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EXECUTIVE SUMMARY

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This study was contracted as MFish project STA2007/01 with the specific objective: To characterise the fishery and update the standardised CPUE indices for STA 5 using data up to the end of the 2006–07 fishing year.

STA 5 is monitored using standardised CPUE for core inshore vessels targeting stargazer. The series, revised on a three-year cycle, was last updated to 2003–04 (MFish project STA 2004/02). This study updates the characterisation of the fishery and confirms that there have been no major changes to the way in which this fishery has operated in the three subsequent years. Most of the catch of STA 5 continues to be taken in targeted bottom trawl and reported on the daily Catch Effort Landing Return form (CELR).

The standardised CPUE is based on landed rather than estimated catch (Starr method). This is unusual for a well reported target species, but is advisable for this species because it is processed at sea and fishers have estimated the processed weight rather than the greenweight on catch effort forms in some instances.

An unusual aspect of this fishery is that considerable amounts of STA 5 have been landed to destination codes "T" (transferred to another vessel) and "R" (retained on board) in some years and, though these data would normally be excluded from the analysis, their utility is further considered in this study. The treatment of these data is discussed but further clarification should be sought by MFish as it was not considered by the Inshore Stock Assessment Working Group, that this species would in practice be retained on board given the premium for freshness, and the understanding that generally these vessels do not have freezing capacity.

The standardised CPUE series is extended by a further three years of data and some minor improvements to the data treatment; core vessel selection, fishery definition, and model parameterisation have not markedly changed the trajectory compared with the previous analysis for the years in common.

Overall, the trajectory of the updated series is flat except for two prominent features; a peak in the mid 1990s that appears to be corroborated by trawl survey biomass indices, and a marked increase in observed catch rates over the two most recent years (2005–06 and 2006–07) that is unchanged by standardisation.

1. INTRODUCTION

1.1 The fishery

Giant stargazer is caught principally around the South Island, and is an important bycatch of the domestic trawl fisheries targeting red cod, tarakihi, flatfish, barracouta, and scampi. In STA 5 however, most (about 80%) of the stargazer catch is taken by inshore vessels targeting this species.

STA 5 entered the Quota Management System (QMS) on 1 October 1986 with a Total Allowable Commercial Catch (TACC) of 1060 t. It was increased to 1500 t in the 1991–92 fishing year under the conditions of an Adaptive Management Programme (AMP) and further increased to 1525 t at the start of the 1994–95 fishing year. The TACC was reduced to 1264 t in 1997, on the removal of STA 5 from the AMP (Figure 1,

Table 1).

Landings increased to 1327 t in 1993–94, declined to 544 t in 1997–98, but subsequently increased. Landings have exceeded the new reduced TACC in 5 years out of 10 but have averaged 1227 t over the last five fishing years (2000–01 to 2006–07).

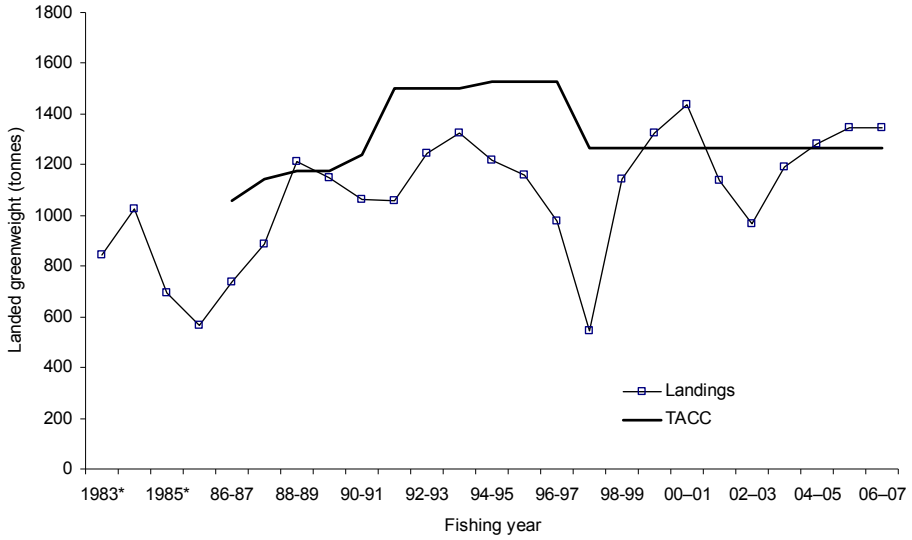

Figure 1: Landings of STA 5 and TACC (tonnes) from 1983-84 to 2006-07 from Ministry of Fisheries (2008).

1.2 Previous work

According to the Medium Term Research Plan for Inshore Finfish STA 5 is monitored using standardised CPUE for core inshore vessels targeting stargazer. The series, revised on a three-year cycle, was last updated to 2003–04 (STA 2004/02).

The previous study STA2004/02 (Manning 2007) was a comprehensive investigation of prospective CPUE analyses, including fisheries defined over a large number of target species, and that is not repeated in this study.

The final series accepted by the Inshore Stock Assessment Working Group was based on a lognormal model of positive landed catches of STA 5 by core vessels that fished using single bottom trawl, targeted stargazer in any statistical area valid for STA 5, and reported on either CELR or TCEPR catch

effort forms. The Working Group requested only that future analyses include form-type as a potential explanatory variable.
The canonical indices obtained from that model suggested that stargazer abundance in STA 5 had remained static, or at worst, declined only slightly over the data series. The pattern in the standardised CPUE indices of a peak in 1993–94 and a subsequent decline to 1995–96 appeared consistent with stargazer relative biomass estimates from research trawl surveys of the Stewart-Snares shelf carried out by RV *Tangaroa,* 1993–1996.

The decisions taken in that study are reviewed below and remain largely unchanged for this study. The characterisation describes a fishery that continues to consist almost exclusively of target bottom trawl, which operates mainly in three statistical areas and reports mainly on Catch Effort Landing Returns (CELRs). The dataset analysed in this study is limited to the inshore statistical areas (025 to 032) and includes a few more vessels, but the main change is in the grooming of landed catch, where landings reported as transferred to another vessel or retained on board have been treated differently from previously.

2. DATA SOURCES AND METHODS

Fishers are required to estimate the weight of only he top five species in the catch (but often fewer are reported) for a day's fishing on Catch Effort Landing Returns (CELRs), or, for individual tows, on Trawl Catch Effort and Processing Returns (TCEPRs). The estimated catch can therefore be an underestimate, especially for bycatch species. Only the landings values, reported on the bottom part of the CELR, or on Catch Landing Returns (CLRs) respectively, represent total catches. These values are available only at the end of the fishing trip, and are not directly linkable to individual fishing events or even to a single day's fishing. The linkage can be simulated by apportioning the landed catch to effort strata within the corresponding trip using procedures that have been developed for monitoring bycatch species in the AMP, and were comprehensively described by Starr (2007)

This study is based on landed catch of STA 5 allocated to effort strata (that portion of a vessel-trip that uses a single fishing method within a single month and statistical area, targeted at just one species) proportionate to the estimated catch, or where there was none, to the number of fishing events (tows). Landings were re-scaled in the dataset to equal the verified totals (

Table 1) from Monthly Harvest Returns (MHR) or, before October 2001, from Quota Management Returns (QMR).

The analyses were done on an extract from the Ministry of Fisheries (MFish) catch effort database "*warehou*" that obtained all trip information associated with any landing of STA 5.

2.1 Landed greenweight versus estimated catch

Analysis of a well reported target fishery would not usually justify the use of landed greenweight allocated to effort stratum (known as the Starr method). Estimated catch and its associated effort can usually be used directly for analysis of CPUE when a species is targeted and/or well reported, but for target species such as stargazer that are processed at sea there is another well known problem caused by fishers erroneously recording the processed weight instead of the greenweight in the catch estimates. This becomes evident if the total estimated catch plotted against the actual landed weight for a trip yields a cluster of points along a trajectory that corresponds to the main conversion factor. This pattern can be seen for trips that targeted stargazer in STA 5 (Figure 2).

In this case, it is appropriate to use the Starr method and to subject the landings data to a suite of error checking and grooming procedures which are fully described in Section 2.4. They include the re-

application of corrected conversion factors used to back-calculate greenweight from landed processed weight, and the consideration of landings destination codes.

Another advantage of using landed, rather than estimated, catch is that the landings forms include QMS Fishstock information, and without it, catches from straddling statistical areas (statistical areas shared by more than one Fishstock) are unidentifiable and must generally be excluded from the dataset. With the benefit of Fishstock information, trips that fished in one of the straddling statistical areas (026, 027) but landed stargazer only to the Fishstock code STA 5 have been retained in the analysis dataset.

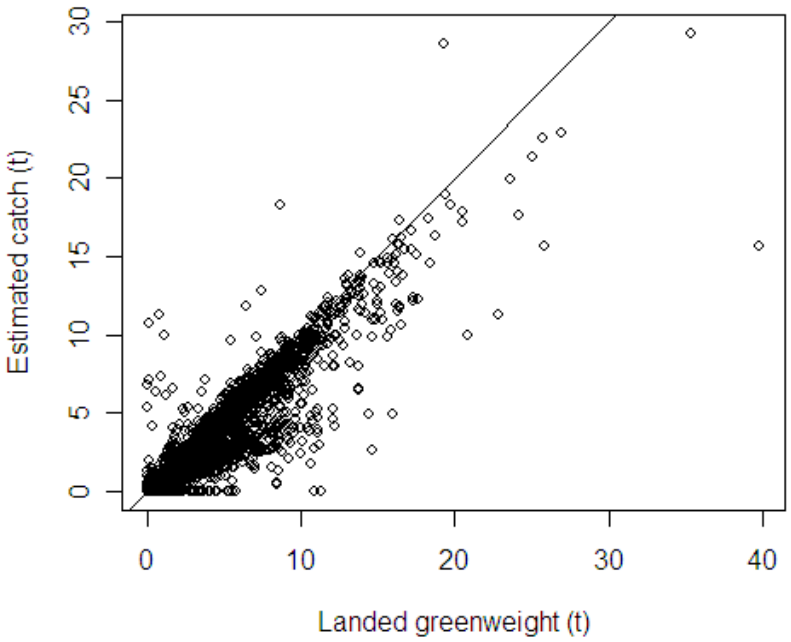

Figure 2: Scatter plot of the landed greenweight (t) compared to the estimated catch (t) in the analysis dataset (at trip-stratum resolution)

2.2 Combining form-types

The Starr methodology provides an elegant way to combine data across form-types because it amalgamates effort to a common trip-stratum resolution which is coarser than either TCEPR or CELR data. Nevertheless the data quality of the two formats is not equal, particularly for the reported target species. In the northern inshore trawl fisheries of QMA 1 combining data across form-types can give overly optimistic CPUE trajectories (Kendrick 2006) for target species, and caution is recommended.

Most of the data used in this study are reported in CELR format. In the earlier years there are small amounts of catch reported on TCEPRs and these were included in the analysis. Sensitivity to their inclusion was evaluated in the previous study by repeating the analyses on CELR data only. That analysis was not accepted by the Working Group, however, and is not repeated this study.

2.3 Inclusion of zero catch information

This study standardises positive catches of stargazer only and does not attempt to model the success of fishing separately.

Previous attempts to include zero catch information in a standardised CPUE analysis of this fishery have proved unconvincing, and that is not surprising in a target fishery. A well determined target fishery

would normally include few genuine zero catch records, and it is general practice in New Zealand fisheries to exclude the zeros if they represent 5% or less of the records available for analysis.

Another important consideration is the resolution of the data. Catch and effort reported on CELRs commonly represent totals for an entire day of fishing (unless there was a change in statistical area or of target species). Unsuccessful tows are unavoidably included in those totals, and, while they may have the effect of lowering the nominal catch rate, they are not individually identifiable. Catch rates calculated from CELR or otherwise amalgamated data therefore inherently include much of the zero catch information and any signal it contains about abundance (Kendrick 2009), so that separate analyses of the probability of capture rarely yields much additional information.

2.4 Methods used for grooming and collation of MFish catch and effort and landings data

An analysis dataset comprised of allocated landed greenweight at trip-stratum resolution was used to characterise the fishery, and to analyse CPUE in statistical areas 025 to 032 targeted at giant stargazer. The methods for collating this dataset are described briefly below, and more comprehensively by Starr (2007).

Candidate trips were identified by searching for all landings to Fishstock code STA 5. Once a list of trips that satisfied this criterion was identified, all effort and landing records associated with these trips were extracted, including landings to any other stargazer Fishstock. Effort and landings datasets were groomed separately before amalgamation and linking.

Outlier values in the effort data were identified from empirical distributions derived from the effort variable (duration or number tows) by identifying records where the values for these variables were in the extreme upper and lower tails of the distribution, and replacing them with the median value of the effort field for the affected vessel. Missing effort data were treated similarly. Where vessel median values were outside the 5th and 95th percentiles for the whole fleet then the trip was dropped entirely. Missing values for statistical area, method, or target species within any trip were substituted with the predominant (most frequent) value for that field over all records for the trip. Trips with all fields missing for one of these descriptors were dropped entirely.

Total landed weight of stargazer for each fishing trip was compared to the distribution of verified landings for stargazer supplied by the Ministry of Fisheries data unit available on CD from MFish. Trip totals that fell outside the upper 90th percentile were compared alongside the total estimated catch of stargazer for the trip and the total effort expended for credibility. Trips that landed 20 t or more of STA 5 were investigated in this way, and in the case of 11 trips for which the landed weight was an order of magnitude greater than the total estimated catch, an input error was assumed and the landed catch was replaced by the total estimated catch.

2.4.1 Conversion factors

Landed greenweight reported at the end of a fishing trip is back-calculated from the landed processed weight using conversion factors that are particular to the species and the processed state. Changes have occurred in these conversion factors over time and are assumed to represent improved estimates. Conversion factor is a calculated field that is retained with every landing event in the catch effort database "*warehou*".

The median conversion factor for each processed state in each fishing year is shown in Table A1, and the years in which a change was made are highlighted The greenweights established using the earlier conversion factors remain unchanged in the database, however, and for some species, they can represent a considerable underestimate of the actual catch. In the case of stargazer, there have been changes to

conversion factors for many of the main processed states, mainly in the first half of the time series and all of them represent an increase so that early landings totals need to be adjusted upwards. For example, the most important landed state for stargazer is DVC (dressed, v-cut). The current conversion factor for DVC is 2.15 kg of greenweight for every kilo of product processed in this way, but before 1996–97 a factor of only 2 was used. Similarly, the conversion factor for stargazer that was landed as HGU (headed and gutted) was increased in 2000–01 from 1.5 to 1.8 kg of greenweight for every kilo of processed fish landed. The most recent conversion factor used for each important processed type was re-applied to the historical series of processed weights to correct for improvements made over time to these ratios.

2.4.2 Destination codes

Each landing record also includes a destination code that describes the fate of the product. Most STA 5 was landed to the category "L" meaning that it was landed to a Licensed Fish Receiver (LFR) in New Zealand, and these data form the basis of the landings kept in the analysis dataset. Other destination codes that describe fish as lost, discarded, eaten, or sold outside New Zealand are also kept in the analysis dataset, but for other codes that describe fish kept on board (R), stored in holding receptacles (Q), or transferred to another vessels (T), the protocol (Starr 2007) has been to exclude them as the risk of double-counting when they are subsequently landed (L) is considered to be high.

This species (see also Starr et al. 2007a & 2007b) is characterised by significant amounts (Table 2) of stargazer landed to destination code "T" meaning that it was transferred to another vessel. In this case, the transferee vessels were not among the vessels fishing for stargazer, and did not subsequently land stargazer to a New Zealand Licensed Fish Receiver so the landings were retained in the dataset as relevant to the effort recorded by that vessel, and this saved 737 tonnes of STA 5 for analysis.

Landings to destination code "R", however, were also considerable (Table 2) and in this case not only were the landings dropped to avoid the possibility of double-counting, but, for vessels that used this code (Figure 3), all records in that year were dropped. This is because landings to code "L" may include "R" fish from a previous trip and are therefore not relevant to the effort in that trip. Vessels that landed stargazer to code "R" did so for a considerable portion of their annual catch of STA 5 (Figure 3), thus making the link between effort and landings for those vessels untenable.

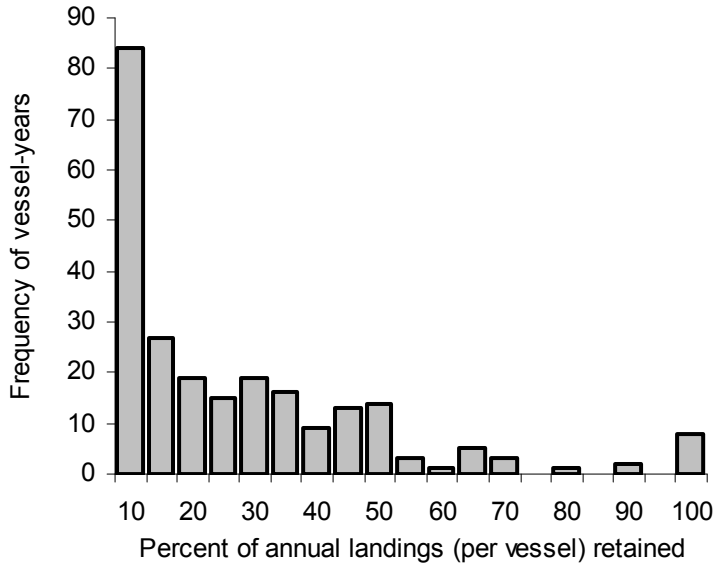

Figure 3: Vessels that employed the destination code "R" for catch retained on board (presumably to be landed at some later date to an LFR with destination code "L") used the code for a considerable portion of their annual catch of STA 5, thus making the link between effort and landings for those vessels untenable.

While a "year" is an arbitrary time period to exclude, it was done to minimise the exclusion of data because reporting practices do change over time. Nevertheless the consequence of this decision was quite severe, especially in recent years when the ratio of catch excluded to catch landed to destination code "R" is particularly high. There was 416 tonnes of STA 5 landed to the destination code "R", but 1919 tonnes were lost when all records for those vessels in those years were excluded (Table 3).

Table 1: Comparison of STA 5 TACC and landed catch totals (t) from the MFish catch and effort forms by fishing year with the total reported landings (t) to the QMS. Also shown are the catch totals (t) which remain after the dataset has been prepared for analysis by dropping trips which reported to more than one stargazer fishstock and fished in a straddling statistical area or that used multiple and incompatible gear types. The estimated catch total is the sum from all trips with matching landing data.

Fishing year	TACC	QMR reported catches	Bottom of form (some edits)	Landed catch for analysis	Estimated catch in dataset	% analysis catch of QMR	% estimated catch of QMR	% estimated catch of analysis
89/90	1 173	1 150	932.6	666.1	523.6	57.9	45.5	78.6
90/91	1 175	1 061	1 073.4	904.9	654.5	85.3	61.7	72.3
91/92	1 239	1 056	1 012.4	854.7	573.4	80.9	54.3	67.1
92/93	1 500	1 247	1 358.6	1 082.1	657.4	86.8	52.7	60.8
93/94	1 500	1 327	1 264.2	1 049.9	765.3	79.1	57.7	72.9
94/95	1 500	1 216	1 239.6	982.4	765.0	80.8	62.9	77.9
95/96	1 525	1 159	1 123.5	888.9	645.4	76.7	55.7	72.6
96/97	1 525	977	970.0	817.1	635.4	83.6	65.0	77.8
97/98	1 525	544	552.7	407.3	322.1	74.9	59.2	79.1
98/99	1 264	1 145	1 118.5	865.3	690.2	75.6	60.3	79.8
99/00	1 264	1 327	1 322.5	977.0	765.3	73.6	57.7	78.3
00/01	1 264	1 439	1 441.1	1 080.6	855.7	75.1	59.5	79.2
01/02	1 264	1 137	1 127.1	819.5	637.5	72.1	56.1	77.8
02/03	1 264	967	974.8	693.9	535.7	71.8	55.4	77.2
03/04	1 264	1 193	1 190.2	986.2	810.2	82.7	67.9	82.1
04/05	1 264	1 282	1 334.6	1 009.8	803.9	78.8	62.7	79.6
05/06	1 264	1 347	1 375.8	1 055.8	858.4	78.4	63.7	81.3
06/07	1 264	1 344	1 360.7	844.0	699.5	68.4	56.7	82.9

Table 2: Total number of records and total landed greenweight (t) of STA 5 in the unedited file by destination code, including whether or not they were retained in the analysis dataset. The "how used" column indicates which destination codes were included in the analysis dataset.

Destination Code	Destination Description	Number records	Greenweight STA 5 (t)	How used
L	Landed to a LFR in NZ	12775	20816	Kept
T	Transferred to another vessel	380	737	Kept*
R	Retained on board vessel	555	416	Not used**
O	Conveyed outside NZ	54	81	Kept
E	Eaten on board	321	8	Kept
NULL	?	13	8	Not used
Q	Put in holding receptacle on land	70	5	Not used
A	ITQ species accidentally lost	36	3	Kept
C	?	4	3	Kept
D	Discarded non-ITQ species	17	2	Kept
F	Fish landed under Section 111	5	0	Kept
B	Stored for bait	2	0	Not used

** Kept because not subsequently re-landed by transferee vessel*

*** All trips for the vessel in the fishing year excluded see Table 3*

Table 3: The amount of STA 5 (t) landed to the destination code "R"; the amount of landed STA 5 (t) consequently excluded by removal of all trips in the vessel-year.

Fishing year	STA 5 (t) landed to dest. code "R"	Total STA 5 (t) in vessel-years
89/90	4	95
90/91	15	69
91/92	38	128
92/93	35	147
93/94	16	77
94/95	81	86
95/96	22	105
96/97	20	68
97/98	7	56
98/99	22	106
99/00	18	94
00/01	4	51
01/02	10	64
02/03	5	79
03/04	38	117
04/05	45	173
05/06	23	175
06/07	15	228
Total	416	1 919

2.4.3 Merging landings with effort

The allocation of landed catch to effort is done by first summarising effort and estimated catch data for a fishing trip, for every unique combination of fishing method, statistical area, and target species (referred to as a "trip-stratum"). This reduces both CELR and TCEPR format records to lower resolution "amalgamated" data, giving fewer records per trip, but retains the original method, area, and target species recorded by the skipper.

The landed greenweight, declared at the end of the trip, is then allocated to the trip strata in proportion to the estimated catch. Where there were no estimated catches during the trip, the allocation is proportionate to the amount of effort.

The data available for each trip included estimated and landed catch of giant stargazer, total hours fished, total number of tows, fishing year, statistical area, target species, month of landing, and a unique vessel identifier. Data retained for the analyses might not represent an entire fishing trip, only those portions of it that qualified, but the amount of landed catch assigned to the part of the trip that was kept would be proportional to the total landed catch for the trip. 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 giant stargazer from the straddling statistical areas (026, 027), or that used a multiple fishing methods with incompatible measures of effort, were dropped entirely.

This method of using allocated landings retained for analysis more than 68% of landed STA 5 in each year. The estimated catch in the groomed dataset represented generally more than 72% of the allocated landings (Table 1).

The allocated landings were raised in the dataset to equal the QMR annual totals, and used to describe the STA 5 fisheries in the characterisation part of this study.

2.4.4 Effect of grooming

The cumulative effect of the grooming procedures described above is shown in
Figure **4**. When adjustments were made to correct for changes in conversion factors the effect was to lift annual totals in the early half of the time series so that they exceeded QMR totals. This effect should also be taken into account in the construction of catch histories for this species. The next greatest effect was from removing records for vessels that landed to destination code "R". This effect is greatest and tended to increase in the most recent four years and is therefore of considerable concern. Ambiguous landings from straddling statistical areas were reasonably consistent through the series and other losses of data were minor or intermittent.

The overall effect is better seen in Figure 5 where the data retained for analysis in each year are compared to the QMR totals and the increasing shortfall, mainly from the removal of data for vessels that retained catch on board (destination code "R"), is evident. There is also a considerable shortfall in estimated catch for this species, which is not expected for a target species but is partly an artefact of processing at sea. The shortfall is caused by fishers erroneously estimating processed weight instead of greenweight.

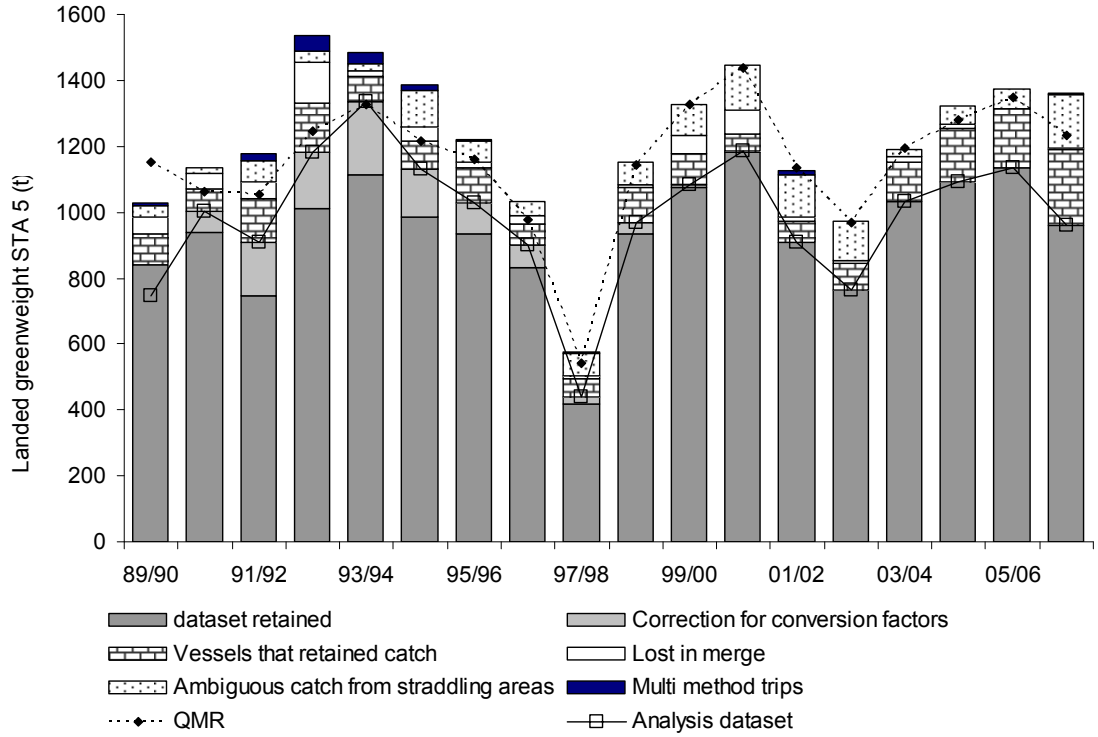

Figure 4: The effects of data grooming procedures on the dataset extracted on the basis of all records for trips that landed to STA 5. Only the lower two categories in each bar were retained for analysis; the other categories all describe the landed greenweight of stargazer lost as a result of removing ambiguous trips.

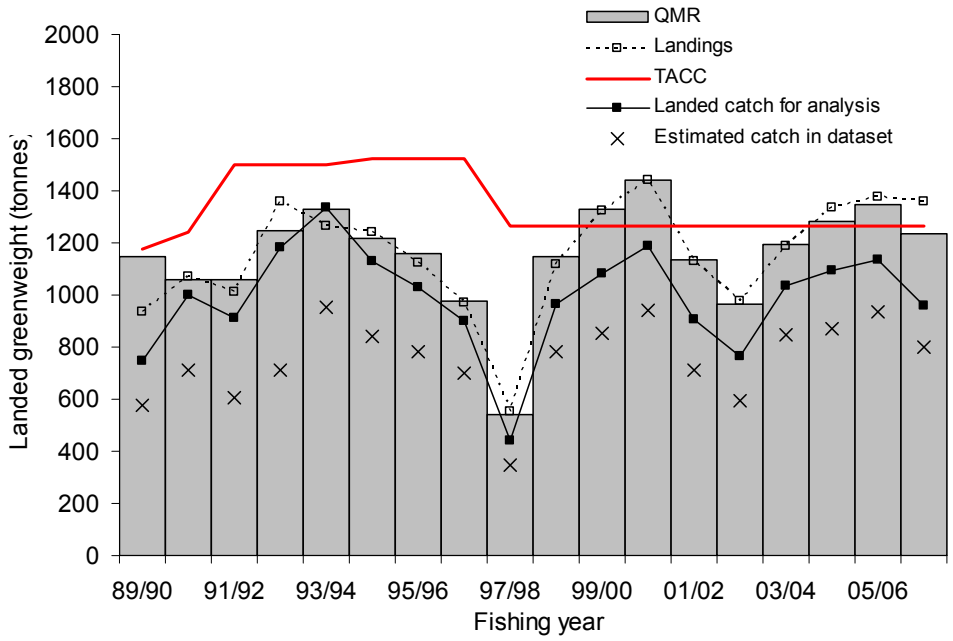

Figure 5: Plot of catch datasets presented in Table 1. The landings are totals reported on Catch Effort forms with some editing; the analysis dataset excludes all landings from trips that landed more than one stargazer fishstock and fished in a straddling statistical area or that used multiple incompatible fishing methods. The estimated catch total is the sum of all estimated catch in the analysis dataset.

2.5 Trawl survey biomass estimates

Relative biomass estimates (Table 4) are available from four research trawl surveys of the Stewart-Snares shelf by RV *Tangaroa*, 1993–96 (Hurst & Bagley 1994, Bagley & Hurst 1995, 1996a, 1996b). While the Stewart-Snares shelf trawl survey series has been discontinued, the survey design was optimised for giant stargazer and precise biomass estimates were obtained that were considered to be monitoring abundance. The trawl survey series was reviewed by Hurst & Bagley (1997).

Table 4: Giant stargazer relative biomass estimates from four research trawl surveys of the Stewart-Snares shelf by RV *Tangaroa*, 1993–96. Coefficients of variation (c.v.s) and reterences are provided.

Trip code	Date	Biomass (t)	c.v. (%)	Reference
TAN9301	Feb-Mar 1993	2 650	20	Hurst & Bagley (1994)
TAN9402	Feb-Mar 1994	3 755	11	Bagley & Hurst (1995)
TAN9502	Feb-Mar 1995	2 452	11	Bagley & Hurst (1996a)
TAN9604	Feb-Mar 1996	1 733	11	Bagley & Hurst (1996b)

2.6 Methods used for catch-per-unit-effort analysis

2.6.1 Defining fisheries

Fisheries are identified in the characterisation as likely candidates in which to monitor abundance of giant stargazer based on a consideration of whether: 1) effort is effective with respect to the species of interest (accounts for a significant proportion of landed catch), 2) the gear type is suitable for sampling, 3) the selected target fisheries are equally effective with respect to the species of interest (similar depth, catch rates, encounter rates, and / or other evidence of association), and 4) there has been reasonable

stability in the operation of the fishery (based on examination of the areal and seasonal distribution of effort).

2.6.2 Core fleet definitions

The data sets used for the standardised CPUE analyses 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 determined a qualifying year, and the number of qualifying years that each vessel participated in the fishery. The effect of these two variables on the amount of landed stargazer retained in the dataset and on the number of core vessels was plotted and examined visually.

The core fleet was selected by choosing variable values that resulted in the fewest vessels while maintaining the largest catch of stargazer. This selection process generally reduced the number of vessels in the dataset by about 70% while reducing the amount of landed stargazer catch by about 20%. Note that the vessels thus selected are not necessarily the top vessels with respect to catching stargazer. The number of trips in each fishing year for the selected vessels and the distribution of the length of participation for the core vessels in each fishery are examined for adequate overlap across years and consistency of coverage through the time series.

2.6.3 Models

A lognormal linear model was fitted to successful landed catches of STA 5, excluding zero catches. Catches were standardised for variance in the explanatory variables using a stepwise multiple regression procedure, selecting until the improvement in model R^2 was less than 0.01. The year effects were extracted as canonical coefficients (Francis 1999) so that confidence bounds could be calculated for each year.

The dependent variable for the lognormal models based on allocated landings was the log of landed weight of STA 5 per record (where a record is a trip/method/statistical area/target species stratum). The explanatory variables offered to the model were: *fishing year* (always forced as the first variable), and *month* (of landing), *statistical area*, *form-type*, and a unique *vessel* identifier. The logs of the total *number of tows* and of *tow duration* were offered as alternative measures of effort to explain catch as a catch rate. Continuous effort variables were offered as third order polynomials.

2.6.4 Sub-stock areas

Previous work has variously used or excluded data from offshore statistical areas, but analysis shows those records to be few. Most of the catch comes from area 030 and also significantly from 029 and 025. There are few catches made in offshore areas and they were excluded on the basis that this is a fairly sedentary species, but the fleets fishing this region are not. The offshore areas were not combined with inshore areas as is often done, on the advice of the AMPWG (Starr et al. 2007a & 2007b) which felt there was the potential for confounding effects introduced by inter-annual patterns of fishing behaviour.

3. RESULTS

3.1 Characterisation of the STA 5 fisheries

Stargazer in STA 5 is taken almost exclusively by single bottom trawl (generally more than 98% of annual landings); the only exception was in the 1997–98 fishing year when 37 tonnes was caught by set net. This was also the year of unusually low catch. Set net has taken small amounts of stargazer in every

year of the time series but has usually accounted for less than 10 tonnes annually. The balance has been taken in midwater tows and by bottom longline (Table 5).

Table 5: Distribution of landed stargazer (STA 5) by method and fishing year in tonnes, and in percent of annual landings. Catches are raised to the annual QMR catch (Table 1) 0 = less than 0.5 t. Percentages sum to 100 by year. BT, bottom trawl; MW, midwater trawl; BLL, bottom longline; SN, setnet; CP, cod pot. 0 = less than 0.5 t.

STA 5

Fishing	Fishing method (t)						Fishing method (%)					
year	BT	MW	BLL	SN	CP	Other	BT	MW	BLL	SN	CP	Other
89/90	1 144	0	-	6	-	-	99	0	-	1	-	-
90/91	1 057	0	-	4	-	-	100	0	-	0	-	-
91/92	1 047	0	0	8	-	-	99	0	0	1	-	-
92/93	1 245	0	0	2	-	0	100	0	0	0	-	0
93/94	1 325	0	0	2	0	0	100	0	0	0	0	0
94/95	1 212	0	-	4	0	-	100	0	-	0	0	-
95/96	1 156	0	-	2	-	-	100	0	-	0	-	-
96/97	972	0	0	4	-	0	100	0	0	0	-	0
97/98	497	1	-	37	-	9	91	0	-	7	-	2
98/99	1 129	1	1	7	-	7	99	0	0	1	-	1
99/00	1 321	1	0	3	-	2	100	0	0	0	-	0
00/01	1 424	6	5	5	-	0	99	0	0	0	-	0
01/02	1 130	1	1	5	-	0	99	0	0	0	-	0
02/03	950	6	0	11	-	0	98	1	0	1	-	0
03/04	1 184	1	0	8	-	-	99	0	0	1	-	-
04/05	1 274	3	0	5	-	-	99	0	0	0	-	-
05/06	1 341	3	0	3	-	-	100	0	0	0	-	-
06/07	1 224	1	0	8	-	-	99	0	0	1	-	-

3.1.1 Bottom trawl

The bottom trawl catch of stargazer in STA 5 is mainly targeted (73–91 % annually) and most of the balance is taken as a bycatch of flatfish tows (2–14 % annually). Small amounts (usually less than 50 tonnes per year, have been taken as a bycatch each of scampi (SCI) in the sub antartctic, and from tows targeted at ling, squid, and hoki (**Error! Reference source not found.**, Table 6)

There is little or no seasonal pattern to targeted catches, with landings distributed through the whole year (Figure 6), but there is a clear spatial pattern, with most of the catch coming from the Stewart-Snares shelf, mostly area 030, and also considerable but smaller amounts from areas 029 and 025 in every year, with catch from area 029 declining steadily in the last half of the time series. Small amounts of catch have been reported from 027 and from the Fiordland areas of 031 and 032, but very little from the offshore areas (Figure 7).

The vast majority of the targeted bottom trawl catch of STA 5 is reported on the daily CELR form (more than 99% in 13 out of the last 14 years, the exception being 96% in 1996–97) but in the earliest years of the time series up to 26% of the targeted catch was reported on TCEPRs (Table 7). Further examination revealed that many of these vessels also had a long history of reporting targeted stargazer catch on CELRs and had switched to reporting on TCEPRs for some months during 1991–92 and 1992–93. There was no evidence that fishing practice had changed with the change in reporting practice.

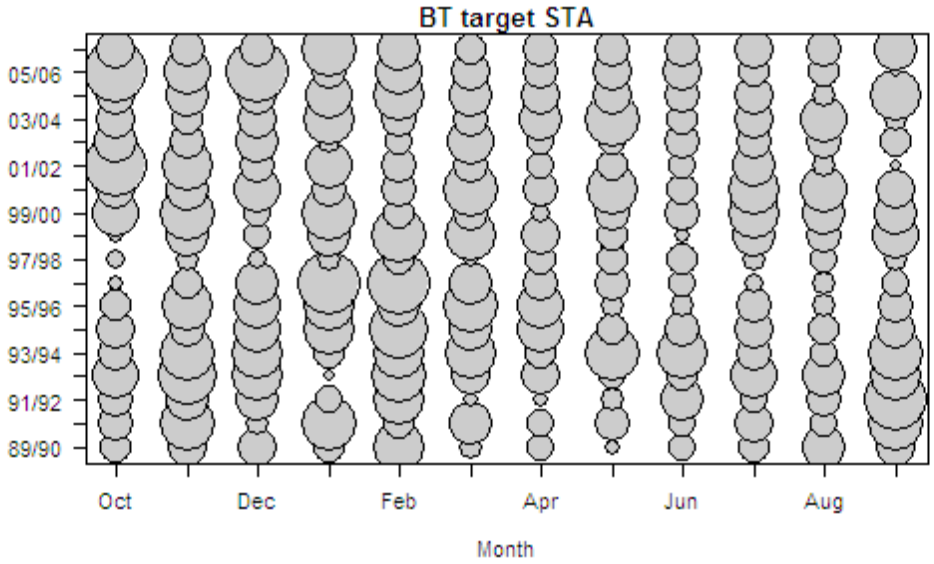

Figure 6: Comparison of the seasonal distribution of targeted bottom trawl stargazer catches by fishing year. Circle areas are proportional to the catch totals by month, target species, summing to the annual totals given in Table 6.

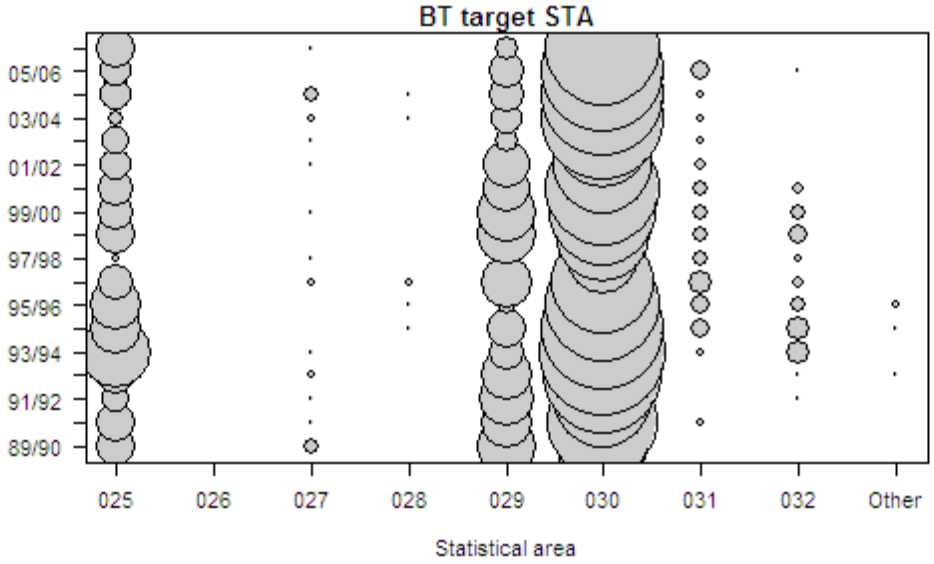

Figure 7: Comparison of the areal distribution of bottom trawl stargazer catches by fishing year. Circle areas are proportional to the catch totals by statistical area, summing to the annual totals given in Table 6.

Table 6: Distribution of bottom trawl caught stargazer by target species (stargazer, flatfish, squid, hoki, ling, hake, red cod, red gurnard and other) and by fishing year for STA 5 in tonnes and percent. Catches are scaled up to the annual QMR catch (Table 1). 0= less than 0.5 tonne. Percentages sum to 100 by year.

Bottom trawl

Fishing	Target species (t)									Target species (%)								
year	STA	FLA	SCI	LIN	SQU	HOK	BAR	GUR	Other	STA	FLA	SCI	LIN	SQU	HOK	BAR	GUR	Other
89/90	1 044.	18	-	29	10	1	12	8	21	91	2	-	3	1	0	1	1	2
90/91	912	67	-	11	19	7	21	6	14	86	6	-	1	2	1	2	1	1
91/92	831	96	15	22	10	24	4	5	40	79	9	1	2	1	2	0	0	4
92/93	1 005.	137	6	52	1	9	6	2	25	81	11	1	4	0	1	0	0	2
93/94	1 190.	84	19	10	3	2	0	5	11	90	6	1	1	0	0	0	0	1
94/95	1 106.	47	15	8	7	12	1	1	14	91	4	1	1	1	1	0	0	1
95/96	994	49	4	11	3	2	76	2	15	86	4	0	1	0	0	7	0	1
96/97	866	56	14	3	15	5	3	1	10	89	6	1	0	2	1	0	0	1
97/98	340	66	17	5	12	22	2	0	32	68	13	4	1	2	4	0	0	6
98/99	906	110	74	1	11	2	-	1	24	80	10	7	0	1	0	-	0	2
99/00	1 058.	150	41	1	5	26	2	12	25	80	11	3	0	0	2	0	1	2
00/01	1 049.	189	69	8	35	33	0	5	36	74	13	5	1	2	2	0	0	3
01/02	859	164	13	12	29	14	2	7	30	76	14	1	1	3	1	0	1	3
02/03	689	91	37	11	45	24	1	7	43	73	10	4	1	5	3	0	1	5
03/04	1 007.	49	32	32	14	17	12	7	14	85	4	3	3	1	1	1	1	1
04/05	1 039.	82	11	27	23	10	15	45	21	82	6	1	2	2	1	1	4	2
05/06	1 092.	98	9	35	10	3	5	28	62	81	7	1	3	1	0	0	2	5
06/07	999	98	4	39	5	1	3	25	49	82	8	0	3	0	0	0	2	4

Table 7: Reporting practice in the STA 5 target bottom trawl fishery. The percent of bottom trawl- caught STA 5 (by landed weight) and percent of effort (tows) reported on the daily form (CELR) and on the tow-by-tow form (TCEPR) by fishing year.

Target STA bottom trawl

Fishing	Number tows (%)		Landed STA 5 (%)	
year	CELR	TCEPR	CELR	TCEPR
89/90	98	2	97	3
90/91	99	1	100	0
91/92	84	16	80	20
92/93	79	21	74	26
93/94	100	0	100	0
94/95	100	0	100	0
95/96	100	0	100	0
96/97	97	3	96	4
97/98	100	0	100	0
98/99	100	0	100	0
99/00	100	0	100	0
00/01	100	0	100	0
01/02	100	0	100	0
02/03	100	0	100	0
03/04	100	0	100	0
04/05	100	0	100	0
05/06	100	0	100	0
06/07	100	0	100	0

3.2 Fishery definitions for standardised CPUE analysis

The fishery in which stargazer might best be monitored is very apparent from the results of the characterisation and confirms the fishery definition used in the previous analysis (Manning 2007) as the most logical and obvious. Most catch has been taken throughout the time series in targeted single bottom trawl by vessels that fished the inshore areas of STA 5 and reported on CELRs. Although STA 5 spans a very wide area, most of the catch is caught in statistical areas on the Stewart-Snare's shelf, in particular statistical area 030 west of Stewart Island, which dominates the catch in every fishing year, with little contribution from areas further south. The data set was restricted to the inshore statistical areas 027 to 032

Both formtypes (CELR and TCEPR) are retained for analysis. Target TCEPR is included because it involved many of the same vessels that also had long histories reporting on CELRs and the TCEPR data represented a brief change in reporting practice. Non-target CELR and target and non-target TCEPR trawl vessels account for only minor amounts of catch.

3.3 Core vessels

The data set was further restricted to data from a core fleet defined as vessels that had completed at least five qualifying trips (target bottom trawl in areas 027 to 032) in at least five years. This reduced the amount of landed greenweight of stargazer in the dataset by 1777 tonnes (from 14 565 tonnes), and reduced the number of vessels from 66 to 15 (Figure 8).

The selected core fleet consisted of 15 vessels, 6 of which had been present in the fishery throughout the entire time series (18 years) and 12 vessels that had participated for at least 10 years. The vessels selected therefore provided excellent coverage and overlap across years (Figure 9). The final dataset is summarised in Table C1.

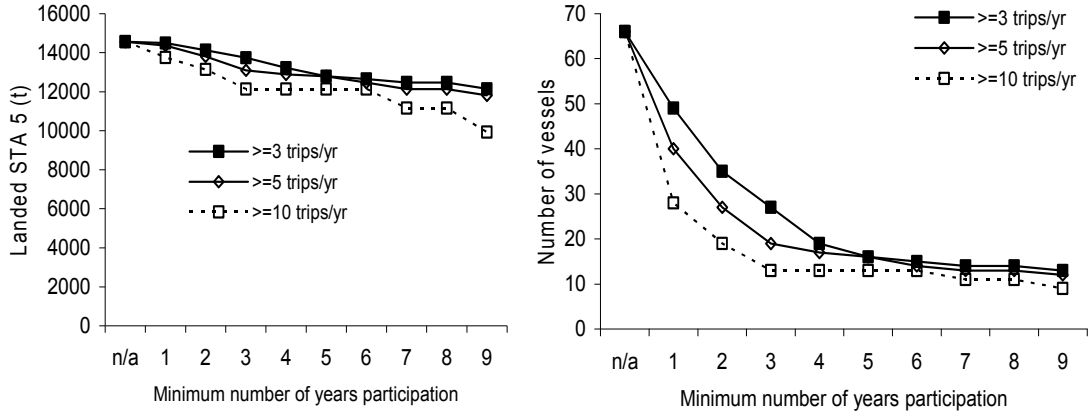

Figure 8: The total landed STA 5 [left panel] and the number of vessels [right panel] retained in the target fishery datasets, depending on the minimum number of qualifying years used to define core vessels. Alternative definitions of a qualifying year (minimum number of trips per year) are indicated in the legends.

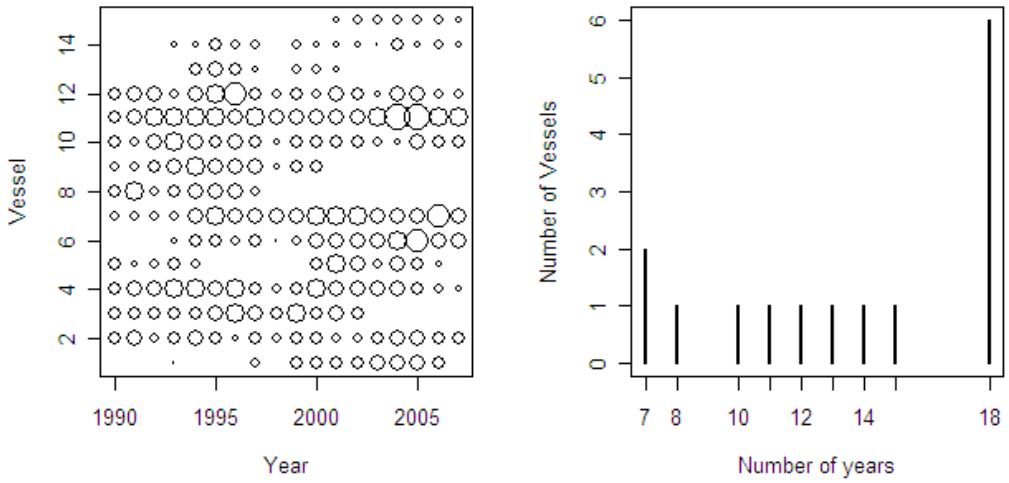

Figure 9: The participation of core vessels in the target bottom trawl fisheries; number of records for each vessel in each fishing year and distribution of length of participation.

3.4 Model selection

The final model selected is described in

Table 8. *Fishing year* was forced as the first variable but explained less than 3% of the variance in catch. The *log of the number of tows* had the greatest explanatory power, entering the model second and explaining an additional 57% of the variance in catch. Unusually, the alternative measure of effort (*log of duration of fishing*) also entered the model, although it came in last and explained only an additional 1.8% of variance. The categorical variables *vessel ID* and *statistical area* were also important and the final model was able to explain 66% of variance in catches. Neither *form-type* nor *month* were accepted into the model and this confirms the lack of contrast seen in the characterisation for seasonal catches and helps to validate the decision to include the anomalous TCEPR format data in the analysis dataset.

Table 8: Order of acceptance of variables into the lognormal model of STA 5 catch by core vessels in the two defined west coast fisheries, with the amount of explained deviance (R^2) for each variable at each step of the selection procedure, n.s. = not significant. Variables accepted into the model are marked with *. Final model R^2 is in bold. Fishing year was forced as the first variable.

Variable	1	2	3	4	5	n.s.
Fishing year*	0.024					
Log(number of tows)*		0.594				
Vessel*		0.080	0.617			
Statistical area*		0.086	0.610	0.646		
Log(duration of tows)*		0.562	0.614	0.642	**0.662**	
Month		0.032	0.598	0.622	0.650	0.666
Form-type		0.024	0.598	0.619	0.646	0.662

This result is similar to that presented by Manning (2007), except that he effectively forced *duration of fishing* as the measure of effort because although both measures were offered to the initial model, duration was already incorporated into the response variable (kg per hour) on the left hand side of the equation and neither measure of effort was accepted as having additional explanatory power. Although he subsequently changed the response variable to catch per record, and moved *duration* to the right hand side of the equation; the *number of tows* was not offered at that stage as an alternative measure of effort.

This study shows there is little difference between the explanatory power of the two measures of effort as main effects (see step 2 in

Table 8), but that they each have slightly different relationships to catch.

3.5 Trends in model year effects

The year effects from the lognormal model of the target bottom trawl fishery in STA 5 are provided in Table D1 and compared (re-scaled) in Figure 10 to the unstandardised indices and to the previous series (Manning 2007). Also shown are relative biomass estimates from four research trawl surveys of the Stewart-Snares shelf by RV *Tangaroa*, 1993–96 (Hurst & Bagley 1994, Bagley & Hurst 1995, 1996a, 1996b).

The greatest effect of standardisation was to drop some points for the two years leading up to 1997–98, which was the year of exceptionally low catches, even though nominal CPUE was increasing at that time. There was little effect of standardisation on the rest of the series. During these years there was a sharp drop in the number of vessels participating in the fishery (see Figure 9), which was possibly a market driven effect. The difference between unstandardised and standardised trajectories is greater than that described by (Manning 2007) and is attributable to the different choice of effort variable.

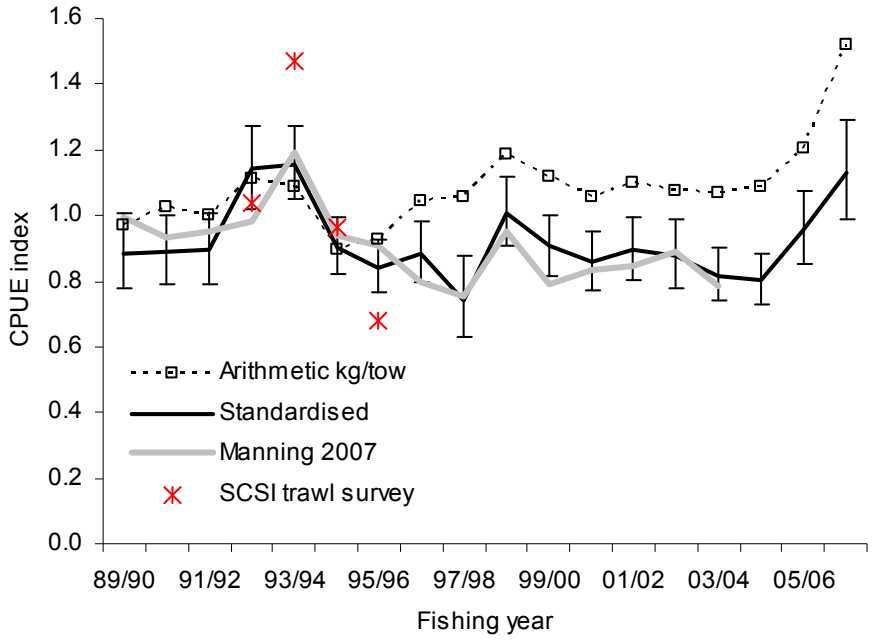

Figure 10: Effect of standardisation for lognormal model of positive landed catches of STA 5 in targeted bottom trawl. Unstandardised (arithmetic) kg/tow, and the previous series from a similar model (Manning 2007) are overlaid for comparison. The biomass indices from a set of *Tangaroa* trawl series (SCSI) are also shown. All series have been rescaled to the geometric mean of the years in common (1992–93 to 1995–96).

The overall effect was to flatten the trajectory, and there is reasonable agreement with the previous series for the years in common despite the different choice of effort variable, except that the first three points of the updated series are higher.

Since the last update there has been a marked increase in CPUE back to levels last seen in 1992–93 and 1993–94. This is also seen in the unstandardised catch rate and is only slightly modified by standardisation. The other prominent feature of the series is the peak in 1993–94 and the subsequent decline to the lowest point in the series in 1997–98 which appears to be corroborated by trawl survey biomass estimates described by Manning (2007).

3.6 Model fits

The diagnostics of the fit of the data to the lognormal assumption are shown in Figure 11. They show a reasonable fit for most of the data but some quite extreme departure at the extremes. Exploration of the residuals showed that the aberrant residuals were associated with very low observed values, and it doesn't seem unreasonable that very small catches in amalgamated data for a target fishery are going to be unusual or unexpected.

To test the leverage of those points, the 33 observations with the smallest landings were excluded from the dataset. This corresponded to landings (for a trip-stratum) of less that 60 kg. The model was refitted and the diagnostics were markedly improved (Figure A1), but there was almost no difference in the year effects (Figure A2).

Expected log catch rates for each significant predictor variable are presented in Figure 12 alongside distribution plots of the underlying data. There is a linear relation between catch and the number of tows for the range within which most of the data occur, and a drop in the number of tows per record and also the absence of many of the core vessels in 1997–98 that the model attempts to account for. The coefficients for each core vessel are well determined with about a two-fold difference in performance between the lowest and highest performing (with respect to catch of stargazer) vessels.

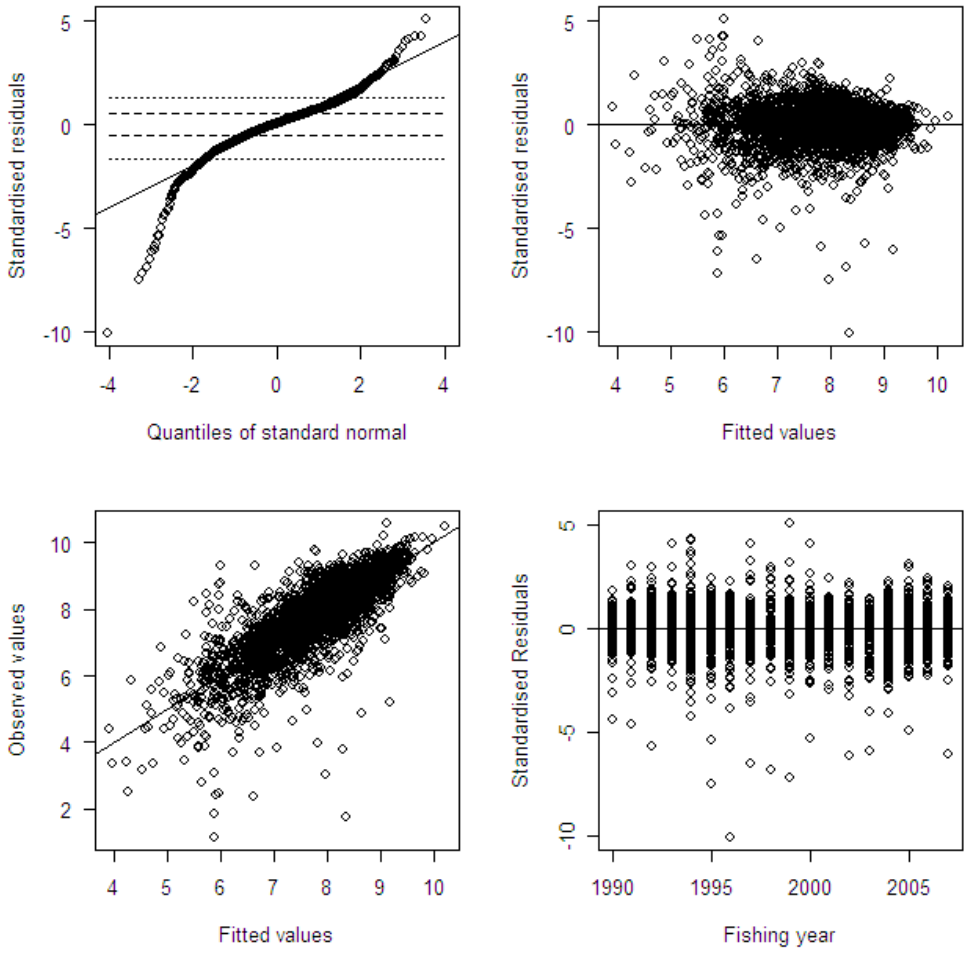

Figure 11: Plots of the fit of the standardised CPUE model to successful catches of STA 5 in the target bottom trawl fishery. Upper left: Q-Q plot of the standardised residuals; Upper right: Standardised

residuals plotted against the predicted model catch per trip; Lower left: Observed catch per trip plotted against the predicted catch per trip. Lower right: Standardised residuals plotted against fishing year.

There are clear differences in predicted catch with statistical area, with consistently higher catches predicted in areas 029 and 030 than in the other inshore areas. Large error bars around the coefficient for area 028 reflect the paucity of data from the area. There has been a shift away from area 029 and into area 030 in the last half of the time series, but as the coefficients for these two areas are similar this shift is unlikely to have caused any confounding with the year effect. The relation between catch and total duration of fishing is asymptotic and plateaus after about 20 hours, although most of the data fall within that range.

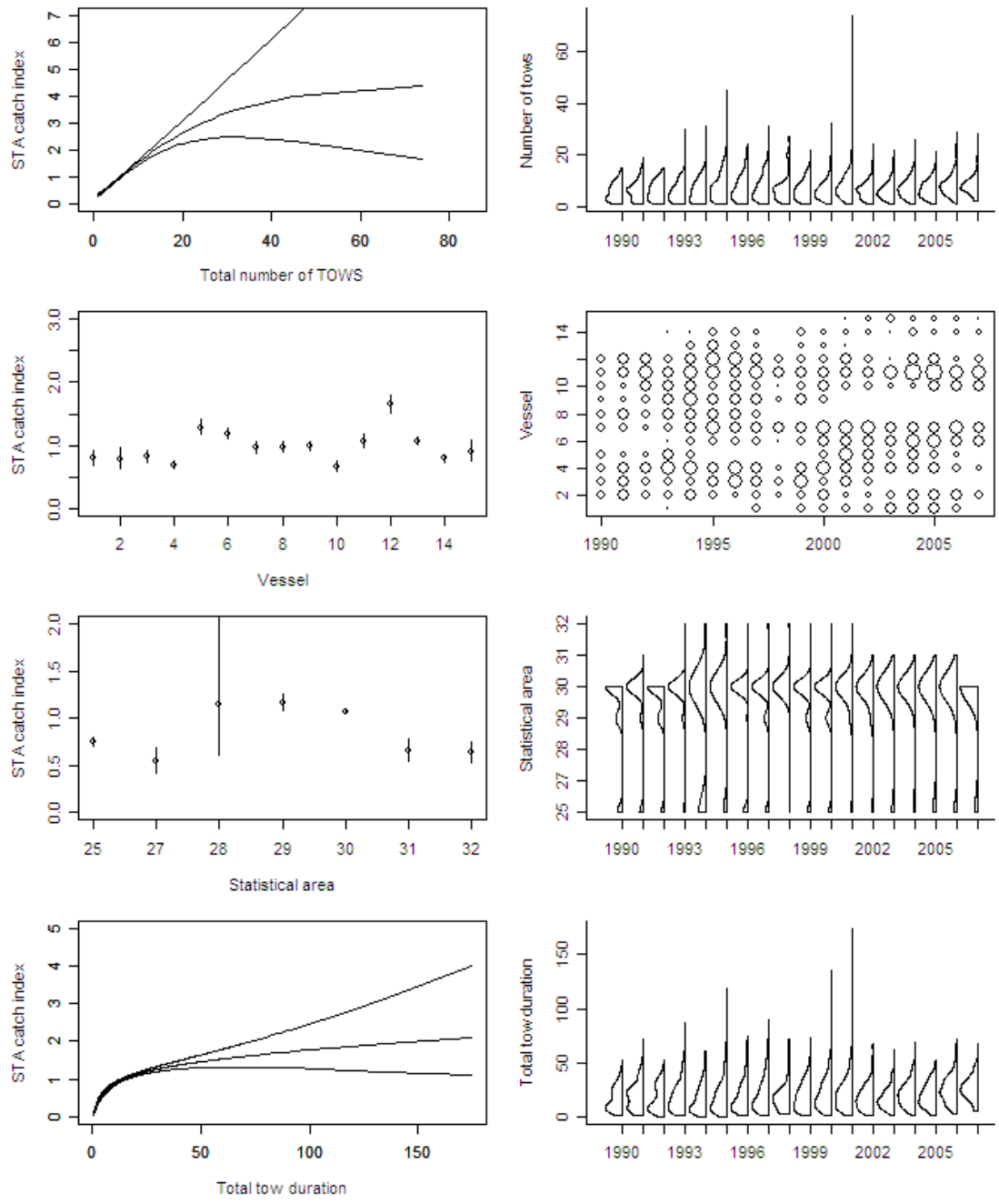

Figure 12: Plots of predicted relative catch per trip for the categorical and continuous variables included in the lognormal model of STA 5 catches in the STA 5 target bottom trawl fishery with 95% confidence

intervals. Distributions of the underlying data for the selected explanatory variables by fishing year. Fishing years are coded using the last year of the pair.

CONCLUSIONS

The fishery in which stargazer might best be monitored is very apparent from the characterisation and confirms the fishery definition used for the previous analysis (Manning 2007) as the most logical and obvious. Most of the catch has been taken throughout the time series in targeted single bottom trawl by vessels that fished the inshore areas of STA 5 and reported on CELRs. Some vessels switched to reporting on TCEPR forms for a short period during 1991–92 and 1992-93 and those data were retained for completeness as they did not reflect a change in fleet or fishing practice. Non-target CELR and TCEPR trawl vessels account for only minor amounts of catch, and although STA 5 spans a very wide area, most of the catch is caught in statistical areas on the Stewart-Snare's shelf, in particular statistical area 030 west of Stewart Island, which dominates the catch in every fishing year, with little contribution from areas further south.

Changes made to the data treatment include the retention of landings that were coded to destination "T" because it could be ascertained that they were not double-counted, and a more rigorous culling of data from vessels that used the destination code "R" to describe landed stargazer. The Working Group felt it was very unlikely that this species was being retained on board as most of these vessels were thought to be ice vessels (not freezer vessels) and the quality and therefore value of this species is heavily reliant on it being landed as soon as possible. The Working Group requested MFish to query fishers about their use of this code. In the meantime it has resulted in a considerable loss of data because it effectively breaks the link between landed catch and effort for those vessels.

Changes made to the standardisation included offering the model a choice of effort variable and the resultant inclusion in the model parameterisation of *number of tows* to help explain variance in catch. There was also a more transparent methodology described for selecting a core fleet of vessels, and *form-type* was offered to (but not accepted by) the model.

The updated series is flat overall but includes two recent years of marked increase. The only other feature is a peak and subsequent decline in the early 1990s that is corroborated by a similar pattern in SCSI trawl survey biomass indices that are considered to have been monitoring abundance.

4. ACKNOWLEDGMENTS

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APPENDIX A: CONVERSION FACTORS ANALYSIS

Table A1: Conversion factors used to back calculate landed greenweight from the main processed states for stargazer in STA 5. The median conversion factor in each fishing year by processed state, and the total landed greenweight in the unedited dataset. Entries highlighted indicate when major changes occurred.

Fishing	Landed state code									
year	DVC	HGU	DRE	DSC	GRE	GUT	MEA	SKF	FIL	Other
Median conversion factor										
89/90		1.8			1	1.1	5.55		2.3	
90/91		1.8	2		1	1.1	5.6			
91/92		1.8	2.5		1	1.15			2.6	
92/93	2	1.8	2.5	2.5	1	1.15	5.6		2.6	
93/94	2	1.5	2.5	2.5	1		5.6			
94/95	2	1.5	2.5	2.5	1	1.15	5.6			
95/96	2	1.5	2.5	2.5	1	1.15	5.6			
96/97	2.15	1.5	2.5	2.5	1	1.15	5.6			
97/98	2.15	1.5	2.5	2.5	1	1.15	5.6		2.6	
98/99	2.15	1.5	2.5	2.5	1	1.15	5.6		2.6	
99/00	2.15	1.5	2.5	2.5	1		5.6	4.65		
00/01	2.15	1.8	2.5	2.5	1		5.6	4.65	2.6	
01/02	2.15	1.8	2.5	2.5	1	1.15	5.6			
02/03	2.15			2.5	1		5.6	4.65		
03/04	2.15			2.5	1	1.15	5.6	4.65		
04/05	2.15			2.5	1	1.15	5.6	4.65		
05/06	2.15			2.5	1		5.6		2.6	
06/07	2.15			2.5	1		5.6			
Total landed greenweight (t)										
89/90		846.8			1.6	0.1	0.0		0.0	73.1
90/91		751.5	506.9		58.2	1.4	0.3			20.7
91/92		544.5	671.1		1.8	3.7			1.4	0.0
92/93	1.8	519.9	640.9	7.4	54.9	100.7	0.1		0.7	
93/94	117.4	634.6	467.1	11.6	6.7		0.0			0.0
94/95	647.7	334.7	353.3	33.9	14.4	0.6	0.9			
95/96	548.3	148.8	518.5	18.5	27.5	0.1	0.1			0.2
96/97	394.4	954.4	411.5	17.6	1.2	10.2	0.0			0.1
97/98	402.2	37.2	141.7	28.9	3.9	0.4	0.2		0.3	1.1
98/99	782.6	14.7	181.6	78.1	1.1	0.3	0.5		0.4	7.9
99/00	1073.7	32.0	316.5	70.5	19.9		1.0	0.1		0.0
00/01	1374.3	69.0	139.7	43.0	1.6		3.8	0.0	0.3	0.0
01/02	1057.5	11.8	66.2	48.8	2.0	0.8	2.1			0.1
02/03	1043.1	9.6	36.8	33.2	1.1		5.0	0.0		
03/04	1036.7	34.0	4.6	15.7	1.0	0.0	2.4	12.4		
04/05	1151.7	29.5	5.8	11.9	2.8	0.2	1.8	1.4		
05/06	1269.7	17.8	1.8	0.3	1.6		2.2		6.5	
06/07	1356.0			5.9	1.4		0.8			
Total	12260.7	4990.7	4464.1	425.3	202.5	118.5	21.5	13.9	9.6	103.2

APPENDIX B. SENSITIVITY TO OUTLIERS

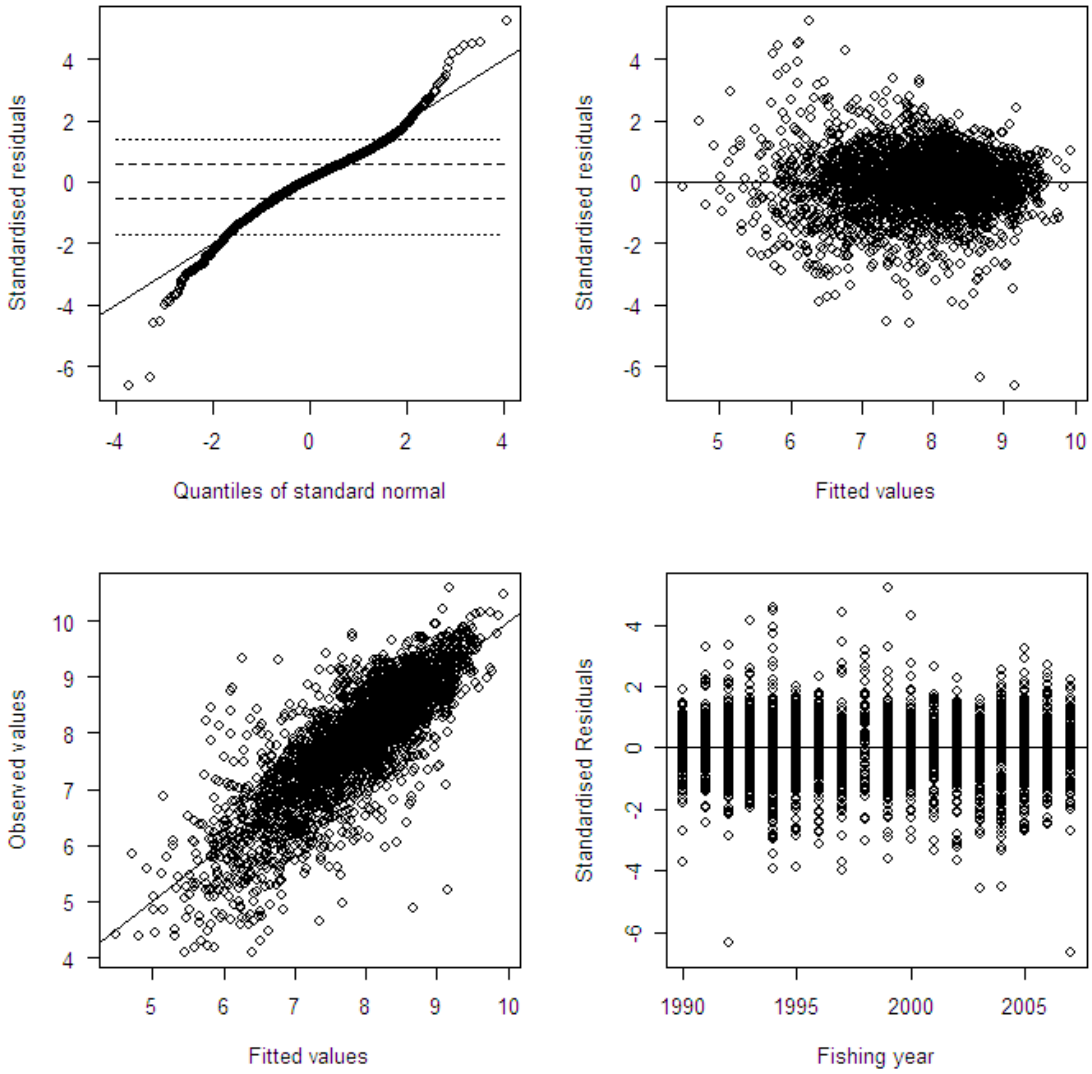

Figure B1: Plots of the fit of the standardised CPUE model to the trimmed (33 records comprising catches smaller than 60 kg removed) dataset of successful catches of STA 5 in the target bottom trawl fishery. [Upper left] Q-Q plot of the standardised residuals; [Upper right] Standardised residuals plotted against the predicted model catch per trip; [Lower left]. Observed catch per trip plotted against the predicted catch per trip. [Lower right] Standardised residuals plotted against fishing year.

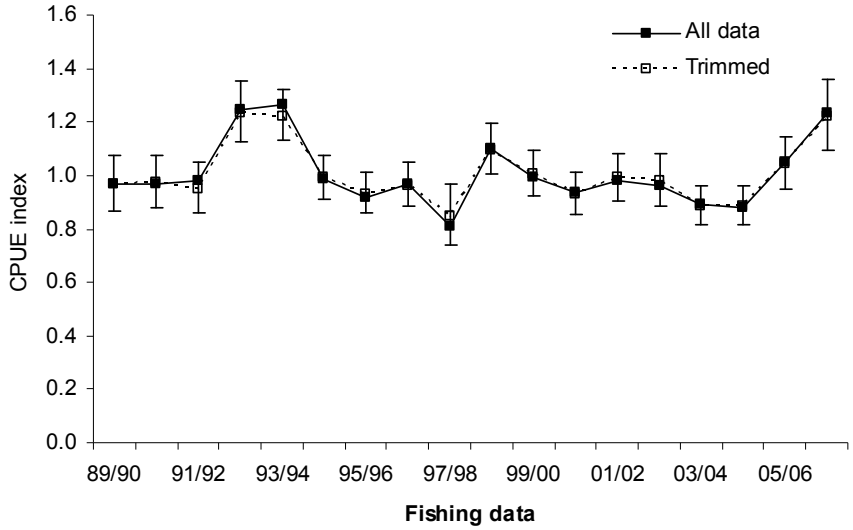

Figure B2: Sensitivity of the year effects to the removal of outliers (33 records containing catches smaller than 60 kg removed).

APPENDIX C: DATA SUMMARIES

Table C1: Data summary for the target bottom trawl fishery defined for standardised CPUE analysis for core vessels; (core vessels based on a minimum of 5 trips per year for at least 5 years); Number of trips, percentage of strata that recorded a zero catch of stargazer, number of core vessels, total number of tows, landed weight of STA 5 (tonnes), and the simple catch rate of STA 5 across qualifying tows (kg/tow).

Fishing year	No. Trips	% zero	No. vessels	No. of tows	STA (t)	CPUE kg/tow
90/91	116	0	10	726	363	500
91/92	146	0	10	971	547	564
92/93	137	0	10	896	515	575
93/94	149	0	13	1117	760	680
94/95	235	0	13	1623	1041	642
95/96	221	0	12	1876	958	511
96/97	219	0	12	1779	869	489
97/98	171	0	13	1396	756	541
98/99	70	0	9	558	275	492
99/00	170	0	12	1253	728	581
00/01	186	0	13	1430	804	563
01/02	183	0	13	1590	840	528
02/03	172	0	12	1214	664	547
03/04	140	0	11	955	510	534
04/05	210	0	11	1601	852	532
05/06	212	0	11	1538	812	528
06/07	146	0	11	1351	794	587

APPENDIX D: CPUE INDICES

Table D1: Relative year effects and 95% confidence intervals for the CPUE model fitted to the target bottom trawl dataset for STA 5. Arithmetic series is the annual CPUE (ratio of sums) relative to the geometric mean of the series.

Fishing year	Arithmetic kg/tow	Standardised Index	SE	Upper bound	Lower bound
89/90	0.900	0.968	0.059	1.090	0.860
90/91	0.950	0.970	0.054	1.081	0.870
91/92	0.930	0.978	0.054	1.090	0.877
92/93	1.030	1.246	0.050	1.378	1.128
93/94	1.010	1.263	0.044	1.379	1.157
94/95	0.830	0.987	0.044	1.078	0.903
95/96	0.860	0.919	0.044	1.004	0.842
96/97	0.970	0.966	0.049	1.064	0.876
97/98	0.980	0.811	0.075	0.943	0.698
98/99	1.100	1.101	0.049	1.213	0.999
99/00	1.040	0.991	0.047	1.088	0.902
00/01	0.980	0.936	0.047	1.029	0.851
01/02	1.020	0.979	0.049	1.080	0.888
02/03	1.000	0.960	0.055	1.071	0.860
03/04	0.990	0.893	0.045	0.978	0.816
04/05	1.010	0.877	0.045	0.959	0.802
05/06	1.120	1.049	0.053	1.166	0.944
06/07	1.410	1.236	0.060	1.394	1.096