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Smooth oreo abundance estimates from the November 2012 acoustic survey of the south Chatham Rise (OEO 4)

New Zealand Fisheries Assessment Report 2014/46

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An acoustic survey to determine the absolute abundance of smooth oreo (*Pseudocyttus maculatus*) in area OEO 4 was carried out between 8 and 26 November 2012 using *Tangaroa* (TAN1214) for acoustic work and *San Waitaki* (SWA1201) for trawling. The survey covered the southeast slope of the Chatham Rise and was the fifth full acoustic survey of the area. Previous acoustic surveys were carried out in 1998, 2001, 2005, and 2009. The 2012 survey covered the same area as the 2001, 2005, and 2009 surveys, which was slightly larger than the 1998 survey area. A stratified design using randomly allocated transects was used for flat ground strata and a random sample of hills was surveyed with either random or systematic 'star' transects. The flat survey included 95 transects (121 had been planned) and 81 tows over 10 flat area strata (6 strata in 1998, 10 strata in 2001, 2005 and 2009), and the hill survey included 37 transects (40 had been planned) and 17 tows over 11 hills (8 hills in 1998, 14 in 2001, 15 in 2005, 12 in 2009, and 12 planned in 2012).

The total estimated abundance of smooth oreo for OEO 4 was 88 600 t with a coefficient of variation (CV) of 42%. About 18% of the total estimate came from one school mark on the flat which was not fished. For the flat areas, the main sources of variability in the abundance estimates were the survey sampling error from backscatter (about 30% CV contribution), the variability of the target strength (TS) of smooth oreo (about 20% CV contribution), and the variability in the species proportions of catches (about 18% CV contribution). For the hills, the main source of variability was survey sampling error (52%), with much lesser contributions from other sources. A potential source of bias was that 39% of the smooth oreo flat abundance estimate was from the Layer and Background mark-types which contained mixed species. The acoustic methodology is well-suited to school mark-types made up of one or two main species, but is less suitable for mark-types such as layers which are composed of multiple species.

1. INTRODUCTION

The south and east Chatham Rise (OEO 4) is the main smooth oreo (*Pseudocyttus maculatus*) fishing area in the New Zealand EEZ (Figure 1), with average annual estimated catch from 2007–08 to 2009–10 of 6200 t (Anderson, 2011). There is also a substantial orange roughy fishery in the area with reported 2011–12 catches of 500 t ("South Rise", Ministry for Primary Industries 2013).

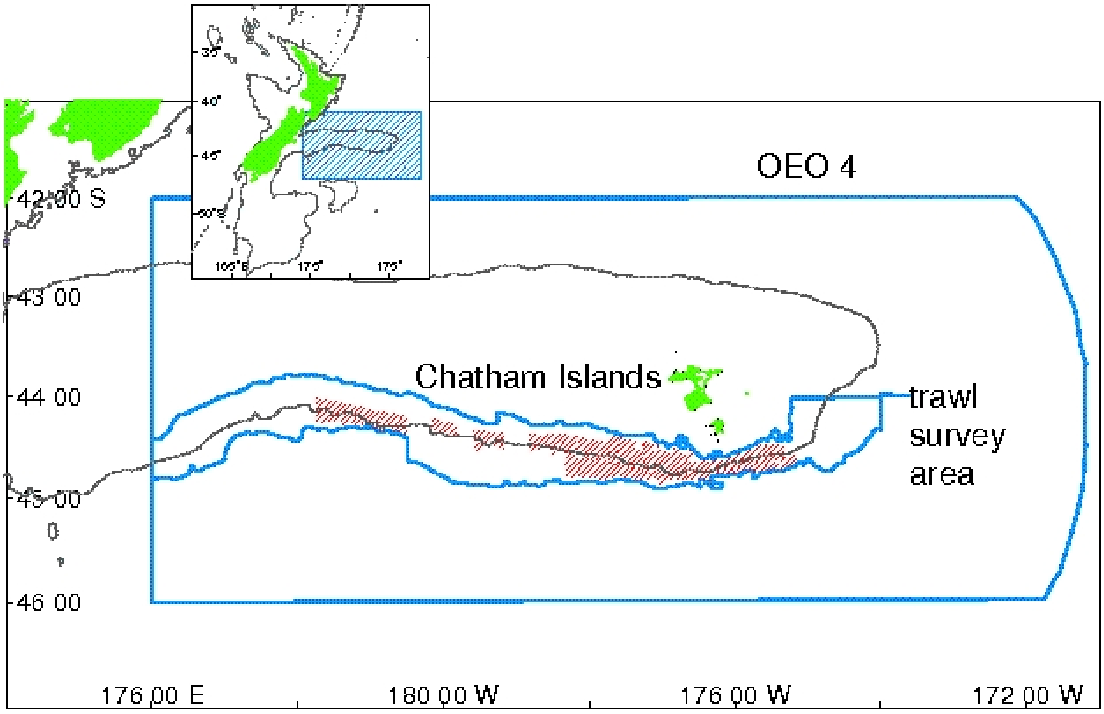

Figure 1: OEO 4 with boundaries of the previous trawl survey area and the 2012 acoustic survey area (shaded area).

Both smooth oreo and black oreo are widespread in OEO 4 between depths of about 600 and 1200 m and typically form aggregations or schools, particularly when spawning. These show on echosounder traces as 'pyramid' or 'ball' marks. Black oreo and smooth oreo also occur in low densities in background layers which may be very extensive. In the early years of the fishery (1986–95), trawl surveys were used to give fishery-independent estimates of abundance. However, the clumped nature of the oreo populations and the low probability of encountering a school led to very high variances and these, together with other problems, meant that the abundance estimates were very uncertain. Although the aggregated nature of oreo distributions is a problem for trawl surveys, it is much better suited to acoustic techniques, particularly since the aggregations are largely monospecific. Some initial investigations of acoustic methods were carried out during the trawl survey in 1995 (Hart & McMillan 1998) and a move to acoustic surveys was made in 1997 (Doonan et al. 1998, 2000). Acoustic surveys covering some or all of OEO 4 were carried out in 1997 (Doonan et al. 1998), 1998 (Doonan et al. 2000), 2001 (Doonan et al. 2003d), 2005 (Doonan et al. 2008b), 2009 (Doonan et al. 2011) and 2012. The last survey is the subject of this report.

The work described in this report was carried out for the Ministry for Primary Industries research project OEO2010/03, titled "Estimation of the abundance of smooth oreo in OEO 4 using acoustic surveys". The overall objective for this project was: To estimate the abundance of smooth oreo (*Pseudocyttus maculatus*) in OEO 4 on the Chatham Rise using acoustic survey. The specific objectives were:

1. To estimate the abundance of smooth oreo (*Pseudocyttus maculatus*) in OEO 4 on the Chatham Rise using acoustic surveys
2. To calibrate acoustic equipment used in the acoustic survey.

2. METHODS

The 2012 survey took place from 8 to 26 November 2012 and used *Tangaroa* for the acoustic work and the Sanford Ltd vessel *San Waitaki* for mark identification trawling. The approach to both survey design and analysis was similar to that for the 1998, 2001, 2005, and 2009 surveys. The survey measured acoustic backscatter together with information on the size and age structure of smooth oreo and the mix of species present in acoustic marks obtained by trawling. A stratified random approach was used (Jolly & Hampton 1990) and the strata were those used in the trawl surveys modified in the light of the 1998 survey results and recent commercial catch data.

2.1 Acoustic principles

The conventional approach of echo-integration was used to estimate areal backscatter of acoustic energy by fish (Burczynski 1982, Do & Coombs 1989, Doonan et al. 2000) which was then apportioned using a mark classification scheme based on extensive matched tow and acoustic data, primarily from the 1998 survey (Doonan & McMillan 2000, Doonan et al. 2000, Barr et al. 2002). Areal backscatter apportioned to different species was converted to numbers of that species by dividing by its target strength and to abundance by multiplying by its average weight. The detailed mathematical analysis used to estimate abundance from the survey results is the same as that used by Doonan et al. (1999).

There are a number of physical factors that affect the accuracy of the estimates of backscatter and the most important for oreo surveys are shadowing, towed body motion, and absorption of sound by seawater (Doonan et al. 2000). Shadowing is a problem when the fish are on the sides of hills or on sloping seafloors. The acoustic transducer projects a conical beam down through the water column with the wave-front forming part of the surface of a sphere. If the axis of the beam is perpendicular to a flat sea bottom, then the sea bottom reflection from the central part of the beam swamps the reflections from fish close to the bottom in the outer parts of the beam. There is thus a volume close to the sea bottom which is not visible to the acoustic gear, called the ‘shadow zone’. The size of the shadow zone depends on the distance of the transducer from the bottom and particularly on the steepness of the nominal bottom. With the transducers used in this survey, on a flat seafloor it is typically about 1 m, but on steep hillsides it can be over 30 m. We estimated the thickness of the shadow zone using the method of Barr (in Doonan et al. 1999) and assumed that the smooth oreo density in the shadow zone was the same as that in the 10 m immediately above. Corrections were calculated for groups of 10 pings and reported as the mean of these for a stratum and snapshot. The final abundance estimate included shadow zone correction.

Transducer motion during a transmit results in the transducer pointing in different directions when transmitting and receiving. Corrections for the decrease in acoustic signal strength due to this motion were made using the method of Dunford (2005). Transducer movement data were collected synchronously with the acoustic data at 50 ms intervals. These data were interpolated to match the acoustic data which were then corrected on a sample-by-sample basis. The corrections required are a function of the difference in pointing angle between transmission and reception and are therefore greatest at longer ranges and when transducer motion is most pronounced. Backscatter was calculated both with and without motion correction for each stratum and snapshot. The final abundance estimate included motion correction.

The absorption of sound by seawater is not well known at 38 kHz (Do & Coombs 1989, Doonan et al. 1999) and this uncertainty is a significant factor where long ranges are involved (e.g., flat background strata). The absorption coefficient was estimated from temperature and salinity data using the relationship derived by Doonan et al. (2003b) and this was used to correct the data from the nominal absorption coefficient (8 dB km^{-1}) applied by the receiver.

2.2 Acoustic system

Acoustic data were collected with two split-beam towed CREST systems (Towbody 3 and Towbody 4 (Coombs et al. 2003) and the *Tangaroa* multi-frequency Simrad EK60 hull system. Towbody 4 was used for the bulk of data-collection along with the hull system and Towbody 3 was used occasionally over flat strata. For the hull system, only the 38 kHz hull data were used in abundance estimation. The towed CREST systems were operated at depths of approximately 100–300 m on flat ground and 200–500 m over the hills and used a similar configuration to that described in Doonan et al. (2008b).

A deep calibration of Towbody 4 was carried out during the survey on 23 November 2012 off Kaikoura and Towbody 3 and the hull echosounders were calibrated during the previous West Coast South Island survey (TAN1210). The calibrations followed the approach described by Foote et al. (1987). A 38.1 mm ± 2.5 µm diameter tungsten carbide sphere with nominal target strength of -42.4 dB was used as a calibration standard. Calibration data are summarised in Table 1. As Towbody 4 was used for both flat and hill transects the depth hysteresis of the transducer required two calibration values, depending on the operating depth of the towbody.

Table 1: Calibration data for the 38 kHz systems used for the 2012 abundance survey. V_T is the in-circuit voltage at the transducer terminals for a target of unit backscattering cross-section at unit range. *G* is the voltage gain of the receiver at a range of 1 m with the system configured for echo-integration. –, no data.

System	Hull	Towbody 3	Towbody 4	
Usage	Flat	Flat	Flat	Hills
Frequency (kHz)	38	38.156	38.156	38.156
Transducer model	ES38B	ES38DD	ES38DD	ES38DD
Transducer serial no.	23083	28332B	28337	28337
Nominal 3dB beam-width (°)	7.0 x 7.0	7.3 x 7.4	6.6 x 6.7	6.6 x 6.7
Effective beam angle (sr)	–	0.0093	0.0081	0.0081
Two way beam angle (dB)	-20.6	–	–	–
Effective pulse length (ms)	–	0.78	0.78	0.78
V_T (V)	–	1050	1150	1214
Nominal Transducer depth (m)	N/A	N/A	175	380
G	–	12 866	15 208	15 208
G_0	25.62	–	–	–
Sa Correction	-0.61	–	–	–

2.3 Trawl gear

San Waitaki used a two-panel Champion 74.4 m net with rockhopper groundrope for most of the tows. This had a total footrope of 69.3 m, and the net was fished with 45 m sweeps and 45 m bridles and used a 60 mm mesh codend. For tows on the flat with this net, doorspread distance was 125–151 m (mean 137 m) measured on 46 of the 52 tows, and headline height was 4.5–7 m (mean 5.5 m) measured on 52 tows. Tows on layer marks were made with the NIWA 6 panel wing net (ratcatcher) which has a groundrope of 49.8 m and used the same 45 m sweeps and bridles but had a 40 mm mesh codend. Doorspread distance was 125–150 m (mean 141 m) measured on 28 of the 30 tows with this net, and headline height was 3–4.5 m (mean 3.6 m) measured on 30 tows.

2.4 Survey design

The survey area was a subset of the earlier trawl survey area (McMillan & Hart, 1994a, 1994b, 1994c, 1995, 1998) which in turn covered only part of the overall OEO 4 area (see Figure 1). The area included both flat and undulating ground ('flat') and hills. The survey area was chosen to yield a target coefficient of variation (CV) of 30% or less while minimising the time taken to complete the work. The 2012 survey area was the same as that used in 2001, 2005, and 2009. After the re-design for the 2001 survey, analysis showed that increases in sampling would bring only minor improvements and that more data on target strength were needed to make further gains in precision (Doonan et al. 2003c). The 2012 survey had a similar level of sampling to that used in 2005 and 2009. The survey effort on hills in 2012 was similar to the effort in 2009. Total hill abundance was not a large proportion of the total abundance in previous surveys so the hills are over-sampled in a strictly statistical sense. The flat area and hills surveyed are shown in Figure 2.

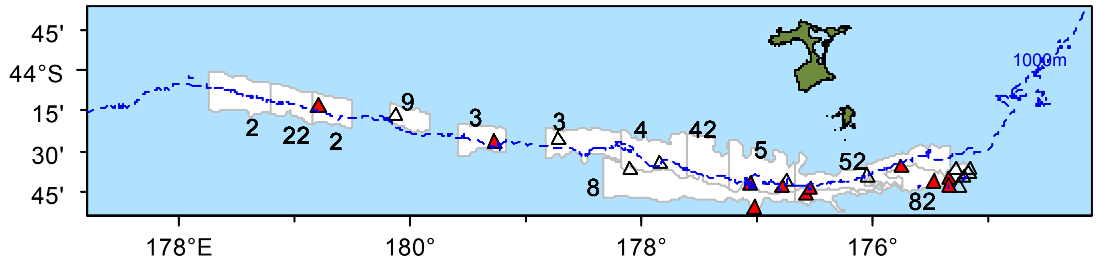

Figure 2: Flat strata and hills surveyed (filled triangles) in 2012. Hills not surveyed are the open triangles. Bold numbers are the stratum codes. Strata 2 and 3 have two separate parts.

2.4.1 Flat area

A conventional stratified random approach was used (Jolly & Hampton 1990) and strata were chosen to cover the main smooth oreo fishing areas and abundance observed from previous research surveys. In each stratum, a number of randomly positioned north-south acoustic transects were generated. Where appropriate, the same transect line covered both strata where these overlapped longitudinally, i.e., stratum 8 with strata 4, 42, and 5; and stratum 82 with stratum 52 (Figure 2). Ten flat strata were surveyed (Table 2). The strata and stratum numbers were the same as those used in the 2001, 2005, and 2009 surveys.

We assumed that:

- Most of the fish were in schools and randomly chosen schools in each stratum were sampled by trawling to obtain species composition and length-frequencies of smooth oreo, black oreo, and other species.
- There was no movement in or out of the acoustic survey area during the time of sampling and therefore we treated all the information for the area and time of sampling as being synoptic or instantaneous.
- The proportion of smooth oreo in and out of the acoustic survey area was relatively constant since 1992 and that this proportion was measured by the trawl surveys carried out in OEO 4 in 1992, 1993, and 1995. This assumption is required for scaling up the acoustic abundance to the larger trawl survey area.

The survey was designed to achieve a CV of 25% for the estimate of total abundance. Three sources of variation were considered when allocating the numbers of acoustic transects and tows in each stratum:

- Sampling error in the acoustic data.
- Sampling error in the proportions of both oreo species in the species mix.

- Experimental error in the determination of the target strength of both oreos.

Table 2: Flat area strata: area, depth range, longitude range, and the relative importance of each stratum as indicated by its percentage contribution to the total abundance of smooth oreo from the 2001, 2005, and 2009 acoustic surveys.

	Stratum	Area (km^2)	Depth (m)	Longitude range	Importance in survey (%)		
East					2001	2005	2009
	4	1 050	800–1 200	178° 10′W–177° 35′W	12	4	8
	42	760	800–1 200	177° 35′W–177° 15′W	11	6	2
	5	1 188	800–1 200	177° 15′W–176° 40′W	9	9	21
	52	1 487	800–1 200	176° 40′W–175° 20′W	33	41	28
	8	1 885	1 200–1 400	178° 20′W–176° 40′W	9	11	6
	82	1 046	1 200–1 400	176° 40′W–175° 10′W	15	12	10
West							
	2	1 594	850–1 150	178° 15′E–178° 50′E	3	2	5
				179° 10′E–179° 30′E			
	22	558	850–1 150	178° 50′E–179° 10′E	0	3	4
	9	367	800–1 000	179° 50′E–179° 50′W	1	2	14
	3	1 543	850–1 150	179° 35′W–179° 10′W	7	10	1
				178° 50′W–178° 10′W			

2.4.2 Hills

Each hill was defined as a stratum. Each hill was surveyed with randomly allocated parallel transects or systematically allocated transects in a ‘star’ pattern (Doonan et al. 2003a). The initial set of hills to be surveyed was chosen from the set of known south Chatham Rise hill complexes and individual hills (agreed at a meeting between the then Ministry of Fisheries, NIWA, and the then Orange Roughy Management Company held on 23 September 1997), as modified by the results of the 1998 survey, catch data, and by recommendations from fishing skippers. It was desirable to select randomly from homogeneous subsets of hills (i.e., hills with similar catch histories and similar sizes) and they were grouped into three categories, A, B, and C, based on rankings using the following criteria.

1. Catch history, i.e., hills which had produced large catches of smooth oreo in the 6 years before 1998 were ranked high priority. The ranking was based on analyses of then Ministry of Fisheries (now Ministry for Primary Industries, MPI) smooth oreo catch and effort data carried out by NIWA.
2. Relative size and potential as oreo habitat.

In 2005, analysis of catch data from 1998–99 to 2003–04 suggested that the survey should be extended to include the Andes complex of hills near 44º 10’ S 174º 30’ W. However, the 2005 survey estimated only about 55 t of smooth oreo (Doonan et al. 2008b) from the Andes, i.e., about 0.05% of the total abundance. In 2009, the Andes were removed from the hill list which saved about 1 day (the rest of the OEO 4 survey takes about 14 days), and the Andes was not considered in 2012.

Eleven hills were sampled including all category A hills (6), 2 in category B, and 3 in category C. The hills for categories B and C were selected at random from those listed below. Hegerville and Nielson’s are large hills so these were surveyed with five parallel transects.

A Most important hills (catches greater than 300 t total in the last two three-year periods). All hills were surveyed (bold). † added in 2005.

Chucky's	**44° 51.4′**	**177° 01.6′ W**
Trev's Pinni	**44° 27.0′**	**179° 16.3′ W**
Hegerville	**44° 42.6′**	**177° 03.5′ W**
Dolly Parton	**44° 46.4′**	**176° 34.6′ W**
Paranoia	**44° 44.3′**	**176° 32.4′ W**
†Nielson's	**44° 43.5′**	**176° 47.0′ W**

B Important hill complex. The Big Chief complex, defined as a box bounded by 44° 35.0′ to 44° 45.0′ S and 175° 25′ to 175° 05′ W. Selected hills are in bold. ‡ Flintstone was selected but was not surveyed.

Big Chief	44° 39.72′	175° 12.90′ W
Tomahawk	44° 38.70′	175° 10.62′ W
Hiawatha	44° 43.32′	175° 15.30′ W
Charlie Horsecock	**44° 40.68′**	**175° 20.52′ W**
‡Flintstone	**44° 37.20′**	**175° 16.98′ W**
Cooks	**44° 43.20′**	**175° 20.40′ W**
Teepee	44° 36.90′	175° 09.78′ W

C Other fishing hills. Selected hills are in bold.

Mt Kiso	44° 25.9′	178° 43.2′ W
Fletcher's Pin	**44° 13.7′**	**179° 12.3′ E**
Mt Nelson	44° 16.9′	179° 52.3′ E
Dory Pimple	44° 36.8′	178° 06.1′ W
Amaltal Pimple	44° 34.8′	177° 50.4′ W
Der Spriggs	44° 41.6′	176° 45.0′ W
Triple catch	North of Dolly Parton (tops: 700, 714, 800m)	
Featherlite	44° 39.7′	176° 03.1′ W
Condom's	**44° 36.4′**	**175° 45.3′ W**
Mangrove	**44° 41.8′**	**175° 28.3′ W**

2.5 Estimating absolute abundance

The overall procedure for estimating abundance was the same as in previous oreo surveys (Doonan et al. 1998b, 2000, 2003c). In previous analyses, the total abundance of the stock with a west/east split (at 178° 20′ W) was estimated as the early stock assessment split the stock area in OEO 4 into a west and an east fishery (Doonan et al. 2008a, 2003a, 2001). The 2012 assessment was simplified into a one area model therefore only total abundance was required (Fu & Doonan, 2013).

Abundance was estimated separately for the flat area and hills. For the former, the acoustic data were classified into mark-types where marks equate approximately to echogram images. The mark classification scheme was an updated version of that used for the 1998 survey (Doonan & McMillan 2000, Doonan et al. 2000, Barr et al. 2002). The abundance of smooth oreo in each mark-type was estimated from the backscatter for each mark, the proportion of smooth oreo in that type (estimated by trawling), the mean acoustic cross-section (target strength) for the mix of species in that mark-type, and the mean weight of the smooth oreo in that mark-type. These were then summed over each stratum, scaled up by the stratum area, and the results summed over all strata (Doonan et al. 2000).

The abundance on each hill was estimated using the method of Doonan et al. (2003a). The mean abundance was calculated for each hill class, multiplied by the total number of hills in that class, and summed over all classes to give total abundance for all hills in the trawl survey area.

The smooth oreo abundance for the whole of OEO 4 was estimated by scaling up the total flat abundance to the trawl survey area, adding the total hill abundance and scaling the sum up to the whole OEO 4 area. The overall analysis scheme is shown diagrammatically in Figure 3 and the following sections expand on aspects of the overall analyses that are specific to this survey.

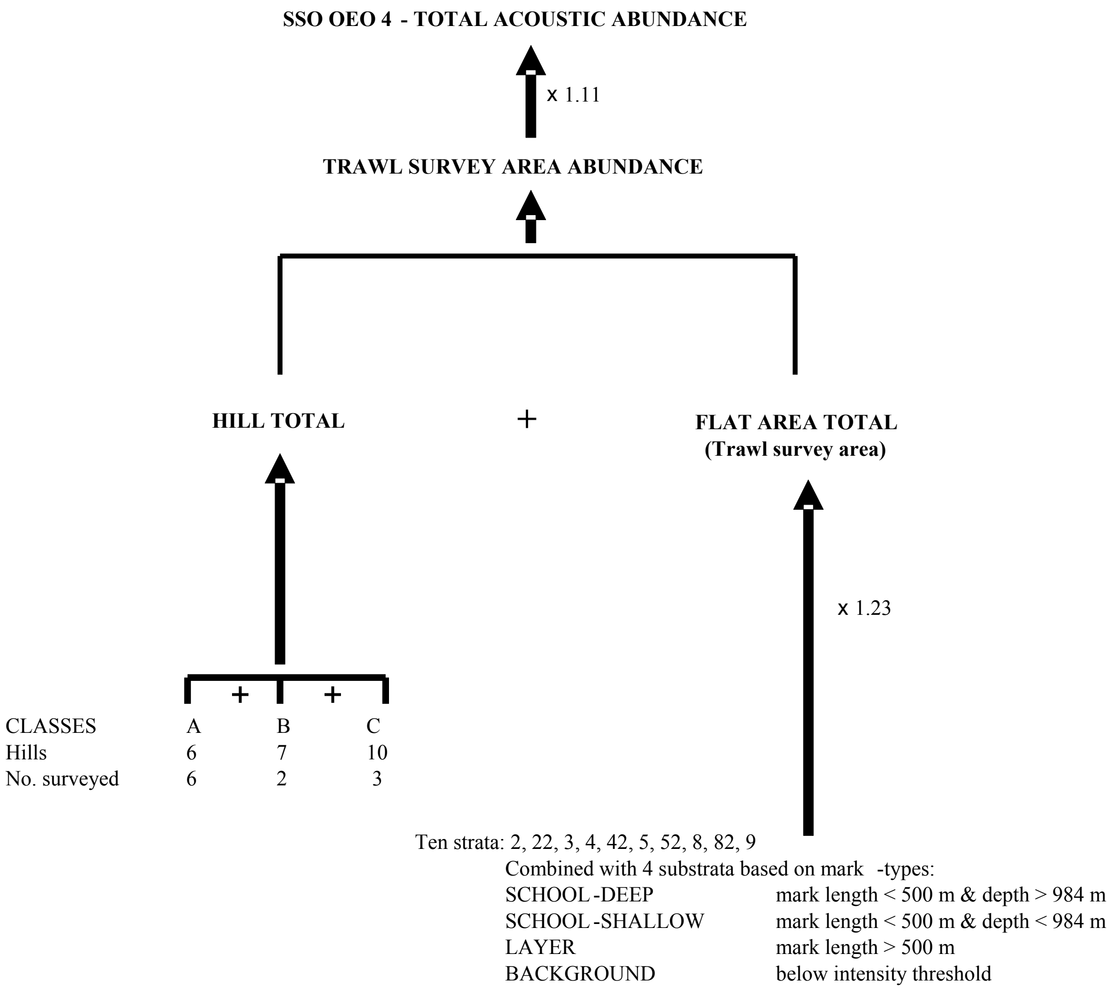

Figure 3: Schematic plan of calculations applied to the smooth oreo (SSO) survey acoustic abundance estimates to derive a total abundance estimate for OEO 4. See Section 2.4 for an explanation of the survey design for hills and 2.5.2 for an explanation of mark-types.

2.5.1 Abundance scaling factors

Two abundance scaling factors were used, first to multiply the flat acoustic survey area up to the trawl survey area and second to multiply the trawl survey area up to the overall OEO 4 area (Figure 3). The first factor was calculated using data from three trawl surveys (TAN9210, TAN9309, and TAN9511) to estimate the proportion of smooth oreo in the acoustic survey area compared to the trawl survey area (McMillan & Hart 1994c, 1995, 1998). That factor is the inverse proportion. A mean smooth oreo density was estimated for each trawl stratum and this was then applied to the subareas in the stratum that were inside the acoustic survey area. The fraction of smooth oreo abundance in the acoustic area was the sum over strata of the mean stratum density times the area within the ground surveyed by acoustics divided by the abundance in the trawl survey area. For the total acoustic area, the factor was 1.23 (6% CV). Since estimates were not required for the west and east parts, we no longer need to define the factor for the west and east separately (2.16 for the west, and 1.16 for the east were estimated in previous surveys).

The second factor was estimated from the ratio of catches in the total OEO 4 area to those in the trawl survey area. The ratio used was 1.11 (85 300/76 800) with a CV of 2%, calculated from data for the fishing years 1986–87 to 2000–01. There is a temporal trend in the ratio with the value increasing from 1.03 in the late 1980s to 1.25 in 1999–2000 and 2000–01. The 1.11 value was used in the 2001, 2005, and survey calculations.

2.5.2 Mark-types

The acoustic data were classified into different kinds of marks for the analysis. The same four types that were identified in the 1998 survey were used (Background, Layer, School-shallow, and School-deep) but the classification criteria were modified slightly in 2001 using the data collected during the 2001 survey (Doonan & McMillan 2000, Doonan et al. 2000, Barr et al. 2002). The mark-types and the planned number of tows on each mark-type for the 2012 survey are in Table 3.

Table 3: 2012 survey. Planned minimum numbers of tows for each flat mark-type by stratum. Mark length was defined using a threshold of -73 dB, but only if the mark was present at a threshold of -76 dB. 500 m is equivalent to 0.270 of a nautical mile. –, outside depth range so not applicable. Background – no mark, Layer - mark length > 500 m, School-shallow - mark length < 500 m and depth < 984 m, School-deep - mark length < 500 m and depth > 984 m.

Flat	Sub-stratum				
Stratum	Mark length < 500 m		Mark length > 500 m	No mark	
	Depth > 984 m	Depth < 984 m			
2	1	1	1	0	
22	1	1	1	1	
9	–	1	1	0	
3	3	3	2	1	
4	2	2	2	0	
42	2	3	2	0	
5	2	2	5	1	
52	3	3	12	0	
8	4	–	1	0	
82	4	–	1	1	
Totals	22	16	28	4	70

Species composition was derived from trawl catches from targeted tows on each mark-type. Tows were carried out on each mark-type within each flat stratum, where they were observed, except for the Background mark-type. We aimed to get at least 5 tows per mark-type per stratum to enable species composition to be estimated using catch data from that stratum only. However, this was not practical due to time constraints and the difficulty of finding certain mark-types in particular strata. For bootstrapping purposes and to avoid reliance on 1 or 2 tows in a stratum, trawl data was supplemented by trawls in the same mark-type in adjacent strata. Data from Background tows were applied to all strata.

2.5.3 Target strength

The target strength relationships for black oreo and smooth oreo used in these analyses were derived from a Monte-Carlo analysis of in situ and swimbladder data (Macaulay et al. 2001), Coombs & Barr 2004) and were:

$$TS_{SSO} = -82.16 + 24.63\log_{10}(L) + 1.0275\sin(0.1165L - 1.765)$$

and

$TS_{\text{BOE}} = -78.05 + 25.3\log_{10}(L) + 1.62\sin(0.0815L + 0.238)$

for smooth oreo and black oreo respectively and where *TS* is the target strength and *L* the fish total length. Estimates for orange roughy and hoki were those used by Doonan et al. (2003d), and for other common species we used relationships based on swimbladder modelling (Macaulay et al. 2001), Table 4. A generic relationship was used for species for which no specific relationship was available as detailed by Doonan et al. (1999).

Table 4: Fish length-target strength relationships used where relationships are of the form $TS = a + b\log_{10}(L)$. The orange roughy estimates are derived from Macaulay et al. (2013), intercept, and the slope from McClatchie,et al. (1999).

Species	Code	Intercept (*a*)	Slope (*b*)
Basketwork eel (*Diastobranchus capensis*)	BEE	-76.7	23.3
Black javelinfish (*Mesobius antipodum*)	BJA	-70.6	17.8
Four-rayed rattail (*Coryphaenoides subserrulatus*)	CSU	-92.5	31.8
Hoki (*Macruronus novaezelandiae*)	HOK	-74.0	18.0
Javelinfish (*Lepidorhyncus denticulatus*)	JAV	-73.5	20.0
Johnson's cod (*Halargyreus johnsonii*)	HJO	-74.0	24.7
Notable rattail (*Coelorinchus innotabilis*)	CIN	-107.8	44.9
Orange roughy (*Hoplostethus atlanticus*)	ORH	-76.71	16.15
Ribaldo (*Mora moro*)	RIB	-66.7	21.7
Ridge scaled rattail (*Macrourus carinatus*)	MCA	-95.5	35.6
Robust cardinalfish (*Epigonus robustus*)	EPR	-70.0	23.2
Serrulate rattail (*Coryphaenoides serrulatus*)	CSE	-135	59.7
White rattail (*Trachyrincus aphyodes*)	WHX	-62.1	18.1
Cod-like		-67.5	20.0
Deepwater swimbladdered		-79.4	20.0
No swimbladder		-77.0	20.0

2.6 Estimating variance and bias

The method of estimating variance and bias was the same as in previous oreo surveys (Doonan et al. 1998, 2000). Variance was estimated separately for the flat and for hills and then combined. Sources of variance were:

- Sampling error in the mean backscatter.
- The proportion of smooth oreo and black oreo in the acoustic survey area.
- Sampling error in catches which affects the estimate of the proportion of smooth oreo.
- Error in the target strengths of other species in the mix.
- Variance in the estimate of smooth oreo target strength.
- Sampling error of fish lengths (negligible).
- Variance of the mean weight, $\overline{w}$, for smooth oreo.

2.6.1 Flat area

The total CV of the abundance estimate was calculated in two parts: one for the abundance in the survey area, and a second resulting from scaling up the abundance in the acoustic survey area to that of the larger trawl survey area. Total CV was given by:

$$\sqrt{(cv_p^2 + 1)(cv_A^2 + 1)}$$

where cv_A is the CV of the abundance in the acoustic survey area, and cv_p is the CV of the factor to account for the proportion of abundance outside the acoustic survey area. To estimate cv_A, the following sources of variation were combined using simple bootstrapping.

- For acoustic sampling, acoustic transects were re-sampled from those within a stratum.
- For catch sampling, the tows were re-sampled from those within the same mark-types.
- For target strength of oreos (TS_{SSO} and TS_{BOE}), the intercept of the target strength-length relationship was randomly shifted using a normal distribution with a zero mean and a standard deviation of 1.0 dB.
- For species with a target strength determined by swimbladder modelling, the a value in the relationship $TS = a + b \log_{10}(L)$ had a random value added to it from a normal distribution that had a zero mean and a standard deviation of 3 dB.
- For target strength of other species, bootstrapping was carried out in two independent parts: one for cod-like species and another for deepwater species. The target strength for each species was re-sampled as described by Doonan et al. (2000) and involved random shifts in the intercepts of the target strength-length relationships (the slope was constant at 20.)

To estimate cv_p for the proportion of oreos in the acoustic survey area, the sample variances from the three estimates using each of three *Tangaroa* trawl surveys (1992, 1993, and 1995) were used.

2.6.2 Hills

The equivalent abundance CV (cv_A) was calculated for each hill. However, there was also a between-hill variance contribution, σ_B^2, because for each of the three hill categories only a subsample of the hills was surveyed (i.e., each hill had a different true abundance and we sampled only some of them).

The model used to estimate the mean abundance of the *j*-th hill in the *i*-th hill category ($b_{i,j}$) is given by:

$$b_{i,j} = \mu_i + \gamma_{i,j} + \varepsilon_{i,j}$$

where μ is the mean for the category, γ accounts for deviations of a hill from the category mean and so has zero mean and standard deviation $\sigma_{B,i}$, and ε accounts for measurement error on a specific hill. The abundance for the *i*-th category is $N_i\bar{b}_{i.}$ where N is the total number of hills in the category and so the variance is:

$$\begin{aligned} & N_i^2 \mathrm{Var}\left(\bar{b}_{i.}\right) \\ & = N_i^2 \left\{ \mathrm{Var}\left(\bar{\gamma}_{i.}\right) + \mathrm{Var}\left(\bar{\varepsilon}_{i.}\right) \right\} \\ & = N_i^2 \left\{ (1-f)\frac{\sigma_{B,i}^{2}}{n_i} + \frac{\overline{\sigma_{W,i}^2}}{n_i} \right\} \end{aligned}$$

where n was the number sampled, *f* is the sample fraction ((n-1)/(N-1)) of hills and $\overline{\sigma_{W,i}^2}$ is the mean variance of sampling error of the surveys on the hills. $\overline{\sigma_{W,i}^2}$ can be estimated and $\sigma_{B,i}^{2}$ can be found from the sample variance of the estimated hill abundances which is equal to $\sigma_{B,i}^{2} + \overline{\sigma_{W,i}^2}$. For the total hill abundance, the variance was the sum of the variances of the three hill categories.

2.6.3 Bias

Potential sources of bias were:

- Classification of marks.
- Differences in relative catchability of other species compared to oreos.
- The species composition and species distribution in the background layer.
- The proportion of oreos in the shadowed zone.
- The validity of the target strength-length relationship used for estimating the target strength of associated species.
- Signal loss from transducer motion.
- Signal loss from bubbles (for the hull transducer).
- Estimation of the absorption rate of sound in water.
- A change in the distribution of oreos on flat ground between the acoustic survey area and the rest of the area between 1998 and the time the distribution was measured in the trawl surveys (1992, 1993, and 1995).
- Fish movements, including oreos moving to the background population from schools on both hills and flat.
- Estimating target strengths from swimbladder casts.

3. RESULTS

3.1 Flat

The numbers of tows and acoustic transects carried out are shown in Table 5. Table 6 shows the number of tows by mark-type and strata, and how tows were supplemented with data from adjacent strata with the same mark-type so that all mark-type/stratum combination had adequate catch data. Supplementation was carried out to get adequate numbers of tows for bootstrapping, i.e., we aimed for five tows, if possible. Six tows on the flat were not used in the flat strata, because five missed the target mark. The sixth was an attempted Background tow which caught more than half a tonne of smooth oreo and so was not included in that (or any other) mark-type. No mark was observed in the echogram, but it was very poor weather and the echogram was also poor.

Table 5: Numbers of transects and tows for each stratum. A further four tows were made on the Background mark-type.

		Number of tows	
Stratum	Number of transects	non- Background	Background
2	6	6	3
22	2	4	3
3	11	11	3
9	7	6	
4	4	5	2
42	12	9	
5	13	7	3
52	12	4	3
8	9	6	3
82	5	2	

Table 6: Number of tows from flat strata by mark-type, and the numbers when stratum-mark-type combinations were supplemented with 2012 tows from adjacent strata.

	On the 2012 survey			Supplemented					
	Number of tows			Total number of tows used			Source of supplemented tows		
Stratum	School-deep	School-shallow	Layer	School-deep	School-shallow	Layer	School-deep	School-shallow	Layer
2	1	3	2	7	3	2	3, 22, 42		
22	2	2	0	6	5	2	2, 3	2	2
3	3	5	3	6	5	3	2, 22		3
9	0	2	0	2	8	3	4	3, 4	
4	2	1	3	3	3	5	42	42	42
42	1	2	2	7	3	5	4, 5	4	4
5	4	0	5	4	3	5		4, 42	
52	2	0	5	6	3	5	5	4, 42	
8	1	0§	3	5	0	3	5		
82	5	0§	1	5	0	6			52

§ Stratum too deep for this mark type.

3.2 Hills

The number of transects and tows carried out on each hill is shown in Table 7.

Table 7: The number of transects and tows for each hill.

Hill	Number of transects	Number of tows
Chucky's	3	1
Trev's Pinni	3	1
Hegerville	4	2
Dolly Parton	3	2
Paranoia	3	1
Nielson's	5	2
Charlie Horsecock	3	2
Cooks	3	1
Fletcher's Pin	3	1
Condom's	3	1
Mangrove	3	2

3.3 Abundance estimates and variances

3.3.1 Flat

The abundance estimate for the flat acoustic survey area was 56 600 t with a CV of 47%. A breakdown of the percentage of the abundance by stratum is shown in Table 8 which showed that most was from the east strata with stratum 52 accounting for 44% of total abundance. The School-deep and School-shallow mark-types accounted for 61%, Background 25%, and Layer 14% of the total abundance on the flat.

Table 8: Flat abundance: percentage by flat stratum.

	Western strata				Eastern strata					
Stratum	2	22	3	9	4	42	5	52	8	82
Abundance (t)	1 888	283	1 505	441	5 251	5 682	5 237	24 177	7 953	4 209
Relative abundance (%)	3	1	3	1	9	10	9	44	14	8

One large acoustic mark observed in stratum 52 on transect 8 (Figure 4) was assumed to be smooth oreo and contributed about 16 000 t (67 %) of the abundance from stratum 52 and about 25% of the total survey abundance estimate. This mark was identified (as #124) by *Tangaroa* survey staff during the acoustic survey and a hull echogram was sent to *San Waitaki* survey staff to investigate but no substantive mark was observed by the catcher vessel along transect 8 at the target depth and position.

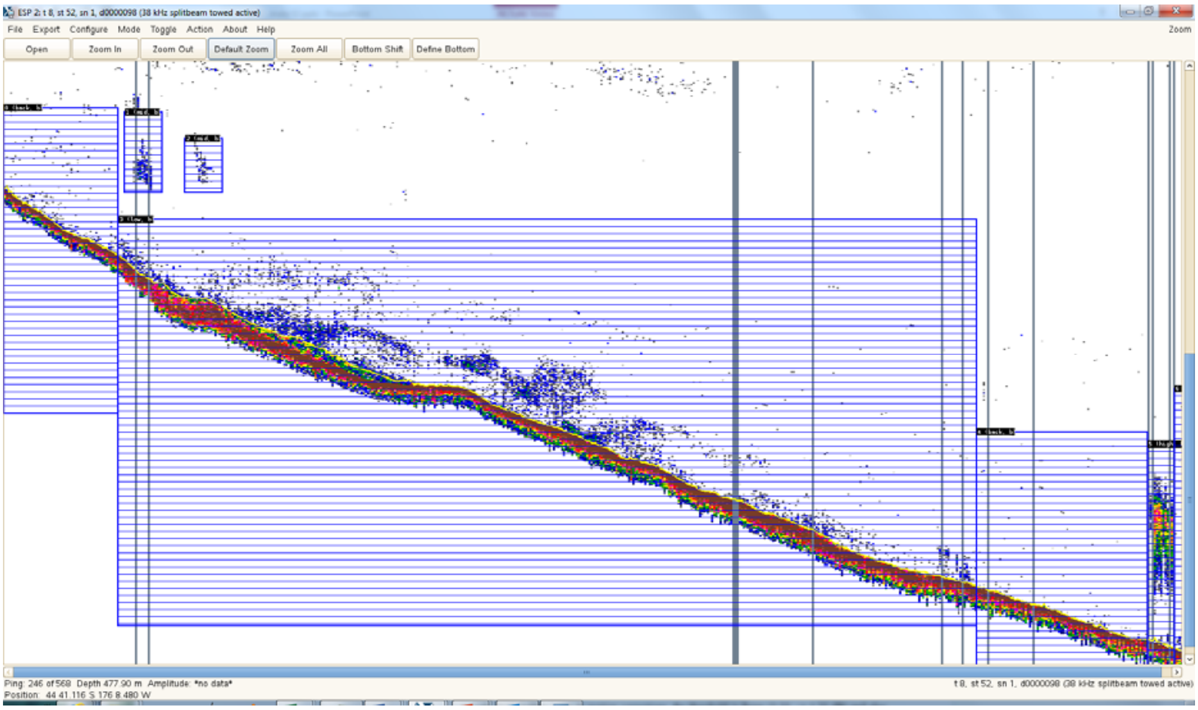

Figure 4: Echogram from transect 8 (carried out north to south), stratum 52, showing the large mark (#124) near the end (right hand side) of the transect. No substantive mark was observed by the *San Waitaki* during a subsequent search along this transect. The bottom depth at the mark was about 1150 m and the mark was about 60 m high and 40 m off the bottom.

Only two successful School-deep mark identification tows (30, 51) were made in stratum 52 during the 2012 survey (see Table 6) in spite of extensive extra searching by *San Waitaki* in this stratum along transects intermediate to those carried out by *Tangaroa*. Tow 31 (1260–1295 m) was aimed at a School-deep mark (#86) observed in Stratum 82 near the longitude of mark #124 but failed to fish the mark and the smooth oreo catch was only 156 kg (total catch 774 kg).

The main sources of variability in the abundance estimates were the sampling error for surveying the backscatter which had a CV of about 30% (Table 9).

Table 9: The CV of the smooth oreo acoustic abundance estimates for the flat ground for each variance source using that source alone (see 2.6.1), i.e., in the catch data source, tows were re-sampled within each mark-type. The cumulative CV is the contribution from the combined sources going from one source at the top to all five sources at the bottom.

Source	CV (%)	Cumulative CV (%)
Sampling error from catch data	20	20
Estimation error in target strength of other species	15	25
Sampling error from backscatter data	32	41
Estimation error in target strength of oreo species	7	41
Estimation error in the scaling factor from acoustic area to trawl survey area	6	42

3.3.2 Hills

The results of the hill survey are summarised in Table 10, and show that the abundance varied widely, from 3 t at Condom's Hill to 1413 t at Hegerville. The estimated total abundance of smooth oreo on hills was 10 132 t with a CV of 29%. The contributions of the four hill categories are shown in Table 11. The between-hill variances were swamped by the sampling variances so the estimate of σ_B^2 was zero. Most of the sampling variation was due to sampling error in the backscatter (Table 12).

Table 10: Hills surveyed, abundance estimates (t), and the sample error of the abundance estimates.

Hill	Category	Abundance (t)	CV (%)
Chucky's	A	352	59
Trev's Pinni	A	65	102
Hegerville	A	1 413	40
Dolly Parton	A	687	103
Paranoia	A	248	68
Nielson's	A	1 315	45
Charlie Horsecock	B	54	75
Cooks	B	484	60
Fletcher's Pin	C	19	90
Condom's	C	3	71
Mangrove	C	1 234	55

Table 11: Total hill abundance and CV by hill category.

Category	Number of hills		Total abundance	
	Surveyed	Total	SSO (t)	CV(%)
A	6	6	4 060	31
B	2	7	1 883	55
C	3	10	4 188	54
Total	11	23	10 132	29

Table 12: The CV (%) from each variation source alone (see Section 2.6) and the median CV for each source over all the hills surveyed for smooth oreo, e.g., in the catches source, tows were re-sampled within each mark-type. *TS* is target strength. Cumulative CV was calculated from the median CVs using $\sqrt{\sum_i cv_i^2}$

	Variation source			
Hill	Backscatter	$TS_{\text{other species}}$	TS_{SSO}	Catch
Chucky's	52	3	20	6
Trev's Pinni	104	2	21	5
Hegerville	35	13	12	2
Dolly Parton	88	1	22	1
Paranoia	65	8	20	7
Nielson's	32	17	13	9
Charlie Horsecock	56	18	3	32
Cooks	46	12	9	33
Fletcher's Pin	89	11	11	23
Condom's	34	24	0	48
Mangrove	10	3	21	47
Median	52	11	13	9
Cumulative CV (%)	52	53	55	55

3.3.3 Total abundance estimates for area OEO 4

The abundance from both the flat (combined scale-up factor = 1.23*1.10) and hills (scale-up factor = 1.10) was scaled up to the overall OEO 4 area and this gave an estimate of the total abundance of smooth oreo of 88 600 t with a CV of 42% (Table 13).

Table 13: Total abundances (t) and CV for the flat and hills (A) with scale-up factors applied. The scale-up factor combines both the acoustic to trawl survey area factor and the trawl survey area to OEO 4 management area factor.

	Abundance	CV (%)
Flat	77 311	47
Hills	11 246	29
Total	88 558	42

3.4 Bias, sensitivities, and corrections

3.4.1 Flat

The sensitivity of the flat abundance estimate to changes in values of contributing parameters is shown in Table 14. Two sources of uncertainty in the 2012 survey produced abundance changes greater than the total flat CV (47% for smooth oreo), and so can be considered as potential sources of bias.

Most sensitivities considered do not represent likely changes, but are based on doubling and halving parameter values (e.g., a 3 dB change in target strength represents a factor of two in the fish per m^2 scale) or switching all of one group into another (e.g., using cod target strength-length relationship for deepwater-like species).

The largest sensitivities, causing a 40–58 % change in abundance were when the intercept of the target strength-length curve for species other than smooth oreo was changed by ±3 dB. The next most important sensitivity occurred when the relative catchabilities of species other than smooth oreo were changed by a factor of two. The 3 dB used in the sensitivities was considered extreme and intended to capture the maximum possible error in our current target strength estimates. Also the catchabilities of other species are unknown, and it is also not known if smooth oreo is more or less catchable than other species. The sensitivities used should be viewed as a mean change for all the other species because there would be a range of values over all the species.

When individual species were excluded from the catch, the maximum change in abundance was 29% for basketwork eel, 15% for black oreo, and 13% for Johnson’s cod. Excluding other species had much smaller effects.

The hull acoustic data showed some electrical background noise in deeper water. As the contribution of the noise was only marginal, with the main affect at depths greater than 1000 m, no noise correction was applied in abundance estimates when the hull data were used. There were seven transects (in strata 4, 42, 5, and 8) for which the hull-based backscatter data were affected by electrical noise. To judge the maximum potential effect of noise on the total abundance, the seven transects above were excluded and this reduced the abundance estimate for flat strata by about 15%.

Abundance from stratum 52 was estimated to be about 23 818 t, accounting for 43% of total abundance in flat strata. One mark (mark #124, School-deep, region 5 in file 98) contributed 15 850 t of abundance. Excluding this mark, i.e., assuming they are not smooth oreo, reduced the abundance for flat strata to 39 530 t (unscaled), and the total abundance for OEO 4 to 64 860 t (scaled) with a reduced CV of 31%.

Table 14: Bias sources for acoustic survey abundance estimates, smooth oreo, OEO 4, flat ground. †, magnitude exceeds CV for flat abundance (smooth oreo 47%). *TS*, target strength.

Source	Smooth oreo abundance change (%)
TS estimate, other species	
Lower intercepts by 3 dB	58†
Increase intercepts by 3 dB	-40
TS estimate of target smooth oreo	
Lower intercepts by 3 dB	21
Increase intercepts by 3 dB	-21
Catchability of other species	
Twice that for target smooth oreo	50†
Half that for target smooth oreo	-35
Species mix used	
Exclude basketwork eel (largest effect)	29
Exclude black oreo second largest effect)	15
Exclude Johnson's cod (third largest effect)	13
Exclude four rayed rattail (fourth largest effect)	7
Notable rattail (fifth largest effect)	5
Exclude any other species	<5

3.4.2 Hills

The sensitivity of the hill abundance estimates to changes in values of contributing parameters is shown in Table 15. Only sources of uncertainty which produced abundance changes greater than the total hill CV (29%) were considered as sources of potential bias. The most important effect was a change in the target strength of smooth oreo. The proportion of black oreo in the species composition was also important.

Table 15: Bias sources for smooth oreo acoustic survey abundance estimates, OEO 4, hills. † exceeds CV for total hill abundance (29%). *TS*, target strength.

Source	Smooth oreo abundance change (%)
TS estimate, other species	
Lower intercepts by 3 dB	19
Increase intercepts by 3 dB	-20
TS estimate of target smooth oreo	
Lower intercepts by 3 dB	59†
Increase intercepts by 3 dB	-40†
Catchability of other species	
Twice that for target smooth oreo	18
Half that for target smooth oreo	-19
Species mix used	
Exclude black oreo (largest effect)	23
Baxters lantern dogfish (second largest effect)	6
Exclude hoki (third largest effect)	4
Exclude any other species	<3

3.4.3 Shadow zone and towbody motion corrections for the flat and hills

Average corrections for each stratum are shown in Table 16. Shadow zone corrections were mostly small except for on the hills, as predicted by the theory (Section 2.1). However, motion corrections are large, with the correction being larger on the hills since the vessel had to travel slower to get the towbody lower in the water column and this tended to increase the towbody motion.

Table 16: Average corrections for shadow zone and towbody motion by stratum. Base abundance (unscaled).

Stratum	Base abundance (t)	Correction factor			Corrected abundance (t)		
		Motion	Shadow	Both	Motion	Shadow	Both
2	1 324	1.84	1.07	1.98	1 749	1 020	1 888
22	221	1.57	1.06	1.66	268	182	283
3	1 401	1.49	1.06	1.58	1 421	1 009	1 505
9	406	1.33	1.02	1.35	432	333	441
4	4 048	1.07	1.20	1.28	4 360	4 905	5 251
42	3 902	1.06	1.09	1.15	5 201	5 375	5 682
5	2 332	1.17	1.11	1.30	4 702	4 479	5 237
52	13 383	1.53	1.16	1.78	20 847	15 751	24 177
8	6 628	1.19	1.06	1.26	7 517	6 687	7 953
82	2 639	1.62	1.08	1.75	3 887	2 600	4 209
Chucky's	143	1.31	1.89	2.46	188	270	352
Trev's Pinni	19	2.05	1.63	3.42	39	31	65
Hegerville	861	1.11	1.48	1.65	955	1 269	1 413
Dolly Parton	88	1.34	2.88	3.90	236	507	687
Paranoia	102	1.50	1.51	2.43	153	154	248
Nielson's	749	1.17	1.49	1.78	863	1 106	1 315
Charlie Horsecock	23	1.26	1.91	2.35	29	44	54
Cooks	92	1.30	4.01	5.26	120	369	484
Fletcher's Pin	8	1.50	1.50	2.38	12	12	19
Condom's	1	1.00	2.00	3.00	1	2	3
Mangrove	413	1.59	1.78	2.99	658	737	1 234

4. DISCUSSION

The time-series of OEO 4 smooth oreo total abundance estimates used for stock assessment are shown in Table 17. The 2012 survey estimate has the highest CV, which is more like the 2008 survey estimate than earlier surveys. The last stock assessment considered the 2008 survey abundance estimate (Fu & Doonan, 2013) but the Deepwater Fishery Assessment Working Group was uncertain about the low 2008 survey abundance estimate and recommended delaying the stock assessment until the 2012 survey abundance result was known. The 2012 survey estimate confirms that smooth oreo abundance has fallen, although perhaps not as far as the 2008 survey result indicated.

Table 17: Total estimated abundance from the 1998, 2001, 2005 and 2012 OEO 4 smooth oreo acoustic surveys.

Survey year	Total	
	Abundance (t)	CV (%)
1998	146 000	33
2001	218 200	22
2005	115 500	28
2008	66 500	36
2012	88 600	42

The large School-deep mark observed on Transect 8, Stratum 52 (#124) accounted for about a quarter of the total estimated abundance. The mark was not observed by the catcher vessel so the species composition of the mark was not known but the analysis assumed that it was composed entirely of smooth oreo because the depth and location were consistent with previously observed smooth oreo marks and catches. Two skippers were presented with echograms from a range of fished and unknown marks from the 2005 and 2012 surveys and were asked to provide the likely species composition. The results varied between skippers for both fished and unfished marks so these data are not presented here but both skippers thought that mark #124 could be smooth oreo. The fish density and mark size (area) of the eight largest biomass School-deep marks from the 2005 smooth oreo acoustic survey and also the 2005 excluded mark were examined to determine if mark #124 was consistent with previous results and these data are presented in Figure 5.

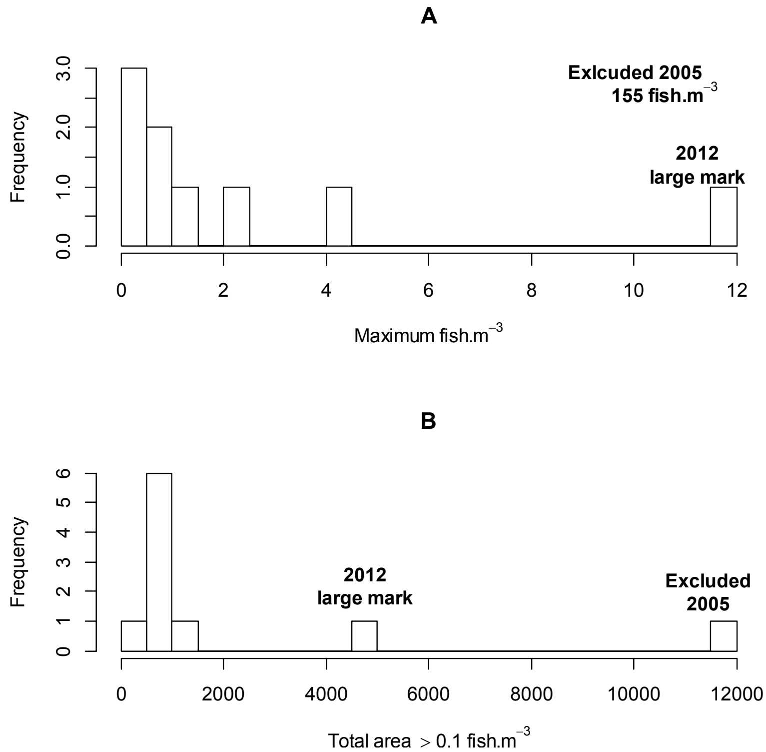

Figure 5: Maximum fish density estimates (upper panel) and total mark area (for 0.1 fish.m^3, lower panel) for 8 marks observed in the 2005 survey, including the mark excluded from the 2005 analysis, and mark #124 from the 2012 survey.

This comparison shows that

1. The estimate of maximum density for mark #124 was about 11 fish.m^{-3} and was 3 times greater than the largest accepted 2005 survey mark (about 4 fish.m^{-3}) so this suggests that the mark could be consistent with those from 2005. Most of the 2005 survey marks analysed had fish densities of 0.5 fish.m^{-3} or less.
2. The estimate of maximum fish density for the excluded 2005 mark was about 39 times greater than the next highest 2005 smooth oreo mark and appears to be inconsistent. A density of 155 fish.m^{-3} also seems biologically improbable for a large fish such as smooth oreo.
3. The estimates of mark area for mark #124 are about 4 times greater than estimates for the largest 2005 mark, and appear consistent. The excluded 2005 mark had an area more than 10 times larger than the largest other 2005 mark and is at the extreme (large) end of the distribution of mark area.

Estimates of fish density from Figure 5 were compared with observed orange roughy fish density from moored camera arrays on Morgue during experimental voyages carried out in June 2010 and June 2012 (O’Driscoll et al. 2011, 2013). Orange roughy acoustic density estimates recorded within the Morgue plume from moored echosounder and hull transects were equivalent to 5 and 20 fish.m^{-3} respectively. These density estimates were very much higher than peak observed visual density estimates of orange roughy of 0.37–1.26 fish.m^{-3} in 2010 and 0.42–1.22 fish.m^{-3} in 2012. The orange roughy visual fish density estimates were similar to those for the eight smooth oreo marks from 2005 (Figure 5). The density estimate for mark #124 was about 3 times larger but still seems consistent with the eight smooth oreo marks from the 2005 survey (Figure 5), while the excluded mark estimate of 155 fish.m^{-3} seems inconsistent.

The distribution and backscatter of marks observed during acoustic transects at the east end of the survey area in 2012 is shown in Figure 6. Mark #124 is at the deeper range of marks seen and had the most backscatter of all the 2012 marks. It was also near to the position of the excluded mark seen in the 2005 survey.

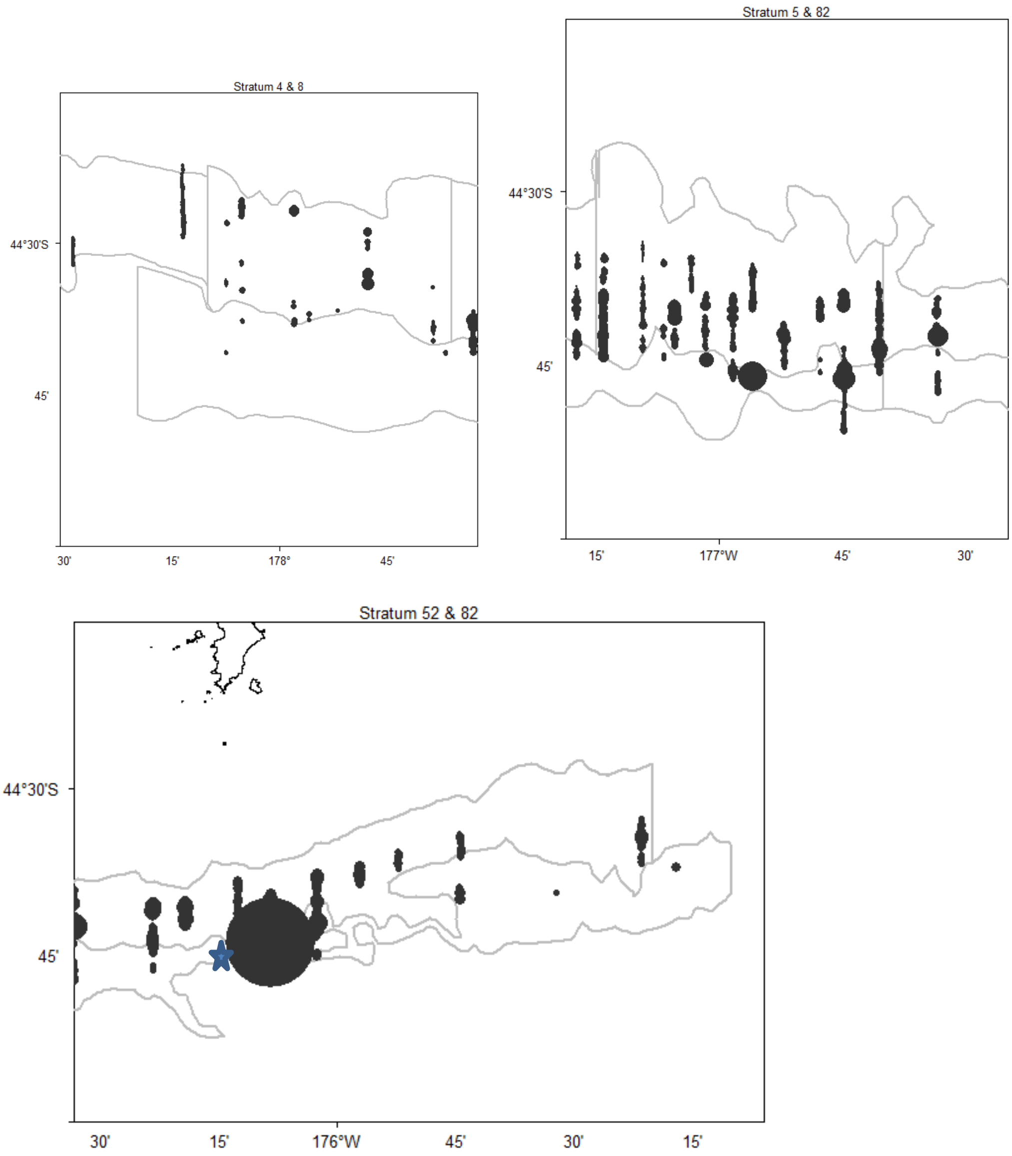

Figure 6: Bubble plot of backscatter from School-shallow and School-deep mark-types from the east part of the survey area. Circle area is proportional to the mean aerial backscatter averaged over 10 pings. The star marks the position of the large mark from the 2005 survey that was excluded from the abundance estimate. Mark #124 is the large circle in the lowest panel.

Figure 7 plots the catches of smooth oreo greater than 1 t at the east end of the survey area from the 2005, 2009, and 2012 surveys to examine the distribution of successful tows on smooth oreo marks. The location of the excluded mark from the 2005 survey, mark #124, and tow 31 from the 2012 survey are also plotted.

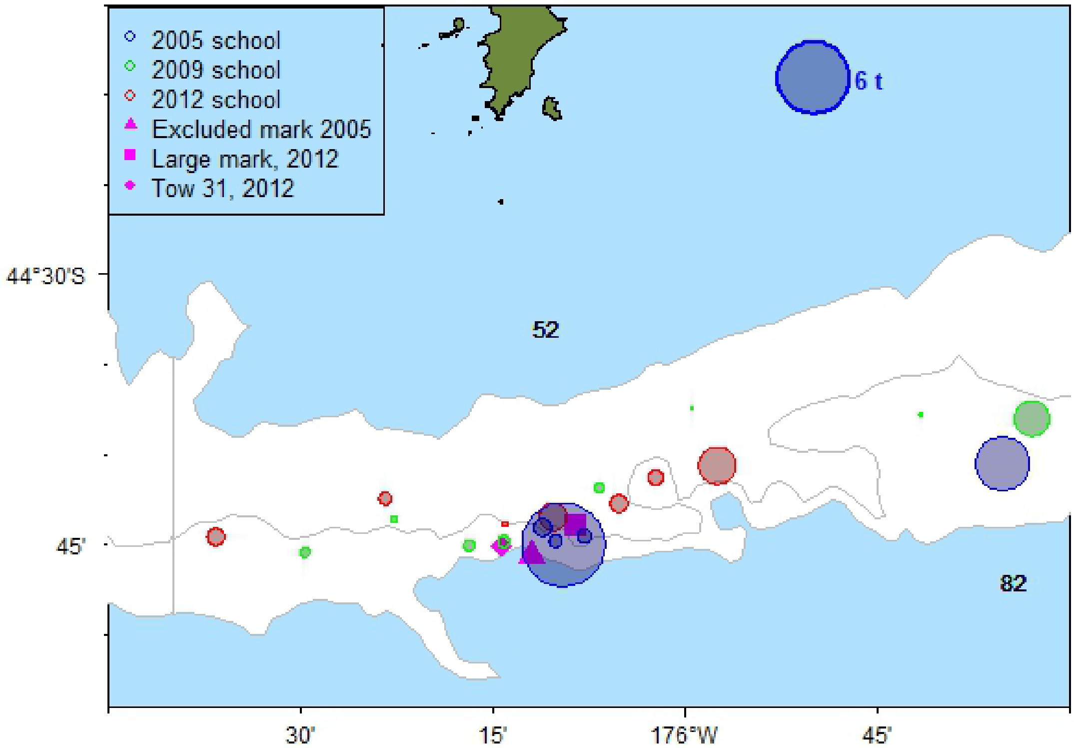

Figure 7: Smooth oreo catches (circles, proportional to catch size) from tows carried out during the 2005, 2009, and 2012 acoustic surveys. Position of one large acoustic mark excluded from the 2005 survey (triangle). Position of acoustic mark #124 of uncertain species composition observed during the 2012 survey. Tow 31 (diamond) which was targeted at (but failed to hit) midwater marks observed near the position of mark #124 in 2012.

This shows that

1. Mark #124 is close to the position of the 2005 survey excluded mark.
2. One relatively large catch of smooth oreo was made during the 2005 survey close to the location of the 2012 mark #124, and to the 2005 excluded mark, suggesting that the location can have marks that may be smooth oreo.

The main source of unmeasured uncertainty in the estimates are from potential bias in target strength and catchabilities (relative to smooth oreo) for species other than smooth oreo (flat strata), and from potential bias in target strength of smooth oreo (hills). There is also uncertainty due to the relatively high proportion of the smooth oreo abundance (39%) from Layer and Background mark-types because these contain a mix of species and the acoustic technique is less appropriate when applied to mixed species marks compared to single species marks.

The large factors used for motion corrections for the extreme eastern strata (52 and 82) and the western strata (9, 3, 2, and 22) are a concern. These appear to be larger than motion corrections from previous surveys and require further investigation. However, it is likely that if there is an error, then the estimated abundance will be lower than reported here and so the conclusion that the abundance has decreased after 2008 will still hold.

Conclusions and recommendations:

1. Large marks of unknown species composition were observed in a relatively small part of the survey area in both the 2005 and the 2012 surveys.
2. A future survey should consider bounding the area as a separate stratum to ensure that survey staff focus effort on any very large marks observed.
3. Future surveys should carry out target identification tows (bottom and midwater trawl) on any substantial marks seen, and the catcher vessel should be close by when the acoustic survey reaches the area that large marks were observed in 2005 and 2012 so that there is minimal delay between observation and target identification work.
4. The estimates of fish density and relative abundance for the 2012 survey mark #124 are intermediate between the estimates made for known marks and the excluded mark from the 2005 survey. The species composition of this mark was not able to be verified by trawling. The uncertain composition of this mark should be reflected in any stock assessment analysis where it is used.

5. ACKNOWLEDGMENTS

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