The Application of Industry Acoustic Techniques to the Surveying of Redfish Stocks:

A Feasibility Study

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OBJECTIVES:

The general objective of this project was to test the feasibility of using industry based acoustic techniques to survey redfish aggregations in a small area between Ulladulla and Bermagui,. The specific objectives of this project were to:

1. Conduct four acoustic surveys of redfish aggregations within a selected research area using a commercial fishing vessel equipped with EchoListener equipment.
2. Repeatedly map the distribution and acoustic density of marks attributable to redfish and derive a range of biomass estimates based on these data.
3. Analyse and report on the feasibility of estimating redfish biomass using industry acoustics.

NON TECHNICAL SUMMARY:

OUTCOMES ACHIEVED

This project developed and conducted three acoustic surveys of the NSW shelf break during the spring of 2000. The specific objectives of this project focussed on redfish, and unfortunately no redfish aggregations were observed. Consequently the general utility of the industry based acoustic technique had to demonstrated with jack mackerel aggregations that were found in the survey area. The implementation of some form of long term industry based abundance surveys is currently being proposed for the SEF. An important implication of the survey design demonstrated here is that a system of fixed station trawl surveys could also incorporate acoustic surveying. Combining two different sampling methods simultaneously within the same survey would greatly increasing the analytical power of the program for little extra expense. Highlighting this potential for the SEF as it contemplates survey design is the major outcome achieved of this project.

Because it is so difficult to decipher trends in fish abundance from the evolution of fishing practices when analysing commercial catch rates, one of SETMAC's highest research priorities is the development of fishery independent measures of stock abundance. Through repeated surveys with standard methodology it is hoped that accurate fishery independent indices of stock abundance can be developed to provide a solid basis for stock assessment in the SEF. At present fisheries independent surveys

are only used in the assessments of orange roughy and blue grenadier. These single species surveys relied on dedicated research vessels and have been relatively expensive. The annual GVP of the SEF is only around $60 million, so it has limited capacity to fund annual $0.5 million surveys for each species. Previous projects demonstrated in theoretical terms the potential cost effectiveness of single frequency acoustic surveys using the hull mounted transducers of commercial fishing vessels. As with all acoustic techniques, results with the industry acoustic approach will work best with species that:

- have a high target strength (i.e have a swim bladder),
- aggregate in shallower water,
- over flat terrain, and in
- relatively pure single species schools.

Unfortunately these types of conditions rarely occur together in the SEF. The winter aggregations formed by redfish (*Centroberyx affinis*), blue grenadier (*Macruronus novaezelandiae*) and spotted warehou (*Seriolella punctata*), probably offer the best opportunity for the future application of industry based acoustics to the quantitative surveying of fish stocks in the SEF.

The immediate objective of this project was to test at a pilot scale the feasibility of surveying redfish aggregations in a small area between Ulladulla and Bermagui, using industry based acoustic techniques during four days of surveying. It was industry's observation when the project began that redfish were at the low point of an availability cycle during 1999 and 2000. Through negotiation with the fishers it was decided to conduct 4 acoustic surveys monthly over July to October, rather than weekly through August, as originally proposed. On the advice of the local marine electronics expert the F.V. Arakiwa was selected as the survey vessel on the basis of providing the best electronic environment for collecting digital acoustic and global positioning data. EchoListener equipment was fitted and used to log the data from each acoustic ping onto the hard drive of a laptop computer. EchoView software was used to:

- view acoustic data
- identify and outline schools, sample school heights and bottom depths,
- export schools data, at two second intervals, into data files for importation into Excel

A survey design was developed with the fishers with the explicit aim of minimising disruption to normal fishing practices. Acoustic surveys commenced with a short (2h) dawn shot to the south, which had the purpose of sampling the depth range of redfish, and providing a general indication of the species composition of the pre-dawn haze settling on to the slope. Following the dawn shot, as the catch was sorted, the vessel would work its way back to the north acoustically scanning the shelf break and slope. The acoustic surveys employed a zigzag track backwards and forwards across the slope over bottom depths of 140-400m. Following the acoustic survey a mark would be sampled for species composition with a second 2hr shot. During all surveys there were two marks present in the surveyed depth zone, but lack of time prevented the composition of both marks being tested with targeted shots in the same day. However it was normally possible to get a good idea of the composition of both marks from the reports of other vessels fishing near by.

Three successful survey days were completed (23 July, 20 August, 16 September) the final survey was aborted due to an extended period of bad weather. During each survey two parallel bands of marks were observed stretching relatively continuously along the slope. A shallower mark close to the shelf break or 'edge' around 150-200m and a deeper band around 300-400m. Neither of these marks were in the 200-300m depth range normally expected of redfish. Sampling of the marks with targeted shots and interviewing other skippers fishing the same marks nearby suggested that the shallower mark was principally comprised of jack mackerel and barracouta, while the deeper mark was principally three-spined cardinalfish and ribbonfish. Redfish were only every present in trace amounts. No marks were observed that could be identified as being largely, or even substantially, comprised of redfish. This situation was not restricted to the survey vessel, few redfish marks were observed through this area of the SEF during the winters of 1999 and 2000, and commercial catch rates were generally low.

The lack of identifiable redfish aggregations in the survey area on survey days prevented the project achieving any of its objectives pertaining to estimating redfish abundance. This is because the schools based analysis relied upon by this approach is reliant on estimating the volume of identifiable species aggregations, and without observing redfish aggregations no data could be collected. However in the interest of testing the general utility of industry acoustics an analysis of the dynamics of the shallower jack mackerel mark has been performed instead. This analysis demonstrates that useful relative abundance data can be gathered using industry based acoustics. While limited in nature these acoustic surveys documented the end of winter decline in acoustic biomass that occurs off southern NSW as the STC moves back to the south of the region. The acoustic biomass of the shallower marked, which was principally jack mackerel declined by 75% between the August and September surveys. These observations provide an interesting counterpoint to May and Blaber's description of the seasonal cycle of SEF species abundance off southeastern Tasmania, where abundance peaks during summer when the STC moves south of southern NSW to those latitudes.

These results suggest that Industry Acoustics could increase the data collecting capacity of the long-term program of fishery independent surveys being proposed for the SEF. Integrating acoustic and trawl sampling into a single survey design similar to that employed by this project would allow simultaneous collection of by data by two independent sampling techniques. The two complementary data sets would greatly enhance the analytical power of the surveys. This study demonstrates that such a survey can be designed to be extremely compatible with normal fishing practices, and thus more likely to be relatively low cost and acceptable to industry. Deployed broadly across the fishery the survey would have potential to simultaneously and cost effectively monitor the abundance trends of the most important species in the SEF ecosystem.

KEYWORDS: Redfish, South East Fishery, industry based acoustic surveys

BackGround

One of SETMAC's highest research priorities is the development of new fishery independent measures of stock abundance. This is because the evolution of fishing practices makes it difficult to decipher trends in fish abundance from fishery dependent catch rate trends (Prince *et al.* 1998; FRDC 97/114).

Through repeated surveys with standard methodology it is hoped that Fishery Independent Surveys will provide an accurate, relative index of stock abundance to underpin high quality stock assessment.

At present within the SEF, fisheries independent surveys are only used in the stock assessments of orange roughy and blue grenadier. These single species surveys have relied upon dedicated research vessel and have proved to be relatively expensive. The annual GVP of the SEF is only around $60 million, so it has limited capacity to fund $0.5 million annual surveys for single species.

A previous FRRF funded "Industry Acoustics" project (Prince & Higginbottom 1996; FRRF 92/93-7) fostered the development of an acoustic and positional digital data logger called the EchoListener. That project demonstrated the potential effectiveness of the technology needed to conduct low cost, but fully quantitative and calibrated, single frequency acoustic surveys using the hull mounted transducers of commercial fishing vessels. The project collected high quality data for winter aggregations of both blue grenadier (Prince & Higginbottom 1996) and redfish (Prince 1996; FRDC 96/157). The Industry Acoustic project also provided the impetus for a researcher (Dr Ian Higginbottom) involved in the project to form a company, SonarData Tasmania P/L, to develop software (EchoView) for viewing and analysing digital acoustic data collected at sea using EchoListener equipment or other digital data loggers.

As with all acoustic techniques, results with the Industry Acoustic approach will be best when working with species that:

- have a high target strength (i.e have a swim bladder),
- aggregate in shallower water,
- over flat terrain, and in
- relatively pure single species schools.

Unfortunately these types of conditions rarely occur together in the SEF. The winter aggregations formed by redfish (*Centroberyx affinis*), blue grenadier (*Macruronus novaezelandiae*) and spotted warehou (*Seriolella punctata*), probably offer the best opportunity for the future application of industry based acoustics to the quantitative surveying of fish stocks in the SEF.

Redfish Acoustics

Fishers report that redfish form acoustically visible aggregations between June and September each year along the edge of the NSW shelf. The redfish aggregations are relatively stable over time, migrate vertically on a diurnal basis, and reach their peak abundance in August-September each year between Eden and Sydney. Where these acoustic layers come within 2-3m of a trawl ground in about 200-250m, large, relatively single species catches of redfish can be made with demersal trawls. This relatively pure species composition, together with the high target strength of redfish, their aggregation stability, and the relatively gentle slope of the bottom in the area of their aggregations, should make the winter redfish aggregations suitable for surveying with acoustic techniques.

The 1993 Industry Survey of Gemfish observed redfish forming extensive, stable, morning aggregations, between Ulladulla and Bermagui (Prince & Wright 1994; FRRF 19/12 & FRDC 93/057). The aggregations were sheet like, up to 150-200m thick, 3-8km across and stretched relatively continuously along the shelf break between Wollongong to Bateman's Bay (150-200km), touching down on the bottom in 200-250m. Large, relatively pure survey catches of redfish from these aggregations confirmed species composition and suggested the use of industry acoustics to define their extent and volume.

High quality calibrated acoustic data on similar redfish aggregations between Wollongong and Ulladulla (Figure 1) were collected opportunistically during the 1996 Industry Survey of Gemfish (Prince 1996).

The Daily Cycle

Whether or not, they contain redfish, most acoustic marks seen at the edge of the continental shelf share the same diurnal vertical migrations. This leads to the same behaviour each sunrise when the acoustic biomass dives, illustrated here by figure 2. This echogram was collected 19 August 2000, as the F.V. Arakiwa steamed over the shelf break and then shot away south along the slope for the dawn shot. As the vessel tracked across the slope (figure 2a), marks are seen on the bottom in 140-160m and against the slope in 180-280m. From around 5.50AM (figure 2a) through until 6.30AM (figure 2b) an acoustically reflective haze is seen diving toward the bottom, from above 160m down to, or below the depth of the dawn shot in 300-320m (figure 2c).

The acoustic marks that form close to the bottom along the slope after the morning dive remain relatively stable during the morning hours, but may begin dispersing back into the water column during the afternoon. The formation of morning marks is relatively stable over days and weeks so that similar shaped marks, of apparently similar species composition, repeatedly forming after dawn in the same depth bands. Prior to each survey the skippers used in this project could confidently predict the approximate depth at which the morning marks would form each day and their species composition.

Need

Considered a low priority species for the SEF for many years the importance of redfish research has greatly increased over the last few years.

Reliable catch and effort statistics have only been collected with SEF1 logbooks since 1986. Trends since 1986 are indicated using the aggregated statistics of the main redfish catching vessels, as used by the Redfish Assessment Group (Figures 3&4). Effort and catch levels remained relatively stable until 1990 when effort began increasing rapidly, more than doubling to around 5,000h/ammum by 1994. With these effort increases, catches also increased from 100-300t prior to 1990, to 600-800t in 1992 and 1993. Since 1994 effort has slowly declined to the current 3,000h/annum. Landings were sharply lower at 400-500t during the period 1994-1997, back around 700t in 1998, then down again to around 300t from 1999 and 2000.

In 1993 the redfish stock was estimated by SEFAG on the basis of catch rate trends and the changing size structure of the catch to be around 10 - 20,000t.

The Redfish Assessment Group (RAG) was established in 1998 to refine and update this assessment. In 1998 SEFAG plenary reviewed the RAG's preliminary assessment which estimated that the redfish biomass is down to 3-4,000t, and likely to continue declining even without further fishing. The RAG's cohort analysis also suggested that over the last five years recruitment rates spiked up to several times historic levels, and then declined to virtually nothing in the terminal years of the analysis.

This assessment was extremely contentious with many researchers who suspected that a strong "terminal year" effect was influencing the cohort analysis. But the assessment was especially contentious with industry members from NSW who fiercely dispute biomass estimates that low. On the basis of the size of acoustic marks they see, and the size of their own shots, they believe the biomass to be considerably higher. The fishers claimed that catch rate trends reflect changing fishing patterns. That quota management has lead to them optimizing the species composition of catches which has lead to decreased targeting of single species aggregations and a decline in catch rates (Prince *et al.* 1998). They claim that changing catchability is producing a misleading stock assessment.

Regardless of the actual state of the redfish resource; the essential problem remains that the assessment will continue to be based upon the same questionable fishery dependent trends, unless quantitative techniques are developed for surveying these stocks independently to evolving fishing practices.

Objectives

The primary objective of this project was to test the feasibility of surveying redfish aggregations in a small area between Ulladulla and Bermagui, using industry based acoustic techniques. Specifically the objectives of this project were to:

4. Conduct four acoustic surveys of redfish aggregations within a selected research area using a commercial fishing vessel equipped with EchoListener equipment.

5. Repeatedly map the distribution and acoustic density of marks attributable to redfish and derive a range of biomass estimates based on these data.

6. Analyse and report on the feasibility of estimating redfish biomass using industry acoustics.

Methods

It was industry's observation before the surveys began (supported by SEF1 returns, figure 3&4) that redfish were at the low point of an availability cycle during 1999 and 2000. Through the winter of both years few if any stable redfish marks were observed between Jervis Bay and Bermagui, redfish catches were sporadic, and catch rates generally low.

In the light of this situation and through negotiation with the fishers of the area it was decided to conduct the 4 acoustic surveys over four months rather than weekly through August, as originally proposed. The industry suggestion was to conduct the surveys monthly during the week following the full moon in July, August, September and October 2000.

On the advice of the local marine electronics expert the South East Trawl Fishing Vessel, the Arakiwa was selected as the survey vessel. The technical advice was that because the wheelhouse of the Arakiwa had recently burnt to hull level and been replaced, the entire electronic system of the vessel was new and thus provided the cleanest available electronic environment for collecting digital acoustic and global positioning system (GPS) data. Consequently, during July 2000, the necessary connections were fitted to the Arakiwa's electronics system, allowing an EchoListener system to tap into the vessels echosounder and GPS system.

Data Acquisition and Analysis

The EchoListener equipment logged the data from each acoustic ping onto the hard drive of a laptop computer. These data were backed up after each day's surveying using a zip drive. At the end of the surveys the laptop computer was returned to the laboratory and the EchoListener Data was downloaded into EchoView software. The EchoView software was used to:

- view acoustic data
- identify and outline schools, sample school heights and bottom depths,
- export schools data, at two second intervals, into data files for importation into Excel

An example of an Excel data set generated in this fashion is provided in Table 1.

Survey Design

The structure of the individual surveys had to be negotiated with the fishers conducting the surveys and by necessity developed through the course of the project. The twin aims of the design process was to develop a reproducible survey design which could:

1. collect useable, quantitative acoustic data, and
2. minimise disturbance to normal fishing patterns.

The imperative behind the second aim is that the long term potential for application of any survey technique in the SEF will depend upon it being industry based and extremely cost effective. Thus the technique must cause minimal disruption to normal fishing and so have minimal cost implications to the fishing operators that will eventually be required to implement surveys.

Figure 5 shows the normal daily fishing pattern being employed in this part of SEF, it was recorded with the EchoListener equipment aboard the Arakiwa 15 July 2000 while the equipment was being installed and tested. The vessel steams out to the edge of the continental shelf and normally shoots south for the dawn shot for around 3 hours, retrieves the net, sorts the catch, and shoots back the other direction for a 3 hour late morning shot, and then steams back to port.

The acoustic surveys commenced with a short (2h) dawn shot, which had the purpose of sampling the depth range redfish are expected to be caught in, and providing a general indication of the species composition of the pre-dawn haze settling on to the slope.

Following the dawn shot, as the catch was sorted, the Arakiwa would work its way back to the north acoustically scanning the shelf break and slope with its acoustic equipment. These surveys used a zig-zag track backwards and forwards across the slope over bottom depths of 140-400m.

On each of the three survey days two parallel bands of marks were observed stretching relatively continuously along the slope. A shallower mark close to the shelf break or 'edge' around 150-200m and a deeper band around 300-400m. Neither of these marks were in the 200-300m depth range normally expected of redfish (see figure 1). Lack of time prevented the composition of both marks being tested with targeted shots in the same day, and t was necessary to choose to sample one or the other of the marks on any day. However it was normally possible to get a good idea of the composition of both marks from the other vessels fishing near by.

Biomass Estimation

In the light of previous experience and discussions with fishers it was envisaged that relatively pure redfish aggregations would be identified by the surveys. Consequently it was originally proposed that the acoustic surveys would be used to define the volume of the redfish schools and then to use surveyed catch rates, together with estimates of swept volume, and catchability to produce a range of biomass estimates for redfish within the survey area.

However, as the Results Section reveals, redfish were only detected in trace amounts and no aggregations were observed that could be attributed (even substantially) to redfish. Thus the result of these surveys is a zero estimate for redfish biomass within the trial area. While the broader implications of this are canvassed in the Discussion Section, the immediate implication for this project was to make it impossible to estimate redfish biomass, as per the original objectives.

Rather than waste the opportunity presented by this project and return a completely nul result, this report attempts to demonstrate the general utility of industry based acoustic techniques for observing and measuring acoustic biomass at the shelf break. To this end the acoustic and trawl catch data collected, have been used to describe more general trends observed in the acoustic biomass during the survey period. The objective of this being to illustrate the data that can be collected and the type of information such studies could provide.

For the sake of testing the feasibility of industry acoustics for collecting indices of abundance at the shelf break the shallower mark was selected arbitrarily to serve as a proxy for a redfish mark.

Results

The project spent 5 days aboard the vessel, an initial setup cruise 15 July, 2000, three successful survey days 23 July, 20 August and 16 September. The last of the planned surveys 21 October had to be aborted due to poor weather.

Day 1 - 23 July 2000

Survey

The Arakiwa's 2h dawn shot (figure 6) only caught about 200kg of redfish (table 2).

Species or Generic Group	Estimated Total Catch (kg)
Redfish	200
Squid	90
Mirror Dory	20
Tiger Flathead	60
Gemfish	5
Misc. Crabs	40
Cucumber Fish	80
Southern Frostfish	50
Misc. Sharks	50
Deepwater Flathead	40

Table 2.

At least some redfish were in the general vicinity. The boats fishing to our north, on the main Ulladulla ground, had better catches, Charissa around 3,500kg and the Santa Maria Star a little less. Well below expectations for that time of season.

There were two strip-like acoustic marks running along the shelf break and slope, but neither of these were in the 200-250m depth band expected of redfish. However expecting there to be most redfish in the shallower mark the first acoustic survey concentrated on the shallower mark (160-200m). A zig-zag survey comprised of 9 sweeps was completed towards the north (figure 6 & 7a-e).

The shallower mark was then sampled with the second (1.75h) shot for the day (figure 6 & 7f). The catch was principally barracouta (*Thyrsites atun*), tiger flathead (*Neoplatycephalus richardsoni*) and small jack mackerel (*Trachurus declivus*). Only 5kg of redfish was caught. The Baronness and Shoalhaven fishing to the north and south of the Arakiwa took similar catches from the same mark.

Species or Generic Group	Estimated Total Catch (kg)
Redfish	5
Squid	5
Mirror Dory	5
Tiger Flathead	70
Barracouta	150
Jack Mackerel	20
Cucumber Fish	10
Southern Frostfish	5
Stingarees & Stingrays	10

Table 3.

This catch composition would not show the true importance of jack mackerel, because the jack mackerel were seen still vigorously escaping the net in large numbers in the final phase of landing the net. The same is probably true to a lesser extent for the barracouta as these fast fish are also capable of avoiding the net. Together with the skippers it was concluded that the shallower mark was principally jack mackerel being preyed upon barracouta

With the shallower mark obviously containing little redfish it was of concern that the deeper of the two marks observed along the shelf break had not been acoustically surveyed, or identified. It was consequently decided to conduct a second acoustic survey for the day (figure 7), this one concentrating on the deeper mark in 300-400m (figure 8g-i). By the time this acoustic survey was completed the marks had begun lifting off the bottom, and it was considered to late in the day to commence a shot to identify the mark. The skippers of the Arakiwa expected the marks would contain mainly southern frost fish (*Lepidopus caudatus*). However the F.V. Rockfish and F.V. Baroness fished the mark several miles to the north with their afternoon shots and caught almost entirely three-spined cardinal fish (*Apogonops anomalus*).

Acoustic Data

The completion of two separate acoustic surveys of shallow and deeper mark is immediately evident in the acoustic data for 27 July, 2000. Figure 8a shows the depth of the bottom of acoustic marks, while figure 8b plots height of the mark against time of day. Both clearly show the separate surveys; the earlier (figure 7a-e) shallower (figure 8a) survey of the compact bottom hugging marks (figure 8b) and the later (figure 7g-i), deeper (figure 8a), hazy marks higher above the bottom (figure 8b).

Throughout this report I choose to use time of day, or survey sweep as the plotted x-value, rather than position. As each data point is spatially and temporally located this analysis can be conducted in either dimension. However a relatively constant speed was maintained through all surveys so time and position are relatively equivalent. Given the limited nature of this study no purpose is served in converting this analysis into units of distance when time serves the same purpose. However, it should be noted that while Time of Day as plotted is sequential, it can be disjointed. This is because only data on acoustic marks have been extracted and no data is presented for regions without acoustic marks.

As discussed above, being unable to identify an acoustic mark that could be substantially attributed to redfish, but wishing to demonstrate the basic utility and potential of industry acoustic techniques, I have selected the shallower mark (160-200m) to study as a proxy for redfish aggregations. It was probably comprised principally of jack mackerel, but also contained other species including barracouta and redfish.

Figure 8c shows the shallower first half of the data set, for height of mark against time, that has been selected for analysis. While figure 8d categorizes the same data into 9 survey sweeps. Even plotted this way these data give some sense of the 25-30m high acoustic marks that were surveyed in 160-200m (figure 8e).

In Table 4 data summary statistics have been estimated for the transects of the first survey. A total 557 data points were extracted for the 9 sweeps of the survey, which had an overall crude mean height of 9.8m. The size of this data set is a function of school numbers and sizes, together with the frequency with which the acoustic data set was sampled when the data were extracted.

Sweep Number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**		
Count of Height	65	34	79	68	64	49	59	31	108	557	**Total n**
Sum of Height	935	301.1	591.4	890.9	903.3	347	521.5	154.9	1037.5	631.4	**Av. Sum of Height**
Average of Height	14.4	8.9	7.5	13.1	14.1	7.1	8.8	5.0	9.6	9.8	**Average Height of Sweep**
Var of Height	30.9	17.7	61.9	96.3	75.5	39.4	42.8	10.4	75.8		

Table 4

The more interesting statistic here is the cross sectional area of the mark along each transect as this provides an index of the acoustic biomass of the mark. Being only a relative measure it is calculated here simply by summing the height data for each survey sweep. A number of conversions and algorithms could be used to convert this relative measure of cross sectional area into estimates of school volume. However, given the limited nature of this analysis, the Sum of Height statistic serves adequately and easily as a proxy for relative acoustic biomass.

The average Sum of Height for the 9 transects was 631, with a range of 301-1037.

Day 2 - 20 August, 2000

Survey

Started with a short (2.5h) dawn shot that fished the 200-400m depth range. The catch contained mainly ribbonfish, crabs and cucumber fish (*Chlorophthalmus nigripinnis*), together with some three-spined cardinal fish and whiptails (*Lepidorhynchus denticulatus*). There were few redfish (60kg).

Species or Generic Group	Estimated Total Catch (kg)
Redfish	60
Squid & Cuttlefish	55
Mirror Dory	50
Southern Frostfish	200
Swimmer Crabs	400
Cucumber Fish	700
Stingarees & Stingrays	10
Ling	5
Mixed Shark	30
Toothed Whiptails	5
ThreeSpined Cardinal Fish	Abundant. Catch not estimated.

Table 5

Without redfish to focus the surveys on, a single zig-zag survey covering the full 140-400m depth range was conducted (figure 9). Again two strip like marks were observed, the shallower mark in 150-180m and the deeper in 330-370m (Figure 10). The deeper mark was only a band of scattered small marks some against the bottom and some a few meters above the bottom.

I wanted to be able to sample both marks in case either contained a reasonable level of redfish. The two skippers of the Arakiwa argued that in this location the shallower "edge shot" was untrawlable due to sandstone slabs. The F.V. Rockfish had a short shot at the shallower mark to the north of the Arakiwa and caught jack mackerel and barracouta, similar to our July survey catch.

With the advice of the Arakiwa's skippers in mind we sampled the deeper mark with a 3h shot which was comprised mainly of ribbon fish. The ribbon fish were apparently mixed with three-spined cardinal fish in the mark, although because of the small size of the cardinalfish the catch undoubtedly underestimated their importance. There were only 3 redfish in the catch.

Species or Generic Group	Estimated Total Catch (kg)
Redfish	1.5 (3 fish)
Squid & Cuttlefish	20
Mirror Dory	70
Southern Frostfish	1,000
Swimmer Crabs	150
Gemfish	5

Ling	5
Mixed Shark	30
Toothed Whiptails	5
Three Spined Cardinal Fish	40

Table 6

Acoustic Data

The different structure of the second survey is immediately evident in the raw acoustic data for 19 August 2000. Figure 11a shows the depth of the bottom of the acoustic mark, and the zigzag structure of the survey, alternately crossing the two marks, is clear. Figure 11b plots height of mark against time of the day for the entire survey. Figure 11c shows the height of mark data for just the shallower mark, while figure 11d are the same data for the shallower mark subdivided into 8 survey sweeps.

The shallower mark was generally 20-30m high, with some sweeps measuring peak heights of 40-60m (figure 11d).

Table 7 provides a data summary for the second survey. A total 552 data points were extracted from 8 sweeps or transect across the mark, producing a range of mean heights 5.5 - 20.3m, and an overall mean height of 12.3m.

Sweep Number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**		
Count of Height	32	66	125	105	22	38	48	116	552	**Total n**
Sum of Height	613.3	639.2	2209.1	1543.6	446.1	393.2	285.8	635.5	845.7	**Av. Height of Sweep**
Average of Height	19.2	9.7	17.7	14.7	20.3	10.3	6.0	5.5	12.9	**Average Height of Sweep**
Var of Height	148.4	162.5	322.4	198.7	108.6	94.5	40.6	25.3		

Table 7

The average Sum of Height for the 8 transects was 846, with a range of 286-2,209.

Day 3 - 16 September

Survey

The 2h dawn shot through 260-300m was affected by catching a 4m thresher shark. Large angular weights in the codend usually collapse a trawl net to some extent reducing catch rates. The other catch was mainly ribbon fish and mirror dory (*Zenopsis nebulosis*) with traces of cucumber fish, squid, whiptails.

Species or Generic Group	Estimated Total Catch (kg)
Redfish	10
Squid & Cuttlefish	20
Mirror Dory	40
Southern Frostfish	80
Cucumber Fish	5
Tiger Flathead	30
Monkfish	5

Mixed Shark	40
Toothed Whiptails	5

Table 8

The Arakiwa initially began acoustic surveying back towards the north at 7.49AM (figure 12 & 13a). But after discussion with the skippers, about my determination to sample the shallower mark during this survey, we broke off acoustic surveying to take advantage of a section of the shelf edge where the skippers thought we might be able to safely trawl along the shelf edge.

At 8.36AM the Arakiwa commenced a targeted shot at the shallower mark in 160-200m, and hauled at 10.57AM (figure 12 & 13b-e) to discover a large slab of sandstone had wedged in the codend. This also would have had an impact on the catch which was mainly tiger flathead with some redfish. However, taking into account reports from vessels fishing around us we concluded there was less jack mackerel and barracouta in the shallower mark.

Species or Generic Group	Estimated Total Catch (kg)
Redfish	25
Squid & Cuttlefish	10
Rubberlip Morwong	20
Tiger Flathead	120
Jack Mackerel	5
Sharks,rays, Stingaree	40
Mixed Species	10

Table 9

The Arakiwa then conducted a zig-zag acoustic survey towards the north (figure 12). There were much fewer acoustic marks (figure 13f-j) than in the two previous surveys. The shallow mark (140-160m) was the main mark and still formed a relatively continuous band along the edge. The deeper mark was just an occasional small to very small (speckle) mark around 260-280m (figure 13f-j).

Acoustic Data

The structure of the raw acoustic data collected on 16 September 2000 is illustrated by figure 14. Figure 14a shows the depth of the bottom of the acoustic mark. Acoustic surveying of the deeper mark (250-350m) is obvious at the beginning of the time series and again at the end. While much of the extended period of marks around 150m was observed during the second shot which interrupted the acoustic survey.

Figure 14b plots height of mark against time of day for the entire day. This shows that only one mark was observed > 15m high, and it was in 280m. Almost all the other marks observed were 5m or less. The different structure of the data collected during the second trawl, is immediately evident with the peaks and troughs in the data being stretched out over time. This effect is due to steaming slowly along the mark, rather than sweeping diagonally across it.

Figure 14c shows the height of mark data for just the shallower mark but throughout the whole day. While figure 14d shows the data from just the 8 survey sweeps. The shallower mark was generally 5-10m high, four marks 15m were observed (figure 14d). In these figures the small segment of zero heights have been inserted to indicate that the 4th sweep of the survey did not detect any mark as it transected across the shallower depth band.

Table 10 provides a data summary for the third acoustic survey. Extracting schools data at 2 second intervals from the acoustic survey 403 data points were collected from the 8 survey sweeps with a range of 0-93.

Sweep Number	1	2	4	5	6	7	8	9		
Count of Height	64	92	0	19	4	83	93	47	403	**Total n**
Sum of Height	254	140.2	0	20.9	4.4	380	579.8	298.7	279.7	**Av. Height of Sweep**
Average of Height	4.0	1.5	0	1.1	1.1	4.6	6.2	6.4	4.1	**Average Height of Sweep**
Var of Height	13.0	1.5	0	0.0	0.0	13.4	26.4	15.0		

Table 10

The height of the shallower mark had declined to 4.1m and our biomass index (Sum of Height) had declined to 280, range 0-580.

Day 4 – 21 October 2000

After a 10 day period when the fleet had been unable to leave port the final acoustic survey was planned for the 21 October. However just prior to reaching the edge of the Continental Shelf the Arakiwa was forced to return to port because of strong south westerly winds. As there was no guarantee on when the fleet would next leave port, and because other commitments were pressing, the survey was aborted. In the event the fleet did not get back out to sea for a further 8 days.

Summary

These industry based acoustic surveys observed the longitudinal mark along the edge of the continental shelf in 140-200m (Table 11), to have an average height of 9.8m in July 2000, and 12.9m in August. Its relative abundance, based on cross-sectional area, was estimated at 631 and 845 during July and August 2000 respectively. By September the average height of the same mark had declined to 3.1m and its relative abundance to 210.

The species composition of survey trawls and the surrounding commercial catches suggests that the bulk of the acoustic biomass in this mark was jack mackerel during both July and August. The decline in the relative abundance index for this mark from 845 in August to 210 in September was apparently due to a decline in jack mackerel abundance.

While not analysed quantitatively, the deeper water marks observed in 300-400m exhibited a similar decline in size in September. That decline was apparently due to a reduction in the abundance of frostfish and three-spined cardinal fish.

Discussion

No Redfish

During these limited acoustic surveys no marks were observed that could be identified as being largely, or even substantially, comprised of redfish. This situation was not restricted to the survey vessel. Few redfish marks were observed through this area of the SEF during the winters of 1999 and 2000, and commercial catch rates were generally low (figure 3 & 4). In terms of the schools based approach to acoustic surveying being employed here, the lack of identifiable redfish aggregations effectively translates into an estimate of zero redfish biomass in the survey area. Clearly some redfish were present through the area, but their abundance was below a level which could be quantified by these methods, effectively zero.

It may be concluded that this result is indicative of low stock abundance and generally supportive of the Redfish Assessment Group's preliminary assessment. But the data presented here are extremely limited and influenced by many factors including the overall abundance of redfish.

Redfish catch rates are strongly cyclical (Figure 15). High catch rates apparently coincide with periods when the Southern Oscillation Index (SOI) is negative (el Niño) and low catch rates with positive SOI values (La Niña). Prince (2001), and Prince & Griffin (2001), postulate that the aggregations of many SEF species form in relation to the annual position of the Tasman Front. During periods of La Niña the Tasman Front moves to the north. In some La Niña years, such as 2000 (Prince 2001), the Tasman Front may lie to the north of the SEF, beyond the northern boundary (Barranjoey Point, Sydney). It could be that in La Niña years catch rates within the fishery are depressed because redfish aggregations forming in the same region relative to the Tasman Front are mainly beyond the northern boundary of the SEF.

Whatever the cause, the lack of identifiable redfish aggregations during these surveys meant that this project has been unable to achieve its stated objectives, which were to:

- Conduct four acoustic surveys of redfish aggregations within a selected research area using a commercial fishing vessel equipped with EchoListener equipment.

- Repeatedly map the distribution and acoustic density of marks attributable to redfish and derive a range of biomass estimates based on these data.

- Analyse and report on the feasibility of estimating redfish biomass using industry acoustics.

Limitation of Industry Acoustics

The presence of some redfish in survey catches without being able to identify a redfish aggregation illustrates the main weakness of the Industry Acoustics approach reliant on a schools based approach.

A species can be present, as some redfish undoubtedly were, but below the threshold that the technique can quantify. Kloser in his draft report on FRDC 99/111 demonstrates the same principle with spawning orange roughy at St Helens Hill during 1999. In that case trawl shots, and the multi-frequency acoustics of CSIRO's towed body array, proved that small schools of orange roughy were spawning at St Helens. But single frequency acoustics will hull mounted transponders were unable to distinguish the roughy schools, from schools of other species, and the acoustic dead zone against the bottom.

This is a threshold issue. Industry Acoustics will never have the same precision as a towed body array and a relatively high threshold will be a part of that imprecision. As long as a useful range of population abundance lies above the threshold the less precise technique may still be useful. Other forms of imprecision may be overcome by increasing the intensity of sampling regimes. Thus in the context of the SEF many lee precise, but relatively inexpensive, surveys may produce more reliable estimates of trends, than a very few, expensive and precise surveys.

Multi-frequency acoustics holds out the promise that in time some species definition will be possible with acoustic surveys (Kloser 2000). However at the current time the CSIRO towed body array is the only multi-frequency acoustic array available for surveying in the SEF. In time the commercial fleet may adopt multi-frequency technology more widely, but until that time interpretation of catch composition will remain the principle means of predicting the composition of acoustic marks.

This raises the issue of using fine mesh cod ends in order to get a more representative catch of the smaller animals that escape from the net. My preference is for techniques that have minimal impact on normal fishing operations so that the future uptake and application of the techniques by industry is eased. I also prefer to accept that all sampling techniques and nets have biases. It seems strange to estimate more precisely the smaller animals escaping through the net, without also estimating the larger and faster animals escaping in front of the net.

It is better to quantitatively understand these biases through the results of studies, such Dr Ian Knuckey's South East Trawl Bycatch Reduction Project (FRDC# 2001/006). That project is directly estimating the selectivity curve many SEF species. This will allow direct estimation of the species and size classes that escape through commercial nets. An approach that is superior to employing fine mesh liners aboard commercial vessels during industry based surveys.

The Potential of Industry Acoustics

The low relative abundance of redfish over the southern Ulladulla grounds during the winter of 2000 thwarted the principle objectives of this project. However the limited analysis presented here, of the size and composition of the two alternative marks that were surveyed, still servse to illustrate the potential utility of this techniques in the SEF.

The limited analysis performed found the longitudinal mark along the edge of the continental shelf in 140-200m, to have an average height of 9.8m in July 2000, and 12.9m in August (Table 11). Its relative abundance, based on cross-sectional area, was estimated at 631 and 845 during July and August 2000 respectively. By September the average height of the same mark had declined to 3.1m and its relative abundance to 210. The species composition of survey trawls and commercial catches suggests that the bulk of the acoustic biomass in this mark was jack mackerel during both July and August. The decline in the relative acoustic abundance from 845 to 210 was apparently due to a decline in jack mackerel abundance in the research area.

While not analysed quantitatively, the deeper water marks observed in 300-400m exhibited a similar decline into September which was apparently due to a reduction in the abundance of frostfish and three-spined cardinal fish in the research area.

The annual cycle of abundance of many SEF species has been previously described by May and Blaber (1989) off southeastern Tasmania where the abundance of many species peaks occur over summer. Fishers of southern NSW describe a similar annual cycle in species abundance, but peaking in late winter (Prince 2000). This limited acoustic survey documents the seasonal decline in fish abundance that occurs off southern NSW after winter, as described by fishers.

Ecosystem Assessment and Management

While this study started with an emphasis on surveying the single species, redfish, to demonstrate the utility of the technique it has ended up demonstrating a potential to be a component of a broader ecosystem survey strategy.

In the SEF at the current time discussion is starting about the need to institute some form of ongoing multi-species fishery independent surveys using the commercial fleet (Prince *et al.* 2001). The basic idea behind this is that a cost effective but fishery independent survey system might be developed if vessels on all the main SEF fishing grounds would agree to seasonally undertake specified “Survey Trawl Shots” in specified locations.

Within this context industry acoustic surveys, as demonstrated by this project, offer great potential to increase the data collecting ability of any long term program of fishery independent surveying.

Many important species in the SEF ecosystem are not highly catchable by demersal trawling. Jack mackerel and three-spined cardinalfish are two cases in point. Both are important fish species at the base of the SEF food chain (Blaber and Bulman 1987) and both are poorly represented in commercial demersal trawl samples. The first because of its swimming speed and pelagic behaviour, the second because of its small size.

Integrating acoustic and trawl sampling into a single survey design could create a capacity to simultaneously collect two different but complementary data sets. This could greatly increase the value of both data sets precisely because species dependent sampling bias will always be an extremely important issue in the SEF. An important issue that can only be studied by collected directly comparable data sets with a range of techniques.

The point here is that for little extra cost the same surveying platform could gather both data sets and greatly increase the power of analysis available.

Benefits

The results of this project will directly benefit the South East Trawl Fishery which is discussing the design and implementation of long term program of fishery independent surveys. Fishery independent surveys are considered necessary for the fishery to accurately monitor the abundance of the 100+ SEF species and, in turn, make it possible for the South East Fisheries Assessment Group to determine the factors influencing stock abundance and commercial catch rates. Improvements in monitoring stock abundance, and understanding the variability of SEF species will lead to improved TAC setting, less management related conflict, and improved management of the resource for the general public.

This flow of benefits is as predicted in the original application.

Further Development

The SETMAC's Research Sub-committee has proposed that a workshop be held to discuss and design a Fishery Independent Survey for the SEF based on the use of commercial fishing vessels and trawl sampling. That workshop should consider the results of this study and consider incorporating the collection of acoustic data into the survey design.

The proposed workshop would initiate a pilot scale implementation of the survey program designed. Incorporation of acoustic techniques into the pilot scale phase of the survey program would make it possible to evaluate the overall utility of using dual survey methods.

Conclusions

Due to a lack of identifiable redfish aggregations during its surveys this project has been unable to achieve its stated objectives, which were to:

- Conduct four acoustic surveys of redfish aggregations within a selected research area using a commercial fishing vessel equipped with EchoListener equipment.

- Repeatedly map the distribution and acoustic density of marks attributable to redfish and derive a range of biomass estimates based on these data.

- Analyse and report on the feasibility of estimating redfish biomass using industry acoustics.

Despite this disappointing result a limited analysis of the other acoustic marks observed has been undertaken to demonstrate the practical potential of deploying industry acoustic techniques in the SEF. In this project the technique has been successfully used to document the seasonal decline in fish abundance that occurs off southern NSW after winter which previously had only been described by fishers. These observations provide an interesting counterpoint to May and Blaber's (1989) description of the seasonal cycle of abundance off southeastern Tasmania which peaks over summer.

The results of this project suggest that Industry Acoustics have great potential for increase the data collecting ability of a long-term program of fishery independent surveys. Integrating acoustic and trawl sampling into a single survey design would create a capacity to simultaneously collect two different, but complementary data sets. Together these data sets would provide a powerful means of quantifying the sampling biases of the individual sampling techniques. This study demonstrates that such a survey can be designed so that it is easily incorporated into relatively normal fishing practice with a correspondingly lower cost. Deployed broadly across the fishery the survey would have potential to simultaneously and cost effectively monitor the ecosystem health of the SEF.

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Appendix 1:

No commercially valuable information or intellectual property has been developed by this project.

Appendix 2:

Consultants Used:

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