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On the decompression regime of fishes' lift from depth to the surface.

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ABSTRACT

As a result of more, than 300 lifts of fishing trawl or special container, designed to assess mesh-damage in cod-end, it was estimated, that pressure decrease, accompaning lift, provoked barotrauma in 6 species of physiclist fishes. The per cent of barotrauma death was estimated for these fishes. The divers' observations showed different behavioural changes in them, for example, coordination disturbance, turning upside down, decreasing of avoidance reaction. Physostomes and swimbladder-absent fishes of 28 species didn't suffer from barotrauma during lift, except some cases, when their death might be explained by thermal shock or gas-bubble disease.

Using the intermittent lift-regime, we succeeded in preventing barotrauma in Alaska pollack, captured at 65 m and brought to the surface in viable condition. The admissible value of single pressure reduction for Alaska pollack and other physoclists is 2-folds reduction of it from initial. In the case of few "steps" the exposure between two lifts should be near "significant" decompression time (completed more than at 50%), but

when there are many steps - the exposure should be prolonged up to the time of total decompression.

"Total" and "significant" decompression time is species-specific, and can't be extrapolated. It needs further determination for different species.

The received data are nessessary for many ichthyological studies, and namely - for determination of trawling effect on fish stocks.

RÉSUMÉ.

Le rapide levage à la surface des chaluts ou des containers-speciaux accumulant poissons déstinés à estimer la survivance et l'influence traumatique des maille menait aux indices caracteristiques du barotrauma chez 6 espèces des poissons physoclistes. Le pourcentage de leur pert à cause du barotrauma était considerable. Les poissons physostomes et les poissons sans vessie gazeuze des 28 espèces n'étaient pas souffert pendant le levage sauf certain cas quand leur perte pouvait être expliquée par le thermochoc ou per la "gaz maladie".

En utilisant le régimé "multi-marches", nous avons réussi à prevenir le barotrauma chez la morue du Pacifique occidental (Theragra chalcogramma) qui était obtenue à 65 m et montée à la surface dans l'état de la pression, pour la morue du Pacifique occidental et pour d'autres poissons physoclistes est 2-fois reduction de cette valeur en comparaison avec celle de départ.

Dans le cas de peu de "marches", l'exposition entre deux levages doit être proche au temps de decompression "considerable" (quand il est terminée par 50% et plus); mais, quand il y a beaucoup de "marches"- l'exposition doit être prolongée jusqu'au temps de decompression totale.

Le temps de decompression "totale" ou "cosiderable" est

éspece-specifique et il ne peut pas être extrapolé . Il est besoin de prendre d'études ultérieures de ce processus chez poissons differents.

INTRODUCTION.

Ichthyological studies and fishing of many species are accompanied by essential decrease of hydrostatic pressure. Besides mechanical damage of fish by the gear, the well-known patterns of barotrauma - such as eyes and stomach expanding, swimbladder and body wall rupture - and resultant death - can be seen. Barotrauma is of little importance for commercial value of fish-product, but it provides essential difficulties for different studies of many benthic and deep-sea fishes. For example, pressure reduction can misrepresent morphomethric values, data on feeding and results of tagging deep-sea fishes. It also should be taken into account during determination of trawling effect on fish stocks (Efanov,1981; Treshev and oth.,1985).Namely it is important in this case to separate damage with cod ends' mesh from barotrauma, which distorts the picture of mesh force and makes it possible the misinterpretation of trawling effect on fish stocks.

So, the objective imagine about mesh damage can be received by minimizing or avoiding at all the barotrauma effect. This in turn, needs both detailed knowledge of fish biology, especially mechanisms of pressure effect on fishes, and concrete observations on specific features of barotrauma during fishing. The description of later is unfortunately too scarce in literature.

It's well-known, that first of all pressure changes the volume of gas enclosures in fish. These are mainly the gases of swimbladder - the organ, found in 75% of all fishes and bearing hydrostatic, communicative and some other functions. The volume changes of swimbladder mostly obey Boyle's law (Jones, 1951; Alexander, 1966). Therefore the 2-fold change of swimbladder volume takes place at every 2-fold absolute pressure changes, i.g. during migration of fishes from the surface to I0m (2 ATA); from 30 to 70m (8ATA), and so on - 150, 310, 630 m.... and back to the surface. This is the main reason for decreasing of pressure effect on fishes while depth increasing (Tsvetkov, I974), and the main explaination of probability for extensive depth vertical migrations, when pressure gradients exceed tenths atmospheres. Slow changes of swimbladder volume during such migrations coincide with the process of gas amount regulation by decompression, and there exist no patterns of barotrauma in ascending animal.

According to morphology and mechanisms of gas regulation in the swimbladder the fishes are divided in physostomes and physoclists. The former are capable to quick (during seconds) expulsion of excess gas from the swimbladder, so pressure reduction isn't accompanied for them by barotrauma. This group includes clupeiforms, eels, pikes, cypriniforms, sturgeons and many others, mainly freshwater, neretic and epipelagic fishes. The resorbtion of gases in physoclists lasts longer (during several hours), and their lift to the surface faster than decompression unavoidably causes barotrauma. This group includes the majority of sea benthic and pelagic fishes - namely all cod-like fishes, rat-tails, majority of perciforms, sea-breams, mullets, hornfishes and many others, includin meso-and-bathypelagic one. Buoyancy changes and mechanisms of their swimbladder-volume regulation are the points of special interest; for the concrete work the problem of safety lift of these fishes without barotrauma is more important.

Working out the methods for preventing sea fishs' barotrauma have interested the investigators far ago. For example, the tagging process of rockfish Sebastes included the lift of captured fishes up to 40 m, where the scuba-diver perforated body and swimbladder wall with the syringe needle and released the excess gas (Gotshall, 1964). Further lift through the zone of sharp pressure change was harmless for these fishes, and a little needle-wound soon healed. It was noticed that such procedure was of no demand for the cod, if the duration of its lift was prolonged. This moment is evidently basic for second method of preventing barotrauma, and knowledge of natural decompression rates in this case is nessessary. These data appeared for different species last years (Tytler, Blaxter, 1973; Tsvetkov, 1974; Treshev and oth., 1985) .

The aim of this work is to compare the barotrauma degree in different species during commercial trawling fishing and to diminish this effect by using the nessessary decompression regime while lifting them to the surface.

MATERIAL AND METHODS.

The experiments were conducted in 1972-1984 at the Baltic and Japanese seas by collaboraters of VNIRO, BALTNIIRH, TINRO. The main data were received during testing of small-meshed semi-hard container, covering the cod end and designed by one of the authors (Efanov, 1975) for appreciation of fish condition while squeezing through trawl mesh. The degree of barotrauma was determined in fishes, lifted to the surface in the cod end or container. Such data were got for 34 species, captured during more than 300 trawlings, each of which lasted 10-180 min. The whole material is shown in Tables I and Ia. Parallel observations by "scuba" divers at 10 and 30 m gave an opportunity of assessment the condition and behaviour of lifted fishes. 52 such observations were conducted.

The improvement of container enabled its separation at desired depth and further lift apart from trawl. This enabled to work out such decompression regime, which prevented barotrauma in lifted fishes, namely Alaska pollack (Theragra chalcogramma) and cod (Gadus macrocephalus). In some cases (for wachna cod - Elegimus gracilis) the fishes , lifted with patterns of barotrauma, were put into high-pressure chamber (PK-IOOm),where the pressure was increased up to the value, equivalent to that, present at the depth of capture. The behaviour and condition of these fishes was observed for 3 hours.

RESULTS AND DISCUSSION.

The observation of fishes, lifted to the surface and put into sea or deck tanks, showed the different effect of equal pressure reduction for different species. The harmlessness of sharp pressure reduction was confirmed for physostomes herrings and anchovy, lifted in the cod end or container - i.g. squeezed through trawl-mesh. These fishes showed normal orientation, coordinated locomotion and schooling in the tanks. Our previous studies and literature data showed high surviving for herring even after scale loss of 22% and more (Zamahaev,I95I; Efanov, I98I), though the total sensitivity of these fishes to mechanical damage is well-known. The opinion about harmlessness of pressure reduction for lifted physostones was confirmed on salmon, whitefish, eel. The redused surviving of physostome smelts and eastern redfin was strange to some extent, for they obviously had expelled the excess gas during lift. Their death can also hardly be explained by mechanical trawl-mesh damage, for even

Table I. The condition of fishes, lifted to the surface without decompression.[x]

Family, species	number of specimens	length cm	swim-bladder morphology	capture depth m	surviving, %	note
I	2	3	4	5	6	7
Clupeidae						
Pacific herring Clupea harengus pallasi (Valenciennes)	55	37-40	physostomes (open)	65	100	in the cod end
Japanese pilchard Sardinops sagax (Schlegel)	34	20-22	open	65	100	- " -
Engraulidae						
Japanese anchovy Engraulus japonicus (Schlegel)	79	13-17	open	65	100	in the container
Osmeridae						
Arctic smelt Osmerus eperlanus dentex (Steindachner)	88	19-26	open	65	32	- " -
Surf smelt Hypomesus pretiosus (Steindachner)	46	12-15	open	65	5	- " -
Gadidae						
Alaska pollack Theragra chalcogramma (Pallas)	3763	38-60	physoclist (closed)	65	79	in the cod end and container
Pacific cod Gadus morhua macrocephalus (Tilensis)	42	26-70	closed	65	33	- " -
Wachna cod Elegimus gracilis (Tilensis)	1245	18-24	closed	65	69	in the container
Stichaeidae						
Shanny Opistocentrus dybowskii (Steindachner)	48	30	absent	65	100	- " -
Gobiidae						
Yellowfin goby Acanthogobius flavimanus (Steindachner)	2112	20-47	absent	65	100	- " -
Large mouth goby Gymnogobius macrognathus (Schmidt)	332	20-47	absent	65	100	- " -

Table I, continued

I	2	3	4	5	6	7
Agonidae						
Jordani poacher Agonomal jordani(Schmidt)	82	20-24	absent	65	I00	in the cod end
Poacher Pallasina bardata (Steindachner)	49	18-24	absent	65	90	in the container
Hexagrammidae						
Alaska greenfish Hexagrammus octogrammus (Pallas)	104	18-38	absent	65	I00	- " -
Atka mackerel Pleurogrammus monopterygius (Pallas)	874	27-35	absent	65	I00	in the cod end and container
Cottidae						
Common sculpin Myoxocephalus brandti (Steindachner)	668	18-25	absent	65	I00	in the container
Buffalo sculpin Enophrys dicerans(Pallas)	46	17-21	absent	65	I00	- " -
Pleuronectidae						
Sohachi flounder Cleisthenes herzensteini (Schmidt)	146	10-26	absent	65	30	- " -
Rock flounder Lepidopsetta bilineata (Ayres)	1436	24-35	absent	65	I00	- " -
Yellofin sole Limanda aspera (Pallas)	I000	20-22	absent	65	I00	in the cod end
	278	10-27	absent	65	60	in the container
Starry flounder Pleuronectes stellatus (Pallas)	162	25-37	absent	65	37	in the cod end
Clupeidae						
Baltic herring Clupea harengus membras L.	61300	12-14	open	30	I00	without fishes damaged by the mesh
Sprattus sprattus balticus (Schneider)	33290	10-11	open	30	100	
Salmonidae						
Salmo salar (L) Atlantic salmon	54	40-50	open	25	100	in the cod end
Coregonidae						
Whitefish Coregonus lavaretus (L.)	318	36-38	open	20-25	I00	- " -

x during 3-hour period after lift

Table Ia. The condition of separate specimens, lifted to the surface without decompression.

Family, species	length cm	capture depth, m	swimbladder morphology	surviving ^x	note
Osmeridae					
European smelt Osmerus eperlanus eperlanus (L)	17	30	physost. (open)	partial	in the cod end and container
Anguillidae					
Common eel Anguilla anguilla (L)	50-60	10-20	open	safety	in the cod end
Cyprinidae					
Eastern redfin Leuciscus brandti (Dyb.)	28	65	open	lethal	in the cod end
Percidae					
European pike-perch Lucioperca lucioperca (L)	42-44	25-30	physoclist. (closed)	partial	- " -
Serranidae					
Japanese sea bass Lateolabrax japonicus (Cuvier)	48-50	65	closed	lethal	- " -
Scorpaenidae					
Schleghel's rockfish Sebastodes schlegheli (Hildendorf)	40	65	closed	lethal	- " -
Trichodontidae					
Japanese sandfish Aretoscopus japonicus (Stein dachner)	10	65	absent	safety	in the container
Bathymasteridae					
Derjugin's searcher Bathymaster derjugini	11	65	?	lethal	- " -
Pholidae					
Gunnel Pholis nebulosus (Houttanyn)	20	65	absent	safety	- " -
Pleuronectidae					
Mud flounder Pleuronectes flesus (L)	25-30	30	absent	safety	in the cod end

^x during 3-hour period after lift

more subtile herring successfully passed through just the same mesh. There are also few reasons for total mass-catch pressure explaination, for fishes concentration in cod end or container was low. Though the mixing of the catch was observed during rising and pulling the cod-end out, and the resultant piercing of soft - rayed fishes by pricks of stiff-rayed had taken place (for example, baltic herring by sticklebacks), these injures were so Characteristic, that we desided to ignore them in this work. We propose, that the main reason for smelt and redfin death may be attributed to substantional temperature changes (up to 9-IO°C), observed during lift. There might be as the direct influence - thermic shock, as the indirect - by gas embolia of blood vessels owing to changes of gas solubility ("gas-bubble disease") During further investigations this factor should be paied more attention.

Lifting to the surface was also harmless for the majority of fishes without swimbladder, except young plaice, squeezed through the cod-ends' mesh and caught by the container. We observed the gas bubbles in the fin vessels of these fishes and some deaths. As in the case with the smelt, this might be due to gas-bubble disease and not to typical barotrauma, for at this stage the plaices have no swimbladder.

The barotrauma was rater distinct in cod-like fishes (Alaska pollack, Pacific cod, Wachna cod), rockfishes and pike-perch - typical physoclistic fishes. After lift in the cod-end or in container they demonstrated gut and eyes expantion, changes of locomotion coordination. The divers' observations at ascending container revealed sharp buoyancy increasing in alaska pollack and wachna cod at 30 m, if the regime of ascending was short and continu ous. Being incapable to resist such buoyancy increase, the fishes gathered in the top side of container and swam on the side or upside-down. Sometimes they tried to dive, and their behaviour at whole strongly resembled that, described in our previous experimental work (Tsvetkov, 1974). Scuba-divers also observed noticible decreasing of avoidance reaction in these fishes to the touch of container wall. At the same time fishes without swimbladder - gobies, poaches and blennies, captured in the container, kept themselves on its bottom with normal orientation and avoidance reaction.

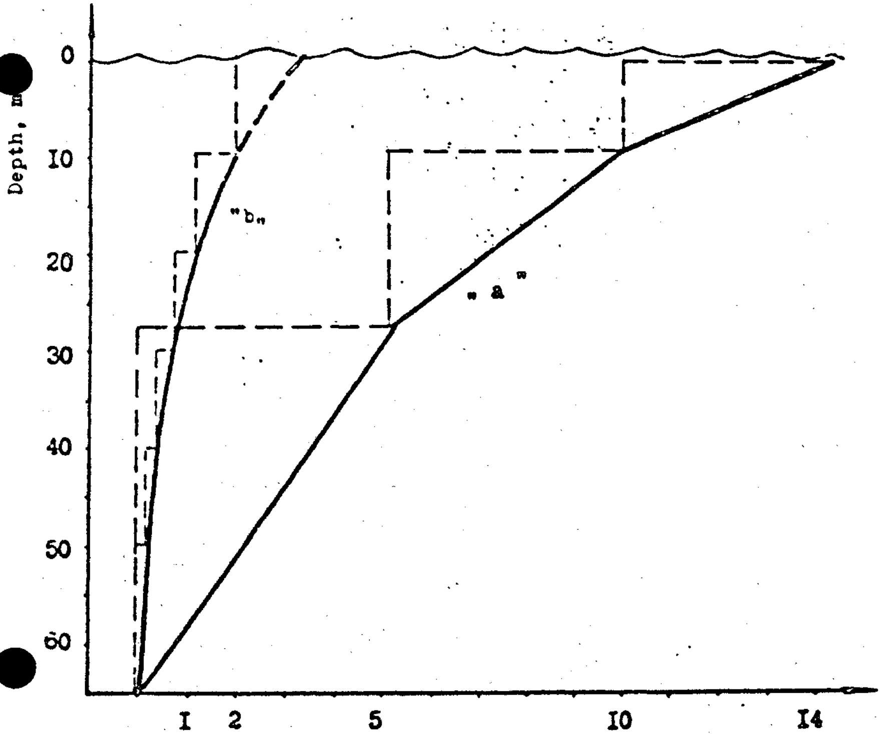
The lift of separated container from 65 m with several periodic stops (Table 2) allowed to avoid barotrauma in alaska pollack and pacific cod to a high extent. There were no dead fishes now, and the divers observed practically normal behaviour of fishes at 30 m. Only in one case - at 10 m the swimming on the side was observed for 27 alaska pollacks (from the total 1564 specimens). This might have happened due to the change of lifting regime during strong wind-drift of the vessel and unknown depth position of container at this time. At a whole the chosen regime of container lift may be concidered successful for alaska pollack. The different responce to such lift was recorded for wachna cod. At 10 m the divers noticed the increase of its swimming activity, further enlarge of abdomen and turning upside-down - at 3 m. Being put into pressure chamber, the fishes restored normal orientation after pressure increase up to 8 ATA, and having received negative buoyancy, sank to the bottom of the tank. Soon, however, all of them died. Probably, the previous barotrauma signes were fatal for these fishes in spite of absence of visible patterns. So, the chosen lift regime may be concidered unsatisfactory for wachna cod.

Table 2. The safety regime of lift for Alaska pollack

Pressure(P) ATA	Stops of containers' lift, m		Exposure time, min.	
			at 11 - 16°C	at 4 - 9°C
7,5		65[x]	30 - 60[x]	30 - 60[x]
		50	15	10
	$P_{initial}/2$	40	15	10
		30	20	15
3,6	Pinit./2	20	30	20
		10	45	30
1,8				
1,0	P.init./2	0	–	–

[x] depth and duration of trawling

All experiments on pressure tolerance of fishes showed, firstly, the necesserty of adequate accessment of temporal factor, and secondly, the safety two-fold pressure reduction practically for all of them. The concrete natural investigation confirmed both thesises - the trawl and container lifting time let all physostome fishes pass the decompression (adaptation to pressure reduction), and typical barotrauma was noticed only during pressure reduction more than two-fold from initial, and faster, than decompression rate. Barotrauma wasn't recorded when pressure changes were less than 2-folds from initial and passed slower or near to decompression time. The later may be achived by decreasing the rate of continuous lift, or by making it intermittent, with periodical ceasing of lift and exposure at every "safety step" (2-fold pressure reduction) during the period, equivalent to decompression time. Such scheme of lift has been offered for the cod, saithe and haddock by Tytler and Blaxter (1973)- Fig. 1 "a". These authors



Duration of lift, hours

Fig.1. Scheme of safety lift to the surface for gadoid fishes.

- - - for intermittent regime

——— for continueous regime

"a" - by Tytler, Blaxter, 1973

"b" - for Alaska pollack, present data at 11-16°C considered the total decompression time for gadoids to be near 5 hours.However we assumed, that in the case of few "steps" lifting with more short exposures also would be safety. The duration of such exposure should be long enough to provide significant part of decompression. It had been shown (Tsvetkov,I974) that many physoclistic fishes elapsed decompression up to 50-60% even during the first hour after 2-fold pressure reduction. This has been confirmed by Alaska pollack lift - with 50-60 min. exposure at the first 2-fold pressure reduction (from 65 m to28), and 75 min further exposure at the second 2-fold reduction of it (from 28 m to 9 m)- Table 2 and Fig. I"b". The next exposure after equivalent pressure reduction was of no sence now, for the fishes had already been lifted to the surface in viable condition, though with excess buoyancy. For some special (for example, behavioural) purposes such surface exposure is necessary, because excess buoyancy essentially changes different behaviour patterns, including avoidance reaction. It became obvious from results of scuba-divers' observations and our previous data (Tsvetkov,I979).

It should be mentioned, however, that in such intermittent scheme the duration of lift itself isn't reflected, though it contributes to decompression. The shortened decompression regime was acceptable for Alaska pollack only due to few quantity of safety steps, when there was no dangerous summation of unfinished decompression cycles. If there were more steps (i.g. the capture depth was deeper), such summation might have taken place. In this case the duration of exposure should be prolonged to the time of total decompression - to 5 hours (according to Tytler and Blaxter, I973).

Our failure with such regime for wachna cod is, probably, due to species-specifity of its decompression curve - the fenomenon, which, as we have mentioned earlier, should be taken into consideration, during working out such regimes. In its turn, this obliges special investigations on decompression for different species: both total and significant (partial).

Only complex resolving all these problems can provide real understanding of such processes as fish damage by cod-end mesh, effectivness of tagging, methods for barotrauma preventing in hydrotechnical constructions, behaviour adequacy of lifted fishes and many other ichthyological problems.

CONCLUSIONS.

Quick lift of trawls or special covering cod-ends' containers, designed to assess mesh-damage in cod-end, resulted in characteristic signes of barotrauma for 6 spesies of physoclistic fishes. The per cent of barotrauma-caused deaths was essential for them. Physostome and swimbladder-absent fishes of 28 species didn't suffer from barotrauma during lift, except some cases, when their death may be explained by thermal shock or gas-bubble disease.

Using the intermittent lift-regime, we succeeded in preventing barotrauma in Alaska pollack, captured at 65 m and brought to the surface in viable condition. The admissible value of single pressure reduction for alaska pollack and other physoclists, is 2-folds reduction of it from initial. In the case of few "steps" the exposure between two lifts should be near "significant" decompression time (completed more, than at 50%), but when there are many steps - the exposure should be prolonged up to the time of total decompression.

"Total" and "significant" decompression time is species-specific, and can't be extrapolated. It needs further determination for different species.

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