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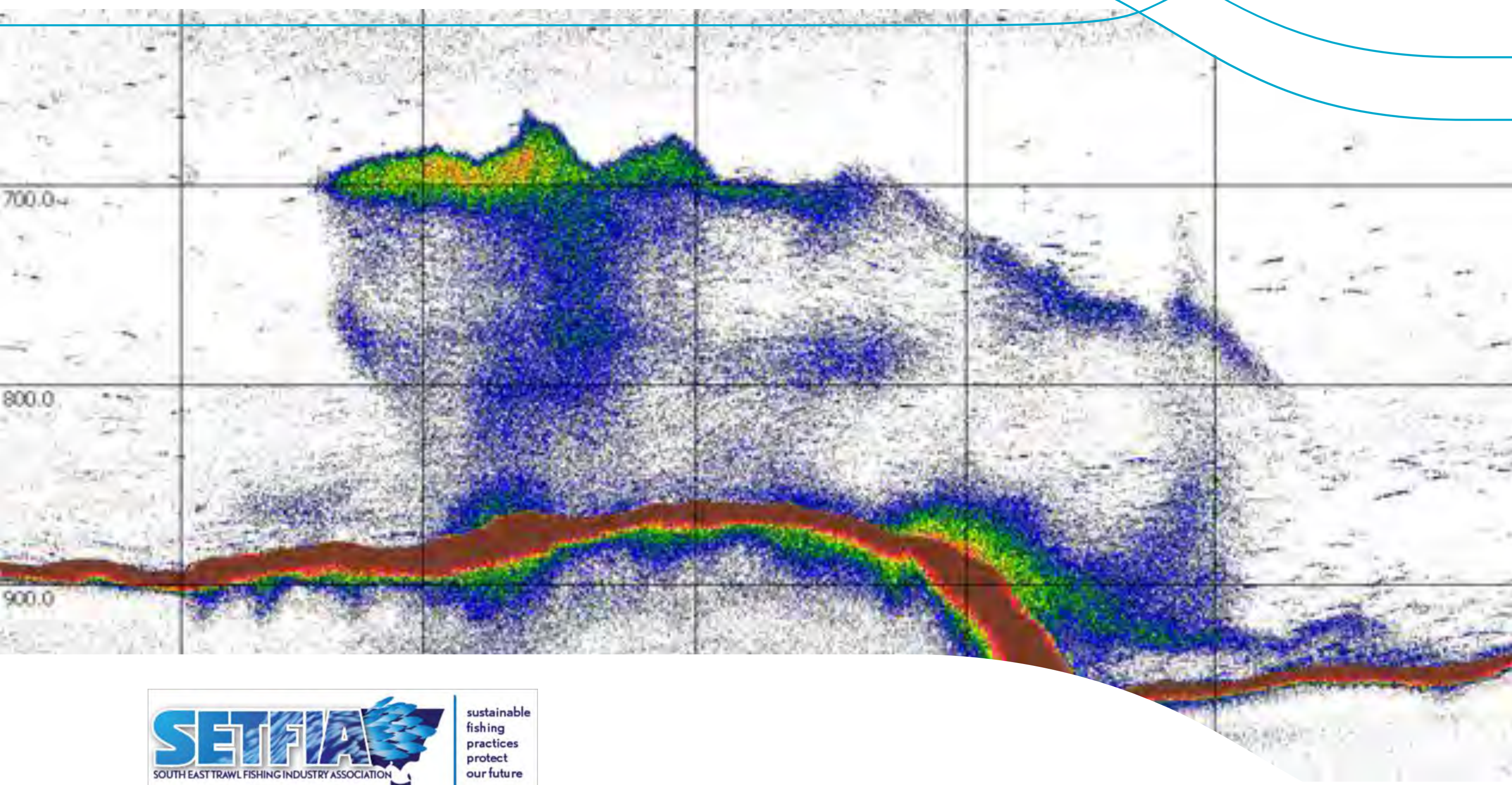
Orange roughy eastern zone spawning biomass 2016

Rudy Kloser, Caroline Sutton, Haris Kunnath and Ryan Downie.

August 2017

SETFIA

Simon Boag



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Executive summary

Based on the 2016 acoustic surveys the biomass of spawning orange roughy on the grounds at 38 kHz and 120 kHz ranges from 24 000 (CV 0.12) to 29 600 (CV 0.22) tonnes for observation or process error analysis respectively. There has been a significant 2 fold increase in spawning biomass at St Helens Hill since 2013. The 38 kHz time series estimate of spawning biomass in 2016 is now higher than that recorded in 2010 and the long term trend is consistent with a recovery of fish to the spawning sites. The 38 kHz snapshot survey biomass estimate in 2016 of 29 600 tonnes (CV 0.22) extends the index of survey observations since 1990.

The 120 kHz biomass estimates were approximately 10% less than the 38 kHz estimates and this relationship is consistent with previous observations (Ryan and Kloser 2016). The difference between 38 kHz and 120 kHz biomass estimates indicates a source of bias in one or both data sets. Until the source of bias is found the average of the 38 kHz and 120 kHz estimates is recommended. The averaged over frequency combined ground estimate is 27 700 tonnes (CV 0.18) assuming process error dominant and 24 000 tonnes (CV 0.12) assuming observational error dominant.

It is important to note that we an error in the 38 kHz transducer calibration data supplied by the manufacturer and have adjusted this and the 2013 data by 18% accordingly.

1 Introduction

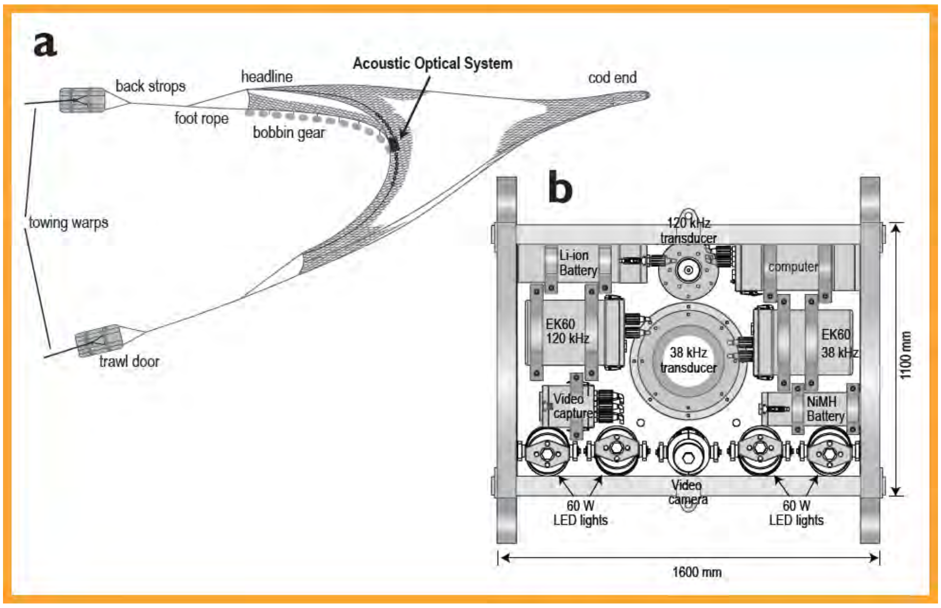
The Eastern Zone orange roughy fishery was reopened in 2014 based on a sustained monitoring program since 2006 that combine with an updated stock assessment model showed the stock was recovering and was above the 20% pre fishery equilibrium level (Kloser et al., 2015; Upston et al., 2014). A major index for the eastern zone spawning stock has been the acoustic surveys that due to multi-frequency species identification and optically verified target strengths provide an estimate of stock biomass at two frequencies (Kloser et al., 2013). As part of the management requirements for the fishery an acoustic survey of the two known spawning sites of St Patrick Head and St Helens Hill was required in 2016 (Figure 1-1). To achieve this a new net attached Acoustic Optical System (AOS) was built to improve the reliability and operator safety of the method as well as advance the technique by incorporating broadband technologies (Figure 1-2). In order to improve the flexibility and cost effectiveness of the surveys the new AOS was smaller and placed on a trailer so that it could be launched at Burns Bay in St Helens. This enabled the survey vessel to be more flexible in its operations.

Figure 1-1 Area of operations for the survey, highlighting the Burns Bay, St Helens Hill and St Patricks head locations.

Scientific objective:

1. Trial a new net attached AOS that is broadband capable (Figure 1-2).
2. Acoustic biomass of spawning orange roughy in the Eastern Zone in 2016.
3. To collect biological data to support target strength, age, length, weight and reproductive potential analyses in 2016.

Figure 1-2. Acoustic optical system a), attached to the headline of a trawl net with the b) old AOS system configuration and c) the new AOS system used on the voyage being tested in Hobart (Mark Green in picture).



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2 Biological sampling

2.1 Biological sampling equipment and methodology

Fish were collected from the trawler *FV Empress Pearl* with a demersal orange roughy net with windows (Table 2-1). The vessel and sampling protocol was the same as for the 2013 survey (Ryan et al. 2014). The *FV Empress Pearl* is smaller than the boats used for previous surveys and while spawning aggregations were targeted, the windows allowed for fish escapes. This ensured that the catches were smaller as the aim was to collect fewer higher quality fish as opposed to larger catches of 5+ tonnes.

Biological data collected and recorded onboard include; total catch weight, catch composition, length, weight, sex, and gonad condition. Otoliths, gonad tissue and muscle tissue samples were also taken for offshore processing of age, fecundity, isotope and heavy metal analysis. Lengths were measured as *Standard Lengths* for Roughy and Oreodories and *Total Length* for Whiptails, sharks and cods. *Standard Length* refers to the length from the tip of the snout to the hypural plate at the base of the tail; *Total Length* refers to the length from the tip of the snout to the tip of the tail (Kloser et al., 2012).

In 2016 (same as for 2013) all lengths were measured using a manual fish measuring board to the lowest cm, for example 34.9 was recorded as 34.0. In previous years when using manual measuring boards, fish were also measured to the lowest cm but the measuring boards had a deliberate +0.5 cm offset which in effect rounds the measures to the nearest cm. When electronic measuring boards were used, fish were measured to the nearest mm and then rounded to the nearest cm. To compare lengths with historic data, half of the fish in each 1cm length group were shifted up to the next group, so in effect the average lengths were increased by 0.5cm. For example, if there were 20 fish at 32 cm, 10 fish were shifted up into the 33cm group. Kloser et al. (2012) describes in greater detail the reasoning behind the length adjustments.

Individual fish weights were measured on motion stabilised scales and recorded in grams to the nearest 100 grams. The scales were calibrated using 1 litre of fresh water (= 1 kilogram). Gonad condition was determined following the CSIRO Orange Roughy Gonad Staging Protocol (Cathy Bulman unpublished guide based on Pankhurst et al. (1987),Table 2-2). All averages are weighted for sample size unless otherwise stated. Spawning Area "population" averages are estimated assuming an even sex ratio.

Table 2-1 Roughy net statistics

Net attribute	
Wing end spread	25 m
Average headline height	3 m (average)
Door spread	80 m
Mesh size @ mouth	150 mm
Mesh size @ cod end	102 mm
Average tow speed	2.7 knots

Table 2-2 Gonad Stages

Gonad Stage	Female	Male
1	Immature/resting	Immature/resting

2	Maturing	Maturing
3	Maturing (yolked eggs present)	Maturing (spermiated, viscous milk present)
4	Mature/Ripe	Ripe (milk freely flowing)
5	Running Ripe	Spent
6	Spent	
7	Atretic	

A total of 635 otoliths were collected from all shots at both grounds where between 4 and 56 otoliths were taken per shot; 482 from St Helens (266 and 216 from female and male fish respectively) and 153 from St Patricks (106 and 47 from female and male fish respectively). Otoliths were placed into envelopes and labelled with Operation number (OP), Standard Length (SL), sex (SX) and specimen number (S#). Otoliths collected from observers in 2012 are included here to complete the time series but were not collected as part of an acoustic survey.

The otoliths from the 2012 and 2016 surveys were analysed by Fish Aging Services Pty Ltd (Table 2-3). using the same methodology as described in (Kloser et al., 2012) and the results were added to the orange roughy age time series. The yearly time series for males and females and St Helens and St Patricks were examined with a linear model to test for significant changes in age.

Table 2-3 Number of male and female orange roughy otoliths successfully read from the 2012 and 2016 surveys from St Helens and St Patricks.

	2012		2016	
	female	male	female	male
St Helens	186	275	242	204
St Patricks	240	270	96	43

A total of 5 Stage 3 gonads were dissected out of fish caught at St Helens, and then frozen for future analysis. A total of 11 tissue samples for isotope analysis were collected from fish caught at St Helens. A linear model was used examine and test significant trends of the yearly time series for female and male fish at St Helens and St Patricks.

2.2 Biological Results

2.2.1 Shot data and bycatch summary

The biological component of the survey was conducted between July 16 and July 22 with 11 successful shots at St Helens Hill and 3 successful shots at St Patricks Head. A total of 20 085 kg of orange roughy were caught, 19 365 kg from 9 shots at St Helens and 720 kg from 3 shots at St Patricks. Total catch weights were variable and ranged from 9 129 kg to 70 kg, with lowest catches at St Patricks. Bycatch was also variable and ranged between 1 % and 28 % (by weight) for all shots. Bycatch was generally low ranging between 1% and 5.5% for most catches and only 3 catches had a proportion by catch by weight greater than 20%. There was a loose correlation between shot weight and bycatch where all shots greater than 1 tonne had correspondingly low bycatches ranging from 1 % to 5.5 %. Table 2-4 summarises the dates, shot weights and by-catch weights for each shot and spawning ground. Appendix C contains the catch composition for each shot.

Table 2-4 Summary of shot dates and weights for St Helens and St Patricks, Eastern Zone, 2013 (* no fish collected from these shots)

Ground	Shot no	Date	shot weight (kg)	bycatch (kg)	% bycatch
St Helens	10	16-Jul-16	425	35	8.2%
	11	17-Jul-16	1503	33	2.2%
	14	18-Jul-16	1215	45	3.7%
	15	19-Jul-16	1217	17	1.4%
	18	19-Jul-16	2635	145	5.5%
	25	20-Jul-16	136	6	4.4%
	26	21-Jul-16	9129	99	1.1%
	30	22-Jul-16	721	151	20.9%
	31*	22-Jul-16	638	158	24.8%
	33	22-Jul-16	1233	63	5.1%
	34*	22-Jul-16	513	48	9.4%
St Helens total			19365	800	4.1%
St Patricks	20	20-Jul-16	248	8	3.2%
	19	20-Jul-16	70	20	28.6%
	22	20-Jul-16	402	12	3.0%
St Patricks total			720	40	5.6%
Survey Total			20085	840	4.2%

2.2.2 Length

Average Length

For 2016 average adjusted length at St Helens was 36 cm for females and 33.5 cm for males. For St Patricks average length was 36.1 cm for females and 33.3 cm for males. Average Lengths for males at both grounds were similar to 2013 and has been relatively unchanged since 2009, although there is in general more variability in lengths for males at St Patricks. Average length for female fish significantly increased by 0.5 cm at both grounds from 2013 to 2016. However, overall orange roughy are on average 1 cm smaller for females and 2cm for males than the fish captured in the early days of the fishery (Figure 2-1, updated from Kloser et al. (2012)).

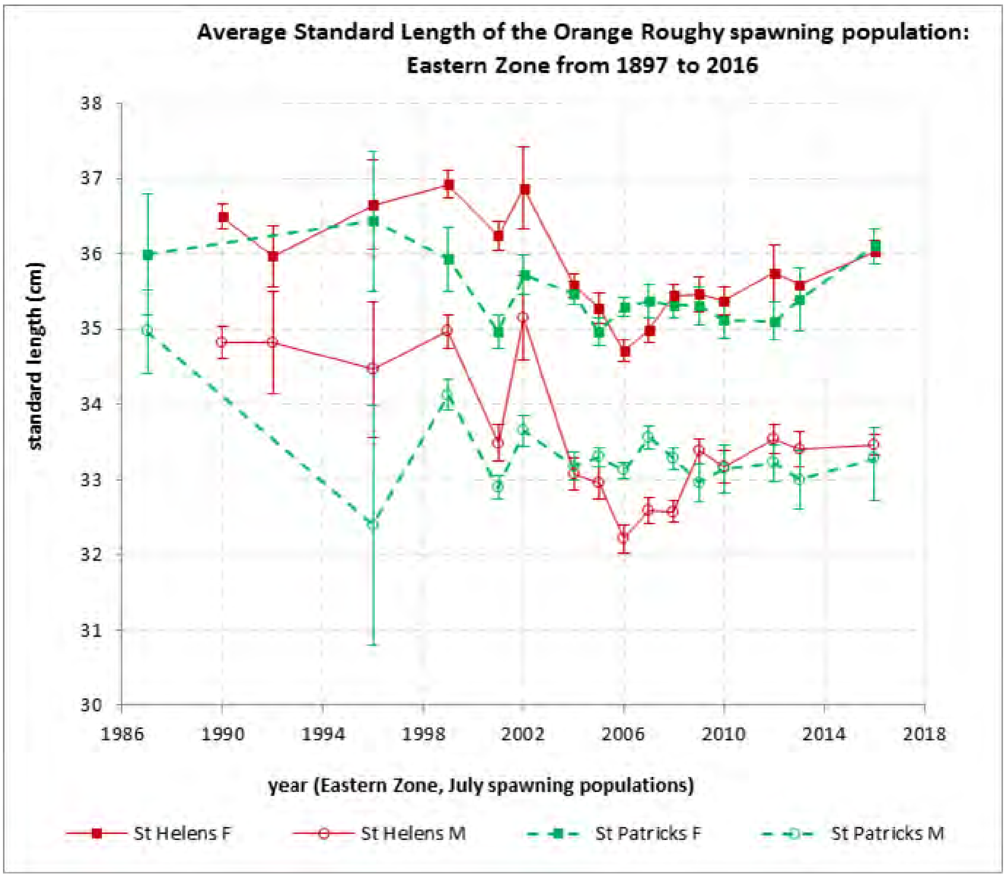

Figure 2-1 Average Standard Length (cm) of orange roughy Eastern Zone spawning population, showing males and females at St Helens and St Patricks for 1987 to 2016. Error bars are 95% confidence limits (updated from Kloser et al. 2012).

Length Frequencies and Mode

Similar to previous surveys length frequencies were generally uni-modal, except for the male fish at St Patricks where there is a small peak of fish of 36 cm in length (Figure 2-2). However the number of fish for St Patricks was quite small (126 female fish) and this small peak represents less than 3 fish. At St Helens the female fish mode was 35 cm and 34 cm for male fish, which is 1cm lower for female fish and 1 cm higher for male fish relative to the 2013 survey. At St Patricks the mode was 36 cm for female fish and 33 cm for males which is 1cm higher for female fish and unchanged for male fish relative to the 2013 survey. In general most of the fish caught were distributed within 1 to 1.5 cm either side of the mode for both grounds. Male fish at St Patricks were more tightly distributed but could be attributed to a sampling artefact due to low numbers sampled. While there is annual variability at both sites for both sexes there is a general trend towards increasing or at least stabilising average lengths (Figure 2-1).

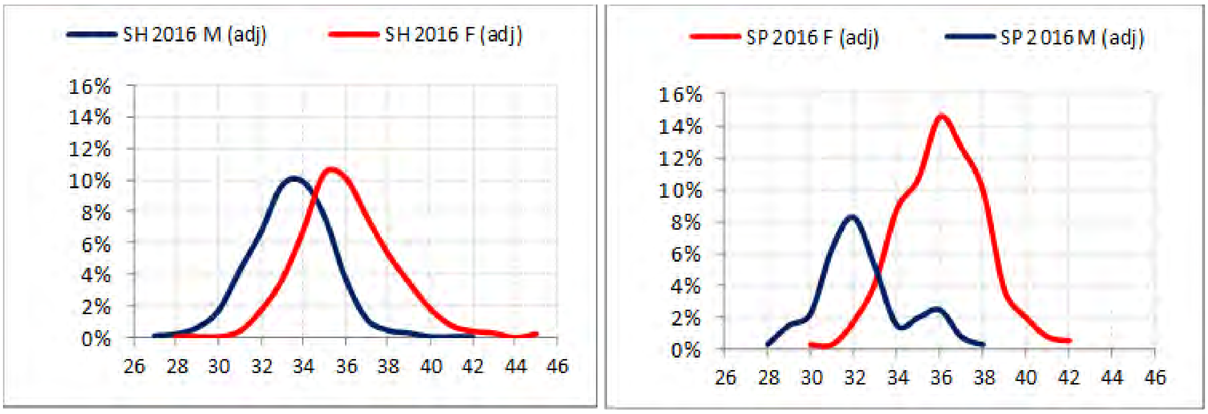

Figure 2-2 Length frequencies (cm) for the 2013 orange roughy Eastern Zone spawning population, showing males (M = blue lines) and females (F= red lines) at St Helens (SH) and St Patricks (SP). Data presented as percentage occurrence of females (F) and males (M) for each cm category. Samples numbers are as follows: SH F = 902, SH M = 791, SP F = 287 and SP M = 126.

Cumulative length frequencies show that the two grounds have very similar length structures. At both grounds 50% of female fish were longer than 35cm, which is an increase of 1 cm from the 2013 survey for female fish at St Patricks (Figure 2-3). For male fish 50 % were longer than 32 cm at St Patricks and 33 cm at St Helens, which is a 1 cm increase for male fish at St Helens. A greater number of larger fish were caught at St Patricks with 10 % of male fish greater than 36 cm relative to 5 % at St Helens. There was a larger proportion of larger female fish caught at St Helens relative to St Patricks but the difference is minor.

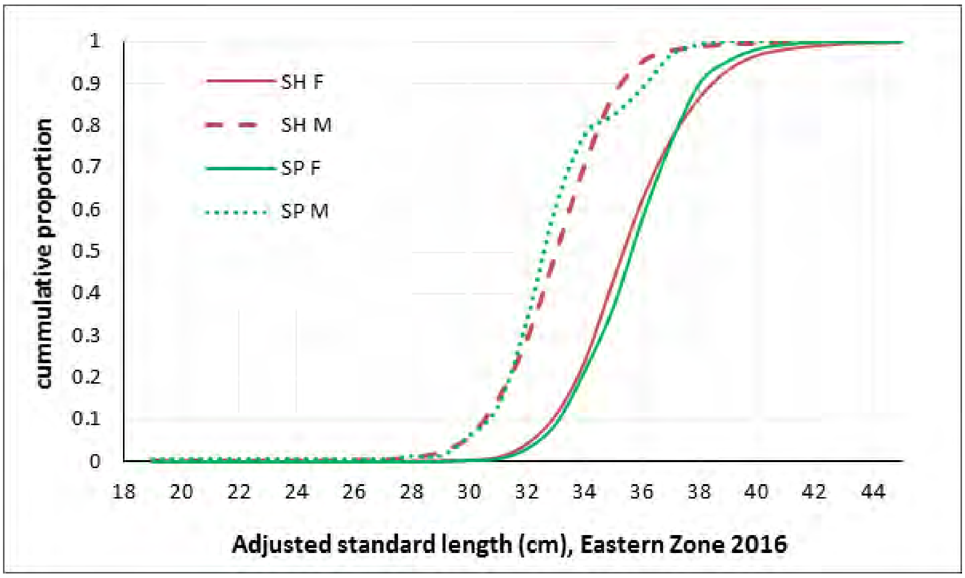

Figure 2-3 Cumulative length frequency (cm) for the 2013 orange roughy Eastern Zone spawning population showing males (dashed line) and females (solid line) at St Helens (red) and St Patricks Hill (green).

Table 2-5 Number of fish measured and mode for standard lengths for males and females measured at St Helens and St Patricks from 1987 to 2013, updated from Kloser et al. 2012.

	St Helens				St Patricks			
	Females		Males		Females		Males	
Year	No. fish	Mode (cm)	No. fish	Mode (cm)	No. fish	Mode (cm)	No. fish	Mode (cm)
1987					146	37	181	36
1990	800	35	459	35				
1992	248	36	92	36				
1996	104	36	47	33	41	37	5	34
1999	840	38	506	36	199	37	550	35
2001	971	37	478	33	691	35	1352	32
2002	59	38	77	36	332	35	612	34
2004	1465	35	527	33	886	34	470	33
2005	702	35	488	33	608	34	1193	33
2006	1520	34	740	32	1394	35	1752	33
2007	1064	35	672	32	362	35	690	33
2008	1402	35	735	33	639	36	889	33
2009	425	35	670	33	334	36	220	33
2010	704	35	355	33	304	36	179	33
2012	211	35	358	33	279	35	323	33
2013	548	36	284	33	107	35	103	33
2016	902	35	791	34	284	36	126	33

Between shot variability

Average lengths for females at St Helens for the 9 shots ranged from 35.4 cm to 36.6 cm (note that all averages were adjusted by 0.5 cm to enable comparison with the historical dataset). Length estimates were consistent between the 9 shots with averages only ranging between 1 cm and error estimates for each average with plus or minus 1 cm about the mean. Average lengths for males at St Helens were more variable between the 9 shots and ranged from 32.5 cm to 34.5 cm, although the error estimates were lower with no more than plus or minus 0.5 cm about the mean for each estimate.

Average lengths at St Patricks ranged from 35.7 cm and 37.0 cm for female fish and 32.1 cm and 34.2 cm for male fish (Figure 2-4). Error estimates for both sexes were generally 1 cm plus or minus about the mean.

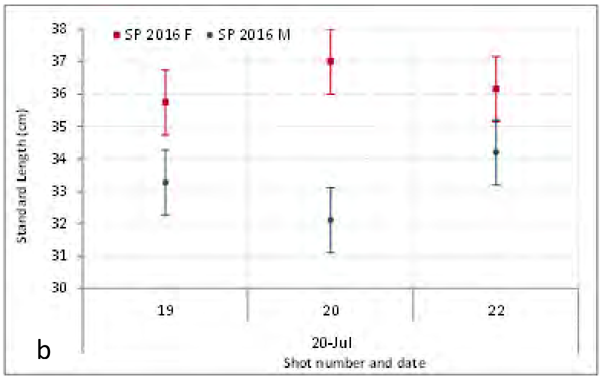

Figure 2-4 The average Standard Length (cm) by shot for males (blue) and females (red) for the Eastern Zone spawning population at a) St Helens and b) St Patricks for 2016. Error bars are 95% confidence intervals.

Average weight for female fish was 1.47 kg for both St Patricks and St Helens. Weights for female fish ranged from 0.90–2.80 kg, which is the same maximum weight for 2013 but reduced range on the lighter side. Average weight for male fish was 1.14 kg and 1.11 kg at St Helens and St Patricks respectively. Male weights ranged from 0.2 - 1.7 kg. Males were on average 0.36 kg lighter than females (Table 2-6).

Table 2-6 Average weight (kg) by shot for male and female fish for the 2013 Orange Roughy Eastern Zone spawning population. SD = Standard Deviation (±) of the sample, N = sample size.

Ground	Operation	Females			Males		
		weight	SD	Nos	weight	SD	Nos
St Helens	10	1.46	0.26	69	1.02	0.17	31
	11	1.49	0.31	47	1.00	0.12	15
	14	1.47	0.37	26	1.22	0.18	34
	15	1.42	0.25	16	1.17	0.19	9
	18	1.54	0.35	46	1.12	0.22	14
	25	1.44	0.17	25	1.22	0.18	36
	26	1.55	0.44	12	1.11	0.18	48
	30	1.39	0.28	30	1.08	0.15	30
	33	1.45	0.21	31	1.17	0.21	69
St Patricks	19	1.51	0.28	26	1.13	0.18	34
	20	1.50	0.24	25	1.04	0.36	9
	22	1.43	0.17	56	1.05	0.13	4

2.2.3 Sex Ratio

The sex ratio for the total survey, combining both grounds, was relatively even but slightly skewed towards females (56:44). Most of the fish were captured at St Helens where the sex ratio pooled for the 9 shots was also even (53:47), whereas for St Patricks the sex ratio for pooled shots was dominated by female fish (69 %). All the largest shots had even sex ratios or were dominated by female fish. On a shot by shot basis sex ratios at St Helens were variable, for example 3 shots were dominated by female fish (> 70%), 3 shots dominated by male fish > 65% and 3 shots had a relatively even sex ratio. At St Patricks 2 of the 3 shots were dominated by females (74 % and 92 %) and one shot had relatively even sex ratio (Table 2-7).

Table 2-7 Sex Ratio by shot, spawning area and for the total survey 2016

Sex		Shots												Site		Survey Total
		St Helens (SH)									St Patricks (SP)			SH	SP	
		10	11	14	15	18	25	26	30	33	19	20	22			
F	Ratio	0.64	0.71	0.48	0.72	0.77	0.34	0.20	0.52	0.33	0.43	0.74	0.92	0.53	0.69	0.56
	Nos	127	142	97	141	154	32	40	103	66	78	25	184	902	287	1189
M	Ratio	0.37	0.29	0.52	0.28	0.23	0.66	0.80	0.49	0.67	0.57	0.26	0.08	0.47	0.31	0.44
	Nos	73	57	105	55	47	63	160	97	134	102	9	15	791	126	917
	Total nos															2106

2.2.4 Gonad Stage

The examination of gonad stage data shows evidence that the fish were actively spawning during the survey. Figure 2-5 shows the proportion of fish at each gonad development stage for males and females at both grounds. The staging data indicate that the majority of fish were caught during the peak spawning event. Greater than 65 % of all female fish sampled at both grounds had either ripe gonads (34 % Stage 4) or were actively spawning (31 % Stage 5) and 28 % where either spent or partially spent. The percentage of spent fish (Stage 6) increased from 8% to 44% as the survey progressed, and supports the observation that peak spawning coincided with the start of the survey.

As with the 2013 survey there was more variability in gonad stage between the two grounds for males relative to females. A significant percentage of male fish at both grounds had immature gonads (stages 1 and 2); 49 % at St Helens and 31 % for St Patricks. Despite this the majority of male fish were actively spawning during the time of the survey. At St Patricks 62 % of the sample were actively spawning (48 % Stage 4) or ripe (14 % Stage 3) and at St Helens 46 % were actively spawning (18 % Stage 4) or ripe (28 % Stage 3).

Overall a larger proportion of female fish had spent gonads (26 % and 37 % of female fish at St Helens and St Patricks respectively) compared to male fish (5 % to72 % of males at St Helens and St Patricks respectively). However gonad staging for male fish is more ambiguous than for female fish, as an immature male gonad looks very similar to a spent male gonad so, it is possible that some of these immature fish were in fact spent fish.

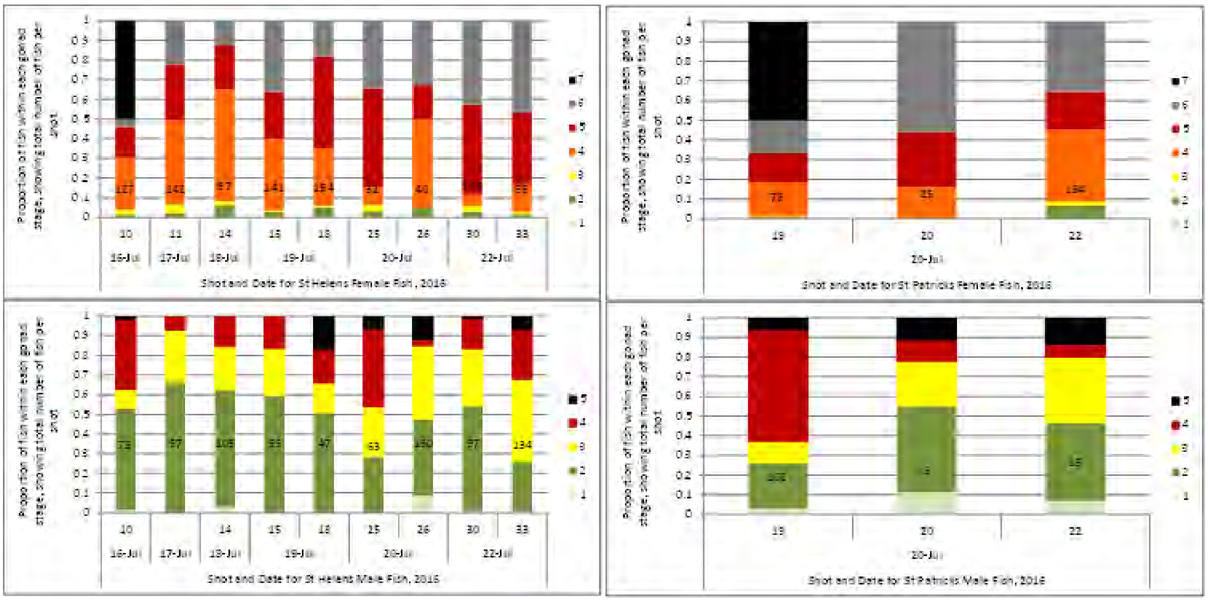

Figure 2-5 Gonad maturity stage for the 2016 Eastern Zone spawning population, showing the proportion of immature, ripe and spent fish in each shot for males and females at St Helens and St Patricks. See table 2-2 for key to stages. Numbers in each column represent the sample size for each shot.

2.2.5 Proportions, sex ratios and weighted averages for length and weight by spawning ground

Fish lengths were similar for St Helens and St Patricks for male and female fish. However for the male and female combined average length was 0.5 cm longer at St Patricks relative to St Helens due to changes in sex ratios (Table 2-8). Correspondingly fish were on average slightly heavier at St Patricks relative to St Helens (Table 2-8). This is the reverse trend for the 2013 survey results and is reflective of the annual variability within population.

Table 2-8 Proportion of male and female fish at each ground and their associated weighted averages for fish length (cm) for the 2016 Eastern Zone spawning population. Lyle length-weight relationship; Female weight (g) = 0.0351 length (cm) $^{2.97}$, male weight (g) = 0.0383 length (cm) $^{2.942}$, weight (both sexes) = 0.0370 length (cm)$^{2.952}$.

Spawning Ground	sex	Proportion	Average Length (cm)	Estimated weight (kg) based on Lyle *et al.* (1991)	No of Fish
St Helens	F	0.53	36.0	1.49	902
	M	0.47	33.5	1.18	791
St Patricks	F	0.69	36.1	1.50	287
	M	0.31	33.3	1.17	126
St Helens (F&M)	F+M	0.80	34.83	1.35	1693
St Patricks (F&M)	F+M	0.20	35.25	1.40	413
SH and SP combined	F	0.56	36.05	1.49	1189
SH and SP combined	M	0.44	33.43	1.18	917
Survey total	All fish	1	34.91	1.36	2106
St Helens (assuming 1:1 sex ratio)			34.74	1.34	Avg of F & M
St Patricks (assuming 1:1 sex ratio)			34.70	1.33	Avg of F & M

2.2.6 Length vs Weight Relationship

Length and weight data from EMP2016 for males are females with the accepted length to weight relationship used for the stock assessments (Upston *et al.*, 2014) are shown in Figure 2-6. The length weight from EMP2016 are relatively evenly scattered around the length-weight equation line as estimated by Lyle *et al.* (1991). The average weight has decreased from 2013 although there is no strong evidence to support that the length-weight relationship has changed. It is likely that observed variability can be attributed to instrumentation or rounding errors as it is difficult to get accurate weights on-board even with a motion compensated balance. It would be advisable to check the length to weight relationship by weighing a subset of fish in a controlled laboratory environment or even dockside to obtain accurate weights where motion compensation is not required.

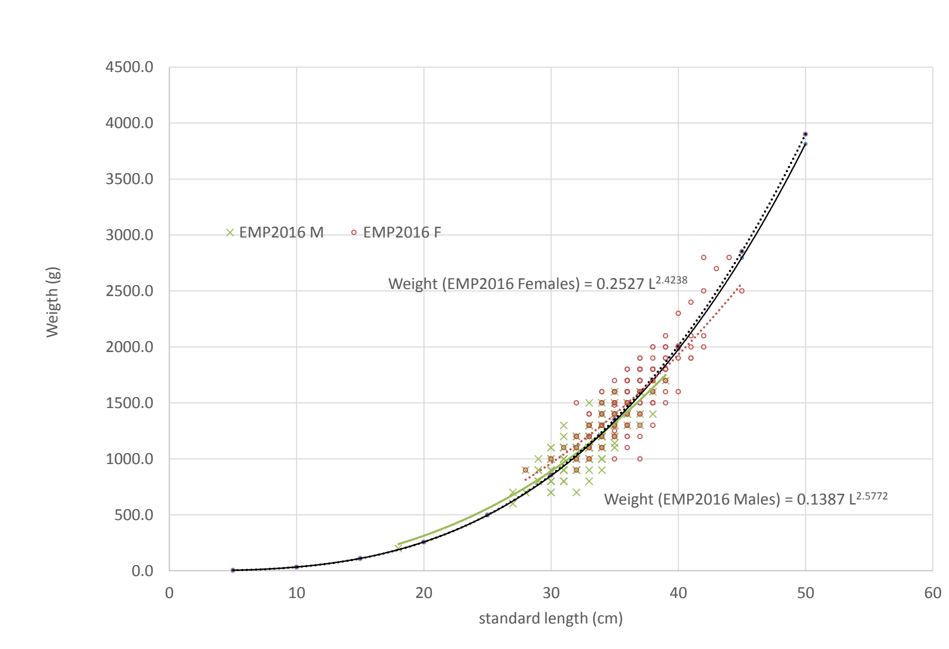

Figure 2-6 Standard length (cm) vs weight (g) for male and female orange roughy from EMP2016. The length-weight relationships as determined by Lyle *et. al,* (1991) for males and females are shown. Black dotted line is the relationship female weight (g) = 0.0351 length (cm) $^{2.97}$. The solid black line for male weight (g) = 0.0383 length (cm) $^{2.942}$. The length – weight relationships for male and female fish for EMP2016 are also shown (dotted red = females, solid green = males).

Given the difference in ship board weight between years of fish at the same length and sex the mean weight of fish was based on the Lyle et al. (1991) equation summarised in Table 2-9.

Table 2-9 Proportion of male and female fish at each ground and their associated weighted averages for fish weight (kg) for the 2016 Orange Roughy Eastern Zone Spawning population.

Spawning Ground	sex	Proportion	Average of Weight (kg)	No of Fish weighted	Estimated weight (kg) based on Lyle *et al.* (1991) repeated from above
St Helens	F	0.51	1.47	302	1.49
	M	0.49	1.14	286	1.18
St Patricks	F	0.69	1.47	107	1.50
	M	0.31	1.11	47	1.17
St Helens (F&M)	**F&M**	**0.79**	**1.31**	**588**	1.35
St Patricks (F&M)	**F&M**	**0.21**	**1.36**	**154**	1.40
SH and SP combined	**F**	**0.55**	**1.47**	**409**	1.49
SH and SP combined	**M**	**0.45**	**1.13**	**333**	1.18
Survey Total	**All fish**	**1**	**1.32**	**742**	1.36
St Helens (assuming 1:1 sex ratio)			**1.30**	**Avg of F & M**	1.34
St Patricks (assuming 1:1 sex ratio)			**1.29**	**Avg of F & M**	1.33

2.2.7 Age

Average age for both sexes and areas has stabilised since the decline observed in the early days of the fishery (Figure 2-7). Based on a linear model there has been a significant decline in average age ($p < 0.001$) for both areas and sexes from 1987 to 2016. Specifically the decline in age is - 0.6 per year for females at St Helens, - 0.4 per year for females at St Patrick, - 0.9 per year for males at St Helens and - 0.8 per year for males at St Patricks. However, average age of male and female fish at both grounds increased up to 5 years from the 2010 survey, with average age increasing from 2010 to 2012 and then decreasing from 2012 to 2016 for all fish except for female fish at St Patricks. Despite the observed variability between 2012 and 2016 there is indication that the decline in average age has stabilised. Based on a linear model the average age for female fish at St Patricks significantly increased by 0.8 per year ($p <.001$) from 2010 to 2016. The slight changes observed for the other time series were not significant (0.2 per year for females at St Helens, 0.7 per year for females at St Patricks, - 0.2 per year for males at St Helens and 0.1 per year for males at St Patricks).

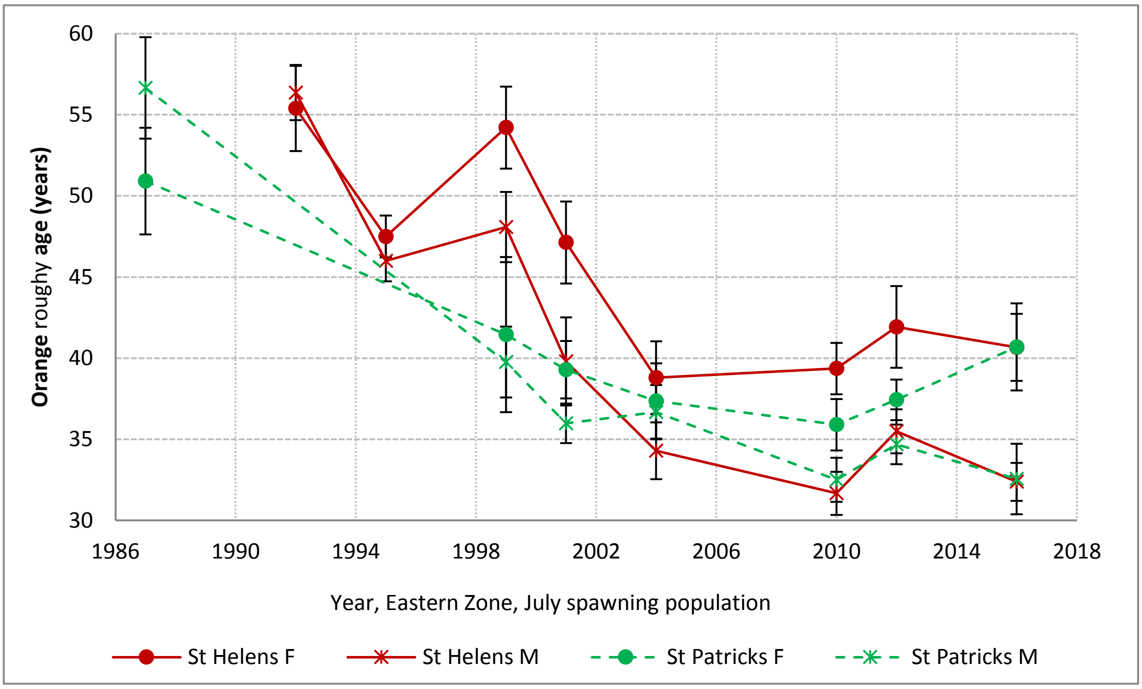

Figure 2-7 Average age of Orange Roughy males and females at St Helens and St Patricks from 1987 to 2016. Selection filter applied (Eastern Zone, July, spawning population). Error bars are 95% confidence intervals. Details of this index are given in Kloser et al. 2012.

The age structure for 2012 and 2016 was unimodal following the same trend to previous years with subtle differences between the two areas, sexes and years (Figure 2-8). There was variability between years and in general fish captured in 2012 were older than those captured in 2016, the biggest difference was for the male fish, where 50 % were older than 32 years in 2012 compared to 30 years in 2016. Female fish from 2012 and 2016 were older than those of the two previous surveys, with 50 % of female fish older than 36 years compared with 2004 and 2010 where 50 % of female fish were older than 33 years. For males the difference in age structure between 2016 and 2010 was not large with 50 % of males of fish captured older than 30 years and male fish captured in 2012 were generally older than those from 2010 and 2016. The general trend of younger fish at St Helens Hill in 2016 compared with 2012 is noteworthy and represents either biological driven changes in fish ages going to spawn and or an observation bias. Given this observation we suggest reviewing other years for age data to further clarify this variability.

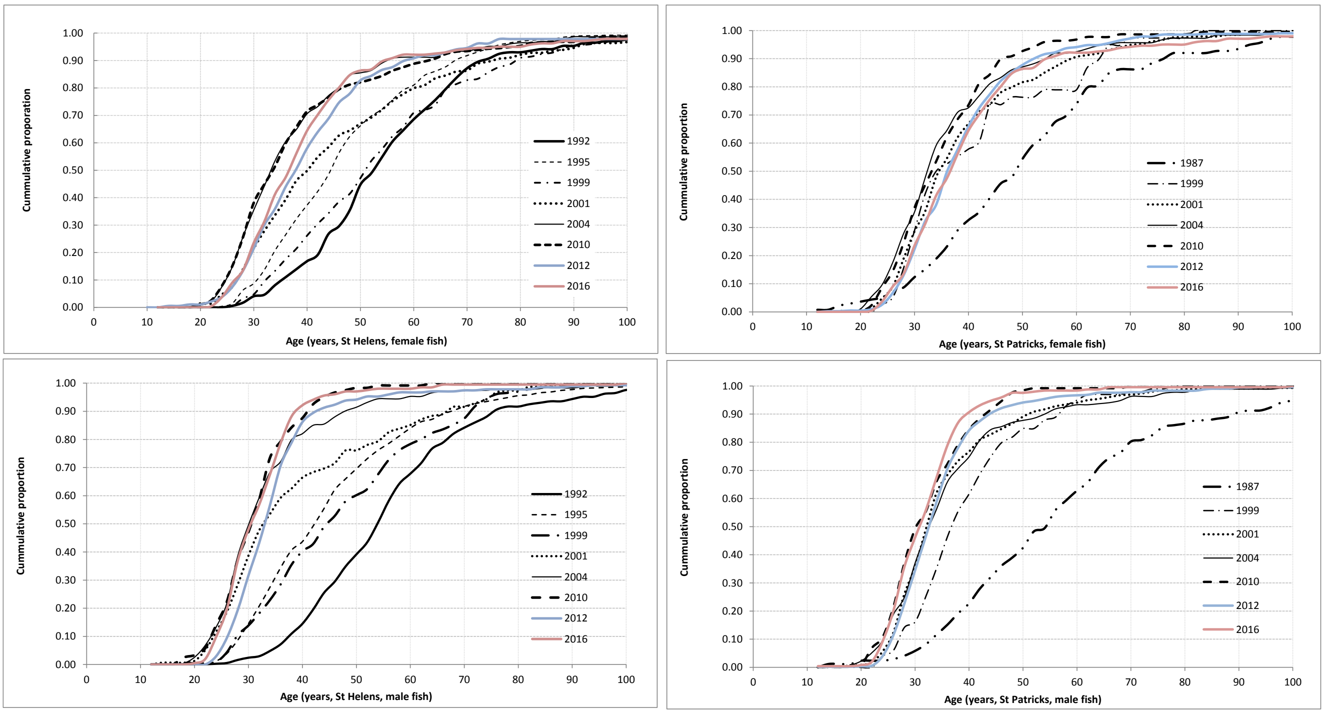

Figure 2-8 Cumulative proportion of orange roughy age (years) for female and male fish at St Helens and St Patricks from 1987 to 2016.

3 Acoustic surveys

3.1 Methods

Methods used were followed as outlined in Kloser et al. (2010) in order to remain consistent with the time series for the recovery monitoring program. Details of the methods are described in Kloser et al. (2010) and Ryan et al. (2014).

The key survey analysis inputs of absorption equation, target strength at 38 kHz and 120 kHz and weight to convert the acoustic data to biomass are given in Table 3-1.

Table 3-1 Acoustic survey analysis information to estimate biomass assuming a 1:1 ratio of male and females.

Acoustic Parameters		St Helens	St Patricks	Comment
Calibration		AOS at depth	Vessel	Refer to appendix A and Table 3.2
Absorption equation		F&G	F&G	Francois and Garrison
Length (cm)		34.7	34.7	Assumed M&F sex ratio 1:1
Target strength 38 kHz (dB re 1 m^2)		-52	-52	
Target strength 120 kHz (dB re 1m^2)		-48.2		
Weight (kg)		1.34	1.33	Derived from the length data
Survey design		grid interlaced	grid	Geometric survey mean for interlaced surveys
Survey CV	process error	geostatistics	geostatistics	Highest combined survey St Helens and St Patricks within 24 hrs
Survey CV	observation error	average	average	Between survey variability

The acoustic calibration parameters used for the analysis were based on recent and historic calibration data for the transducers (Table 3-2, Appendix A). Importantly a new deep-water calibration facility (DECAF) has independently measured the beamwidth at depth and used to calculate the equivalent beam angle (EBA). The results differed significantly from the manufactures calculated EBA values by 18 % for the 38 kHz transducer and 5% for the 120 kHz transducer. These new measurement translate to an 18% and 5% increase in biomass for all 38 kHz and 120 kHz surveys respectively where these transducer were used. This effects the 2013 and 2016 surveys and the biomass estimates for these surveys have been updated accordingly.

Table 3-2 Acoustic calibration parameters for the AOS at a mean depth of 600 m and vessel used in the analysis, refer to Appendix A for details.

AOS calibration parameters	**38 kHz**	**120 kHz**
Serial number	28362	109
EBA (dB re 1 ster.)*	-20.89	-20.48
Gain (dB)	24.33	27.49
Sa corr. (dB)	-0.53	-0.31
Sound speed m s^{-1}	1493	1493
Absorption (dB/m)	0.00946	0.03337
Beam width (deg.)	6.9	7.2
Vessel calibration		
EBA (dB re 1 ster.)	-20.53	
Gain (dB)	26.55	
Sa corr. (dB)	-0.46	
Sound speed (m s^{-1})	1504	
Absorption (dB m)	0.00934	
Beam width (deg.)	7.1	

***Measured value based on deep water calibration of beam pattern- Appendix A**

3.2 Results

During the voyage there were four St Helens' AOS surveys and three St Patricks' vessel surveys with several AOS single pass species identification tows. A large body of fish was seen at St Helens that appeared to go deeper during the surveys (Figure 3-1). The noise performance of the AOS system for the 38 kHz and 120 kHz was improved from previous years and low noise recordings achieved on the 120 kHz system to 500 m range (Figure 3-1). The orange roughy inferred marks from the vessel sounder at St Patricks were dynamic and appeared high in the water column at times that were verified as orange roughy using the AOS (Figure 3-3).

The surveys and biological sampling at St Patricks and to a lesser extent St Helens were influenced by a strong ~2 knot current to the south of high temperature surface water (17 deg.). This was due to the very large warm water eddy that was sitting off the coast at the time (Figure 3-2).

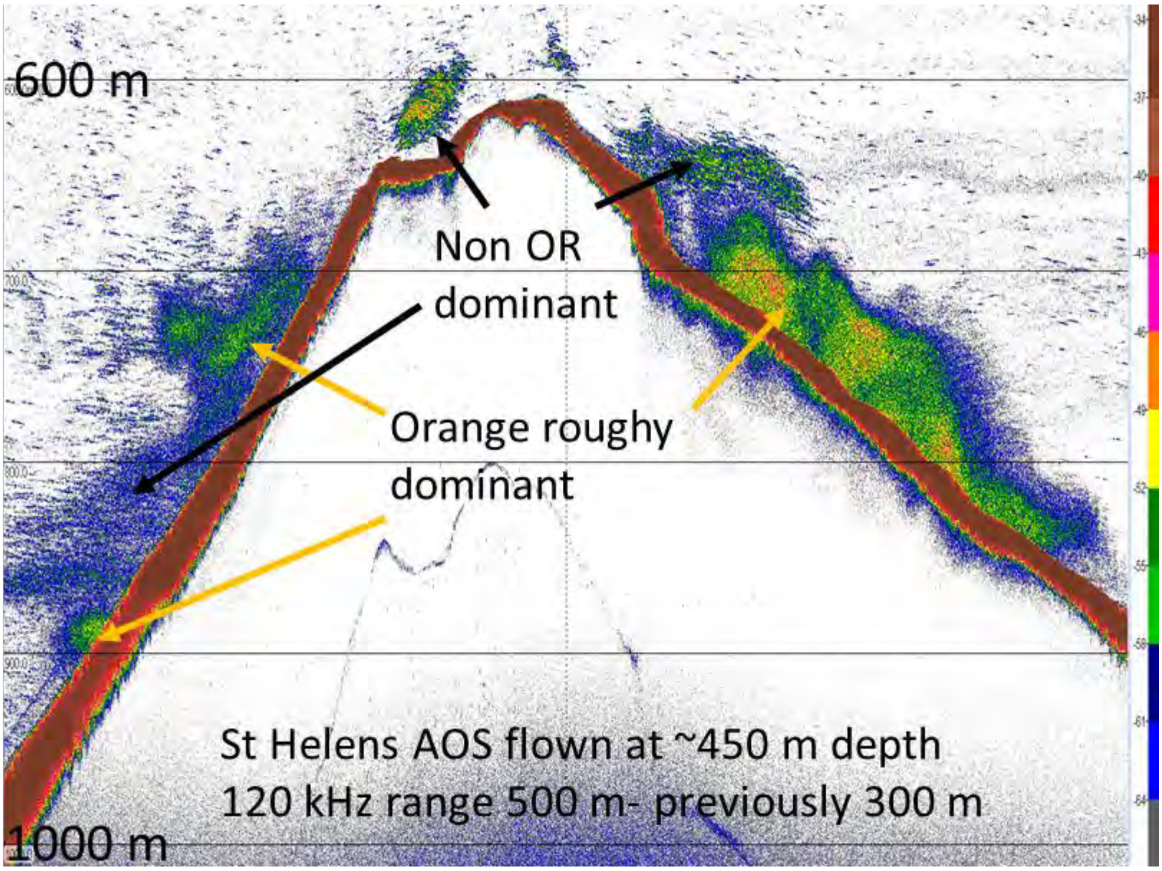

Figure 3-1 St Helens Hill example of Acoustic Optical System (AOS at ~500 m depth) data highlighting the orange roughy school for Operation 08 Transect 5, frequency 120 kHz south to north. Note the very good signal to noise achieved for the 120 kHz transducer improved by ~6 dB on previous years. Transect position and orange roughy relative biomass along transects shown in Figure 3-5. Identification of orange roughy dominant schools based on 38 kHz and 120 kHz frequency differencing, Kloser et al. (2013).

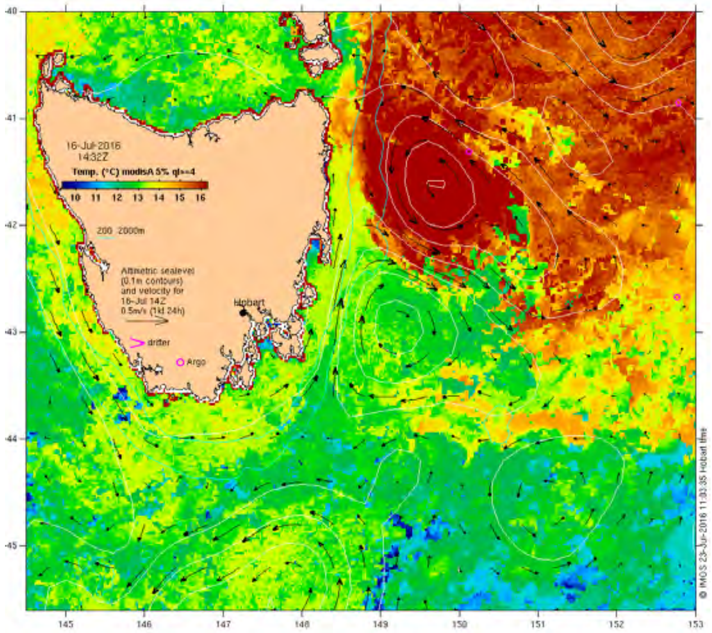

Figure 3-2. Large warm water eddy off the East coast of Tasmania that generated a strong southerly current of warm surface waters making deployment and retreival of gear challenging at times. The influence of this eddy on the spawning population is unknown.

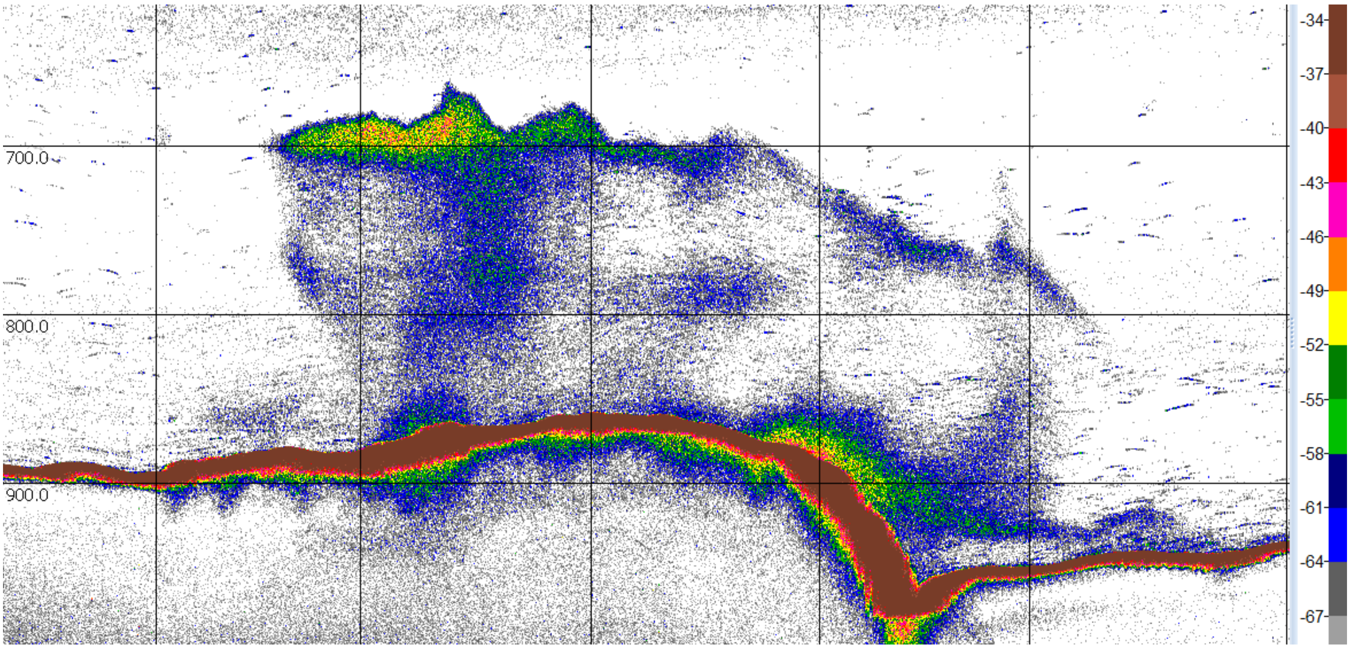

Figure 3-3 St Patricks Head example of Acoustic Optical System 120 kHz (AOS at ~500 m depth) data used to verify the vessel mounted surveys highlighting the orange roughy school observed 150 m above the seabed linking to the seafloor.

A summary of all the surveys highlights the 4 fold difference in biomass between the St Helens Hill and St Patricks grounds (Figure 3-4).

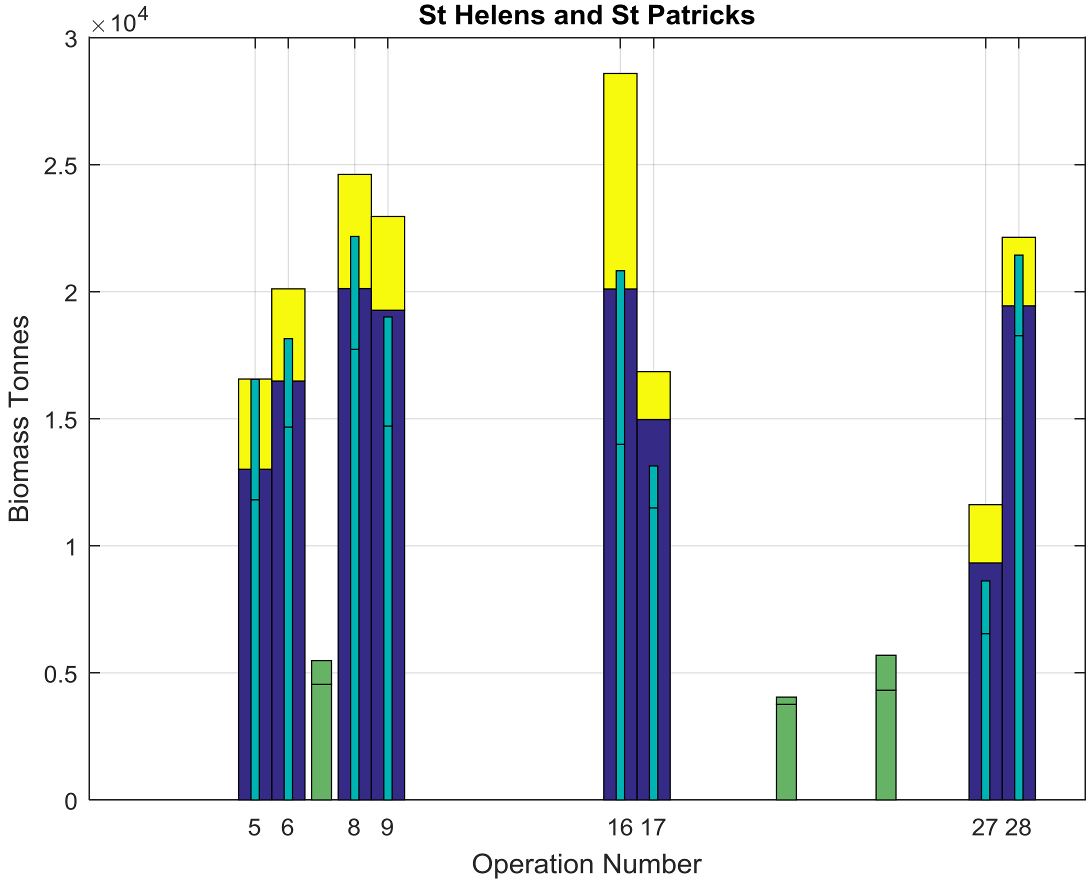

Figure 3-4. Summary of the survey biomass estimates for the various operations for St Helens 38 kHz, dark blue above seabed echo and yellow estimate of biomass in the "dead zone". The 120 kHz biomass estimate is shown as the narrow aqua bar with the above and "dead zone" biomass estimates separated by a bar. The St Patricks biomass estimates are in green with the above and "dead zone" biomass estimates separated by a bar.

3.2.1 St Helens Hill

The survey strategy at St Helens involved interlaced transects where the odd and even were done separately (Figure 3-4, Figure 3-5). This was done for two reasons; first it enabled the AOS to be checked after each even and odd survey to ensure it was functioning correctly and secondly it enabled the survey mean to be determined using a combined and interlaced mean method to check if fish movement was a factor for the surveys. As there was no statistical difference between the non-interlaced and interlaced means only the non-interlaced means are reported. The survey estimates ranged from 15 000 tonnes to 22 700 tonnes between 4 surveys and two frequencies. The mean of the four surveys was 20 400 tonnes and 17 500 tonnes respectively with a combined frequency estimate of 19 000 tonnes and a CV of 10% (Table 3-3).

The position of the schools at St Helens changed during the voyage with schools seen on both the northern and southern sides of the Hill in the earlier surveys. During the latter two surveys more fish were concentrated in the northern sector (Figure 3-5). Compared to the 2013 survey the positions of schools remained relatively stable throughout the voyage with the highest consistent concentration in the northern central region.

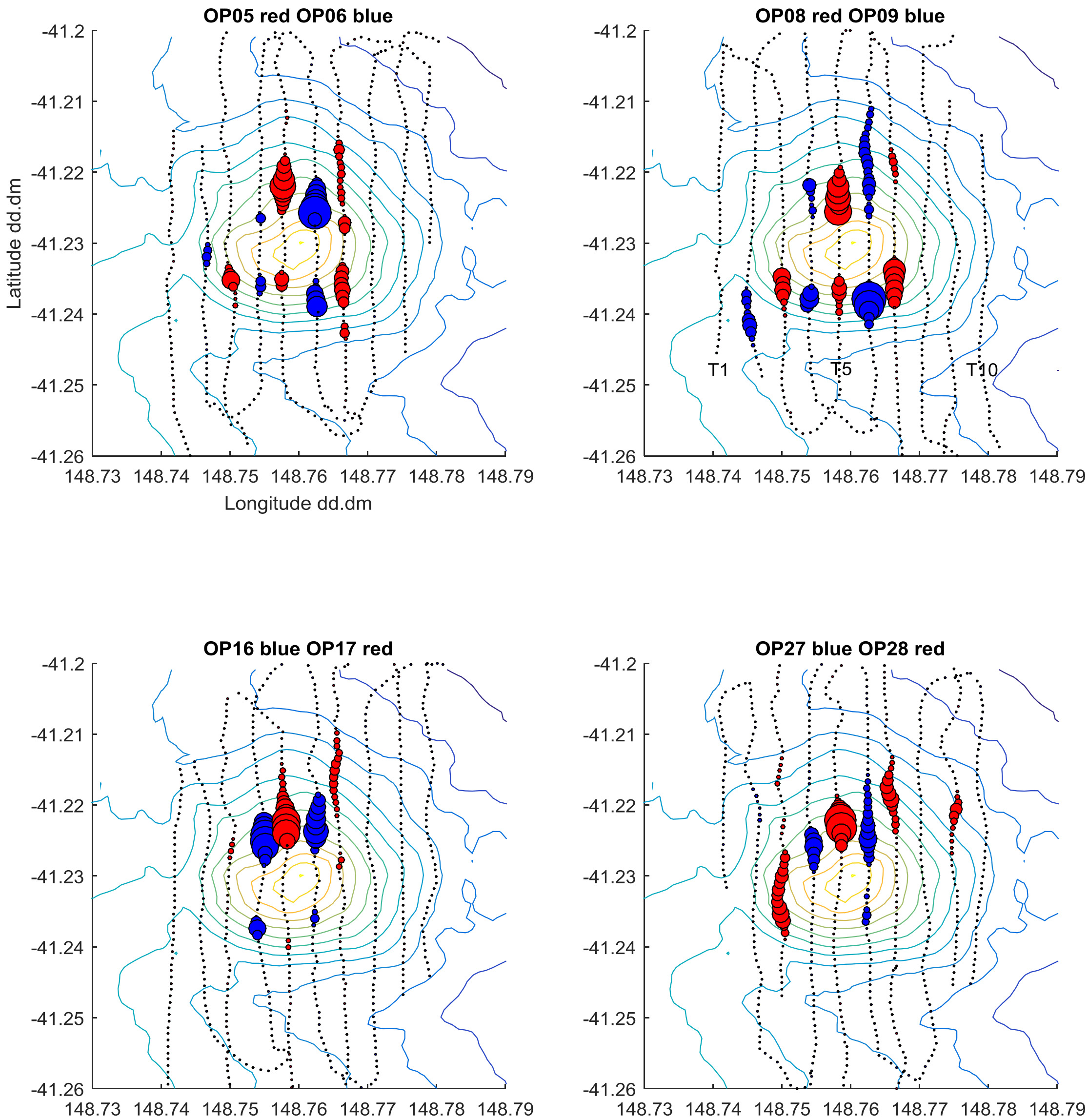

Figure 3-5 Maps of the relative biomass of orange roughy at 38 kHz using the net attached AOS at St Helens Hill along the odd transects (red) and even transects (blue) for the surveys summarised in Figure 3-4 and Table 3-3. Underlay of the bathymetry contours in 50 m intervals, 600 to 1200 m. Echogram of transect 5 (T5) for OP08 is shown in Figure 3-1.

Table 3-3 Summary of St Helens Hill surveys at 38 kHz and 120 kHz for the above deadzone echo biomass, deadzone (DZ) biomass and total biomass in tonnes with estimated coefficient of variation (CV). Maximum survey at St Patricks and St Helens is highlighted in italicised bold assuming process error dominates the survey variability. The observation mean of the 38 kHz, 120 kHz and combined frequency surveys is highlighted in bold.

Date UTC	OP	Freq. kHz	Biomass (t) above DZ	Biomass (t) DZ	Biomass (t) Total	CV	DZ %
15-Jul	5-6	38	14751	3589	18340	0.21	20
		120	13245	4109	17354		24
16-Jul	***8-9***	***38***	***19700***	***4090***	***23790***	***0.18***	***17***
		120	***16223***	***4368***	***20592***		***21***
19-Jul	16-17	38	17541	5182	22723	0.20	23
		120	12744	4242	16986		25
21-Jul	27-28	38	14387	2494	16882	0.16	15
		120	12411	2620	15031		17
Mean		**38**	**16595**	**3839**	**20434**	**0.16**	**19**
		120	**13656**	**3835**	**17491**	**0.13**	**22**
Observation error mean combined frequencies					**18962**	**0.10**	

St Patricks

At St Patricks three vessel 38 kHz surveys were done with a combined mean biomass of 5 100 tonnes and a CV of 18% (Table 3-4). Maps of the distribution of identified orange roughy schools shows that the fish were dynamic between surveys and moved from the deeper depths to shallow depths between surveys (Figure 3-6). This movements of schools made survey sampling more challenging and dynamic to capture the extent of the population.

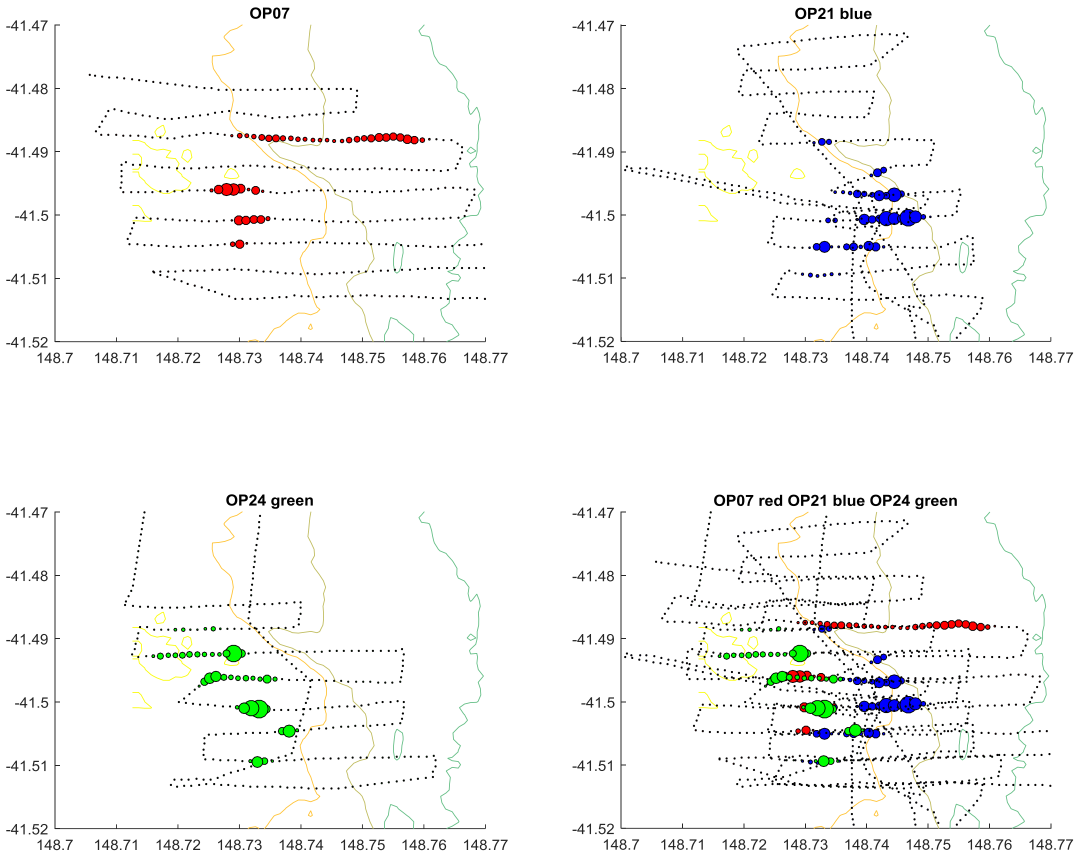

Figure 3-6 Maps of the relative biomass of orange roughy at St Patricks Head along transects with the vessel mounted 38 kHz transducer for the surveys summarised in Figure 3-4 and Table 3-4. Underlay of the bathymetry contours in 50 m intervals, 600 to 1200 m.

Table 3-4 Summary of the biomass estimates from St Patricks ground using the vessels 38 kHz transducer.

St Patricks surveys Date UTC	OP	Biomass (t) 38 kHz	Biomass (t) DZ	Biomass (t) total	DZ%
16-Jul	7	4548	936	5485	17
20-Jul	21	3762	285	4047	7
20-Jul	24	4317	1377	5694	24
			Mean biomass	**5075**	16
			CV	**0.18**	

3.2.2 Combined ground biomass

The combined biomass for the two grounds can be estimated in two ways assuming either observation or process errors dominate.

If observation error dominates it assumes that fish are equally available between surveys and the average of all the surveys would be a good indication of the biomass from both St Helens and St Patricks' grounds. If this is the case then the combined biomass (38 kHz and 120 kHz averaged) at both grounds is 24 000 tonnes with a CV of 12%.

If process error dominates and it is the availability of fish to the acoustic survey that causes most variation between surveys then the maximum biomass within a 24 hour window is the best estimate of the biomass. In this case for the 38 kHz frequency it is 29 600 tonnes with a CV of 21% or 27 700 tonnes (CV 18%) for the mean of the 38 kHz and 120 kHz surveys.

Table 3-5 Biomass estimates based on 38 kHz and 120 kHz AOS surveys at St Helens Hill and 38 kHz vessel St Patricks Head surveys. Estimates based on the maximum biomass scenarios for total biomass (addition of above acoustic bottom and estimated deadzone component Table 3-3).

	Operation	120 kHz biomass(tonnes)			38 kHz biomass(tonnes)			CV
		OR1	DZ	Total	OR1	DZ	Total	
St Helens	8-9	16223	4368	20592	19700	4090	23790	0.18
St Patricks 38 kHz	7	4788	985	5773	4788	985	5773	0.35
Combined biomass		**21011**	**5354**	**26365**	**24487**	**5076**	**29563**	**0.21**

4 Discussion

Based on the 2016 surveys there has been a large factor of two increase in biomass observed at St Helens Hill from that estimated in 2013 and higher than that observed in 2010. At St Patricks Head the estimate of biomass has remained relatively constant (considering survey CV's) for the past four survey years, and previous to that there were major variations (Table 4-1 and Figure 4-1). Based on the long term series of surveys from 1990 to 2016 the 2016 survey results are consistent with a recovering fishery and the snapshot biomass estimate is higher than the total spawning population predicted by the 2014 stock assessment model (Figure 4-1).

The 120 kHz biomass estimates were approximately 10% less than the 38 kHz estimates and consistent with previous surveys (Ryan and Kloser 2016). This difference between 38 kHz and 120 kHz biomass estimates indicates a source of bias in one or both data sets. After the survey a calibration change was observed in the 120 kHz system but this appeared to have happened after the survey (Appendix A). Until the source of bias is found the average of the 38 kHz and 120 kHz estimates is recommended. The combined ground estimate (averaged over frequencies) is 28 000 tonnes (CV 0.21) assuming process error dominant and 24 000 tonnes (CV 0.12) assuming observational error dominant.

Table 4-1 Biomass series based on the 38 kHz biomass estimate (maximum within 24 hrs with DZ included) at St Helens Hill and St Patricks Head from 1999 to 2016 and proportion of total at St Helens Hill (Kloser et al. 2015). Note 2013 result adjusted due to new EBA calibration result based on this report.

	Year					
Location	1999	2006	2010	2012	2013	2016
St Helens Hill	5200	10280	19200	12058	11265	23790
St Patricks Head	14773	1456	6200	7136	6458	5773
Percentage at St Helens Hill	26	88	76	63	64	80
Total (tonnes)	19973	11736	25400	19194	17723	29563

In this report we have altered two methods that should be noted. Firstly, we altered how weight of fish is calculated by using measured fish length and the Lyle et al. (1991) length to weight equations. This was done to reduce bias (~5%) from shipboard measured weights that were not consistent with changes in length. We recommend that all fish weights for previous years be calculated using this methods and adjustment to the acoustic series done accordingly. The second method change was to use the Equivalent Beam Angle (EBA) calculated from our new deep-water calibration measurements. This has had the effect of altering the 2013 and 2016 surveys by 18% and 5% for the 38 kHz and 120 kHz surveys respectively. We recommend that checks are done on previous transducers' EBA where possible and in the future calibrations of the beam pattern done at depth for all new transducers.

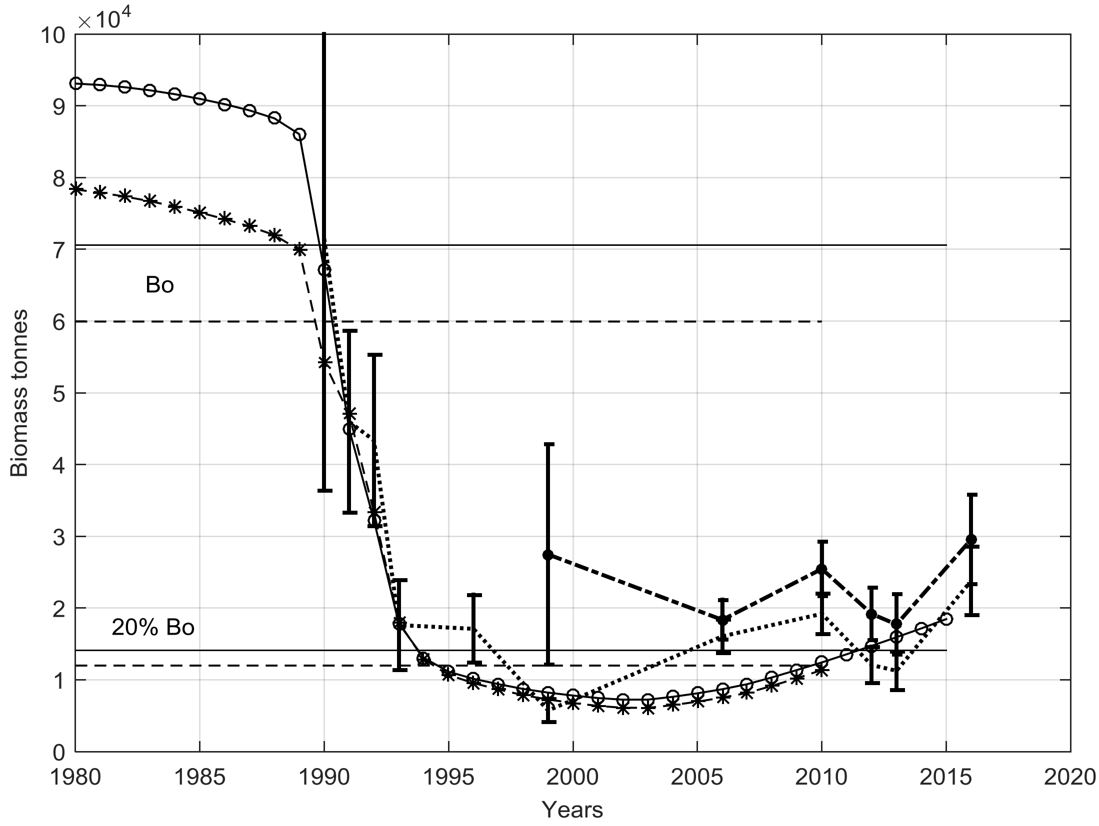

Figure 4-1 Estimated change in spawning biomass at St Helens Hill (dashed line, s.d. solid line) based on a vessel mounted survey in 1990 and towed body surveys from 1991 to 2016 (Table 5 Kloser et al. 2015 and Table 4-1). Combined St Patricks and St Helens spawning orange roughy estimate of acoustic biomass in 1999, 2006 to 2016 (dot dashed line, s.d. solid line). Stock assessment model in 2006 for spawning biomass of orange roughy prior to updated acoustic biomass estimates due to change in target strength (star, dashed line) and the 2014 stock assessment model that includes target strength and acoustic surveys up to 2013 (circle, solid line) Kloser et al. (2015).

The general trend of younger fish at St Helens Hill in 2016 compared with 2012 is noteworthy and represents, either biological driven changes in fish ages going to spawn and or an observation bias. Given this observation we suggest ageing otoliths collected in other years to help further clarify this variability and its potential influence on the stock assessment model.

Appendix A Calibration report

AOS calibration

The application of AOS for Orange Roughy biomass survey require deep-water calibration of the transducers to ensure unbiased estimates of biomass (Simmonds and MacLennan, 2005). Accordingly, the transducers were routinely installed on a Deepwater Calibration Acoustic Facility (DeCAF) to examine the depth-dependent variations in the echosounder on-axis gain G_0 (dB re 1). The calibration deployments were conducted before and after the biomass survey. The G_0 and equivalent two-way beam angle Ψ (dB re 1 sr) of the transducers (adjusting for the difference in sound speed at 600 m) were applied in the echo-integration based biomass estimation.

Echosounder calibrations

The DeCAF system as described in Malan et al. (2016) was used to calibrate the transducers (Table 1) simultaneously from the surface down to 800 m water depth. The DeCAF deployments were conducted in suitable weather conditions (> 1100 m water depth) with calibration stopovers at 100 m depth intervals (Figure 1). The overall on-axis performance of the echosounders were evaluated by the established sphere calibration methods (Demer et al., 2015) by adjusting the G_0 and filter attenuation correction factor $S_a corr$ (dB re 1).

The recorded calibration data files were processed using a custom *Matlab-Echoview* software suite that was developed to facilitate the analyses. The raw data were first exported to *Echoview* post-processing software [version 6.1 or higher; Echoview (2015)]. A multi-frequency calibration *template* was used to extract the necessary data required for the analyses. The resulting sphere target strength (TS; dB re 1 m^2) and associated GPT settings were processed within *Matlab* using a Graphical User Interface (GUI). The GUI enabled the user to dynamically adjust parameters (such as the on-axis criteria, TS limits, and depth ranges) to export results in a systematic way.

The established intrinsic non-linear changes in the sphere TS with depth were characterized by a polynomial variation in G_0 (Ryan and Kloser, 2016; Ryan et al., 2009). This polynomial function was integrated in the GUI to calibrate *in situ* TS at each depth with an on-axis criteria $\leq$ 0.3 dB.

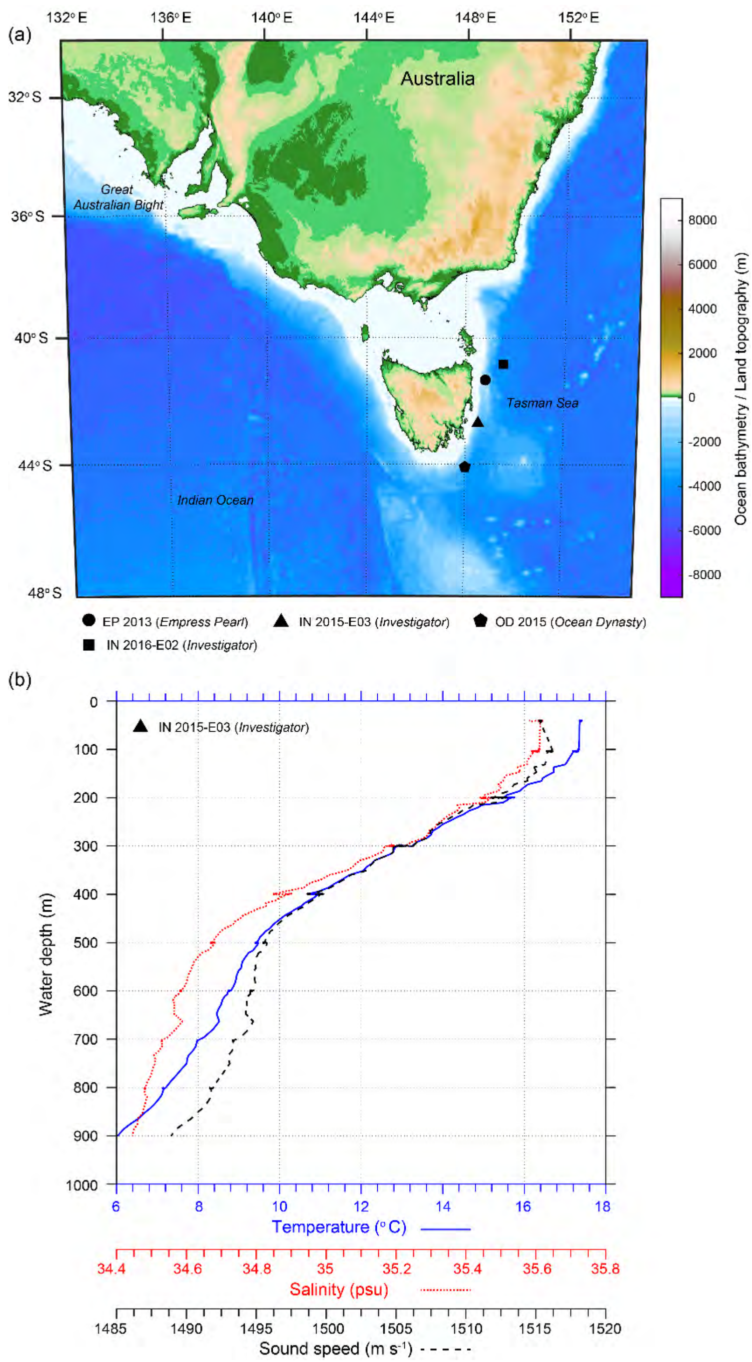

Figure 1. The map shows the geographic location of the calibration deployments using the DeCAF (IN 2015-E03, OD 2015, and IN 2016-E02) and AOS (EP 2013) systems. The environmental parameters were measured during all the deployments and utilized in the respective calibration analyses.

Table 1. Transducer specifications.

Transducer specifications		
Transducer model	Simrad ES38-DD	Simrad ES120-7CD
Serial number	28362	109
Frequency (kHz)	38	120
Nominal beamwidth (°)	7.4\7.5	7.4\7.3
Nominal Ψ (dB re 1 sr)	–20.2	–20.3

Results

The depth-dependent calibrated G_0 variations of the echosounding systems are in accordance with the available deep-water calibration results, demonstrating reasonable repeatability (Figure 2) of transducer measurements over the years (except for 120 kHz calibration results in IN 2016-E02). The 120 kHz sphere TS acquired during IN 2016-E02 was observed to be nearly –2 dB less sensitive as compared to the remaining deployments. Accordingly, the biomass estimations at 38 and 120 kHz were achieved using the results of IN 2015-E03 and OD 2015 respectively.

The calibration results at 38 and 120 kHz are tabulated in Table 2 and 3 respectively. The summary of calibration parameters utilized in the biomass estimations are given in Table 4.

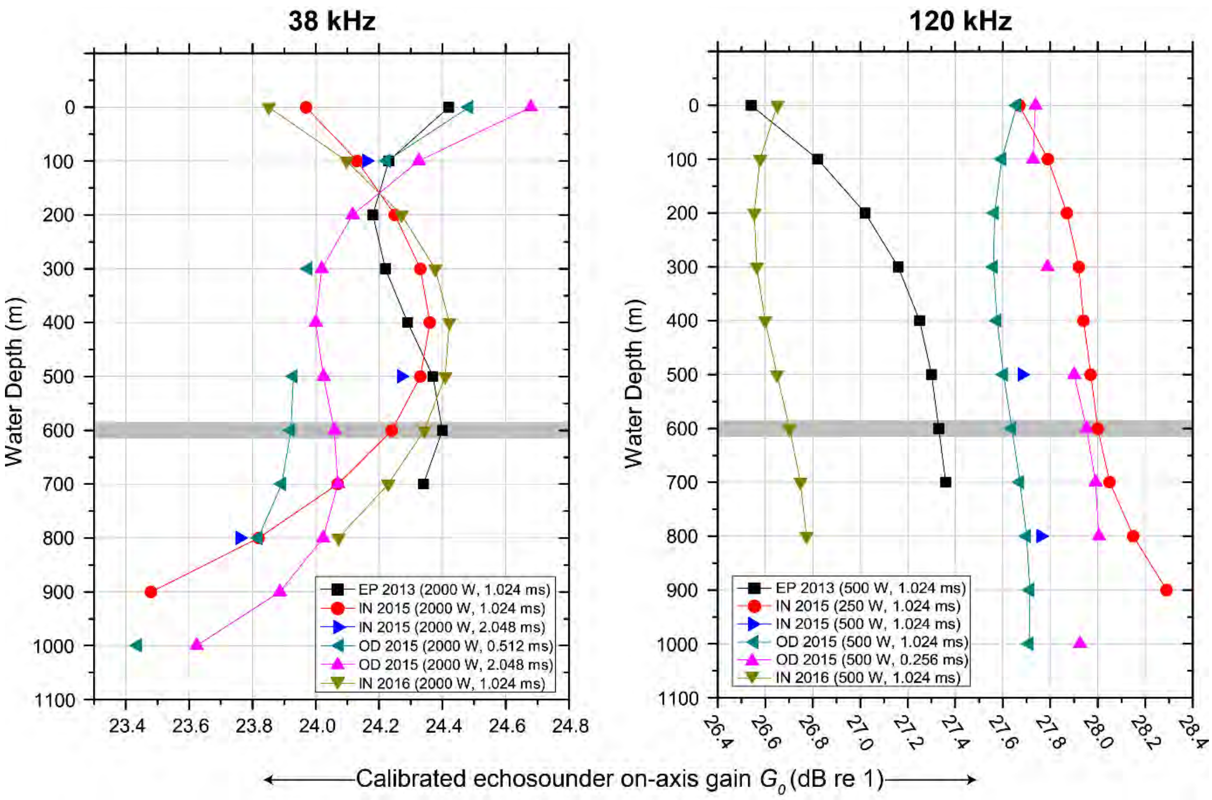

Figure 2. Represents depth-dependent repeatability in calibrated G_0 over the calibration deployments.

Table 2. Calibration results for combined up and down calibration deployments at 38 kHz (IN 2015-E03). Values used for final calibration are highlighted.

Transducer serial number:	ES38-DD 28362									
Transducer tank Ψ:	–20.2									
Depth bins	0	100	200	300	400	500	600	700	800	900
Targets	14270	9092	5577	5692	3731	10040	4653	2644	4278	3269
G_0	24.06	24.06	24.31	24.36	24.32	24.30	24.29	24.06	23.81	23.51
$S_a corr$	-0.55	-0.57	-0.60	-0.51	-0.53	-0.57	-0.57	-0.54	-0.49	-0.42
G_0 (poly)	23.97	24.13	24.25	24.33	24.36	24.33	24.24	24.07	23.82	23.48
$S_a corr$ (poly)	-0.56	-0.55	-0.55	-0.56	-0.56	-0.56	-0.55	-0.53	-0.49	-0.42

Table 3. Calibration results for combined up and down calibration deployments at 120 kHz (OD 2015). Values used for final calibration are highlighted.

Transducer serial number:	ES120-7CD 109									
Transducer tank Ψ:	–20.3									
Depth bins	0	100	200	300	400	500	600	700	800	900	1000
Targets	19	32	23	35	12	57	37	49	15	15	35
G_0	27.57	27.62	27.66	27.52	27.63	27.56	27.59	27.72	27.74	27.69	27.69
$S_a corr$	-0.37	-0.38	-0.33	-0.28	-0.26	-0.29	-0.35	-0.36	-0.30	-0.24	-0.22
G_0 (poly)	27.65	27.59	27.56	27.56	27.57	27.60	27.63	27.67	27.69	27.71	27.71
$S_a corr$ (poly)	-0.43	-0.35	-0.31	-0.29	-0.30	-0.31	-0.33	-0.33	-0.32	-0.29	-0.22

Table 4. Summary of calibration parameters used for biomass estimation at 600 m.

Final calibration parameters				
Transducer model	Simrad ES38-DD	Simrad ES120-7CD		
G_0 (dB re 1)	24.29	27.59		
$S_a corr$ (dB re 1)	–0.57	–0.35		
Adjusted Ψ (dB re 1 sr)	–20.16	–20.25		
Absorption (dB m^{-1})	0.0093	0.0338		
Sound speed (m s^{-1})	1494	1495		
38 kHz				
	x d^3	+ x d^2	+ x d	+ c
G_0 polynomial parameters	-1.37548e-09	-1.22856e-06	0.00167556	23.9715
$S_a corr$ polynomial parameters	8.31257e-10	-7.78144e-07	0.000181693	-0.563257
120 kHz				
G_0 polynomial parameters	-1.07049e-09	1.93084e-06	-0.00080898	27.6591
$S_a corr$ polynomial parameters	1.51381e-09	-2.31502e-06	0.00101742	-0.436243

Monitoring echosounder performance

It is inevitable that the performance of deep-water transducers and associated electronic components may degrade gradually or abruptly over a prolonged period of time owing to a combination of factors including: the system electronics, ageing effects, data acquisition settings (power, pulse length, and range to the calibration sphere), environmental conditions (air bubbles, temperature, and pressure) in the survey area, density and composition of the calibration sphere, and position of the target sphere within the acoustic beam (Demer et al., 2015).

A brief summary of historic calibration parameters for 38 (Table 5) and 120 kHz (Table 6) transducers at the 600 m water depth is provided to evaluate the echosounder performance. The related variations in calibrated G_0 and $S_a corr$ at 600 m are displayed in Figure 3.

Table 5. Summary of historic calibration parameters for 38 kHz transducer at 600 m including the wharf side calibrations.

Transducer model	Simrad ES38-DD					
Frequency (kHz)	38					
Voyage	EP 2013	IN 2015-E03	OD 2015	Wharf	Wharf	IN 2016-E02
Date	18/07/2013	22/04/2015	10/09/2015	04/07/2016	05/08/2016	18/12/2016

Data acquisition settings								
Power (W)	2000	2000	2000	2000	2000	2000	2000	2000
Pulse length (ms)	1.024	1.024	2.048	0.512	2.048	1.024	1.024	1.024
Calibration parameters								
G_0 (dB re 1)	24.37	24.29	24.27*	23.93	24.13	24.18	24.24	24.34
$S_a corr$ (dB re 1)	-0.49	-0.57	-1.47*	-0.67	-0.40	-0.62	-0.77	-0.79
Adjusted Ψ (dB re 1 sr)	-20.17	-20.16	-20.15*	-20.16	-20.16	-	-	-20.16
Absorption (dB m^{-1})	0.00946	0.00938	0.00942*	0.00945	0.00945	-	-	0.00941
Sound speed (m s^{-1})	1493	1494	1496*	1493	1493	-	-	1494

* At 500 m.

Table 5. Summary of historic calibration parameters for 120 kHz transducer at 600 m including the wharf side calibrations.

Transducer model	Simrad ES120-7CD							
Frequency (kHz)	120							
Voyage	EP 2013	IN 2015-E03		OD 2015		Wharf	Wharf	IN 2016-E02
Date	18/07/2013	22/04/2015		10/09/2015		04/07/2016	05/08/2016	18/12/2016
Data acquisition settings								
Power (W)	500	250	500	500	500	500	500	500
Pulse length (ms)	1.024	1.024	1.024	1.024	0.256	1.024	1.024	1.024
Calibration parameters								
G_0 (dB re 1)	27.38	27.99	27.69*	27.59	27.88	27	25.91	26.70
$S_a corr$ (dB re 1)	-0.25	-0.35	-0.32*	-0.35	-0.59	-0.60	-0.34	-0.32
Adjusted Ψ (dB re 1 sr)	-20.26	-20.25	-20.24*	-20.26	-20.26	-	-	-20.25
Absorption (dB m^{-1})	0.03337	0.03381	0.03526*	0.0339	0.0339	-	-	0.03353
Sound speed (m s^{-1})	1493	1494	1496*	1494	1494	-	-	1494

* At 500 m.

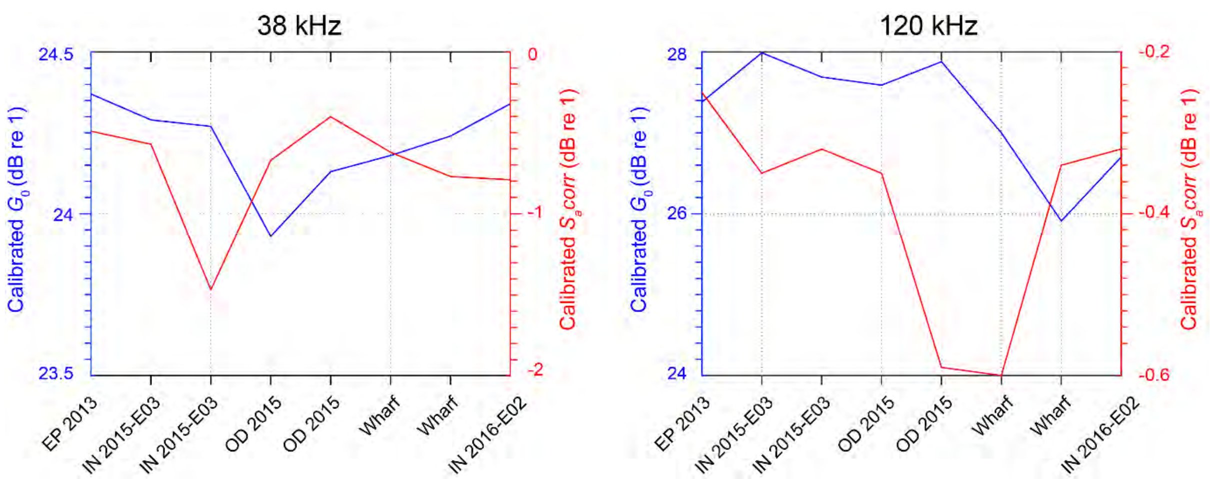

Figure 3. Represents variations in calibrated G_0 and $S_a corr$ (at 600 m) over the calibration deployments. The wharf side calibrations are also included to monitor the performance.

Computation of accurate Ψ

The equivalent two-way beam angle Ψ (dB re 1 sr) of the transducer is an important calibration parameter in echo-integration based biomass estimation. It was assumed that the manufacturer specified Ψ is correct (adjusting for the difference in sound speed) due to the difficulty in obtaining an independent measurement. Recently, using the DeCAF the system we have computed the accurate Ψ by comprehensive mapping of the transducer beam pattern. The measured Ψ of both the transducers are observed to be consistently lower than the nominal values specified by the manufacturer, of note in ES38-DD (Figure 4).

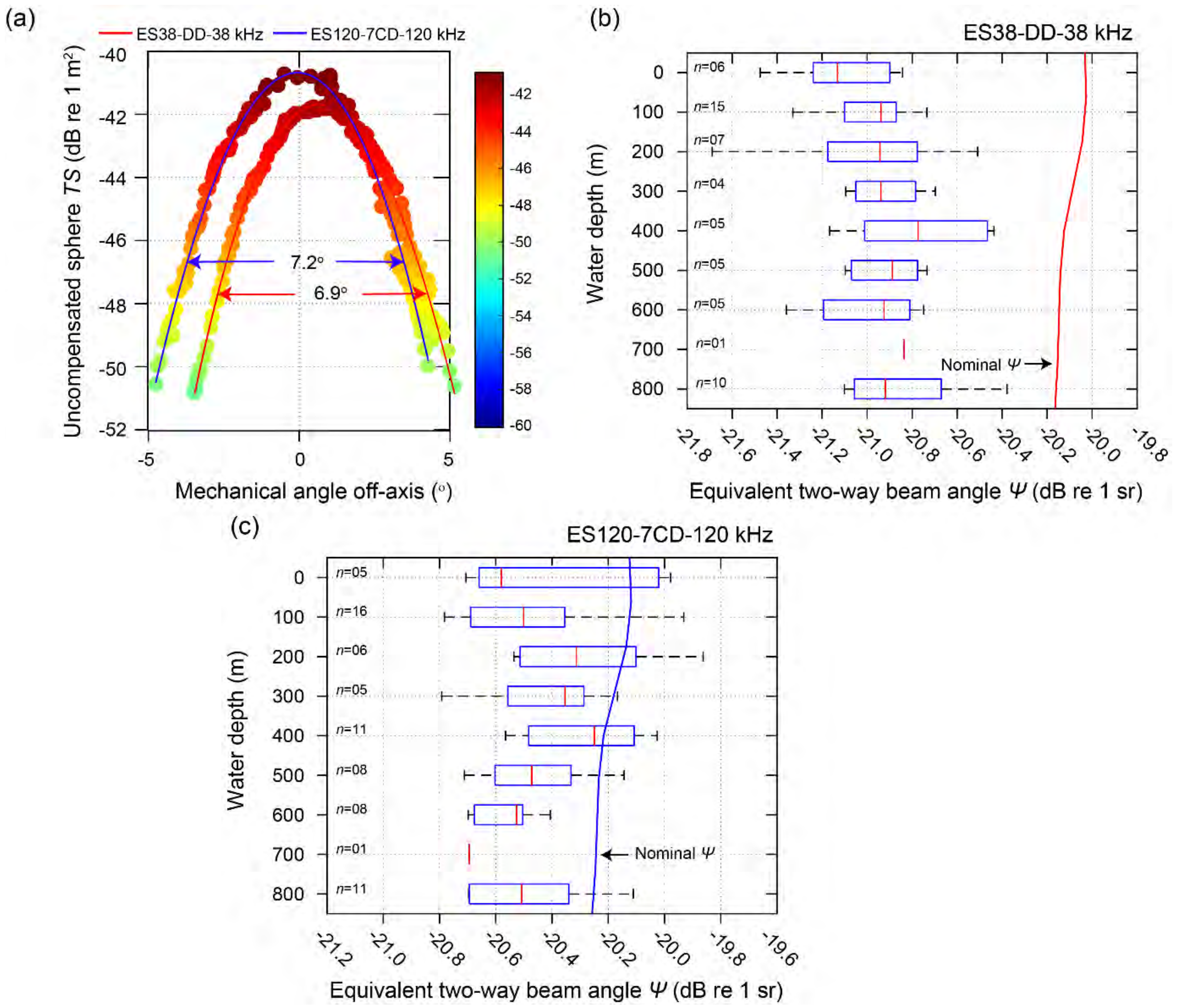

Figure 4. (a) Typical two-way beam pattern characteristics of the transducers are represented as a function of DeCAF mechanical angles off-axis. The box plots represent depth vs. Ψ variation for (b) ES38-DD and (c) ES120-7CD transducers. The vendor specified nominal Ψ values are juxtaposed to assess the accuracy.

Appendix B Bycatch composition

Table 4-2 Bycatch composition by weights (kg) for the orange roughy Eastern

															Totals (kg)		
	St Helens shots (kg)											St Patricks shots (kg)			SH	SP	Survey
Species	**10**	**11**	**14**	**15**	**18**	**25**	**26**	**30**	**31**	**33**	**34**	**19**	**20**	**22**			
Basketwork eel					2										2		2
Blue Grenadier	1	5	1	5				22	18	5				2	57	2	59
Briar shark					8					1			13		9	13	22
Cardinal fish						2		13	2	8	2				27		27
Johnsons Cod	29	22	33	3	15		50	73	80	7	12	1		1	324	2	326
Longnose velvet dogfish							30	4		6				8	40	8	48
octopus			2												2		2
Orange Roughy	390	1470	1170	1200	2490	130	9030	570	480	1170	465	240	50	390	18565	680	19245
Pacific spookfish					2										2		2
Plunkets dogfish					16				40		10				66		66
Ribaldo	1				5			1	3	1	1	2			12	2	14
Rudderfish													1			1	1
Smooth oreo	1						11								12		12
Southern Chimaera							1	4					6		5	6	11
Southern lantern shark	1	2	7		86		1	11	5	30	15				158		158
Spikey Oreo	1	2	1	6	8	1	4	22	10	5		4			60	4	64
squid				2	2						4				8		8
Warty Oreo	1	2		1		3	1	1							9		9
Whiptail			1		1		1				4	1		1	7	2	9
Totals	425	1503	1215	1217	2635	136	9129	721	638	1233	513	248	70	402	19365	720	20085

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