1	173.6	89.6	0.1	2.8	7.6	2.8
12/13	129.8	1.1	2.6	10.5	144.1	90.1	0.8	1.8	7.3	2.3
Total	5 845.1	35.8	173.2	171.6	6 225.8	93.9	0.6	2.8	2.8	100.0

Table E.1B: Distribution of landings (%) by method of capture and fishing year for SKI 2 North (SKI 2N) and SKI 2 South (SKI 2S) based on trips which landed gemfish. The final column gives the annual total landings for BT in each sub-region. These values are plotted in Figure 6.

Fishing	Distribution (t)					Distribution (%)				
year	BT	MW	BLL	Other	Total	BT	MW	BLL	Other	Total
SKI 2N										
89/90	153.5	0.0	6.0	0.0	159.6	96.2	0.0	3.8	0.0	3.3
90/91	163.2	0.4	21.3	0.3	185.3	88.1	0.2	11.5	0.1	3.8
91/92	197.1	156.4	28.5	0.1	382.2	51.6	40.9	7.5	0.0	7.9
92/93	108.4	77.4	53.8	7.7	247.4	43.8	31.3	21.8	3.1	5.1
93/94	62.5	240.4	38.3	17.2	358.4	17.5	67.1	10.7	4.8	7.4
94/95	84.6	410.2	10.4	0.1	505.3	16.7	81.2	2.1	0.0	10.4
95/96	147.2	306.0	8.9	0.4	462.4	31.8	66.2	1.9	0.1	9.5
96/97	265.4	121.6	5.2	0.3	392.5	67.6	31.0	1.3	0.1	8.1
97/98	145.2	20.5	3.5	0.3	169.5	85.7	12.1	2.0	0.2	3.5
98/99	149.9	6.5	3.4	0.0	159.9	93.8	4.1	2.1	0.0	3.3
99/00	279.5	12.3	2.1	0.0	293.9	95.1	4.2	0.7	0.0	6.0
00/01	137.2	30.5	3.2	0.0	170.8	80.3	17.8	1.9	0.0	3.5
01/02	97.5	4.3	2.1	0.0	103.9	93.9	4.1	2.0	0.0	2.1
02/03	132.9	13.9	5.3	0.0	152.1	87.3	9.1	3.5	0.0	3.1
03/04	123.3	17.8	9.0	0.0	150.1	82.2	11.8	6.0	0.0	3.1
04/05	119.4	4.6	8.7	–	132.7	90.0	3.4	6.6	–	2.7
05/06	67.3	19.8	10.3	0.3	97.7	68.9	20.3	10.5	0.3	2.0
06/07	94.7	15.5	9.5	0.5	120.1	78.9	12.9	7.9	0.4	2.5
07/08	65.6	33.7	11.3	0.2	110.8	59.2	30.4	10.2	0.1	2.3
08/09	52.8	3.4	12.7	0.1	69.1	76.4	5.0	18.4	0.2	1.4
09/10	81.6	4.3	9.8	0.1	95.8	85.1	4.5	10.2	0.1	2.0
10/11	92.3	56.3	12.8	0.0	161.4	57.2	34.9	7.9	0.0	3.3
11/12	91.0	2.1	14.1	0.0	107.2	84.8	2.0	13.2	0.0	2.2
12/13	50.9	12.2	11.8	0.1	75.0	67.8	16.3	15.7	0.2	1.5
Total	2 963.1	1 570.2	302.0	27.7	4 863.1	60.9	32.3	6.2	0.6	100.0
SKI 2S										
89/90	864.9	16.8	4.2	2.1	888.0	97.4	1.9	0.5	0.2	11.9
90/91	669.4	12.9	1.3	0.3	684.0	97.9	1.9	0.2	0.0	9.1
91/92	762.1	7.7	6.5	10.3	786.7	96.9	1.0	0.8	1.3	10.5
92/93	706.2	36.3	1.1	4.8	748.4	94.4	4.9	0.1	0.6	10.0
93/94	650.0	19.2	2.9	6.5	678.6	95.8	2.8	0.4	1.0	9.1
94/95	365.0	11.8	0.2	2.8	379.8	96.1	3.1	0.0	0.7	5.1
95/96	347.1	6.4	0.3	0.3	354.2	98.0	1.8	0.1	0.1	4.7
96/97	484.8	8.4	0.0	27.4	520.5	93.1	1.6	0.0	5.3	7.0
97/98	392.8	3.6	0.0	47.0	443.5	88.6	0.8	0.0	10.6	5.9
98/99	159.1	2.4	1.0	16.3	178.7	89.0	1.3	0.6	9.1	2.4
99/00	207.3	3.4	0.1	4.1	214.9	96.5	1.6	0.0	1.9	2.9
00/01	145.4	5.5	1.3	–	152.2	95.5	3.6	0.9	–	2.0
01/02	156.9	3.4	1.0	0.1	161.3	97.2	2.1	0.6	0.0	2.2
02/03	154.3	5.1	1.1	0.0	160.4	96.2	3.1	0.7	0.0	2.1
03/04	146.9	4.8	1.7	0.0	153.4	95.8	3.1	1.1	0.0	2.0
04/05	104.8	7.7	4.6	0.1	117.3	89.4	6.6	4.0	0.1	1.6
05/06	73.4	2.4	10.2	0.5	86.5	84.8	2.8	11.8	0.6	1.2
06/07	192.3	3.1	4.8	0.0	200.3	96.0	1.6	2.4	0.0	2.7
07/08	121.2	7.6	5.7	0.5	134.9	89.8	5.6	4.2	0.3	1.8
08/09	112.9	2.9	1.9	0.5	118.2	95.5	2.5	1.6	0.4	1.6
09/10	72.6	3.5	3.0	0.0	79.1	91.7	4.4	3.8	0.0	1.1
10/11	115.1	14.4	3.6	0.0	133.1	86.4	10.8	2.7	0.0	1.8
11/12	41.6	0.5	3.6	0.0	45.8	90.9	1.2	7.8	0.1	0.6
12/13	53.0	2.9	6.0	0.8	62.7	84.5	4.5	9.6	1.4	0.8
Total	7 098.9	192.7	66.4	124.6	7 482.5	94.9	2.6	0.9	1.7	100.0

Table E.1C: Distribution of landings (%) by method of capture and fishing year for SKI 1 west coast (SKI 1W) based on trips which landed gemfish. The final column gives the annual total landings for BT in the sub-region. These values are plotted in Figure 6.

Fishing	Distribution (t)					Distribution (%)				
year	BT	MW	BLL	Other	Total	BT	MW	BLL	Other	Total
SKI 1W										
89/90	5.2	–	–	0.1	5.3	97.8	–	–	2.2	0.1
90/91	11.4	–	–	0.0	11.4	100.0	–	–	0.0	0.3
91/92	66.5	–	–	0.0	66.5	100.0	–	–	0.0	1.8
92/93	196.9	–	0.2	0.0	197.1	99.9	–	0.1	0.0	5.4
93/94	498.0	–	0.0	0.2	498.2	100.0	–	0.0	0.0	13.6
94/95	526.1	–	0.0	0.2	526.3	100.0	–	0.0	0.0	14.4
95/96	319.5	–	0.3	0.0	319.7	99.9	–	0.1	0.0	8.7
96/97	592.2	0.0	0.6	0.0	592.8	99.9	0.0	0.1	0.0	16.2
97/98	416.8	–	0.7	0.0	417.6	99.8	–	0.2	0.0	11.4
98/99	211.9	–	2.0	6.6	220.4	96.1	–	0.9	3.0	6.0
99/00	239.8	0.0	0.8	12.6	253.2	94.7	0.0	0.3	5.0	6.9
00/01	217.8	0.0	0.9	30.1	248.8	87.5	0.0	0.3	12.1	6.8
01/02	68.6	0.0	0.4	0.8	69.8	98.3	0.0	0.6	1.1	1.9
02/03	45.2	0.0	0.7	0.1	45.9	98.3	0.1	1.4	0.1	1.3
03/04	9.8	0.3	3.0	0.1	13.3	73.9	2.4	22.9	0.8	0.4
04/05	8.2	0.1	3.5	0.2	12.0	68.6	0.9	28.9	1.6	0.3
05/06	5.1	0.2	1.6	0.1	7.0	72.7	2.5	22.8	1.9	0.2
06/07	10.0	0.0	2.5	0.2	12.8	78.3	0.2	19.8	1.7	0.3
07/08	38.2	0.3	1.2	0.2	39.9	95.7	0.8	2.9	0.6	1.1
08/09	23.3	–	0.6	0.1	24.1	96.7	–	2.7	0.6	0.7
09/10	8.5	0.0	1.8	0.2	10.5	80.8	0.2	17.0	2.0	0.3
10/11	22.1	0.0	1.5	0.1	23.7	93.3	0.0	6.4	0.3	0.6
11/12	22.2	0.0	2.4	0.4	25.0	88.7	0.1	9.7	1.5	0.7
12/13	20.0	0.0	5.1	0.2	25.3	79.0	0.0	20.1	0.8	0.7
Total	3 583.3	1.1	29.7	52.6	3 666.7	97.7	0.0	0.8	1.4	100.0

Table E.2A: Distribution of bottom trawl landings (%) by month and fishing year for SKI 1 East Northland (EN) and Bay of Plenty (BoP) based on trips which landed gemfish. The final column gives the annual total BT landings in each sub-region. These values are plotted in Figure 8.

Fishing												Month	
year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
EN													
89/90	0.1	0.0	–	–	0.0	0.1	0.2	12.9	83.5	0.5	1.8	0.9	315
90/91	0.3	0.1	1.0	0.1	0.3	0.0	0.3	28.5	65.8	0.5	1.0	2.0	372
91/92	0.6	0.7	0.0	0.1	0.0	0.1	1.2	18.0	77.6	0.1	0.8	0.8	318
92/93	0.1	0.1	0.1	0.1	0.0	0.1	0.6	55.6	42.6	0.1	0.7	0.1	391
93/94	0.2	0.1	0.0	0.0	0.0	0.0	1.1	43.0	54.5	0.3	0.7	0.0	366
94/95	0.0	0.8	0.2	0.0	0.1	0.1	0.3	52.9	44.6	0.2	0.0	0.8	346
95/96	0.5	0.0	0.3	0.2	0.0	0.0	0.1	40.5	55.5	2.0	0.6	0.3	222
96/97	0.2	0.7	0.2	0.0	0.8	0.6	1.1	6.4	86.3	1.6	1.7	0.4	143
97/98	0.3	0.7	1.0	0.7	0.1	0.2	0.3	14.8	78.5	0.7	2.1	0.6	88
98/99	0.4	0.2	0.1	0.0	0.0	0.0	0.1	2.8	89.7	4.2	0.4	2.1	83
99/00	1.5	1.0	0.3	0.0	0.0	0.1	0.3	0.5	88.9	2.2	1.5	3.7	85
00/01	0.8	0.3	2.9	1.1	1.7	0.1	0.9	3.8	57.0	3.2	5.6	22.6	20
01/02	0.5	4.4	2.6	0.4	0.0	0.1	0.1	2.4	84.7	2.9	0.0	1.8	45
02/03	2.1	7.2	6.1	0.0	0.5	1.3	2.1	0.3	38.4	24.5	7.0	10.6	5
03/04	0.3	4.5	0.2	1.2	4.2	1.5	1.2	0.2	77.9	2.1	5.6	1.2	7
04/05	0.6	0.8	0.6	0.9	0.0	0.4	5.4	3.1	85.9	0.4	1.8	0.1	12
05/06	1.0	5.4	2.3	0.7	0.4	4.3	2.6	37.7	2.2	0.5	18.0	24.9	24
06/07	4.8	10.2	6.8	1.8	0.7	0.3	2.3	25.8	44.4	1.1	1.7	0.2	19
07/08	13.3	6.7	11.5	0.7	4.3	3.1	7.3	9.9	14.7	4.6	9.9	14.0	6
08/09	4.1	28.8	6.3	0.8	7.2	3.9	6.8	0.6	9.8	1.1	23.0	7.6	3
09/10	0.3	1.3	1.9	0.0	0.2	6.1	2.4	2.7	69.7	7.9	3.2	4.2	10
10/11	4.7	15.3	1.3	0.2	10.3	1.7	1.1	3.2	11.6	1.7	18.7	30.1	5
11/12	10.3	15.0	1.9	1.2	2.5	3.7	8.2	10.4	39.7	3.9	2.7	0.5	3
12/13	2.5	2.3	0.9	14.2	0.7	12.9	26.5	2.8	19.6	3.6	13.8	0.0	5
Mean	0.4	0.6	0.4	0.1	0.2	0.2	0.7	30.9	63.2	0.8	1.2	1.3	2 892
BoP													
89/90	0.3	0.6	0.7	0.5	0.2	0.1	0.2	33.8	41.3	0.1	12.6	9.8	888
90/91	1.1	0.5	1.4	0.3	0.3	0.3	0.5	31.7	32.6	1.3	24.6	5.3	726
91/92	1.3	4.6	2.4	0.8	0.6	0.5	4.0	39.4	31.5	0.2	10.4	4.2	607
92/93	1.4	1.0	0.6	0.1	0.0	0.4	9.7	72.8	10.7	0.2	2.2	0.9	661
93/94	8.4	5.3	1.6	0.6	0.3	0.6	1.9	57.4	21.7	0.2	1.3	0.6	256
94/95	0.2	6.1	1.7	2.3	0.3	1.6	2.2	62.3	15.2	0.7	4.8	2.7	156
95/96	1.0	7.7	6.0	1.1	1.6	2.0	1.7	55.2	9.8	0.6	4.1	9.2	201
96/97	1.0	4.6	1.9	1.0	1.5	1.5	5.4	33.2	39.0	1.0	0.8	9.1	241
97/98	12.6	9.9	4.9	2.3	1.8	1.5	5.0	23.8	35.0	0.4	1.4	1.3	144
98/99	4.2	11.5	8.7	3.9	2.2	1.6	1.1	24.7	22.8	1.2	9.1	9.1	65
99/00	5.5	13.0	16.4	1.7	2.2	3.4	5.5	11.5	33.5	0.9	2.9	3.7	45
00/01	3.1	7.1	9.3	6.0	3.9	5.5	2.6	10.1	32.2	0.4	15.2	4.6	51
01/02	4.4	19.3	21.9	5.3	1.8	2.5	2.9	20.0	14.3	0.5	3.3	3.8	62
02/03	1.9	6.5	7.0	4.1	1.4	0.2	0.6	14.1	57.5	2.3	2.4	1.8	131
03/04	6.8	6.6	8.7	6.0	0.9	0.8	2.3	21.9	43.4	0.3	0.9	1.7	173
04/05	6.6	8.1	1.9	3.7	0.5	0.8	1.0	20.1	54.4	0.9	0.2	1.7	197
05/06	1.0	2.6	2.3	0.8	0.3	0.8	2.3	74.5	6.5	0.5	0.8	7.7	166
06/07	5.6	9.2	5.8	2.2	1.8	3.0	1.7	41.5	27.7	0.1	0.2	1.2	155
07/08	0.7	2.5	3.4	1.1	0.6	0.6	0.9	2.9	80.8	0.0	0.8	5.7	147
08/09	1.8	2.3	3.7	0.2	0.9	0.4	1.0	80.0	4.1	0.5	1.9	3.0	138
09/10	0.7	1.4	5.6	1.6	0.5	1.8	1.4	14.7	70.8	0.5	0.5	0.6	190
10/11	2.5	7.9	3.0	1.0	1.0	2.2	5.3	35.5	37.6	1.5	0.5	2.1	160
11/12	1.3	3.8	5.6	0.6	2.8	1.7	4.1	69.4	5.9	1.6	1.0	2.2	155
12/13	1.6	8.1	2.8	0.7	1.6	2.8	5.5	28.5	37.6	2.8	0.5	7.4	130
Mean	2.3	3.9	3.0	1.2	0.7	0.9	3.0	40.8	31.7	0.6	7.2	4.6	5 845

Table E.2B: Distribution of bottom trawl landings (%) by month and fishing year for SKI 2 North (SKI 2N) and SKI 2 South (SKI 2S) based on trips which landed gemfish. The final column gives the annual total BT landings in each sub-region. These values are plotted in Figure 8.

Fishing year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep (Month)	Total
SKI 2N													
89/90	7.6	26.7	10.3	15.0	5.3	4.7	6.5	14.6	2.2	0.5	1.4	5.4	153
90/91	5.0	24.0	31.6	4.9	1.4	0.9	3.6	19.8	3.5	0.1	0.8	4.3	163
91/92	25.1	23.8	14.1	5.6	5.8	2.9	8.7	3.2	0.9	0.1	5.5	4.3	197
92/93	4.5	15.3	31.5	9.9	7.6	6.1	1.8	19.6	0.6	0.2	0.1	2.9	108
93/94	17.8	24.3	25.7	9.0	3.4	1.7	4.6	2.4	2.2	0.1	5.3	3.7	63
94/95	1.6	52.2	17.6	11.1	3.3	3.8	4.6	1.5	2.0	0.7	0.2	1.5	85
95/96	7.8	34.8	16.5	0.7	1.8	0.5	3.0	7.1	0.5	0.2	0.2	26.9	147
96/97	10.6	15.1	38.1	9.0	16.4	4.5	0.9	1.9	0.7	0.1	1.8	0.9	265
97/98	17.3	16.3	9.2	23.5	12.9	5.8	1.4	5.8	1.7	0.3	0.1	5.7	145
98/99	3.7	19.9	12.9	15.0	3.5	22.2	9.9	6.6	2.9	0.1	0.4	2.9	150
99/00	13.1	4.7	24.8	22.9	2.4	8.0	3.8	11.8	1.0	0.7	0.0	6.9	280
00/01	24.1	17.3	13.8	9.0	4.0	5.8	6.6	12.4	1.9	0.9	0.0	4.3	137
01/02	18.3	42.0	6.2	7.6	0.3	7.6	10.9	1.1	1.1	0.0	0.0	4.9	98
02/03	4.3	35.2	30.8	9.7	8.1	2.0	1.1	2.1	5.7	0.2	0.5	0.4	133
03/04	0.2	7.8	33.3	26.6	4.9	1.6	16.5	2.0	3.4	3.3	0.1	0.4	123
04/05	11.1	48.1	18.9	8.6	2.4	2.4	6.2	0.2	0.1	0.1	0.1	1.8	119
05/06	2.8	38.7	10.5	0.9	7.4	23.3	0.6	6.9	3.4	0.8	0.9	3.9	67
06/07	13.0	40.5	15.4	8.2	3.3	9.2	3.4	2.4	3.8	0.1	0.2	0.5	95
07/08	4.6	19.0	20.7	34.0	6.2	2.6	1.4	2.0	3.5	0.1	0.6	5.2	66
08/09	5.0	7.9	49.2	13.6	7.1	4.1	0.5	2.3	8.4	0.1	1.0	0.8	53
09/10	1.7	9.2	48.2	4.7	4.5	2.4	1.1	3.5	7.5	0.6	3.9	12.6	82
10/11	32.6	26.7	12.4	5.6	5.0	2.4	3.0	3.1	6.1	0.9	1.2	1.0	92
11/12	6.5	25.3	17.5	10.5	13.5	3.0	6.8	3.8	6.3	0.8	1.7	4.4	91
12/13	9.5	13.1	21.3	26.2	9.3	2.7	2.5	3.9	9.2	0.8	0.2	1.3	51
Mean	11.0	23.0	22.1	12.1	6.0	5.5	4.8	6.6	2.6	0.5	1.1	4.8	2 963
SKI 2S													
89/90	5.5	12.6	1.8	13.4	17.0	7.2	6.2	27.7	2.8	0.2	0.1	5.5	864.9
90/91	7.6	15.8	10.5	6.5	8.5	4.3	11.0	31.1	3.5	0.2	0.2	1.0	669.4
91/92	7.8	14.5	7.9	11.6	17.2	16.2	12.7	9.3	0.3	0.0	0.5	2.0	762.1
92/93	2.1	17.9	16.2	16.9	7.3	8.0	19.9	11.0	0.2	0.1	0.1	0.2	706.2
93/94	0.5	10.9	16.3	9.0	7.9	8.6	20.9	24.2	0.9	0.2	0.3	0.5	650.0
94/95	4.7	9.7	6.4	5.7	12.4	29.4	18.3	11.4	0.2	0.2	0.5	1.1	365.0
95/96	6.2	3.8	14.0	4.1	5.9	23.6	27.2	13.3	1.0	0.4	0.1	0.3	347.1
96/97	1.3	8.6	4.8	6.2	12.9	18.7	28.8	18.4	0.1	0.0	0.0	0.1	484.8
97/98	1.6	10.2	9.8	3.7	16.1	26.0	22.4	10.1	0.1	0.0	–	0.0	392.8
98/99	0.6	6.0	11.1	4.5	4.4	11.0	46.0	16.1	0.1	–	0.0	0.2	159.1
99/00	2.2	4.2	6.8	21.2	33.9	15.6	11.7	3.7	0.1	0.1	0.0	0.4	207.3
00/01	1.0	4.6	6.3	37.3	29.9	8.4	4.6	5.1	0.7	0.7	0.7	0.8	145.4
01/02	0.3	5.0	11.3	8.0	7.0	18.0	35.0	7.8	4.8	1.7	0.6	0.4	156.9
02/03	0.3	2.7	11.3	17.3	28.0	19.2	5.2	13.9	0.1	0.7	0.1	1.3	154.3
03/04	0.8	10.2	4.4	22.7	25.1	20.4	2.4	11.4	1.2	1.3	0.0	0.0	146.9
04/05	0.8	11.1	24.7	31.7	10.9	14.0	2.8	2.2	0.2	–	0.0	1.6	104.8
05/06	4.2	12.7	12.3	5.7	8.1	37.0	3.2	11.9	1.9	1.8	0.2	1.0	73.4
06/07	4.3	33.3	5.6	39.1	3.7	1.5	4.9	6.3	0.9	0.0	0.0	0.2	192.3
07/08	0.6	19.5	27.9	15.8	18.8	4.8	8.3	1.7	2.4	0.0	0.1	0.1	121.2
08/09	5.6	17.7	25.5	17.2	13.4	8.5	7.6	4.1	0.0	0.0	0.0	0.4	112.9
09/10	1.2	11.2	23.6	16.6	24.7	12.8	2.3	6.5	0.3	0.0	0.2	0.6	72.6
10/11	3.0	30.2	14.3	16.9	15.7	10.0	1.4	5.8	1.2	0.3	0.4	0.9	115.0
11/12	13.3	25.9	33.7	7.0	9.8	2.8	4.7	0.1	1.0	0.2	0.7	0.8	41.6
12/13	4.6	14.6	37.6	19.2	4.0	11.5	7.9	0.3	0.1	0.2	0.1	0.1	53.0
Mean	3.8	12.6	10.7	12.4	13.3	13.3	15.5	15.5	1.2	0.2	0.2	1.3	7098.9

Table E.2C: Distribution of bottom trawl landings (%) by month and fishing year for SKI 1 west coast (SKI 1W) based on trips which landed gemfish. The final column gives the annual total BT landings in each sub-region. These values are plotted in Figure 8.

Fishing												Month	
year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
SKI 1W													
89/90	–	1.5	3.3	–	–	4.9	3.8	14.6	69.4	0.0	0.0	2.4	5
90/91	0.0	–	–	–	–	–	0.8	8.2	89.1	0.4	0.0	1.5	11
91/92	0.4	0.3	0.3	0.0	0.0	0.1	0.3	0.4	57.2	37.2	0.0	3.8	67
92/93	–	0.1	0.2	–	0.2	0.8	0.4	1.5	80.4	16.0	0.5	0.0	197
93/94	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	97.0	2.2	0.4	0.2	498
94/95	0.0	0.0	0.0	0.0	0.0	0.1	0.6	0.2	96.5	0.6	0.1	1.9	526
95/96	0.0	0.2	0.0	0.0	0.0	0.1	1.4	1.9	82.0	13.9	0.5	0.0	319
96/97	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.2	99.0	0.6	0.1	0.0	592
97/98	0.0	0.0	0.0	0.0	0.6	0.8	0.5	0.6	86.7	1.5	8.5	0.7	417
98/99	0.6	0.1	0.0	0.1	0.0	0.1	0.2	0.3	91.6	4.7	1.6	0.5	212
99/00	0.2	0.0	0.0	0.0	0.3	0.6	0.2	3.7	93.8	0.8	0.0	0.3	240
00/01	0.0	–	0.0	0.1	0.0	0.3	0.6	1.6	88.6	8.6	0.1	0.0	218
01/02	0.0	0.0	0.4	0.1	0.1	0.2	1.1	2.9	92.5	1.4	0.1	1.1	69
02/03	0.0	0.6	0.1	1.3	2.5	0.8	1.4	5.1	73.8	8.2	4.8	1.4	45
03/04	0.6	1.2	2.3	2.3	9.1	7.8	2.8	0.5	69.5	0.0	1.6	2.1	10
04/05	0.8	1.7	5.0	0.7	10.1	9.8	3.2	2.3	63.2	1.4	1.0	0.8	8
05/06	3.3	6.5	7.8	0.6	11.2	21.3	5.4	0.4	18.2	1.6	20.9	2.7	5
06/07	0.1	1.8	3.7	1.4	3.0	8.5	18.7	1.6	38.4	1.4	21.3	0.1	10
07/08	0.2	0.0	0.1	0.1	0.7	0.3	0.9	3.5	73.1	0.9	2.2	18.0	38
08/09	0.0	0.5	0.2	0.9	0.7	10.1	3.1	1.0	36.2	16.7	20.3	10.0	23
09/10	0.8	0.3	1.7	2.1	1.5	18.1	11.9	4.8	3.7	0.4	54.0	0.6	8
10/11	0.1	0.9	3.7	0.1	10.1	4.0	7.3	1.3	0.5	0.1	71.7	0.2	22
11/12	2.1	0.9	3.3	0.1	0.6	1.1	2.7	2.0	2.0	16.0	53.8	15.2	22
12/13	0.2	0.2	0.5	0.2	1.1	0.6	8.8	0.7	37.1	0.4	15.2	35.1	20
Mean	0.1	0.1	0.1	0.1	0.3	0.5	0.6	1.0	88.8	4.7	2.5	1.1	3 583

Table E.3A: Distribution of bottom trawl landings (%) by target species and fishing year for SKI 1 East Northland (EN) and Bay of Plenty (BoP) based on trips which landed gemfish. The final column gives the annual total BT landings in each sub-region. These values are plotted in Figure 9.

Fishing	Target Species								
year	SKI	TAR	HOK	SCI	LIN	BYX	RBY	OTH	Total
EN									
89/90	94.9	4.2	–	0.2	–	–	–	0.7	315
90/91	94.7	3.2	0.0	0.9	–	–	–	1.2	372
91/92	91.6	4.5	0.0	0.4	0.0	–	–	3.5	318
92/93	95.9	2.5	1.1	0.2	–	–	0.0	0.3	391
93/94	97.1	2.0	0.0	0.4	–	–	–	0.5	366
94/95	97.8	1.4	0.1	0.2	–	–	–	0.5	346
95/96	96.0	1.5	0.1	1.6	–	0.0	–	0.8	222
96/97	94.4	1.8	3.0	0.1	0.1	–	0.0	0.5	143
97/98	93.9	1.1	2.8	1.0	–	–	0.2	1.0	88
98/99	97.2	1.4	0.1	1.0	0.0	–	–	0.3	83
99/00	90.7	4.4	0.3	1.2	1.8	0.1	0.0	1.5	85
00/01	61.4	31.6	0.0	4.6	0.9	0.1	0.0	1.4	20
01/02	88.4	1.0	0.1	6.2	0.0	2.0	0.5	1.7	45
02/03	62.9	6.3	–	12.9	10.7	0.0	0.0	7.2	5
03/04	81.2	6.2	0.1	3.9	0.1	1.9	0.0	6.7	7
04/05	85.3	8.1	1.9	0.4	0.0	0.5	–	3.8	12
05/06	5.0	25.7	1.5	1.1	1.4	56.6	0.1	8.7	24
06/07	24.0	23.8	3.7	0.0	33.7	1.1	0.6	13.2	19
07/08	8.6	34.0	1.3	7.1	18.0	23.9	2.3	4.8	6
08/09	1.0	61.2	8.8	0.0	10.2	1.6	2.4	14.7	3
09/10	9.0	14.2	55.2	2.6	9.3	6.7	0.0	3.0	10
10/11	–	37.5	3.4	3.1	15.1	29.7	3.2	7.9	5
11/12	0.0	61.1	3.5	0.2	3.7	7.2	13.0	11.3	3
12/13	6.2	18.2	25.9	16.3	12.6	–	6.1	14.9	5
Mean	92.6	3.5	0.7	0.7	0.5	0.7	0.1	1.3	2 892
BoP									
89/90	89.3	1.9	0.0	3.2	–	–	0.0	5.5	888
90/91	88.7	4.9	0.1	5.7	–	–	–	0.6	726
91/92	83.1	9.7	1.1	4.9	–	–	0.1	1.1	607
92/93	90.1	6.6	0.5	1.2	0.0	–	–	1.7	661
93/94	86.9	6.7	2.3	3.3	0.0	–	0.4	0.4	256
94/95	71.8	13.4	8.0	4.8	0.0	–	0.1	1.9	156
95/96	70.6	10.6	14.3	3.0	0.1	0.0	0.2	1.2	201
96/97	72.6	3.9	19.0	2.4	–	0.0	0.0	2.0	241
97/98	69.0	7.3	19.9	1.1	0.1	–	0.0	2.7	144
98/99	52.9	11.9	17.1	4.6	5.2	–	1.2	7.1	65
99/00	16.4	19.0	30.1	28.1	0.6	0.0	–	5.9	45
00/01	42.0	13.1	6.0	21.2	0.3	0.0	13.7	3.8	51
01/02	36.9	16.9	8.4	21.6	1.4	0.0	1.1	13.8	62
02/03	72.4	8.8	5.4	7.1	3.8	–	0.8	1.7	131
03/04	68.4	11.0	11.1	5.5	0.9	–	0.4	2.7	173
04/05	76.5	9.7	6.9	5.2	0.3	–	0.4	1.0	197
05/06	74.3	7.3	6.2	4.0	6.8	–	0.0	1.5	166
06/07	64.0	15.6	8.3	7.1	2.4	–	1.2	1.4	155
07/08	80.6	2.9	4.8	3.1	4.1	0.0	3.5	0.9	147
08/09	79.5	5.9	5.3	4.3	2.3	0.0	1.0	1.6	138
09/10	80.7	4.5	6.5	3.2	2.9	0.0	1.2	1.0	190
10/11	61.8	12.4	15.6	5.3	0.4	0.0	3.3	1.2	160
11/12	64.7	11.6	11.6	7.2	0.9	0.0	3.2	0.9	155
12/13	53.2	7.6	23.3	6.3	4.4	–	4.3	0.9	130
Mean	78.9	7.2	5.6	4.6	0.9	0.0	0.7	2.2	5 845

Table E.3B: Distribution of bottom trawl landings (%) by month and fishing year for SKI 2 North (SKI 2N) and SKI 2 South (SKI 2S) based on trips which landed gemfish. The final column gives the annual total BT landings in each sub-region. These values are plotted in Figure 9.

Fishing	Target Species								
year	SKI	TAR	HOK	SCI	LIN	BYX	RBY	OTH	Total
SKI 2N									
89/90	26.4	47.9	23.8	–	–	0.0	–	1.9	153
90/91	58.9	35.8	3.0	0.1	0.1	–	–	2.2	163
91/92	74.0	22.0	1.5	0.1	0.0	–	0.4	2.0	197
92/93	64.2	31.3	0.4	0.1	–	0.0	0.2	3.8	108
93/94	49.5	40.5	4.5	0.3	–	0.0	2.3	2.9	63
94/95	23.3	60.3	8.0	2.6	–	0.0	0.8	4.9	85
95/96	70.9	26.4	1.1	0.2	–	0.0	0.7	0.7	147
96/97	91.3	5.7	1.1	0.3	–	0.2	–	1.4	265
97/98	84.3	6.7	7.3	0.1	–	0.0	0.0	1.5	145
98/99	84.1	12.0	2.6	0.1	–	0.0	0.4	0.8	150
99/00	93.1	5.3	0.6	0.2	–	0.0	0.2	0.6	280
00/01	75.4	17.2	0.5	0.2	0.1	0.0	4.7	2.0	137
01/02	87.7	10.1	1.5	0.1	–	0.0	0.0	0.6	98
02/03	74.9	17.0	6.1	0.1	0.1	0.0	0.6	1.2	133
03/04	60.4	20.8	13.2	0.0	0.0	0.1	3.3	2.1	123
04/05	70.4	22.0	4.6	0.2	0.0	0.8	1.4	0.6	119
05/06	52.5	37.5	2.5	0.2	1.1	0.7	3.1	2.4	67
06/07	34.2	56.2	4.3	0.0	0.7	0.2	3.3	1.2	95
07/08	6.3	84.2	0.5	0.0	2.0	0.2	3.9	2.9	66
08/09	18.4	66.5	7.9	–	4.2	0.2	0.3	2.4	53
09/10	51.1	28.7	12.3	0.0	2.4	0.1	0.3	5.2	82
10/11	49.6	40.6	5.1	0.0	2.5	0.1	0.6	1.6	92
11/12	19.0	65.6	6.0	–	4.7	0.2	2.1	2.5	91
12/13	5.7	67.7	15.7	–	7.3	0.0	0.1	3.6	51
Mean	63.9	27.5	4.9	0.2	0.6	0.1	1.0	1.8	2 963
SKI 2S									
89/90	81.7	11.1	3.5	1.9	0.3	0.5	0.2	0.8	864.9
90/91	64.0	3.4	4.7	5.6	0.1	13.2	3.4	5.5	669.4
91/92	90.9	3.3	1.5	3.1	0.1	0.0	0.4	0.7	762.1
92/93	87.7	1.3	5.2	3.1	0.0	0.0	1.1	1.6	706.2
93/94	87.0	1.6	7.0	2.6	0.0	0.2	–	1.6	650.0
94/95	89.7	3.3	2.6	2.9	0.3	0.1	–	1.1	365.0
95/96	74.7	3.8	16.6	4.2	–	0.1	0.0	0.6	347.1
96/97	75.1	1.6	17.9	4.8	0.0	0.1	–	0.5	484.8
97/98	55.8	0.4	35.8	5.2	–	0.8	0.7	1.2	392.8
98/99	73.9	1.3	7.6	16.3	–	0.5	0.1	0.3	159.1
99/00	85.3	1.2	4.8	7.1	0.0	0.6	0.2	0.8	207.3
00/01	76.3	3.1	5.7	13.1	0.0	1.0	0.1	0.8	145.4
01/02	58.9	2.4	1.5	34.1	0.0	1.3	0.0	1.8	156.9
02/03	67.5	4.6	4.2	19.7	0.1	2.2	0.0	1.8	154.3
03/04	74.2	5.8	4.0	14.6	–	0.3	–	1.1	146.9
04/05	57.0	16.0	4.3	13.6	–	6.4	1.1	1.6	104.8
05/06	47.2	25.2	2.9	22.1	0.0	0.2	0.1	2.3	73.4
06/07	62.9	19.1	2.4	8.4	0.0	4.1	1.3	1.7	192.3
07/08	12.1	59.6	1.4	14.3	2.5	1.6	3.4	5.1	121.2
08/09	38.3	36.6	4.0	4.3	0.3	15.1	0.0	1.4	112.9
09/10	28.8	29.2	4.0	21.7	0.6	9.9	3.9	1.9	72.6
10/11	42.3	18.1	7.7	20.1	0.8	4.8	2.7	3.5	115.1
11/12	28.4	42.6	0.9	9.8	0.6	1.2	0.0	16.5	41.6
12/13	47.0	31.0	2.3	6.3	0.3	0.5	–	12.6	53.0
Mean	74.3	6.9	7.4	6.6	0.1	2.2	0.7	1.8	7098.9

Table E.3C: Distribution of bottom trawl landings (%) by target species and fishing year for SKI 1 west coast (SKI 1W) based on trips which landed gemfish. The final column gives the annual total BT landings in each sub-region. These values are plotted in Figure 9.

Fishing	Target Species								
year	SKI	TAR	HOK	SCI	LIN	BYX	RBY	OTH	Total
SKI 1W									
89/90	67.1	20.8	–	2.0	–	–	–	10.1	5
90/91	87.6	8.6	–	0.5	–	–	0.5	2.8	11
91/92	78.0	17.3	–	0.1	3.4	–	–	1.2	67
92/93	71.4	27.9	–	0.0	0.2	–	–	0.5	197
93/94	93.9	2.3	–	0.0	0.4	–	–	3.4	498
94/95	98.9	0.8	–	–	0.0	–	–	0.3	526
95/96	98.5	1.2	0.2	–	–	–	–	0.1	319
96/97	99.2	0.3	0.3	–	0.0	–	–	0.1	592
97/98	98.0	1.7	0.0	–	0.0	–	0.0	0.2	417
98/99	98.9	0.6	0.0	0.1	0.0	0.0	–	0.3	212
99/00	97.2	0.5	0.2	–	0.3	–	0.0	1.8	240
00/01	98.2	0.2	0.5	–	0.4	–	0.0	0.8	218
01/02	94.6	0.9	0.6	–	0.9	0.3	–	2.6	69
02/03	85.4	7.1	0.0	–	2.3	3.2	–	2.0	45
03/04	67.2	9.4	0.8	–	2.3	1.9	0.0	18.3	10
04/05	62.8	24.5	–	0.4	0.5	0.4	0.1	11.4	8
05/06	–	49.6	0.0	–	37.2	0.0	–	13.2	5
06/07	–	17.7	–	–	73.2	1.4	0.1	7.7	10
07/08	67.7	2.6	0.0	–	28.2	0.0	0.4	1.2	38
08/09	20.1	7.7	4.2	–	61.8	–	–	6.2	23
09/10	8.3	15.9	0.1	–	66.8	0.1	–	8.8	8
10/11	0.9	10.9	0.0	–	82.4	3.0	–	2.8	22
11/12	1.4	8.5	1.0	–	84.0	0.0	–	5.0	22
12/13	19.4	3.9	0.1	0.8	72.9	–	0.0	2.8	20
Mean	92.4	3.3	0.2	0.0	2.8	0.1	0.0	1.2	3 583

Appendix F. SKI 2 GEMFISH CPUE ANALYSES

F.1 General overview

Ten SKI 2 CPUE analyses (Table 13) were investigated, five of which were based on daily amalgamated records (see Section 2.3.1) while the remaining five used event-level (tow-by-tow) records. The daily analyses were preferred because there were insufficient data before 1993–94 in the tow-by-tow data sets and it was in this early period that the gemfish CPUE dropped precipitously.

Three of the ten fisheries are reported in detail with diagnostics, tabular output and plots for the selected model. These serve as examples for the closely allied models, all of which contain a great deal of overlapping data with the example analyses, leading to similar diagnostics in each case:

- Appendix G: SKI 2_BT(MIX+SKI)(daily);
- Appendix H: SKI 2_BT(MIXnoSKI)(towbytow);
- Appendix I: SKI 2_BT(SCI)(daily);

Model selection tables, tables of CPUE indices and plots of the positive catch series and of the combined, binomial and positive catch series are provided in Appendix J for the seven CPUE series without detailed diagnostics.

F.2 Methods

F.2.1 Data Preparation

The identification of candidate trips for these analyses and the methods used to prepare them are described in Section 2.3.1 in the main report. Landings were allocated to effort at the "daily effort stratum" resolution procedure described on page 7 or to event (tow-by-tow) level records, depending on the analysis model.

Those groups of events that satisfied the criteria of target species, method of capture and statistical areas that defined each fishery were selected from available fishing trips. Any effort strata that were matched to a landing of school shark were termed "successful", and may include relevant but unsuccessful effort given that a "daily-effort stratum" represents amalgamated catch and effort. Consequently, the analysis of catch rates when using a "daily-effort stratum" record in successful strata also incorporates some zero catch information. This is not the case for the event-level analyses.

List of explanatory variables offered to the models:

"daily effort stratum" models	**event-level models (tow-by-tow)**
fishing year	fishing year
month	month
area	area
vessel	vessel
target species	target species
poly(log(duration), 3)	poly(log(duration), 3)
poly(log(num[ber tows]), 3)	poly(log(bottom [depth]), 3)
	poly(log(speed), 3)
	poly(log([wingspread] width), 3)
	poly(log([headline] height), 3)
	poly(log(swept_distance), 3)
	poly(log(swept_area), 3)
	poly(log(swept_volume), 3)

The dependent variable will be log(catch) where catch will be the scaled daily landings. Data might not represent an entire fishing trip; just those portions of it that qualified. Trips were not dropped because they targeted more than one species or fished in more than one statistical area.

Datasets were further restricted to core fleets of vessels, defined by their activity in the fishery, thus selecting only the most active vessels without dropping too much of the available catch and effort data.

F.2.2 Analytical methods for standardisation

Arithmetic CPUE $\left(\hat{A}_y\right)$ in year *y* was calculated as the mean of catch divided by effort for each observation in the year (including zero catch observations):

Eq. F.1 $$\hat{A}_y = \frac{\sum_{i=1}^{N_y} C_{i,y} / E_{i,y}}{N_y}$$

where $C_{i,y}$ is the [*catch*] and $E_{i,y} = T_{i,y}$ ([*tows*]) in record *i* in year *y*, and N_y is the number of records in year *y*. Note that $T_{i,y} = 1$ for event-level analyses.

Unstandardised CPUE $\left(\hat{U}_y\right)$ in year *y* is the geometric mean of the ratio of catch to effort for each record *i* in year *y*:

Eq. F.2 $$\hat{U}_y = \exp\left[\frac{\sum_{i=1}^{N_y} \ln\left(C_{i,y} / E_{i,y}\right)}{N_y}\right]$$

where C_i, $E_{i,y}$ and N_y are as defined for Eq. F.1. Unstandardised CPUE assumes a log-normal distribution, but does not take into account changes in the fishery. This index is the same as the "year index" calculated by the standardisation procedure, when not using additional explanatory variables and using the same definition for $E_{i,y}$. Presenting the arithmetic and unstandardised CPUE indices in this report provides measures of how much the standardisation procedure has modified the series from these two sets of indices.

A standardised abundance index (Eq. F.3) was calculated from a generalised linear model (GLM) (Quinn & Deriso 1999) using a range of explanatory variables including [*year*], [*month*], [*vessel*] and other available factors:

Eq. F.3 $$\ln(I_i) = B + Y_{y_i} + \alpha_{a_i} + \beta_{b_i} + ... + f\left(\chi_i\right) + f\left(\delta_i\right) .... + \varepsilon_i$$

where $I_i = C_i$ for the i^{th} record, Y_{y_i} is the year coefficient for the year corresponding to the i^{th} record, α_{a_i} and β_{b_i} are the coefficients for factorial variables *a* and *b* corresponding to the i^{th} record, and $f\left(\chi_i\right)$ and $f\left(\delta_i\right)$ are polynomial functions (to the 3rd order) of the continuous variables χ_i and δ_i corresponding to the i^{th} record, *B* is the intercept and ε_i is an error term. The actual number of factorial and continuous explanatory variables in each model depends on the model selection criteria. Fishing year was always forced as the first variable, and month (of landing), statistical area, target species, and a unique vessel identifier were also offered as categorical variables. Number of tows $\left(\ln\left(T_i\right)\right)$ was offered to the models based on "daily-effort" records and fishing duration $\left(\ln\left(D_i\right)\right)$ was offered to "daily-effort" and event-based models as continuous third order polynomial variables.

A diagnostic procedure was applied to the successful (positive) catch records by fitting alternative regressions based on five statistical distributional assumptions (lognormal, log-logistic, inverse Gaussian, gamma and Weibull) and which predicted catch based on a reduced dataset of six explanatory variables (year, month, area, vessel, target species and $\left(\ln\left(T_i\right)\right)$ – the last variable was only included for the "daily-effort" models). The distribution which resulted in the model with the lowest negative log-likelihood was used in the subsequent step-wise CPUE analysis.

For the positive catch records, log(catch) was regressed against the full set of explanatory variables in a stepwise procedure, selecting variables one at a time until the improvement in the model R^2 was less than 0.01. The order of the variables in the selection process was based on the variable with the lowest AIC, so that the degrees of freedom were minimised.

Canonical coefficients and standard errors were calculated for each categorical variable (Francis 1999). Standardised analyses typically set one of the coefficients to 1.0 without an error term and estimate the remaining coefficients and the associated error relative to the fixed coefficient. This is required because of parameter confounding. The Francis (1999) procedure rescales all coefficients so that the geometric mean of the coefficients is equal to 1.0 and calculates a standard error for each coefficient, including the fixed coefficient.

The procedure described by Eq. F.3 is necessarily confined to the positive catch observations in the data set because the logarithm of zero is undefined. Observations with zero catch were modelled by fitting a linear regression model based on a binomial distribution and using the presence/absence of gemfish as the dependent variable (where 1 is substituted for $\ln(I_i)$ in Eq. F.3 if it is a successful catch record and 0 if it is not successful), using the same data set. Explanatory factors were estimated in the model in the same manner as described for Eq. F.3. Such a model provides an alternative series of standardised coefficients of relative annual changes that is analogous to the equivalent series estimated from the positive catch regression.

A combined model, which integrates the lognormal and binomial annual abundance coefficients, was estimated for all models using the delta distribution, which allows zero and positive observations (Vignaux 1994):

Eq. F.4
$$^{C}Y_y = \frac{^{L}Y_y}{\left(1 - P_0\left[1 - {1}/{^{B}Y_y}\right]\right)}$$

where $^{C}Y_y$ = combined index for year y

$^{L}Y_y$ = lognormal index for year i

$^{B}Y_y$ = binomial index for year i

P_0 = proportion zero for base year 0

Confidence bounds, while straightforward to calculate for the binomial and lognormal models, were not calculated for the combined model because a bootstrap procedure (recommended by Francis 2001) has not yet been implemented in the available software.

Appendix G. DIAGNOSTICS AND SUPPORTING ANALYSES FOR MIXED TARGET (INCL SKI) BOTTOM TRAWL USING DAILY STRATUM RESOLUTION [SKI2_BT(MIX+SKI)(DAILY)] CPUE STANDARDISATION

G.1 Introduction

This analysis is presented as an example of the diagnostics associated with the bottom trawl "daily-effort stratum" models that are offered a mixed suite of target species, with the assumption that a consistent gear configuration was used to capture the species in the target suite. The diagnostics for the SKI2_BT(MIXnoSKI)(daily) model will be very similar to the diagnostics reported here because the data for the two models overlap by 90%.

G.2 Fishery definition

SKI2_BT(MIX+SKI)(daily): The fishery is defined from bottom trawl fishing events which fished in Statistical Areas 011, 012, 013, 014, 015, 016, 017, 018, 019 declaring target species GUR, SNA, TAR, LIN, BAR, HOK, SKI. All form types (CELR, TCEPR, TCER) were included from fishing years 1989–90 to 2012–13.

G.3 Core vessel selection

The criteria used to define the core fleet were those vessels that had fished for at least 5 trips in each of at least 5 years using trips with at least 1 kg of catch. These criteria resulted in a core fleet size of 55 vessels which took 77% of the catch (Figure G.1).

G.4 Data summary

Table G.1: Number of number of core vessels, trips, daily effort strata, number of events that have been "rolled up" into daily effort strata, calculated number of events per daily-effort stratum, number of tows, sum of hours fished, sum of landed SKI (t), proportion of trips with catch and proportion of daily-effort strata with catch by fishing year for core vessels (based on a minimum of 5 trips per year in at least 5 years) in the SKI2_BT(MIX+SKI)(daily) fishery.

Fishing year	Vessels	Trips	Daily effort strata	Events	Events per stratum	Number of tows	Sum duration (h)	Catch (t)	Trips with catch (%)	Strata with catch (%)
1990	33	739	1 805	1 854	1.027	4 567	17 024.2	752.5	55.21	51.75
1991	35	950	2 353	2 556	1.086	6 071	22 924.9	461.9	51.16	47.22
1992	36	1 156	2 625	3 025	1.152	6 639	26 167.9	702.2	46.28	44.84
1993	37	1 098	2 670	2 877	1.078	6 676	27 531.0	585.7	50.36	48.16
1994	37	1 033	2 698	3 310	1.227	6 528	26 673.3	452.0	50.15	47.15
1995	36	1 052	2 572	3 153	1.226	6 293	25 330.0	350.3	43.92	42.81
1996	34	859	2 097	2 876	1.371	5 329	20 359.6	177.6	35.04	34.38
1997	33	944	2 408	3 235	1.343	6 323	23 566.1	200.6	29.77	28.07
1998	33	863	2 123	2 729	1.285	5 552	20 225.7	54.1	28.74	29.06
1999	31	806	1 891	2 687	1.421	5 098	18 462.8	117.1	29.90	29.14
2000	30	739	1 862	2 349	1.262	4 977	18 577.0	106.9	28.28	27.82
2001	31	735	1 969	2 763	1.403	5 446	20 045.9	48.9	34.01	28.69
2002	30	710	1 792	2 669	1.489	4 875	17 290.3	76.1	40.42	32.25
2003	30	779	2 014	2 858	1.419	5 416	19 896.2	80.2	48.14	36.79
2004	30	767	2 041	3 102	1.520	5 682	20 332.7	149.1	46.81	38.95
2005	30	852	2 357	3 336	1.415	6 687	24 502.4	91.0	33.69	28.64
2006	30	830	2 371	3 462	1.460	7 006	25 326.1	74.6	36.39	33.45
2007	27	799	2 447	3 879	1.585	7 251	25 267.1	223.2	47.18	38.25
2008	28	737	2 344	6 676	2.848	6 678	23 291.8	122.2	44.10	31.06
2009	29	854	2 672	7 712	2.886	7 712	26 937.0	124.3	42.97	30.65
2010	29	942	2 986	8 715	2.919	8 715	30 177.6	112.8	45.12	31.85
2011	31	891	2 928	8 750	2.988	8 750	29 667.0	157.2	56.00	39.14
2012	28	863	2 571	7 586	2.951	7 586	26 536.4	114.6	55.85	42.71
2013	24	748	2 352	6 944	2.952	6 944	24 654.4	88.2	51.20	37.33

G.5 Core vessel selection

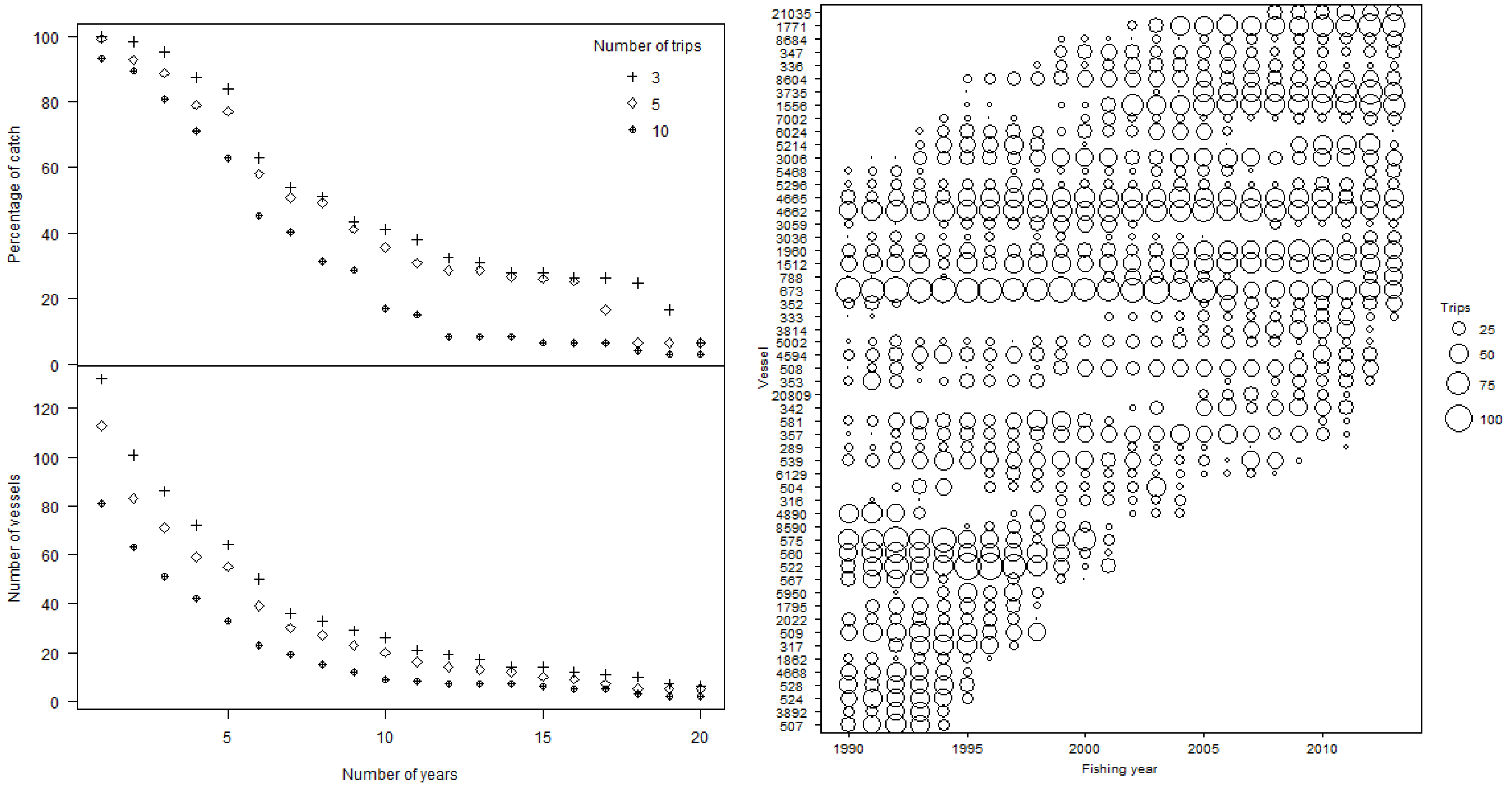

Figure G.1: [left panel] total landed SKI and number of vessels plotted against the number of years used to define core vessels participating in the SKI2_BT(MIX+SKI)(daily) dataset. The number of qualifying years (minimum number of trips per year) for each series is indicated in the legend. [right panel]: bubble plot showing the number of daily-effort strata for selected core vessels (based on at least 5 trips in 5 or more fishing years) by fishing year.

G.6 Exploratory data plots for core vessel data set

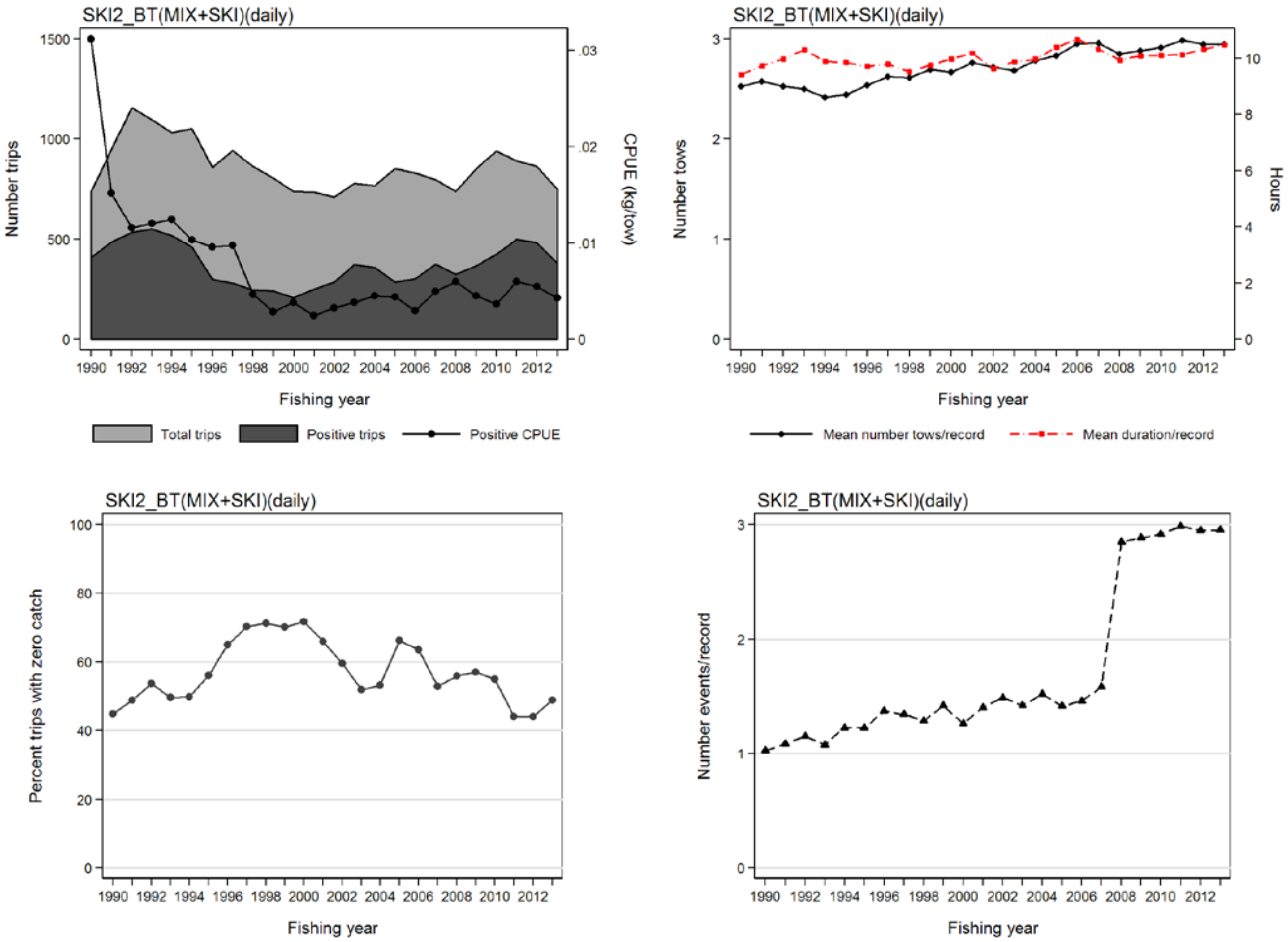

Figure G.2: Core vessel summary plots by fishing year for model SKI2_BT(MIX+SKI)(daily): [upper left panel]: total trips (light grey) and trips with gemfish catch (dark grey) overlaid with median annual arithmetic CPUE (kg/tow) for all trips *i* with positive catch: $A_y = \text{median}\left(C_{y,i}/E_{y,i}\right)$; [upper right panel]: mean number tows and mean duration per daily-effort stratum record; [lower left panel]: proportion of trips with no catch of gemfish; [lower right panel]: mean number of events per daily-effort stratum record.

G.7 Selection of distribution for positive catch records

The best distribution was lognormal.

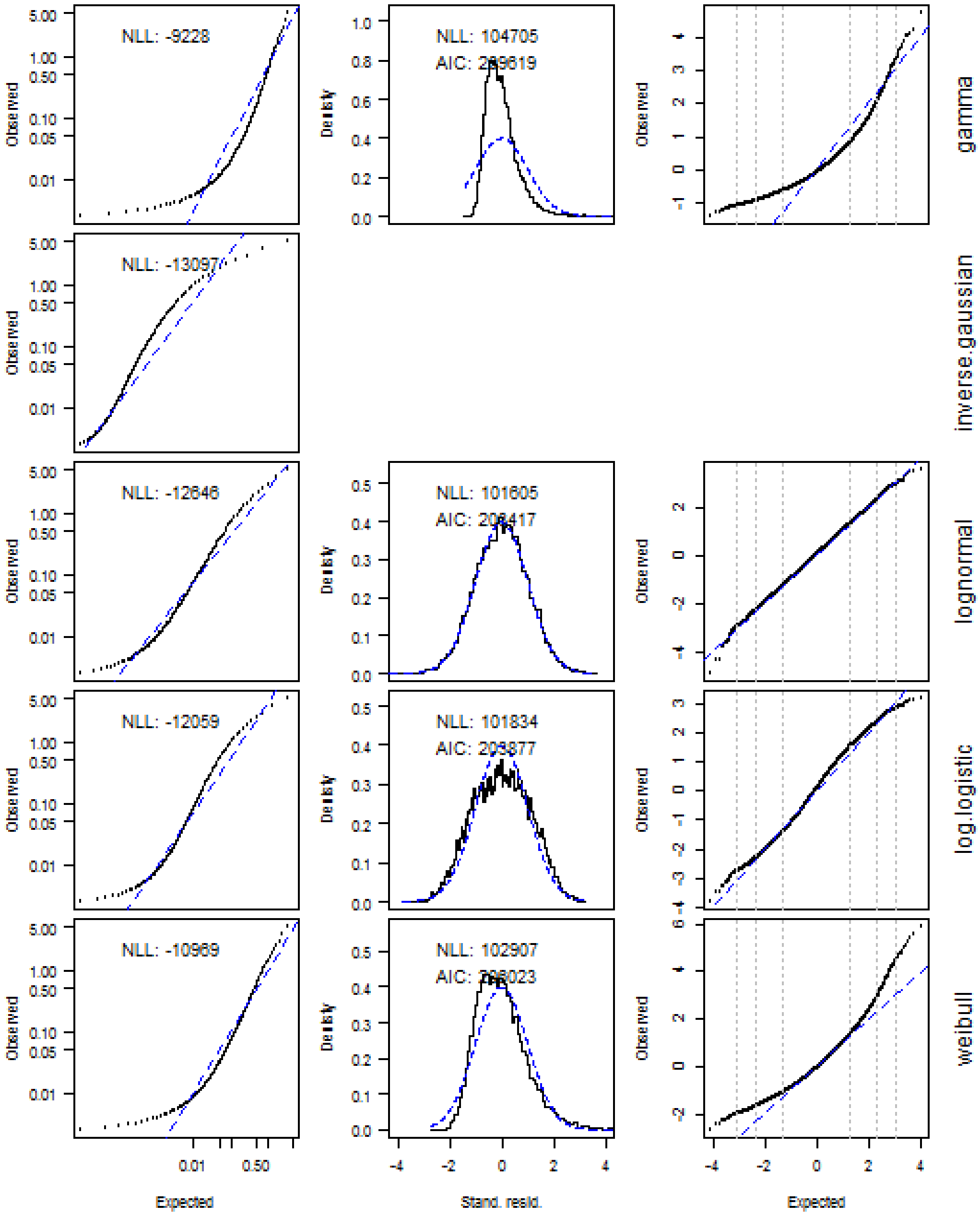

Figure G.3: Diagnostics for alternative distributional assumptions for catch in the gemfish SKI2_BT(MIX+SKI)(daily) model. Left: quantile-quantile plot of observed catches (centred (by mean) and scaled (by standard deviation) in log space) versus maximum likelihood fit of distribution (missing panel indicates that the fit failed to converge); Middle: standardised residuals from a generalised linear model fitted using the formula catch ~ fyear + month +area+ vessel + log(sets) and the distribution (missing panel indicates that the model failed to converge); Right: quantile-quantile plot of model standardised residuals against standard normal (vertical lines represent 0.1%, 1% and 10% percentiles). NLL = negative log-likelihood; AIC = Akaike information criterion.

G.8 Positive catch model selection table

Four explanatory variables entered the model after fishing year (Table G.2), with area and number of tows non-significant. A plot of the model is provided in Figure G.4 and the CPUE indices are listed in Table G.4.

Table G.2: Order of acceptance of variables into the lognormal model of successful catches in the SKI2_BT(MIX+SKI)(daily) fishery model for core vessels based on the vessel selection criteria of at least 5 trips in 5 or more fishing years, with the amount of explained deviance and R^2 for each variable. Variables accepted into the model are marked with an *, and the final R^2 of the selected model is in bold. Fishing year was forced as the first variable.

Variable	DF	Neg. Log likelihood	AIC	R^2	Model use
fishing year	25	-108 584	217 218	8.79	*
target species	31	-104 517	209 097	38.52	*
month	42	-103 102	206 289	46.41	*
vessel	96	-101 790	203 772	52.82	*
poly(log(duration), 3)	99	-101 530	203 259	53.99	*
area	107	-101 395	203 003	54.59	
poly(log(num), 3)	110	-101 332	202 885	54.86	

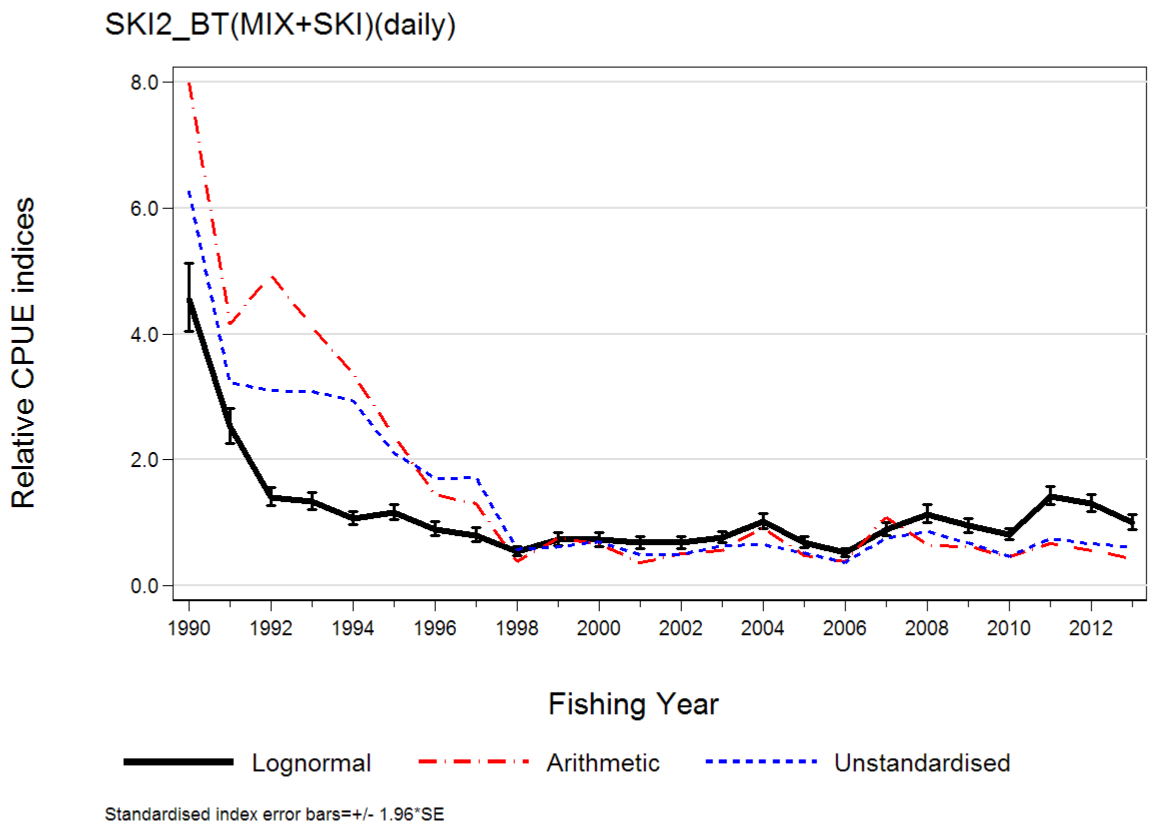

Figure G.4: Relative CPUE indices for gemfish using the lognormal non-zero model based on the SKI2_BT(MIX+SKI)(daily) fishery definition. Also shown are two unstandardised series from the same data: a) Arithmetic (Eq. F.1) and b) Unstandardised (Eq. F.2).

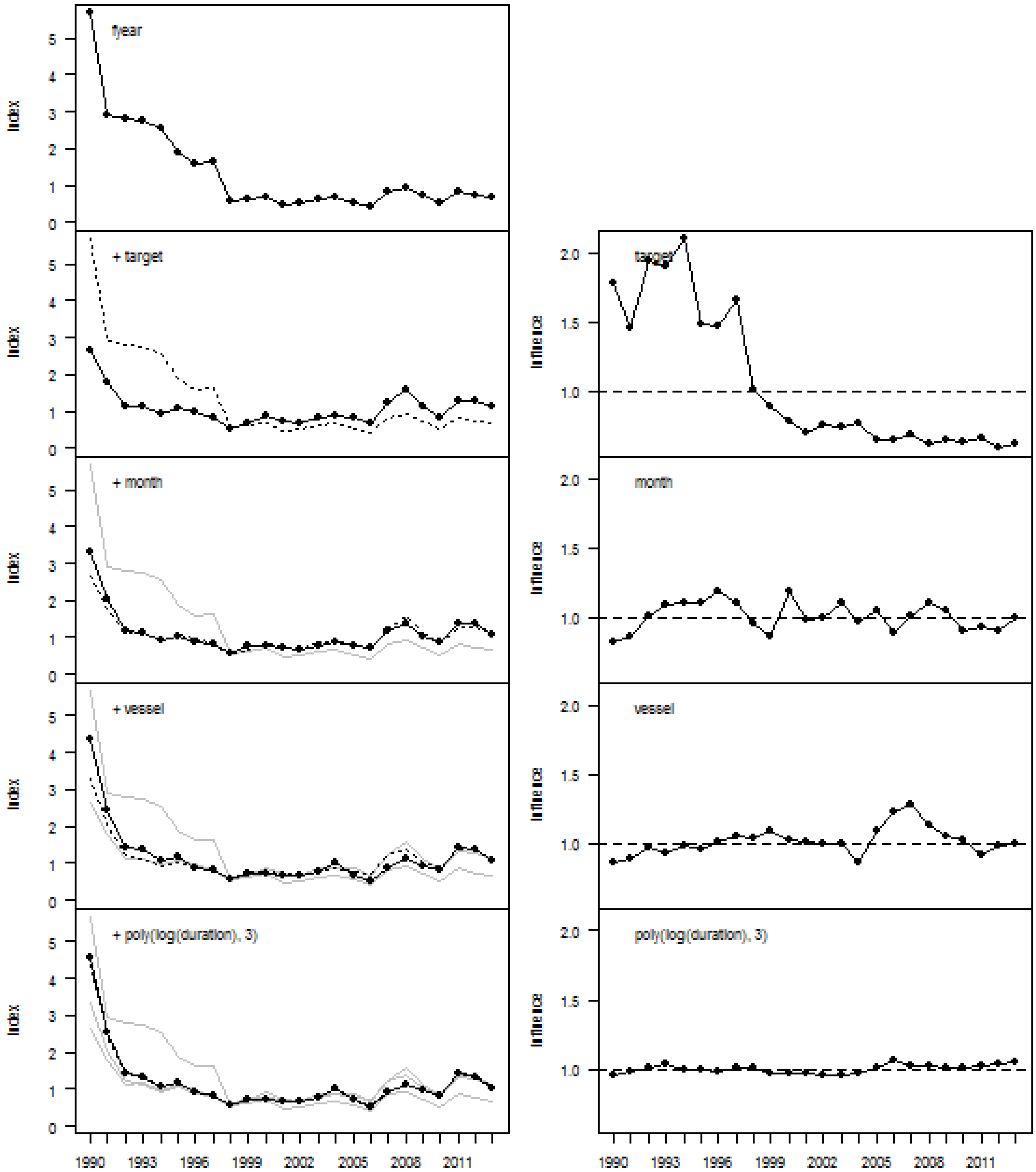

Figure G.5: [left column]: annual indices from the lognormal model of SKI2_BT(MIX+SKI)(daily) at each step in the variable selection process; [right column]: aggregate influence associated with each step in the variable selection procedure.

G.9 Residual and diagnostic plots

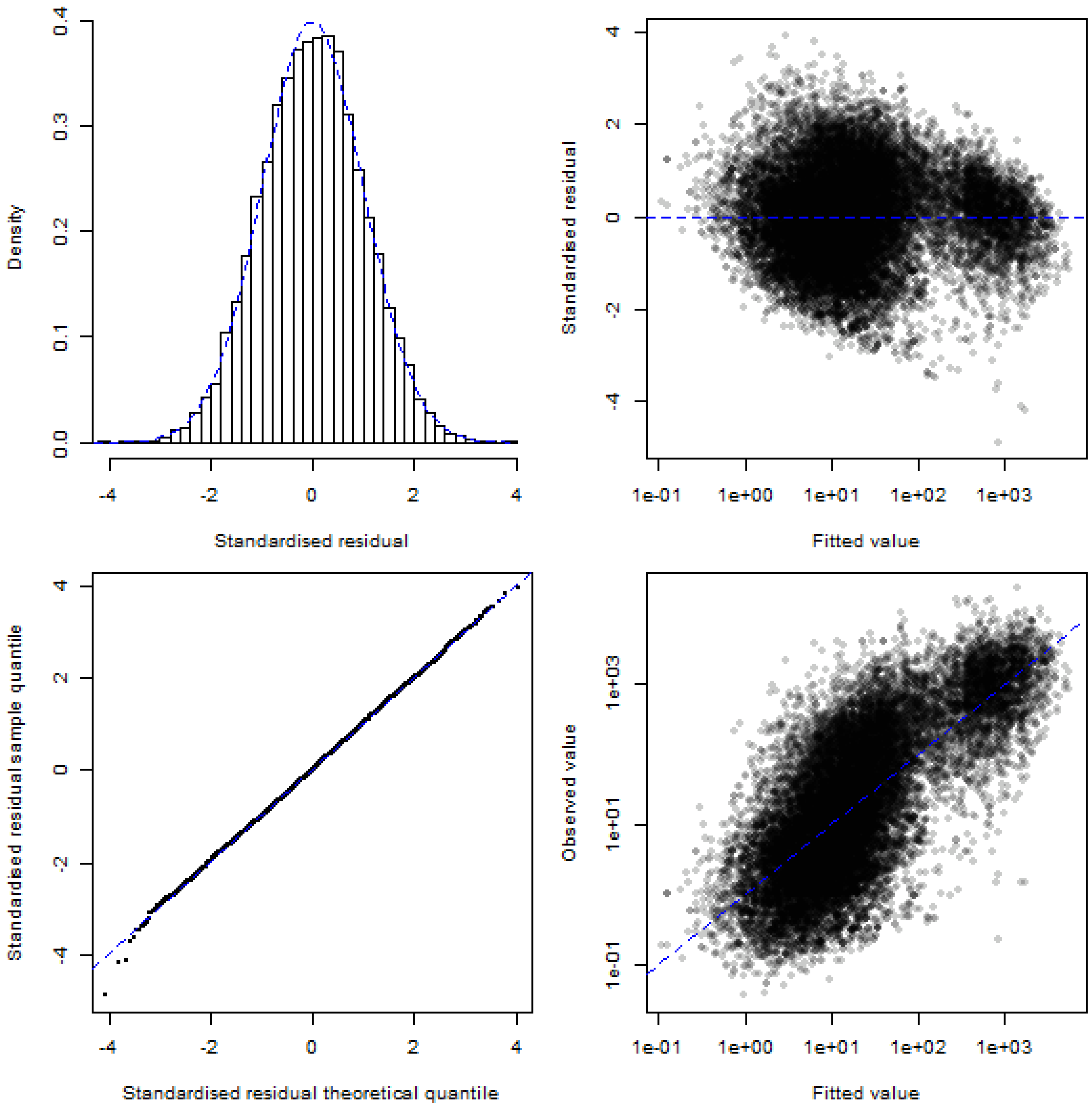

Figure G.6: Plots of the fit of the lognormal standardised CPUE model to successful catches of gemfish in the SKI2_BT(MIX+SKI)(daily) fishery. [Upper left] histogram of the standardised residuals compared to a lognormal distribution (SDSR: standard deviation of standardised residuals. MASR: median of absolute standardised residuals); [Upper right] Q-Q plot of the standardised residuals; [Lower left] Standardised residuals plotted against the predicted model catch per trip; [Lower right] Observed catch per record plotted against the predicted catch per record.

G.10 Model coefficients

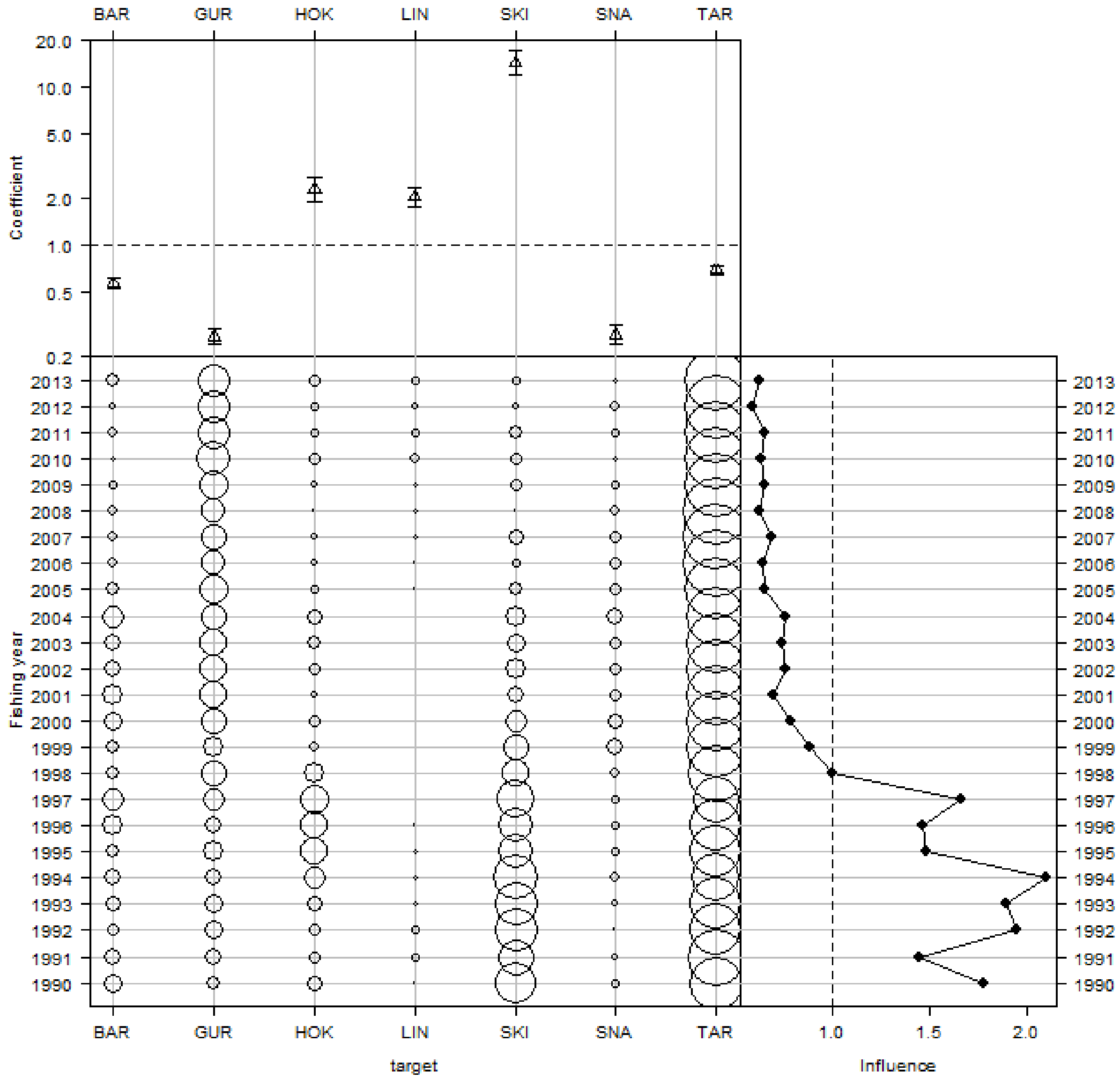

Figure G.7: Effect of target species in the lognormal model for the gemfish SKI2_BT(MIX+SKI)(daily) fishery. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

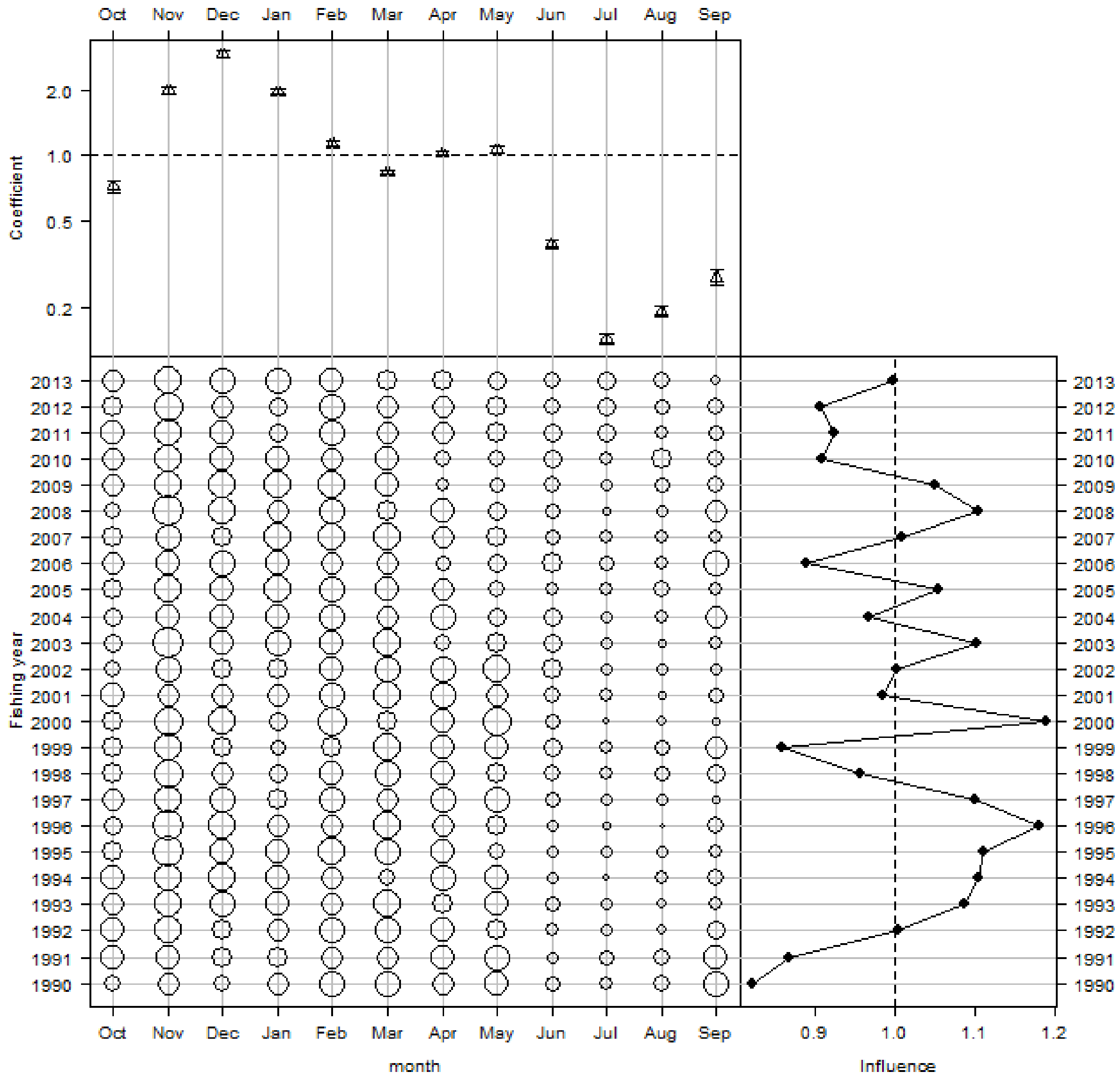

Figure G.8: Effect of month in the lognormal model for the gemfish SKI2_BT(MIX+SKI)(daily) fishery. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

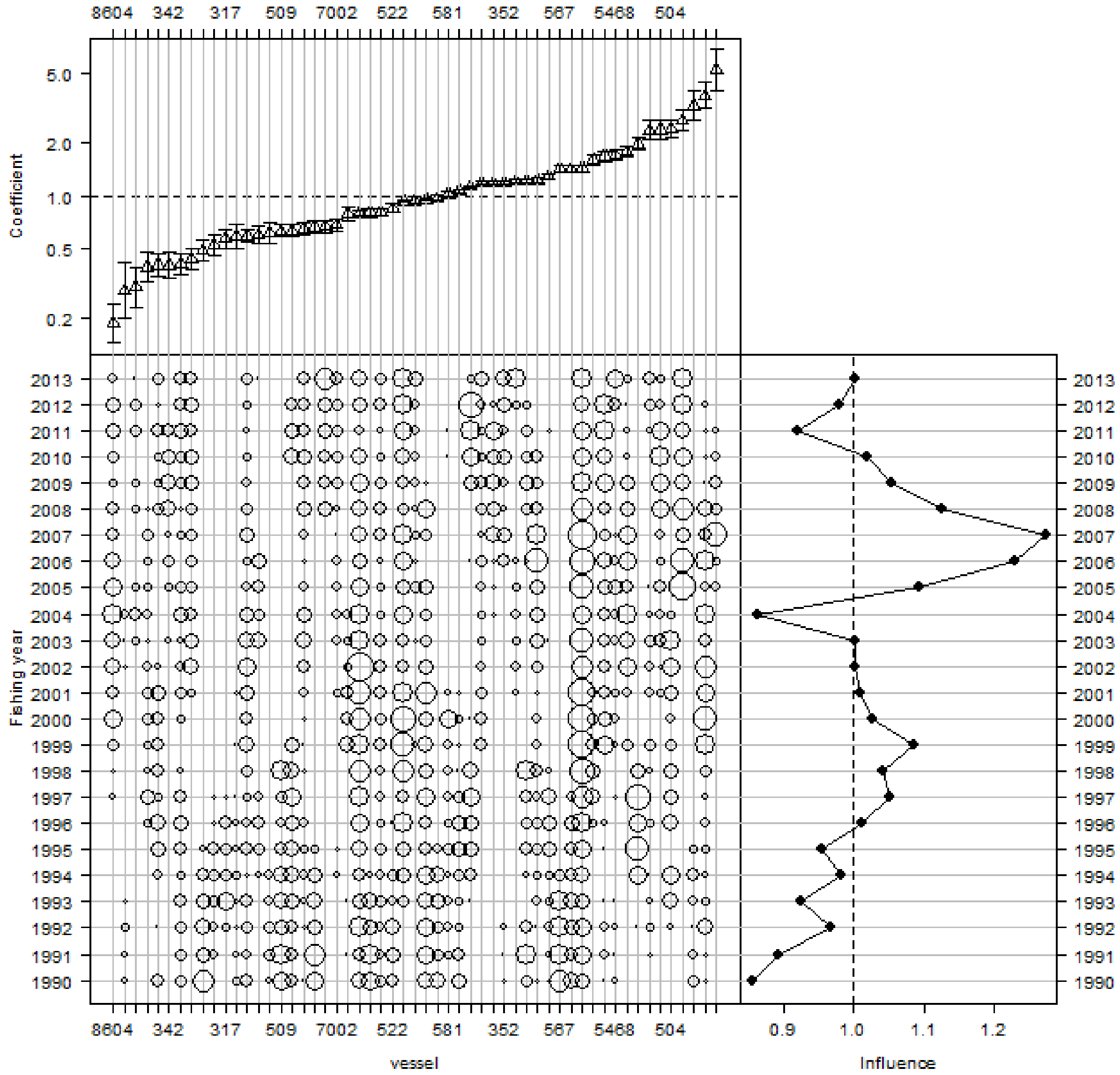

Figure G.9: Effect of vessel in the lognormal model for the gemfish SKI2_BT(MIX+SKI)(daily) fishery. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

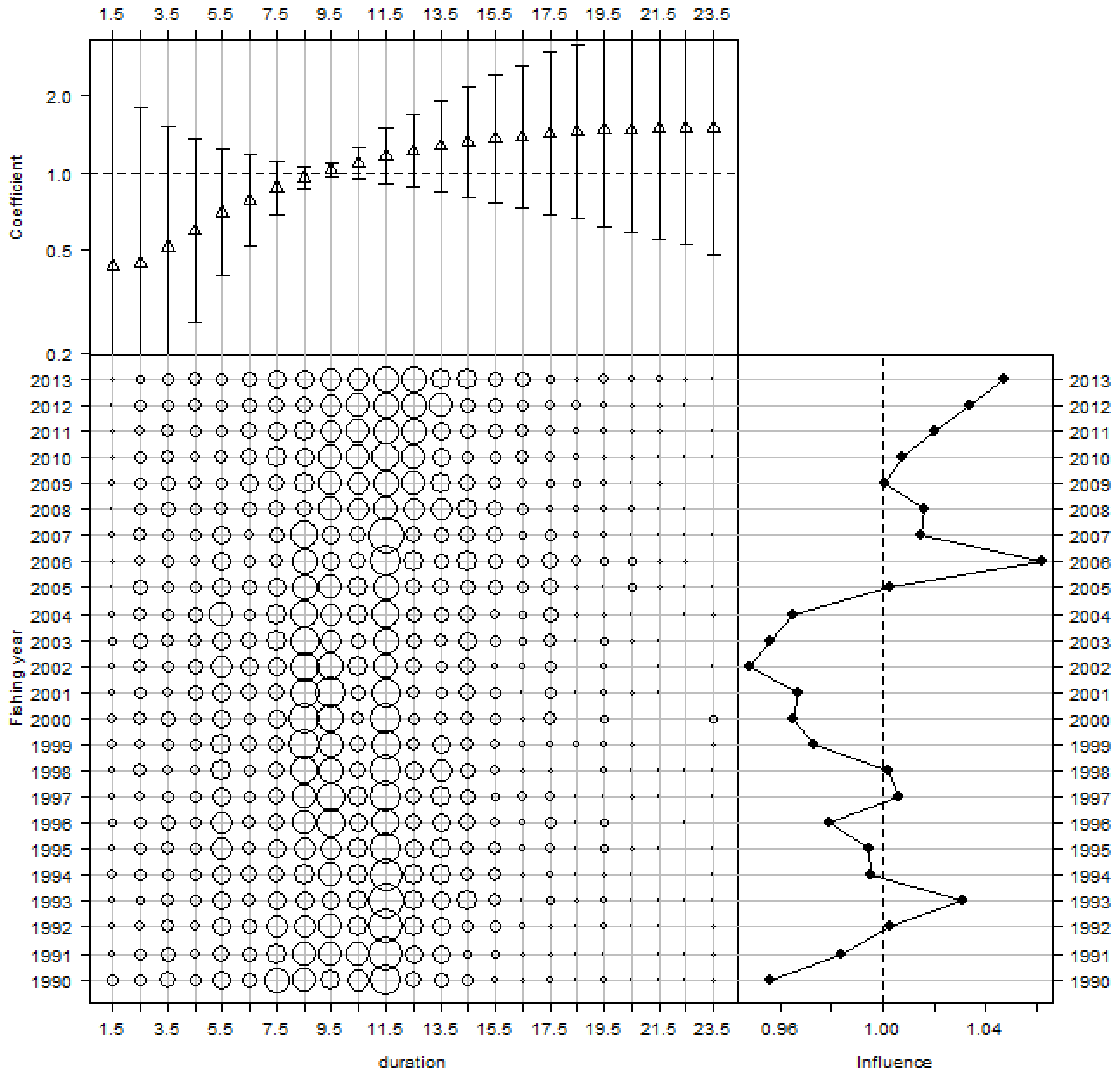

Figure G.10: Effect of duration in the lognormal model for the gemfish SKI2_BT(MIX+SKI)(daily) fishery. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

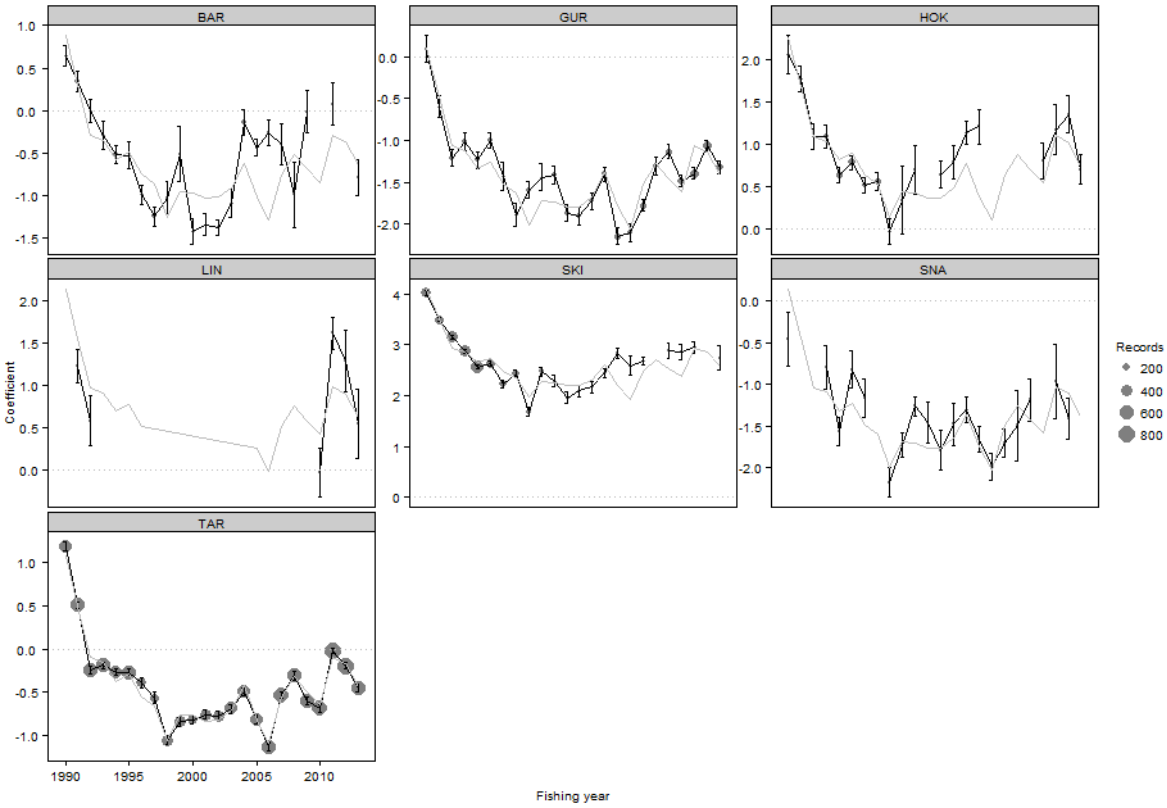

Figure G.11: Residual implied coefficients for target×fishing year interaction (not offered) in the gemfish SKI2_BT(MIX+SKI)(daily) lognormal model. Implied coefficients (black points) are calculated as the normalised fishing year coefficient (grey line) plus the mean of the standardised residuals in each fishing year and area. These values approximate the coefficients obtained when a target×year interaction term is fitted, particularly for those target×year combinations which have a substantial proportion of the records. The error bars indicate one standard error of the standardised residuals.

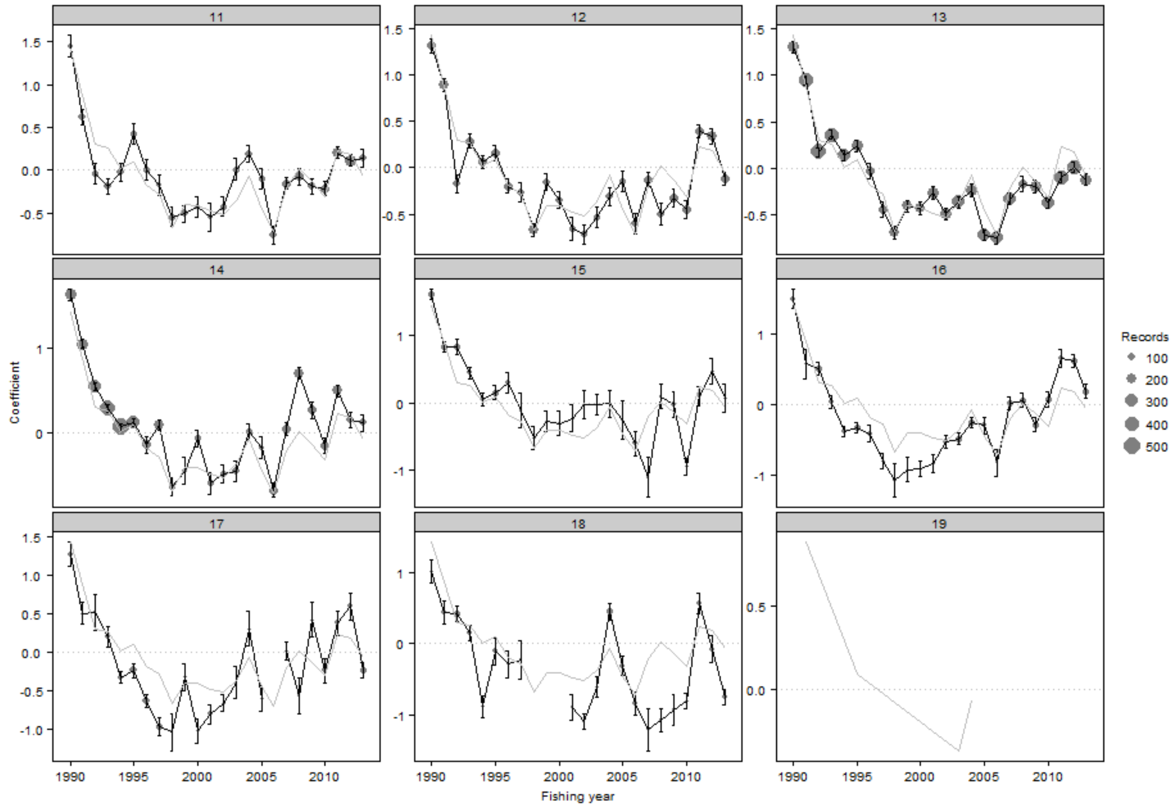

Figure G.12: Residual implied coefficients for area×fishing year interaction (not offered) in the gemfish SKI2_BT(MIX+SKI)(daily) lognormal model. Implied coefficients (black points) are calculated as the normalised fishing year coefficient (grey line) plus the mean of the standardised residuals in each fishing year and area. These values approximate the coefficients obtained when an area×year interaction term is fitted, particularly for those area×year combinations which have a substantial proportion of the records. The error bars indicate one standard error of the standardised residuals.

G.11 Logistic (binomial) model selection table

Three explanatory variables entered the model after fishing year (Table G.3), with area and duration non-significant. Number tows was discarded by the model. A plot of the binomial model and the combined delta-lognormal model is provided in Figure G.13 and the CPUE indices are listed in Table G.4.

Table G.3: Order of acceptance of variables into the binomial (logistic) model of successful catches in the gemfish SKI2_BT(MIX+SKI)(daily) fishery model for core vessels based on the vessel selection criteria of at least 5 trips in 5 or more fishing years), with the amount of explained deviance and R^2 for each variable. Variables accepted into the model are marked with an *, and the final R^2 of the selected model is in bold. Fishing year was forced as the first variable.

Variable	DF	Neg. Log likelihood	AIC	R^2	Model use
fishing year	24	-36 140	72 329	2.97	*
target species	30	-32 197	64 453	20.59	*
month	41	-30 591	61 264	27.07	*
vessel	95	-29 249	58 688	**32.22**	*
area	103	-29 084	58 374	32.83	
poly(log(duration), 3)	106	-28 975	58 162	33.24	
poly(log(tows), 3)	–	–	–	–	

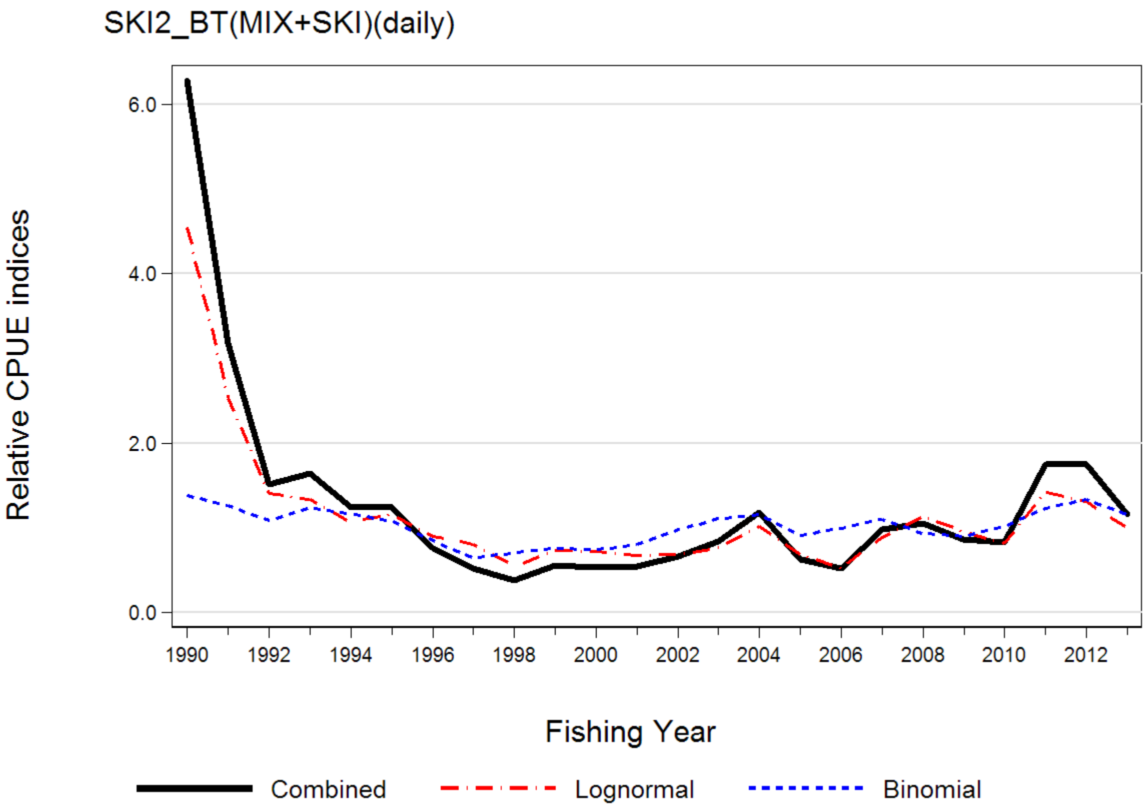

Figure G.13: Relative CPUE indices for gemfish using the lognormal non-zero model based on the SKI2_BT(MIX+SKI)(daily) fishery definition, the binomial standardised model using the logistic distribution and a regression based on presence/absence of SKI, and the combined model using the delta-lognormal procedure suggested by Vignaux (1994).

G.12 CPUE indices

Table G.4: Arithmetic indices for the total and core data sets, geometric and lognormal standardised indices and associated standard error (SE) for the core data set by fishing year for the gemfish SKI2_BT(MIX+SKI)(daily) analysis. All series (except SE) standardised to geometric mean=1.0.

Fishing	All vessels						Core vessels
year	Arithmetic	Arithmetic	Geometric	Standardised	SE	Binomial	Combined
1990	7.383	7.995	6.275	4.546	0.0606	1.381	6.280
1991	3.870	4.161	3.225	2.525	0.0562	1.258	3.176
1992	5.311	4.943	3.097	1.404	0.0532	1.080	1.516
1993	4.769	4.113	3.086	1.331	0.0521	1.236	1.645
1994	3.027	3.365	2.945	1.067	0.0513	1.161	1.239
1995	2.249	2.380	2.107	1.157	0.0533	1.076	1.245
1996	1.629	1.440	1.699	0.896	0.0634	0.848	0.760
1997	1.577	1.300	1.715	0.801	0.0666	0.641	0.513
1998	0.701	0.372	0.574	0.542	0.0677	0.705	0.382
1999	0.882	0.758	0.611	0.729	0.0714	0.761	0.555
2000	0.606	0.663	0.697	0.722	0.0739	0.739	0.534
2001	0.286	0.361	0.490	0.676	0.0704	0.797	0.538
2002	0.365	0.500	0.496	0.681	0.0696	0.976	0.664
2003	0.474	0.559	0.632	0.763	0.0621	1.105	0.843
2004	0.749	0.922	0.654	1.019	0.0604	1.154	1.176
2005	0.454	0.480	0.516	0.686	0.0652	0.911	0.624
2006	0.353	0.383	0.367	0.522	0.0613	0.994	0.518
2007	0.999	1.086	0.760	0.891	0.0572	1.103	0.983
2008	0.685	0.640	0.856	1.131	0.0632	0.931	1.053
2009	0.642	0.621	0.674	0.951	0.0601	0.900	0.856
2010	0.479	0.455	0.465	0.815	0.0564	1.018	0.829
2011	0.712	0.665	0.744	1.417	0.0521	1.229	1.742
2012	0.577	0.553	0.666	1.306	0.0531	1.336	1.744
2013	0.411	0.427	0.609	0.997	0.0604	1.154	1.151

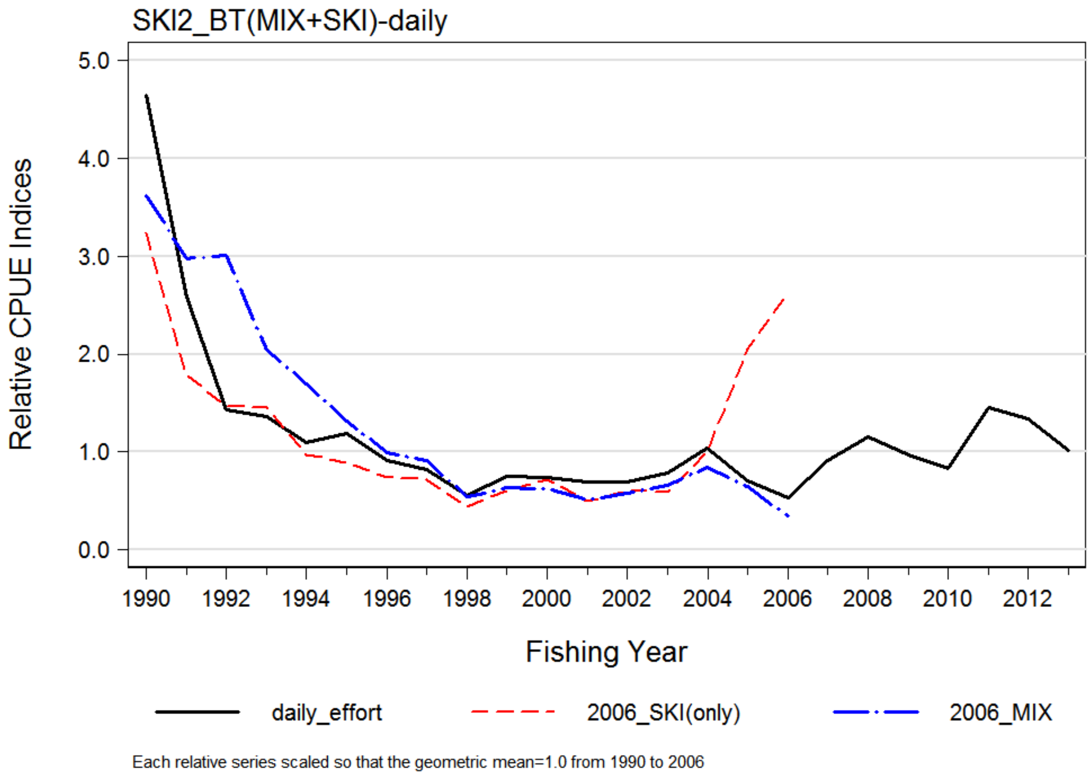

Figure G.14: Comparison of SKI 2_BT(MIX+SKI)(daily) model with two similar models from Fu et al. (2008).

Appendix H. DIAGNOSTICS AND SUPPORTING ANALYSES FOR MIXED TARGET (EXCL SKI) BOTTOM TRAWL USING TOW-BY-TOW RESOLUTION [SKI2_BT(MIXNOSKI)(TOWBYTOW)] CPUE STANDARDISATION

H.1 Introduction

This analysis is presented as an example of the diagnostics associated with the bottom trawl event-level (tow-by-tow) models that are offered a mixed suite of target species, on the assumption that a consistent gear configuration is used to capture the species in the target suite. The diagnostics for the SKI2_BT(MIX+SKI)(towbytow) model will be very similar to the diagnostics reported here because the data for the two models overlap by 92%.

H.2 Fishery definition

SKI2_BT(MIXnoSKI)(towbytow): The fishery is defined from bottom trawl fishing events which fished in Statistical Areas 011, 012, 013, 014, 015, 016, 017, 018, 019 declaring target species GUR, SNA, TAR, LIN, BAR, HOK. Only form types (TCEPR, TCER) were included from fishing years 1993–94 to 2012–13.

H.3 Core vessel selection

The criteria used to define the core fleet were those vessels that had fished for at least 5 trips in each of at least 5 years using trips with at least 1 kg of catch. These criteria resulted in a core fleet size of 23 vessels which took 59% of the catch (Figure H.1).

H.4 Data summary

Table H.1: Number of number of core vessels, trips, number records, number events (=number tows), events per stratum, number of tows, sum of hours fished, sum of landed SKI (t), proportion of trips with catch and proportion of tows with catch by fishing year for core vessels (based on a minimum of 5 trips per year in at least 5 years) in the SKI2_BT(MIXnoSKI)(towbytow) fishery.

Fishing year	Vessels	Trips	Number records	Events	Events per stratum	Number of tows	Sum duration (h)	Catch (t)	Trips with catch (%)	Strata with catch (%)
1994	5	121	1 196	1 196	1.0	1 196	3 796.8	8.95	32.2	42.9
1995	6	156	1 376	1 376	1.0	1 376	4 980.7	14.25	43.0	40.3
1996	10	193	1 988	1 988	1.0	1 988	5 823.8	18.62	45.1	48.8
1997	8	211	1 760	1 760	1.0	1 760	5 455.7	25.07	46.9	29.4
1998	7	233	1 599	1 599	1.0	1 599	4 650.9	8.84	31.3	25.8
1999	7	245	1 947	1 947	1.0	1 947	5 409.2	11.13	31.8	24.7
2000	6	171	1 757	1 757	1.0	1 757	3 853.2	6.05	42.7	36.4
2001	8	197	1 305	1 305	1.0	1 305	3 407.0	5.47	43.7	34.2
2002	8	183	1 101	1 101	1.0	1 101	3 145.4	8.56	43.7	42.9
2003	8	190	1 446	1 446	1.0	1 446	4 347.9	17.80	56.3	38.5
2004	10	214	1 797	1 797	1.0	1 797	5 645.7	33.35	57.0	37.2
2005	8	205	1 849	1 849	1.0	1 849	6 003.3	31.80	53.7	29.8
2006	10	195	1 851	1 851	1.0	1 851	5 783.4	20.74	59.0	39.0
2007	9	189	2 164	2 164	1.0	2 164	7 233.9	42.48	60.3	32.8
2008	20	605	5 352	5 352	1.0	5 352	17 355.4	104.30	48.3	27.2
2009	21	615	5 365	5 365	1.0	5 365	17 713.3	64.20	48.6	27.3
2010	19	644	5 868	5 868	1.0	5 868	20 431.2	47.21	49.1	27.3
2011	19	597	5 767	5 767	1.0	5 767	19 598.5	55.36	54.3	27.0
2012	19	614	5 283	5 283	1.0	5 283	18 297.0	69.66	59.5	32.8
2013	16	455	4 094	4 094	1.0	4 094	14 545.2	42.80	57.6	30.9

H.5 Core vessel selection

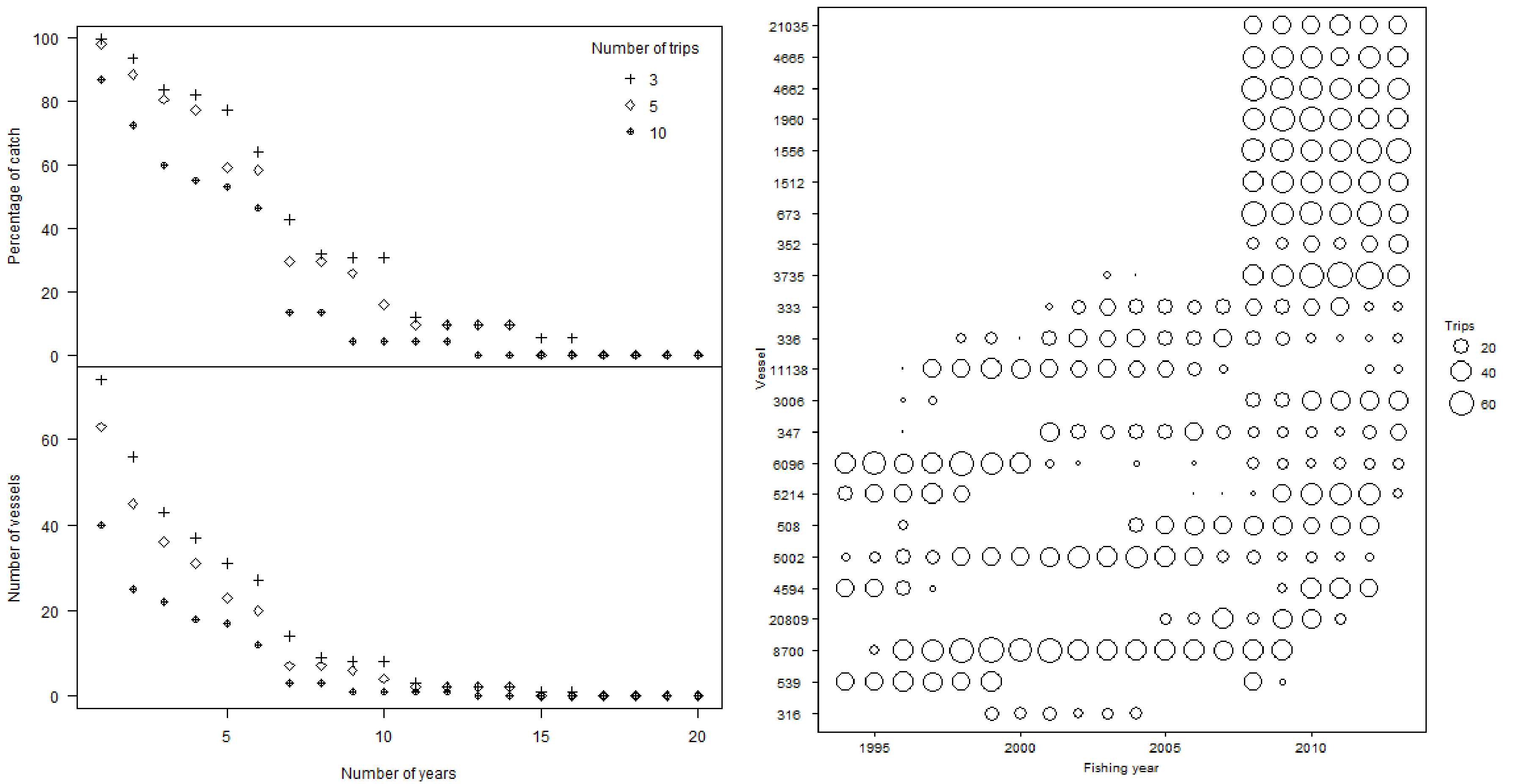

Figure H.1: [left panel] total landed SKI and number of vessels plotted against the number of years used to define core vessels participating in the SKI2_BT(MIXnoSKI)(towbytow) dataset. The number of qualifying years (minimum number of trips per year) for each series is indicated in the legend. [right panel]: bubble plot showing the number of daily-effort strata for selected core vessels (based on at least 5 trips in 5 or more fishing years) by fishing year.

H.6 Exploratory data plots for core vessel data set

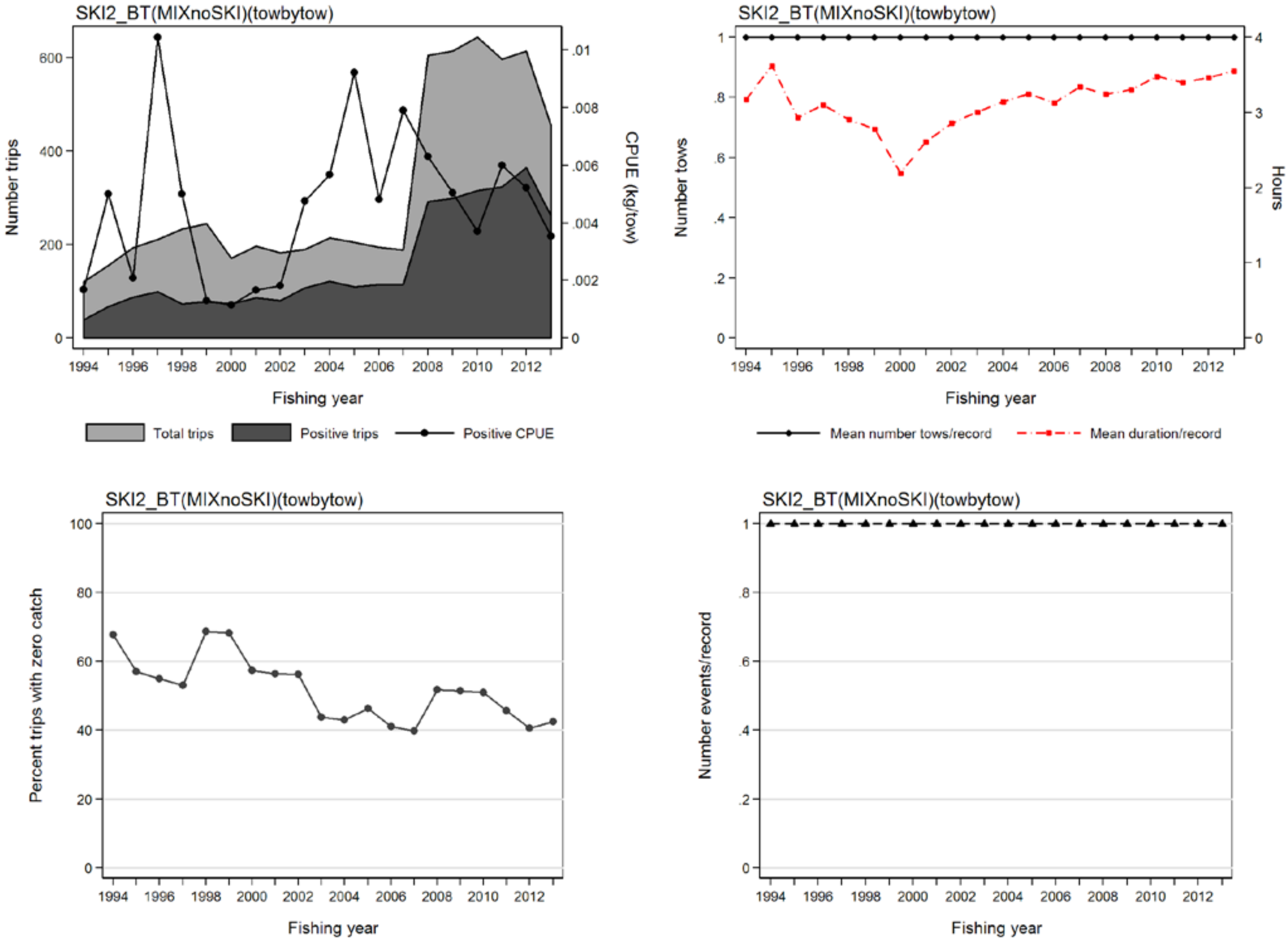

Figure H.2: Core vessel summary plots by fishing year for model SKI2_BT(MIXnoSKI)(towbytow): [upper left panel]: total trips (light grey) and trips with gemfish catch (dark grey) overlaid with median annual arithmetic CPUE (kg/tow) for all trips *i* with positive catch: $A_y = \text{median}\left(C_{y,i}/E_{y,i}\right)$; [upper right panel]: mean number tows and mean duration per daily-effort stratum record; [lower left panel]: proportion of trips with no catch of gemfish; [lower right panel]: mean number of events per event (=tow) record.

H.7 Selection of distribution for positive catch records

The best distribution was lognormal.

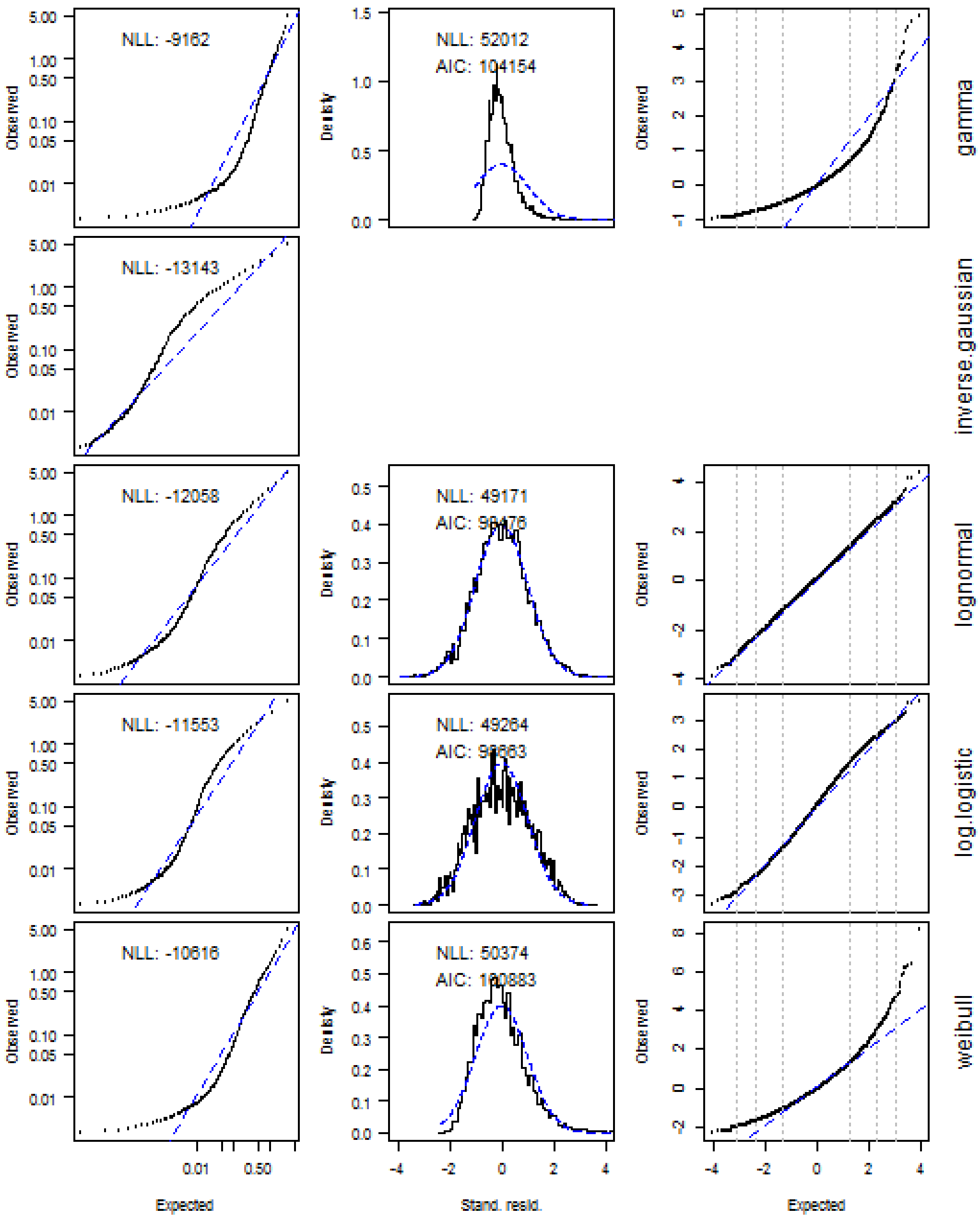

Figure H.3: Diagnostics for alternative distributional assumptions for catch in the gemfish SKI2_BT(MIXnoSKI)(towbytow) model. Left: quantile-quantile plot of observed catches (centred (by mean) and scaled (by standard deviation) in log space) versus maximum likelihood fit of distribution (missing panel indicates that the fit failed to converge); Middle: standardised residuals from a generalised linear model fitted using the formula catch ~ fyear + month +area+ vessel + log(sets) and the distribution (missing panel indicates that the model failed to converge); Right: quantile-quantile plot of model standardised residuals against standard normal (vertical lines represent 0.1%, 1% and 10% percentiles). NLL = negative log-likelihood; AIC = Akaike information criterion.

H.8 Positive catch model selection table

Four explanatory variables entered the model after fishing year (Table H.2), with target species, three polynomials associated with net specifications and log(duration) being non-significant. The variables log(width), log(swept_area) and log(swept_distance) were discarded by the model. A plot of the model is provided in Figure H.4 and the CPUE indices are listed in Table H.4.

Table H.2: Order of acceptance of variables into the lognormal model of successful catches in the SKI2_BT(MIXnoSKI)(towbytow) fishery model for core vessels based on the vessel selection criteria of at least 5 trips in 5 or more fishing years, with the amount of explained deviance and R^2 for each variable. Variables accepted into the model are marked with an *, and the final R^2 of the selected model is in bold. Fishing year was forced as the first variable.

Variable	DF	Neg. Log likelihood	AIC	R^2	Model use
fishing year	21	-55 029	110 099	8.18	*
month	32	-53 147	106 358	26.75	*
area	40	-51 027	102 134	43.22	*
poly(log(bottom depth), 3)	43	-50 042	100 171	49.56	*
vessel	65	-49 209	98 549	**54.36**	*
target species	70	-49 122	98 385	54.84	
poly(log(swept_volume), 3)	73	-49 060	98 265	55.18	
poly(log(height), 3)	76	-49 041	98 234	55.28	
poly(log(width), 3)	79	-49 023	98 205	55.37	
poly(log(duration), 3)	82	-49 018	98 200	55.40	
poly(log(width), 3)	–	–	–	–	
poly(log(swept_area), 3)	–	–	–	–	
poly(log(swept_distance), 3)	–	–	–	–	

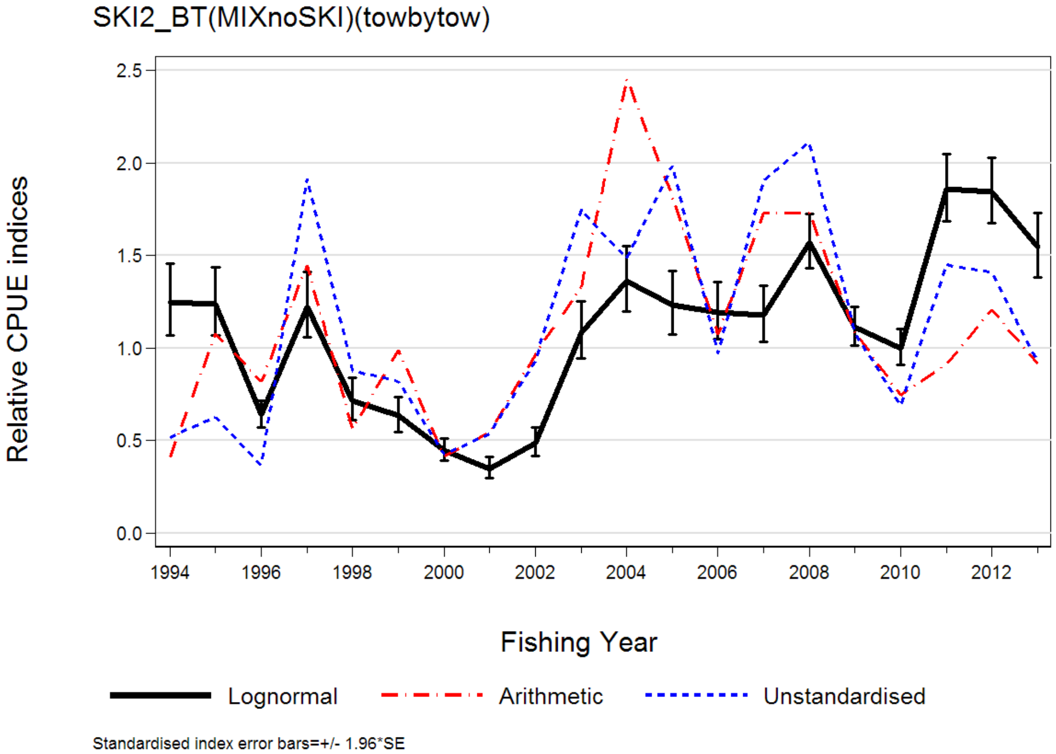

Figure H.4: Relative CPUE indices for gemfish using the lognormal non-zero model based on the SKI2_BT(MIXnoSKI)(towbytow) fishery definition. Also shown are two unstandardised series from the same data: a) Arithmetic (Eq. F.1) and b) Unstandardised (Eq. F.2).

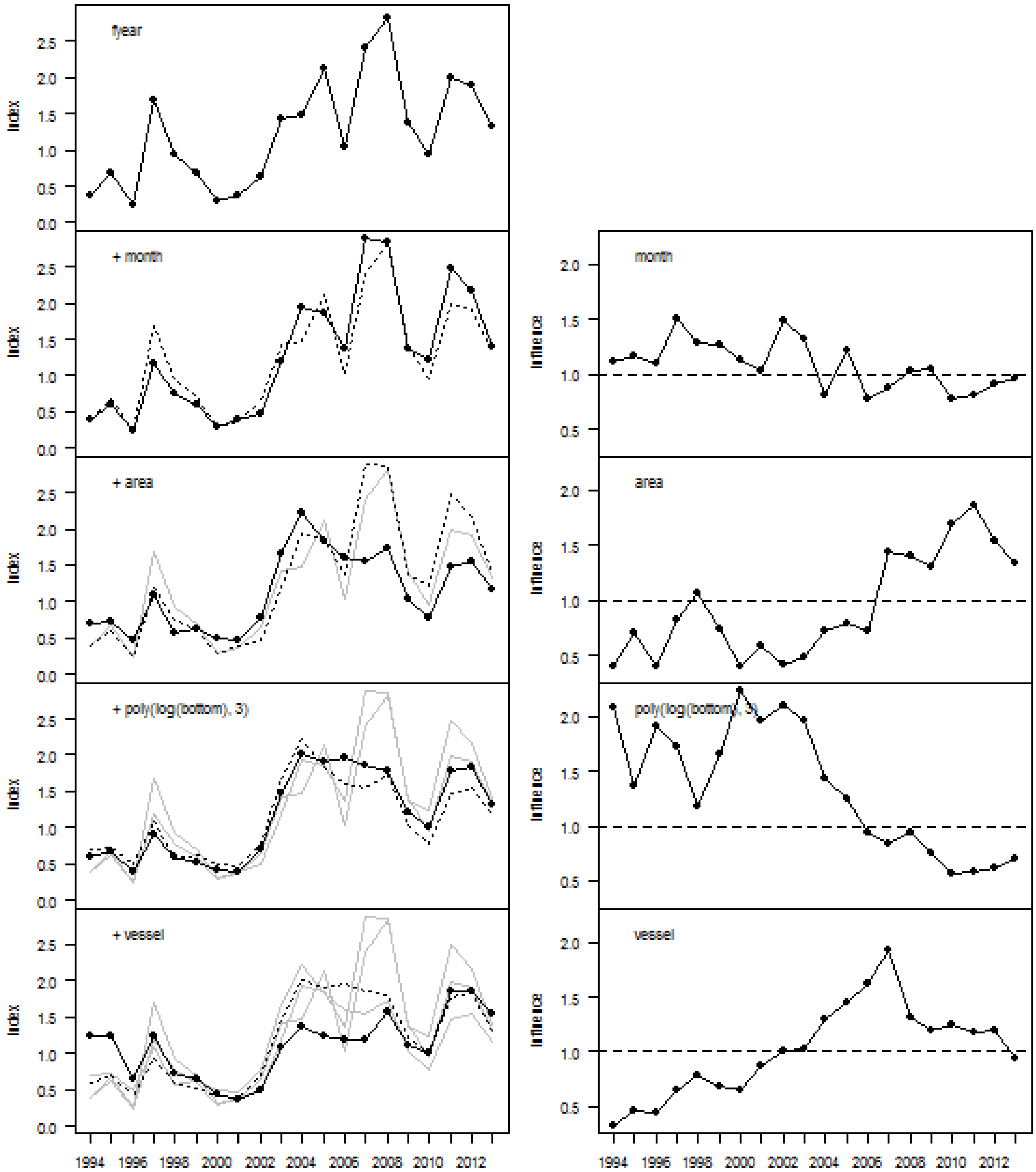

Figure H.5: [left column]: annual indices from the lognormal model of SKI2_BT(MIXnoSKI)(towbytow) at each step in the variable selection process; [right column]: aggregate influence associated with each step in the variable selection procedure.

H.9 Residual and diagnostic plots

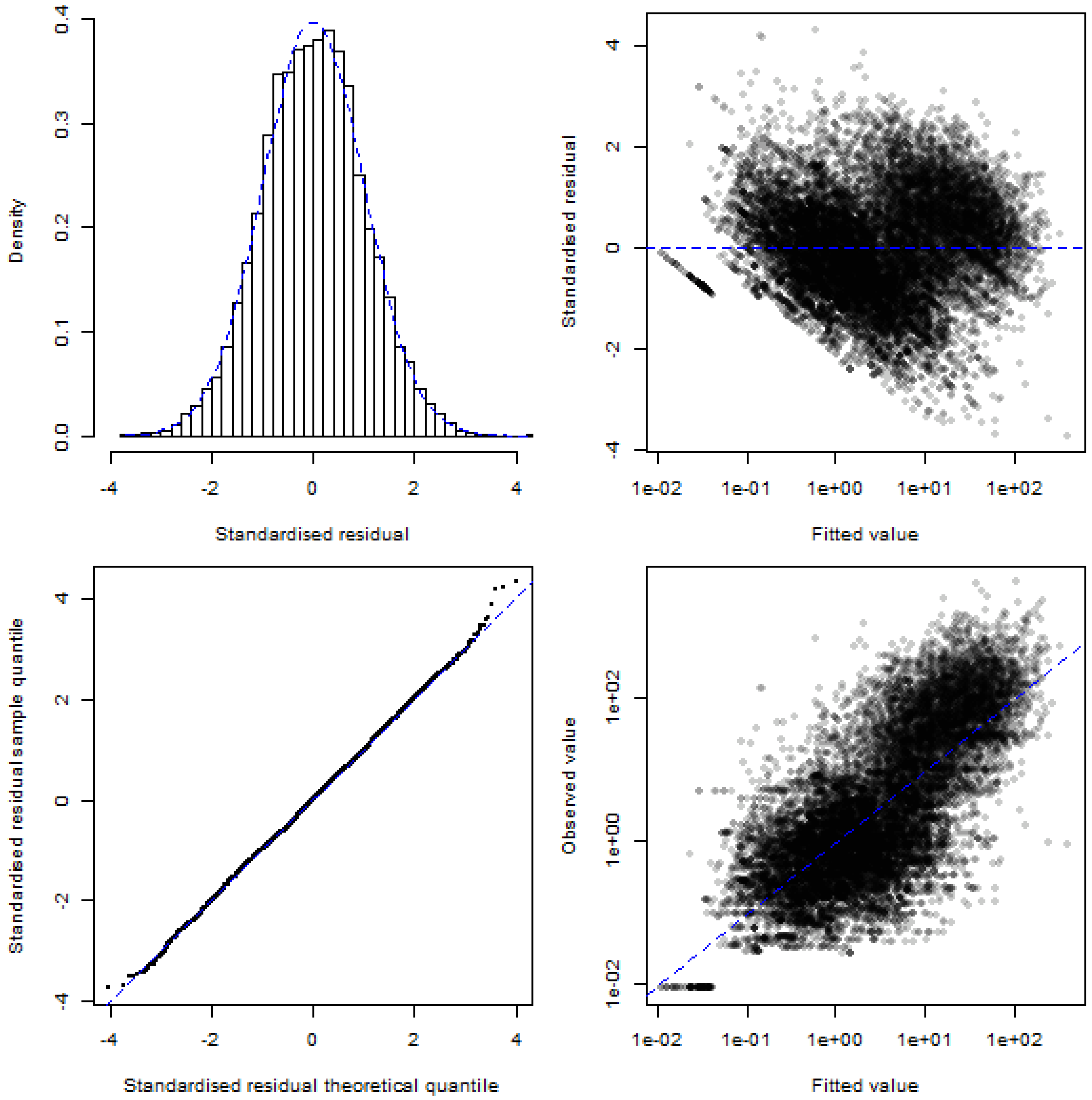

Figure H.6: Plots of the fit of the lognormal standardised CPUE model to successful catches of gemfish in the SKI2_BT(MIXnoSKI)(towbytow) fishery. [Upper left] histogram of the standardised residuals compared to a lognormal distribution (SDSR: standard deviation of standardised residuals. MASR: median of absolute standardised residuals); [Upper right] Q-Q plot of the standardised residuals; [Lower left] Standardised residuals plotted against the predicted model catch per trip; [Lower right] Observed catch per record plotted against the predicted catch per record.

H.10 Model coefficients

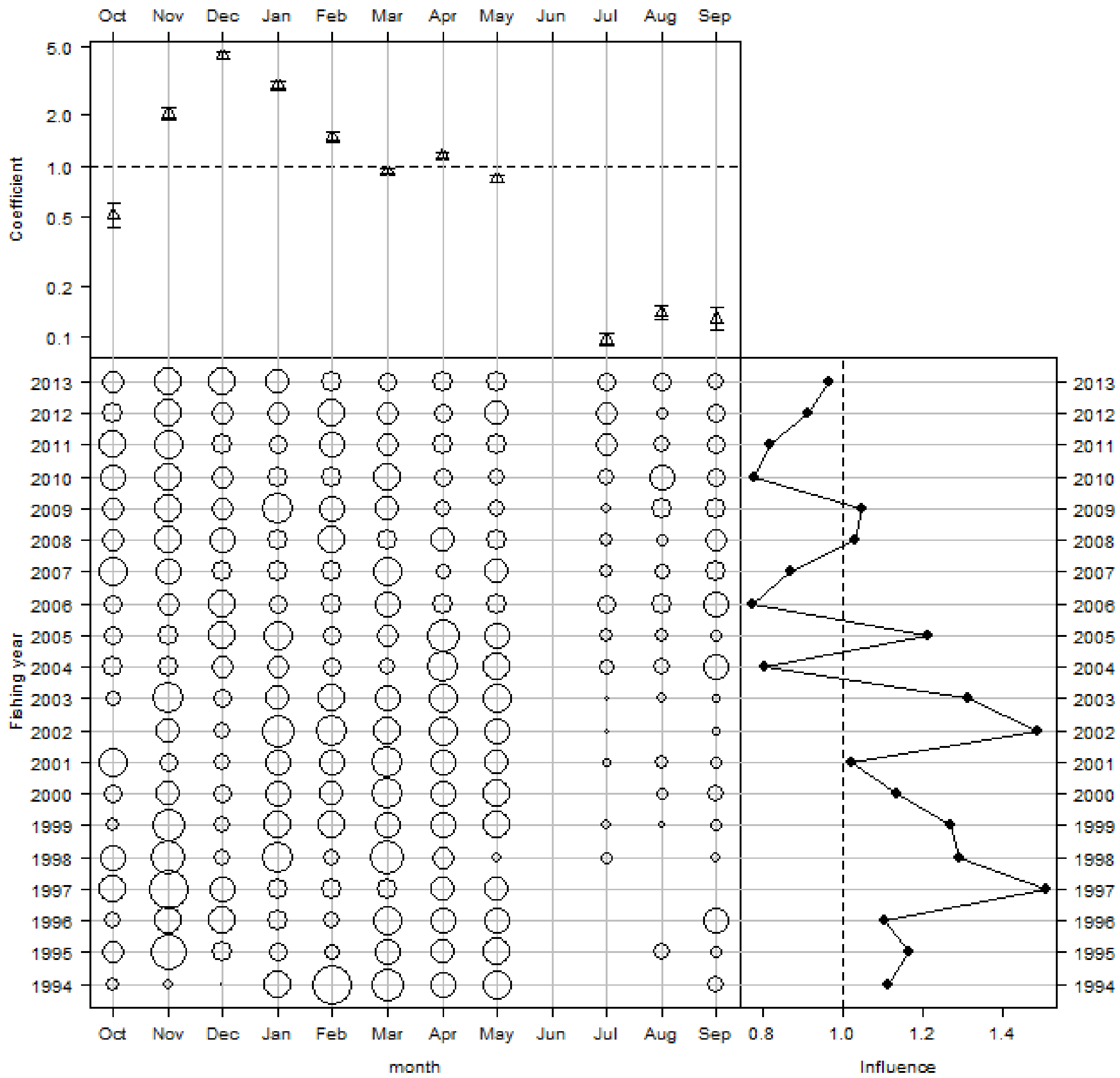

Figure H.7: Effect of month in the lognormal model for the gemfish SKI2_BT(MIXnoSKI)(towbytow) fishery. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

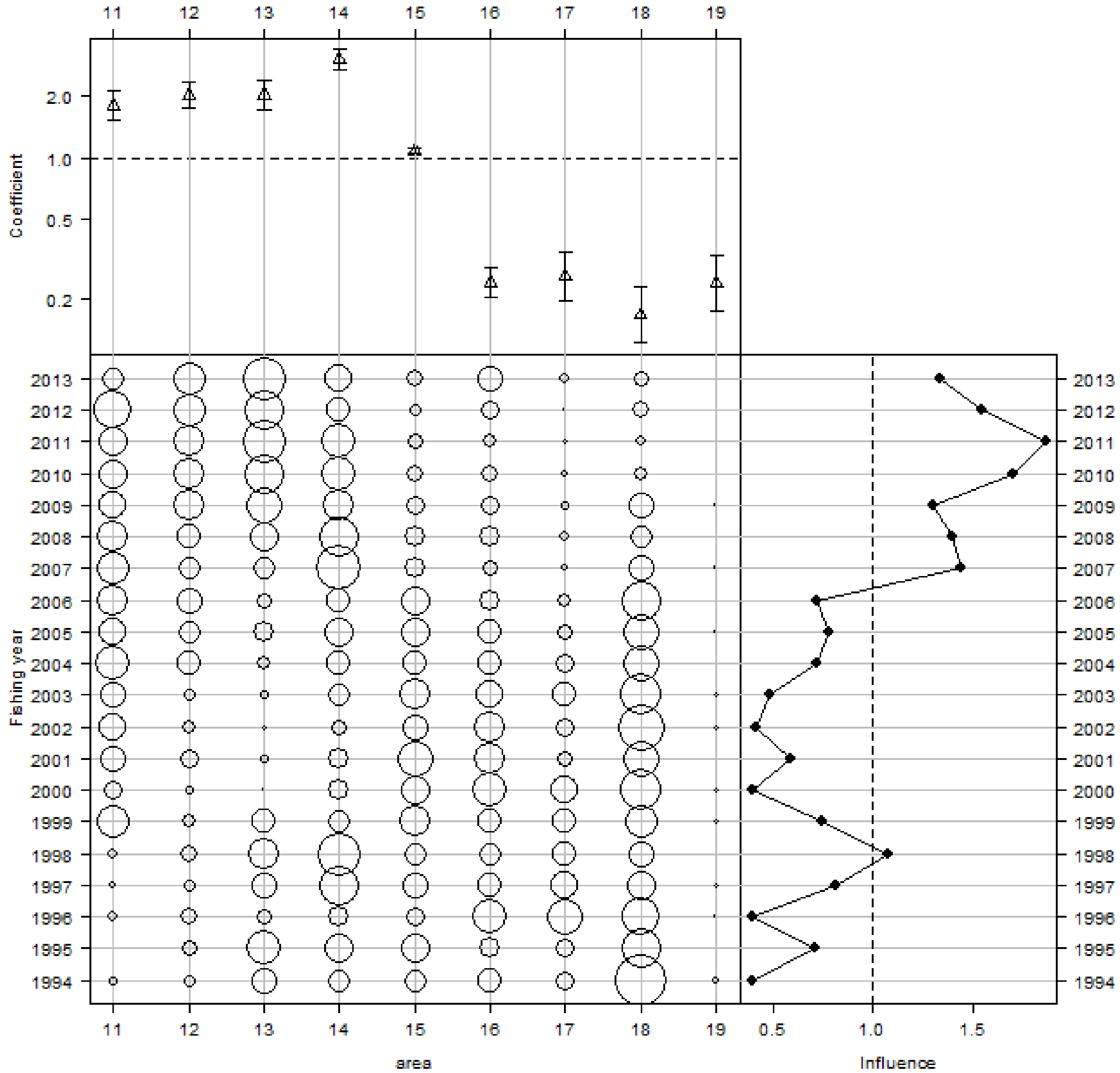

Figure H.8: Effect of area in the lognormal model for the gemfish SKI2_BT(MIXnoSKI)(towbytow) fishery. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

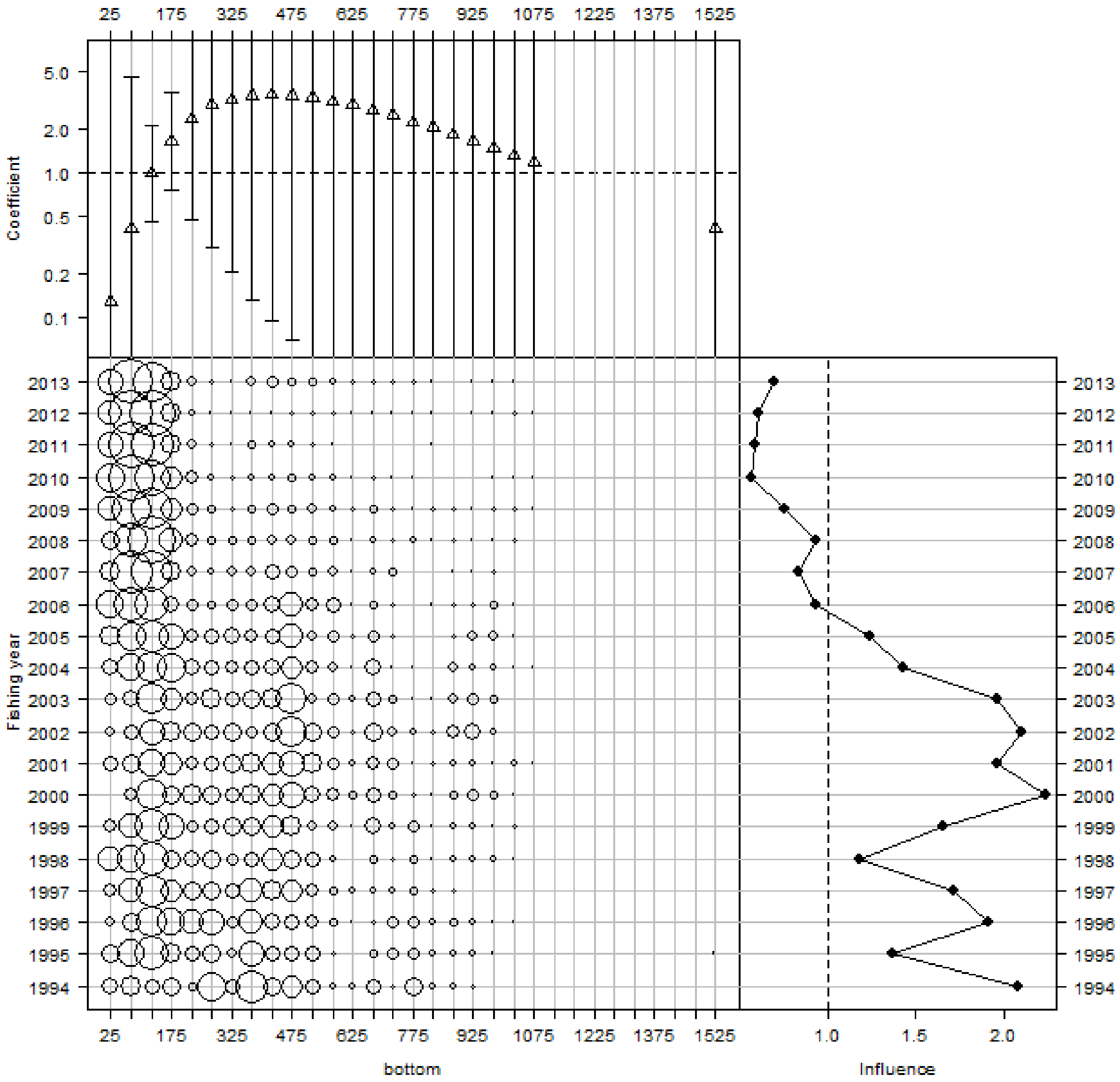

Figure H.9: Effect of bottom depth in the lognormal model for the gemfish SKI2_BT(MIXnoSKI)(towbytow) fishery. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

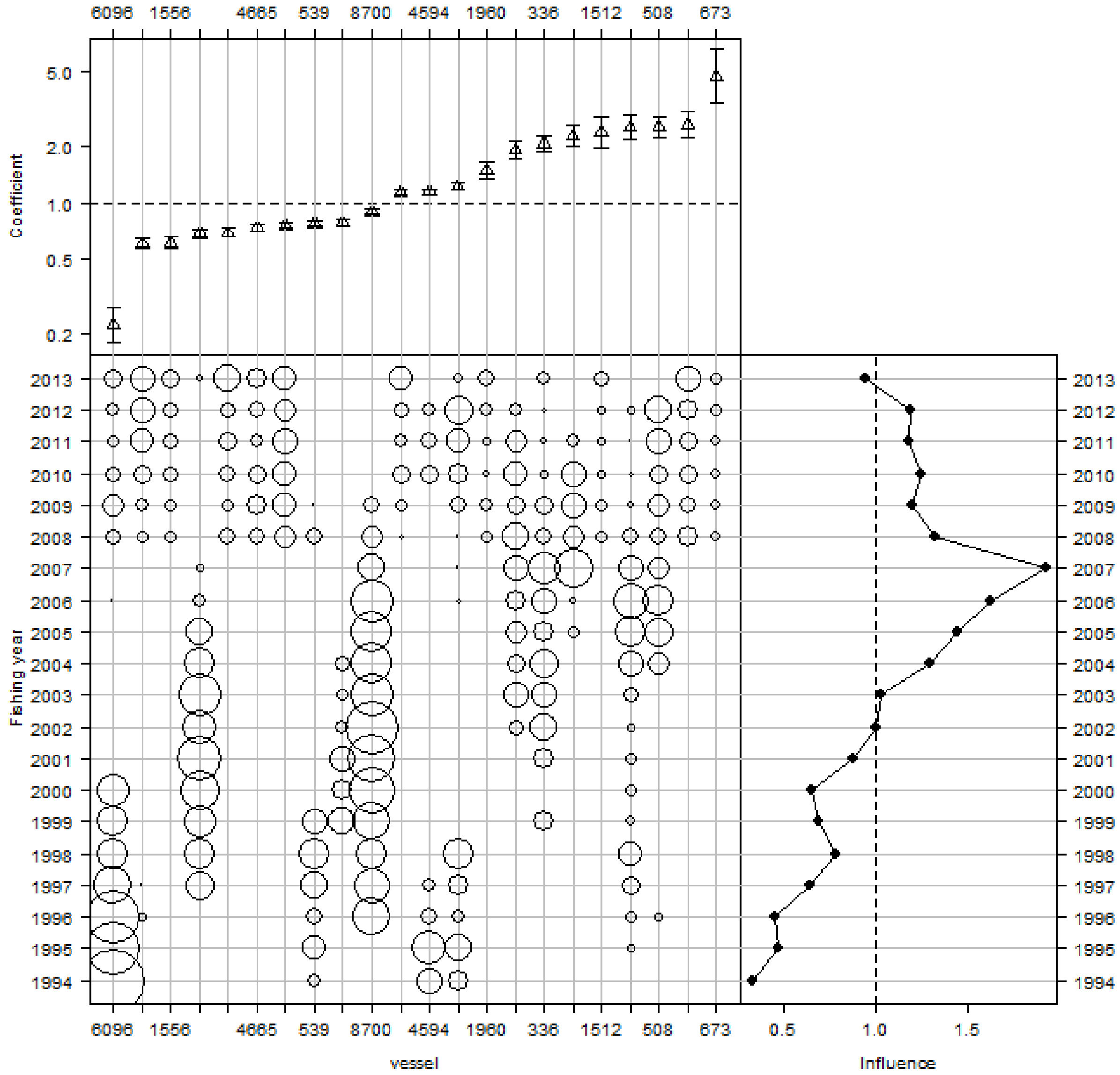

Figure H.10: Effect of vessel in the lognormal model for the gemfish SKI2_BT(MIXnoSKI)(towbytow) fishery. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

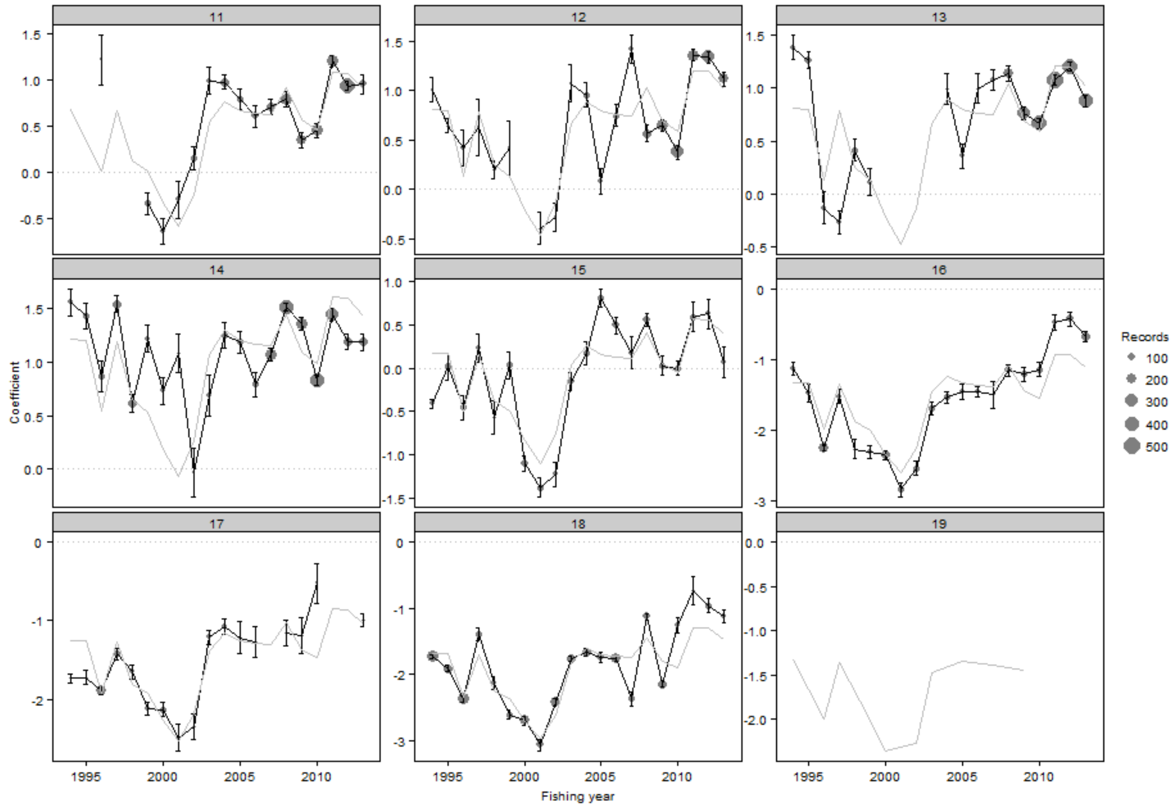

Figure H.11: Residual implied coefficients for area×fishing year interaction (not offered) in the gemfish SKI2_BT(MIXnoSKI)(towbytow) lognormal model. Implied coefficients (black points) are calculated as the normalised fishing year coefficient (grey line) plus the mean of the standardised residuals in each fishing year and area. These values approximate the coefficients obtained when an area×year interaction term is fitted, particularly for those area×year combinations which have a substantial proportion of the records. The error bars indicate one standard error of the standardised residuals.

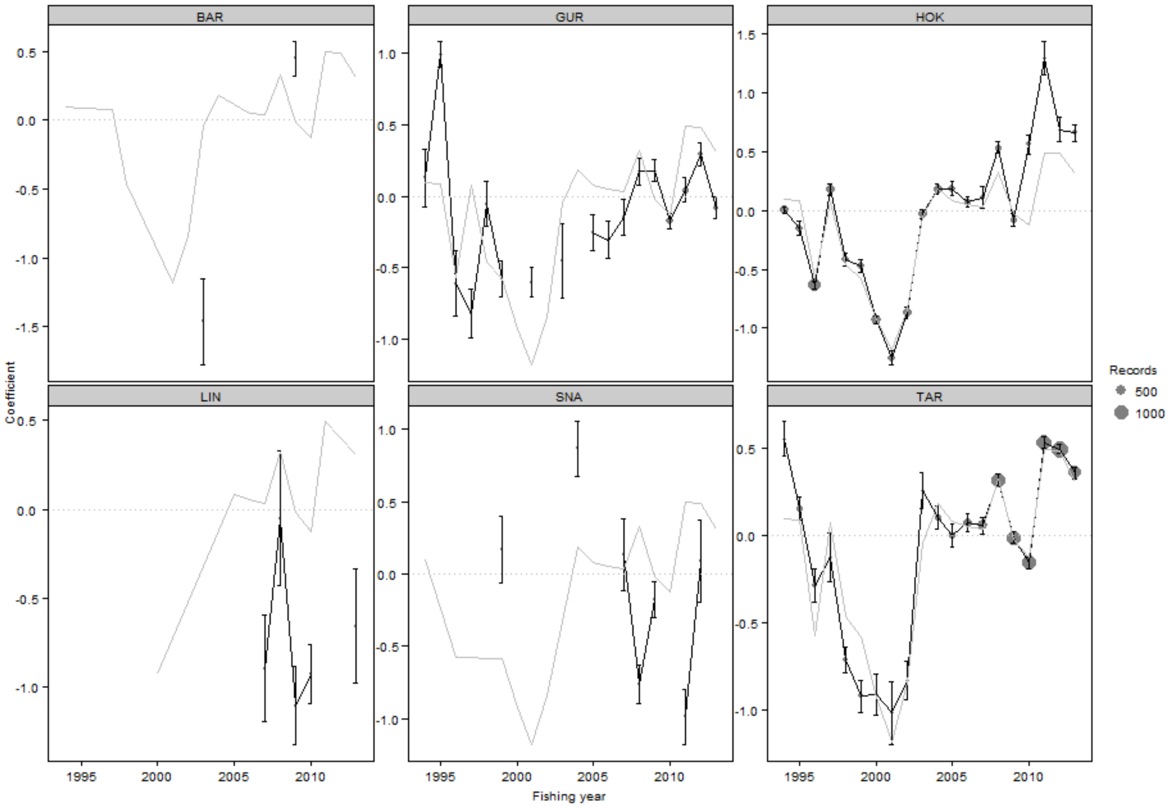

Figure H.12: Residual implied coefficients for target×fishing year interaction (not offered) in the gemfish SKI2_BT(MIXnoSKI)(towbytow) lognormal model. Implied coefficients (black points) are calculated as the normalised fishing year coefficient (grey line) plus the mean of the standardised residuals in each fishing year and area. These values approximate the coefficients obtained when a target×year interaction term is fitted, particularly for those target×year combinations which have a substantial proportion of the records. The error bars indicate one standard error of the standardised residuals.

H.11 Logistic (binomial) model selection table

Three explanatory variables entered the model after fishing year (Table H.3), with target species, area and three measures associated with tow specifications non-significant. Headline height, net width, duration and vessel speed were discarded by the model. A plot of the binomial model and the combined delta-lognormal model is provided in Figure H.13 and the CPUE indices are listed in Table H.4.

Table H.3: Order of acceptance of variables into the binomial (logistic) model of successful catches in the gemfish SKI2_BT(MIXnoSKI)(towbytow) fishery model for core vessels based on the vessel selection criteria of at least 5 trips in 5 or more fishing years), with the amount of explained deviance and R^2 for each variable. Variables accepted into the model are marked with an *, and the final R^2 of the selected model is in bold. Fishing year was forced as the first variable.

Variable	DF	Neg. Log likelihood	AIC	R^2	Model use
fishing year	20	-32 536	65 113	2.39	*
poly(log(bottom depth), 3)	23	-30 755	61 555	11.37	*
vessel	45	-29 969	60 027	15.14	*
month	55	-29 466	59 042	17.50	*
target species	60	-29 333	58 786	18.11	
area	68	-29 223	58 582	18.62	
poly(log(swept_area), 3)	71	-29 157	58 456	18.92	
poly(log(swept_volume), 3)	74	-29 100	58 347	19.19	
poly(log(swept_distance), 3)	77	-29 089	58 332	19.23	
poly(log(height), 3)	–	–	–	–	
poly(log(width), 3)	–	–	–	–	
poly(log(duration), 3)	–	–	–	–	
poly(log(speed), 3)	–	–	–	–	

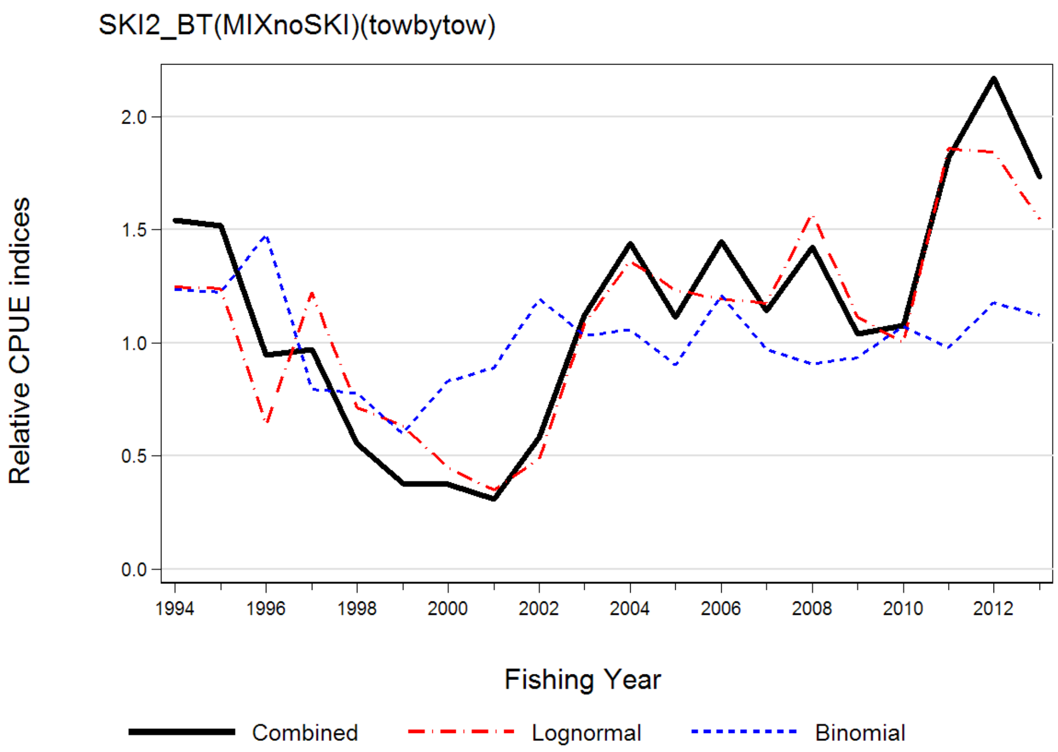

Figure H.13: Relative CPUE indices for gemfish using the lognormal non-zero model based on the SKI2_BT(MIXnoSKI)(towbytow) fishery definition, the binomial standardised model using the logistic distribution and a regression based on presence/absence of SKI, and the combined model using the delta-lognormal procedure suggested by Vignaux (1994).

H.12 CPUE indices

Table H.4: Arithmetic indices for the total and core data sets, geometric and lognormal standardised indices and associated standard error (SE) for the core data set by fishing year for the gemfish SKI2_BT(MIXnoSKI)(towbytow) analysis. All series (except SE) standardised to geometric mean=1.0.

Fishing	All vessels						Core vessels
year	Arithmetic	Arithmetic	Geometric	Standardised	SE	Binomial	Combined
1994	1.421	0.413	0.519	1.248	0.0787	1.236	1.543
1995	0.805	1.081	0.628	1.240	0.0747	1.224	1.519
1996	1.222	0.819	0.366	0.640	0.0575	1.480	0.947
1997	1.295	1.449	1.917	1.223	0.0728	0.794	0.972
1998	4.107	0.565	0.876	0.715	0.0809	0.778	0.556
1999	0.796	0.987	0.822	0.634	0.0759	0.599	0.380
2000	0.620	0.416	0.425	0.450	0.0668	0.831	0.374
2001	0.588	0.542	0.539	0.349	0.0839	0.889	0.310
2002	0.592	0.967	0.931	0.488	0.0781	1.196	0.584
2003	0.931	1.326	1.749	1.086	0.0723	1.032	1.121
2004	2.042	2.454	1.486	1.362	0.0659	1.058	1.441
2005	1.397	1.819	1.986	1.233	0.0715	0.903	1.113
2006	0.942	1.075	0.970	1.195	0.0652	1.211	1.447
2007	1.601	1.729	1.907	1.176	0.0654	0.971	1.142
2008	1.194	1.729	2.113	1.571	0.0473	0.906	1.423
2009	0.802	1.088	1.081	1.113	0.0481	0.935	1.041
2010	0.519	0.745	0.689	1.002	0.0485	1.075	1.076
2011	0.677	0.912	1.451	1.859	0.0495	0.978	1.818
2012	0.852	1.207	1.409	1.843	0.0487	1.177	2.169
2013	0.680	0.916	0.927	1.547	0.0576	1.122	1.736

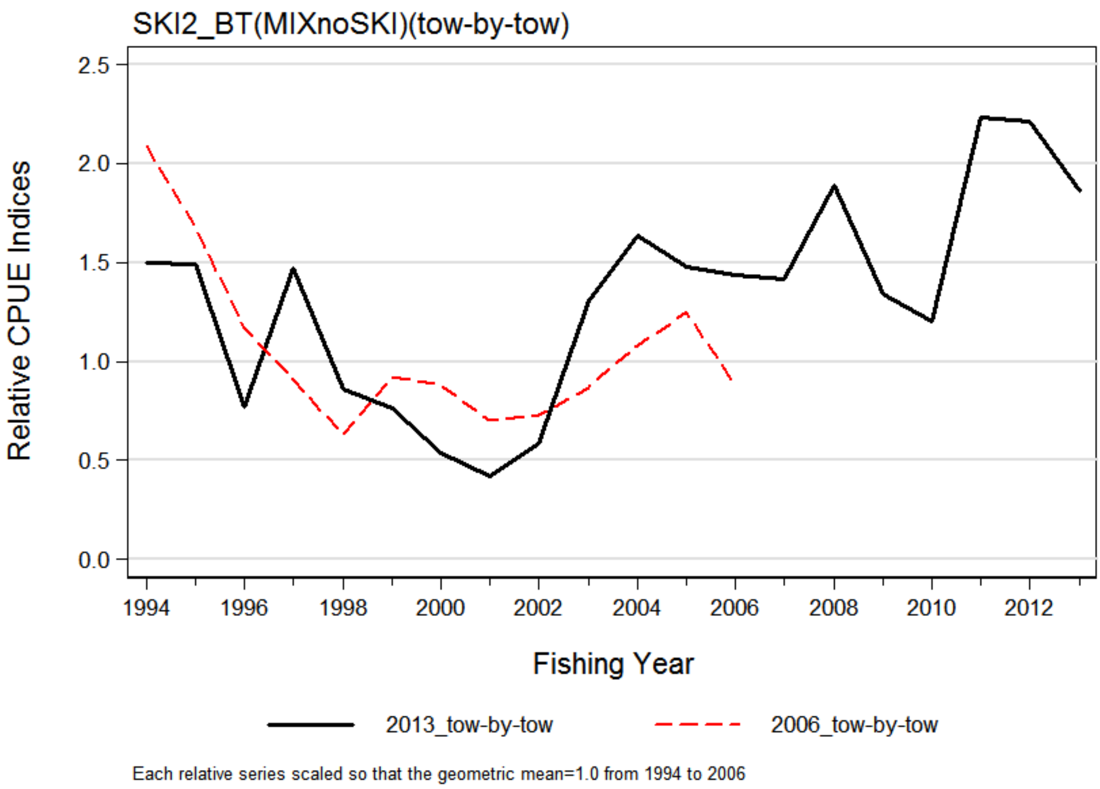

Figure H.14: Comparison of the lognormal SKI 2_BT(MIXnoSKI)(towbytow) model with a similar model from Fu et al. (2008).

Appendix I. DIAGNOSTICS AND SUPPORTING ANALYSES FOR SCAMPI BOTTOM TRAWL USING DAILY STRATUM RESOLUTION [SKI2_BT(SCI)(DAILY)] CPUE STANDARDISATION

I.1 Introduction

This analysis is presented as an example of the diagnostics associated with the bottom trawl "daily-effort stratum" models that fish for scampi. This analysis is separated from the other target species because the gear configuration used to capture scampi differs substantially (towing speeds are slower and net size, including headline height, are much smaller) from the gear used to target the species offered to the models presented in Appendix G and Appendix H.

I.2 Fishery definition

SKI2_BT(SCI)(daily): The fishery is defined from bottom trawl fishing events which fished in Statistical Areas 014, 015 declaring target species SCI. All form types (CELR, TCEPR, TCER) were included from fishing years 1989–90 to 2012–13.

I.3 Core vessel selection

The criteria used to define the core fleet were those vessels that had fished for at least 3 trips in each of at least 4 years using trips with at least 1 kg of catch. These criteria resulted in a core fleet size of 8 vessels which took 88% of the catch (Figure I.1).

I.4 Data summary

Table I.1: Number of number of core vessels, trips, daily effort strata, number of events that have been "rolled up" into daily effort strata, calculated number of events per daily-effort stratum, number of tows, sum of hours fished, sum of landed SKI (t), proportion of trips with catch and proportion of daily-effort strata with catch by fishing year for core vessels (based on a minimum of 3 trips per year in at least 4 years) in the SKI2_BT(SCI)(daily) fishery.

Fishing year	Vessels	Trips	Daily effort strata	Events	Events per stratum	Number of tows	Sum duration (h)	Catch (t)	Trips with catch (%)	Strata with catch (%)
1990	5	21	263	843	3.2	843	3 342.9	9.94	61.9	44.9
1991	6	38	453	1 509	3.3	1 509	6 942.5	27.55	86.8	57.4
1992	8	39	488	1 533	3.1	1 533	7 912.7	20.98	74.4	51.4
1993	7	38	397	1 179	3.0	1 179	5 978.0	18.78	86.8	51.4
1994	8	34	506	1 402	2.8	1 402	7 679.4	16.43	79.4	43.9
1995	6	29	271	787	2.9	787	4 301.9	10.30	82.8	43.5
1996	8	27	326	896	2.7	896	5 358.8	13.49	88.9	58.6
1997	8	31	356	1 099	3.1	1 099	6 395.5	21.86	64.5	69.4
1998	8	33	371	1 058	2.9	1 058	6 611.6	18.02	78.8	60.7
1999	8	32	515	1 467	2.8	1 467	9 308.7	25.37	90.6	68.0
2000	8	40	571	1 540	2.7	1 540	9 921.9	14.55	82.5	42.7
2001	8	36	619	1 688	2.7	1 688	11 338.5	19.24	83.3	37.2
2002	8	40	956	2 480	2.6	2 480	16 750.7	33.40	87.5	51.7
2003	7	25	519	1 264	2.4	1 264	9 255.6	22.28	96.0	49.1
2004	6	10	266	665	2.5	665	4 620.6	20.24	90.0	54.1
2005	6	14	201	486	2.4	486	3 370.3	12.96	78.6	46.8
2006	6	14	228	566	2.5	566	3 922.4	12.49	85.7	39.9
2007	6	18	290	754	2.6	754	5 184.9	15.33	94.4	57.6
2008	6	16	243	638	2.6	638	4 406.2	17.02	93.8	60.9
2009	3	8	127	334	2.6	334	2 367.0	2.80	87.5	52.8
2010	5	18	277	731	2.6	731	5 134.6	14.89	77.8	45.1
2011	4	19	299	845	2.8	845	5 865.7	21.98	94.7	54.2
2012	4	10	171	465	2.7	465	3 309.4	3.88	100.0	35.1
2013	4	10	134	365	2.7	365	2 583.7	2.82	70.0	51.5

I.5 Core vessel selection

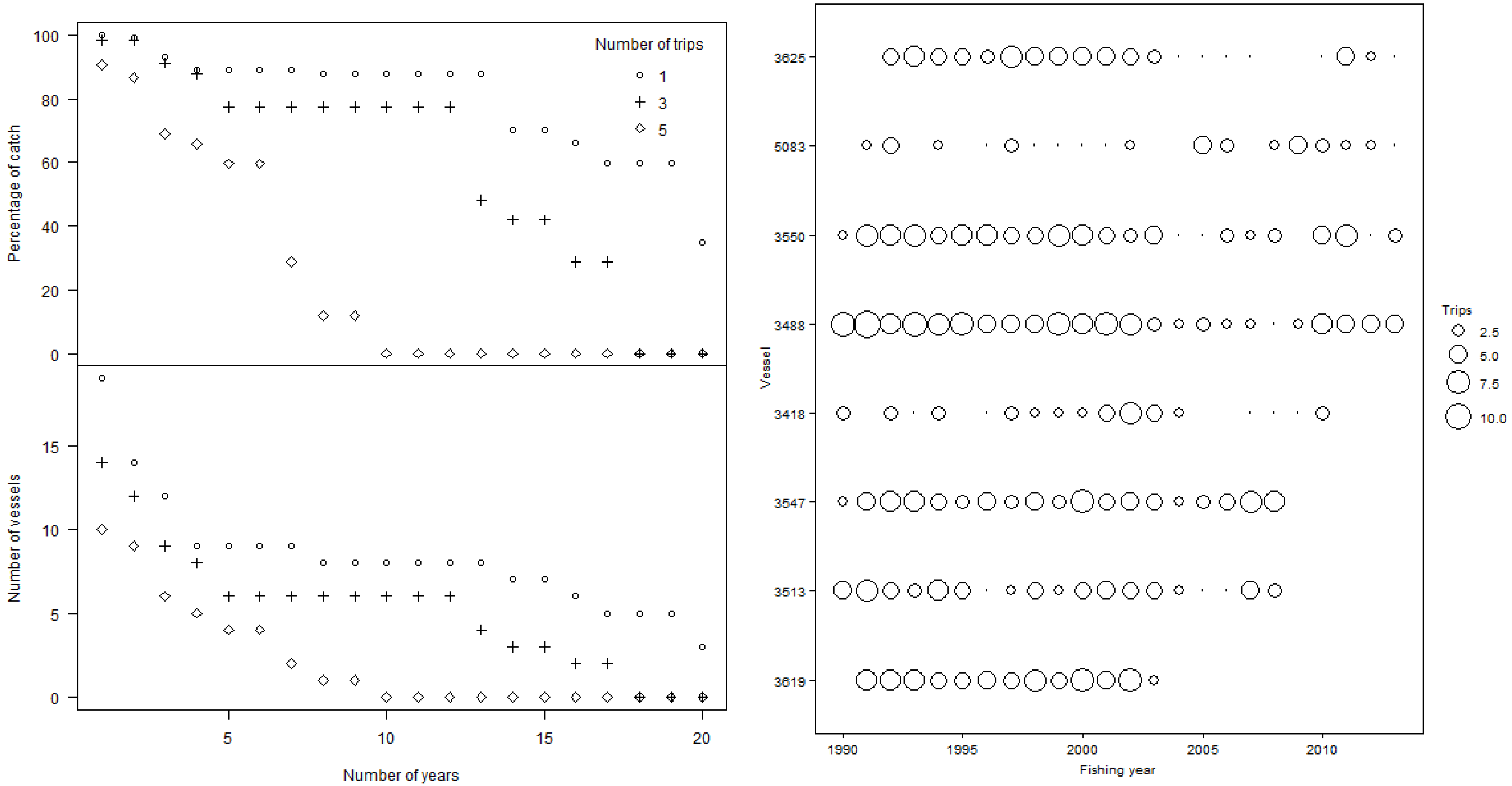

Figure I.1: [left panel] total landed SKI and number of vessels plotted against the number of years used to define core vessels participating in the SKI2_BT(SCI)(daily) dataset. The number of qualifying years (minimum number of trips per year) for each series is indicated in the legend. [right panel]: bubble plot showing the number of daily-effort strata for selected core vessels (based on at least 3 trips in 4 or more fishing years) by fishing year.

I.6 Exploratory data plots for core vessel data set

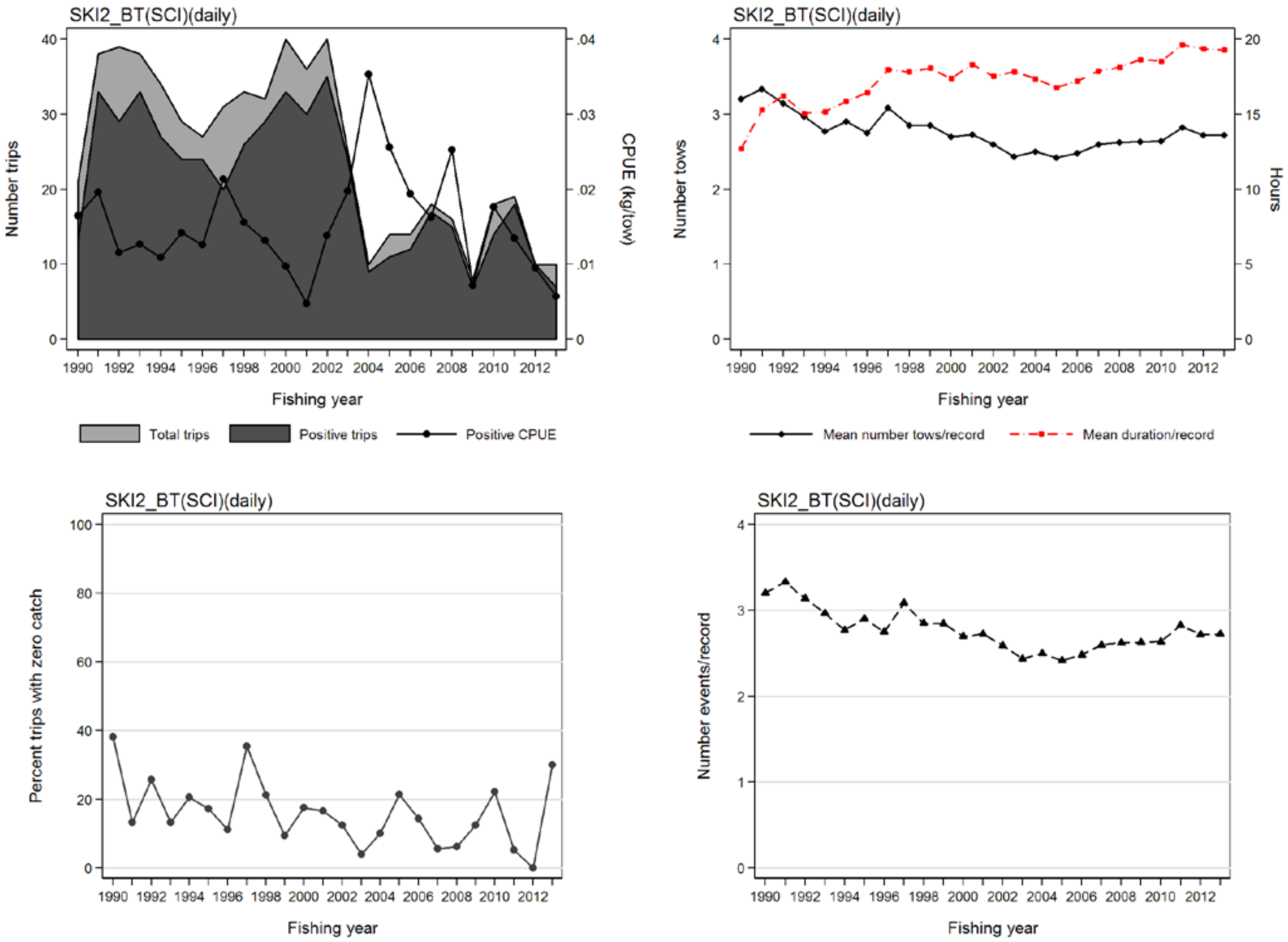

Figure I.2: Core vessel summary plots by fishing year for model SKI2_BT(SCI)(daily): [upper left panel]: total trips (light grey) and trips with gemfish catch (dark grey) overlaid with median annual arithmetic CPUE (kg/tow) for all trips *i* with positive catch: $A_y = \text{median}\left(C_{y,i} / E_{y,i}\right)$**; [upper right panel]: mean number tows and mean duration per daily-effort stratum record; [lower left panel]: proportion of trips with no catch of gemfish; [lower right panel]: mean number of events per daily-effort stratum record.**

I.7 Selection of distribution for positive catch records

The best distribution was log-logistic.

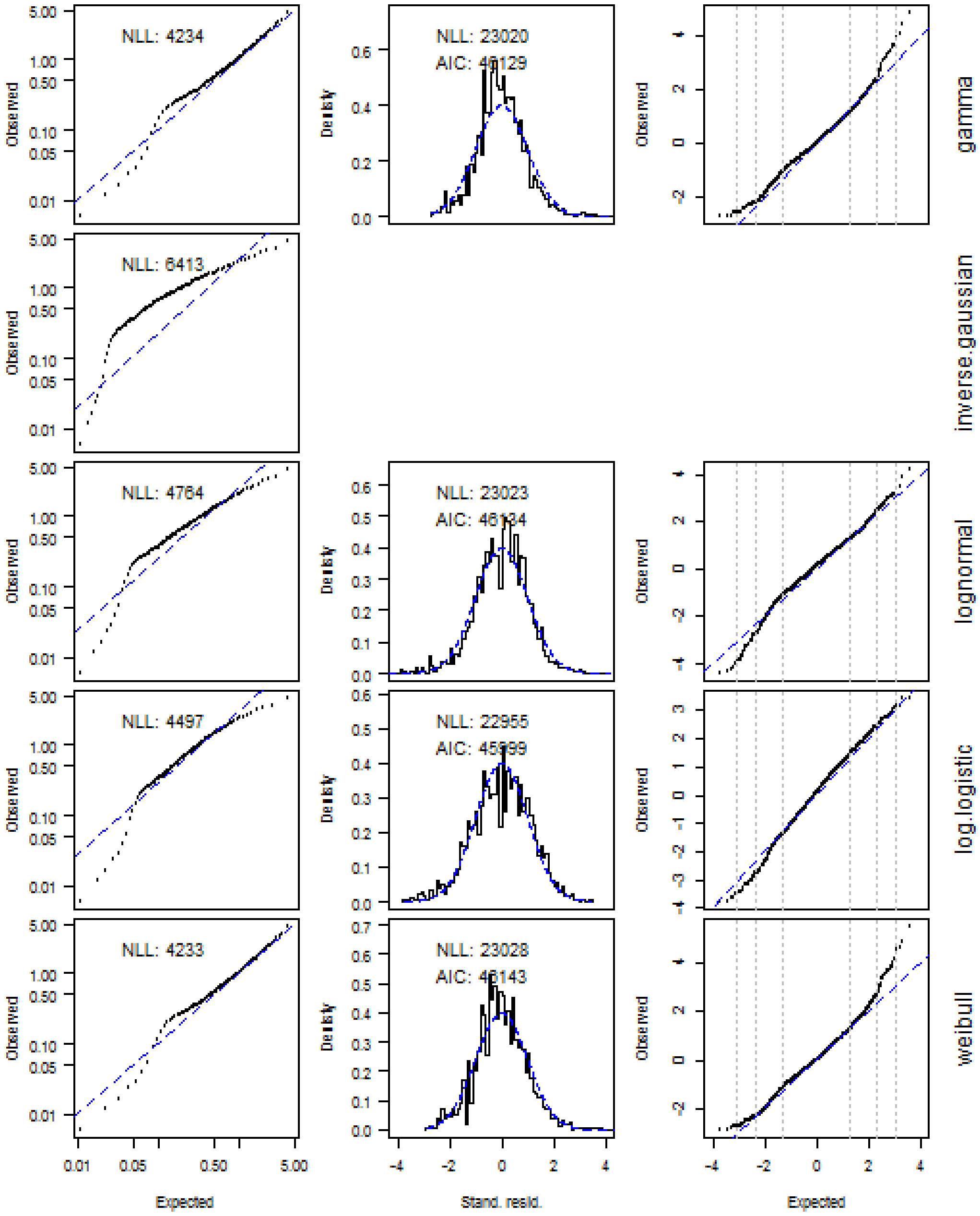

Figure I.3: Diagnostics for alternative distributional assumptions for catch in the gemfish SKI2_BT(SCI)(daily) model. Left: quantile-quantile plot of observed catches (centred (by mean) and scaled (by standard deviation) in log space) versus maximum likelihood fit of distribution (missing panel indicates that the fit failed to converge); Middle: standardised residuals from a generalised linear model fitted using the formula catch ~ fyear + month +area+ vessel + log(sets) and the distribution (missing panel indicates that the model failed to converge); Right: quantile-quantile plot of model standardised residuals against standard normal (vertical lines represent 0.1%, 1% and 10% percentiles). NLL = negative log-likelihood; AIC = Akaike information criterion.

I.8 Positive catch model selection table

Three explanatory variables entered the model after fishing year (Table I.2), with area being non-significant. The model discarded number of tows as an explanatory variable. A plot of the model is provided in Figure I.4 and the CPUE indices are listed in Table I.4.

Table I.2: Order of acceptance of variables into the log-logistic model of successful catches in the SKI2_BT(SCI)(daily) fishery model for core vessels based on the vessel selection criteria of at least 3 trips in 4 or more fishing years, with the amount of explained deviance and R^2 for each variable. Variables accepted into the model are marked with an *, and the final R^2 of the selected model is in bold. Fishing year was forced as the first variable.

Variable	DF	Neg. Log likelihood	AIC	R^2	Model use
fishing year	25	-23 701	47 452	8.47	*
month	36	-23 067	46 206	31.71	*
vessel	43	-22 964	46 015	34.87	*
poly(log(duration), 3)	46	-22 879	45 851	**37.37**	*
area	47	-22 870	45 835	37.63	
poly(log(tows), 3)	–	–	–	–	

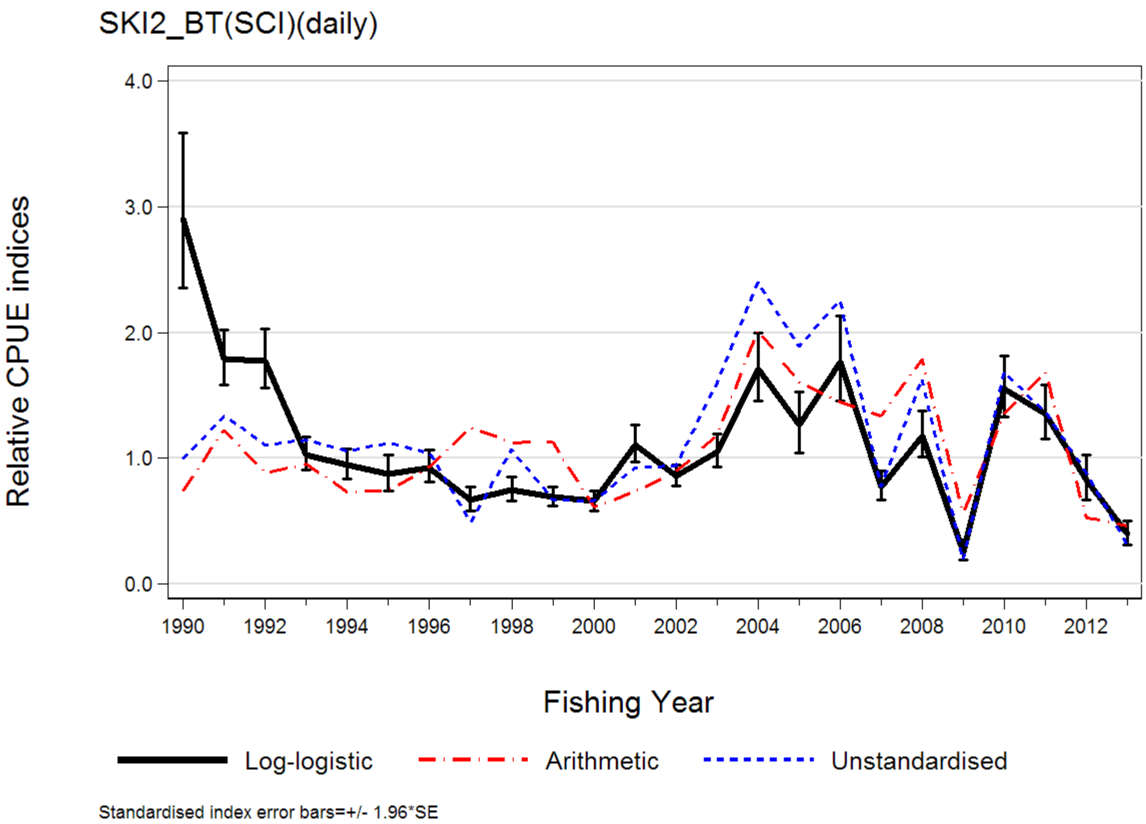

Figure I.4: Relative CPUE indices for gemfish using the log-logistic non-zero model based on the SKI2_BT(SCI)(daily) fishery definition. Also shown are two unstandardised series from the same data: a) Arithmetic (Eq. F.1) and b) Unstandardised (Eq. F.2).

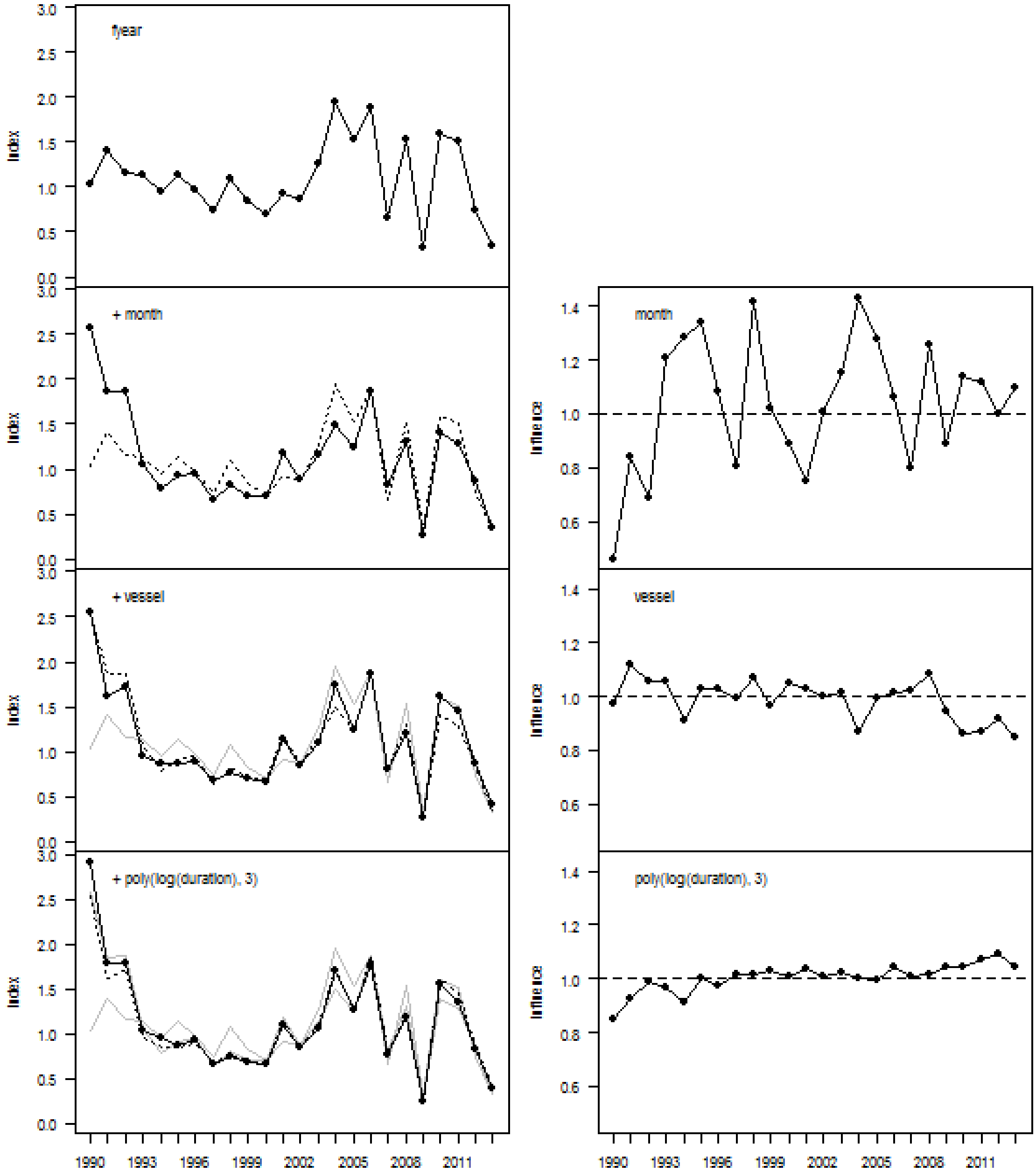

Figure I.5: [left column]: annual indices from the log-logistic model of SKI2_BT(SCI)(daily) at each step in the variable selection process; [right column]: aggregate influence associated with each step in the variable selection procedure.

I.9 Residual and diagnostic plots

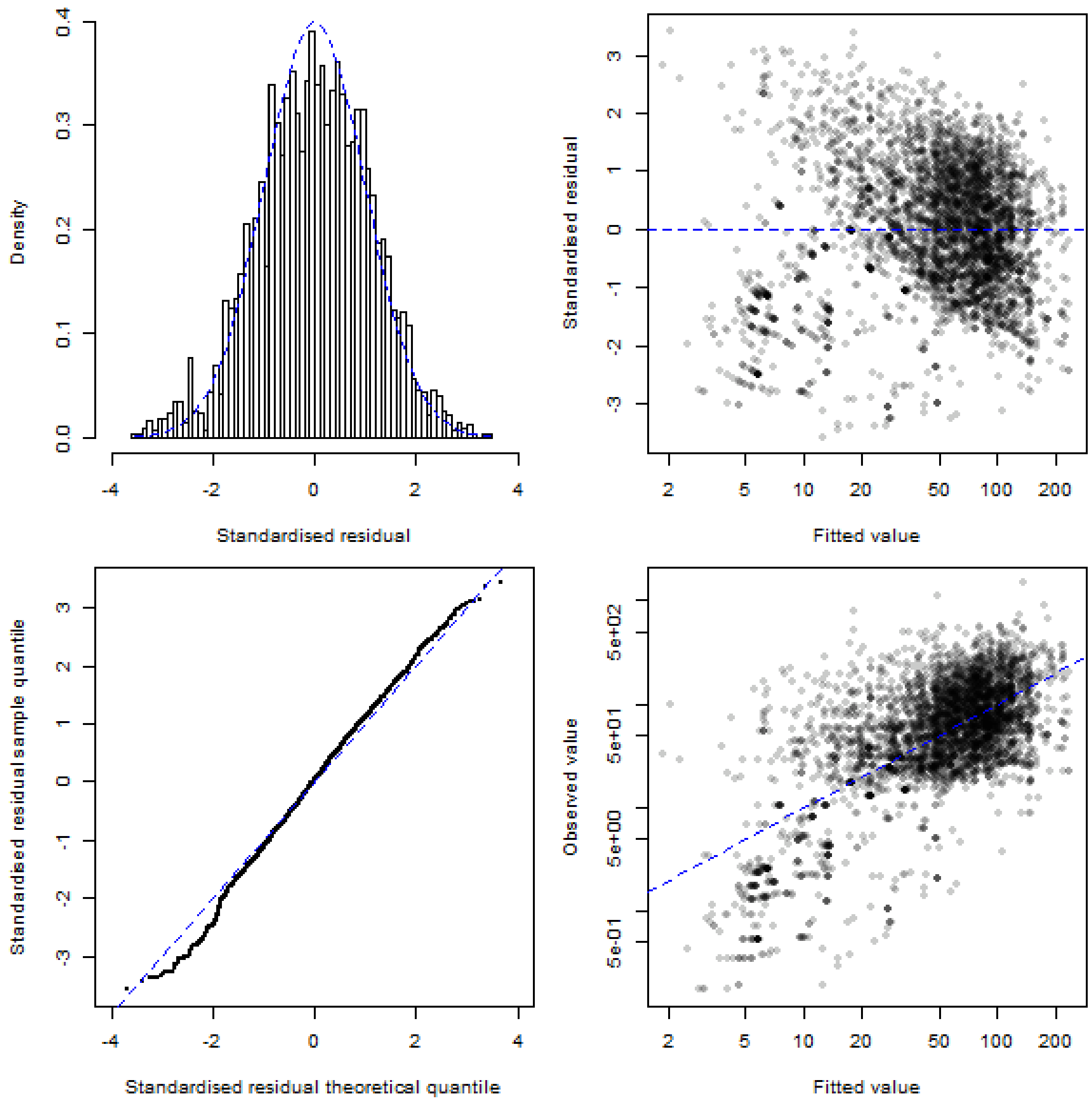

Figure I.6: Plots of the fit of the log-logistic standardised CPUE model to successful catches of gemfish in the SKI2_BT(SCI)(daily) fishery. [Upper left] histogram of the standardised residuals compared to a log-logistic distribution (SDSR: standard deviation of standardised residuals. MASR: median of absolute standardised residuals); [Upper right] Q-Q plot of the standardised residuals; [Lower left] Standardised residuals plotted against the predicted model catch per trip; [Lower right] Observed catch per record plotted against the predicted catch per record.

I.10 Model coefficients

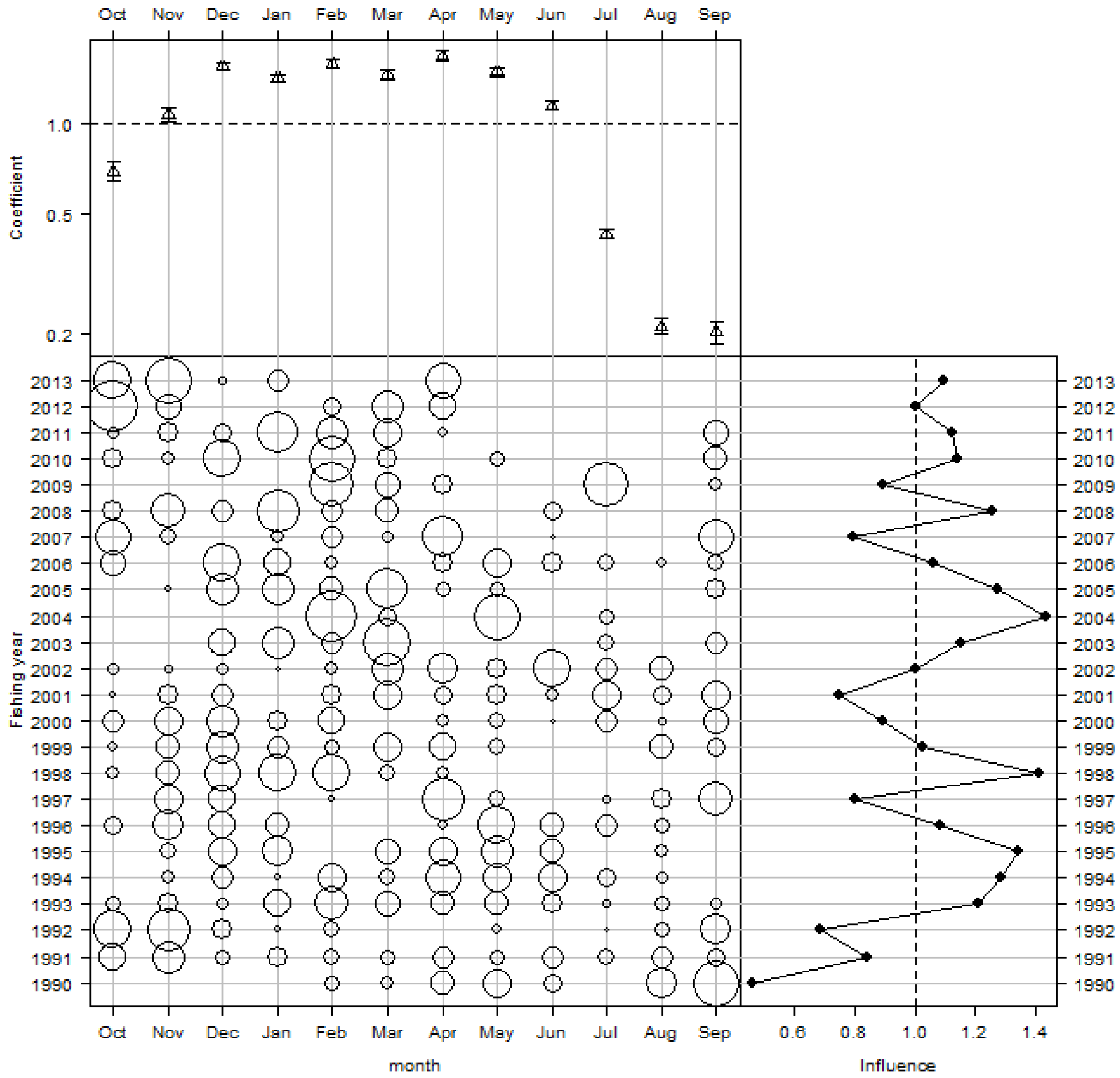

Figure I.7: Effect of month in the log-logistic model for the gemfish SKI2_BT(SCI)(daily) fishery. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

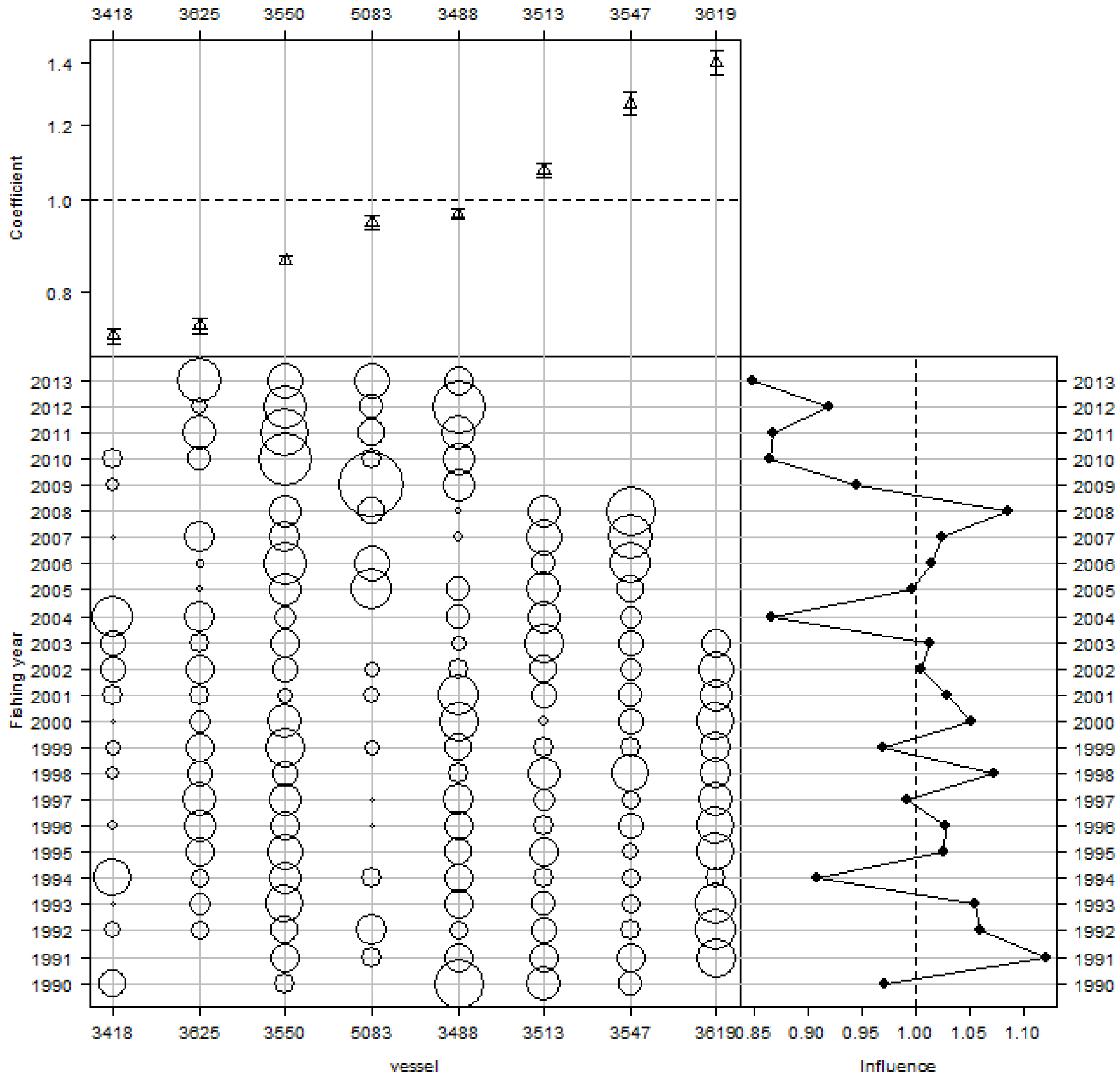

Figure I.8: Effect of vessel in the log-logistic model for the gemfish SKI2_BT(SCI)(daily) fishery. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

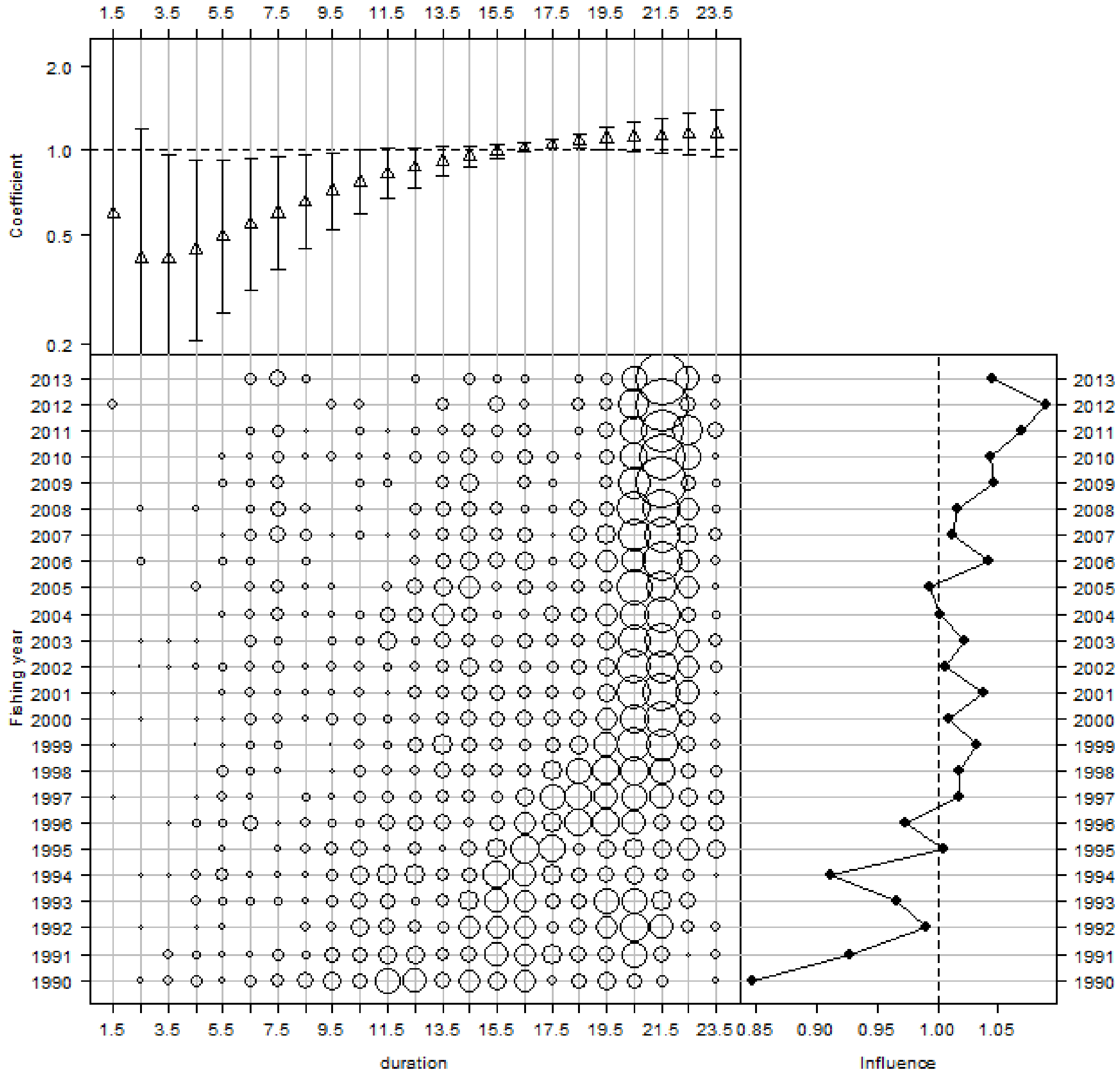

Figure I.9: Effect of duration in the log-logistic model for the gemfish SKI2_BT(SCI)(daily) fishery. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

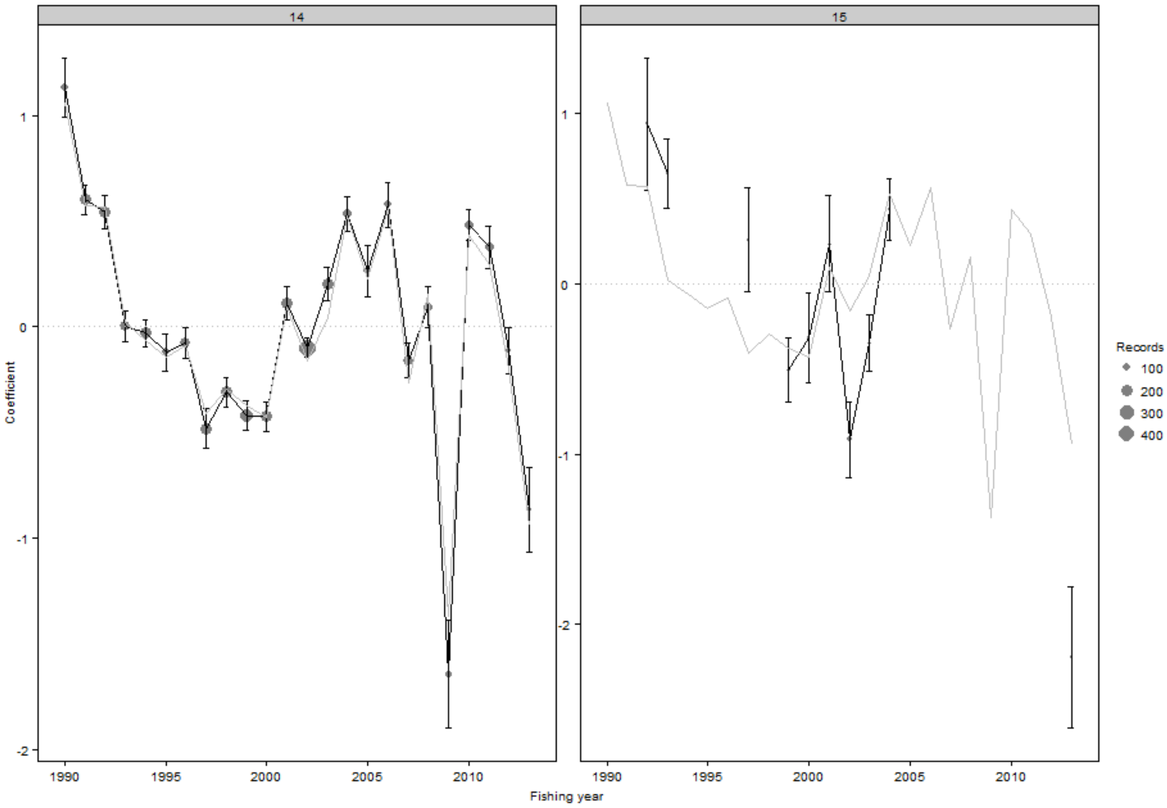

Figure I.10: Residual implied coefficients for area×fishing year interaction (not offered) in the gemfish SKI2_BT(SCI)(daily) log-logistic model. Implied coefficients (black points) are calculated as the normalised fishing year coefficient (grey line) plus the mean of the standardised residuals in each fishing year and area. These values approximate the coefficients obtained when an area×year interaction term is fitted, particularly for those area×year combinations which have a substantial proportion of the records. The error bars indicate one standard error of the standardised residuals.

I.11 Logistic (binomial) model selection table

Three explanatory variables entered the model after fishing year (Table I.3), with area and number of tows non-significant. A plot of the binomial model and the combined delta-log-logistic model is provided in Figure I.11 and the CPUE indices are listed in Table I.4.

Table I.3: Order of acceptance of variables into the binomial (logistic) model of successful catches in the gemfish SKI2_BT(SCI)(daily) fishery model for core vessels based on the vessel selection criteria of at least 3 trips in 4 or more fishing years), with the amount of explained deviance and R^2 for each variable. Variables accepted into the model are marked with an *, and the final R^2 of the selected model is in bold. Fishing year was forced as the first variable.

Variable	DF	Neg. Log likelihood	AIC	R^2	Model use
fishing year	24	-5 770	11 589	3.79	*
month	35	-5 384	10 838	15.04	*
poly(log(duration), 3)	38	-5 267	10 610	18.26	*
vessel	45	-5 191	10 471	**20.31**	*
area	46	-5 177	10 445	20.68	
poly(log(num), 3)	49	-5 172	10 443	20.79	

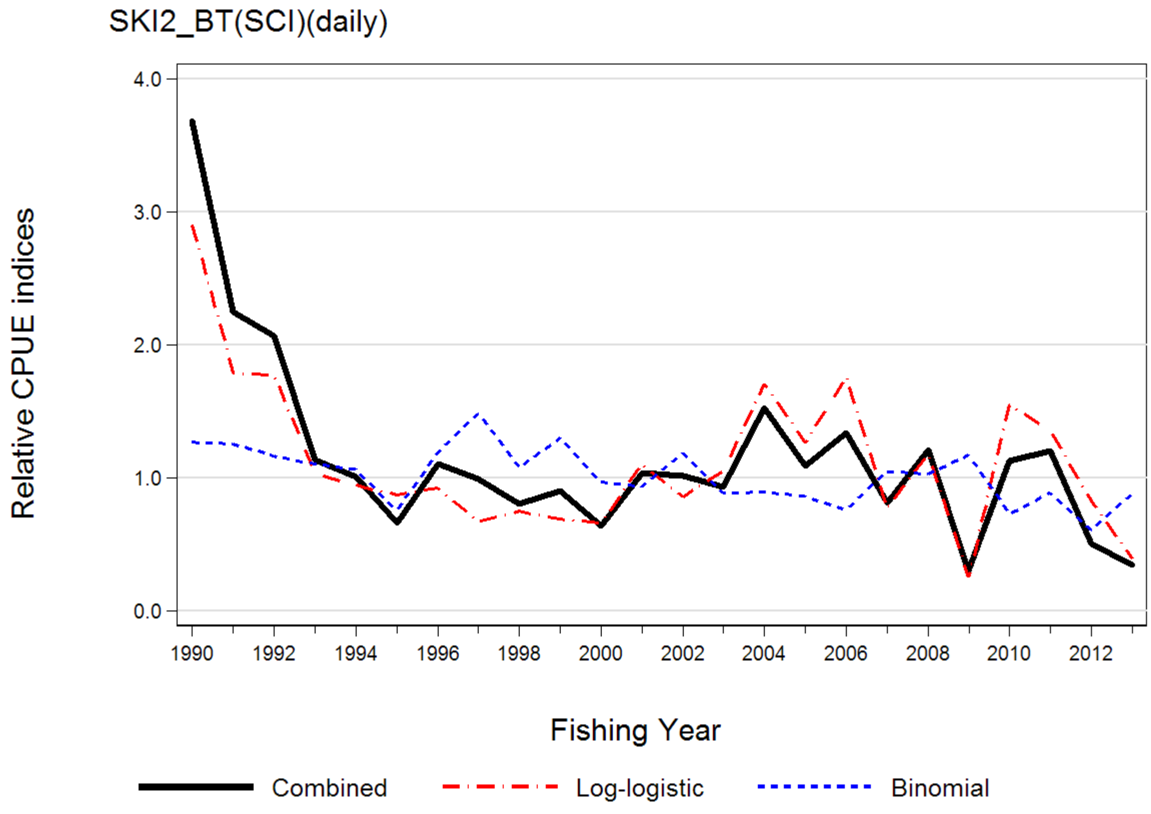

Figure I.11: Relative CPUE indices for gemfish using the log-logistic non-zero model based on the SKI2_BT(SCI)(daily) fishery definition, the binomial standardised model using the logistic distribution and a regression based on presence/absence of SKI, and the combined model using the delta-log-logistic procedure suggested by Vignaux (1994).

I.12 CPUE indices

Table I.4: Arithmetic indices for the total and core data sets, geometric and log-logistic standardised indices and associated standard error (SE) for the core data set by fishing year for the gemfish SKI2_BT(SCI)(daily) analysis. All series (except SE) standardised to geometric mean=1.0.

Fishing	All vessels						Core vessels
year	Arithmetic	Arithmetic	Geometric	Standardised	SE	Binomial	Combined
1990	0.914	0.740	0.993	2.907	0.1074	1.269	3.690
1991	1.088	1.227	1.339	1.789	0.0618	1.257	2.248
1992	0.833	0.882	1.106	1.777	0.0669	1.163	2.067
1993	0.896	0.950	1.144	1.028	0.0661	1.104	1.135
1994	0.712	0.730	1.057	0.945	0.0647	1.065	1.006
1995	0.720	0.745	1.121	0.872	0.0834	0.756	0.659
1996	0.896	0.927	1.042	0.925	0.0699	1.191	1.102
1997	1.200	1.241	0.488	0.670	0.0722	1.486	0.995
1998	1.076	1.124	1.070	0.749	0.0655	1.076	0.806
1999	1.086	1.128	0.670	0.692	0.0545	1.305	0.903
2000	0.586	0.609	0.658	0.657	0.0625	0.969	0.637
2001	0.708	0.734	0.923	1.106	0.0671	0.936	1.035
2002	1.100	0.889	0.941	0.858	0.0491	1.186	1.018
2003	1.293	1.182	1.596	1.053	0.0647	0.887	0.934
2004	1.845	2.016	2.400	1.708	0.0805	0.893	1.526
2005	1.328	1.607	1.889	1.264	0.0975	0.861	1.089
2006	1.533	1.449	2.256	1.762	0.0971	0.760	1.339
2007	1.240	1.335	0.775	0.772	0.0763	1.049	0.810
2008	1.728	1.787	1.633	1.178	0.0791	1.030	1.213
2009	0.908	0.568	0.184	0.256	0.1614	1.172	0.300
2010	1.253	1.347	1.686	1.552	0.0802	0.728	1.129
2011	1.632	1.688	1.371	1.354	0.0810	0.890	1.205
2012	0.533	0.528	0.884	0.826	0.1119	0.607	0.502
2013	0.446	0.462	0.309	0.394	0.1225	0.879	0.346

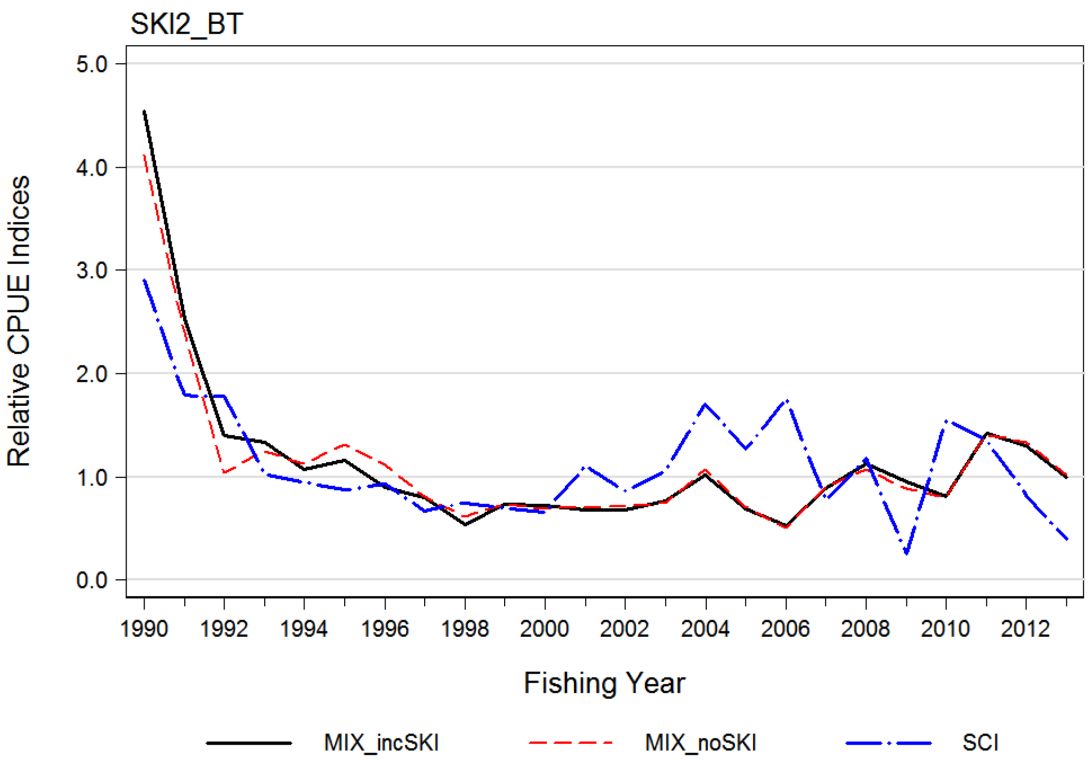

Figure I.12: Comparison of SKI 2_BT(MIX+SKI)(daily) model with SKI 2_BT(MIXnoSKI)(daily) model and SKI 2_BT(SCI)(daily) model.

Appendix J. MODEL SELECTION TABLES, CPUE INDEX SERIES AND CPUE PLOTS FOR REMAINING SKI 2 CPUE ANALYSES

J.1 SKI2_BT(MIXnoSKI)(daily)

J.1.1 Positive catch model selection table

Table J.1: Order of acceptance of variables into the lognormal model of successful catches in the SKI2_BT(MIXnoSKI)(daily) fishery model for core vessels based on the vessel selection criteria of at least 5 trips in 5 or more fishing years, with the amount of explained deviance and R^2 for each variable. Variables accepted into the model are marked with an *, and the final R^2 of the selected model is in bold. Fishing year was forced as the first variable.

Variable	DF	Neg. Log likelihood	AIC	R^2	Model use
fishing year	25	-76 291	152 632	2.7	*
month	36	-75 000	150 073	16.46	*
vessel	81	-73 907	147 976	26.59	*
target species	86	-73 436	147 044	30.56	*
poly(log(duration), 3)	89	-73 237	146 651	32.18	*
area	97	-73 075	146 345	**33.46**	*
poly(log(num), 3)	100	-73 043	146 286	33.71	

J.1.2 Logistic (binomial) model selection table

Table J.2: Order of acceptance of variables into the binomial (logistic) model of successful catches in the gemfish SKI2_BT(MIXnoSKI)(daily) fishery model for core vessels based on the vessel selection criteria of at least 5 trips in 5 or more fishing years), with the amount of explained deviance and R^2 for each variable. Variables accepted into the model are marked with an *, and the final R^2 of the selected model is in bold. Fishing year was forced as the first variable.

Variable	DF	Neg. Log likelihood	AIC	R^2	Model use
fishing year	24	-31 750	63 548	1.87	*
vessel	69	-29 991	60 121	11.12	*
month	80	-28 577	57 315	18.10	*
target species	85	-27 390	54 951	**23.67**	*
area	93	-27 224	54 634	24.43	
poly(log(duration), 3)	96	-27 127	54 446	24.87	
poly(log(tows), 3)	–	–	–	–	

J.1.3 CPUE indices

Table J.3: Arithmetic indices for the total and core data sets, geometric and lognormal standardised indices and associated standard error (SE) for the core data set by fishing year for the gemfish SKI2_BT(MIXnoSKI)(daily) analysis. All series (except SE) standardised to geometric mean=1.0.

Fishing	All vessels						Core vessels
year	Arithmetic	Arithmetic	Geometric	Standardised	SE	Binomial	Combined
1990	5.510	2.540	2.468	4.117	0.0769	1.447	5.959
1991	1.905	1.869	1.881	2.403	0.0686	1.247	2.998
1992	1.255	1.493	0.962	1.036	0.0684	1.092	1.132
1993	1.575	1.129	1.186	1.247	0.0666	1.238	1.544
1994	1.347	0.863	1.183	1.127	0.0666	1.117	1.259
1995	1.221	1.240	1.520	1.316	0.0636	1.082	1.424
1996	1.304	1.313	1.498	1.118	0.0756	0.833	0.932
1997	0.987	0.930	1.076	0.805	0.0812	0.608	0.490
1998	1.246	0.435	0.609	0.615	0.0755	0.724	0.445
1999	0.393	0.502	0.625	0.733	0.0777	0.762	0.559
2000	0.440	0.566	0.803	0.695	0.0795	0.742	0.515
2001	0.395	0.591	0.669	0.703	0.0748	0.783	0.550
2002	0.285	0.480	0.613	0.711	0.0742	0.976	0.694
2003	0.633	0.915	0.868	0.749	0.0658	1.105	0.827
2004	0.919	1.159	0.822	1.068	0.0641	1.161	1.241
2005	0.758	0.842	0.757	0.706	0.0679	0.909	0.641
2006	0.640	0.748	0.599	0.504	0.0633	0.994	0.501
2007	1.226	1.396	1.091	0.905	0.0592	1.110	1.005
2008	1.702	1.679	1.492	1.071	0.0650	0.930	0.997
2009	1.252	1.284	1.043	0.883	0.0621	0.897	0.792
2010	0.794	0.775	0.734	0.802	0.0583	1.019	0.817
2011	1.227	1.206	1.126	1.411	0.0543	1.239	1.748
2012	1.454	1.481	1.141	1.334	0.0546	1.358	1.811
2013	0.897	0.981	1.007	1.017	0.0621	1.162	1.182

J.1.4 CPUE plots

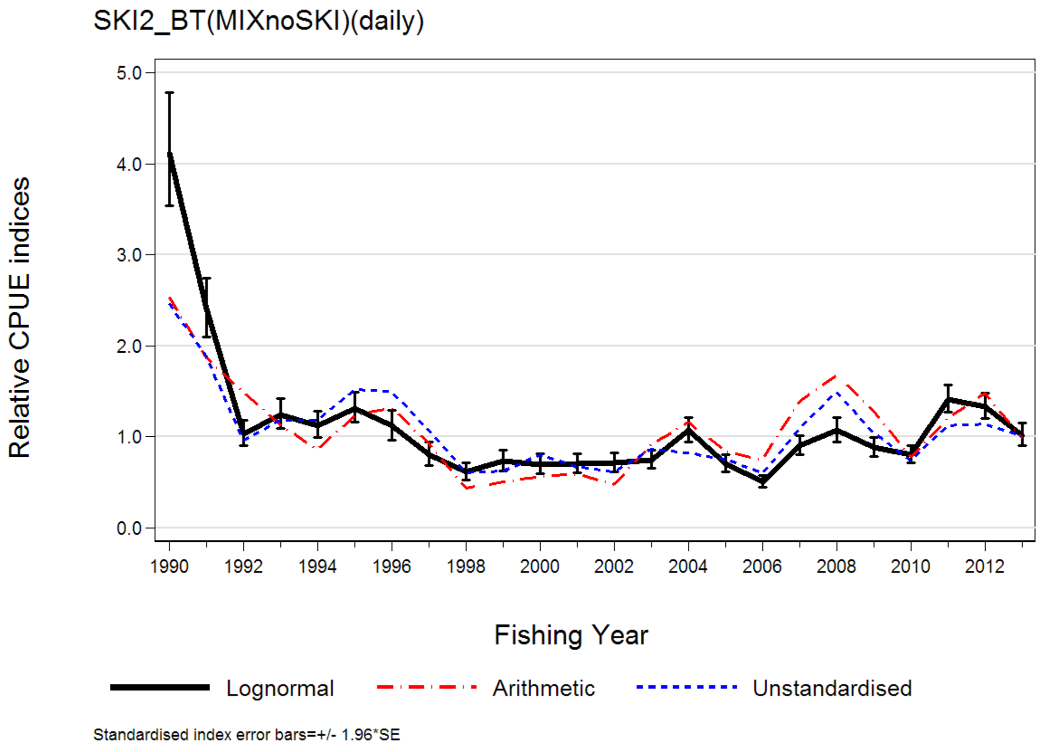

Figure J.1: Relative CPUE indices for gemfish using the lognormal non-zero model based on the SKI2_BT(MIXnoSKI)(daily) fishery definition. Also shown are two unstandardised series from the same data: a) Arithmetic (Eq. F.1) and b) Unstandardised (Eq. F.2).

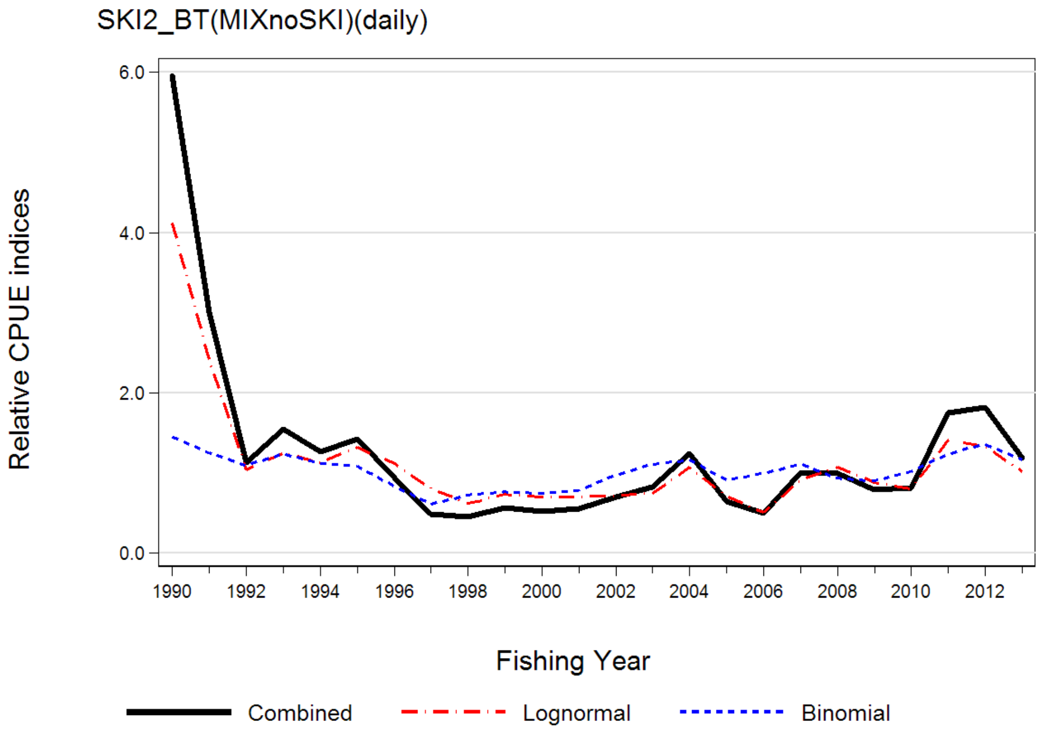

Figure J.2: Relative CPUE indices for gemfish using the lognormal non-zero model based on the SKI2_BT(MIXnoSKI)(daily) fishery definition, the binomial standardised model using the logistic distribution and a regression based on presence/absence of SKI, and the combined model using the delta-lognormal procedure suggested by Vignaux (1994).

J.2 SKI2_BT(MIX+SKI)(towbytow)

J.2.1 Positive catch model selection table

Table J.4: Order of acceptance of variables into the lognormal model of successful catches in the SKI2_BT(MIX+SKI)(towbytow) fishery model for core vessels based on the vessel selection criteria of at least 5 trips in 5 or more fishing years, with the amount of explained deviance and R^2 for each variable. Variables accepted into the model are marked with an *, and the final R^2 of the selected model is in bold. Fishing year was forced as the first variable.

Variable	DF	Neg. Log likelihood	AIC	R^2	Model use
fishing year	21	-90 480	181 002	6.96	*
target species	27	-85 307	170 667	43.73	*
vessel	51	-82 970	166 041	55.17	*
month	62	-80 726	161 576	63.95	*
area	70	-79 556	159 252	67.83	*
poly(log(bottom depth), 3)	73	-78 769	157 683	70.20	*
poly(log(height), 3)	76	-78 722	157 595	70.34	
poly(log(swept_volume), 3)	79	-78 704	157 566	70.39	
poly(log(width), 3)	82	-78 689	157 543	70.43	
poly(log(duration), 3)	85	-78 679	157 528	70.46	
poly(log(swept_area), 3)	88	-78 673	157 523	70.48	
poly(log(speed), 3)	–	–	–	–	
poly(log(swept_distance), 3)	–	–	–	–	

J.2.2 Logistic (binomial) model selection table

Table J.5: Order of acceptance of variables into the binomial (logistic) model of successful catches in the gemfish SKI2_BT(MIX+SKI)(towbytow) fishery model for core vessels based on the vessel selection criteria of at least 5 trips in 5 or more fishing years), with the amount of explained deviance and R^2 for each variable. Variables accepted into the model are marked with an *, and the final R^2 of the selected model is in bold. Fishing year was forced as the first variable.

Variable	DF	Neg. Log likelihood	AIC	R^2	Model use
fishing year	20	-36 535	73 110	4.71	*
target species	26	-32 788	65 629	20.88	*
month	36	-32 108	64 288	23.60	*
vessel	60	-31 515	63 149	25.92	*
poly(log(bottom depth), 3)	63	-30 901	61 927	28.27	*
area	71	-30 803	61 749	28.64	
poly(log(swept_area), 3)	74	-30 742	61 632	28.87	
poly(log(height), 3)	77	-30 693	61 540	29.05	
poly(log(duration), 3)	80	-30 682	61 523	29.09	
poly(log(width), 3)	83	-30 678	61 522	29.11	
poly(log(swept_volume), 3)	85	-30 675	61 521	29.12	
poly(log(speed), 3)	–	–	–	–	
poly(log(swept_distance), 3)	–	–	–	–	

J.2.3 CPUE indices

Table J.6: Arithmetic indices for the total and core data sets, geometric and lognormal standardised indices and associated standard error (SE) for the core data set by fishing year for the gemfish SKI2_BT(MIX+SKI)(towbytow) analysis. All series (except SE) standardised to geometric mean=1.0.

Fishing	All vessels						Core vessels
year	Arithmetic	Arithmetic	Geometric	Standardised	SE	Binomial	Combined
1994	1.707	0.853	0.688	1.470	0.0653	1.225	1.801
1995	0.765	0.503	0.390	1.225	0.0666	1.185	1.452
1996	1.013	1.347	0.480	0.636	0.0487	1.326	0.843
1997	2.412	4.425	5.718	0.916	0.0528	0.823	0.754
1998	2.889	3.219	5.215	0.658	0.0567	0.898	0.591
1999	3.406	3.537	1.721	0.674	0.0609	0.618	0.416
2000	6.553	6.013	1.792	0.548	0.0522	0.828	0.454
2001	3.698	4.123	2.145	0.405	0.0603	0.894	0.362
2002	2.584	3.001	2.427	0.568	0.0598	1.204	0.683
2003	2.233	2.298	2.430	0.928	0.0587	1.054	0.978
2004	2.302	2.226	1.698	1.068	0.0565	1.053	1.125
2005	1.573	1.481	1.395	1.249	0.0636	0.926	1.158
2006	0.753	0.656	0.378	1.247	0.0622	1.176	1.466
2007	1.126	0.920	1.092	1.246	0.0608	0.983	1.224
2008	0.220	0.228	0.695	1.556	0.0463	0.891	1.386
2009	0.214	0.221	0.400	1.136	0.0463	0.916	1.040
2010	0.183	0.216	0.266	1.000	0.0464	1.060	1.060
2011	0.332	0.387	0.605	1.797	0.0468	0.975	1.752
2012	0.182	0.195	0.483	1.809	0.0469	1.155	2.088
2013	0.143	0.123	0.316	1.544	0.0559	1.103	1.703

J.2.4 CPUE plots

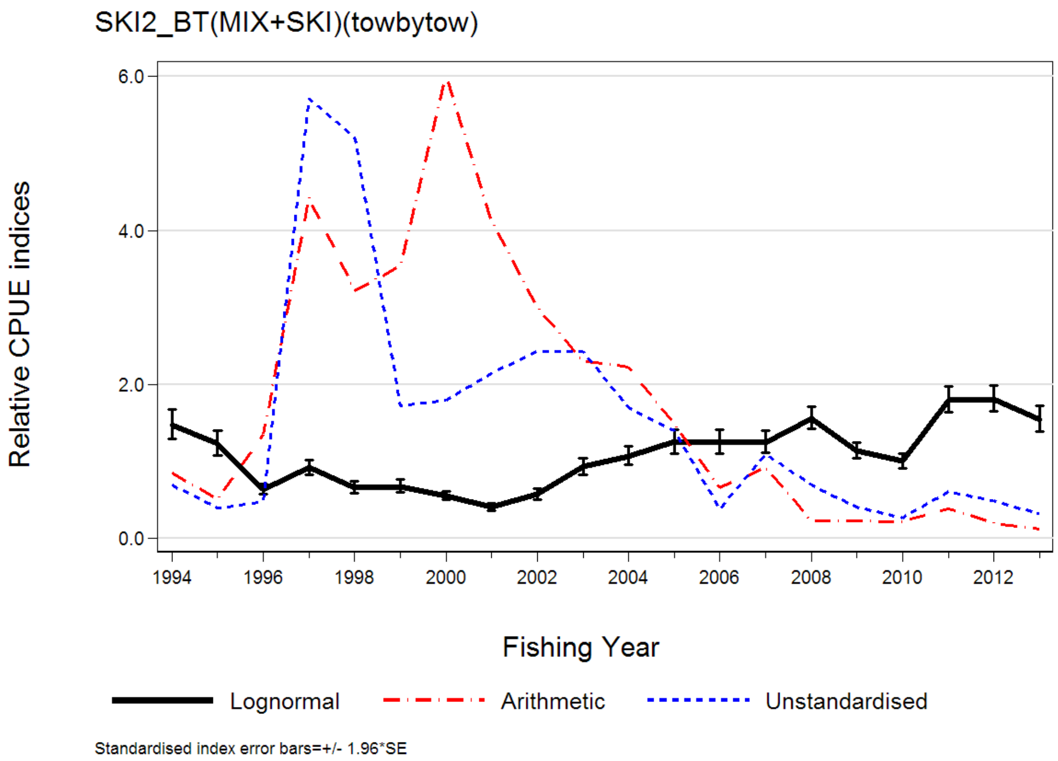

Figure J.3: Relative CPUE indices for gemfish using the lognormal non-zero model based on the SKI2_BT(MIX+SKI)(towbytow) fishery definition. Also shown are two unstandardised series from the same data: a) Arithmetic (Eq. F.1) and b) Unstandardised (Eq. F.2).

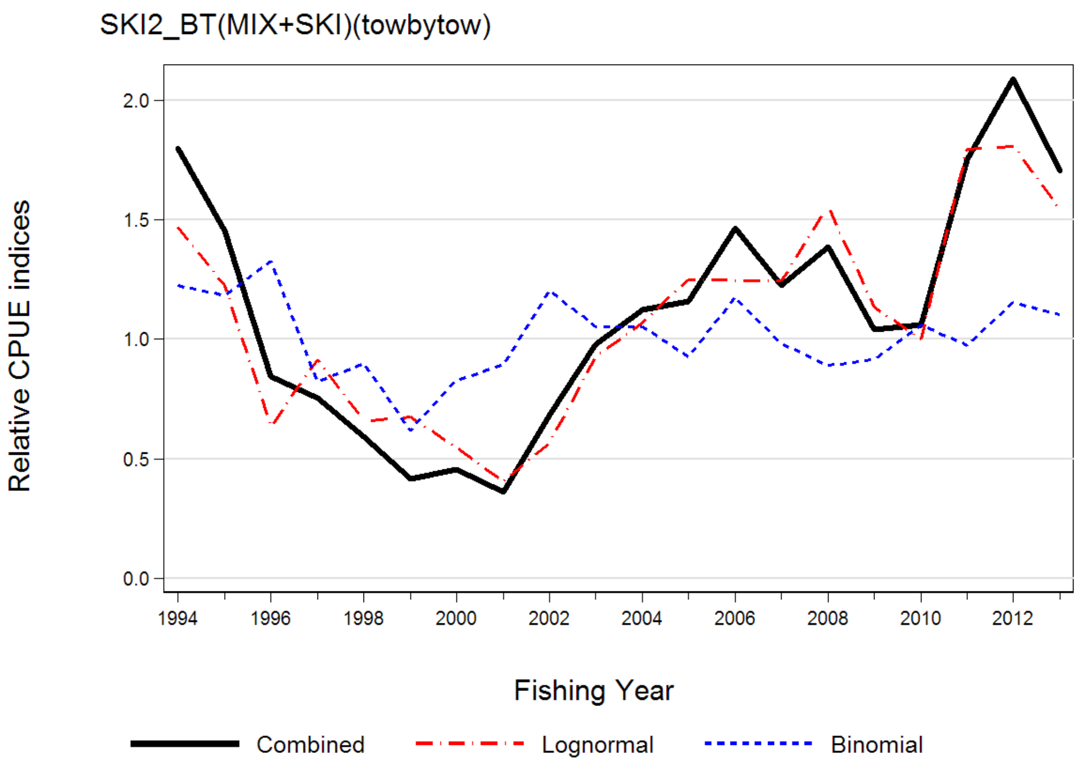

Figure J.4: Relative CPUE indices for gemfish using the lognormal non-zero model based on the SKI2_BT(MIX+SKI)(towbytow) fishery definition, the binomial standardised model using the logistic distribution and a regression based on presence/absence of SKI, and the combined model using the delta-lognormal procedure suggested by Vignaux (1994).

J.3 SKI2_BT(SCI)(towbytow)

J.3.1 Positive catch model selection table

Table J.7: Order of acceptance of variables into the log-logistic model of successful catches in the SKI2_BT(SCI)(towbytow) fishery model for core vessels based on the vessel selection criteria of at least 3 trips in 4 or more fishing years, with the amount of explained deviance and R^2 for each variable. Variables accepted into the model are marked with an *, and the final R^2 of the selected model is in bold. Fishing year was forced as the first variable.

Variable	DF	Neg. Log likelihood	AIC	R^2	Model use
fishing year	21	-24 480	49 003	16.43	*
month	32	-22 382	44 829	64.13	*
poly(log(speed), 3)	35	-22 226	44 523	66.32	*
poly(log(width), 3)	38	-22 141	44 358	67.46	*
vessel	44	-22 104	44 295	67.95	
poly(log(swept_distance), 3)	47	-22 095	44 284	68.05	
area	48	-22 091	44 277	68.11	
poly(log(bottom depth), 3)	51	-22 086	44 274	68.17	
poly(log(height), 3)	54	-22 081	44 271	68.23	
poly(log(duration), 3)	–	–	–	–	
poly(log(swept_area), 3)	–	–	–	–	
poly(log(swept_volume), 3)	–	–	–	–	

J.3.2 Logistic (binomial) model selection table

Table J.8: Order of acceptance of variables into the binomial (logistic) model of successful catches in the gemfish SKI2_BT(SCI)(towbytow) fishery model for core vessels based on the vessel selection criteria of at least 3 trips in 4 or more fishing years), with the amount of explained deviance and R^2 for each variable. Variables accepted into the model are marked with an *, and the final R^2 of the selected model is in bold. Fishing year was forced as the first variable.

Variable	DF	Neg. Log likelihood	AIC	R^2	Model use
fishing year	20	-9 469	18 978	4.09	*
month	30	-9 213	18 486	8.52	*
vessel	36	-9 155	18 383	9.49	
poly(log(width), 3)	39	-9 125	18 329	10.00	
poly(log(swept_volume), 3)	42	-9 102	18 289	10.38	
area	43	-9 090	18 266	10.59	
poly(log(bottom depth), 3)	44	-9 079	18 246	10.78	
poly(log(height), 3)	47	-9 072	18 238	10.89	
poly(log(duration), 3)	50	-9 065	18 231	11.00	
poly(log(swept_area), 3)	–	–	–	–	
poly(log(swept_volume), 3)	–	–	–	–	
poly(log(swept_distance), 3)	–	–	–	–	

J.3.3 CPUE indices

Table J.9: Arithmetic indices for the total and core data sets, geometric and log-logistic standardised indices and associated standard error (SE) for the core data set by fishing year for the gemfish SKI2_BT(SCI)(towbytow) analysis. All series (except SE) standardised to geometric mean=1.0.

Fishing	All vessels						Core vessels
year	Arithmetic	Arithmetic	Geometric	Standardised	SE	Binomial	Combined
1994	0.878	0.887	1.347	0.832	0.0516	1.128	0.938
1995	1.088	1.056	1.888	0.992	0.0701	0.777	0.771
1996	1.143	1.116	1.344	0.876	0.0561	1.167	1.023
1997	1.373	1.342	0.322	0.789	0.0465	1.568	1.237
1998	1.104	1.108	1.078	0.775	0.0547	1.095	0.848
1999	1.023	0.995	0.520	0.787	0.0460	1.317	1.036
2000	0.575	0.565	0.561	0.735	0.0581	0.812	0.597
2001	0.699	0.624	0.839	1.015	0.0528	0.818	0.829
2002	1.028	0.810	1.133	1.154	0.0433	0.994	1.147
2003	1.205	0.937	1.740	1.328	0.0512	0.875	1.162
2004	1.640	1.677	2.624	1.540	0.0649	0.798	1.229
2005	1.290	1.767	2.019	1.587	0.0951	0.983	1.560
2006	1.296	1.246	2.499	2.306	0.0916	0.742	1.712
2007	1.141	1.145	0.473	1.175	0.0540	1.358	1.596
2008	1.457	1.422	1.384	1.292	0.0677	1.006	1.300
2009	0.760	1.415	1.832	1.080	0.1724	1.071	1.157
2010	1.133	1.244	1.380	1.869	0.0633	0.976	1.824
2011	1.493	1.674	1.111	1.259	0.0590	1.237	1.557
2012	0.473	0.457	0.597	1.143	0.1373	0.477	0.545
2013	0.428	0.299	0.120	0.101	0.0852	1.522	0.154

J.3.4 CPUE plots

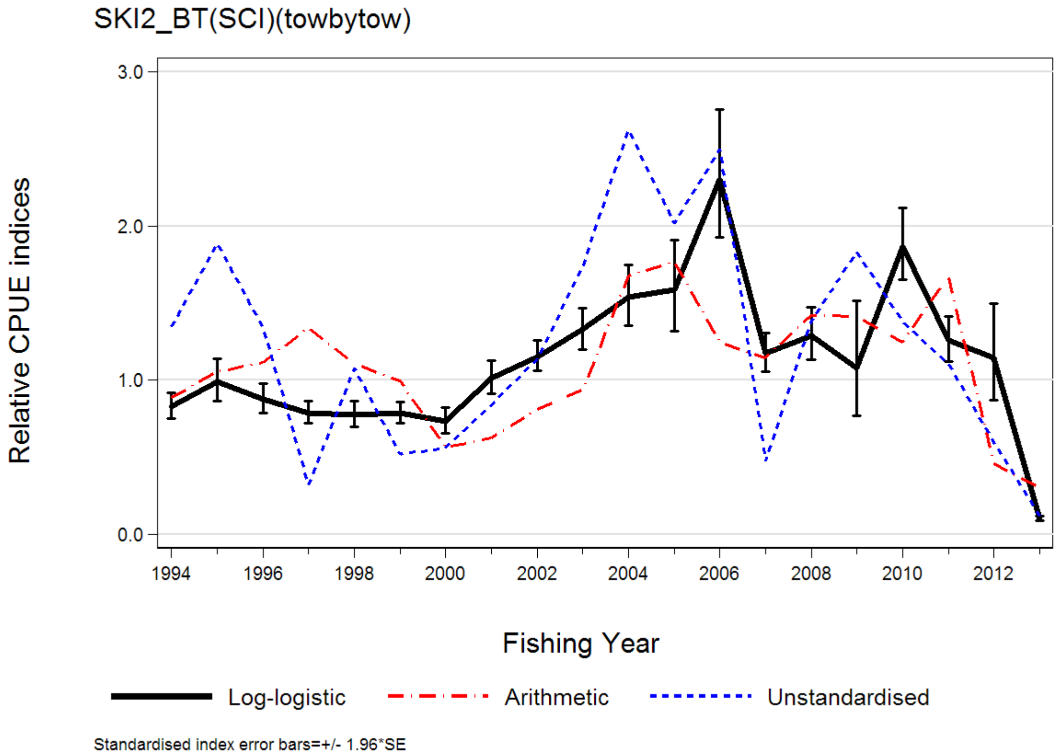

Figure J.5: Relative CPUE indices for gemfish using the log-logistic non-zero model based on the SKI2_BT(SCI)(towbytow) fishery definition. Also shown are two unstandardised series from the same data: a) Arithmetic (Eq. F.1) and b) Unstandardised (Eq. F.2).

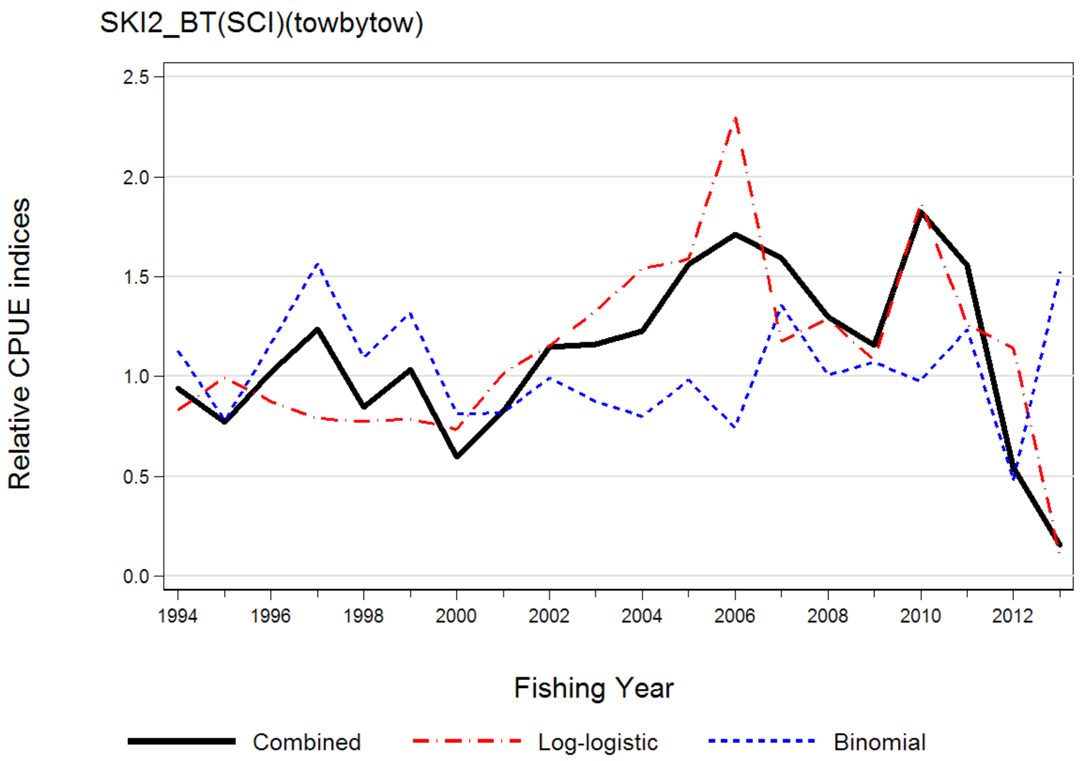

Figure J.6: Relative CPUE indices for gemfish using the log-logistic non-zero model based on the SKI2_BT(SCI)(towbytow) fishery definition, the binomial standardised model using the logistic distribution and a regression based on presence/absence of SKI, and the combined model using the delta-log-logistic procedure suggested by Vignaux (1994).

J.4 SKI2_BT(MIX+SKI)(daily)(11-17)

J.4.1 Positive catch model selection table

Table J.10: Order of acceptance of variables into the lognormal model of successful catches in the SKI2_BT(MIX+SKI)(daily)(11-17) fishery model for core vessels based on the vessel selection criteria of at least 5 trips in 5 or more fishing years, with the amount of explained deviance and R^2 for each variable. Variables accepted into the model are marked with an *, and the final R^2 of the selected model is in bold. Fishing year was forced as the first variable.

Variable	DF	Neg. Log likelihood	AIC	R^2	Model use
fishing year	25	-103 828	207 706	8.80	*
target species	31	-99 980	200 023	38.43	*
month	42	-98 509	197 101	47.02	*
vessel	93	-97 207	194 601	53.61	*
poly(log(num), 3)	96	-96 956	194 104	**54.79**	*
area	102	-96 782	193 768	55.59	
poly(log(duration), 3)	–	–	–	–	

J.4.2 Logistic (binomial) model selection table

Table J.11: Order of acceptance of variables into the binomial (logistic) model of successful catches in the gemfish SKI2_BT(MIX+SKI)(daily)(11-17) fishery model for core vessels based on the vessel selection criteria of at least 5 trips in 5 or more fishing years), with the amount of explained deviance and R^2 for each variable. Variables accepted into the model are marked with an *, and the final R^2 of the selected model is in bold. Fishing year was forced as the first variable.

Variable	DF	Neg. Log likelihood	AIC	R^2	Model use
fishing year	24	-34 448	68 945	2.98	*
target species	30	-30 567	61 194	21.11	*
month	41	-29 052	58 186	27.50	*
vessel	92	-27 782	55 748	**32.58**	*
poly(log(duration), 3)	95	-27 644	55 478	33.12	
area	101	-27 530	55 263	33.56	
poly(log(num), 3)	104	-27 526	55 260	33.58	

J.4.3 CPUE indices

Table J.12: Arithmetic indices for the total and core data sets, geometric and lognormal standardised indices and associated standard error (SE) for the core data set by fishing year for the gemfish SKI2_BT(MIX+SKI)(daily)(11-17) analysis. All series (except SE) standardised to geometric mean=1.0.

Fishing	All vessels						Core vessels
year	Arithmetic	Arithmetic	Geometric	Standardised	SE	Binomial	Combined
1990	7.283	7.615	6.100	4.772	0.0619	1.433	6.836
1991	4.158	4.148	3.213	2.813	0.0579	1.276	3.589
1992	5.346	5.068	3.103	1.457	0.0557	1.056	1.539
1993	4.501	4.099	3.200	1.442	0.0540	1.239	1.786
1994	3.116	3.394	3.070	1.157	0.0523	1.145	1.324
1995	2.046	2.006	2.052	1.194	0.0543	1.058	1.263
1996	1.651	1.401	1.666	0.894	0.0646	0.850	0.760
1997	1.675	1.350	1.887	0.860	0.0686	0.648	0.557
1998	0.713	0.387	0.566	0.553	0.0680	0.747	0.413
1999	0.886	0.776	0.598	0.700	0.0721	0.777	0.544
2000	0.618	0.671	0.706	0.698	0.0749	0.741	0.518
2001	0.301	0.383	0.509	0.661	0.0717	0.829	0.548
2002	0.380	0.518	0.529	0.644	0.0709	0.991	0.638
2003	0.471	0.572	0.639	0.743	0.0635	1.112	0.827
2004	0.736	0.942	0.643	0.894	0.0634	1.111	0.994
2005	0.444	0.479	0.491	0.654	0.0677	0.882	0.577
2006	0.345	0.380	0.342	0.521	0.0627	0.972	0.506
2007	0.987	1.078	0.779	0.901	0.0585	1.071	0.965
2008	0.677	0.637	0.869	1.087	0.0639	0.919	0.999
2009	0.634	0.617	0.669	0.947	0.0606	0.888	0.841
2010	0.475	0.455	0.457	0.792	0.0572	1.017	0.805
2011	0.690	0.653	0.712	1.284	0.0535	1.215	1.560
2012	0.571	0.553	0.639	1.294	0.0539	1.343	1.738
2013	0.415	0.433	0.618	1.051	0.0619	1.154	1.213

J.4.4 CPUE plots

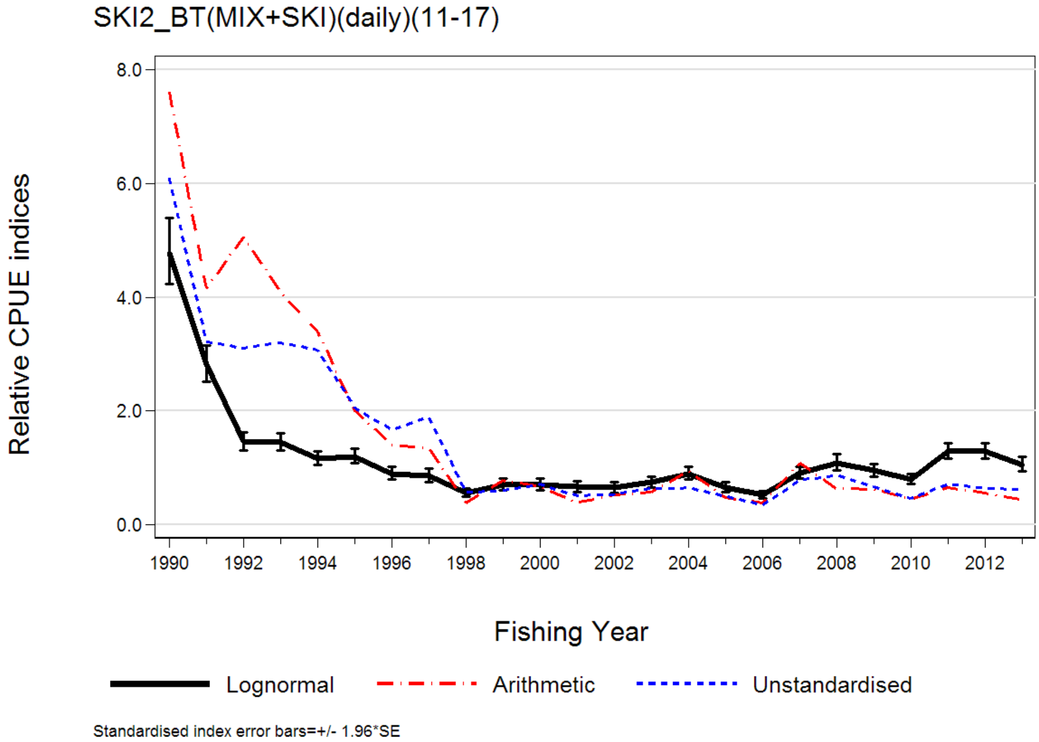

Figure J.7: Relative CPUE indices for gemfish using the lognormal non-zero model based on the SKI2_BT(MIX+SKI)(daily)(11-17) fishery definition. Also shown are two unstandardised series from the same data: a) Arithmetic (Eq. F.1) and b) Unstandardised (Eq. F.2).

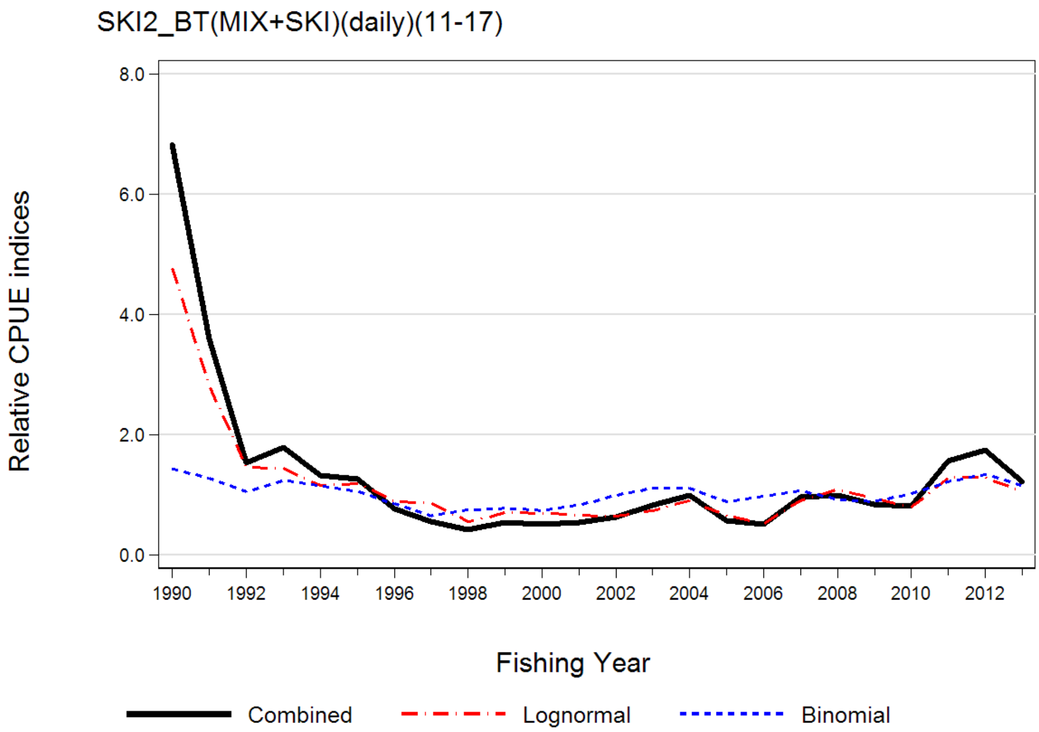

Figure J.8: Relative CPUE indices for gemfish using the lognormal non-zero model based on the SKI2_BT(MIX+SKI)(daily)(11-17) fishery definition, the binomial standardised model using the logistic distribution and a regression based on presence/absence of SKI, and the combined model using the delta-lognormal procedure suggested by Vignaux (1994).

J.5 SKI2_BT(MIXnoSKI)(daily)(11-17)

J.5.1 Positive catch model selection table

Table J.13: Order of acceptance of variables into the lognormal model of successful catches in the SKI2_BT(MIXnoSKI)(daily)(11-17) fishery model for core vessels based on the vessel selection criteria of at least 5 trips in 5 or more fishing years, with the amount of explained deviance and R^2 for each variable. Variables accepted into the model are marked with an *, and the final R^2 of the selected model is in bold. Fishing year was forced as the first variable.

Variable	DF	Neg. Log likelihood	AIC	R^2	Model use
fishing year	25	-72 793	145 637	2.84	*
month	36	-71 461	142 995	17.73	*
vessel	78	-70 361	140 877	28.30	*
target species	83	-69 861	139 887	32.64	*
poly(log(duration), 3)	86	-69 677	139 527	**34.16**	*
area	92	-69 568	139 319	35.06	
poly(log(num), 3)	95	-69 535	139 259	35.32	

J.5.2 Logistic (binomial) model selection table

Table J.14: Order of acceptance of variables into the binomial (logistic) model of successful catches in the gemfish SKI2_BT(MIXnoSKI)(daily)(11-17) fishery model for core vessels based on the vessel selection criteria of at least 5 trips in 5 or more fishing years), with the amount of explained deviance and R^2 for each variable. Variables accepted into the model are marked with an *, and the final R^2 of the selected model is in bold. Fishing year was forced as the first variable.

Variable	DF	Neg. Log likelihood	AIC	R^2	Model use
fishing year	24	-30 133	60 314	1.83	*
vessel	66	-28 478	57 087	11.01	*
month	77	-27 131	54 417	18.01	*
target species	82	-25 915	51 994	**24.01**	*
area	88	-25 779	51 734	24.66	
poly(log(duration), 3)	91	-25 679	51 540	25.14	
poly(log(num), 3)	94	-25 674	51 537	25.16	

J.5.3 CPUE indices

Table J.15: Arithmetic indices for the total and core data sets, geometric and lognormal standardised indices and associated standard error (SE) for the core data set by fishing year for the gemfish SKI2_BT(MIXnoSKI)(daily)(11-17) analysis. All series (except SE) standardised to geometric mean=1.0.

Fishing	All vessels						Core vessels
year	Arithmetic	Arithmetic	Geometric	Standardised	SE	Binomial	Combined
1990	5.852	2.658	2.525	4.104	0.0786	1.510	6.196
1991	2.058	1.765	1.920	2.568	0.0712	1.260	3.236
1992	1.226	1.385	0.867	0.950	0.0718	1.081	1.028
1993	1.647	1.143	1.192	1.249	0.0697	1.243	1.552
1994	1.393	0.866	1.192	1.178	0.0681	1.130	1.331
1995	1.169	1.241	1.544	1.287	0.0651	1.069	1.376
1996	1.325	1.326	1.504	1.064	0.0775	0.845	0.899
1997	1.048	0.972	1.171	0.894	0.0857	0.615	0.550
1998	1.263	0.462	0.607	0.635	0.0772	0.773	0.491
1999	0.392	0.517	0.613	0.726	0.0799	0.777	0.564
2000	0.446	0.583	0.828	0.701	0.0835	0.695	0.488
2001	0.413	0.635	0.707	0.717	0.0776	0.814	0.584
2002	0.294	0.490	0.654	0.707	0.0763	0.992	0.701
2003	0.620	0.924	0.875	0.758	0.0679	1.113	0.844
2004	0.867	1.128	0.783	0.940	0.0681	1.115	1.048
2005	0.727	0.819	0.713	0.637	0.0710	0.878	0.559
2006	0.615	0.730	0.561	0.501	0.0651	0.970	0.486
2007	1.199	1.355	1.119	0.928	0.0611	1.076	0.999
2008	1.668	1.656	1.527	1.118	0.0659	0.917	1.026
2009	1.228	1.264	1.041	0.937	0.0631	0.885	0.829
2010	0.779	0.770	0.727	0.822	0.0597	1.022	0.841
2011	1.154	1.147	1.074	1.361	0.0560	1.230	1.673
2012	1.426	1.464	1.104	1.328	0.0558	1.369	1.819
2013	0.898	0.984	1.027	1.029	0.0643	1.162	1.196

J.5.4 CPUE plots

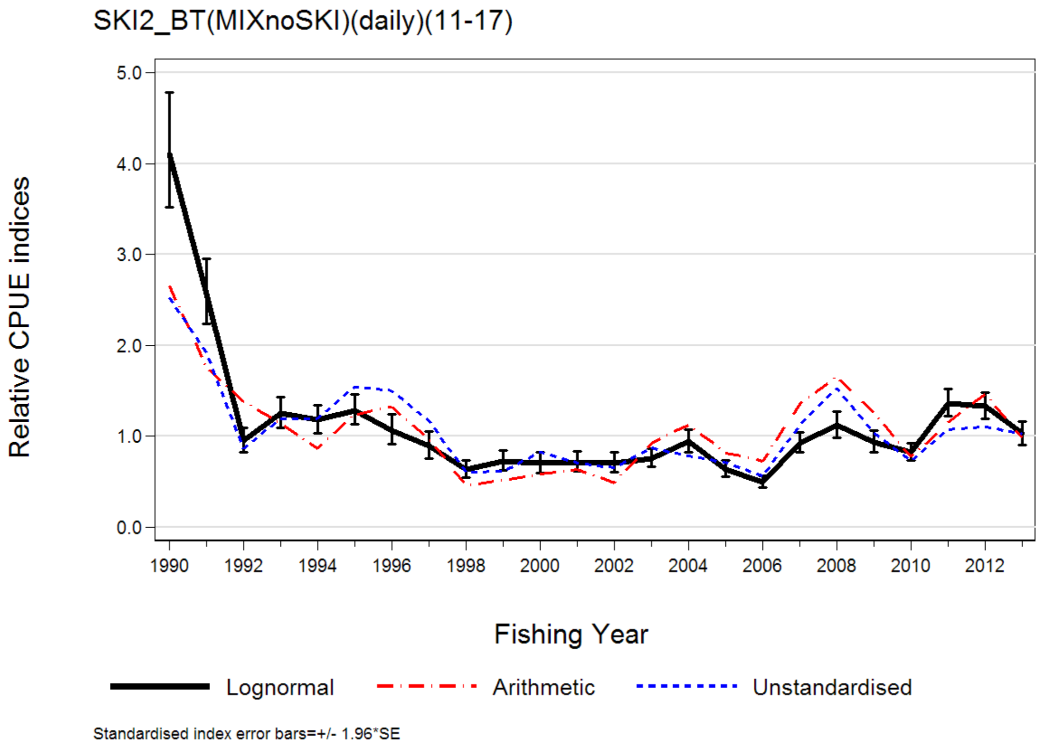

Figure J.9: Relative CPUE indices for gemfish using the lognormal non-zero model based on the SKI2_BT(MIXnoSKI)(daily)(11-17) fishery definition. Also shown are two unstandardised series from the same data: a) Arithmetic (Eq. F.1) and b) Unstandardised (Eq. F.2).

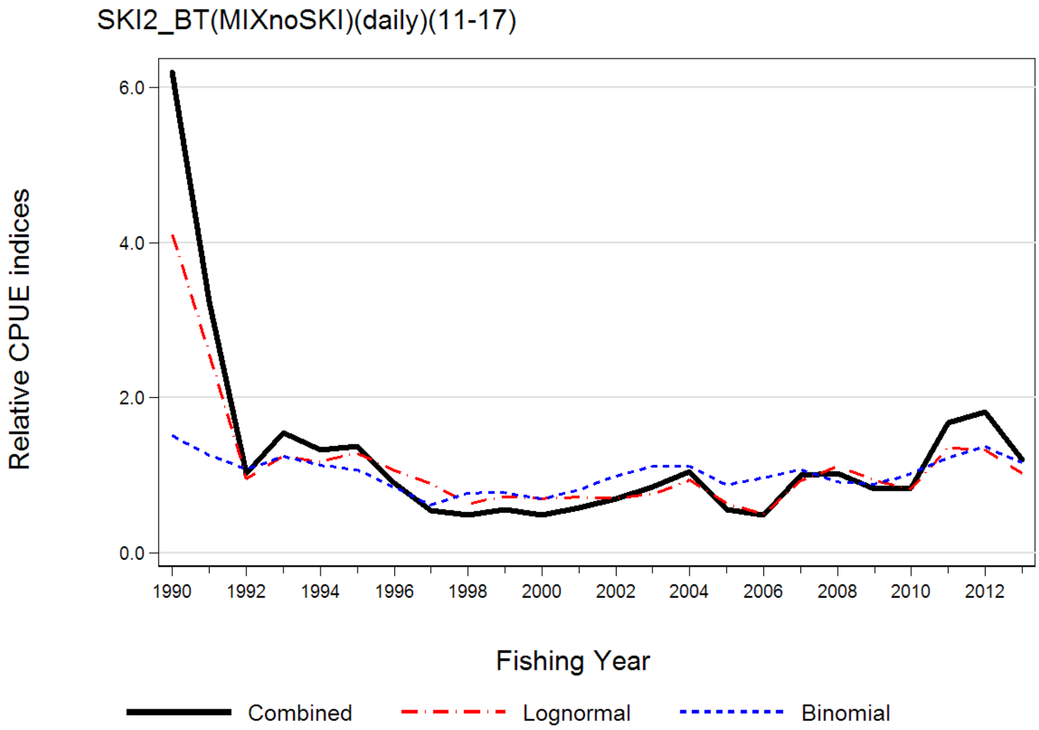

Figure J.10: Relative CPUE indices for gemfish using the lognormal non-zero model based on the SKI2_BT(MIXnoSKI)(daily)(11-17) fishery definition, the binomial standardised model using the logistic distribution and a regression based on presence/absence of SKI, and the combined model using the delta-lognormal procedure suggested by Vignaux (1994).

J.6 SKI2_BT(MIX+SKI)(towbytow)(11-17)

J.6.1 Positive catch model selection table

Table J.16: Order of acceptance of variables into the lognormal model of successful catches in the SKI2_BT(MIX+SKI)(towbytow)(11-17) fishery model for core vessels based on the vessel selection criteria of at least 5 trips in 5 or more fishing years, with the amount of explained deviance and R^2 for each variable. Variables accepted into the model are marked with an *, and the final R^2 of the selected model is in bold. Fishing year was forced as the first variable.

Variable	DF	Neg. Log likelihood	AIC	R^2	Model use
fishing year	21	-84 836	169 715	9.19	*
target species	27	-80 840	161 734	41.84	*
month	38	-78 914	157 904	53.08	*
vessel	62	-76 716	153 555	63.28	*
poly(log(bottom), 3)	65	-75 821	151 772	66.77	*
area	71	-75 251	150 645	**68.82**	*
poly(log(height), 3)	74	-75 211	150 570	68.95	
poly(log(swept_volume), 3)	77	-75 196	150 546	69.01	
poly(log(width), 3)	80	-75 181	150 522	69.06	
poly(log(speed), 3)	83	-75 171	150 508	69.09	
poly(log(swept_distance), 3)	86	-75 164	150 500	69.12	
poly(log(swept_area), 3)	–	–	–	–	
poly(log(duration), 3)	–	–	–	–	

J.6.2 Logistic (binomial) model selection table

Table J.17: Order of acceptance of variables into the binomial (logistic) model of successful catches in the gemfish SKI2_BT(MIX+SKI)(towbytow)(11-17) fishery model for core vessels based on the vessel selection criteria of at least 5 trips in 5 or more fishing years), with the amount of explained deviance and R^2 for each variable. Variables accepted into the model are marked with an *, and the final R^2 of the selected model is in bold. Fishing year was forced as the first variable.

Variable	DF	Neg. Log likelihood	AIC	R^2	Model use
fishing year	20	-32 580	65 200	4.38	*
target species	26	-28 941	57 934	21.89	*
poly(log(bottom), 3)	29	-28 263	56 585	24.89	*
vessel	53	-27 510	55 125	28.13	*
month	63	-26 989	54 103	**30.32**	*
poly(log(swept_area), 3)	66	-26 915	53 962	30.63	
area	72	-26 850	53 845	30.89	
poly(log(swept_volume), 3)	75	-26 815	53 780	31.04	
poly(log(duration), 3)	78	-26 810	53 777	31.06	
poly(log(width), 3)	81	-26 807	53 776	31.07	
poly(log(swept_distance), 3)	–	–	–	–	
poly(log(height), 3)	–	–	–	–	
poly(log(speed), 3)	–	–	–	–	

J.6.3 CPUE indices

Table J.18: Arithmetic indices for the total and core data sets, geometric and lognormal standardised indices and associated standard error (SE) for the core data set by fishing year for the gemfish SKI2_BT(MIX+SKI)(towbytow)(11-17) analysis. All series (except SE) standardised to geometric mean=1.0.

Fishing	All vessels						Core vessels
year	Arithmetic	Arithmetic	Geometric	Standardised	SE	Binomial	Combined
1994	1.951	1.020	1.356	1.748	0.0827	1.070	1.871
1995	0.776	0.516	0.473	1.410	0.0786	1.104	1.556
1996	1.059	1.359	0.508	0.608	0.0573	1.246	0.757
1997	2.638	4.196	5.297	0.824	0.0577	0.839	0.691
1998	2.848	3.164	4.527	0.619	0.0610	1.017	0.630
1999	3.388	3.654	1.923	0.678	0.0683	0.633	0.429
2000	7.483	7.076	2.627	0.543	0.0609	0.903	0.490
2001	4.154	4.244	2.387	0.405	0.0672	0.952	0.385
2002	2.914	3.171	3.483	0.512	0.0705	1.014	0.519
2003	2.383	2.509	3.148	0.843	0.0688	1.001	0.843
2004	2.399	2.286	1.703	1.000	0.0646	1.035	1.035
2005	1.564	1.513	1.415	1.209	0.0729	0.951	1.150
2006	0.742	0.670	0.288	1.232	0.0748	1.091	1.344
2007	1.078	0.888	1.053	1.458	0.0675	1.013	1.478
2008	0.196	0.212	0.529	1.493	0.0518	0.928	1.386
2009	0.190	0.207	0.357	1.250	0.0529	0.921	1.152
2010	0.163	0.197	0.192	0.994	0.0504	1.118	1.111
2011	0.294	0.349	0.429	1.817	0.0500	1.032	1.876
2012	0.162	0.176	0.365	1.788	0.0514	1.195	2.136
2013	0.130	0.110	0.232	1.552	0.0607	1.124	1.745

J.6.4 CPUE plots

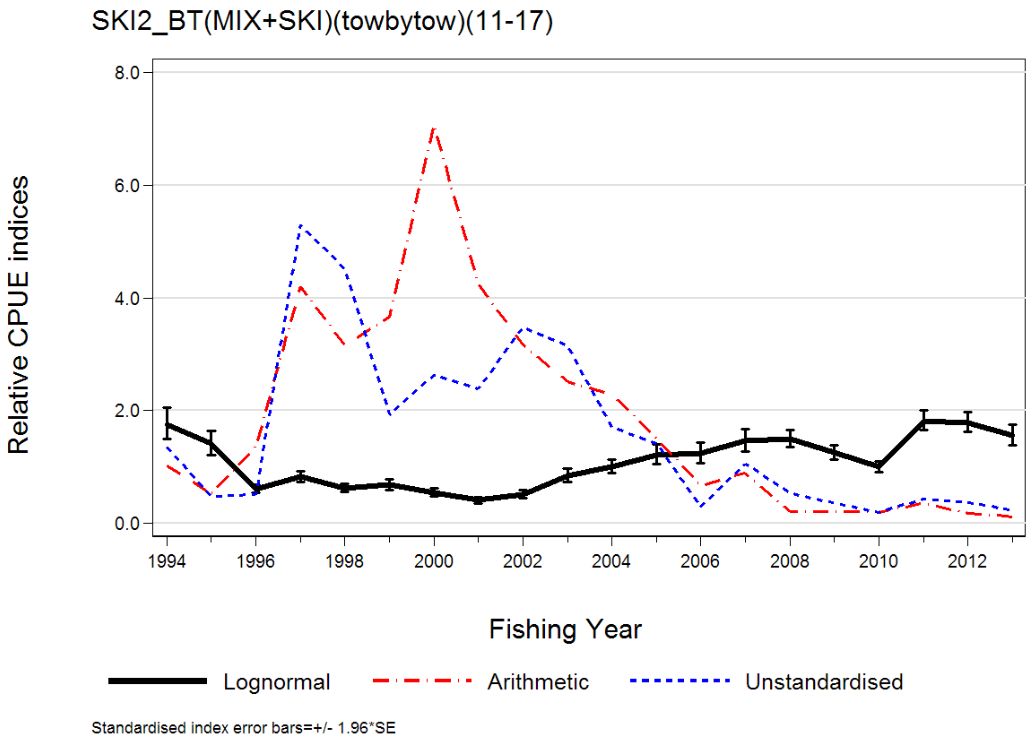

Figure J.11: Relative CPUE indices for gemfish using the lognormal non-zero model based on the SKI2_BT(MIX+SKI)(towbytow)(11-17) fishery definition. Also shown are two unstandardised series from the same data: a) Arithmetic (Eq. F.1) and b) Unstandardised (Eq. F.2).

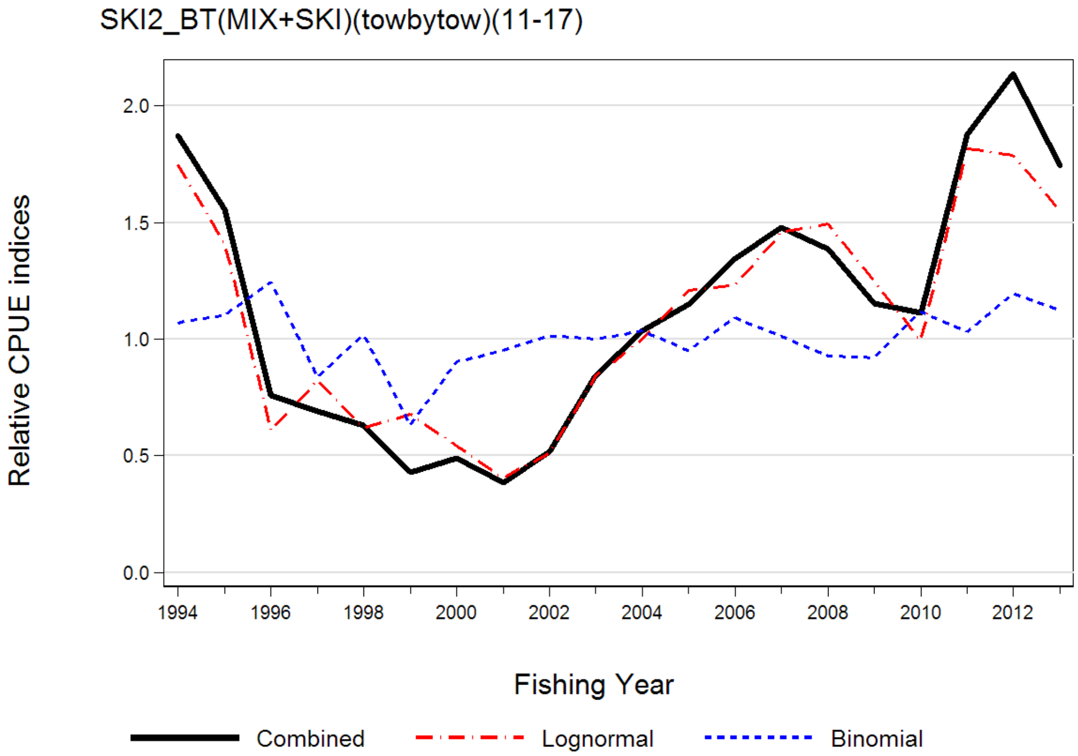

Figure J.12: Relative CPUE indices for gemfish using the lognormal non-zero model based on the SKI2_BT(MIX+SKI)(towbytow)(11-17) fishery definition, the binomial standardised model using the logistic distribution and a regression based on presence/absence of SKI, and the combined model using the delta-lognormal procedure suggested by Vignaux (1994).

J.7 SKI2_BT(MIXnoSKI)(towbytow)(11-17)

J.7.1 Positive catch model selection table

Table J.19: Order of acceptance of variables into the lognormal model of successful catches in the SKI2_BT(MIXnoSKI)(towbytow)(11-17) fishery model for core vessels based on the vessel selection criteria of at least 5 trips in 5 or more fishing years, with the amount of explained deviance and R^2 for each variable. Variables accepted into the model are marked with an *, and the final R^2 of the selected model is in bold. Fishing year was forced as the first variable.

Variable	DF	Neg. Log likelihood	AIC	R^2	Model use
fishing year	21	-50 538	101 117	6.29	*
month	32	-48 519	97 102	29.72	*
area	38	-47 264	94 604	41.24	*
poly(log(bottom depth), 3)	41	-46 248	92 578	49.16	*
vessel	63	-45 624	91 374	**53.49**	*
target species	68	-45 553	91 241	53.96	
poly(log(swept_volume), 3)	71	-45 499	91 139	54.32	
poly(log(width), 3)	74	-45 477	91 103	54.45	
poly(log(height), 3)	77	-45 466	91 087	54.53	
poly(log(speed), 3)	80	-45 460	91 079	54.57	
poly(log(swept_distance), 3)	–	–	–	–	
poly(log(swept_area), 3)	–	–	–	–	
poly(log(duration), 3)	–	–	–	–	

J.7.2 Logistic (binomial) model selection table

Table J.20: Order of acceptance of variables into the binomial (logistic) model of successful catches in the gemfish SKI2_BT(MIXnoSKI)(towbytow)(11-17) fishery model for core vessels based on the vessel selection criteria of at least 5 trips in 5 or more fishing years), with the amount of explained deviance and R^2 for each variable. Variables accepted into the model are marked with an *, and the final R^2 of the selected model is in bold. Fishing year was forced as the first variable.

Variable	DF	Neg. Log likelihood	AIC	R^2	Model use
fishing year	20	-28 505	57 050	1.27	*
poly(log(bottom depth), 3)	23	-26 795	53 635	11.11	*
vessel	45	-25 976	52 042	15.58	*
month	55	-25 529	51 167	**17.96**	*
target species	60	-25 436	50 993	18.44	
poly(log(swept_area), 3)	63	-25 355	50 837	18.87	
area	69	-25 279	50 697	19.26	
poly(log(swept_volume), 3)	72	-25 240	50 625	19.47	
poly(log(duration), 3)	75	-25 235	50 620	19.49	
poly(log(speed), 3)	–	–	–	–	
poly(log(swept_distance), 3)	–	–	–	–	
poly(log(height), 3)	–	–	–	–	
poly(log(width), 3)	–	–	–	–	

J.7.3 CPUE indices

Table J.21: Arithmetic indices for the total and core data sets, geometric and lognormal standardised indices and associated standard error (SE) for the core data set by fishing year for the gemfish SKI2_BT(MIXnoSKI)(towbytow)(11-17) analysis. All series (except SE) standardised to geometric mean=1.0.

Fishing	All vessels						Core vessels
year	Arithmetic	Arithmetic	Geometric	Standardised	SE	Binomial	Combined
1994	1.764	0.494	0.665	1.594	0.1114	1.069	1.703
1995	0.828	1.112	0.783	1.555	0.0920	1.146	1.783
1996	1.291	0.829	0.339	0.627	0.0716	1.416	0.888
1997	1.443	1.395	1.885	1.077	0.0835	0.819	0.882
1998	4.143	0.579	0.823	0.665	0.0901	0.898	0.598
1999	0.804	1.040	0.917	0.655	0.0895	0.608	0.398
2000	0.746	0.506	0.465	0.412	0.0852	0.926	0.381
2001	0.680	0.566	0.558	0.346	0.1012	0.967	0.334
2002	0.629	0.962	0.949	0.369	0.1028	0.966	0.357
2003	0.991	1.462	2.031	0.976	0.0915	0.968	0.945
2004	2.100	2.486	1.401	1.333	0.0787	1.042	1.389
2005	1.344	1.845	2.107	1.175	0.0849	0.921	1.082
2006	0.898	1.063	0.819	1.158	0.0796	1.112	1.289
2007	1.523	1.663	2.104	1.413	0.0735	0.997	1.409
2008	1.057	1.604	1.905	1.501	0.0534	0.941	1.412
2009	0.708	1.016	1.133	1.238	0.0555	0.935	1.157
2010	0.458	0.675	0.588	1.014	0.0533	1.136	1.152
2011	0.572	0.817	1.216	1.917	0.0534	1.037	1.988
2012	0.753	1.088	1.260	1.837	0.0540	1.217	2.236
2013	0.612	0.819	0.806	1.570	0.0633	1.146	1.799

J.7.4 CPUE plots

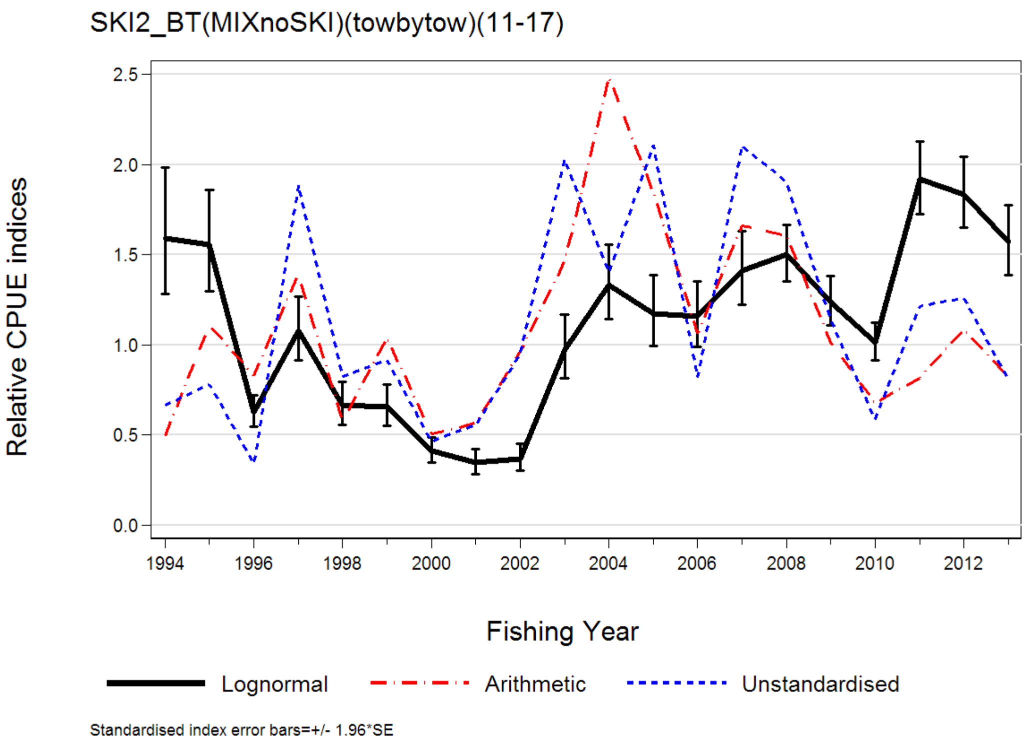

Figure J.13: Relative CPUE indices for gemfish using the lognormal non-zero model based on the SKI2_BT(MIXnoSKI)(towbytow)(11-17) fishery definition. Also shown are two unstandardised series from the same data: a) Arithmetic (Eq. F.1) and b) Unstandardised (Eq. F.2).

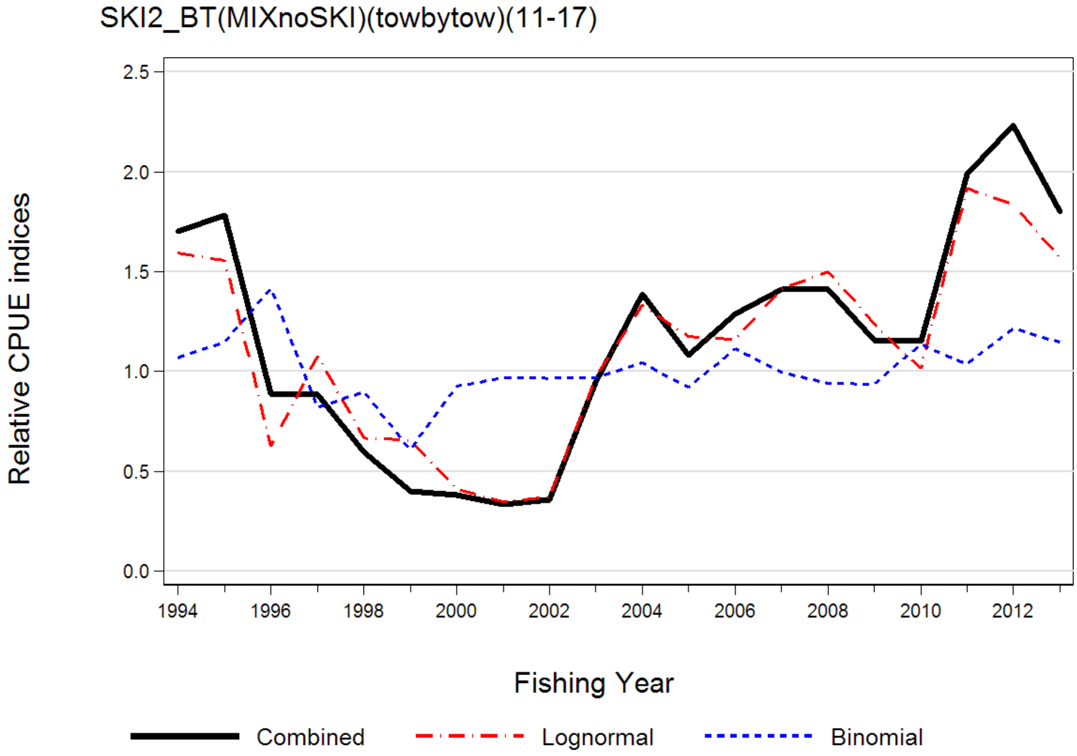

Figure J.14: Relative CPUE indices for gemfish using the lognormal non-zero model based on the SKI2_BT(MIXnoSKI)(towbytow)(11-17) fishery definition, the binomial standardised model using the logistic distribution and a regression based on presence/absence of SKI, and the combined model using the delta-lognormal procedure suggested by Vignaux (1994).

Appendix K. CHECKING FOR LEVERAGE FROM DATA AT EXTREME SOUTHERN END OF SKI 2 (AREAS 018 AND 019)

K.1 Introduction and Methods

There was concern that the large amount of data in Area 018 may be influencing the series trend estimated by the various SKI 2 models. As well, Area 018 is administratively part of SKI 3, not SKI 2. The large quantity of data in this statistical area is demonstrated by the large size of the distributional circles in Figure H.8, particularly in the early years (there is no corresponding plot for the SKI 2-BT(MIX+SKI)(daily) model because area was not selected when that model was fitted). Accordingly, each of the four models which included Areas 018 and 019 was rerun with these areas dropped. Otherwise, the model selection choices were the same (these models are described as Models No. 7, 8, 9, 10 in the text table at the beginning of Section 3).

K.2 Results

The estimated annual year coefficients are very similar for the models which only differ by the inclusion/exclusion of Area 018 and 019 (Figure K.1). The differences seem to be slightly greater for the event-based models than for the daily-effort models.

Correlation coefficients between the area-specific coefficients and the model year coefficients are high for all areas, including Area 018 (Table K.1). This result indicates a strong degree of consistency across eight of the nine statistical areas (Area 019 has too few data to make meaningful comparisons). The correlations between the model year indices and the year indices specific for each target species categories are more variable, but are high for the target species categories with adequate amounts of data (Table K.2).

Table K.1: Correlation coefficients between the area-specific area×year residual implied coefficients and the overall model fishing year coefficients for four model categories, with two models in each category: in each case, one model includes Area 018 and the other model excludes this area. Areas where the correlation coefficient is at least 0.6 are coloured in yellow.

	Area 011 – Area 019				Area 011 – Area 017			
	MIX+SKI	MIX	MIX+SKI	MIX	MIX+SKI	MIX	MIX+SKI	MIX
Area011	0.90	0.90	0.61	0.66	0.91	0.91	0.61	0.63
Area012	0.92	0.92	0.74	0.83	0.92	0.92	0.81	0.88
Area013	0.96	0.96	0.85	0.72	0.97	0.96	0.89	0.83
Area014	0.94	0.91	0.90	0.59	0.95	0.92	0.93	0.72
Area015	0.84	0.75	0.85	0.88	0.83	0.71	0.86	0.90
Area016	0.88	0.86	0.95	0.94	0.86	0.85	0.95	0.94
Area017	0.82	0.82	0.63	0.70	0.80	0.77	0.68	0.74
Area018	0.76	0.69	0.84	0.88	–	–	–	–
Area019	0.23	-1.00	0.35	0.46	–	–	–	–

Table K.2: Correlation coefficients between the target species-specific target×year residual implied coefficients and the overall model fishing year coefficients for four model categories, with two models in each category: in each case, one model includes Area 018 and the other model excludes this area. Target species categories where the correlation coefficient is at least 0.6 are coloured in yellow.

	Area 011 – Area 019				Area 011 – Area 017			
	MIX+SKI (daily)	MIX (daily)	MIX+SKI (tow-by-tow)	MIX (tow-by-tow)	MIX+SKI (daily)	MIX (daily)	MIX+SKI (tow-by-tow)	MIX (tow-by-tow)
BAR	0.67	0.69	0.21	0.47	0.60	0.60	0.25	0.47
GUR	0.90	0.91	0.39	0.38	0.90	0.90	0.53	0.54
HOK	0.73	0.60	0.93	0.93	0.70	0.50	0.92	0.93
LIN	0.68	0.10	0.47	0.72	0.64	0.03	0.35	0.48
SKI	0.86	–	0.87	–	0.86	–	0.92	–
TAR	0.99	0.99	0.92	0.93	0.99	1.00	0.91	0.95
SNA	0.78	0.80	-0.30	-0.12	0.78	0.78	-0.23	-0.03

Figure K.1: Comparison of annual CPUE trends for four model categories, compared pairwise with two models in each category: in each case, one model includes Area 018 and the other model excludes this area; [upper left panel]: SKI 2_BT(MIX+SKI)(daily); [upper right panel]: SKI 2_BT(MIXnoSKI)(daily); [lower left panel]: SKI 2_BT(MIX+SKI)(towbytow); [lower right panel]: SKI 2_BT(MIXnoSKI)(towbytow).