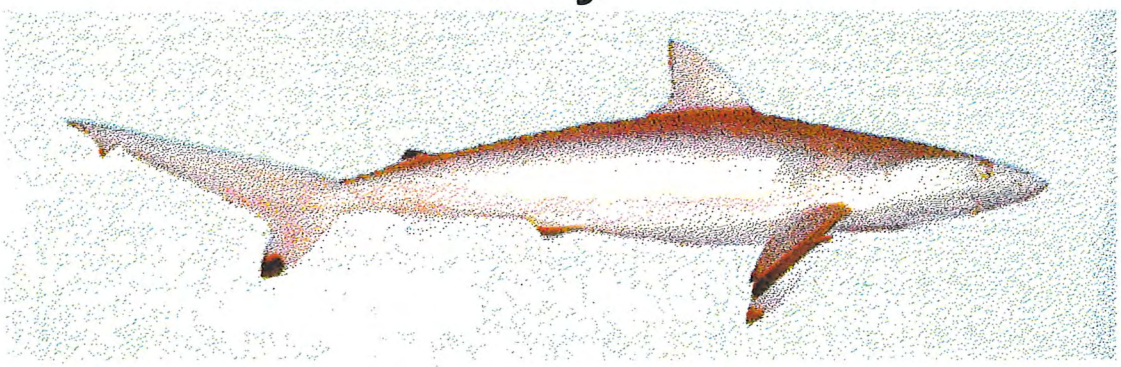
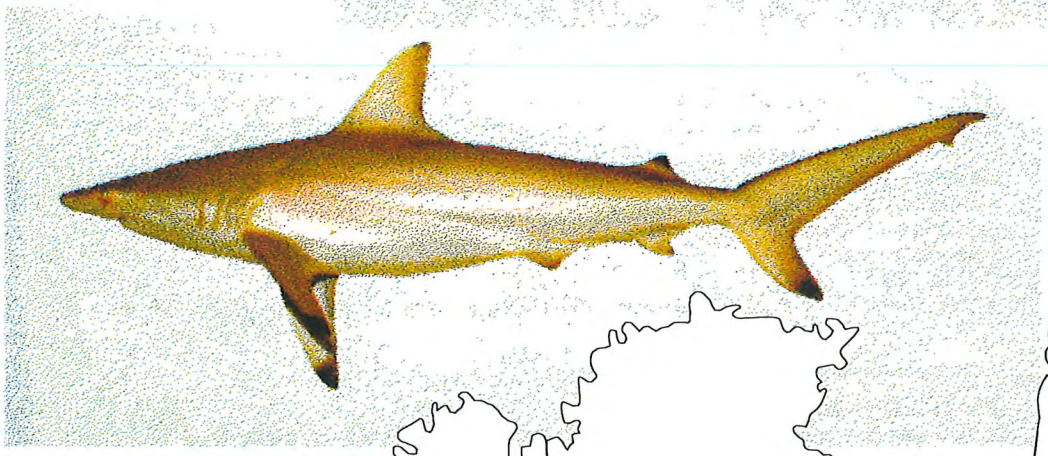
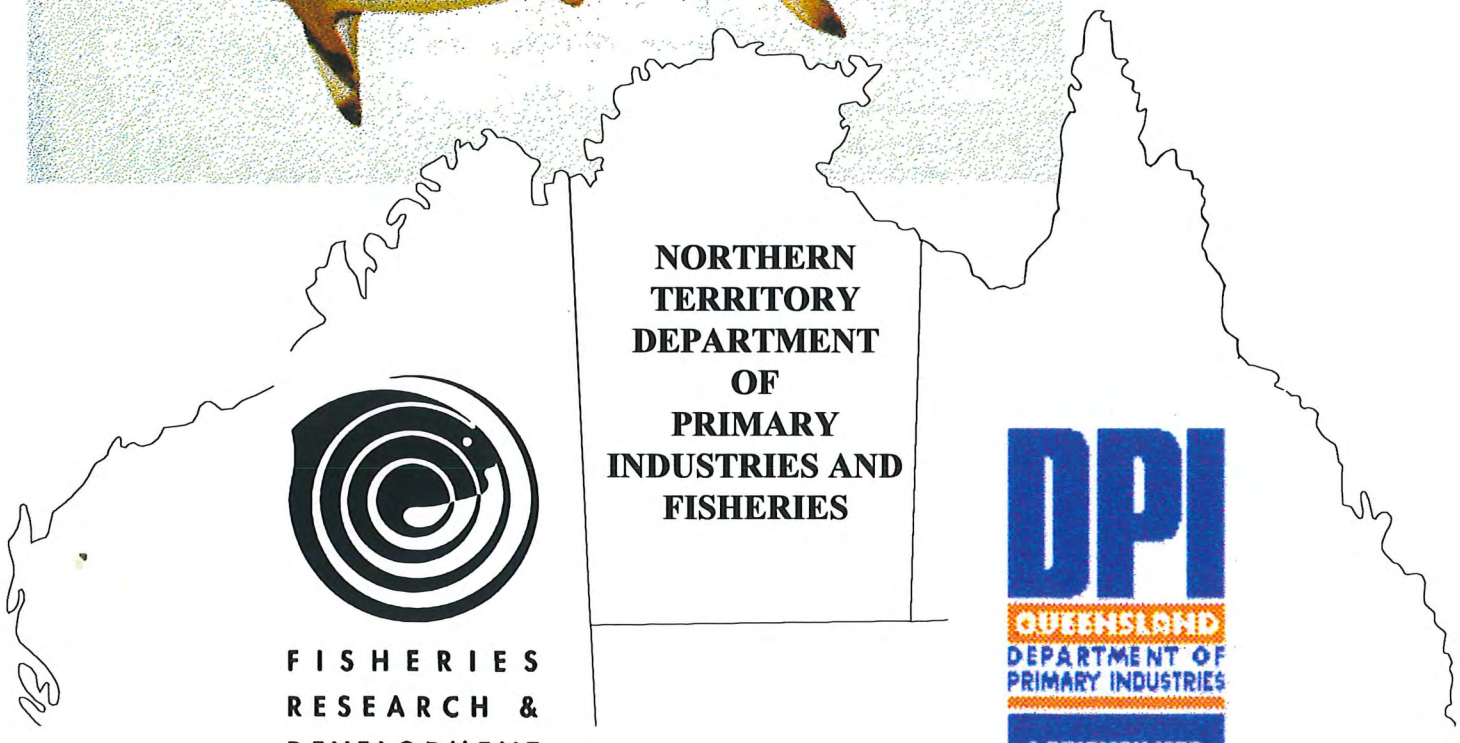
INCREASING THE MARKETABILITY of COMMERCIAL NORTHERN SHARK by ELIMINATING THE INCIDENCE of TOUGH FLESH

PROJECT 93/190

S.L.Slattery







NORTHERN TERRITORY DEPARTMENT OF PRIMARY INDUSTRIES AND FISHERIES

FISHERIES RESEARCH & DEVELOPMENT CORPORATION

DPI QUEENSLAND DEPARTMENT OF PRIMARY INDUSTRIES AGRIBUSINESS

SUMMARY

The major influences on the texture of cooked shark are of biological origin. There are significant differences between the two species, the sexes, shark of different sizes and the time of the year they were caught.

Recommendations

(i) Keep the length of shot to a minimum to reduce the amount of time a dead shark remains in the water. Dead shark left in the net for some time will result in the presence of ammonia in the flesh.

(ii) Do not keep shark larger than 85 cm fork length.

(iii) Use gill nets with no larger than 10 cm mesh size.

(iv) Do not keep male *Carcharhinus sorrah* unless smaller than 65 cm fork length.

(v) Bleed and gut shark as soon as possible after they are brought on deck.

(vi) Keep the shark out of direct sunlight and use running deck hoses to keep the shark carcasses cool.

(vii) To avoid the possibility of thaw rigor the shark should be kept until rigor is established before freezing. They should be kept in a seawater wash tank to prevent overheating. If placed in refrigerated seawater (RSW) they must be in rigor before fillets should be removed for freezing.

(viii) The temperature of the RSW should be maintained close to 0°C at all times.

Acknowledgements

The author would like to gratefully acknowledge the following people for their assistance while conducting this investigation - Peter Pender (Management Officer, NT Dept. Primary Industries and Fisheries) for his support both on and offshore, Andrew Cusack (IFIQ) for working under difficult conditions; Ray Davies and the crew of the fishing vessel 'Merindah Pearl' and Rob Ludlow and his crew for their support of the project and their cooperation in collecting samples and Allan Bremner (IFIQ) and Stephen Nottingham (IFIQ) for the many hours spent ensuring this investigation and the final report to be successful.

CONTENTS

Page

1. BACKGROUND

There was no **Background** section required by FRDC when the application for this project was submitted. A brief summary of the information that prompted the project follows.

There was a growing body of concern that shark caught in northern waters frequently displayed tough texture. Consumer complaints were received and product was returned. Processors considered the problem to be serious. From phone interviews of buyers it was determined that the problem was sporadic and possibly occurred mainly in large shark. Two species of shark form the basis of the fishery *Carcharinus sorrah* and *Carcharinus tilstoni*. The latter is long and stocky and was thought to be less of a problem than the shorter and thinner *C. sorrah.* From length-weight relationship equations for the two species, using a similar length, *C. tilstoni* is the heavier fish. This suggested that *C. sorrah* to be offender.

The visible symptoms were often ambiguous, but dryness of the fillets, with at times characteristics of freezer burn and a red colouring to the fillet were the main descriptions applied. Product from Taiwan had also suffered from the problem of unacceptably tough texture.

Analysis of three samples tested at IFIQ identified definite toughness which was described as rubbery, chewy and dry with a low overall acceptability. Both species displayed these characteristics. A number of conditions such as cold shock, thaw rigor and poor deck handling could have been responsible.

2. NEED

Problems with tough flesh are hindering the development of the northern and warm water shark fishery. Numerous complaints have been received from the market in Victoria and consignments of shark trunks and fillets have been returned. There is a demand for shark in the southern states, mostly in the Melbourne market. This demand cannot be met by the Southern Shark Fishery which is described as being dangerously overfished. The potential to meet this market need with northern shark is in jeopardy because of a problem of extremely tough flesh. The result is that there is low buyer confidence in northern shark, it does not fetch a high price, does not have high market acceptance and up to 1800 tonnes of shark fillets are being imported annually from Chile, Taiwan and Namibia.

The incidence of tough shark has been described as being as high as one in three although accurate records have not been kept but at least two species *C. sorrah* and *C. tilstoni* have been implicated. In private, both fishermen and processors have expressed considerable concern but they are loathe to publicise the extent of the problem, for obvious reasons.

There are a number of likely causes of tough flesh:

(i) inherent muscle structure leading to toughness in some species;
(ii) age related changes in the connective tissues or, most likely;
(iii) cold-shock setting of the muscle due to rapid chilling prerigor.

There are no systematic observations which would help decide which of these causes is the most important, or worse still, whether a combination of is involved. There is anecdotal evidence but this has been contradictory. It is therefore necessary to conduct a planned investigation of the relevant factors within each species.

In raw fish, the muscle fibres are soft and gel-like while the connective tissue is tough. In cooked fish flesh, the collagen of the connective tissue gelatinises and its contribution to toughness becomes less than that of the muscle proteins which coagulate on cooking to become firm.

If the collagen is crosslinked, as occurs in older land animals such as beef and sheep, then it does not gelatinise to the same extent on cooking and may remain tough. This is not the most likely cause of toughening in the *C. sorrah* and *tilstoni* (known previously as *C. limbatus*) as flesh from young specimens has been found to be tough and data from tagging studies indicate these species do not live to any great age and are mature at 2-3 and 3-4 years respectively. The amount of connective tissue, however will still contribute to the overall flesh texture.

The contribution of the muscle proteins to toughness depends on the flesh pH and the degree of contraction of the muscle fibres. It is likely that the degree of contraction is the most important. When some warm water species with high remaining energy levels are chilled then muscle contraction results. If they are frozen in this state then the fibres are "locked" in this shortened form leading to a considerable increase in toughness and a loss of moisture on cooking. The process of shortening is reversible if the flesh is rewarmed, but this is impractical in a large fish like a shark since normal rigor mortis may set in before the rewarming could take place. Rigor mortis is not reversible.

3. OBJECTIVES

3.1 Overall objective

To identify the causes of tough flesh in northern sharks

3.2 Particular objectives

(i) To record the time course of rigor mortis in each specie.

(ii) To identify which species, if any, may undergo the cold-shock reaction.

(iii) To examine the connective tissue structure particularly for changes and toughening related to age.

(iv) To develop recommended handling procedures for the various shark species.

(v) To transfer these results in the form of a workshop and booklets (pamphlets).

3.3 Objectives achieved

The causes of toughness in northern shark have been identified. There is tenuous evidence to support cold shock or thaw rigor in shark. There is considerable individual variation. Even when either of these conditions were present they are overweighed by biological factors of species, sex, size and season of capture.

Easy to comply with recommendations have been formulated. Modification of catch gear, selection criteria of individuals to keep and on deck handling is necessary to reduce the incidence of tough shark.

4. METHODS

4.1 Collection of samples

The on-board handling procedures and testing methodology were determined from a field trip on Moreton Bay in June 1993. Samples of normal and tough shark were obtained from Markwells Pacific Limited for evaluation to provide industry standards for toughness. Shark was purchased from a retail outlet and evaluated for measurement of sarcomere length and mechanical texture. Good replication was obtained for sarcomere length measurement by laser. The data sheets for collating information about each shark and are present in Appendix 1.

The major field experiments were conducted during three cruises. The first was a two week cruise in August 1993. The next was a two week cruise in April 1994 and because a breakdown on the vessel limited the number of samples obtained, a third trip of one week duration occurred at the end of April 1994. Samples were obtained from chilling/freezing experiments using strips of muscle and on board handling treatment of shark trunks. The latter experiments were to conducted on two species of shark, *Carcharhinus sorrah* (school shark) and *Carcharhinus tilstoni* (black-tip or black-spot shark) of two different sizes chilled immediately, kept on deck until rigor had developed or until rigor was resolved. The shark were then stored chilled at two different temperatures in refrigerated seawater (RSW) for two time periods then frozen.

4.2 Handling of shark and sample collection

Only live shark landed on board were selected for experimentation. The animals were removed from the net, subdued by clubbing on the head in the region of the eyes and bled by cutting the caudal fin. Data was collected on size and sex of the two species targetted. All the shark were measured using the distance between the tip of the head of the shark and the internal curve of the caudal fin. This method is easier to apply and more accurate (Lyle and Timms 1984) than using total length.

The shark was then finned and reduced to a trunk by removing the head behind the pectoral fins, eviscerated and washed according to the method of Kreuzer (1978) where the deck hose is used to flush out any remaining blood from the main vein. The pH at the head region was recorded using a stab electrode attached to a hand held digital pH meter (TPS. Electronics, Brisbane), an identification tag was inserted and a sample of approximately 50 g removed from this region.

The sample was frozen immediately and returned to the laboratory for analysis of nucleotides and lactate.

4.3 Shrinkage experiments

The original plan for this investigation was to conduct minor experiments at the start of the first field trip to identify whether a cold shock reaction could be the cause of shark meat toughening before continuing on to the much large sample collection for textural behaviour according to the state of rigor. The amount of time involved in conducting these trials, the target of 20 individuals per treatment and the low rate of capture of live sharks necessitated these two experiments be carried out concurrently.

Shark were selected at random for shrinkage experiments. Fillets were taken from one side of a shark trunk, skinned, and the red muscle trimmed off. Pieces of approximately 20 x 10 cm were cut with the longitudinal cut being made in a head to tail direction. These were placed on a stainless steel tray in as close to their original shape as possible. A pH stab electrode was placed in one end while thermocouples were placed in both. The stab electrode was linked to a Digital pH-mV Meter LC80A (TPS Electronics Pty Ltd, Brisbane, Australia) which was standardised with reference buffers at the start of each set of the net. The pH meter and the thermocouples were connected to a Datataker 600 Data logger (Data Electronics Australia Pty Ltd, Boronia, Victoria).

Wooden pegs were placed a few centimeters in from the ends of the muscle strip with the distance between them approximately 8 to 12 cm. The shark strips were subjected to cooling using a number of methods, sitting in an ice slurry, chiller room or in a freezer room. The information gained from each experiment determined the next modifications to be applied. Measurements of the spacing between the two wooden pegs were taken intermittently at about 10 min intervals using a plastic dial caliper (Bel-Art Products, New Jersey, USA). Nucleotide and lactate samples were taken before and after cooling and frozen in liquid nitrogen. The datalogger recorded readings every 10 s throughout the trial. These readings were stored as an ASCII file which was later combined with the peg measurements. The data were converted to values of temperature, pH and shrinkage (percentage of reduction of initial peg spacing), and presented in graph form.

Subsamples were removed from the strip at the end of the chilling period and after thawing, cooked in a microwave oven (2 min on high setting) on-board and appraised by the experimenter and the skipper of the vessel for the initial experiments. For later experiments, conducted during the second cruise, this appraisal was conducted at the laboratory The remaining piece of fillet was placed in a plastic bag with identification card, frozen and returned to the laboratory for analysis of nucleotides and lactate and, when sufficient material was left, for tasting, textural grading by the investigator (using a scale of 1 for tender to 7 for very tough) and mechanical evaluation using a model 1130 Instron Universal Testing Machine. Appendix 2 shows a shark fillet prior to a shrinkage trial.

4.4 Rigor experiments

The trunks were either placed in refrigerated seawater (RSW) immediately, or, held on deck with a deck hose running over them until rigor was established and then placed in RSW, or, held until rigor had resolved and then placed in RSW. The progress of rigor was monitored by using the method of Iwamoto and others (1987). A peg was placed at the midpoint of the trunk and a vertical measurement was obtained between the fork of the caudal fin and the table on which the trunk rested when the tail half of the trunk was unsupported. With the onset of rigor the muscles contracted raising the tail region. When the measurement approached zero and stabilised, full rigor was achieved. As the muscles relaxed and the tail reached the position noted during the prerigor state then the shark was accepted as being in postrigor and placed in RSW. While the measurement and time of observation were recorded, only the time taken to achieve rigor and the end of this state have been used for analysis.

The trunks were stored in RSW at either of two temperatures. Normally the lower the temperature the better the condition of the product being stored. A temperature of 1°C was determined as suitable for this experiment. As cold shock occurs both in beef and some tropical species of fish when the muscle temperature is reduced to below 15°C this temperature was used as for comparison. The storage times in RSW used were 6, 12 or 24 hr. Due to low numbers of live shark being caught a modification to the RSW treatment was made. After the required storage time was complete the trunk was removed and a fillet, the anterior half of the trunk from the side opposite to the tag, was taken. The skin was left on and the fillet was placed in a sealable plastic bag along with the identification number from the tag and the storage time. The fillet was then placed in a carton with other fillets in the freezer. The trunk was returned to the RSW for a further storage time. This time depended on the species and sex of the shark and the numbers required to fill particular groups. After the second period the trunk was removed, a fillet cut and placed in the freezer as the earlier fillet.

4.5 Sample preparation

On return to the laboratory the samples were removed from the plastic bag and cut into a number of subsamples. These corresponded to the tests to be performed; nucleotides, lactate, sarcomere length and shear force analysis. They were cut using a butchers bandsaw while frozen and were placed into individual labeled snap lock plastic bags.

The subsamples intended for chemical analysis were cut up and placed in a Waring blender while frozen. The subsamples to be appraised for shear force values were skinned while frozen and trimmed of dark muscle and previously exposed surfaces. They were then left to thaw for two hours at room temperature. The pH of the raw shark was measured using the stab electrode described earlier and the flesh was then rated using three point scales for thaw colour (0=white and 2=pink) and thaw texture derived from the resistance to cutting of the sample by a knife (0=soft and 2=tough).

4.6 Chemical analysis

4.6.1 Nucleotide degradation profiles

Shark muscle (10 g) was homogenised with 50 mL 0.6N perchloric acid for 1 min in a Waring blender. The blended material was filtered through Whatman No. 1 paper and the acid filtrate quickly neutralised to pH 6.8 with 2N potassium hydroxide. This extract was stored on ice for 30 min, after which the precipitated potassium perchlorate was removed by filtration through 0.45 µm filter discs. Separations were achieved on a Nova-PAK C_{18} column (150 x 3.9 mm, Waters Associates, Millipore Corporation, Massachusetts, USA) in series with a reverse phase µ-Bondapak C_{18} stainless steel column (300 x 3.9 mm, Waters Associates) with a mobile phase 0.06M K_2HPO_4 + 0.04M KH_2PO_4 containing 50 mL methanol per litre. The flow rate was 2ml/min. The absorbance detector was set at 254 nm and the response for each of the six nucleotides was calibrated by injecting a cocktail of each reference compound containing 1.068 µmmoles/mL adenosine 5′-triphosphate (ATP), 0.894 µmoles/mL adenosine 5′–diphosphate (ADP), 0.99 µmoles/mL adenosine 5′–monophosphate (AMP), 1.045 µmoles/mL inosine 5′–monophosphate (IMP), 0.939 mmoles/mL Inosine (HxR) and 1.102 µmmoles/mL Hypoxanthine (Hx). Separation of the ATP and ADP peaks was difficult for most samples run. The data has been combined for both of these nucloetides. The level for AT/DP quoted in the tables is actually the combined concentrations of ATP and ADP.

4.6.2 Lactate

For lactate analysis an aliquot of the extract prepared for nucleotide analysis was applied to a Aminex HPX-87H stainless steel column (300 x 7.8 mm, Bio-Rad Laboratories, North Ryde, NSW) which was heated to 40°C. A 0.01N H_2SO_4 mobile phase was applied with a flow rate of 0.6 mL/min. The absorbance detector was set at 210 nm and the response for a lactate standard was calibrated by injecting a sample containing 81.8 µmoles/mL.

4.7 Textural analysis

Samples of shark fillet obtained before the field trips were cooked in a microwave oven for a range of times. At the half way mark the cooking was halted, the pieces of fillet turned over and cooking continued for a similar time. At the end of cooking the internal temperature of the samples was measured and the visual appearance appraised. The shortest cooking time which resulted in an internal temperature above 80°C and in which the flesh appeared to be cooked throughout was 50 s at the high power level for each side. This used as the standard for cooking all samples at the laboratory. In instances where there appeared to be uncooked areas the shark were exposed to a further 10 s of microwaves. The samples were left to cool at least 30 min before testing.

Mechanical assessment of texture was performed using a modified Lee-Kramer shear cell attached to a Model 1130 Instron Universal Testing Machine. Due to the limited amount of meat present the successful modification used in previous experiments (Slattery and others 1989) was employed in which a mounting block was inserted into the shear cell to hold a plug of meat 16 x 25 x 25 mm (approx. 6-11 g load). Two 3 mm shear blades, driven by a 1KN force at

20mm/min, penetrated the meat perpendicularly to the surface muscle fibres and across the grain of that surface. The Instron was interfaced with a Data Systems Adapter which had a sample rate of 18.2pts/s which plotted the compression chart. The derived chart was divided into two sections identified as muscle and connective tissue according to the method of Moller (1981).

Measurements were made of the load at peak height (KN), energy required (J) for each peak and the total combined energy to shear a plug of raw and cooked (one minute microwave on High power) shark fillet and adjusted for weight of sample. Duplicate samples were analysed and means of these recordings were used for later statistical analysis.

4.8 Sarcomere length

Sarcomere length was evaluated using a Laser diffraction method and was carried out at the CSIRO Meat Research Laboratory, Cannon Hill, Brisbane on a fee-for-service basis. Shark fillets used for the determination of cooking time were analysed at the laboratory above to determine the suitability of this technique. The method was effective in measuring sarcomere length of shark muscle and the data obtained showed little variation of sarcomere length for a number of sites on a fillet.

4.9 Statistical analysis

Initial analysis of the data was performed using correlation coefficients and one-way analysis of variance (ANOVA). Further analysis of variance was performed using the method of least squares for non-orthogonal models. Initially all factors and the two way interactions were included in the analysis and higher order interactions were grouped together and used in the error term. When non significant ($P>0.05$) two way interactions were found then they were omitted from the next model to improve the efficiency of the remaining tests. Least square means from the final model were compared using linear contrasts except for the two way tables where the available degrees of freedom did not allow for multiple comparisons. In these cases it is usually obvious why the interaction between factors is significant.

5. RESULTS

Appendix 3 lists the definitions of abreviations and labels used in displaying the results obtained.

5.1 Evaluation of industry samples

A total of ten shark were obtained from Markwells Pacific Limited. These consisted of five labelled as "soft" while the remainder were designated as being "tough". All were tested using the Instron. Below is a table of the data obtained for the energy expressed in joules required to shear a standard sized piece of shark muscle.

Table 1. Total shear force energies (J) required to shear commercial shark samples.

Group	Sample Number	Ravte		Cavte	
		Replicate 1	Replicate 2	Replicate 1	Replicate 2
Soft	1	-	0.2967	0.3769	0.3526
	2	0.2931	0.3109	0.3192	0.2144
	3	0.4365	0.3988	0.2207	0.2554
	4	0.5520	0.4595	0.2444	0.2787
	5	0.4568	0.3517	0.1761	0.1998
	Mean	**0.3591**		**0.2641b**	
Tough	1	0.4930	0.3446	0.4296	0.4340
	2	0.4354	0.4818	0.3678	0.3621
	3	-	0.3814	0.6792	0.5510
	4	0.3653	0.3679	0.4179	0.4352
	5	0.4561	0.3517	0.3301	0.3580
	Mean	**0.4059**		**0.4365a**	

* Means followed by different letters are significantly different at the 1% level.

The data was subjected to analysis of variance. No significant differences were found for raw shear force values. Significant differences were present at the 1% level for cooked shark. The level of 0.44 joules will be considered the industry standard and will be used for determining whether a shark is tough.

5.2 Samples obtained from field collection

5.2.1 Biological information

A total 67 female and 132 male *C. sorrah* and 77 female and 88 male *C. tilstoni* were caught during the three cruises. The length-frequency data was plotted for each sample belonging to either species and each sex. These can be observed in Figures 1 to 3 presented in Appendix 4. The time required for shark to go into rigor varied between individuals. The minimum, maximum and mean times required for both sex of each specie to enter rigor can be seen in the following table.

Table 2. Time taken (decimal hours) for rigor to develop in shark.

Species	Sex	No.	Mean	SD	Minimum	Maximum
S	F	39	2.93a	1.802	0.33	7.95
S	M	70	2.44a	1.833	0.25	7.62
T	F	42	2.75a	1.419	0.08	6.25
T	M	39	2.79a	1.615	0.58	6.25

* Means followed by different letters are significantly different ($P<0.01$).

It was observed on a number of occasions that individual muscle groups went into and through rigor at different rates. This could be felt through the skin of the shark and seen in the visual distinction of individual myotomes under the skin. As it took the majority of muscle tissue through contraction to produce the rigidity necessary to raise the tail section to the horizontal this reading was kept as the main indicator of rigor. The amount of time required for rigor to end varied quite a lot and was lengthy in many cases. Table 3 displays a summary of this information.

Table 3. Time take (decimal hours) for rigor to resolve in shark.

Species	Sex	No.	Mean	SD	Minimum	Maximum
S	F	19	7.04a	2.651	3.22	12.17
S	M	22	7.85a	2.593	4.00	14.00
T	F	18	8.64a	2.327	4.60	14.63
T	M	19	7.69a	1.682	4.25	10.50

* Means followed by different letters are significantly different ($P<0.01$).

As the size of an animal can inpact on rigor time a comparison between the length of the individual and rigor times was made. The results are shown in the following table.

Table 4. Correlation coefficients between length and time taken (decimal hours) for rigor to establish (Inrigor) and resolve (Postrigor) in shark.

		Inrigor		Postrigor	
Species	Sex	No.	*r*	No.	*r*
S	F	40	0.8636	19	0.9515
S	M	68	0.7911	22	0.9490
T	F	39	0.8496	22	0.9254
T	M	41	0.8686	18	0.9395

The bigger the shark the longer it takes to go into and out of rigor. The progression of rigor has been compared to some of the biological and chemical parameters of freshly caught shark and the sarcomere length of thawed shark fillets using correlation analysis (Table 5). As the additional treatment of storage in RSW before freezing was involved, it would be inappropriate to directly compare rigor progression with the chemical characteristics of thawed shark fillets.

Table 5. Correlation coefficients between time taken to rigor stage and biological and chemical condition of freshly landed and thawed shark.

Parameter	Inrigor r	Number	Postrigor r	Number
TN Start	0.8133	185	0.9366	76
K Start	0.6685	182	0.7960	82
L Start	0.8045	151	0.9182	69
pH Start	0.8497	186	0.9459	84

There is good correlation between rigor times and chemical parameters.

5.2.2 Shrinkage experiments

The figures displayed in Appendix 5 show the pH, internal temperatures at the head and tail ends of individual pieces and measured lengths between pegs for all the different treatments. The average sea temperature for these experiments was 29 to 31°C.

5.2.2.1 Shrinkage using an ice slurry

Rough conditions made it difficult to measure the fillets. The following table summarises the data obtained. A cold room and a freezer room were then utilised to observe shrinkage behaviour. This work was very time consuming as a maximum of only three individual sharks could be tested for every set of the net.

Table 6. Physical and chemical parameters of shark chilled in a tray on ice.

SPP	Sex	Size cm	Tag Number	Sample Treatment	Shrinkage %	K Start	K End
T	F	87	3601	Chill	9.4	6	10
S	M	83	3603	Chill	left 2 right 4	4	7

5.2.2.2 *Shrinkage under freezing conditions*

Two strips of muscle from five *C. tilstoni* and two *C. sorrah* were chilled till frozen in the blast freezer. As this treatment resulted in consistent temperature and pH readings fillets from both sides of the shark were tested. The following table displays the species, sex and size of an individual shark specimen, the treatment it was exposed to, the proportion it shrank during the study, when the majority of this occurred, the K value before and after the treatment and the taste appraisal of the cooked flesh.

Table 7. Physical, chemical and taste parameters of shark chilled on a tray in the freezer room.

SPP	SEX	Size cm	Tag Number	Sample Treatment	Shrinkage %	Stage of most shrinkage	K Start	K End	Taste Appraisal
T	F	100	3605	CF	3.8	none	6	4	-
S		67	3607	CF	12.4	below 0°C	0	9	left tender, flakey right hard, bitter, prominant collagen
T		71	3609	both CF	left 8.1 right 5.8	steady steady	4	5	hard to tough
T		69	3611	both CF	left 0.9 right 2.3	steady steady	7	7	tender
S		76	3613	both CF	left 21.9 right 17.8	below 0°C	0	6	hard to tough
T		71	3615	both CF	left 0.4 right 4.3	steady -0°C	5	9	dry, chewy, muscle fibre separated
T		105	3617	both CF	left 0.2 right 5.2	none at end	4	2	hard and curled

The amount of shrinkage ranged between 0.2 and 8.1% for *C. tilstoni* and 12 and 22% for *C. sorrah*. The pattern of shrinkage varied between samples. Some had a steady rate of contraction while others shrank quicker after an internal temperature of 0°C was reached. The K values did not change much over the contraction. The pH also remained stable. All shark samples but one had hard to tough textures when tasted.

5.2.2.3 *Shrinkage under chilling, warming then freezing conditions*

Because cold shock can be reversed by warming an intermediate stage of warming was introduced to provide a better understanding of the mechanism involved. The first three samples involved chilling in the freezer to 0°C. The first shark (3619) had fillets from both sides removed then treated this way. The next two samples (17 & W3578) had two pieces of one fillet removed and one piece was exposed to the previous conditions while the other was kept in the freezer to identify whether different shrinkages could occur. The results obtained were mixed. A second modification of using the cold room allowed a slower cooling rate to identify at which particular temperatures most of the shrinkage occurred. Not having the convenience of a controlled cooling cabinet these comparisons were the only avenue available on a working vessel

to understand the shrinkage behaviour at particular temperatures. This treatment involved cooling the strips for one and a half hours, removal of one strip for the freezing, warming the remaining strip until the expansion stopped and then chilling until frozen. This was carried out on fillets from both sides for two shark (25/8 & W3676). As there did not appear to be much difference between the sides a comparison between the two temperature regimes was conducted for three shark (W3689, 5 & 29/8) using a single fillet for samples.

The following table displays the species, sex and size of an individual shark specimen, the treatment it was exposed to, the proportion it shrank during the study, when the majority of this occurred, the K value before and after the treatment, the raw and cooked shear force values obtained and the taste appraisal of the cooked flesh.

Table 8. Physical, chemical, Instron and taste parameters of shark chilled on a tray then frozen or warmed till shrinkage stopped then frozen. Results for trip one.

SPP	SEX	Size cm	Tag Number	Sample Treatment	Shrinkage %	Stage of most shrinkage	K Start	K End	Ravte	Cavte	Taste Appraisal
S		70	3619	both C*WF	left 3.5 right 0	steady none	7	19	.264	.285	soft and flakey
T		105	17	C*F C*WF	12 13	-0°C -0°C	9 9	4 -	- -	- -	dry, rubbery, chewy
T	F	110	W3578	C*F C*WF	3.7 19.1	steady warming	0 0	26 5	.368 .441	.996 .565	tough -
S	-	68	25/8	both CWF	left 3.2 right 8.4	steady start	7	20	.215	.163	chewy, not tough, moist
T	F	83	W3676	both CWF	left 3.7 right 2.1	at 10°C above 10°C	8	7	.434	.622	- -
S		76	W3689	CF CWF	3.2 7.3	steady steady	9 9	4 -	- -	- -	- -
T		84	5	CF CWF	0.4 2.5	steady steady	- -	5 -	- -	- -	- -
S		71	29/8	CF CWF	3.6 20.2	steady -0°C	7 7	- -	- -	- -	- dry and chewy

In most cases there was still little change in K value. There was no obvious differences between fillets from different sides of the same fish. The amount of shrinkage was quite different for the two temperature regimes. The time available for this to occur was obviously quite different for the two treatments. Shrinkage of up to 20.2% was exhibited by *C. sorrah* while *C. tilstoni* achieved a maximum of 19.1%. On the second cruise the latter treatment was continued for a further five shark to determine whether the same behaviour was operating for this season. The data obtained from this experiment conducted during the second trip is contained in the following table.

Table 9. Physical and chemical parameters of shark chilled in a tray then frozen or warmed till shrinkage stops then frozen. Results for trip two.

SPP	SEX	Size cm	Tag Number	Sample Treatment	Shrinkage %	Stage of most shrinkage	pH Start	pH Thaw	K Start	K End	L Start	L End	Sarc	Ravte	Cavte	Taste Appraisal
T	M	90	W3751	CF	-	-	6.03	6.13	2	7	78	-	1.5	.384	.315	- hard and chewy, no visible collagen
				CWF	8.9	start	6.03	6.07	2	14	78	102	1.5	.322	.390	- sl tender
T	M	100	W3758	CWF	17.4	above 0°C	-	6.00	2	23	75	-	1.5	.281	.852	- chewy with elastic collagen
S	M	68	W3764	CF	-	-	6.16	6.19	0	14	36	73	1.3	.352	.269	- flakey, sl dry and chewy
				CWF	8	above 0°C	6.16	6.27	0	-	36	55	1.7	.399	.229	- sl hard, dry
T	M	66	W3779	CF	-	-	6.06	6.27	0	15	25	53	1.6	.465	.313	- tender
				CWF	9.8	steady	6.06	6.19	0	24	25	66	1.7	.328	.281	- tender,sl dry
S	M	66	W3783	CF	-	-	5.87	6.03	15	-	-	-	-	.242	.767	- very dry, hard
				CWF	14.3	below 0°C	5.87	6.00	15	7	-	65	1.7	.407	.778	- dry and chewy

As similar trends were observed a modification was introduced to provide more insight into the mechanism of shrinkage. A third piece was cut from the fillet, placed on a separate tray and kept warm in the area outside the cold rooms. Pegs and thermocouples were inserted and measurements made at the same time as the sample that was chilled then warmed. A total of six *C. tilstoni* and four *C. sorrah* were exposed to these conditions. The data collected is displayed in the following two tables.

Table 10. Biological, physical and chemical parameters of shark kept warm, chilled in a tray then frozen or chilled then warmed till shrinkage stopped then frozen.

Tag Number	SPP	SEX	Size cm	Sample Treatment	% Shrink	Site of most shrinkage	pH Start	pH Thaw	*d* pH	AT/DP Start	AT/DP End	*d* AT/DP	AMP Start	AMP End	*d* AMP	IMP Start	IMP End	*d* IMP	AllP Start	AllP End	*d* ALLP	K Start	K End	*d* K	L Start	L End	*d* L	Sarc
				CF	-	-		6.00	-0.18		0	0.12		.77	-.77		6.49	-0.70		7.26	-0.05		17	15		-	-	1.4
W3784	S	M	80	CWF	15.5	start	6.18	5.99	-0.19	0.12	.04	0.08	0	.64	-.64	7.19	5.54	-1.65	7.31	6.22	-1.09	2	18	16	36	105	69	-
				W	13.8	start		5.96	-0.22		0	0.12		.58	-.58		5.59	-1.60		6 17	-1.14		16	14		100	64	1.6
				CF	-	-		5.87	-0.12		-	-	-	-	-		-	-		4.69	-		-	-		-	-	-
W3796	T	F	91	CWF	9.6	start	5.99	5.85	-0.14	0.07	.12	?	.52	.42	.06	5.5	5.72	0.22	6.09	4.95	0.17	28	18	-10	62	32	-30	2.0
				W	6.8	start		5.83	-0.16		0	0.07		.65	-.11		5.81	0.31		3.96	0.37		29	1		97	35	1.5
				CF	-	-		5.98	-0.27		.04	1.89		.49	-.04		4.16	0.04		2.65	-1.50		46	40		60	36	1.8
W3825	T	F	68	CWF	3.6	steady	6.25	6.08	-0.17	1.93	.12	1.81	.14	.08	-.21	4.12	4.75	0.63	6.19	5.64	-1.24	6	26	20	24	60	36	2.0
				W	7.8	steady		5.89	-0.36		.09	1.84		.25	-.20		3.62	-0.50		5.74	-2.23		25	19		36	12	2.0
				CF	-	-		6.08	-0.24		0	2.31		.24	.15		2.41	-1.91		6.01	-4.18		10	1		67	13	1.4
W3826	S	F	64	CWF	9.7	steady	6.32	6.03	-0.29	2.31	0	2.31	.2	.41	-.09	4.32	5.23	0.91	6.83	4.73	-1.19	9	13	4	54	69	15	1.9
				W	10.7	steady		6.07	-0.25		.08	2.23		.40	-.05		5.26	0.94		4.25	-1.09		13	4		47	-7	1.4
				CF	-	-		6.05	-0.34		0	3.85		.14	.21		5.87	1.38		6.19	-2.62		13	13		-	-	1.9
W3842	T	M	93	CWF	12.1	above 0°C	6.39	5.90	-0.39	3.85	0	3.85	.29	.38	.19	4.49	4.35	-0.14	8.63	6.31	-3.90	0	15	15	59	84	25	1.2
				W	11.2	steady		5.90	-0.40		.07	3.78		.34	.27		3.84	-0.65		6.10	-4.38		9	9		55	-4	1.8
				CF	-	-		6.05	-0.22		-	-		-	-.23		-	-		5.00	-		-	-		-	-	1.5
W3843	T	M	81	CWF	10.2	steady	6.18	6.00	-0.20	1.8	.17	1.63	.13	.11	-.37	3.45	6.52	3.07	5.38	5.78	1.42	25	27	2	60	108	48	1.5
				W	10.0	steady		5.99	-0.24		0	1.80		.10	-.50		3.92	0.47		6.26	-1.36		41	16		65	5	1.6
				CF	-	-		5.96	-0.19		.04	0.43		.08	-.42		6.07	0.63		6.62	-0.01		15	15		-	-	1.5
W3845	T	F	116	CWF	5.3	steady	6.15	5.98	-0.17	0.47	.14	0.33	.29	.10	-.35	5.44	6.07	0.63	6.20	5.72	0.11	0	16	16	56	109	53	2.1
				W	7.1	steady		5.94	-0.21		0	0.47		.02	-.26		6.08	0.64		6.27	-0.10		14	14		92	36	1.7
				CF	-	-		6.14	-0.01		.05	1.82		.39	.33		4.56	1.93		4.65	0.34		8	5		51	20	1.3
W3847	T	F	68	CWF	19.9	start	6.15	6.24	0.09	1.87	.16	1.71	.16	.53	.18	2.63	5.09	2.46	4.66	6.84	1.12	3	17	14	31	68	37	1.4
				W	6.9	steady		6.36	0.21		.04	1.83		.66	.48		5.56	2.93		4.17	1.60		33	30		87	56	1.8
				CF	-	-		6.15	-0.13		.15	4.69		.52	.42		5.95	1.24		6.62	-3.03		15	-5		63	26	1.8
W3850	S	F	66	CWF	15.9	near 0°C	6.28	6.07	-0.21	4.84	.11	4.73	.1	.45	.35	4.71	5.16	0.45	9.65	5.72	-3.93	20	25	5	37	58	21	1.5
				W	6.7	steady		5.88	-0.40		.13	4.71		.36	.26		5.78	1.07		6.27	-3.38		19	-1		74	37	1.6
				CF	-	-		5.98	-0.08		.09	0.98		.43	-.33		4.13	-1.75		4.65	-3.02		36	36		63	26	1.8
W3976	S	F	63	CWF	10.7	start	6.06	5.84	-0.22	1.03	.11	0.92	.76	.58	-.18	5.88	6.15	0.27	7.67	6.84	-0.83	0	22	22	37	62	25	1 7
				W	12.6	start		5.88	-0.18		.09	0.98		.28	-.48		3.80	-2.08		4.17	-3.50		30	30		97	60	1.5

Table 11. Instron parameters, shrinkage, taste appraisal and texture grade of shark either kept warm, chilled in a tray then frozen or chilled then warmed till shrinkage stopped then frozen.

Tag Number	Sample Treatment	Shrinkage %	Rav mu pk	Rav col pk	Rav mu e	Rav col e	Rav te	Cav mu pk	Cav col pk	Cav mu e	Cav col e	Cav te	Grade	Taste Appraisal
W3784	CF	-	.019	.052	.223	.298	.493	.080	.183	.561	.685	1.250	7	-v tough,dry, rubbery
	CWF	15.5	.009	.023	.098	.132	.229	.064	.134	.565	.403	.970	6	-tough, dry, chewy
	W	13.8	.013	.019	.152	.108	.259	.070	.088	.572	.320	.891	7	-v tough,dry
W3796	CF	-	.016	.034	.127	.221	.348	.030	.031	.239	.101	.340	4	-firm, chewy
	CWF	9.6	.015	.038	.170	.216	.387	.026	.034	.274	.137	.411	2	-soft,sl dry
	W	6.8	.014	.043	.113	.251	.364	.024	.033	.236	.115	.354	1	-tender,moist
W3825	CF	-	.019	.039	.169	.220	.384	.027	.028	.185	.091	.276	2	-tender,sl dry
	CWF	3.6	.012	.034	.132	.225	.358	.015	.019	.193	.083	.277	1	-tender,moist
	W	7.8	.013	.031	.163	.175	.339	.026	.029	.186	.096	.282	2	-tender,sl dry
W3826	CF	-	.014	.032	.139	.278	.410	.033	.045	.342	.206	.558	4	-firm, dry
	CWF	9.7	.012	.037	.135	.223	.362	.025	.035	.258	.175	.432	5	-hard,chewy
	W	10.7	.013	.037	.140	.253	.393	.036	.049	.371	.223	.600	5	-hard, dry
W3842	CF	-	.014	.036	.179	.192	.375	.020	.025	.209	.082	.292	4	-firm, chewy, dry
	CWF	12.1	.013	.034	.173	.212	.385	.027	.033	.286	.106	.387	4	-firm, chewy, dry
	W	11.2	.015	.035	.162	.222	.378	.031	.033	.275	.115	.391	2	-soft, dry
W3843	CF	-	.019	.046	.194	.341	.541	.012	.022	.099	.166	.265	2	-soft, sl dry
	CWF	10.2	.016	.037	.188	.250	.437	.025	.024	.225	.072	.276	2	-soft, dry
	W	10	.011	.035	.138	.185	.327	.027	.030	.276	.099	.327	2	-soft, dry
W3845	CF	-	.018	.043	.199	.278	.479	.041	.056	.428	.182	.621	5	-hard, dry, chewy
	CWF	5.3	.015	.036	.173	.230	.388	.033	.048	.403	.179	.590	3	-sl soft, dry
	W	7.1	.017	.039	.214	.236	.450	.040	.061	.481	.208	.708	5	-hard, dry, chewy
W3847	CF	-	-	-	-	-	-	.008	.023	.067	.172	.240	2	-tender, dry,flakey
	CWF	19.9	.017	.042	.218	.241	.457	.009	.021	.084	.161	.246	2	-tender, dry
	W	6.9	.018	.042	.171	.257	.427	.009	.016	.073	.142	.215	1	-tender
W3850	CF	-	.020	.033	.223	.215	.431	.023	.031	.237	.107	.343	4	-firm,not tough
	CWF	15.9	.012	.025	.092	.248	.339	.019	.023	.203	.086	.289	1	-tender, moist
	W	6.7	.010	.035	.100	.148	.247	.026	.027	.239	.089	.328	4	-sl chewy,dry
W3976	CF	-	.015	.027	.152	.132	.283	.156	.020	.177	.064	.244	-	-
	CWF	10.7	.008	.027	.097	.147	.243	.032	.036	.264	.139	.404	5	-dry, hard and chewy,
	W	12.6	.008	.021	.096	.122	.218	.037	.034	.238	.094	.333	4	-dry and sl chewy

When the grades for texture were compared with the cooked shear force parameters using Pearson's correlation coefficients values between 0.7 and 0.78 were obtained. In the two treatments measured for shrinkage, the amount of shrinkage was analysed for correlation with the grade and Instron parameters. This resulted in very low values, both positive and negative. There was also no correlation between the grade or cooked shear force parameters and any of the chemical parameters, with the exception of starting IMP levels (r=0.58-0.8).

The data presented in Tables 10 and 11 was also analysed by two-way ANOVA with the different individuals providing the replication. No significant differences were found between the treatments except for some raw shear force parameters. The significant differences found between the treatments for the raw total energy, muscle energy and muscle peak values obtained using the Instron have been listed in the table following.

Table 12. Means and significant differences of treatments for the Instron parameters.

	Sample	Treatment	
Instron parameter	CF	CWF	W
Ravte p<0.05	0.416a	0.348b	0.331b
Ravmue p<0.05	0.178a	0.142b	0.140b
Ravmupk p<0.05	0.017a	0.013b	0.013b

* Means followed by different letters are significantly different (P<0.05).

For most of the variables significant differences were found between individuals. The next table displays the significant differences, when present, between individuals for data obtained using the Instron Universal Testing Machine and textural grading.

Table 13. Means and significant differences of individuals from all treatments for the Instron parameters and sensory grade.

Instron parameter	Tag Number									
	W3784	W3796	W3825	W3826	W3842	W3843	W3845	W3847	W3850	W3976
Cavte p<0.01	1.036a	0.368bc	0.278c	0.530bc	0.357bc	0.312c	0.640b	0.234c	0.320c	0.327c
Cavmue p<0.01	0.566a	0.250cd	0.188d	0.324c	0.257cd	0.200d	0.437b	0.075e	0.226d	0.226d
Cavcole p<0.01	0.469a	0.118b	0.090b	0.201b	0.101b	0.112b	0.196b	0.159b	0.094b	0.099b
Cavmupk p<0.01	0.071a	0.026bc	0.023cd	0.031bc	0.026bc	0.021cd	0.038b	0.009d	0.023cd	0.028bc
Cavcolpk p<0.01	0.135a	0.033b	0.023b	0.043b	0.030b	0.025b	0.055b	0.020b	0.027b	0.030b
Grade p<0.01	6.667a	2.333cd	1.667d	4.667ab	3.33bcd	2.00d	4.33bc	1.667d	3.0bcd	4.74ab
Ravte p<0.05	0.327bc	0.366ab	0.360ab	0.388ab	0.379ab	0.435a	0.439a	-	0.339abc	0.248c

* Means followed by different letters are significantly different at the stated level across the row.

The table following displays the significant differences, when present, between individuals for chemical parameters.

Table 14. Means and significant differences of individuals from all the treatments for the chemical parameters.

Chemical Parameter	Tag Number									
	W3784	W3796	W3825	W3826	W3842	W3843	W3845	W3847	W3850	W3976
pH Thaw p<0.01	5.98bc	5.85c	5.98bc	6.06bc	6.01bc	5.96bc	5.96bc	6.25a	6.03b	5.9bc
d pH p<0.01	-0.20a	-0.14b	-0.27bc	-0.26bc	-0.38c	-0.22bc	-0.19b	0.10a	-0.25bc	-0.16b
d AT/DP p<0.01	0.11g	-	1.85d	2.28c	3.83b	-	0.41f	1.79d	4.71a	0.93e
AMP End p<0.01	0.66a	0.54ab	0.27bc	0.35bc	0.29bc	0.11c	0.07c	0.53ab	0.44ab	0.43ab
d IMP p<0.01	1.32a	-	-0.06a	0.02a	-0.20ab	-	-0.63ab	-2.44b	-0.92ab	1.19a
d All P p<0.01	0.76bcd	-	1.66abc	2.15abc	3.63a	-	0cd	-1.02d	3.45a	2.45ab
K End p<0.05	17.0cd	23.7abcd	32.3ab	12.0d	12.3d	34.2a	15.0d	19.3cd	19.7bcd	29.3abc
d K p<0.01	15.0abc	-4.3d	26.3ab	3.0cd	12.3abcd	9.2bcd	15.0abc	16.3abc	-0.3cd	29.3a

* Means followed by different letters are significantly different at the stated level.

5.2.3 Rigor experiments

Shark fishermen requested more specific information. An extra handling treatment of holding the trunks till post-rigor and an extra storage time of 24 hr for pre- and inrigor storage was therefore included, although priority was given to completing the initial design. To expedite the completion of treatments, which was dependent on catch conditions, one fillet was removed from the trunk for freezing after storage in refrigerated sea water (RSW) and the trunk then returned to the RSW for a further period of time. Because of the difficulty in obtaining shark for some of the categories a lower target of 15 shark, 75% of the original number of replicates, was set. Difficulties were anticipated in obtaining samples during the second trip (timed for the middle of the cyclone season). To provide a better appraisal of biological parameters even numbers of members of both sex were also targeted.

While the attempt was made to obtain even numbers of the two species, *C. sorrah* was more prevalent in the catch. Initially, trunks were exposed to an RSW storage temperature of 1°C but as the quota was for *C. sorrah* was filling, a second storage tank at 15°C was utilised concurrently. This led to an uneven number of samples for each category but has made more effective use of the shark coming on-board. As a result, more shark were sampled than was possible earlier. This did inconvenience the handling of the commercial catch by removing another of the RSW tanks but helped reduce the risk of not obtaining the required numbers.

Through the multiple use of individuals, a total 120 female and 197 male *C. sorrah* and 118 female and 111 male *C. tilstoni* samples were retained for analysis at the laboratory. A total of 300 kg of shark samples were shipped to the laboratory for testing. Here they were cut into smaller pieces for the various tests being preformed. The samples were evaluated as they were removed from storage. The post rigor samples were given a low priority and were evaluated last. Some samples were too small to conduct all the tests designated. Because of the large number of samples being handled, moved about and subdivided, identification numbers of a few

samples became illegible so it was not possible to confirm the origin of the sample for analysis. When the information obtained from these individuals was insufficient and not effective to use in the investigation they were removed from the analyses. The table below shows the number of samples of each species and sex exposed to the various treatments.

Table 15. Numbers of samples of each sex and species and the treatments applied.

Rigor Stage	Species	Sex	RSW °C	No. of trunks per treatment	No. samples and time in RSW 6hr	12hr	24hr
Pre rigor	S	F	1	13	8	19	5
Pre rigor	S	M	1	35	14	20	13
Pre rigor	T	F	1	19	8	11	4
Pre rigor	T	M	1	20	7	9	5
Pre rigor	S	F	15	9	7	8	1
Pre rigor	S	M	15	14	11	9	3
Pre rigor	T	F	15	9	9	9	0
Pre rigor	T	M	15	16	7	7	0
In rigor	S	F	1	10	7	7	3
In rigor	S	M	1	32	13	25	23
In rigor	T	F	1	14	10	9	6
In rigor	T	M	1	12	8	12	4
In rigor	S	F	15	10	10	7	1
In rigor	S	M	15	18	15	17	0
In rigor	T	F	15	11	9	9	0
In rigor	T	M	15	9	7	7	0
Post rigor	S	F	1	16	7	15	0
Post rigor	S	M	1	18	6	13	0
Post rigor	T	F	1	11	7	11	0
Post rigor	T	M	1	18	7	17	0
Post rigor	S	F	15	8	8	7	0
Post rigor	S	M	15	8	7	8	0
Post rigor	T	F	15	8	8	8	0
Post rigor	T	M	15	7	7	7	0

Because of the uneven replication it was not possible to use two or three-way analysis of variance to evaluate the data. Another method using Least-Squares Analysis of Variance (LSM) had to be employed to investigate interactions. The following table displays the model for significant differences between biological or treatment parameters and all the possible interactions for the variables tested using this form of analysis.

Table 16. Analysis of all parameters using least square means for shark collected during the rigor experiment.

FACTOR / VARIABLE	SEASON	SPP	TRT	SEX	BRC	BRT	SIZE	SEASON*SPP	SEASON*TRT	SEASON*SEX	SEASON*BRC	SEASON*BRT	SEASON*SIZE	SPP*TRT	SPP*SEX	SPP*BRC	SPP*BRT	SPP*SIZE	TRT*SEX	TRT*BRC	TRT*BRT	TRT*SIZE	SEX*BRC	SEX*BRT	SEX*SIZE	BRC*BRT	BRC*SIZE	BRT*SIZE
Sarc	*	ns	ns	ns	ns	ns	ns	ns	ns	ns	*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
L End	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	**	*	ns	ns	ns	*	*	ns	ns	ns	ns	ns	ns	ns	ns	ns
***d* L**	*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	**	ns	ns	ns	ns	ns	**	ns	ns	ns	*	ns	ns	ns	ns	ns
TN End	ns	*	ns	ns	ns	ns	ns	ns	ns	ns	**	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
K End	**	**	**	ns	**	ns	ns	ns	ns	ns	*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
***d* K**	**	*	ns	ns	**	ns	ns	ns	ns	ns	**	**	ns	**	ns	ns	ns	ns	**	ns	ns	ns	ns	ns	ns	ns	*	ns
pH Thaw	ns	ns	**	ns	**	*	ns	ns	**	ns	ns	ns	ns	ns	ns	ns	ns	ns	*	ns	ns	*	ns	ns	ns	ns	*	ns
Ravmupk	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Ravcolpk	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Ravmue	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	*	ns	ns	ns	ns	ns	ns	ns	ns	ns
Ravcole	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Ravte	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Cavmupk	**	**	ns	**	ns	ns	**	ns	ns	ns	ns	ns	ns	*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	**	ns	ns	ns
Cavcolpk	**	**	ns	**	ns	ns	**	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	**	ns	ns	ns
Cavmue	*	**	ns	**	ns	ns	**	ns	*	ns	ns	ns	*	*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	**	ns	ns	ns
Cavcole	ns	**	ns	**	ns	ns	**	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	**	ns	ns	ns
Cavte	*	**	ns	**	ns	ns	**	ns	ns	ns	ns	ns	ns	*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	**	ns	ns	ns

Relationships between factors (treatments) and variables (physical and chemical data) are not significant (ns), significant at 5% (*) or at 1% (**).

The non-significant interactions were then pooled into the error term to improve the testing on the other terms. The following table displays these results.

Table 17. Levels of significance for biological and treatment terms.

FACTOR / VARIABLE	SEASON	SPP	TRT	SEX	BRC	SIZE	SEASON*TRT	SEASON*BRC	SPP*TRT	SPP*SEX	TRT*BRC	SEX*SIZE
Sarc	**	ns	*	ns	ns	ns	ns	**	ns	ns	ns	ns
L End	ns	ns	ns	ns	*	ns	ns	ns	**	*	ns	ns
***d* L**	*	**	ns	ns	ns	ns	ns	*	**	*	**	ns
TN End	ns	ns	ns	ns	**	ns	ns	**	ns	ns	ns	ns
K End	**	**	**	ns	**	ns	ns	**	ns	ns	ns	ns
***d* K**	**	**	**	*	**	ns	*	**	ns	*	**	ns
pH Thaw	ns	ns	**	ns	**	ns	**	ns	ns	ns	*	ns
Ravmupk	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Ravcolpk	ns	ns	ns	ns	*	ns	ns	*	ns	ns	ns	ns
Ravmue	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	*	ns
Ravcole	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Ravte	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Cavmupk	**	**	ns	**	ns	**	ns	ns	ns	**	ns	**
Cavcolpk	**	**	ns	**	ns	**	ns	ns	ns	ns	ns	**
Cavmue	**	**	ns	**	*	**	*	ns	ns	*	ns	**
Cavcole	ns	**	*	**	ns	**	ns	ns	ns	ns	ns	*
Cavte	*	**	ns	**	ns	**	*	ns	ns	*	ns	**

Relationships between factors (treatments) and variables (physical and chemical data) are not significant (ns), significant at 5% (*) and significant at 1% (**).

An example of how the Least-Squares Analysis of Variance produces data can be seen in the following table.

Table 18. Least-Squares Analysis of Variance for Total Shear Force Energy.

SOURCE	D.F.	Sum of squares	Mean Squares	F ratio	Probability
Total	543	13.27969			
Total reduction	17	3.504256	.206133	11.092	.0000
MU-YM	1	.041985	.041985	2.259	.1334
SEASON	1	.115977	.115977	6.241	.0128
SPP	1	1.099375	1.099375	59.156	.0000
TRT	2	.101717	.050859	2.737	.0657
SEX	1	.657871	.657871	35.399	.0000
BRC	1	.040856	.040856	2.189	.1388
SIZE	1	1.531299	1.531299	82.397	.0000
SEASON*TRT	2	.113129	.056564	3.044	.0485
SEASON*BRC	1	.045731	.045731	2.461	.1173
SPP*TRT	2	.034529	.017264	.929	.3956
SPP*SEX	1	.0925289	.092589	4.982	.0260
TRT*BRC	2	.033905	.016953	.912	.4023
SEX*SIZE	1	.299309	.299309	16.105	.0001
REMAINDER	526	9.775434	.018584		

Mean = .03646 Error standard deviation = .01978 CV = 54.26 R Squared = .264 R = .514

The aspects of primary interest evaluated by this method are the cooked shear force data for the different species, sex, size, season, rigor condition and brine storage conditions and the interactions present. The cooked total shear force energy is the energy required to shear through a cooked piece of shark fillet. Both the muscle and collagen components contribute to resistance to shearing. From the analysis the least square means which are significantly different can be identified. The following tables display these for each variable and interaction group where significant differences are present.

Table 19. Least-Square Means of significantly different groups for Cooked Total Shear Force Energy (Cavte).

Factor	Group	Least-Squares Mean
SEASON[1]	**Spring**	**.4001a**
	Autumn	.3598b
SPP	**S**	**.4323a**
	T	.3276b
SEX	F	.3427b
	M	**.4172a**
SIZE	<85 cm	.3186b
	>85 cm	**.4413a**
SEASON*TRT[1]	Spring*prerigor	.3634
	Spring*inrigor	.3872
	Spring*postrigor	**.4497**
	Autumn*prerigor	.3695
	Autumn*inrigor	.3442
	Autumn*postrigor	.3658
SPP*SEX[1]	S*F	.3800
	S*M	**.4845**
	T*F	.3053
	T*	.3499
SEX*SIZE	F*<85 cm	.3081
	F*>85 cm	.3773
	M*<85 cm	.3291
	M*>85 cm	**.5053**

Least-Square Means with different letters are significantly different at the 1% level (P<0.01). When the factor has a superscript then the level is 5%. The group with the highest mean is in bold.

The data for the combined shear force energy of cooked shark flesh for each species have been plotted against fork length. Both of these figures can be viewed in Appendix 6. The selectivity of different gill-net mesh sizes for the two species are present as Figures 6.3 and 6.4. Using the catch data for size classes of each species present in Figures 3.2 and 3.3 the probability of that size shark being tough has been calculated. This has been combined with the probability of catching that size shark (selectivity index) to obtain the probability of catching a tough shark (Figures 6.5 and 6.6) for three net mesh sizes. The final figure, 6.7, shows the data for both species, adjusted for their proportion of the overall catch for each mesh size. The influences of the various factors on the individual components of shear

force energy were then appraised. The following four tables display the results of least-square mean analysis of variance.

Table 20. Least-Square Means of significantly different groups for Muscle Shear Force Energy (Cavmue).

Factor	Group	Least-Squares
SEASON	**Spring**	**.2613a**
	Autunm	.2308b
SPP	**S**	**.2828a**
	T	.2093b
SEX	F	.2224b
	M	**.2698a**
SIZE	<85 cm	.2081b
	>85 cm	**.2841a**
SEASON*TRT[1]	Spring*prerigor	.2412
	Spring*inrigor	.2510
	Spring*postrigor	**.2917**
	Autumn*prerigor	.2410
	Autumn*inrigor	.2255
	Autumn*postrigor	.2260
SPP*SEX[1]	S*F	.2492
	S*M	**.3164**
	T*F	.1955
	T*M	.2232
SEX*SIZE	F*<85 cm	.2033
	F*>85 cm	.2414
	M*<85 cm	.2128
	M*>85 cm	**.3268**

Least-Square Means with different letters are significantly different at the 1% level (P<0.01). When the factor has a superscript then the level is 5%. The group with the highest mean is in bold.

Table 21. Least-Square Means of significantly different groups for Collagen Shear Force Energy (Cavcole).

Factor	Group	Least-Squares Mean
TRT[1]	prerigor	.1253b
	inrigor	.1274b
	postrigor	**.1489a**
SPP	**S**	**.1495a**
	T	.1183b
SEX	F	.1203b
	M	**.1474a**
SIZE	<85 cm	.1106b
	>85 cm	**.1572a**
SEX*SIZE[1]	F*<85 cm	.1048
	F*>85 cm	.1358
	M*<85 cm	.1164
	M*>85 cm	**.1785**

Least-Square Means with different letters are significantly different at the 1% level (P<0.01). When the factor has a superscript then the level is 5%. The group with the highest mean is in bold.

Table 22. Least-Square Means of significantly different groups (P<0.01) for Muscle peak load (Cavmupk).

Factor	Group	Least-Squares Mean
SEASON	**Spring**	**.26131a**
	Autumn	.2308b
SPP	**S**	**.2828a**
	T	.2093b
SEX	F	.2224b
	M	**.2698a**
SIZE	<85 cm	.2081b
	>85 cm	**.2841a**
SPP*SEX	S*F	.2492
	S*M	**.3164***
	T*F	.1955
	T*M	.2232
SEX*SIZE	F*<85 cm	.2033
	F*>85 cm	.2414
	M*<85 cm	.2128
	M*>85 cm	**.3268***

Least-Square Means with different letters are significantly different at the stated level, the highest mean is in bold.

Table 23. Least-Square Means of significantly different groups (P<0.01) for Collagen peak load (Cavcolpk).

Factor	Group	Least-Squares Mean
SEASON	**Spring**	**.0433a**
	Autumn	.0309b
SPP	**S**	**.0436a**
	T	.0306b
SEX	F	.0327b
	M	**.0415a**
SIZE	<85 cm	.0304b
	>85 cm	**.0438a**
SEX*SIZE	F*<85 cm	.0293
	F*>85 cm	.0361
	M*<85 cm	.0315
	M*>85 cm	**.0515***

Least-Square Means with different letters are significantly different at the stated level, the highest mean is in bold.

Table 24. Least-Square Means of significantly different group for Sarcomere length.

Factor	Group	Least-Squares Mean
TRT[1]	prerigor	1.883b
	inrigor	**1.938a**
	postrigor	**1.960a**
SEASON	**Spring**	**1.97a**
	Autumn	1.88b
SEASON*BRC	**Spring*1°C**	**2.01**
	Spring*15°C	1.93
	Autumn*1°C	1.86
	Autumn*15°C	1.91

Least-Square Means with different letters are significantly different at the 1% level (P<0.01). When the factor has a superscript then the level is 5%. The group with the longest mean is in bold.

The chemical variables were then analysed. The data of pH after thawing in the laboratory contained a number of significantly different groups which are presented in the table below.

Table 25. Least-Square Means of significantly different group for thawed pH.

Factor	Group	Least-Squares Mean
TRT[1]	prerigor	6.02b
	inRigor	5.97b
	postrigor	**5.87a**
BRC	1°C	5.98b
	15°C	**5.92a**
SEASON*TRT	spring*prerigor	6.02
	spring*inrigor	5.99
	spring*postrigor	**5.81**
	autumn*prerigor	6.01
	autumn*inrigor	5.96
	autumn*postrigor	5.92
TRT*BRC	prerigor*1°C	6.07
	prerigor*15°C	5.96
	inrigor*1°C	6.00
	inrigor*15°C	5.95
	postrigor*1°C	**5.88**
	postrigor*15°C	**5.85**

Least-Square Means with different letters are significantly different at the 1% level (P<0.01). When the factor has a superscript then the level is 5%. The groups with the lowest means are in bold.

Table 26. Least-Square Means of significantly different group for thawed K value.

Factor	Group	Least-Squares Mean
SEASON	**spring**	**35.3a**
	autumn	27.4b
SPP	S	27.4b
	T	**35.3a**
TRT	prerigor	24.5b
	inrigor	27.7b
	postrigor	**41.9a**
BRC	1°C	29.2b
	15°C	**33.5a**
SEASON*BRC[1]	spring*1°C	31.2
	spring*15°C	**39.4**
	autumn*1°C	27.2
	autumn*15°C	27.6

Least-Square Means with different letters are significantly different at the 1% level (P<0.01). When the factor has a superscript then the level is 5%. The groups with the highest mean is in bold.

Table 27. Least-Square Means of significantly different group for thawed Lactate level.

Factor	Group	Least-Squares Mean
BRC[1]	1°C	72.8b
	15°C	**79.8a**
SPP*TRT	**S*prerigor**	**81.8**
	S*inrigor	67.5
	S*postrigor	74.5
	T*prerigor	76.3
	T*inrigor	**83.8**
	T*postrigor	73.9
SPP*SEX[1]	S*F	71.7
	S*M	**77.6**
	T*F	**81.5**
	T*M	74.5

Least-Square Means with different letters are significantly different at the 1% level (P<0.01). When the factor has a superscript then the level is 5%. The groups with the highest mean is in bold.

Table 28. Least-Square Means of significantly different group for difference between thawed pH and capture pH.

Factor	Group	Least-Squares Mean
SEX	**F**	**-0.35a**
	M	-0.29b

Least-Square Means with different letters are significantly different at the 1% level (P<0.01)

Table 29. Least-Square Means of significantly different group for delta K value.

Factor	Group	Least-Squares Mean
SEASON	**spring**	**17.1a**
	autumn	5.3b
SPP	S	8.6b
	T	**13.7a**
TRT	prerigor	7.1b
	inRigor	6.5b
	postrigor	**19.9a**
SEX[1]	**F**	**12.7a**
	M	9.6b
BRC	1°C	8.7b
	15°C	**13.6a**
SEASON*TRT[1]	spring*prerigor	11.5
	spring*inrigor	9.3
	spring*postrigor	**30.3**
	autumn*prerigor	2.6
	autumn*inrigor	3.6
	autumn*postrigor	9.6
SEASON*BRC	spring*1°C	10.9
	spring*15°C	**23.2**
	autumn*1°C	6.5
	autumn*15°C	4.0
SPP*SEX	S*F	8.3
	S*M	9.0
	T*F	**17.1**
	T*M	10.3
TRT*BRC	prerigor*1°C	5.8
	prerigor*15°C	8.3
	inrigor*1°C	7.5
	inrigor*15°C	5.4
	postrigor*1°C	12.7
	postrigor*15°C	**27.2**

Least-Square Means with different letters are significantly different at the 1% level ($P<0.01$). When the factor has a superscript then the level is 5%. The groups with the highest mean is in bold.

Table 30. Least-Square Means of significantly different group for delta Lactate level.

Factor	Group	Least-Squares Mean
SEASON[1]	spring	0.4b
	autumn	**13.9a**
SPP	S	1.7b
	T	**12.6a**
SEASON*BRC[1]	spring*1°C	-6.5
	spring*15°C	7.2
	autumn*1°C	**16.8**
	autumn*15°C	11.0
SPP*TRT	S*prerigor	15.1
	S*inrigor	-5.5
	S*postrigor	-4.5
	T*prerigor	12.6
	T*inrigor	**23.6**
	T*postrigor	1.6
SPP*SEX	S*F	-4.4
	S*M	7.8
	T*F	**16.2**
	T*M	8.9
TRT*BRC	prerigor*1°C	4.4
	prerigor*15°C	**23.3**
	inrigor*1°C	17.2
	inrigor*15°C	0.8
	postrigor*1°C	-6.1
	postrigor*15°C	3.2

Least-Square Means with different letters are significantly different at the 1% level ($P<0.01$). When the factor has a superscript then the level is 5%. The groups with the highest mean is in bold.

The following tables summarise the main influences on the variables by the factors investigated.

Table 31. Key groups from the investigation responsible for high values within the shear force data

Factor	Cavte	Cavmue	Cavcole	Cavmupk	Cavcolpk
Season	spring	spring	-	spring	spring
SPP	*C.* sorrah	*C.* sorrah	*C.* sorrah	*C.* sorrah	*C.* sorrah
SEX	male	male	male	male	male
SIZE	>85 cm	>85 cm	>85 cm	>85 cm	>85 cm
TRT	-	-	postrigor	-	-
SPP*SEX	*C.* sorrah*male	*C.* sorrah*male	-	*C.* sorrah*male	-
SEX*SIZE	males*>85 cm	males*>85 cm	males*>85 cm	males*>85 cm	males*>85 c
Season*TRT	spring*postrigor	spring*postrigor	-	-	-

Table 32. Key groups from the investigation responsible for low values of sarcomere and thawed pH and high values for chemical parameters.

Factor	Sarcomere	Thaw pH	Thawed K value	Thawed Lactate	d K	d L
Season	spring	-	spring	-	spring	autumn
SPP	-	-	*C.* tilstoni	-	*C.* tilstoni	-
SEX	-	-	-	-	female	male
SIZE	-	-	-	-	-	-
TRT	prerigor	postrigor	postrigor	-	postrigor	-
BRC	-	-	15°C	15°C	15°C	-
SPP*SEX	-	-	-	*C.* sorrah*male	*C.* tilstoni*female	*C.* tilstoni*female
SEX*SIZE	-	-	-	-	-	-
Season*TRT	-	spring*postrigor	-	-	spring*postrigor	-
Season*BRC	spring*1°C	-	spring*15°C	-	spring*15°C	autumn*1°C
TRT*BRC	-	postrigor*1°C	postrigor*15°C	-	-	postrigor*15°C	prerigor*1°C
SPP*TRT	-	-	-	-	-	*C.* tilstoni*inrigor

6. DISCUSSION

6.1 Evaluation of industry samples

The "tough" samples required approximately twice as much energy to shear as the "soft" samples. There was a reasonable amount of variability of shear force value within the two groups. Appraisal of the shear force deformation profiles indicated that the myofibrillar protein component was responsible for the differences obtained. For further discussion a shark requiring a total shear force in excess of 0.44J will be referred to as being tough.

6.2 Biological information

The graphs generated (Appendix 4) showed very similar trends in size groupings to those obtained by an earlier and much larger sampling (Lyle and Timms 1984). While the graphs were made using fork length and those of Lyle (1984) used the measurement to the furtherest tip of the caudal fin, by using the conversion formula supplied in a later paper (Stevens & Wiley 1986) the pairs of graphs fit quite well. This indicates that a good representation of the available population was obtained.

The time a shark takes to enter rigor is quite long considering they were held at deck temperature (Table 2). Such long times are usually seen in fish which have been iced (Stroud 1969). This indicates that the shark have high energy reserves and are in good condition when they are landed. The times also show that there is a large variability between individuals with extensive differences between minimum and maximum.

It is recognised that small fish go into rigor more quickly than large and that there are considerable differences between species (Hobbs 1982). The latter is not the case for the two species studied. There was no significant difference between the mean times for rigor to develop or resolve for species or for sex. This suggests that any handling recommendations developed could be used for both species.

When the length of individuals was compared with their rigor times high correlation coefficients were obtained (Table 4). While the amount of activity at capture will impact on the time it takes for rigor to establish by using up ATP, the process for it to resolve is not. The longer time required for a shark to come out of rigor correlated with length (Table 4).

The correlation coefficients obtained (Tables 2-5), when comparing biological and chemical condition to the time required for rigor to establish, were not as high for as those obtained for the time rigor took to resolve. Some of the data obtained may be misleading. Poulter and others (1981) state that correlation of biochemical changes and the occurrence of rigor is fraught with difficulties because of several possible pathways which can operate. The relation between the K value of fresh caught shark and rigor time should result in a negative correlation. It is, however, lower than other parameters. It is a well known fact that rigor of the muscle occurs when ATP decreases below a certain concentration (Iwamoto and others 1987). As further ATP is consumed the muscle progresses through rigor. The more ATP present at the start, the higher the intensity (Ikeda 1980) and the longer it takes for rigor to establish and then to start to

resolve. A more exhausted fish has less glycogen reserves and has a quicker onset and resolution of rigor (Poulter and others 1981). Some of the shark have obviously been struggling in the net before landing and have depleted their ATP. This results in a higher K value at capture than shark which have not struggled and this has contributed to the positive correlation.

Shark with a variety of stress levels will always be present when the capture method is by gill-net, especially if it has been in the water for a number of hours. The other chemical indicator, lactate, increases as ATP breaks down so that a high lactate at the start should indicate a reduction in ATP due to struggling and therefore a shorter rigor time. The high correlation obtained reflects the similar trend observed previously with K value. Because there was further treatment of the shark trunks no direct comparison of this parameter can be made with the post-storage pH, K value or lactate.

6.3 Shrinkage experiments

6.3.1 Shrinkage using an ice slurry

Because of rough conditions it was not feasible to use an ice slurry to cool strips of shark muscle (Table 6). The shrinkage data obtained from three samples exposed to this procedure could be viewed with suspicion.

6.3.2 Shrinkage under freezing conditions

The tough condition of thawed shark muscle when cooked did suggest that some shrinkage process may be operating (Table 7). As the rigor times had not been established by this stage it was unclear whether a thaw rigor, cooked rigor or cold shock reaction was operating. The amount of shrinkage did vary between different sides of a shark. The fact that different muscle bundles went into rigor at different times demonstrated that the energy levels vary quite considerably between sides and within a fillet. This indicated that multiple treatments should be carried out on pieces taken from one fillet only. The shrinkage levels ranged from minor amounts up to 20%. The degree of shrinkage did show some association with the degree of toughness when tasted. There was no change in the pH of the flesh during this treatment.

The slight change in K value during this treatment indicated that there was little muscle activity present. In cold shock situations the ATP levels remains constant during stiffening because of fast resynthesis of ATP from ADP by the glycolytic process (Nambudiri and Gopakumar 1988). As it was impossible to measure sarcomere length of freshly caught shark the change from starting levels induced by the treatment is not available. This parameter was evaluated only when a number of treatments were present for comparison.

6.3.3 Shrinkage under chilling, warming then freezing conditions

The behaviour of the chilled piece of fillet for this experiment was similar to chilled shark of previous runs (Table 8). For all of these samples only two individuals exhibited any difference between rates of shrinkage for chilled only and those portions which were warmed. In most cases the warmed portion had levels of shrinkage equal to or slightly higher than pieces of shark fillet which were chilled only. This behaviour is not consistent with the theory of a normal cold

shock phenomena operating. All or at least the majority of samples would be expected to shrink to a greater extent when chilled than specimens kept at room temperature for any length of time. The two shark which did exhibit major differences were both small females of each species.

Because the fillet was divided many of these samples were too small to conduct all of the physical and chemical tests. The information, provided by those that were evaluated, suggests that the shear force data supports the taste appraisal. Chilling the fillet in the cold room provided more time to study the shrinkage behaviour so that the next series of experiments, during the second trip, incorporated this method.

When these experiments were carried out during the second cruise much larger pieces of fillet were used. This allowed all of the tests to be carried out. Again there was variation in the degree of shrinkage with no pattern of behaviour due to species, sex or size apparent (Table 9). The extent of shrinkage was associated with a higher cooked energy requirement for shearing and tougher texture as appraised by tasting. In most fillets the K values were low at the start with some increase due to the treatment. This was reflected by an increase in lactate concentration. Fresh caught, well iced shark has a muscle pH near 6.0 (Otwell 1985). Waller (1980a and b) found shark of lower visual quality had higher pH levels with good quality between 6.0 and 7.0, aparently good between 7.0 and 8.0 while poor quality shark exhibited a pH between 8.0 and 9.0. Most of the shark studied here had a low pH. There was no change in pH during the chilling, warming and freezing sequences. Any changes in pH during storage, for these experiments, were only minor mostly as an increase after thawing.

The sarcomere lengths were similar for all treatments. There was also no discernible trend for raw shear force energy requirement. The shear force energy values were higher for samples which were appraised by tasting as having tough characteristics. There was no apparent differences between the chilled only and the chilled and warmed portions. This behaviour led to the final modification to the shrinkage experiments.

To finally determine whether the toughness present was precipitated by the treatments or inherent in the fillet, a portion of a fillet was retained at room temperature while two other pieces from the same fillet were placed in the cold room. One of these was kept in the cold room for the duration of the experiment while the other was removed after some time when the shrinkage appeared to slow down. It was then warmed to room temperature until there was no more apparent shrinkage and returned to the cold room. The data obtained for chemical, physical and sensory parameters is extensive (Tables 10 and 11). Unfortunately some tests were not performed because of insufficient material. The smaller sample size was due to having to divide the one targeted site on a fillet into three pieces. The cooked shear force evaluation was given the highest priority. The limited sample size restricted the texture grading to one person.

The taste appraisal identified a wide range of textures. The correlation found between the textural grade evaluated during taste appraisal and the Instron generated data demonstrates that a valid appraisal of sensory texture has been made. Many authors have found significant correlations at this magnitude between data obtained from the LEE-Kramer Shear Press and sensory tenderness (Szczesnaik and Torgeson 1965).

Significant differences using ANOVA were found between the treatments, but only for some of the raw physical parameters evaluated by the Instron (Table 12). The pieces chilled, then directly frozen, had higher values for total shear force energy, for the muscle component of the shear

force energy and for the peak load of force for the muscle component than did the pieces kept warm or chilled, then warmed. The sarcomere lengths of the shark fillet pieces were not affected by the treatments. The contraction of muscle tissue should be identifiable through sarcomere measurement with shorter sarcomere lengths being associated with tough fibres. The varying time it takes individuals for rigor to become established could interfere with degree of behaviour during the various treatments. If an individual had a long rigor time the shrinkage trial could be completed before rigor was established so that cold shock or thaw rigor could occur even in the warmed portion. There should still be some differences because the rate of rigor development depends on temperature (Stroud 1969, Iwamoto and others 1987) but these could be much less than for a shark just about to enter rigor.

The presence of two different species and individuals of very different sizes, present here, does not lead to effective evaluation for treatment and biological influences when the final collection is only 10 shark. The amount of shrinkage, for the two treatments that were measured, exhibited by the pieces were not significantly different. There were no significant differences evident between treatments for cooked physical parameters as evaluated by the Instron, only between individuals (Tables 13 and 14). The taste appraisal identified many shark with "tough" characteristics. Most of these individuals had total shear force values higher than the industry samples.

The behaviour of the fillets cannot be used to confirm the presence of cold shortening. In mammalian meat cooking temperatures greater than 60°C are necessary before the increased peak shear force values associated with cold shortening can be demonstrated (Purchas 1973, Bouton and others 1974). The freezing of prerigor muscle has also been associated with another form of toughening called thaw rigor. In this condition there is marked shortening and exudation of excessive quantities of drip which may amount to 30-40% of the muscle weight on thawing. During thaw rigor the fall in the considerable level of ATP present in the pre-rigor frozen muscle is quite rapid because of the release of calcium ions (Lawrie 1979). The rate of ATP breakdown is affected by the rate of pre-rigor freezing, (the faster the freezing the quicker ATP is metabolised) and by the rate of thawing. The rate of contraction is dependent on the rate of thawing, ATP can fall up to 10 times faster than during normal rigor mortis.

Shark muscle that is chilled and frozen prerigor should have a reasonable amount of ATP present in the frozen flesh. The levels observed in these pieces of fillet were not significantly different to that found in the muscle when the other treatments had been applied. In all cases there was very little ATP left in the tissue returned to the laboratory. These changes occur with thaw rigorg. The different treatments had no effect on the sarcomere length indicating little difference in the degree of contraction of the muscle between treatments. This suggests that thaw rigor is not the cause of the treatment differences.

6.4 Rigor experiments

The planned replication of 20 individuals per treatment was not achieved. A minimum of 15 was caught (Table 15). Rather than removing many individuals from the overall study, with some treatment groups even containing the desired quota of 20, an alternative method of statistical analysis to analysis of variance was utilised. While not as neat as normal ANOVA, least-squares analysis of variance does allow the testing of interaction differences between groups of uneven

size (Table 16). By removing factors where little or no significant differences occur the efficiency of the analysis can be improved so that a final few pertinent variables can be investigated. This refining of the data resulted in the model present in Table 17.

The variable of primary interest is the energy required to shear shark flesh and how it is influenced (Tables 18 and 19). The shear force value of cooked fish muscle decreases as rigor progresses (Dunasjski 1979). This investigation found there were no significant differences between the shear force values specifically for the rigor state of shark. The analysis of the shear force data demonstrated that the prime influences on the texture of northern shark flesh are biological in nature. This was intimated in the shrinkage experiments where variation of cooked shear force values was related to individuals.

The species, sex and size are all major influences on the cooked texture of shark fillets. This was demonstrated for both muscle and collagen components of the shear force energy and their individual peak loads. Overall the smaller species *C. sorrah* were tougher than *C. tilstoni*, males tougher than females and the larger size group (>85 cm) tougher than smaller shark. For these categories the least-square means were similar to the values obtained for commercially "tough" shark. The individual variability within these factors was large and interactions identified subgroups containing the toughest individuals. The sex*size interaction identified the large males as being much tougher than any other group for all shear force parameters. The trends of total shear force energy (Cavte) in relation to fork length for each sex of each species present in Figures 6.1 and 6.2 show how these categories differ. The species*sex interaction while significant had less impact and was only present for the muscle component.

The variability of fish and fish products can be due to a number of biological factors many of which are seasonal (Howgate 1977). While the season the shark were caught did show differences, they were not as large as the previous factors. Shark caught in the spring were tougher than those caught in autumn (Table 18). This could be because of feed availability or other conditions not readily discernable in this study. The temperature of the fillets at the start of the shrinkage trials was on average 5°C higher in the spring. The interaction effect found for season*treatment identified shark that were caught in the spring and kept on deck until rigor had subsided were tougher. This significance was due to the muscle shear force energy (Table 20) and was absent for muscle peak load (Table 21) and the collagen component parameters. The other significant influence on texture by treatment (rigor condition) was present only for collagen shear force energy (Table 22). It was absent for the collagen peak load (Table 23). The postrigor shark collagen component required higher energy levels for shearing. All these interactions suggest that keeping shark till postrigor can lead to toughness. A carcharinid shark from the Gulf of Mexico if badly handled on deck is known to produce formaldehyde from the reduction of TMAO during frozen storage (Cheuk 1985). Keeping shark on deck for the time required for rigor to be resolved would enhance the production of formaldehyde and could help explain the observed interactions.

6.5 Biological factors

For this investigation an understanding of the biology of the two shark species will shed light on the data obtained by these experiments. As identified by Hatae and others (1984) texture differences between species can be large. While there are two different shark caught by fishermen, they are from the same genus so species differences may not be the prime reason for

textural differences. The aging of individuals also results in tougher textures (Love and others, 1974; Montero and Borderias, 1990). The growth rate of *C. sorrah* is reasonably fast for the first three years but decreases rapidly (Stevens and Wiley 1986). The growth rate of *C. tilstoni* while being relatively fast it is slower than *C. sorrah* and it slows at a constant rate. Both species reach sexual maturity between 2 and 4 years of age. *C. sorrah* attains a maximum size of 1.3 m while *C. tilstoni* grows to a maximum size 2.1 m (Lyle and others 1984). An individual *C. sorrah* would be older than an individual from the species *tilstoni* of similar size. The age difference would be reflected in thicker muscle fibres and more crosslinking of connective tissue, both known to influence texture. This behaviour is reflected in the significant difference found, for all shear force variables, between the two sizes analysed. The mesh size of the nets used by the fishermen in this investigation caught shark 60 cm and longer regardless of species therefore biasing the catch for older individuals of the smaller species. Another aspect may be that the basic muscle and connective tissue of a *C. sorrah* fillet is denser than one from a *C. tilstoni* of the same age resulting in tougher flesh. With the extra samples examined there was not enough time available during the project to investigate this theory.

The breeding strategy of these two species is responsible for textural differences between the sexes. The reproductive cycle and gestation period of the two species from northern waters is virtually identical (Stevens and Wiley 1986). The female Carcharinids are viviparous, retaining the embryos in the uterus with the yolk sac forming a sort of "yolk placenta" (Bannister 1993). As the yolk is used up, the relationship between the embryo and the maternal tissues becomes complex and intimate, and the young are nourished by the food in the maternal blood in a manner analagous to that of mammals. Mating occurs in February and March and ovulation by March-April. Gestation can be considerably lengthy, taking up to a year before the young are born giving birth in summer. At birth the size of *C. sorrah* is about 52 cm total length while *C. tilstoni* pups average 60 cm. Litter size increases with maternal length. This behaviour places considerable nutritional strain on females during the development of the embryos and in times of starvation tissue protein is mobilised (Howgate 1977). The males do not suffer as much during these times. The majority of female shark caught during the spring cruise had maturing embryos present. The growth rates between the sexes also differs (Davenport and Stevens 1988). The growth curves of male *C. sorrah* start out steeply and then flatten out after two to three years while the females have a steadier growth rate which slowly declines yet continues for many years more than the males. There does not appear to be much difference between the growth rates of male and female *C. tilstoni*. These biological aspects would result in the observed textural differences between the sexes.

As mentioned earlier, the age of a fish does have an impact on the muscle and connective tissue and thus the textural quality of a fillet. The group of shark larger than 85 cm would be older than those of a smaller size regardless of species. There were large differences between the least-squares means obtained for all of the Instron measurements.

The interactions between the biological factors help identify the toughest group which can then be excluded from the catch that is to be processed. Males larger than 85 cm, of either species, have the highest means for all the Instron derived variables. The means for the other groups are below the level of the shark commercially identified as being "tough". These characteristics are very easy to identify as soon as the shark have been removed from the net. The males copulatory appendages are quite visible and because of the distinctive line anterior to the dorsal fin present on *C. sorrah*, the species of the individual can readily be determined. Unless the individual is small it would be best to remove all male *C. sorrah* from the catch. By applying a

strip of bright coloured adhesive tape 85 cm long to the deck, wash tanks or a pacifying club the fork length of other shark can be quickly measured.

Another strategy which could be applied is to alter the mesh size of the net being used. The selectivity of several net mesh sizes for each species has been evaluated by McLoughlin and Stevens (1994). By changing to a 10 cm mesh there is only a 15% chance of catching *C. sorrah* and a 45% chance of catching *C.* tilstoni greater than 85 cm fork length. Any shark larger than this will have even less chance of being caught and so will be excluded from the catch. If a gill-net mesh size of 15 cm is used then the chances of catching shark of this size and larger of both species increases dramatically, 92% and 94% respectively.

Using the Selectivity Indicies developed by these authors (Figures 6.3 and 6.4) and the probability of a shark of a particular fork length class being tough, from the catch data, the chance of catching a tough shark of each species by three gill-net mesh was calculated (Figures 6.5 and 6.6). When the probability of catching a tough shark of either species was calculated adjusting for catch rate a final probability of catching a tough shark of any species or size could be determined (Figure 6.7). Using a gill-net with a mesh size of 10 cm the catch is likely to comprise 4.7% with tough texture. When larger sized mesh is used a greater proportion of the catch will be tough, 10.4% using a 15 cm mesh and 9.1% using a 20 cm mesh. If the industry adopts a 10 cm mesh as a standard this constitutes a reduction by one half the number of tough shark that will be caught.

This change would also reduce the number of shark with mercury content higher than allowed by the Australian Food Standards Code, as mercury content is directly related to length of a shark. Lyle (1984) recommended that shark greater than 1m total length from northern waters not be presented for sale. This sized shark is equilavent to the 85 cm fork length used by this investigation to separate the catch by size.

The interaction between season and rigor stage prior to storage also contains, for the shear force energy, a significantly "tough" group. Shark caught in spring and kept on deck till rigor has subsided have the highest resistance to shearing. This group behaves similarly for the muscle energy component. Rigor stage also demonstrated impacts on the collagen component of the energy required for shearing but the interaction with season is absent. This difference is not apparent for the peak loads for both components indicating a general hardening of tissue rather than the presence of a particularly tough portion. Bouton and Harris (1972) found in meat that shear force values are less affected by variations in connective tissue strength than by changes in the myofibrillar structure.

There were no major significant effects by any biological or handling factor on the shear force data of raw shark flesh. When present they were significant at the 5% level and restricted to only one component and one type of measurement of that component. When compared with the observations made in cooked portions these are of little importance. The effect of chilling prerigor on the fillets during the shrinkage study has not been apparent in the rigor experiments. Bouton and others (1974), Bouton and others (1975) and Purchas (1973) have shown that myofibrillar coagulation was required before toughening associated with cold-shortening could be demonstrated by shear force values.

Sarcomere length displayed trends that were quite different to the shear force data. Davey (1984) found for meat that sarcomere shortening was not completely explained by shear force

values when investigating cold induced toughness. The rigor condition of a shark held significant differences. Shark that were placed directly in RSW, held there for some time and then frozen, had significantly shorter sarcomere lengths than shark which were kept on deck until rigor was established or had resolved. Both inrigor and postrigor shark exhibited similar longer sarcomere lengths. Shark caught during spring had significantly longer sarcomere lengths than those caught in autumn. There may have been some difference in deck temperatures between these two seasons which could have cotributed to this behaviour. Shark caught during spring and stored in RSW at 1°C had significantly longer measurements than those stored at lower temperatures and during spring in either temperature. The data analysis reported no influence by size or species on this outcome, parameters known to have an impact on fish muscle (Dunajski 1979). This is an indication that chilling and then freezing of prerigor shark will cause muscle contraction. After cooking the biological aspects completely overrides any prerigor chilling influences.

The chemical variables were influenced by a variety of factors. The thawed pH contained significantly different groups for rigor condition and RSW temperature and the interactions of rigor condition and season and rigor condition and RSW. Kramer and Peters (1981) found good negative correlation between pH level and toughness as measured by a Kramer shear-compression cell. Low pH indicated tougher texture for yellowtail rockfish. While the pH of thawed shark did differ in a similar manner with rigor stage before chilling then freezing (Table 25), the shark shear force values showed no differences for this treatment. Kelly (1969) has reported that muscle pH at the time of freezing determines whether flavour or texture will be the major criterion determining acceptability. Waller (1980b) found that good quality shark became unacceptable due to textural changes. Cheuk (1985) and Waller (1980a and b) have found that the pH of shark increased during ice and frozen storage due to ammonia production. This investigation found the thaw pH decreased as the rigor stage prior to RSW storage progressed. Shark stored in the higher temperature RSW also had lower pH levels. The only significant differences present for changes in pH from capture levels to thaw levels were for sex with the females displaying a greater drop in pH (Table 28). While not significantly different pH decreased more as rigor progressed for both temperature of, and time in RSW. This behaviour suggests that excessive production of ammonia or formaldehyde during storage is not occurring and that textural changes were not influenced by changes to proteins present in the fillet.

The K value of thawed fillets contained significantly different groups for season, species, rigor condition, RSW temperature and the interaction between season and RSW temperature (Table 26). The largest difference was present between postrigor shark which had the highest K values of any factor and the other stages. This finding is not unusual as K value normally increases as rigor progresses. The similarity between the K value of inrigor and that of prerigor shark suggests that there is little loss in quality by keeping shark until they enter rigor before they are placed in RSW and then frozen. The higher temperature RSW resulted in higher K values. As cold shock is not directly involved in the toughening observed in this investigation, the use of as low a temperature RSW as possible should be adopted for processing shark.

The amount of change of K value (*d* K) was influenced by the same factors as thaw K value (Table 29). Minor differences were also present for sex and the interaction of season and rigor stage. This behaviour makes the choice between preventing deterioration through rapid chilling and the need to avoid freezing prerigor shark easier by showing that little quality would be lost by holding the shark until rigor is established. While the warmer RSW temperature did lead, as expected, to significantly higher K values, when the actual values are viewed this finding does

not hold much impact. The difference between shark caught in spring and autumn is much larger. The interaction between season and RSW temperature and season and rigor condition shows that there is greater breakdown of nucleotides possible during spring than autumn. It shows that the shark should not be kept until postrigor and that the lower the RSW temperature used the better. *C. tilstoni*, especially the females, exhibited higher K values at the end of storage than *C. sorrah*. This species might have had higher energy reserves and thus produce more ATP breakdown.

The lactate levels of thawed shark did not contain as many significantly different groups as the K values nor were those present similar (Table 27). Although of a lower level of significance than K value, the higher RSW storage temperature also contributed to changes in quality by a greater production of lactate. The interactions between species and rigor condition and species and sex did not reveal any definite trends. When the overall high levels for any factor are taken into account these differences have little impact. The amount of change in lactate level (d L) gives better insight into the data and the various processing procedures conducted (Table 30). The presence of negative values for some individuals indicates the variability of results obtained for this method of analysis. The interaction between season and temperature of RSW identified by LSM did not reveal any major trends except indicate that changes in lactate can be quite variable. Unlike the changes in K value the shark caught in autumn showed greater change in lactate level.

The chemical parameters used for this investigation indicate that good quality shark meat can be produced when trunks are kept until rigor is established, before freezing. The shark should be placed in a wash tank or RSW. An RSW temperature as close to 0°C should be used for any long term storage before freezing to reduce any further loss in quality.

7. CONCLUSION

Rigor mortis in these species of shark normally sets in within 3 hr but onset may be as rapid as 30 min or as long as 8 hr. The shark remain in rigor for about 8 hr but this can range from 3 to 14 hr.

Chilling shark prerigor leads to slight shortening of the muscle fibres and it is recommended they be chilled or frozen only after rigor has commenced. Once they have entered the rigor process further muscle shortening does not occur and it is recommended that the RSW be kept at a temperature of 0°C to provide rapid chilling.

Even if some shortening occurs in the raw muscle these effects are completely overridden by biological factors. Older and larger shark are tougher with *C. sorrah* being the toughest species, particularly the males.

In order to prevent tough shark entering the market it is recommended that a mesh size of 10 cm be used as the industry standard and that male *C. sorrah* be eliminated from the catch.

8. REFERENCES

Bannister, K. 1993. The book of the shark. New Burlington Books, London.

Bouton, PE and Harris, PV. 1972. A comparison of some objective methods used to assess meat tenderness. Journal of Food Science 37: 218-221.

Bouton, PE, Harris, PV, Shorthose, WR. and Ratcliff, D. 1974. Changes in the mechanical properties of veal muscles produced by myofibrillar contraction state, cooking temperature and cooking time. Journal of Food Science 39: 869-875.

Bouton, PE, Harris, PV, and Shorthose, WR. 1975. Possible relationships between shear, tensile, and adhesion properties of meat and meat structure. Journal of Texturae Studies 6: 297-314.

Cheuk, WL.1985. Effects of on-board handling and processing techniques on the quality of shark from the Gulf of Mexico. Dissertation Abstracts International 47 (1) 15: No. 8605133.

Davenport, SR and Stevens, JD. 1988. Age and growth of two commercially important carcharhinid sharks from northern Australia. Australian Journal of Marine and Freshwater Research 39: 417-433.

Davey, LC. 1984. The structure of muscle and its properties as meat, in Bailey, AJ (ed). Recent advances in the chemistry of meat. Special Publication No. 47, The Royal Society of Chemistry, London: 1-21.

Dunajski, E. 1979. Texture of fish muscle. Journal of Textural Studies 10: 301-318.

Hatae, K, Yoshimatsu, F and Matsumoto, JJ. 1984. Discriminative characterization of different texture profiles of various cooked fish muscles. Journal of Food Science 49: 721-726.

Hobbs, G. 1982. Changes in fish after catching. in Aitken, A, Mackie, IM, Merritt, JH and Windsor, ML. Fish handling and processing, Her Majesty's Stationery Office, Edinburgh, 20-27.

Howgate, P. 1977. Aspects of fish texture, in Birch, GG, Brennan, JG and Parker, KJ (eds). Sensory Properties of Foods. Applied Science Publishers Ltd, London: 249-269.

Ikeda, S. 1980. Other organic components and inorganic components. in Connell, JJ (ed). Advances in fish science and technology, Fishing News Books, Farnham, England: 111-123.

Iwamoto, M, Yamanaka, H, Watabe, S and Hashimoto, K. 1987. Effect of storage temperature on rigor-mortis and ATP degeneration in plaice Paralichthys olivaceus muscle. Journal of Food Science 52 (6): 1514-1517.

Kramer, DE and Peters, MD. 1981. Effect of pH and prefreezing treatment on the texture of yellowtail rockfish (Sebastes flavidus) as measured by the Ottawa Texture Measuring System. Journal of Food Technology 16: 493-504.

Kreuzer, R and Ahmed, R. 1978. Shark utilization and marketing. FAO of the United Nations, Rome.

Lawrie, RA. 1979. Meat science. Pergamon Press, Oxford.

Love, RM. 1974. Variability in Atlantic cod (Gadus morhua) from the northeast Atlantic: a review of seasonal and enviro nmental influences on various attributes of the flesh. Journal of the Fisheries Research Board of Canada 32 (12): 2333-2342.

Lyle,JM. 1984. Mercury in shark from Northern Territory waters. North Australia's multi-species shark fishery, Fishery Report No. 12 Volume 2, Department of Primary Production, Northern Territory.

Lyle,JM, Pyne, RR, Hooper, J and Croaker, SL. 1984. A preparatory evaluation of the development of an shark fishery industry in Northern Territory waters. North Australia's multi-species shark fishery, Fishery Report No. 12 Volume 1, Department of Primary Production, Northern Territory.

Lyle,JM, and Timms, CJ. 1984. Exploratory fishing survey of shark and other fish resources found in Northern Territory inshore waters. North Australia's multi-species shark fishery, Fishery Report No. 12 Volume 4, Department of Primary Production, Northern Territory.

McLoughlin, KJ and Stevens, JD. 1994. Gill-net selectivities for two species of commercial carcharhinid shark taken in northern Australia. Australian Journal of Marine and Freshwater Research 45: 521-534.

Moller, AJ. 1981. Analysis of Warner-Bratzler shear pattern with regard to myofibrillar and connective tissue components of tenderness. Meat Science 5: 247-260.

Montero, P and Borderias, J. 1990. Influence of age on muscle connective tissue in trout (*Salmo irideus*). Journal of the Science of Food and Agriculture 51: 261-269.

Nambudiri, DD and Gopakumar, K. 1988. Cold shock reactions in tropical fishes. Journal of Food Science and Technology 25 (2): 89-91.

Otwell, WS. 1984. Shark processing and handling. in Sharks: Manual on shark fishing, Florida Sea Grant Report SGR-73: 22-34.

Poulter, RG, Curran, CA and Disney, JG. 1981. Chill storage of tropical and temperate water fish - differences and similarities, in Advances in technology in the chilling, freezing, processing, storage and transport of fish, especially underutilized species. International Institute of Refrigeration, Paris: 111-123.

Purchas, RW. 1973. Some aspects of raw meat tenderness. A study of some factors affecting its change with cooking and a new means of measurement. Journal of Food Science 38: 556-559.

Slattery, SL, Dionysius, DA, Smith,RAD and Deeth, HC. 1989. Mushiness in the blue swimmer crab, Portunus pelagicus (L). Food Australia 41 (4): 698-703 and 709.

Stevens, JD and Wiley, PD. 1986. Biology of two commercially important carcharhinid sharks from northern Australia. Australian Journal of Marine and Freshwater Research 37: 671-688.

Szczesniak, AS. and Torgeson, KW. 1965. Methods of meat texture measurement viewed from the bac kground of factors affecting tenderness. Avances in Food Research 14: 33-165.

Stroud, GD. 1969. Rigor in fish, the effect on quality. Torry Advisory Note No. 36.

Waller, PF. 1980a. Spoilage and spoilage indicators in shark held in ice. Food Technology in Australia 32 (3): 161-166.

Waller, PF. 1980b. Spoilage and spoilage indicators in frozen shark. Food Technology in Australia 32 (4): 184-187.

9. DIRECT BENEFITS AND BENEFICIARIES

The shark fishermen and processors in the Northern Territory and Queensland and the buyers and processors in the South will benefit. The adoption of recommended handling practices will lead to buyer confidence in the product which in turn should lead to increased sales and a decreased need to import product eg from Taiwan.

9.1 Flow of benefits

Northern Territory	70%
Queensland	30%

Potential for benefits to Western Australia.

10. INTELLECTUAL PROPERTY

There are no existing outstanding arrangements on intellectual property. At the request of the shark fishers association the release of results from this project have been postphoned until the finalisation of the Offshore Constitutional Settlement. This new treaty is intended to decide bycatch quotas for shark by fishers without shark endorsements.

11. STAFF

S Slattery	Chemist	IFIQ	50% of time
A Cusack	Technician	IFIQ	100% of time
A Bremner	Senior Principal Scientist	IFIQ	10% of time
P Pender	Management Officer	NTDPIF	20% of time

12. PROJECT BUDGET

The Northern Territory Department of Primary Industries and Fisheries was the Account Officer for this projects budget. A statement from the budget manager follows this section. Any queries should be directed to the budget manager on phone number 089 892 125 or fax number 089 892 174.

FORM B

FISHERIES RESEARCH & DEVELOPMENT CORPORATION
STATEMENT OF RECEIPTS & EXPENDITURE
for the period ended 9 December 1994

TRUST FUND:	FRDC
PROJECT OFFICER:	Mr P Pender
PROJECT NO :	93/190
GRANTEE :	Dept of Primary Industry & Fisheries
TITLE OF PROJECT:	Increasing the marketability of commercial northern shark by eliminating the incidence of tough flesh
DUE COMPLETION:	June 1994 (extended)

GRANT	IFIQ	DPIF	TOTAL
Salaries	43,078.00	0.00	43,078.00
Travel	9,500.00	2,360.00	11,860.00
Operating	17,000.00	0.00	17,000.00
Capital	2,500.00	0.00	2,500.00
Total	72,078.00	2,360.00	74,438.00

Expenditure	Salaries	Travel	Operating	Capital	Total
A Uncommitted c/f 1 July	3,436.28	3,639.56	-7,161.70	1,250.00	1,164.14
B Outstanding Commitments (c/f 1 July)	0.00	0.00	0.00	0.00	0.00
C Refunds of Grant	0.00	0.00	0.00	0.00	0.00
D Cash Received from Trust Fund	13,269.50	2,965.00	4,250.00	625.00	21,109.50
E Approved Transfers (form C)	0.00	0.00	0.00	0.00	0.00
F Cash Available (A+B-C+D+-E)	16,705.78	6,604.56	-2,911.70	1,875.00	22,273.64
G Expenditure	16,128.50	2,965.00	4,250.00	625.00	23,968.50
H Outstanding commitments (30 June)	0.00	0.00	0.00	0.00	0.00
I Total funds committed (G+H)	16,128.50	2,965.00	4,250.00	625.00	23,968.50
J Unspent &Uncommitted 30 June (F-I)	577.28	3,639.56	-7,161.70	1,250.00	-1,694.86
K Other Income (Paid to Trust Fund)					

Note: In addition to the above statement, DPIF has also sent $500 as a contribution to 1994/95 Workshop.
Note: DPIF's final payment to IFIQ will be reduced by the amount of $1694.86 above. This refers to 93/94 expend incurred by DPIF
Note: Row B should be the same as Row H from previous year and Row A the same as Row J from previous year.

Certificate of Accounting Officer
I hereby certify that this statement of receipts and expenditure is correct

A Palmer	ANNA PALMER	Budgets Mgr	13-12-94
(Signature)	(Printed Name)	(Designation)	(Date)

T921717.XLS

APPENDIX 1

SHRINKAGE MEASUREMENTS

FISH NO.	Date	Time	Specie	Sex	Length	Weight
3615	20/8	11.35	T	M	71	

CHILLED FILLET						
Time	00·31 00·50	0·51 1·05	1·14 1·30	1·40 1·56	3616 Kend	
Left	2·995 4·942	" 3·8? "	4·656 "	4·874	frozen muscle fibres partially separated	
Right	5·473 "	5·423	5·453 5·336	5·239 "	cooked flavour, old dry	

FISH NO.	Date	Time	Specie	Sex	Length	Weight
3617	21/8	7.25 ~~8.4~~	T	M	105	

CHILLED FILLET						
Time	8·14 8·30	8·40 8·54	9·15 EST	9·2?	end	3618
Left	5·65 ~~5·67~~ 5·674	5·572 5·66	~~5·7~~ 5·639	5·639 solid	COOKED	hard curled
Right	5·960	5·909 "	~~5·945~~ 5·945	5·651		tasty

FISH NO.	Date	Time	Specie	Sex	Length	Weight
3619	22/8	6.50 AM	T 2.5 compression	M		thin strips

CHILLED FILLET						
Time	7·02 7·09	7·32	7·45	8·00 solid → 8·26 washing	8·46	9·16 9·30
Left	5·152 "	"	5·122 "	5·024		4·954 "
Right	5·157 "	5·190	" 5·193	"	5·134 "	5·129

FISH NO.	Date	Time	Specie	Sex	Length	Weight
3619	2nd drill	compressed	T S	M	70	

CHILLED FILLET						
Time	10·05	10·30	firm	whole strip		
Left	4·937	4·970	cooked – soft, sl bitter	sl foamy		3620
Right	5·154	5·124				

FISH NO.	Date	Time	Specie	Sex	Length	Weight

CHILLED FILLET						
Time						
Left						
Right						

12

HANDLING TREATMENTS

FISH NO.	Date	Time	Specie	Sex	Length	Weight
3507/3508 K	22/8	10 15	S	M	76	pH 6.30
Time						
Rigor measure						
Rigor conditions	Pre / Post	Brine Temp	1 / 15	Brine Time	6 / 12	+ 24

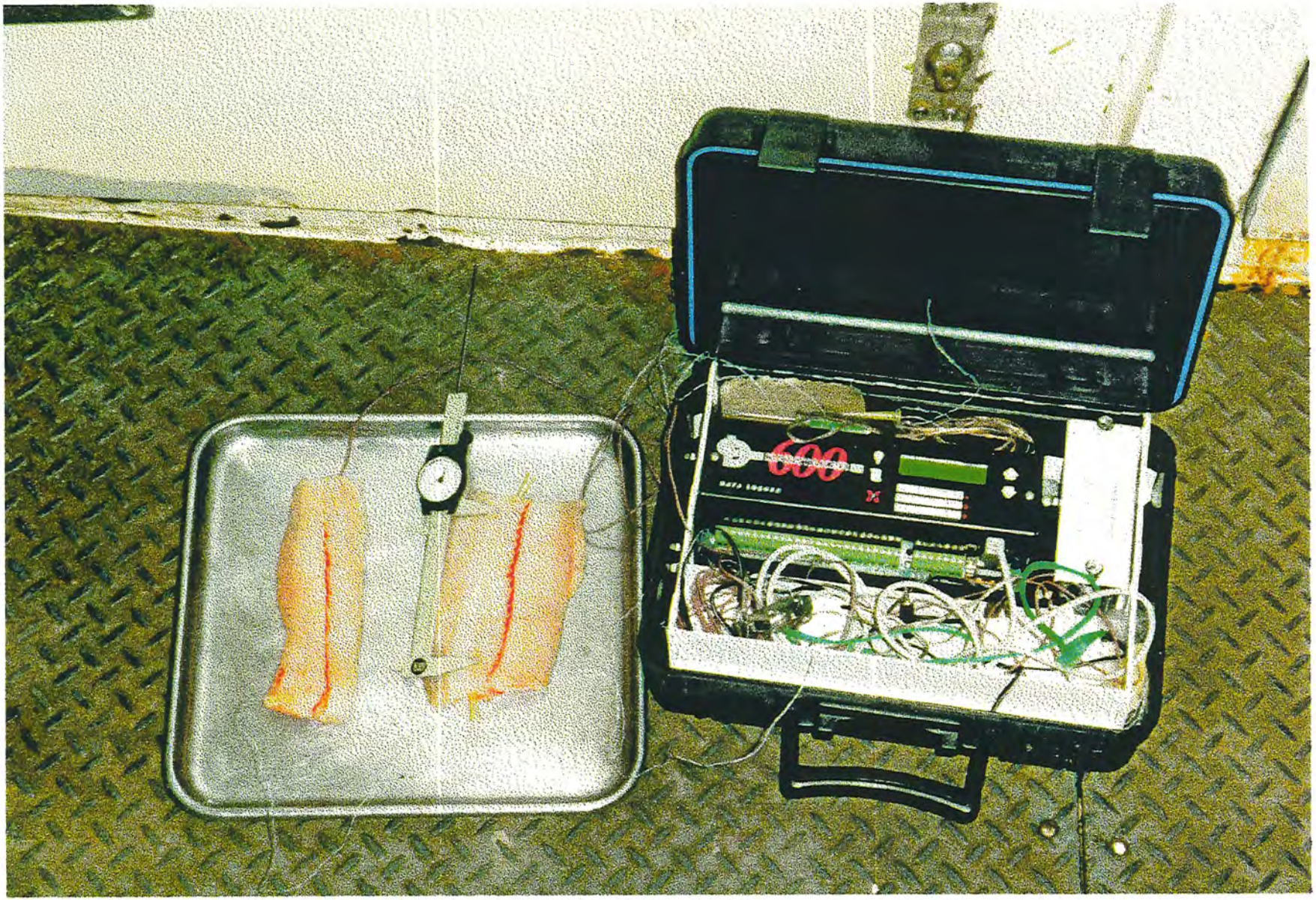
FISH NO.	Date	Time	Specie	Sex	Length	Weight
3509/3510 K	22/8	10.30	S	M	71	pH 6.24
Time	10.40 63.6	11.05 53.0	11.45 12.20 53.0 51.5	1.30 IR		
Rigor measure						
Rigor conditions	Pre / Post IN RIGOR	Brine Temp	1 / 15	Brine Time	6 / 12	+ 24

FISH NO.	Date	Time	Specie	Sex	Length	Weight
3511/3512 K	22/8	10 30	S	M	77	pH 6.01
Time NOTE: SUFFOCATED	10.45 55.0	11.05 0	11.45 0 IR			
Rigor measure		NOT FULL RIGOR				
Rigor conditions	Pre / Post IN RIGOR	Brine Temp	1 / 15	Brine Time	6 / 12	+ 24

FISH NO.	Date	Time	Specie	Sex	Length	Weight
3513/3514 K	22/8	10 30	T	F	69	pH 6.45
Time						
Rigor measure						
Rigor conditions	Pre / Post	Brine Temp	1 / 15	Brine Time	6 / 12	+ 24

FISH NO.	Date	Time	Specie	Sex	Length	Weight
3515/3516 K	22/8	10.25	S	M	71	pH 6.17
Time	10.37 54.2	11.05 11.45 54.2 0 IR				
Rigor measure					+ 24	
Rigor conditions	Pre / Post IN RIGOR	Brine Temp	1 / 15	Brine Time	6 / 12	

APPENDIX 2


600

APPENDIX 3

CODE	SAMPLE TREATMENTS
Chill	Placed on a try on ice
CF	Cooled in cold room to 0°C then frozen
C*F	Cooled in freezer till frozen
C*WF	Cooled in freezer till below 0°C, warmed then frozen
CWF	Cooled in cold room to 0°C, warmed then frozen
W	Kept warm at deck temperature

FACTOR	DEFINITION	GROUPS
SPP	Species	S=*C. sorrah*, T=*C. tilstoni*
TRT	Rigor stage prior to storage	Pre-, In-, Postrigor
BRC	Temperature of RSW used for storage	1°C, 15°C
BRT	Storage time in RSW	6, 12, 24 hours
SEX	Sex	F=female, M=male
SEASON	Timing of trips	spring, autumn
SIZE	Based on fork length	<85cm, >85cm

VARIABLE	DEFINITION
Sarc	Sarcomere length of samples returned to laboratory
pH Start	pH of shark at capture
pH Thaw	pH of samples returned to laboratory
d pH	Change in pH between capture and after returning to laboratory
L Start	Lactic acid level of shark at capture (liquid nitrogen stored)
L End	Lactate of samples returned to laboratory
d L	Change in lactate level between capture and after returning to laboratory
AT/DP Start	Combined adenosine 5'-triphosphate and adenosine 5'-diphosphate levels at capture (liquid nitrogen stored)
AT/DP End	Combined ATP and ADP level of samples returned to laboratory
d AT/DP	Change in AT/DP level between capture and after returning to laboratory
AMP Start	adenosine 5'-monophosphate of shark at capture (liquid nitrogen stored)
AMP End	adenosine 5'-monophosphate of samples returned to laboratory
IMP Start	Inosine 5'-Monophosphate of shark at capture (liquid nitrogen stored)
IMP End	IMP of samples returned to laboratory
All PStart	Combined ATP, ADP, AMP, IMP level of shark at capture (liquid nitrogen stored)
All PEnd	Combined ATP, ADP, AMP, IMP level of samples returned to laboratory
d All P	Change in All P level between capture and after returning to laboratory
EndHxr	Hypoxanthine of samples returned to laboratory
EndTN	Total nucleotides of samples returned to laboratory
KStart	K value of shark at capture
KEnd	K value of samples returned to laboratory
*d*K	Change in K value between capture and after returning to laboratory
Ravmupk	Load at muscle peak (KN) of raw thawed sample (average of 2)
Ravcolpk	Load at collagen peak (KN) of raw thawed sample (average of 2)

Ravmue	Energy of muscle peak (J) of raw thawed sample (average of 2)
Ravcole	Energy of collagen peak (J) of raw thawed sample (average of 2)
Ravte	Energy of combined muscle and collagen components (J) of raw thawed sample (average of 2)
Cavmupk	Load at muscle peak (KN) of cooked thawed sample (average of 2)
Cavcolpk	Load at collagen peak (KN) of cooked thawed sample (average of 2)
Cavmue	Energy of muscle peak (J) of cooked thawed sample (average of 2)
Cavcole	Energy of collagen peak (J) of cooked thawed sample (average of 2)
Cavte	Energy of combined muscle and collagen components (J) of cooked thawed sample (average of 2)
Grade	Rating of cooked samples prior to Instron evaluation (scale 1=tender to 7=very tough)

APPENDIX 4

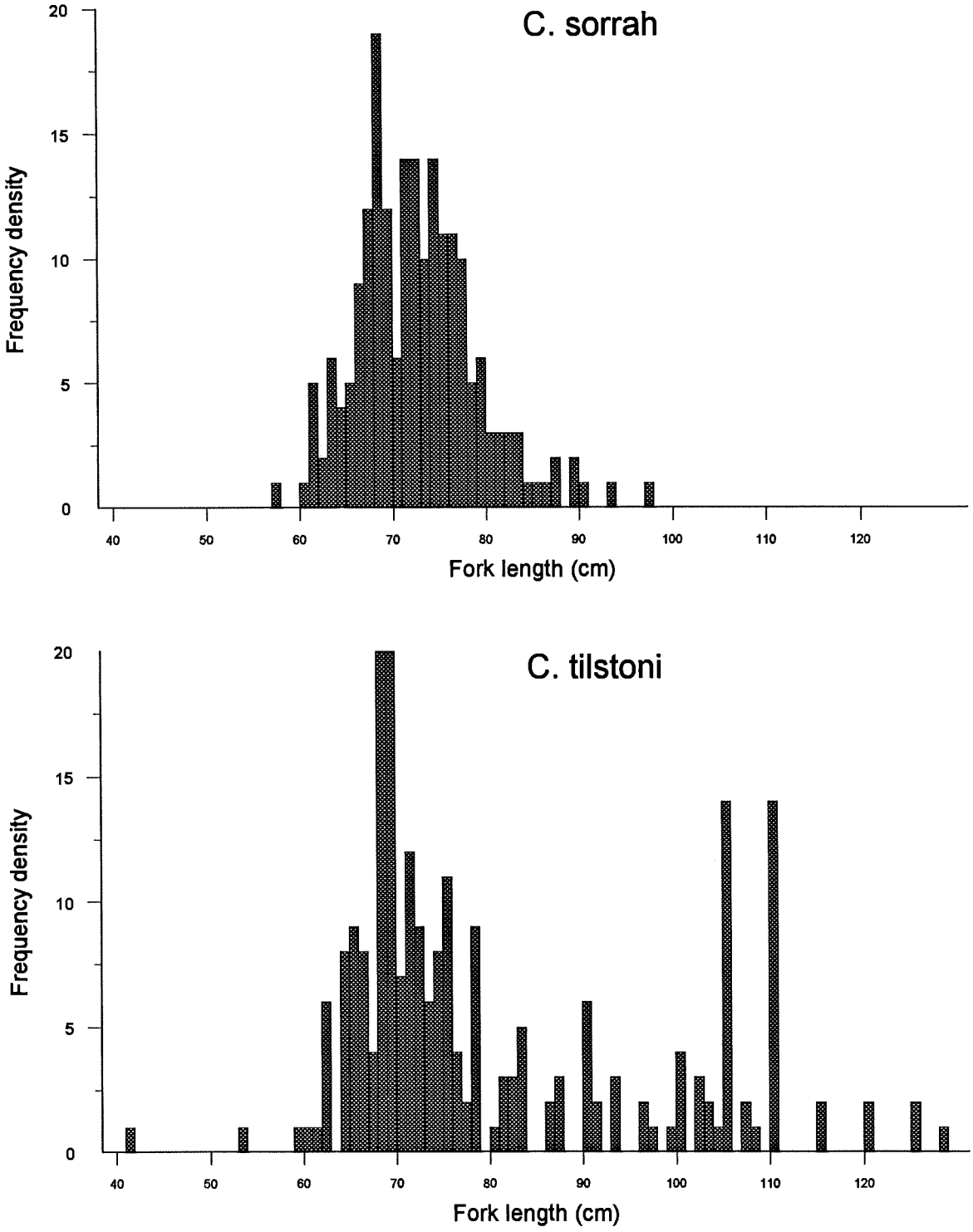
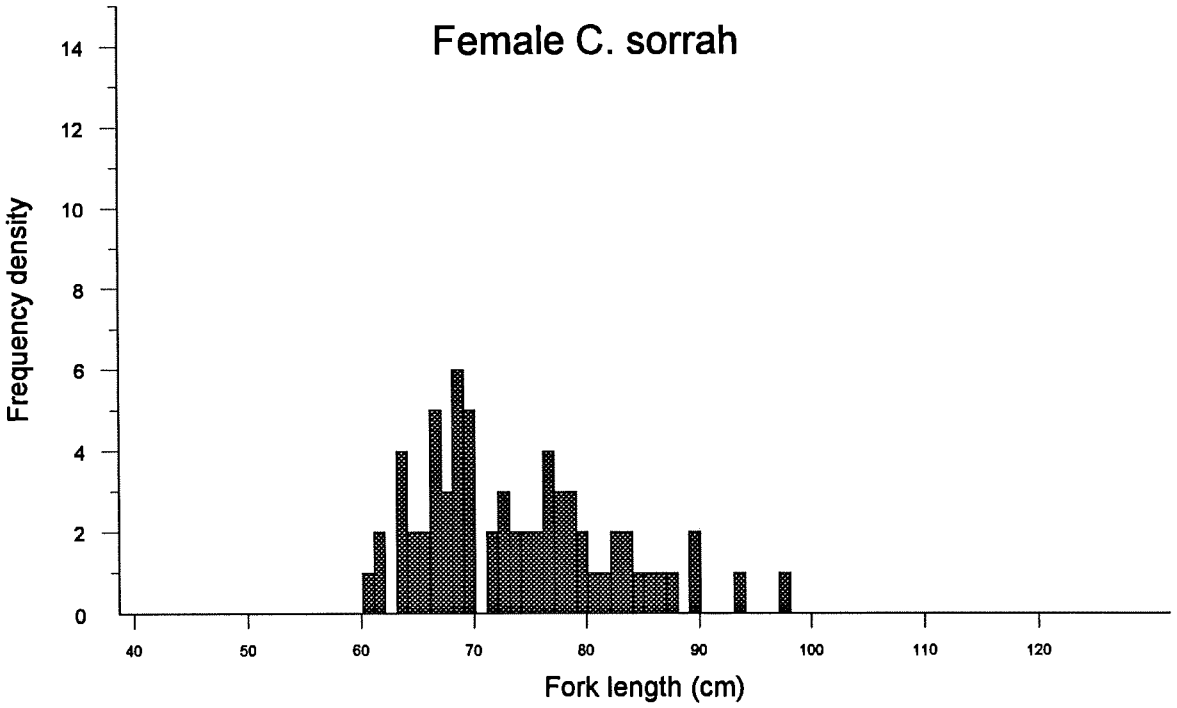


Figure 4.1. Length-frequency distributions for all C. sorrah and C. tilstoni caught during three trips.



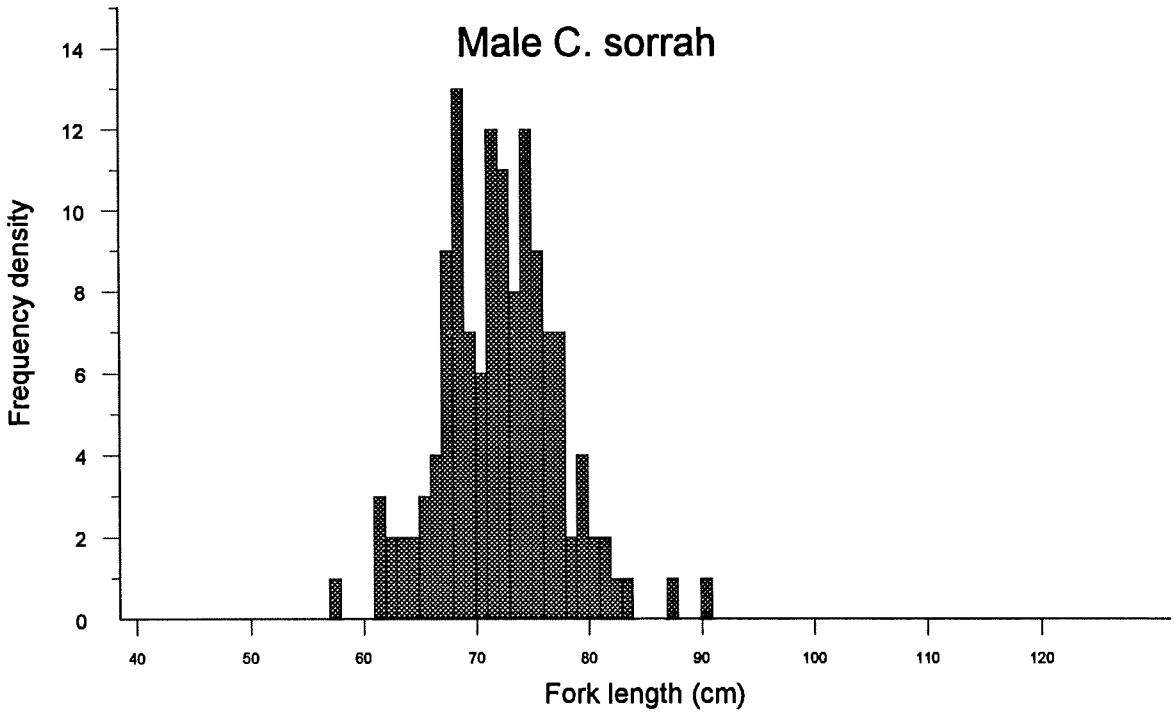


Figure 4.2. Length-frequency distributions for female and male C. sorrah caught during three trips.

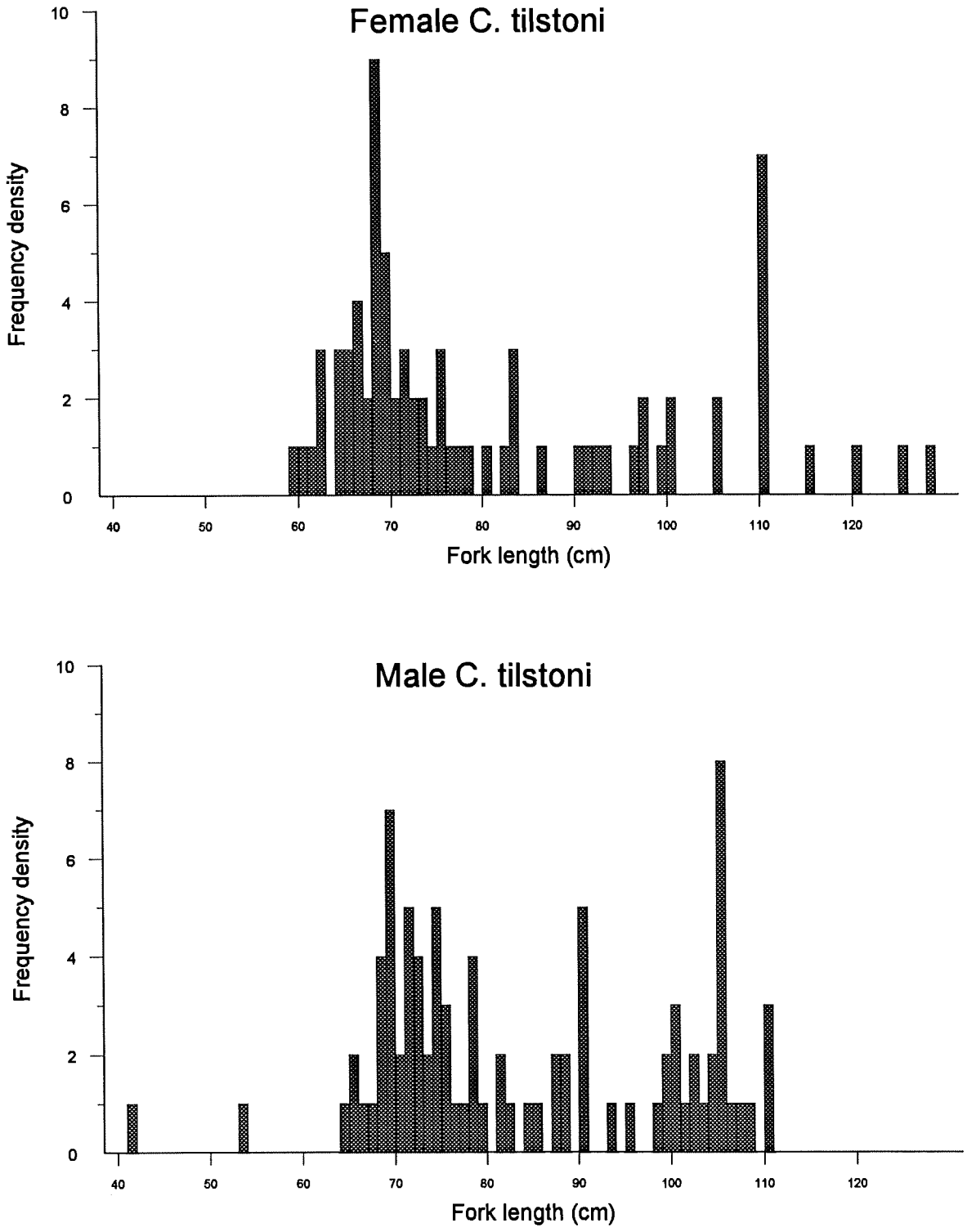


Figure 4.3. Length-frequency distributions for female and male C. tilstoni caught during three trips.

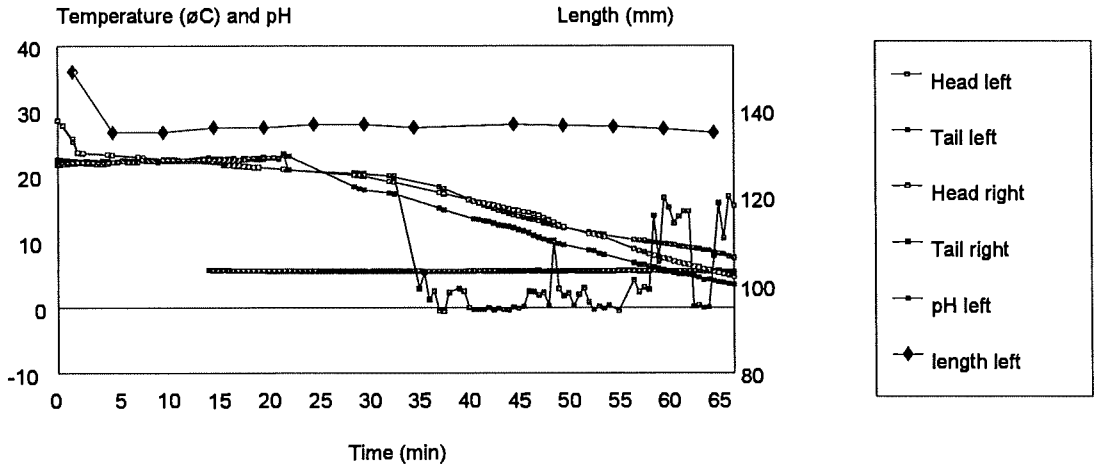
APPENDIX 5

5.1 SHRINKAGE MEASUREMENTS USING A TRAY ON ICE

Figure 5.1.1

In tray on ice during rough conditions

3601



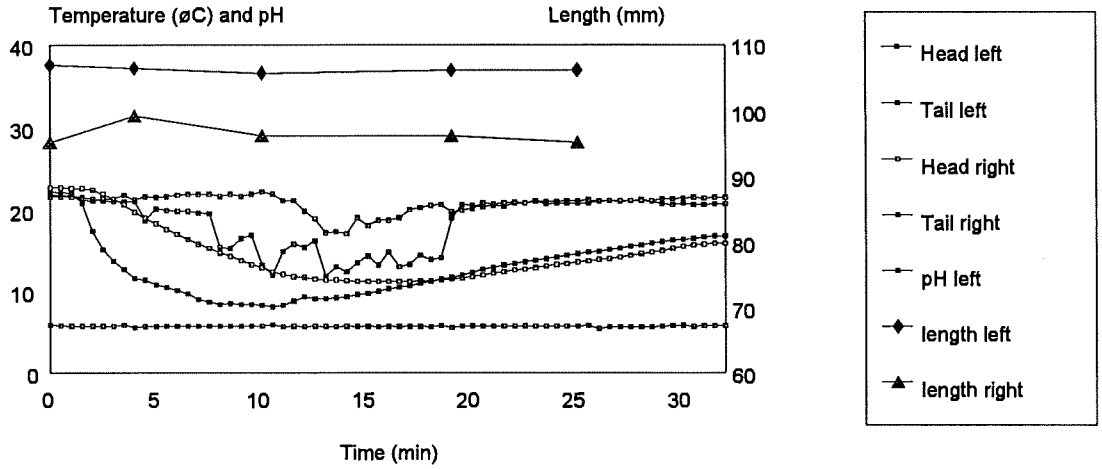
C.tilstoni, F, 87cm, left shrank 9.4%

Start K=6 and Final K=10

Figure 5.1.2

In tray on ice during rough conditions

3603



C.sorrah, M, 83cm, left shrank 2% and right shrank 4%

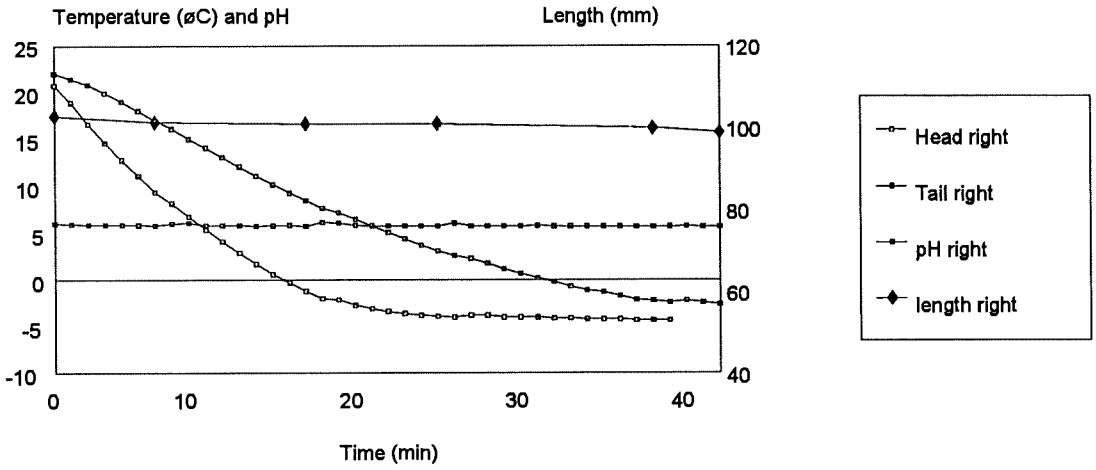
Final K=7

5.2 SHRINKAGE MEASUREMENTS USING A TRAY IN A FREEZER ROOM CHILLED TILL FROZEN

Figure 5.2.1

In freezer room

3605



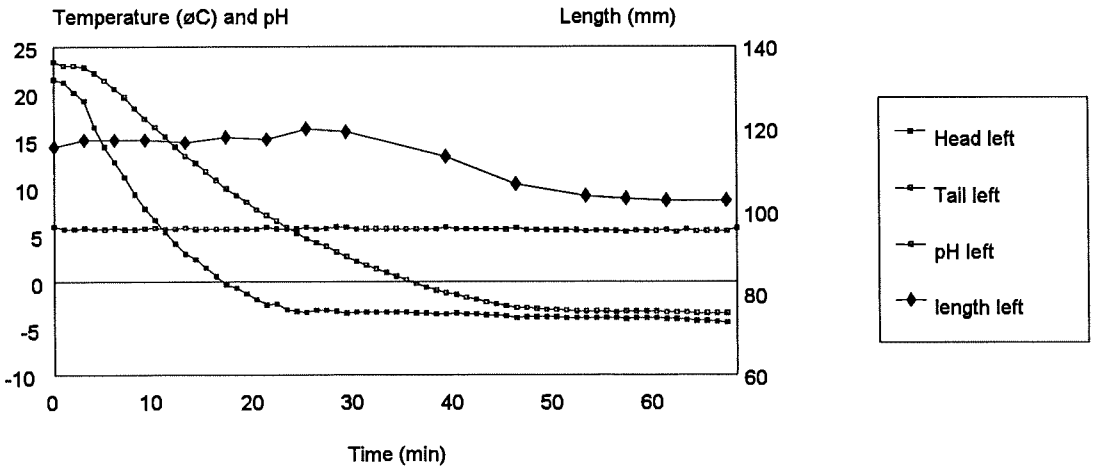
C. tilstoni, F, 100cm, shrank 3.8%

Start K=6 and Final K=4

Figure 5.2.2

In freezer room

3607



C. sorrah, M, 67cm, shrinkage 12.4%, hard and connective tissue prominate

Start K=0 and Final K=9

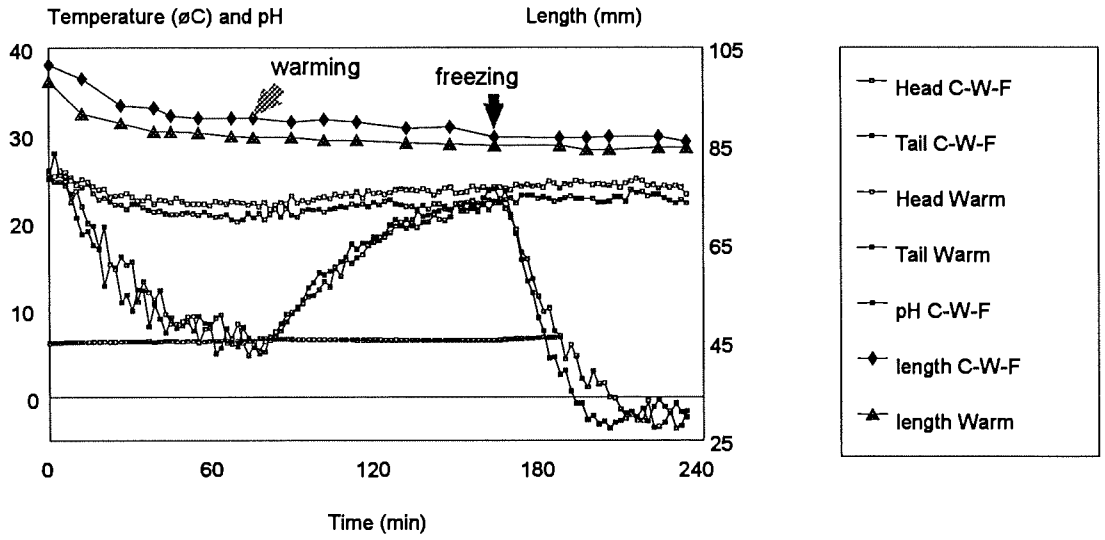
5.3 SHRINKAGE MEASUREMENTS USING A TRAY IN A COLD ROOM

CHILLED, WARMED THEN CHILLED TILL FROZEN

Figure 5.3.1

In cold room then freezer or outside then freezer or just kept warm

W3784

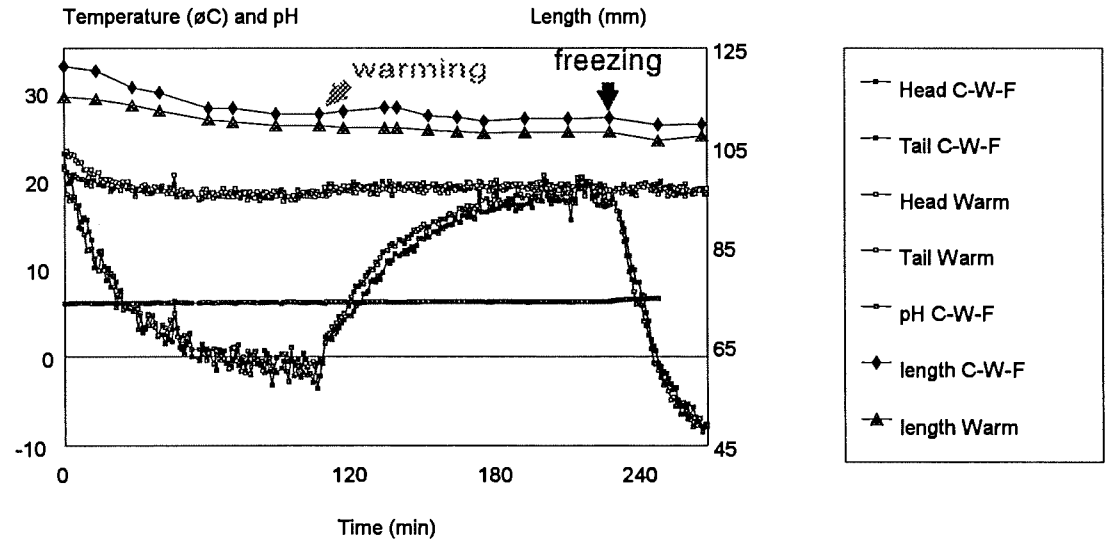


C.sorrah, M, 80cm, shrinkage C-W-F 15.5% tough, Warm 13.8% very tough

Figure 5.3.2

In cold room then freezer or outside then freezer or just kept warm

W3796

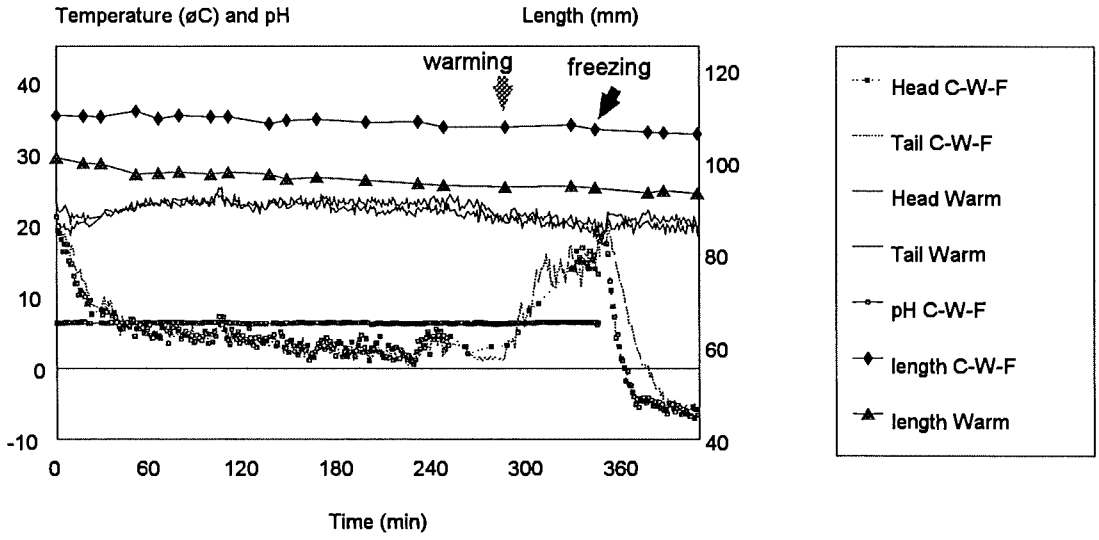


C.tilstoni, F, 91cm, shrinkage C-W-F 9.6% soft, Warm 6.8% tender

Figure 5.3.3

In cold room then frozen or warmed then frozen or just kept warm

W3825

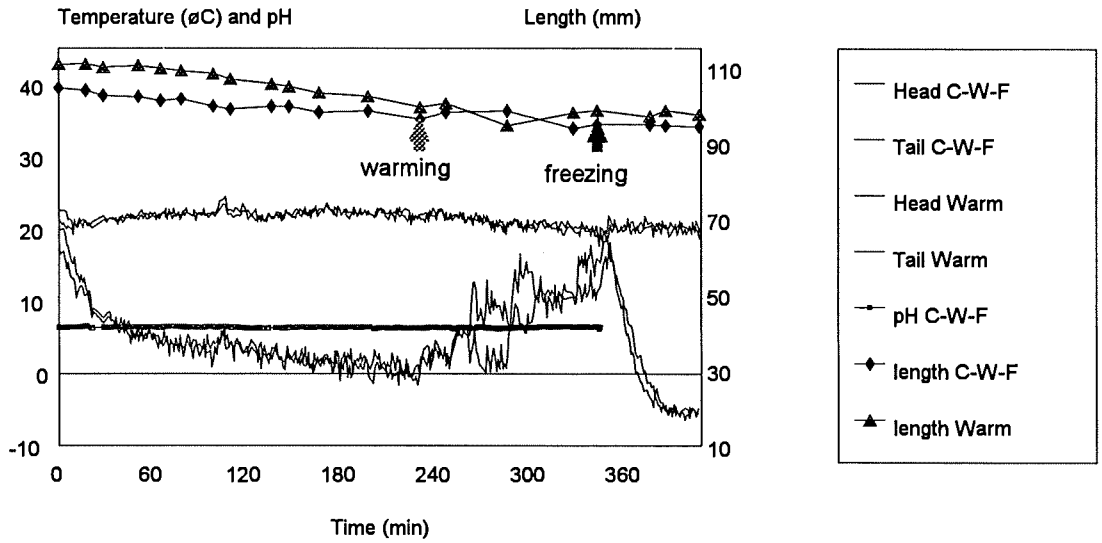


C.tilstoni, F, 68cm, shrinkage C-W-F 3.6% tender, Warm 7.8% tender

Figure 5.3.4

In cold room then freezer or outside then freezer or just kept warm

W3826

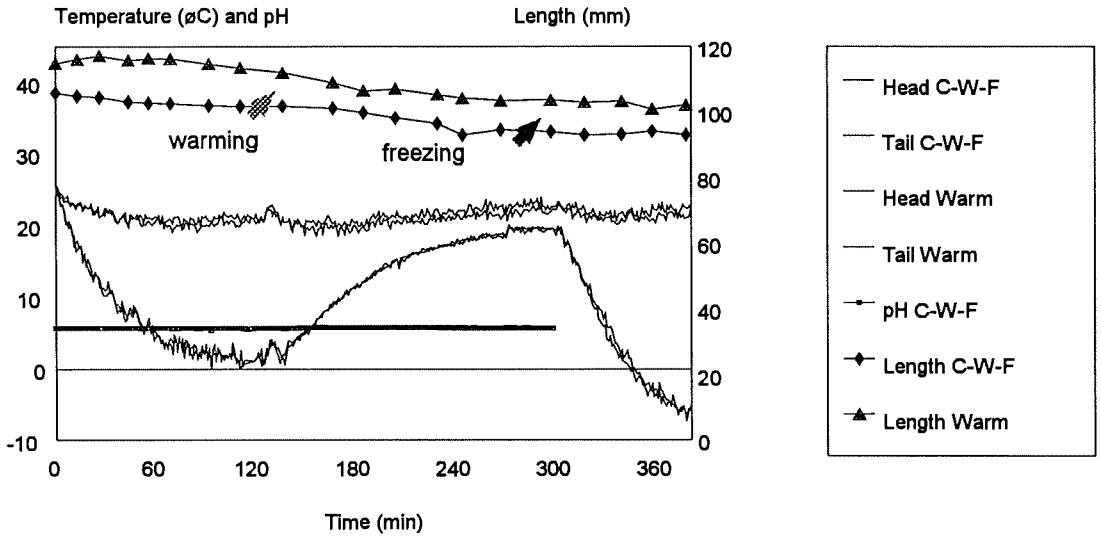


C.sorrah, F, 64cm, shrinkage C-W-F 9.7% hard, Warm 10.7% hard

Figure 5.3.5

In cold room then freezer or outside the freezer or just kept warm

W3842

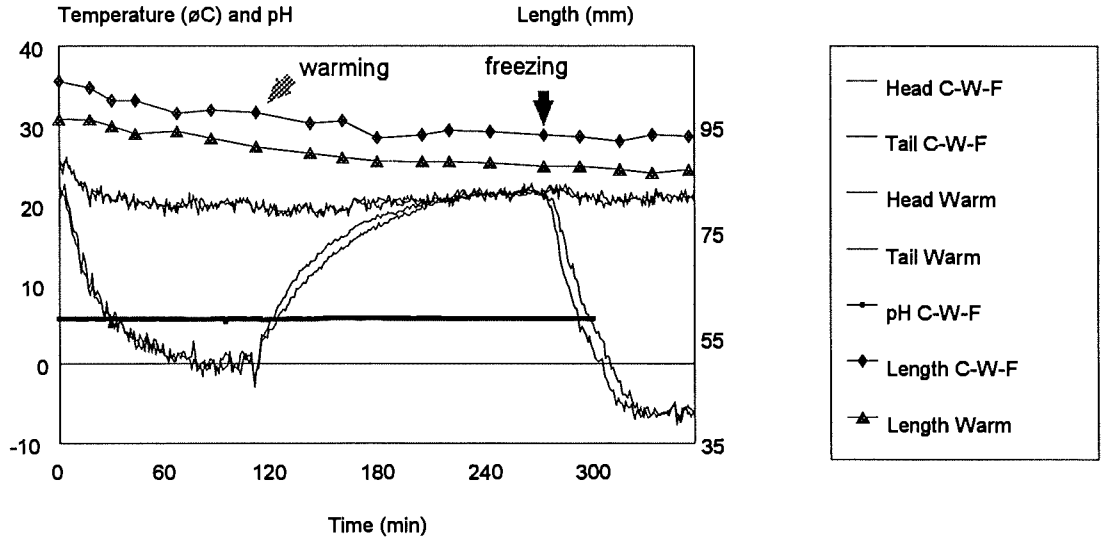


C.tilstoni, M, 93cm, shrinkage C-W-F 12.1% firm, Warm 11.2% soft

Figure 5.3.6

In cold room then freezer or outside then freezer or just kept warm

W3843

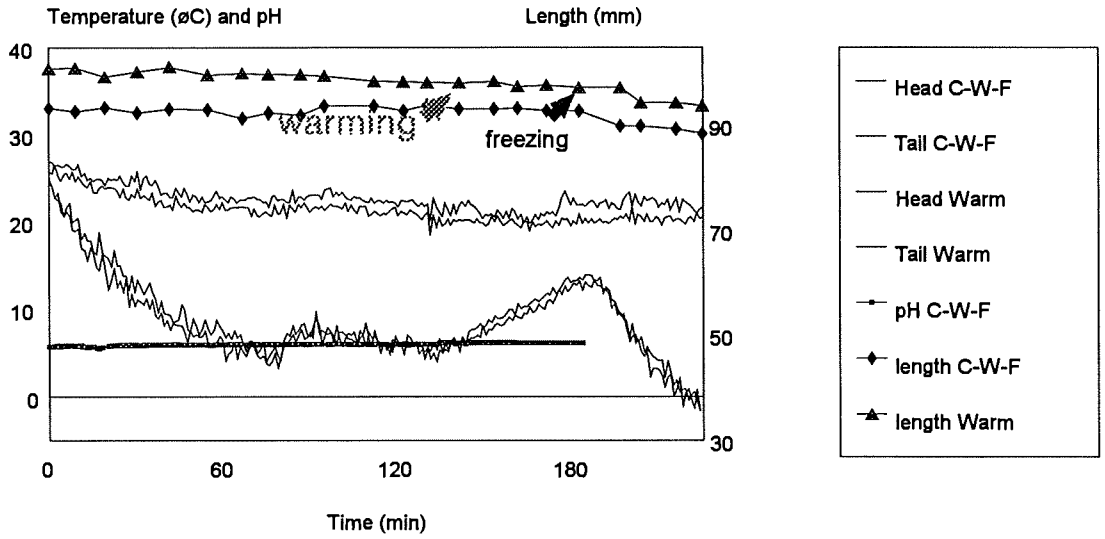


C.tilstoni, M, 81cm, shrinkage C-W-F 10.2% soft, warm 10% soft

Figure 5.3.7

In cold room then freezer or outside then freezer or just kept warm

W3845

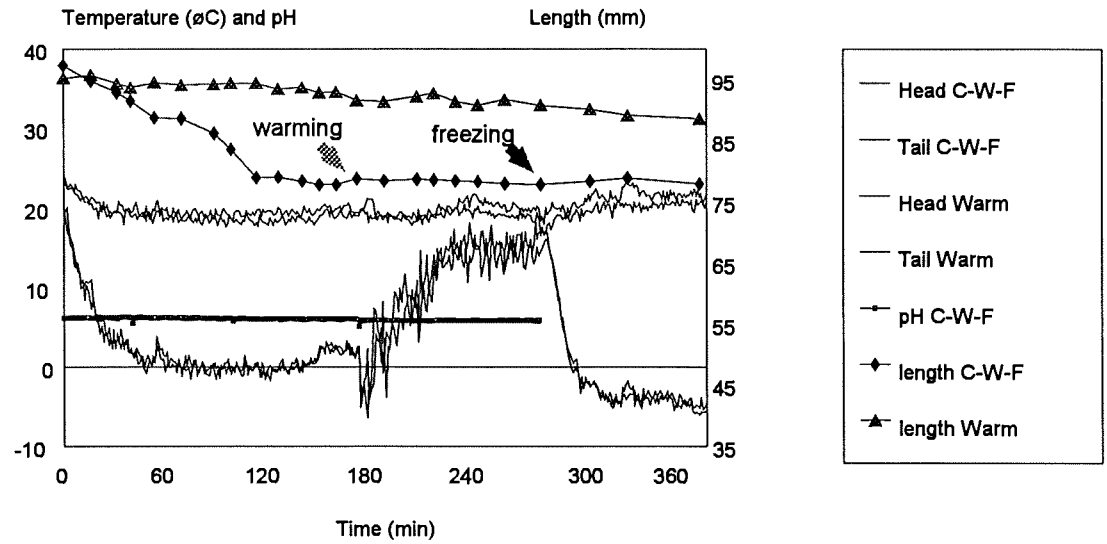


C.tilstoni, F, 116cm, shrinkage C-W-F 5.3% sl soft, Warm 7.1% hard & chewy

Figure 5.3.8

In cold room then freezer or outside then freezer or just kept warm

W3847

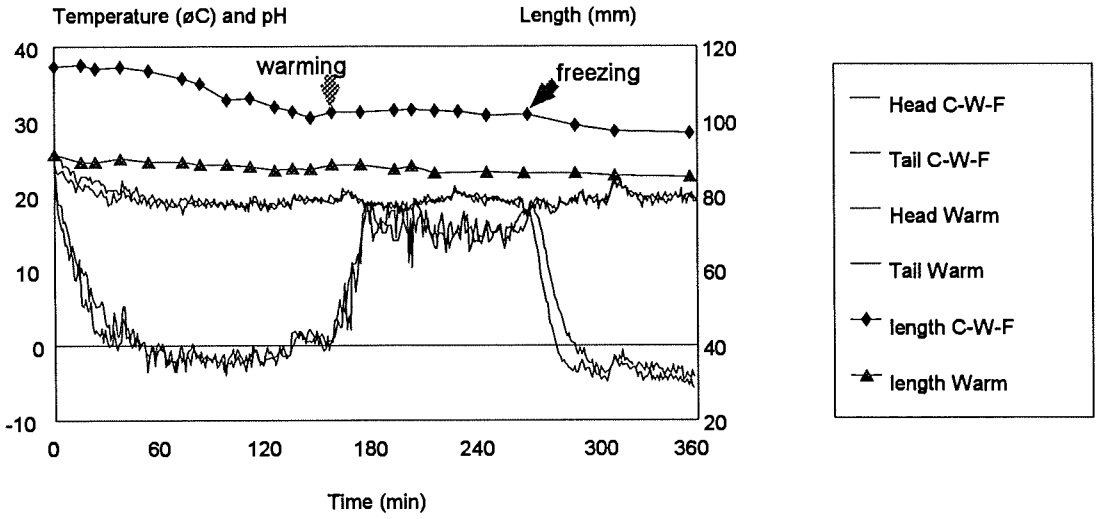


C.tilstoni, F, 68cm, shrinkage C-W-F 19.9% tender, Warm 6.9% tender

Figure 5.3.9

In cold room or outside then freezer or just kept warm

W3850

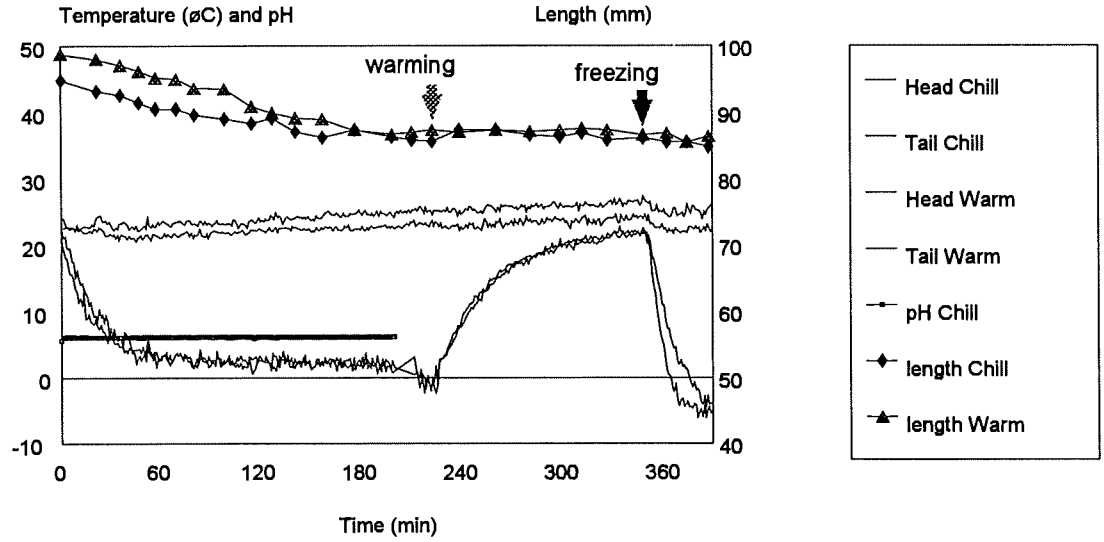


C.sorrah, F, 66cm, shrinkage C-W-F 15.9% tender, Warm 6.7% sl chewy

Figure 5.3.10

In cold room then freezer or outside then freezer or just kept warm

W3976



C.sorrah, F, 63cm, chill shrinkage 10.7% warm shrinkage 12.6%

APPENDIX 6

Figure 6.1 Shear Force Energy required for different sized C. sorrah

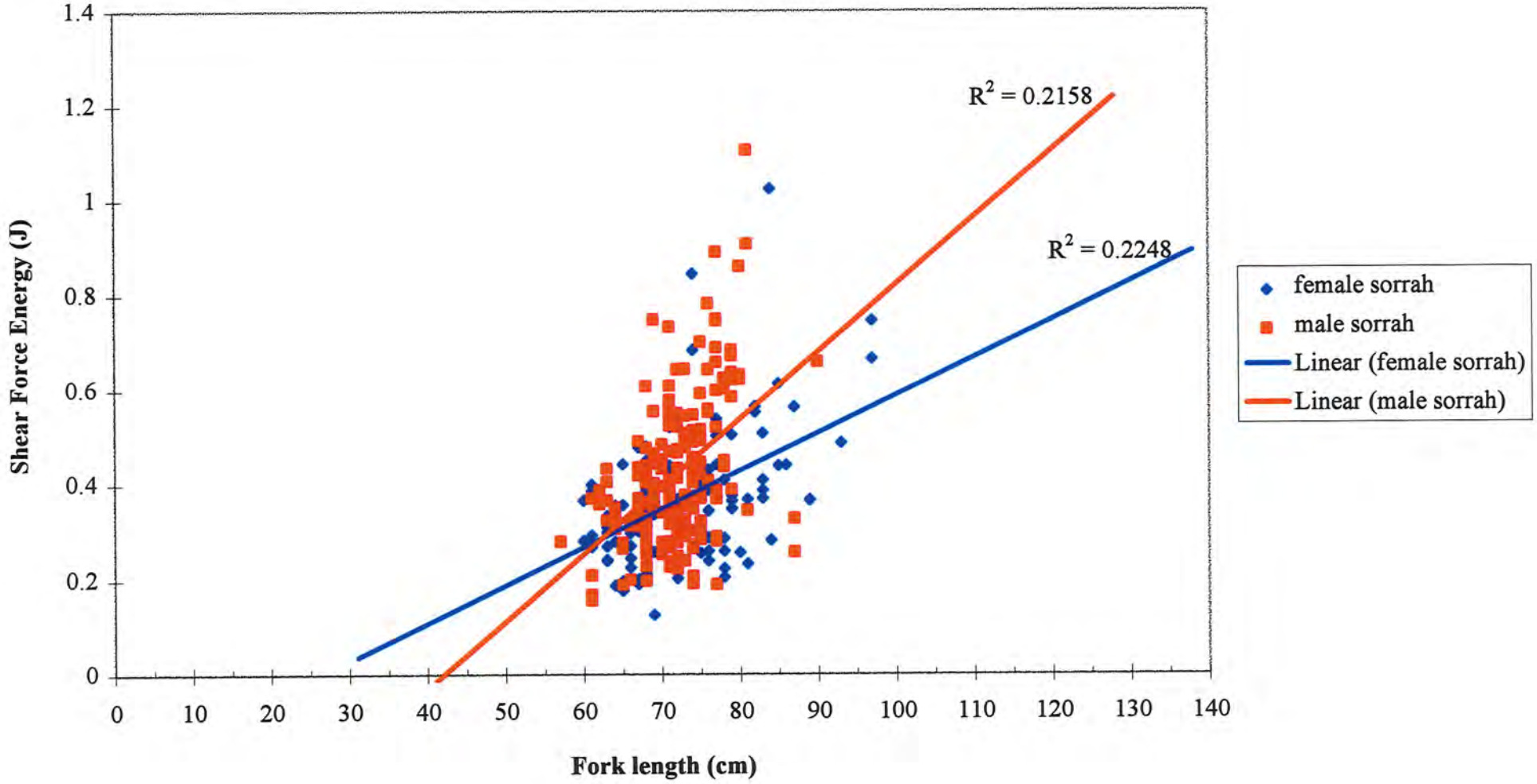


Figure 6.2 Shear Force Energy for different sized *C. tilstoni*

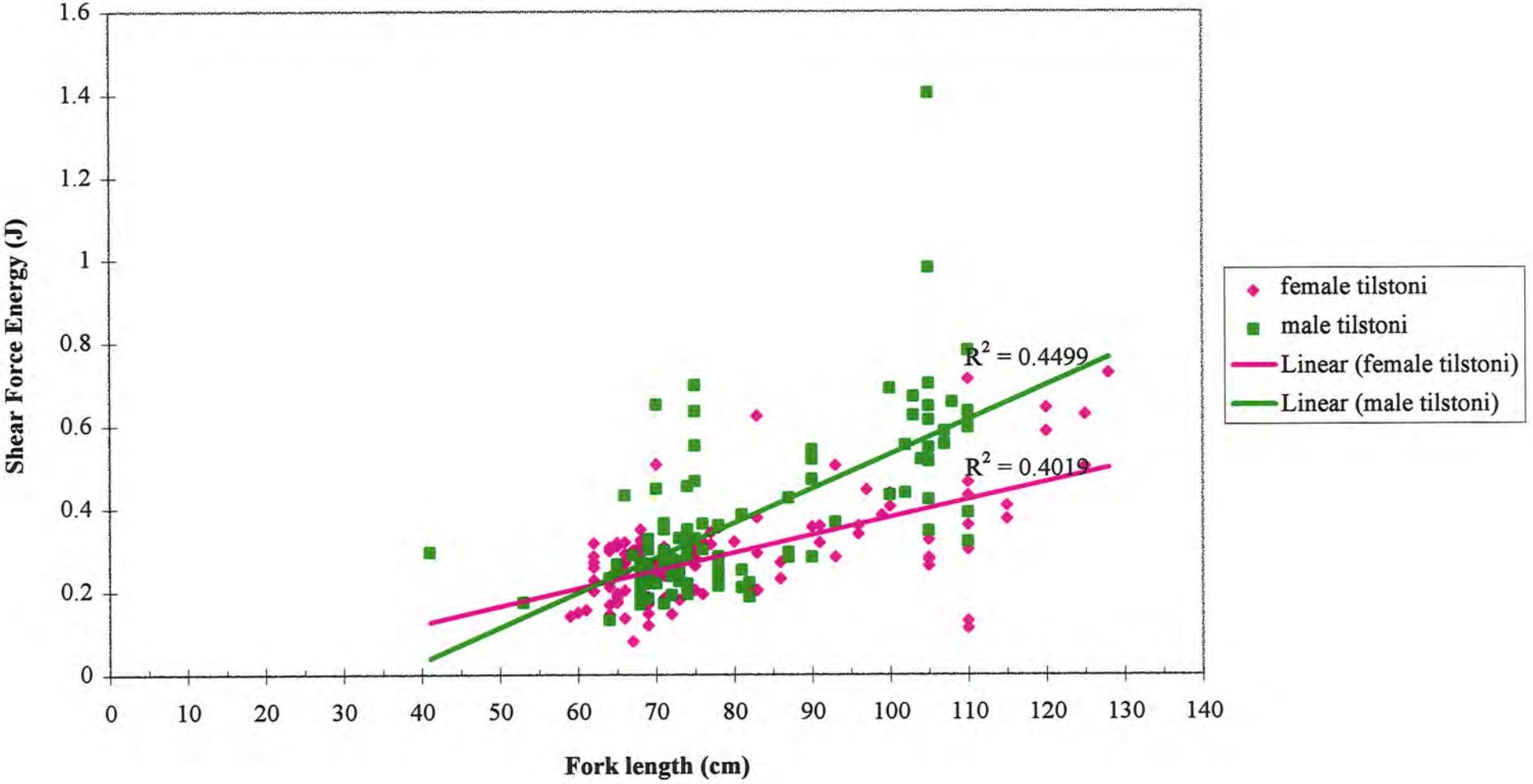


Figure 6.3 Gear selectivity indicies for C. sorrah

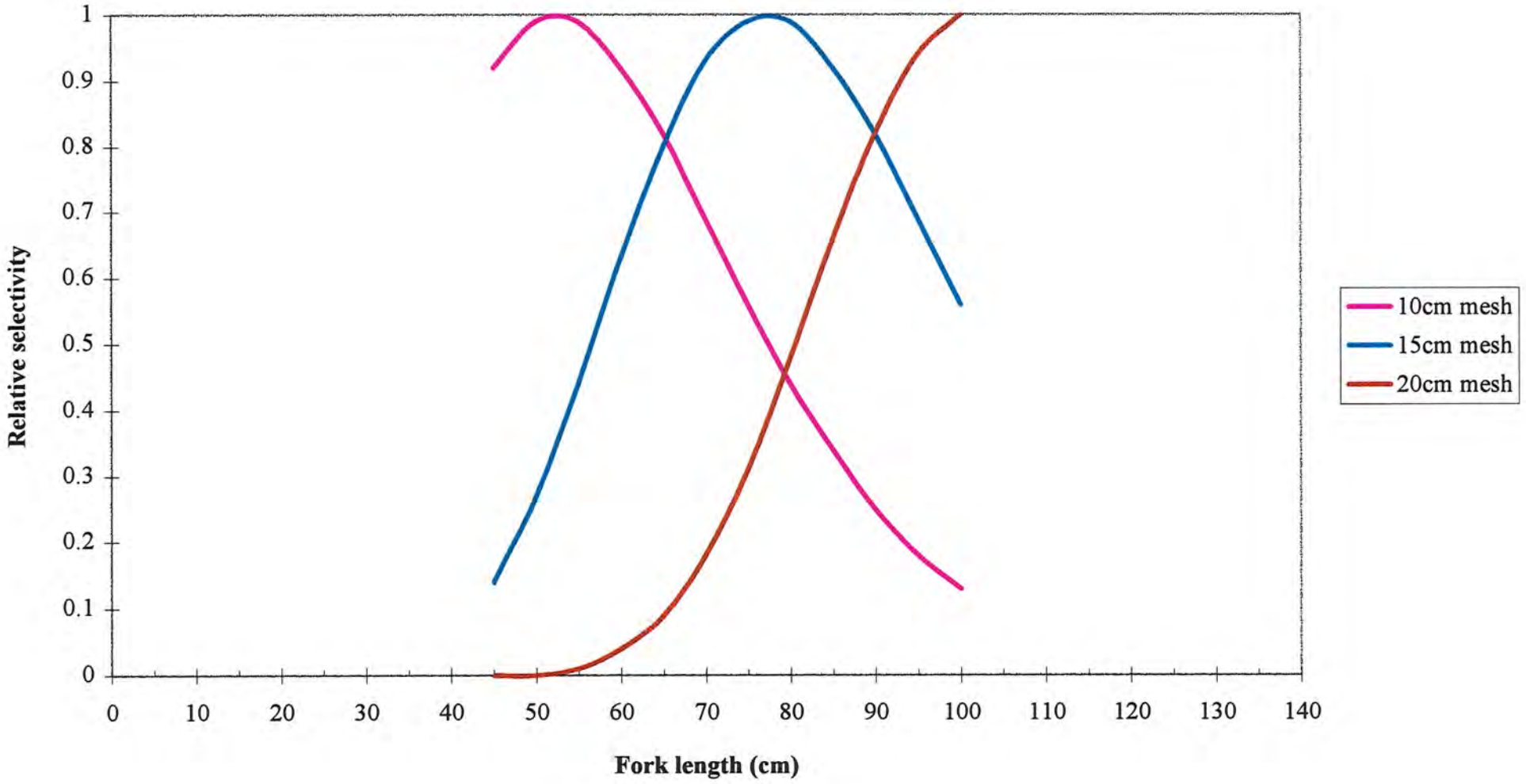


Figure 6.4 Gear selectivity for C. tilstoni

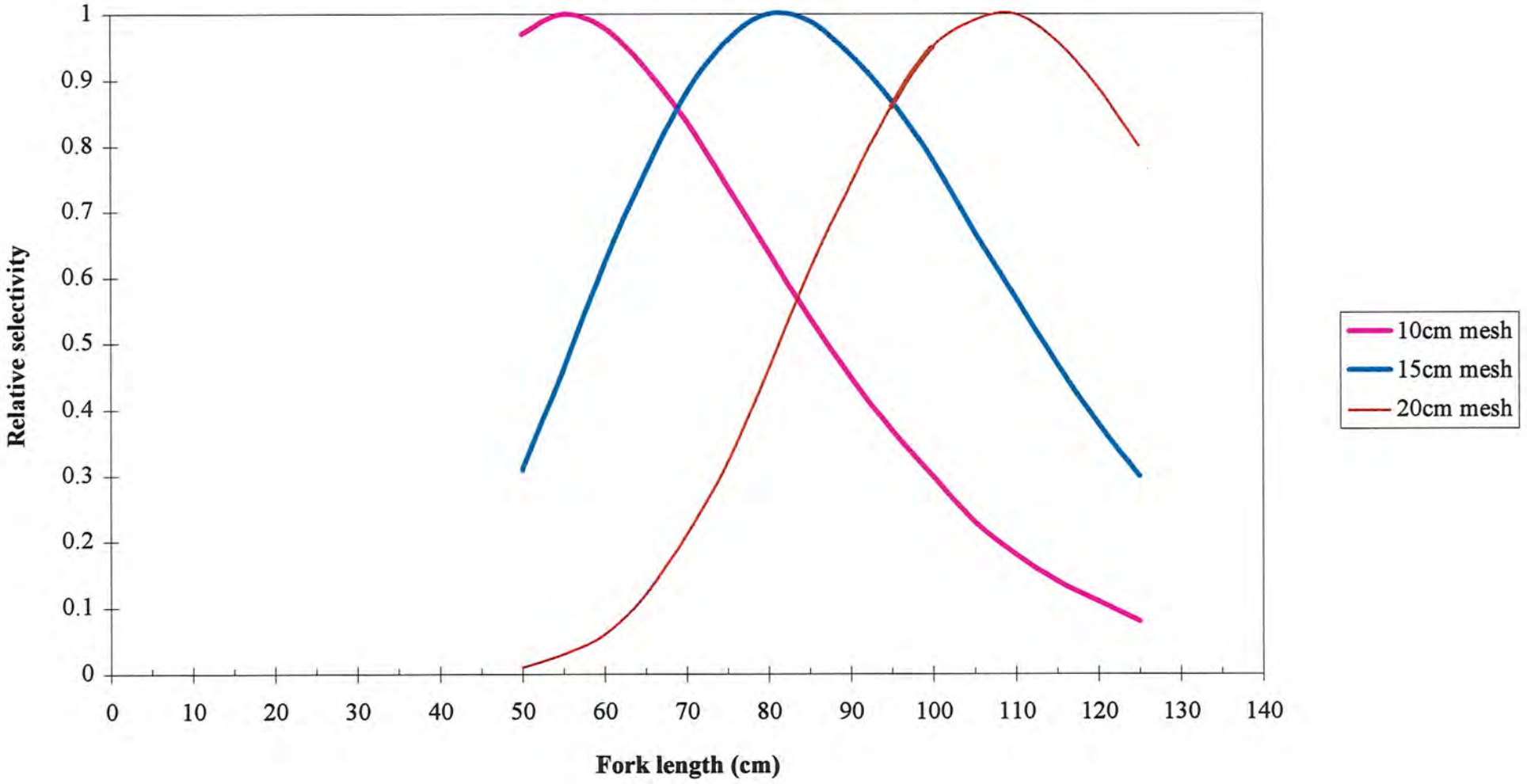


Figure 6.5 Probability of mesh catching a tough *C.sorrah* shark

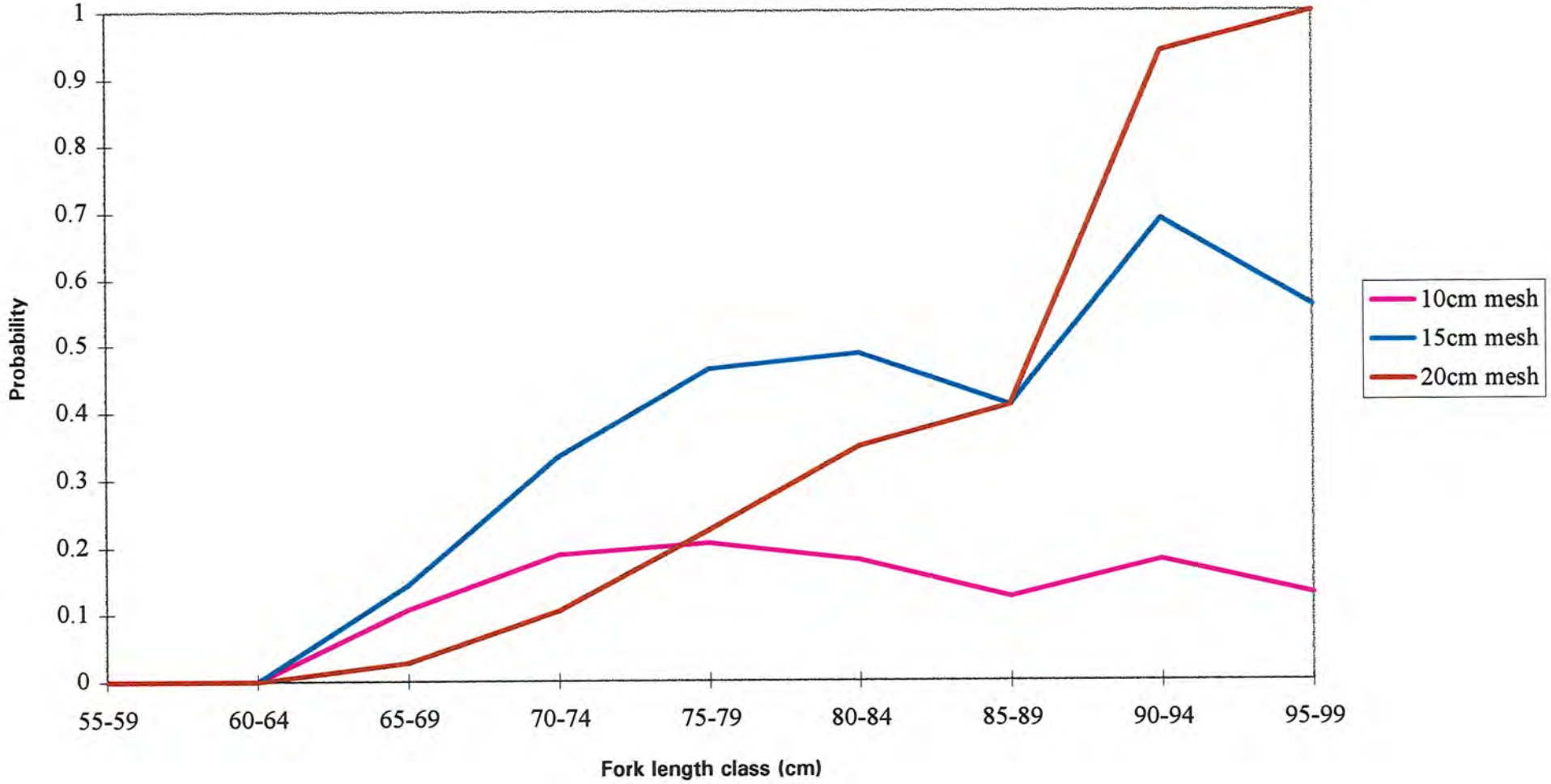


Figure 6.6 Probability of catching a tough *C. tilstoni* shark

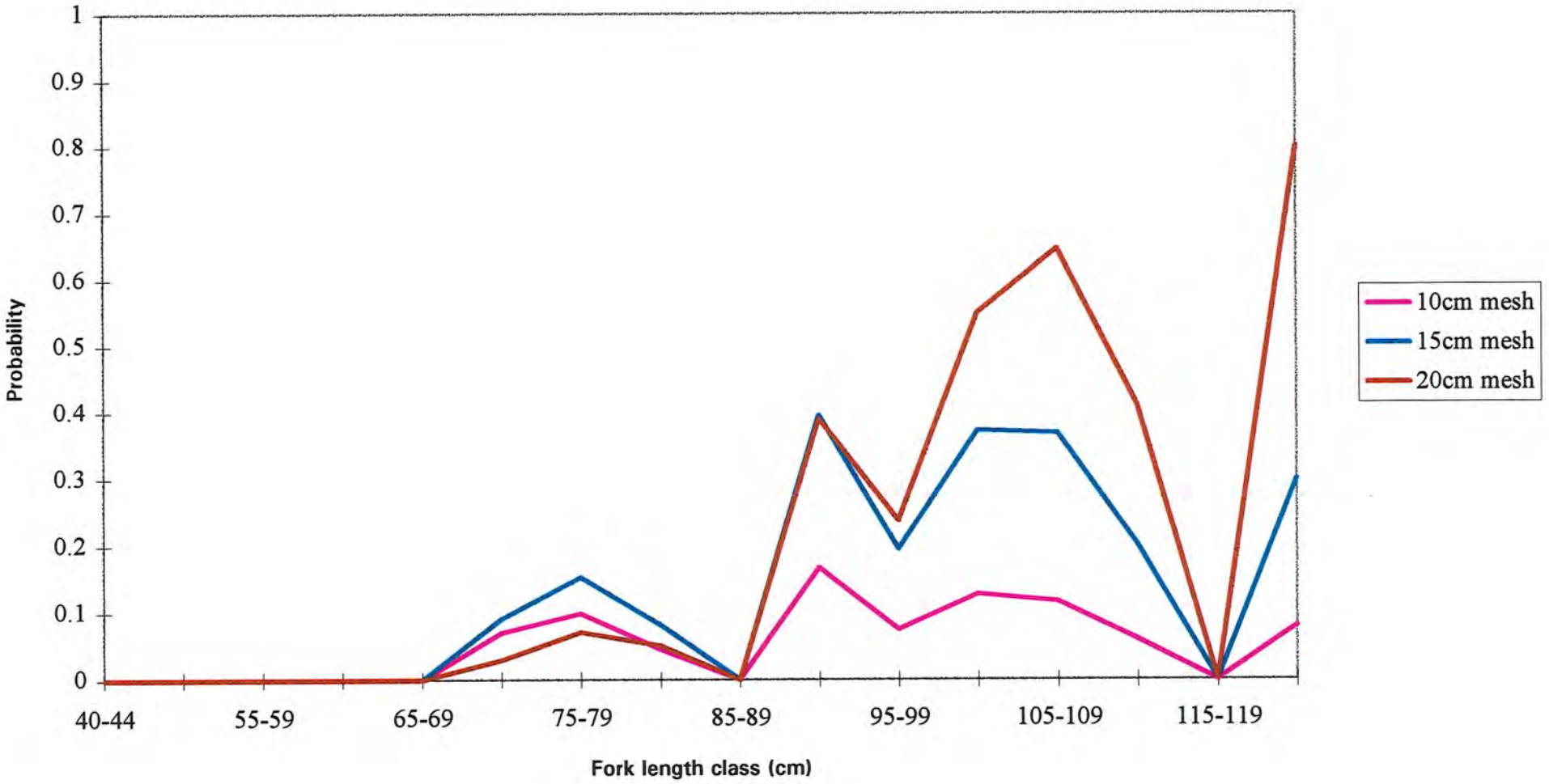


Figure 6.7 Probability of catching a tough shark of either species adjusted for catch rate