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School of Fisheries
University of Washington
Seattle, Washington 98195

Rockfish Investigations off the Oregon Coast

by

G. L. Thomas, Craig Rose, and Donald R. Gunderson

TECHNICAL REPORT

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Roy E. Nakatani, Acting for the Director

INTRODUCTION

The University of Washington (UW) participated in the National Marine Fisheries Services (NMFS) R/V CHAPMAN cruise to investigate widow rockfish off the coast of Oregon from 20 to 26 April 1981. This effort was used to continue an ongoing evaluation of new techniques and equipment for assessing shelf rockfish stocks. The field survey was designed to target widow rockfish because of the recent development of this resource in the Pacific coast trawl fisheries. The behavior of the widow rockfish, schooling at night in midwater, makes this species vulnerable to hydroacoustic techniques for stock assessment.

Echo integration data were collected in the Oregon fishing areas to supplement the UW survey information on schooling behavior. Previous data have indicated that the schooling behavior of this rockfish is highly dynamic within a night. In addition, widow rockfish schools appear to form only in very specific geographical areas along the continental shelf break. The current design of acoustic surveys is to transect without replication. Several assumptions are then required to extrapolate the acoustic measurements into fish biomass. The most questionable of these assumptions may be that the fish aggregations are stable in time and space. Only a limited amount of quantitative information on the diel stability of the widow rockfish schools is available. Therefore, the collection of more data on the temporal variability of the widow rockfish schooling behavior was an important objective.

A second objective of this cruise was to evaluate the R/V CHAPMAN search-light sonar system. The feasibility of sonar mapping with an OMNI sector scanning sonar and echo integration using a Simrad EK-38 scientific echosounder are currently being examined as methods for widow rockfish stock assessment (Gunderson et al. 1980). The sonar mapping utility is a current topic of research whereas echo integration is a proven technique and is used as a standard for comparison. In the present investigation, a SIMRAD SQ sonar was used in conjunction with the standard echo integration procedures to evaluate the utility of the search-light systems and draw analogies with the previously used sector scanning system.

The preceding objectives were justification for our participation in this cruise. In addition, we provided the NMFS with estimates of the nekton biomass along selected transects in several Oregon fishing areas. Preliminary estimates of the nekton biomass were requested by NMFS prior to this report's completion date because of the June schedule of the 1981 Commission meeting on "point of concern" management philosophy. These figures were biased high because of the inclusion of several "bottom integrations" by the shipboard processor wherever high concentrations of fish were found to contact the bottom. This report includes two sections: first; the echosounder revised estimates of nekton biomass with information on the diel variability in schooling behavior of the fish targets, and, second, an evaluation of the search-light sonar system on the R/V CHAPMAN.

METHODS

All field work was conducted between April 20-26, 1981 on the R/V CHAPMAN. The R/V CHAPMAN is a 39 m NOAA stern trawler. The vessel was equipped with a SIMRAD SQ sonar and CQ Scope which were evaluated for their potential as an assessment tool. An EPSCO Loran C plotter was used to map the transect routes.

The survey design consisted of running a series of approximately parallel transects equal distance apart through areas known for widow rockfish commercial fishing; Crater, Fingers, Heceta Bank, and Cape Blanco (Fig. 1). In areas where the bathymetric range of widow occurrence was known (Heceta Bank) the transects were run parallel to the depth contours within 3 pre-established isobath strata (50-75f, 75-100f, and 100-125f). In areas where the isobath range was unknown (the Cape Blanco, Fingers and Crater areas) transects were run approximately perpendicular to the depth contours. Figures 2-3 illustrate the transect grids run on the April cruise by survey area. All transects were run at night at a boat speed of approximately 4 knots, since high acoustic noise interfered with the collection of data at higher ship speeds. The sections of tracklines in the Crater area which were observed to have a high density of acoustic targets were repeated on the nights of 21 April and 25 April.

Acoustic Equipment

Echosounder

Echo integration data were collected using a conventional echo sounder/data acquisition system (Fig. 4). An EK-38 Simrad scientific sounder was used in conjunction with a 38 kHz transducer with a full beam angle of 11^{o} at -3dB (Fig. 5). The source level was 121 dB//ubar at 1 m and the receiving sensitivity of the transducer was -73.7 dB//1 volt per ubar. The transducer was housed in a 2-ft modified Braincon V-fin and towed from a CTD beam. A pulse length of 0.6 ms was used throughout the study with data collection rate of 24 pings/min for the 0-500 m range and 48 pings/min for the 0-250 m range. The acoustic signal was monitored with a Tectronics oscilloscope, recorded in real time on chart paper, integrated in real time in 40 ping intervals on a Biosonics 120 integrator and stored on magnetic tape with a TEAC 3440 A tape recorder for subsequent analysis.

Sonar

Sonar data were collected using a SIMRAD SQ search-lite sonar. The SQ sonar operated at a frequency of 27 kHz. The range, pulse lengths, and transmission rate which were employed were either 750 m, 2 ms and 45 pings/min; or, 375 m, 1 ms and 96 pings/min., respectively. The SQ sonar has a retractable hull-mounted transducer. The transducer sweeping pattern may be programmed or controlled manually.

The sweep pattern of the SQ sonar can be represented by a selectable proportion of a 10^{o} shell of a cone with the ship at its apex.

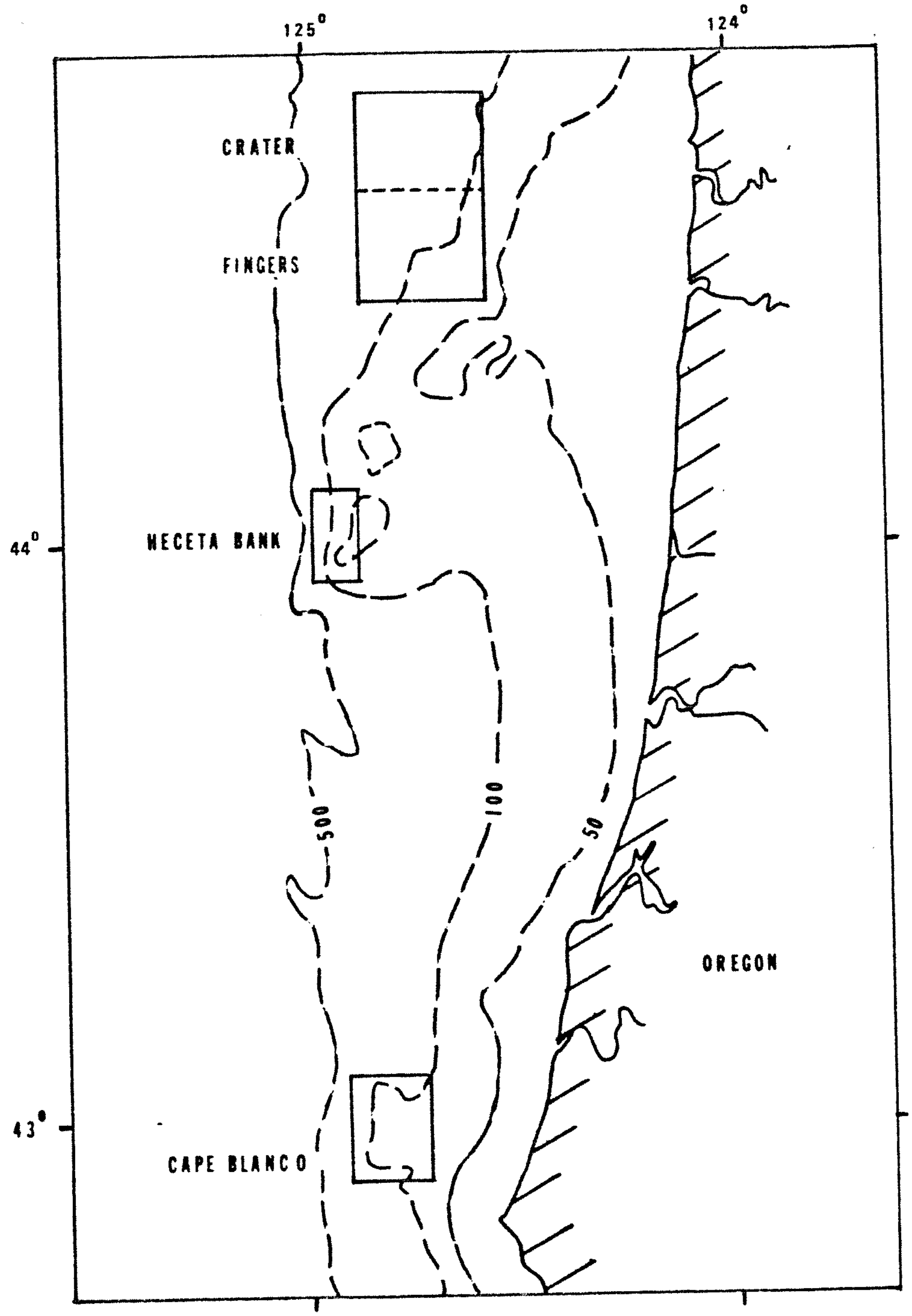

Fig. 1. The four commercial widow rockfish fishing areas (Crater, Fingers, Hecata Bank, and Cape Blanco) surveyed during the 20-26 April 1981 leg of the R/V CHAPMAN cruise (depth contours in fathoms).

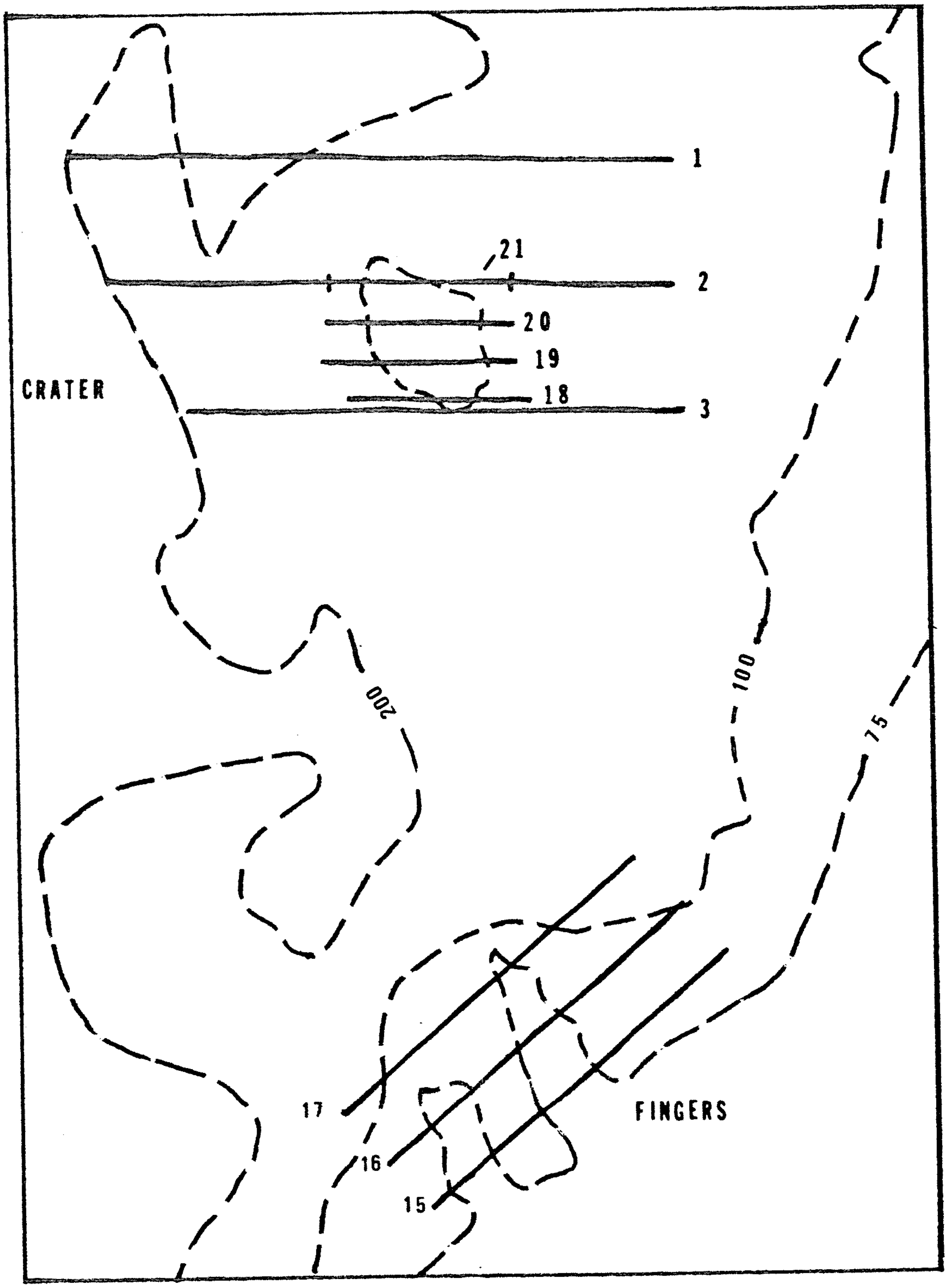

Fig. 2. Transect grids run in the Crater and Fingers areas during the 20-26 April 1981 leg of the R/V CHAPMAN cruise (depth contours in fathoms).

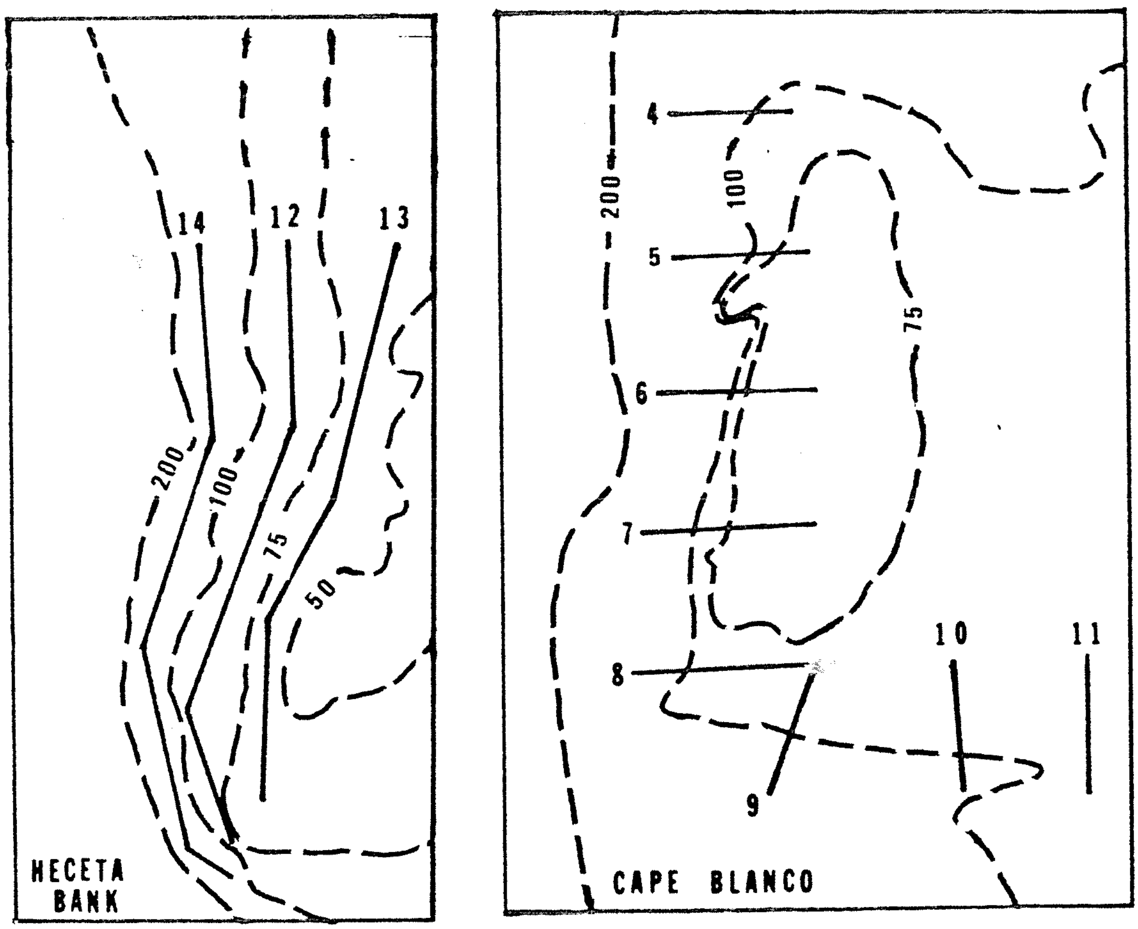

Fig. 3. Transect grids run in the Hecata Bank and Cape Blanco areas during the 20-26 April R/V CHAPMAN cruise (depth contours in fathoms).

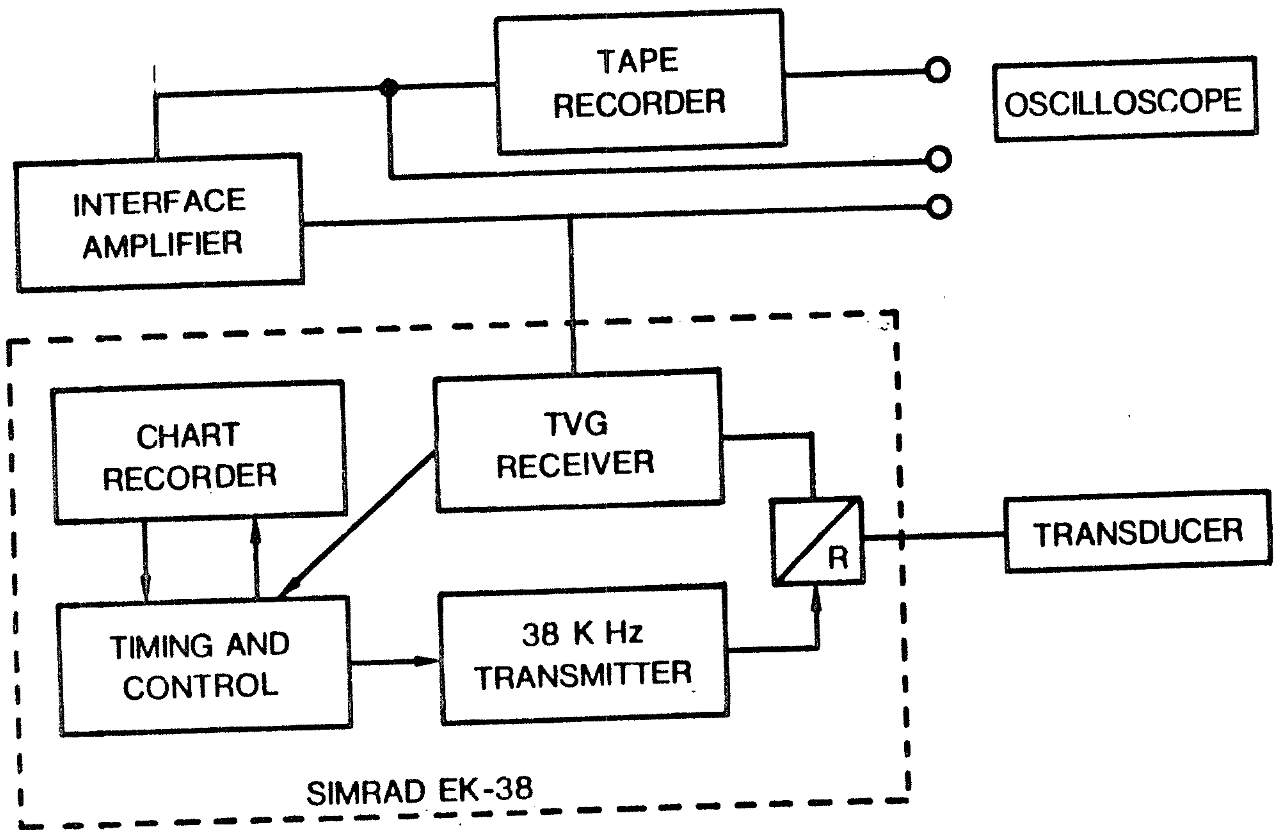

Fig. 4. **Block diagram of the echosounder data acquisition system.**

UW FORM NO. 565 (Rev 4-75)

RECEIVER ______

FREQUENCY 38.0 kHz

DATE 12-14-75 OP. ______

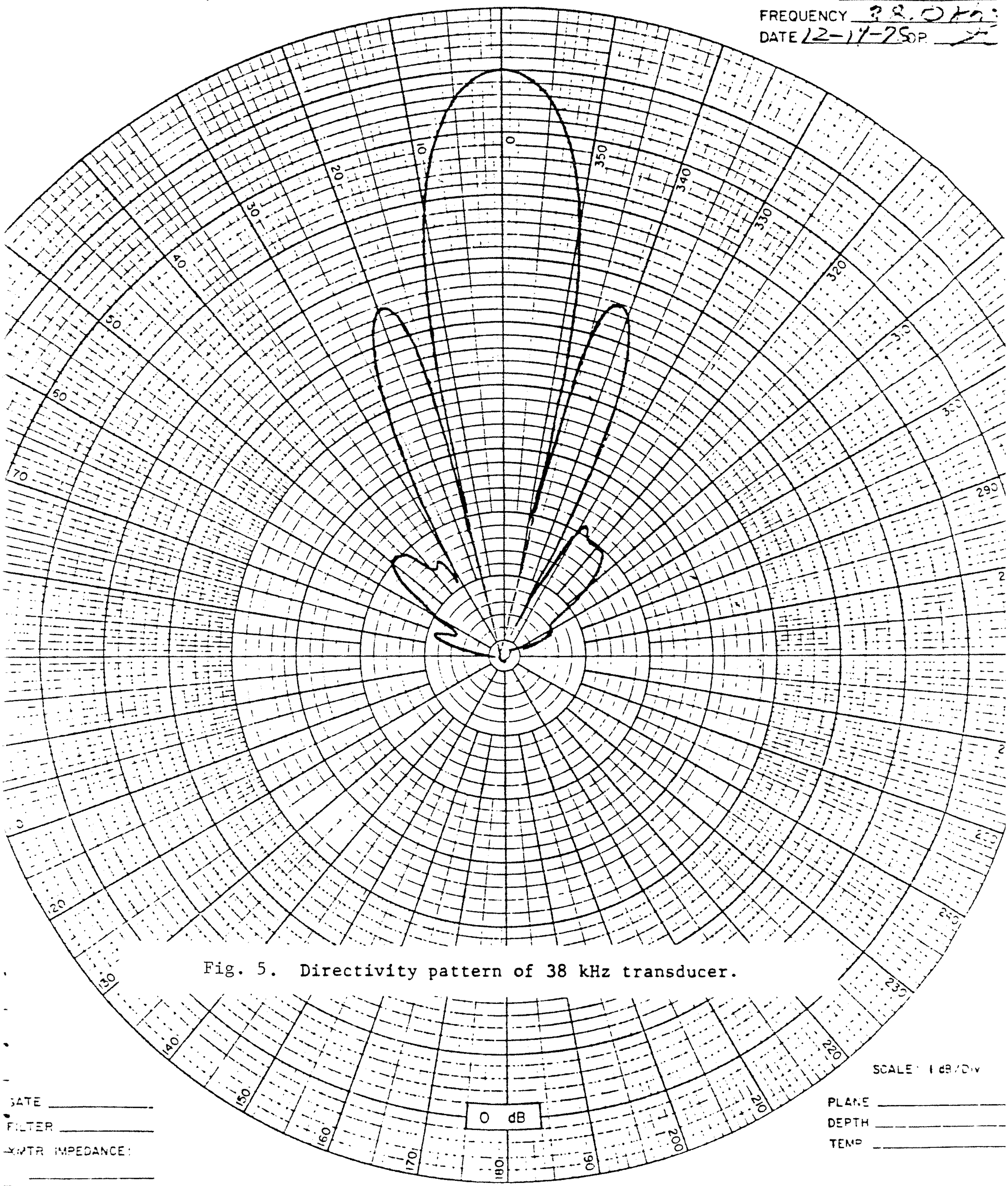

Fig. 5. Directivity pattern of 38 kHz transducer.

DATE ______

FILTER ______

XMTR IMPEDANCE: ______

PLANE ______

DEPTH ______

TEMP ______

TRANSMITTING SENSITIVITY, T_v:

______ -G 25.0 $-S_s$ -206.3 +R 15.6 -V 24.2 = 172.2 dBμPa/

TRANSMITTING POWER RESPONSE, T_w:

T_v ______ -Ω ______ +Z ______ = ______ dBμPa/W

EFFICIENCY: T_w ______ -D ______ -170.6 ______ dB= ______

Figure 6 illustrates the sweeping characteristics of the SQ system during the survey. The distance to port and starboard of the sweep is dependent on the beam tilt (0^{o}-90^{o}). At 90^{o} tilt there is no sweep and the SQ functions as a typical echosounder. The sonar was programmed on this survey for a 45^{o} tilt with a 30-sec 60^{o} complete sweep (60^{o} starboard to 60^{o} port in 15 sec). The selection of these sweep characters represents a compromise between maximizing the distance to each side of the vessel swept while minimizing the chance of failing to detect fish schools that occurred directly under the vessel. The final selection was based on observation of the length of widow rockfish schools (mean length = 90 m) in 1980.

The SQ operates without a time-varied-gain (TVG) in the sweep mode. No correction for TVG was made because of the qualitative nature of the SQ data output, i.e., by CRT or echogram.

The SQ sonar was operated simultaneously with the EK-38 along transect lines. The SQ data were recorded in real time by a chart recorder (echogram) and displayed on a CRT screen giving the range and bearing of the acoustic targets. This information was recorded on video cassette using an RCA C004 camera and a Panasonic tape recorder. The echogram was of limited usefulness because of the difficulty in determining at what angle the sonar sweep detected targets.

Data Analysis

Echosounder

The technique used to estimate biomass from the echosounder data was based upon the principal that the acoustic intensity of a signal reflected from fish targets is proportional to the mean individual backscattering cross-section of the target per unit of biomass. Detailed explanations of this technique can be obtained in Moose and Ehrenberg (1971), Ehrenberg and Lytle (1972), Moose (1971) and Thorne (1978).

Echosounding was conducted continuously along transects. The integrator was set to measure voltages from 5 to 500 m, in the following 15 depth ranges, 5-50, 50-70, 70-90, 90-110, 110-130, 130-150, 150-170, 170-190, 190-210, 210-230, 230-250, 250-300, 300-350, 350-400, 400-500. The density estimates were averaged over every 40 transmissions (approximately every 160 or 80 m of transect depending upon transmission rate). The relative densities were converted to absolute values after the cruise from calibration data and by assuming a target strength of -35 dB/kg. All calculations were based on the system gain as measured with the calibration oscillator at 150 msec (112.5 m). Laboratory calibration of the EK-38 performance in 1981 indicated the system was operating the same as in the 1980 and 1979 checks. Thorne (1979) demonstrated the EK-38 time-varied-gain deviations from ideal had an insignificant effect on the estimates of biomass per unit of surface area.

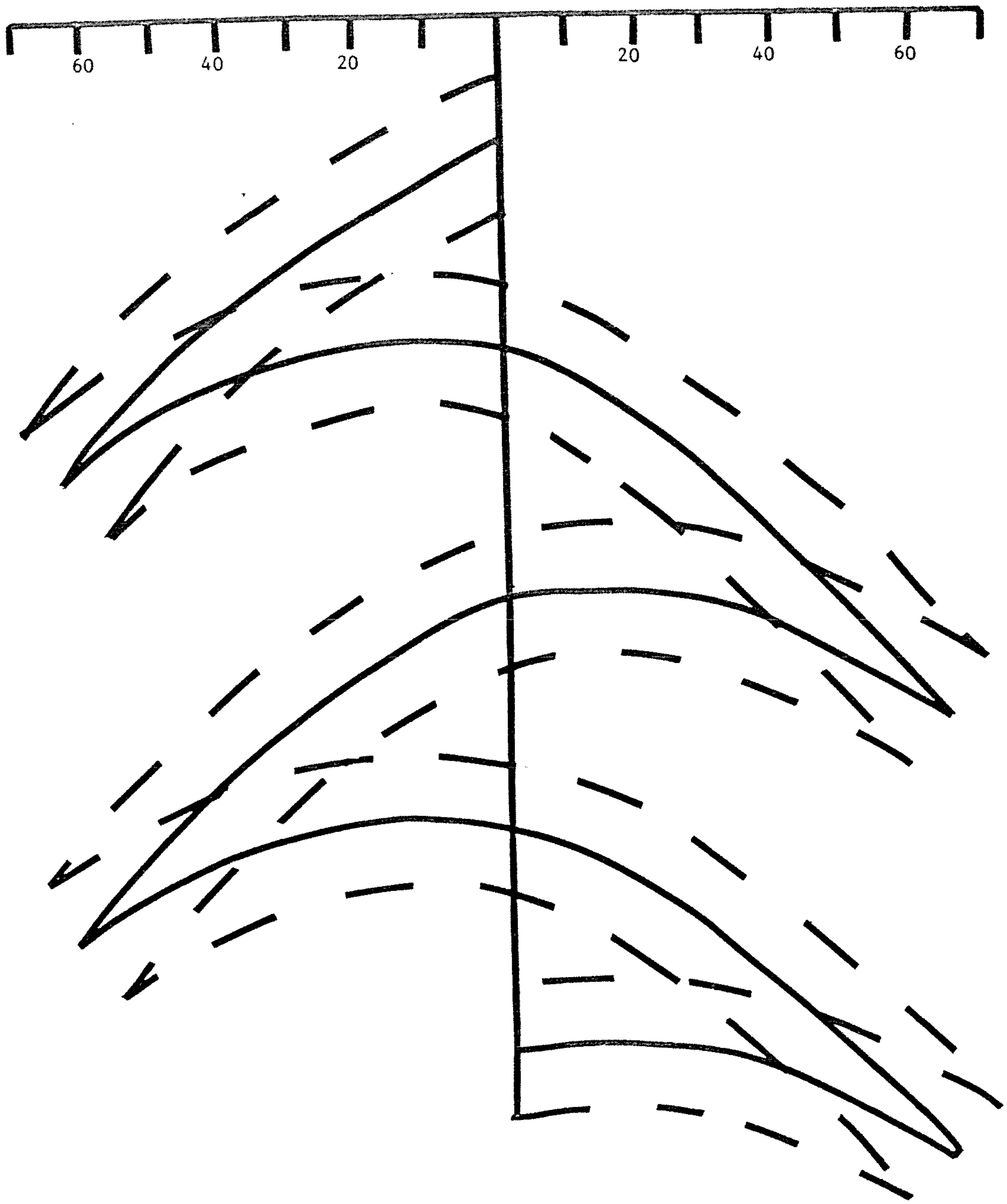

Fig. 6. Theoretical coverage of the SIMRAD SQ search light sonar along a transect line (scale in 10 meter increments, boat speed 4 knots) during the R/V CHAPMAN survey.

The total biomass of fish was determined by extrapolating the estimates of fish biomass/unit area over the approximate surface area represented by the integration outputs. The survey results were divided into four areas: the Crater, the Fingers, Haceta Bank, and Cape Blanco. The Crater area was surveyed twice, the second survey being conducted on a different night in an area suspected to have the highest fish density. Each survey area was divided into strata with one transect per strata. The density estimate from each transect (D_i) was assumed to represent the average density in that strata. A weighted mean density ($\bar{D}$) was computed for each survey area because the transect lines were not equal in length.

$$\bar{D} = \sum_{i=1}^{R} l_i \; D_i \Big/ \sum_{i=1}^{R} l_i = \sum_{i=1}^{R} l_i \; D_i / L$$

where l_i = length of transect i
D_i = density estimate (g/m^2) for transect i
R = number of transects
L = total transect length for the R transects censused

The variance of this estimate was estimated from:

$$Var(\bar{D}) = \sum_{i=1}^{R} l_i \; (D_i - \bar{D})^2 / L \; (R-1)$$

The biomass (B) and its variance in a survey area was computed by the following formulae:

$$B = (A/10^6) \; \bar{D}$$

B = biomass in mt
A = total survey area (m^2)

and

$$Var\;(B) = (A/10^6)^2 \; Var \; \bar{D}$$

The density estimates on each transect (D_i) were edited carefully for echo type and bottom integration. First there were several "echo types" present on the echogram record. These echos were classified on the basis of their horizontal and vertical characteristics and depth in the water column. Three basic descriptive characteristics were used; layer (L), school (S), or groups of layers and schools combined (G). Three basic descriptive depths were used; surface (S) midwater (M) and Bottom (B) portions of the water column. All echogram targets were assigned one of the nine possible categories (examples in Figs. 7 and 8). All midwater and bottom echo types were employed in determining the "potential" widow rockfish targets. Second, the majority of echo types were on bottom during this survey, and this created difficulties in the

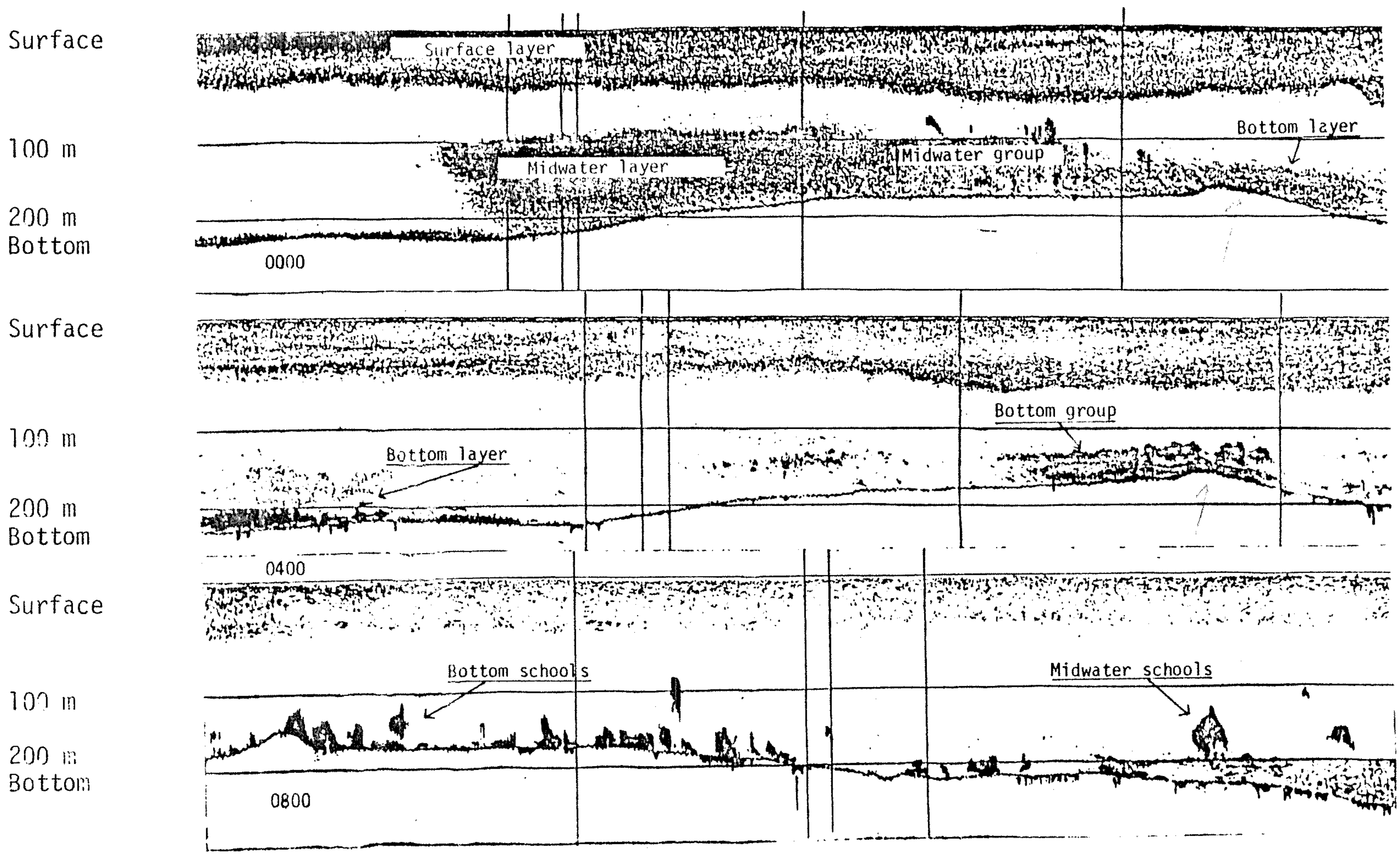

Fig. 7. Diel variation in the nekton distribution between 0000, 0400, and 0800 runs of the same transect (T-21) over suspected widow rockfish concentrations (R/V CHAPMAN, 22 April 1981, Crater area Oregon continental shelf).

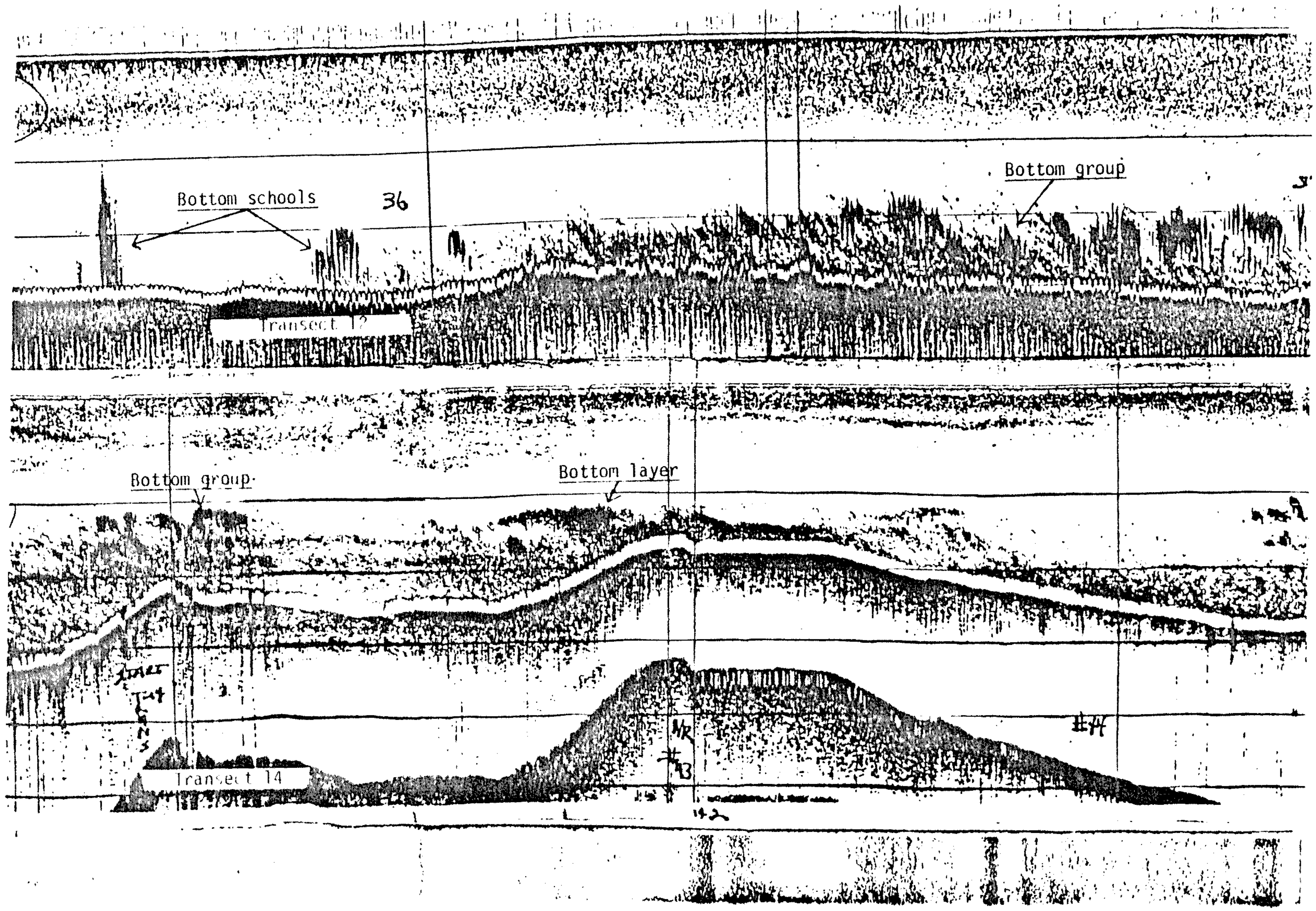

Fig. 8. Acoustic echoes which contributed to the high biomass integration values on transects 12 and 14 on the Heceta Bank (24 April 1981), R/V CHAPMAN, Oregon continental shelf.

ability to discriminate fish from bottom. Therefore, all unusually high values within 10 f of bottom were individually examined and edited out if not represented on the echogram. This method constitutes an inescapable bias which underestimates the fish density as the fish move closer to the bottom or as the bottom roughness increases and/or when the bottom slope changes rapidly.

Sonar

It was not feasible to use standard transect theory (Burham et al. 1980) in analyzing the search-light sonar data. The two primary assumptions were violated; that all schools located directly under the transect line were detected, and that detection was a decreasing function with distance. These assumptions were not met primarily because the sonar sweep did not sample all of the acoustic transect line and, an increasing proportion of area along the transect was sampled with distance (Fig. 6). Other problems resulted from the overlap between the end and the start of successive sonar sweeps. In addition to these theoretical limitations it was difficult to discriminate schools due to poor near-bottom resolution and side-lobe interference. The absence of a TVG in the sweeping mode and the inability to adjust the data for attenuation and spreading of sound in water made it invalid to compare the fish targets observed at difference distances from the boat. Therefore, the present evaluation of the SQ sonar system was limited to a qualitative description of the targets observed on the two output display modes, the CRT and echogram.

Net Samples

A Canadian midwater "diamond" trawl with bottom doors was used for collecting biological data. The midwater trawl gear and operations were new to the R/V CHAPMAN and since successful midwater trawling for widow rockfish requires considerable experience and the proper gear types, there were insufficient trawl data to identify the acoustic targets as to species composition. Therefore, the biomass will be expressed as "nekton" and the percentage of the nekton biomass attributable to widow rockfish can be determined by NMFS personnel using supplementary information from the commercial fishery.

Results

Echosounder

The estimated densities (g/m^2) and biomass (mt) of fish and other nekton in the five survey areas are presented in Table 1. The highest densities were observed in Cape Blanco and Heceta Bank areas (6.47 and 4.89 g/m^2 surface, respectively). However, a large amount of variability between transects was observed in these areas. For instance, the trackline density (D_i) observations ranged between 0.06 and 26.22 g/m^2 and 0.12 and 10.88 g/m^2 in these two areas.

The Crater area was surveyed on two separate nights, 21-22 and 26 April. The range in density on the second night overlapped the measurements on the first night (0.00-6.75 and 0.66 and 5.86, respectively).

The nekton density along transect 21 was examined for diel and between-day variability. Transect 21 was repeated 4 times; at 0000, 0400 and 0800 April 22 and 0500 April 25 (Table 1 and 2). The lowest density (0.26 g/m^2) was observed when transect 21 was repeated on 26 April. In addition, the repetitions of transect 21 on 22 April displayed an increasing trend with time and suggested a high degree of temporal serial correlation. The largest change was noted between dark and daylight measurements. Echograms revealed that these changes were associated with changes in both horizontal and vertical distribution of the nekton targets (Fig. 7). It may be important to note that the largest density was observed after first daylight at 0800, April 21. The representative echograms also illustrate the difficulty in defining a school, layer or group (Figs. 7 and 8).

Sonar

A larger number of acoustic targets were observed on the CRT display than on the wet paper echogram. This may be partially due to the fact that many of near-bottom targets on the wet paper were difficult to separate from what appeared to be a side-lobe detection of the bottom. Since this source of interference did not obscure the targets near bottom as much on the CRT display, and the CRT display indicated the position of the target in the sweep, the CRT data was considered the best data presentation for the sonar targets. Even though the CRT data output was used, it was still not feasible to define and enumerate the schools along each transect because the discontinuous sampling along the transect line made it difficult to tell whether the observations were from a series of small schools or a large continuous school. A strip transect technique was developed for evaluating school density, however, this technique was not refined when the transect with the largest number of sonar-detected off-bottom schools (transect 21 on April 26) was found to have one of the lowest echo integration density estimates (Table 1). Further extrapolations of the SQ sonar data were not presented because of several questions about the validity of this procedure.

DISCUSSION

Sonar

The evaluation of the Simrad SQ sonar performance was qualitative because of the limited data display modes (CRT and echograms) and the absence of calibration measurements on system performance. The factory manual contains selected system specifications but these are inadequate for quantifying the acoustic signals. Three steps are necessary in

Table 1. The estimated mean fish and nekton density (g/m^2) and biomass (mt) by location, date, and transect on the R/V CHAPMAN cruise, 21-26 April 1981.

Location	Date	Transect	Length (nw)	Density	Mean density $\bar{D}$	Var $\bar{D}$	Area (nm^2)	Biomass $\bar{B}$	Var $\bar{B}$
Crater	4/21	1	10.08	1.78					
"	4/22	2	9.24	5.86	2.82	2.45	66.73	646	1.28×10^5
"	"	3	8.11	0.66					
Cape Blanco	4/23	4	2.26	16.17					
" "	"	5	2.35	26.22					
" "	"	6	2.52	4.50					
" "	"	7	2.87	1.12	6.47	11.31	58.55	1301	4.56×10^5
" "	"	8	3.30	1.79					
" "	4/24	9	1.32	1.63					
" "	"	10	2.09	0.34					
" "	"	11	2.09	0.06					
Hecata Bank	"	12	9.50	4.67					
" "	4/25	13	9.92	0.12	4.89	9.44	25.41	427	7.17×10^4
" "	"	14	8.26	10.88					
Fingers	"	15	7.96	1.78					
"	"	16	7.96	1.01	1.73	.19	21.90	130	1.07×10^3
"	"	17	6.60	2.54					
Crater	4/26	18	3.01	0.00					
"	"	19	3.76	0.00	1.79	2.83	10.14	62	3.43×10^3
"	"	20	3.39	6.75					
"	"	21	3.04	0.26					

Table 2. The estimated fish density (g/m^2) and biomass (mt) from transect 21 in the Crater area at 0000, 0400, and 0800 on 22 April 1981 (R/V CHAPMAN, Oregon continental shelf, NMFS rockfish survey, 8.0 nm^2).

Run	Time	Density	nmi^2	Biomass (mt)
1	0000 (dark)	1.97	6.08	41
2	0400 (dark)	5.68	6.08	118
3	0800 (light)	29.99	6.08	625
	$\bar{x} = 9.62 \times 10^5$, $s^2 = 1.36 \times 10^{12}$, $s/\bar{x} = 1.21$			

order to quantify future SQ performance: 1) make pre- and post-cruise calibrations with standard signals; 2) install a calibration oscillator to measure system stability and gain during the surveys; and 3) install a digital or analog data storage system. In addition a quantitative interpretation of acoustic signal returns was not possible since the SQ sonar operates without a time varied gain (TVG) in the sonar mode and the data was limited to visual display. Interference resulting from a strong bottom signal and possible large beam pattern side-lobes made separation of near bottom fish signals from non-fish echoes difficult to impossible during this survey. The fact that the majority of strong acoustic signals were in the near bottom depth region further complicated data analysis.

This evaluation of the search-light sonar is inconclusive. Perhaps the use of a search-light sweep pattern with different transmission/ receiving and data presentation charactistics may be useful to resource assessment techniques. Commercial fishermen use the system in a shallower sweeping mode for long-range detection of large schools. There may be some way to integrate this ability into a multiple-stage sampling program, however, under present survey design the SQ sonar has limited usefulness.

Echosounder

Widow rockfish are known to form schools at night at specific locations along the continental shelf break. The formation of schools at these locations displays a large amount of diel, daily and seasonal variability. Futhermore, the preliminary acoustic measurements we have made indicate a large degree of interaction between neighboring schools in an area. For instance, they indicate a diel cycle between dispersion, schooling, and layer formation which incorporate both vertical and horizontal shifts in distribution.

This suggests that the entire aggregation of schools in one specific location, i.e., Crater, Cape Blanco, etc., may be operating as one unit (i.e., a school patch) and the individual schools within these patches are only temporary concentrations. The success of measuring the density of such a temporally dynamic patch will require determining whether or not it is stabel enough to make repeatable measurements.

The inability to repeat acoustic measurements of fish density on the same transect within the nighttime period indicates the severity of this problem. Without repeatable measurements the density values and extrapolations of biomass have litte utility. Unfortunately the allocation of boat time to make replicate measurements has been minimal to non-existent in past surveys. Only one acoustic line is run over a fish concentration (school or patch of schools) in the standard acoustic survey. Essentially the survey design needed for widow rockfish stock assessment is two-stage, first locating or identifying the patches of fish and then measuring them. Accurate measurements will require mapping the horizontal and vertical extensions of the patch. Diel series of measurements are needed to determine the magnitude of temporal variability which should indicate the time limitation for collecting valid samples.

One confounding factor when measuring temporal variability of widow rockfish concentrations is fishing pressure. It is anticipated that fishing pressure is capable of disrupting the schooling behavior of this species. Measurement of this effect is a different problem. Therefore it may be critical that the school/patch stability measurements be made in controlled or unfished areas. If a repeatable measurement technique is developed then a field evaluation of the cropping-effect of the fishing fleet on a patch of fish may be feasible. This also could lead to determination of patch recruitment rates and patch interactions.

The second source of uncertainty is target identification. The best procedure for target identification is to directly subsample with a net (midwater trawl in this case). The severity of this problem can be demonstrated from the data collected in 1980 on the F/V Muir Melach survey, where widow rockfish schools appeared to break up at daylight and other species formed large schools. In the Crater area the largest biomass was observed in schools after daylight. The high daylight fish density measurements may have resulted from species other than widow rockfish schooling in the study area.

An observer program on commercial fishing vessels is an alternative approach to solving this problem. Trawl catch and echosounder data collected at night on fishing vessels is one way to determine the actual species composition of the nighttime schooling assemblage. This information, of course, will not be available in unfished areas, and a commercial vessel could be chartered to provide species composition in "control" survey areas.

Scattering layers of plankton generally do not complicate interpretation of the data because of their low and very uniform amplitude. For instance, surface plankton layers in the top 50 m of the water column (SL) weren't included in the integration totals because it was highly unlikely that they contained widow rockfish. However, the deeper layers were included because a portion of the rockfish biomass could have been located within them. Additional editing of acoustic data may be possible if sufficient trawl data are collected on future surveys or observer programs.

Another area of uncertainty is that of target strength. The value of -35 dB/kg was considered the best estimate of reflective characteristics of the widow rockfish. Thorne (1979) considered that the maximum extent of uncertainty around the -35 dB assumption was ± 2 dB. This indicates the real density values could be overestimated by as much as 58%, or underestimated by as much as 37%. Additional measurements of target strength especially with respect to depth will be necessary to evaluate the acoustic survey data on widow rockfish.

Finally, a source of system performance error results from the fact that a 38 kHz transducer towed at the surface is not ideal for separating fish targets from the bottom in 70-100 f of water. The lack of near-bottom precision on this survey introduced a bias by underestimating the biomass where fish schools were near the bottom. Much of this error could be avoided by using a higher frequency system (i.e., 120 kHz) with the transducer towed deep (i.e., 100 m). This system may be the only way to census the several other rockfish species of interest which are more demersal than the widow rockfish.

Recommendations

1. Establish a quantitatively repeatable sample unit (a school or school patch) by documenting the diel and daily distribution patterns of a widow rockfish concentration. This will require; (1) intensive and repetitive transecting in an area of high fish density which is free from commercial fishing pressure and, (2) the use of a high frequency (120 kHz) deep towed acoustic system.

2. Evaluate the target strength assumption of -35 dB/kg over the vertical distribution of this species.

3. Promote the development of the sector scanner as a scientific measurement tool. Explore the possibilities of using it's scanning capabilities to locate and map high fish concentration areas which can be intensively measured with the deep-tow system.

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