SPRFMO

4th Meeting of the Scientific Committee

The Hague, Kingdom of the Netherlands
10 - 15 October 2016

SC-04-17

New Zealand Annual Report

Ministry for Primary Industries

Ministry for Primary Industries
Manatū Ahu Matua

New Zealand National Report on Fishing and Research Activities in the SPRFMO Area during 2015

SPRFMO number SC-04-17

MPI Technical Paper No: 2016/xx

ISBN No: (online)
ISSN No (online)

September 2016

New Zealand Government

Growing and Protecting New Zealand

Ministry for Primary Industries
Manatū Ahu Matua

Disclaimer

Every effort has been made to ensure the information in this document is accurate.

MPI does not accept any responsibility or liability whatsoever for any error of fact, omission, interpretation or opinion that may be present, however it may have occurred.

Requests for further copies should be directed to:

Publications Logistics Officer
Ministry for Primary Industries
PO Box 2526
WELLINGTON 6140

Email: brand@mpi.govt.nz
Telephone: 0800 00 83 33
Facsimile: 04-894 0300

This publication is also available on the Ministry for Primary Industries website at http://www.mpi.govt.nz/news-resources/publications.aspx

Contents

Page

1 Description of Fisheries

1.1 PELAGIC FISHERIES

New Zealand conducted no pelagic fishing for *Trachurus* species in the SPRFMO Area during 2015. *Trachurus murphyi* is taken sporadically within the northern half of New Zealand's EEZ (Langley et al. 2016) but, although this species was common in New Zealand waters in the early 1990s, the average catch between 2009 and 2014 was <100 tonnes per annum.

1.2 BOTTOM FISHERIES

New Zealand high seas bottom trawl and line fisheries were last described in detail in the impact assessment '*New Zealand Bottom Fishing Activities by New Zealand Vessels Fishing in the High Seas in the SPRFMO Area during 2008 and 2009'* (New Zealand Ministry of Fisheries 2008b) available at http://www.southpacificrfmo.org/benthic-impact-assessments/. Bottom fishing activities during 2015 operated in largely the same way, and were conducted in accordance with the impact assessment and management measures described in that report.

New Zealand vessels have been bottom fishing in the SPRFMO Area since before 1990 (Clark 2008a). Specific high seas fishing permits for the SPRFMO Area were implemented in 2007-08, following adoption of the SPRFMO interim measures in May 2007. The total number of New Zealand vessels permitted to fish in the SPRFMO Area and with the capability for bottom fishing and the numbers of vessels which actually bottom fished in the Convention Area since 2002 are shown in Table 1.

Table 1: Summary of the number of New Zealand vessels permitted to bottom fish in the SPRFMO Area and with the capability for bottom fishing, and the number of vessels which actually fished in the Area per year with either bottom trawl or line, since 2002. The data are by permit year, which is 1 May to 30 April.**

Vessel Permit Year	Number of Vessels Permitted to Fish SPRFMO Area	No. of Vessels that Actively Bottom Fished in the SPRFMO Area	Bottom Trawling	Bottom Lining
2002–2003	*55	22	19	3
2003–2004	*66	24	17	7
2004–2005	*60	28	17	11
2005–2006	*58	22	12	10
2006–2007	*38	12	8	4
2007–2008	25	7	4	3
2008–2009	21	10	5	5
2009–2010	24	9	7	2
2010–2011	27	9	7	2
2011–2012	24	9	6	3
2012–2013	24	8	5	3
2013–2014	24	8	5	3
2014–2015	31	10	6	4
2015–2016	31	9	5	4

* There were no specific high seas permits for the SPRFMO Area prior to 2007. These were the numbers of New Zealand vessels issued with general high-seas permits that indicated that they had the capability to bottom trawl.
** Historical numbers in this table have been corrected and differ from those tabulated in New Zealand's 2014 National Report

Vessel numbers declined from a peak of 23 in 2002 and has been stable at between 4 and 8 vessels since 2007. The number of vessels line fishing increased from 3 in 2003 to a peak of 11 in 2005 before fluctuating between 2 and 5 vessel since. The distribution of vessel size of the permitted vessels from 2006-07 is shown in Table 2, with no clear trend in vessel size over time. The main areas utilised by New Zealand bottom fishing vessels outside of the New Zealand EEZ since 2002 are shown in Figure 1.

Table 2: Distribution of vessel size (length overall in metres) for New Zealand vessels permitted to bottom fish in the SPRFMO Area for the permit years (May - April) from 2006-07.

	Length overall (m)									
Permit year	≤ 11.9	12–17.9	18–23.9	24–29.9	30–35.9	36–44.9	45–59.9	60–74.9	≥ 75	Total
2006/07	0	1	6	8	3	8	2	8	2	38
2007/08	0	1	4	3	3	8	0	4	2	25
2008/09	0	0	3	3	4	8	2	6	0	21
2009/10	0	1	3	1	5	6	0	6	2	24
2010/11	0	1	3	3	4	8	2	6	0	27
2011/12	1	1	3	1	2	8	2	6	0	24
2012/13	1	1	3	1	2	8	2	6	0	24
2013/14	0	1	3	2	2	7	2	6	1	24
2014/15	0	1	8	2	3	6	3	7	1	31
2015/16	0	1	7	3	4	7	3	4	2	31

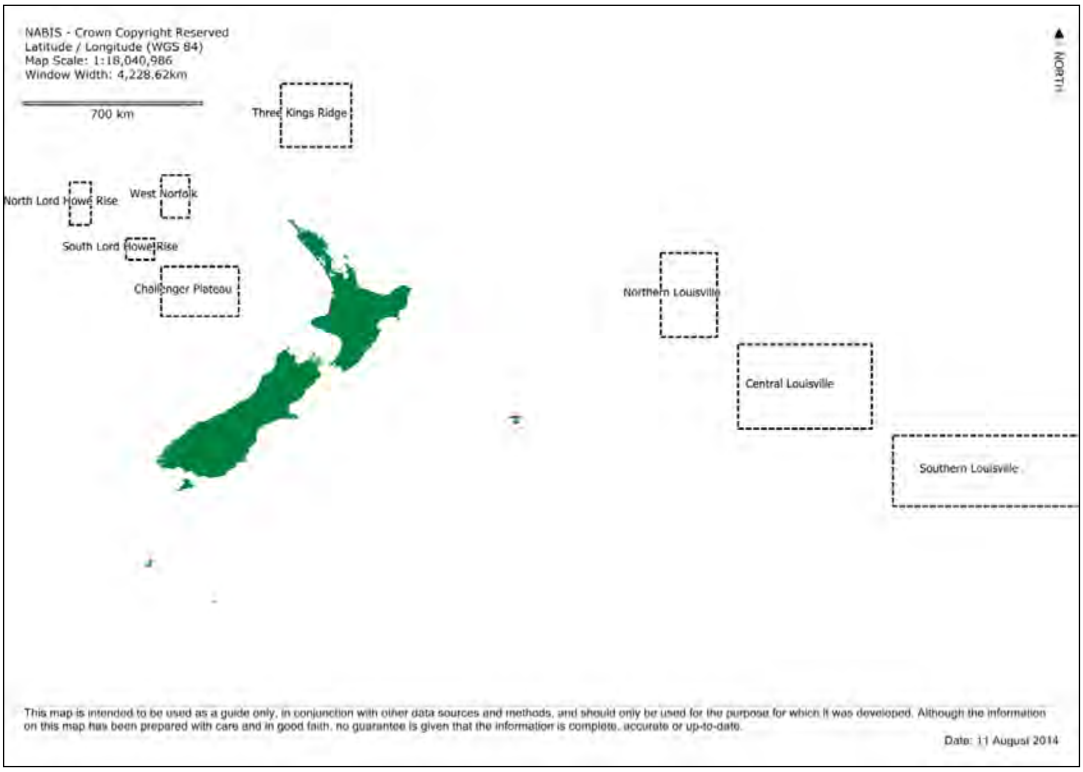


Figure 1: The areas bottom fished by New Zealand trawlers in the SPRFMO Area since 2002.

2 Catch, Effort and CPUE Summaries

2.1 BOTTOM TRAWL FISHERIES

The annual fishing effort (number of vessels and number of bottom trawl tows for which catch was recorded) and landed catch by calendar year of the main bottom trawl target and bycatch species are summarised in Table 3. The number of bottom trawl tows decreased from about 3 000 per year in 2002 and 2003, to a minimum of about 200 in 2008, then increased again to about 1 200 in 2010 and 2011, before dropping to the second lowest recorded since 2000 in 2014. Over 900 tows were conducted in 2015, the highest since 2011, and the highest recorded number of tows per vessel. This pattern broadly mirrors that in the number of vessels fishing over the same time period.

Orange roughy (*Hoplostethus atlanticus*) continues to be the main bottom trawl target species, contributing 80% of the total bottom trawl catch since 2002 (varying by year between 67% and 99%) (see Table 3). Other species making minor contributions to catches include oreos 5% (0–16%), cardinalfish 4% (0–8%) and alfonsino 4% (0–13%). There were substantially higher catches of alfonsino and cardinalfish in 2010 and 2011, but these declined in 2012 and 2013 and neither was reported in 2014. Cardinalfish constituted 3% of the total catch in 2015 and alfonsino constituted 1%.

Midwater trawling for bentho-pelagic species occurred in 2011 for the first time in any quantity (there were 1 and 15 midwater tows in 2009 and 2010 respectively), with three permitted trawlers executing a total of 61 tows principally targeting alfonsino (ALF) close to the seabed. It has been determined that such fishing is included in the SPRFMO definition of bottom fishing (see Report from SC2) and is therefore included in this section. Effort was roughly the same in this fishery for 2011 and 2012 in terms of numbers of vessels and numbers of tows. In 2013 only one vessel fished using a midwater trawl but there was a marked increase in effort, with 120 tows. The same vessel also fished bottom trawl gear on the same trips as it fished midwater gear. Despite the 2-fold increase in the number of midwater tows in 2013, catches remained similar to previous years. There was no midwater trawling for bentho-pelagic species in 2014 but there were 21 tows by two vessels in 2015. The proportion of alfonsino in the reported catch of midwater trawls has shown a progressive increase from 39% in in 2011 to 84% in 2013 and 92% in 2015.

The trends in orange roughy catch and effort from 2002 in the main fishing areas are summarised in Tables 4 and 5 and also shown in Figure 2. The decline in orange roughy catches from 2002 to 2008 was associated with the decline in fishing effort in the main historical fishing areas of the NW Challenger Plateau and Louisville Ridge (Tables 4 and 5). After 2008, effort on the NW Challenger Plateau increased, as did effort on the Lord Howe Rise and Louisville Ridge. Catches of orange roughy in 2015 were slightly higher than in 2013 and 2014 for all areas except the Louisville Ridge where catches were slightly lower. These reductions reflected changes in fishing effort.

Table 3: Annual fishing effort (number of vessels and tows) and catch (tonnes) of the main target and bycatch species (identified by FAO species codes) by New Zealand vessels bottom trawling (top) and midwater trawling for bentho-pelagic species (bottom) in the SPRFMO Area from 2002 (see Appendix 1 for list of species codes and names). Year is calendar year. The number of tows reported here is the number of tows which recorded a fish catch, and excludes tows where there was no catch.

Bottom trawling

Year	No. Vessels	No. Tows	Tows/ Vessel	ORY	ONV	BOE	EPI	ALF	SSO	RIB	RTX	SCK	All Species
2002	23	2 944	128	2 578	–	121	159	17	50	43	61	37	3 180
2003	19	2 928	154	1 973	–	62	226	94	25	92	84	56	2 937
2004	17	1 952	115	1 697	–	90	42	85	91	46	34	8	2 188
2005	17	2 186	129	1 597	–	268	189	26	75	63	67	5	2 395
2006	12	1 135	95	1 415	–	57	21	28	6	33	27	15	1 652
2007	8	415	52	866	–	151	–	2	22	9	5	1	1 076
2008	4	208	52	837	2	–	–	2	<0.1	3	0.1	1	846
2009	6	547	91	928	5	–	16	5	<0.1	7	0.1	2	958
2010	7	1 167	167	1 474	9	12	22	244	10	15	6	13	1 864
2011	7	1 158	165	1 079	16	12	108	176	4	22	7	9	1 486
2012	6	652	109	721	10	4	2	39	3	5	7	2	805
2013	5	760	152	1 164	11	20	3	28	5	6	1	-	1 261
2014	5	403	81	998	6	7	0	0	5	2	0	0	1 028
2015	5	959	192	1 287	11	2	48	9	10	5	0	0	1 513

Midwater trawling for benthopelagic species

Year	No. Vessels	No. Tows	Tows/Vessel	ALF	EDR	ONV	BWA	All Species
2011	3	61	20	64	76	21	2	164
2012	3	59	20	115	25	0	3	145
2013	1	120	120	122	9	0	10	145
2014	0	0	–	0	0	0	0	0
2015	2	21	11	34	0	0	2	37

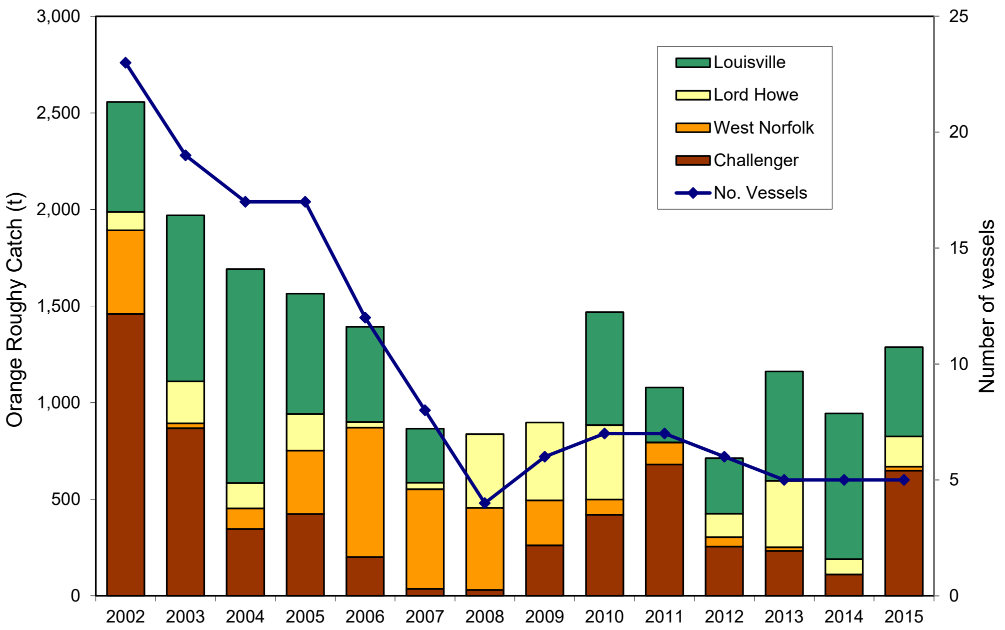


Figure 2: Trends in effort (the number of bottom trawl vessels fishing, number of tows) and total landings of orange roughy (tonnes) for each of the four main areas fished by New Zealand bottom trawl vessels in the SPRFMO Area by calendar year from 2002. The reference years are 2002–2006.

Table 4: Bottom trawl effort (number of tows) in the main areas fished by New Zealand bottom trawl vessels fishing in the SPRFMO Area by calendar year from 2002. Reported effort for the Challenger Plateau includes effort on the Westpac Bank.

Year	Challenger Plateau	West Norfolk Ridge	Lord Howe Rise	Louisville Ridge	Other Areas	All Areas
2002	2 152	298	181	890	10	3 531
2003	2 072	88	470	774	95	3 499
2004	853	110	449	1 340	14	2 766
2005	1 039	323	256	838	41	2 497
2006	411	264	139	588	18	1 420
2007	76	176	37	126	–	415
2008	26	104	78	–	–	208
2009	156	252	229	–	11	648
2010	409	58	388	303	12	1 170
2011	437	84	379	258	–	1 158
2012	166	58	121	296	11	652
2013	189	27	128	299	7	7 600
2014	64	–	70	263	6	403
2015	582	32	124	221	–	959

Table 5: Total estimated catches (tonnes) of orange roughy from the main areas fished by New Zealand bottom trawl vessels fishing in the SPRFMO Area by calendar year from 2002. –, less than 1 tonne. Landings from the Westpac Bank area (part of the Challenger Plateau) are reported against New Zealand's ORH7A stock that straddles the boundary of the SPRFMO Area. Catches from there between 2002 and 2010 were largely from research surveys.

Year	Challenger Plateau	Westpac Bank (ORH7A)	West Norfolk Ridge	Lord Howe Rise	Louisville Ridge	Other Areas	All Areas
2002	1 460	–	432	96	568	22	2 578
2003	868	–	25	218	859	3	1 973
2004	347	–	106	132	1 106	5	1 697
2005	425	–	327	190	623	33	1 597
2006	202	–	670	29	493	22	1 415
2007	36	–	515	34	280	–	866
2008	31	–	426	380	–	–	837
2009	238	23	233	403	–	31	928
2010	415	5	79	385	584	6	1 474
2011	675	5	113	1	285	–	1 079
2012	247	8	49	121	288	8	721
2013	230	3	19	344	565	3	1 164
2014	57	54	0	79	754	54	998
2015	530	118	20	157	462	–	1 287

2.2 BOTTOM LINE FISHERY

The annual fishing effort (number of vessels and hooks fished) and catch of the main bottom line target and bycatch species are summarised in Table 6. The number of active line vessels increased from 3 in 2003, to 11 in 2005, then declined and has fluctuated between 3 and 5 vessels since 2007. The numbers of hooks set rose from 50,000 in 2003 to peak at 500,000 in 2006 and then declined to a low of 48,000 in 2010, after which it increased substantially to a new peak of 780,000 in 2014. In 2015, less than one-quarter of the hooks were set than in 2014 but the catch of the main target species increased slightly (Table 7). The reasons for these large fluctuations in effort and catch are not known.

Table 6: Effort and estimated catches for New Zealand vessels bottom lining in the SPRFMO Area by calendar year from 2002. Effort is presented as the number of vessels, trips, and number of hooks set, with catches in tonnes of the target and bycatch species (see Appendix 1 for a list of species codes and names).

Year	No. Vessels	No. Trips	No. Hooks **(000's)**	Hooks/ Vessel **(000's)**	BWA	HAU	DGS	MOW	RXX	YTC	ROK	TOP	Total catch (t)
2002	–	–	–	–	–	–	–	–	–	–	–	–	–
2003	3	7	53	18	6	7	1	1	–	–	–	1	17
2004	7	18	269	38	116	24	–	6	2	1	–	3	154
2005	11	29	384	35	102	31	13	10	2	3	1	–	163
2006	10	49	502	50	271	95	6	6	2	2	2	–	385
2007	4	29	423	106	144	31	4	5	3	3	1	–	202
2008	3	15	302	101	67	43	1	2	<1	1	8	–	123
2009	5	12	236	47	58	23	7	1	<1	–	<1	–	89
2010	2	5	48	24	15	24	–	1	<1	<1	<1	–	45
2011	2	6	71	36	23	25	6	<1	<1	<1	<1	–	57
2012	3	10	90	30	44	40	2	3	<1	<1	<1	–	95
2013	3	13	479	160	64	41	6	3	<1	1	1	–	124
2014	4	18	784	196	33	45	4	11	<1	<1	2	–	99
2015	4	15	179	45	35	63	4	2	<1	<1	1	–	126

Bluenose BWA (*Hyperoglyphe antarctica*) was historically the main bottom line target species but catches declined from 2006 and the annual catch has been similar to that of wreckfish (HAU, *Polyprion oxygeneios* and *P. americanus*) since about 2010 (roughly 20–60 t. Together these two reporting codes (three species) made up 76–95% of the catch between 2003 and 2015, averaging 84% overall, and they accounted for 79% of the catch in 2014 and 78% in 2015. Other species making minor contributions to bottom line catches include spiny dogfish (DGS), king tarakihi (MOW) and sea perch (ROK). The increase and subsequent decrease in bluenose catches by main fishing areas since 2002 is shown in more detail in Table 7. Figure 3 shows that the moderate catches in the mid-2000s have fallen to much lower levels recently, in line with the reduction in effort over time. There are no clear trends in nominal CPUE (Figure 4) and the reasons for the large fluctuations and apparent correlation between the two main species, especially in recent years, are not known.

Table 7: Total catch of bluenose, BWA, from the main areas fished by New Zealand bottom line vessels fishing in the SPRFMO Area by calendar year since 2002.

Year	Challenger Plateau	West Norfolk Ridge	Three Kings Ridge	Louisville Ridge	Other Areas	All Areas
2002	–	–	–	–	–	–
2003	–	5	1	–	–	6
2004	103	12	–	–	1	116
2005	38	27	24	–	14	102
2006	91	114	48	–	19	271
2007	59	47	39	–	–	144
2008	24	33	8	2	–	67
2009	13	29	16	–	–	58
2010	2	13	–	–	–	15
2011	–	11	11	–	–	23
2012	11	15	18	–	–	44
2013	31	10	24	–	–	64
2014	8	11	14	–	–	33
2015	23	10	2	–	–	35

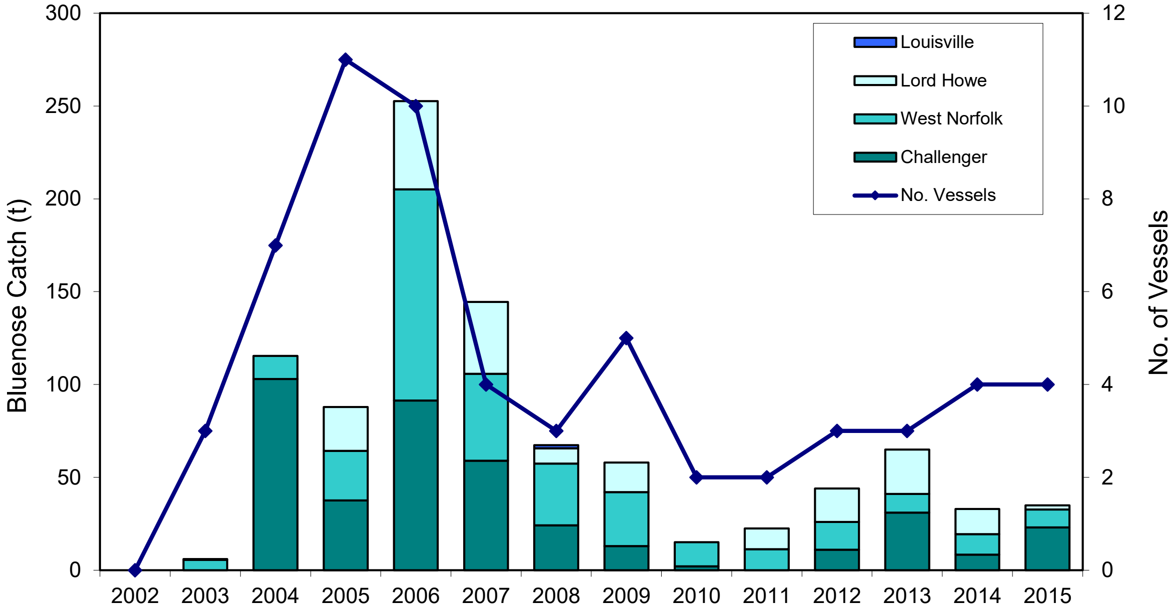


Figure 3: Trends in number of bottom line vessels and total bluenose catch from the four main areas fished by New Zealand bottom line vessels in the SPRFMO Area by calendar year from 2002.

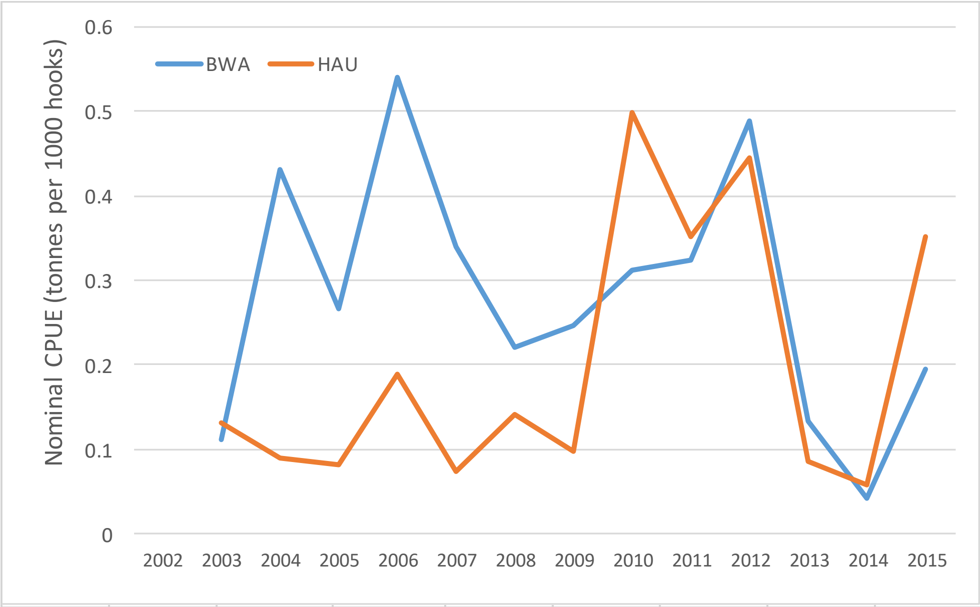


Figure 4: Trends in nominal CPUE (tonnes per 1000 hooks set) for bluenose (BWA) and wreckfish (HAU) by New Zealand bottom longline vessels fishing in the SPRFMO Area since 2002 (effort data not separated by nominated target species).

3 Fisheries Data Collection and Research Activities

3.1 FISHERIES CATCH & EFFORT DATA COLLECTION SYSTEMS

The data collection systems implemented for New Zealand high seas bottom trawl and line fishing vessels have been described previously (Ministry of Fisheries, 2008b). Detailed tow-by-tow catch and effort data for all high seas fishing operations have been collected since 2007 using the at-sea catch and effort logbooks and landings recording forms described therein. Detailed observer Benthic Materials Forms have been completed for all observed bottom fishing (trawling and lining) to record benthic bycatch to the lowest possible taxonomic level. In addition, Vulnerable Marine Ecosystem (VME) Evidence Forms are used by observers in the move-on areas for trawlers.

3.2 ESTIMATION OF ORANGE ROUGHY SUSTAINABLE CATCH LIMITS

3.2.1 Historical analyses

During 2009 the Ministry of Fisheries commissioned a research project on ‘Development of Estimates of Annual Sustainable Catches, and of Sustainable Feature Limits, for Orange Roughy Bottom Trawl Catches in Specific Fishing Sub-Areas in the Proposed Convention Area of the South Pacific RFMO’. A final research report for this project was provided as an information paper to the 9th SPRFMO Science Working Group (SWG) meeting (Clark et al. 2010, SWG-09-INF-01). A summary of the results of this work was provided as a paper to the Deepwater Sub-Group (Penney et al. 2010a, SWG-09-DW-02). Figure 5 shows a summary of this work, with the trends in orange roughy catch (t), CPUE (t/tow, with standard errors) and estimated Maximum Constant Yield (MCY), Maximum Annual Yield (MAY), ½MB_0 and 2002-2006 average catch reference levels from Clark et al. (2010) shown for the main fishing areas (see also Table 8, reproduced from Penney 2010a).

Table 8 (reproduced after Table 3 of Penney 2010a): Summary of predicted biomass (from the seamount meta-analysis), estimated MCY and MAY (from predicted biomass), estimated MSY (estimated as $0.5MB_0$) and average annual orange roughy catches over the 2002–2006 reference years.

Fishing Area	Predicted Biomass (t)	MCY	MAY	½MB_0	2002-06 Average
Lord Howe	4,130	60	80	93	134
West Norfolk	5,350	80	100	120	315
NW Challenger	8,800	130	170	198	666
North Louisville	7,510	110	150	169	214
Central Louisville	38,620	580	770	869	238
South Louisville	5,200	80	100	117	284
Total	69,610	1,040	1,380	1,566	1,852

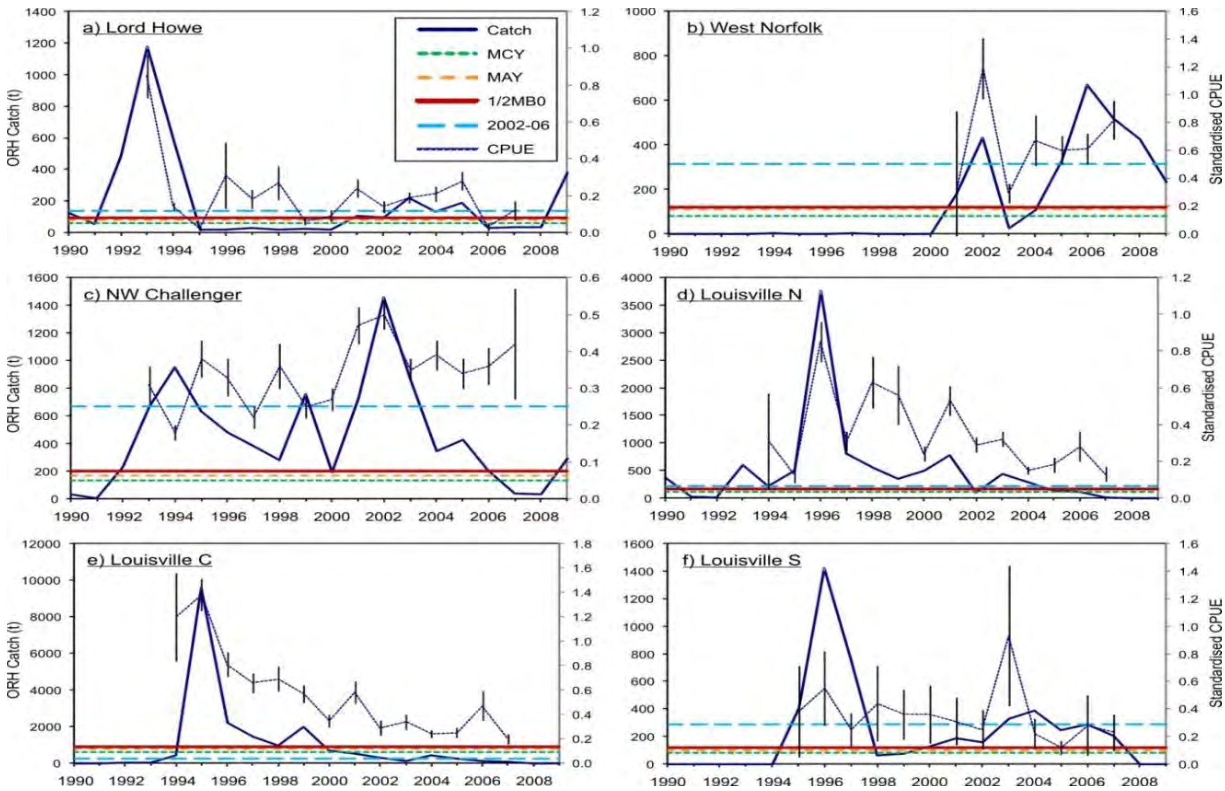


Figure 5: Summary of trends in total orange roughy catch (t), CPUE (t/tow, with standard errors) and estimated MCY, MAY, ½MB_0 and 2002–2006 average catch reference levels for each fishing area (from Penney 2010a).

This work is being progressively updated and expanded largely as anticipated by Tingley (2014b) and papers describing progress were presented to the third meeting of the Scientific Committee in September 2015 (Clark et al. 2015, Cryer 2015). Key developments in this work are that:

- models predicting the unfished biomass of orange roughy on individual features inside and outside New Zealand's EEZ have been published, noting that predictions for three features inside New Zealand's EEZ were substantially lower than the accumulated catch;
- analysis of several stock structure indicators suggests that slight changes to the areas used for stock assessment purposes are required;
- spatially-structured CPUE models have been developed and fitted to New Zealand catch and effort information only. Model sensitivity to key assumptions has been assessed;
- simulation testing of the spatially-structured CPUE approach has been instigated using data from fisheries with more complete data;
- preliminary Bayesian state-space biomass dynamic models have been fitted to the CPUE indices and the New Zealand time series of catch;
- work has started on acquiring the catch histories from other bottom fishing nations that are required to finalise these models.

3.2.2 Models predicting unfished biomass from physico-chemical data

Clark et al. (2016a) fitted a generalised additive model (GAM) predicting unfished biomass from latitude, summit depth, sea surface temperature anomaly (an indication of frontal zones), and the level of spawning activity. The physical variables are readily available for hitherto unfished seamounts and, although spawning level may initially be unknown, this was the least important of the model variables, and contributed only 5% of total deviance in $\log B_0$ (6% of explained deviance). Model fits were broadly aligned with actual cumulative catch for most seamounts (Figure 6), although the model substantially underestimated the unfished biomass for three seamounts on the Chatham Rise, potentially as a result of migration of orange roughy the from nearby slope or other nearby seamounts. Clark et al. (2016a) concluded that the physical characteristics of seamounts can be broadly informative about the likely level of orange roughy biomass across relatively large areas, but predictions for individual seamounts can be inaccurate.

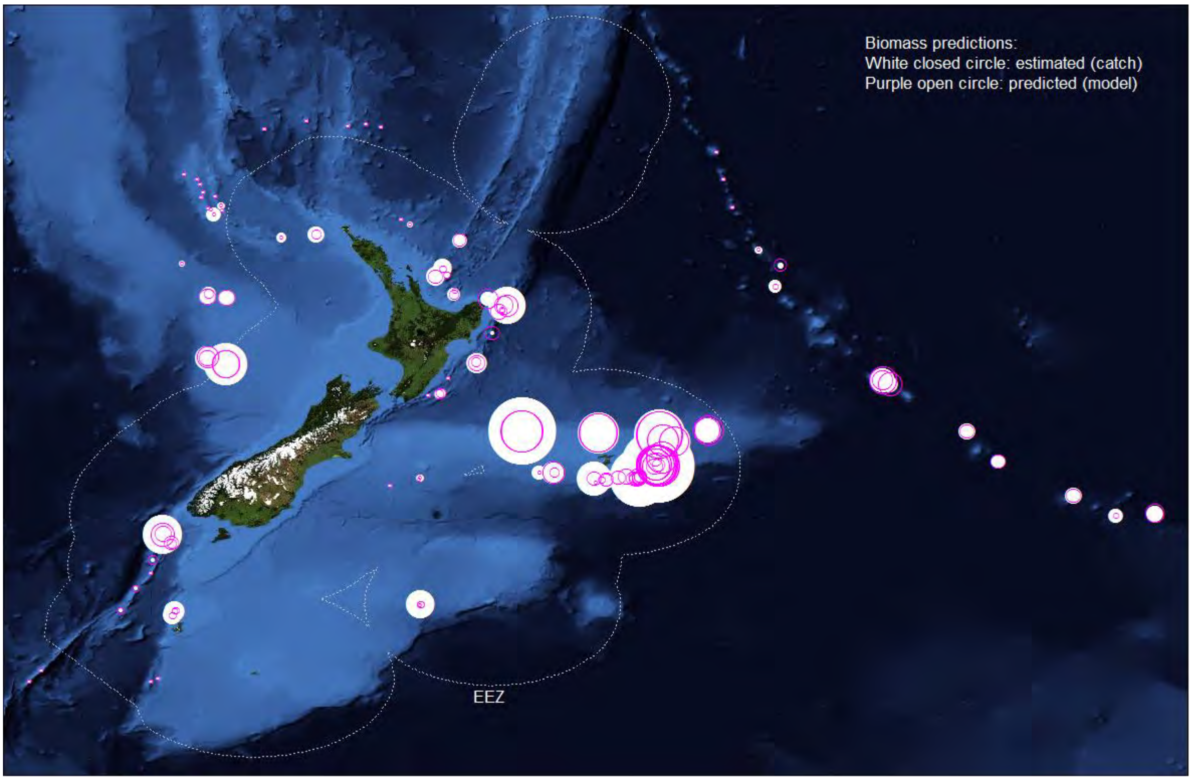


Figure 6 (after Fig. 11 of Clark et al. 2016a): Comparison of estimated unfished biomass of orange roughy based on catch history (closed white circles) and model-predicted biomass based on physical characteristics (open purple circles) on seamounts in New Zealand's EEZ and western SPRFMO Area. Circles standardised by area, maximum 15,000 t

3.2.3 Stock structure indicators

The stock structure of orange roughy in the SPRFMO Area is uncertain and the distribution of fishing effort has been used to denote putative areas for stock assessment or management (Clark 2004, 2008a). Clark et al. (2016b) updated the available information for fisheries and stocks in the western part of the SPRFMO Area. They adopted an holistic approach using multiple data sets to increase the chance of correctly defining stocks, given that no single data set was likely to provide unequivocal guidance (after Dunn and Forman 2011). They considered the distribution of catch, the location of spawning grounds, differences in life history characteristics including patterns in length frequencies, length/age at maturity, genetic studies using allozymes or mitochondrial DNA, otolith composition and shape, morphometric parameters, and parasite composition and load. As expected, the various data sets were not in complete agreement on the number of stocks or their boundaries. However, Clark et al. (2016b) considered the available data were consistent with the existing areas assumed for stock assessment in the Tasman Sea: Lord Howe Rise, Northwest Challenger Plateau, Southwest Challenger Plateau, West Norfolk Ridge, and South Tasman Rise. The Louisville Ridge was previously divided into three sub-areas for catch description and analysis and the recent work suggested that three sub-areas be retained, but with boundaries revised based on the timing of spawning (Figure 7, new area boundaries shown in red). These revised areas were adopted for subsequent CPUE and biomass dynamic modelling.

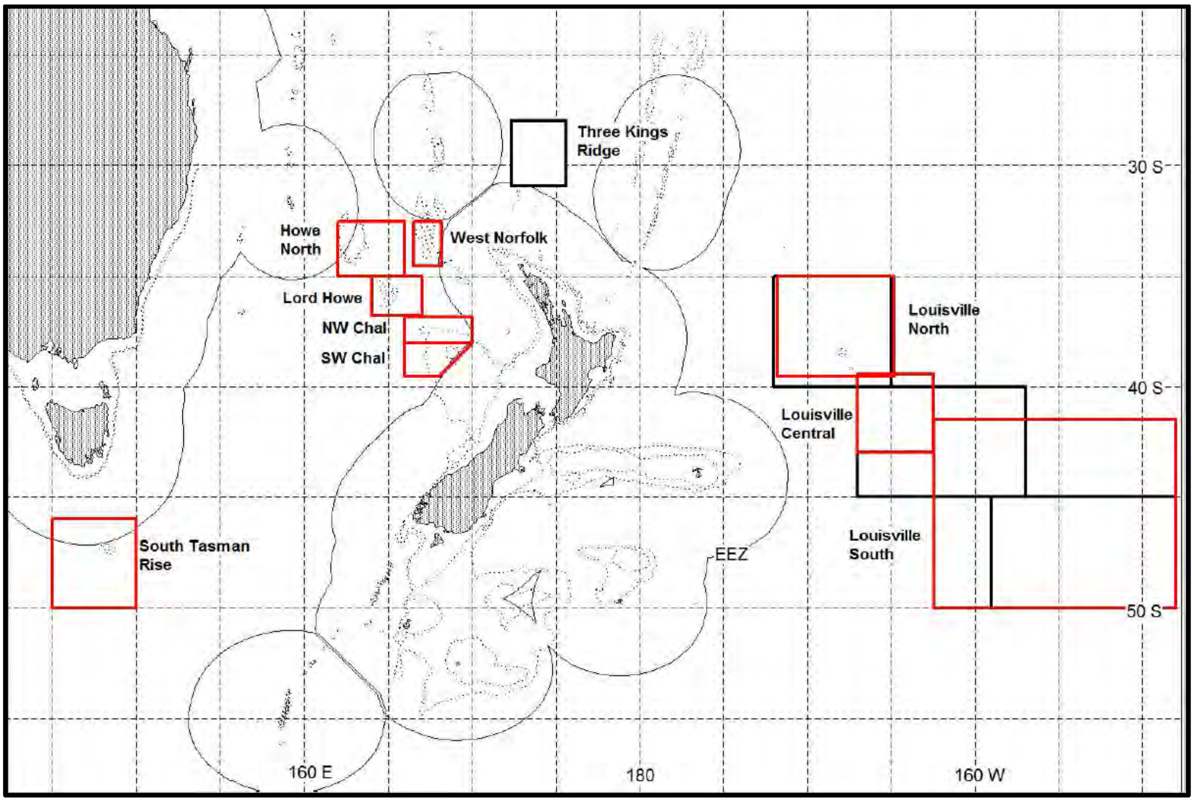


Figure 7 (after Clark et al. 2016b): Comparison of new areas assumed for stock assessment purposes (in red) and previous areas (in black). Where both are coincident, red boxes overlie black boxes. There has been no change for the Three Kings Ridge area. Fishing by New Zealand vessels within each of these boxes is restricted to within part of the 2002–2006 New Zealand footprint, a small proportion of the area of each box (see Appendix 2 for indicative maps of areas open to fishing).

3.2.4 Spatially-structured CPUE analysis

Commercial catch and effort (CPUE) data are the only information available to evaluate stock status of orange roughy in the SPRFMO Area. CPUE data from fisheries targeting spawning or aggregating species present many challenges for the development of indices of abundance because they tend to be patchy in space and time and targeting behaviour can change over time. Often CPUE from such fisheries is found to be uninformative as a raw indicator of stock abundance (e.g., Clark et al. 2010). For instance, non-random temporal changes in the spatial distribution of fishing effort (i.e. shifts in the focus of fishing between subareas within the fishing grounds), can lead to serious bias in the abundance trend or year effects (Walters 2003, Campbell 2004, Carruthers et al. 2011). To alleviate this type of bias, New Zealand has developed spatial CPUE models to evaluate stock status of data-limited species for several fisheries in the EEZ. The approach has also been developed for orange roughy stocks in the SPRFMO Area using the potential biological stocks described in Section 3.2.3. Overall population abundance is assumed to be distributed among several subareas (Walters 2003) and an annual abundance index can be estimated as the weighted average of catch rates in each of the areas if subareas are small enough to allow for approximately random fishing within each. This approach assumes slow mixing between subareas, which appears to be a valid assumption in slow-growing, deepwater fish stocks (Roux and Doonan 2015). More detail is provided in a separate paper to SC4 and in Roux et al. (2016).

Relevant tow-by-tow catch and effort data for New Zealand vessels fishing between 1989 and 2014 were used in the spatial analysis, including fishing location, fishing patterns (i.e. trawl depth, speed, tow duration, etc.), estimated catch and vessel specifications. Data from the southern Challenger Plateau and the northern part of the Lord Howe Rise were excluded because catch and effort data were too sparse. Standardised spatial CPUE indices were estimated using the hybrid GLM-imputation method described by Carruthers et al. (2011). A lognormal, interaction step-wise GLM was fitted to log-transformed, non-zero catch-effort data (tonnes per tow). Year effects and year-subarea interaction effects were extracted from the final model and used to predict standardised CPUE values for year-subareas strata in which fishing occurred. For each area, a table of standardized catch rates was constructed that contained a row for every fishing year and a column for each subarea. Year-subarea cells with no data (i.e., fewer than 5 tows) were populated using the imputation methods described by Walters (2003):

- Backward imputation (before the start of the fishery in a subarea) was carried out by assigning the maximum catch rate recorded during the first three years of fishing to earlier years.
- Forward imputation (following the most recent fishing in a subarea) was carried out by assigning the mean catch rate from the last three years of data to subsequent years.
- Linear interpolation between years was used to populate missing data where fishing occurred sporadically.

The CPUE time series within each of the subareas were normalised to have a geometric mean of 1 and the weighted sum across subareas in each year was considered an annual index. Bootstrap re-sampling was used to estimate variability in the annual indices; each of 500 bootstrap replicates included GLM standardisation, imputation, subarea-weighting and summation to the annual index.

The temporal trends of standardised spatial CPUE (estimated using the hybrid GLM-imputation method) were markedly different, and more stable, than trends in nominal (unstandardised) CPUE and GLM-standardised CPUE ignoring spatial structure (Figure 8). Sometimes the standardised spatial CPUE showed a steeper decline than the standardised CPUE ignoring spatial structure (NW Challenger and central Louisville Ridge) but sometimes the converse was true (Lord Howe Rise). Estimated confidence limits varied substantially between years and areas. Indices for early years in the time series are typically less precise than those later, and those for the early years on the NW Challenger and southern Louisville Ridge are particularly imprecise (Figure 9). Most CPUE models were not very sensitive to choices about imputation methods.

3.2.5 Preliminary biomass dynamic models

A cohort-aggregated biomass dynamics model (BDM) was fitted using Bayesian techniques to the catch histories and standardized spatial CPUE indices for each stock. The model predicts changes in exploited biomass over time in response to catch and a simple production function, in this case the generalized production function described by McAllister et al. (2000). This function has only three parameters: the maximum intrinsic growth rate *r* (the maximum rate of population increase as the biomass approaches zero); the arithmetic mean unfished biomass *K*; and a shape parameter *n* that defines the inflection point of the production function relative to *K*. Parameters were estimated within a Bayesian state-space framework that re-formulates the process equation to include time-dependent process errors and an observation process that relates the abundance index to the unobserved biomass with observation error and according to an estimated catchability scalar, q. The inclusion of process error allows the model to account for inter-annual variability in stock biomass caused by temporal changes in biological processes that are not explicitly modelled (e.g., variability in recruitment or availability). For all runs reported here, process error standard deviation was fixed (at 0.05). A uniform prior was assumed for *ln(K)* which gives lower weight to higher *K* values (after McAllister 2013) but the upper and lower bounds were chosen to allow parameter space to be fully explored during estimation. Because *r* and *K* are typically highly correlated in these models, an informative prior for *r* was constructed from available life-history data using methods described in McAllister et al. (2001). Bayesian estimation of the posterior distributions of estimated and derived parameters was achieved using Markov chain Monte Carlo chains. Model convergence was assessed by comparing cumulative posterior distributions of *r*, *K*, and q among multiple MCMC chains. The information content of the abundance indices was assessed by conducting separate model runs with and without the index and comparing the results.

Models for the Lord Howe Rise and NW Challenger stocks showed signs of poor convergence and produced estimated biomass trajectories and estimated values for unfished biomass, K, with very wide confidence limits. Models for the other four areas showed no strong convergence problems and fitted the standardized spatial CPUE indices reasonably well (Figure 10).

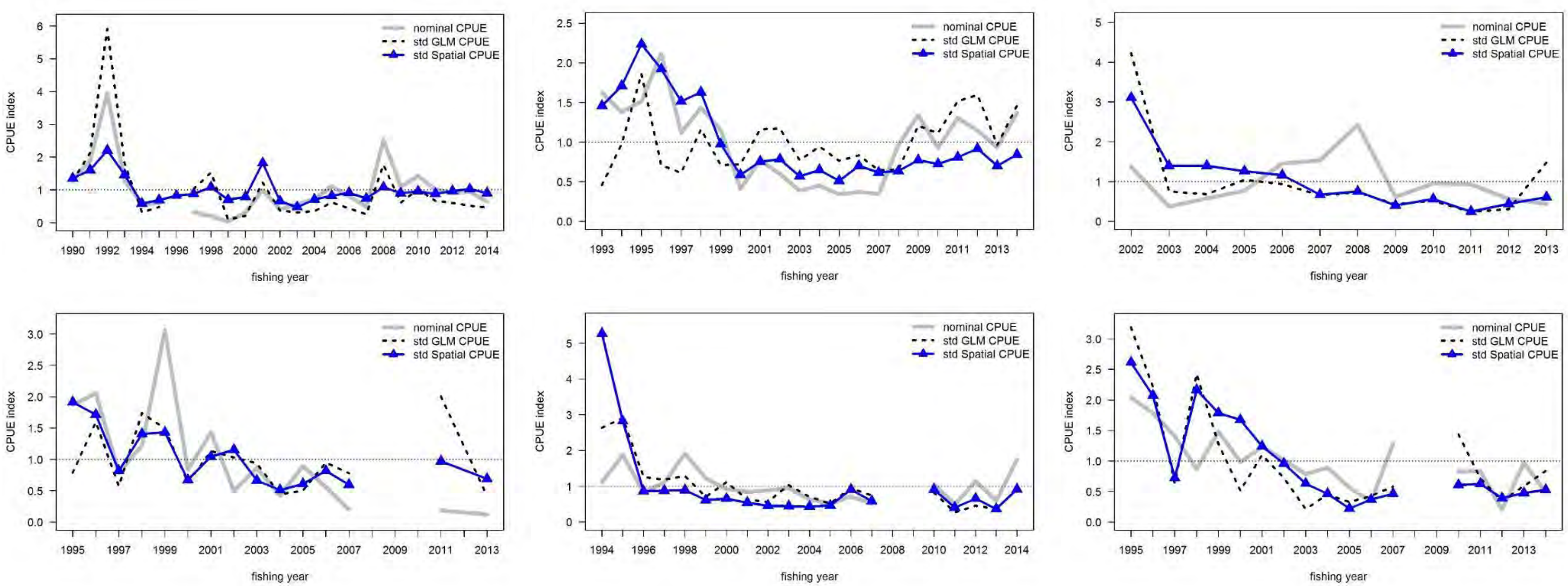


Figure 8: Comparisons of indices estimated as nominal CPUE (grey lines), using standardised CPUE (typical GLM procedure, black dotted lines), and standardised spatial CPUE (using the hybrid interaction GLM and data imputation, blue lines) Tasman Sea fisheries are on the top row (left to right, Lord Howe Rise, Northwest Challenger, West Norfolk Ridge) and Louisville Ridge fisheries are on the bottom row (left to right, North, Central, and South areas).

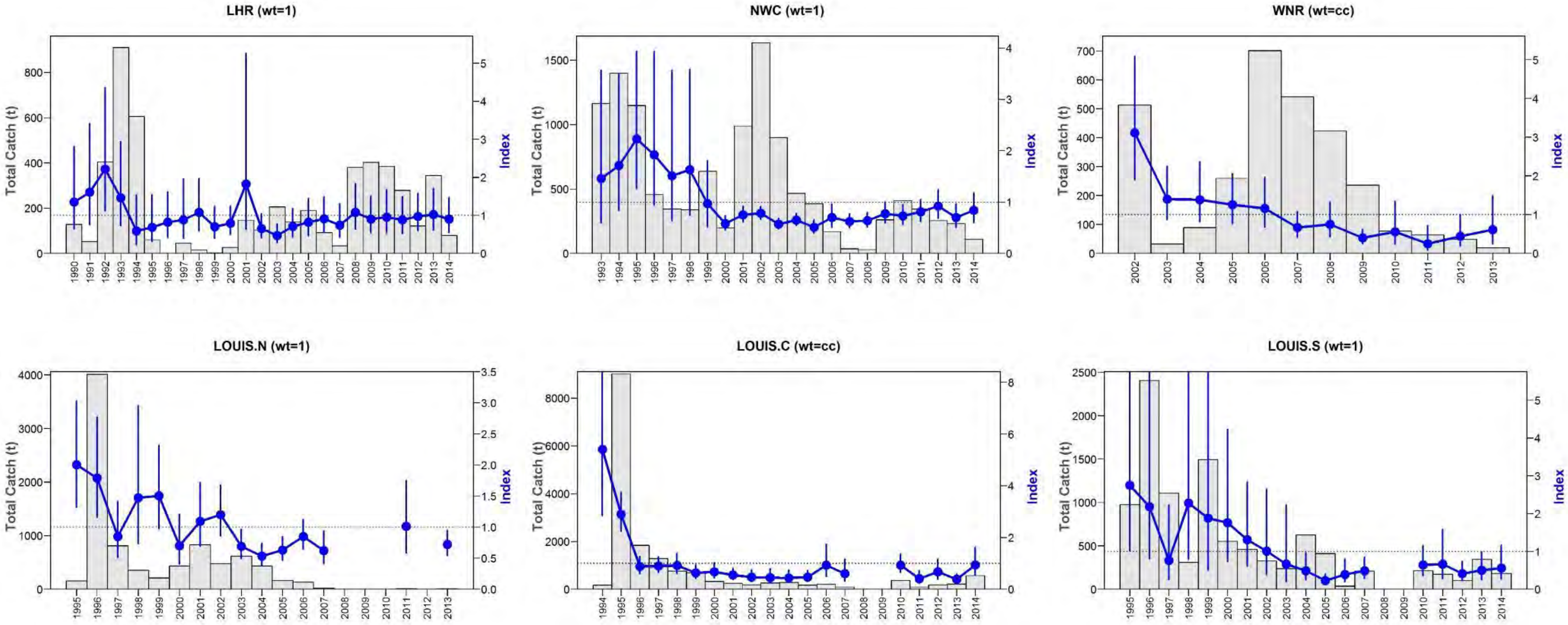


Figure 9: Catch series (grey bars, left axes) and normalised, standardised spatial CPUE indices of abundance (blue line/full circles, right axes) for orange roughy stocks in the Tasman Sea region (top row) and Louisville Ridge (bottom row) within the SPRFMO Area. Error bars are 95% bootstrap confidence intervals. Area weightings: *wt*=1: equal catchability in all subareas, *wt*=cc: subarea catchability proportional to cumulative catch.

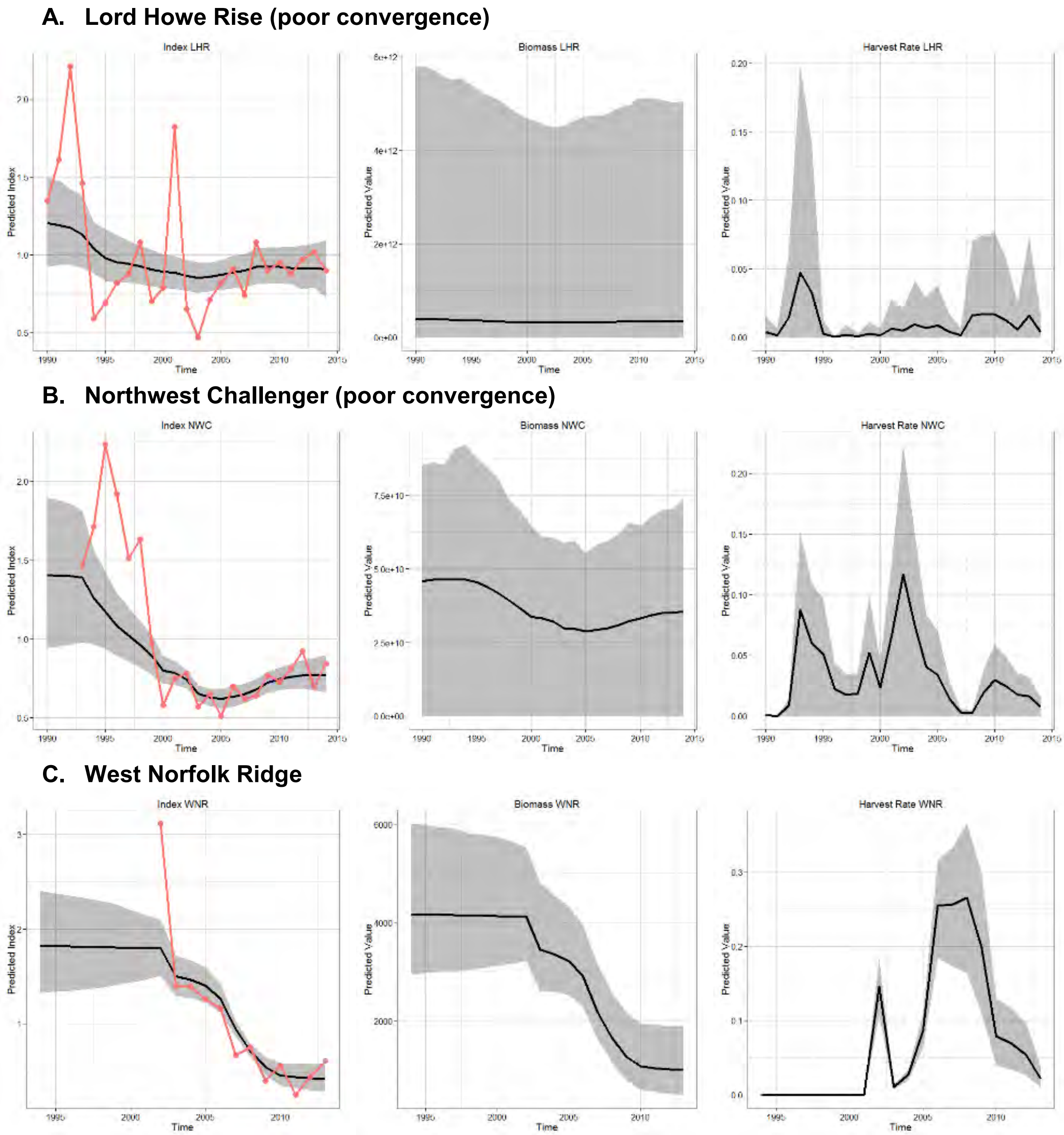


Figure 10: Model estimates (black lines) with 95% confidence limits (grey shading) of the expected abundance index (left); biomass trajectory (centre); and estimated harvest rate (right) for orange roughy stocks in the Tasman Sea. The spatial hybrid CPUE index is shown as a red line in the left plots.

Preliminary estimates of the key estimated parameters r and K and derived parameters MSY (maximum sustainable yield, in tonnes per annum), B_{MSY} (spawning biomass necessary to achieve MSY), $B_{current}$, HR_{MSY} (the harvest rate to achieve MSY), $HR_{current}$, and stock status relative to unfished biomass are shown in Table 9. Estimates for the Lord Howe Rise and the NW Challenger stocks are very poorly constrained but those for the other four stocks are estimated reasonably well. Although the confidence intervals all overlapped, the preferred BDM models fitted a higher maximum intrinsic population growth rate r (median 0.075) in the Central Louisville stock than in other stocks where models converged (median estimates 0.052–

0.054, similar to the prior) (Table 9). BDM estimates of unfished biomass for the Louisville Ridge (total 45 900 t across the three stocks) was also similar to the unfished biomass predicted by the seamount meta-analysis (51 500 t after adjusting for seamounts located beyond the distribution range for orange roughy, Clark et al. 2010). Results for Tasman Sea fisheries were not comparable with the seamount meta-analysis because the BDM models used catch and effort data from both features and slope whereas Clark et al. (2010) focussed only on features.

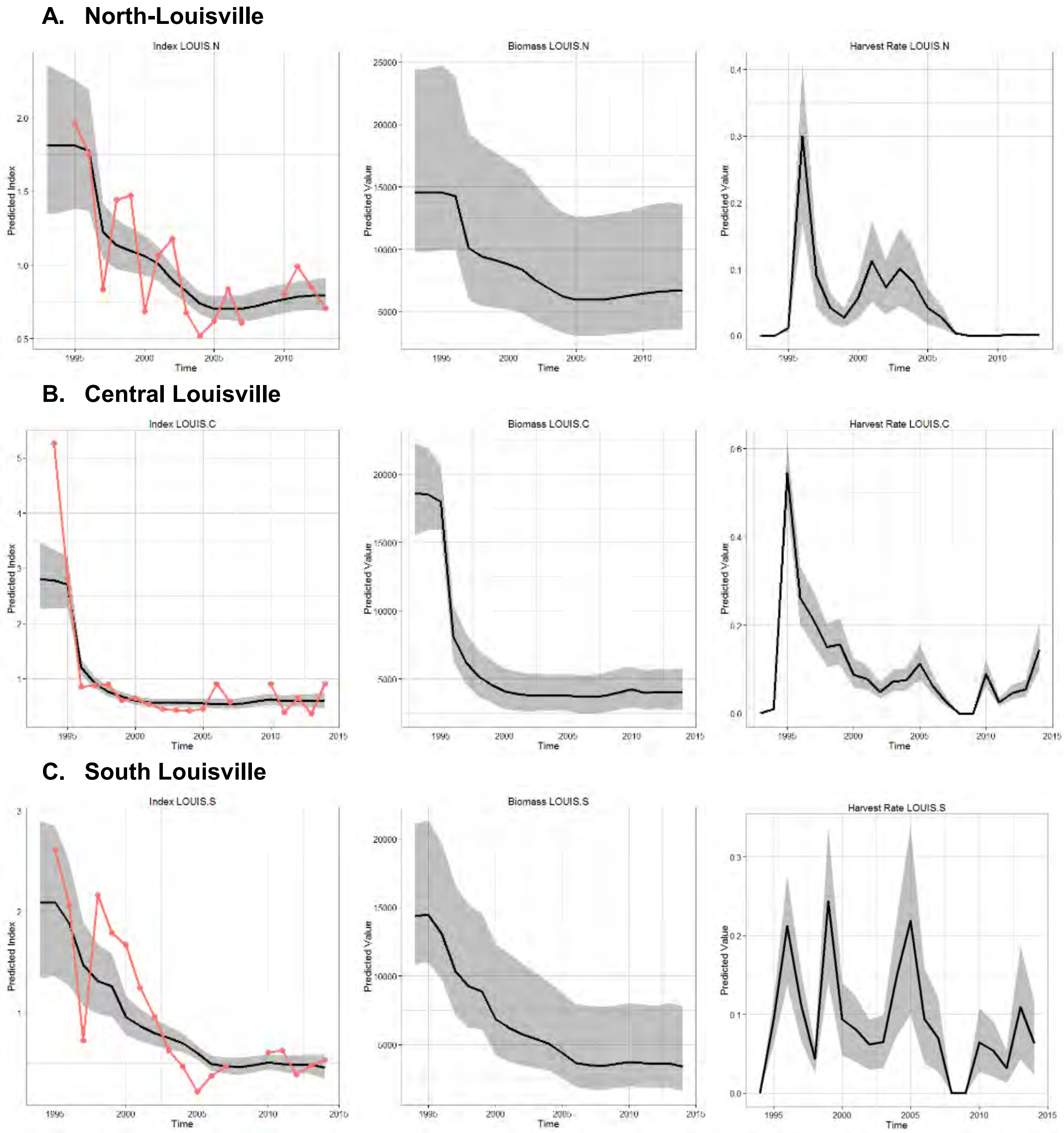


Figure 10 contd.: Model estimates (black lines) with 95% confidence limits (grey shading) of the expected abundance index (left); biomass trajectory (centre); and estimated harvest rate (right) for orange roughy stocks on the Louisville Ridge. The spatial hybrid CPUE index is shown as a red line in the left plots.

Table 9. Summary of preliminary estimates from successfully converged BDM models of orange roughy using catch and effort data from New Zealand vessels only, including posterior distributions of estimated model parameters (r and K); estimates of current biomass ($B_{current}$) and harvest rate ($HR_{current}$); MSY-based reference points (MSY, assumed B_{MSY} and HR_{MSY}) and current status relative to K (i.e. $B_{current}/B_0$). All values are medians (95% CI)).

Stock	r	K	MSY	B_{msy}	$B_{current}$	HR_{MSY}	$HR_{current}$	Status
Louisville North	**0.052** (0.023–0.116)	**13 520** (9 682–24 551)	**110** (49–253)	**4056** (2 905–7 366)	**5937** (3 625–13 602)	**0.03** (0.01–0.06)	**8.0E–04** (0.0004–0.0015)	**0.44** (0.32–0.63)
Louisville–Central	**0.075** (0.037–0.131)	**18 526** (15 274–22 627)	**210** (107–343)	**5558** (4 582–6 788)	**4004** (2 751–5 801)	**0.04** (0.02–0.07)	**0.14** (0.10–0.21)	**0.22** (0.15–0.30)
Louisville–South	**0.054** (0.022–0.120)	**13 854** (10 715–21 095)	**116** (51–232)	**4156** (3 215–6 329)	**3004** (1 580–7 780)	**0.03** (0.01–0.06)	**0.06** (0.02–0.12)	**0.22** (0.13–0.41)
West Norfolk Ridge	**0.054** (0.023–0.130)	**4050** (2 913–6 015)	**33** (14–75)	**1215** (874–1 805)	**930** (494–1 898)	**0.03** (0.01–0.07)	**0.02** (0.01–0.04)	**0.23** (0.13–0.40)

Validation and sensitivity testing of similar Bayesian state-space BDM models has been conducted on comparable deepwater fish stocks within New Zealand's EEZ (Edwards and McAllister 2014) and shows that they can provide similar estimates of stock status to those from more complex age-structured population models fitted using CASAL. BDM models were less successful at estimating the absolute scale of current and initial biomass. The predictive performance of models for the SPRFMO Area was assessed using cross-validation which showed consistency in model outputs after removal of the last five years of data. Sensitivity tests showed that a broad range of assumed values of B_{MSY}/K 0.25 to 0.60 around the base of 0.30 had minimal impact on estimates of initial biomass and stock status relative to the initial biomass. For comparison, the deterministic equilibrium SSB that supports the MSY from the straddling stock ORH 7A (also within the SPRFMO Area) was estimated to be 24.5% of the unfished biomass (95% CI 22.9–24.9%) (Cordue 2014). The BDM approach used here has been found to be sensitive to process error assumptions and work is currently under way to estimate process error standard deviation for orange roughy stocks inside the NZ EEZ.

It is important to note that these preliminary model results use only New Zealand catch and effort information and cannot be finalised until the catch of all bottom fishing nations is included. This is particularly important for the Lord Howe Rise and NW Challenger Plateau areas (where models did not converge) because Australian and other nations' vessels often accounted for > 50% of the annual catch from 1988 until the mid-2000s (Clark 2008a). Results for those two areas are likely to change when all catch data have been included. Results for other areas are likely to change less because the New Zealand catch is a higher proportion of the total catch. It would also be useful to include detailed catch and effort information of other nations into the CPUE analyses to minimise the need for imputation, but this is less critical than the need for complete catch information.

3.3 CHALLENGER PLATEAU ORANGE ROUGHY STOCK STATUS

Following stock sustainability concerns, the fishery on the straddling stock of orange roughy on the southern Challenger Plateau was closed in 2000. Since 2006 a programme of combined trawl and acoustic surveys has been conducted to re-assess the status of this stock (MPI, 2013), and the fishery was re-opened on 1 October 2010 with a total allowable commercial catch (TACC) limit of 500 tonnes, increased to 1 600 tonnes on 1 October 2014.

Scientific biomass surveys for this straddling stock were conducted in each year of 1987–1989, 2006, and 2009–2013 (Figure 11). A formal stock assessment was initiated in late 2013 that resulted in a peer-reviewed stock assessment for this stock being accepted by MPI's Deepwater Fisheries Assessment Working Group and subsequently by New Zealand's Fishery Assessment Plenary for use in the future management of this fishery (MPI, 2014b). The spawning biomass (New Zealand-specified stock ORH 7A) is estimated to have been steadily increasing since just before the fishery closure in 2000–2001 (Figure 12). According to New Zealand's Harvest Strategy Standard, the stock is now considered to be fully rebuilt (at least a 70% probability that the lower end of the management target range of 30–40% B_0 has been achieved). The estimated fishing intensity was low (1–2%) and fairly constant until 2014. The next stock assessment is planned for early 2019.

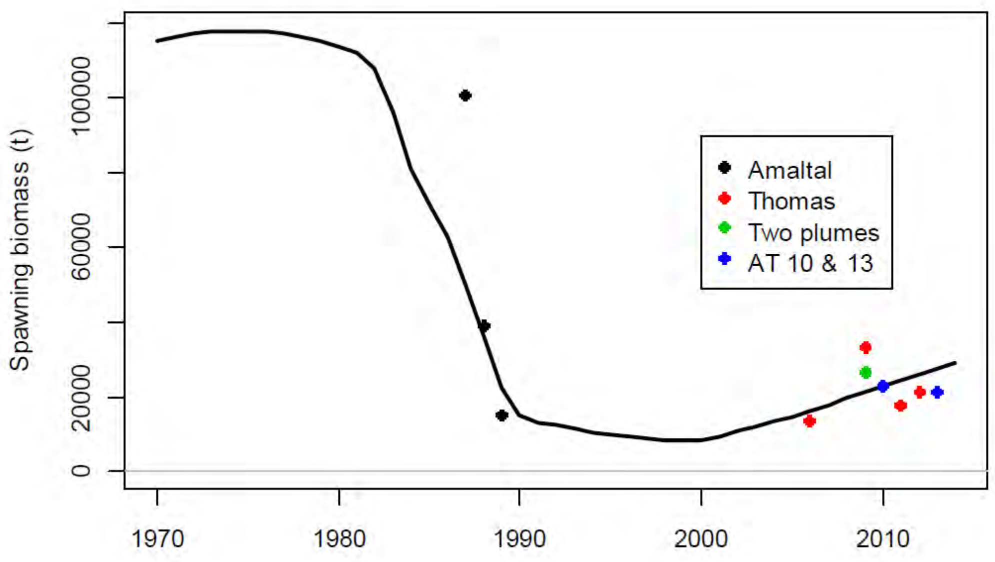


Figure 11 (after Cordue 2014): Base model (MPD) fit to biomass indices from the Amaltal Explorer, Thomas Harrison, the "two-plumes" survey in 2009, and the combined acoustics and trawl surveys in 2010 and 2013. Indices are all scaled to spawning biomass using estimated catchabilities from the base model MPD.

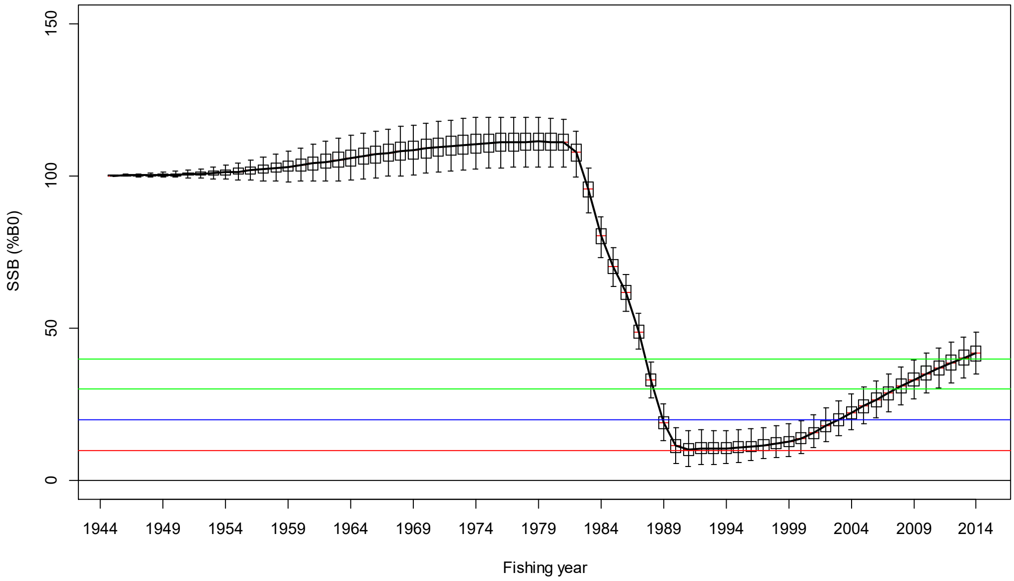


Figure 12 (after Cordue 2014): Spawning-stock biomass trajectory for ORH 7A estimated from the base model MCMC chain. The box in each year covers 50% of the estimated distribution and the whiskers extend to 95% of the distribution. The hard limit 10% B_0 (red), soft limit 20% B_0 (blue), and biomass target range 30–40% B_0 (green) are marked by horizontal lines.

3.4 DEVELOPMENT OF STOCK ASSESSMENT OR IN-SEASON MANAGEMENT APPROACHES FOR SQUID

New Zealand has been working on methods of assessing its EEZ squid stocks in-season. Hurst et al. (2012) carried out a detailed characterisation of SQU6T (Auckland Islands) and SQU1T (Snares Islands) fisheries and a preliminary evaluation of potential in-season management approaches. McGregor (2013) and McGregor & Tingley (2016) further developed these analyses and the depletion method as described in Roa-Ureta (2012, see also McGregor & Large 2015 paper to SC3).

Squid have life-cycles that are not amenable to typical fish population modelling approaches. Most squid live for only around one year, spawn and then die, resulting in an entirely new stock each year, the size of which is driven largely by environmental factors. The population size each year can be estimated using models of fishery-driven depletion, and this has been done successfully in-season for a small number of fisheries. New Zealand has explored a De Lury depletion model allowing multiple cohorts similar to that used in the Falkland Islands fishery for *Loligo gahi*. The model was fitted to data from the 2008 Auckland Islands squid fishery because appropriate length frequency data, commercial catch and effort data, and length-to-weight conversion parameters were available. These data were found to have sufficient signal to fit the depletion model and the modelled catches showed a good fit to the observed catches (Figures 13 and 14). The model was sensitive to changes in the assumed value of natural mortality. Although the approach looks promising, further work is required before this approach can be used in-season, including using data from other seasons, finding appropriate values for natural mortality and assessing the likelihood that this method can succeed in any given year McGregor & Tingley (2016). Successful implementation requires information on the annual squid life cycle, including the occurrence and timing of seasonal cohorts, direction and scale of ontogenetic migrations, location of spawning grounds and environmental drivers affecting within-season recruitment pulses and natural mortality.

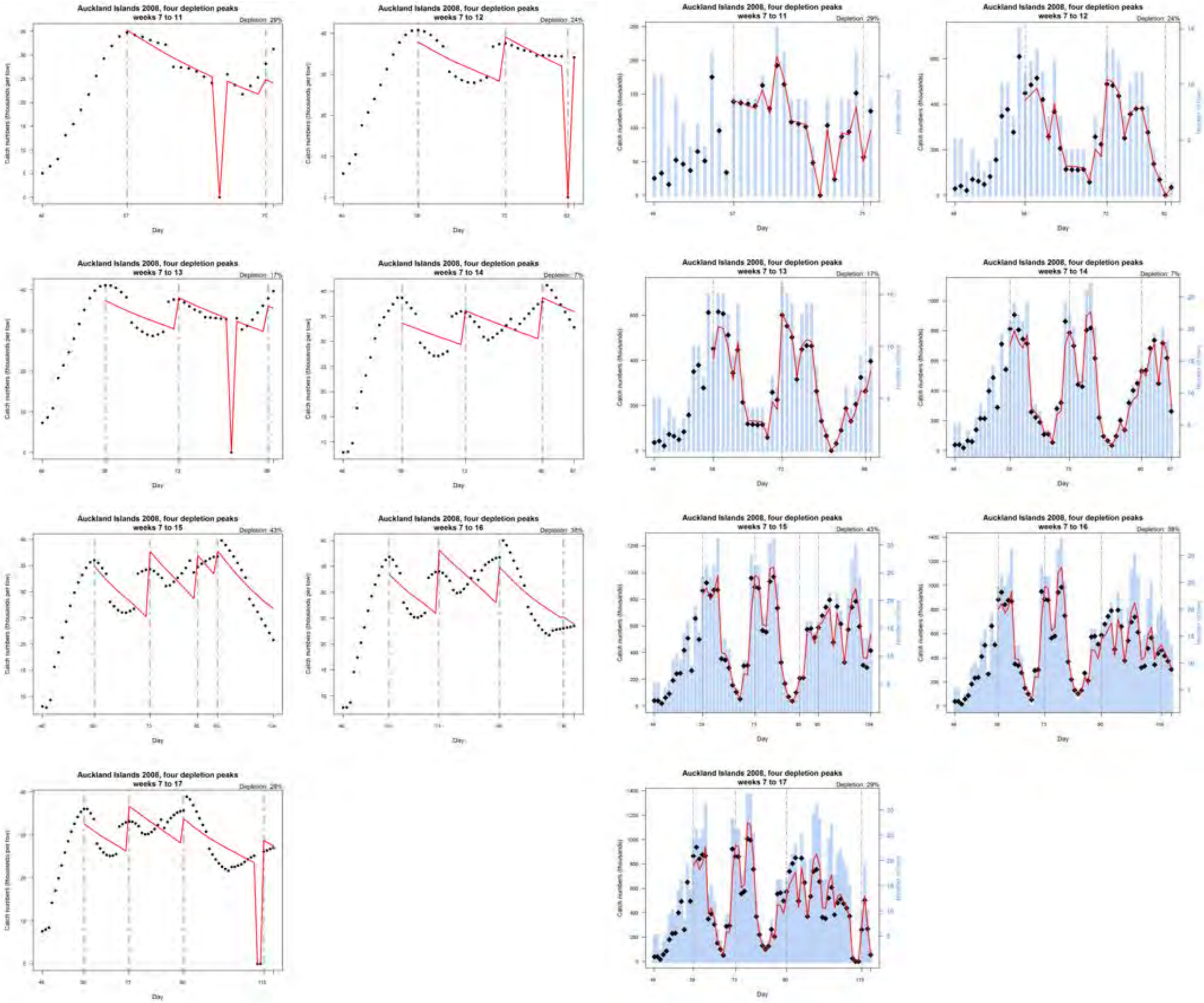


Figure 13: Fits of **McGregor & Tingley's (2016)** base case depletion model (left panels, red line) to the smoothed time series of fleet CPUE (catch in thousands of squid per tow, black circles) and to the smoothed time series of fleet catch per day (right panels, thousands of squid, black diamonds, blue bars are the number of tows in each day) for weeks 11–17 **of New Zealand's Auckland Islands squid fi**shery in 2008.

3.5 GEOSPATIAL PREDICTION OF VMES AND DEVELOPMENT OF DECISION SUPPORT TOOLS

New Zealand continues to develop geospatial data files on seabed bathymetry, fishing footprints and VME distribution for provision to the SPRFMO Secretariat and inclusion in the SPRFMO Geospatial Database.

3.5.1 Habitat suitability modelling

Following publication of the first global habitat suitability models for scleractinian corals (Tittensor et al. 2009), the Ministry of Fisheries initiated work to evaluate the potential for using such predictive habitat models to evaluate the likelihood of encountering VMEs in the SPRFMO Area. A methods paper describing potential approaches to using geospatial data and habitat suitability models to evaluate likelihood of occurrence of VMEs in the SPRFMO Area, was submitted to the SWG Deepwater Sub-Group (Penney 2010b, SWG-09-DW-03). Subsequent work evaluating these habitat suitability approaches for the SPRFMO Area was conducted for the Ministry for Primary Industries by Rowden et al. (2013).

The development of models at a variety of scales has continued since 2013. This work has been funded by New Zealand's Ministry of Business, Innovation, and Employment, with additional support from the Ministry for Primary Industries. Difficulties have been encountered developing such models for the entire SPRFMO Area. Anderson et al. (2016a) describe the results of habitat suitability models constructed for four deep-sea reef-forming coral species at the "SPRFMO Area-scale" using maximum entropy (MaxEnt) and boosted regression tree (BRT) modelling approaches (Figure 14). In order to test model predictions a photographic survey was conducted on a set of seamounts in an un-sampled area on the Louisville Seamount Chain (Clark et al. 2015). The likelihood of habitat suitable for reef-forming scleractinian corals on these seamounts was predicted to be variable, but very high in some regions, particularly where levels of aragonite saturation, dissolved oxygen, and particulate organic carbon were optimal. However, the observed frequency of coral occurrence in analyses of survey photographic data was much lower than expected, and patterns of observed versus predicted coral distribution were not highly correlated. The poor performance of these broad-scale models was attributed to lack of species absence data to inform the models, low precision of global bathymetry models, and lack of data on the geomorphology and substrate of the seamounts at scales appropriate to the modelled taxa. This study demonstrates the need to use caution when interpreting and applying broad-scale, presence-only model results for fisheries management and conservation planning in data poor areas of the deep sea. Future improvements in the predictive performance of broad-scale models will rely on the continued advancement in modelling of environmental predictor variables, refinements in modelling approaches to deal with missing or biased inputs, and incorporation of true absence data.

New models at a finer "New Zealand region-scale" were therefore developed where data were better suited to achieving reliable models. Anderson et al. (2016b) utilised BRT and MaxEnt habitat suitability modelling techniques, to create potential distribution maps for 11 VME indicator taxa in the New Zealand area and adjacent seas (Figure 15, left). New and more accurate bathymetry data were combined with existing environmental, chemical and physical data to produce a set of 45 predictor variables describing conditions at the seafloor. Nine of these variables were selected for use in the models based on low covariance and high explanatory power. These included descriptors of terrain smoothness, particulate organic carbon export, salinity, water density, dissolved oxygen, and, for some taxa, aragonite, calcite, or silicate.

Historical biological survey data were used to provide models with absence data (BRT) or target-group background data (MaxEnt). Model agreement was high, with each model predicting similar areas of suitable habitat both in the vicinity of known VME indicator taxa presence locations as well as across broad regions of un-sampled seafloor. Model performance measures, including cross-validation testing against sets of spatially independent data, did not clearly indicate a preferred modelling method across all taxa. Previous habitat suitability modelling efforts have rarely accounted for model precision, and in this study a boot strap re-sampling technique was used to produce model uncertainty maps to accompany each habitat suitability map (Figure 15, right). Because of the similar performance of BRT and MaxEnt methods in this study, it was concluded that the best approach to incorporating the results into decision-support tools for spatial management planning is to average predictions and uncertainty from both (i.e. from ensemble models).

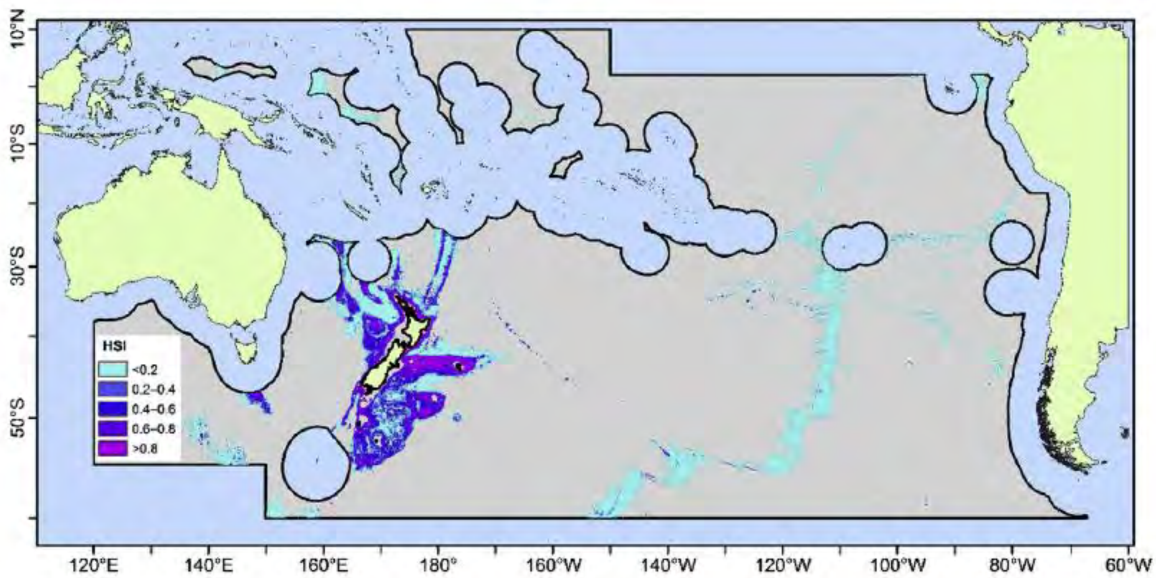


Figure 14: Predicted relative habitat suitability (Habitat Suitability Index, 0-1) for the SPRFMO Area and the New Zealand EEZ from a boosted regression tree habitat suitability model for four reef-forming scleractinian coral species (VME indicator taxa).

For management of bottom trawling in relation to VMEs, models would ideally focus directly on VME habitat (e.g. coral reef) rather than individual species or combined taxa (e.g. coral species or taxonomic group). The identification of such habitat, and the use of abundance data rather than presence-absence, relies heavily on photographic surveys and currently there are insufficient records at the regional scale in New Zealand waters and at the broad scale across the SPRFMO Area. Sub-regional or small-scale models at a resolution considerably finer than 1 km^2 are possible for VME habitat for small areas where camera and multibeam surveys have been undertaken, such as on the Louisville Seamount Chain.

Work to produce such models is on-going, and therefore more detailed information is provided here about the modelling approaches that are being used. To construct "seamount-scale" habitat suitability models, species presence-absence and abundance data were compiled for seven seamounts on the Louisville Seamount Chain (Figure 16) from the video transect survey carried out in 2014 (Clark et al. 2015). Data for one key VME indicator taxon, the reef-building scleractinian coral *Solenosmilia variabilis,* and two taxa considered to be indicators for the reef habitat formed by the coral (brisingid seastars, Order Brisingida; and sea-lilies and feather stars, Order Crinoida) were extracted from this dataset (the latter were included to check if there is a close association between coral reefs and the so-called VME habitat indicators). Data for these taxa were arranged into 25 m^2 cells (approximately 2.05 m x 12.19 m), a size which matches the resolution of the multibeam (MBES) bathymetry and backscatter data collected during the survey.

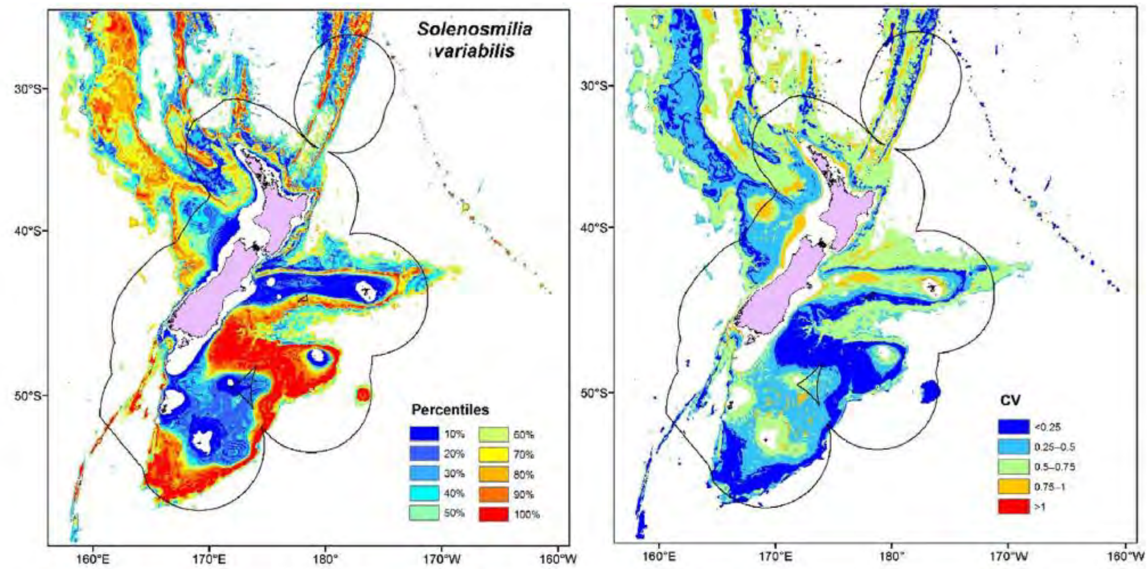


Figure 15: Predicted relative habitat suitability (probability percentiles, 10-100%) for the New Zealand region from a maximum entropy habitat suitability model for the reef-forming scleractinian coral species *Solenosmilia variabilis* (VME indicator taxon) (left), and model uncertainty (CV) (right).

A set of over 100 topographical terrain variables (e.g., slope, aspect, ruggedness, curvature, backscatter) were derived from MBES bathymetry data collected from six of the seven seamounts surveyed (Anvil Seamount was excluded as backscatter data were not available), at a resolution of 25 m^2, and subsequently reduced to a set of 50 based on a process of eliminating highly correlated variables using Pearson product-moment correlation coefficients. Values for each of these 50 variables were then assigned to each of the 25 m^2 species record cells. This set of variables was further reduced by building presence/absence General Additive Models (GAMs) using all variables together in addition to single-variable models. Variables were retained or discarded based on their chi-square score in the all-variable model, and their AUC (area under the receiver operating characteristic curve) score in single-variable models. In addition to assessing the performance of variables, the relationship among variables using a cluster dendrogram was also considered, and Pearson product-moment correlation coefficients. Preference was given to retaining variables that had low correlations with other variables and occurred in unique clusters, so as to avoid losing information that was not also provided by other variables as well as to avoid only including high-performing variables that provided similar information. The number of variables was first reduced to a set of 20, which were then used to build a second GAM model. This set was further reduced to a set of eight variables using the methods described above, which was used for all subsequent models.

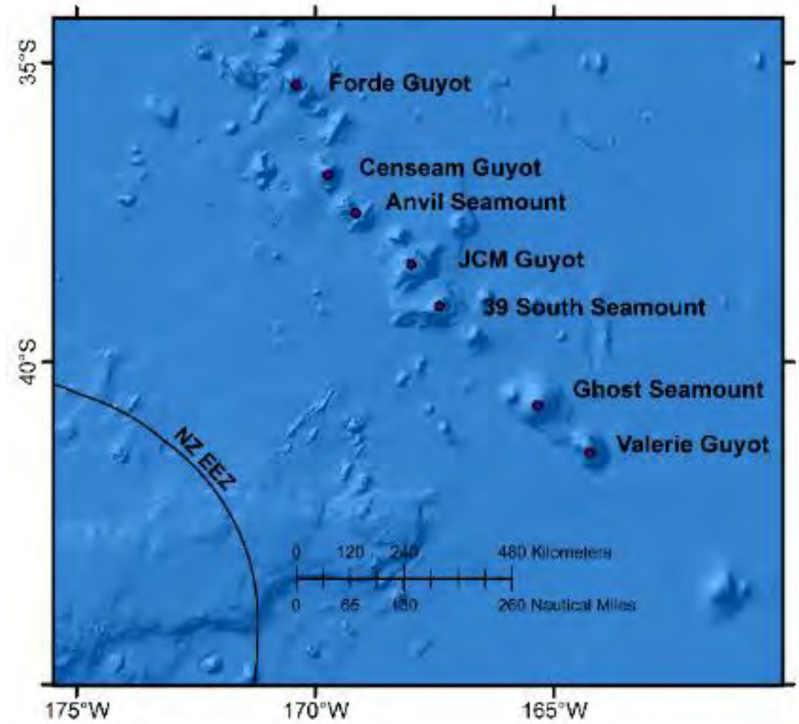


Figure 16: Location of the video surveyed seamounts on the Louisville Seamount Chain.

In order to account for the inherent spatial autocorrelation in the model data, a pattern where observations are related to one another by their geographic distance, we created an additional predictor, the residual autocovariate (RAC), representing the similarity between the residual from initial models at a location compared with that of neighbouring locations. This method has been shown to be able to account for spatial autocorrelation without compromising model performance, and can easily be implemented in most modelling approaches (Crase et al. 2012). The final set of nine variables used in each of the models is shown in Table 10.

Table 10: Final set of environmental variables used in the seamount-scale habitat suitability models.

Variable	Name	Description
Distance	dist	Distance (km) along a line running NW to SE through the axis of the seamount chain
Slope	X1sl	Slope (degrees)
Aspect	X15asCAT	Aspect of slope based on a focal mean neighbourhood size of 15 cells, in categorical form (equivalent to the 16 points of the compass)
Depth	depth	Depth of the cell (m)
Slope SD	X7slS7	Standard deviation of slope values within a 7x7 grid, based on a focal mean neighbourhood size of 7 cells
Curvature	X15cu	Mean curvature based on a focal mean neighbourhood size of 15 cells
Vector Ruggedness Measure	X15vr5	Mean VRM within a 5x5 grid, based on a focal mean neighbourhood size of 15 cells
Backscatter	BS	Backscatter values
Residual Autocorrelation Variable	RAC	Variable derived from residuals of initial models to account for spatial autocorrelation

Three modelling methods were used for habitat suitability modelling; BRT, General Additive Models (GAMs), and Random Forests (RF). Initial sets of presence-absence and abundance models were produced for each VME indicator/habitat taxon and each method resulting in preliminary predictive maps of presence probability and abundance for each of the six seamounts examined.

BRT models were fitted in R (R Core Team, 2016) using a standard approach, including optimisation of the learning rate and number of trees by internal cross validation (Elith et al. 2008), and setting tree-complexity to 3 to allow a level of interactions between terms. The minimum number of trees for each model was set to 1000. For construction of presence-absence models a Bernoulli (=binomial) distribution was assumed and for abundance models (count data) a Poisson distribution was assumed. GAMs were developed in R using the "mgcv" package in R (Wood 2006). For presence or absence models, a binomial distribution was assumed during model construction and prevalence was set to 0.5. For abundance models, a zero-inflated Poisson distribution was used. For all models, predictors were fitted with smooth terms allowing up to 4 degrees of freedom. RF models were constructed using the "randomForest" package in R (Liaw and Wiener 2002). For all models, 501 trees were run, which was always sufficient to allow the error rate to stabilize. Prevalence was set to 0.5 for all presence/absence models. Different values of "mtry", the number of variables used in each tree node, were explored during initial model construction using the "tuneRF" function in the "randomForest" package. Default values (square root of the number of environmental variables for classification models, one-third of the number of environmental variables for regression models), consistently produced the best results and were used in all models.

Example maps of preliminary predicted habitat suitability (probability of presence) are shown for BRT and GAM models for Crinoida in Figures 17 and 18. The probability ranges differ between models due to the prevalence setting used in the GAM models (by the random removal of absence records so that there are equal numbers of presence and absence records), but otherwise the outputs show similar patterns across most of the seamounts. Lower probabilities of crinoid presence are indicated over much of the flat tops of the seamounts, with higher probabilities on the sloping sides – especially around the perimeters. Both models indicate higher overall probabilities on Forde than on the other seamounts and the BRT model in particular suggests higher probabilities in the northern part of the seamount than in the southern part (see Figure 18).

Work is continuing on development of abundance models, model performance measures, model precision estimates, and combination of outputs into ensemble models.

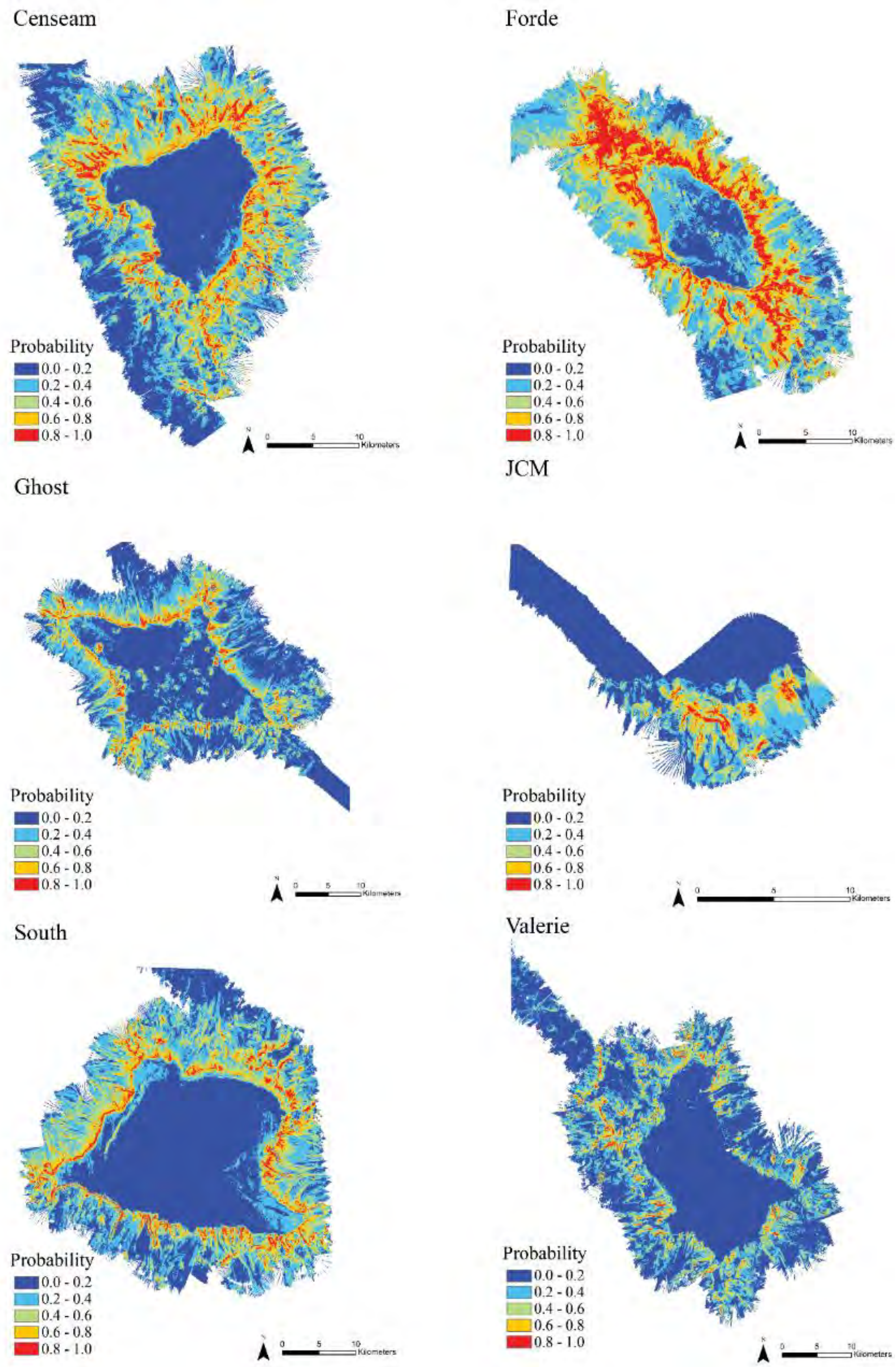


Figure 17: Predicted probability of the presence (0-1) from a GAM model of Crinoidea (VME habitat indicator taxa) on six seamounts of the Louisville Seamount Chain.

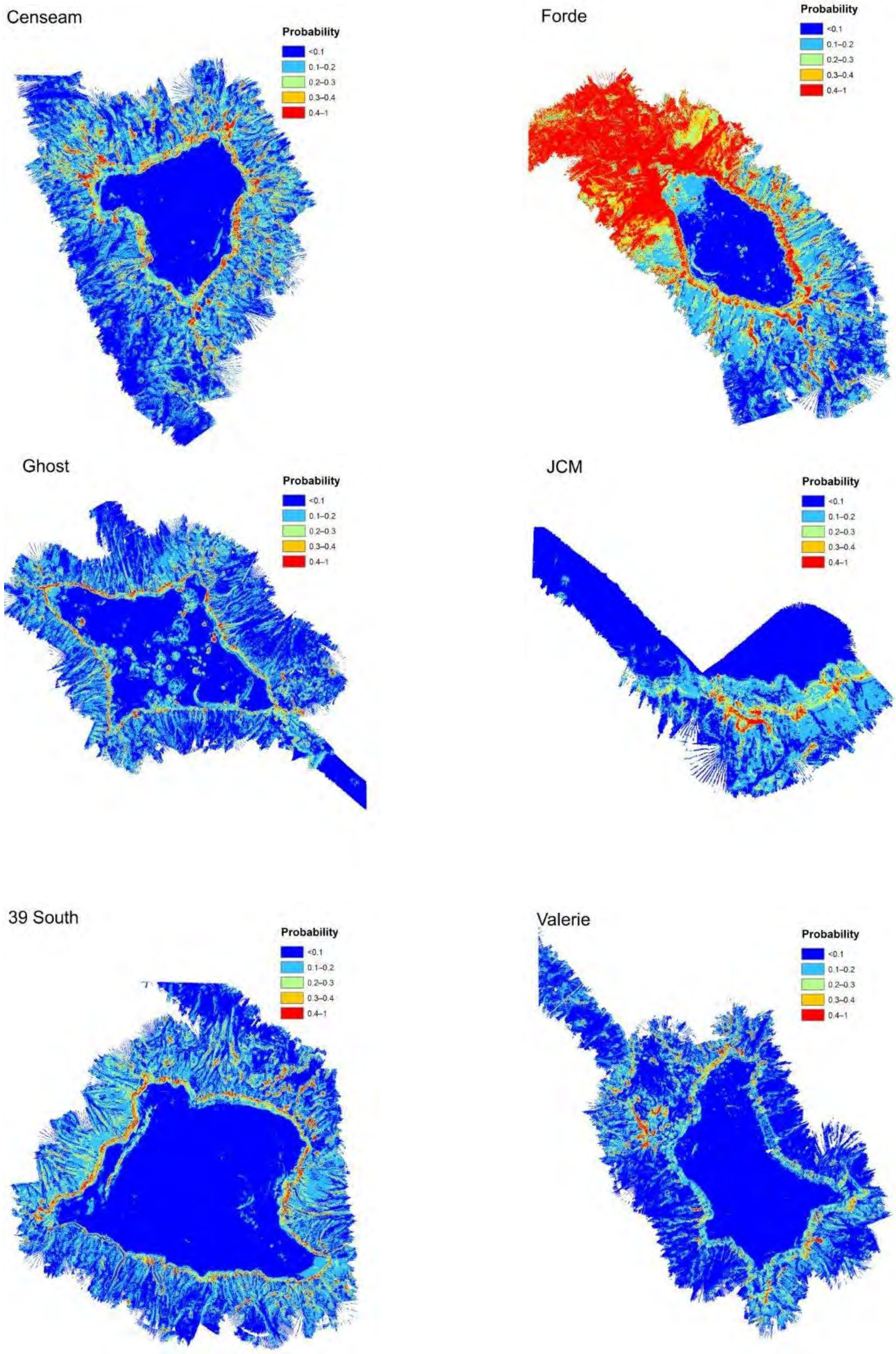


Figure 18: Predicted probability of the presence (0-1) from a BRT model of Crinoidea (VME habitat indicator taxa) on six seamounts of the Louisville Seamount Chain.

3.5.2 Decision-support tools

Predicted distributions of VME indicator taxa from habitat suitability models can be combined with the distribution of bottom fishing to design spatial management areas that provide for fishing while avoiding significant adverse impacts on VMEs (noting that the utility of such analyses depends on the quality of the input data). Decision-support tools are available to design spatial management measures, and New Zealand has focussed primarily on the use of Zonation software (e.g., Moilanen 2007; M0ilanen et al. 2014) to demonstrate the utility of the method and explore sensitivity to scenario choices. The initial development work focused on the SPRFMO Area (Rowden et al. 2015) but, because of the limitations in the broad-scale habitat suitability models underlying the analysis (Anderson et al. 2016a), subsequent work has focused on the New Zealand region instead (which includes some western parts of the SPRFMO Area) because New Zealand region-scale models are thought to be more reliable (Anderson et al. 2016b) Preliminary results of this work were reported to SC3, where details for the input data are also described (Cryer 2015, SC-03-DW-04).

Preliminary sensitivity analyses using Zonation were re-run using updated New Zealand region-scale habitat suitability models for VME indicator taxa (Anderson et al. 2016b) and New Zealand fishing data (up to June 2015). All input data for the Zonation analysis were gridded to cells of 1 km^2 over the study area, which was defined by the extent of the habitat suitability models for VME indicator taxa. Zonation outputs include maps of prioritisation, where areas are identified from the highest to lowest priority in terms of VME protection for a particular scenario. Other outputs include the mean proportion of each taxon range protected across the full range (i.e. 0-100% of total area protected) of area put into protection under different scenarios.

Zonation scenarios were progressively run to examine:

- Changing the type of habitat suitability model used to represent VMEs
- Including model uncertainty
- Weighting the importance of different VME indicator taxa
- Producing aggregated solutions more suitable for management
- Exclusion of EEZs
- Influence of a naturalness condition based on trawl history
- Including midwater and/or bottom trawling catch data for 'cost trade-off'
- Using different time periods for the fishing 'cost trade-off'

Following the conclusion of Anderson et al. (2016b) (see above), ensemble models of VME indicator taxa were chosen as the best type of model on which to base the Zonation analysis.

Sensitivity analysis analyses for the inclusion of model uncertainty were performed to determine how uncertainty in habitat suitability models influenced model scenarios. Model uncertainty is partly related to predicted levels of habitat suitability (Anderson et al. 2016b). Model uncertainty layers were weighted to emphasise how different uncertainty weightings could be used to de-prioritise those areas where predictions of suitable habitat for VME indicator taxa are less certain. These analyses suggested an "optimal" uncertainty weighting of 0.2 for these models (values of 0.2, 0.5, 1.0, 2.0, and 5.0 were tested) that discounts low suitability areas but does not lead to maps that include only high suitability areas.

Importance weightings were simulated in scenarios to reflect higher perceived value of prioritising areas that are suitable for four scleractinian coral species (reef-forming corals that provide habitat for diverse and functionally important ecosystems; Henry & Roberts 2007, Cathalot et al. 2015), and lower perceived value of selecting areas where crinoids and brisingids may occur (secondary VME habitat indicators, but not VME indicator taxa themselves; Parker et al. 2009). Three weighting combinations were trialled, and a down-weighting of the latter two taxa, and a 5x up-weighting of scleractinian species was chosen as an appropriate representation of perceived VME protection priorities.

To maximise suitability for management enforcement via simplified boundaries and aggregated prioritisation solutions, different rules to promote aggregation of highest priority cells were performed. Two aggregation options were used in the scenarios. The first compared the effect of using "Edge Removal" (i.e. cells preferentially given lower values at edges of groups of cells). The second used the "Boundary Length Perimeter" (BLP) option (using BLP values of 0.01, 0.1, and 0.5), which discounts cells based on the cumulative perimeter length of all cells remaining in an analysis. A value of 0.5, coupled with the Edge Removal rule, was most optimal for promoting some aggregation of cells and minimising high priority given to individual cells, but not over-aggregating the prioritisation solutions. The resulting scenario was termed the Base prioritisation model scenario (or Base scenario for short).

Because spatial management measures to protect VMEs are to be developed for the SPRFMO Area only, the inclusion of areas within EEZs is inappropriate for the following steps in the Zonation analysis. However, first a comparison was made of the Base scenario output including and excluding the EEZs in order to assess whether excluding EEZs had a noticeable effect on the distribution of high priority areas for VME protection. If it did, it would raise significant questions about the value of identifying areas for VME protection in the SPRFMO area exclusive of identifying areas for protection within EEZs. The resulting comparison showed that the effect of removing the EEZs was seemingly negligible (Figure 19, compare area on Lord Howe Rise).

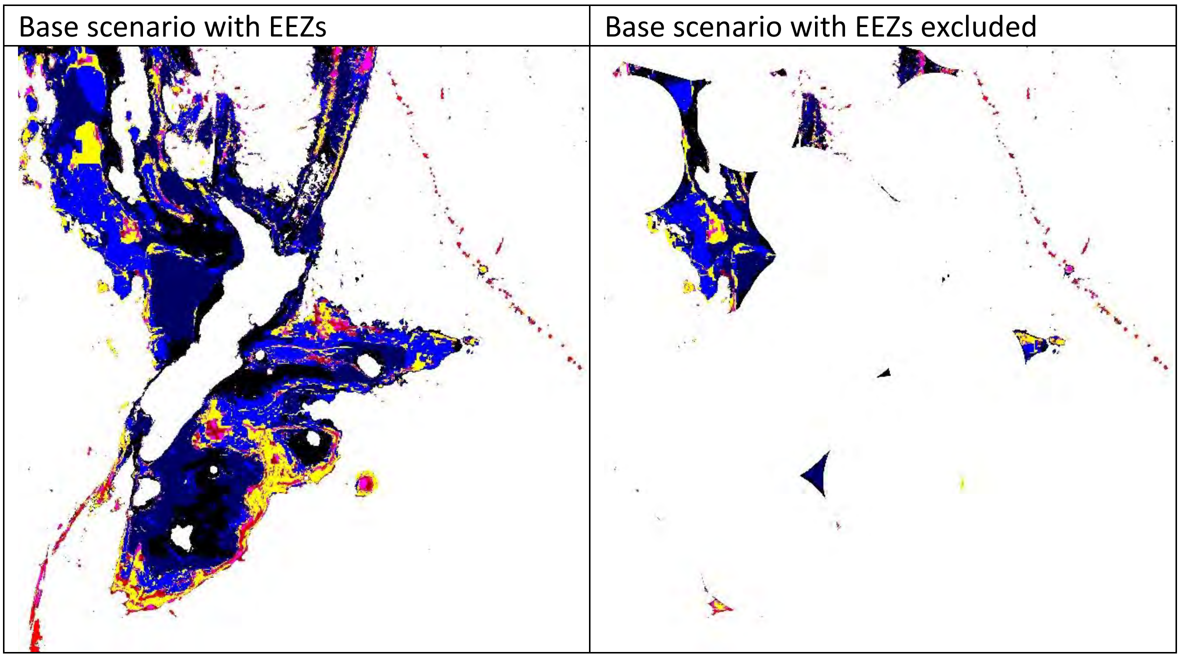


Figure 19: Zonation output for Base prioritisation model scenario (ensemble model; 0.2 weighing of uncertainty; 5x weighting of coral taxa and down-weighting of habitat indicator taxa; Edge Removal on and Boundary Length Perimeter set at 0.5) with and without EEZs. [top 2% priority = red, 2-5% = brown, 5-10% = pink, 10-25% = yellow, 25-50% blue; 50-100% = black]

For the next step in the Zonation analysis, data for fishing effort were used to derive two proxy "condition" measures for naturalness to generate a scenario in which areas of low naturalness (i.e. already likely to be impacted by bottom trawling) are de-prioritised for protection. Data were for all fishing years combined, and for both bottom and midwater trawls (midwater trawls targeting bentho-pelagic species are included in the SPRFMO definition of bottom fishing (Tingley 2014a, SC-02-10, see also report from SC2). The first measure was the number of trawls converted to a distribution from 0-1, normalised to the maximum number of trawls. The second used 30 trawls as a minimum threshold for naturalness, such that all cells with trawls of <30 were given a value of 0, and the rest of cells were normalised to the maximum number of trawls. The inverse of the normalised number of trawls was used to indicate habitat condition, with larger values indicating high naturalness, and lower values indicating a degraded state of naturalness. . Outputs suggest that the effect of including a naturalness in the Zonation analysis is minimal, which could be a consequence of the original scale of the fishing data and VME indicator taxa data, or the timeframe over which the biological data underpinning the models were collected. Nonetheless, the naturalness input layer based on >30 trawls per cell was used for further scenarios, because trawling effect research suggests that threshold impacts occur for coral habitat on seamounts (Clark et al. 2010), and its inclusion acts as an example of how naturalness can be included in Zonation analyses..

The "cost trade-off" option in Zonation is used to optimise the identification of high priority areas for VME protection but avoid high cost areas (i.e. where fishing takes place and high catches have been historically returned). Generally, the trade-off function will attempt to find cells with similar VME values, but that have low cost (i.e. relatively lower fish catch). Often, alternative cells can be found, although the solution may require a larger number of total cells to achieve the same value for VMEs when optimising for both VMEs and cost.

First the cost trade-off option was used to assess the influence of fishing method on the output by running scenarios for no cost, and cost using catch data from all bottom trawls, all midwater trawls, and combined bottom and midwater trawls. The results from these scenarios show that the no cost and midwater trawl cost outputs are similar, while the pattern of area prioritisation changes more noticeably when bottom trawl cost is included (Figure 20, compare Lord Howe area). Thus the combined midwater and bottom trawl cost output resembles the output for the bottom trawl cost alone (Figure 21). Because the following analysis were designed to show differences related to bottom trawling only, catch from bottom trawls was chosen as the cost input for further scenarios.

The current SPRFMO reference period of bottom trawl footprints and catch limits is 2002-2006. The final set of sensitivity analysis for the use of Zonation for designing spatial management measures assessed the difference between the prioritisation output for this reference period and other time periods for 'cost trade-off' scenarios. The differences between fishing periods reflect spatial and temporal variability in catch and effort (as related to changes in fishing practice and management measures) (Clark 2008a, Clark et al. 2010, Roux et al. 2016). There is a noticeable difference in the distribution of high prioritisation areas between the earliest fishing period (1990-2001) and the two later fishing periods (2002-2006, and 2007-2015). Not surprisingly the 'cost trade-off' prioritisation output for all years resembled a combination of the outputs for the three fishing time periods.

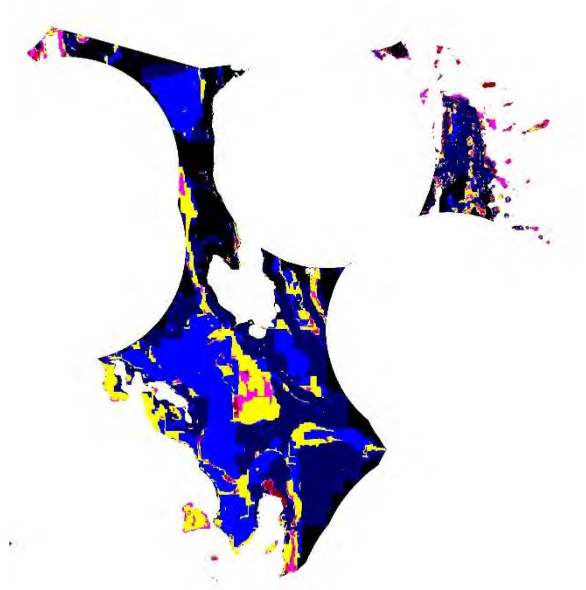
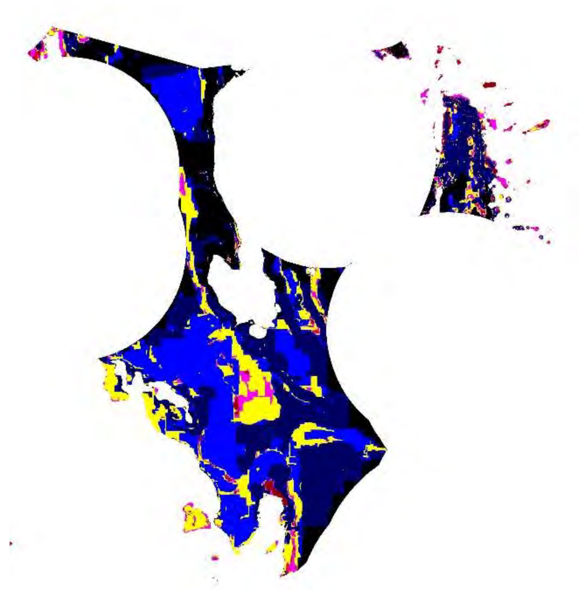
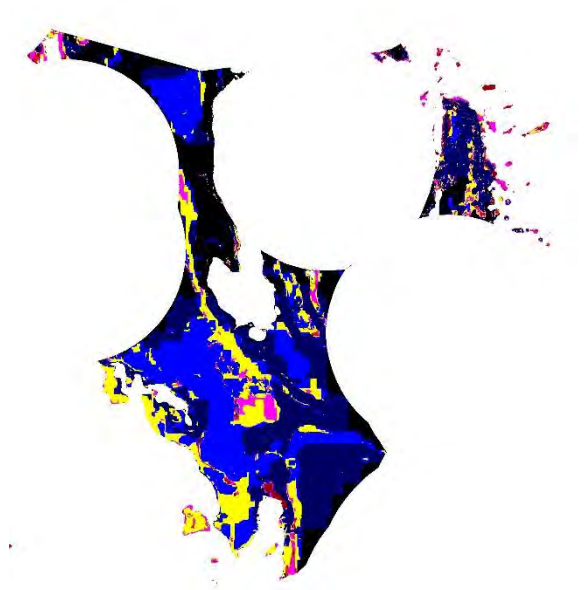
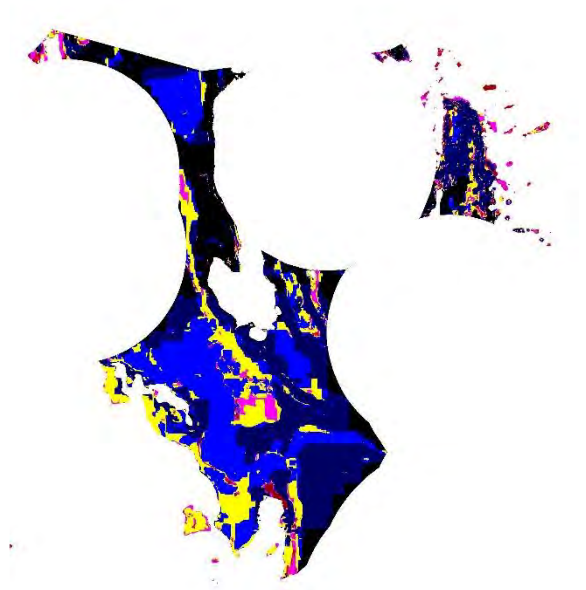
Base scenario with naturalness (i.e. no fishing ‘cost trade-off’)	Base scenario with naturalness, and midwater trawl catch ‘cost trade-off’
	
Base scenario with naturalness, and bottom trawl catch ‘cost trade-off’	Base scenario with naturalness, and midwater and bottom trawl catch ‘cost trade-off’
	

Figure 20: Zonation output for Base prioritisation model scenario and naturalness (>30 tow threshold) without and with ‘cost trade-off’ using catch by midwater trawl, bottom trawl, and both midwater trawl and bottom trawl – showing North West of study area only [top 2% priority = red, 2-5% = brown, 5-10% = pink, 10-25% = yellow, 25-50% blue; 50-80% = dark blue; 80-100% = black]

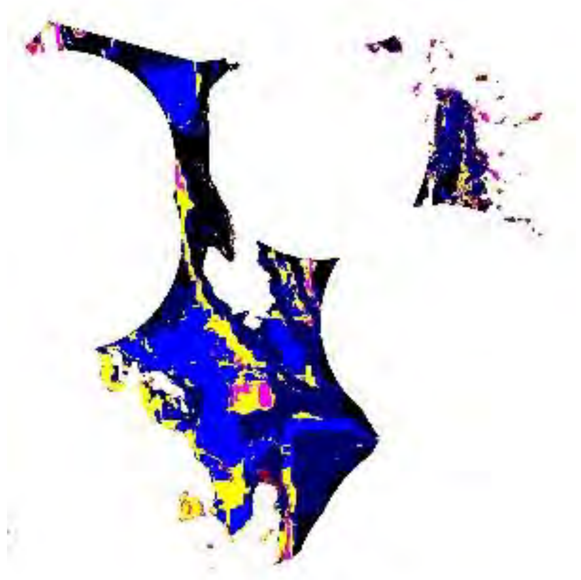
Base scenario with naturalness, and bottom trawl catch (1990-2001) 'cost trade-off'	Base scenario with naturalness, and bottom trawl catch (2002-2006) 'cost trade-off'
	
Base scenario with naturalness, and bottom trawl catch (2007-2015) 'cost trade-off'	Base scenario with naturalness, and bottom trawl catch (1990-2015) 'cost trade-off'
	

Figure 21: Zonation output for Base prioritisation model scenario and naturalness (>30 tow threshold) with 'cost trade-off' using catch by bottom trawl from 1990-2001, 2002-2006, 2007-2015 and all years – showing North West of study area only [top 2% priority = red, 2-5% = brown, 5-10% = pink, 10-25% = yellow, 25-50% blue; 50-80% = dark blue; 80-100% = black]

The proportion of the bottom trawl footprint lost to fishing if high priority areas for VME indicator taxa are protected (i.e. one measure of the cost to fishing) differed between scenarios with different reference 'cost trade-off' time periods (Table 11). Differences between fishing periods reflect spatial and temporal variability in catch and effort (as related to changes in fishing practice and management measures, see Clark 2008a, Clark et al. 2010, Roux et al. 2016). The proportions of the trawl footprint lost under the 2002-2006 'cost trade-off' scenario, where high priority areas (top 25%) for VME indicator taxa are protected, were greater than for other reference time periods, and all years.

Table 11: Percentage of trawl footprint lost to fishing in the study area, if priority areas for VME indicator taxa (lowest % equals highest priority for protection) are closed under "cost trade-off" scenarios using different reference time periods.

	Priority cells for VME indicator taxa								
Scenario	5%	10%	15%	20%	25%	50%	75%	90%	100%
Bottom trawl (1990-2001)	0.05	0.24	0.28	0.69	2.60	82.19	97.84	99.26	100.00
Bottom trawl (2002-2006)	0.29	3.61	8.46	14.93	19.82	61.21	92.31	96.84	100.00
Bottom trawl (2007-2015)	0.72	0.88	2.18	2.42	2.78	79.27	95.65	99.30	100.00
Bottom trawl (all years)	0.07	0.42	1.25	5.70	8.22	76.05	97.11	99.37	100.00

Zonation was used to calculate the mean proportion of each VME indicator taxon's range that is protected, if priority areas for VME indicator taxa are closed under a no cost trade-off scenario, and under 'cost trade-off' scenarios using different reference time periods (Table 12). The same values were calculated for scleractinian coral species only (Table 13). The difference in the mean proportions of the ranges if high priority areas (top 5–25 %) for VME indicator taxa are protected under a no cost and the cost trade-off scenarios are relatively small (< 6%). These tables also include, for comparison, the same values calculated for the areas closed to bottom trawling in 2009 (Penny et al. 2009). The mean proportion of each VME indicator taxon's range protected by these closed areas is smaller than the proportion protected if priority areas (top 5–50%) were selected for closure based on one of the 'cost trade-off' scenarios using Zonation. This difference is particularly noticeable for the highest priority areas (top 5–10%). It is worth noting that the values in the table are based on the predicted range of VME indicator taxa across the entire study area (only part of which is covered by the bottom trawl footprint) and are based on all levels of predicted habitat suitability (1–100%). Future assessments should include the proportions of protection for areas predicted to be highly suitable (e.g., >60%) for each VME indicator taxon.

The main outcome of this work is the demonstration of the practical utility of using habitat suitability models for VME indicator taxa (where reliable predicted distributions for VME are available), historical fishing data, and a decision-support tool to develop options for the spatial management within the SPRFMO Area. However, it is clear that, before a formal analysis can be undertaken to identify priority areas for spatial management, further analysis and data are required. For example, only fishing data for the New Zealand fishery were used in this demonstration analysis, and it is probable that fishing by other SPRFMO countries (e.g. Australia) occurs outside of the New Zealand fishing footprint. In addition, the analysis presented here did not include the full extent of the New Zealand fishing footprint because the "regional-scale" habitat suitability model does not extend to the eastern end of the Louisville Seamount Chain). Ideally, future analyses will include habitat suitability models for VME indicator that cover this area, and will have been field validated for accuracy. In addition, it was not possible to include a bioregional approach in the Zonation analysis, because suitable biogeographic schemes are not currently available for the area covered by the analysis. Using a bioregional approach has potential benefits for VME protection (Rowden et al. 2015). When data for population connectivity (derived from genetic studies of VME indicator taxa) becomes available this can also be included in future Zonation analysis.

Most important of all, stakeholder engagement in future analyses needs to be extended. Although stakeholders provided some input to the analyses presented here through the Stakeholder Advisory Group of the South Pacific VME project and MPI's South Pacific Fishery Assessment Working Group, this was not done in a structured manner while the bulk of the analysis was taking place. Analyses focussed on developing actual candidate spatial management areas for a revised bottom fishing measure for SPRFMO Area should involve all stakeholders throughout the process.

Table 12: Mean percentage of each taxon's range protected (across the entire study area, and all levels of habitat suitability), if priority areas for VME indicator taxa (lowest % equals highest priority) are closed under a no 'cost trade-off' scenario (= Base scenario including naturalness) and under 'cost trade-off' scenarios using different reference time periods.

	Priority cells for VME indicator taxa								
Scenario	5%	10%	15%	20%	25%	50%	75%	90%	100%
Base scenario including naturalness (>30 tows)	43	60	71	78	83	95	99	99	100
Cost trade-off (bottom trawl (1990-2001)	40	56	66	73	78	95	98	99	100
Cost trade-off (bottom trawl (2002-2006)	42	58	69	76	81	95	98	99	100
Cost trade-off (bottom trawl (2007-2015)	42	59	70	76	82	95	99	99	100
Cost trade-off (bottom trawl (all years)	40	56	66	73	78	95	98	99	100
Closed areas	10	32	55	67	75	91	98	99	100

Table 13: Mean percentage of each scleractinian coral species' range protected (across the entire study area, and all levels of habitat suitability), if priority areas for VME indicator taxa (lowest % equals highest priority) are closed under a no cost trade-off scenario (= Base scenario including naturalness) and under cost trade-off scenarios using different reference time periods.

	Priority cells for scleractinian coral species only								
Scenario	5%	10%	15%	20%	25%	50%	75%	90%	100%
Base scenario including naturalness (>30 tows)	73	88	94	96	98	99	100	100	100
Cost trade-off (bottom trawl (1990-2001)	69	83	88	91	92	99	100	100	100
Cost trade-off (bottom trawl (2002-2006)	71	86	91	95	96	99	100	100	100
Cost trade-off (bottom trawl (2007-2015)	72	87	92	95	96	99	100	100	100
Cost trade-off (bottom trawl (all years)	69	83	88	91	93	99	100	100	100
Closed areas	9	52	83	89	92	97	100	100	100

New Zealand's Ministry for Primary Industries (MPI) convened an expert workshop in February 2015 to review scientific approaches to assessing the impact of mobile bottom fishing methods on benthic fauna and habitats (Ford et al. 2016). The experts were asked to address the question: "*What is the best scientific approach to assessing trawl and dredge impacts on benthic fauna and habitats in New Zealand in the short, medium and long-term*?" The experts were divided on the best approach but were able to reach a compromise that, in the short to medium-term, a fishing impact/productivity modelling approach using the spatial overlap of fishing and the distribution of species or habitats was a useful starting point for in-zone risk assessment. The experts thought this framework would be a powerful screening tool for prioritising the species or habitats most likely to warrant research or management attention.

MPI has since commissioned a project (BEN2014-01) to develop methods under this framework using indicator taxa to infer habitat-level impact and status where seabed habitat mapping is incomplete. Two parallel methods (overlap metric and spatial population models) are being applied to quantify impact spatially and compare status trajectories under current, historical and putative future footprint scenarios. This approach relies on similar habitat suitability and fishery footprint information as the SPRFMO VME and Zonation analyses presented here, but it also requires information on functional and life history traits to estimate susceptibility to fishing gear and recovery potential.

It is expected that the preliminary results of this methods development project will be available in time for SC5.

4 Summary of Observer and Port Sampling Programmes

4.1 OBSERVER COVERAGE

Reporting of the New Zealand observer programme activities in the SPRFMO Area during 2015, are included in a separate New Zealand SPRFMO Annual Observer Implementation Report (SC-04-xx).

A total of five New Zealand bottom trawlers operated under permit in the SPRFMO Area during 2015 and all 16 trips carried New Zealand scientific observers, representing 298 vessel days and 981 bottom tows. All fishing days were observed and 782 of the 981 tows (80%) were observed. Scientific observers measured fish from 7% of bottom trawl tows (Table 14). A total of 13 016 fish were measured, over 99% of which were the principal catch species, orange roughy, the remainder being alfonsinos. Midwater trawl gear for bentho-pelagic species was used only sporadically in the SPRFMO Area during 2015 and no fish were measured from these tows.

Four New Zealand bottom longline vessels operated in the SPRFMO Area during 2015, with two trips carrying a scientific observer. During the observed trips, a total of eight vessel days and 29 bottom longline sets were observed (97% of sets for those days, see Table 14). A total of 220 fish were measured, including 170 (77% of fish measured) of the principal target species, bluenose. For bottom longline, 12% of fishing days were observed (14% of sets and 16% of trips. All Dahn line fishing days and sets were observed and 13.8% of handline fishing days were observed.

Table 14: Summary of observer and sampling coverage of bottom and midwater trawl and bottom longlining, handlining, and Dahn lining fishing effort in the SPRFMO Area during 2015. Days and events (trawl tows or line sets) relate to observed trips and days only.

Method	No. trips	Vessel days	Total events	Events observed	Events measured	Retained catch (kg)	Measured catch (kg)	No. Fish Measured
Bottom trawl	16	298	981	782	71	1 804 554	17 623	13 016
Midwater trawl	2	4	6	4	0	4 135	0	0
Bottom longline	2	8	30	29	21	17 421	1 536	220
Hand lines	1	4	70	70	29	4 206	948	87
Dahn lines	1	6	33	33	26	3 164	1 441	178

Note: Tows/sets reported here are all tows conducted, including those which made no catch, and so may exceed the tows which made a catch, as reported in the effort summary tables. Landings in this table are in greenweight and include all species caught.

4.2 BIOLOGICAL SAMPLING AND LENGTH/AGE COMPOSITION OF CATCHES

The deepwater fisheries continued to be monitored by scientific observers during 2015 and a summary of the length-frequency sampling is provided in Table 15. A high proportion of all fish measured were orange roughy, the principal demersal trawl target species, with most of the remaining fish measured being the principal bottom longline target species, bluenose.

The length-frequency distribution of the orange roughy measured from demersal trawl fishing in 2015 is shown in Figure 22. A similar length-frequency distribution plot for the principle bottom longline caught species bluenose is shown in Figure 23. Comparison of length frequency distributions from the past 6 years (Figures 24–26) suggests that the size of orange roughy caught in bottom trawls is relatively consistent between years (Figure 24, left panel). The small average size of orange roughy recorded in 2015 probably stemmed from shifts in the location of fishing. The recorded sizes of bluenose and wreckfish vary considerably between years (Figure 24, right panel and Figure 25), potentially as a result of small sample sizes or shifts in fishing locations. Length frequency distributions for alfonsino (Figure 26) suggest broadly similar sizes caught in bottom and midwater trawls, with some variation between years, especially when few fish were measured.

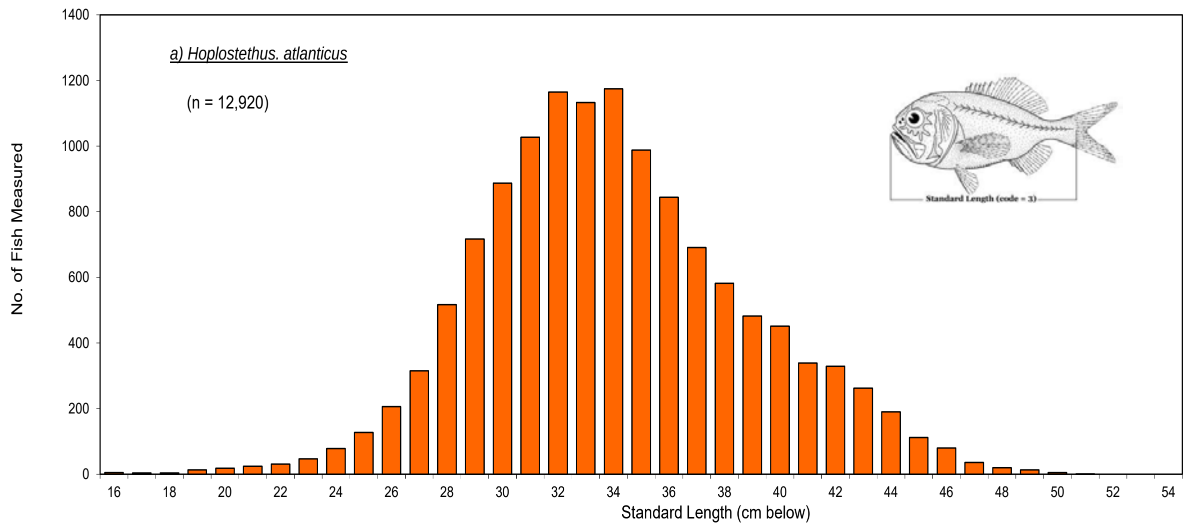


Figure 22: Length frequency distribution (unscaled) for orange roughy (*Hoplostethus atlanticus*) measured by scientific observers aboard New Zealand bottom trawl vessels fishing in the SPRFMO Area during 2015.

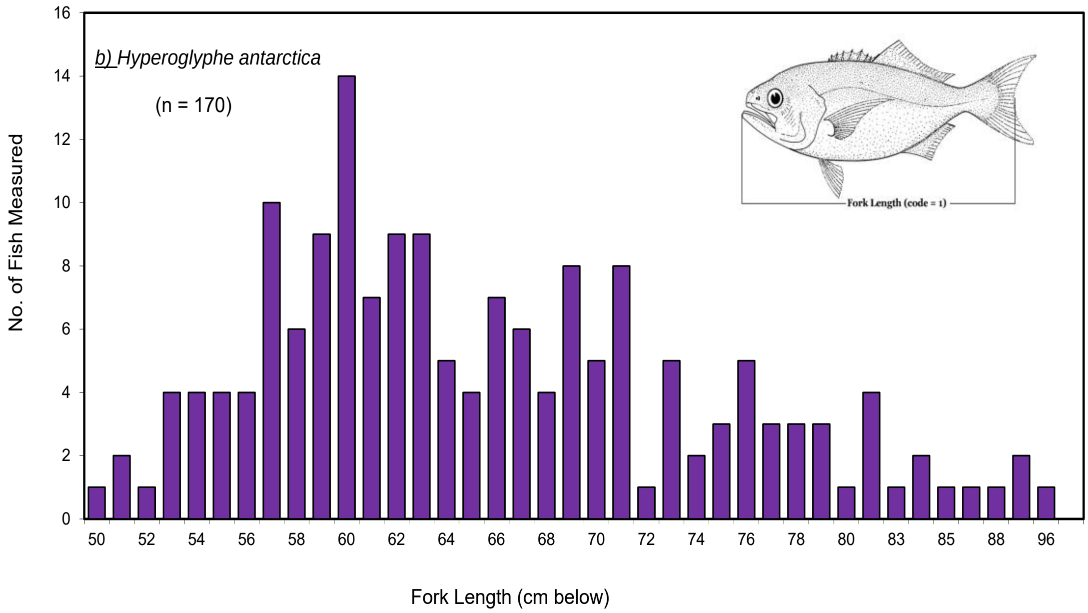


Figure 23: Length frequency distribution (unscaled) for bluenose (*Hyperoglyphe antarctica*) measured by scientific observers aboard New Zealand bottom longlining vessels fishing in the SPRFMO Area in 2015.

Table 15: Summary of length-frequency sampling for those species or species groups with a sample size of ~100 fish or more conducted by scientific observers aboard New Zealand vessels conducting bottom fishing in the SPRFMO Area in 2015.

Scientific Name	Method	Common Name	Measure Used	Length (cm) Min	Mean	Max	Number Measured
Hoplostethus atlanticus	Bottom trawl	Orange roughy	standard	15	34.02	51	12,920
Hyperoglyphe antarctica	Bottom longline	Bluenose	fork	50	66.16	96	170
Beryx spp.	Bottom trawl	Alfonsino	fork	25	33.06	42	96
Polyprion spp.	Bottom longline	Wreckfish	fork	58	101.97	145	159
						Total	13,345

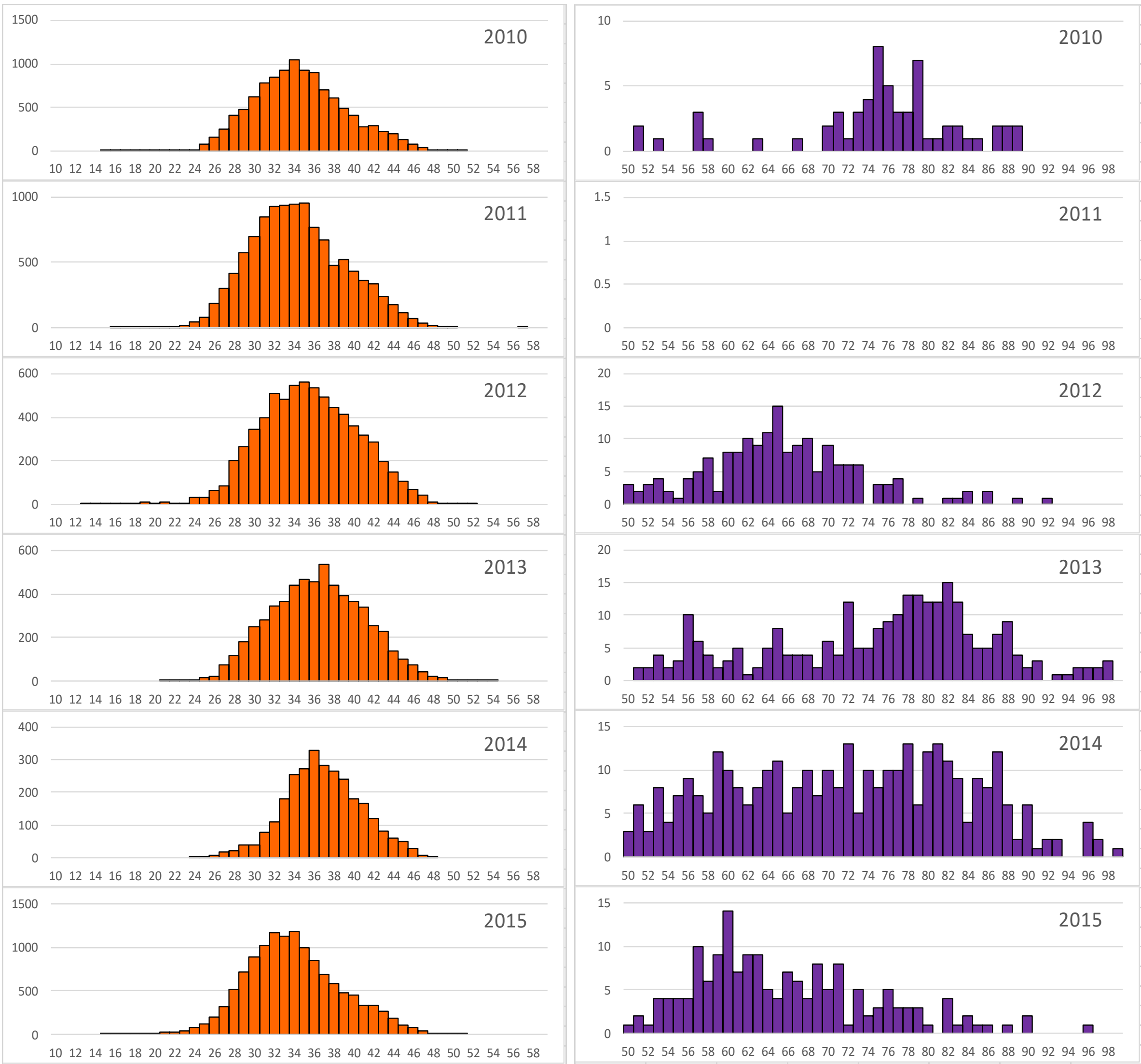


Figure 24: Length frequency distributions (unscaled) for the main demersal target species measured by scientific observers aboard New Zealand vessels fishing between 2010 and 2015 in the SPRFMO Area. Left panel, orange roughy from bottom trawls; right, bluenose from bottom longlines.

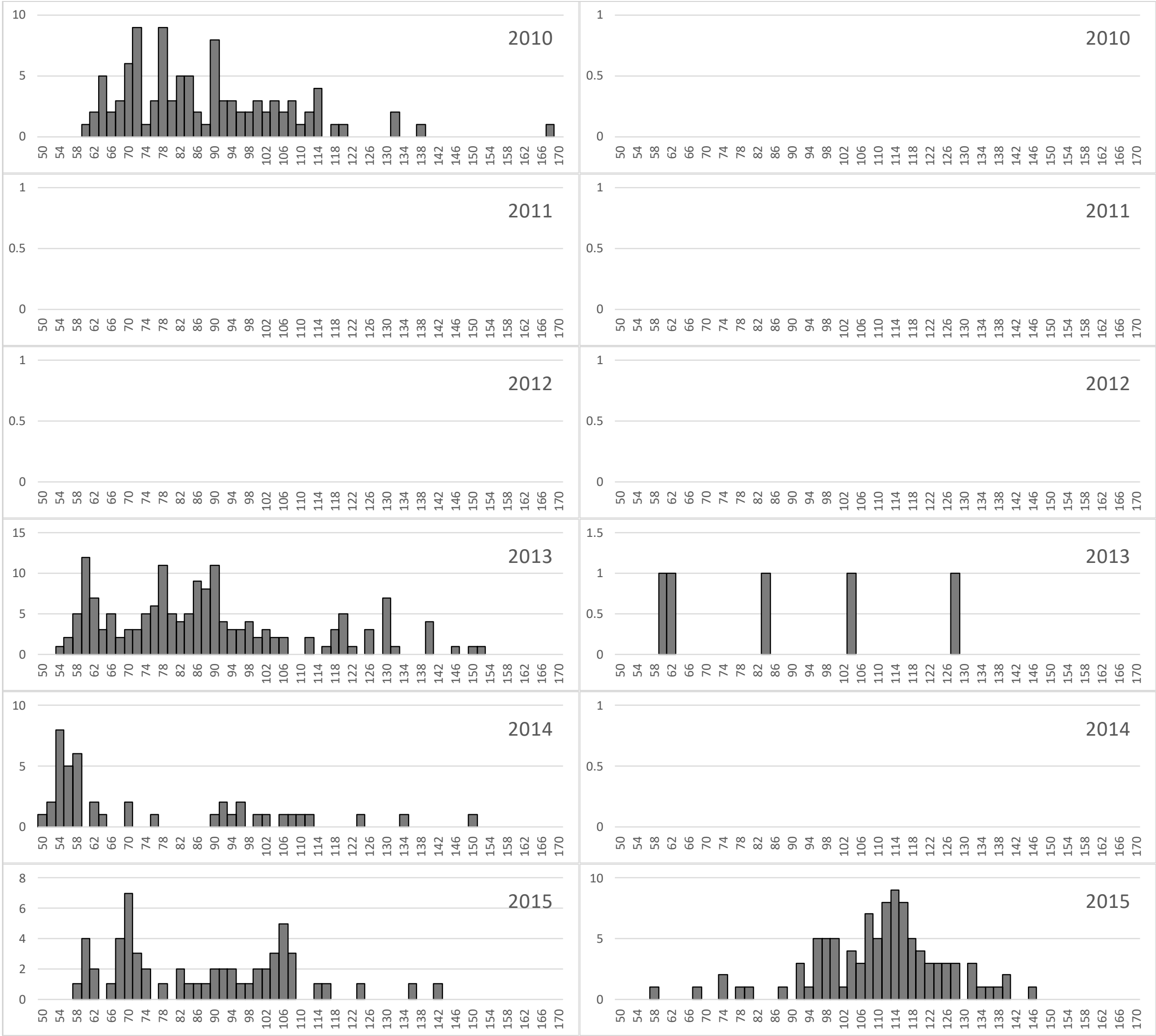


Figure 25: Length frequency distributions (unscaled, 2 cm bins) for wreckfish measured by scientific observers aboard New Zealand vessels bottom longlining between 2010 and 2015 in the SPRFMO Area. Left panel, bass, *Polyprion americanus*; right, hapuku, *Polyprion oxygeneios*.

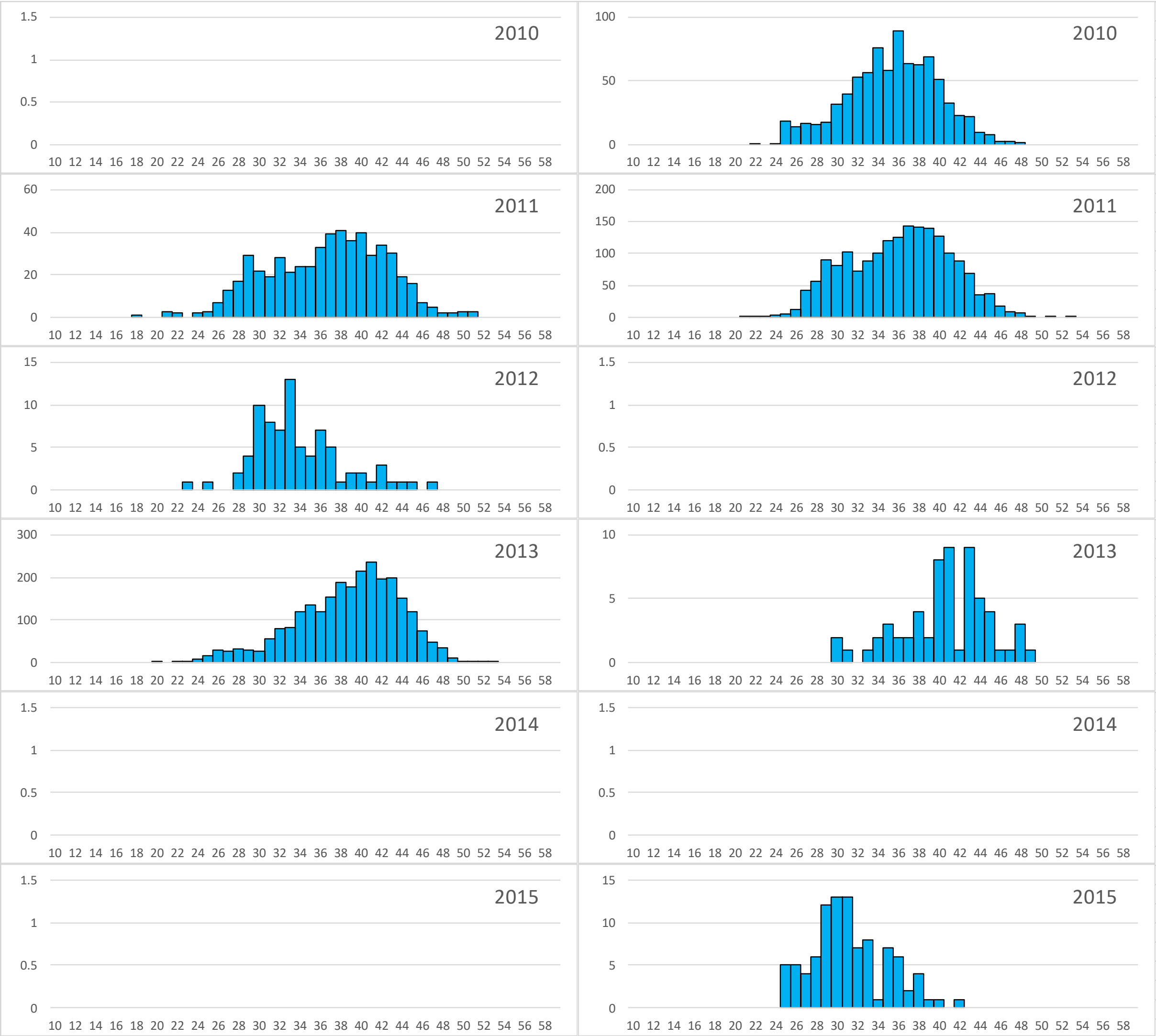


Figure 26: Length frequency distributions (unscaled) for alfonsino (*Beryx splendens* and *B. decadactylus* combined) between 2010 and 2015 measured by scientific observers aboard New Zealand trawl vessels fishing in the SPRFMO Area. Left panel, from midwater trawls; right, from bottom trawls.

Observers also collected information on the bycatch of benthic fauna, whether or not a vessel is fishing in a move-on area that may require rapid assessment of VME indicator taxa for the purpose of assessing whether the move-on rule is triggered. In total, over 600 such records of benthic bycatch, almost half of which were of corals, have been made from a wide range of fishing locations since 2009 (Table 16). This information will be available for New Zealand's review of its bottom fishery impact assessment and contribute to the development of the comprehensive bottom fishing measure.

Table 16: Number of records from observer benthic bycatch forms for corals, sponges, other invertebrates, fish, detritus and substratum taken by New Zealand vessels since 2010.

	Coral	Sponge	Invert	Fish	Detritus	Substratum	Challenger
2010	14	4	10	0	2	2	32
2011	14	6	21	1	1	1	44
2012	11	3	5	1	1	1	22
2013	13	3	3	0	1	1	21
2014	3	2	4	0	0	1	10
2015	24	16	20	2	15	2	80
Subtotal	79	34	63	4	20	8	209
							Lord Howe Rise
2010	20	3	12	0	0	1	36
2011	16	4	20	0	2	2	44
2012	9	1	8	0	1	1	20
2013	16	3	7	0	1	1	28
2014	7	2	2	0	0	0	11
2015	14	2	12	0	1	1	30
Subtotal	82	15	61	0	5	6	*169
							Louisville Ridge
2010	14	3	8	0	0	2	27
2011	12	2	4	0	0	2	20
2012	12	0	7	0	0	1	20
2013	10	4	2	0	0	1	17
2014	8	1	1	0	0	1	11
2015	12	0	3	0	0	2	17
Subtotal	68	10	25	0	0	9	112
							West Norfolk
2010	17	6	10	0	0	1	34
2011	14	9	7	0	0	1	31
2012	8	3	0	0	1	1	13
2013	13	4	3	0	1	2	23
2014	0	0	0	0	0	0	0
2015	9	3	1	0	1	1	15
Subtotal	61	25	21	0	3	6	116
Grand total	290	84	170	4	28	29	606

* Of the 169 records on benthic bycatch forms from the Lord Howe Rise, 27 (16%) were from blocks closed to bottom fishing by trawl methods since 2015 (ref paper SC-03-DW-03)

4.3 Monitoring Captures of Seabirds, Marine Mammals, Reptiles, and Other Species of Concern

New Zealand observers are present on all New Zealand vessels using the method of bottom trawl or midwater trawl for bentho-pelagic species in the SPRFMO Area and observe a high proportion (70–100%) of trawl tows. In addition, New Zealand observers are present on about 10% of bottom line fishing trips by New Zealand vessels and typically observe 10–15% of all line sets each year. Observers record a wide variety of information, to SPRFMO data standards or better, including the application of mitigation devices and protocols for seabirds. Since 1993, these observers have recorded the capture of three fur seals by trawl vessels, and one of these was returned alive (Table 17). Over the same time period, seven seabirds were observed captured by trawl vessels, five of which were released alive. One seabird, probably a grey-faced petrel, was observed captured and killed by a bottom longline vessel in 2014. No estimates of total captures have been made because the observations are so few.

Table 17: All records from observer non-fish bycatch forms for seabirds, marine mammals, reptiles, and other species of concern captured by New Zealand vessels since 1993. It should be noted that the observer coverage of trawl events is close to 100% whereas that for line methods is only 10–15%.

	Area	Fishing method	Common name	Status on capture
1993	Lord Howe Rise	Trawl	New Zealand fur seal	Dead
1993	Challenger	Trawl	New Zealand fur seal	Dead
2000	Challenger	Trawl	Sooty shearwater	Alive
2002	Challenger	Trawl	Wandering albatross (unidentified)	Dead
2002	Challenger	Trawl	Wandering albatross (unidentified)	Dead
2006	Louisville Ridge	Trawl	New Zealand fur seal	Alive
2006	Louisville Ridge	Trawl	Broad-billed prion	Alive
2014	Three Kings Ridge	Bottom longline	Great-winged petrel	Dead
2015	Lord Howe Rise	Trawl	Great-winged petrel	Alive
2015	Lord Howe Rise	Trawl	Great-winged petrel	Alive
2016	Challenger	Trawl	White-faced storm petrel	Alive

4.4 PORT SAMPLING PROGRAMMES

New Zealand does not have a port sampling programme.

5 Implementation of Management Measures

5.1 DESCRIPTION OF MANAGEMENT MEASURES

A detailed description of New Zealand's implementation of the SPRFMO interim conservation and management measures adopted in 2007 can be found in Ministry of Fisheries (2008b) and Penney *et al*. (2009). The management approach is summarised below:

High seas bottom trawling measures were established in the SPRFMO Area in the form of high seas fishing permit conditions, imposed from 1 May 2008. The key elements of these permit conditions include:

- Schedules designating open, move-on and closed bottom trawling areas within the historical (2002–2006) New Zealand high seas bottom trawl fishing footprint, and prohibiting bottom trawling within closed areas and everywhere else in the SPRFMO Area. These areas were last modified in 2015.
- The move-on rule VME Evidence Process for bottom trawling within move-on areas, with the requirement to report to the Ministry for Primary Industries and move-on 5 nautical miles from where the VME Evidence threshold is reached.
- A requirement to carry at least one observer on all bottom trawling trips. Observers are provided by the Ministry for Primary Industries and the costs are recovered from industry.

The effect of these measures has been to close bottom trawling in 41% of the total 217 463 km^2 New Zealand bottom trawl footprint surface area, with 30% made subject to a move-on rule, and 29% left open to bottom trawling with no move-on requirements. The open area represents 0.13% of the entire SPRFMO Area but much of the SPRFMO Area is too deep for bottom trawling. In 2015, New Zealand changed the status of three of the 20-minute blocks within its trawl footprint, opening one and closing two, subject to New Zealand's move-on rule (SC-03-DW-03). Maps showing the areas open to New Zealand vessels using trawl and line fishing methods included in the SPRFMO definition of bottom fishing are shown in Appendix 2.

The interim measures adopted in 2009 were implemented through high seas fishing permit conditions that came into effect in February 2010 (renewed each year). Fishing for *Trachurus* species and the use of gillnets are prohibited, and notice to the Ministry for Primary Industries is required in advance of transiting the SPRFMO Area with gillnets.

5.2 IMPLEMENTATION OF THE VME EVIDENCE PROCESS AND MOVE-ON RULE

The VME Evidence Process and move-on rule implemented within move-on blocks in the bottom trawl fishing footprint are described in Ministry of Fisheries (2008b) and Parker *et al.* (2009). Scientific observers deployed on New Zealand bottom trawling trips in the SPRFMO Area are required to complete VME Evidence Process forms for each tow conducted within a move-on area.

The move-on-rule has been triggered in the demersal fishery only six times in the 221 trawl tows in move-on areas conducted since 2008 (Table 18). This average rate of less than 3% of tows triggering a move-on is less than the expected rate of about 8% predicted by Penney (2014), probably because the catch rates of VME taxa in the SPRFMO Area are lower than from inside the New Zealand EEZ. The move-on-rule was triggered mostly by exceeding one or more of the weight thresholds of individual VME taxa (five occasions) and less by exceeding the trigger level of three different indicator taxa from the list of such taxa that make up the biodiversity component of the evidence process (one occasion).

Table 18: Data relating to the implementation of the move-on-rule within the New Zealand bottom trawl fishery. The numbers of tows are those fished in the move-on-rule areas only.

Bottom trawling in move-on-rule areas							
Year	No Tows	Observed tows.	Percentage observed	No of move-on events	Exceeded thresholds	Exceeded biodiversity count	Percentage of tows moved-on
2008	3	2	67%	0	–	–	0.0%
2009	18	18	100%	1	1	0	5.6%
2010	56	50	89%	2	2	0	4.0%
2011	79	77	97%	2	2	0	2.6%
2012	22	22	100%	1	0	1	4.5%
2013	14	14	100%	0	–	–	0.0%
2014	2	2	100%	0	–	–	0.0%
2015	44	44	100%	0	–	–	0.0%

In the midwater trawl fishery for bentho-pelagic species, the move-on-rule has never been triggered but there have been relative few tows (Table 19). Such fishing is now considered to be included within the SPRFMO definition of bottom fishing. New Zealand conducted no midwater trawling for bentho-pelagic species in 2014 and only a small amount in 2015.

Table 19: Data relating to the implementation of the move-on-rule within the New Zealand midwater trawl fishery for bentho-pelagic species. The numbers of tows are those fished in the move-on-rule areas only.

Midwater trawling for bentho-pelagic species in move-on-rule areas							
Year	No Tows	Observed tows.	Percentage observed	No of move-on events	Exceeded thresholds	Exceeded biodiversity count	Percentage of tows moved-on
2008	0	0	–	–	–	–	–
2009	0	0	–	–	–	–	–
2010	6	6	100%	0	–	–	0.0%
2011	16	16	100%	0	–	–	0.0%
2012	7	7	100%	0	–	–	0.0%
2013	5	5	100%	0	–	–	0.0%
2014	0	0	–	0	–	–	–
2015	0	0	–	0	–	–	–

5.3 MANAGEMENT OF THE CHALLENGER PLATEAU STRADDLING STOCK ORANGE ROUGHY FISHERY

The fishery on the straddling orange roughy stock on the Challenger Plateau, which was closed from 2000 to 2009, was re-opened on 1 Oct 2010 following assessments that indicated that the biomass has increased above the reference level for re-opening of the fishery (at least a 70% probability that the biomass has rebuilt above 20% B_0, Ministry of Fisheries 2008a). Applying a harvest strategy consistent with that implemented for orange roughy fisheries within the New Zealand EEZ could have indicated a TAC of up to 1,022 t for this stock. However, a cautious approach was taken to ensure continued re-building towards B_{MSY}, and it was reopened with a Total Allowable Catch (TAC) of 525 t. The TAC comprised a 500 t Total Allowable Commercial Catch (TACC) and an allowance of 25 tonnes for other sources of fishing-related mortality. The TAC and TACC were both increased in 2014. Since 2014, the New Zealand bottom trawl footprint has included two open blocks (of six) on the Westpac Bank in the SPRFMO Area where the stock straddles the New Zealand EEZ.

5.4 EXPLORATORY FISHERY FOR TOOTHFISH

New Zealand presented a proposal to the Scientific Committee in 2015 (Cryer & Fenaughty 2015 SC-03-DW-01) for a 2-year exploratory fishery for toothfish (Patagonian toothfish, *Dissostichus eleginoides*, and Antarctic toothfish, *Dissostichus mawsoni*) using the method of bottom longlining. This proposed fishery was outside New Zealand's existing bottom line fishing footprint and in excess of average catches during the criterion tears 2002–2006. The Scientific Committee assessed New Zealand's proposal and:

- **confirmed** that the proposal was acceptable under Article 22 (CMM 2.03) and the Bottom Fishery Impact Assessment Standard;
- **recognised** the cautious, exploratory nature of the proposal and the scientific benefits of the proposed data collection, including the understanding of the distribution, movement and stock structure of toothfishes;
- **emphasised** the importance of implementing stringent seabird mitigation measures throughout the surveys, including integrated weighted lines, bird scaring lines when setting gear and strict offal management;
- **suggested** that, in addition to being reviewed by New Zealand's domestic working group and the SPFRMO SC, data and analyses from the surveys should be shared with CCAMLR; and
- **stressed** that its evaluation did not indicate any commitment to extending this survey beyond 2017 or to extending New Zealand's footprint if a toothfish fishery is eventually proved in this area (these decisions being for the Commission).

The Compliance and Technical Committee and Commission considered the proposal in 2016 and approved a 2-year exploratory fishery with a retained catch limit of 30 tonnes of *Dissostichus* spp. (both species combined) each year (see CMM 4.14).

Preparatory and design work continued through late 2015 and 2016 and the first exploratory fishing was conducted between 2 and 9 August 2016. Preliminary results have been presented to two of New Zealand's domestic working group and are the subject of a separate paper to SC4 (Fenaughty & Cryer 2016). A more comprehensive analysis will be available for SC5 in 2017.

6 References

Anderson, O.F., Guinotte, J.M., Rowden, A.A., Clark, M.R., Mormede, S., Davies, A.J., Bowden, D.A. (2016a). Field validation of habitat suitability models for vulnerable marine ecosystems in the South Pacific Ocean: Implications for the use of broad-scale models in fisheries management. *Ocean and Coastal Management 120*: 110–126.

Anderson, O.F. Guinotte, J.M., Rowden, A.A., Tracey, D. Mackay, K., Clark, M.C. (2016b). Habitat suitability models for predicting the occurrence of vulnerable marine ecosystems in the seas around New Zealand. *Deep-Sea Research Part I 115*: 265–292.

Bull B; Francis RICC; Dunn A; McKenzie A; Gilbert DJ; Smith MH; Bian R; Fu D. (2012). CASAL (C++ algorithmic stock assessment laboratory) User Manual.

Campbell RA (2004). CPUE standardisation and the construction of indices of stock abundance in a spatially varying fishery using general linear models. *Fisheries Research 70*:209-27.

Carruthers TR; Ahrens RN; McAllister MK; Walters CJ (2011). Integrating imputation and standardization of catch rate data in the calculation of relative abundance indices. *Fisheries Research, 109*: 157-167.

Cathalot C, Van Oevelen D, Cox TJ, Kutti T, Lavaleye M, Duineveld G, Meysman FJ. (2015). Cold-water coral reefs and adjacent sponge grounds: Hotspots of benthic respiration and organic carbon cycling in the deep sea. *Frontiers in Marine Science 19*:2-37.

Clark, M.R. (2004). Descriptive analysis of orange roughy fisheries in the New Zealand region outside the EEZ: Lord Howe Rise, Northwest Challenger Plateau, West Norfolk Ridge, South Tasman Rise, and Louisville Ridge to the end of the 2002–03 fishing year. *New Zealand Fisheries Assessment Report 2004/51*. 36 p.

Clark, M.R. (2008a). Descriptive analysis of orange roughy fisheries in the New Zealand region outside the EEZ: Lord Howe Rise, Northwest Challenger Plateau, West Norfolk Ridge, South Tasman Rise, and Louisville Ridge to the end of the 2005–06 fishing year. *New Zealand Fisheries Assessment Report No. 2008/12*. 46 p.

Clark, M.R. (2008b). Descriptive analysis of orange roughy fisheries in the region outside the EEZ: Lord Howe Rise, Northwest Challenger Plateau, West Norfolk Ridge, and Louisville Ridge to the end of the 2006–07 fishing year. *New Zealand Fisheries Assessment Report 2008/66*. 24 p.

Clark, M.R.; Anderson, O.F.; Bowden, D.A; Chin, C.; George, S.G.; Glasgow, D.A.; Guinotte, J.M.; Hererra, S.; Osterhage, D.M.; Pallentin, A.; Parker, S.J.; Rowden, A.A.; Rowley, S.J.; Stewart, R.; Tracey, D.M.; Wood, S.A,; Zeng, C. (2015). *Vulnerable Marine Ecosystems of the Louisville Seamount Chain: voyage report of a survey to evaluate the efficacy of preliminary habitat suitability models.* New Zealand Aquatic Environment and Biodiversity Report No. 149. 86 p.

Clark, M.R., B. Bull & D.M. Tracey, (2001). *Development of estimates of biomass and sustainable catches for orange roughy fisheries in the New Zealand region outside the EEZ: CPUE analyses, and application of the "seamount meta-analysis" approach*. New Zealand Fisheries Assessment Report 2010/19, 47 pp. (SWG-09-INF-02)

Clark, M.R., M.R. Dunn & O.F. Anderson, (2010). The estimation of catch levels for new range roughy fisheries on seamounts: a meta-analysis of seamount data. *New Zealand Fisheries Assessment Report 2001/75*, 40 pp. (SWG-09-INF-01)

Clark, M.R., M.J. Roux & M. Cryer, (2015). New Zealand research relevant to the assessment of stocks of orange roughy (*Hoplostethus atlanticus*). Paper for the Scientific Committee of the South Pacific Fisheries Management Organisation. SC-03-xx, 31 pp.

Clark, M.R.; Anderson, O.F.; McKenzie, A.; Doonan, I.J. (2016). Estimating orange roughy stock size on seamounts: a meta-analysis of physical seamount characteristics. *New Zealand Fisheries Assessment Report 2016/47*. 19 p.

Clark, M.R.; McMillan, P.J.; Anderson, O.F.; Roux, M-J. (2016). Stock management areas for orange roughy (*Hoplostethus atlanticus*) in the Tasman Sea and western South Pacific Ocean. *New Zealand Fisheries Assessment Report 2016/19*. 27 p.

Cordue, P.L. (2014). The 2014 orange roughy stock assessments. *New Zealand Fisheries Assessment Report 2014/50*. 135 p.

Crase B; Liedloff AC; Wintle BA (2012). A new method for dealing with residual spatial autocorrelation in species distribution models. *Ecography, 35*: 879-888

Cryer M (2015). Progress on predicting the distribution of Vulnerable Marine Ecosystems and options for designing spatial management areas for bottom fisheries within the SPRFMO Convention Area. Paper for the 3rd Meeting of the SPRFMO Scientific Committee, Vanuatu 28 September-3 October 2015. 33 p.

Cryer M; Fenaughty J (2015). Proposal for exploratory bottom longlining for toothfish by New Zealand vessels outside the bottom lining footprint during 2016 and 2017: Description of proposed activities and impact assessment Paper SC-03-DW-01_rev1 for the 3rd Meeting of the SPRFMO Scientific Committee, Port Vila, Vanuatu, 28 September - 3 October 2015

Dunn MR, Forman JS (2011) Hypotheses of spatial stock structure in orange roughy *Hoplostethus atlanticus* inferred from diet, feeding, condition, and reproductive activity. PLoS ONE 6(11): e26704. doi:10.1371 / journal.pone.0026704

Edwards CTT; McAllister MK (2014). Application of a surplus production model to New Zealand stocks with time series data on catch and abundance. CCAMLR WG-SAM working group meeting, 15th May 2014

Fenaughty J; Cryer M (2016). Report on the first year's fishing under New Zealand's exploratory fishery for toothfish within the SPRFMO Convention Area. Paper for the 4th Meeting of the SPRFMO Scientific Committee, The Hague 7 to 15 October 2016. 7 p.

Ford, R.B.; Arlidge, W.N.S.; Bowden, D.A.; Clark, M.R.; Cryer, M.; Dunn, A.; Hewitt, J.E.; Leathwick, J.R.; Livingston, M.E.; Pitcher, C.R.; Rowden, A.A.; Thrush, S.F.; Tingley, G.A.; Tuck, I.D. (2016). Assessing the effects of mobile bottom fishing methods on benthic fauna and habitats. *New Zealand Fisheries Science Review 2016/2*. 47 p.

Henry LA, Roberts JM. 2007. Biodiversity and ecological composition of macrobenthos on cold-water coral mounds and adjacent off-mound habitat in the bathyal Porcupine Seabight, NE Atlantic. *Deep Sea Research Part I: Oceanographic Research Papers. 54*:654-72.

Hurst, R.J., Ballara, S.L., MacGibbon, D., Triantafillos, L. (2012). Fishery characterisation and standardised CPUE analyses for arrow squid (*Nototodarus gouldi* and *N. sloanii*), 1889-90 to 2007-08, and potential management approaches for southern fisheries. *New Zealand Fisheries Assessment Report* 2012/47, 303 pp.

Liaw A, Wiener M. (2002). Classification and regression by randomForest. *R News 2(3)*:18-22.

McAllister MK; Pikitch EK; Babcock EA (2001). Using demographic methods to construct Bayesian priors for the intrinsic rate of increase in the Schaefer model and implications for stock rebuilding. *Canadian Journal of Fisheries and Aquatic Sciences 58*:1871-1890.

McAllister MK; Babcock EA; Pikitch EK; Prager MH (2000). Application of a non-equilibrium generalized production model to South and North Atlantic swordfish: combining Bayesian and demographic methods for parameter estimation. *Collected Volume of Scientific Papers ICCAT 51*:1253-1550

McAllister MK (2013). A generalized Bayesian surplus production stock assessment software (BSP2). *ICCAT SCRS*/13/100.

McGregor, V.L. (2013). Investigation and development of post-season modelling of Arrow squid in the Snares and Auckland Islands. Master's Thesis, Victoria University of Wellington, New Zealand.

McGregor, V.L. & K. Large (2015) New Zealand research relevant to the assessment of stocks of squid. Paper for the Scientific Committee of the South Pacific Fisheries Management Organisation. SC-03-xx, 11 pp.

McGregor, V; Tingley, GA (2016). A preliminary evaluation of depletion modelling to assess New Zealand squid stocks. *New Zealand Fisheries Assessment Report 2016/25*. 28 p.

Ministry of Fisheries (2008a). *Harvest Strategy Standard for New Zealand Fisheries*. Wellington, New Zealand, ISBN 978-0-478-11914-3, 25 pp.

Ministry of Fisheries, (2008b). *New Zealand Bottom Fishing Activities by New Zealand Vessels Fishing in the High Seas in the SPRFMO Area during 2008 and 2009*. Ministry of Fisheries - Bottom Fishery Impact Assessment submitted to SPRFMO under the requirements of the SPRFMO Interim Measures for Bottom Fisheries, 102 pp.

Moilanen A (2007). Landscape zonation, benefit functions and target-based planning: unifying reserve selection strategies. *Biological Conservation 134*:571-579.

Moilanen A; Pouzols FM; Meller L; Veach V; Arponen A; Leppanen J; Kujala (2014). Zonation v.4 software: user manual. 288 p. Available at: http://cbig.it.helsinki.fi/files/zonation/zonation_manual_v4_0.pdf

MPI (2013). Ministry for Primary Industries. *Report from the Fisheries Assessment Plenary May 2013: stock assessments and yield estimates. Part 2: John Dory to Red Gurnard*. pp 453-925.

MPI (2014a). Ministry for Primary Industries. *Report from the Fisheries Assessment Plenary May 2014: stock assessments and yield estimates. Part 1: Introductory Sections to Jack Mackerel*. pp 1-464.

MPI (2014b). Ministry for Primary Industries. *Report from the Fisheries Assessment Plenary May 2014: stock assessments and yield estimates. Part 2: John Dory to Red Gurnard*. pp 465-950.

Parker, S.J., A.J. Penney & M.R. Clark, (2009). Detection criteria for managing trawl impacts on vulnerable marine ecosystems in high seas fisheries of the South Pacific Ocean. *Mar. Ecol. Prog. Ser.*, 397: 309 – 317.

Penney, A.J., S.J. Parker & J.H. Brown, (2009). Protection measures implemented by New Zealand for vulnerable marine ecosystems in the South Pacific Ocean. *Mar. Ecol. Prog. Ser.*, 397: 341 - 354.

Penney, A.J., (2010a). *An approach to estimation of sustainable catch limits for orange roughy in the SPRFMO Area*. Paper to the SPRFMO SWG, 11 pp. (SWG-09-DW-02).

Penney, A.J., (2010b). Use of geospatial data and predictive habitat models to evaluate the likelihood of presence of vulnerable marine ecosystems in the SPRFMO Area. Paper to the SPRFMO SWG, 12 pp. (SWG-09-DW-02).

Penney, A.J. (2014). Review of the biodiversity component of the New Zealand Vulnerable Marine Ecosystem Evidence Process. *New Zealand Aquatic Environment and Biodiversity Report No 135*. 40 pp. (SC-02-DW-01).

R Core Team (2016). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org

Roa-Ureta, R.H. (2012). Modelling in-season pulses of recruitment and hyperstability-hyperdepletion in the *Loligo gahi* fishery around the Falkland Islands with generalized depletion models. ICES Journal of Marine Science, 69: 1403-1415.

Roux MJ; Doonan IJ 2015 cpue

Roux MJ; Doonan IJ; Edwards CTT; Clark MR (2016). Low information stock assessment of orange roughy Hoplostethus atlanticus in the SPRFMO Convention Area. Draft New Zealand Fisheries Assessment Report provided for discussion at MPI SPACWG 8 August 2016.

Rowden A.A.; Clark M.R.; Lundquist C.J.; Guinotte J.M.; Anderson O.F.; Julian K.A.; Mackay K.A.; Tracey D.M.; Gerring P.K. (2015). Developing spatial management options for the protection of vulnerable marine ecosystems in the South Pacific Ocean region. *New Zealand Aquatic Environment and Biodiversity Report No. 155*. 76 p.

Rowden, A.A.; Guinotte, J.M.; Baird, S.J.; Tracey, D.M.; Mackay, K.A.; Wadhwa, S. (2013). Developing predictive models for the distribution of vulnerable marine ecosystems in the South Pacific Ocean region. New Zealand Aquatic Environment and Biodiversity Report No. 120. 70 p.

Tingley GA (2014a). An assessment of the potential for near-seabed midwater trawling to contact the seabed and to impact benthic habitat and Vulnerable Marine Ecosystems (VMEs). Paper SC-02-10 for the 2nd Meeting of the SPRFMO Scientific Committee, Honolulu, Hawaii, USA, 1-7 October 2014. 11 p.

Tingley GA (2014b). The estimation of initial biomass and catch limits for orange roughy in the SPRFMO Area. Paper SC-02-DW-03 for the 2nd Meeting of the SPRFMO Scientific Committee, Honolulu, Hawaii, USA, 1-7 October 2014. 13 p.

Tittensor, D.P., A.R. Baco, P.E. Brewin, M.R. Clark, M. Consalvey, J. Hall-Spencer, A.A. Rowden, T. Schlacher, K.I. Stocks & A.D. Rogers, (2009). Predicting global habitat suitability for stony corals on seamounts. *J. Biogeogr.,* 36: 1111–1128.

Tittensor, D.P., A.R. Baco, J.M. Hall-Spencer, J.C. Orr & A.D. Rogers, (2010). Seamounts as refugia from ocean acidification for cold-water stony corals. *Mar. Ecol*. 31, 212-225.

Wood S. (2006). Generalized additive models: an introduction with R. *CRC Press*. Boca Raton, USA. 385 p.

7 Appendix 1. List of Species Codes, Scientific Names and Common Names Used

FAO Code	NZ Code	Scientific Name	Common Name
ALF	BYX	*Beryx splendens, B. decadactylus*	Alfonsino & Long-finned beryx
BOE	BOE	*Allocyttus niger*	Black oreo
BWA	BNS	*Hyperoglyphe antarctica*	Bluenose
DGS	SPD	*Squalus spp.*	Spiny dogfish, northern spiny dogfish
EDR	SBO	*Pseudopentaceros richardsoni*	Southern boarfish
EPI	CDL	*Epigonus telescopus*	Deepsea cardinalfish
HAU	HPB	*Polyprion oxygeneios, P. americanus*	Wreckfish (Hapuku & Bass)
MOW	KTA	*Nemadactylus sp.*	King tarakihi
ONV	SOR	*Neocyttus rhomboidalis*	Spiky oreo
ORY	ORH	*Hoplostethus atlanticus*	Orange roughy
RIB	RIB	*Mora moro*	Ribaldo
ROK	SPE	*Helicolenus spp.*	Sea perch
RTX	RAT	*Macrouridae (Family)*	Rattails
RXX	SKI	*Rexea spp.*	Gemfish, southern kingfish
SCK	BSH	*Dalatias licha*	Seal shark
SEM	WAR	*Seriollela brama*	Common warehou
SEP	SWA	*Seriollela punctata*	Silver warehou
SNK	BAR	*Thyrsites atun*	Barracouta
SSO	SSO	*Pseudocyttus maculatus*	Smooth oreo
TOP	PTO	*Dissostichus eleginoides*	Patagonian toothfish
YTC	KIN	*Seriola lalandi*	Kingfish

8 Appendix 2. Areas open to New Zealand flagged vessels for bottom fishing

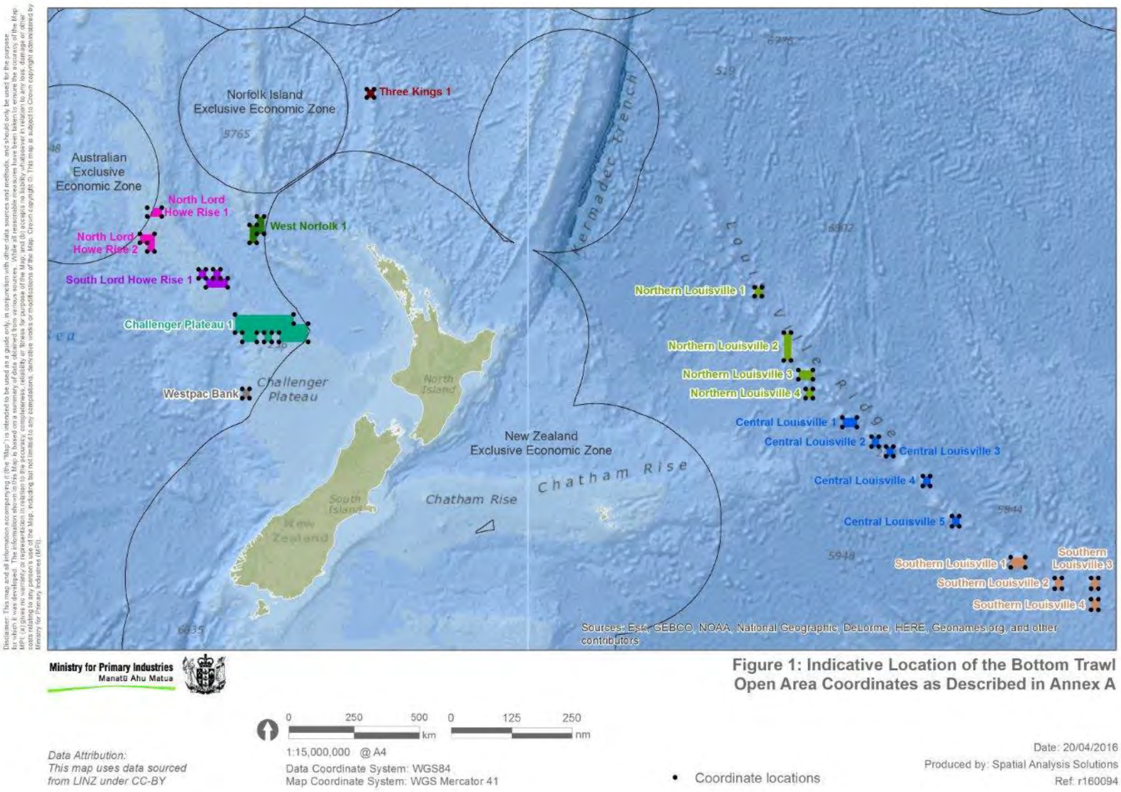


Figure 1: Indicative Location of the Bottom Trawl Open Area Coordinates as Described in Annex A

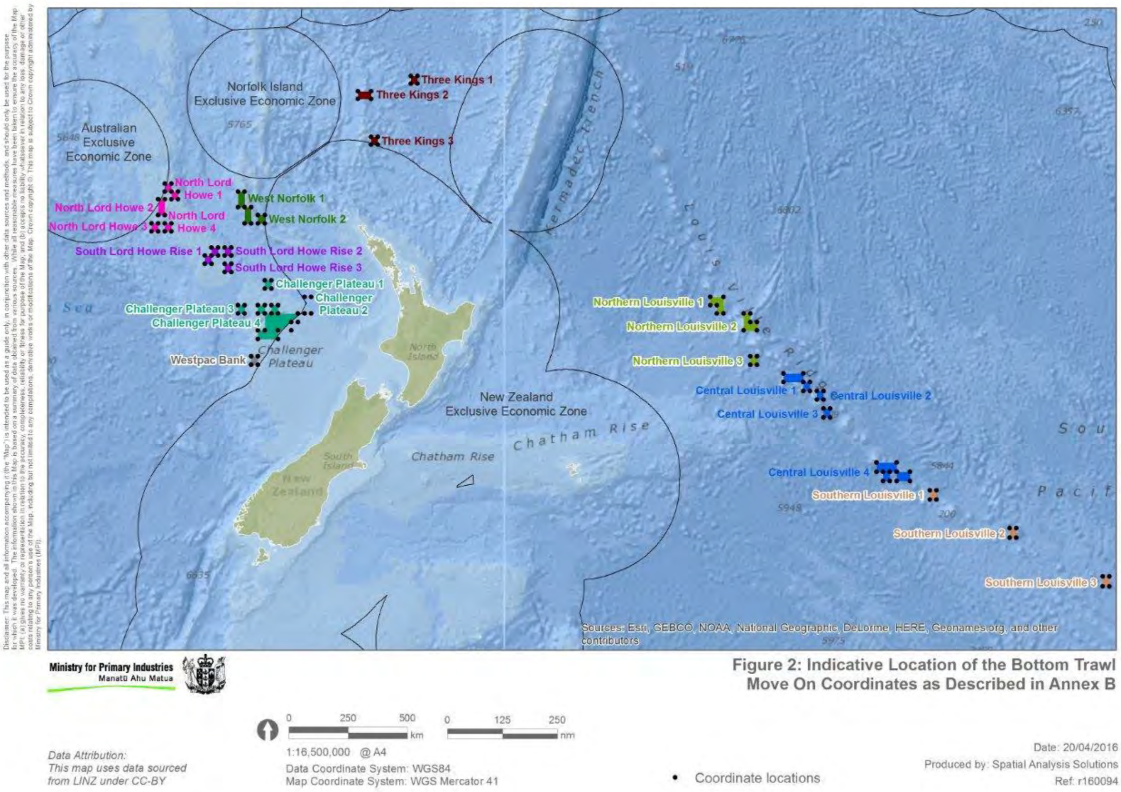
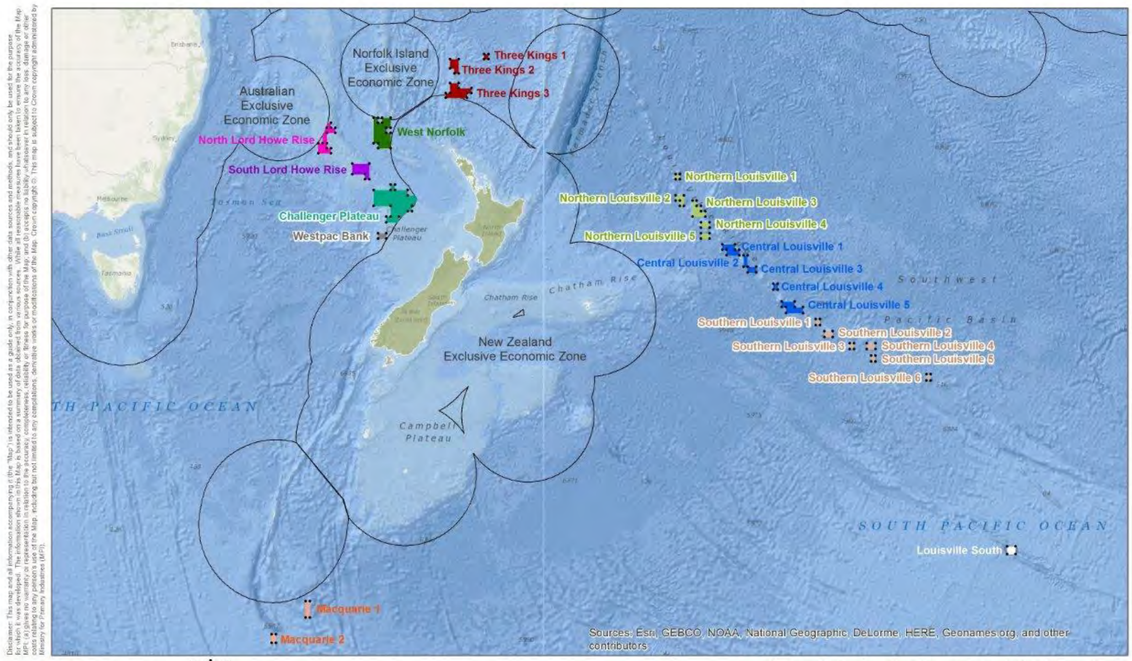


Figure 2: Indicative Location of the Bottom Trawl Move On Coordinates as Described in Annex B



Ministry for Primary Industries
Manatū Ahu Matua

Figure 3: Indicative Location of the Open Area Coordinates for Bottom Longline as Described in Annex C

0 400 800 km 0 200 400 nm
1:26,000,000 @ A4
Data Coordinate System: WGS84
Map Coordinate System: WGS Mercator 41

Data Attribution:
This map uses data sourced from LINZ under CC-BY

Date: 19/04/2016
Produced by: Spatial Analysis Solutions
Ref: r160094