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On survival rates of Baltic cod after capture

by

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1. Introduction

This paper presents results of investigations as a response to Council Resolution 1975/4:22. However, no special research vessel time could be allotted for survival experiments and the work had to be done during routine trips of R.V."SOLEA", 3-6 November 1975, 8-18 November 1975 and 25 May - 1 June 1976. No planning was carried out in advance for the 17 experiments in November 1975 and the evaluation of the trials in May 1976 was also hampered by the lack of some information.

2. Method

After emptying the cod-end on deck cod were sorted in two size categories (limit about 45 cm), put into baskets and weighted. Usually 4 hands picked the fish simultaneously from the evenly spread catch. One or two baskets of the lot containing small cod were selected at random for experiment. The period between the time the cod-end came on-board and the moment the cod were released in tanks was recorded as "Time on Deck". At the end of the experiment dead cod were seperated from the living fish and each category was measured. A fish was classified as "dead" if it was motion-less and did not move its gill covers during an observation period of about 5-10 seconds. In cases of doubt the behaviour of a cod was additionally watched when kept in water again. Rigor mortis was not recorded but on questioning investigators it was stated that most cod classified as dead were in the state of Rigor mortis.

In the commercial fishery cod to be discarded are left on deck until fish for consumption is gutted and stowed away. This effect was simulated by keeping fish in plastic baskets containing 20 kg each which resulted in a layer of cod about as high as will be obtained if a catch of some 30-40 baskets is spread on deck.

One of the tanks contained 2000 litres of water. A pipe replaced its content within about one hour. There was an additional air supply. However, the bubbles seemed to be too big in order to add

oxygen. This container was stocked with 40 kg of cod. Two smaller tanks had no equipment attached. Water together with air was supplied by loose pipes. The bubbles were also very big. A measurement of the amount of water passing was not possible. However, one of the taps of the water pump was connected with the big tank, the other one with the two small ones. It was concluded therefore that the latter may have been supplied with the same amount of water as the former. The smaller tanks have been stocked by 20 kg of cod each. Because of misinformation they were thought to have a volume of 1000 litres each, whereas the correct figure turned out to be 500 litres. But survival is not thought to have been affected by the heavier stocking. Table 4 shows the results of experiments from which comparison between tanks is possible since they concern cod from the same haul. No significant difference was found from these data, although the number is small.

After release in tank about 85 mg O_2/hour/kg cod is consumed which figure is steadily reduced thereafter. Crowding does also diminish consumption (G.Sundnes,1957; R.Saunders,1963; K.Kock, 1974). Kock,1974, kept cod after trawling at similar conditions as in the small tanks. He found a reduction of the oxygen content from 7 to about 4.7 ml/l within 90 minutes and no changes thereafter. A tank of 500 l water (7 mg O_2/l)would contain 3500 mg oxygen. With the above mentioned consumption rate this amount will nearly be halved in one hour. It can only be kept at this level if the losses are accounted for by the water (and oxygen) supply. Since the mortalities in the differently stocked containers of the present experiments were not shown to differ significantly, the oxygen content is thought to have reached a balance level sufficiently high. The results from the different tanks were therefore pooled in Table 1.

In each of the trials listed in Table 1, except No 18 and No 42, cod were kept until the end of the experiment without recording occurence of mortality in between.

Lack of time did not permit towing of more than 5 hours which is much less than in the commercial fishery. During the main fishing season, in spring 1976, average catches of some 50 baskets

per haul were registered in the fishery. A possible effect of catches of this size on survival was not assessed since the highest yield obtained amounted to some 20 baskets (Table 1). Survival may be affected by variables other than listed in Table 1. During some of the hauls in May 1976 there was bright sunshine which directly or by way of temperature may have increased mortality of cod exposed on deck. In May cod may have been affected differently as compared to November because of the spawning season and the higher temperature in May. However, the number of observation is too small to analyse such effects in detail.

3. Results and Discussion

Main losses are stated to occur during the first hours after capture (Hylen, 1958; Kock, 1974). With the exception of haul 4, cod have been kept in tanks for at least 5 hours. However, fish in the last experiment were in the 3 holds for nearly 20 hours and dead specimens have been removed at intervals (Figure 1). This revealed that high mortality occured within 4 hours. Almost no losses were observed after about seven hours. This applies to all three tanks which were stocked by cod of haul 42 (n_1=104, n_2=43, n_3=43). But it is also indicated from an experiment of haul 18. It may be concluded at present that the investigations in May 1976, when fish were kept for 5 hours in tank resulted in a slight overestimation of survival.

Simple regression technique showed that the exposure on deck may significantly affect survival and that otherwise only the correlation between duration of towing and survival may be slightly significant. But Fig.2 suggests the lengths of cod also to be important. Lack of detailed experiments do not allow to establish a functional relationship between the independent variables listed and survival. Under the assumption of linear relationship multiple regression technique was therefore applied. At first data have been divided accordinging to season (sets 1/2, 5/6) and fishing region (sets 3,4) and they were finally pooled. Various combinations of variables were also used, so that 11 sets of estimations are presented in Tables 2 and 3.

Total catch and duration of the haul are not strictly independent of each other. Yet, part of their effects may be fully independent,

i.e. stress in itself from crowding and duration of stress from period of towing. In some of the sets both variables have been taken into consideration.

An unfortunate result of the analysis is, that, contrary to what is expected, an increase in catch would positively affect survival. Equally, towing time (set 1) and duration of stay in tank (set 10) would also increase survival. The latter seem to be an effect of the lower mortality in November 1975 (Fig.2) when cod were generally kept in experiment for a longer period. Set 1 refers to 17 trials in November 1975 when the duration of the hauls was only between 1 and 2 hours. Finally, arrangement of exposure on deck was such that short periods (high survival) coincided with high catches. However, the variables in question have but a minor effect on survival and their partial correlation coefficients are not significantly different from zero.

Tables 2 and 3 show that Time on Deck, Average Length and Depth of Fishing all have an influence on survival, which is statistically significant. Their effect is so pronounced that for the range of the variables investigated each of them may change survival by about 20-40 %. However, this does only apply to the pooled data of sets 7-11 (Table 5). Values of sets 1 and 2 are especially aberrant. Other variables mentioned earlier may be acting which is also obvious from the intercept and its high standard error. Further, linear correlation may be a model too simple to fit the relation between survival and the independent variables. But with the present knowledge the use of the pooled data shown here is suggested. However, for these sets application of three variables shown to have a significant effect on survival is sufficient for assessments. The additional use of any of the other variables will only slightly alter the results of calculations (Table 5). The relevant formula is:

$$S = 14.4 - 0.25D + 1.45L - 0.49T,$$

where S = survival in %
D = depth of towing in m
L = average length of discarded cod in cm
T = time of exposure on deck in minutes.

It is recommended to use this equation pending better results.

Summary

42 experiments were exercised November 1975 and May 1976. In a multiple correlation survival was related to 7 variables listed in Table 1. Effect of season and fishing place on survival and of sunshine on cod exposed on deck have not been evaluated. Within the ranges of variables shown in Table 1 only the time on deck before fish was released in tanks (T), the average length of cod (L) and the depth of towing (D) were found to have a significant effect on survivals (S). Consideration of the other variables did not alter the results. It is suggested that survival of Baltic cod be estimated by means of the formula

$$S = 14.4 - 0.25D + 1.45L - 0.49T.$$

The analysis revealed some inconsistencies. Further investigations are needed which take care of effects not considered here. Controlled experiments could enable establishment of a functional relationship.

References:

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Table 1: Survival experiments with Baltic cod in November 1975 (No's 1-17) and May 1976 (No's 18-42) on board RV "SOLEA"

NO	FISHING PLACE	TOT CATCH OF COD	TOWING-DEPTH	TOWING-TIME	COD IN EXPERIMENT: TIME ON DECK	TIME IN TANK	WEIGHT	AVER. LENGTH	SUR-VIVAL
		Kg	m	Min	Min	Min	Kg	cm	%
1	KIEL BAY	66	18	60	20	1045	25	26.8	55.0
2	"	78	24	60	19	905	24	23.6	15.8
3	"	50	23	60	15	585	14	23.2	63.7
4	"	146	23	60	25	175	29	17.9	3.1
5	"	31	23	60	15	360	11	23.4	60.0
6	N.ARKONA	195	42	60	23	1015	50	28.1	28.9
7	E.BORNH.	50	72	60	20	435	50	24.2	24.7
8	"	65	52	60	10	835	50	32.6	49.0
9	"	390	54	90	28	900	50	31.0	7.6
10	"	50	68	60	30	1015	50	26.3	20.4
11	N.ARKONA	50	20	60	30	380	33	35.9	41.3
12	"	260	46	120	35	830	50	30.9	12.7
13	KIEL BAY	341	26	120	45	1335	16	22.9	11.5
14	"	92	26	60	30	1405	50	21.4	11.7
15	"	341	26	120	25	2875	50	24.7	55.8
16	"	325	26	120	30	1365	33	30.8	49.7
17	"	168	26	120	35	1375	65	24.8	35.7
18	KIEL BAY	36	23	60	20	300	36	26.0	14.8
19	N.ARKONA	104	44	60	10	300	45	27.0	21.8
20	"	102	47	180	95	300	40	38.6	1.7
21	"	364	49	240	120	300	53	25.6	0.0
22	E.BORNH.	92	87	60	10	300	40	34.9	25.5
23	"	848	90	300	7	300	53	31.1	22.5
24	"	452	93	180	71	300	40	30.6	0.7
25	"	750	94	300	63	300	53	30.9	0.0
26	"	404	94	180	40	300	40	33.8	3.8
27	"	184	97	75	31	300	80	38.5	31.8
28	"	172	96	60	49	300	40	38.0	29.9
29	"	391	96	240	77	300	40	31.5	0.0
30	"	176	100	120	60	300	80	37.3	26.2
31	"	306	96	120	4	300	40	34.4	54.2
32	"	281	96	60	57	300	80	32.9	7.7
33	"	482	96	240	32	300	40	32.6	12.1
34	"	934	88	120	9	300	80	35.4	55.2
35	"	742	98	90	30	300	40	32.8	20.4
36	"	430	92	60	40	300	80	33.8	15.9
37	"	1054	89	240	9	300	53	33.1	38.1
38	"	844	90	180	5	300	40	32.2	48.7
39	"	278	92	60	4	300	80	32.9	50.9
40	"	292	92	60	27	300	40	35.5	32.6
41	"	626	91	120	20	300	53	32.2	25.6
42	"	474	90	180	4	300	53	34.7	33.2

Table 2: Multiple correlation of survival and various variables, coefficients of partial correlation (top) and their level of significance (bottom)

SET NO	DATE	NO OF EXPER-IMENTS n	NO OF VARIA-BLES	VARIABLES								MUL-TIPLE COR-REL.
				1 WEIGHT OF COD IN TANK, Kg	2 TIME OF COD IN TANK, Min	3a TOTAL CATCH OF COD Kg	3b TOTAL CATCH OF COD Number	4 DEPTH OF FISHING m	5 DURATION OF HAUL Min	6 AVER. LENGTH OF COD IN TANK, cm	7 TIME ON DECK OF COD, Min	
1	Nov. 75	17	4					-.5097 .10	.4386 .20	.3675 .20	-.6997 .01	.7741 .025
2	Nov. 75	17	4			.0018 1.0		-.5156 .10		.4041 .20	-.5423 .05	.7096 .10
3	May 76	21	4			.3102 .25			-.2912 .25	.4596 .10	-.7699 .001	.8768 .001
4	May 76	21	4				.1330 .60		-.1956 .50	.4015 .10	-.7960 .001	.8653 .001
5	May 76	25	5			.3238 .20		-.1608 .50	-.2952 .20	.3955 .10	-.6630 .005	.8318 .001
6	May 76	25	5				.2686 .25	-.1193 .70	-.2424 .30	.4046 .10	-.7236 .001	.8250 .001
7	Nov 75 May 76	42	4					-.3499 .05	-.0261 .90	.3587 .05	-.6394 .001	.7069 .001
8	Nov 75 May 76	42	4			.0434 .80		-.3549 .05		.3665 .025	-.6687 .001	.7073 .001
9	Nov 75 May 76	42	5			.0831 .70		-.3638 .025	-.0737 .70	.3691 .025	-.5737 .001	.7116 .001
10	Nov 75 May 76	42	7	-.0495 .80	.2232 .20	.0669 .70		-.2195 .20	-.0812 .70	.3836 .025	-.5703 .001	.7267 .001
11	Nov 75 May 76	42	3					-.3810 .020		.3644 .025	-.6727 .001	.7066 .001

Table 3: Multiple correlation as in Table 2, regression coefficients (top) and their standard errors (bottom)
g = weight
n = number

SET NO	b_0	b_1	b_2	b_{3g}	b_{3n}	b_4	b_5	b_6	b_7
1	43.10840 24.47938					-.46347 .22577	.31044 .18340	1.16408 .84955	-1.95785 .57676
2	45.69920 27.88205			.00027 .04109		-.51869 .24867		1.44160 .94141	-1.30795 .58481
3	-47.34383 46.71372			.01458 .01116			-.04526 .03716	2.58668 1.24892	- .48690 .10086
4	-37.54786 51.07303				.00492 .00915		-.02917 .03653	2.39517 1.36481	- .52899 .10051
5	- 8.19496 24.42048			.01789 .01198		-.10788 .15156	-.05450 .04048	1.58945 .84557	- .34023 .08806
6	-14.80741 26.45489				.01119 .00919	-.07889 .15020	-.04140 .03801	1.75483 .90859	- .37522 .08202
7	14.90193 15.20279					-.24337 .10698	-.00574 .03617	1.43271 .61268	- .48405 .09563
8	13.86445 15.02289			.00264 .00968		-.26466 .11461		1.46525 .61112	- .48715 .08903
9	13.14034 15.74559			.00702 .01398		-.27520 .11733	-.02251 .05066	1.52007 .63669	- .45419 .10798
10	5.39662 17.16803	-.04733 .16296	.00744 .00556	.00559 .01437		-.18187 .13802	-.02496 .05294	1.52623 .62824	- .45063 .11114
11	14.41325 14.69552					-.24960 .09823		1.44585 .59923	- .48979 .08738

Table 4: Survival in 3 different tanks and average length of cod in tank

HAUL NO	TANK SIZE 2000 l		500 l		500 l	
	$\bar{l}$, cm	S,%	$\bar{l}$, cm	S,%	$\bar{l}$, cm	S,%
19	26.3	21.2	29.1	23.5		
21	27.9	0	29.2	0	21.7	0
23	33.6	33.7	28.9	14.9	29.6	13.2
25	30.6	0	31.7	0	30.7	0
30			39.3	27.6	35.5	22.9
34			36.0	63.6	34.8	46.5
36			34.4	8.0	32.2	25.5
37	33.5	44.3	32.5	26.9	33.1	35.8
39			32.9	51.9	33.0	50.0
41	32.7	28.6	31.8	28.6	31.9	17.2
42	33.5	30.8	36.4	39.5	35.9	32.6

Table 5: Survival (%) as generated by the range of values of one variable each, the others being kept constant at their average value, set numbers as in Table 2

VARIABLE / SET NO	TOT.CATCH OF COD,Kg	TOWING- DEPTH,m	TOWING- TIME,Min	TIME ON DECK,Min	TIME IN TANK,Min	WEIGHT IN TANK,Min	AVER. LENGTH,cm
RANGE	30-1054	18-100	60-300	4-120	175-1405*	11-80	18-39
AV.	300	60	120	30	580	47	30
1		48-10		79-0			15-40
2		41- 0		52-0			1-32
3				27-0			0-38
4				31-0			0-38
5		26-17		30-0			3-36
6		26-20		32-0			2-38
7		38-18		41-0			11-41
8		39-18		41-0			11-41
9		40-17		40-0			10-41
10	26-32	35-20	29-23	40-0	25-34	29-26	9-41
11		39-18		41-0			11-41

* except haul 15

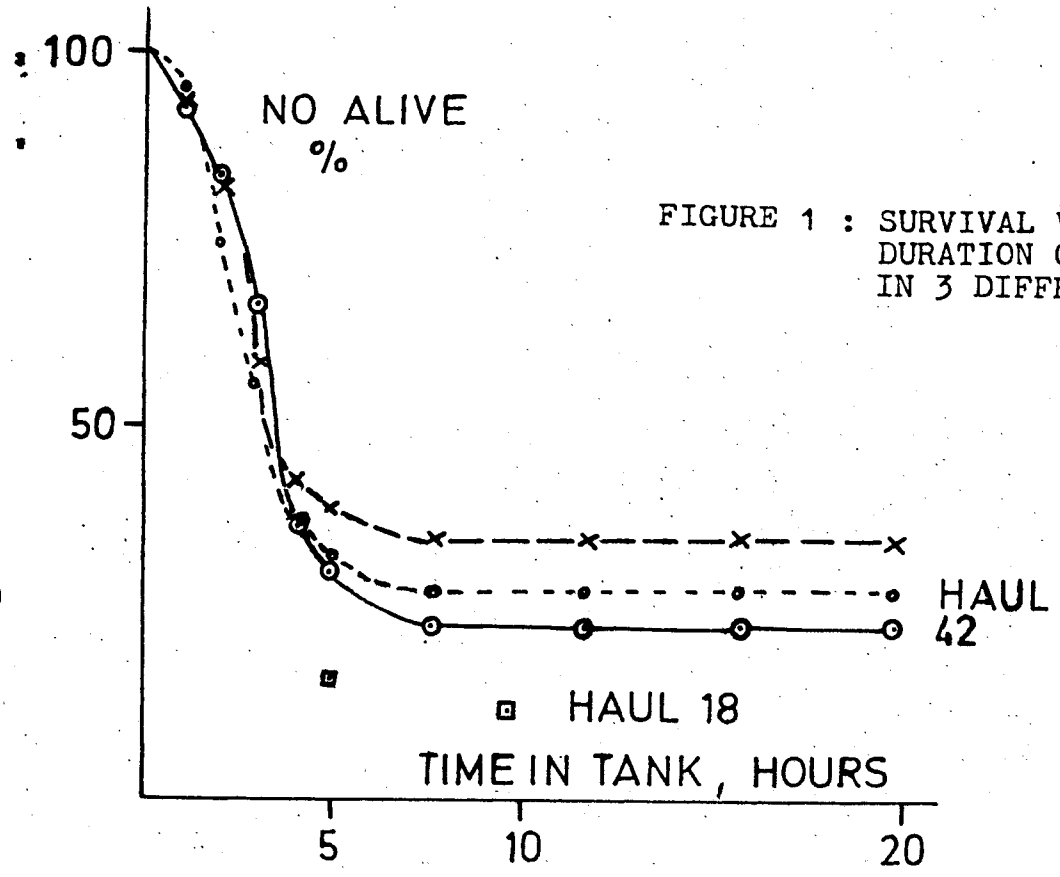

FIGURE 1 : SURVIVAL VERSUS DURATION OF STAY IN 3 DIFFERENT TANKS

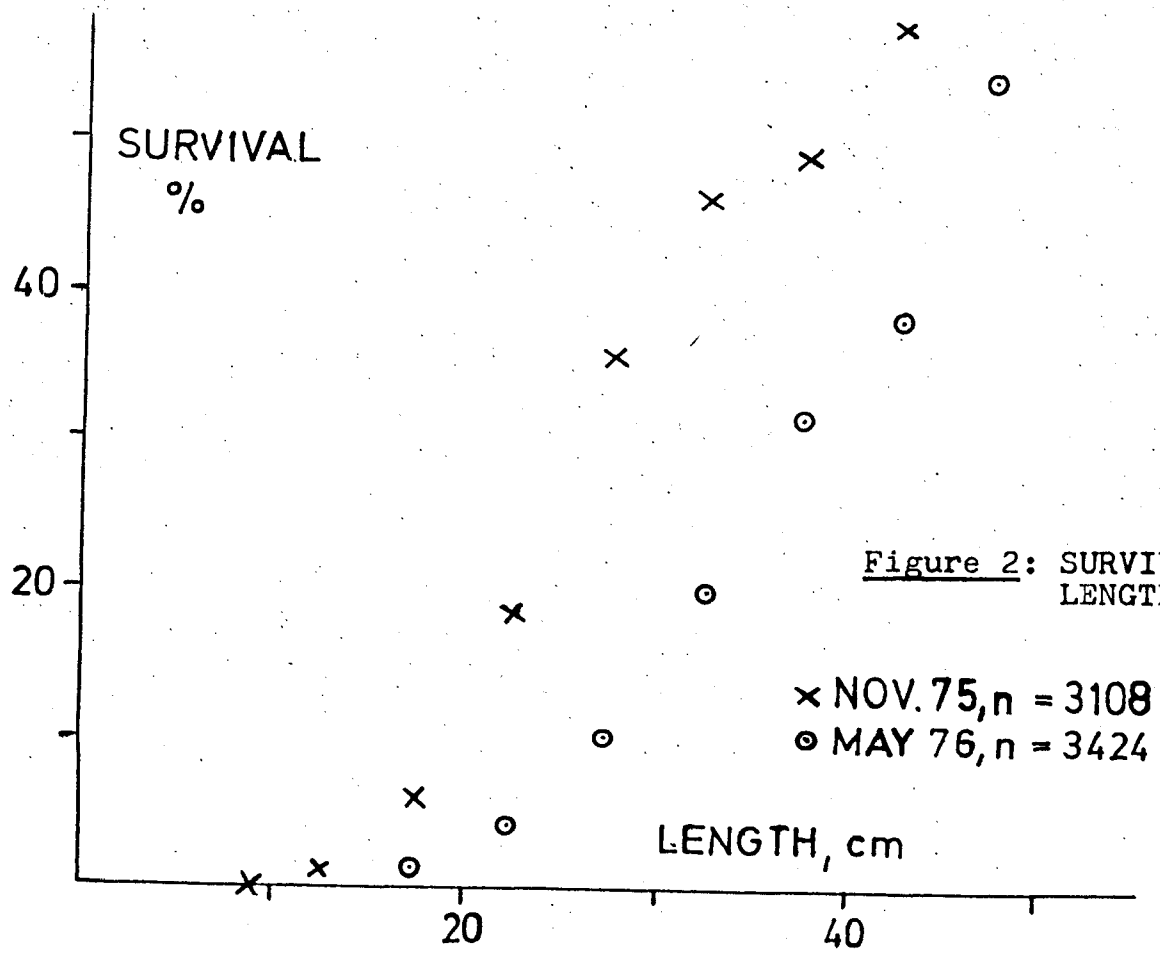

Figure 2: SURVIVAL VERS. LENGTH OF COD