ORH7B Cook Canyon Acoustic Biomass Survey, June/July 2019

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Fisheries Support

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Executive summary

The Cook Canyon region was visited four times by the commercial fishing vessel *Amaltal Mariner* over a three-week period between the 26th June and 16th of July to conduct surveys of orange roughy (*Hoplostethus atlanticus*). Each visit took approximately 24 hours which combined vessel-based acoustic transect surveys and demersal trawl shots to support echogram interpretation and provide biological samples. 700 otolith pairs were retained for age analysis. Spawning condition was measured and indicated that the acoustic surveys had been carried out through the peak-of-spawn period. Eight vessel-based acoustic snapshots were completed. The aggregation was limited to a small area of approximately two square nautical miles at essentially the same location as observed during surveys in 2015, 2016 and 2017. Biomass estimates ranged from 196 to 1393 tonnes for the eight surveys. The 1393 tonne estimate was based on classification of three acoustic 'marks' as orange roughy. One of these marks was in the water column 60 m above the seafloor and 900 m away from the main aggregation. Knowledge gained from many orange roughy surveys using multifrequency classification of orange roughy aggregations shows that this type of feature is not uncommon, which was a key factor in supporting this interpretation. Multifrequency acoustics were not available on this survey to positively confirm this classification. The biomass estimate of 1393 tonnes would reduce to 970 tonnes if this water column aggregation was excluded. This large range in biomass reflects the dynamic nature of the spawning aggregation where availability of orange roughy to the acoustics can vary widely over short time periods. The relatively high survey sampling C.V's (0.21 to 0.64) may also contribute to the large range in biomass.

Single-frequency, vessel-based acoustic biomass estimates of the deep-living, low reflectivity orange roughy have a range of significant uncertainties. Compared to other orange roughy management zones in New Zealand, spawning aggregation densities at Cook Canyon are particularly low and they are amongst the deepest (~900m). This meant that signal from orange roughy aggregations was only slightly above that of the surrounding backscatter from other biology and noise. As a check for potential bias, backscatter signal from 22 areas surrounding orange roughy aggregations were echointegrated. If this level of 'background' backscatter exists within the aggregations then, on average, results would be biased high by 30%. This may be a worst case as avoidance reactions of orange roughy aggregations observed by Acoustic Optical Systems (AOS) show that the space occupied by orange roughy can be quite clear of other sources of backscatter (Ryan and Kloser, 2016). The vessel-based biomass estimates have a Deep Water Working group (DWWG) recommended correction multiplier of 1.3 to account for signal loss due to vessel motion and bubble layer attenuation. For three of the four surveys where motion was measured, signal loss was insignificant (< 2%), while signal loss due to bubble attenuation was not apparent in the echogram data; thus, the DWWG multiplier may be biasing the results high. The biomass estimates use the Doonan et al. (2003) absorption equation. The absorption equation of Francois and Garrison (1982) would increase biomass estimates by 30% at this location. These uncertainties are either significantly reduced or eliminated using deeply deployed platforms (e.g. multifrequency towed body, AOS).

Despite a reasonably high level of uncertainty associated with various parameters in the biomass estimation process, these surveys were able to locate and identify orange roughy aggregations with a high degree of confidence in most instances. Biomass estimates were produced that were comparable to those made from the 2017 surveys (627 to 930 tonnes, n=3) with the deeply deployed AOS. In comparison with other significant orange roughy (ORH) spawning locations in New Zealand this is a small body of fish that occupies a limited area making it potentially vulnerable to overfishing if not carefully managed. This survey approach,

of brief excursions from a commercial fishing programme, could be a model for future years where cost-effective monitoring methods are needed when the value of the fishery is not high.

1. Introduction

The ORH7B Quota Management Area has been closed to fishing from 2008/09 and a program of acoustic biomass surveys has been launched in order to assess current orange roughy biomass with a view to seeking a commercial reopening. This initiative commenced with an acoustic biomass survey of the Cook Canyon and surrounding area in 2015 (Ryan and Tilney, 2015), when a small aggregation was encountered on the edge of the Cook Canyon. A trawl survey in 2016 (Doonan et al., 2016), and a further acoustic survey in 2017 (Ryan and Tilney, 2017), found the aggregation in the same location (Figure 1). The 2015 and 2017 surveys incorporated the use of a dual-frequency, head-rope-mounted AOS, which served to confirm that the surveyed aggregation comprised primarily orange roughy. The backscatter signal on vessel echosounders during the above surveys was only marginally detectable above that of the background noise, indicating that orange roughy were aggregated at very low densities. As there was uncertainty whether these surveys occurred at the best time with respect to the spawning event, a new survey design was implemented during 2019 involving four visits to the Cook Canyon spawning area between 25 June and 16 July, which it was envisaged would cover the entire spawning event and offer the best opportunity to survey spawning aggregations at their maximum density.

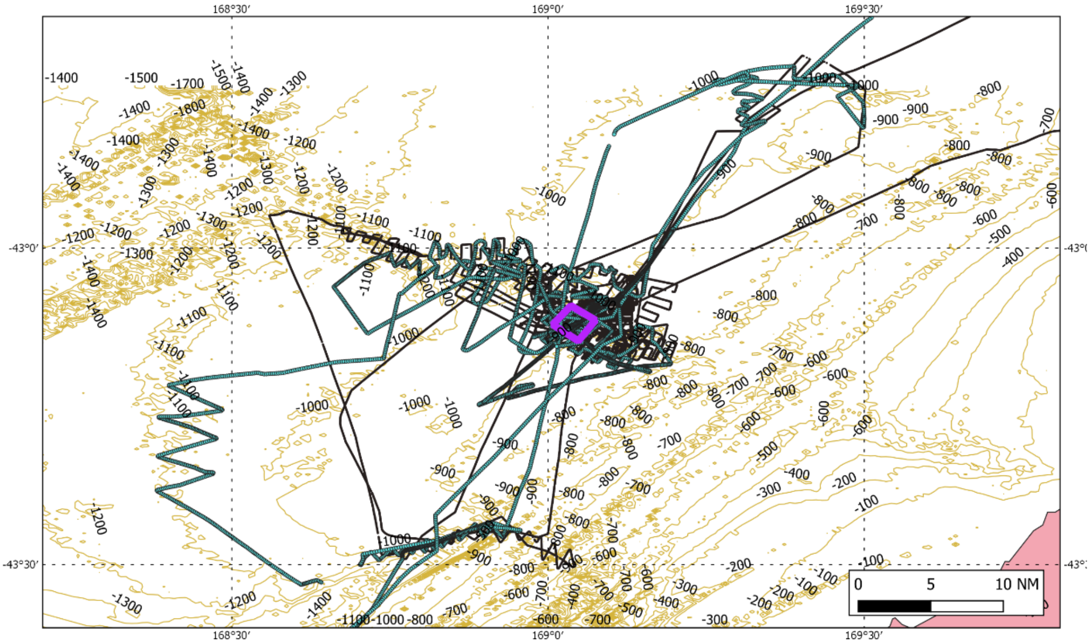

Figure 1. Map of 2015 and 2017 survey tracks (green and black lines respectively). Purple box indicates location of the main spawning aggregation which was the primary focus of the 2019 surveys.

Specific Project Objective

To estimate the spawning biomass of orange roughy in ORH7B during June-July 2019 for use in a revised stock assessment to inform the management of this stock.

Voyage Objectives

1. To search for orange roughy spawning aggregations in and around the Cook Canyon area.
2. To estimate the spawning abundance of orange roughy in the area with a target coefficient of variation (c.v.) of the estimate of 20 - 30% using an acoustic survey.

3. To collect biological material to inform the acoustic data.

2. Methods

Acoustic surveys

The acoustic surveys using a calibrated Simrad ES60 38 kHz echosounder with ES80 acquisition software were undertaken aboard the Talley's 'fresher' vessel *Amaltal Mariner* during four, six-day voyages to West Coast South Island where hoki was being targeted in the Hokitika Canyon. For one day during each voyage, when the weather was suited to acoustic surveying, the vessel broke off from hoki fishing and steamed south to Cook Canyon. The orange roughy aggregation was easily found by grid-searching. The main aggregation was centred around 43° 07'S, 169° 02'E, where it had previously been found in 2015, 2016 and 2017. Transect surveys were completed by the ship's officers in consultation with Rob Tilney (voyage leader, biological sampling, management of acoustic surveys) following written guidelines provided by CSIRO (see Appendix A). These guidelines were designed to ensure that transect surveys were carried out in accordance with DWWG requirements. These include ensuring transect surveys encompass the full extent of the aggregations and that transects are 'interlaced', that is a set of transects are carried out in one direction with a return set of transects bisecting the first survey. This design is used to minimize potential bias due to fish movement orthogonal to the transect direction (Simmonds and MacLennan, 2005). Further, a minimum transect spacing of 0.25 nautical miles, with 6-8 transects per snapshot, was recommended.

Biomass estimation

The acoustic surveys were analysed using Echoview 10 software where echogram regions were classified as orange roughy. Following DWWG guidelines seawater absorption at 38 kHz was estimated using the equations of Doonan et al. (2003). Also, as per DWWG guidelines biomass estimates were multiplied by a factor of 1.33 to correct for bias due to bubble layer attenuation and signal loss due to vessel motion.

These regions were echointegrated to provide along-track Nautical Area Scattering Coefficient (NASC) values in 100 m intervals. The mean NASC (m^2/nautical miles^2) within the survey area A (nautical miles squared) defined by area encompassed by survey transect lines plus a half-transect space extra added either side of the first and last transects), mean fish weight W (kg) and mean target strength (TS) were used to estimate orange roughy biomass (Equation 1).

$$Biomass = \frac{\overline{NASC} * \frac{\overline{W}}{1000} * A}{4 * pi * 10^{\frac{\overline{TS}}{10}}} \qquad \text{(Equation 1)}$$

The orange roughy TS estimate of Kloser et al. (2013), based on a mean fish length of 34.5 cm, was applied. Adjustment was made to the nominal TS to scale values to the fish standard length (SL) observed at each spawning ground, assuming a TS – length slope of 16.15 (McClatchie et al., 1999) where TS = 16.15*log(SL) + 76.83.

Mean orange roughy weight was estimated from the biological samples taken during the voyages. A population sex ratio of 50:50 was assumed when estimating both weight and TS.

Biological sampling

Information on average orange roughy length and weight, required to inform the acoustic data, required catches to be taken and an allocation was secured via Special Permit, which provided for a maximum of 50 t to be caught. A total of seven target-identification tows were undertaken to facilitate biological sampling of lengths, weights, sex ratio, spawning state and otolith collection.

3. Results

Biological sampling

Orange roughy spawning state

Biological sampling of orange roughy from target-identification trawl tows indicated that spawning was underway at the commencement of surveying on 26 June, with 20% of female gonads being in spawning condition and 10% in spent condition. By the second visit, on 4 July, spawning had advanced with around 30% of females in spawning condition and 35% in spent/partially spent condition. By the third visit on 9-10 July, around 39% were spawning and 55% spent/partially spent. As there was no indication that the aggregation was dispersing it was decided to undertake a fourth survey visit to Cook Canyon on 16 July. The aggregation was still present, although at a lower density than before. The spawn was clearly nearing an end with 19% of female gonads in spawning condition and 78% spent (Figure 2).

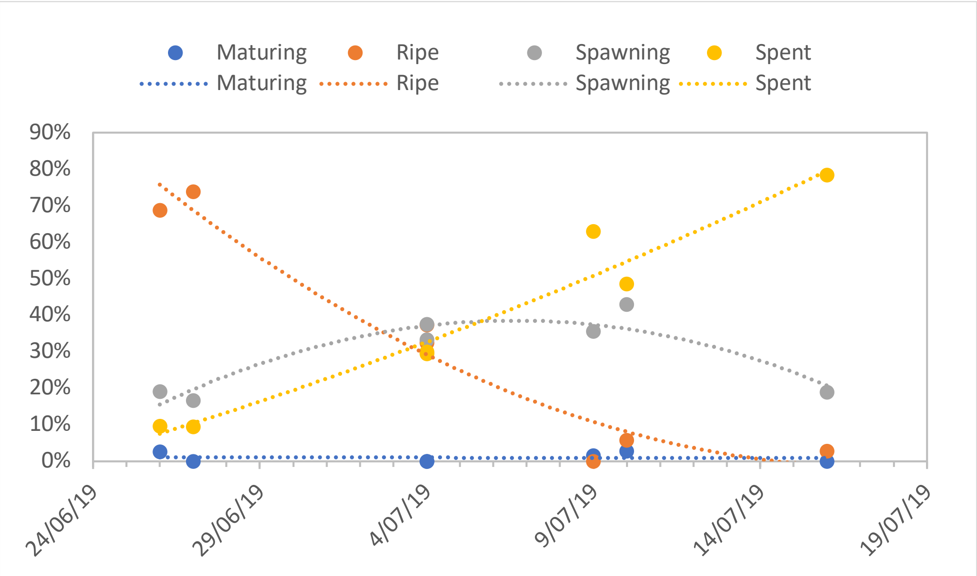

Figure 2: Female orange roughy gonad development state during the survey period.

Orange roughy size range

The modal size of female orange roughy was larger than for males at around 38 cm and 36 cm standard length respectively (Figure 3). Mean lengths and weights were 36.6 cm and 1,601 g for females and 34.1 cm and 1,236 g for males. The sex ratio was close to parity with 52.5% of sampled fish being female and 47.5% being male. 700 otolith samples were collected for use in determining age structure and year-class strengths.

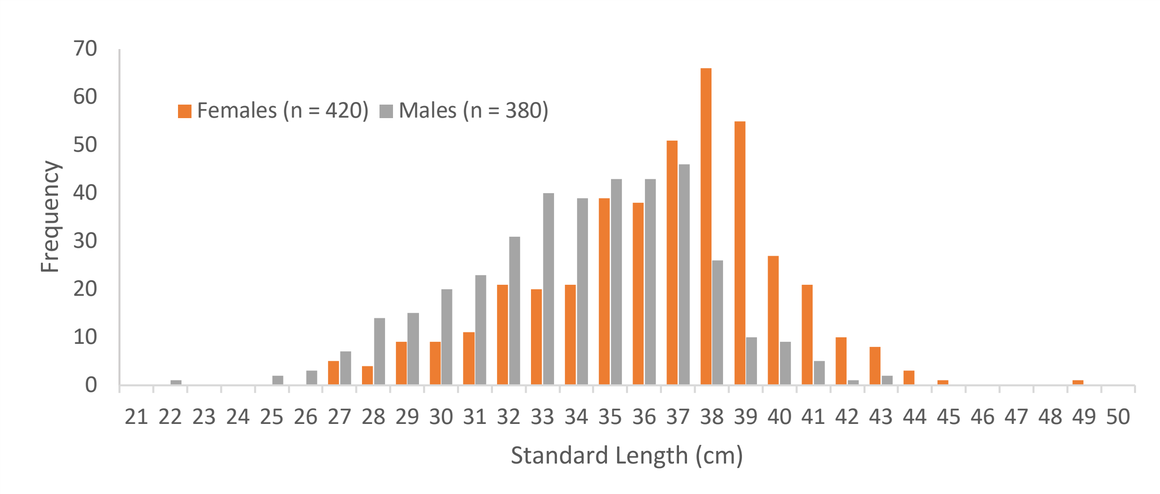

Figure 3: Orange roughy length-frequency (unstandardised) by sex at Cook Canyon.

Catch composition

Seven target-identification tows yielded estimated catch weights ranging from 2.5 to 18 t. The objective was to limit individual bag sizes to 5 - 8 t to the extent possible. Catch sensors were strategically attached to the codend and the net was hauled immediately following triggering of the first sensor. Orange roughy comprised between 94.7 % and 99.6% of each catch and overall averaged 98.8% by weight. The main bycatch species were deep water sharks (leafscaled gulper shark, Plunket's shark, smoothskin dogshark and seal shark), ribaldo, hoki and hake (Figure 4). A complete list of species and catches is provided in Appendix B.

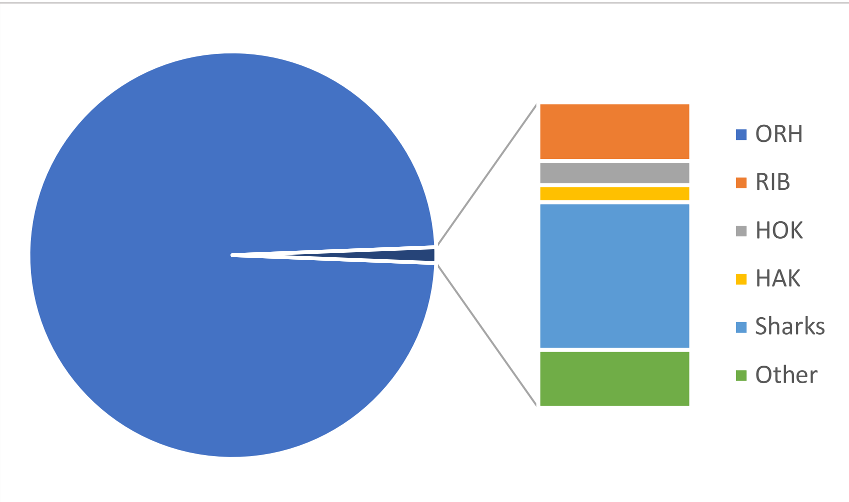

Figure 4: Average catch composition by weight from seven target identification tows on the orange roughy aggregation at Cook Canyon.

Acoustic snapshots

The Cook Canyon was visited on four occasions between the 26th June and 16th of July (Table 1). A single aggregation of spawning orange roughy was located at essentially the same location on each visit (Figure 5). Intensive grid-searching and acoustic surveying revealed that the aggregation tended to strengthen after dusk and would generally disperse before dawn. Searching over a wider area around the spawning location failed to find any additional aggregations. Snapshots comprising between 4 and 10 interleaved transects were steamed at between 5 and 9 knots depending on sea conditions, and ranged in duration from 30 to 128 minutes. Conditions were favourable on all but one visit, when the wind was estimated to be ~20 knots and transects for snapshot 3 had to be run with the weather (i.e. in one direction only instead of the recommended interlaced design). A total of eight snapshots were undertaken in all (Table 1, Figure 6).

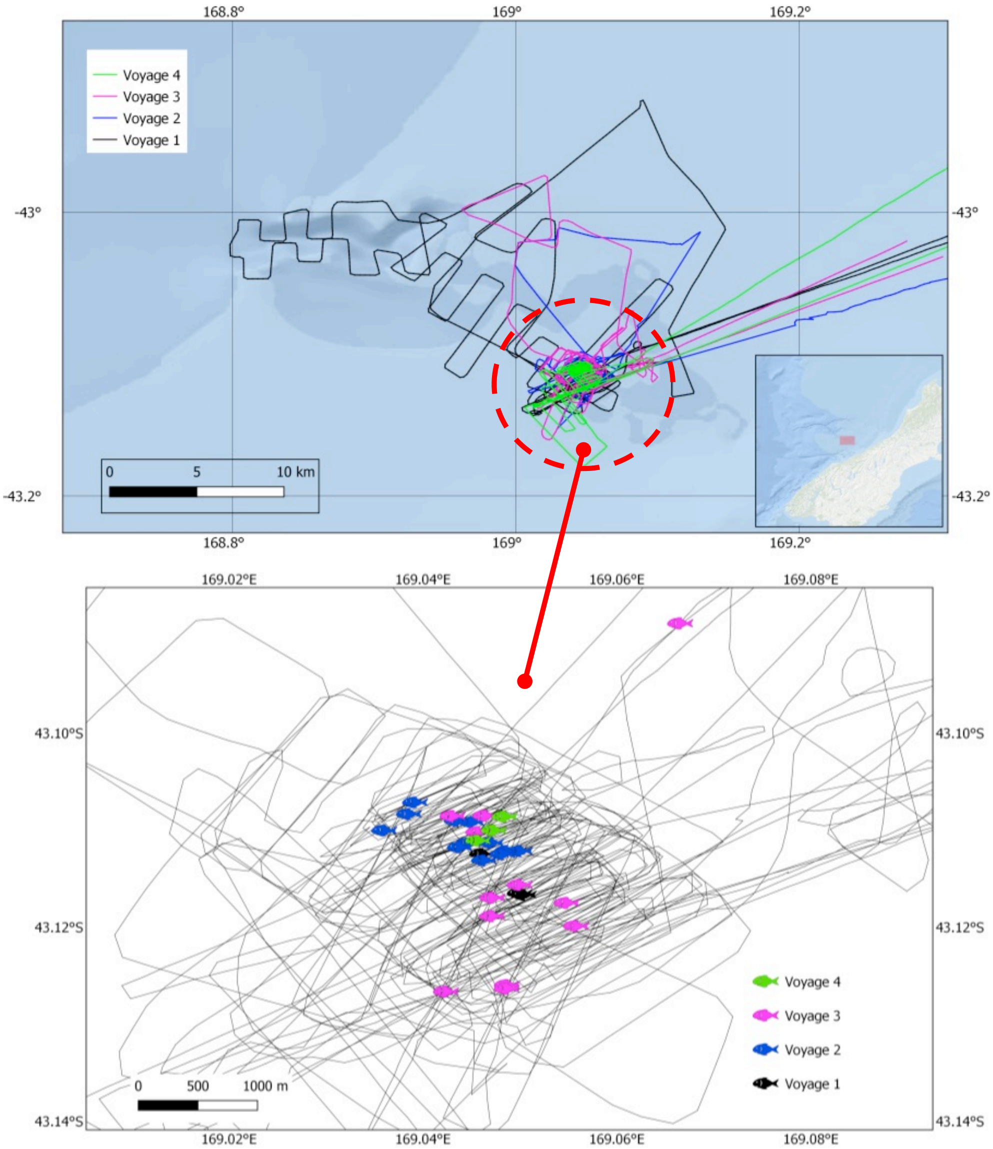

Figure 5. Top Panel. 2019 ORH7B vessel survey track in and around Cook Canyon. Bottom Panel. Location of orange roughy aggregations observed throughout the survey program indicated by fish markers colour coded according to voyage

Table 1: Acoustic snapshot timing and parameters.

Snapshot No.	Date	Snapshot Start Time	No. Transects	Avg. Vessel Speed (knots)	Snapshot Duration (minutes)
1	26/06/19	13:51	6	9.1	59
2	26/06/19	21:32	6	9.0	67
3	03/07/19	23:32	9	5.8	128
4	04/07/19	03:36	9	6.6	121
5	09/07/19	12:23	6	7.2	67
6	09/07/19	21:16	5	8.3	76
7	10/07/19	00:43	10	7.6	75
8	16/07/19	07:31	4	7.1	30

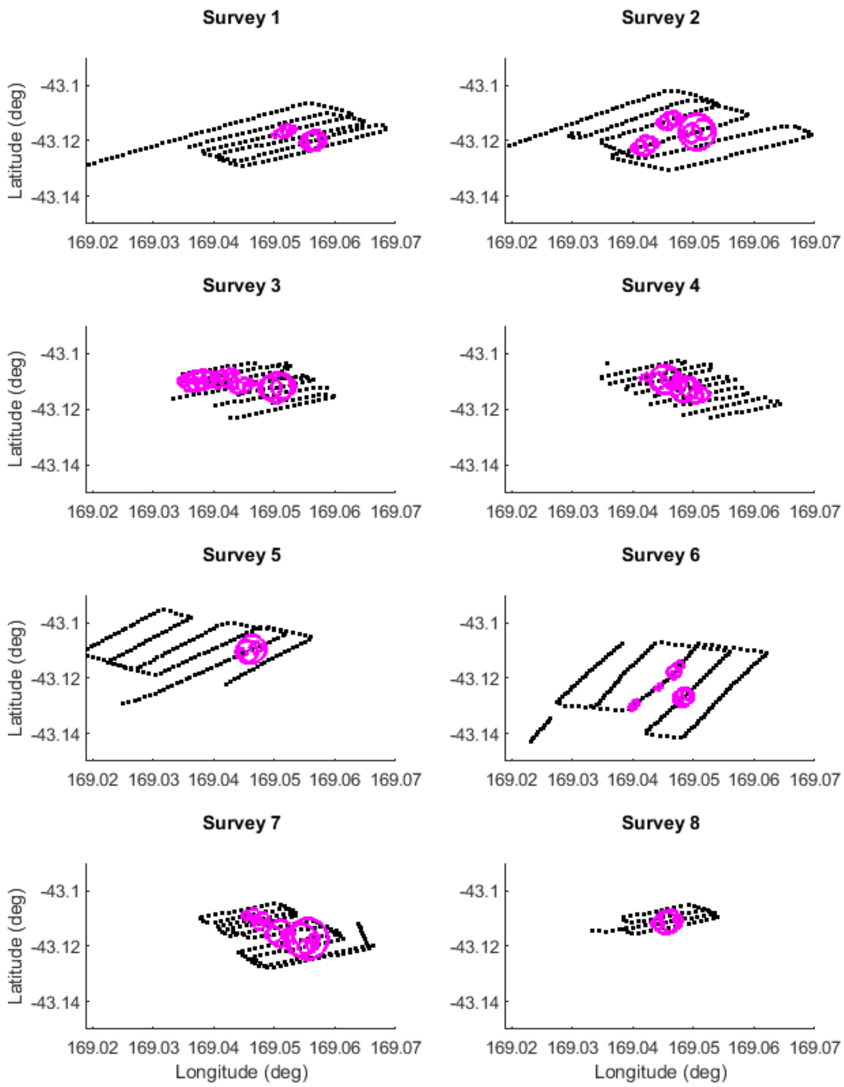

Figure 6. Vessel track of eight snapshot acoustic surveys. Magenta circles are scaled by mean along track NASC per 100 m intervals.

Echogram interpretation and species identification

The orange roughy aggregation, as viewed on the echosounder, resembled finger-like plumes extending from the seabed vertically up to around 100 m into the water column (Figure 7). The form of these aggregations resembled classic orange roughy plumes. Trawl catches were 95% or higher orange roughy by weight. The location of the 2019 aggregation was essentially identical to what was observed in 2015 (Ryan and Tilney, 2015), 2016 (Doonan, 2016) and 2017 (Ryan and Tilney, 2017), of which the 2015 and 2017 surveys had multifrequency acoustics and video to support interpretation. These factors combined to provide a high degree of confidence when classifying echogram regions to orange roughy in most instances. Survey 2 had a possible orange roughy mark at ~60 m above the seafloor and 900 m away from the main aggregation (Figure 8). Knowledge gained from many orange roughy surveys using multifrequency classification of orange roughy aggregations shows that this type of feature is not uncommon which was a key factor in supporting this interpretation. Multifrequency acoustics was not available on this survey to positively confirm this classification. The biomass estimate of 1393 tonnes would reduce to 970 tonnes if this water column aggregation was excluded (Table 4). This large change in biomass highlights sensitivity to interpretation that is more acute when there are small numbers of low-signal aggregations.

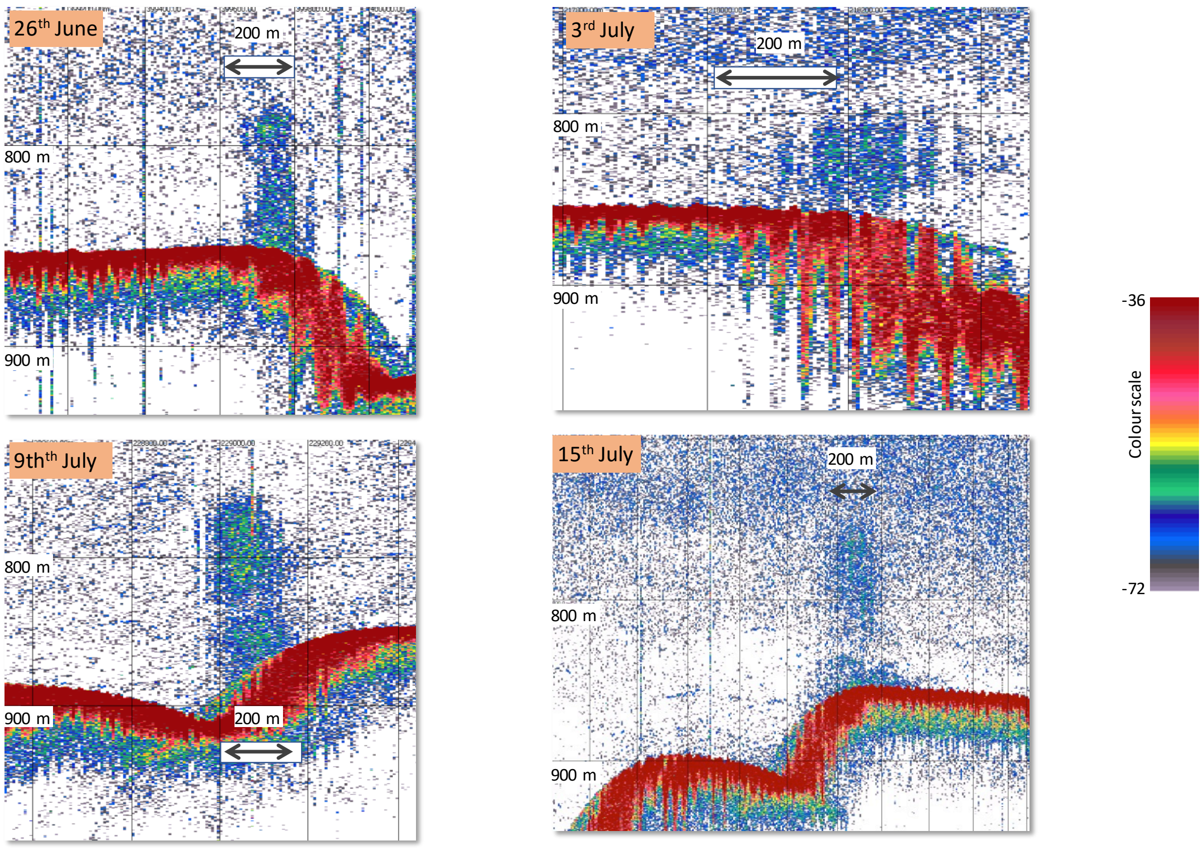

Figure 7: Echosounder screen-shots from acoustic snapshots of the orange roughy spawning aggregation located at the edge of Cook Canyon from each of the four voyages.

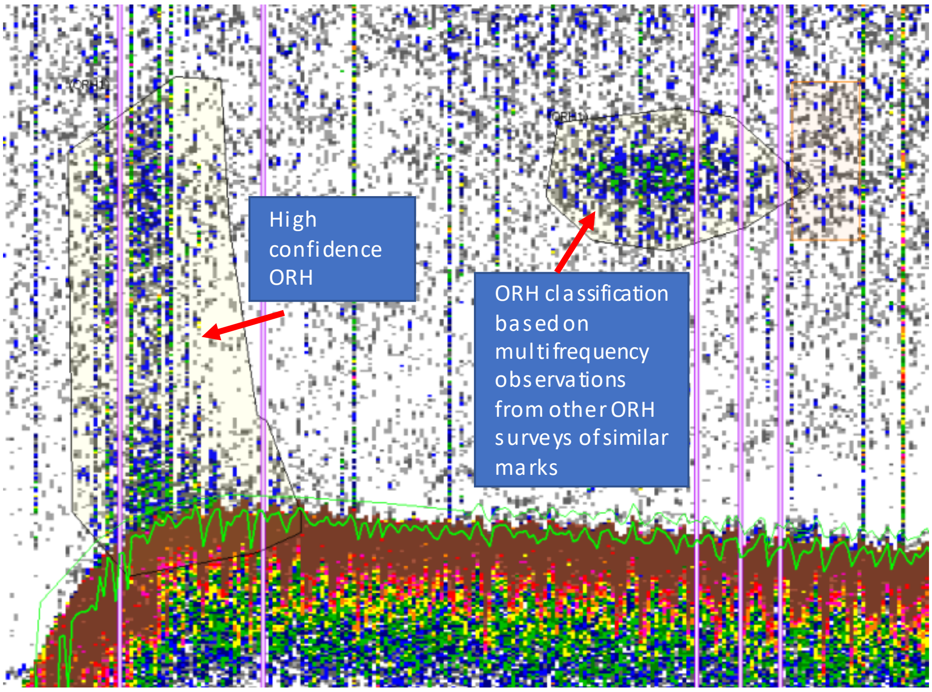

Figure 8. Orange roughy marks from a transect from Survey 2.

Biomass estimation

The vessel's commercial echosounder was calibrated prior to the voyage using the standard sphere method (Demer et al., 2015). Key calibration settings are given in Table 2.

Table 2. Calibration settings for 2019 acoustic surveys

Power (W)	Pulse length (ms)	Gain (dB)	Sa correction (dB)	Equivalent beam angle (dB re 1st)
2000	2.048	27.04	-0.29	-20.7*

* Using nominal value as factory beam pattern report could not be located.

Weight and TS estimates used when estimating biomass were as follows (Table 3).

Table 3. Weight and TS estimates for Cook Canyon orange roughy. Combined weight and TS were used for biomass estimation.

	Female	Male	Combined
Mean length (cm)	36.60	34.10	35.35
Mean weight (kg)	1.60	1.24	1.42
Mean TS (dB re 1 m^2)	-51.58	-52.08	-51.82

Biomass estimates for eight acoustic snapshot surveys are presented in Table 4. The recommended biomass estimates are in bold text with deadzone contribution as a percentage of total biomass in brackets. These estimates treat the interlaced survey as a single set of transects. Alternate biomass estimations were based on separating the interlaced pattern into two surveys (survey A running in one direction, survey B return transects bisecting survey A transects) and combining either by arithmetic or geometric mean (see Discussion section on why these are not the recommended estimates for these surveys).

Table 4. Summary of biomass estimates. Recommended estimates are in bold font with deadzone contribution as a percentage of total biomass in brackets.

Survey No	Date	Survey Area (n.mi^2)	No transects	Mean NASC (m^2/ni.m^2)	**Total biomass (tonnes)**	CV	Survey A	Survey B	Combined (mean A and B)	Combined (geometric mean)
1	26-Jun	1.051	6	12	**318 (9.6%)**	0.48	299	613	456	428
2	26-Jun	1.54	6	36.7	**1393* (7.4%)**	0.35	2294	552	1423	1125
3	3-Jul	0.489	9	80.8	**927 (2.6%)**	0.21	851	887	869	868
4	4-Jul	0.437	9	69.5	**746 (7%)**	0.31	1289	257	773	575
5	9-Jul	1.249	6	17.6	**511 (1.8%)**	0.64	0	1084	542	0
6	9-Jul	1.78	5	11.5	**473 (0.8%)**	0.38	388	591	489	479
7	10-Jul	0.421	10	95.1	**958 (4.4%)**	0.33	616	1200	908	859
8	16-Jul	0.179	4	45.3	**198 (6%)**	0.58	0	516	258	0

* alternate interpretation where orange roughy mark with lower certainty removed reduces this estimate to ~ 970 tonnes.

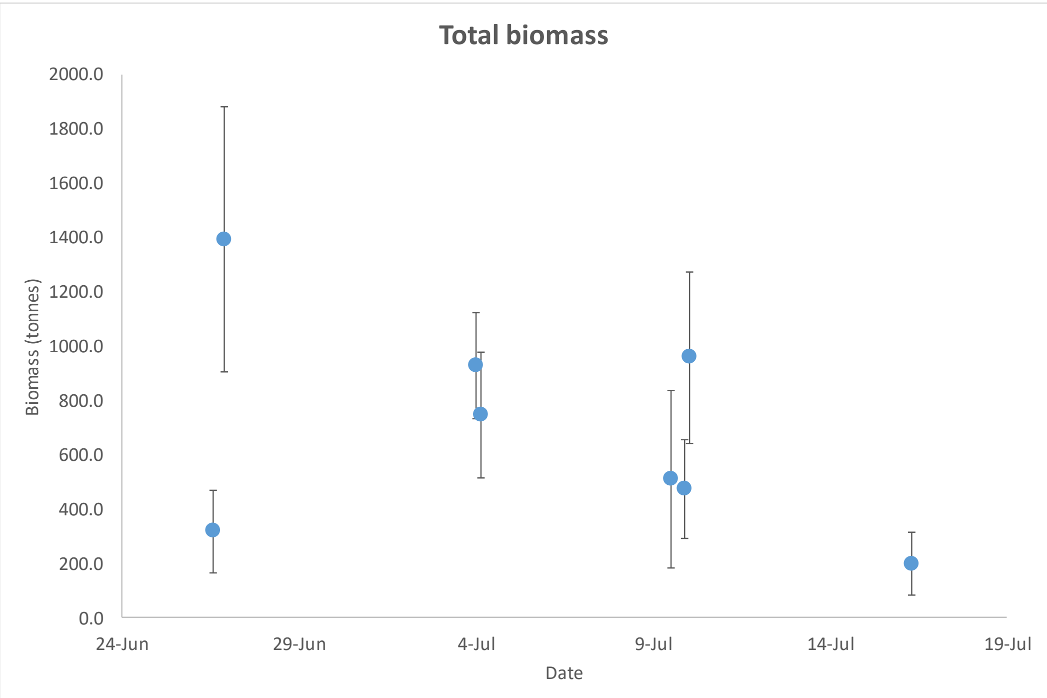

Figure 9. Summary of biomass estimates. Error bars are +/- 1 standard deviation of estimated survey sampling variability

4. Discussion

The Cook Canyon region was visited four times over a three-week period between the 26th June and 16th of July. Each visit took approximately 24 hours which combined vessel-based acoustic transect surveys and demersal trawl shots to support echogram interpretation and provide biological samples. Eight vessel-based acoustic snapshots and seven demersal trawls were completed. 700 otolith samples were collected for use in determining age structure and year-class strengths. The location of the main aggregation varied only slightly with the surveys contained within an area of approximately 2 nautical miles (Figure 5). Further, the 2019 orange roughy spawning aggregations were located in essentially the same location as identified during the 2015, 2016 and 2017 surveys of this region (Ryan and Tilney, 2015; Doonan et al., 2016; Ryan and Tilney, 2017). The form and density of the main aggregation was similar to what was acoustically observed in 2015 and 2017.

The main aggregation had the form of a 'classic' orange roughy spawning plume (Figure 7) which, along with targeted trawl catches showing low bycatch (94.7% to 99.% ORH by weight), gave high confidence in echogram interpretation. The density of orange roughy within the aggregations, as measured by the acoustics, was low, averaging approximately 1 fish per 100m3. By comparison, spawning ORH fish densities in the ORH7A Challenger region recorded during 2018 surveys (Ryan et al., 2019) were reviewed for this report and found to be in the order of 5 to 50 fish/100m^3. These very different densities are curious from a biological perspective where it might be expected that spawning reproduction requires a certain density to ensure success. The plot of female gonad development (Figure 2) shows that spawning was underway prior to survey commencement but that the spawning event was reasonably well described by the biological sampling program. However, as gonad staging indicated that peak spawning (interpreted as occurring when 20% of female gonads are in spent condition) occurred during the first snapshot on 26 June, it would have been preferable to have commenced surveying a week earlier to encapsulate the build-up to peak spawning.

All survey designs followed an interlaced pattern to reduce possible bias due to fish movement (Simmonds and MacLennan, 2005). Effectively there are two surveys conducted, one where transects move across the fish aggregation in one direction (Survey A) and then a second set in the other direction bisecting the first set of transects (Survey B). This design allows for the data to be treated in a number of ways. The method preferred by DWWG is to estimate the biomass of Survey A and Survey B separately and combine these by taking their geometric mean (i.e. $\sqrt{Survey\ A * Survey\ B}$). For the 2019 surveys this method is problematic for a range of reasons. When Survey A and Survey B are equal, the geometric and arithmetic mean will be the same. As Survey A and Survey B diverge, the geometric mean will be less than the arithmetic mean. At the extreme where one survey observed no fish while the other did, the biomass determined using the geometric mean will be zero. A geometric mean of zero occurred for surveys 5 and 8 where respectively biomasses of 1084 and 516 tonnes were recorded on the return surveys but zero biomass on the initial surveys. Surveys 2 and 4 had biomass estimates that differed by a factor of between four to five between the Survey A and Survey B values, also leading to geometric means that were significantly lower than the arithmetic means. A minimum transect separation of 0.25 nautical miles was specified to account for the footprint of the acoustics to avoid oversampling in the across track direction. This, combined with the fact that the extent of the main aggregation was small, meant that only a few transects were needed to bound the school. Transect numbers ranged from 4 to 10 for the 8 surveys. This meant that when the interlaced transects were separated into Survey A and Survey B there were sometimes very few transects to work with, there being orange roughy on only one or two lines.

Consequently, when the surveys were separated into the two components, each had poor spatial coverage that poorly sampled the underlying population, leading to unreliable estimates with very high survey sampling variance. Given the small area of the aggregations the interlaced surveys could be completed rapidly taking between 1 to 2 hours at most. Although it is unlikely that fish movement would be significant in this timeframe, the interlaced design intrinsically mitigates these effects should they occur. Given the above discussion it is proposed that biomass estimates will be more robust and have a lower survey sampling CV if the surveys are treated as single entities. Thus, the biomass estimates presented in bold in Table 4 are the recommended estimates.

Biomass estimates ranged from 196 to 1393 tonnes for the eight surveys over a three-week period. A more conservative interpretation of ORH marks would reduce the 1393 tonne estimate to 970 tonnes. Deadzone contributions were generally low due to the aggregations mostly being high in the water column with minimal connection to the seafloor. A high degree of variability in biomass is noted. Survey 1 biomass for example was a factor of four less than that of Survey 2 despite being completed within a 24-hour period of each other. This is not completely surprising as the 'acoustic availability' of orange roughy has been observed by both fishers and scientists to vary widely, with build-up and decline over day-night periods. It is noteworthy that the two snapshots with the lowest biomass estimates (snapshots 1 & 8) were undertaken during daylight hours (Table 1, Table 4). These surveys were designed to have multiple, brief visits to the Cook Canyon over an extended period to track the progress of the spawn and take acoustic snapshots through time. The design did not allow the vessel to remain at the spawning location over multiple days to monitor the dynamics of the aggregation over longer periods. The 2019 vessel- based biomass estimates are of the same order as those obtained from the 2017 survey which estimated biomasses of between 627 and 930 tonnes using a deeply-towed Acoustic Optical System (38 kHz data), (Ryan and Tilney, 2017).

Uncertainty

Orange roughy are a particularly difficult species to survey using acoustics due to the depths at which they live and because they have relatively low reflectivity due to the lack of a gas-filled swim-bladder. They co-exist with gas-filled swim-bladder species that can have acoustic reflectance of between 10 - 100 times greater. Vessel-based surveys can have large biases due to range- dependant error effects in sound absorption estimation, signal loss due to motion effects and signal degradation due to weather effects, the latter causing positive bias due to noise and negative bias due to attenuation of the acoustic signal from the surface bubble layer. The use of deeply-deployed platforms can reduce range dependant errors and eliminate signal degradation due to weather effects (Kloser, 1996). A further enhancement is the addition of multiple frequencies to deployed platforms. The combination of 38 kHz and 120 kHz has proven to be highly effective in identifying orange roughy (Kloser et al., 2002). Multifrequency AOS deployments were carried out at this location in 2015 and 2017 and gave a good understanding that this aggregation was orange roughy with very little indication of significant numbers of co-occurring species. This information has supported our interpretation that the main aggregation is orange roughy.

A strategy of this survey program was to break from hoki fishing to survey Cook Canyon at the calmest point during each one-week fishing trip. This served to minimize the effects of motion and signal degradation as much as possible. Motion data were not recorded for the first four surveys due to technical issues. Estimates of signal loss due to motion were made from motion data logged at 5 Hz using the (Dunford, 2005) algorithm where surveys 5, 6 and 7 had a loss of about 2%. Survey 8 had a loss of 24%.

The recommended biomass estimates include the DWWG-specified 1.3 multiplier, which is intended to combine the effects of signal loss due to vessel motion and that due to bubble layer attenuation. This is a large correction that is being universally applied across a range of vessels and locations despite being based on a study involving one particular vessel at one location. It is recommended that further work be done to better understand the suitability of applying this universal correction factor across different vessels and locations.

This survey had a pragmatic approach where brief visits by a vessel during a hoki fishing program enable observations potentially to be made right through the spawning event. The use of a dedicated vessel with deeply deployed platform (e.g. AOS) might give a technically superior outcome but could be cost prohibitive for this small fishery. The trade-off against deployed platforms is that the 2019 estimates are based on vessel acoustics with the higher level of uncertainty already discussed.

The use of vessel acoustics for this fishery is at the margins where the backscatter signal from the orange roughy aggregations is only slightly above that of the surrounding backscatter. The problem is essentially one of signal-to-noise where the orange roughy backscatter can be considered signal and the noise a combination of actual noise and backscatter from other biological sources. For larger fisheries with more densely aggregated orange roughy (e.g. Chatham Rise, Rekohu) signal-to-noise may not be such an issue. For Cook Canyon the contribution of 'noise' to the backscatter from the orange roughy aggregations could be a significant source of positive bias. To investigate this, 22 regions identified as orange roughy from the eight Cook Canyon surveys and adjacent regions of water column were echointegrated. The orange roughy regions were assumed to contain signal from orange roughy plus the 'noise' component, while the adjacent regions measured just the 'noise. This simple analysis found on average 30% of the signal within the identified orange roughy regions might be due to 'noise' (Figure 10). If correct, biomass estimates would be biased by the same amount. This 'noise' contribution would be less if the amount of non-roughy species within the orange roughy regions was less than that of the adjacent backscatter. In support of this possibility Ryan and Kloser (2016) noted regions of 'empty water' appeared in instances when orange roughy rapidly moved out of a region due to a scare reaction in response to deployed platforms.

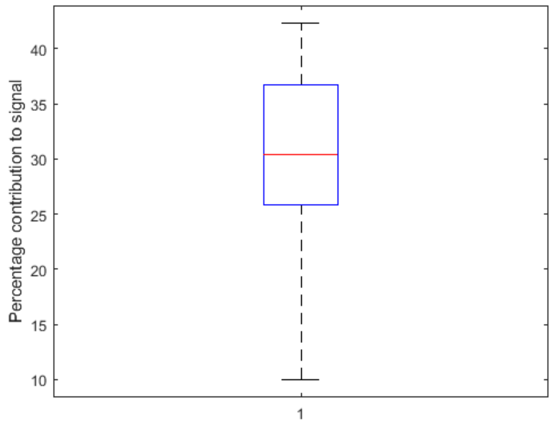

Figure 10. Percentage contribution to signal from within 22 orange roughy regions at the Cook Canyon spawning site.

A summary of key uncertainties is provided in Table 5.

Table 5. Summary of key uncertainties for Cook Canyon biomass estimates

Parameter	Amount (%)	Comment
Absorption estimate	30	The widely used Francois and Garrison (1982) absorption estimate would increase biomass by 30% for Cook Canyon orange roughy depths of ~ 870 m. More research recommended to directly measure absorption at both 38 kHz and 120 kHz.
DWWG Correction factor	-30	This correction factor combines motion and attenuation due to presumed bubble layer effects. Alternative is to directly correct for motion effects with recommendation for more research to understand bubble attenuation effects across a range of vessels and situations.
Motion effects	Uncorrected between 2-30%, corrected expect residual error of only a few percent.	Directly correct for motion effects by measuring a Nyquist sampling frequency.
‘Noise’ contribution	Up to +30%	Contribution to signal by noise and co-occurring species could be as much as 30% for these regions of low acoustic backscatter. Uncertainty can be reduced through use of deeply deployed multifrequency platforms. Estimates at 120 kHz have better signal-to-noise than 38 kHz (factor of 2) but perhaps higher uncertainty in absorption estimate

5. Conclusions

Despite a reasonably high level of uncertainty associated with various parameters in the biomass estimation process, these surveys were able to locate and identify orange roughy aggregations with a high degree of confidence in most instances. Biomass estimates were produced that were comparable to those made from the 2017 surveys (627 to 930 tonnes, n=3) with the deeply deployed AOS. In comparison with other significant orange roughy spawning locations in New Zealand this is a small body of fish that occupies a limited area making it vulnerable to overfishing if not carefully managed. Should commercial fishing operations recommence careful monitoring is recommended. This survey program of brief excursions from a commercial fishing program is an effective model for future surveys where cost-effective monitoring methods are needed when the value of the fishery is not high.

Acknowledgements

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6. Appendix A. 2019 Survey Guidelines

Surveys of Orange Roughy at the Cook Canyon Spawning Grounds, Winter 2019

Tim Ryan 13/06/2019

Overview

Acoustic surveys of Cook Canyon were made in 2015 (CSIRO), 2016 (NIWA) and 2017 (CSIRO). All three surveys located a single spawning plume at about the same location (~ 169:02E, 43:07S). Extensive surveying around the Canyon and wider area did not locate any other spawning aggregations. The 2019 surveys should combine focus on main spawning location with searching around the Cook Canyon region. In 2015 and 2017 some surveying of other locations up to 30 n.miles away from Cook Canyon was done but did not find orange roughy. Unless there is new information to do otherwise, these regions outside of Cook Canyon should not be surveyed in 2019. Focus should be on the main Cook Canyon feature (Figure 11).

Figure 11. Cook Canyon region with historic location of spawning orange roughy (purple rectangle).

Survey guidelines

Survey activities

1. Conduct ~ 8 transects of 0.25 n.mile spacing at the main spawning box. Use interlaced pattern – so transect spacing at 0.5 n.miles for first set then fill in between on return. Figure 12 shows a possible survey pattern but this should be modified to centre around the main body of the aggregation. This survey should take ~ 2-3 hours at 10 knots and would recommend conducting at least one such survey at this location regardless of whether there are significant orange roughy. Most likely be best to do this as first activity to give thorough search at the location where the main body of orange roughy are likely to be. Aim to have the transects perpendicular to the longest

axis of the aggregation (Figure 13). At Cook Canyon this may not be all that clear cut due to lack of strong depth gradient and weather may dictate direction of transect lines.

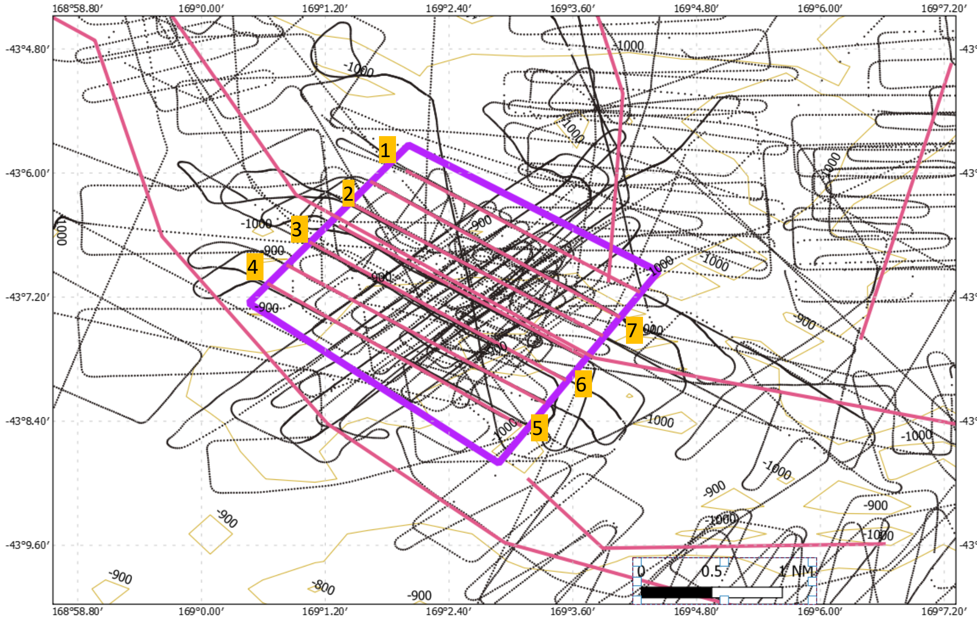

Figure 12. Possible survey design for main spawning location consisting of 7 transects of interlaced design.

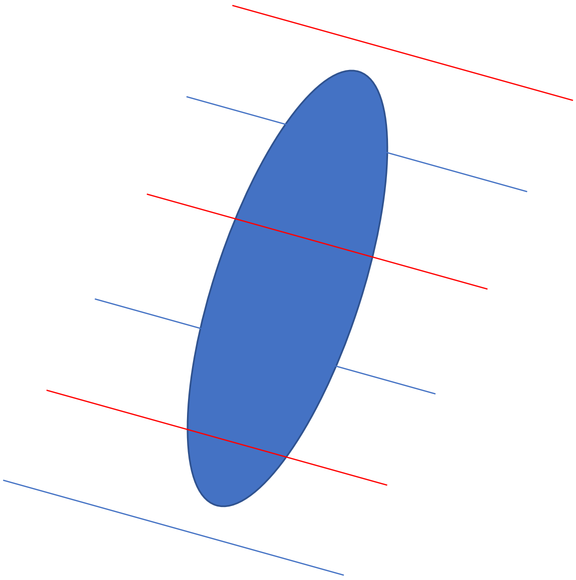

Figure 13 Conceptual survey lines perpendicular to main body of fish with bounding lines at each end. Red lines show the first three lines. Blue lines are the return ‘fill in’ lines

2. Wider area searching using 2017 searching patterns (Figure 11) as a guide. These were based on local knowledge of skipper with extensive Cook Canyon experience. If significant orange roughy are found conduct localised parallel transects of ~ 6-8

transects interlaced of minimum 0.25 n.mile spacing ensuring outer transects have no orange roughy marks so as to bound the survey area.

3. Trawling as needed to ID orange roughy marks and for biological sampling

7. Appendix B. Catch composition at Cook Canyon

Code	Common Name	Scientific Name	Weight (kg)	No.	No. Stations
BEE	Basketwork eel	*Diastobranchus capensis*	6.02	2	3
BSH	Seal shark	*Dalatias licha*	119.73	6	3
BSL	Black slickhead	*Xenodermichthys spp.*	1.21	5	3
CFA	Banded rattail	*Coelorinchus fasciatus*	0.15	1	4
CHX	Pink frogmouth	*Chaunax pictus*	0.3	1	1
CIN	Notable rattail	*Coelorinchus innotabilis*	0.12	4	1
CKA	Kaiyomaru rattail	*Coelorinchus kaiyomaru*	0.1	1	2
CMA	Mahia rattail	*Coelorinchus matamua*	4.72	29	5
CMX	McMillan's rattail	*Coryphaenoides mcmillani*	0.67	12	3
CSE	Serrulate rattail	*Coryphaenoides serrulatus*	0.32	1	1
CSQ	Leafscale gulper shark	*Centrophorus squamosus*	45.74	4	4
CSU	Four-rayed rattail	*Coryphaenoides subserrulatus*	0.20	1	1
CYO	Smooth skin dogfish	*Centroscymnus owstoni*	46.96	4	3
CYP	Longnose velvet dogfish	*Centroscymnus crepidater*	12.64	8	5
DIP	Twin light dragonfishes	*Diplophos* spp.	0.04	1	1
FRO	Frostfish	*Lepidopus caudatus*	0.50	1	1
GSP	Pale ghost shark	*Hydrolagus bemisi*	1.36	2	2
HAK	Hake	*Merluccius australis*	40.54	11	4
HAS	Slender cod	*Halargyreus* sp.	3.28	16	4
HOK	Hoki	*Macruronus novaezelandiae*	57.86	30	6
HTR	Trojan starfish	*Hippasteria phrygiana*	0.08	1	1
JAV	Javelin fish	*Lepidorhynchus denticulatus*	1.38	6	2
LHO	Omega prawn	*Lipkius holthuisi*	0.02	1	1
LPI	Giant lepidion	*Lepidion inosimae*	17.54	1	1
ORH	Orange roughy	*Hoplostethus atlanticus*	57,764.00	41,053	7
OSD	Other sharks and dogs	*Selachii*	36.90	2	2
PLS	Plunket's shark	*Proscymnodon plunketi*	73.42	4	3
RIB	Ribaldo	*Mora moro*	138.89	129	7
RUD	Rudderfish	*Centrolophus niger*	0.90	1	1
SMC	Small-headed cod	*Lepidion microcephalus*	5.32	10	5
SND	Shovelnose spiny dogfish	*Deania calcea*	27.47	9	7
SOR	Spiky oreo	*Neocyttus rhomboidalis*	2.06	5	4
SPE	Sea perch	*Helicolenus* spp.	2.08	3	3
SQU	Arrow squid	*Nototodarus* spp.	0.80	1	1
SSM	Smallscaled brown slickhead	*Alepocephalus antipodianus*	3.69	3	2
TOP	Pale toadfish	*Ambophthalmos angustus*	1.28	1	1
TRS	Cape scorpionfish	*Trachyscorpia eschmeyeri*	0.74	1	1
UNI	Unidentified		0.02	2	1
WHX	White rattail	*Trachyrincus aphyodes*	82.14	29	7
ZOR	Rat-tail star	*Zoroaster* spp.	0.30	1	1

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