MECHANICAL ASPECTS OF THE SINGLE-PIECE CURVED SHELL FISHHOOK

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The curved shell fishhooks which appear in California, Polynesia, and elsewhere have received a great deal of primary and secondary interest in the literature. Descriptions of the outward appearances of the hooks have led observers to conclude culture contact purely on form and materials (Ekholm 1950:350; Covarrubias 1954:67), and unusual methods of transportation have been postulated (Heizer 1949). Neither the form nor the materials have been investigated in a systematic manner; nor have the mechanical functions of the hooks received scrutiny. This paper will investigate the structure and function of this type hook and certain aspects of its distribution in order to place the problem of diffusion in perspective.

The form of the curved shell fishhook has been variously described as "C" shaped, circular (Heizer 1949:93), and "U" shaped (Buck 1932a:203). Each of the above describes the pervading curved nature of the hook. For this paper, a single-piece curved shell fishhook will be any fishhook made of one piece of shell where a line may be drawn on the average vector of the point to intercept either the shank or some other portion of the hook.

The descriptive analysis of the parts of the single-piece curved shell fishhook used here is suggested by Buck (1932:202-203) and modified for general application. (See Figure 1.)

The functions of a fishhook may be described in three general areas:

1. The attraction of the fish to the hook
2. Setting the hook in the body of the fish
3. Holding the fish from escaping

These functions will be considered separately below.

Hook Attraction

Hooks are designed either to carry bait or to attract fish by means of a lure. Most fish attraction seems to be based on some property of food, and the lure may resemble some visual quality of food. From observations made of feeding habits in aquariums, it would seem that fish estimate the palatability of materials in their mouths after only one other external cue such as shape, thus making fishing with hook and line feasible.

The shell fishhook without augmentation has the property of a lure (Linton 1926:26). Most of the hooks found by Harrington (1928) in a California site were of <u>Haliotis</u> <u>cracherodii</u> (black abalone) and <u>H.</u> <u>rufescens</u> (red abalone). One side of the shell is iridescent and the other side is colored. Similar shells such as <u>Pinctada</u> <u>gltsoffi</u> (pearl oyster) in the Pacific and <u>Aetheria</u> (Nile oyster) of Egypt and the Sudan have the above qualities and have been used for the manufacture of single-piece shell fishhooks.

Attention is paid to both sides of the hook. The dull side of the hook may be ground to remove any or most of the colored portion leaving necre

(Beaglehole 1938:199). The dull portion may be ground to give a desired shade of color. Buck (1932b:174) describes the process of grinding the shell for the proper color and placing the shell in water to judge the correct shade. Certain shells from certain localities in Polynesia were sought for color and shade. Conditions of weather, time of day, and the feeding practices of fish determine the color of the lure (Buck 1932b:175).

Shell fishhooks were also used with bait. Buck (1938:293) reports that they were baited with shellfish in Mangareva. While the bait of aboriginal California, South America, Egypt and Shaheinab is unknown, it may be that the hooks were baited with similar materials, if bait was used.

The curved shell fishhook is used as a lure, a bait carrier, or both. It would seem likely that most groups using this type hook would use both qualities of the hook for the added certainty involved. This combination of characteristics makes this type of hook more versatile than the hook with which only bait is used--an important consideration when subsistence is geared to the sea.

Hook Setting

The process of securing the fish once the bait or lure has been taken into the mouth presents an intriguing problem. Some of the curved hooks have clearance of only 5 mm. from the point to the shank limb (Harrington 1928:23-168). While it is easier for a fish to take a hook with a wide point clearance, it is also easier for the fish to escape the hook. It takes the fish longer to force his jaws over the narrow point clearance, but it is more difficult to expel it (Buck 1932b:168).

Once the hook is in the mouth of the fish, it must be so designed that the fish cannot escape. It was found that "the greatest penetration power of the hooks occurs when the line of penetration is coincident with the direction of the force applied" (Gakrulson 1956:120). With the hook resting at the end of the line this presents no problem, for the point of the hook is 180° to the fish line. The point is then coincident with the direction of force which would be away from the pole. A hook under pressure from a fish striking the bait pivots at the point of attachment reducing the angle of penetration. (See Figure 2.)

The decline of the angle of penetration is in direct proportion to the ratio of the shank limb to the point limb. When the two limbs are parallel and of equal length, and the length of the bend is equal to the length of the point limb, the angle of penetration is 90°. At no time can the ideal angle of 180° be reached when the shank limb is parallel to the point limb and the point of attachment has a flexible line attached. (See Table 1.) With modification of the point limb or shank limb or both, this ideal angle is achieved or closely approximated. The range of degrees included in the most efficient angles cannot be determined experimentally, but the closer the angle is to 180°, the more efficient the hook; conversely, the more the angle is to 90°, the less efficient the hook.

The curved shell fishhook modifies either the whole hook or the point limb. Figure 3 represents a functional model of the curved hook without pressure being applied. The point is incurved to the line and gives an angle greater than the ideal angle of penetration. The same hook under pressure applied at the point pivots and reduces this angle to near the ideal. The effective shank limb is equal in length to the point limb. Thus the approximation of the ideal angle of penetration is achieved through the incurve nature of the point limb. (See Figure 3.) A modification of the point limb would be unsuitable for certain types of fishing. Where the fish strikes on the run at a moving object, the portion of the hook most likely taken is the bend. If the bend of the curved shell fishhook is taken and the point limb is incurved, the point would be functionally covered by the point limb. The point limb of the bonita hook (see Figure 4) is either parallel to the shank limb or slightly outcurved while the shank limb is incurved allowing for the maximum angle of penetration. (See Figure 4.)

In summary, the curved shell fishhook can only be used in certain situations. Ethnographically, they have been used as surf, boat, and rock fishing. They seem to be designed for a fish that explores the bait and ferrets portions of food in inedible matrices.

There are three methods of presenting the point of any hook for the most effective angle of penetration. They are:

1. a long shank
2. an incurved point
3. an incurved shank

The curved hook is designed so that the hook will set even though the shank is short.

Hook Holding

Once the hook is set in some portion of the fish, the function of the hook is to hold the fish so that it may be retrieved. This function may be augmented by either the addition of some auxiliary mechanism such as a barb, through the action of the fisherman, or by the nature of the hook form. In any of the above cases, if the hook is lodged in the gut of the fish, the problem of holding is solved.

With the bonita hook, the forward motion of the boat keeps the line taut so that it is difficult to throw the hook.

With a stationary line, the problem is compounded by the tendency of the fish to resist the confinement of the line. Some fish run with the line; others jump and flail and try various motions to dislodge the hook.

Barbs are placed on the hook to inhibit the fish from working free. Some of the curved shell fishhooks have barbs, most do not. After the hook is set, force from the line or force from the fish to free himself generally results in the fish passing down the point limb and resting on the bend. The barb is usually placed just below the point to inhibit the upward movement of the fish.

The shank plays an important part in holding. If the shank is too long, the point of attachment forms a fulcrum when the fish applies pressure from various angles and acts as a lever to free the fish. A short shank does not provide leverage to the same degree. The disadvantage of the short shank in holding is directly related to the angle of penetration. When a short-shanked hook is under stress, the bite of the hook is reduced often not allowing the fish to pass down the point limb. (See Figure 2.)

The bite of the curved shell fishhook is not reduced under stress for the hook rotates on the axis of a circle. After the hook is set, the resting equilibrium is regained bringing the point over the bend. Since there is little shank to provide leverage for movement of the hook, the fish is firmly secured.

This rotation of the shell fishhook has the added advantage of not placing the pressure of the strike totally on the hook, but rather on the fish line at the point of attachment. Pressure is not on the hook until it is fully set and the fish has descended to the bend; then only that portion of the hook from the bend to the point of attachment which receives pressure is reduced. Because of the brittle nature of the shell material, this reduction in the hook area receiving stress is important.

All but a small percentage of the single-pieced shell fishhooks examined were curved. An exception to the curved shape was found in the Marquesas (Linton 1923:1, LXXI). The point is not incurved and the length of the shank limb is 50 percent to 100 percent greater than the point limb. This hook appears to be thicker than the incurved ones found in the same area. Apparently this thickness is related to the absence of the structural advantage found in the curved hooks.

Materials

The properties of the materials used in the manufacture of fishhooks are, ideally, the following:

1. strength
2. resilience.

Shell, bone, wood, thorns, stone, ivory, turtle shell, and coconut shell constitute the major materials used in the manufacture of single-piece curved hooks. Only shell and stone lack both properties of strength and resilience.

While some of the curved hooks from California were made from the cross sections of the long bone of deer (Harrington 1928:23 *et passim*), most are of shell.

Poverty of materials may be used as an argument for the selection of shell for fishhooks in some areas of the Pacific, but this argument would not hold for California, Egypt, South America, or the Sudan. Each of these areas use shell for the majority of the fishhooks during one period and each has an abundance of wood and large-boned animals. Seemingly, the lure quality of the shell was the factor in its selection.

From the measurements of 126 whole and partially curved fishhooks of *Haliotis* taken from the Burton Mound in Santa Barbara, California (Harrington

1928:90-130), it was found that the average width was 5 mm. and the thickness was 2.5 mm. It was noted that the bone hooks in the same site fit in all measurements into the distributional curves of the shell hooks. (See Table 2.)

A strength of materials test was made on *H. rufescens* of 5 mm. thickness and varying widths. At 2.5 mm. the material would shear 9.75 kg. applied 5 mm. from the fulcrum. The amount of pressure needed to break the shell became less as the thickness decreased and the lever became longer. (See Table 3.)

From Table 3, it can be seen that shell is a weak material and it has no resilience. This limitation of material should be reflected in the measurements of the hooks. If these relationships exist, there can be reasonable assurance in making statements to the effect that the form of the hook is partially from an appreciation of the material and is imposed by the material.

The assumption has been made that the incurved nature of the hook is related to the necessarily shortened shank; and that the shank must be shortened to insure hook strength. A partial, yet inconclusive demonstration of this is shown in the straight shanked shell hooks of the Marquesas which are characterized by thick shafts. If the above assumption holds, there should be a correlation between the total size of the hook and the width of the shaft. There should also be a correlation between the width and the thickness of the shaft. As the hook increases in size, the shaft should reflect this increased width. As the width increases, the thickness should also increase proportionately.

The data from the Burton Mound site is used for testing these assumptions. The number of complete hooks is 10; the number of partial hooks is 116 giving a total of 126 single-piece shell fishhooks.

In testing the correlation between the size of the hook and the width of the shaft, the outside total width of the hook was used to represent size. The null hypothesis to be tested is that the probability of correlation between the width of the hook and the width of the shaft will be greater than .05. That is, any regular relationship between the two could occur by chance more than 5 percent of the time. Anything less than .05 will be considered to reject the null hypothesis and accept the assumption that the width of the hook and the width of the shaft are functionally related. (See Table 4.) The formula (Edwards 1954:148) for the correlation coefficient is:

$$r = \frac{\sum x^1 y^1 - \frac{(\sum x^1)(\sum y^1)}{n}}{\sqrt{\left(\sum x^{1,2} - \frac{(\sum x^1)^2}{n}\right)\left(\sum y^{1,2} - \frac{(\sum y^1)^2}{n}\right)}}$$

The ratio between the two is .521. Using a one-tailed test of significance, the probability of the above occurring by chance is less than 2 percent. This rejects the null hypothesis. The assumption that hook size and shaft width are functionally related holds. (See Table 5.) Using the above formula, we find that the ratio between shaft width and thickness is .486 and the probability is less than .01. Thus, the assumption of the functional relationship between the width and thickness of the shaft holds.

Hook size, shaft width, and shaft thickness vary in relation to each other. A thick shaft on a small hook could occur less than 2 percent of the time; conversely, a thin shaft on a large hook has the same probability of occurrence. These relationships seem to imply an appreciation of the strength of shell and the relative pressure which various hook sizes must withstand. This further seems to imply that the thickness of the shell is directly related to the total size of the hook. The gross forms of the hook are probably directly related to the limitations of the strength of the materials.

Conclusions and Discussion

The form of the shell fishhook seems limited by materials. While the shell material offers the advantage of being a natural lure, it is brittle and lacks strength. In order to have the long point or shank limbs required for the usual type fishhook functions, the shell would have to be thick and wide--thus limiting the hook's usefulness. If the shaft is to be made thin, the lengths of the shank, the angle of penetration can only be maintained by incurving the point limb or the shank. If the shank limb is incurved and point limb is straight, the hook is more likely to break than if both limbs are curved.

Therefore, the curved nature of the shell fishhook seems to be a product of the limitations of material and of design solutions to these limitations.

The distribution of the single-piece curved shell fishhook is not restricted to one area, but rather, is world-wide. The hooks have been found in the Pacific, in North America, in South America, and in Africa (Buck 1932, Childe 1956, Harrington 1928, Bird 1943, Brunton 1937, Cole 1954). Arguments for the diffusion of the hook on the grounds of form and materials are untenable. The distribution of the hook form seems to be a product of a type of ecology and the derived technology used to exploit it.

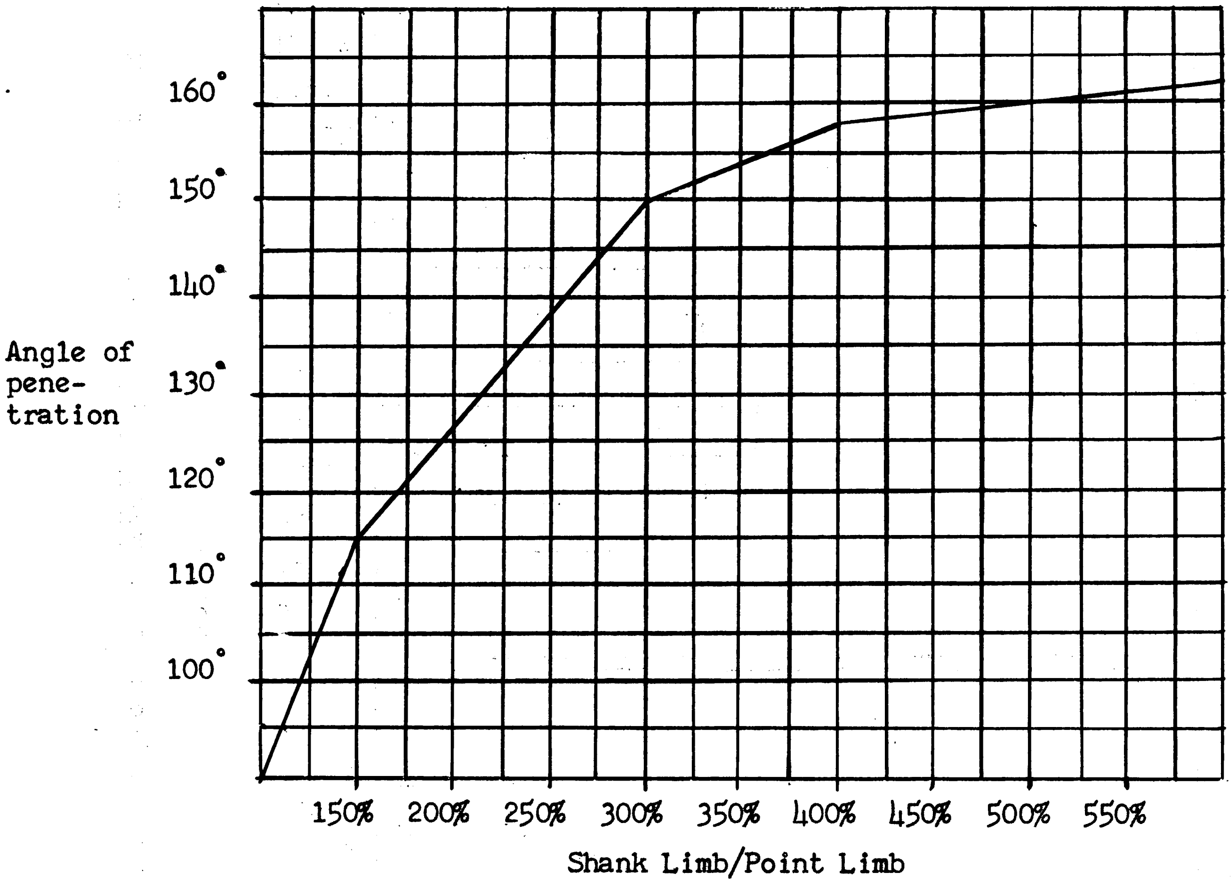


Table 1

The angle of penetration of a fishhook with the point limb and shank limb parallel and the length of the bend equal to the length of the point limb. Calculated in the percentage of the shank length greater than the point limb length.

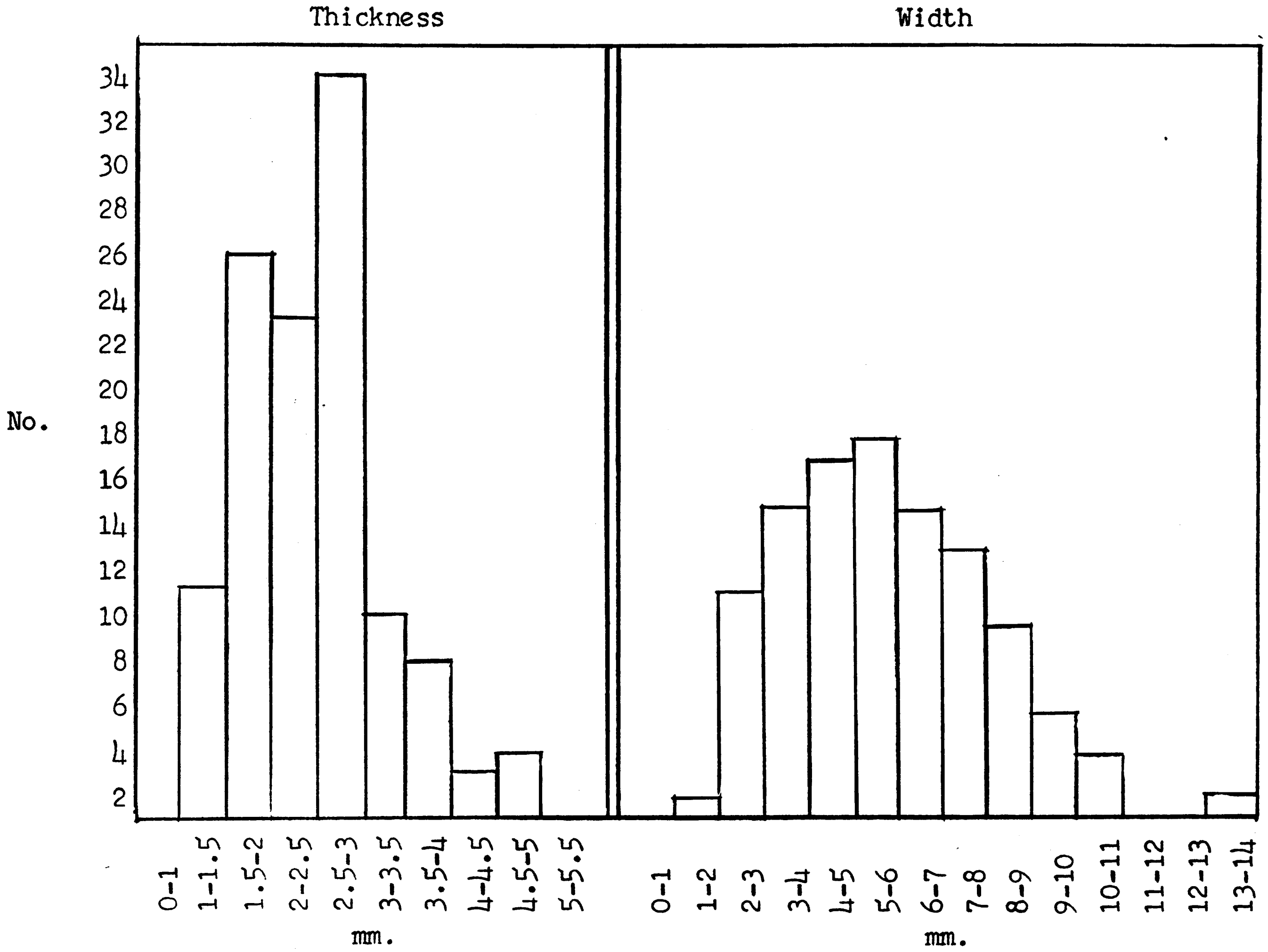


Table 2

The thickness and width of hooks of _H_. _cracherodii_ and _H_. _rufescens_ from the Burton Mound Site.

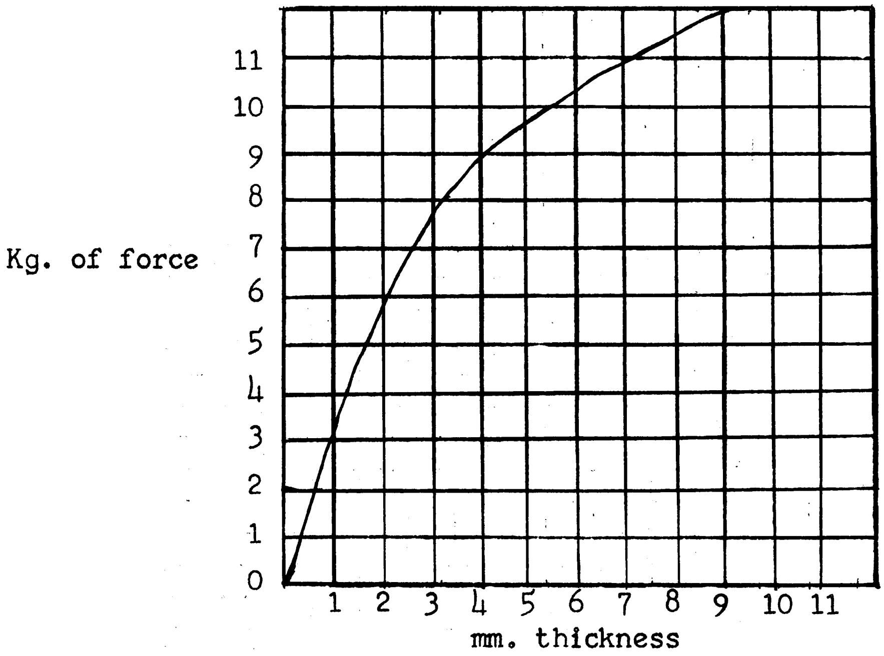


Table 3

Strength of H. rufescens of varied thickness and a width of 5 mm.

Thickness

mm.																
8																
7																
6									1							
5						2	3			2						
4				1	3	3	4	3	2							
3		2	4	8	19	7	7	5	4	3	1			1		
2		6	7	7	3	3	4	3							1	
1		1	2													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

mm.

Width

Table 4

A correlation of shaft width and thickness of 126 whole and partial fishhooks from the Burton Mound Site.

Bend width	1	2	3	4	5	6	7	8	9	10	11 mm.
mm. 32											x
31											
30											
29											
28											
27									x		
26											
25							x	x	x		
24											
23								x			
22						x					
21											
20						x	x				
19											
18											
17											
16											
15											
14											
13											
12											
11			x								

Shaft width

Table 5

A correlation table of shaft and bend widths of 10 fishhooks from the Burton Mound site.

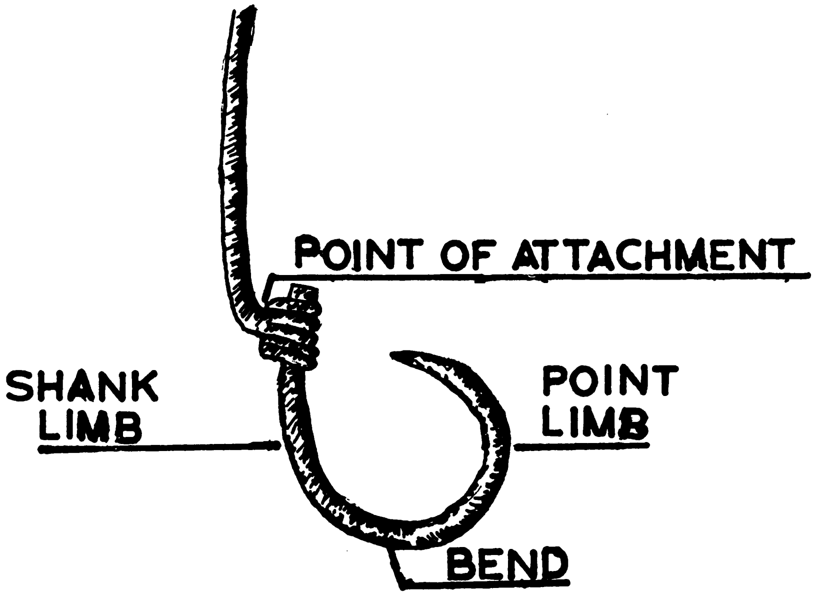


Figure 1.

Structural aspects of single-piece shell fishhooks.

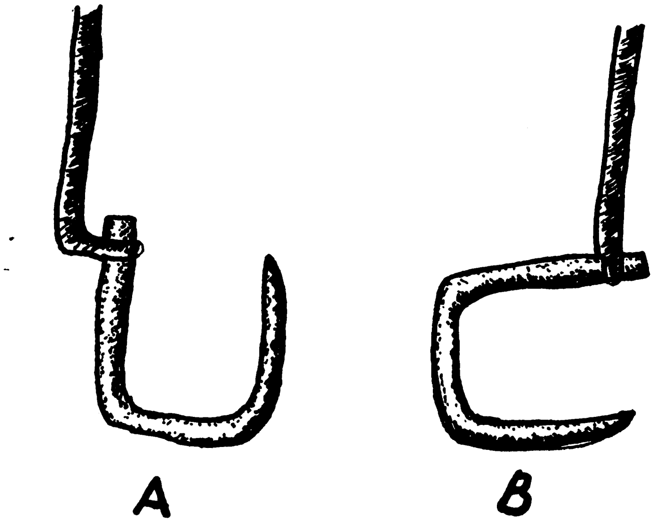
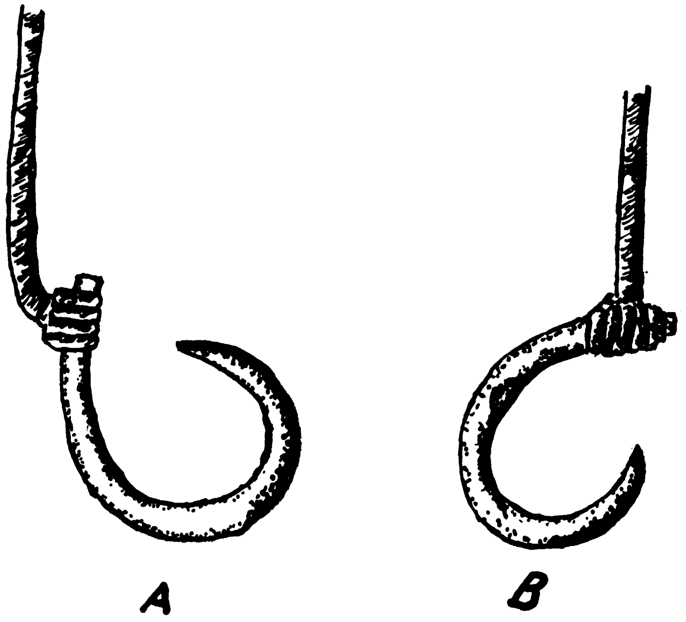


Figure 2.

Rotation of a hook with pressure applied to the point

a. Hook at rest
b. Hook under stress



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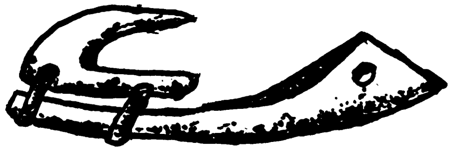

Figure 4.

A bonita hook.

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