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Studies on Counting the Echo Pattern of Individual Fish by Pattern Analysis Method—II Identification of the Echo Pattern

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In order to judge and count the echo pattern of the individual fish from echo data obtained by hard wears and system as mentioned in the previous paper, the soft wear (Module *"AUPACS"*) is proposed, and some functions and supplemental techniques of this method are explained.

1) The mask method is the main part of this module, and this function is to compare the echo pattern with the mask designed beforehand.

2) Moreover, POT method is the first supplemental technique, and this function is to select an echo pattern from several echo patterns, derived from one target sequentially, by the goodness of linkage of echo elements. This method is effective for the selection echo patterns where depth values are constant.

3) EL method, the second technique, is the process to eliminate elements which construct the echo pattern.

4) By these two supplemental techniques adopted with the mask method, the echo pattern is identified more precisely than the case where the mask method alone is used.

5) The main purpose to apply these two methods are to diminish the number of recognized echo patterns for one sample (multicounting error).

6) When field data is analyzed, it is necessary to set other parameters (slice level, ship speed etc.) at the optimum level for analysis, because it is difficult to solve the multicounting error only by this module.

7) In the condition mentioned above, it is recognized that this module identifies the echo pattern precisely with only a few exceptions.

In the previous paper[1], the author proposed the new method for counting the echo pattern of fish by the pattern analysis technique in order to study the dynamics of the exploited fish population. The function and performance of the hard wear for this project were reported with some examples.

In order to judge and count the echo pattern of the individual fish from the echo data recorded and stored by hard wears, it is necessary to process the echo data by several modules of soft wears.

The purpose of this paper is to propose the soft wear for the identification of the echo pattern (Module *"AUPACS"*) and to improve this method for adjusting the counts of echo pattern by two supplemental techniques with some numerical examples obtained by R. V. Tansei Maru.

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Basic Conception of Module *"AUPACS"*

Mask Method The observed data, obtained by the system of data processing mentioned in the previous paper, is the group of the value of time of arrival (depth) in some transmissions. Each value of time of arrival is plotted on the chart of which the vertical axis is depth (D) and the horizontal axis is the transmission number (T). The observed pattern consists of points which are decided the value of depth and that of transmission number. This point is called the "element" in this project afterwards.

In order to identify the pattern of large individual fish, observed pattern in record is compared with the surrounding part of the pattern. For comparison of the observed pattern with the surrounding part, the mask method is proposed in this project.

The conception of this method is the same as that in the case of the ordinary recording paper of echo sounder. For this method, it is necessary to define a standard pattern, designated as the "mask", for comparison beforehand. This mask consists of two parts; the right part (R part) and the wrong part (W part), and is always designed so that the size of the right part is the same as that of the other part, because this condition is a necessity for the following sign test.

The mask is put on the recorded chart on which echo pattern are printed out by the computer and the goodness of fit is measured, that is, the number of elements of observed pattern in each part of the mask is counted, and the number of elements in the wrong part is compared with the theoretical value which is calculated from the formulae[2] shown as follows;

$$N_J=\left[\frac{N_T-1}{2}-K\sqrt{N_T+1}\right] \quad \begin{array}{l}\alpha=0.005: K=1.2879,\ l=1\\ \alpha=0.025: K=0.9800,\ l=5\end{array}$$

where,

N_T : Total counted number of elements. $N_T=N_W+N_R$

N_W : Number of elements in the wrong part.

N_R : Number of elements in the right part.

N_{Jl} : Critical value in the significant level α (integer part).

$N_W \leq N_{Jl}$: Significant in the level α.

$N_W > N_{Jl}$: Not significant in the level α.

This comparison is the sign test whether there are the same number of elements in the one parts as that in another part or not. (Fig. 1) The result of sign test is indicated by the condition code (C_J) and this value is stored with some parameters. Relationship between the result of test and the value of C_J is shown as follows;

$N_W > N_{J5}$: $C_J = 0$
$N_W = N_{J5}$: $C_J = 1$
$N_{J5} > N_W > N_{J1}$: $C_J = 2$
$N_W = N_{J1}$: $C_J = 3$
$N_{J1} > N_W$: $C_J = 4$

where,

N_{J5} : Critical value in the significant level $\alpha = 0.025$.

N_{J1} : Critical value in the significant level $\alpha = 0.005$.

POT Method Potential index (I_p, POT*) indicates the goodness of linkage between elements in the right part (R part). (Fig. 2) By the mask method, more than one count are obtained from one echo pattern frequently, because there is the difference of the size of the mask from that of the echo pattern (multicounting error). In order to decrease multicounts of patterns to desirable value (generally one), this method was supposed and available in the case that the depth value of these counts is constant. The value of I_p increases as the goodness of linkage between elements in the P part increases, so the most desirable value of I_p is its maximum. When the maximum value of I_p is indicated in some locations continuously, the pattern located in the minimum value of T is accepted.

$$I_p = [\sum_i \sum_j [\sum_{i'} \sum_{j'} X_{ij} \cdot X_{i'j'}]] / 2 \cdot N_R$$

$X = 0$: Absence of the element.

$X = 1$: Presence of the element.

i : Value of T-axis in R part.

j : Value of D-axis in R part.

X_{ij}: is indicated as the existence of the element in each position in R part.

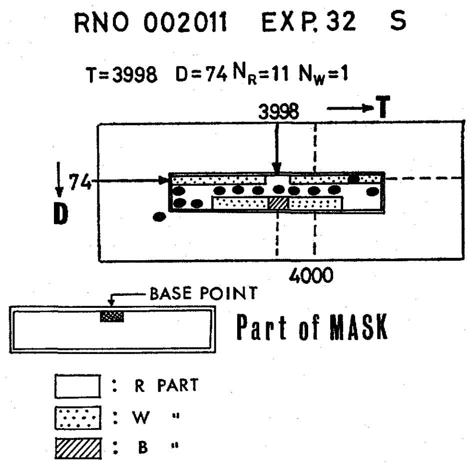

Fig. 1. Example of the echo pattern obtained by the floating buoy in KT–68–5 and the mask used for trial.
The structure of this mask is shown in the top of Fig. 4.
●: echo element.
RNO: Sample code of data-set converted from the analog echo data recorded by KT–68–5.
EXP: Experiment number (serial number) in this cruise.
S: Depth code. Function is explained in Table 1.
T=3998: Number of acoustic transmission of adjusted base point set the mask.
D=74: Number of depth unit of adjusted base point set the mask.

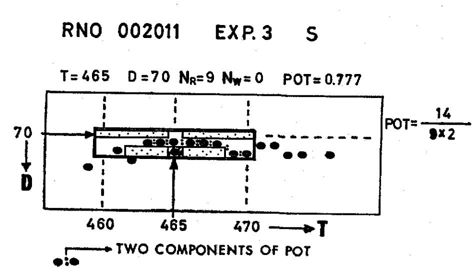

Fig. 2. Example of I_p (POT) of echo pattern. The numerator of POT is sum of components (:).

* This notation is used for the computer program.

$X_{i'j'}$: The existence of the element in the surrounding position for the position (i,j) (except $i=i'$ and $j=j'$), and its position also located in the R part. $(i-1\leq i'\leq i+1, j-1\leq j'\leq j+1)$

For this project, the value of I_p of T' $(=T-7)$ is compared with values of I_p in 14 values of $T(T$---T-6, T-8---T-14). If these conditions are satisfied, the echo pattern is accepted.

EL Method (Elimination of Elements) When a group of elements is judged to be the echo pattern of individual fish by the method, elements which construct the pattern are eliminated. This process seems to be very effective for the prevention of the multicounting error beforementioned.

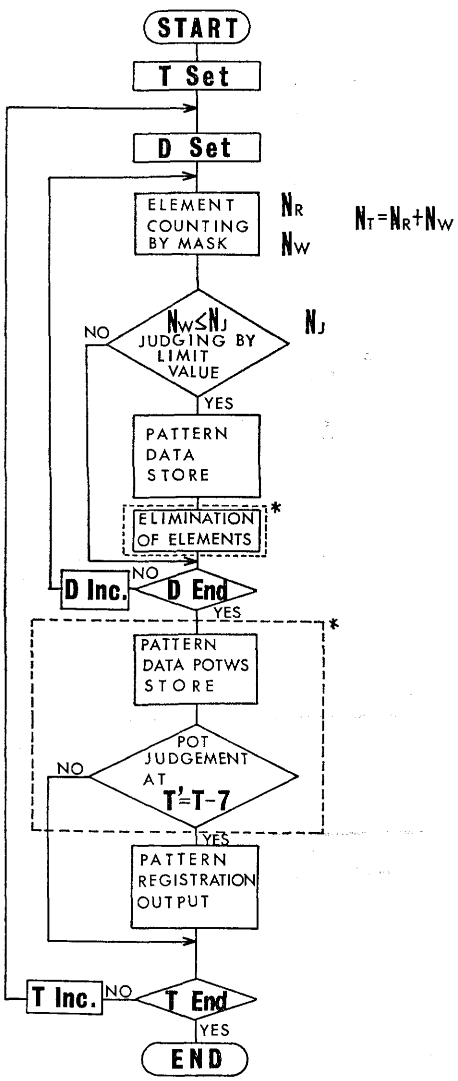

Fig. 3. Flow chart of Module *"AUPACS"*. Sections with asterisk are supplemental functions.

Procedure of analysis Procedure of the Module *"AUPACS"* supplemented by these two techniques is given below and the flow chart is shown in Fig. 3. Before this module is operated, it is necessary to prepare masks in each depth ranges.

1) Firstly, the initial value of T is set, and this initial value of T is decided from the maximum width of the used mask. After the analysis is finished in T, T increases by one unit.

2) The initial value of D is set. It is necessary to decide this value of D by the range of depth which is designed beforehand. The increment of D is the unit of depth (for example 0.75 or 0.5 m).

3) The mask is selected out of the group of masks from D. This mask is put on the base point, and elements are counted in each part of the mask. (N_R and N_W)

4) Calculating the limit value (N_{Jl}) by the total elements (N_T) and the significant level (α). The pattern

is tested from the comparison between N_W and N_{Jl}. In this project, it is recognized that this pattern is that of individual fish when C_J is from 1 to 4.

5–1) If $N_W \leq N_{J5}$, some data of that pattern are stored temporally in each value of T, that is, T, D, N_R, N_W, C_J and I_p. Elements in R part of mask are eliminated.

5–2) If $N_W > N_{J5}$, this pattern is neglected and some data are not stored.

6) D is increased by one unit, and the process mentioned above is repeated until the final value of D.

7) When the judgement was completed in a value of T, pattern data is transformed and stored in the working storage for the analysis if I_p.

8) I_p of T' $(=T-7)$ is compared with values of I_p for two ranges of T (T---T–6, T–8---T–14) in the same depth. When these conditions mentioned before is satisfied, the pattern data is registered or stored, and echo counts is increased in the depth range involved this pattern.

9) T is increased by one unit, and this process is repeated until the final value of T.

10) Number of pattern is stored cumulatively for several depth ranges in each time length decided beforehand.

From these procedures, computer programs were produced by three computers (OKITAC 5090C, FACOM 270–20 and FACOM 230–45S). In 1968, this program was developed by OKITAC 5090C, and the complete algorithm was applied for FACOM 270–20. Each program was produced by assembler languages (OKISAP and FASP). For the batch system of this module, FORTRAN program was completed by FACOM 230–45S in 1974.

Mask and Data

Mask From the basic conception of this project, the mask pattern is to be designed automatically from the field data by the soft wear *"AMDESS"*, but in this paper, basing on many examples of the recorded pattern obtained in KT–68–5 and KT–68–24,*[3] the mask was designed for trial for each of three depth ranges, not by the module *"AMDESS"*. These masks are shown in Fig. 4 with some characteristics. Each mask is made according to the echo patterns of smallest size among many patterns located in the same depth range.

Data In this paper, echo data of six experiments among those records which were obtained in the cruise (KT–68–5) by R. V. Tansei Maru in Sagami Bay in April 1968.[3] Details of experiments and targets are shown in Table 1. These echo samples were recorded in five depth layers, and thus these depth layers are denoted by five depth codes (S, M, M1, M2 and D). Each sample represents by the code paired the experiment number with five depth codes. 17 samples were taken for this analysis.

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* Cruise Number of R. V. Tansei Maru.

Counts by the Mask Method and Multicounting Error

Firstly, echo patterns were recognized and counted for 17 samples by the mask method. There are four types of counting results for one target.

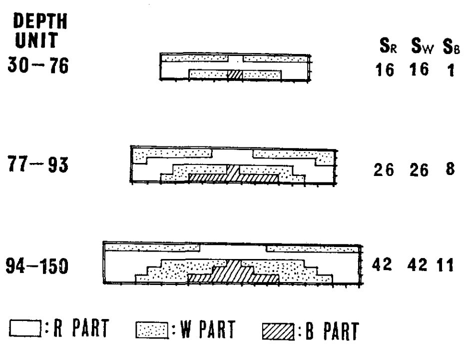

Fig. 4. Structures of masks used in this report for trial. B part is not contained in the mask, and neglected for the pattern analysis.
S_R: The size of space occupied by elements in the right part (R part).
S_W: The size of space occupied by elements in the wrong part (W part).
S_B: The size of space occupied by elements in the bypass part (B part).
Each mask is designed so that the size of R part is the same that of W part.

TYPE–I It was possible to recognize and count only one pattern from one target.

TYPE–II More than one pattern were recognized in the same depth continuously from one target. (Fig. 5)

TYPE–III More than one pattern were recognized in the same depth discontinuously from one target.

TYPE–IV More than one pattern were obtained over more than one depth unit from one target.

Table 1. Details of target experiments and recorded echo patterns in KT–68–5

Exp. No.	Buoy No.	Direction (°)	Distance (m)	Code of Echo Pattern			
3	1	170	1	3S		3M	3D
5	2	333	6	5S		5M	
7	1	162	3.2	7S		7M	7D
30	1	125	0	30S	30M1	30M2	30D
32	2	327	0	32S		32M	
33	1	290	0	33S		33M	33D
			Depth code	S	M1	M2(M)	D
			Depth (d.u.)	70–74	92	98–104	107–108

1 d.u.=0.75 m
Code of echo pattern is indicated by the combination of experiment number and depth code.
About depth code, the same symbol is given in the same level of depth layer.

Results of echo patterns in each type are shown in the upper part of Table 2. Comparing with the results by eyesight, the echo pattern was almost checked and recognized

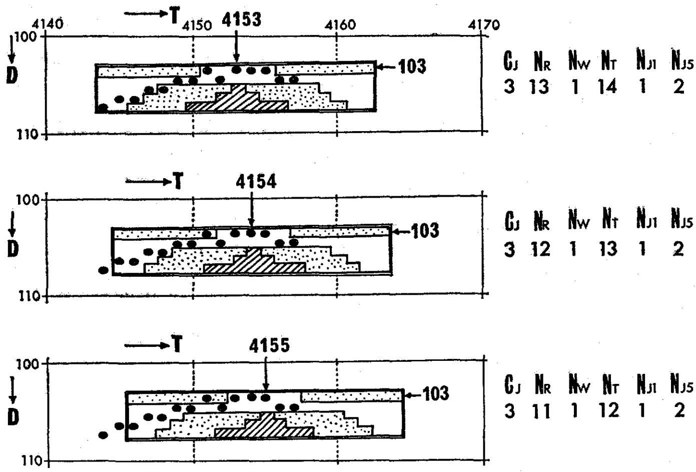

Fig. 5. Echo pattern of TYPE–II checked by the mask method alone.
In three sequential values of T (T=4153, 4154 and 4155) the one echo pattern was multicounted in the same depth (D=103 depth unit). In this example EL method was not used.
C_J, N_R, N_W, N_T, N_{J1} and N_{J5}: See the text.

Table 2. Judging results in each type by three methods for recognizing the echo pattern

Type Method	I	II	III	IV
MASK	5S (1)	3D 5M 7S 7M 32S 33S (6)	3S 7D 30S 30M1 33D (5)	3M 30M2 30D 32M 33M (5)
MASK+ POT	3D 5S 5M 32S (4)	7S 7M 33S (3)	3S 7D 30S 30M1 33D (5)	3M 30M2 30D 32M 33M (5)
MASK+ POT+ EL	3S 3D 5S 5M 7S 7M 7D 32S 30M1 32M 33S 33D (12)	(0)	30S (1)	3M 30M2 30D 33M (4)

The code of echo pattern is shown in Table 1.
The number within parenthesis is shown as that of samples judged to be in each type.

by the mask method, but the echo patterns were multicounted in many cases.

Among 17 samples, there was only one (5S) of TYPE–I, and in another cases echo patterns were multicounted and the number of patterns rages from 2 (3S) to 21 (30D). Arrangement of elements and the mask for the sample (5S) is shown in Fig. 6. In this case, the differance between the size of mask and echo pattern was not so considerably, but in the sample 5M the size of echo pattern was smaller than that of the mask. On the contrary, in the sample 30D the size of the pattern was extremely larger than that of the mask. (Fig. 7)

It seems that the echo pattern was multicounted by the mask method because there

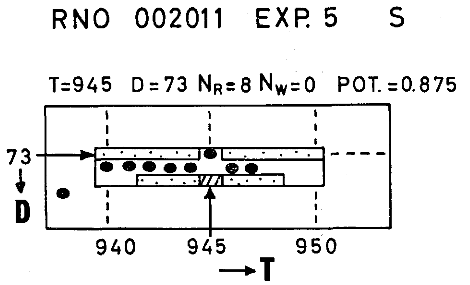

Fig. 6. Echo pattern of pattern code 5S with mask. Example of the simple type pattern.

are the size-variability of recorded echo pattern. Even if the ship passed by the same ship speed near the same buoy from the same distance, echo patterns are very variable. So, in the field data it is impossible to neglect the variability for the shape of the echo pattern.

The multi-counting phenomena always appeares 'depending on the size of the mask in this judgement. So, it results that this error can not be extinguished completely by the designing method of mask and the judging process.

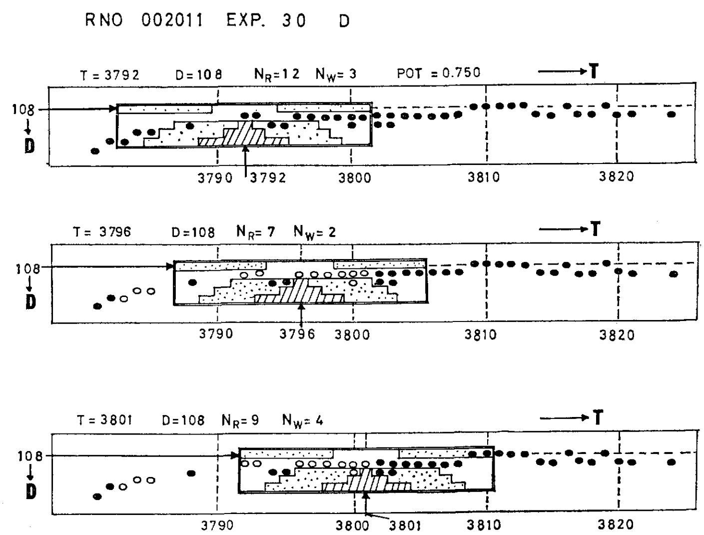

Fig. 7. Structure of the large sized echo pattern (Pattern code 30D) and examples of results of judgement by the total method (MASK+POT+EL). Contents of these pattern are shown in the lower part of Table 3 (Values with asterisk).
●: Recorded echo element.
○: Echo element eliminated already in the present step of judgement, so these elements were not counted in each part (R, W part).

Effect of POT and EL Methods

Counting results were obtained by the POT method with the mask method. This combined use is effective to diminish the multicounting error when patterns were recognized countinuously in the same depth unit and series of I_p was unimodal. In this case, the multicounting error is perfectly disappeared using this combined use. But in another cases (bimodal of TYPE–II, TYPE–III and IV), it is difficult to control this error.

Nextly, the total method (Mask, POT and EL method) was supposed to decrease variability of pattern counts. Results of judging of echo pattern in 17 samples by the total method are shown in the lower part of Table 2. Examples of judging by the total method are shown in Table 3.

EL method is considerably effective in the case of the continuous multicounting error in the same depth. In 12 among 17 samples, results of TYPE–I were obtained. It is recognized that the counting error was hardly appeared in three types (I—III) with one exception. But it seems difficult to dissolce TYPE–IV error completely. For this problem, it would be necessary to use some other conditions (set of the slice level, ship speed etc.) with this method.

From these results, being effective for identifying the echo pattern of individual fish, the total method was decided as the judging technique for this project.

Discussion

Generally, it is scarcely easy to identify the echo pattern, which located randomly with noise elements and of which size is very variable, by the soft wear with the same algorithm as that by the eyesight, because it is very difficult to analyze the mechanism to identify the pattern by the human eyesight.

In this project, the new technique is attempted for the purpose, and details of the method were explained with some examples. But the following problems are very important to identify the echo pattern.

The shape of echo pattern of individual fish is so variable that it is very difficult to identify and to count this pattern by the method designed beforehand. This variability of the shape is caused by two types of factors, the parametric and the variable factors. Variable factors (behavior of fish, pitching and rolling of ship etc.) being impossible to control by the method of measurement. The level of each parametric factors are set at the optimum condition of measurement. In this project, some parametric factors were selected. These factors (ship speed, the slice level of echo pulse and depth layer of echo pattern etc.) are decided by account of the acoustic searching performance of the fish detector on board.

In the field experiment, it is necessary to set the level of parameteric factors for the optimum status. The echo pattern was identified and counted in some ranges of depth on account of the combined effect of several factors for the shape of the pattern.

Especially, the shape of the echo pattern becomes to be small size as the ship speed increases. Thus the number of elements contained in the echo pattern decreased and it is difficult to judge the pattern. On the contrary, when the ship speed decreases, the echo pattern becomes wide shape and have many elements, and the probability of multicounting

Table 3. Results of judgement for echo patterns by two methods (combined method (MASK+POT) and the total method (MASK+POT+EL)).

RNO 002011 Exp. 3 Buoy 1 170° (1 m)

	S		M				D	
	$D=70$		$D=98$		$D=99$		$D=107$	
T	MASK+POT	MASK+POT +EL	MASK+POT	MASK+POT +EL	MASK+POT	MASK+POT +EL	MASK+POT	MASK+POT +EL
462							4 13/0 0.769	4 13/0 0.769
463			1 15/5 1.000	1 15/5 1.000			4 14/1 0.785	1/1
464							4 14/1 0.785	2/1
465	3 9/0 0.777	3 9/0 0.777					4 14/1 0.859	3/1
466			3 17/4 0.823	6/0			4 15/1 0.866	4/1
467			1 17/5 0.823	8/2		1 9/1 0.666	4 16/1 0.875	5/1
468							4 16/1 0.875	5/1
469	1 10/1 1.000	5/0	1 16/5 0.750	3/0	1 16/5 0.937	2/1	4 15/1 0.875	5/1
470					2 16/4 1.062	3/1	4 15/1 0.866	5/1
471					1 15/5 1.000	4/1	4 14/1 0.857	5/1
472							3 13/1 0.846	4/1
473							4 12/0 0.833	4/0
474							3 11/1 0.818	4/1
475							1 10/1 0.800	4/1
476							1 9/1 0.777	4/1
477							1 8/1 0.750	4/1
n	2(2)	[1]	3(4)	[1]	1(3)	[1]	1(16)	[1]
n'			4(7)	[2]				

RNO 002011 Exp. 30 Buoy 1 125° (0 m)

	M_2						D			
	$D=98$		$D=99$		$D=101$		$D=107$		$D=108$	
T	MASK+ POT	MASK+ POT+EL	MASK+ POT	MASK+POT +EL	MASK+ POT	MASK+ POT+EL	MASK+ POT	MASK+ POT+EL	MASK+ POT	MASK+POT EL
3780					1 8/0 0.750	1 8/0 0.750				

3781					1 8/0 0.875	1/0				
3792									1 12/3 0.750	*1 12/3 0.750
3793									1 13/3 0.769	2/3
3794					1 12/2 1.000	6/2			4 15/1 0.733	5/2
3795									3 14/2 0.785	6/1
3796									3 15/3 0.800	* 7/2
3797									1 15/4 0.800	7/3
3798										
3799			1 14/4 0.714	1 14/4 0.714					1 15/5 0.866	7/4
3800			1 14/4 0.714	1/4					2 16/4 0.875	8/4
3801			1 14/4 0.785	2/4					1 17/5 0.941	* 9/4
3802			1 14/4 0.857	3/4					1 16/5 0.937	9/5
3803			1 13/4 0.846	3/4						
3804										
3805										
3806										
3807										
3808									1 17/5 1.058	13/5
3809			1 13/4 0.615	6/4					4 19/3 1.157	3 16/3 0.895
3810			2 14/3 0.714	9/2					4 18/3 1.111	1/4
3811			3 15/2 0.733	1 10/2 0.600			1 16/5 1.062	5/0	4 19/2 1.052	3/2
3812	1 13/4 0.692	3/0	1 13/4 0.769	1/2			1 15/5 0.800	6/0	3 17/3 0.823	4/2
2813	3 14/2 0.712	4/0	1 13/4 0.769	3/1					1 14/4 0.714	4/3
3814	1 13/3 0.692	5/0	1 13/4 0.769	5/0			1 13/3 0.769	6/0	1 13/4 0.769	5/1
3815							1 13/4 0.538	6/1		
n	1(3)	[0]	2(11)	[2]	2(3)	[1]	1(4)	[0]	3(17)	[2]
n′			5(17)	[3]					4(21)	[2]

Numerical values in each position indicate C_J, N_R/N_W and I_p from left to right, and values with the underline are those judged by the POT method. Values without C_J and I_p were not significant.

n : Counts in each depth unit for one sample.

n′ : Total counts of echo pattern when patterns were judged in several depth units for one sample.

2(3) : the number out of parenthesis is counts of patterns judged by the combined use (MASK+POT). The number within parenthesis is counts of patterns judged by the mask method alone.

[1] : Counts of patterns judged by the total method (MASK+POT+EL).

Values with asterisk are shown in Fig. 7.

error increases. So, there are the optimum level of ship speed for this measurement, and it had better to decide the standard ship speed for this analysis.

In this process, designing the mask is the most important problem of this project, because there are many factors which have the effect on the shape of the mask. The echo pattern varies so considerably even in the same target that the shape of the mask must be designed taking account of the range of this variation.

In this report, masks used for analysis were designed by the manual for trial, not designed by the module "*AMDESS*". There were discordance in some degree between the shape of observed pattern and that of the mask. From the consideration obtained by this mathod, it is preferably to use masks which are designed from the measured echo data by the automatic method in several depth layers in order to increase the goodness of fit between observed patterns and the mask. Details of Module "*AMDESS*" will be reported in a coming paper.

As mentioned above, it was recognized that the method for identifying the echo pattern was very available for this project except some problems.

References

1) T. Ishii: This Bull., **41**, 251–264 (1976).
2) A. M. Mood and W. J. Dixon: *J. Amer. Stat. Assoc.*, **41**, 557–566 (1946).
3) T. Ishii, T. Kuroki, M. Nishimura, K. Shibata, H. Yamanaka, and J. Morita: This Bull., **41**, 1087–1094 (1975).