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The Effects of Icing and Freezing on the Length and Weight of Groundfish Species

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Introduction

Death and preservation change both the length and weight of a fish from its live "normal" condition. A knowledge of such changes is frequently of importance, e.g., in deducing the fresh length of tagged fish returned by commercial vessels, in the enforcement of minimum length regulations for fishery conservation, and in deducing the fresh length and weight of specimens preserved for laboratory examination.

The present paper presents data on the effects of icing and freezing on the lengths and weights of cod (*Gadus morhua* L.), haddock (*Melanogrammus aeglefinus* (L.)), American plaice (*Hippoglossoides platessoides* (Fabricius)), winter flounder (*Pseudopleuronectes americanus* (Walbaum)), and Atlantic argentine (*Argentina silus* (Ascanius)). No data have previously been presented for winter flounder or argentine and very little for haddock.

A considerable body of published data has accumulated on the effects of death and of preservation in formalin and alcohol, and by icing and freezing. However, this literature is widely scattered and, as a review seems called for, this is presented here.

Material and Methods

Cod used in icing experiments were caught by a commercial inshore longline vessel out of Lockeport, N.S., and landed gutted. These were measured and weighed ashore within 5 hours of removal from the sea and before rigor mortis set in. A few were just beginning to stiffen. After measurement they were placed in boxes with ice.

Cod, haddock, plaice, and winter flounder used in freezing experiments were captured by otter trawl in Passamaquoddy Bay, N.B. These were measured on deck within 45 minutes of capture — usually within a much shorter time — tagged, and placed in tanks of running sea water. The fish remained in the tanks 1-4 hours before they could be taken ashore and weighed. Although survival in the tanks was good, particularly among plaice and winter flounder, most fish were dead on weighing. Immediately after weighing the fish were placed individually in air-tight plastic bags and stored in a freezer at -16°C.

Argentines captured on the Nova Scotian and St. Pierre Banks were measured immediately after capture, sometimes tagged, placed in plastic bags in numbers between 10 and 25 per bag, and put in a freezer aboard ship. One sample after measurement was stored in ice for 24 hours, remeasured and weighed, then frozen in a plate freezer in plastic bags containing 10 fish each.

All frozen fish were thawed in fresh water and remeasured and reweighed immediately thawing was complete.

Results

Effects of icing

To determine the effects of icing on length and weight of cod, 50 fish were iced and stored for 17 hours and a further 55 were stored in ice for 41 hours before reweighing and remeasuring. The latter group were re-iced for a further 24 hours, then weighed and measured again.

The average length decreased by 0.4% after 17 hours in ice but increased again slightly after 41 hours to -0.2%, and after 65 hours there was an increase over the original length of 0.8% (Table 1). Weight after 17 and 41 hours on ice was 1.0% higher than when fresh but, after 65 hours, had dropped to -0.6% of the original weight. Only in the weight change after 17 hours was the magnitude of the change related to initial length, smaller fish gaining slightly more weight than larger fish (P = 0.05).

One hundred and thirty-six argentines stored in ice for 24 hours lost 0.5% of their fresh length (Table 2). The slope of the regression equation of percentage change on fish length did not differ significantly from zero (P = 0.05), indicating that the percentage loss did not vary with fish length.

Effects of freezing

Seven separate argentine samples were measured fresh, frozen aboard ship, and thawed after a time period of at least 1 month. The loss in length varied from 2.3-6.3% among samples (Table 3).

Table 3 also shows that results are affected by whether total, fork, or standard length is measured. (Standard length is the length from the tip of the snout to the notch in the caudal peduncle.) All three lengths were measured on the sample from cruise C.142. The percentage changes in fork and total lengths were closely similar but that in standard length was 0.8-1.0% greater. In terms of actual lengths, there was an average decrease of 1.1 cm in standard length but only of 0.9 cm in total and fork lengths. This would suggest that not only had the caudal fin not shrunk at all but, in fact, it had increased in length by 0.2 cm. This is a most unlikely occurrence and the results undoubtedly reflect a bias involved in shipboard measurements of either fork and total lengths or standard length of argentines.

The relationship of percentage change to initial length was examined in three batches of fish (Tables 2 & 4). Regression equations of percentage change on fish length indicated that, in one case (H.85), the change was positively related to fish length, in one (C.126) it was not affected by fish length, and in the other (C. 131) it was negatively related (P = 0.05). The fact that fish from H.85 had been iced for 24 hours prior to freezing should not influence these results as it has already been shown that icing affected all sizes equally. Thus, there do not appear to be any consistent trends in relative length change with length of fish although under some circumstances such trends occur.

The effects of freezing on weight of argentines were determined from one sample which had been on ice 24 hours prior to weighing (H.85). After being frozen for 2 months, the weight increased on average by 0.8% (Table 5). Small fish gained more weight than large fish (P = 0.01).

Cod, haddock, plaice, and winter flounder all lost length and weight on freezing. All four species show a slight tendency to shrink more with increase in time frozen, at least during the first 15 days. The relationship of weight loss to time frozen is more variable and does not show consistent trends (Table 6). The average losses for fish thawed after freezing for 8 days or more were:

	Length %	Weight %
Cod	2.9	0.5
Haddock	1.9	1.0
Plaice	2.1	0.3
Winter flounder	2.6	0.6

The effect of repeated freezings and thawings was tested (Table 7). All four species lost progressively more length and weight with increase in number of thawings.

The effect of leaving fish soaking in water beyond the time they were considered fully thawed was tested. Weight increased progressively up to the termination of the experiment after 24 hours (Table 8). Length changed little, decreasing slightly in all species but winter flounder.

The rapid uptake of water probably explains much of the variation in weight shown in Table 6, as a relatively short delay in weighing after thawing would alter the results considerably.

The shrinkage of cod due to rigor mortis was measured indirectly. All cod used in the above experiments were measured immediately on capture and before rigor set in. Twenty other cod were left for about 6 hours before measuring at which time they were fully in rigor. These were frozen, 10 being thawed after 12 hours, the other 10 after 8 weeks. After 12 hours frozen, cod in rigor had shrunk 0.7% compared with 1.8% for fresh cod. After 8 weeks, the figures were 1.7 and 3.7% respectively. It seems therefore that shrinkage due to rigor alone was between 1 and 2%.

Literature Review

Parker (1963), studying changes associated with anaesthesia and death in young sockeye salmon (*Oncorhynchus nerka*) immersed in water, concluded that the live weight of a fish is affected by the particular stage of osmoregulation at the time of weighing, that osmoregulation is affected by prolonged anaesthesia, and that the relative rate of water uptake is related to size of fish. He also found that water uptake continued after death, and it can be deduced from his figure that the average rate of uptake was approximately 0.7% per hour during the first 3 or 4 hours after death.

Shetter (1936) found that the average shrinkage in length of brook trout (*Salvelinus fontinalis*) due to rigor mortis was 2.6%. Burgner (1962) found a shrinkage of 2-3% in red salmon smolts (*Oncorhynchus nerka*), and Johansen (1907) found a shrinkage of 2.2% in European plaice (*Pleuronectes platessa*) due to the same cause. Shrinkage of larval fish due to rigor mortis may be proportionally much greater than for juveniles and adults. Bal (1943) reports a shrinkage of 2 mm (22%) on death of a larval specimen of *Argentina sphyraena* L. measuring 9 mm when alive.

Preservation of *Argentina sphyraena* in 70% alcohol for 8 months produced a decrease in weight of 16% and a decrease in length of 2% (Halliday, 1966). Length changes were independent of initial length but weight changes were dependent on initial weight, small fish losing more weight than large fish.

A number of workers have considered the effects of formalin preservation (Table 9). Shrinkage in length usually occurs and this may be as great as 6.0% of the original length, depending on species. Small fish may shrink proportionally more than large fish in the cisco, *Leucichthys artedi* (Hile, 1936), in *Oncorhynchus nerka* (Burgner, 1962), and in *Clupea harengus* (Humphreys, 1965). These differences due to size are not always exhibited as Parker (1963) found no differences in relative shrinkage due to size in *O. nerka*. Weight changes vary greatly from -15 to +11%. Parker (op. cit.) demonstrated that the direction of weight change was dependent on the ionic concentration of the formalin solution. In freshwater formalin he found that weight rapidly increased to 116-127% of initial weight, then subsequently fell to 105-111% with time. In saltwater formalin weight initially fell to 87-91% but subsequently rose to 91-95% of live weight. He also found that the larger relative weight changes were associated with the smaller fish.

Previous workers (Table 10) have found that length usually decreases, possibly as much as 1.6%, with storage on ice. Weight too usually decreases, results varying between +2 and -14%, depending on several factors. Cutting (1951) found that weight loss of iced fish on commercial trawlers depended on length of time in storage and amount of pressure exerted on them by other fish and ice laid on top of them. Cutting also noted that fish stored in boxes and thus not subjected to pressure as are those stored in pounds usually gain 1-2%, a result which agrees with that of MacCallum *et al.* (1967). The iced fish reported by Ellison (1934) to lose 8% of their weight were also exposed to pressure in the hold of a commercial vessel.

Freezing invariably causes a reduction in the length and weight of fishes (Table 11). The extent of the reduction varies greatly, depending on the techniques used in freezing and thawing and also the size of the fish. Airtight wrapping during refrigeration reduces desiccation, and thus weight loss, very markedly (Boyd *et al.*, 1967). The results of desiccation are well shown by Humphreys' (1965) results, small herring losing almost 60% of their fresh weight. Much of this weight loss is recovered when the fish are thawed in water (Anthony and Chenoweth, 1965).

Discussion

The length of a fish undergoes considerable and fairly rapid change from the time of death. In the case of weight, changes may occur before death if osmoregulation is disturbed by anaesthesia or the stress of capture. All methods of preservation alter the length and weight of fish to some degree and the magnitude of these changes varies greatly, depending on species, size, and details of preservation technique. Parker's (1963) conclusion that, for formalin preservation, "It is necessary that treatments be thoroughly described and unless these factors are standardised within any experiment, the comparison of results may simply reflect differences due to treatment rather than differences in the environment." holds true for other methods of preservation. No general correction factor can be established to derive fresh lengths and weights from measurements on preserved specimens.

It does appear that icing has least effect on length and weight, changes in both frequently being less than 1% if the fish are well treated, i.e. if pressure is kept to a minimum, and this technique is to be recommended for short-term storage. Furthermore, if frozen fish are thawed in water and weighed immediately thawing is complete, weights will usually be within 1% of the fresh value.

There is seldom any problem in obtaining accurate length measurements of fishes aboard a research vessel. An accurate weighing technique for individual, small fish at sea has still to be devised. However, a combination of lengths measured at sea with weights from fish stored in ice or frozen should produce length-weight relationships accurate enough for most purposes.

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Table 1. Effects of icing on the length and weight of cod. (Combined results of two experiments; measurements after 41 and 65 hours based on the same fish.)

Fork length cm	17 hours			41 hours			65 hours		
	No.	% length change	% weight change	No.	% length change	% weight change	No.	% length change	% weight change
45-49	6	-0.7	+1.6	11	0.0	+1.5	11	+0.8	-0.6
50-54	9	-0.4	+2.2	10	-0.4	+1.3	10	+1.0	-0.8
55-59	11	0.0	+1.1	11	+0.2	+0.3	11	+1.4	-0.9
60-64	6	-0.5	+0.5	13	-0.5	+1.2	13	+0.4	-0.7
65-69	9	-0.3	+0.4	4	-0.7	+0.3	4	+1.1	-0.2
70-74	6	-0.7	+0.2	5	-0.3	+0.8	5	0.0	+0.4
75-79	3	0.0	+0.3	1	+1.3	+0.9	1	+1.3	0.0

Table 2. Effects of icing for 24 hours and subsequent freezing for 2 months on the length of argentines. (* - significant at 5% level.)

Standard length cm	No.	% length change after icing	% length change after freezing
22	1	-1.3	-3.6
23	2	0.0	-2.4
24	11	-0.3	-2.4
25	9	-0.7	-2.3
26	10	-1.0	-2.7
27	11	-0.8	-2.7
28	8	-0.9	-2.8
29	10	-0.4	-2.3
30	11	-0.8	-2.3
31	12	-0.4	-2.2
32	11	-0.5	-2.0
33	11	-0.4	-1.9
34	9	-0.3	-2.3
35	6	-0.0	-2.2
36	11	-0.6	-2.2
37	1	-0.8	-2.1
Average		-0.6	-2.3
Regression parameters			
Elevation		-1.1467	-3.4692
Slope		0.0209	0.0385*
Correlation coefficient		0.2880	0.6018

Table 3. Effect of freezing on the length of argentines. (T.L. = total length; F.L. = fork length; S.L. = standard length.)

Cruise	Sample No.	Length measured	% change
C.126	1	F.L.	-5.0
"	2	"	-5.1
"	3	"	-5.5
"	4	"	-5.9
C.127	1	F.L.	-6.3
C.131	1	F.L.	-3.9
C.142	1	T.L.	-2.3
"	"	F.L.	-2.5
"	"	S.L.	-3.3

Table 4. The relationship between percentage change and initial length in argentines (* - significant at 5% level).

Fork length cm	C.126		C.131	
	No.	% change	No.	% change
21	13	-6.1	-	-
22	20	-4.9	-	-
23	17	-5.1	-	-
24	26	-4.9	-	-
25	43	-6.5	-	-
26	40	-6.0	-	-
27	37	-5.1	-	-
28	23	-5.4	-	-
29	38	-5.7	-	-
30	28	-5.8	9	-3.3
31	18	-5.4	11	-3.8
32	17	-5.5	26	-3.7
33	25	-5.4	28	-3.9
34	20	-5.2	28	-4.1
35	11	-6.9	16	-3.7
36	9	-6.2	9	-4.4
Regression parameters				
Elevation	-4.7795		1.0318	
Slope	-0.0209		-0.1464*	
Correlation coefficient	-0.3314		-0.8586	

Table 5. Effects of freezing for 2 months on the weight of argentines which had been on ice 24 hours before initial weighing (** - significant at 1% level).

Original weight g	No.	% weight change
100-149	6	+1.9
150-199	31	+1.1
200-249	13	+1.1
250-299	14	+0.5
300-349	13	+1.0
350-399	16	+0.4
400-449	8	+0.5
450-499	10	+0.3
500-549	6	+0.4
550-599	4	-0.4
600-649	-	-
650-699	1	+0.2
Average		+0.8
Regression parameters		
Elevation		1.0064
Slope		-0.0028**
Correlation coefficient		-0.8875

Table 6. Percentage length and weight changes in cod, haddock, plaice, and winter flounder in relation to length of time frozen.

	Cod			Haddock			Plaice			Winter flounder		
Days frozen	No. of fish	% length change	% weight change	No. of fish	% length change	% weight change	No. of fish	% length change	% weight change	No. of fish	% length change	% weight change
0.5	26	-1.8	-0.2	29	-1.4	-1.0	21	-1.5	-0.8	40	-1.9	-0.2
1.5	10	-2.3	+0.1	-	-	-	-	-	-	-	-	-
8	7	-2.4	+1.1	20	-1.9	-1.4	17	-1.8	-0.5	29	-2.4	-0.4
15	-	-	-	19	-2.0	-0.6	11	-2.4	0.0	30	-2.6	-0.5
29	10	-3.1	-2.1	-	-	-	-	-	-	21	-2.3	-1.2
57	10	-3.7	-0.6	10	-1.9	-1.1	-	-	-	20	-3.0	-0.3

Table 7. Percentage length and weight changes in cod, haddock, plaice. and winter flounder in relation to number of times frozen.

	Cod			Haddock			Plaice			Winter flounder		
Days frozen	No. of fish	% length change	% weight change	No. of fish	% length change	% weight change	No. of fish	% length change	% weight change	No. of fish	% length change	% weight change
0.5	26	-1.8	-0.2	29	-1.4	-1.0	21	-1.5	-0.8	40	-1.9	-0.2
8	8	-2.6	+0.3	10	-2.6	-3.1	21	-3.0	-2.4	30	-3.0	-0.5
15	-	-	-	-	-	-	10	-4.0	-6.6	30	-3.4	-1.9
22	8	-3.8	-2.6	-	-	-	-	-	-	-	-	-
29	-	-	-	-	-	-	-	-	-	20	-3.9	-4.7
57	7	-4.6	-3.1	10	-3.8	-3.5	-	-	-	-	-	-

Table 8. Percentage length and weight changes in cod, haddock, plaice, and winter flounder on soaking in water after thawing.

	Cod			Haddock			Plaice			Winter flounder		
Hours soaking	No. of fish	% length change	% weight change	No. of fish	% length change	% weight change	No. of fish	% length change	% weight change	No. of fish	% length change	% weight change
0	28	-2.5	-2.8	57	-1.8	-0.8	29	-2.2	0.0	30	-2.6	-0.3
4	28	-2.6	+2.7	56	-2.2	+0.7	18	-2.5	+4.4	29	-2.3	+4.0
9	28	-2.6	+5.1	58	-2.4	+2.8	29	-2.6	+5.7	30	-2.3	+7.0
24	28	-2.7	+8.5	58	-2.6	+4.5	29	-2.6	+6.5	30	-2.3	+9.9

Table 9. Changes in length and weight of fishes due to formalin preservation.

Species	% length change	% weight change	Author	Remarks
Leucichthys artedi	-1.6	- 4.1	van Oosten, 1929	Weight change from fish fixed in 4% formalin, stored in alcohol
	-0.5	-12.6	Hile, 1936	Fixed in 10% formalin, stored in 70% alcohol
	-2.7	-15.3	"	"
Salvelinus fontinalis	-5.4	-	Shetter, 1936	10% formalin
Salmo trutta	-5.2	-	"	"
Oncorhynchus nerka	-5.2	-	Burgner, 1962	"
	-6.0	-	"	"
	-4.1	+10.4	Parker, 1963	3.8% freshwater formalin
	-3.2	+10.7	"	"
Oncorhynchus gorbuscha	-4.4	+ 5.5	"	"
	-3.8	- 4.9	"	3.8% seawater formalin
Oncorhynchus keta	-4.2	+ 4.6	"	3.8% freshwater formalin
	-5.4	- 7.3	"	3.8% seawater formalin
Clupea harengus	-0.5	- 7.8	Humphreys, 1965	Small fish 5% formalin
	-2.2	- 4.2	"	Large fish "
	-0.5	-	Williamson, 1914	1% formalin
Coregonus albula	-	+ 2.2	Järvi, 1920	
Pond carp	+0.7	+ 3.6	Amosov, 1960	4% formalin; fixed alive
	-0.1	- 2.4	"	4% formalin; fixed after soaking in water
Amur wild carp	-0.8	+6.0/+8.5	"	4% formalin; fixed alive
	-0.9	- 0.5	"	4% formalin; fixed after soaking in water

Table 10. Changes in length and weight of fishes due to icing.

Species	% length change	% weight change	Author	Remarks
-	-	-8.0	Ellison, 1934	
Limanda ferruginea	-1.2/-1.6	-	Lux, 1960	Based on 2 experiments
Hippoglossoides platessoides	-1.0	-	Pitt, 1967	
Pleuronectes platessa	+0.8	-3.1	Cutting, 1951	
Melanogrammus aeglefinus	+0.3/-1.6	-2.0/-14.3	"	Range } Based on 2 experiments for length and 15
" "	-	-6.1	"	Average} experiments for weight
Gadus morhua	+1.6/-1.4	+1.9/-13.2	"	Range } Based on 11 experiments for length and 85
"	-	-2.3	"	Average} experiments for weight
"	-	+0.1/+1.7	MacCallum et al., 1967	Based on 7 experiments run for 1-3 days
Eopsetta jordani	(-0.5 cm)	-	Harry, 1956	Percentages not available
Parophrys vetulus	(-0.5 cm)	-	"	" " "
Microstomus pacificus	(-0.5 cm)	-	"	" " "

Table 11. Changes in length and weight of fishes due to freezing.

Species	% length change	% weight change	Author	Remarks
Scomber scombrus	-0.9	-2.5	Williamson, 1900	
Clupea harengus	-2.4/-4.1	- 0.1/-6.0	Anthony & Chenoweth, 1965	5 experiments; thawed in water
"	-1.3/-4.5	- 6.4/-11.2	"	2 experiments; thawed in air
"	-1.0/-3.2	-11.7/-59.3	Humphreys, 1965	Not thawed; divided into size groups
"sole"	-	- 0.7/-1.1	Boyd et al., 1967	2 experiments; not thawed; cellophane wrapped and boxed'
"	-	- 7.7/-7.8	"	2 experiments; not thawed; boxed only
Eopsetta jordani	(-0.5 cm)	-	Harry, 1956	Percentages not available
Parophrys vetulus	(-0.5 cm)	-	"	" " "
Microstomus pacificus	(-1.0 cm)	-	"	" " "