FEASIBILITY OF MECHANICAL SKINNING OF BLUE SHARK

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This report presents physical properties of Blue Shark (Prionace glauca) which are useful in designing skinning and gutting systems. Information on tensile strength and breaking elongation of blue shark skin and flesh, shear strength and shear work of skin and flesh, and adhesive work required to peel the skin from the flesh is presented.

INTRODUCTION

Sharks are among the most ancient and notorious of the fish living today in the world ocean. Despite the shark's "man-eating" reputation the fact is that catching shark for human consumption is a long-standing practice all over the world. Over 10 million kg of shark are caught annually in the U.S. (Gordievskaia, 1973). Most is processed into sticks or sold overseas.

Blue shark (Prionace glauca), found in abundance in the waters off southern California, is considered underutilized as a food source. Further, blue sharks are considered a pest by most commercial and sport fishermen. They are frequently caught incidentally with squid, a main component of the blue shark diet. They are considered migratory and are a pelagic species.

It is possible to catch large numbers of blue shark despite the fact that they are territorial and do not swim in schools. The authors of this paper observed this "long-line" technique, Figure 1, aboard the commercial fishing vessel JJ. It is a labor intensive operation. Over 250 hooks are baited and clipped to the stainless steel line. The line is set for up to 5 hours while the boat is drifting on the open sea. Blue sharks from 1.2 - 2.5 m (approx. 4 - 8 ft) are caught this way. The line is then winched back aboard and the sharks are removed from the line, gaffed, and restrained manually on a gutting table. The tail is severed to "bleed" the shark and the fins are removed with a knife. The shark is then gutted and beheaded. The unskinned carcass is dropped into the hold and chilled by cold salt-water spray. The "long line" is then winched

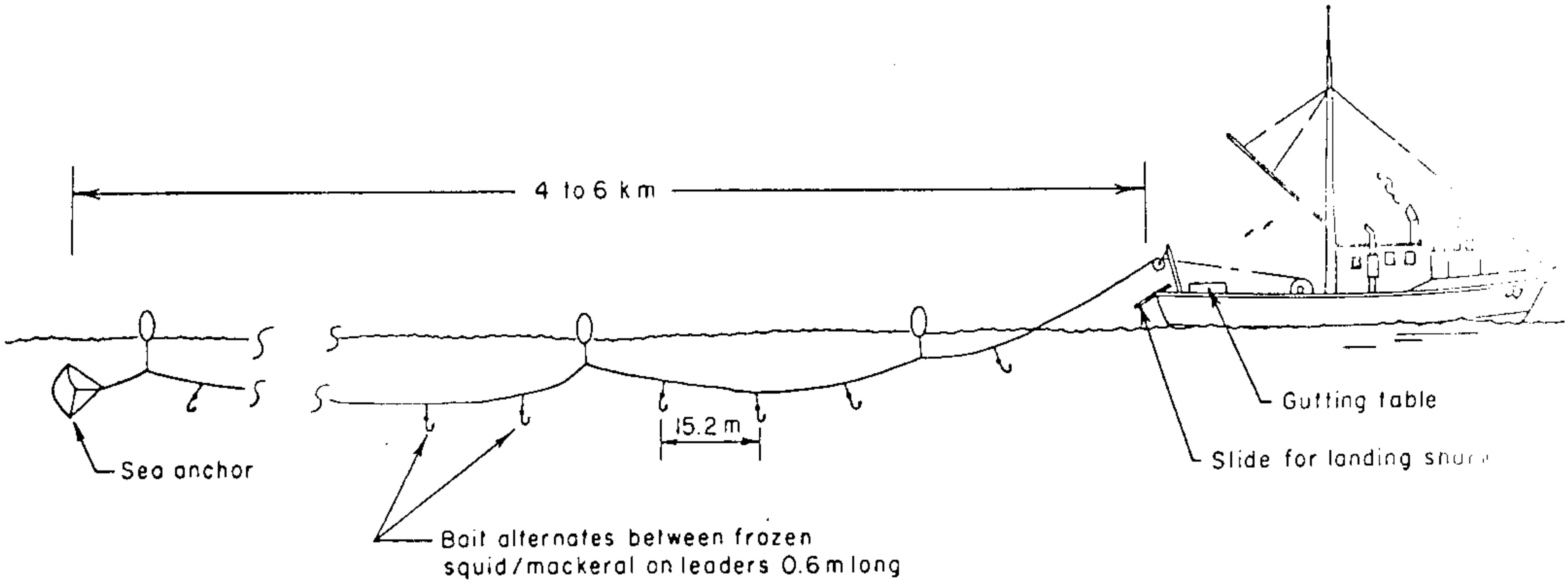


Figure 1. Long Line Fishing Method for Blue Shark as Practiced on Commercial Fishing Vessel JJ.

again and the next shark is removed from the line.

The fishermen receive \$0.59-\$0.66/kg (\$0.27-\$0.30/lb) for the unskinned blue shark carcasses at San Pedro, CA (Katz, 1980). It is sliced into filets and each piece is then skinned. It is estimated that 30-50% of the meat is lost when the shark filets are skinned by the processor (Christen, 1979). The fins are of value and are dried and shipped to the Orient for shark fin soup.

Despite the unpopularity of shark meat in North America, members of the seafood industry feel there is a big need for the development of a machine to skin blue shark (Gary, 1979). A wider market for blue shark products is being sought. For example, if removed in one piece the skin is of value as a hide for making leather.

Questionnaires were sent to members of the Japan Marine Products Importers Association, Tokyo, Japan, and to members of the Japan External Trade Organization. The companies that expressed an interest in marketing blue shark skin/hide numbered four, in marketing meat - five, and in the marketing of the fins - nine. Company names and addresses are listed in the appendix.

The machine proposed to skin blue shark could initiate its utilization, as a source of meat, fins, and hide.

DESIGN PARAMETERS

Ocean Leather Corporation, Newark, New Jersey, has been converting shark skins into leather for shoes and other prestige leather goods since 1972 (Brody, 1965). Their required hide shape is pictured in Figure 2. Further, they require hides at least 1.2 m (40 in) long and free from sour spots (decomposition), butcher cuts (knife cuts into the hide during skinning process), fighting scars, and burnt spots (prolonged exposure to sun awaiting processing). To insure top quality hides they insist the hide be removed in as short a time as possible after the shark is caught. The hides cannot be frozen or exposed to fresh

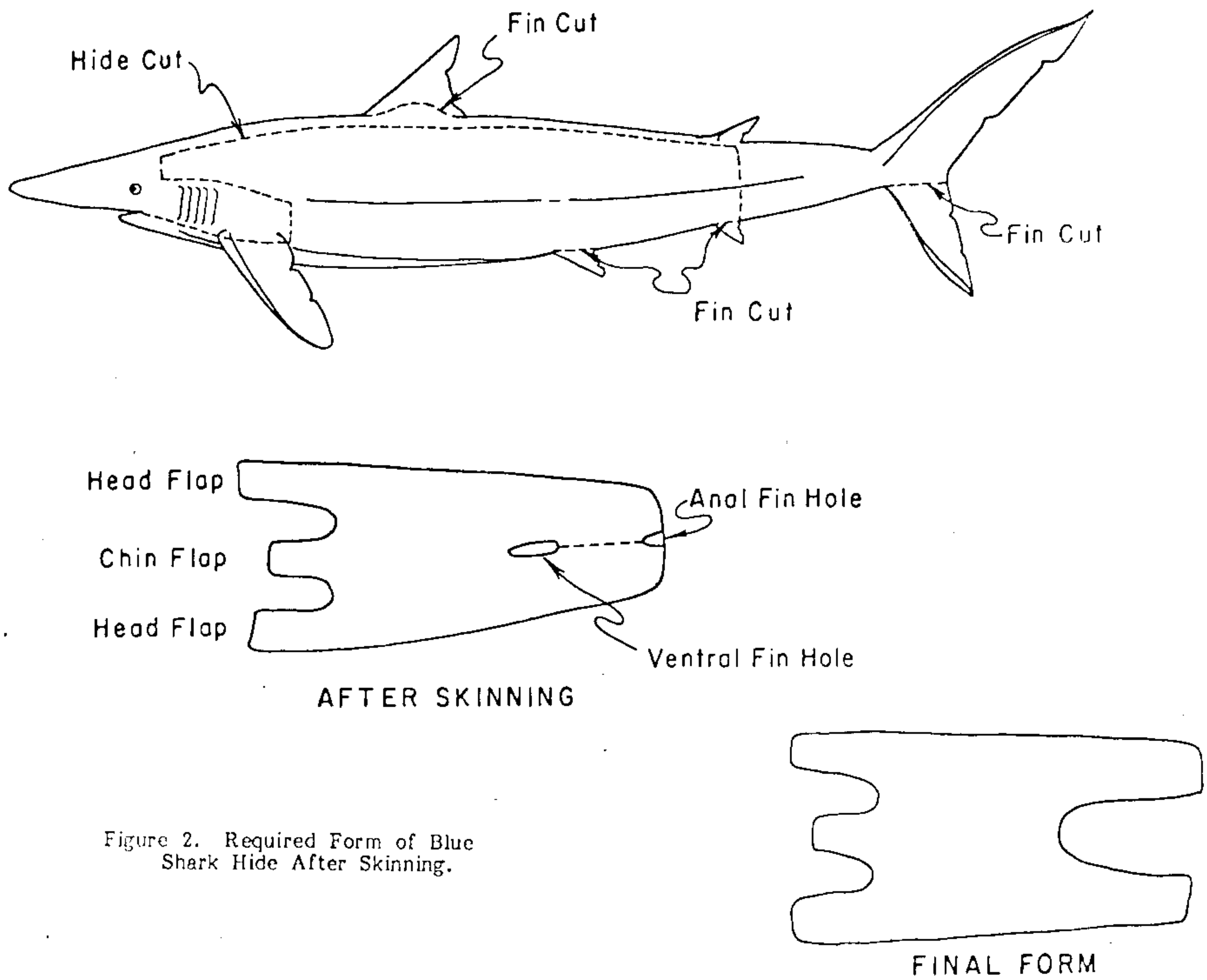


Figure 2. Required Form of Blue Shark Hide After Skinning.

water without causing wrinkles. They must be fleshed (excess meat removed), salted or pickled to preserve them, and packed for shipment.

To successfully provide blue shark products for these markets and be compatible with existing fishing techniques a shark skinning machine would have to be mounted on board ship. The shark could then be processed immediately after being caught. The shark would have to be restrained and killed prior to processing because they are capable of violent movements for up to 40 minutes after landing.

The major objective of this report was to determine physical properties of blue shark important in the design and development of a skinning machine.

EXPERIMENTAL PROCEDURES

Sample Collection and Preparation

Three frozen blue shark (Prionace glauca) were donated by the commercial fishing vessel JJ for use in these tests. Head, fins, viscera, and tails had been removed prior to shipment. Overall length of these sharks is estimated to range from 1.2 - 1.8 m (4 - 6 ft).

The carcasses were thawed at room temperature and samples of skin or flesh were cut at or near the three sections indicated in Figure 3. Samples were taken from the carcasses up to 15 cm anterior and posterior of the indicated sections, numbered 1, 2, and 3. The sample positions at these sections were further differentiated, Figure 3, into a, b, and c. Sample position "a" denotes those skin and flesh samples on the dorsal side of the horizontal skeletogenous septum. Position "b" samples were taken from the ventral side of the horizontal skeletogenous septum and dorsal with respect to the skin color demarkation line. Position "c" samples consist of the white skin covering the ventral surface of the shark and the flesh it covers. Samples were taken from either side of the horizontal skeletogenous septum because of the

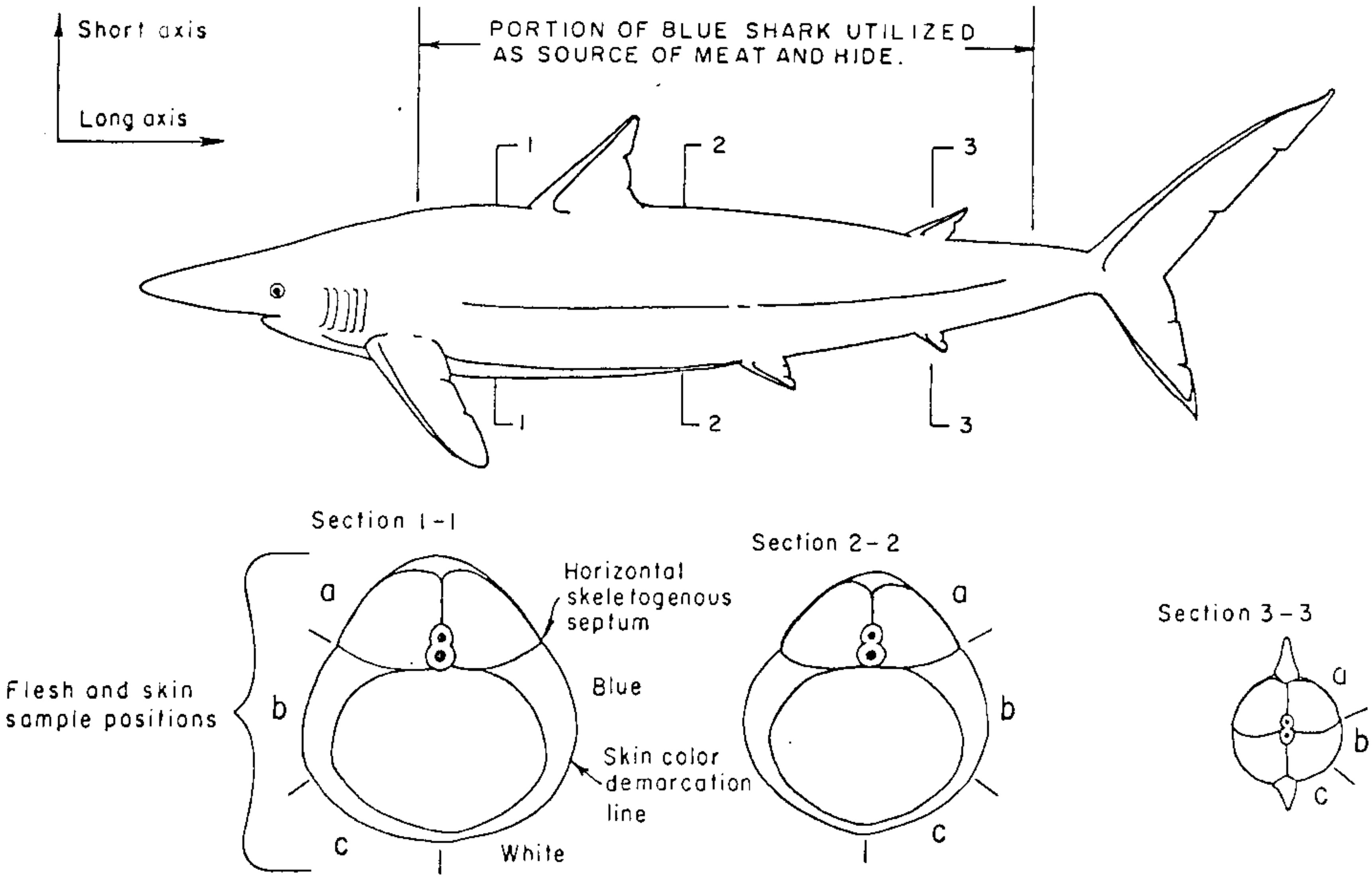


Figure 3. Sample positions used in determining physical properties of Blue Shark skin and flesh.

difficulty it caused in preparing samples.

Each shark was split longitudinally with the shark's right side used for experiments parallel to the long axis, Figure 3, and the shark's left side used for experiments parallel to the short axis. Samples of flesh and skin were cut, Figure 4 (a), (b), so that the plane of the blade of the Warner-Bratzler Shear Press, Figure 5, was parallel to the long or short axis as it applied a shear force. The tensile forces applied by the Instron Universal Testing Machine, Figure 6, to the flesh and skin samples, Figure 4, (c), (d), were applied parallel to the long or short axis. The samples used to determine the adhesive work required to separate the skin from the flesh, Figure 4 (e), were cut so that the skin was peeled back in a direction parallel with the long or short axis.

Two samples from each of the five pictured in Figure 4 were taken from each section and position on the three shark carcasses, with the exception of the flesh tensile tests. Because of the thin cross section of the shark flesh and the adherence of the Pleuroperitoneal cavity membrane at c, and the "grain" of the meat at position a, flesh tensile samples were difficult to prepare.

Apparatus and Measurements

Tests to determine tensile strength and breaking elongation (ultimate elongation) of blue shark flesh and skin and the work required to separate the skin from the flesh, adhesion work, were performed on an Instron Universal Testing Instrument (Model TM-M, Instron Engineering Corp., 2500 Washington Street, Canton, MA 02021). The instrument was operated in a tensile mode with a cross head velocity of 50 cm/min, with a chart speed of 100 cm/min, a 50 kg tension load cell, and jaw type fixtures.

A Warner-Bratzler type shear press, Figure 5, was used to determine the shear strength and shear work of blue shark flesh and skin. The shear blade

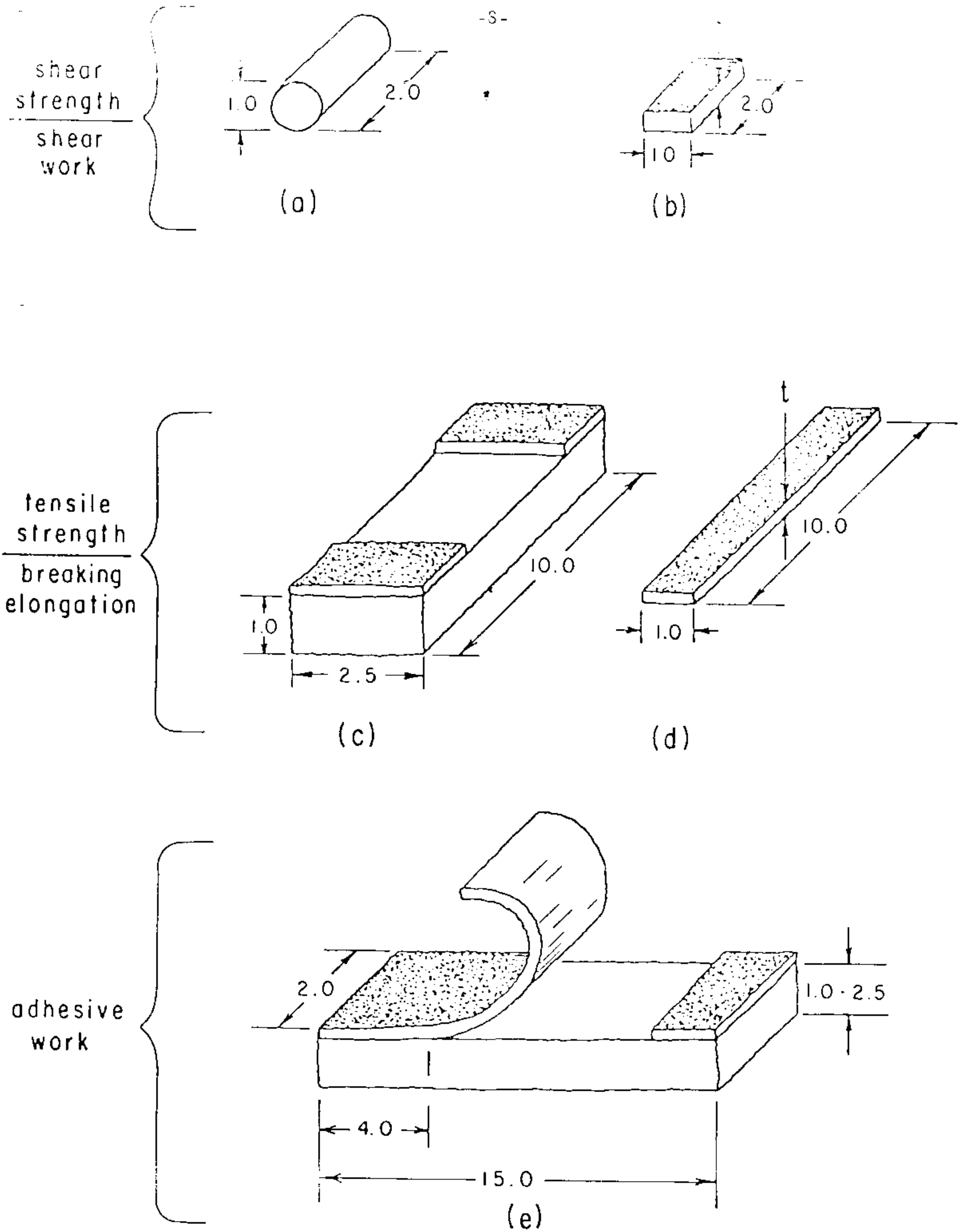


Figure 4. Sectioning of Blue Shark samples: (a), (c) flesh, (b), (d)

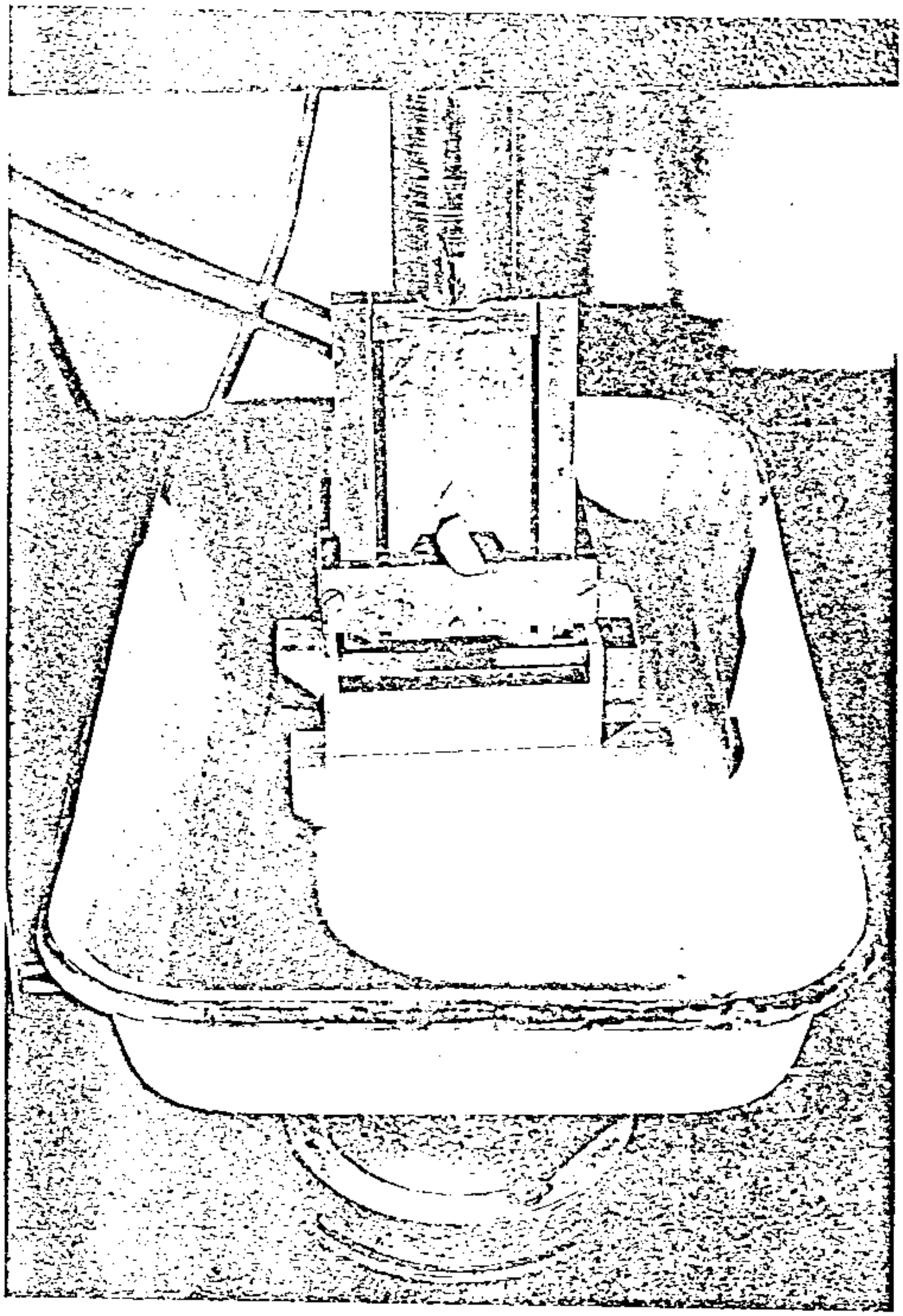


Figure 5. Warner-Bratzler Shear Press and sample of Blue Shark flesh.

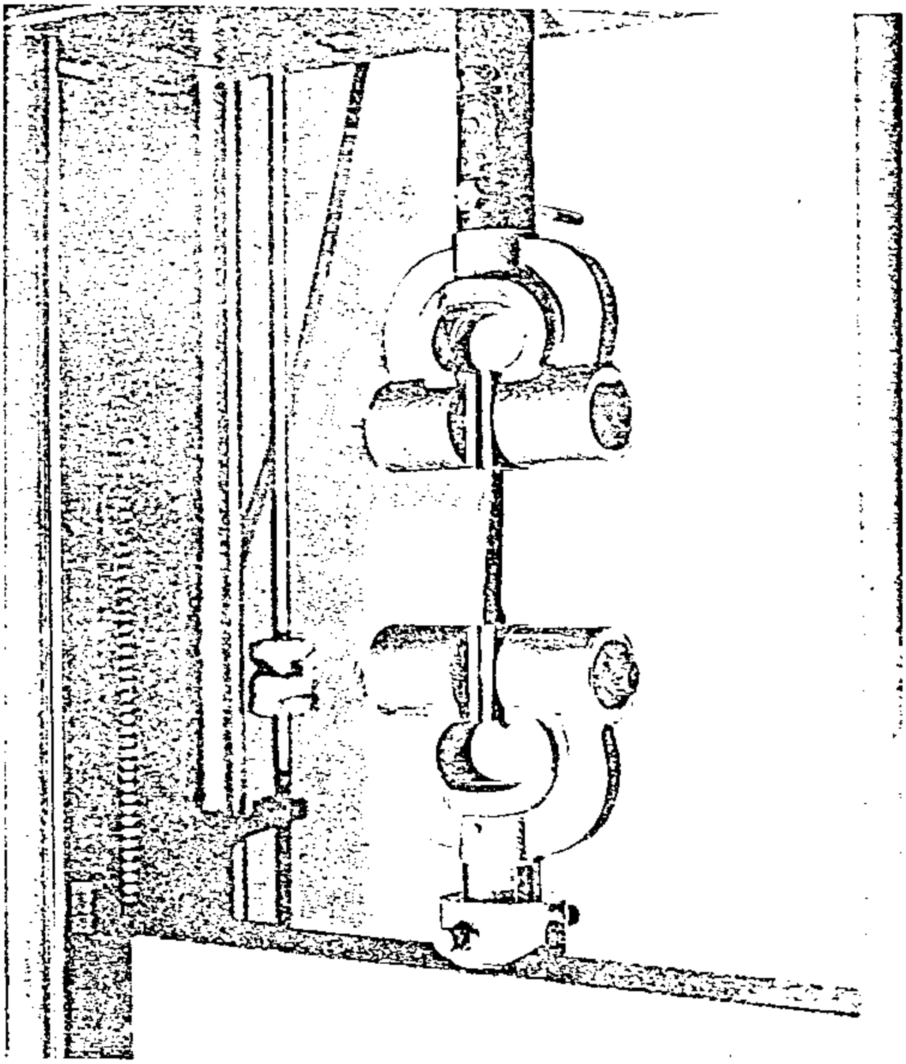


Figure 6. Tensile test of Blue Shark skin mounted in jaws of Instron Universal Testing Machine.

was mounted in the crosshead of the Instron Testing Instrument and the anvil, against which the blade shears the shark samples, rests on the Instron's 50 kg compression load cell, Figure 5. Crosshead speed remained 50 cm/min and chart speed 100 cm/min. The equation used to calculate shear strength, S, for this type of double shear is described by Mohsenin (1968):

$$S = \frac{F}{2A}$$

where F is the maximum force recorded by the Instron, Figure 7 (b), and A is the cross sectional area of the shark sample.

Tensile strength and breaking elongation of flesh and skin were measured with the samples of skin and flesh held in the jaw fixtures, Figure 6. The crosshead moved upward until the sample ruptured. The maximum force was recorded for calculation of tensile strength, and the distance the crosshead traveled for calculation of breaking elongation. A schematic representation of the Instron output is shown in Figure 7 (a).

Adhesive work was determined by performing a modified T-peel test (ASTM D1876-61T). The shark peel specimens are seen in Figure 4 (c) and in the jaws of the Instron in Figure 8. With the Instron in a tensile mode the crosshead moves upward peeling the skin from the flesh. Figure 7 (c) gives a schematic representation of the Instron output for the adhesive work tests.

RESULTS AND DISCUSSION

Tensile Strength and Breaking Elongation

The range of recorded values for tensile strength of blue shark skin, Figure 9, was found to be 2 orders of magnitude greater than the tensile strength of the flesh at sample position b, Figure 10. The tensile strength of the skin ranged from 3 to 13 MPa.* No significant differences appear for tensile strength of skin with respect to section (1, 2, 3) or axis (long, short).

*For definitions of units of measurement see Appendix A, page 25.

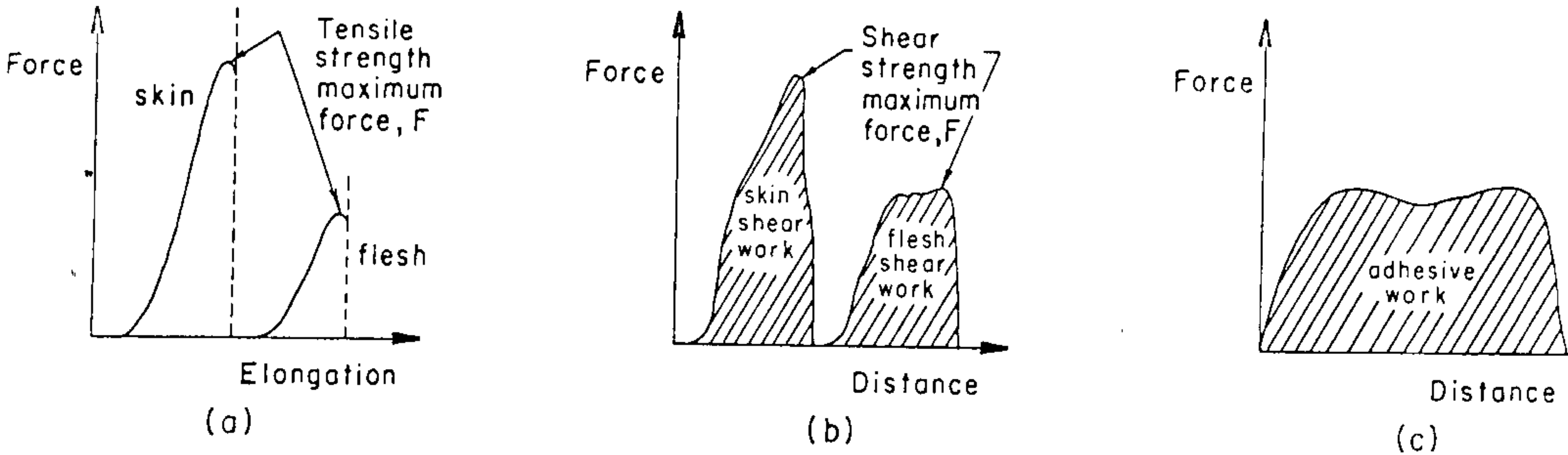


FIGURE 7. SCHEMATIC FORCE-DISTANCE CURVES FOR (a) TENSILE, (b) SHEAR, AND (c) ADHESION TEST.

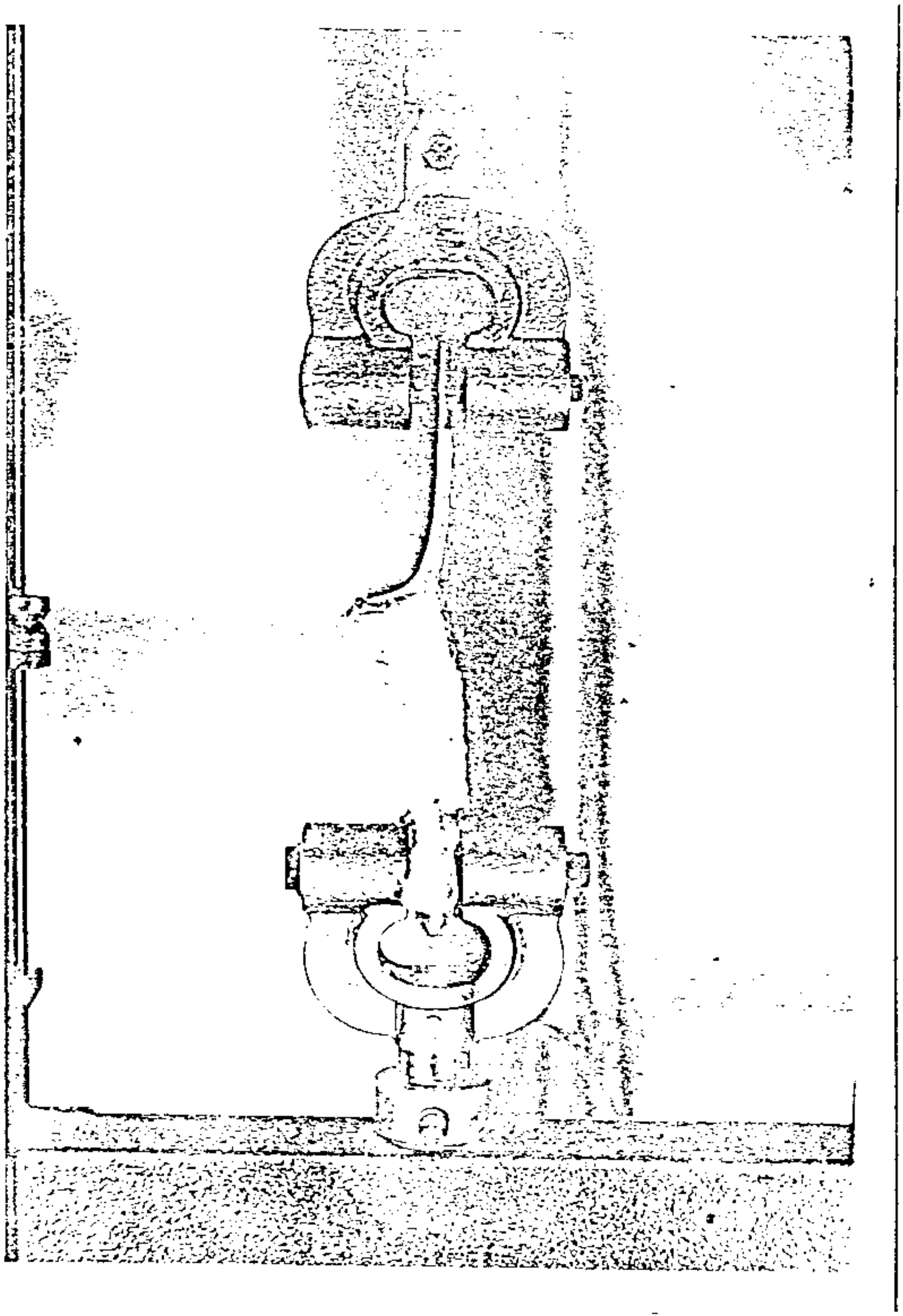


Figure 8. Blue Shark sample ready for adhesion testing in Instron Universal Testing Machine.

The tensile strength of shark skin at sample position c does tend to be higher than those for positions a and b. This is despite the fact that the skin at position c, the white skin covering the shark's ventral surface, is quite thin and supple.

Breaking elongation of blue shark skin varied from 70 to 240%, Figure 9. The majority of skin samples tested stretched over 100% before breaking. Breaking elongation of blue shark flesh at position b, along the long axis, ranged from 20-100%, Figure 10.

Shear Strength and Shear Work

Figure 11 and Figure 12 show the range of shear strength and shear work recorded for skin and flesh respectively. Using a Warner-Bratzler shear press, the shear strength of the blue shark skin, 1.5-12.5 MPa, was found to be 10 times greater than that of the flesh, 30 to 600 kPa (Kilo Pascal). The shear strength of the dorsally located skin, position a, tended to be less than that for the ventral surface, position c. Because of the greater thickness of the skin at position a, the dorsal area, the range of values recorded for shear work, 2-6 J, have the tendency to be higher than those for position b, 1-4 J, and the ventral surface, position c, 0.5-4.5 J. Little variance was found in shear strength or shear work of skin with respect to section or axis direction.

The range of shear work recorded for blue shark skin, 0.5-6.0 J, was almost 3 times greater than that for flesh (0.01-2.2 J).

Adhesive Work

The range of values recorded for adhesive work, pulling skin from flesh, in the blue shark samples tested was 0.2-3.2 kJ/m^2, Figure 13. The highest values recorded occurred when peeling the skin covering the tail of the shark, section 3, parallel with the shark long axis. In general, the adhesive work

FIGURE 9. TENSILE STRENGTH AND BREAKING ELONGATION OF THAWED BLUE SHARK SKIN
(Instron Universal Testing Machine)

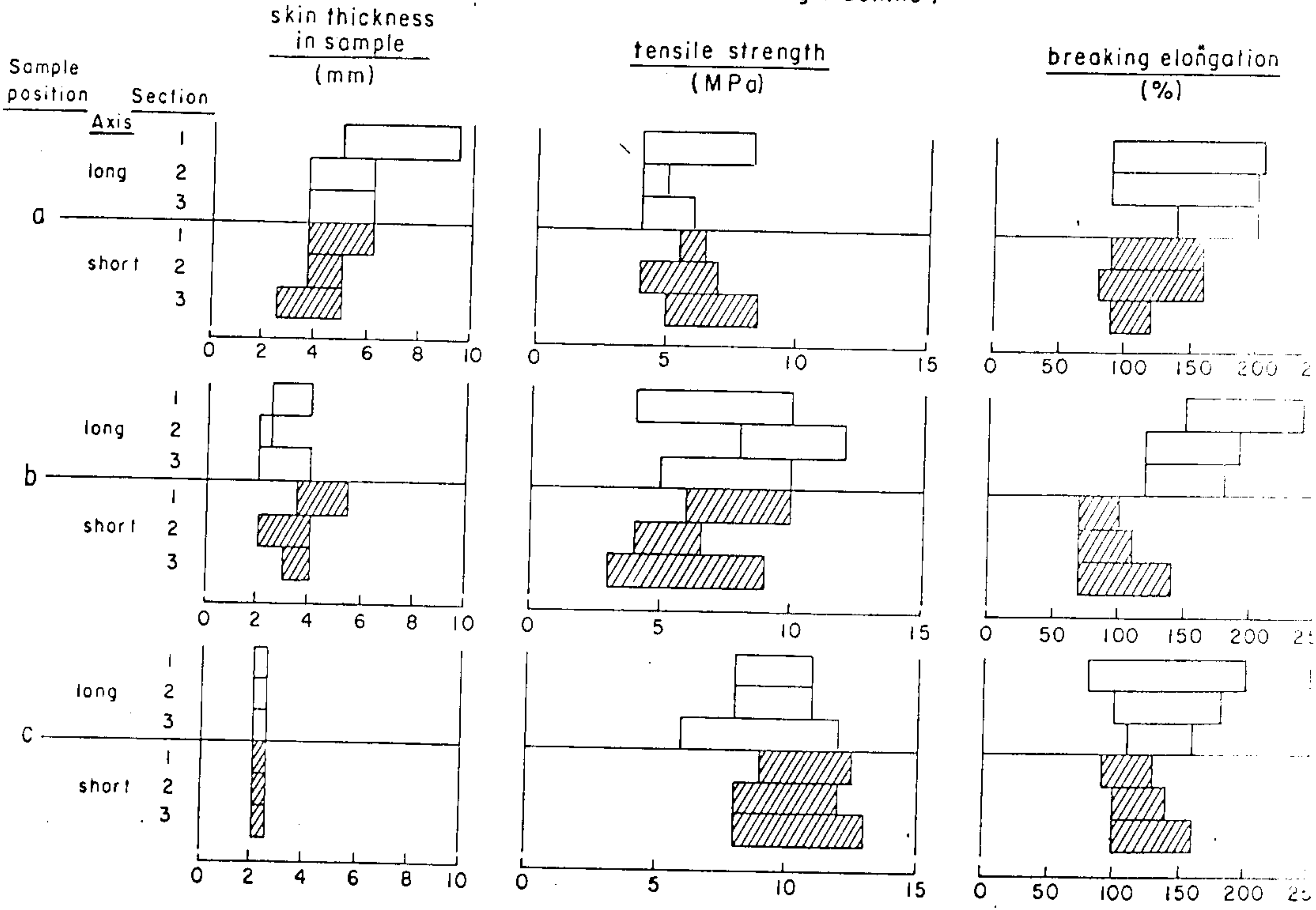


FIGURE 10. TENSILE STRENGTH AND BREAKING ELONGATION OF THAWED BLUE SHA FLESH

(Instron Universal Testing Machine)

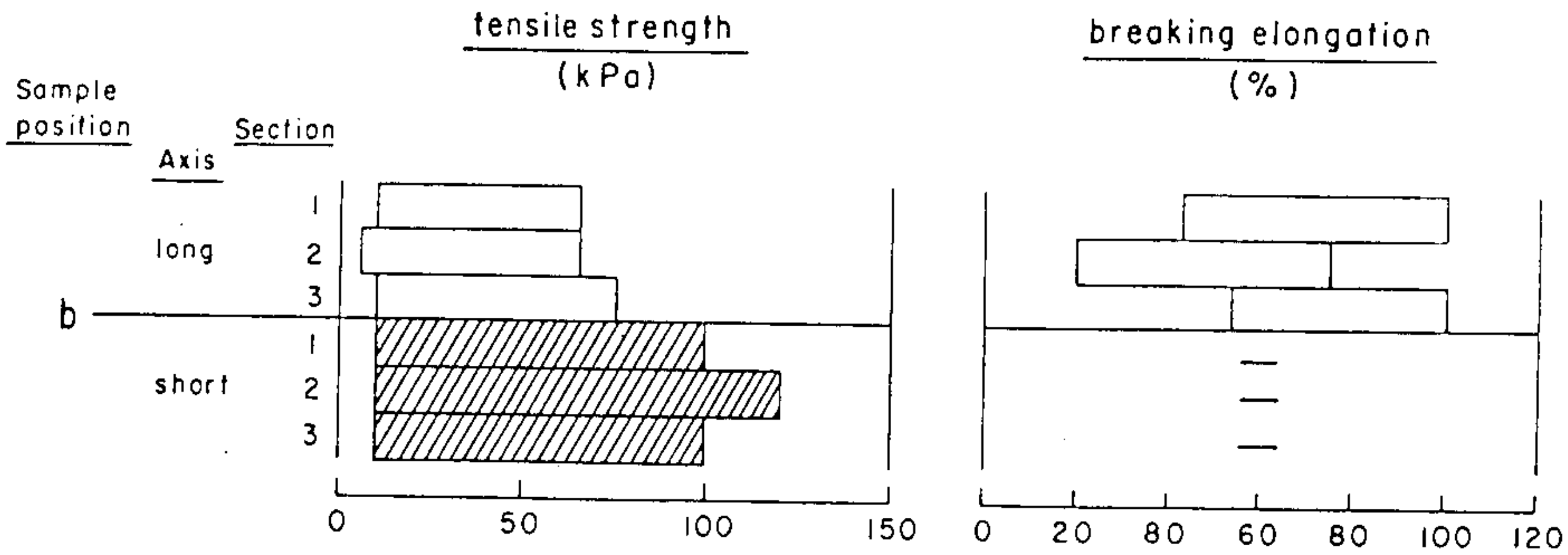


FIGURE 11. SHEAR STRENGTH AND SHEAR WORK OF THAWED BLUE SHARK SKIN
(Warner-Bratzler Shear Press)

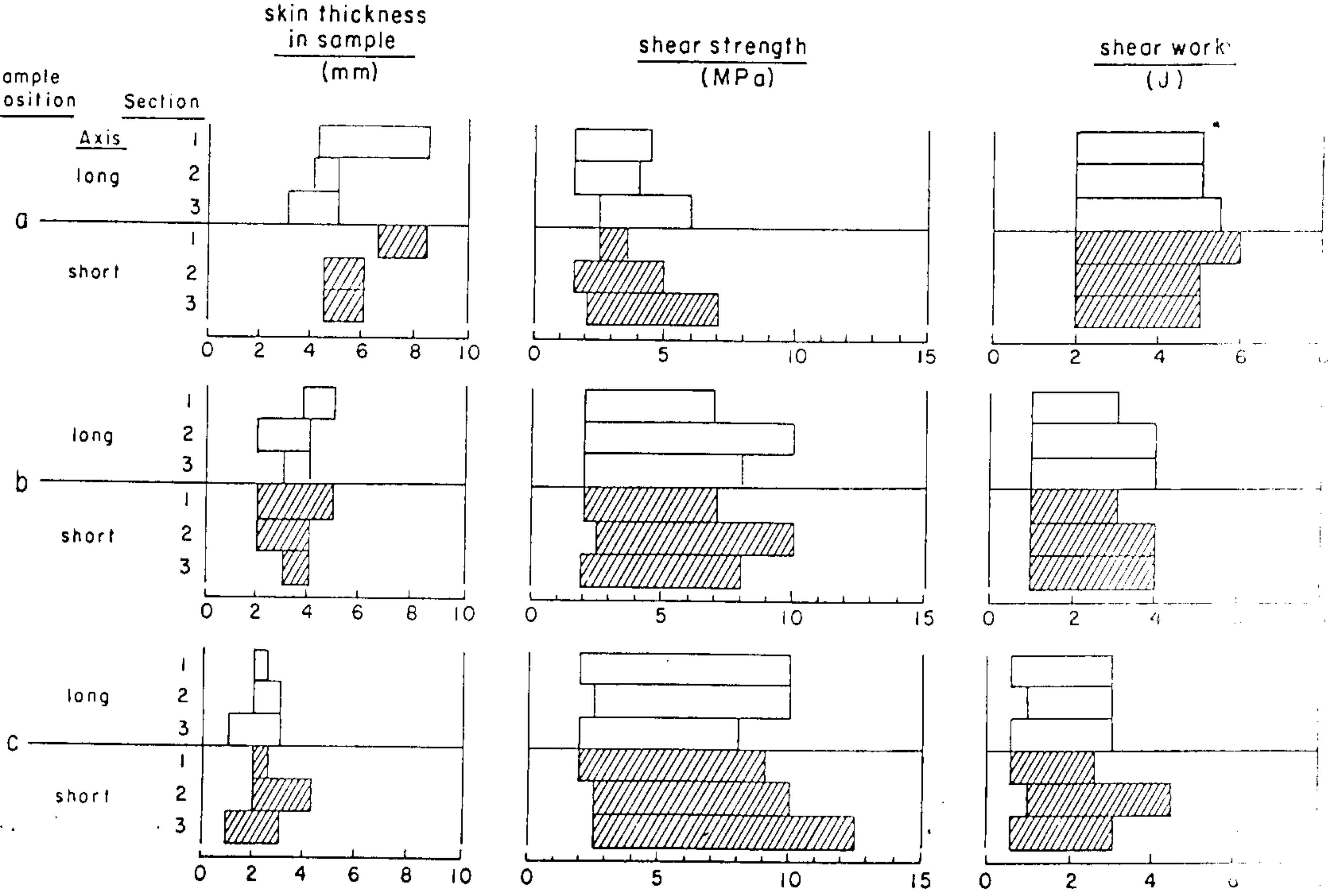


FIGURE 12. SHEAR STRENGTH AND SHEAR WORK OF THAWED BLUE SHARK FLESH
(Warner - Bratzler Shear Press)

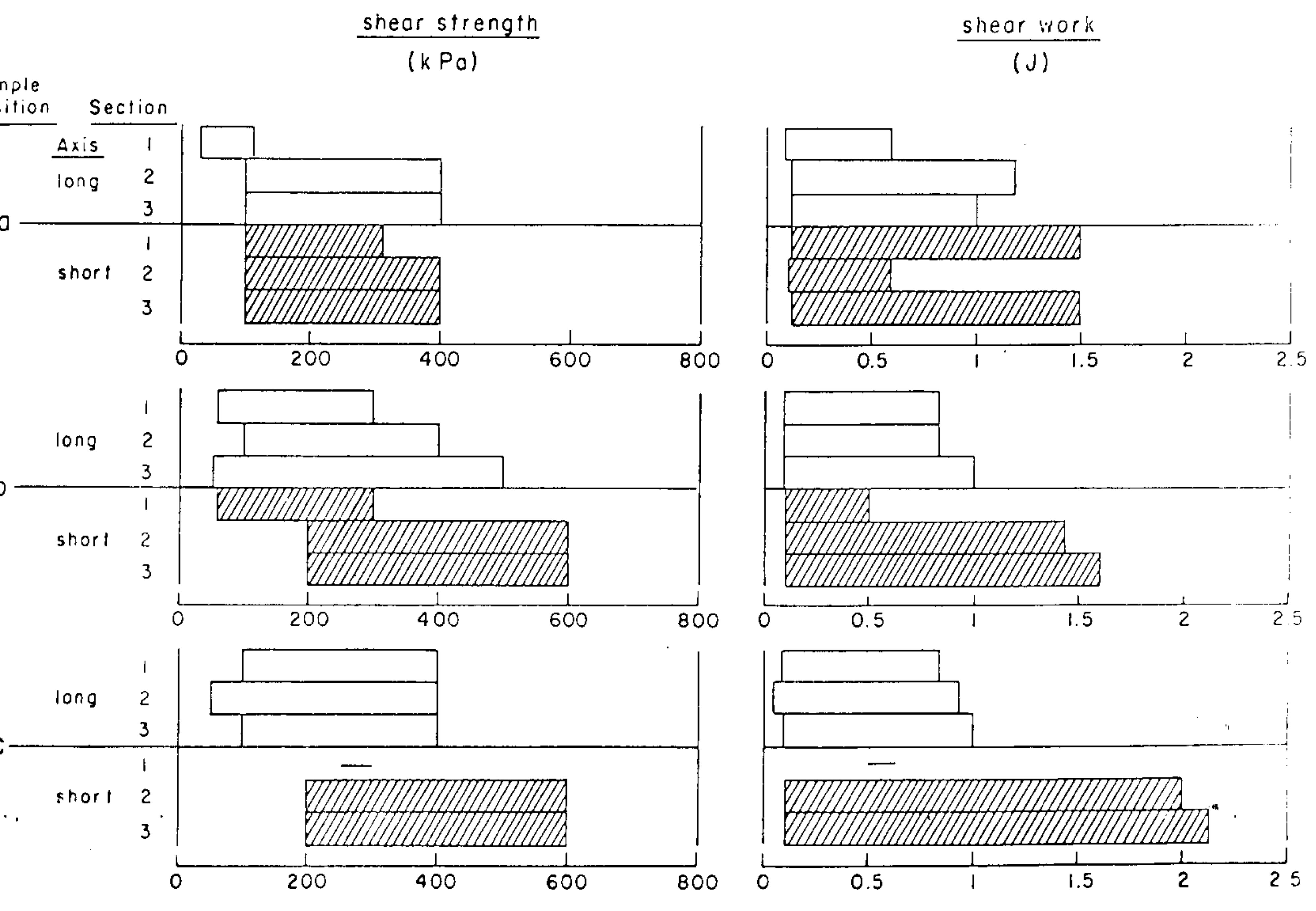
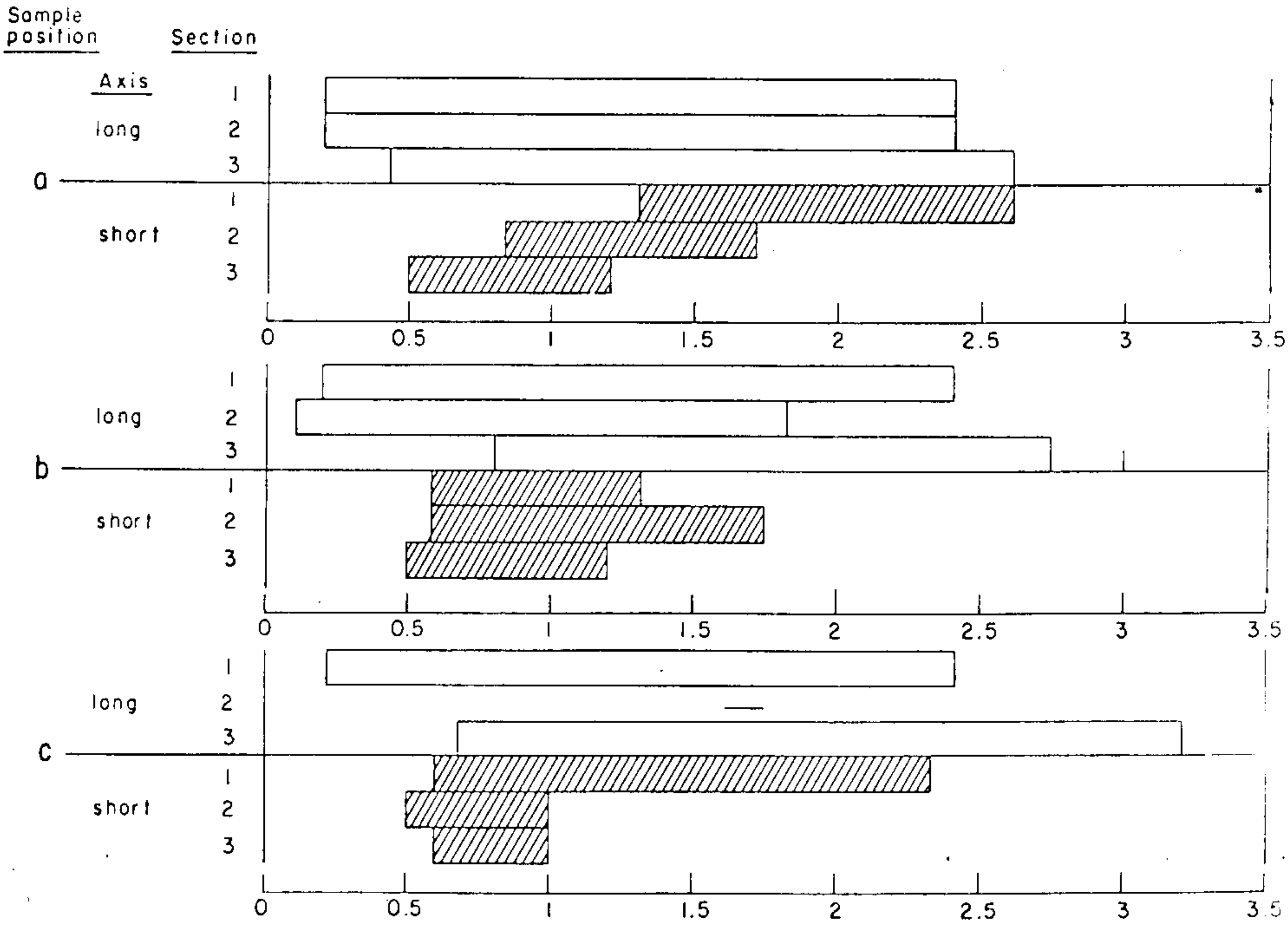


FIGURE 13. ADHESIVE WORK REQUIRED TO SKIN THAWED BLUE SHARK

(Instron Universal Testing Machine)

(kJ/m^2)



for the short axis tests was lower. Elongation of skin during peeling was negligible. These two facts could be of some advantage when skinning the shark in the manner to be proposed.

CONCLUSIONS AND PROPOSED DESIGN OF SKINNING MACHINE

As was noted, the adhesive work required to skin blue shark for the short axis tests was lower than that for the long axis. It was also observed by the authors that the amount of meat remaining on the skin after the peel tests for short axis was less than that for the long axis. Also, the amount of meat remaining after the peel tests was also lower than that left when the sharks are skinned with a knife, paring the skin away from the flesh manually. If the skins are pulled, parallel to the short axis, from the shark, it would make it easier to "flesh" the hide once it was removed. These observations, plus the requirement by shark hide processors that no "butcher cuts" be made in the hide, make it advantageous to peel the skin from the shark rather than cut it away from the flesh.

The authors envision a machine, on board ship, which would restrain the shark by means of a row of pneumatic or hydraulically driven gaffs mounted on a rigid beam. These would penetrate the dorsal surface of the shark, after removal of the dorsal fin, and into the spine, skull, and brain. The spine and skull of sharks is cartilaginous and would be easily penetrated. This would effectively kill the shark and reduce the nervous activity and movements of the shark (Nelson, 1980) which would interfere with the skinning process and hide quality. Although the hide has been ruptured on the dorsal side, the form of the hide desired is still intact. The caudal and pectoral fins could then be removed and saved. The tail is then severed and the shark is bled.

It was found that a hand operated knife used to cut open deer carcasses for gutting, by cutting from the inside, was successful in making a cut the full length of the shark on the dorsal side of the carcass. This knife, called a Field Dressing Knife, is manufactured by Wyoming Knife Corporation, Casper, Wyoming, 82601. A knife of this type could be mechanically operated to follow the row of restraining spikes proposed above along the dorsal ridge of the shark starting the skinning process. This hide cut, Figure 2, is made on the left and right hand sides of the dorsal ridge as close to its apex as possible. Because of the toughness of the hide replaceable or disposable blades would be required.

Skin grippers of the type commercially used to manually remove strips of skin from dogfish sharks (Atlas, 1978) could be modified to grip the blue shark skin at the incisions along the dorsal ridge described above. Cables attached to these grippers could then mechanically pull the skin away from the flesh, around to the ventral side, and off the carcass. The hide could then be fleshed and trimmed to the form of Figure 2. The carcass would then be gutted and put in cold storage.

However, the horizontal skeletogenous septum (Figure 3) may have to be severed from the inside of the skin. The adhesive work required at its point of attachment to the skin was found to be 2-3 times that at other points on the body. The shear work required to sever it is approximately equal to that for the skin on the dorsal surface. Perhaps the Field Dressing Knife recommended to cut through the skin at the dorsal surface could be reinserted to make the cut along the horizontal skeletogenous septum. This type of knife would minimize the risk of making "butcher cuts" in the hide.

The authors conclude that a machine could be built to pull the skin from the blue shark in one piece, as a commercial means of skinning the shark, by pulling from dorsal to ventral surface, parallel with the short axis.

SUMMARY

1. Tensile strength of blue shark skin ranged from 3-13 MPa and was 2 orders of magnitude greater than that of the flesh.
2. Shear strength of the skin was approximately equal to the tensile strength of the skin and ranged from 1.5 - 12.5 MPa. Shear strength of the skin was 10 times greater than that of the flesh.
3. Shear work for blue shark skin ranged from 0.5 - 6.0 J and was 3 times greater than that for the flesh.
4. The adhesive work required to peel the skin from the flesh of blue shark ranged from 0.1 - 3.2 kJ/m^2. Less work was required to peel the shark parallel with its short axis.

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8. Nelson, Donald R. Personal communication, 1980. Professor of Biology, California State University, Long Beach, CA. February 13.

APPENDIX

Company	Interest expressed in marketing the following blue shark products:
Daimaru Kogyo Kaisha, Ltd. 10-9, 2-Chome, Ginza Chuo-ko Tokyo 104, JAPAN	(meat, fins)
Inoue & Co., Ltd. Foreign Trade Dept. 5-1, 2-Chome, Kaminarimon Taito-ku, Tokyo, JAPAN	(hide)
Nozaki & Co., Ltd. Business Administration Dept. 16-19 Ginza 7-Chome, Chuo-ku Tokyo, JAPAN	(meat, fins)
Kasho (USA), Inc. One California Street Suite 1110 San Francisco, CA 94111	(meat, hide, fins)
M. Hirasawa, Inc. Import Department Tokyo Window Bldg., 6-8 Kuramae 4-Chome, Toito-ku Tokyo 111, JAPAN	(meat, hide, fins)
Kaiko, Inc. 6F Naka Bldg. 14-17, 2-Chome Tsukiji Chuo-ku Tokyo 104, JAPAN	(meat, fins)
Kobe Yoko Ltd. 9th Floor K.I.M.M. Bldg. 4-2-8 Isobe-Dori Furiai-ku Kobe 651, JAPAN	(fins)
International Marine Products Co. 1-17, 4-Chome Tsukiji Chuo-ku Tokyo 104, JAPAN	(fins)
Mitsui & Co., (USA), Inc. One California Street, Suite 3000 San Francisco, CA 94111	(hide, fins)
Fuso Trading Co., Ltd. Naka Bldg., 14-17 2-Chome Tsukiji Chuo-ku Tokyo 104, JAPAN	(hide, fins)

APPENDIX A

UNITS OF MEASUREMENT

ENERGY (Work)

J = joule = N•m = newton meter

PRESSURE OR STRESS (force per area)

Pa = pascal = N/m^2

MPa = megapascal = pascal • 10^6

kPa = kilopascal = pascal • 10^3

FORCE

N = newton = kg • m/s^2

MASS

kg = kilogram = 2.2 pounds

LENGTH

m = meter = 39.37 inches