Ministry for Primary Industries
Manatū Ahu Matua

GUR 3 Fishery Characterisation and CPUE

New Zealand Fisheries Assessment Report 2013/37

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ISSN 1179-5352 (online)
ISBN 978-0-478-41426-4 (online)

June 2013

New Zealand Government

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The fisheries taking red gurnard (*Chelidonichthys kumu*) from 1989–90 to 2010–11 on the east coast of the New Zealand South Island (GUR 3) are described, based on compulsory reported commercial catch and effort data held by the Ministry for Primary Industries (MPI, formerly the Ministry of Fisheries). Only two bottom trawl fisheries (the target red cod fishery and the target flatfish fishery) take this species in significant amounts and these catches are primarily by-catch in the mixed species trawl fisheries which characterise the GUR 3 Quota Management Area. Detailed characteristics of the landing data, as well as the spatial, temporal, target species and depth distributions relative to the catch of gurnard in these fisheries are presented. Annual performance of the GUR 3 catch and some regulatory information are also presented.

Commercial Catch Per Unit Effort (CPUE) analyses, based on the compulsory reported commercial catch and effort data from the major bottom trawl fisheries, are used to estimate changes in abundance for this species in this QMA. These estimated abundance trends are then available for informing MPI on the need for potential management action in GUR 3.

Research trawl information for red gurnard off the east coast of the South Island is presented for 14 surveys, covering the period 1992 to 2009. Two trawl surveys series were implemented in this period: one in the winter months of May and June and the other in the summer (December/January). The first six surveys (1992–1996) took place in the winter. This survey was replaced by a summer survey that was repeated 5 times between 1996–97 and 2000–01, but which was discontinued because of concerns that it was too variable to provide reliable time series of biomass estimates. The winter survey was reinstated in 2007 and was repeated twice in 2008 and 2009. A fourth winter survey was conducted in May–June 2012, after the data for this report were compiled.

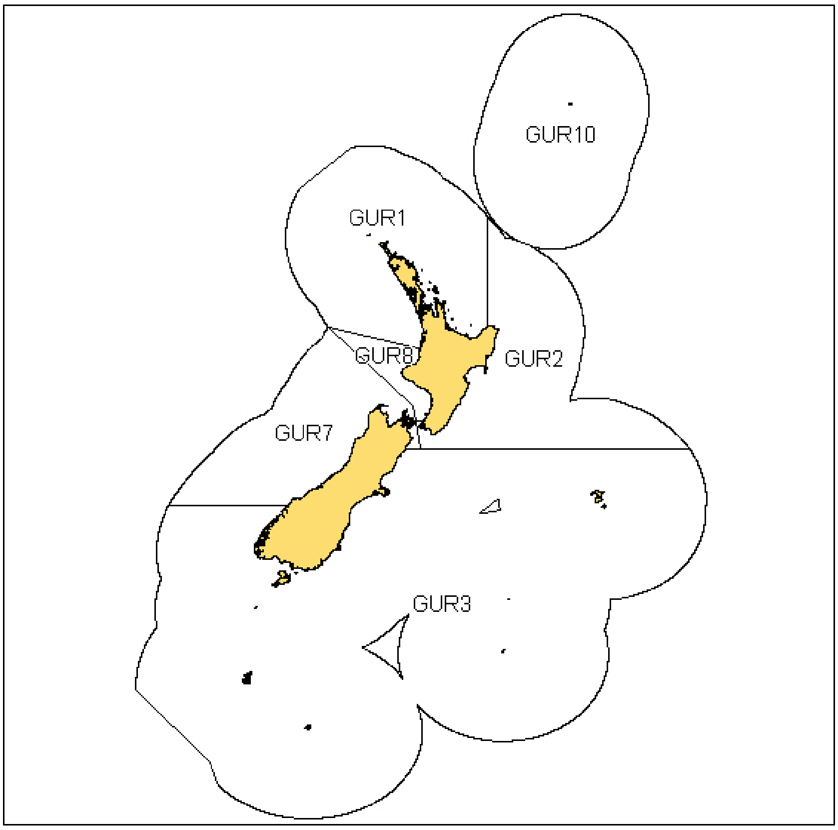

Figure 1: Map of the New Zealand EEZ showing the red gurnard Quota Management Areas (QMAs).

1. INTRODUCTION

GUR 3 was brought into the Quota Management System (QMS) at its inception in 1986 and has contributed between 13 and 28 % of the total NZ-EEZ landings of red gurnard between 1989–90 and 2010–11. In terms of total landings, it is the second largest of the GUR QMAs, after GUR 1. GUR 3 is the largest of the GUR FMAs in terms of area, occupying most of the east coast of the South Island (apart from Cloudy Bay and the eastern entrance to Cook Strait), Foveaux Strait, Stewart Island and Fiordland on the south and western parts of the South Island and all of the Chatham Islands (Figure 1). The TACC for GUR 3 was increased about 15% in 1990–91 under the conditions of the newly created Adaptive Management Programme (AMP). A further 50% increase was granted in 1997–98 in recognition of an apparent increase in the GUR 3 abundance. The GUR 3 TACC was reduced to 800 t in 2002–03 because abundances had apparently decreased, but was increased back to 900 t in 2009–10 due to a reversal in the apparent abundance. The text table below summarises these changes to the TACCs for this Fishstock:

Fishstock	Year TACC changed	TACC prior to change	AMP or new TACC	% increase
GUR 3	1991–92	524	600	14.5%
GUR 3	1996–97	601	900	49.7%
GUR 3	2002–03	900	800	-11.1%
GUR 3	2009–10	800	900	12.5%

The GUR 3 AMP is no longer active, having been discontinued by the Minister of Fisheries in 2009–10. The TACC was also increased in 2009–10 and has since remained unchanged. The Southeast Finfish Management Company (SEFMC) has retained its previous commitment to monitor this Fishstock using periodic CPUE standardisations.

This report summarises fishery and landings characterisations for GUR 3, as well as presenting CPUE standardisations, derived from trawl data originating from GUR 3, which are used to estimate changes in relative abundance in this QMA. Abbreviations and definitions of terms used in this report are presented in Appendix A.

2. INFORMATION ABOUT THE STOCK/FISHERY

2.1 Biology

Red gurnard (*Chelidonichthys kumu*) is a common species throughout the New Zealand EEZ, with total commercial catches of approximately 2 000 to 4 000 t per year. It is mainly caught as a bycatch species in coastal bottom trawl fisheries, although there is some target fishing as well. Ageing work has been done on this species by Elder (1976), Sutton (1997), Hanchet et al. (2000) and Lyon & Horn (2011). This species is fast growing, reaching sexual maturity at an age of 2–3 years at a mean fork length of about 23 cm (Ministry of Fisheries 2011). M is estimated to be 0.35 for female (maximum age 13 years) and 0.29 for male (maximum age 16 years) red gurnard. These estimates are probably biased high as they were taken from a fished population.

2.2 Catches

GUR 3 landings exceeded the TACC from 1993–94 to 1996–97 (Figure 2; Table 1). Landings then dropped considerably between 1997–98 and 1999–00 (Figure 2; Table 1), leading to a TACC decrease in 2002–03. Landings rose after 1999–00, exceeding the lowered TACC in 2002–03 at 888 t. Landings since then have exceeded the TACC in seven of eight succeeding fishing years. Recent landings have been the largest since the series began in 1986–87, with 1 004 t recorded in 2006–07 and 1 018 t in 2009–10. Catches dropped to 929 t in 2010–11 but remained above the TACC.

Table 1: Total landings (t) and TACCs (t) for gurnard in GUR 3 from 1986–87 to 2011–12. Landings and TACCs from 1986–87 to 2000–01 are from Quota Management Returns (QMR). Landings from 2001–02 to 2011–12 are from Monthly Harvest Returns (MHR).

Fishing		GUR 3	Fishing		GUR 3
year	Landings	TACC	year	Landings	TACC
86/87	210	480	99/00	410	900
87/88	389	486	00/01	569	900
88/89	532	489	01/02	716	900
89/90	694	501	02/03	888	800
90/91	660	524	03/04	725	800
91/92	539	600	04/05	854	800
92/93	484	601	05/06	957	800
93/94	711	601	06/07	1 004	800
94/95	686	601	07/08	842	800
95/96	628	601	08/09	939	800
96/97	640	900	09/10	1 018	900
97/98	476	900	10/11	929	900
98/99	396	900	11/12	915	900

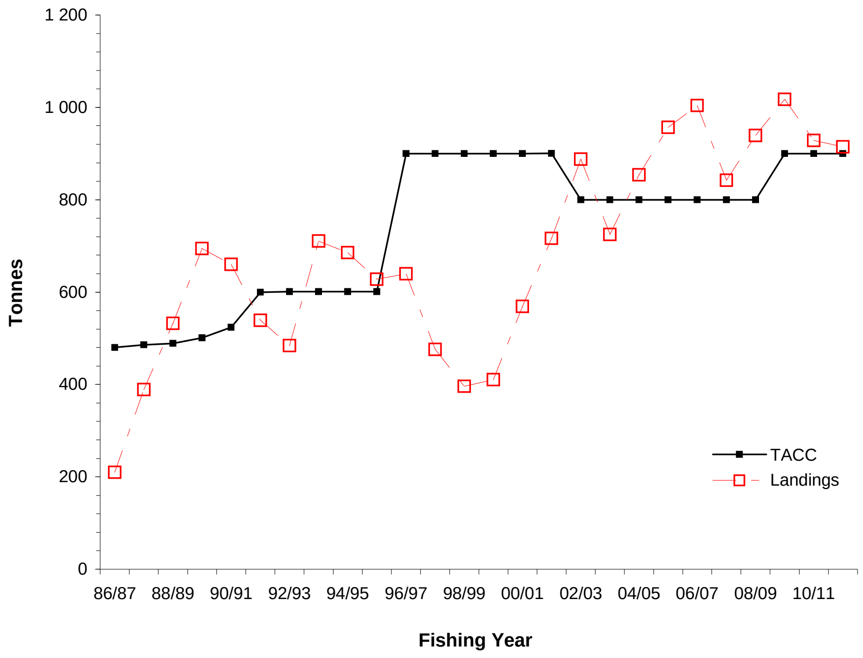

Figure 2: Plot of GUR 3 landings and TACCs from 1986–87 to 2011–12 (see Table 1 for data sources).

2.2.1 Recreational catches

Recreational catches in New Zealand are poorly known, an observation which applies to all inshore finfish FMAs, including GUR 3. A series of regional and national surveys, which combined phone interviews with randomly selected diarists, have been conducted since the early 1990s (Tierney et al. 1997, Bradford 1998, Boyd & Reilly 2005; see Table 2), but the results from these surveys are not considered to be reliable by many 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 the chapter on kahawai, Ministry of Fisheries 2011)

Table 2: Estimated catch of GUR 3 by recreational fisheries based on diary surveys conducted in the indicated years. Data for the south regional surveys (1991–92) from Tierney et al. (1997); 1996 survey results from Bradford (1998); 2000 and 2001 survey results from Boyd & Reilly (2005).

QMA/FMA	Number	c.v. (%)	Point est. (t)	Range (t)	No. diarists	Mean Weight
South Region Survey (1 Sept 1991 to 30 Nov 1992)						
GUR 3	no estimate	–	–	–	–	–
1996 Nationwide survey						
GUR 3	1 000	–	–	–	–	–
2000 Nationwide survey						
GUR 3	11 000	70	5.4	1.6–9.1	–	–
2001 "Roll-over" nationwide survey						
GUR 3	9 000	32	4.2	–	13	481 g

Estimates of recreational catch for GUR 3 are low, all being under 10 t in a year (Table 2). The early recreational surveys did not estimate a catch weight for GUR 3.

2.3 Regulations Affecting the Fishery

2.3.1 Deemed values

The data provided by MPI indicate that almost all red gurnard are landed "green" and consequently there have not been any important changes in the gurnard conversion factors (see Section 2.4.2). Deemed values, the penalty applied to landing quota species when the fisher has insufficient ACE (Annual Catch Entitlement) to balance the landings, have been used as the deterrent to control overcatch in GUR 3. However, if these penalties are set too high, there is the potential for dumping at sea and consequent loss of catch information. Deemed values are generally set by Ministry for Primary Industries "*above ACE price and below landed (port) price*" (Scott Walker, Ministry for Primary Industries, *pers. comm.*). Deemed values penalties were increased for GUR 3 for 2008–09 to discourage the overcatch of red gurnard by adjusting the percentage scales for amount of overcatch in excess of ACE (Table 3). The TACC was reviewed for the 2009–10 fishing year and the TACC was increased. The deemed value regime was also reviewed at this time and was decreased in response to a port price survey that indicated a fall in port price for GUR 3. The deemed value was increased for the 2011–12 fishing year in response to changes in the port price (Table 3).

Table 3: Annual and interim deemed values for GUR 3 by fishing year from 2001–02 (source: Ray Voller, Ministry of Fisheries, *pers. comm.* and Mark Geytenbeek, Ministry for Primary Industries, *pers. comm.*). Also shown is the amount by which ACE must be exceeded for deemed value penalties to apply. '–': not applicable

Fishing Year	MHR landings (t)	TACC (t)	Annual Deemed Value [1] ($/kg)	Interim Deemed Value [2] ($/kg)	Excess of ACE for deemed value penalties to apply: $100*\left(\sum \text{landings}_y / \sum \text{ACE}_y\right)$
2001–02	716	900	$0.85	$0.43	120%
2002–03	888	800	$0.85	$0.43	120%
2003–04	725	800	$0.85	$0.43	120%
2004–05	854	800	$0.85	$0.43	120%
2005–06	957	800	$0.85	$0.43	120%
2006–07	1004	800	$0.85	$0.43	120%
2007–08	842	800	$1.60	$0.80	120%
2008–09	939	800	$1.60	$0.80	150% [3]
2009–10	1 018	900	$1.50	$0.75	130% [4]
2010–11	929	900	$1.50	$0.75	130% [4]
2011–12	–	900	$1.70	$0.85	120%

[1] applied at end of year to landings not covered by ACE but less than lower limit shown in final column
[2] applied when landing in excess of ACE but refunded if ACE is subsequently provided
[3] applicable deemed values in excess of ACE: 150%=$2.08; 160%=$2.56; 180%=$2.88; 200%=$3.20
[4] applicable deemed values in excess of ACE: 130%=$1.65; 140%=$1.95; 150%=$2.25; 160%=$2.40; 180%=$2.70; 200%=$3.00

2.3.2 Closures for the protection of Hector's dolphins

2.3.2.1 Regulatory closures applicable to trawling

From 1 October 2008, year-round closure regulations to protect Maui and Hector's dolphin were implemented for all of New Zealand by the Minister of Fisheries. These closures extend on the east and south coasts of the South Island from Cape Jackson in the Marlborough Sounds to Sandhill Point on the most western side of Te Wae Wae Bay. These closures include the Hector's dolphin preferred areas in FMA 3 and FMA 5 and prohibit trawling within two nautical miles from shore unless flatfish nets with defined low headline heights are used.

2.3.2.2 Voluntary closures applicable to trawling

Voluntary measures for the protection of Hector's dolphins were implemented through the adoption of a Code of Practice (CoP) developed by the SEFMC from the 1999–00 fishing year. The only provisions in the voluntary CoP that apply to trawlers are:

- that trawlers use their best endeavours to limit the use of bottom trawling whilst in waters inside the 30 metre depth contour;
- to not use bottom trawl within the 30 m depth contour at any time during the hours of darkness; and,
- to not deploy high opening trawl gear inside the 50 metre depth contour.

2.4 Analysis of GUR 3 Catch and Effort Data

2.4.1 Methods used for 2012 analysis of MPI catch and effort data

Data extracts were obtained from the MPI Warehou database (Ministry of Fisheries 2010). One extract consisted of the complete data (all fishing event information along with all gurnard landing information) from every trip which recorded landing gurnard from GUR 3, starting from 1 October 1989 and extending to 30 September 2011. A further extract was obtained, consisting of all trips using the method BT that targeted RCO, FLA (also: ESO, SFL, LSO, GFL, FLO, YBF, BFL), BAR, GUR, STA, TAR, WAR, ELE, SPD (also: NSD, OSD), SQU, JMA, LIN, SKA, HOK, or SKI, and fished at least one event in GUR 3 (see Appendix A for definitions of abbreviations). Once these trips were identified, all fishing event data and gurnard landing data from the entire trip, regardless of method of capture, were obtained. These data extracts (MPI replog 8402) were received 13 February 2012. The first data extract was used to characterise and understand the fisheries taking gurnard. These characterisations are reported in Sections 2.4.2 and 2.4.3. The remaining extract was used to calculate CPUE standardisations (Section 3 and Appendix E).

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).

The procedure described by Starr (2007) drops trips which fished in ambiguous "straddling" statistical areas (the statistical area boundaries do not coincide with the QMA boundaries–see Appendix B) and which reported more than one red gurnard QMA in the landing data. This expansion can also be done by statistical area without regard to the QMA of landing, resulting in no landing data being dropped but losing the capacity to link captures and effort to a specific QMA. Appendix D lists the total landings by statistical area that are obtained by the two alternative expansion methods (i.e., by statistical area or by QMA), thus documenting the extent of the loss of catch information incurred when trips which fished in straddling statistical areas and landed to multiple QMAs are dropped. The loss for the GUR 3 data set was small in terms of overall catch, with less than 1% of total catch lost when the Fishstock expansion method is compared to the "Statistical Area" expansion method.
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. These data were amalgamated into a common level of stratification known as a "trip stratum" (summed fishing method, statistical area and target species data within the trip: see 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. Landed catches of gurnard by trip were then allocated to the "trip strata" in proportion to the estimated gurnard catches in each "trip stratum". In situations when trips recorded landings of gurnard 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 gurnard landings

were allocated proportionally to effort (tows for trawl data and length of net set for setnet data) in each "trip stratum".

Table 4: Comparison of GUR 3 QMR/MHR catch (t), reported by fishing year, with the sum of the GUR 3 corrected landed catch totals (bottom part of the MPI CELR 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 8402: 1989–90 to 2010–11.

Fishing Year	QMR/MHR (t)	Total landed catch (t)	% landed/ QMR/MHR	Total Analysis catch (t)	% Analysis /Landed	Total Estimated Catch (t)	% Estimated /Analysis
89/90	694	607	87	587	97	517	88
90/91	660	638	97	620	97	574	92
91/92	539	509	94	500	98	439	88
92/93	484	466	96	461	99	396	86
93/94	711	699	98	691	99	639	92
94/95	686	684	100	623	91	569	91
95/96	628	603	96	594	99	532	90
96/97	640	618	97	608	98	531	87
97/98	476	486	102	469	96	394	84
98/99	396	421	106	393	93	331	84
99/00	410	433	106	400	92	347	87
00/01	569	584	103	557	95	507	91
01/02	716	723	101	698	97	623	89
02/03	888	882	99	877	99	830	95
03/04	725	710	98	705	99	668	95
04/05	854	849	99	839	99	769	92
05/06	957	949	99	946	100	905	96
06/07	1 004	1 002	100	990	99	960	97
07/08	842	836	99	826	99	827	100
08/09	939	912	97	908	100	913	101
09/10	1 018	1 006	99	999	99	1 016	102
10/11	929	905	98	898	99	898	100
Total	15 764	15 525	98	15 189	98	14 186	93

[1] includes all landings in replog 8402 except for 8 trips excluded for being "out of range" (see Appendix C)

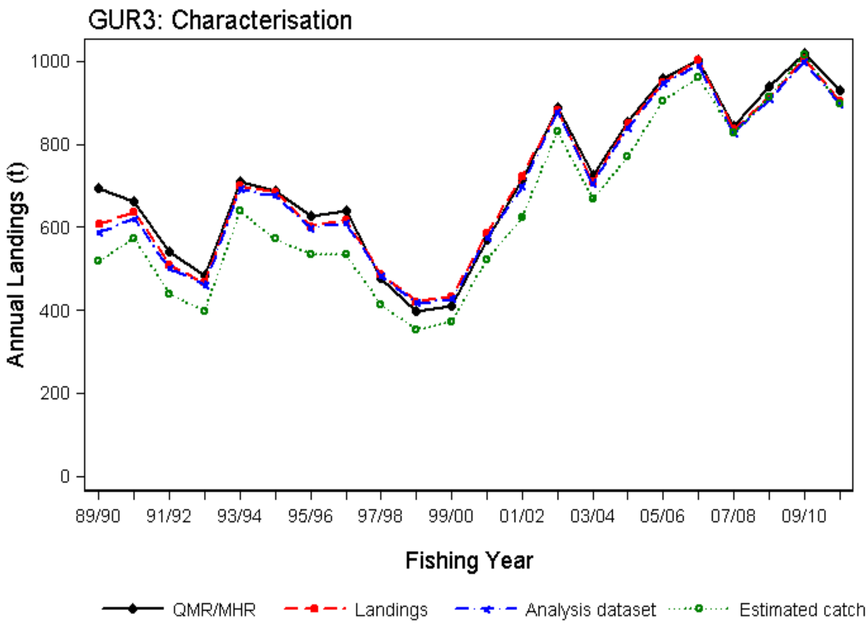

Figure 3: Plot of the GUR 3 catch dataset totals presented in Table 4. The estimated catch total is the sum of the estimated catch in the analysis dataset.

The annual totals at different stages of the data preparation procedure are presented in Table 4 and Figure 3. Total landings in the data set are similar to the landings in the QMR/MHR system, except for a 13% shortfall in landings in the first year of data (1989–90), which was affected by the changeover to a new system of data reporting. Landings by year in the subsequent fishing years vary from –6% to +6% relative to the QMR/MHR annual totals (Table 4). The shortfall between landed and estimated catch by trip varies from –21% to +1% by fishing year and may be diminishing in recent years (Table 4). A scatter plot of the estimated and landed catch by trip shows that relatively few trips overestimate the landing total for the trip (Figure 4 [left panel]). The distribution of the ratios of the landed relative to estimated catch shows a skewed distribution with many ratios greater than 1.0 and with a mode slightly above 1.0 (Figure 4 [right panel]).

The 5% to 95% quantiles (excluding trips where there was no estimated catch) for the ratio of landed to estimated catch range from 0.5 to 2.0 for the dataset, with the median and mean ratios showing the landed catch 0% and 16% higher respectively than the estimated catch (Table 5). On average, 30% of trips estimated no catch of gurnard but then reported GUR in the landings (Table 5). These landings represented 6% of the total GUR landings over the period, totalling 941 tonnes over all years (Table 5). The introduction of the new inshore forms (NCELR and TCER), which record fishing activity at the event level, has reduced the proportion of trips which estimate no gurnard while landing this species, with the GUR landings in this category accounting for 8–12% of the total GUR 3 landings in the most recent four years, down from over 20% of trips prior to the change in formtype (Table 5).

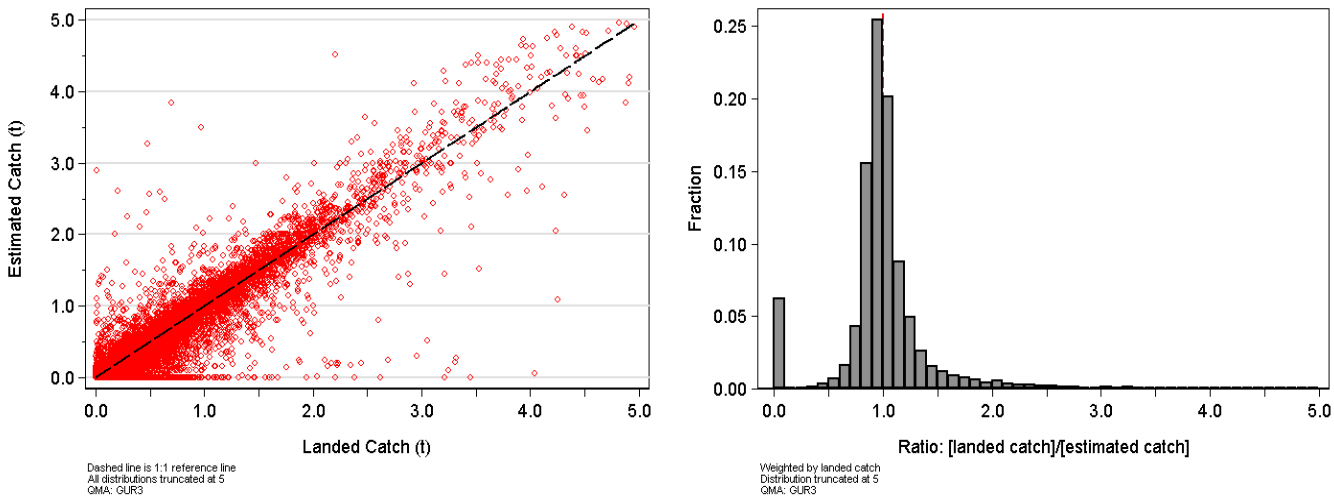

Figure 4: Scatter plot of the sum of landed and estimated gurnard catch for each trip in the GUR 3 analysis dataset [left panel]. Distribution (weighted by the landed catch) of the ratio of landed to estimated catch per trip [right panel]. Trips where the estimated catch is zero have been assigned a ratio of zero.

Catch totals in the fishery characterisation tables have been scaled (Eq. 1) 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 then scaling all the landed catch observations $\left(L'_{i,y}\right)$ by trip-stratum with this ratio:

Eq. 1
$$L'_{i,y} = L_{i,y} \frac{\mathbf{QMR}_y}{\sum_{i=1}^{A_y} L_{i,y}}$$

where $\mathbf{QMR}_y$ = QMR/MHR landings in year y;

$L_{i,y}$ = landing of GUR 3 for trip-stratum i in year y;

A_y = number of trip-strata records for GUR 3 in year y.

Table 5: Summary statistics pertaining to the reporting of estimated catch from the GUR 3 analysis dataset.

Fishing year	Trips with landed catch but which report no estimated catch: Trips: % relative to total trips	Landings: % relative to total landings	Landings (t)	Statistics (excluding zeros) for the ratio of landed/estimated catch by trip: 5% quantile	Median	Mean	95% quantile
89/90	25	8	53	0.53	1.00	1.17	2.00
90/91	33	5	35	0.56	1.00	1.15	2.00
91/92	35	7	39	0.55	1.00	1.34	2.00
92/93	39	11	55	0.55	1.00	1.19	2.13
93/94	34	7	49	0.60	1.00	1.13	2.00
94/95	36	9	59	0.53	1.00	1.12	1.99
95/96	33	10	60	0.50	1.00	1.12	2.01
96/97	36	13	81	0.50	1.00	1.15	2.00
97/98	39	15	73	0.47	0.99	1.07	2.00
98/99	38	15	58	0.47	0.99	1.13	1.92
99/00	40	13	55	0.47	0.97	1.09	2.00
00/01	39	11	62	0.49	0.97	1.09	2.00
01/02	34	7	52	0.52	0.98	1.13	2.10
02/03	30	5	41	0.50	0.99	1.52	2.00
03/04	28	5	39	0.58	0.97	1.22	2.07
04/05	24	6	54	0.50	0.98	1.14	2.17
05/06	25	4	41	0.55	0.98	1.15	2.00
06/07	20	4	36	0.53	0.98	1.10	2.00
07/08	12	1	10	0.50	1.00	1.15	2.16
08/09	10	1	10	0.50	0.99	1.13	2.04
09/10	8	1	6	0.50	0.99	1.13	2.00
10/11	8	1	11	0.55	1.00	1.17	2.00
Total	30	6	980	0.50	1.00	1.16	2.00

Table 6: Destination codes in the unedited landing data received for the GUR 3 analysis. The "how used" column indicates which destination codes were included in the characterisation and CPUE analyses. These data summaries have been restricted to GUR 3 landings over the period 1989–90 to 2010–11.

Destination code	Number of events	Green weight (t)	Description	How used
L	104 788	16 767.7	Landed in NZ (to LFR)	Keep
U	105	53.2	Bait used on board	Keep
C	229	42.9	Disposed to Crown	Keep
E	411	7.5	Eaten	Keep
A	86	5.5	Accidental loss	Keep
W	282	3.0	Sold at wharf	Keep
O	12	2.5	Conveyed outside NZ	Keep
F	149	1.4	Section 111 Recreational Catch	Keep
S	2	0.0	Seized by Crown	Keep
T	336	206.5	Transferred to another vessel	Drop
R	1 473	116.9	Retained on board	Drop
Q	493	22.4	Holding receptacle on land	Drop
NULL	64	4.9	Nothing	Drop
D	16	1.2	Discarded (non-ITQ)	Drop
B	89	0.3	Bait stored for later use	Drop

2.4.2 Description of the GUR 3 landing information

Landing data for gurnard were provided for every trip which landed GUR 3 at least once, with one record for every reported GUR landing (including landings from all GUR Fishstocks landed by a trip that also landed GUR 3) from the trip. Each of these records contained a reported green weight (in kilograms), 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 6), 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 6). However, other codes (e.g., A, O and C; Table 6) also potentially described valid landings and were included in this analysis. A number of other codes (notably R, Q and T; Table 6) were not included because it was felt that these landing were likely to 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. The quantity of dropped landings, both in terms of total tonnage and as a proportion of the total landings, was very low for GUR 3 (Table 6).

Table 7: Total greenweight reported and number of events by state code in the landing file used to process the GUR 3 characterisation and CPUE data, arranged in order of descending landed weight (only for destination codes indicated as "Keep" in Table 6). These data summaries have been restricted to GUR 3 from 1989–90 to 2010–11.

State code	Number of events	Total reported green weight (t)	Description
GRE	100 651	15 552.5	Green (or whole)
DRE	346	55.7	Dressed
GUT	582	55.2	Gutted
FIL	427	47.2	Fillets: skin-on
HGU	351	27.7	Headed and gutted
MEA	163	18.4	Fish meal
Other	120	8.9	Other[1]

[1] includes (in descending order of total landings): gilled and gutted tail-on, dressed-v cut (stargazer), fillets: skin-off, squid wings, fins, fillets: skin-off trimmed, headed, gutted, and tailed, fillets: skin-off untrimmed

Table 8: Median conversion factors for the five most important state codes reported in Table 7 (in terms of total landed greenweight) and the total reported greenweight by fishing year in the edited file used to process GUR 3 landing data. These data summaries have been restricted to GUR 3 over the period 1989–90 to 2010–11. '–': no observations

Fishing						Landed State Code
Year	GRE	DRE	GUT	FIL	HGU	OTH
	Median Conversion Factor					
89/90	1	–	1.1	2.6	1.5	1.1
90/91	1	1.8	1.05	–	1.65	–
91/92	1	1.8	1.05	2.05	1.65	–
92/93	1	1.8	1.05	2.05	1.65	–
93/94	1	1.8	1.05	2.05	1.65	5.6
94/95	1	1.8	1.05	2.05	1.65	5.6
95/96	1	1.8	1.05	2.05	1.65	2.6
96/97	1	1.8	1.05	2.05	1.65	3.3
97/98	1	1.8	1.05	2.05	1.65	5.6
98/99	1	1.8	1.05	2.05	1.65	5.6
99/00	1	1.8	1.05	2.05	1.65	5.6
00/01	1	1.8	1.05	2.05	1.65	5.6
01/02	1	1.8	1.05	2.05	1.65	5.6
02/03	1	1.8	1.05	2.05	1.65	5.6
03/04	1	1.8	1.05	2.05	1.65	2.6
04/05	1	1.8	1.05	2.05	1.65	4.1
05/06	1	1.8	1.05	2.05	1.65	5.6
06/07	1	1.8	1.05	–	1.65	5.6
07/08	1	1.8	1.05	2.05	1.65	5.6

Fishing Year	Landed State Code GRE	DRE	GUT	FIL	HGU	OTH
08/09	1	1.8	1.05	2.05	1.65	2.6
09/10	1	1.8	1.05	2.05	1.65	5.6
10/11	1	1.8	1.05	2.05	1.65	5.6
	Total Landings (t)					
89/90	640.2	–	1.5	0.1	6.1	0.0
90/91	639.5	3.1	2.2	–	1.5	–
91/92	500.5	5.1	0.8	1.6	5.4	–
92/93	461.1	1.2	1.0	2.3	3.6	–
93/94	694.4	0.9	0.7	4.3	2.7	0.0
94/95	677.0	5.2	0.5	3.1	1.5	0.1
95/96	589.2	5.2	3.4	20.8	1.2	3.1
96/97	613.0	1.4	2.1	2.0	0.5	0.5
97/98	496.1	1.2	2.6	2.0	0.8	2.3
98/99	415.0	0.7	1.3	1.8	0.3	3.7
99/00	426.3	5.3	1.6	1.1	0.1	1.6
00/01	577.0	0.8	2.1	4.1	0.3	0.8
01/02	710.4	2.6	6.4	1.5	0.1	2.8
02/03	874.3	2.1	5.5	0.4	0.7	0.6
03/04	719.5	3.6	1.3	0.1	0.8	1.7
04/05	848.6	0.6	1.9	0.6	0.3	0.6
05/06	939.3	3.4	3.9	1.2	0.4	4.2
06/07	1 000.5	1.2	1.0	–	0.1	0.5
07/08	839.8	2.7	0.7	0.0	0.0	0.2
08/09	917.6	1.9	1.4	0.0	0.8	0.6
09/10	1 004.1	5.7	2.6	0.0	0.1	1.9
10/11	903.6	1.8	10.5	0.1	1.0	1.9
Total	15 487.0	55.8	55.1	47.1	28.2	27.4

Table 9: Distribution of total landings (t) by red gurnard Fishstock and by fishing year for the set of trips that recorded GUR 3 landings. Landing records with improbable greenweights have been dropped (see Appendix C).

Fishing year	GUR1	GUR2	GUR3	GUR7	GUR8	Total
89/90	0.7	1.4	648	14	0.9	664
90/91	0.7	14	646	25	0.6	686
91/92	1.5	5.4	513	14	4.1	539
92/93	4.9	3.1	469	37	6.1	520
93/94	0.4	7.0	703	19	5.6	735
94/95	1.0	4.5	687	23	10	726
95/96	1.7	7.2	623	18	12	662
96/97	2.4	1.3	620	18	19	660
97/98	4.0	4.3	505	17	35	565
98/99	0.1	4.3	423	20	12	459
99/00	2.7	3.3	436	19	2.3	464
00/01	1.7	10	585	34	13	644
01/02	1.2	10	724	30	21	786
02/03	2.0	15	884	47	14	962
03/04	0.6	6.6	727	36	20	790
04/05	1.6	7.1	853	14	27	902
05/06	0.6	4.9	952	41	23	1 022
06/07	0.4	8.5	1 003	36	4.5	1 052
07/08	0.5	10	843	38	7.4	899
08/09	6.1	9.3	922	33	13	984
09/10	1.7	15	1 014	47	7.8	1 086
10/11	6.4	11	919	63	5.8	1 006
Total	43	164	15 701	643	264	16 814

Almost all of the valid landing data for GUR 3 were reported using state code GRE with the majority of the remaining landings using the state code DRE (Table 7; Table 8). The few remaining landings were spread among HGU, GUT and MEA codes. There were no important changes in the conversion factors used for this species over the period of available data (Table 8). Total landings available in the data set are almost entirely for GUR 3, indicating that trips which land GUR 3 rarely fish in other gurnard QMAs (Table 9).

Just under seventy percent of the GUR 3 landings have been reported on CELR forms over the 22 years of record, with the remaining landings reported using CLR forms and about 0.1% on NCELR forms (Table 10). The CLR form is used by vessels using the TCEPR forms to report their effort as well as the new TCER form developed specifically for small inshore trawl vessels. The NCELR form is used exclusively to report setnet effort and landings, but this method of capture is rare for GUR 3. The use of these new forms, mainly beginning in 2007–08, has resulted in a substantial drop in the use of the CELR form, which dropped to below 20 percent of the GUR 3 landings after being greater than 80% of landings in the years previous (Table 10). The introduction of these new forms can also be seen in the effort data associated with these trips, with a strong decline in the number of days fishing associated with the CELR form after 2006–07 (Table 10).

Table 10: Distribution by form type for landed catch by weight for each fishing year in GUR 3. Also provided is the number of days fishing and the associated distribution of days fishing by form type for the effort data using statistical areas consistent with GUR 3. Forms other than CELR and NCELR report their landings on CLR forms.

	Landings (%)[1]			Days Fishing (%)[2]			Days Fishing					
Year	CELR	CLR	NCELR	CELR	TCEPR	TCER	CELR	TCEPR	TCER	NCELR	Other[3]	Total
89/90	80	20	0	80	20	–	6 500	1 618	–	–	–	8 118
90/91	93	7	0	81	19	–	6 454	1 552	–	–	–	8 006
91/92	82	18	0	82	18	–	6 068	1 334	–	–	–	7 402
92/93	85	15	0	81	19	–	6 358	1 490	–	–	–	7 848
93/94	91	9	0	84	16	–	7 307	1 434	–	–	–	8 741
94/95	92	8	0	81	19	–	6 985	1 587	–	–	–	8 572
95/96	85	15	0	75	25	–	6 495	2 223	–	–	–	8 718
96/97	88	12	0	81	19	–	7 349	1 769	–	–	–	9 118
97/98	84	16	0	77	23	–	7 272	2 123	–	–	–	9 395
98/99	92	8	0	81	19	–	7 276	1 719	–	–	–	8 995
99/00	89	11	0	80	20	–	6 885	1 733	–	–	–	8 618
00/01	92	8	0	79	21	–	6 880	1 830	–	–	–	8 710
01/02	76	24	0	75	25	–	6 397	2 180	–	–	–	8 577
02/03	79	21	0	77	23	–	7 175	2 147	–	–	–	9 322
03/04	88	12	0	84	16	–	6 326	1 199	–	–	–	7 525
04/05	83	17	0	80	20	–	7 418	1 868	–	–	–	9 286
05/06	82	18	0	79	21	–	7 132	1 870	–	–	56	9 058
06/07	86	14	0.3	70	23	–	5 994	1 988	–	567	31	8 580
07/08	17	82	0.5	8	22	61	556	1 595	4 455	636	30	7 272
08/09	17	82	0.4	7	18	67	515	1 327	4 818	510	38	7 208
09/10	17	83	0.2	4	16	73	312	1 264	5 584	481	30	7 671
10/11	16	84	0.5	4	22	65	333	1 740	5 060	586	20	7 739
Total	69	31	0.1	67	20	11	123 987	37 590	19 917	2 780	205	184 479

[1] Percentages of landed greenweight
[2] Percentages of number of days fishing
[3] includes 135 days for LCER (lining), and 70 days for LTCER (lining trip)

2.4.3 Description of the GUR 3 fishery

2.4.3.1 Introduction

Distributions by statistical area, major fishing method and target species in this section are provided by summarised statistical areas, methods and target species as described in Table 11.

Table 11: Definitions of statistical area group (Appendix B), major method and target species codes used in the distribution tables and plots in this report. Number of events is the number of effort records in analysis dataset; number of records is the number of trip-strata in analysis dataset; sum(landings) is sum of landings after using "Fishstock expansion" method (Appendix D).

Statistical area code	Statistical area group definition	Number of events	Number of records	Sum landings (t)
018	018, 019	12 179	9 608	251.3
020	020, 021	42 208	24 159	3 532.8
022	022, 023	81 475	38 646	6 048.5
024	024, 301	32 800	21 532	927.1
026	026, 302, 303	28 570	9 317	676.7
025	025	11 515	4 774	1 286.5
030–032	030, 031, 032	23 832	7 185	1 637.2
027–029	027, 028, 029	19 017	3 409	425.7
ChatRise	049–052, 401–412	14 397	3 270	397.5
SubAnt	501–504, 601–625	6 842	721	5.2
Method designation	Methods included			
BT	Bottom trawl	240 968	107 483	14 189.2
DS	Danish seine	1 781	1 369	859.8
SN	Setnet	14 959	12 007	74.9
MW	Mid-water trawl	14 139	1 481	57.9
OTH	Other (Bottom pair trawl and bottom longline are the remaining methods reporting >1 t of GUR 3)	988	281	6.9
Target species code[1]	Target species definition			
FLA	Flatfish (including all related species)	90 062	47 327	4 542.3
RCO	Red cod	51 252	28 126	4 422.5
BAR	Barracouta	20 306	6 414	1 452.0
GUR	Red gurnard	3 588	2 150	1 042.8
STA	Stargazer	12 066	4 146	919.8
TAR	Tarakihi	12 913	5 499	687.6
ELE	Elephantfish	4 507	2 041	448.3
WAR	Blue warehou	2 562	1 086	367.2
SPD	Spiny dogfish	1 833	759	71.7
SQU	Squid	17 036	2 939	58.6
OTH	Remaining 13 species > 5 t of total bottom trawl landings in ranked descending order: rig, jack mackerel, sea perch, ling, silver warehou, hoki, gemfish, rough skate, leatherjacket, skate, hapuku & bass, blue cod, school shark	24 843	6 996	176.5

[1] Bottom trawl method

2.4.3.2 Distribution of landings and effort by method of capture and statistical area

GUR 3 shares several statistical areas with other red gurnard Fishstocks, including Area 018 with GUR 2 and GUR 7 and Area 032 with GUR 7 (Appendix B). The GUR 3 fishery is taken almost entirely by the bottom trawl fishery, with 94% of the landings over the past 22 years taken by this method (Table 12; Figure 5). There are some unusual errors in the data for this species, including nearly 100 t of estimated catch taken mainly in the Chatham Islands over a number of fishing years using the "diving" fishing method. The most likely explanation is that these observations are data errors where the code for kina (SUR) has been interpreted as the code for gurnard (GUR). These records have been dropped from this analysis and do not appear in any of the data summaries. A Danish seine fishery which captures this species (among others) gained importance in Pegasus Bay from 2002–03 and then gradually expanded into the Canterbury Bight (Table 13).

Table 12: Total landings (t) and distribution of landings (%) of red gurnard from trips which landed GUR 3 by statistical area group and important fishing methods (Table 11), summed from 1989–90 to 2010–11. Landings (t) have been scaled to the QMR totals using Eq. 1. '–': no data in cell.

Statistical						Fishing Method						Fishing Method
Area	BT	DS	SN	MW	Other	Total	BT	DS	SN	MW	Other	Total
Region	Total landings (t)						Distribution of landings (%)					
018	246	1	16	0.4	0.1	264	1.6	0.01	0.10	0.00	0.00	1.7
020	3 178	496	11	2.3	1.1	3 688	20.2	3.1	0.07	0.01	0.01	23.4
022	5 873	381	19	10	3.6	6 287	37.3	2.4	0.12	0.06	0.02	39.9
024	953	1	11	0.0	0.1	964	6.0	0.01	0.07	0.00	0.00	6.1
026	695	0.4	0.5	2.0	0.2	698	4.4	0.00	0.00	0.01	0.00	4.4
025	1 300	–	5	17	0.3	1 322	8.2	–	0.03	0.10	0.00	8.4
030-032	1 682	1	7	0.0	1.1	1 690	10.7	0.00	0.05	0.00	0.01	10.7
027-029	411	–	0.3	24	–	435	2.6	–	0.00	0.15	–	2.8
ChatRise	399	–	8	3.0	0.6	411	2.5	–	0.05	0.02	0.00	2.6
SubAnt	4.1	–	0.0	1.2	–	5.4	0.03	–	0.00	0.01	–	0.03
Total	14 741	880	78	59	7.0	15 764	93.5	5.6	0.5	0.4	0.0	100

Table 13: Percent distribution of landings by statistical area group (Table 11) from 1989–90 to 2010–11 for the bottom trawl and Danish seine methods for trips which landed GUR 3. Annual landings by method are available in Table 14 and the rows sum to 100%. '–': no fishing.

Fishing										Statistical Area Group
Year	018	020	022	024	026	025	030–032	027–029	ChatRise	SubAnt
	Bottom trawl distribution (%)									
89/90	2.5	35.3	42.5	6.1	2.6	2.3	5.8	0.3	2.6	0.0
90/91	3.2	36.6	38.6	5.1	1.3	2.0	10.7	0.4	1.9	0.1
91/92	1.1	24.3	41.0	8.5	3.2	4.9	11.6	0.9	4.3	0.0
92/93	5.6	30.9	39.9	6.6	2.3	5.5	8.5	0.5	0.2	0.0
93/94	2.0	30.6	43.3	7.9	2.8	4.0	8.0	1.1	0.4	0.0
94/95	3.1	32.7	44.4	7.2	2.8	2.1	5.7	1.0	0.9	0.0
95/96	4.3	22.4	44.3	6.4	4.5	7.7	7.0	2.1	1.3	0.0
96/97	2.9	21.2	55.7	4.4	3.4	4.8	5.5	0.9	1.3	0.0
97/98	2.1	21.2	40.1	5.2	5.9	11.2	6.5	3.6	4.1	0.1
98/99	3.0	26.0	35.7	6.3	2.7	7.7	15.0	1.1	2.5	0.0
99/00	1.6	29.0	36.3	6.3	2.5	6.1	12.2	4.1	1.9	0.0
00/01	2.8	31.0	32.5	4.3	3.6	5.2	13.0	2.3	5.4	0.0
01/02	2.2	16.6	29.2	4.7	6.0	8.5	17.0	5.6	10.2	0.0
02/03	0.5	15.9	40.2	5.3	5.8	11.3	10.5	7.8	2.7	0.0
03/04	0.5	16.2	38.6	7.8	7.2	11.2	13.6	2.0	2.9	0.0
04/05	0.9	12.3	34.9	6.5	7.2	12.1	18.1	4.9	3.0	0.1
05/06	1.0	14.2	37.4	5.3	7.3	7.9	14.2	7.3	5.3	0.0
06/07	0.6	17.4	35.5	4.9	6.3	17.1	9.9	5.4	2.9	0.0
07/08	0.4	14.5	37.0	6.3	5.4	20.7	10.5	2.7	2.5	0.0
08/09	0.0	15.5	43.8	7.0	5.4	12.6	14.1	0.9	0.7	0.0
09/10	0.2	17.6	42.5	8.1	5.4	9.9	13.9	1.1	1.3	0.0
10/11	0.2	12.4	42.2	11.7	5.1	10.7	15.6	1.1	1.0	0.0
Mean	1.7	21.6	39.8	6.5	4.7	8.8	11.4	2.8	2.7	0.0

Table 13 (cont.):

Fishing Year	018	020	022	024	026	025	030-032	027-029	ChatRise	SubAnt
	Statistical Area Group									
	Danish seine distribution (%)									
02/03	0.0	97.0	3.0	–	0.0	–	0.0	–	–	–
03/04	2.8	83.9	11.8	–	1.5	–	0.0	–	–	–
04/05	0.0	73.9	26.1	–	0.0	–	0.0	–	–	–
05/06	0.0	61.4	37.8	–	0.0	–	0.8	–	–	–
06/07	0.0	48.2	51.8	–	0.0	–	0.0	–	–	–
07/08	0.0	44.7	55.3	–	0.0	–	0.0	–	–	–
08/09	0.2	50.0	49.8	–	0.0	–	0.0	–	–	–
09/10	0.0	55.9	44.1	–	0.0	–	0.0	–	–	–
10/11	0.1	61.8	37.6	–	0.0	–	0.0	–	–	–
Mean	0.1	56.4	43.3	–	0.0	–	0.1	–	–	–

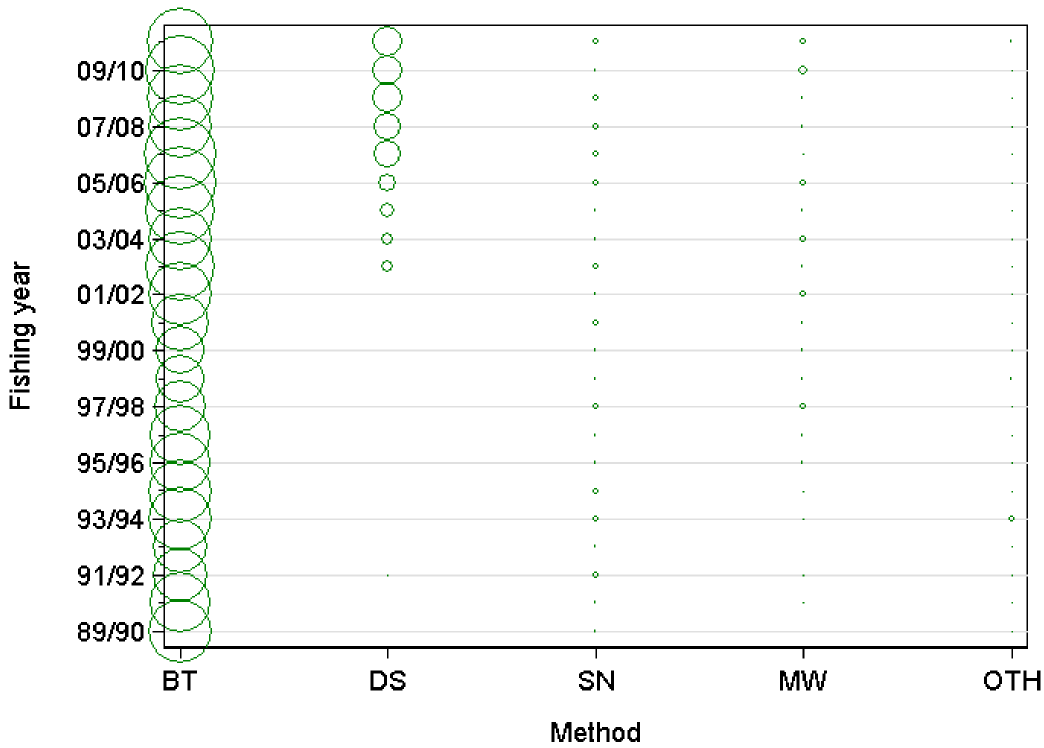

Figure 5: Distribution of catches for the major fishing methods by fishing year from trips which landed GUR 3. Circles are proportional to the catch totals by method and fishing year, with the largest circle representing 884 t (2006–07; BT).

The GUR 3 trawl catch is mainly taken in Statistical Areas 020 or 022, with some trawl catches taken in the western part of Foveaux Strait in Southland (Figure 6; Table 12). The distribution of bottom trawl effort by year is similar to the catch distribution, although effort expended in Areas 024 and 026 lands relatively less GUR 3 than in Areas 020 and 022 (Figure 6). There does not appear to be any obvious trend in the annual distribution of bottom trawl catch or effort between statistical areas, indicating that the relative importance of these areas has been more or less constant over the period covered by the data (Table 13; Figure 6).

A new fishery using the Danish seine method has developed off the central east coast of the South Island, beginning in Area 020 around 2002–03 but has since been reasonably evenly split in terms of annual landings between Areas 020 and 022 from 2006–07 (Table 13). Total Danish seine landings of gurnard have exceeded 100 t of GUR landings per year since 2006–07 and have been around 150 t or greater per year from 2008–09 onwards (Table 14; Figure 7).

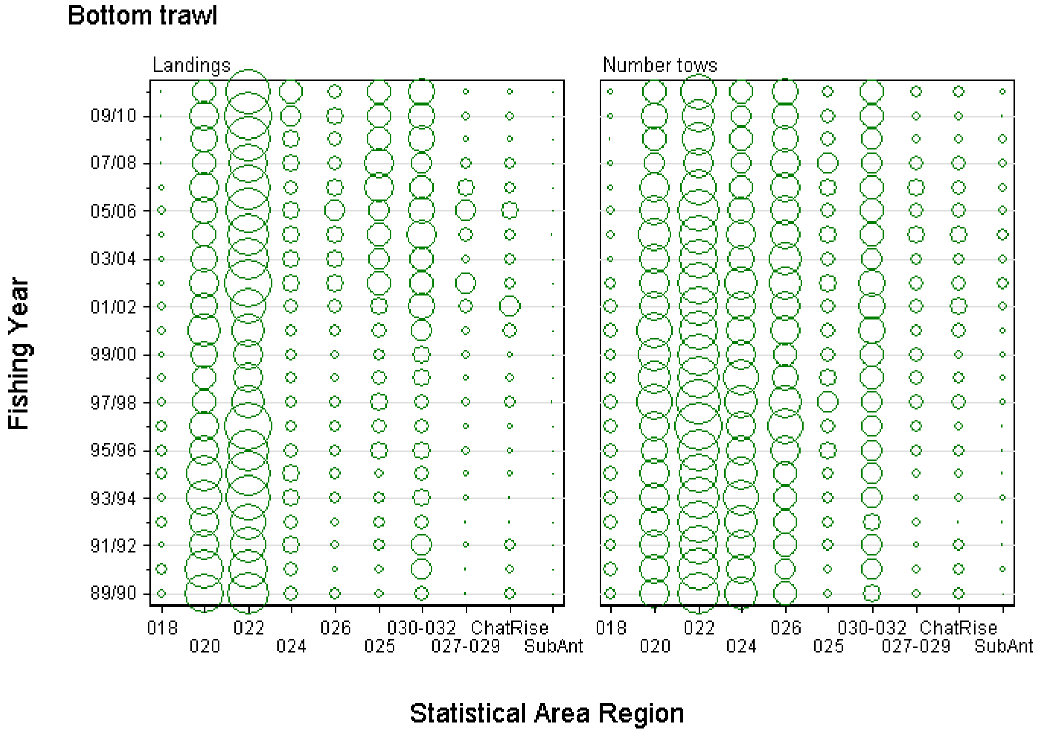

Figure 6: Distribution of landings and effort for the bottom trawl method by statistical area and fishing year from trips which landed GUR 3. Circles are proportional: [catches] largest circle is 354 t for 022 in 1996–97; [effort] largest circle 9 177 tows for 022 in 1996–97.

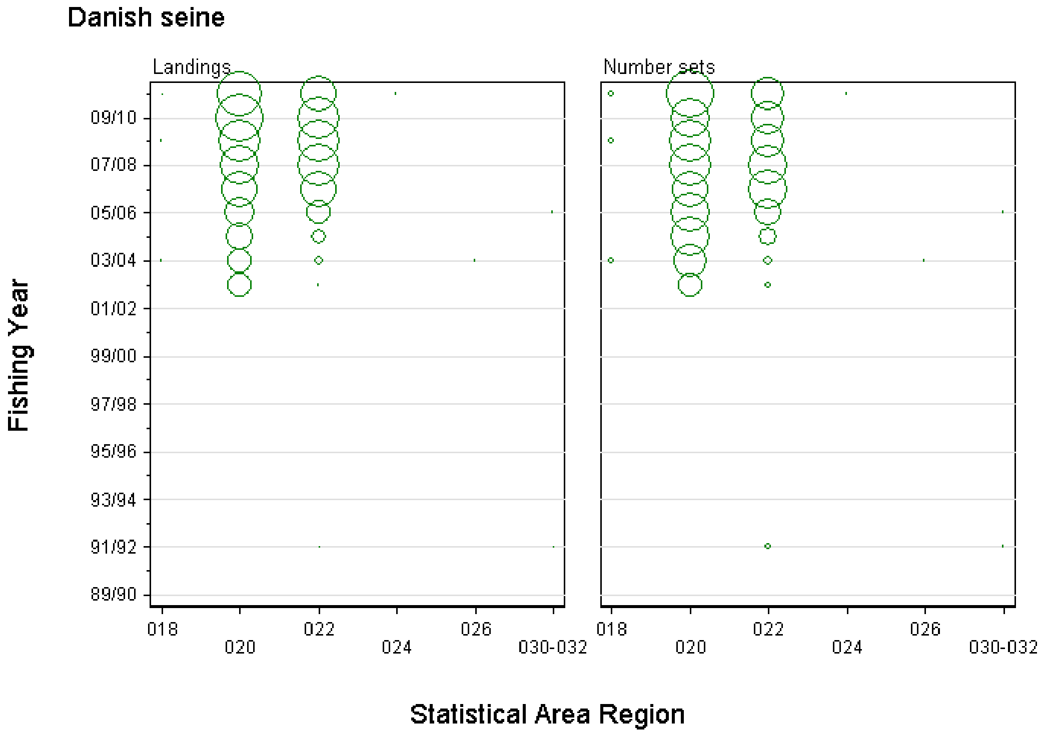

Figure 7: Distribution of landings and effort for the Danish seine method by statistical area and fishing year from trips which landed GUR 3. Circles are proportional: [catches] largest circle 96 t in 2009–10 for 020; [effort] largest circle 616 sets in 2010–11 for 020.

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

Fine scale landings and effort data are available for the total bottom trawl fleet taking gurnard from 1 Oct 2007 onwards. A plot (Figure 8) of total landings gridded into 0.1×0.1° cells, summed over all four years, shows that gurnard are taken near the coast all the way from the top of Pegasus Bay to the western part of Foveaux Strait and Te Wae Wae Bay. Catch concentrations are especially high in Pegasus Bay, Canterbury Bight and the eastern and western entrances to Foveaux Strait (Figure 8). Bottom trawl gurnard CPUE distribution is very similar to the distribution of catch, although the high CPUE grids appear to be more localised than the grids showing total landings (Figure 9).

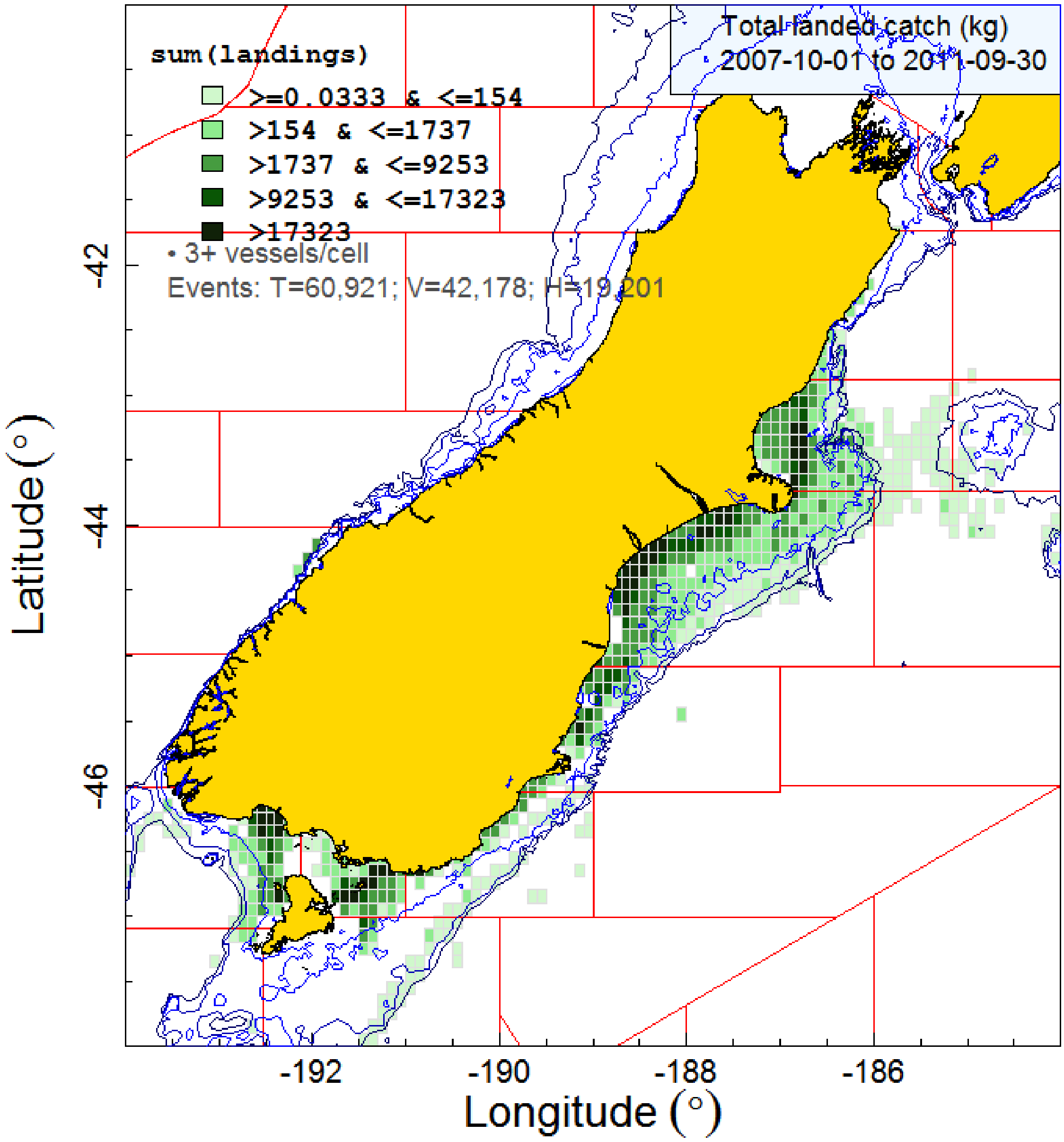

Figure 8: Total bottom trawl landings for gurnard in GUR 3, arranged in 0.1°×0.1° grids, summed from 2007–08 to 2010–11. Legend colours divide the distribution of total landings into approximate 0–25%, 25–50%, 50–75%, 75–90% and +95% quantiles. Only grids with at least three reporting vessels are plotted with the legend showing the total (T), visible (V) and hidden (H) events caused by this rule. Boundaries for the general statistical areas (Appendix B) are shown and the bathymetry indicates the 100 m, 200 m and 400 m depth contours.

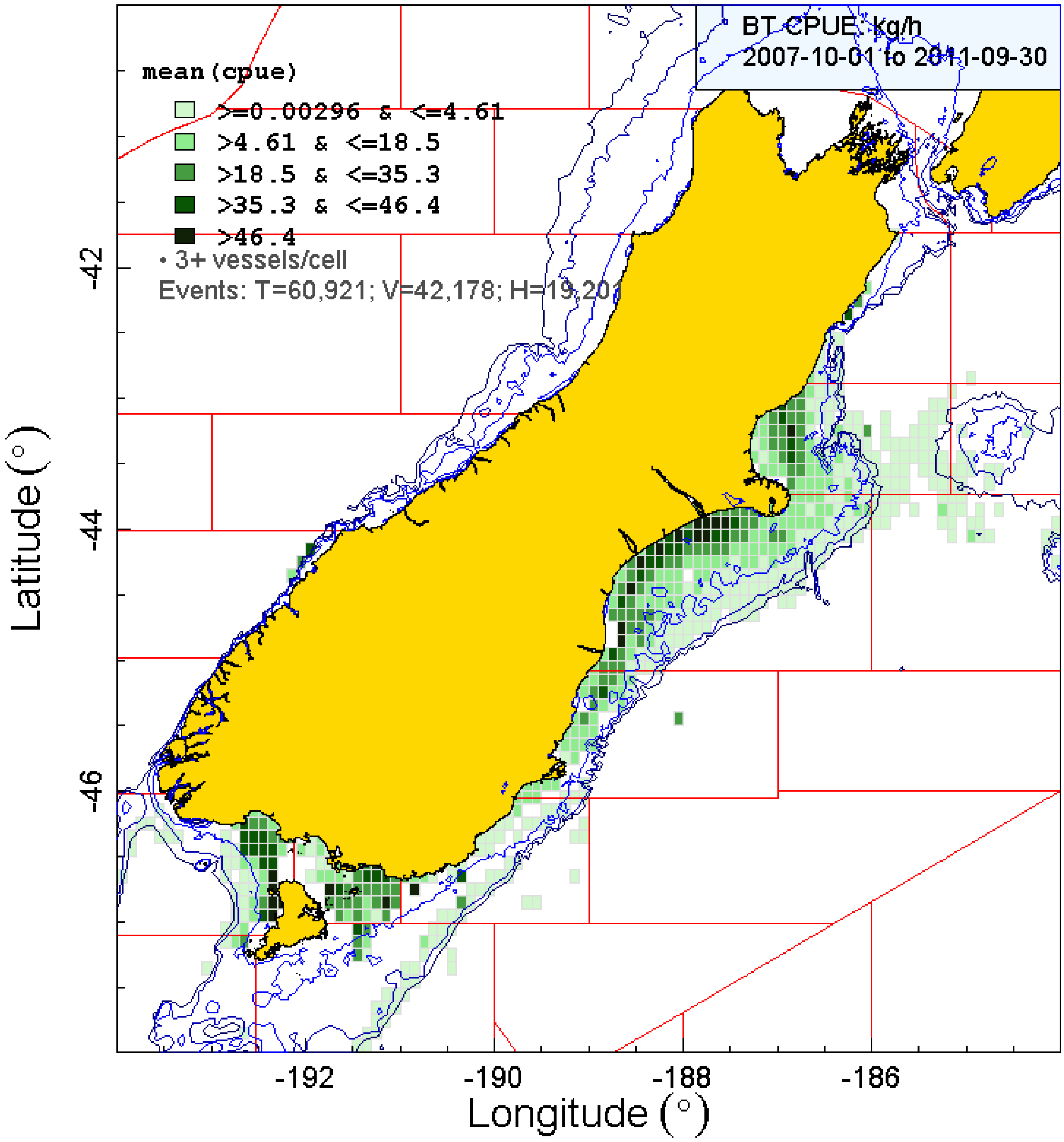

Figure 9: Mean bottom trawl CPUE (kg/h) for gurnard in GUR 3, arranged in 0.1° × 0.1° grids, averaged over 2007–08 to 2010–11. Legend colours divide the distribution of total landings into approximate 0–25%, 25–50%, 50–75%, 75–90% and +95% quantiles. Only grids with at least three reporting vessels are plotted, with the legend showing the total (T), visible (V) and hidden (H) events caused by this rule. Boundaries for the general statistical areas (Appendix B) are shown and the bathymetry indicates the 100 m, 200 m and 400 m depth contours.

2.4.3.4 Seasonal distribution of landings

There is a broad seasonal distribution of bottom trawl catch from GUR 3, with an even distribution of catch taken in almost every month up to the end of April or May, after which there is a decline in catch and the relative proportion of catch in the latter half of the fishing year (Table 14; Figure 10). The emergent Danish seine fishery appears to be most active with respect to gurnard in the first three months of the fishing year, after which it tapers off and becomes more variable than the trawl fishery in the autumn and winter (Table 14; Figure 10). Seasonal bottom trawl catches by statistical area show some pattern, with catches in Southland (Area 025, Areas 030–032 and Areas 027–029) concentrated in the earlier months of the fishing year compared to the two large east coast fisheries in Areas 020 and 022 (Figure 11A and Figure 11B). The areas with most abundant levels of catch (020, 022, and 024) show a more even distribution of GUR 3 catch over the year.

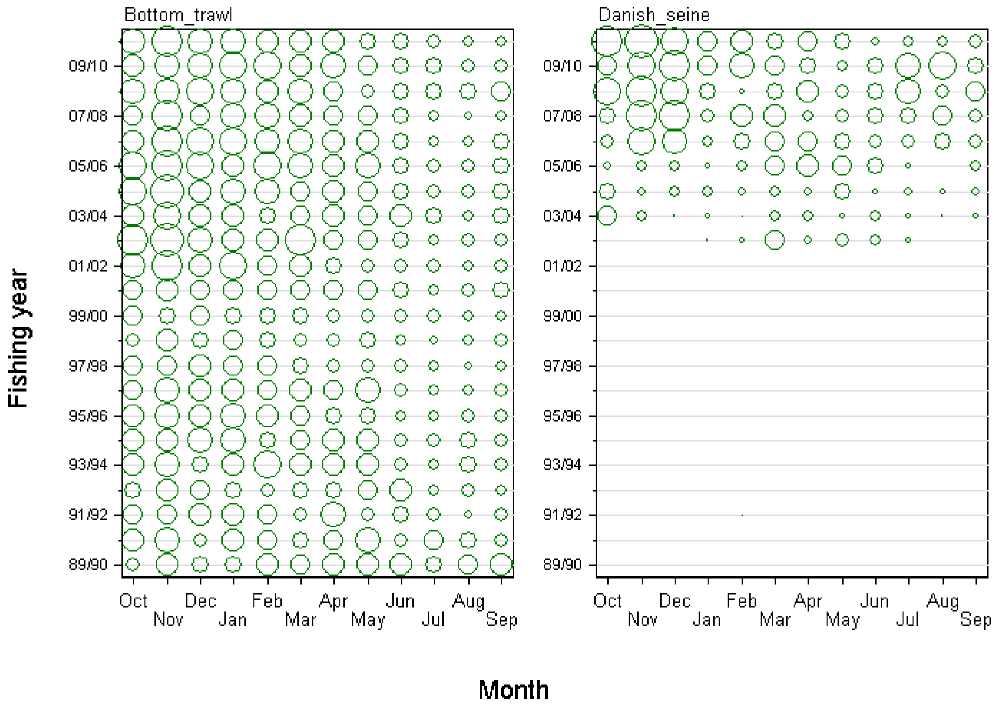

Figure 10: Total landings by month and fishing year for bottom trawl based on trips landing GUR 3. Circle sizes are proportional in each panel: [bottom trawl] largest circle 159 t in 2002–03 for Nov; [Danish seine]: largest circle 31 t in 2010–11 for Nov.

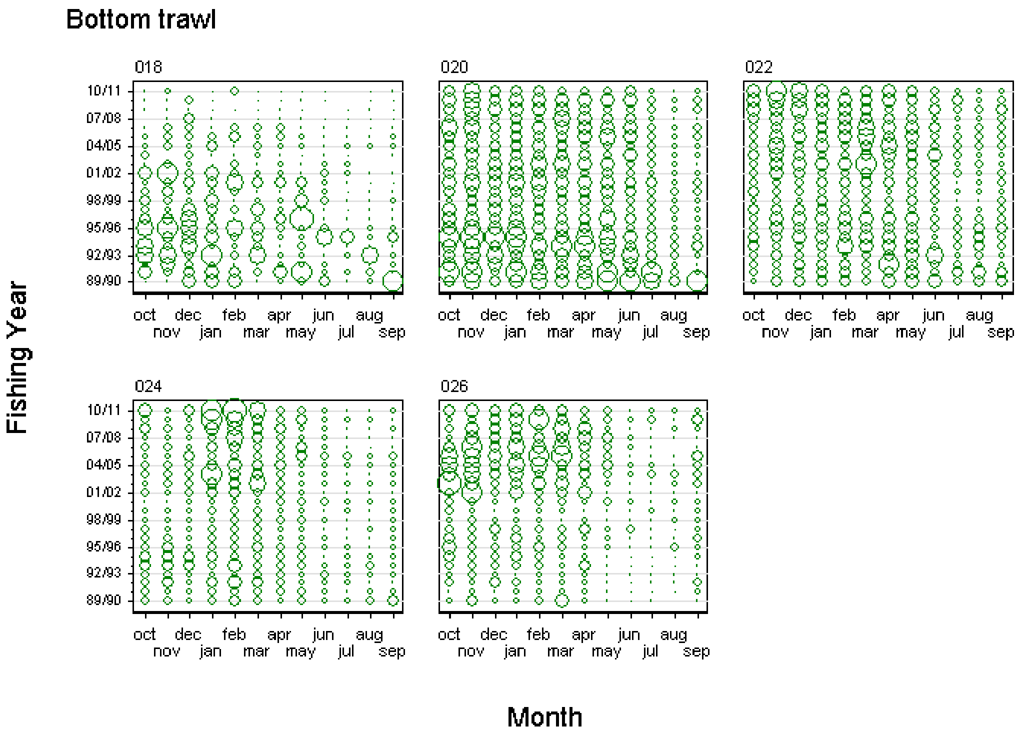

Figure 11A: Distribution of landings for the bottom trawl method for the first five grouped statistical areas (Table 11) for month and fishing year from trips which landed GUR 3. Circle sizes are proportional within each panel: maximum values: 018 (6.5 t in 1996–97 for May); 020 (36 t in 1994–95 for Nov); 022 (72 t in 2002–03 for Mar); 024(24 t in 2010–11 for Feb); 026 (16 t in 2002–03 for Oct).

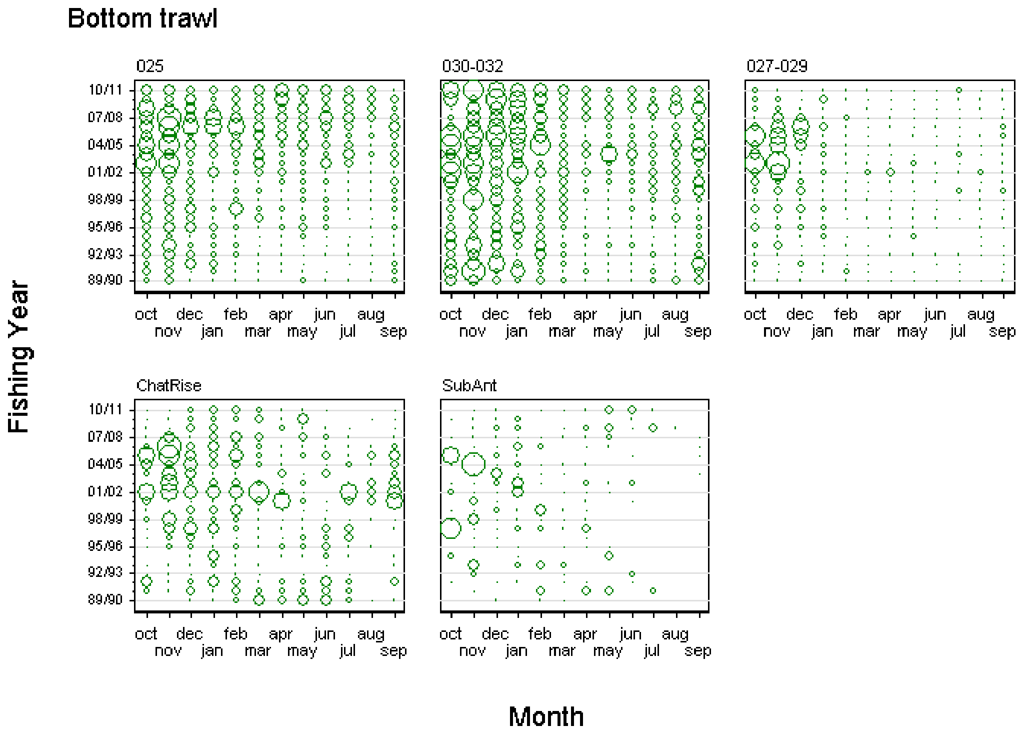

Figure 11B: Distribution of landings for the bottom trawl method for the final five grouped statistical areas (Table 11) for month and fishing year from trips which landed GUR 3. Circle sizes are proportional within each panel: maximum values: 025 (34 t in 2007–08 for Nov), 030–032 (30 t in 1990–91 for Nov); 027–029 (34 t in 2002–03 for Nov); ChatRise: (15 t in 2006–07 for Nov); SubAnt (0.5 t in 2004–05 for Nov).

Table 14: Percent distribution of landings by month and total annual landings (t) of GUR 3 from 1989–90 to 2010–11 for the bottom trawl and Danish seine methods for trips which landed GUR 3. Landings (t) have been scaled to the QMR totals using Eq. 1; [–]: no landings in this cell.

Fishing											Month		
Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total (t)
	Bottom trawl distribution (%)												
89/90	4.6	10.5	6.0	6.7	9.2	7.4	10.2	10.5	11.1	6.4	7.4	9.9	692
90/91	11.0	13.3	4.5	11.7	8.2	6.1	7.6	13.9	4.6	8.1	6.1	4.9	658
91/92	9.2	10.4	13.9	11.8	9.0	5.8	16.6	6.0	7.4	4.3	1.5	4.2	536
92/93	7.8	15.0	9.7	7.4	6.8	8.2	7.3	10.5	15.5	4.0	4.9	3.0	482
93/94	9.1	11.8	6.5	9.3	14.2	11.3	11.0	10.9	4.4	3.1	4.9	3.5	703
94/95	10.6	11.6	12.6	13.0	6.3	8.6	9.9	9.8	4.7	4.3	5.2	3.4	681
95/96	10.5	14.7	10.8	13.1	11.3	8.8	6.8	7.3	3.5	3.0	5.2	5.1	624
96/97	8.1	12.8	11.9	11.2	9.1	11.1	8.6	12.9	4.4	2.9	2.5	4.4	636
97/98	13.2	10.8	14.5	13.1	12.2	8.6	6.0	6.1	5.1	3.6	2.5	4.3	463
98/99	6.1	17.3	10.4	12.4	9.5	8.5	8.3	10.2	5.5	2.4	3.5	5.9	390
99/00	11.6	11.3	12.2	9.1	10.7	9.3	5.9	8.2	6.5	6.3	3.6	5.4	406
00/01	10.2	11.0	10.0	8.9	9.4	10.5	9.5	8.7	6.3	3.3	4.4	7.8	563
01/02	11.7	20.2	9.0	14.0	7.9	10.8	6.5	4.4	3.9	4.3	2.7	4.6	709
02/03	15.0	18.6	9.5	8.2	9.2	14.7	5.9	6.4	4.0	2.5	2.7	3.2	856
03/04	10.3	14.8	10.6	9.7	5.8	8.4	10.0	8.0	9.5	5.6	2.1	5.1	689
04/05	12.4	18.4	9.2	11.3	10.4	6.4	9.0	6.7	4.3	3.5	3.7	4.7	809
05/06	12.5	14.5	11.4	7.7	11.5	9.7	7.4	9.3	5.1	3.2	2.8	5.0	884
06/07	7.1	16.2	12.0	12.2	10.5	11.0	8.1	8.5	5.2	2.4	2.5	4.3	884
07/08	7.2	18.8	8.3	12.4	13.6	10.7	8.6	8.3	4.9	3.1	1.5	2.7	701
08/09	10.7	11.7	12.9	12.1	9.7	10.4	6.5	4.1	5.8	5.0	4.6	6.5	780
09/10	8.8	10.2	11.5	13.6	13.4	7.7	10.3	7.0	5.5	5.1	3.2	3.9	831
10/11	12.2	16.9	11.5	11.8	9.4	9.8	9.2	5.5	6.0	3.2	2.3	2.2	764
Mean	10.1	14.3	10.3	10.9	10.0	9.4	8.6	8.2	5.9	4.0	3.6	4.7	14 741[1]

Table 14 (cont):

Fishing Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep (Month)	Total (t)
	Danish seine distribution (%)												
02/03	–	–	–	1.8	4.6	44.4	10.0	22.8	11.4	5.0	–	–	24
03/04	34.7	12.2	1.6	2.8	0.1	12.2	11.8	2.8	13.7	3.5	0.6	4.2	28
04/05	23.1	6.8	9.4	8.7	4.1	9.2	3.7	18.5	3.3	6.4	2.8	4.1	38
05/06	3.0	5.3	5.3	1.8	4.9	18.4	21.0	19.5	12.9	1.8	–	6.0	65
06/07	5.5	17.9	17.6	3.9	8.0	9.2	9.9	6.4	4.8	4.8	7.8	4.2	116
07/08	6.3	19.6	19.4	4.1	10.5	10.8	2.5	3.7	5.7	6.7	7.1	3.6	135
08/09	15.0	19.3	14.8	4.9	0.8	6.0	9.6	3.0	4.5	11.7	4.0	6.3	153
09/10	5.9	13.8	15.3	7.0	10.8	6.7	4.2	2.4	4.5	11.5	13.3	4.6	171
10/11	18.0	21.0	14.4	7.7	10.3	6.1	7.2	5.3	1.1	2.9	2.0	4.2	149
Mean	10.8	16.0	14.1	5.3	7.3	9.6	7.8	6.3	5.2	7.1	5.9	4.6	879[1]

[1] Total of all years (t)

2.4.3.5 Distribution of landings by declared target species

The red cod and flatfish target fisheries using bottom trawl gear are the main fisheries which take gurnard in QMA 3, with these two target species each accounting for about 30% of the landed catch (Table 15). Other target trawl fisheries which take red gurnard include barracouta, gurnard, stargazer and tarakihi (Table 15; Figure 12). The relative importance of the red cod target catch has dropped considerably since the mid-2000s, with a corresponding increase in the importance of the flatfish, barracouta and, notably, the target gurnard fishery (Table 16).

Table 15: Landings (t) and distribution of landings (%) of red gurnard from trips which landed GUR 3 by target species and important fishing methods (Table 11), summed from 1989–90 to 2010–11. Landings (t) have been scaled to the QMR totals using Eq. 1. [–]: no landings in this cell.

Statistical Area Region	BT	DS	SN	MW	Other	Total	BT	DS	SN	MW	Other	Total
	Fishing Method: Total landings (t)						Fishing Method: Distribution of landings (%)					
FLA	4 713	294	0	–	0	5 008	29.9	1.9	0.0	–	0.0	31.8
RCO	4 616	289	0	0	3	4 908	29.3	1.8	0.0	0.0	0.0	31.1
BAR	1 506	–	–	20	–	1 526	9.6	–	–	0.1	–	9.7
GUR	1 086	16	0	–	2	1 104	6.9	0.1	0.0	–	0.0	7.0
STA	953	–	0	–	0	953	6.0	–	0.0	–	0.0	6.0
TAR	709	140	3	–	0	852	4.5	0.9	0.0	–	0.0	5.4
ELE	462	40	4	–	–	507	2.9	0.3	0.0	–	–	3.2
WAR	375	–	3	22	–	399	2.4	–	0.0	0.1	–	2.5
SPO	28	74	31	–	0	133	0.2	0.5	0.2	–	0.0	0.8
SPD	74	21	9	0	–	104	0.5	0.1	0.1	0.0	–	0.7
SQU	61	–	–	4	1	66	0.4	–	–	0.0	0.0	0.4
OTH	157	6	27	13	1	204	1.0	0.0	0.2	0.1	0.0	1.3
Total	14 741	880	78	59	7	15 764	93.5	5.6	0.5	0.4	0.0	100.0

The emerging Danish seine fishery in Areas 020 and 022 appears to be mainly targeted at red cod and flatfish, with some bycatch of gurnard in the tarakihi target fishery (Table 15; Figure 12). In the first two years of this fishery (2002–03 and 2003–04), there was some significant targeting of red gurnard, although even in that year the fishery was still primarily directed at flatfish (Table 16).

Plots of the distribution of target trawl fisheries by statistical area shows that the red cod bottom trawl fishery predominates in Areas 018, 020 and 022, while target trawl fishing for flatfish taking GUR 3 is relatively more important in the more southerly east coast South Island statistical areas and in Southland (Figure 13A and Figure 13B). A barracouta target trawl fishery also takes gurnard in Area 022, which is also the statistical area where most of the target fishing for gurnard is taking place.

Table 16: Percent distribution of landings by target species (Table 11) from 1989–90 to 2010–11 for the bottom trawl and Danish seine methods for trips which landed GUR 3. Annual landings by method are available in Table 14; [–]: no landings in this cell.

Fishing											Target species	
Year	FLA	RCO	BAR	GUR	STA	TAR	ELE	WAR	SPO	SPD	SQU	OTH
	Bottom trawl distribution (%)											
89/90	30.5	28.3	12.1	13.5	5.4	3.1	2.3	0.5	0.0	1.2	0.2	2.9
90/91	37.5	24.1	11.6	14.3	6.7	2.7	1.0	0.7	0.1	0.1	0.1	1.2
91/92	27.4	41.1	8.9	3.2	9.8	5.5	1.4	1.0	0.1	0.0	0.0	1.4
92/93	28.3	49.6	6.9	5.3	5.3	1.3	0.6	0.2	0.0	0.5	0.1	1.9
93/94	28.9	53.7	3.2	3.1	5.8	3.1	0.6	0.1	0.0	0.0	1.1	0.3
94/95	24.5	57.4	6.5	4.4	3.6	1.4	1.0	0.0	0.1	0.1	0.7	0.3
95/96	29.6	47.8	9.1	3.4	4.9	2.6	1.0	0.1	0.0	0.4	0.5	0.6
96/97	27.5	56.6	7.1	1.3	2.2	3.0	0.5	0.2	0.2	0.2	0.5	0.8
97/98	33.9	47.3	9.7	0.7	2.1	3.7	0.1	1.2	–	0.0	0.6	0.7
98/99	49.0	31.8	7.4	1.9	3.6	3.2	0.3	0.8	0.0	0.0	1.0	0.8
99/00	43.5	32.2	9.4	3.1	7.5	1.3	0.1	1.3	0.0	0.2	0.4	1.0
00/01	33.4	41.9	7.9	4.9	4.1	5.3	0.4	0.5	0.0	0.0	0.3	1.3
01/02	30.8	26.7	13.5	7.3	8.6	5.4	1.3	1.8	0.1	0.8	1.1	2.6
02/03	25.9	26.1	25.9	8.3	3.7	2.8	2.0	4.6	0.0	0.0	0.3	0.4
03/04	32.4	27.7	13.9	6.0	9.4	4.1	4.4	0.9	0.2	0.0	0.3	0.8
04/05	32.0	23.6	8.7	6.4	10.4	4.7	3.8	8.5	0.1	0.9	0.3	0.6
05/06	24.6	26.2	6.7	9.9	9.8	7.5	3.6	8.7	0.0	1.7	0.8	0.5
06/07	28.6	18.4	11.4	11.6	6.3	10.6	4.8	5.9	0.0	1.1	0.6	0.7
07/08	36.6	22.2	10.3	7.3	5.0	6.5	7.3	3.3	0.1	0.6	0.2	0.5
08/09	39.0	16.7	9.3	9.8	6.1	6.7	8.8	1.7	0.6	0.6	0.1	0.6
09/10	36.9	13.0	9.8	11.3	8.3	7.8	7.9	2.0	0.8	0.9	0.1	1.2
10/11	35.3	10.9	9.0	12.8	9.3	6.7	7.6	4.0	1.1	0.3	0.1	2.8
Total	32.0	31.3	10.2	7.4	6.5	4.8	3.1	2.5	0.2	0.5	0.4	1.1
	Danish seine distribution (%)											
02/03	68.3	4.1	0.0	27.6	0.0	–	–	0.0	–	–	0.0	–
03/04	62.0	23.0	0.0	14.7	0.0	0.2	–	0.0	–	–	0.0	0.1
04/05	82.3	17.7	0.0	–	0.0	–	–	0.0	–	–	0.0	–
05/06	53.5	45.0	0.0	0.8	0.0	0.1	–	0.0	0.5	–	0.0	–
06/07	48.2	26.2	0.0	2.4	0.0	18.8	2.2	0.0	1.5	0.8	0.0	0.0
07/08	24.8	38.8	0.0	1.2	0.0	20.6	12.1	0.0	2.5	–	0.0	–
08/09	15.4	37.4	0.0	–	0.0	32.5	4.8	0.0	6.9	–	0.0	3.2
09/10	24.9	34.8	0.0	–	0.0	15.0	2.7	0.0	11.6	10.9	0.0	–
10/11	26.0	30.5	0.0	0.3	0.0	10.2	6.2	0.0	25.4	0.6	0.0	0.8
Total	33.4	32.8	0.0	1.8	0.0	16.0	4.6	0.0	8.4	2.3	0.0	0.7

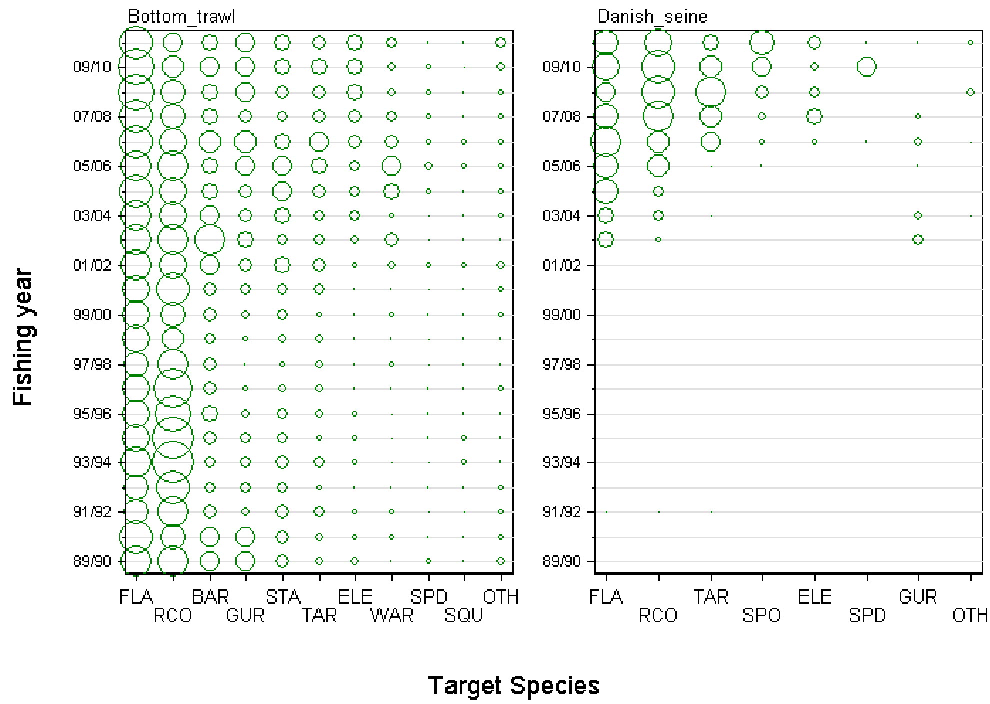

Figure 12: Total landings by target species (Table 11) and fishing year for the bottom trawl method based on trips which landed GUR 3. Circle sizes are proportional in each panel: [bottom trawl] largest circle 391 t in 1994–95 for RCO; [Danish seine]: largest circle 60 t in 2009–10 for RCO.

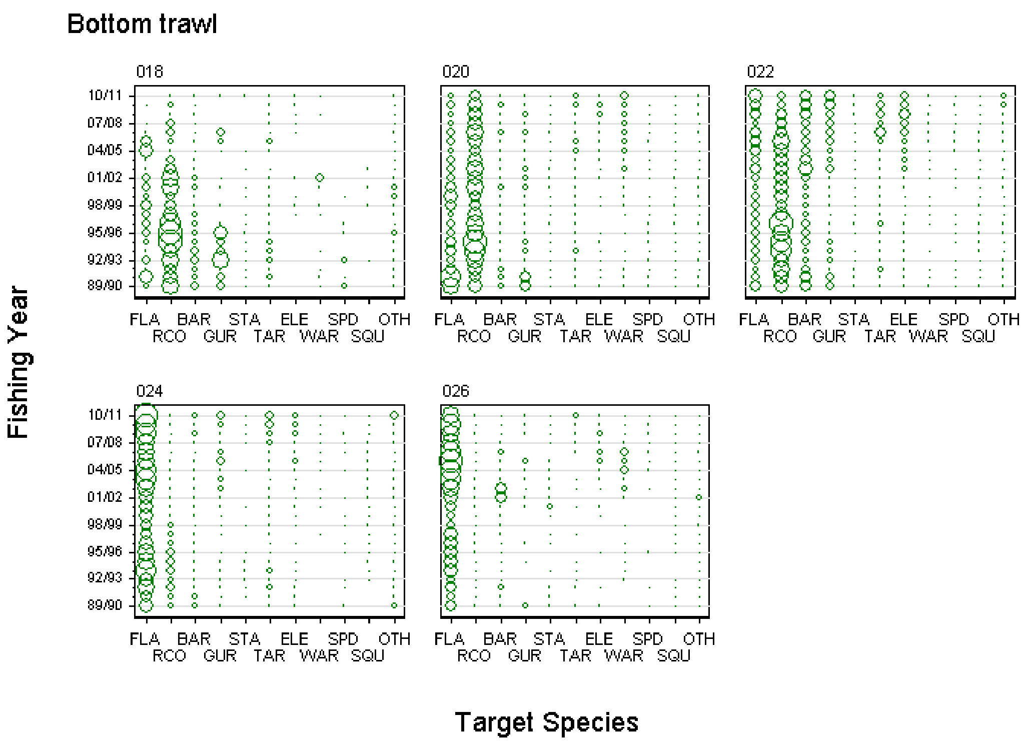

Figure 13A: Distribution of landings for the bottom trawl method for the first five grouped statistical areas by target species (Table 11) and fishing year from trips which landed GUR 3. Circle sizes are proportional within each panel: maximum values: 018 (15 t in 1994–95 for RCO); 020 (163 t in 1994–95 for RCO); 022 (245 t in 1996–97 for RCO); 024(56 t in 2010–11 for FLA), 026 (52 t in 2005–06 for FLA).

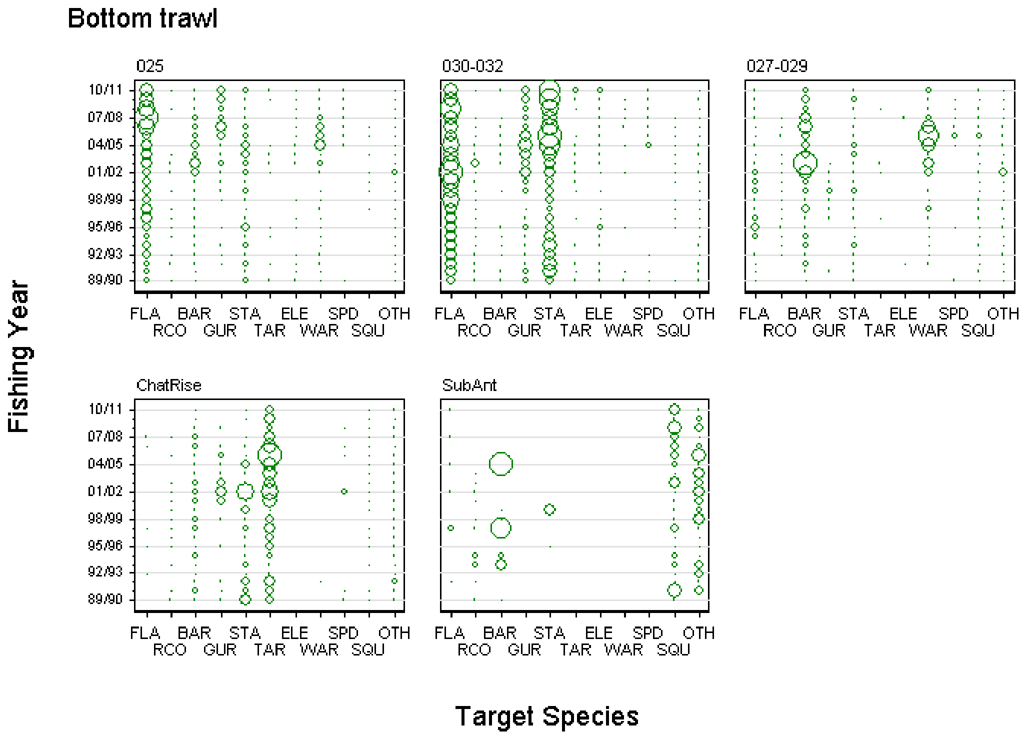

Figure 13B: Distribution of landings for the bottom trawl method by grouped statistical area for target species (Table 11) and fishing year from trips which landed GUR 3. Circle sizes are proportional within each panel: maximum values: 025 (124 t in 2007–08 for FLA), 030–032 (75 t in 2001–02 for FLA) and 027-029 (51 t in 2002–03 for BAR); ChatRise (42 t in 2005–06 for TAR); SubAnt (0.5 t in 2004–05 for BAR).

2.4.4 Preferred bottom trawl fishing depths for gurnard

Prior to the introduction of the TCER form in October 2007, depth information was only available from TCEPR forms. NCELR forms, although by individual set, do not record depth information. The TCEPR and TCER forms provide tow-by-tow information for the depth of capture of red gurnard from those tows where red gurnard were either declared as the target species or there was an estimated catch of red gurnard recorded for the tow. A summary of these reports stratified by the declared target species showed that red gurnard in GUR 3 are mainly taken between 16 and 110 m of depth, with mean and median values between 45 and 50 m (Table 17).

The depth distribution of tows which caught or targeted red gurnard in GUR 3 showed differences between fisheries which reflected the preferred depth range for each declared target species. For instance, the target red cod and barracouta fisheries appear to take red gurnard at shallower depths than the tarakihi and stargazer bottom trawl fisheries, which is likely to be a function of how the fishery operates on its target species (Figure 14). At the shallow extreme, the target flatfish fishery in QMA 3 operates in a similar, but possibly more shallow, depth range to the target red gurnard fishery. There appears to be a seasonal component to the depths fished, with an apparent shift to a deeper depth range for GUR in the months of July-September for BAR, TAR (Figure 15A), STA, ELE, GUR and WAR (Figure 15B, Table 18). This shift may reflect a shift in the target species depth distribution in these months rather than the GUR depth distribution, but it could be either, with only FLA showing no shift in depth distribution amongst the eight species investigated (Table 18).

Table 17: Annual summary statistics from distributions of bottom depth from bottom trawl TCER and TCEPR records for effort that targeted or caught red gurnard by target species category in valid statistical areas for GUR 3. This table is based on all tows in the dataset (1989–90 to 2010–11).

		Depth (m)			
Target species category	Number of observations	Lower 5% of distribution	Mean of distribution	Median (50%) of distribution	Upper 95% of distribution
Bottom trawl					
FLA	22 641	14	35	34	63
RCO	7 037	21	50	48	83
BAR	5 576	28	66	55	111
TAR	3 870	40	83	80	150
STA	2 831	29	87	80	150
ELE	2 255	13	33	30	60
GUR	1 528	18	43	40	78
WAR	1 508	38	73	80	111
SPD	378	28	68	65	127
SPO	206	12	27	25	57
Other	766	15	86	89	180
Total	48 596	16	50	45	110

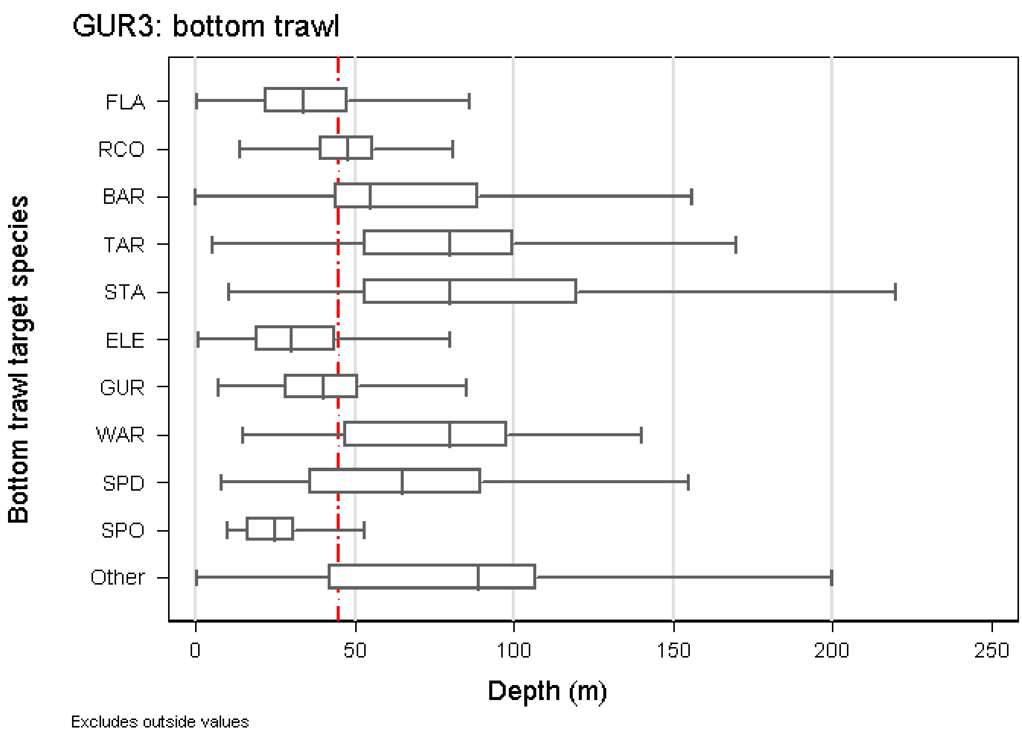

Figure 14: Box plot distributions of depth from combined bottom trawl TCEPR and TCER records for tows that targeted or caught gurnard by target species category in statistical areas valid for GUR 3 between 1989–90 to 2010–11. Horizontal line indicates the median depth from all tows which caught or targeted red gurnard.

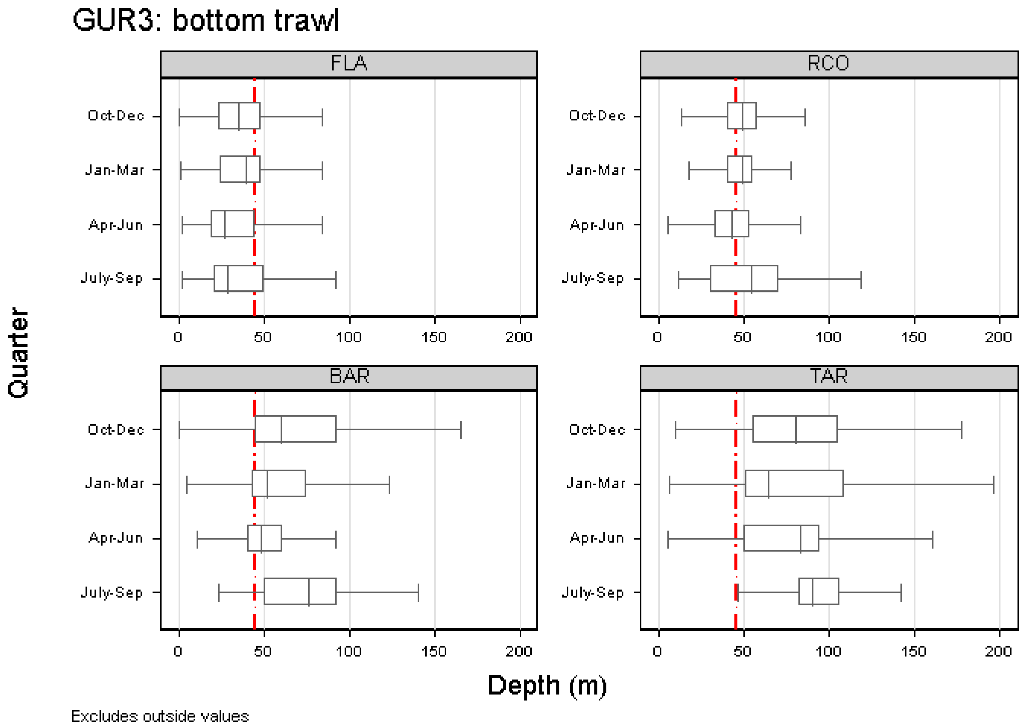

Figure 15A: Box plot distributions showing quarterly depth distributions from bottom trawl TCEPR and TCER records for tows that targeted or caught red gurnard by the four major target species categories in statistical areas valid for GUR 3 between 1989–90 to 2010–11. Vertical line indicates the median depth from all tows which caught or targeted red gurnard.

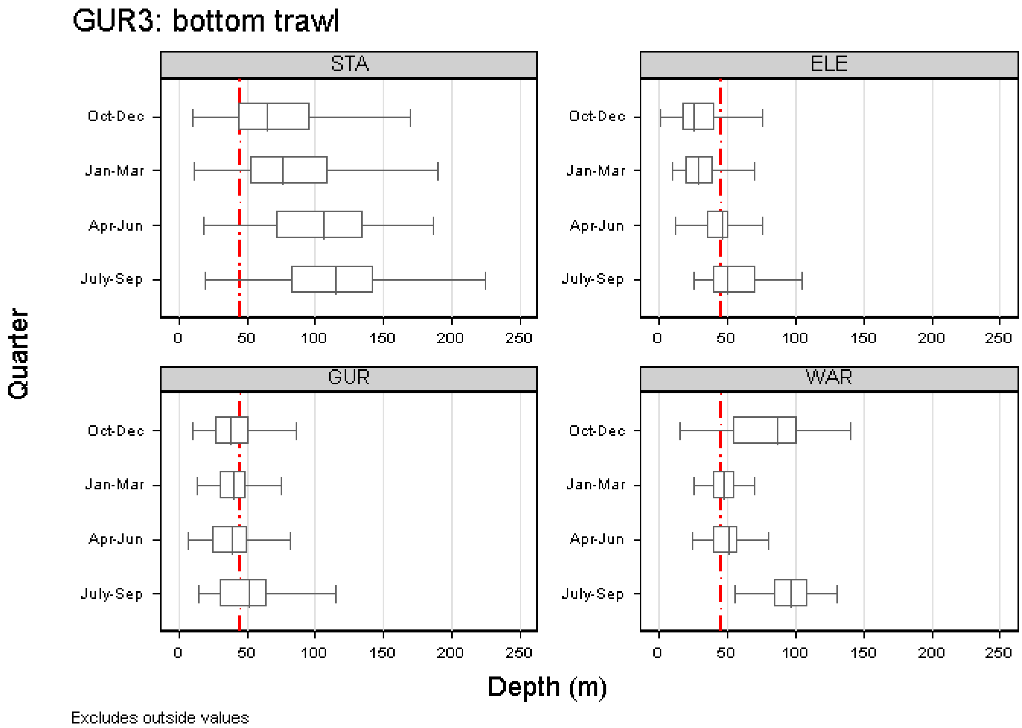

Figure 15B: Box plot distributions showing quarterly depth distributions from bottom trawl TCEPR and TCER records for tows that targeted or caught red gurnard by the fifth to eighth target species categories in statistical areas valid for GUR 3 between 1989–90 to 2010–11. Vertical line indicates the median depth from all tows which caught or targeted red gurnard.

Table 18: Quarterly summary statistics from distributions of bottom depth from bottom trawl TCER and TCEPR records for effort that targeted or caught red gurnard for the top eight target species categories with the greatest number of depth observations in valid statistical areas for GUR 3. This table is based on all tows in the dataset (1989–90 to 2010–11). Annual totals can be found in Table 17.

					Depth (m)
Target species and quarter	Number of observations	Lower 5% of distribution	Mean of distribution	Median (50%) of distribution	Upper 95% of distribution
FLA					
Oct-Dec	6 350	15	36	35	65
Jan-Mar	6 774	16	37	39	60
Apr-Jun	4 680	11	32	27	61
July-Sep	4 837	13	35	29	65
RCO					
Oct-Dec	2 227	20	51	49	85
Jan-Mar	2 648	30	51	49	80
Apr-Jun	1 804	20	45	43	78
July-Sep	358	15	53	54	101
BAR					
Oct-Dec	3 162	27	69	60	110
Jan-Mar	1 352	28	61	52	109
Apr-Jun	756	26	58	48	118
July-Sep	305	30	79	76	160
TAR					
Oct-Dec	732	38	83	80	140
Jan-Mar	1 698	40	81	64	150
Apr-Jun	883	38	80	83	140
July-Sep	556	45	97	90	170
STA					
Oct-Dec	1 021	28	75	65	140
Jan-Mar	1 030	25	81	76	135
Apr-Jun	331	45	102	106	155
July-Sep	449	58	115	115	170
ELE					
Oct-Dec	1 325	12	30	25	54
Jan-Mar	623	15	31	29	53
Apr-Jun	185	21	44	46	68
July-Sep	122	32	55	50	90
GUR					
Oct-Dec	496	16	40	39	70
Jan-Mar	484	18	42	40	75
Apr-Jun	380	18	40	40	65
July-Sep	168	20	58	52	143
WAR					
Oct-Dec	1 043	40	81	87	112
Jan-Mar	373	36	50	48	87
Apr-Jun	36	32	53	51	92
July-Sep	56	62	96	97	120

3. STANDARDISED CPUE ANALYSIS

Two fisheries were selected for monitoring GUR 3 when this Fishstock was last reviewed by the AMP Working Group (Ministry of Fisheries 2011). That review made the following recommendations:

- Separate CPUE analyses north and south of the Banks Peninsula (as recommended in 2008) showed virtually identical trends. For this review, analyses were therefore redone for all valid statistical areas combined.

- The BT(FLA) and BT(MIX) targeted indices across all valid statistical areas should be the main CPUE indices calculated for this stock in future. Statistical area should be an explanatory variable in the standardised models, and effects of (Area * Year) interaction checked to make sure that the indices are not diverging.
- The [Working Group] again recognised the substantial amount of data available for this fishery, and noted that a stock assessment should be feasible. Close correspondence between indices in all areas indicate that such an assessment should be for a single GUR3 stock including all areas north and south of the Banks Peninsula and in Foveaux Strait.
- It would be useful in future reviews (for all stocks) to have a brief section on regulatory history and key operational changes that may have altered targeting, reporting, catch rates, efficiency and selectivity.

The CPUE series defined for this report were:

a) **BT (MIX): East coast and south coast, South Island, mixed species bottom trawl –** GUR 3 bottom single trawl in Statistical Areas 018, 020, 022, 024, 026, 025, and 030, target RCO, STA, BAR, TAR GUR;

b) **BT (FLA): East coast and south coast, South Island, flatfish bottom trawl –** GUR 3 bottom single trawl in Statistical Areas 018, 020, 022, 024, 026, 025, and 030, target FLA.

Data were prepared in the manner as described in Section 2.4.1 and Appendix Section E.2.1. The analytical methods used can be found in Appendix Section E.2.2. Detailed results are presented for each of the above CPUE series in Appendix E and the diagnostics can be found in Appendix F. In addition, a third series was prepared as a sensitivity to test for the effects of switching from a daily formtype (CELR) to the tow-by-tow formtype (TCER) (Appendix G.1):

c) **BT (MIX)-trip: East coast and south coast, South Island, mixed species bottom trawl, trip stratum –** GUR 3 bottom single trawl in Statistical Areas 018, 020, 022, 024, 026, 025, and 030; this dataset consisted of trips which targeted any of TAR, GUR, STA, BAR, RCO at least once, which then qualified the complete trip. These trips were amalgamated to the level of a statistical area, which effectively created a trip level data set because few trips would enter more than one statistical area within the period of a trip.

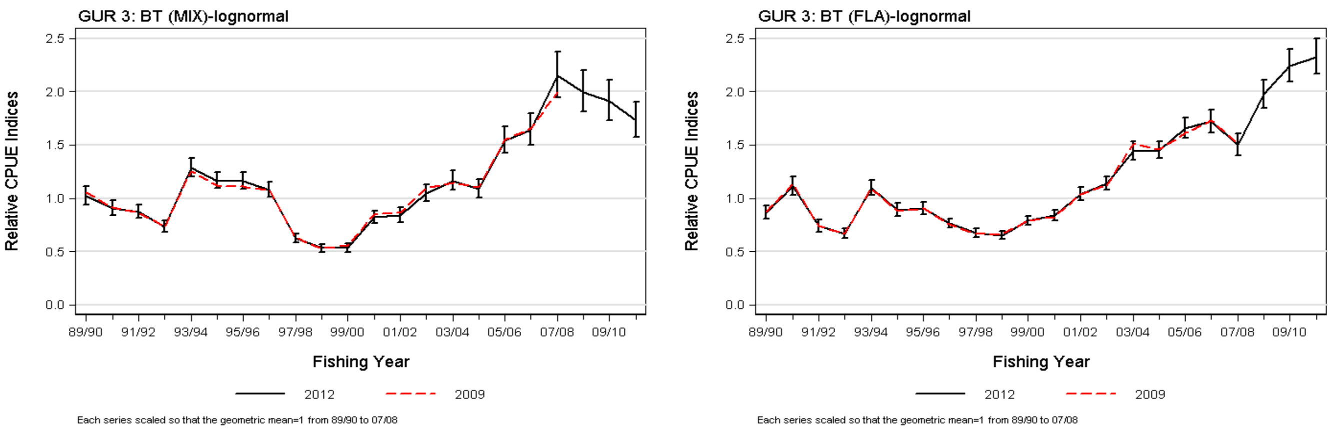

Figure 16: Comparison of 2009 standardised CPUE analyses with those prepared for this report: [left panel]: BT (MIX) mixed species east coast and south coast South Island bottom trawl fishery; [right panel]: BT (FLA) flatfish target east coast and south coast South Island bottom trawl fishery. Each series is based on an assumed lognormal distribution and error bars show plus or minus two Standard Errors.

There is good agreement between the two final series accepted by the 2009 AMP review (see quotation above from Ministry of Fisheries 2011) and the series generated for this report (Figure 16). This comparison is complicated by the fact that a different distributional assumption has been made for this analysis compared to the lognormal assumption made in 2009. Consequently the comparisons made in Figure 16 are made using regressions based on the lognormal distribution, not the Weibull distribution that was selected for the 2012 analysis.

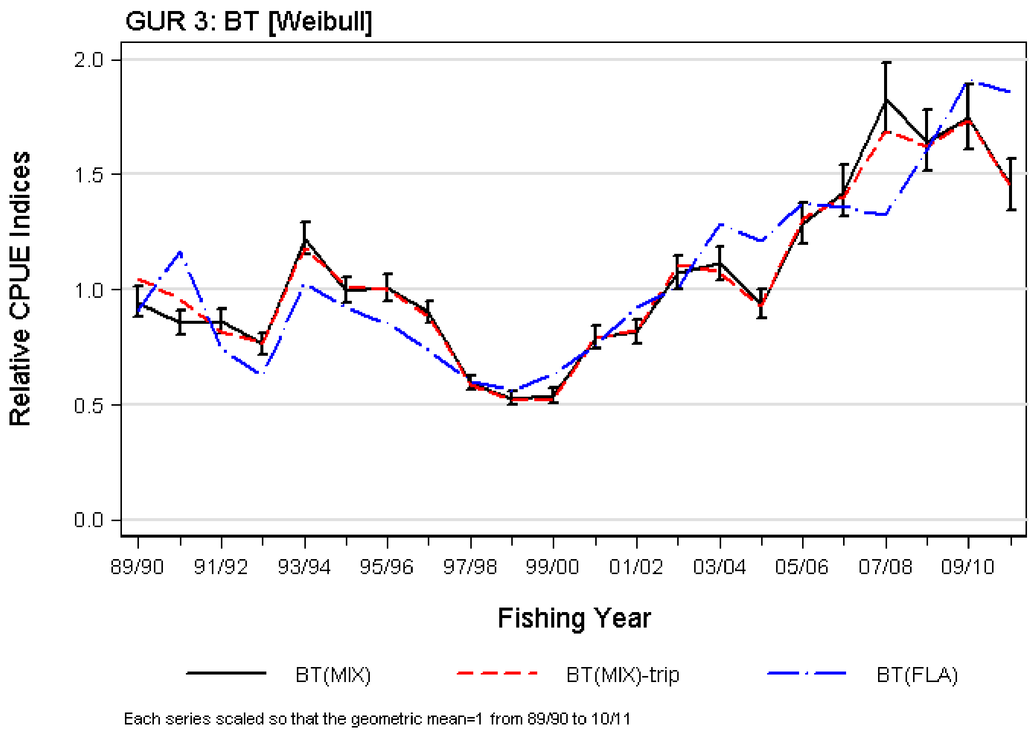

Figure 17: Comparison of two 2012 BT (MIX) standardised CPUE analyses with the BT (FLA) analysis: a) the BT (MIX) and the BT (FLA) are "trip-stratum" based analysis and b) BT (MIX)-trip analysis uses data rolled up to the level of an effective trip. Each series is based on an assumed Weibull distribution and error bars show plus or minus two Standard Errors.

There is almost no difference between the BT (MIX) series based on the trip-stratum level of amalgamation and an analysis using the same data but with an amalgamation to the level of a "trip", showing that the change to the TCER form type from the 2007–08 fishing year did not have much effect on this estimated CPUE trend (Figure 17). Finally, the comparison between the two models [BT (MIX) and BT (FLA)] indicates that the two series may be diverging, although they both show fairly strong increasing trends since the early 2000s (Figure 17). The BT (MIX) series may have peaked in the year of the last review (2007–08), with a small declining trend evident since then. On the other hand, the BT (FLA) series has continued to rise up to the 2009–10 fishing year and has then levelled off.

4. TRAWL SURVEY ABUNDANCE INDICES

4.1 Winter RV *Kaharoa* surveys

The time series of east coast South Island winter (May-June) trawl surveys (Beentjes & Stevenson 2000) conducted by the RV *Kaharoa* showed highly variable biomass indices for red gurnard over the period 1991 to 1996 (Table 19; Figure 18). This survey had moderate to high c.v.s (range 27 to 40%) and it was uncertain at the time how well it was capable of monitoring gurnard. This survey covered an area from Shag Point (near Moeraki) in the south to the Waiau River (south of Kaikoura) in the north. It covered bottom depths from 30 m to 400 m between these landforms with the exception of untrawlable grounds. This survey was suspended in 1996 and replaced with a summer design covering the same area.

Table 19: Total and recruited biomass indices with survey coefficients of variation (c.v.) for red gurnard from the east coast South Island winter (May–June) trawl surveys. Data are from Beentjes & Stevenson (2000, 2008, 2009) and Beentjes et al. (2010). Corrected 1994 survey estimate from M. Stevenson (NIWA *pers. comm.*). Recruited biomass estimates include gurnard greater than 30 cm fork length.

Year	Trip code	Number stations	Number + stations[3]	Total Biomass (t)	c.v. (%)	Recruited Biomass (t)	c.v. (%)
1991	KAH9105	55	23	763	40	744	40
1992	KAH9205	80	21	142	30	120	30
1993	KAH9306	74	22	576	31	551	31
1994 [1]	KAH9406	100	31	123	34	121	34
1996	KAH9606	118	37	505	27	496	27
2007 [2]	KAH0705	94	34	1 453	35	1 155	35
2008 [2]	KAH0806	96	43	1 309	34	1 209	33
2009 [2]	KAH0905	87	39	1 725	30	1 663	30

[1] these biomass estimates differ from those in Beentjes & Stevenson (2000) due to the exclusion of four tows with usability code >2

[2] excludes shallow 10–30 m strata for comparability to the earlier winter surveys

[3] number tows with gurnard present

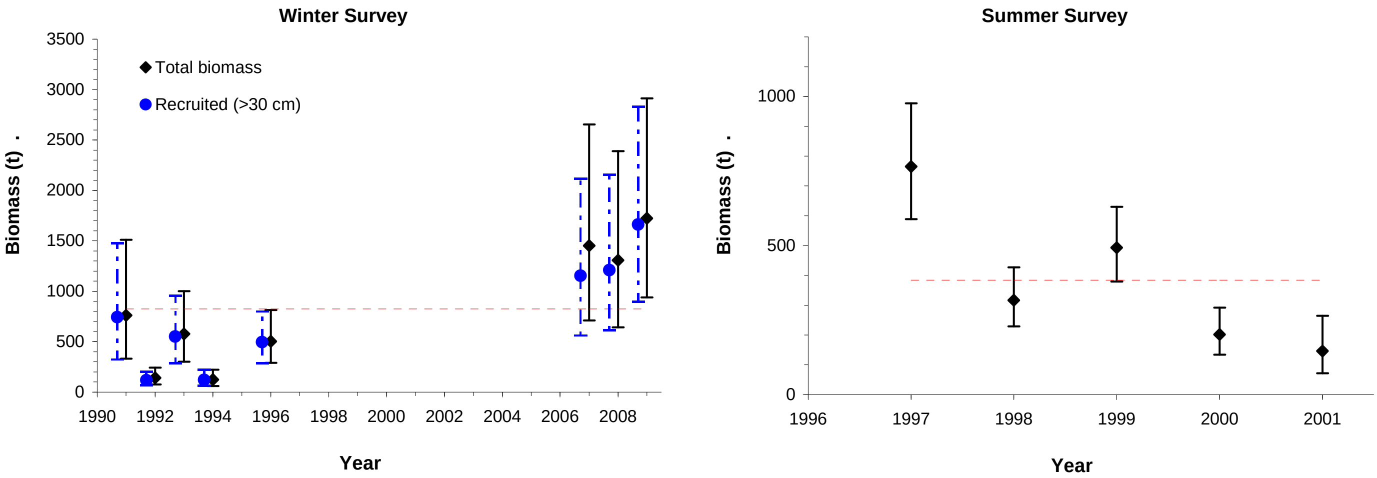

Figure 18: Total and recruited biomass indices for red gurnard from the east coast South Island winter (May–June) trawl surveys [left panel]. Total biomass indices for red gurnard from the east coast South Island summer (December–January) trawl surveys [right panel]. Approximate 95% confidence intervals are estimated from the survey c.v.s assuming a lognormal distribution. Horizontal dotted line indicates mean total biomass from each survey

Table 20: Relative biomass indices (t) and coefficients of variation (c.v.) for red gurnard from the east coast South Island summer (December–January) trawl surveys. 1996–97 to 1999–2000 data are from Beentjes & Stevenson. (2001) and the 2000–01 estimate from Stevenson & Beentjes (2002).

Year	Trip Code	Biomass (t)	c.v.
1996–97	KAH9618	765	13%
1997–98	KAH9704	317	16%
1998–99	KAH9809	493	13%
1999–00	KAH9917	202	20%
2000–01	KAH0014	146	34%

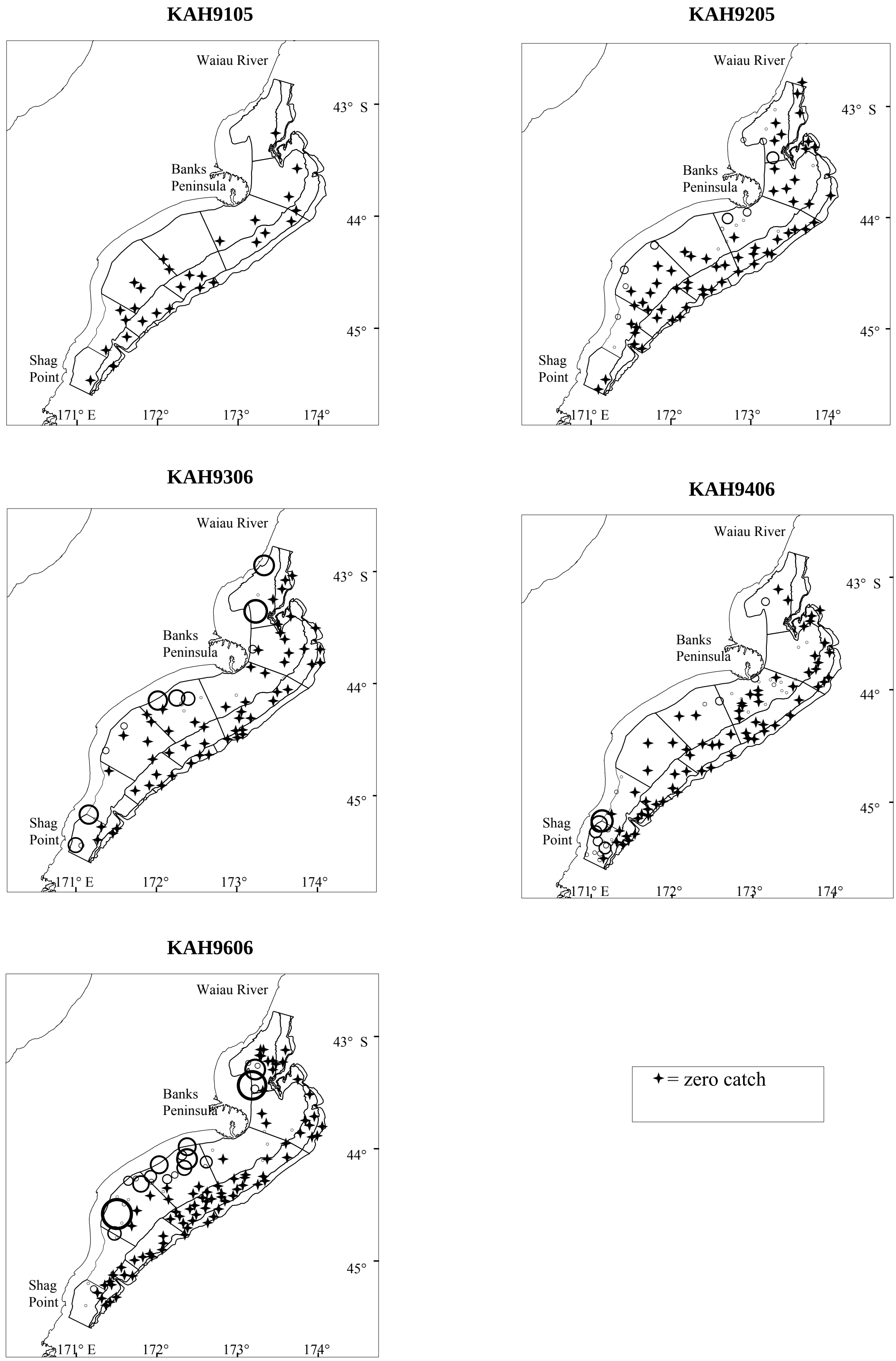

Figure 19A: Maps (Stevenson *pers. comm.*) showing the location of all tows for the first five winter east coast South Island RV *Kaharoa* surveys (Table 19) with the tows taking red gurnard indicated by circles proportional to the density of the tow (maximum circle size for all panels is 475 kg/km^2).

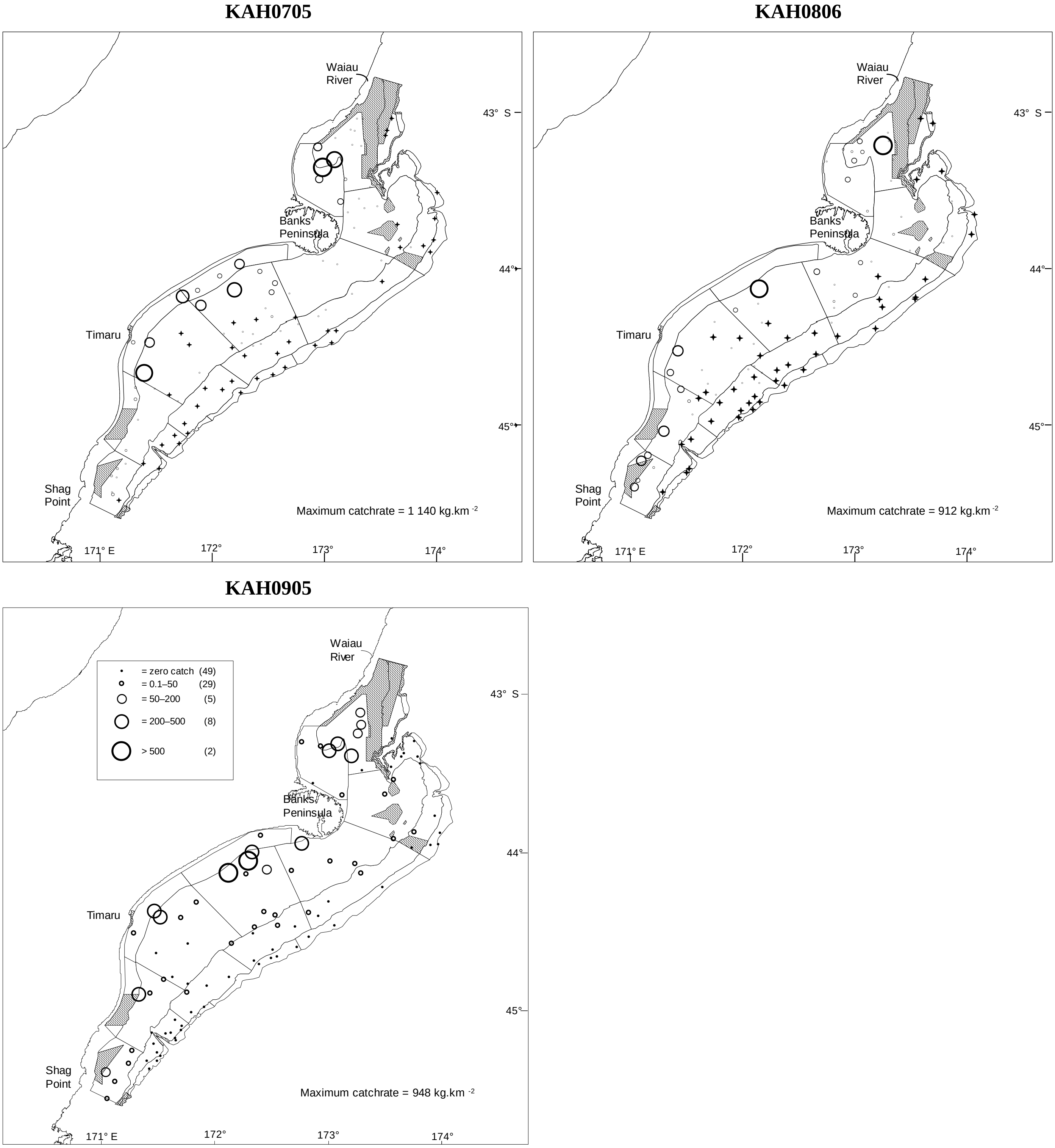

Figure 19B: Maps (Stevenson *pers. comm.*) showing the location of all tows for the resumed series of winter east coast South Island RV *Kaharoa* surveys (Table 19) with the tows taking red gurnard indicated by circles proportional to the density of the tow as indicated in each panel. Note that the shallow 10–30 m strata are shown but were not included in the biomass estimates.

The winter survey was resumed in May 2007 for reasons described in Section 4.2.1 and was repeated in May-June of 2008 and 2009. Results for these resumed surveys appear to be consistent with the previous surveys, both in terms of estimated biomass levels and c.v.s (Table 19; Figure 18). Plots of the locations of tows which captured red gurnard are presented by survey in Figure 19A (five early surveys) and Figure 19B (resumed 2007, 2008 and 2009 surveys).

4.2 Summer RV *Kaharoa* surveys

The winter survey described in the previous section was replaced in 1996 by a summer survey directed at red gurnard, among other species (Beentjes & Stevenson 2001). Additional shallow water (10 m to 30 m) strata were added to the design from Cape Wanbrow in the south to the Kowai River in the north. These new strata are within the area covered by the previous winter survey and were added to improve the coverage of elephantfish and red gurnard. This survey was initiated in December 1996 and was repeated in each year up to December 2000–January 2001. A review of the survey design by the Inshore Fishery Assessment Working Group (IFAWG) in March 1997 concluded that this survey was likely to be suitable for monitoring red gurnard.

Biomass indices for red gurnard for the summer survey appeared to be highly variable (Table 20). Coefficients of variation were generally lower than for the winter survey, but the summer survey appeared to be affected (at least in some years) by an apparent changing catchability due to variation in weather conditions between years. The general trend in the indices presented in Figure 18 is downward, but this observation may have been the result of changing catchability for a number of species and was not consistent with how red gurnard was being observed in the wider fishery (Figure 17). An analysis by Francis et al. (2001) indicated that this survey, along with the east coast survey on the east coast of the North Island (which was also discontinued), had the greatest amount of variation between years across all the species surveyed. This was interpreted as an indication that the assumption of constant average catchability between years (which underlies every trawl survey) may not be correct.

4.2.1 Resumption of the winter series of east coast South Island trawl surveys

The IFAWG agreed at a meeting held on 27 March 2001 that the current summer east coast South Island trawl survey was not reliably monitoring many of the fish populations in FMA 3 and that it would be discontinued (WG-INSHORE-01/29). This was due to the apparent patterns of changing catchability between survey years (discussed in previous paragraph and in Francis et al. [2001]). Analysis of the existing data for both the winter and summer trawl surveys (Francis & Horn 2005) led to the decision to resume the winter series of east coast South Island trawl surveys, beginning in May 2007. This decision was based on the reasoning that the resumed series would be comparable to five earlier surveys conducted from 1991 to 1996, thus allowing for long-term comparisons for a range of species in this important fishery (Table 19).

4.3 Trawl Survey Biological Data

4.3.1 Age Distributions

Scaled age frequency distributions from 1992 to 1994 from the east coast South Island winter trawl survey show the progression of the strong 1991 year class which first entered the fishery in 1992 as a 1+ cohort (Sutton 1997; Figure 20). These age compositions must be considered uncertain due to the small sample size of otoliths. However, the presence of a strong 1991 year class may provide a partial explanation of the high CPUE observed in 1994 (as this year class recruited fully into the fishery). The relative drop in CPUE since that period in the middle 1990s may be because no subsequent large year classes have appeared.

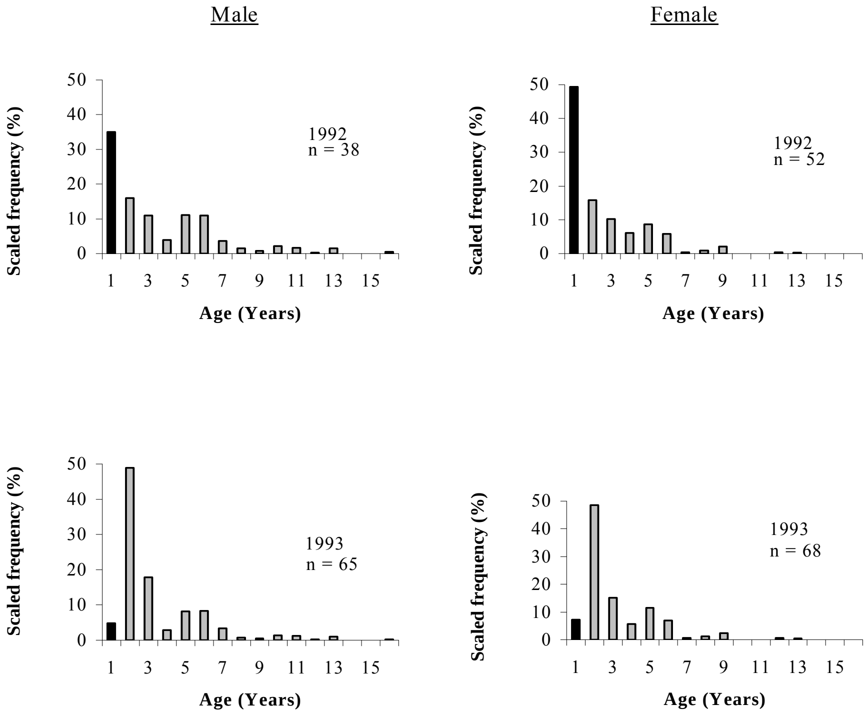

Figure 20: Scaled age frequency histograms for male and female red gurnard surveyed from the east coast of the South Island in May-June 1992 and 1993. Year and number of otoliths read (n) are shown on the histograms. The black bars illustrate the progression of strong year classes. Data from Sutton (1997).

Table 21: Number of otoliths aged and the number of trawls sampled from the summer RV *Kaharoa* trawl surveys.

Trip code	Number of trawls	Sex: Female	Male	Unknown	Total
kah9606	28	32	38		70
kah9618	55	116	84		200
kah9704	40	93	68	7	168
kah9809	42	120	102	1	223
kah9917	48	109	89		198
kah0014	12	120	90		210
Total	225	590	471	8	1069

The number of otoliths available from the summer RV *Kaharoa* trawl surveys are provided in Table 21. There are not many samples and the calculated age frequency distributions do not show clear patterns of abundance or strong year classes.

4.3.2 Winter RV *Kaharoa* surveys length distributions

Scaled numbers at length for gurnard by sex from the winter series of east coast South Island trawl surveys show growth between years (particularly from 2007), with one survey (KAH9205) showing a bimodal distribution created by incoming recruits (Figure 21A, Figure 21B). Cumulative plots of the proportion by length show some progression between the survey years, with 1992 showing the effect of the bimodality (Figure 22). The three recent surveys appear to have distributions which consist of small fish, lying to the left of the most of the other distributions. The remaining surveys progress to larger mean sizes, with the 1994 and 1996 surveys showing the largest sizes, which would be consistent with the decline in the fishery which started following the 1996–97 fishing year. The survey years with the smallest mean lengths are 1992 and 2007 (Table 22).

4.3.3 Summer RV *Kaharoa* surveys length distributions

Summarised length frequency data for gurnard by sex from the summer series of east coast South Island trawl surveys appear to be even more variable between years than the winter surveys (Figure H.1). KAH9704 shows very few fish with a small mode of young fish, while KAH9809 is bimodal, with large numbers of both small and large fish. It does not seem probable that these two consecutive surveys were monitoring the same population randomly.

Table 22: Number measured and mean length (cm) of female and male gurnard for each of the winter surveys of the east coast South Island.

	Number measured		All fish		Fish ≥ 30 cm F.L.	
Year	Female	Male	Female	Male	Female	Male
1991	224	199	39.1	37.8	40.3	38.4
1992	236	137	31.8	33.0	41.7	39.0
1993	448	500	36.9	34.7	37.8	35.6
1994	164	165	40.4	38.0	40.6	38.5
1996	355	583	39.4	36.2	39.9	36.6
2007	557	931	32.4	31.5	36.2	34.3
2008	756	721	36.9	33.3	38.1	34.8
2009	767	875	37.2	33.5	38.0	34.6

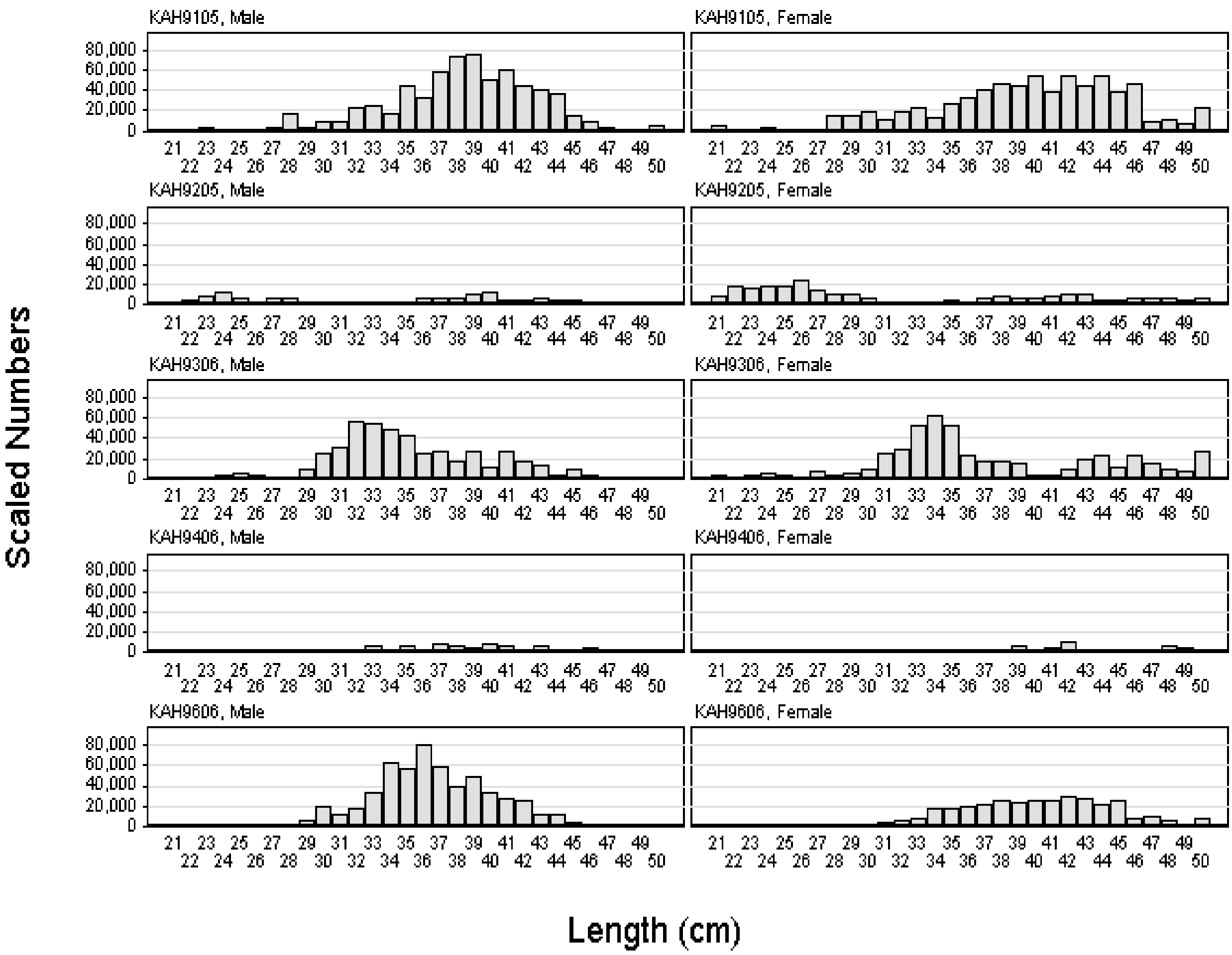

Figure 21A: Scaled numbers (relative to survey density) of gurnard (combined 30–400 m strata) by sex and length for the winter east coast South Island trawl surveys from 1991 to 1996. Data have been binned into 1 cm length classes.

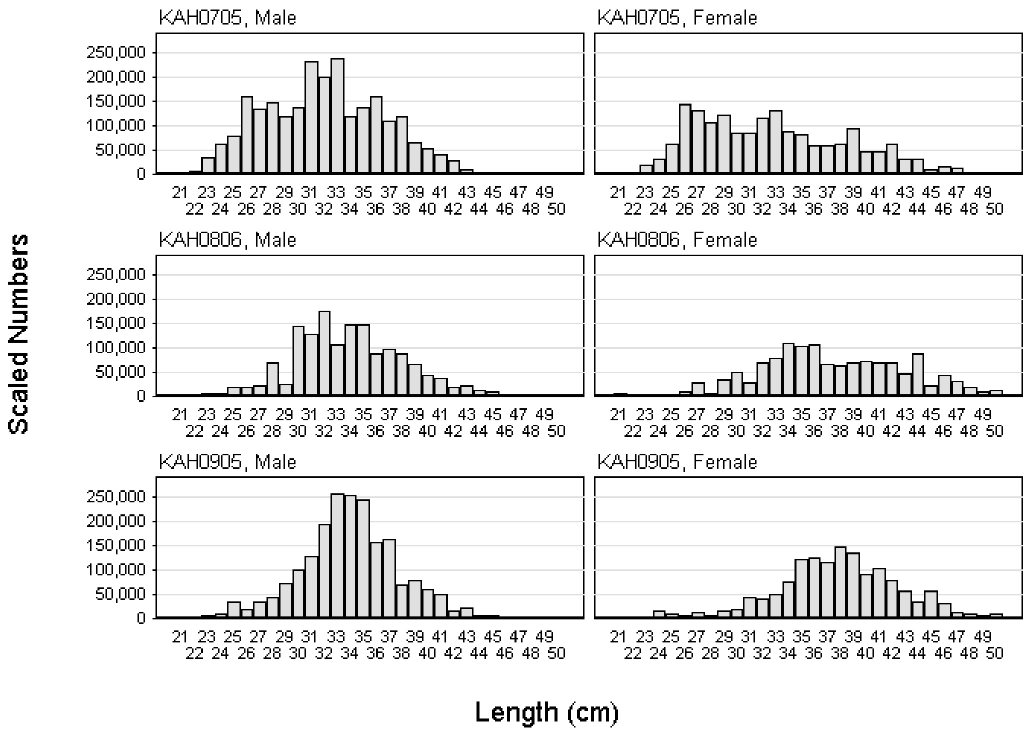

Figure 21B: Scaled numbers (relative to survey density) of gurnard (combined 30–400 m strata) by sex and length for the winter east coast South Island trawl surveys from 2007 to 2009. Data have been binned into 1 cm length classes.

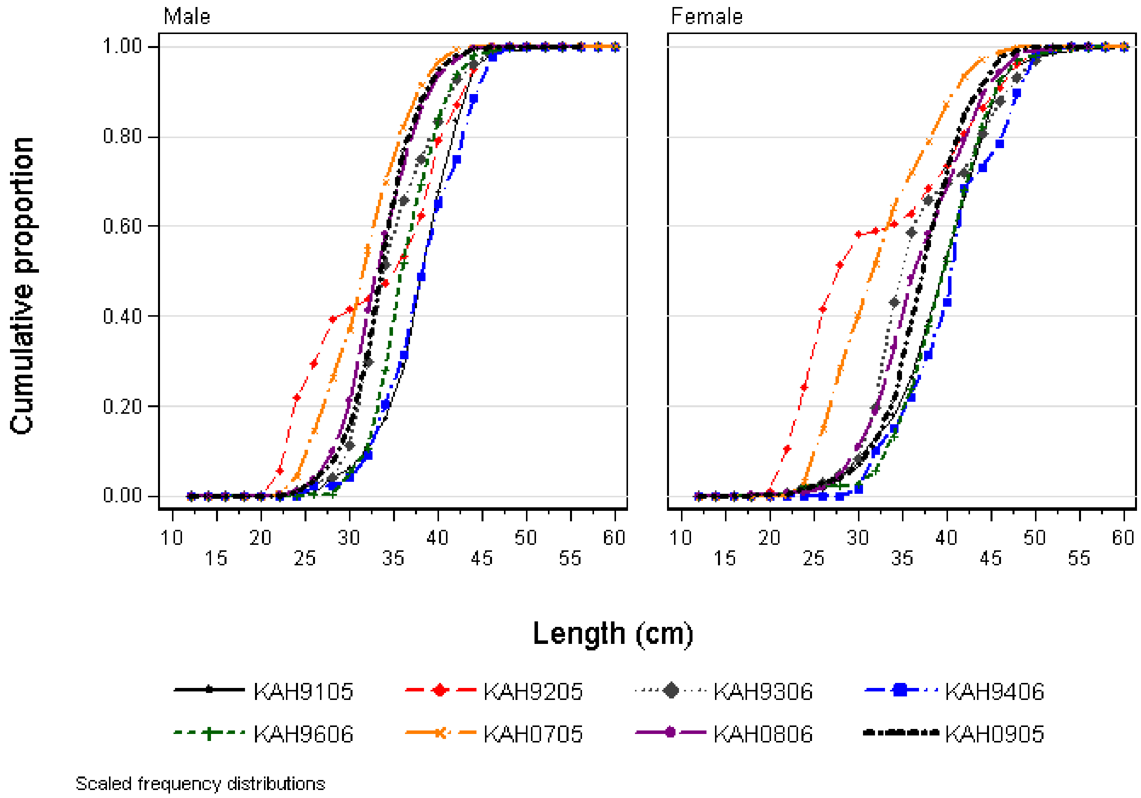

Figure 22: Cumulative scaled length frequencies for gurnard (combined 30-400 m strata) for each sex for the winter east coast South Island trawl surveys from 1991 to 1996 and 2007 to 2009.

4.4 Comparison of available biomass indices for GUR 3

Figure 23 plots the available index series for GUR 3 (winter surveys, summer surveys and the BT (MIX) and BT (FLA): Figure 17). It also plots the QMR landings on the same relative scale. The CPUE indices pass through the centre of both the summer and winter series but are less variable than either of the two survey series (Figure 23). There is consistency between the two CPUE series, the index derived from the QMR catches and the winter survey series. The summer series is inconsistent with all of the other series.

The large between year variations in the biomass estimates for gurnard in the winter series of biomass indices from the 1990s, along with the contradictory declining trend estimated by the summer series (Figure 18; Figure 23), indicate that the survey catchability for this species may vary for reasons other than fish abundance, particularly for the summer series. The instability in the summer survey sampled length frequency distributions (Figure H.1) indicates that there are likely to be annual variations in catchability which are undesirable for monitoring this population. Given this high level of interannual variability, it would seem that continued monitoring using commercial catch and effort data is also required for this Fishstock.

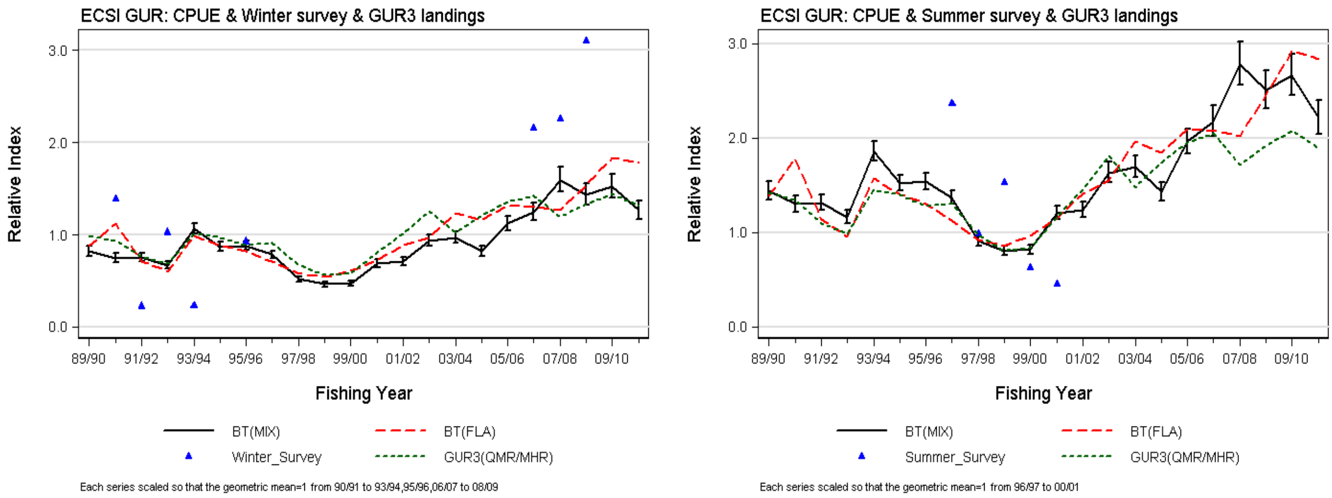

Figure 23: Comparison of the available GUR 3 biomass indices: 1989–90 to 2010–11. Plots include the indices of total survey biomass (winter or summer), the non-zero BT (MIX) and BT (FLA) CPUE indices (Figure 17) and the total GUR 3 QMR/MHR landings. Each series has been plotted relative to the geometric mean of the years shown at the bottom of each graph panel.

5. SUMMARY

The available information points to a Fishstock which is presently in a period of apparent high abundance. There is no information available about how long this situation may last, apart from the observation that the 2007 survey had much smaller fish than the succeeding surveys (Figure 21B). This may be indicative of a recruitment pulse which is passing through this Fishstock and which may be responsible for the current high level in the BT (FLA) fishery (Figure 17).

6. ACKNOWLEDGEMENTS

This work was funded by the stakeholders in the South East Finfish Management Company Limited. We thank the MPI Information & Data Management team for providing the catch/effort data in a timely manner and Mike Stevenson (NIWA) for providing additional survey estimates.

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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**
AMP & AMP WG	Adaptive Management Programme, also the AMP Working Group: MPI Fishery Assessment Working Group charged with evaluation of the progress of these projects
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.4 for an example) (Bentley et al. 2011)
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
destination code	code indicating how each landing was directed after leaving vessel (see Table 6)
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 gurnard 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 form type)
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 gurnard and other NZ finfish
IFAWG	MPI Inshore Fishery Assessment Working Group: no longer active; replaced by the SINSWG (South Island) and North Island Inshore Working Group
landing event	weight of gurnard off-loaded from a vessel at the end of a trip. Every landing has an associated destination code and there can be multiple landing events with the same destination code 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 (formerly the Ministry of Fisheries)
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 gurnard management (see Appendix B)
QMR	Quota Management Report: monthly harvest reports submitted by commercial fishermen to the Ministry for Primary Industries. 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
SEFMC	Southeast Finfish Management Company Ltd: industry group representing stakeholders in GUR 3

Term/Abbreviation	Definition
SINSWG	MPI Southern Inshore Working Group
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 a gurnard QMA which are identified in catch/effort returns. The boundaries for these statistical areas do not always coincide with the QMA 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 Appendix E and Appendix G

Code	Definition	Code	Description
BLL	Bottom longlining	BAR	Barracouta
BPT	Bottom trawl—pair	BCO	Blue Cod
BS	Beach seine/drag nets	BNS	Bluenose
BT	Bottom trawl—single	BYX	Alfonsino & Long-finned Beryx
CP	Cod potting	ELE	Elephant Fish
DL	Drop/dahn lines	FLA	Flats
DS	Danish seining—single	GSH	Ghost Shark
HL	Handlining	GUR	Gurnard
MW	Midwater trawl—single	HOK	Hoki
RLP	Rock lobster potting	HPB	Hapuku & Bass
SLL	Surface longlining	JDO	John Dory
SN	Set netting (including Gill nets)	JMA	Jack Mackerel
T	Trolling	KIN	Kingfish
TL	Trot lines	LIN	Ling
		MOK	Moki
EN	East Northland	RBY	Ruby Fish
BoP	Bay of Plenty	RCO	Red Cod
ECNI	East Coast North Island	RSN	Red Snapper
ECSI	East Coast South Island	SCH	School Shark
WCNI	West Coast North Island	SCI	Scampi
		SKI	Gemfish
		SNA	Snapper
		SPD	Spiny Dogfish
		SPE	Sea Perch
		SQU	Arrow Squid
		STA	Giant Stargazer
		SWA	Silver Warehou
		GUR	Gurnard
		TRE	Trevally
		WAR	Blue Warehou

Appendix B. MAP OF MINISTRY FOR PRIMARY INDUSTRIES STATISTICAL AND MANAGEMENT AREAS

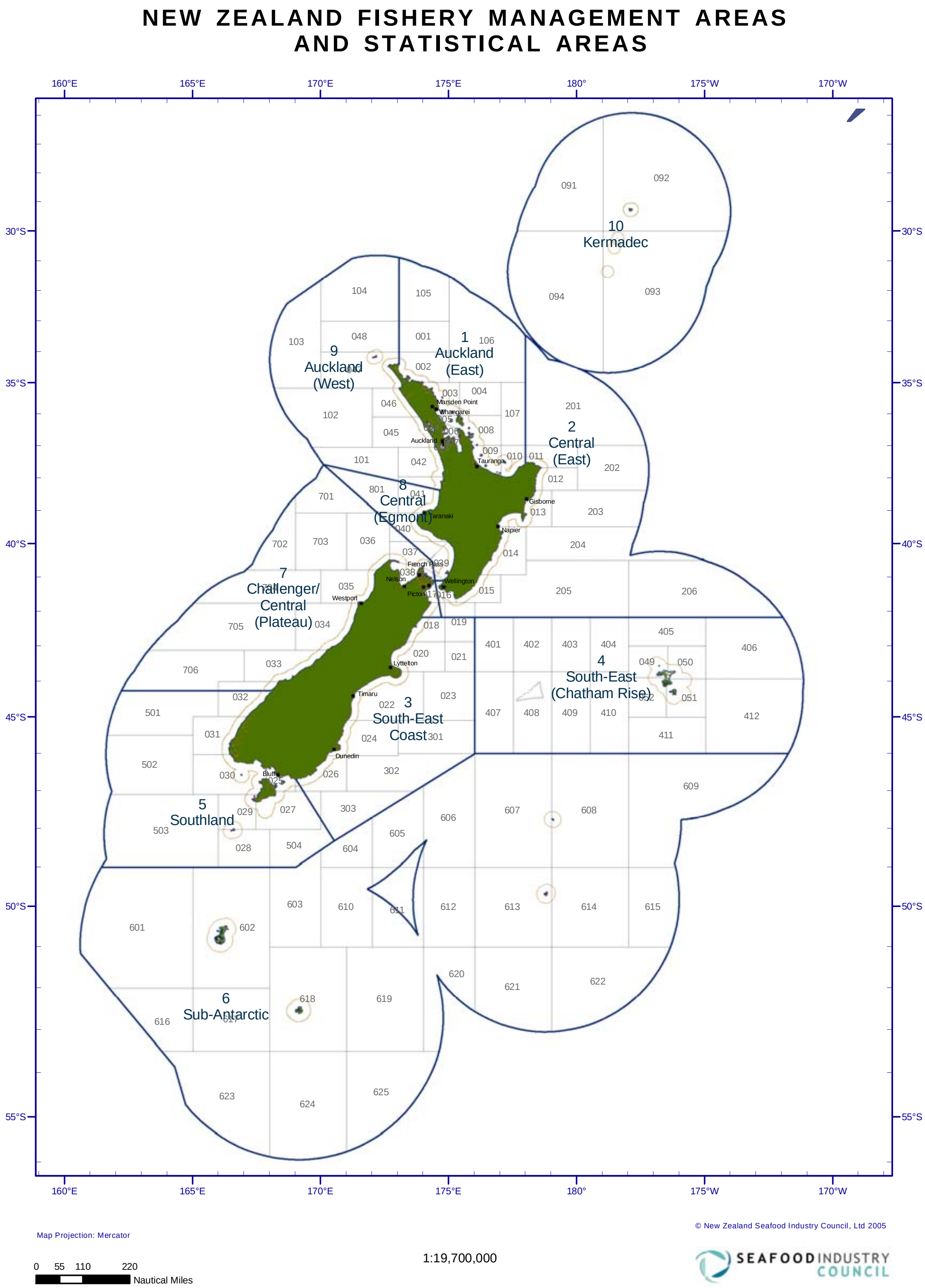

Figure B.1: Map of Ministry for Primary Industries statistical areas and Fishery Management Area (FMA) and Statistical Area boundaries, showing locations where FMA boundaries are not contiguous with the statistical area boundaries

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 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. 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 used for this new 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, identified as being 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 starting 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 search covered a plausible range for the ratio ($rat_{t,s}$: Eq. C.2), looking for the ratio and trip landing thresholds which resulted in the closest totals to the observed QMR/MHR landings.

C.3 Equations

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

Eq. C.1

$$G_{t,s}^{d} = \sum_{i=1}^{n_t} gwt_{t,s,i}$$

$$G_{t,s}^{c} = \sum_{i=1}^{n_t} CF_s * W_{t,i} * B_{t,i}$$

$$G_{t,s}^{e} = \sum_{j=1}^{m_t} est_{t,s,j}$$

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

$G_{t,s}^{c}$ = 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 $B_{t,i}$;

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

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

Eq. C.2

$$r1_{t,s} = G_{t,s}^{d} \big/ G_{t,s}^{c}$$

$$r2_{t,s} = G_{t,s}^{d} \big/ G_{t,s}^{e}$$

$$rat_{t,s} = \min(r1_{t,s}, r2_{t,s})$$

where $G_{t,s}^{d}$, $G_{t,s}^{c}$ and $G_{t,s}^{e}$ 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 $G_{t,s}^{d}$, 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^2 (Eq. C.3) relative to the annual QMR/MHR totals.

Eq. C.3

$$gg_y^z = \sum_{1}^{p_y^z} L_y^z$$

$$Ssq^z = \sum_{y=89/90}^{y=10/11} \left(gg_y^z - MHR_y\right)^2$$

where p_y^z 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_y^z is a landing record included in year *y* for iteration *z*.

MHR_y is the corresponding MHR/QMR landing total for GUR 3 in year *y*.

C.4 Results

This approach dropped 8 trips in GUR 3 from a total of 101 000 GUR 3 trips, accounting for 71 t of landings (Table C.1). By comparison, 25 trips representing 112 t were dropped in the previous GUR 3 analysis performed in 2009 (Starr et al. 2009). For this data set, the procedure did not result in much change, with reasonably good agreement between the raw landings and the QMR/MHR totals, although the sum of the landings exceeded the QMR/MHR totals in the late 1990s (Figure C.1).

Table C.1: Results from a search over two parameters defined above: A) a quantile cut-off which selected the set of large landings over which to search and B) the ratio (Eq. C.2) defining the maximum criterion for accepting a landing. The quantile/ratio pair with the lowest Ssq^z (Eq. C.3) is highlighted in colour (maximum ratio accepted=9.0 and quantile cut-off=99.9%).

Quantile	Minimum ratio $(rat_{t,s})$ cut-off						Minimum ratio $(rat_{t,s})$ cut-off					
cut-off:	4	5	6	7	8	9	4	5	6	7	8	9
	GUR 3: Number trips dropped						GUR 3: "*Ssq*" (Eq. C.3)					
97	36	36	33	28	26	23	8 396	8 396	8 308	7 819	7 690	7 527
98	28	28	26	24	22	21	8 097	8 097	8 084	7 709	7 580	7 484
99	23	23	21	20	18	17	8 016	8 016	8 012	7 774	7 645	7 569
99.5	16	16	14	13	13	12	7 572	7 572	7 578	7 366	7 366	7 290
99.9	10	10	10	9	9	8	7 385	7 385	7 385	7 173	7 173	7 145
99.99	0	0	0	0	0	0	7 334	7 334	7 334	7 334	7 334	7 334

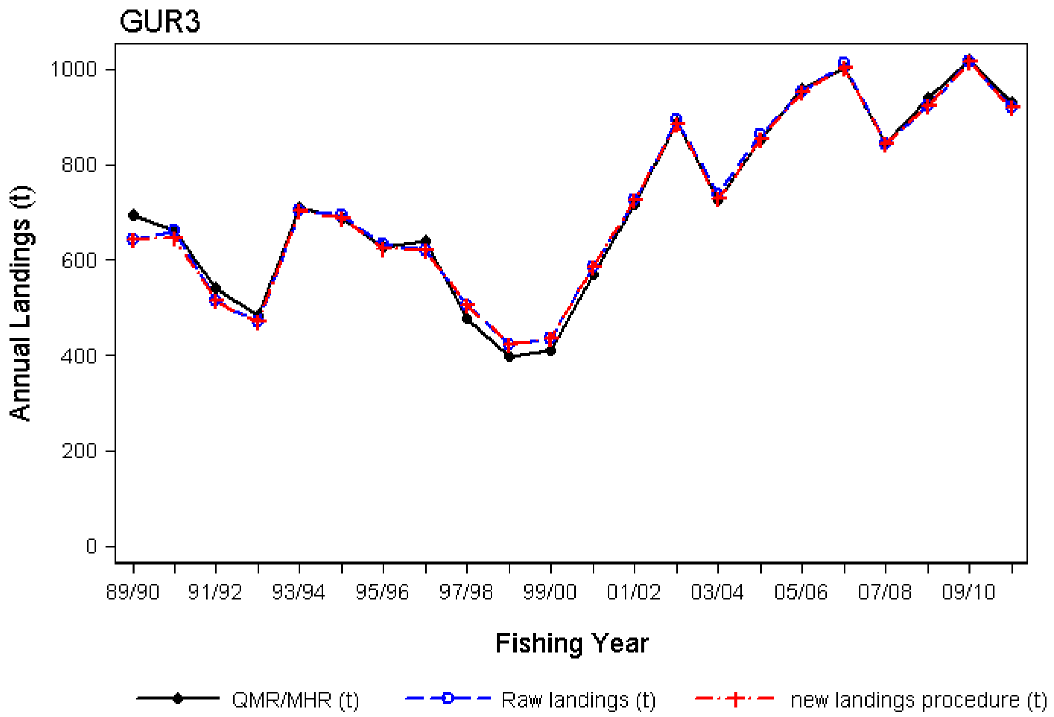

Figure C.1: Comparison of QMR/MHR annual total landings for GUR 3 with two extracts: A: unedited or "raw" landings; and B: total landings after dropping the eight landings identified using the two-way search algorithm described in Table C.1 which resulted in the lowest Ssq^z criterion as defined in Eq. C.3.

Appendix D. COMPARISON BY STATISTICAL AREA OF TWO DATA PREPARATION METHODS

This appendix compares total GUR 3 landings by statistical area from data sets prepared in two ways:

1. "Fishstock expansion": uses the method of Starr (2007) where trips are dropped which fished in statistical areas valid for more than one Fishstock and which declared more than one Fishstock in the landing data;
2. "Statistical area expansion": scales all estimated catches by statistical area within a trip by the total trip landings, without reference to the Fishstock of capture.

Table D.1 provides a measure of how much data are lost as a consequence of dropping trips which fished in the ambiguous statistical areas and landed to multiple GUR Fishstocks. The "Fishstock expansion" procedure is necessary to provide Fishstock-specific advice because catches using the "Statistical Area expansion" procedure will potentially contain catches from multiple Fishstocks. The latter procedure retains landings from ambiguous statistical areas, but the capacity to trace the landings to specific Fishstocks has been lost. Ninety tonnes were dropped when using the "Fishstock expansion" method compared to "Statistical area expansion" method, representing less than 1% of the total valid landings in the dataset (Table D.1), demonstrating that there is little difference between the two methods of data preparation for GUR 3 which is likely to be a consequence of the relatively small degree of movement made by the participants in the GUR 3 fisheries. Sixty-five tonnes of the dropped landings occur in Statistical Area 032 (marked in grey in Table D.1), indicating that this Statistical Area is likely to be poorly characterised in this analysis. However, the total catch in this Statistical Area is less than 100 t over 22 years, suggesting that the actual loss of information will be small.

Table D.1: Total catch (1989–90 to 2010–11) by statistical area resulting from the "Fishstock expansion" data preparation procedure compared with the equivalent catch resulting from the "Statistical Area expansion" preparation procedure (described above). Only statistical areas valid for GUR 3 are included in this table.

Statistical Area	Statistical area expansion	Fishstock expansion	Difference (t)	Difference (%)	Statistical Area	Statistical area expansion	Fishstock expansion	Difference (t)	Difference (%)
018	262.0	250.2	- 11.8	-4.5%	405	0.3	0.3	0.0	3.4%
019	0.8	1.1	0.3	42.9%	406	0.7	0.7	0.0	0.1%
020	3 518.9	3 511.0	- 7.9	-0.2%	407	0.6	0.6	0.0	0.7%
021	22.0	21.8	- 0.2	-1.0%	408	0.1	0.1	0.0	6.5%
022	6 033.9	6 033.1	- 0.7	0.0%	409	0.1	0.1	0.0	-5.5%
023	15.6	15.4	- 0.2	-1.4%	410	0.1	0.1	0.0	-1.1%
024	927.0	926.9	- 0.1	0.0%	412	0.2	0.2	0.0	0.1%
025	1 287.1	1 286.5	- 0.5	0.0%	502	0.2	0.2	0.0	0.0%
026	673.5	672.4	- 1.1	-0.2%	503	0.0	0.0	0.0	0.0%
027	382.9	378.9	- 4.0	-1.0%	504	2.2	2.1	- 0.1	-4.8%
028	13.3	12.0	- 1.3	-9.5%	602	2.9	2.3	- 0.6	-21.6%
029	32.8	32.7	- 0.2	-0.5%	603	1.2	1.2	0.0	3.2%
030	1 597.6	1 599.9	2.3	0.1%	604	0.0	0.0	0.0	0.0%
031	5.8	5.8	0.0	0.0%	605	0.1	0.1	0.0	0.0%
032	95.9	31.3	- 64.7	-67.4%	606	0.0	0.0	0.0	0.0%
049	77.2	76.3	- 0.8	-1.0%	607	0.0	0.0	0.0	-1.4%
050	266.6	269.2	2.7	1.0%	608	0.0	0.0	0.0	0.0%
051	34.2	34.2	0.0	0.0%	609	0.1	0.1	0.0	0.0%
052	8.5	8.4	- 0.1	-1.1%	610	1.3	1.3	0.0	0.9%
301	0.2	0.2	0.0	0.0%	611	0.1	0.1	0.0	0.0%
302	4.1	4.1	0.0	0.0%	617	0.0	0.0	0.0	0.0%
303	0.2	0.2	0.0	0.0%	618	0.1	0.0	- 0.1	-84.2%
401	3.0	1.6	- 1.5	-48.2%	619	0.1	0.0	- 0.1	-91.2%
402	1.1	1.1	0.0	-0.4%	620	0.0	0.0	0.0	0.0%
403	0.8	0.8	0.0	0.0%	624	0.0	0.0	0.0	0.0%
404	3.7	3.7	0.0	-0.9%	Total	15 268.8	15 179.0	- 89.8	-0.6%

Appendix E. EAST AND SOUTH COAST SOUTH ISLAND GURNARD CPUE ANALYSIS

E.1 General overview

When the east coast South Island trawl survey was discontinued (after 2001), standardised CPUE based on non-zero GUR 3 catches in the flatfish bottom trawl fishery was accepted as an alternative index of abundance (Annala et al. 2003). A second CPUE series was developed in 2005, based on the bottom trawl fishery targeted at red cod to contrast or corroborate the series from the shallower flatfish (Sullivan et al. 2005). In 2009, the series based on the red cod fishery was expanded to be more representative of the mixed species inshore trawl fishery (Starr et al. 2009).

Starr et al. (2009) also examined the possibility of separate substocks north and south of Banks Peninsula, but the separate analyses showed virtually identical trends in each of the two fisheries and the AMP Working Group recommended that both series should be calculated across all valid statistical areas in future. Given the preferred depth distribution of red gurnard in these two fisheries, it was decided that it would be unnecessary to include the offshore statistical areas in the CPUE standardisation.

This study extends the revised analyses presented in 2009 with a further three years of data. Improvements include the evaluation of alternative error distributions, and the production of "residual implied coefficient" plots to explore potential interaction effects in these models. There is also the potential that the shift to the more detailed TCER forms in recent years has affected the indices. This possibility is explored using alternative datasets amalgamated to a coarser resolution in the mixed target species analysis.

E.2 Methods

E.2.1 Data preparation

The identification of candidate trips for these analyses and the methods used to prepare these data have been described in Section 2.4.1.

The potential data variables available from each trip include estimated and landed catch of red gurnard, the number of tows, total duration of fishing, the fishing year, statistical area, target species, month of landing, and a unique vessel identifier. Data might not represent an entire fishing trip; just those portions of it that qualified, but the amount of landed catch assigned to the part of the trip that was kept is proportional to the total landed catch for the trip based on the estimated catches which are used to apportion the landings to each "trip stratum". Trips were not dropped because they targeted more than one species or fished in more than one statistical area. Trips landing more than one Fishstock of any species from one of the straddling statistical areas were dropped.

An alternative dataset for the mixed target fisheries was prepared by selecting trips which targeted any of TAR, GUR, STA, BAR, RCO at least once, which then qualified the complete trip. These trips were amalgamated to the level of a statistical area, which effectively created a trip level data set because few trips enter more than one statistical area within the period of a trip. This data set is identified as "trip" in the remainder of this report.

E.2.2 Analytical methods for standardisation

Arithmetic CPUE $\left(\hat{A}_y\right)$ in year y was calculated as the total catch for the year divided by the total effort in the year:

Eq. E.1 $$\hat{A}_y = \frac{\sum_{i=1}^{n_y} C_{i,y}}{\sum_{i=1}^{n_y} E_{i,y}}$$

where $C_{i,y}$ is the [*catch*] and $E_{i,y} = T_{i,y}$ ([*tows*]) or $E_{i,y} = H_{i,y}$ ([*hours_fished*]) for record *i* in year *y*, and n_y is the number of records in year *y*.

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

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

where C_i, $E_{i,y}$ and n_y are as defined for Eq. E.1. Unstandardised CPUE makes the same log-normal distributional assumption as the standardised CPUE, 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 provide measures of how much the standardisation procedure has modified the series from these two sets of indices.

A standardised abundance index (Eq. E.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. E.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. Tows $\left(\ln\left(T\right)_i\right)$ and fishing duration $\left(\ln\left(H_i\right)\right)$ were offered to the model as continuous third order polynomial variables.

This model was fit in two steps to the successful (positive) catch records. First, alternative regressions based on five statistical distributional assumptions (lognormal, log-logistic, inverse Gaussian, gamma and Weibull) predicted catch based on a dataset with a reduced set of six explanatory variables (year, month, area, vessel, target species and $\left(\ln\left(T_i\right)\right)$. The distribution which resulted in the model with the lowest negative log-likelihood was then selected for use in the final model. The second step involved repeating the regression using the selected distribution: regressing log(catch) 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. Datasets were restricted to core fleets of vessels, defined by their activity in the fishery, thus selecting only the most active vessels without unduly constraining the amount of catch and effort available for analysis.

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. E.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 gurnard as the dependent variable (where 1 is substituted for $\ln(I_i)$ in Eq. E.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. E.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 using the delta distribution, which allows zero and positive observations (Vignaux 1994):

Eq. E.4

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

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) had not yet been implemented in the available software. The positive catch model almost always represents the major portion of the signal in the combined model and there is concern that the information added by the binomial model may be an artefact of the data amalgamation procedure and not always interpretable as a biomass index. The binomial model is presented here for information and to contrast with the positive catch model.

E.2.3 Fishery definitions for CPUE analysis

Two fisheries are defined for GUR 3 CPUE analysis. One is based on the bottom trawl fishery targeted at the suite of flatfish species and the other based primarily on the bycatch of gurnard in the inshore bottom trawl fishery targeted at a mix of species. The flatfish fishery tends to be operated in a more shallow depth range than the mixed target species fishery (Figure 14).

BT (MIX) – Mixed target bottom trawl; The Fishery is defined from bottom trawl fishing events which fished in any (inshore) statistical area valid for GUR 3 and targeted red cod, stargazer, barracouta, tarakihi or red gurnard. This definition allowed the use of total effort and not just successful effort in the analysis of catch rates;

BT (FLA) – Flatfish target bottom trawl; The Fishery is defined from bottom trawl fishing events which fished in any (inshore) statistical area valid for GUR 3 and targeted one of the flatfish species. This definition allowed the use of total effort and not just successful effort in the analysis of catch rates.

Other models that were fit during this study are summarised without full diagnostics. They include a suite of similar model fits assuming alternative error distributions, models of positive catch based on datasets that were amalgamated to trip resolution, binomial models of the probability of catch success fit to the complete dataset including zeros, and finally a model which shows the effect of combining the binomial indices with the indices from the lognormal model (Eq. E.4). These models are presented as sensitivities in Appendix G.

E.3 Unstandardised CPUE

E.3.1 BT (MIX): mixed target bottom trawl

The number of trips in this fishery peaked in 1993–94 at almost twice the 1990–91 levels and has declined steadily since then to a level at present that is equal with the lowest in the series (Figure E.1).

Catch rates of red gurnard in successful trips reflect the performance of the RCO target fishery in the first half of the series, peaking in the mid 1990s and declining to half that catch rate by the late 1990s, but have since increased steeply in the 2000s, despite declining effort, to the highest level of the study period at nearly 100 kg per tow in 2009–10 (Figure E.1).

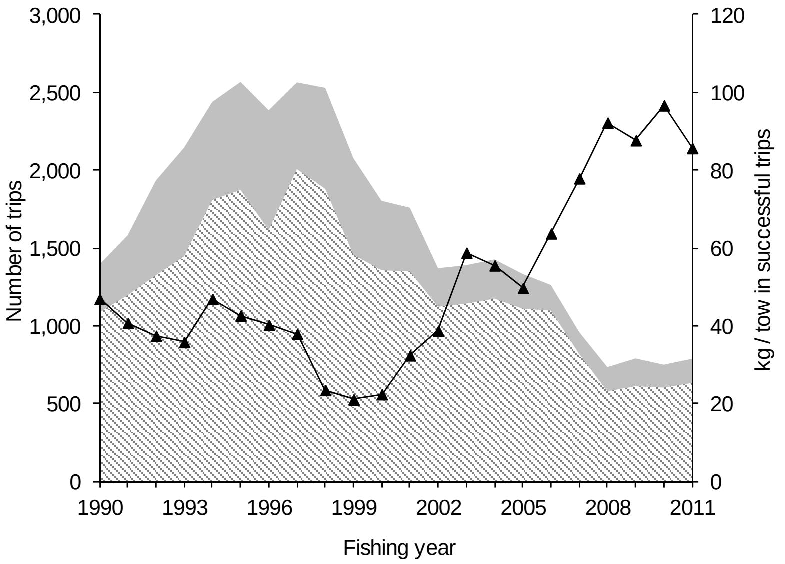

Figure E.1: Number of trips targeted at red cod, stargazer, barracouta, tarakihi or red gurnard by bottom trawl in BT (MIX), (dark area), the number in trips that landed GUR 3 (light area) and the simple catch rate (kg/tow) of GUR 3 in successful trips, by fishing year.

The proportion of trips that reported zero catches decreased from around 30% in 1989–90 to about 15 % in 2007–08 (Figure E.2). This statistic is relative to the abundance of other commonly caught species and the observed trend may reflect changes in the underlying abundance of the target species as much as in the abundance of red gurnard, but it would be expected to decline if abundance of red gurnard were increasing.

The roll-up of data to trip-stratum is shown in Figure E.2 and shows no trend to the number of original records per strata that might confound the apparent trend in proportion zero catches. The last four points are markedly higher and reflect the change to a new form type that records tow-by-tow resolution data. The average number of tows amalgamated to a trip-stratum is higher in the second half of the time series and reflects changes in fishing practice that may include fewer changes of statistical area or target species within a fishing trip or shorter trips or a combination of both.

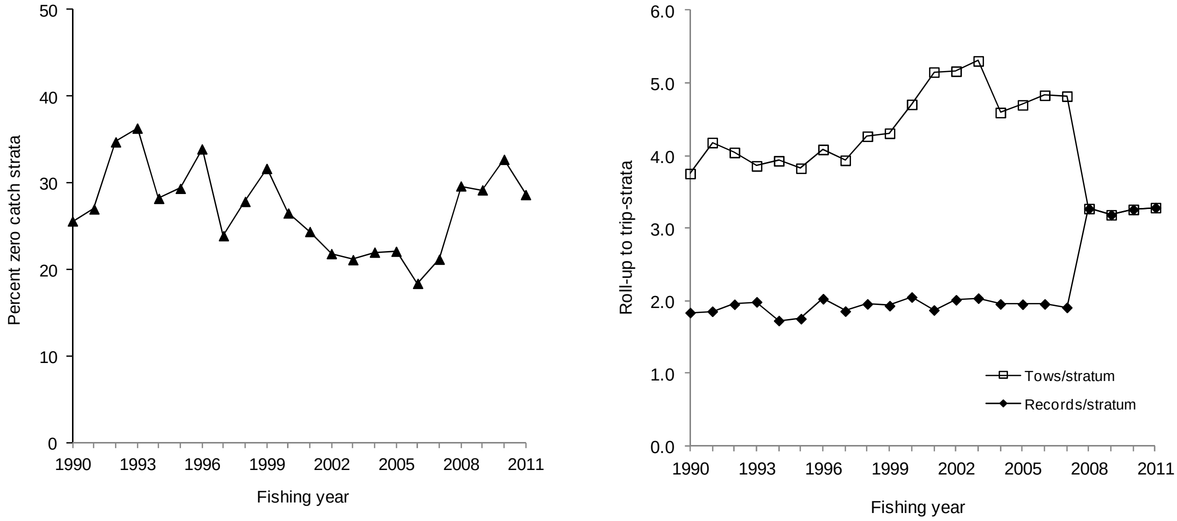

Figure E.2: [left]: the proportion of zero catch trip-strata in all qualifying BT (MIX) trips (before selection of core vessels), and [right]: the effect of data roll-up indicated by the ratio of original records per trip-stratum, and number of tows per trip-stratum by fishing year .

E.3.2 BT (FLA): GUR 3 target flatfish bottom trawl

The number of trips in this fishery peaked in 1998–99 at almost twice the 1990–91 levels and has declined steadily since then to a level at present that is the lowest in the series (Figure E.3). Catch rates of red gurnard in successful trips have, against the trend in effort, increased steadily since the late 1990s to peak at 34 kg per tow in 2008–09, and dropped slightly in the subsequent two years.

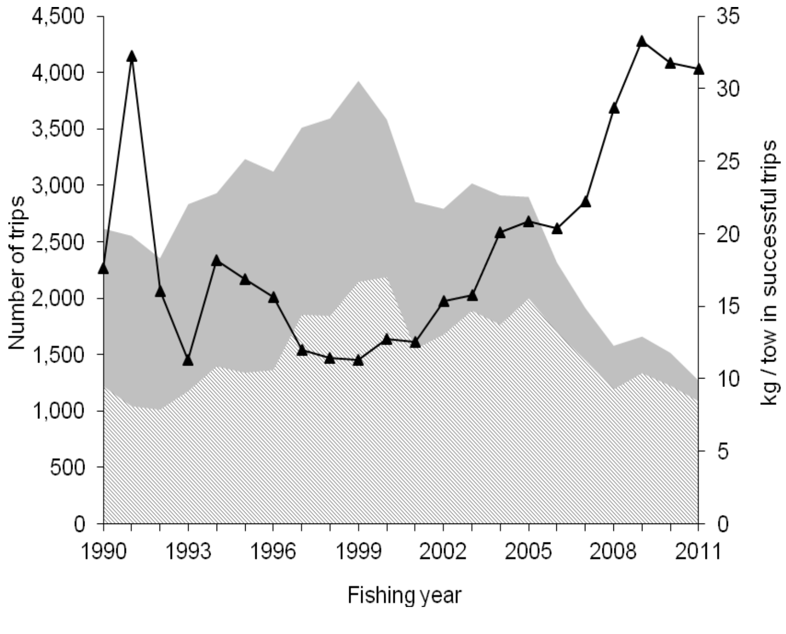

Figure E.3: Number of trips that targeted flatfish by bottom trawl in BT (FLA) (dark area), the number in trips that landed GUR 3 (light area) and the simple catch rate (kg/tow) of GUR 3 in successful trips, by fishing year.

The proportion of trips that reported zero catches of gurnard has decreased steadily over most of the period from around 55% in 1990–91 to less than 15 % in 2010–11 (Figure E.4). The roll-up of data to trip-stratum is shown in Figure E.4 and shows no trend in the number of original records per strata that might confound the apparent trend in proportion zero catches. Recent points are markedly higher and reflect the change to a new form type that records tow-by-tow resolution data.

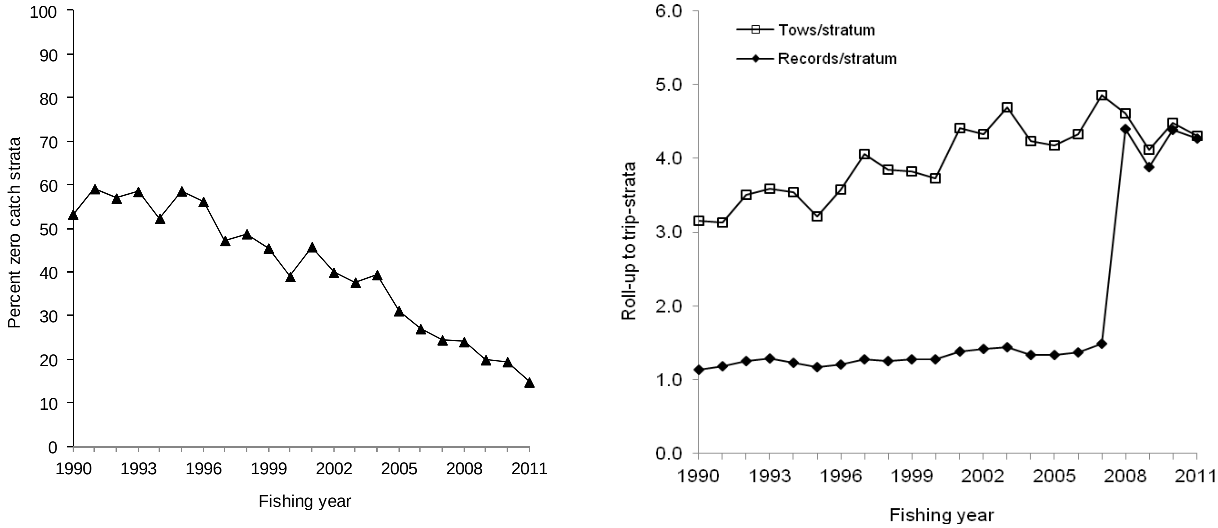

Figure E.4: The proportion of zero catch trip-strata in all qualifying BT (FLA) trips (before selection of core vessels) [left], and the effect of data roll-up indicated by the ratio of original records per trip-stratum, and number of tows per trip-stratum by fishing year [right].

E.4 Standardised CPUE analysis

E.4.1 Core fleet definitions

The data sets used for the standardised CPUE analysis were further restricted to those vessels that participated with some consistency in the defined fishery. Core vessels were selected by specifying two variables: the number of trips that defined a qualifying year, and the number of years that each qualifying vessel participated in the fishery. The effect of these two variables on the amount of landed gurnard retained in the dataset and on the number of core vessels is depicted for each of the defined fisheries in Figure F.1 and Figure F.2. The core fleet was selected by choosing variable values that resulted in the fewest vessels while maintaining the largest catch of gurnard.

Core vessels in the BT (RCO) fishery were defined as those that had fished at least 10 trips in a minimum of 8 years (Figure F.1). These criteria resulted in a core fleet size of 56 vessels which took 80% of the catch. Core vessels in the BT (FLA) fishery were defined as those that had fished at least 10 trips in a minimum of 8 years (Figure F.2). These criteria resulted in a core fleet size of 80 vessels which took 71% of the catch. Data sets for the final core vessels are summarised in Table F.1.

E.4.2 Model selection and trends in model year effects

E.4.2.1 BT (MIX): mixed target bottom trawl fishery

The Weibull distribution model provided the best fit to the positive catches in the BT (MIX) dataset (Figure G.1). The final model (Table E.1) explained 36% of the variance in log(catch), largely by standardising for changes in the duration of fishing. Target species, vessel and statistical area also entered the model but little effect on the annual indices, as shown by the small amount of shift in the annual indices in the stepwise plot in Figure E.5.

Table E.1: Summary of final Weibull model for the BT (MIX) fishery based on the vessel selection criteria of at least 10 trips in 8 or more fishing years. Independent variables are listed in the order of acceptance to the model. AIC: Akaike Information Criterion, R^2: proportion of deviance explained (Nagelkerke pseudo-R^2), Final: a flag indicating if the variable was included in final model; Fishing year (fyear) was forced as the first variable.

Term	DF	Log likelihood	AIC	R^2 (%)	Final
fyear	23	-182 473	364 991	6.39	*
poly(log(duration) 3)	26	-179 230	358 512	24.68	*
target	30	-178 238	356 537	29.53	*
vessel	370	-177 106	354 952	34.68	*
area	376	-176 768	354 288	36.15	*
month	387	-176 558	353 891	37.04	
poly(log(num) 3)	390	-176 493	353 766	37.31	
form	393	-176 490	353 766	37.33	

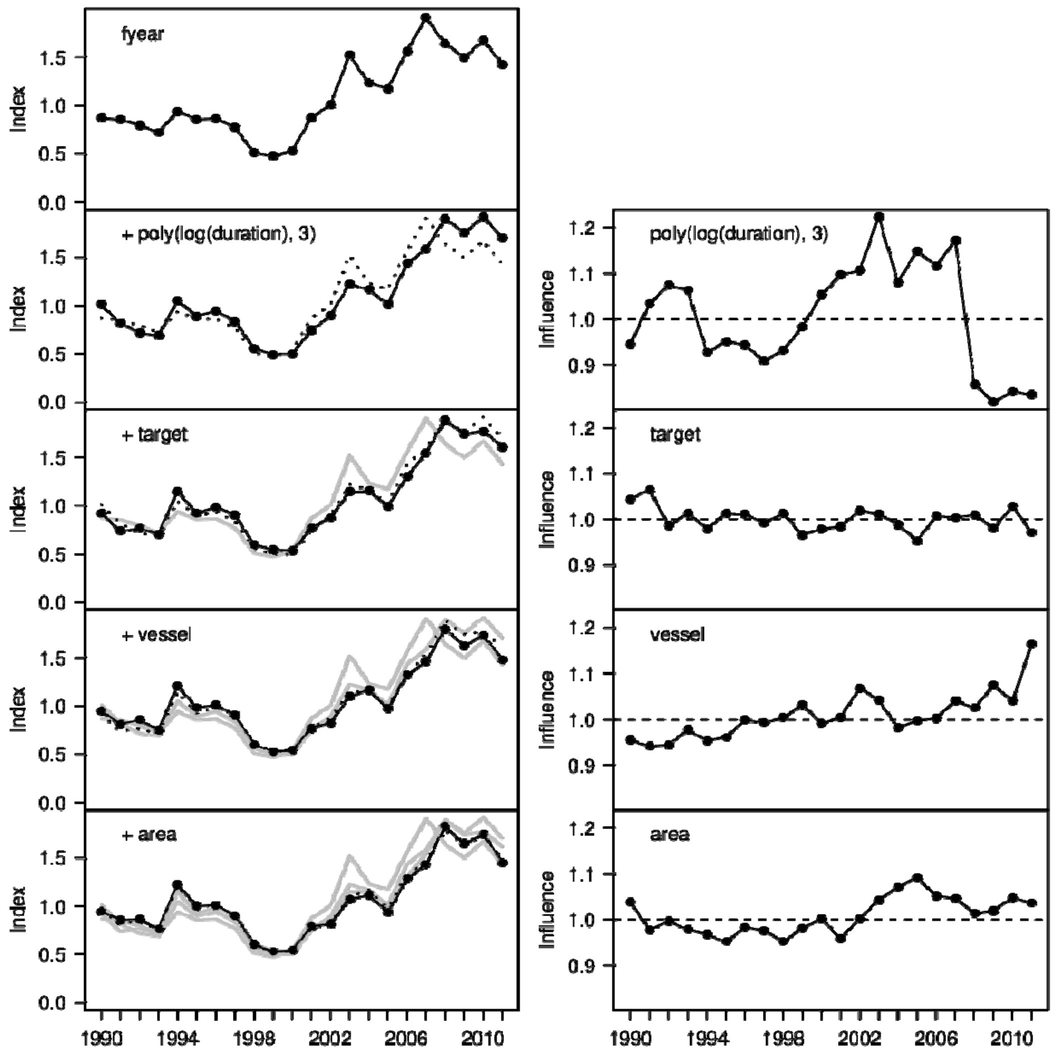

Figure E.5: Step and annual influence plot for BT (MIX). (a) CPUE index at each step in the selection of variables. The index obtained in the previous step (if any) is shown by a dotted line and for steps before that by grey lines. (b) Annual influence on observed catches arising from a combination of its model coefficients and its distributional changes over years, for each explanatory variable in the final model.

Diagnostic residual plots for the final Weibull model are given in Figure F.3 and show a good fit over the range in which most of the data occurs, although there is some unmodelled process in the residuals and departure from the distributional assumptions at the extremes of the residual distribution. Residual implied coefficient plots which model the area×fishingyear interactions indicate that there is reasonable similarity among the area-specific year indices, with the exception of Area 26 which has very little data and the final years of the Area 25 series (Figure F.4). The targetspecies×fishingyear interaction plots show quite good consistency in the year indices for each target species category (Figure F.5).

There is a trend of increasing duration from the late 1990s through to the mid 2000s, followed by a sharp decline to a low level that is coincident with the switch to the new form (Figure F.6). The effect of duration entering the model is to smooth the increase from the low in 1999–00 and to lift the indices in the most recent four years. The effect of changes in targeting have been neutral over most of the study period (Figure F.7), but the gradual loss of the poorer performing vessels in the core fleet has been responsible for increasing the observed catch rate in this fishery and a consequent reducing in the year indices when these changes are standardised (Figure F.8). Changes in the area explanatory variable have been neutral with respect to the year indices (Figure F.9).

E.4.2.2 BT (FLA): flatfish target bottom trawl fishery

As seen in the BT (MIX) model, the Weibull distribution model provided the best fit to the positive catches in the BT (FLA) dataset (Figure G.5). The final model (Table E.2) explained 48% of the variance in log catch, with vessel having the most explanatory power and the duration selected as the most informative measure of effort. Month and area also entered the model, but there was very little effect on the annual indices from the addition of these explanatory variables (Figure E.6), indicating that there has been little variation in the manner that these variables have operated in the fishery.

Table E.2: Summary of final Weibull model based on the vessel selection criteria (at least 10 trips in 8 or more fishing years) in the BT (FLA) fishery. Independent variables are listed in the order of acceptance to the model. AIC: Akaike Information Criterion, R^2: Proportion of deviance explained; Final: a flag indicating if the variable was included in final model. Fishing year (fyear) was forced as the first variable.

Term	DF	Log likelihood	AIC	R^2 (%)	Final
fyear	23	-180 458	360 963	5.63	*
vessel	289	-172 774	346 125	39.83	*
poly(log(duration) 3)	292	-171 332	343 247	44.70	*
month	303	-170 856	342 318	46.22	*
area	309	-170 381	341 379	47.70	*
poly(log(num) 3)	312	-170 166	340 956	48.35	

Diagnostic residual plots for the final Weibull model are given in Figure F.10 and show a good fit over the range in which most of the data occurs, although there is some unmodelled process in the residuals and departure from the distributional assumptions at the extremes of the residual distribution. Residual implied coefficient plots which model the area×fishingyear interactions indicate that there is reasonable similarity among the area-specific year indices in the southeast and southern sections of the South Island (Figure F.11). There is some departure from the annual indices in Areas 020 and 022, but these are distant areas away from the main FLA fishery.

A gradual loss from the core fleet of the poorer performing vessels has led to an increase in the unstandardised annual index and a drop in the standardised index as this effect is factored out (Figure F.12). The effect of duration was also positive, but small, stemming from a slight trend towards longer fishing duration (Figure F.13). Both month (Figure F.14) and area (Figure F.15) entered the model, but neither variable had much impact on the model year indices.

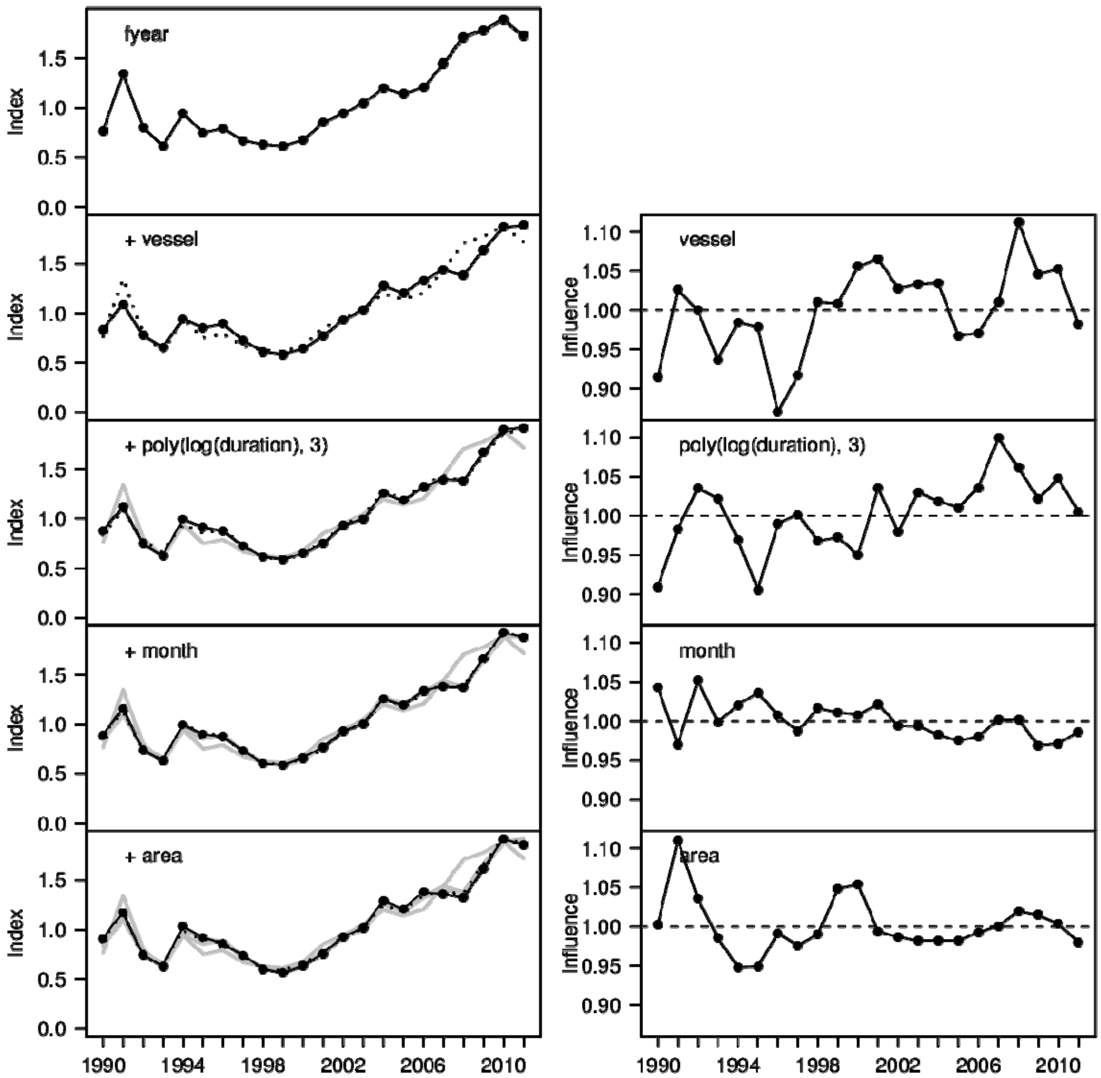

Figure E.6: Step and annual influence plot for BT (FLA). (a) CPUE index at each step in the selection of variables. The index obtained in the previous step (if any) is shown by a dotted line and for steps before that by grey lines. (b) Annual influence on observed catches arising from a combination of its model coefficients and its distributional changes over years, for each explanatory variable in the final model.

E.4.3 Trends in model year effects

E.4.3.1 BT (MIX): mixed target bottom trawl fishery

The standardised fishing year indices show a cyclical pattern of abundance with a profound slump that bottomed in the late 1990s, but was followed by a strong and steady recovery beginning in the early 2000s. The indices and the trends are well-determined with close error bars and changes in direction sustained over several years. There is good agreement over the years in common with the previous series estimated from a similar model in spite of the change in the underlying model distribution (Figure E.7).

The effect of the standardisation procedure was slight over most of the time series but appears to have more effect towards the end of the series because of the overall change in the fishing fleet and a trend towards longer tow duration which resulted in a lowering and flattening of the unstandardised CPUE series between 2005–06 and 2010–11. Both the unstandardised and the standardised CPUE indicate that there had been a large increase in abundance during the 2000s to an apparently stable or slightly declining level which has persisted since 2006–07 (Figure E.7).

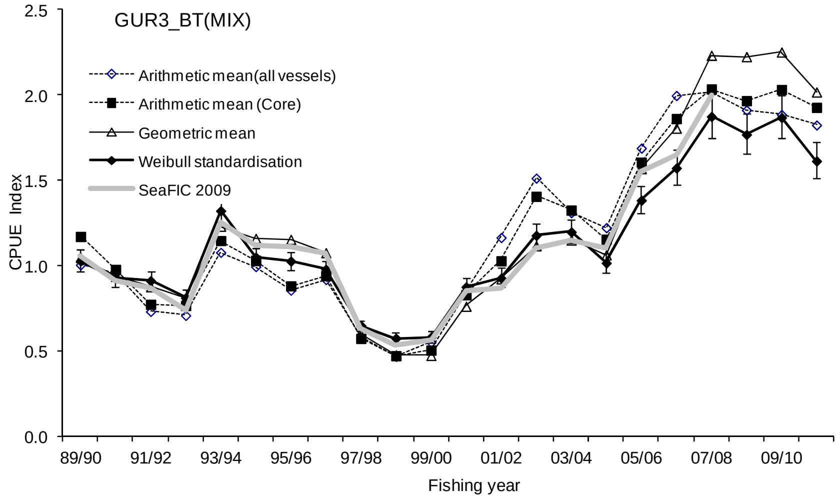

Figure E.7: The effect of core vessel selection, standardisation, and combining of indices on the raw CPUE (kg/tow) of gurnard in the BT (MIX) fishery. The previous index series for a similar model presented in 2009 is shown in grey and all series have been rescaled relative to the years in common.

E.4.3.2 BT (FLA): flatfish target bottom trawl fishery

The standardised fishing year indices show the same basic pattern as seen in the BT (MIX) model: a distinctive low in 1997–98, followed by a recovery to levels that are the highest of the series. The main difference between this analysis and the BT (MIX) model is that this series may still be increasing, whereas the MIX series appears to have levelled out over the most recent five years. The indices and the trends are well-determined with tight error bars with trends generally sustained over several years. There is good agreement over the years in common with the previous series estimated from a similar model (Figure E.8).

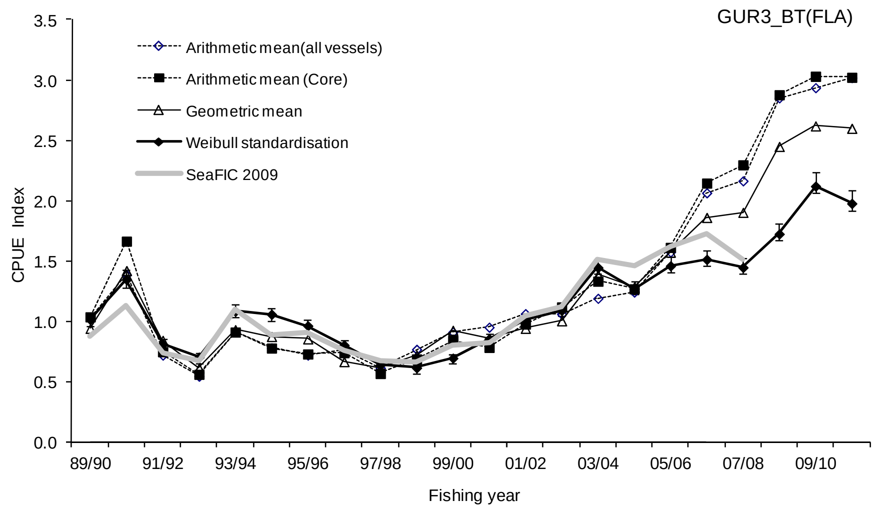

Figure E.8: The effect of core vessel selection, standardisation, and combining of indices on the raw CPUE (kg/tow) of red gurnard in the BT (FLA) fishery. The previous indices for a similar model presented in 2009 are shown and all series have been rescaled relative to the years in common.

The effect of the standardisation procedure is most evident in the last half of the time series, diverging in the last 6 years from an unstandardised series based on catch per tow. This may indicate that there has been improved targeting of gurnard by fishers, but both the unstandardised and the standardised CPUE indicate that there had been a large increase in abundance during the 2000s (see Figure G.7).

Appendix F. DIAGNOSTICS FOR GURNARD (EAST COAST) CPUE STANDARDISATIONS

F.1 Core vessel selection

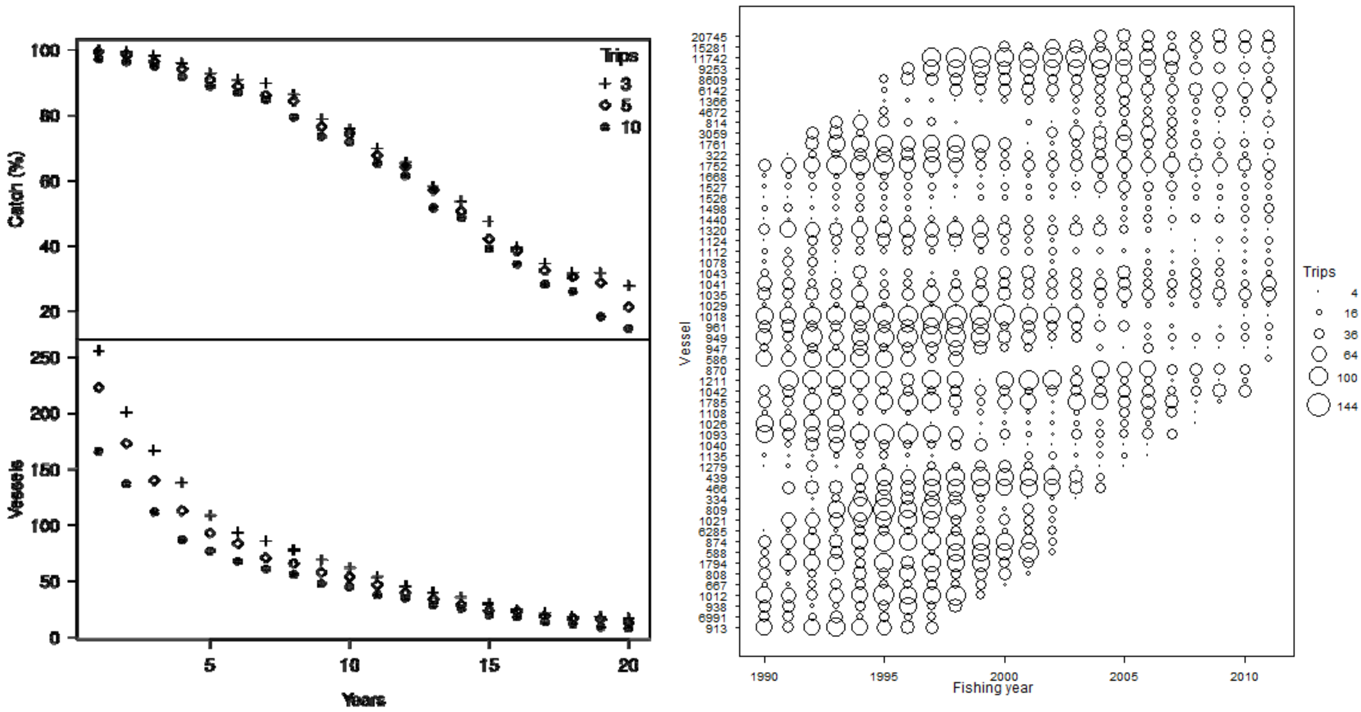

Figure F.1: Total landed GUR 3 [top left] and the number of vessels [bottom left] retained in the BT (MIX) dataset depending on the minimum number of qualifying years and the minimum number of trips used to define core vessels. The distribution of trips by fishing year for the selected core vessels (defined as 10 trips per year in 8 years) is shown on the right.

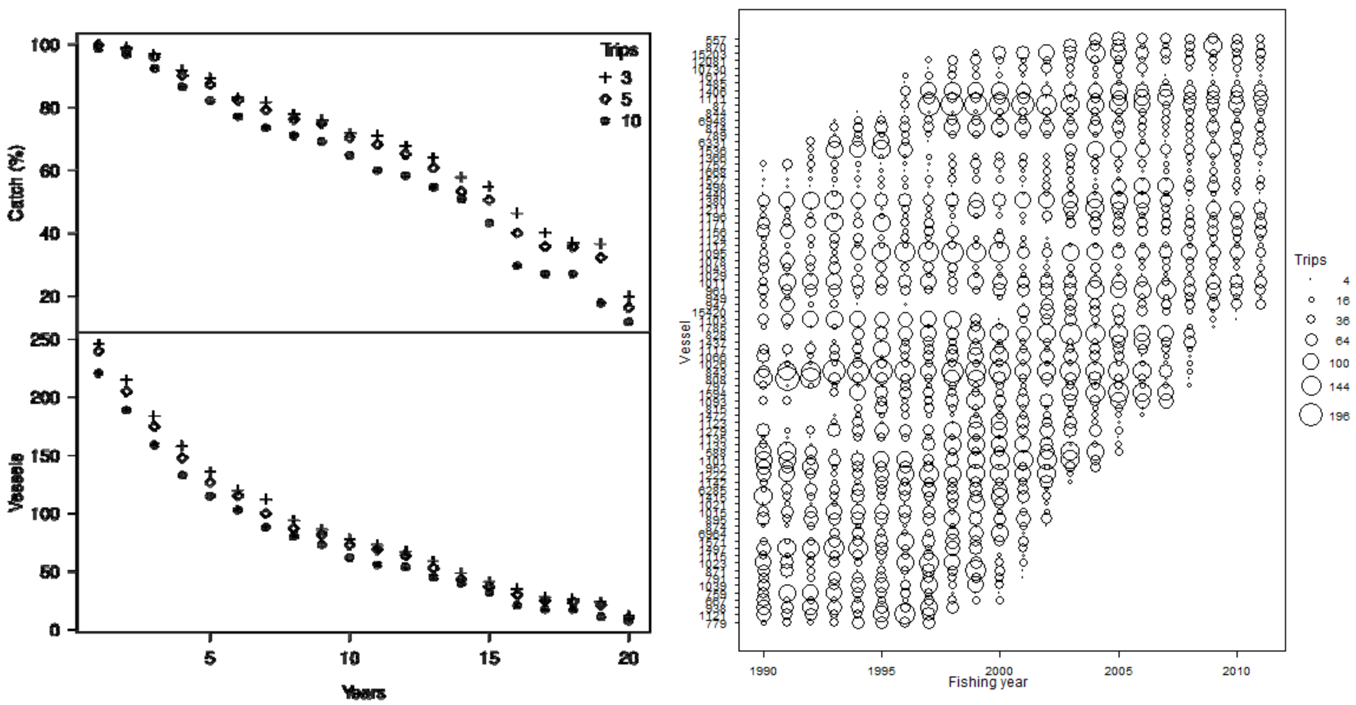

Figure F.2: Total landed GUR 3 [top left] and the number of vessels [bottom left] retained in the BT (FLA) dataset depending on the minimum number of qualifying years and the minimum number of trips used to define core vessels. The distribution of trips by fishing year for the selected core vessels (defined as 10 trips per year in 8 years) is shown on the right.

F.2 Data summaries

Table F.1: Number of vessels, trips, trip strata, events, sum of catch, sum of tows (or net length) and sum of hours fishing for core vessels in the BT (MIX) and BT (FLA) CPUE analyses by fishing year.

	BT (MIX)								BT (FLA)							
Fishing year	Vessel	Trips	Trip-strata	events	Catch	Tows	Hours	% zero	Vessel	Trips	Trip-strata	events	Catch	Tows	Hours	% zero
1990	36	1 393	1 598	2 941	221.0	6 000	20 781	25.6	55	2 620	2 629	2 999	86	8 281	20 262	53.3
1991	40	1 581	1 801	3 347	238.7	7,531	25,364	27.0	52	2 556	2 565	3 044	135	8 037	22 330	59.1
1992	46	1 934	2 254	4 403	248.3	9 117	33 129	34.7	56	2 357	2 360	2 962	76	8 281	22 568	57.0
1993	46	2 145	2 466	4 901	240.0	9 518	34 644	36.3	61	2 837	2 850	3 679	67	10 216	26 981	58.5
1994	47	2 439	2 655	4 593	369.9	10 434	34 089	28.2	65	2 934	2 950	3 633	123	10 451	26 098	52.3
1995	47	2 568	2 759	4 845	339.1	10 561	35 055	29.4	63	3 237	3 269	3 829	97	10 503	26 081	58.6
1996	47	2 385	2 556	5 189	295.2	10 445	33 356	33.9	67	3 125	3 171	3 846	104	11 342	28 753	56.2
1997	49	2 564	2 761	5 136	324.4	10 870	34 699	23.9	70	3 515	3 570	4 547	117	14 460	34 165	47.2
1998	45	2 530	2 740	5 367	211.1	11 696	35 608	27.9	68	3 597	3 654	4 600	111	14 029	33 344	48.8
1999	43	2 078	2 198	4 253	147.3	9 472	28 941	31.7	63	3 930	3 960	5 082	123	15 155	37 107	45.5
2000	42	1 803	1 965	4 037	165.3	9 248	29 070	26.5	67	3 587	3 621	4 615	127	13 513	34 154	39.0
2001	44	1 759	1 867	3 498	255.2	9 619	30 672	24.4	66	2 857	2 896	4 015	117	12 780	31 700	45.8
2002	44	1 370	1 535	3 093	253.1	7 927	25 001	21.8	60	2 796	2 835	4 006	145	12 271	28 607	39.9
2003	38	1 389	1 577	3 214	412.0	8 367	27 976	21.1	55	3 021	3 089	4 465	178	14 475	34 346	37.7
2004	37	1 426	1 628	3 188	336.1	7 481	24 909	22.0	54	2 915	2 958	3 967	187	12 522	29 958	39.4
2005	36	1 333	1 548	3 026	306.7	7 276	24 631	22.1	54	2 901	2 934	3 924	207	12 235	29 943	31.1
2006	37	1 262	1 447	2 833	387.2	6 993	24 406	18.4	50	2 319	2 360	3 225	174	10 208	26 489	27.0
2007	34	959	1 152	2 202	357.1	5 553	20 689	21.2	47	1 916	1 953	2 912	181	9 481	25 336	24.4
2008	31	734	1 083	3 543	255.8	3 543	12 619	29.6	46	1 582	1 678	7 376	194	7 738	19 841	24.0
2009	30	789	1 216	3 874	265.3	3 874	14 133	29.2	40	1 663	1 767	6 867	216	7 262	19 905	19.9
2010	33	749	1 198	3 906	283.8	3 906	14 356	32.7	38	1 519	1 647	7 219	205	7 377	20 043	19.4
2011	31	787	1 236	4 061	265.4	4 061	15 229	28.6	37	1 272	1 396	5 950	170	6 010	16 244	14.8

F.3 BT (MIX): diagnostic plots

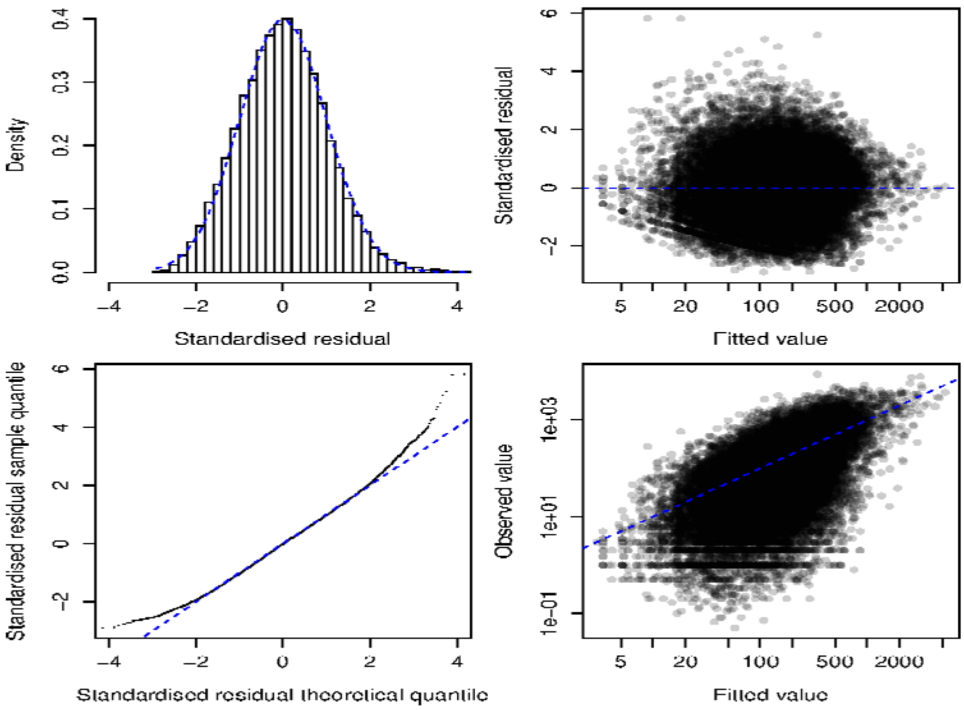

Figure F.3: Plots of the fit of the standardised CPUE model to successful catches in the BT (MIX) fishery. [Upper left] histogram of the standardised residuals compared to a Weibull distribution (SDSR: standard deviation of standardised residuals. MASR: median of absolute standardised residuals); [Lower left] Q-Q plot of the standardised residuals; [Upper right] Standardised residuals plotted against the predicted model catch per trip; [Lower right] Observed catch per record plotted against the predicted catch per record.

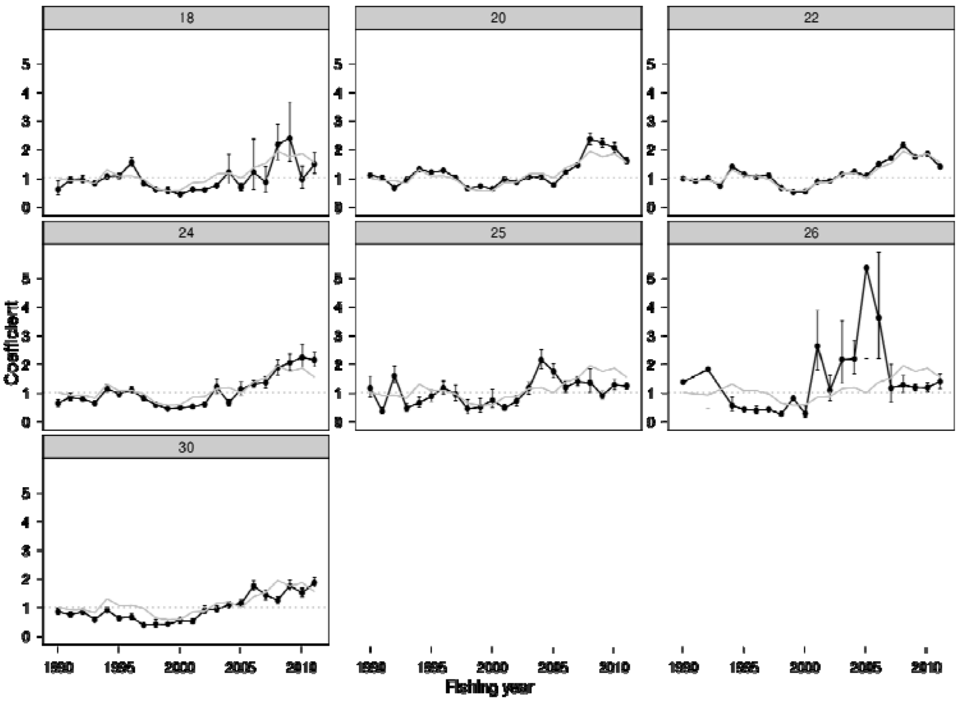

Figure F.4: Residual implied coefficients for each area in each fishing year for the BT (MIX) CPUE analysis. Implied coefficients are calculated as the sum of the fishing year coefficient plus the mean of the residuals in each fishing year in each area. The error bars indicate one standard error of residuals. The grey line indicates the model's overall fishing year coefficients.

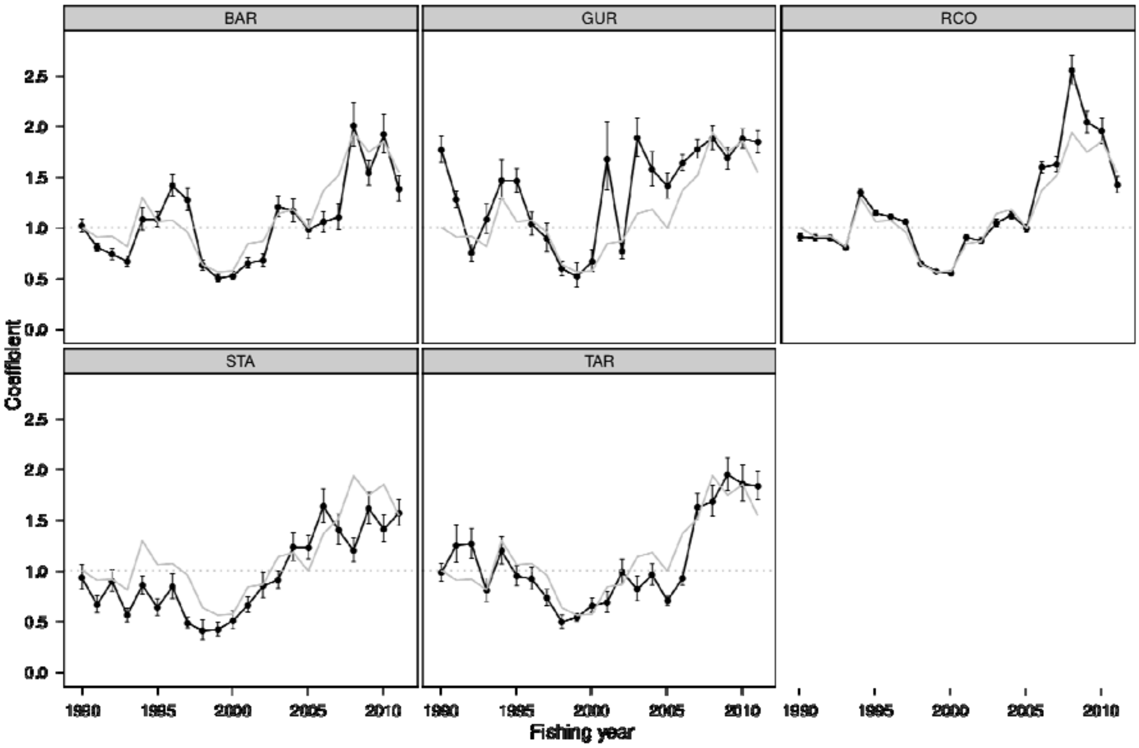

Figure F.5: Residual implied coefficients for target×fishing year interactions in the BT (MIX) fishery. Implied coefficients (black points) are calculated as the normalised fishing year coefficient (grey line) plus the mean of the standardised residuals for each target in each fishing year. These values 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.

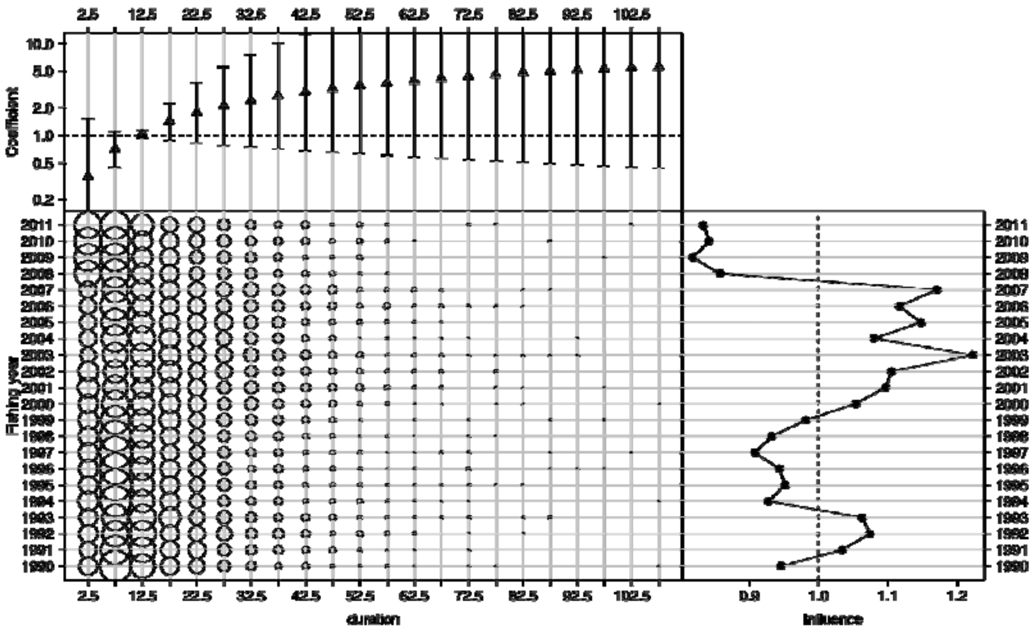

Figure F.6: Effect of log(duration) in the Weibull model for the BT (MIX) fishery. Top: effect by level of variable (left-axis: log space, additive; right-axis: natural space, multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

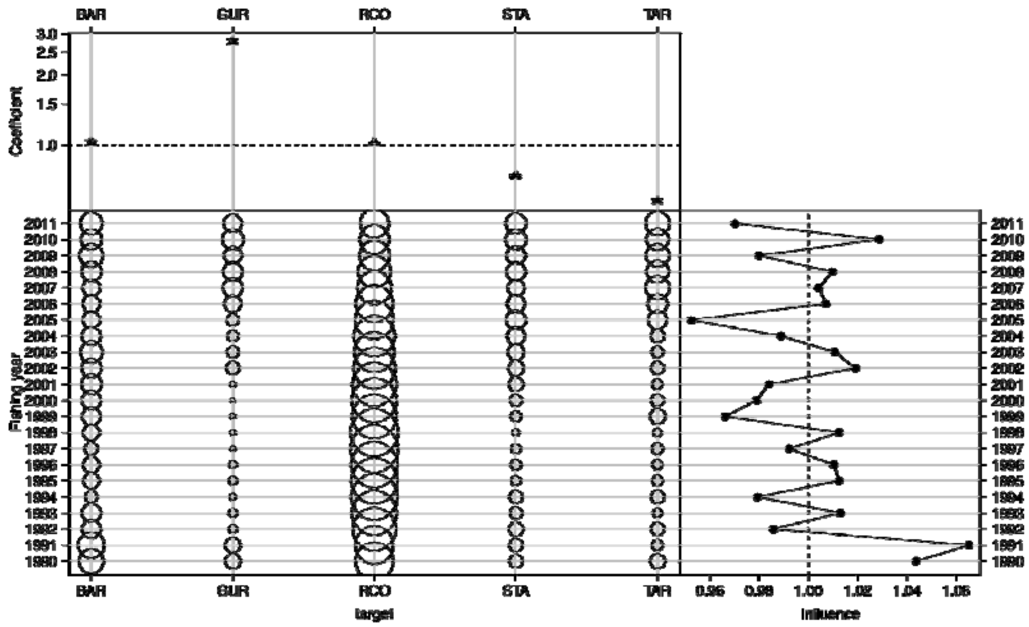

Figure F.7: Effect of target in the Weibull model for the BT (MIX) fishery. Top: effect by level of variable (left-axis: log space, additive; right-axis: natural space, multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

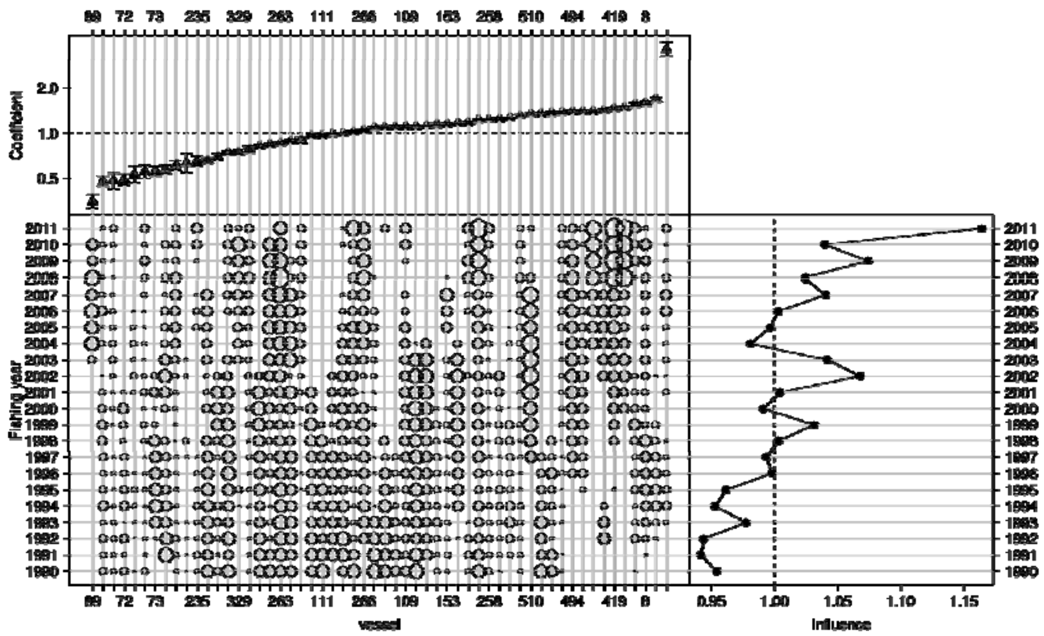

Figure F.8: Effect of vessel in the Weibull model for the BT (MIX) fishery. Top: effect by level of variable (left-axis: log space, additive; right-axis: natural space, multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

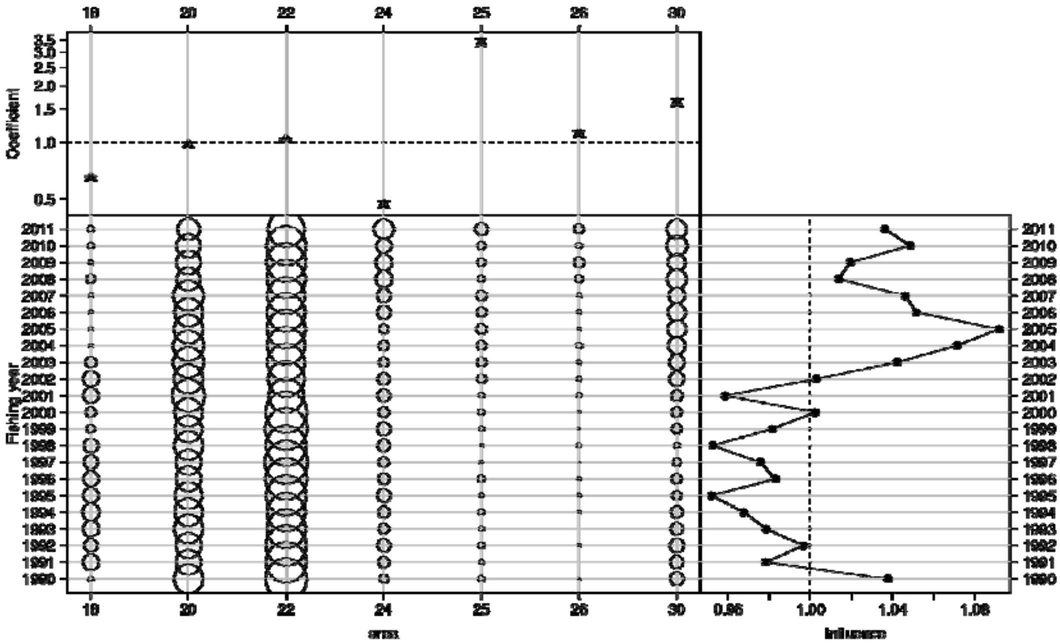

Figure F.9: Effect of area in the Weibull model for the BT (MIX) fishery. Top: effect by level of variable (left-axis: log space, additive; right-axis: natural space, multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

F.4 BT (FLA): diagnostic plots

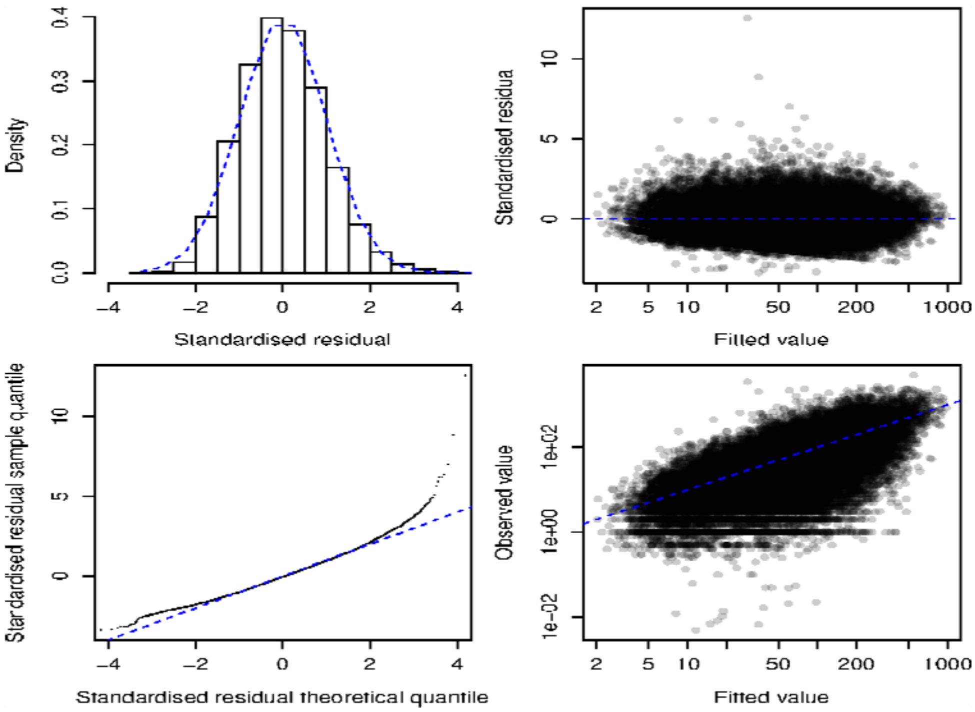

Figure F.10: Plots of the fit of the standardised CPUE model to successful catches in the BT (FLA) fishery. [Upper left] histogram of the standardised residuals compared to a Weibull distribution (SDSR: standard deviation of standardised residuals. MASR: median of absolute standardised residuals); [Upper 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.

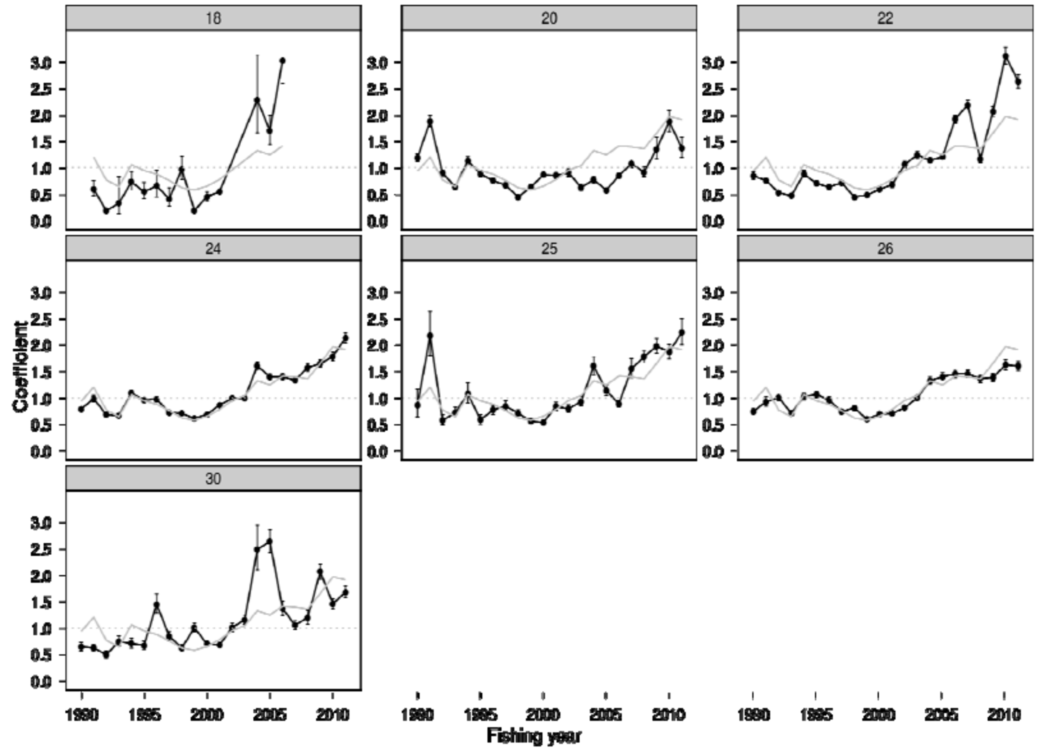

Figure F.11: Residual implied coefficients for each area in each fishing year for the BT (FLA) CPUE analysis. Implied coefficients are calculated as the sum of the fishing year coefficient plus the mean of the residuals in each fishing year in each area. The error bars indicate one standard error of residuals. The grey line indicates the model's overall fishing year coefficients.

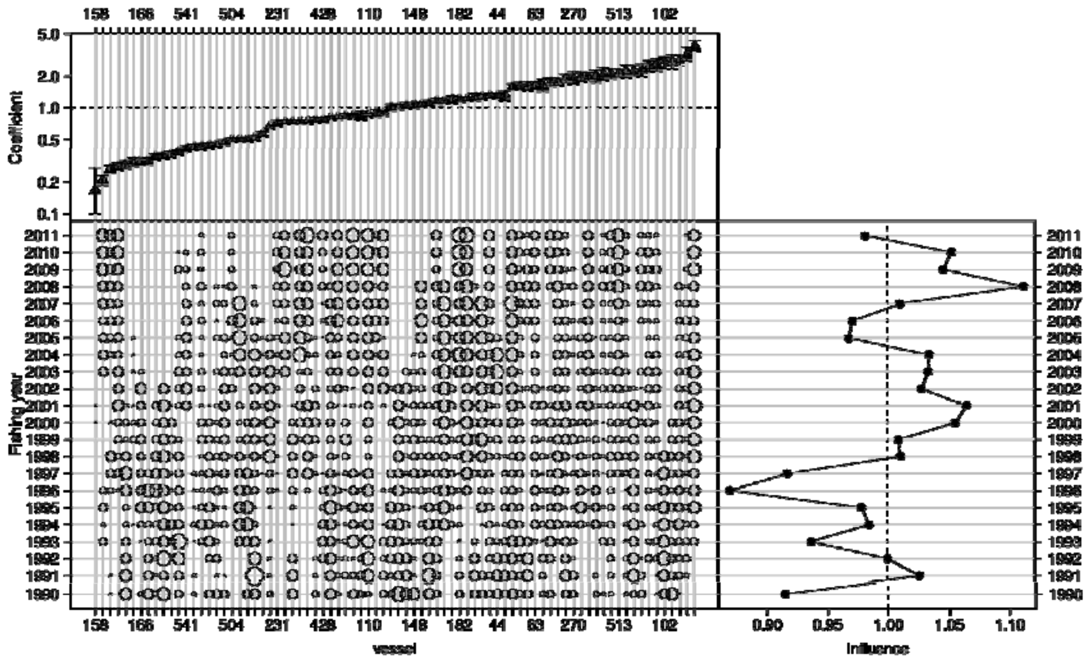

Figure F.12: Effect of vessel in the lognormal model for the BT (FLA) fishery. Top: effect by level of variable (left-axis: log space, additive; right-axis: natural space, multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

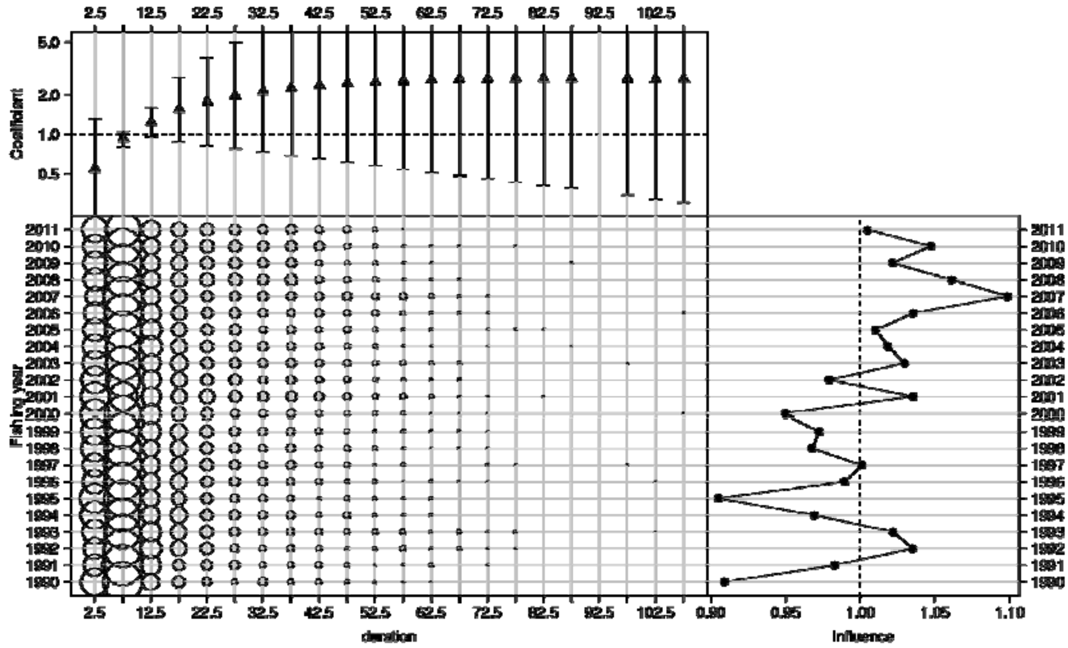

Figure F.13: Effect of log(duration) in the lognormal model for the BT (FLA) fishery. Top: effect by level of variable (left-axis: log space, additive; right-axis: natural space, multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

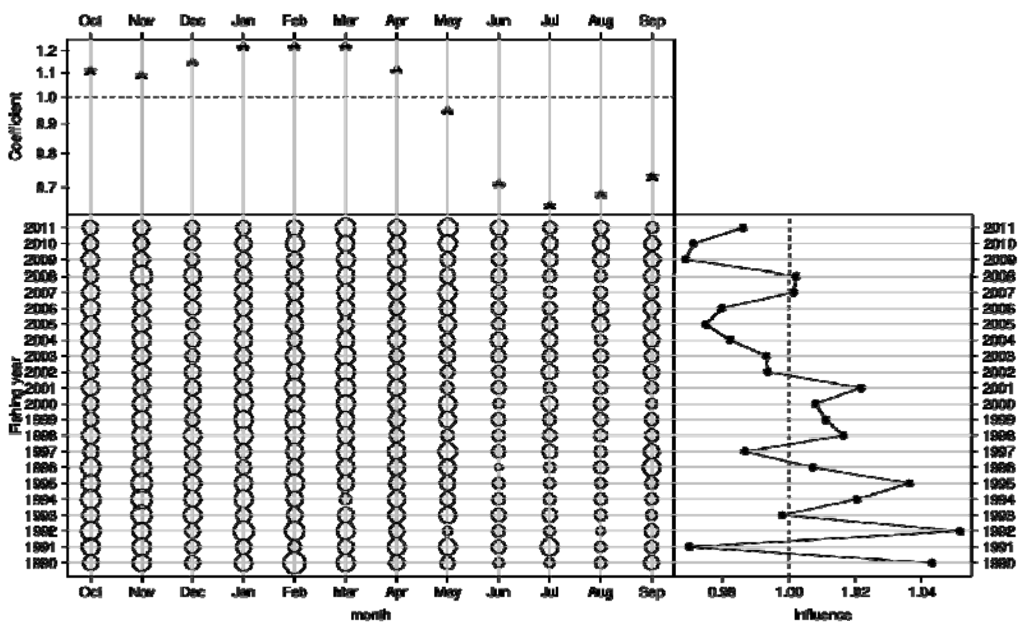

Figure F.14: Effect of month in the lognormal model for the BT (FLA) fishery. Top: effect by level of variable (left-axis: log space, additive; right-axis: natural space, multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

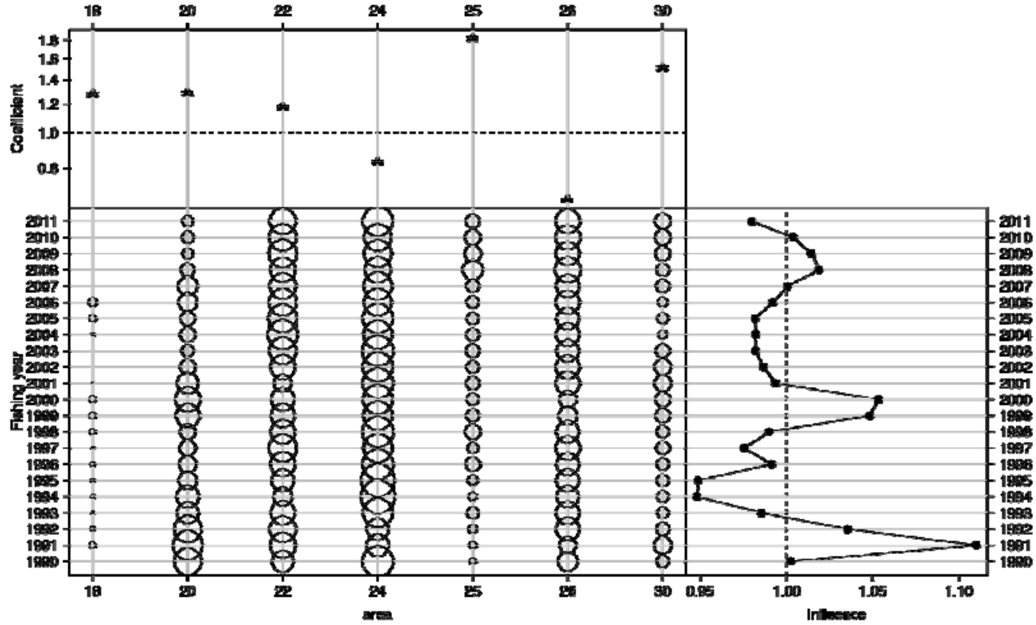

Figure F.15: Effect of area in the lognormal model for the BT (FLA) fishery. Top: effect by level of variable (left-axis: log space, additive; right-axis: natural space, multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

F.5 CPUE indices

Table F.2: Arithmetic indices for the total and core data sets, geometric and Weibull standardised indices and associated standard error for the core data set by fishing year for the two CPUE models.

	BT (MIX)					BT (FLA)				
Fishing	All	Core				All	Core			
Year	Arithmetic	Arithmetic	Geometric	Weibull	SE	Arithmetic	Arithmetic	Geometric	Weibull	SE
1990	0.9461	1.1493	1.0191	0.9446	0.03494	0.8751	0.8609	0.8337	0.9112	0.03261
1991	0.8605	0.8848	0.8205	0.8544	0.03306	1.2315	1.3265	1.2391	1.1680	0.03513
1992	0.6729	0.7078	0.7904	0.8619	0.03111	0.6144	0.7168	0.7966	0.7466	0.03480
1993	0.6742	0.7009	0.7216	0.7650	0.03039	0.4712	0.5127	0.5533	0.6271	0.03177
1994	0.9641	1.0330	1.0582	1.2206	0.02794	0.7822	0.8580	0.9352	1.0301	0.02984
1995	0.9078	0.9151	1.0319	0.9980	0.02750	0.6720	0.6713	0.8003	0.9194	0.03024
1996	0.8148	0.8180	1.0350	1.0078	0.02934	0.6185	0.5625	0.7020	0.8542	0.02967
1997	0.8291	0.8272	0.9409	0.9003	0.02647	0.6611	0.6219	0.5828	0.7375	0.02567
1998	0.5249	0.5060	0.5251	0.5961	0.02720	0.5279	0.4857	0.5666	0.6033	0.02572
1999	0.4392	0.4279	0.4455	0.5289	0.03084	0.6559	0.5111	0.5907	0.5625	0.02445
2000	0.4993	0.4622	0.4412	0.5380	0.03109	0.7787	0.7111	0.7879	0.6334	0.02399
2001	0.7433	0.7129	0.6410	0.7921	0.03191	0.8329	0.6490	0.7091	0.7570	0.02775
2002	0.9981	0.8618	0.7421	0.8142	0.03390	0.9200	0.8393	0.8139	0.9257	0.02677
2003	1.3801	1.2687	0.9859	1.0717	0.03338	0.9067	0.9718	0.8715	1.0135	0.02546
2004	1.2197	1.2165	1.0714	1.1109	0.03342	1.0194	1.1205	1.2005	1.2884	0.02622
2005	1.1349	1.0545	0.9723	0.9367	0.03425	1.0825	1.1474	1.1472	1.2095	0.02484
2006	1.5603	1.4668	1.4203	1.2861	0.03442	1.3753	1.4138	1.4057	1.3735	0.02703
2007	1.8421	1.7010	1.6469	1.4265	0.03916	1.7706	1.6983	1.5864	1.3591	0.02865
2008	1.8598	1.9174	2.0866	1.8244	0.04269	1.8553	1.9816	1.5856	1.3229	0.03075
2009	1.7831	1.8483	2.0332	1.6438	0.04069	2.4469	2.5921	2.0708	1.6081	0.02963
2010	1.7326	1.9152	2.0575	1.7444	0.04170	2.5188	2.8058	2.3112	1.9143	0.03063
2011	1.6999	1.8287	1.9152	1.4522	0.04033	2.5911	2.8442	2.3196	1.8597	0.03218

Appendix G. COMPARISONS WITH OTHER CPUE MODELS (SENSITIVITIES)

G.1 BT(MIX): GUR 3 mixed target bottom trawl fishery

Regression models using five different distributional assumptions (lognormal, log-logistic, inverse Gaussian, gamma and Weibull) predicted catch based on a reduced set of explanatory variables (year, month, vessel, area, target and log(number of tows). These models were evaluated by examination of residual diagnostics and the model with the lowest negative log likelihood was selected for the final stepwise regression (Figure G.1). The Weibull error distribution provided the best fit of the positive catch records to the core dataset for the BT (MIX) regression. The sensitivity of the final model indices to the choice of error distribution is shown in Figure G.2.

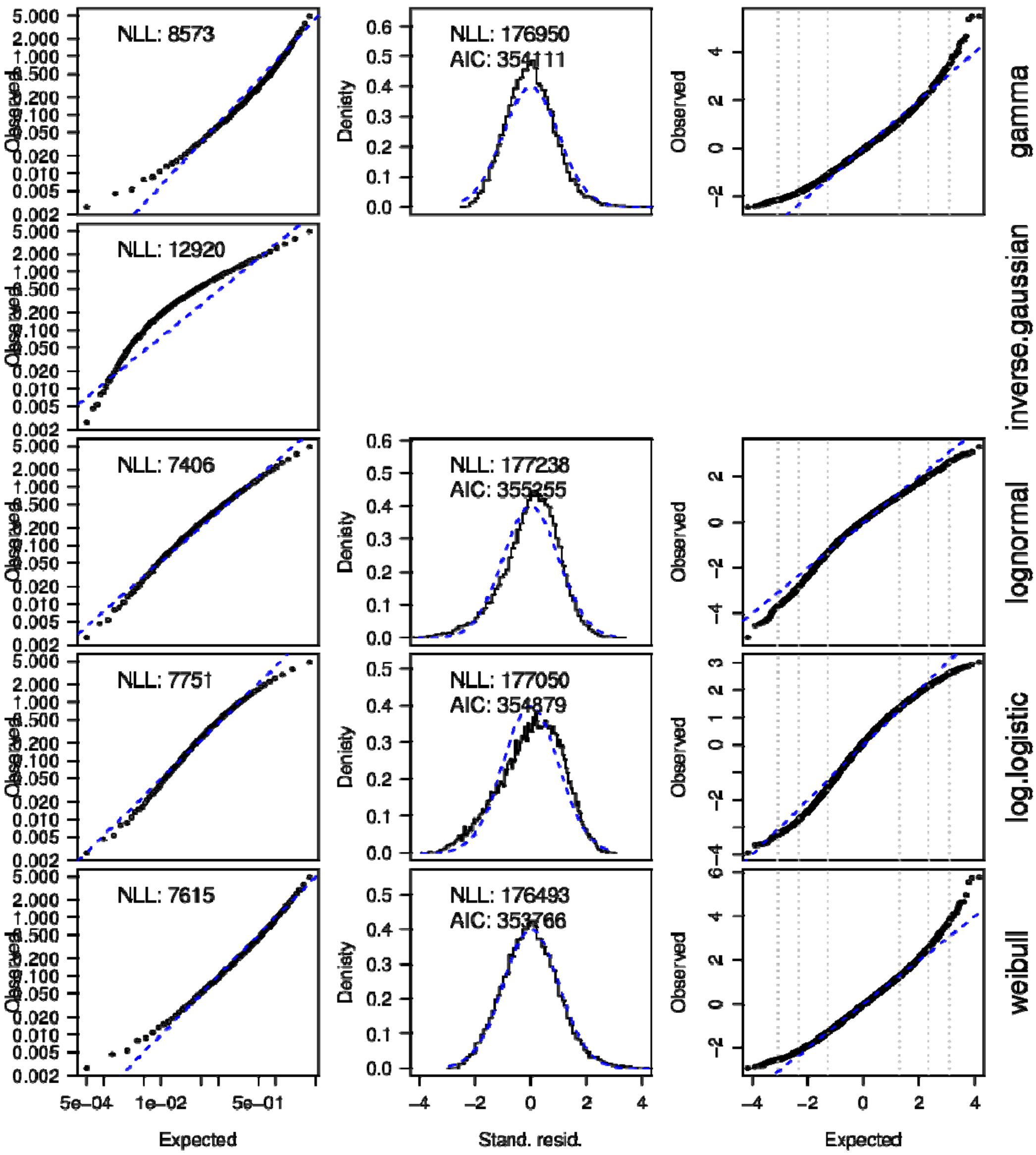

Figure G.1: Diagnostics for alternative distributional assumptions for catch in the GUR3_BT(MIX) fishery. Left: maximum likelihood fit (dotted) to observed catches (solid, scaled by their mean); Middle: standardised residuals from a model catch ~ fyear + month + area + vessel + target + poly(log(num); Right: quantile-quantile plot of standardised residuals of model. LL = log-likelihood of fit. The distribution with the lowest log-likelihood was Weibull.

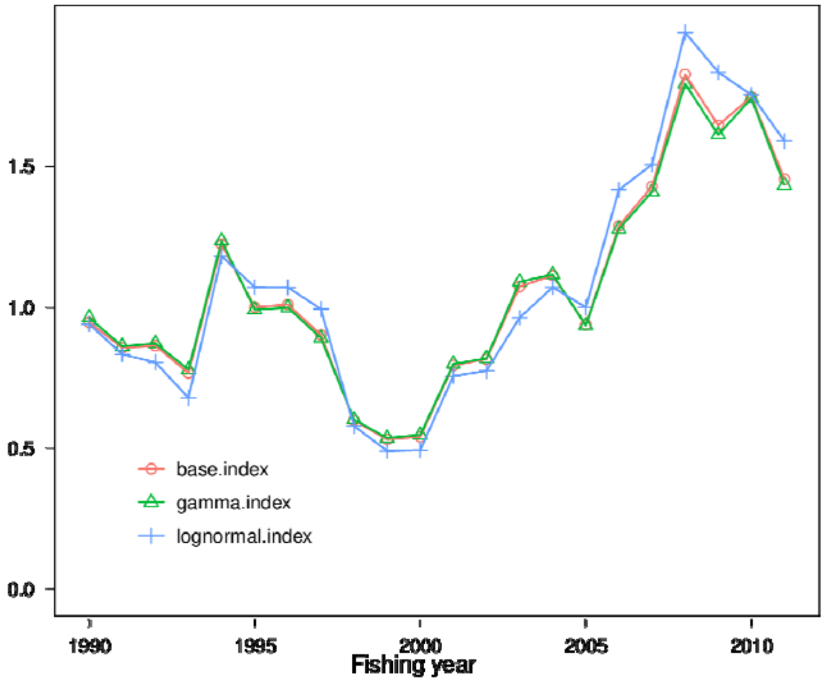

Figure G.2: Comparison between the Weibull index (base) and indices from lognormal and gamma models fitted to the same dataset using the same parameterisation.

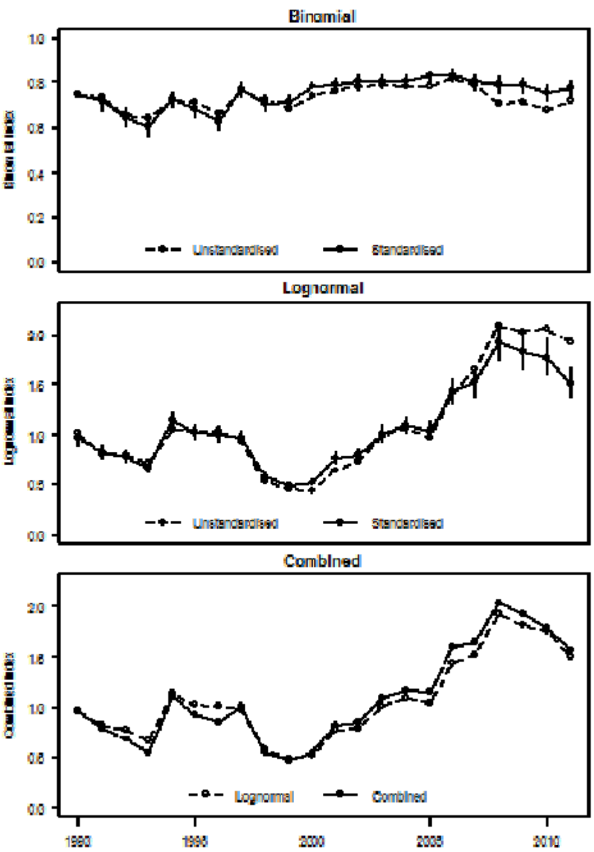

Figure G.3: The effect of standardisation on the raw CPUE of red gurnard by core vessels in the GUR3_BT(MIX) fishery. Top: Binomial index of probability of capture. Middle: Lognormal index of magnitude of catch, broken line is the raw CPUE (kg / tow), the solid line is the standardised CPUE canonical indices with plus or minus two Standard Error bars. Bottom: The effect on the Lognormal index from combining it with the Binomial index

A binomial model of the probability of capture was fit to the full core dataset (including zero catches) and changes the unstandardised probability of capture very little, but the resulting year indices confirm the overall pattern of increase evident in standardised catch rates. When the binomial is combined with the lognormal model, the effect is slight, exaggerating the magnitude of the peaks and lows of that series without affecting the overall trends (Figure G.3). The binomial and combined models are not presented here in any further detail.

An alternative analysis done on data amalgamated to the resolution of a trip is summarised in Table G.1. This analysis was conducted on the premise that this level of resolution should be sufficiently coarse to be unaffected by the switch to the new form. While there is some lengthening of the total duration of fishing associated with each trip, this effect preceded the introduction of detailed forms, which were brought in at the beginning of 2007–08 (

Figure G.4). There is a drop in the mean influence which is coincident with that year, but it is to a level seen previously.

Table G.1: Summary of an alternative Weibull model for the GUR3_BT (MIX) fishery based data amalgamated to trip resolution.

Term	DF	Log likelihood	AIC	R^2 (%)	Final
fyear	23	-182 399	364 845	8.01	*
poly(log(duration) 3)	26	-179 157	358 367	26.21	*
vessel	381	-178 025	356 813	31.68	*
area	387	-177 517	355 807	34.00	*
month	398	-177 303	355 402	34.95	
poly(log(num) 3)	401	-177 249	355 300	35.19	

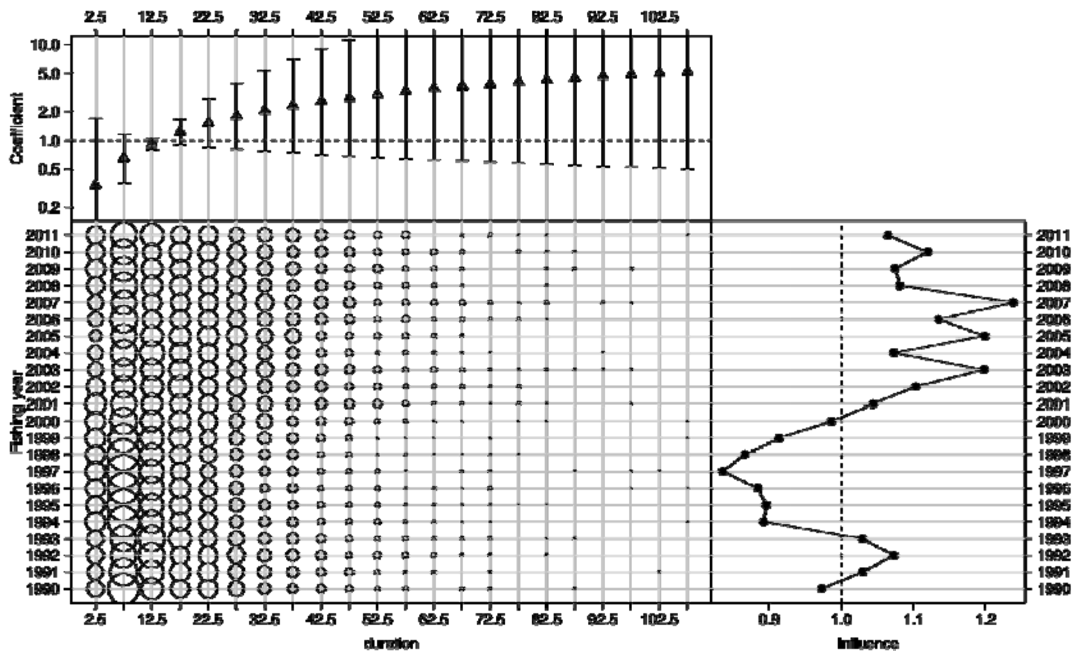

Figure G.4: Effect of log(duration) in the Weibull model for the BT (MIX) fishery based on data amalgamated to trip resolution. [Top]: variable coefficients. [Bottom-left]: distribution of trips by fishing year for the effort variable; [Bottom-right]: cumulative effect of log(duration) by fishing year .

G.2 BT (FLA): GUR 3 target flatfish bottom trawl fishery

Regression models using five different distributional assumptions (lognormal, log-logistic, inverse Gaussian, gamma and Weibull) predicted catch based on a reduced set of explanatory variables (year, month, vessel, area, target and log(number of tows). These models were evaluated by examination of residual diagnostics and the model with the lowest negative log likelihood was selected for the final stepwise regression (Figure G.5). The Weibull error distribution provided the best fit of the positive catch records to the core dataset for the BT (MIX) regression. The sensitivity of the final model indices to the choice of error distribution is shown in Figure G.6.

A binomial model of the probability of capture was fit to the full core dataset (including zero catches) and changes the unstandardised probability of capture very little, but the resulting year indices confirm the overall pattern of increase evident in standardised catch rates. The effect of combining the binomial series with a lognormal series was to estimate an even stronger increase in recent years (Figure G.3). The binomial and combined models are not presented here in any further detail.

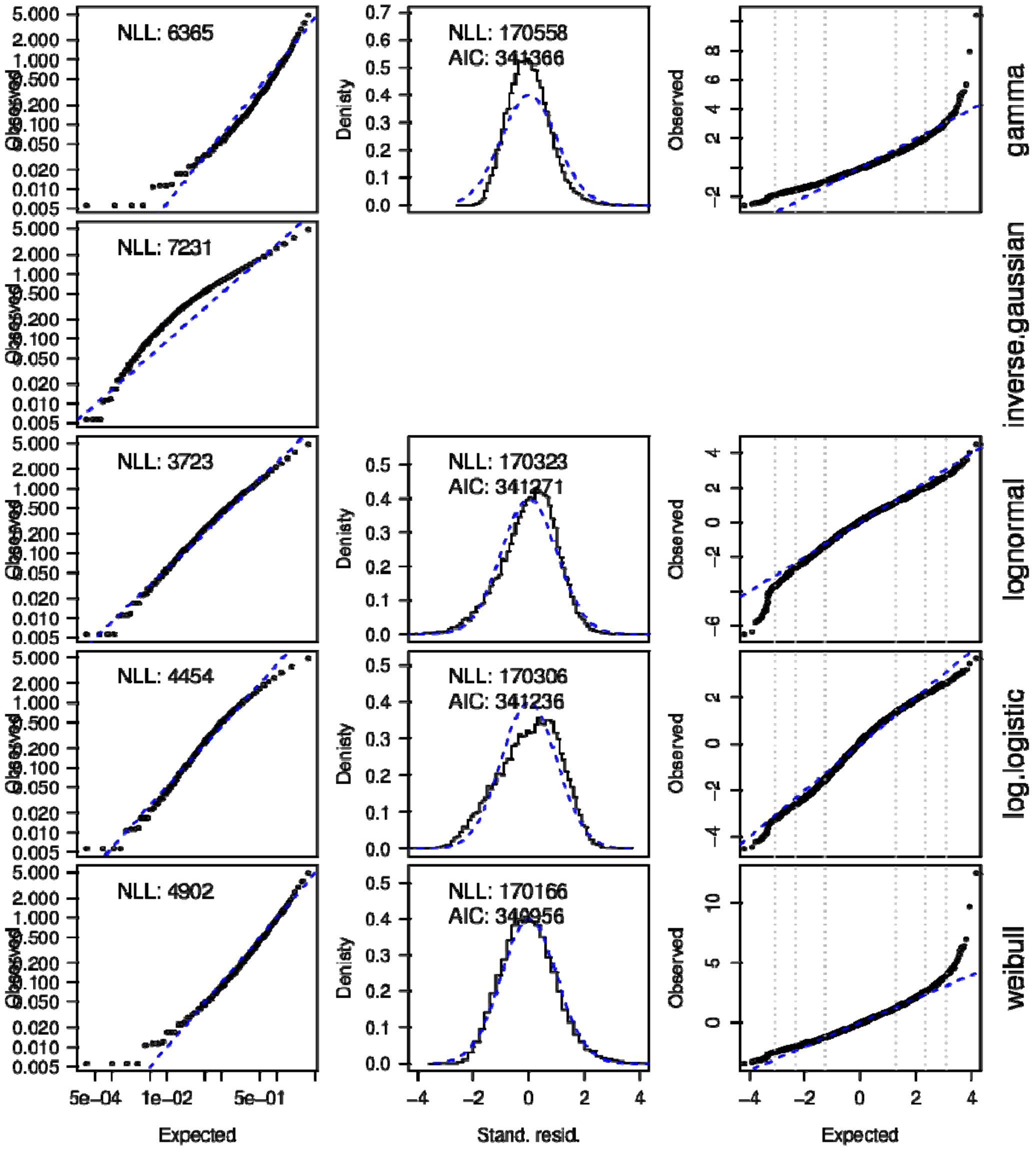

Figure G.5: Diagnostics for alternative distributional assumptions for catch in the GUR3_BT(FLA) fishery. Left: maximum likelihood fit (dotted) to observed catches (solid, scaled by their mean); Middle: standardised residuals from a model catch ~ fyear + month + area + vessel + target + poly(log(num); Right: quantile-quantile plot of standardised residuals of model. LL = log-likelihood of fit. The distribution with the lowest log-likelihood was Weibull.

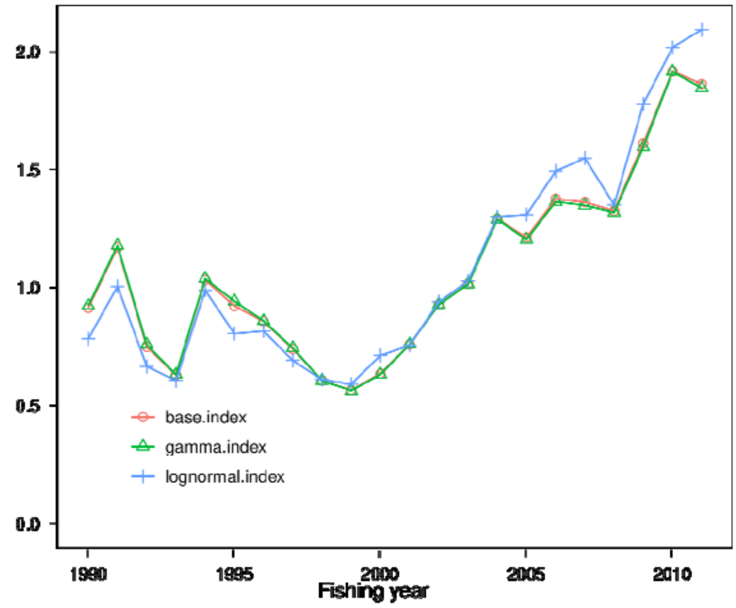

Figure G.6: Comparison between the Weibull index (base) and indices from a lognormal and gamma models fitted to the same dataset using the same parameterisation.

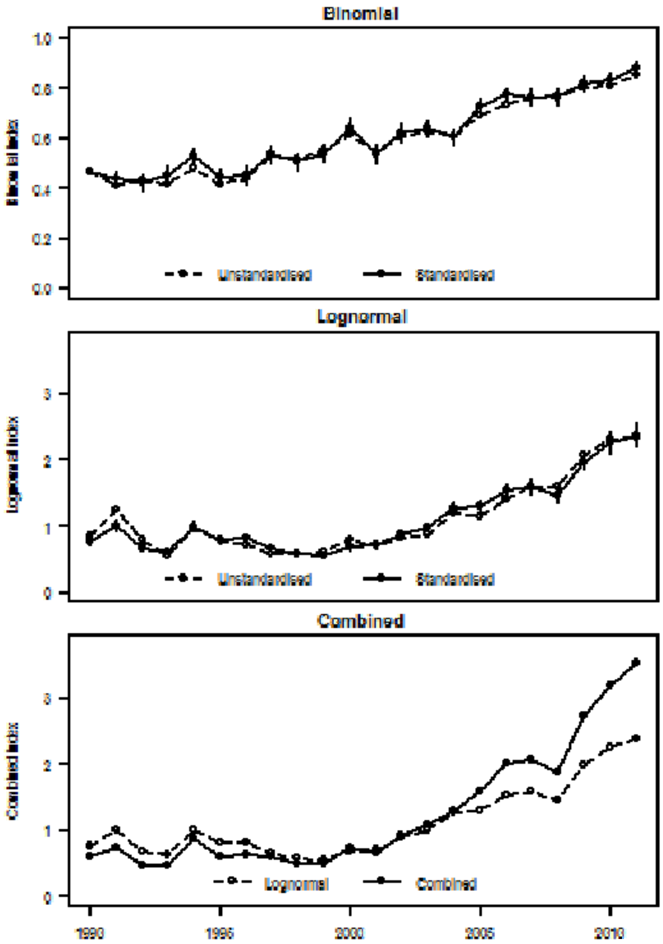

Figure G.7: The effect of standardisation on the raw CPUE of GUR by core vessels in the BT (FLA) fishery. Top: Binomial index of probability of capture. Middle: Lognormal index of magnitude of catch, broken line is the raw CPUE (kg / tow), the solid line is the standardised CPUE canonical indices with plus or minus two Standard Error bars. Bottom: Combined index of expected catch.

Appendix H. GURNARD LENGTH DISTRIBUTIONS FROM EAST COAST SOUTH ISLAND SUMMER SURVEYS

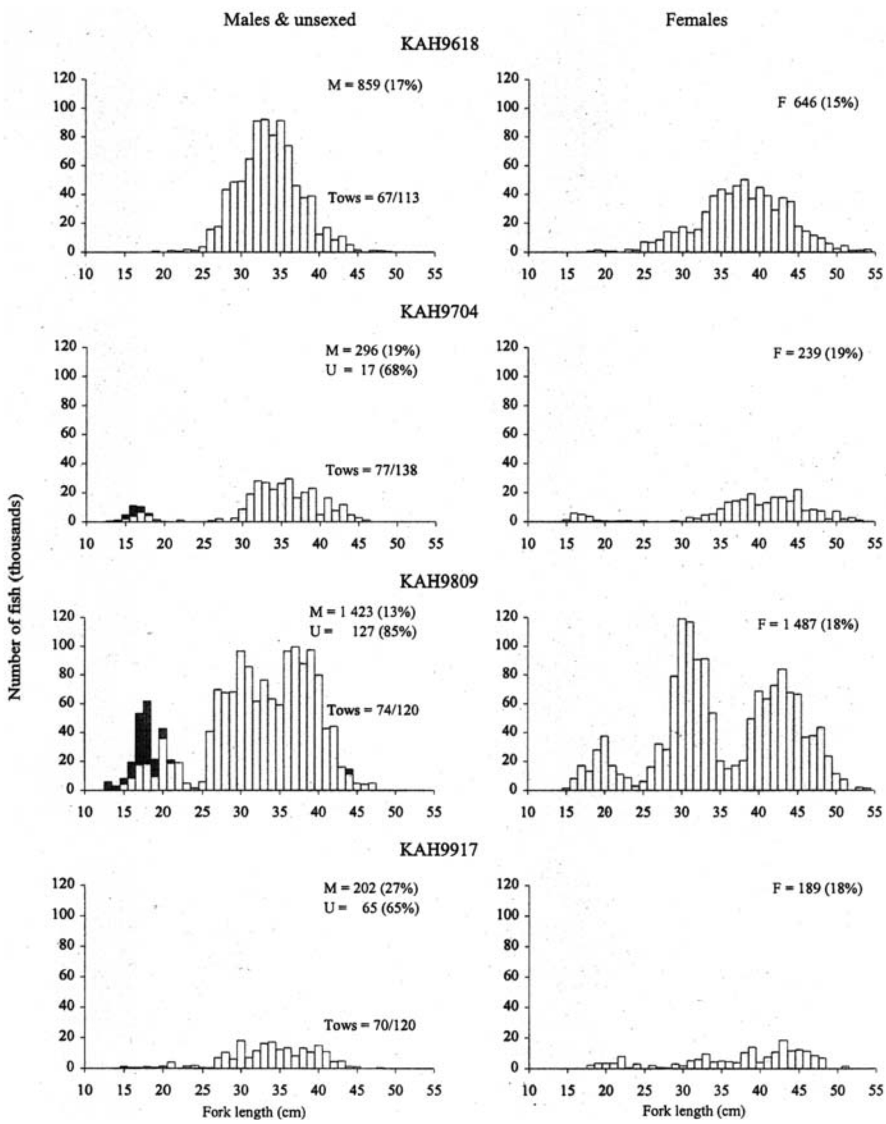

Figure H.1: Scaled (relative to tow densities) length distributions for males and unsexed [left panel] and females [right panel] from the summer east coast South Island trawl surveys. Survey trip numbers by year with the associated biomass estimates are provided in Table 20.