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Home Range, Primary Home Range, Swimming Speeds and Habitat Preference of the Largemouth Bass, the Bluegill, the Yellow Perch and the Pumpkinseed as Determined Via Radio Telemetry

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by

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VITA

The author, Pamela A. Fish, is the daughter of the late Fred J. Fish and Mildred (Johnson) Fish. She was born January 19, 1958, in Evergreen Park, Illinois.

Her elementary education was obtained in parochial schools of the Archdiocese of Chicago, and secondary education at Mother McAuley High School for girls, Chicago, Illinois, where she graduated in 1975.

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INTRODUCTION

A number of earlier studies since the 1940's have investigated the ecology of freshwater predatory fish species. Most of these studies asked the same basic question: Why are these fish where they are? The answer to this question is found through the investigation of freshwater fishes community structure.

Many of the earlier studies looked at fish movements as the key to the interactions that compose a freshwater fish's community. One of the earliest studies by Ball (1947) indicated that largemouth bass moved randomly throughout a lake. Gerking on the other hand (1953) demonstrated that a number of freshwater fishes, for example the smallmouth bass and a number of other stream dwelling centrarchids, establish home ranges. Lewis and Flickinger (1967) in a ten acre lake showed that the largemouth bass establishes a home range. Hasler and Wisby (1958) demonstrated that the largemouth bass and green sunfish homed after displacement in a one-half acre pond. Parker and Hasler (1959) showed the largemouth bass, the bluegill and the pumpkinseed to have homing tendencies and that certian bass have more of a tendency to home than others. Gunning and Shoop (1963) demonstrated that the longear sunfish and blue-

gill establish home ranges in streams. They also found that the size of the home range was dependent on the size of the fish and time.

Because most of these studies depended on recapturing marked fish, daily or even weekly movements of fish could not be ascertained. With the advent of radio telemetry in the late 1950's, home ranges of fish could be measured more precisely and in larger bodies of water. Also daily fish movements could be studied, swimming speeds determined and various aspects of the fishes environment could be examined to determine why they establish home ranges and what factors are important in determining home range size.

One of the first studies to measure home range areas of largemouth bass via radio telemetry was by Winter (1976). He found these fish establish home ranges varying in size from 0.275 to 1.41 hectares. Other studies by Diana (1977 and 1980) used radio telemetry to study swimming speeds and habitat utilization of the northern pike. My purpose was to measure home range and primary home ranges of the largemouth bass, the bluegill, the yellow perch and the pumpkinseed. I also looked at variations in home ranges such as a fish having more than one home range in a single season or more than one primary home range within the home range area. Habitat preference of the various species was studied as well as the fishes' swimming speeds within each of these habitats. This was undertaken to determine what physiographic factors are important in freshwater fishes home range, how a fish uti-

lizes its home range and what causes a fish to establish a home range.

MATERIAL AND METHODS

Material

Eleven Largemouth Bass (Micropterus salmoides), nine Bluegills (Lepomis macrochirus), six Pumpkinseed (Lepomis gibbosus) and four Yellow Perch (Perca flavescens) were studied via radio telemetry. The Largemouth bass were 21.5cm to 37.6cm ($\bar{x}$=26.3cm) in length, bluegills from 15.5cm to 19cm ($\bar{x}$=17.4cm), pumpkinseed from 13.8cm to 16cm ($\bar{x}$=15.1cm) and yellow perch from 19.8cm to 22.5cm ($\bar{x}$=21cm). Fish were caught by seining at specific locations in Cedar Lake, a 115 hectare lake located in Lake County, Illinois. Three largemouth bass were caught by hook and line. The fish were transported back to Loyola University, where within four days a transmitter was attached.

Transmitters were supplied by the AVM Instrument Company in Champaign, Illinois. They were continuous wave pulsating transmitters with frequencies between 49.3 to 49.6 MHz. These frequencies were chosen because of their superior ability to transmit radio waves thru water.

Two different size transmitters were used. Large transmitters weighing 4.5g were placed primarily on largemouth bass, while smaller transmitters weighing 2.6g were placed on smaller fish. The 4.5g transmitters were powered by a mercury 1.35 volt battery and had the following dimensions; 3cm x 1.2cm x 0.5cm. The average current drain of this transmitter is .07ma (milliamps) and with a rated

capacity of 8.0 ma-days, the theoretical life span of the larger transmitter is 114 days. The 2.6g transmitter was also powered by a mercury 1.35 battery and had a diameter of 0.7cm. and a height of 0.4cm. Its rated capacity is 1.8ma-days with an average current drain of .07ma. This smaller transmitter has a theoretical life span of 25 days. These theoretical values do not take into account various environmental factors, such as the temperature of the water, which can alter the drain on a battery.

The model LA 12 telemetry receiver from the AVM Instrument Company was used. It has as standard equipment twelve 25KHz channels with the capacity to receive at least two signals on each channel without overlapping individual frequencies. Thus the receivers have the capacity to receive up to 24 transmitters at one time. The receivers were powered by a 12 volt portable motorcycle battery which allowed up to six days of continuous tracking without recharging.

Two types of antennas were used during the study. One type of antenna was the M-Yagi hand held type. This is a highly-directional antenna with a square configuration of 75cm on each side. It is a smaller version of the Yagi antenna and while it does not have the full potential of receiving as a Yagi does, it has the main advantage of being portable. This antenna was mainly used in obtaining triangulation data.

The second type of antenna is a miniature loop

antenna. It has a rectangular configuration with a metal base and measures 8cm x 13cm. This antenna was mainly used in resectioning data as it is highly directional and very accurate over short distances.

METHODS

Transmitters were activated by soldering the circuit activating wire to the battery terminal. Once the connection was complete the entire unit was covered with a thin layer of silicon or hard wax to protect the circuits and battery from possible water leakage. If the fish was less than 16.5cm in length, cork shavings approximately 4mm thick were placed around the entire unit and siliconed or hot waxed into position. This provided neutral buoyancy to the weight of the transmitter. Then three strands of eight pound monofilament fishing line were tied to the antenna portion of the transmitter by three modified fisherman knots. The lines were threaded through a needle and inserted thru the muscle beneath the dorsal fin. This line was secured to a four hole button with square knots to prevent slippage.

Once the transmitter was attached, the fish was observed in a holding tank until it exhibited normal swimming behavior. Adaption time to the transmitter differed among the four species. Observations for the first four hours of a largemouth bass showed the fish leaning to the side of the transmitter. Between the fifth and seventh hour

the fish became more upright and exhibited near normal activity. By seven to nine hours after attachment the fish showed complete adaptation with no evidence of impaired movement due to the transmitter. Trials on bluegills, pumpkinseeds and yellow perch all exhibited the same type of behavior with complete adaptation reached within six to eight hours. These observations are in agreement with those reported by Gallepp and Magnuson (1972) on bluegills and Winter (1976) on largemouth bass.

Once the fish was adapted to the transmitter it was transported back to Cedar Lake and released at the point of capture. Swimming direction and other activities were initially noted by visual observation and later by radio tracking.

Fish were tracked from predetermined stations along the shoreline of Cedar Lake as well as from boats. A total of 32 stations were set up every 51.6 to 73.3 meters along the shoreline as well as the island in the lake.

Radio tracked readings were taken simultaneously by two people at two different stations. The following method was used to determine a fish's location. The antenna was held out parallel to the water surface. A signal strength meter on the receiver was watched as the antenna was moved along an arc from side to side until the highest point on the meter was noted. The antenna was then moved to the left until the meter read two points below the highest reading. At this position a compass reading of the direction of the

antenna was noted. The antenna was then brought back to the highest meter reading position and then moved to the right till the signal again dropped two points and a compass reading was taken. These two readings were noted and their bisect was found. The two direction angles from the two stations were then plotted on a hydrographic map of Cedar Lake, where upon the location of the fish was noted. It took approximately 20 seconds to find the two angles that determine the bisect. This process was repeated every five minutes for approximately 1.0 to 1.5 hours.

A method termed resectioning was used when the fish could not be tracked from shore because of depth or signal interference caused by aquatic macrophytes. This method involves searching for the fish from a boat and scanning the area with the antenna until a signal is noted. When this signal was received at the same strength for 360^0 a compass reading was taken with a sighting compass to buoys set up along shore at specific stations. These compass readings were also plotted on a hydrographic map of Cedar Lake and the fish's position noted.

Error involved in these methods was determined by attaching a transmitter to a line and bobber and putting the bobber out in the lake at various depths and distances. Triangulation error was 1.8^0 when the transmitter was 130 meters offshore (Table 1). This distance was chosen because the majority of fish were tracked at distances less than this. In distance this error is 1.68 meters and decreases

as distance from shore decreases. At 30 meters the error is 0.7 meters.

Error in resectioning was also determined in a similar manner yet distance from the actual test transmitter was measured. In a weedless area of the lake, distance from the actual transmitter averaged 13.9cm and was considered negligible. In a weedy area of the lake error was 3.0 meters. This error is mainly due to diffraction of the radio waves by aquatic vegetation (Table 2).

The ability to receive the signal at various depths was also tested. Within the first 6 meters of water the signal dropped off rapidly, such that no signal could be detected at 10.6 meters or deeper (Table 3).

All of these tests were done using the M-Yagi hand held antenna. In trials with the minature loop antenna, whether the transmitter was in open water or heavy weeds, the small antenna pinpointed the transmitter with no measurable error.

A hydrographic map of Cedar Lake was drawn by mapping out the shoreline and island with sighting compasses and poles (Figure #7). Weed bed dimensions and depths were determined with sighting compasses and an echo sounder that recorded on a strip chart the sounder charts were then re-recorded on a map of Cedar Lake. The areas of the five habitats namely sand, light weeds, heavy weeds, edge of weeds (edge effect) and open water were determined with the use of a planimeter from the map of Cedar Lake. Temperature

and oxygen profiles were taken at various sites during the study.

TABLE 1

ERROR IN TRIANGULATION

Actual Transmitter Location (degrees)	Calculated Transmitter Location (degrees)	Degree Error	
54^0	53.5^0	-0.5^0	
54^0	56^0	$+2.0^0$	
61^0	63^0	$+2^0$	
58^0	60^0	$+2^0$	
58.5^0	57^0	-1.5^0	$\bar{x}=1.8^0$
60^0	58^0	-2^0	
54^0	56.5^0	$+2.5^0$	
54^0	53.5^0	-0.5^0	
57^0	59^0	$+2^0$	
57^0	60^0	$+3^0$	

Note: Error based on trials where transmitter 130 meters offshore and one position determined.

TABLE 2

ERROR IN RESECTIONING

No Weed Area

Trial	Error in cm.	
1	30.48	
2	15.24	
3	0	$\bar{x}$=13.97 cm
4	10.16	

Weedy Area

Trial	Error in meters	
1	3.03	
2	2.43	
3	3.03	$\bar{x}$=3.03 meters
4	3.64	

TABLE 3

DEPTH VS. DISTANCE SIGNAL RECEIVED

Depth (meters)	Distance (meters)
1.5 - 3.0	151.7
4.5 - 6.0	60.7
7.5 - 9.1	15.2
10.6 - deeper	No signal received

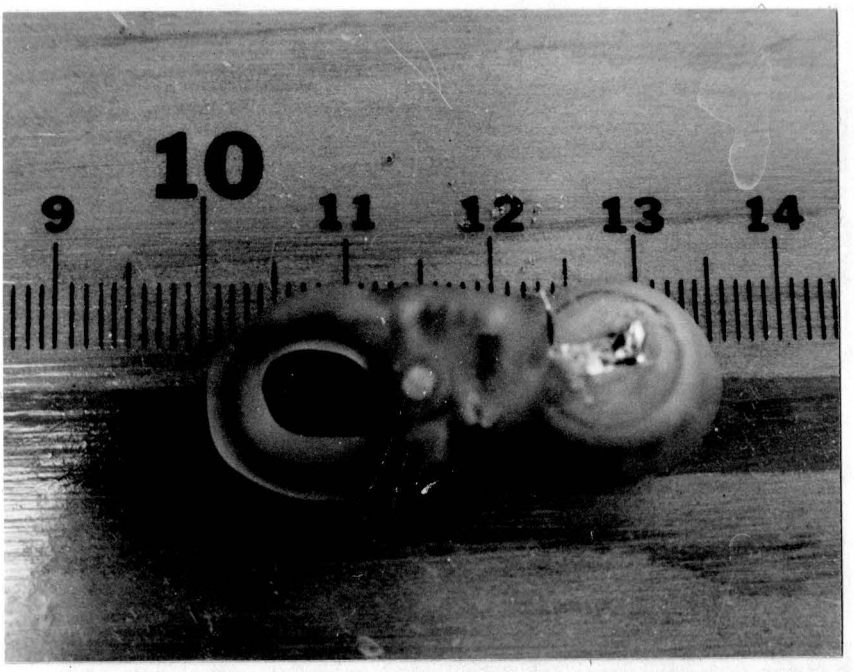


Figure 1: Large transmitter weighing 4.5g

Figure 2: Small transmitter (left), Small transmitter with cork (right).

Figure 3: Radio transmitter being attached to a yellow perch beneath dorsal fin.

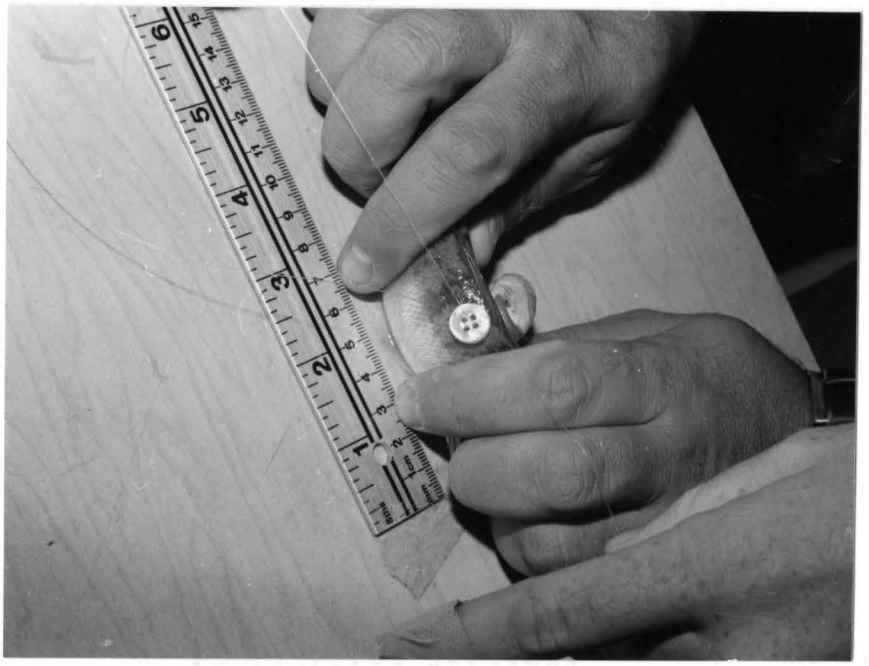


Figure 4: Yellow perch with transmitter and button.

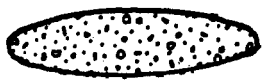
Figure 5: Largemouth bass in holding tank with transmitter attached.

Figure 6: Bluegill in holding tank with transmitter attached.

LEGEND FOR MAP OF CEDAR LAKE

Heavy Weeds

Light Weeds



Sand

Open Water

Shoreline

Island or Mainland as Indicated

Key to Symbols

Hx . . . . . .Heavy Weed Bed #x

Lx . . . . . .Light Weed Bed #x

OSLW . . . . .Offshore Light Weeds

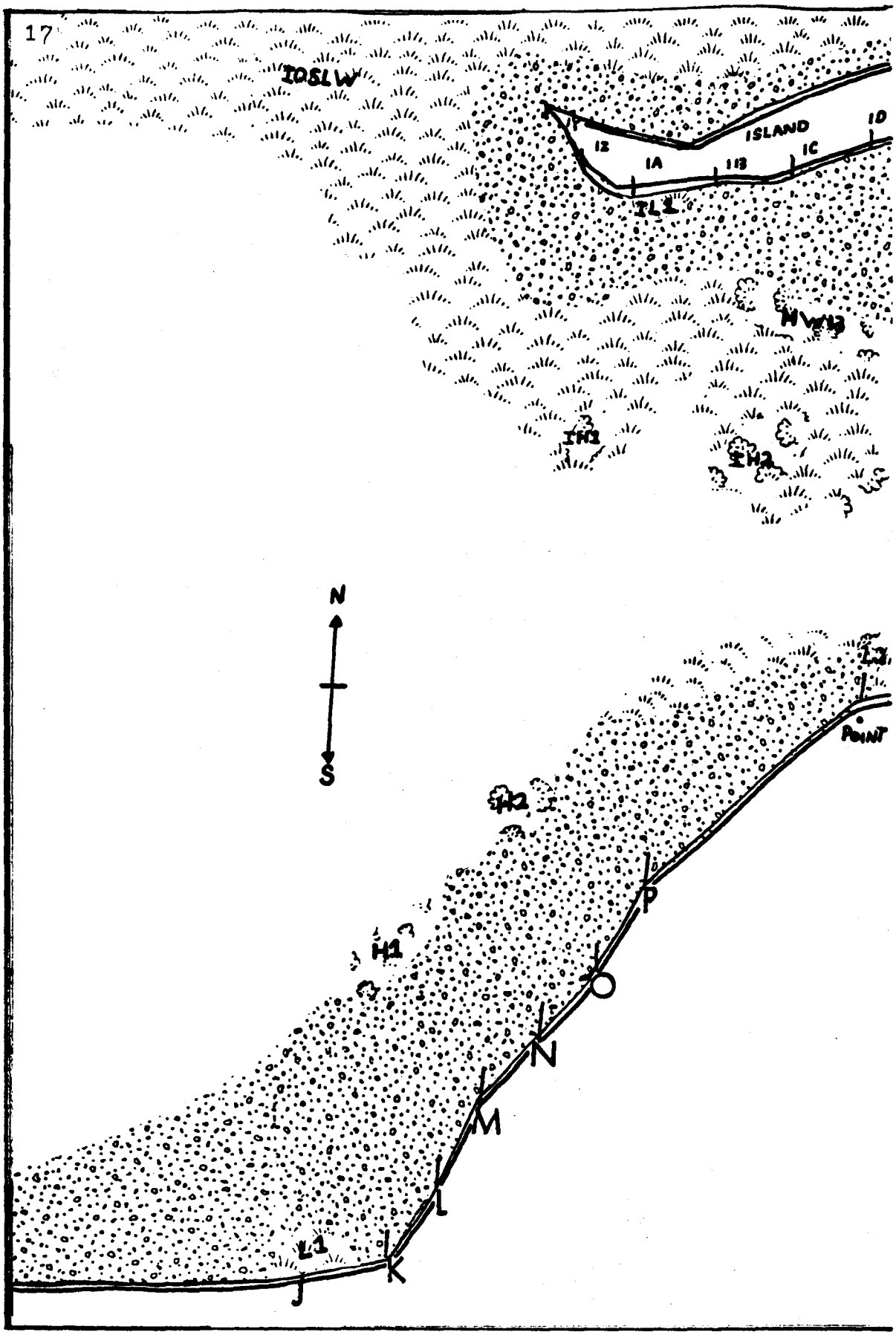
HSWB . . . . .Heavy Horseshoe Shaped Weed Bed

IHx. . . . . .Island Heavy Weed Bed #x

ILx. . . . . .Island Light Weed Bed #x

HWB. . . . . .Hedgerow Heavy Weed Bed

IOSLW. . . . .Island Offshore Light Weeds


IOSLW
ISLAND
ID
I2
IA
I1B
IC
IL2
HW1B
IH1
IH2
N
S
I2
POINT
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L1
K
J

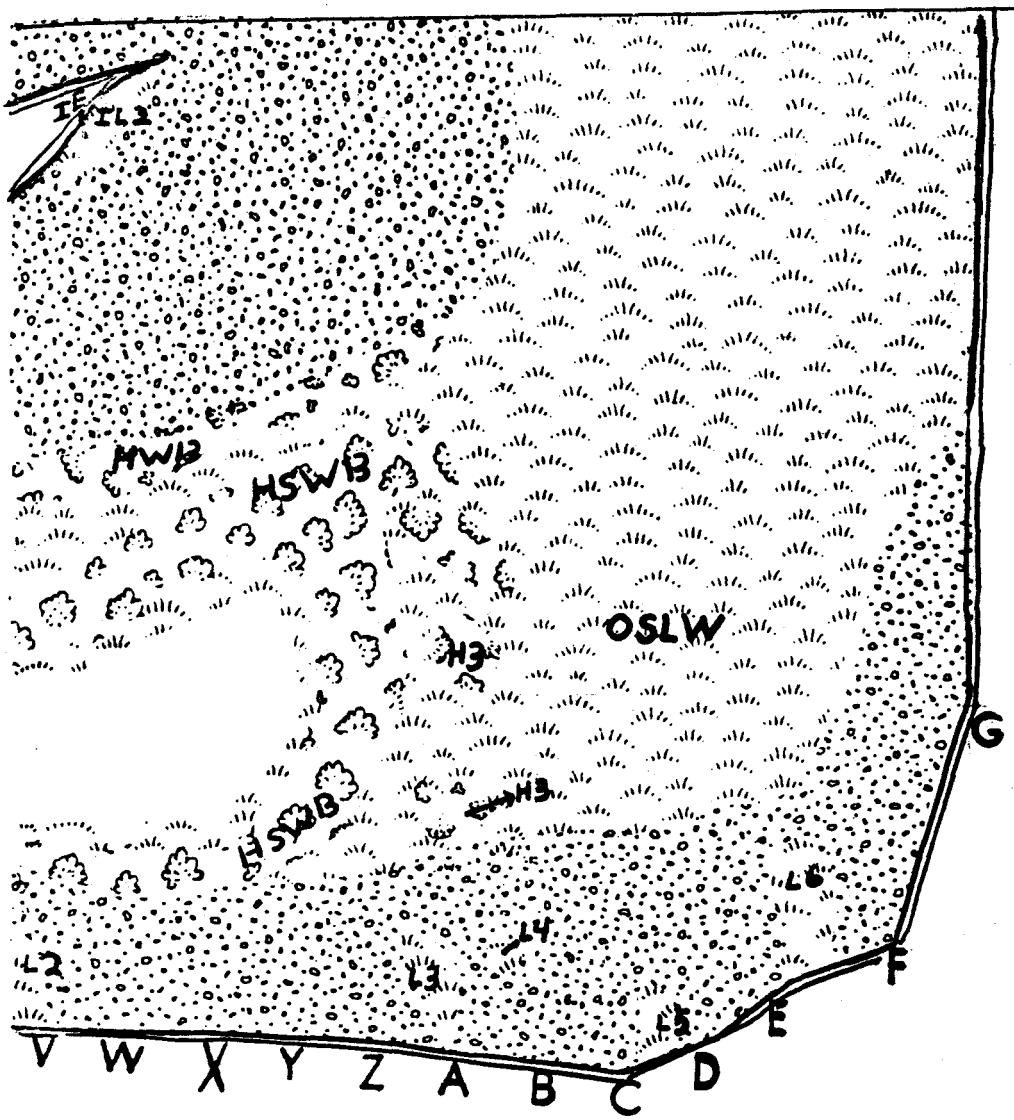


Figure: 7
Cedar Lake
(1cm=37m)

HOME RANGE RESULTS

A home range is the area determined thru radio tracking that a fish occupies for five consecutive days or more. One result of knowing a fish's home range is that it allows a particular fishes' location to be more predictable.

Home range areas were measured by the convex polygon method described by Winter (1976). This envolves connecting the outermost tracking points to form the most convex polygon possible. This method insures that the polygon that is drawn is the only possible one that can be formed by the existing points.

Besides a home range a fish may establish a primary home range. A primary home range is the area of the home range where a fish is primarily found. This area is differentiated from the home range by excluding any tracked loction that occurs more than 60.69 meters or 200 feet from any other tracked location. Thus a primary home range is usually a smaller section of the home range although it may be the entire home range. It contains the majority of tracked locations and is the area the fish primarily resides in and utilizes.

Largemouth Bass Home Range Results

Largemouth bass were studied to determine their home range and primary home range areas. Six largemouth bass revealed one home range and one primary home range. One revealed one home range with two primary home rangs. Two

largemouth bass exhibited two home range areas, while only one fish exhibited a home range with no separate primary home range area.

Largemouth Bass #1 exhibited a home range area of 1.50 hectares. This area was located along stations W to C and at its farthest point from shore extended outward 122 meters. This home range was set up in the same area the fish was caught and released (Figure 8).

Largemouth Bass #1's home range included a number of different habitats. The inshore section of this home range contained light weed beds #3 and #4 and the sand that surrounded these weed beds and extended along stations W to Z. The outer section of the home range was composed of part of the heavy horseshoe-shaped weed bed, parts of the offshore light weeds and heavy weed bed #3. All of these areas exhibit an ecotone between light weeds and sand and heavy weeds and sand.

Largemouth Bass #1's primary home range measured 0.82 hectares. This area of primary utilization was composed of the eastern and western most ends of the home range with the majority of data points noted within the eastern end. This primary home range contained light weed bed #4, the offshore light weeds and ecotones between light weed and sand. The edge of light weed bed #3 was also found within this primary home range.

The majority of five minute data revealed the fish moving in and out of the light weed bed areas. For example

the five minute data obtained on June 2, 1980, show the fish moving along the edge of light weed bed #4 and #3 and the offshore light weeds. This example along with numerous others reveal this fish's preference for the light weed-sand ecotone.

Largemouth Bass #3 exhibited one home range area that measured 1.44 hectares. This area was located along shoreline stations V to Z and extended 122 meters out from shore at its farthest point (Figure 9).

Largemouth Bass #3's home range included an inshore sandy area and an outer heavy weed bed area. This heavy weed bed was part of the heavy horseshoe shaped weed bed and was bordered on the north side by open water and on the south side by sand. Small amounts of light weeds were found along the border of this heavy weed bed yet the majority of this area was composed of a heavy weed-sand ecotone. As with Largemouth Bass #1, Largemouth Bass #3 primarily utilized the eastern and western most parts of this home range with only a few locations in the center.

Largemouth Bass #3 also established one primary home range that measured 1.16 hectares. This area encompassed most of the home range area yet eliminated part of the inshore sandy area. The majority of five minute data locations indicated this fish in and around the heavy horseshoe shaped weed bed with only a few days' data positioning the fish solely over sand or in open water.

It should be noted here that Largemouth Bass #1 and

Largemouth Bass #3's home range and primary homes range partially overlapped. That area of the two fish's home ranges which was found along stations W to Z was noted to overlap during the same time period. It was never known whether both fish were within this overlapped area at the same time, although it may have occurred (Figure 10).

Largemouth Bass #4 exhibited a home range area of 0.18 hectares. This area was found along stations A and B and at its furthest point from shore extended outward 122 meters. This home range was located in the vicinity where the fish was caught and released (Figure 11).

Largemouth Bass #4's home range was composed entirely of light weeds and sand. The inshore section of the home range was found to contain part of light weed bed #3 and #4, while the outer part of the home range was composed of the offshore light weed bed. Sand was found between these weed bed areas creating a light weed-sand ecotone.

Largemouth Bass #4 also exhibited a primary home range measuring 0.11 hectares. This area encompassed most of the home range area yet excluded some of the sandy area found between the inner and outer light weed beds. The majority of data points indicated the fish within the light weed beds or along their edges. Only twice was the fish positioned over sand. For these reasons the sandy area between the inner and outer light weed beds only appear to be utilized by the fish as a means of traveling from one weed bed to another.

Island Largemouth Bass #6 established a home range that measured 0.59 hectares. This area was set up off the south shore of the island, along stations IA to IB and extended 165 meters out from shore. This area corresponded to the location where the fish was caught and released (Figure 12).

Island Largemouth Bass #6 home range was composed almost entirely of light weeds. The northern most section of the home range contained the offshore island light weeds, some inshore sandy area and the edge of the heavy hedgerow weed bed. The southern most section of the home range contained some open water, the edge of island heavy weed bed #1 and again the offshore light weeds. The majority of data points located this fish within light weeds and only twice within open water or over sand.

Island Largemouth Bass #6 exhibited a primary home range of 0.43 hectares. Like Largemouth Bass #5, Island Largemouth Bass #6's primary home range encompassed most of the home range area. That area which was excluded from the home range was the outer lateral edges and was compased of light weeds and some sandy area. The majority of data points indicated the fish within light weeds, although the ecotone was often utilized. For example, the edge of the two heavy weed beds were within this primary home range area. Both of these heavy weed bed areas exhibit numerous data points revealing this fish's heightened utilization of the ecotone.

Largemouth Bass #7 exhibited a home range area that measured 0.53 hectares. This area was set up along shoreline stations Z to C and extended 85 meters out from shore. This area like all the previous largemouth bass, corresponded to the place where the fish was caught and released (Figure 13).

Largemouth Bass #7's home range only contained light weeds and sand. The outer section of this area contained the edge of the offshore light weeds and thus a light weed-sand ecotone. The inshore section of the home range contained light weed beds #3 and #4 and the sand that surrounded them.

Largemouth Bass #7 exhibited a primary home range that measured 0.44 hectares. This primary home range excluded the northwest corner of the home range and thus part of light weed bed #3 and the sand that surrounded it. The majority of tracked locations within this primary home range showed the fish in light weed bed #3 and #4 and the small strip of sand that separated these weed beds. Only twice was the fish found solely over sand. For example, on August 8th, five minute data exhibited the fish entering light weed bed #4 at its northern end and emerging one hour later out the southern end of this weed bed. Within this entire time the fish was found solely within light weed bed #4 and its ecotone.

Ecotones were also heavily utilized within this primary home range. On numerous occasions the fish was located

along the edge of the inshore light weed beds, as two out of the three data points that position the fish within the outer section of the primary home range reveal the fish at the light weed bed-sand ecotone.

Largmouth Bass #8 established a home range area that measured 0.68 hectares. This area was located along stations Z to C and at its furthest point from shore extended outward 122 meters. This home range was established in the area where the fish was caught and released (Figure 14).

Largemouth Bass #8's home range included a number of different habitats. The inshore portion of the home range was composed of light weed beds #3 and #4 and the sand that surrounded these areas. The outer section of the home range was composed of heavy weed bed #3 and the offshore light weeds. A number of ecotones were also prevalent, namely the light weed-sand and heavy weed-light weed ecotone. The majority of ecotone utilization by Largemouth Bass #8 was along the light weed-sand edge.

Largemouth Bass #8 established a primary home range that measured 0.50 hectares. This area encompassed most of the home range yet, like Largemouth Bass #7, excluded light weed bed #3 and the sand that immediately surrounded it. The majority of data locations within this primary home range indicated the fish in and around light weed bed #4. On September 19, and September 24, 1980, five minute data positioned Largemouth Bass #8 along the ecotone of light weed bed #3 for at least one full hour. September 5th, and

Setpember 26, 1980, show the fish moving in and out of the same light weed bed for the hour this fish was tracked. These examples, plus other data, indicate the extensive use of light weed bed #4 by Largemouth Bass #8.

Other areas of utilization by Largemouth Bass #8 included heavy weed bed #3 and the outer light weed-sand ecotone. Neither area was used as extensively as light weed bed #4.

It was also observed that Largemouth Bass #7 and Largemouth Bass #8's home ranges and primary home ranges partially overlapped during the same time periods. The inshore portion of these two fishes' home ranges which occur along staions Z to B was found to overlap. This again indicates the heavy utilization by both fish of light weed #4, its edge and the sand that surrounds it (Figure 15).

Each of the previous six largemouth bass had one home range and one primary home range. However, some fish were found to utilize two particular areas of the home range exclusively with no known location points found between these two areas. These fish were determined to have two primary home ranges. If a fish were observed to utilize two distinctly separate areas of the home range and no two data points were within 60.69 meters or 200 feet of each other, the fish was determined to have two primary home ranges. These two areas can and should be used alternately by the fish, otherwise two home ranges would result. Two primary home ranges were exhibited by Largemouth Bass #10.

Largemouth Bass #10 exhibited one home range and two primary home ranges within this one home range. The home range measured 1.45 hectares and was located off of the southeast edge of the island along shoreline stations IE to IF. At its farthest point from shore this home range extended outward 195 meters. As with the previous six bass, this home range was established in the same area the fish was caught and released (figure 16).

Largemouth Bass #10's home range was composed of three different habitats. The inshore section of the home range was composed of light weed bed #I2 and the sand that surrounded it. The outer portion of the home range area was composed of the heavy hedgerow weed bed. The rest of the home range area was composed entirely of sand.

The first of the two primary home ranges measured 0.33 hectares. This primary home range was the one closest to the island and contained light weed bed #I2 and the sand that surrounded it. The ecotone created by this light weed - sand transition was heavily utilized by the fish.

The second primary home range area measured 0.22 hectares. This primary home range was at the southern most part of the home range area. This area contained part of the heavy hedgerow weed bed, the light weeds that bordered it on the south side, and the sand that bordered on the north. Also included in this primary home range was the ecotone of the heavy horseshoe shaped weed bed. The majority of data points in this primary home range indicated the fish within

the heavy weeds and along their edges.

Although primary home range #1 was used more frequently by the fish, both primary home ranges were utilized alternately. A number of different days' data revealed the fish in one primary home range during one part of the day and the other part of the home range another part of the day. No pattern to this utilization could be found, although weather did play a role. When winds were out of the south causing rough lake water, the fish utilized the offshore or second primary home range. When the wind was out of the north the fish tended to utilize the first primary home range. It should also be noted here that the area between the two primary home ranges was never found to be utilized by the fish.

Largemouth Bass #10 was also the only fish studied that utilized an area so close to shore. A number of tracking locations and actual sightings revealed the fish in one foot of water and four to five feet from the shoreline. One possible explanation is that there are overhanging trees along stations IE to IF and this may have provided a suitable and protected habitat for the fish.

Largemouth Bass #11 exhibited a home range area that measured 1.11 hectares. This home range was set up along stations A to E and at its furthest point from shore extended outward 146 meters. This home range was established in the same area the fish was caught and released (Figure 17).

The inshore portion of Largemouth Bass #11's home range contained portions of light weed beds #3 and #4 and the sand that surrounded these weed beds and separated them from the outer light weeds. The outer section of the home range was composed entirely of the offshore light weeds. An ecotone between light weeds and sand was also found in Largemouth Bass #11's home range, although only one location was obtained placing the fish within this area.

Largemouth Bass #11 exhibited no primary home range area as no one area of the home range contained enough data points to be condsidered to have been primarily utilized by the fish. The hypothesized reason was that not enough data points were obtained before radio transmission was lost to differentiate a primary home range area from the home range.

Within this study two largemouth bass exhibited more than one home range area. If a fish were found to leave one established home range area and set up another area, that fish was determined to have established two home ranges. In order for these two areas to be home ranges the fish cannot return to the original area or utilize both areas during the same time period. In this study two largemouth bass, namely Largemouth Bass #2 and #12, each exhibited two home range areas.

Largemouth Bass #2's first home range measured 0.80 hectares. This home range occurred along stations Y to A and extended 110 meters out from shore at its furthest point. This first home range was established in the same

area the fish was caught and released (Figure 18).

Largemouth Bass #2's first home range was found to encompass a number of different habitats. The inshore section of the home range contained part of light weed bed #3 and the sand that surrounded this weed bed and extended along the shoreline. The outer section of the first home range contained part of the heavy horseshoe shaped weed bed and part of the offshore light weeds. The ecotone between heavy weeds-sand was also located within this home range area.

Largemouth Bass #2 exhibited one primary home range within this first home range. This primary home range area measured 0.52 hectares. This area encompassed most of the home range yet excluded the northwest corner of the home range. The area that was excluded consisted of the heavy horseshoe shaped weed bed, the ecotone of heavy weeds and sand and parts of the inshore sandy area. From figure 18, it was apparent that the primary home range was composed entirely of light weeds and sand. The majority of five minute data indicates the fish moving between the inshore light weed bed #3 and the offshore light weeds, again appearing only to utilize the sand as a means of getting from one weed bed to another.

Home range #1 and primary home range #1 were utilized by the fish for the first 68 days after it was released. On the 69th day Largemouth Bass #2 was located 457 meters west southwest from the original home range area. Here the fish

set up a new home range and primary home range where, for the duration of the transmitter's life, the fish remained (Figure 19).

Home range #2 was set up along stations J to N and extended 164 meters out from shore. This home range area measured 2.07 hectares and was composed of heavy weed bed #1, the open water that bordered the weed bed on one side, and the sand that bordered it on the other. The edge of heavy weed bed #2 was also enclosed within the home range area (Figure 20).

Largemouth Bass #2 established a primary home range within home range #2 that measured 1.64 hectares and included most of home range #2's area. In differentiating this primary home range from the home range area, the single location of Largemouth Bass #2 in heavy weed bed #2 was eliminated. Thus, heavy weed bed #2 and the sand that immediately surrounded it were eliminated from this primary home range area. Within the primary home range the most data points are located in and around heavy weed bed #1 with five minute data revealing short excursions (less than one hour) by the fish into open water. The sandy area inshore of heavy weed bed #1 was also heavily utilized by the fish, although most of this data indicate the fish making at least one pass per hour near the edge of the heavy weed bed. For example, on June 28, 1980, the fish was being tracked over sand. Ten minutes into this tracking period the fish made a short pass along heavy weed bed #1 and then continued its

movements back over sand. Thirty minutes later the fish was noted again at the edge of heavy weed bed #1. This utilization of the heavy weed bed-sand ecotone by this fish was a recurring pattern throughout the entire tracking period.

It should be noted that Largemouth Bass #2 first home range and primary home range were found to overlap with Largemouth Bass #1's and #3's home range and primary home range areas during the month of June. Again it was not known whether these fish were in the same area at precisely the same time although it may have occurred. Furthermore, this overlap with its implication of exploitative competition may be the reason for Largemouth Bass #2 to leave home range #1 and establish another home range, in a different part of the lake (Figure 10).

Largemouth Bass #12 also exhibited two home range areas, yet only one of these home ranges exhibited a primary home range area. Home Range #1 measured 0.69 hectares and was set up 268 meters north from the area where the fish was caught and released. This home range was composed almost entirely of the offshore light weeds. A small section of the heavy horseshoe shaped weed bed was within this home range area. Thus, a heavy weed-light weed ecotone was present and utilized by the fish (Figure 21).

This fish utilized this home range for eight days after its release. Thus a primary home range was not differentiated from the home range area.

Seven days after the fish left home range #1, Large-

mouth Bass #12 established another home range off of the west end of the island (Figure 22). This home range measured 0.24 hectares and was composed entirely of light weeds (Figure 23).

Largemouth Bass #12 established a primary home range within home range #2. This primary home range measured 0.01 hectares and again was composed entirely of light weeds. This primary home range may be underestimated as only a small number of locations were obtained.

Largemouth Bass Home Range Statistics

A number of linear correlations were performed on the home range and primary home range areas to determine if there was any correlation between these areas and the size of the fish or the number of days tracked. In some cases a fish was determined to have more than one home range or primary home range area. In these cases both home ranges or primary home ranges were correlated with the size of the fish or the number of tracked days. If a fish exhibited no primary home range, as in the case of Largemouth Bass #11 the fish was excluded from the calculation of that correlation.

The first statistical test performed was to determine if there was a correlation between largemouth bass home range areas and the number of tracked days. The null hypothesis was accepted; $r=0.15$ ($p>0.05$). This result was expected, as each fish was thought to have been tracked

enough times to reveal an accurate representation of a largemouth bass home range area.

The second correlation performed correlated the largemouth bass primary home range area and the number of days the fish were tracked. Here again the null hypothesis was that there is no difference in primary home range size and the number of days a fish was tracked. The hypothesis was accepted, $r=0.51$; $(p>0.05)$. Again this result was expected as each fish was determined to have been tracked enough times to reveal an accurate representation of a largemouth bass primary home range area.

It must be noted here that the previous two correlations also indicate that the area of the home range is not a function of time. Rather than finding the home range expanding or contracting over time, the fish would establish a new home range and primary home range. For example, Largemouth Bass #2 exhibited two home ranges and two primary home range areas. After plotting the data for the first few tracking days, this fish's initial home range did not increase or decrease over time; yet the fish was found to leave one home range and establish another. This also occurred with Largemouth Bass #12.

The third correlation tested the size of the largemouth bass versus the size of their home ranges. The null hypothesis was that there is no difference in size of largemouth bass and the areas of their home ranges. This hypothesis was accepted, $r=-0.4$; $(p>0.05)$. Here a negative

correlation was obtained. Although not significant, the possibility of obtaining a significant negative correlation exists. For example Largemouth Bass #4, which was the largest in size of all studied largemouth bass, measuring 37.6cm, exhibited a home range of only 0.18 hectares, which was the smallest recorded home range in the study. It is this 37.6cm largemouth bass that may have contributed heavily to this negative correlation. However, it was noted that some of the larger largemouth bass do have smaller home ranges than the smaller largemouth bass.

The fourth and final correlation was between the size of the largemouth bass and the size of their primary home range areas. The null hypothesis was that there is no difference in the size of the fish and the size of their primary home range areas. This null hypothesis was accepted, $r=-0.29$; $(p>0.05)$. Again a negative, nonsignificant correlation was obtained.

TABLE 4

LARGEMOUTH BASS HOME AND PRIMARY HOME RANGE RESULTS

BASS #		HOME RANGE (hectares)		PRIMARY HOME RANGE (hectares)	SIZE (cm)	DATES TRACKED
I		1.50		0.82	25.1	6-2-80 6-12-80
2	HR#1	0.80	PHR#1	0.52	24.8	6-8-80 8-14-80
	HR#2	2.07	PHR#2	1.64		8-15-80 11-26-80
3		1.44		1.16	27.1	6-10-80 7-16-80
4		0.18		0.11	37.6	7-1-80 7-17-80
I6		0.59		0.43	24.5	7-19-80 8-18-80
7		0.53		0.44	21.5	8-2-80 8-20-80
8		0.68		0.50	24.8	8-12-80 8-29-80
I10		1.45	PHR#1	0.33	25.0	9-5-80 12-23-80
			PHR#2	0.22		
11		1.11		--	24.0	5-28-81 6-7-81
12	HR#1	0.69	PHR#1	--	28.5	5-28-81 6-4-81
	HR#2	0.24	PHR#2	0.01		6-11-81 7-28-81

LEGEND FOR LARGEMOUTH BASS ILLUSTRATIONS

Heavy Weeds

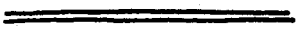
Light Weeds

Sand

Open Water

Home Range Line

Primary Home Range Line



Shoreline

Triangulation Data

Island or Mainland as Indicated

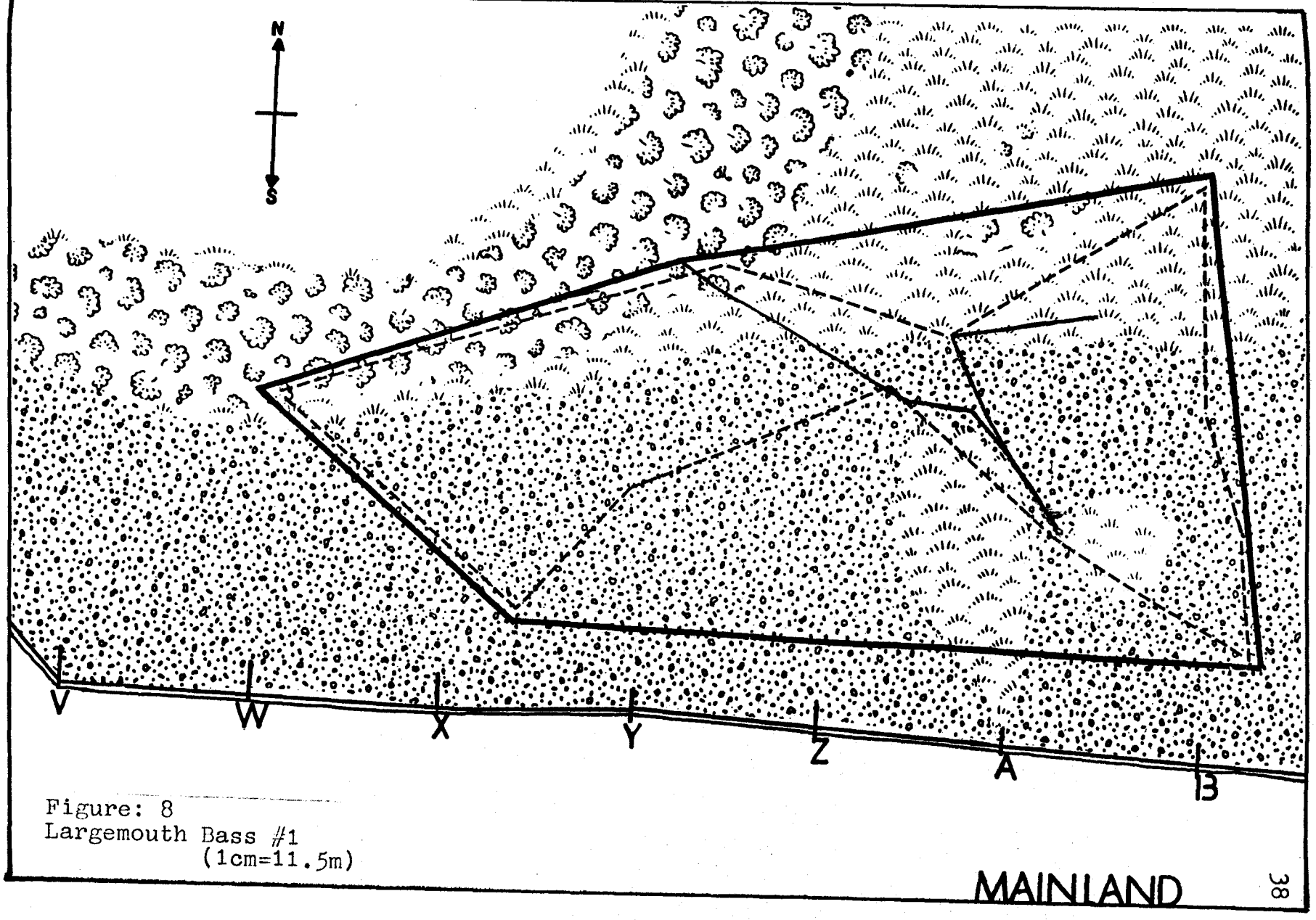


Figure: 8
Largemouth Bass #1
(1cm=11.5m)

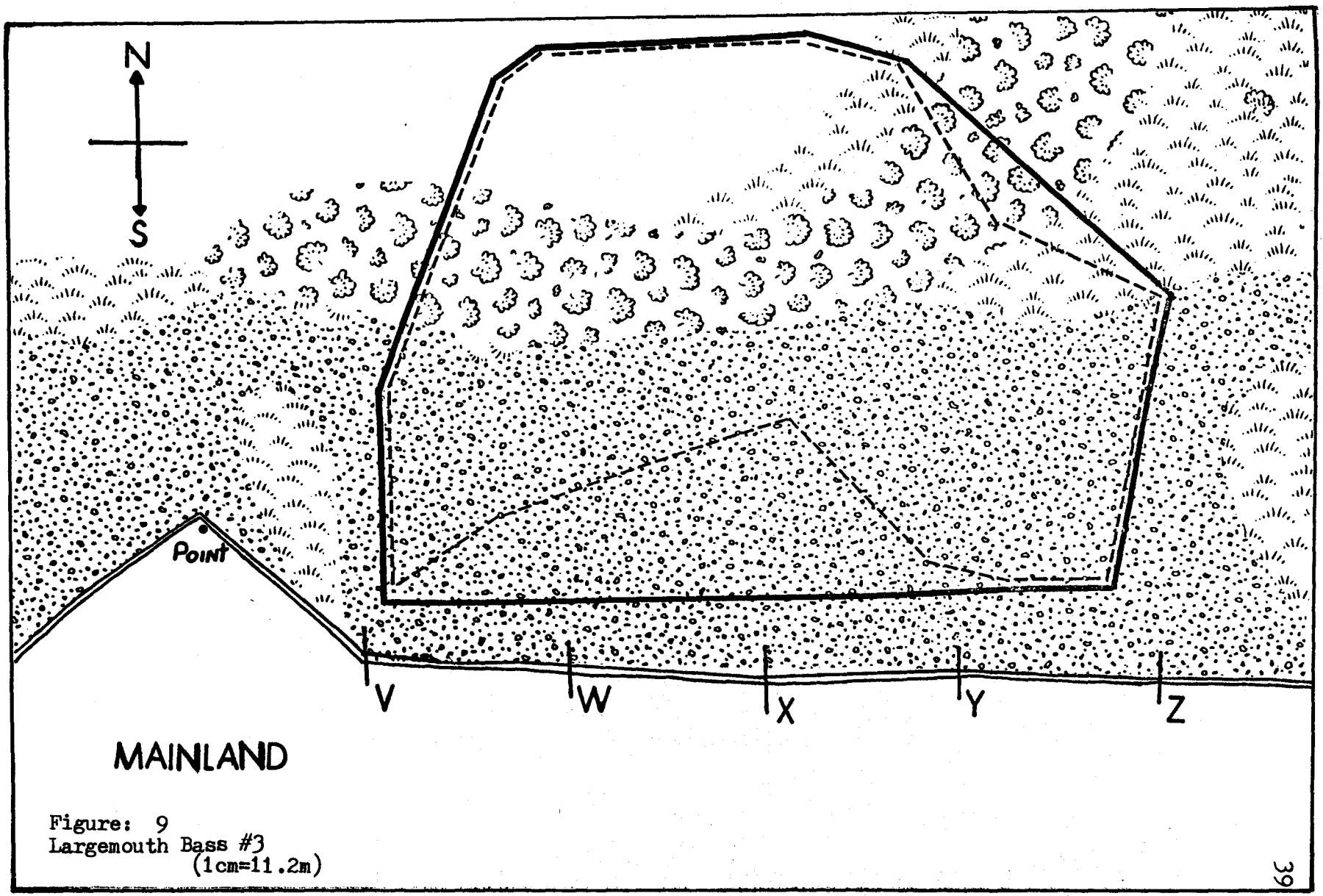


Figure: 9
Largemouth Bass #3
(1cm=11.2m)

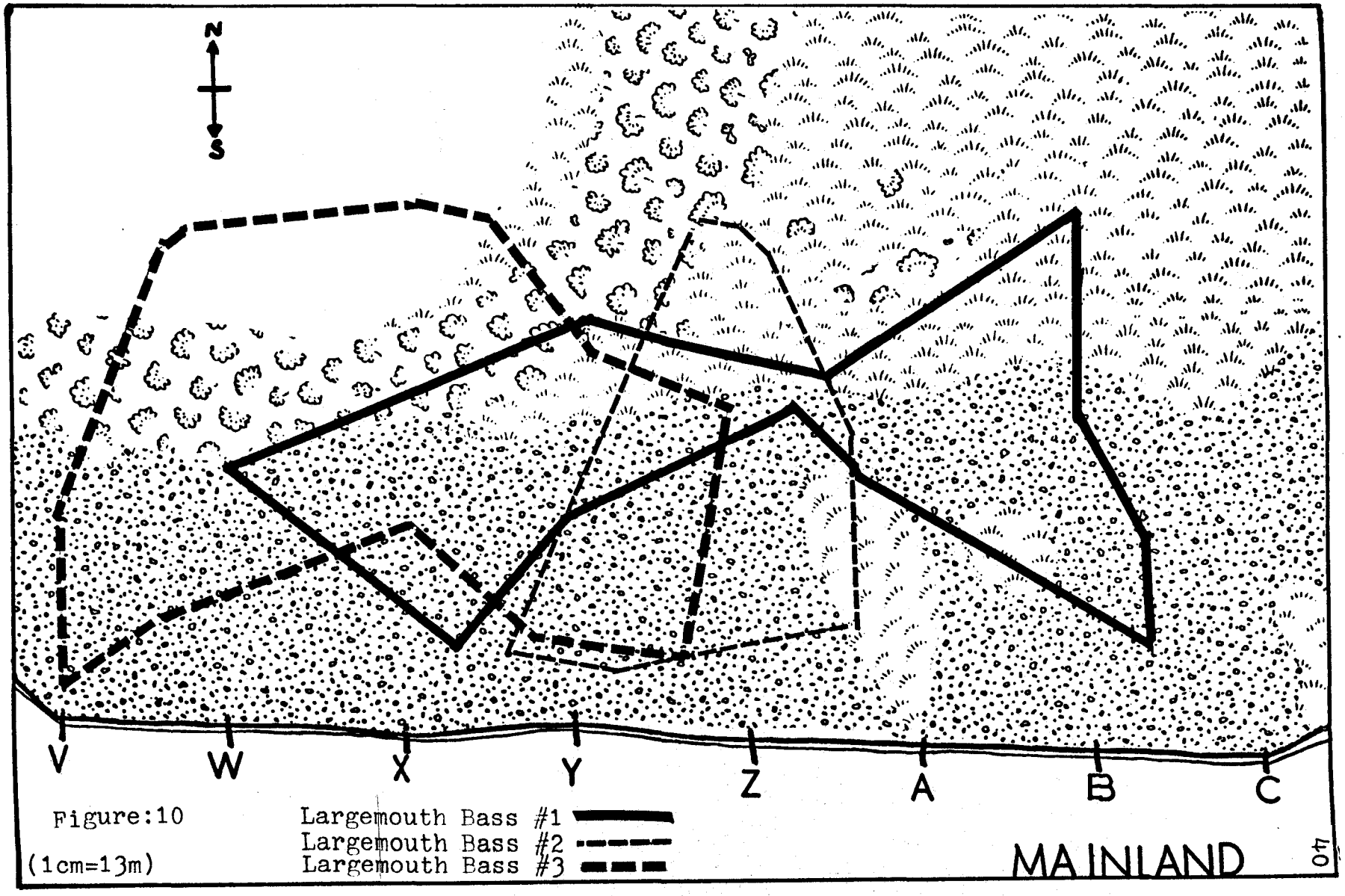


Figure:10

(1cm=13m)

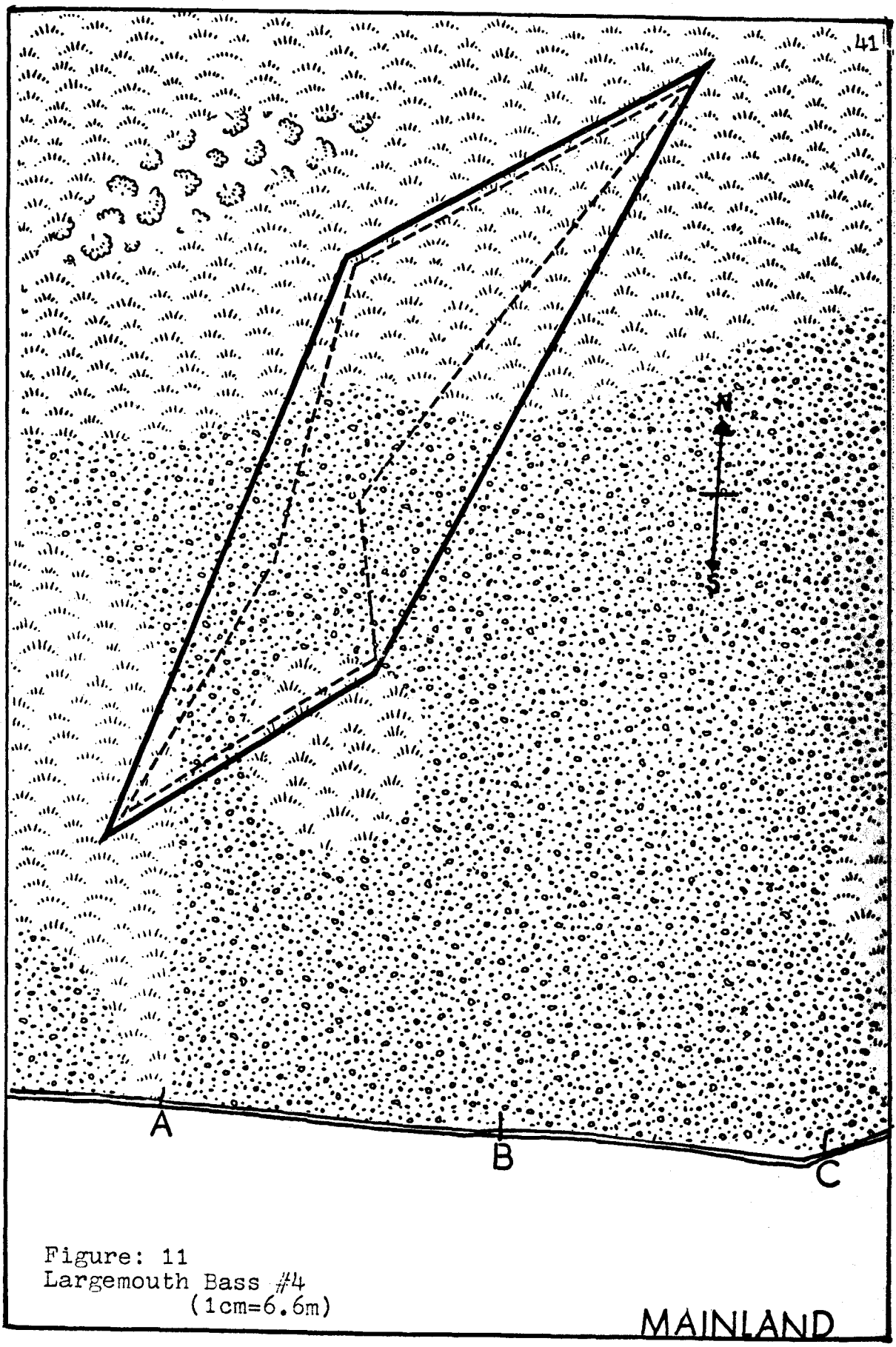


Figure: 11
Largemouth Bass #4
(1cm=6.6m)

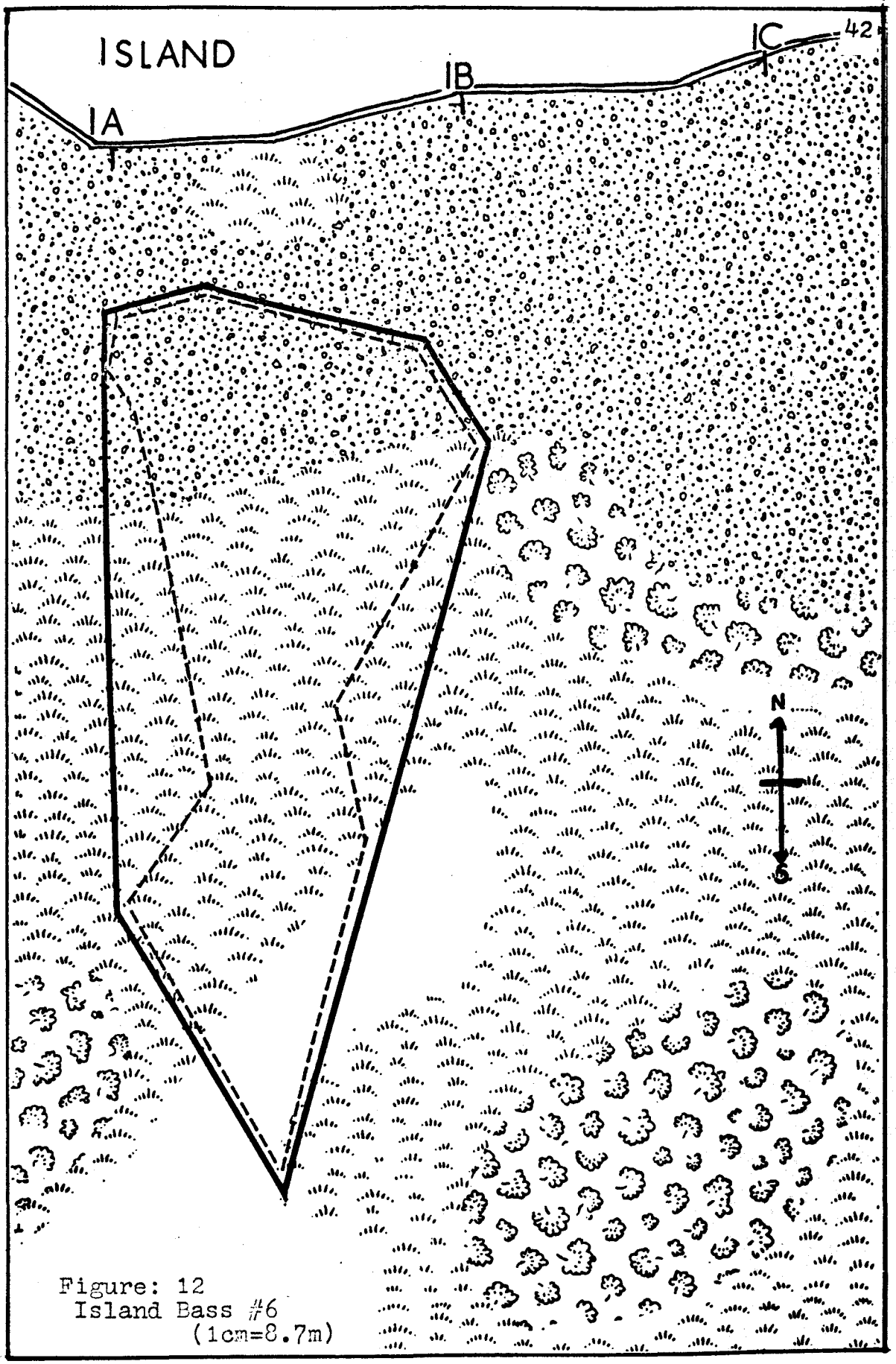


Figure: 12
Island Bass #6
(1cm=8.7m)

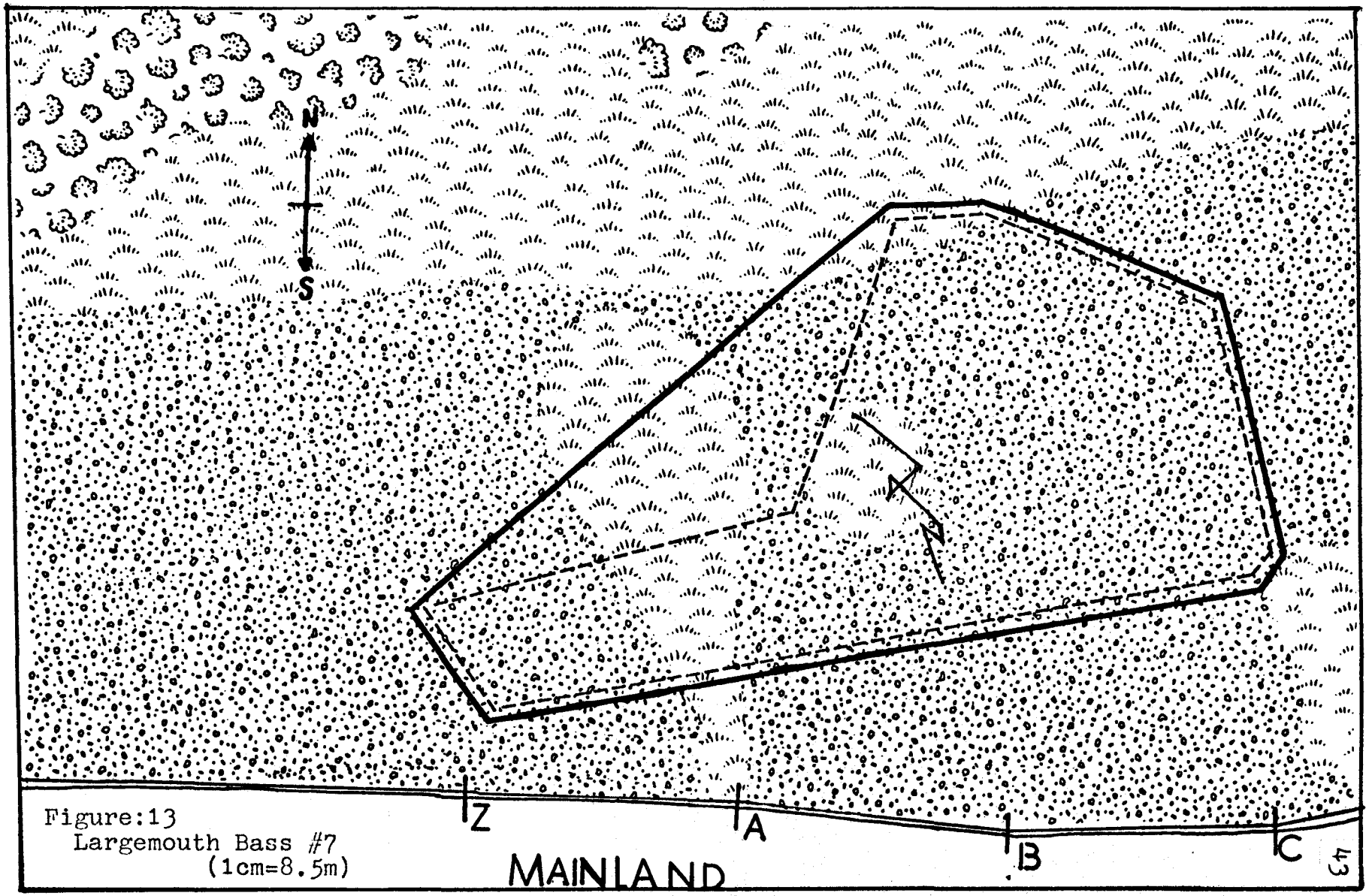


Figure:13
Largemouth Bass #7
(1cm=8.5m)

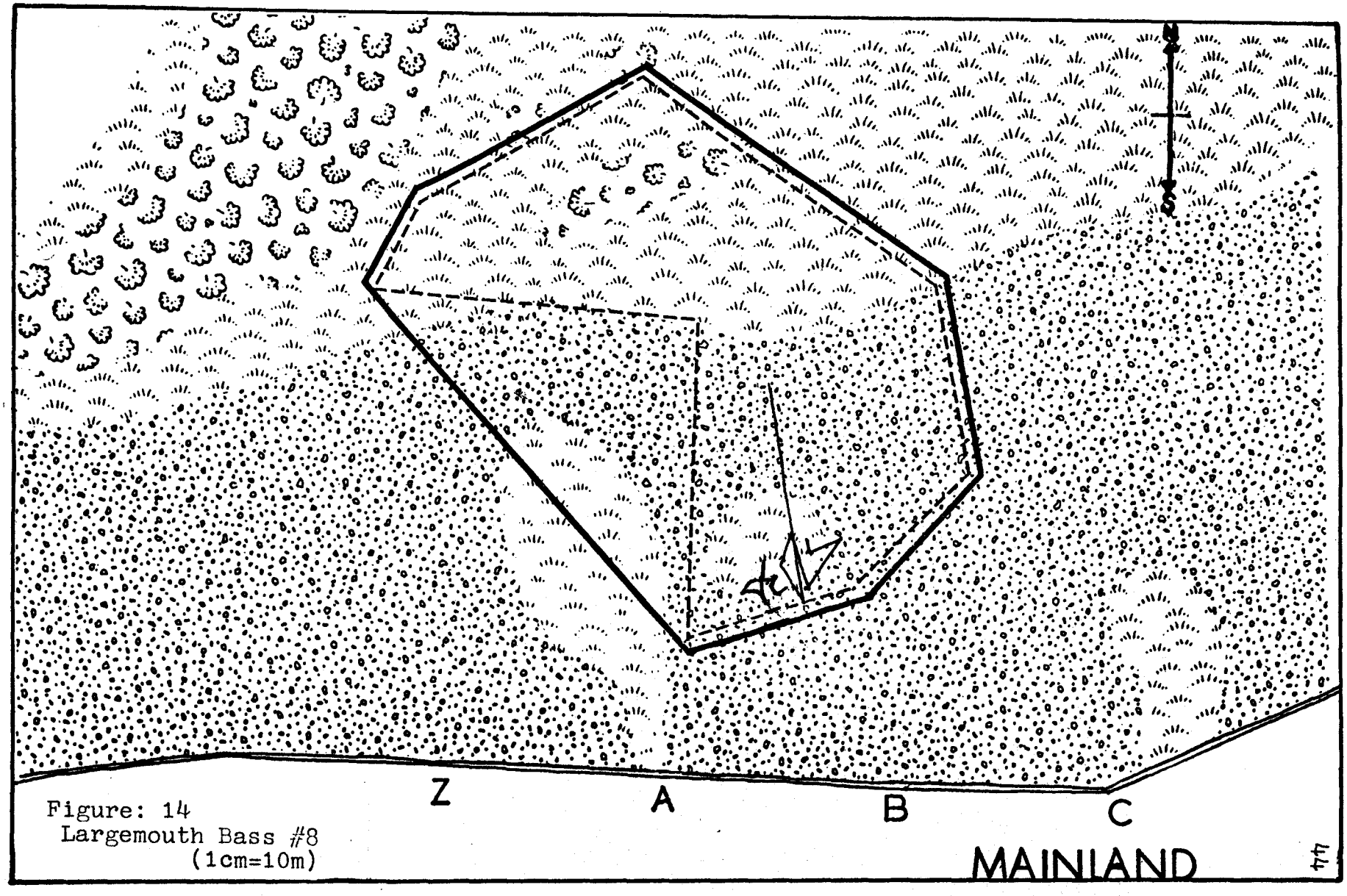


Figure: 14
Largemouth Bass #8
(1cm=10m)

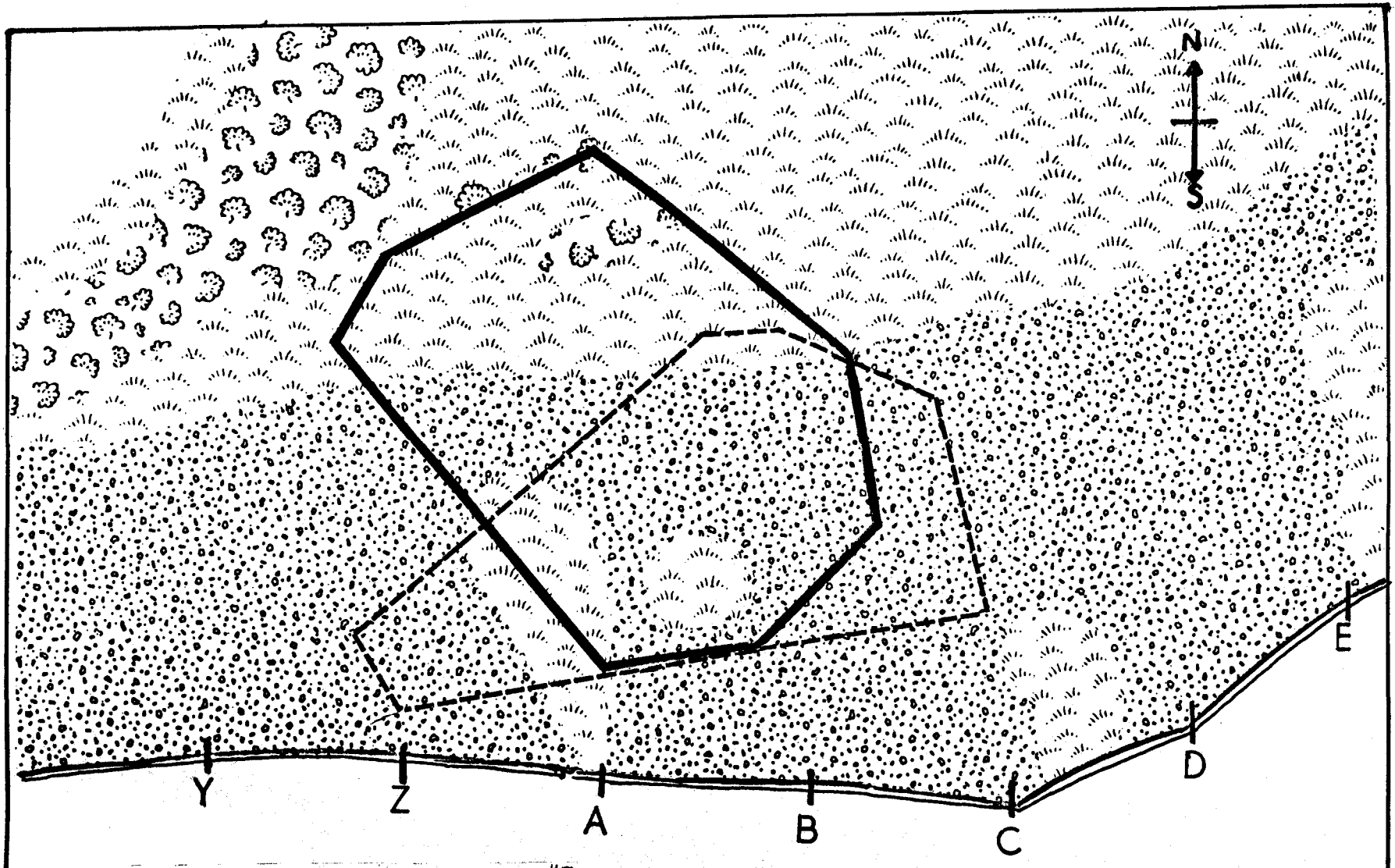


Figure: 15

Largemouth Bass #7 ----------
Largemouth Bass #8 ==========
(1cm=11.3m)

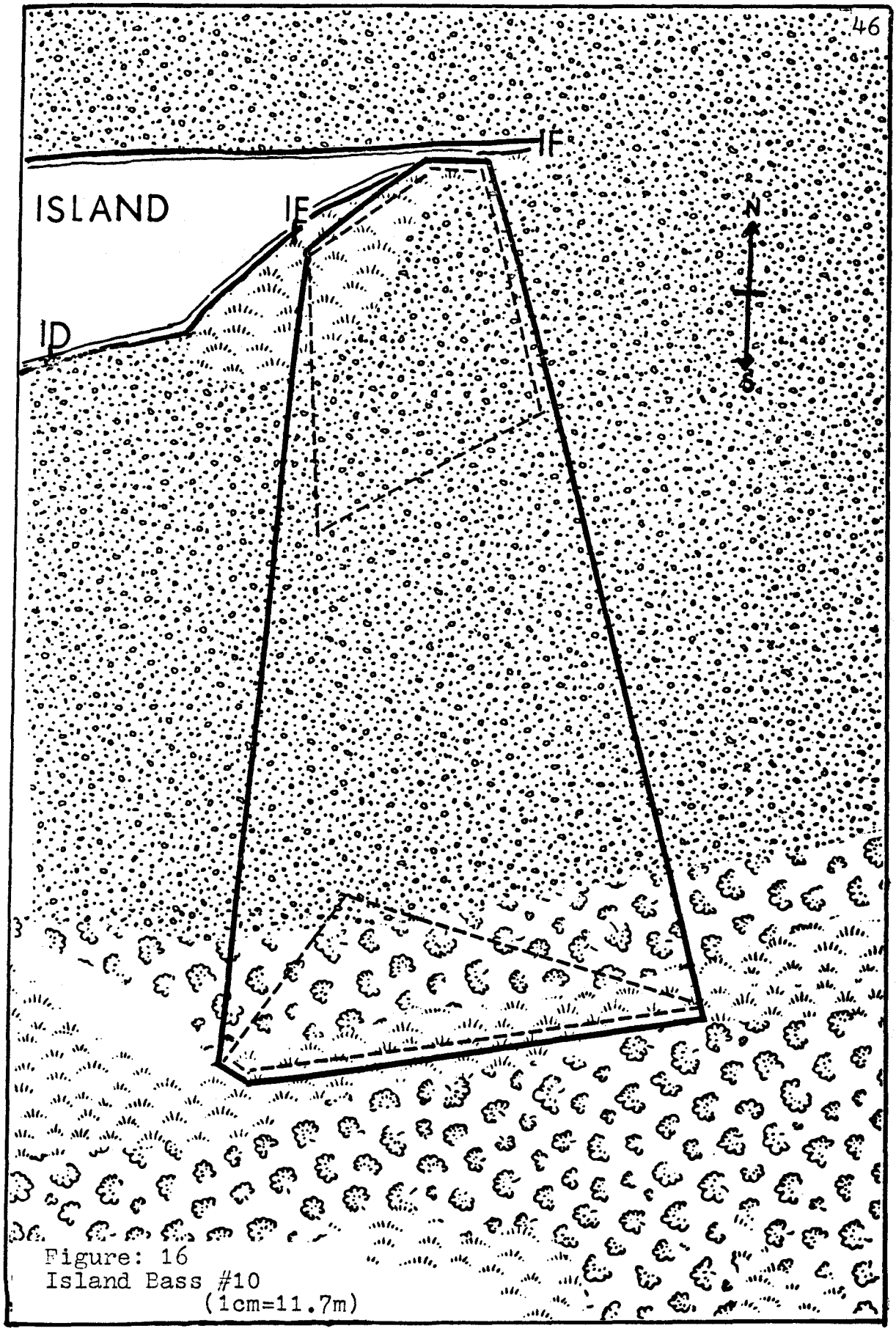


Figure: 16
Island Bass #10
(1cm=11.7m)

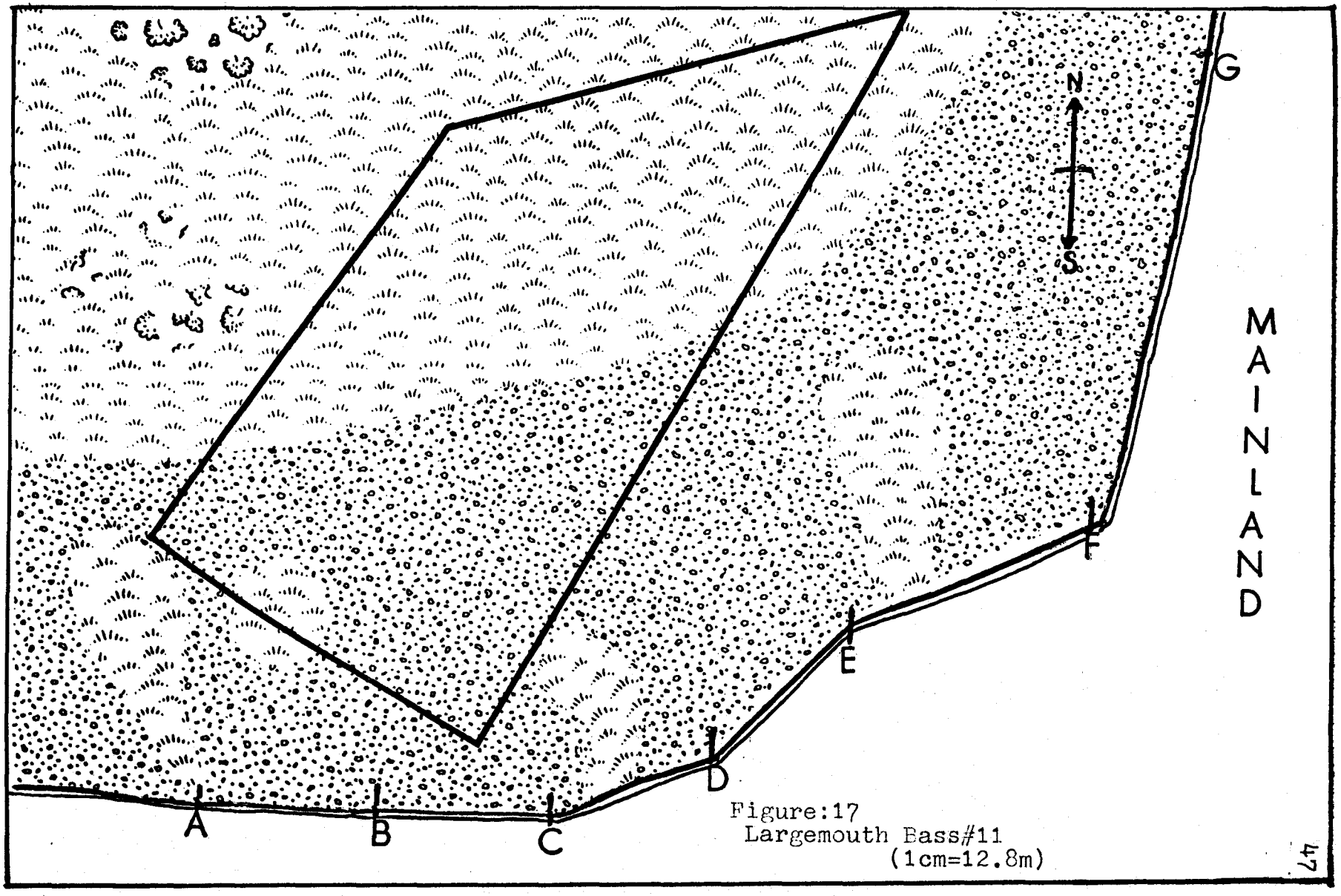


Figure:17
Largemouth Bass#11
(1cm=12.8m)

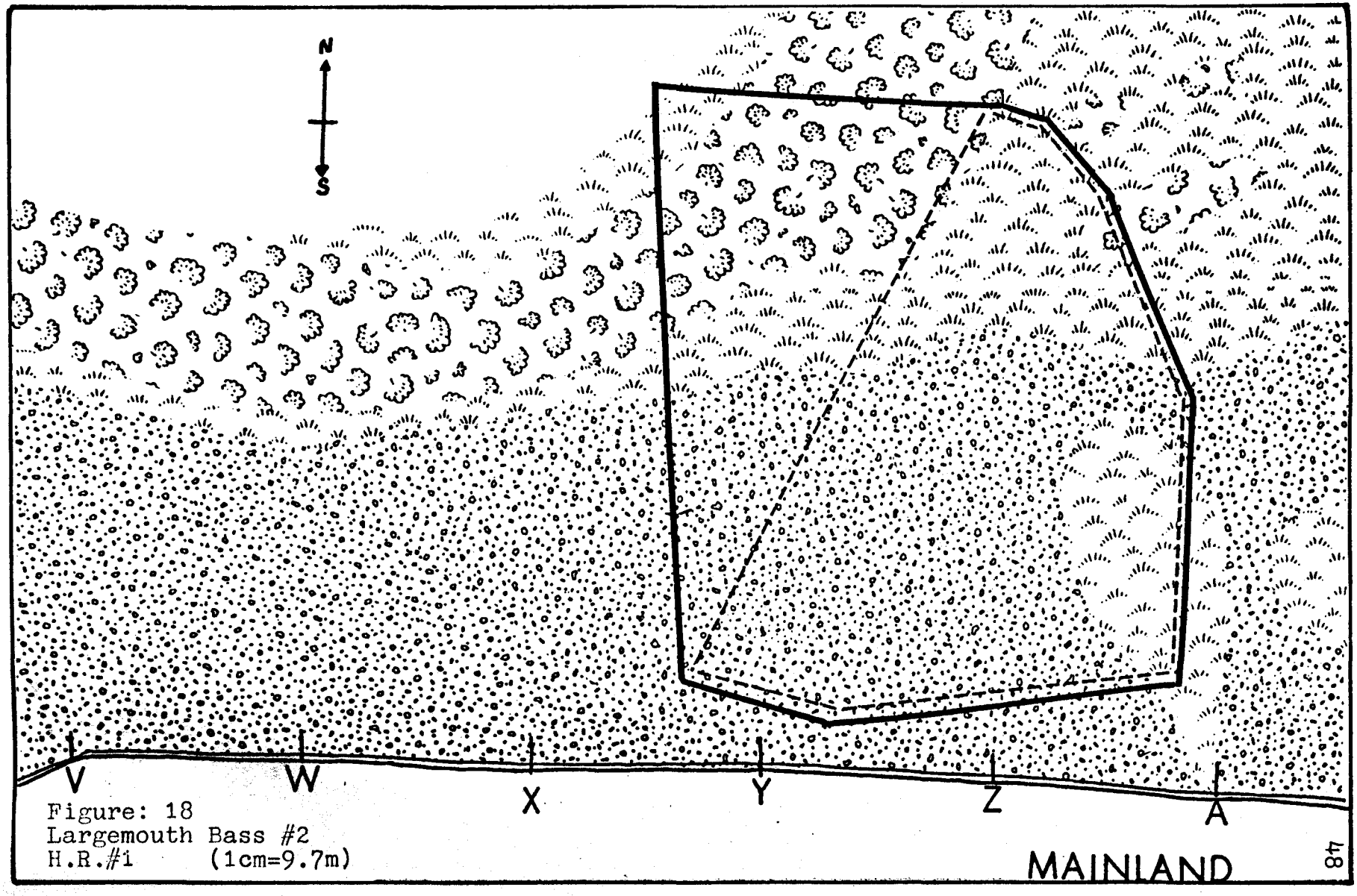


Figure: 18
Largemouth Bass #2
H.R.#1 (1cm=9.7m)

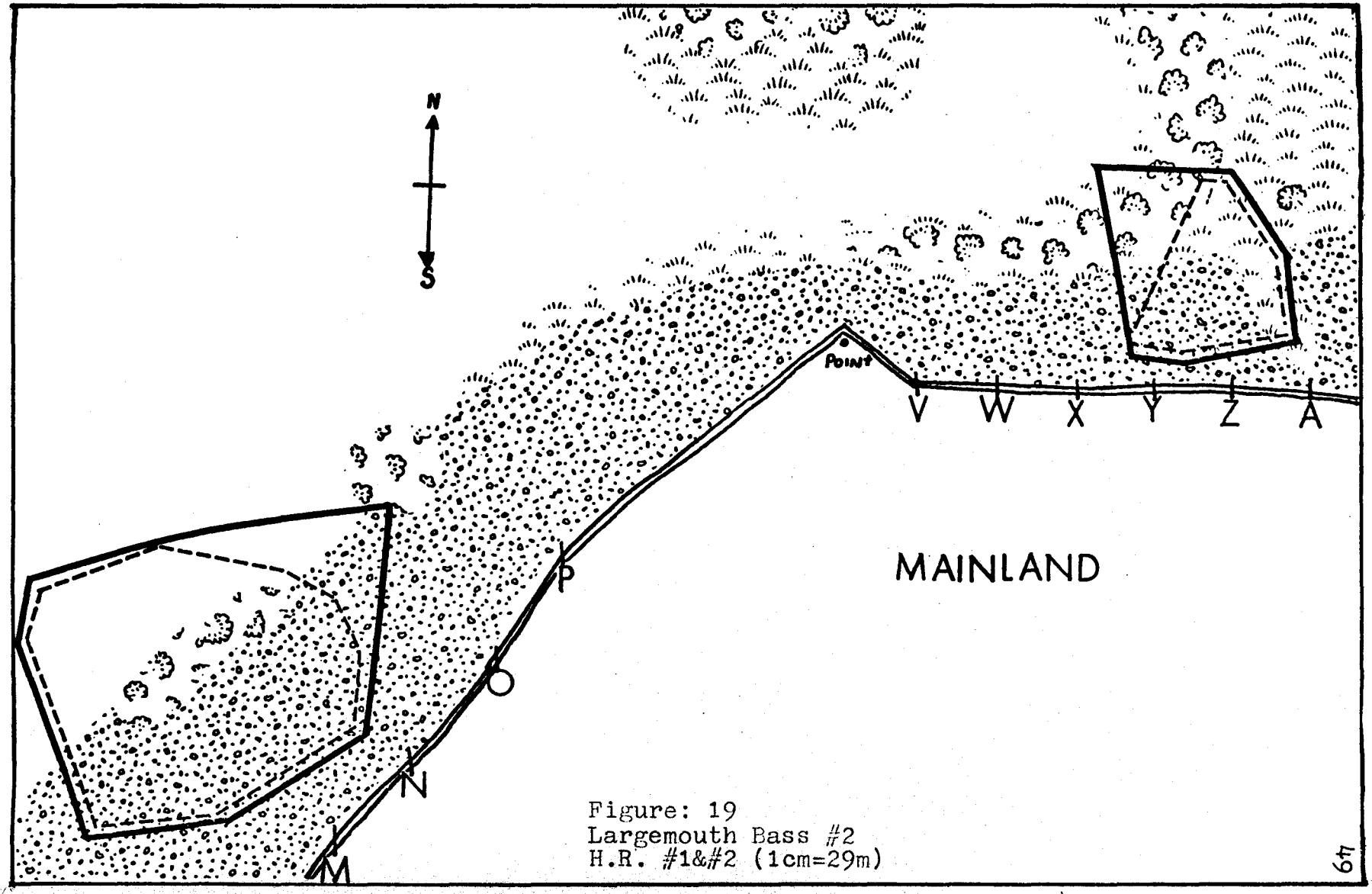


Figure: 19
Largemouth Bass #2
H.R. #1&#2 (1cm=29m)

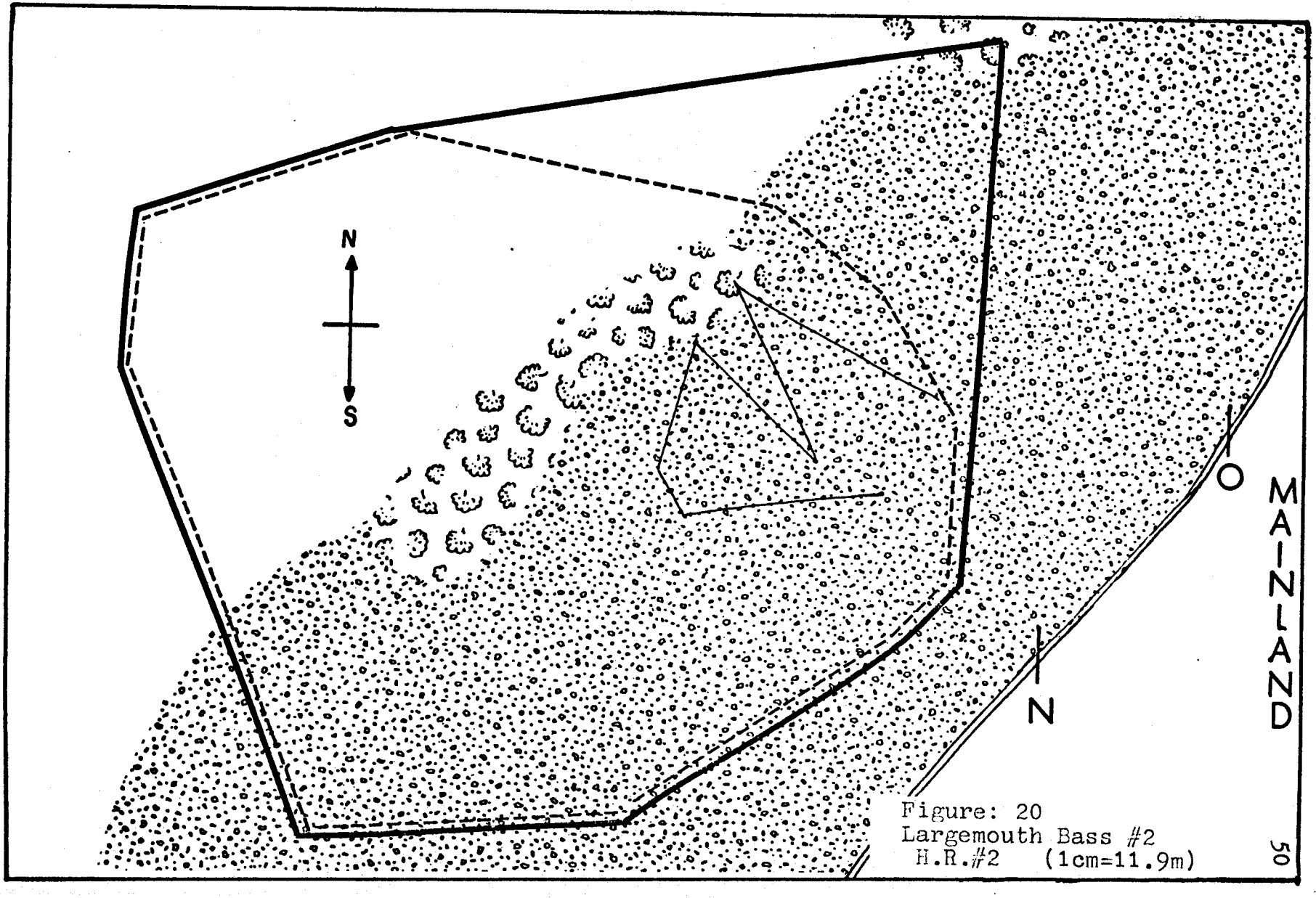


Figure: 20
Largemouth Bass #2
H.R.#2 (1cm=11.9m)

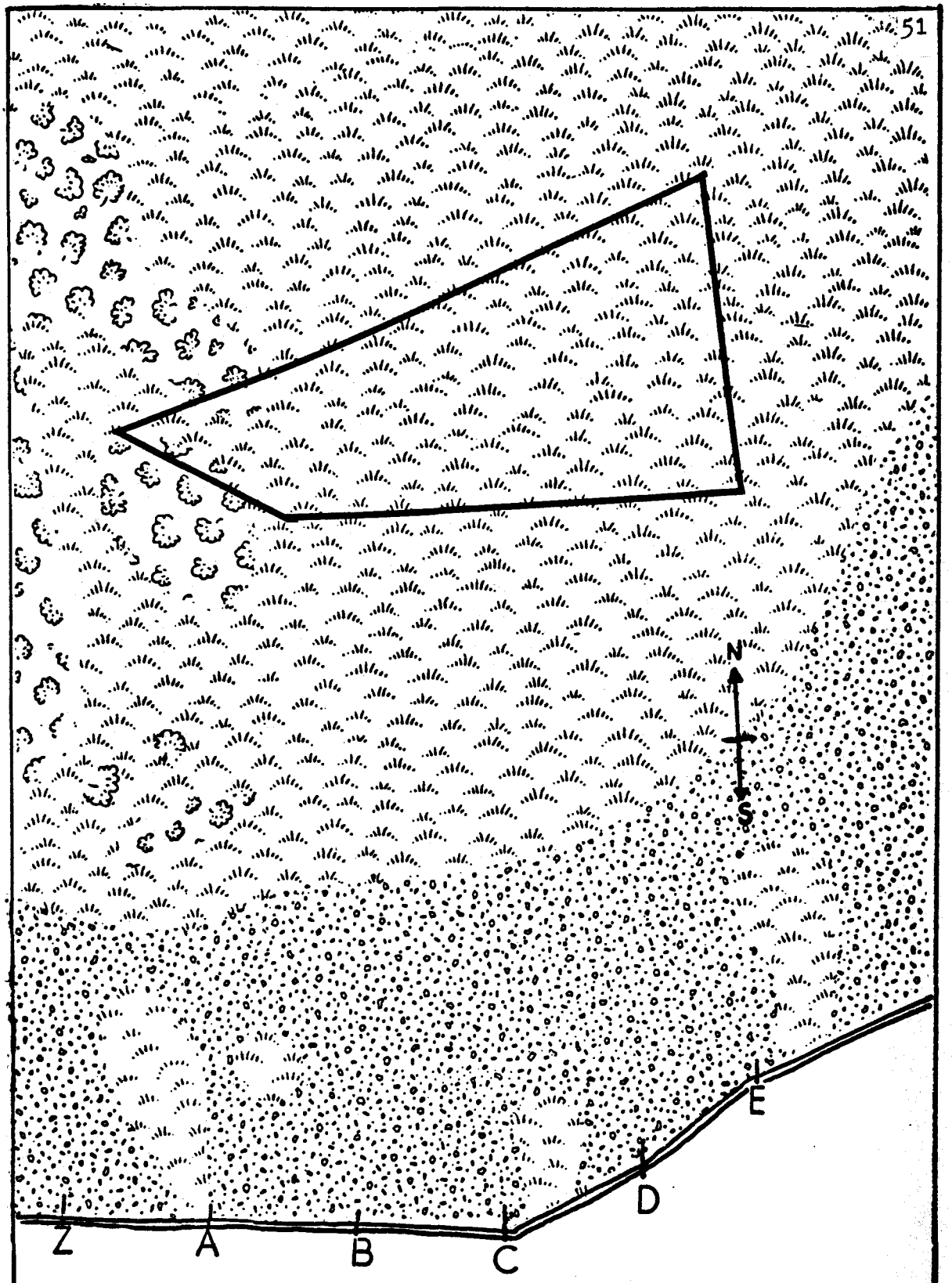


Figure: 21
Largemouth Bass #12
H.R.#1 (1cm=16.3m)

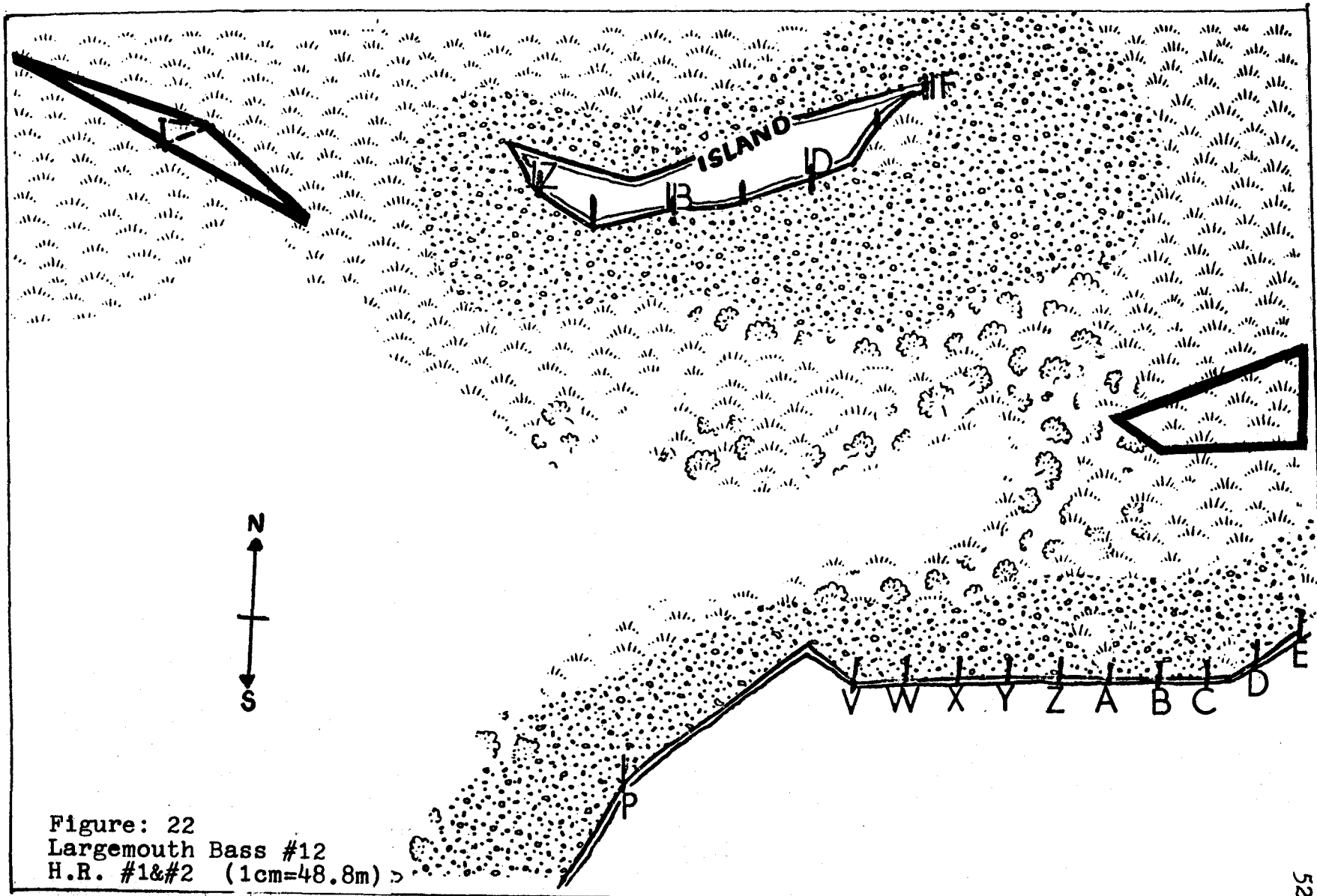


Figure: 22
Largemouth Bass #12
H.R. #1&#2 (1cm=48.8m)

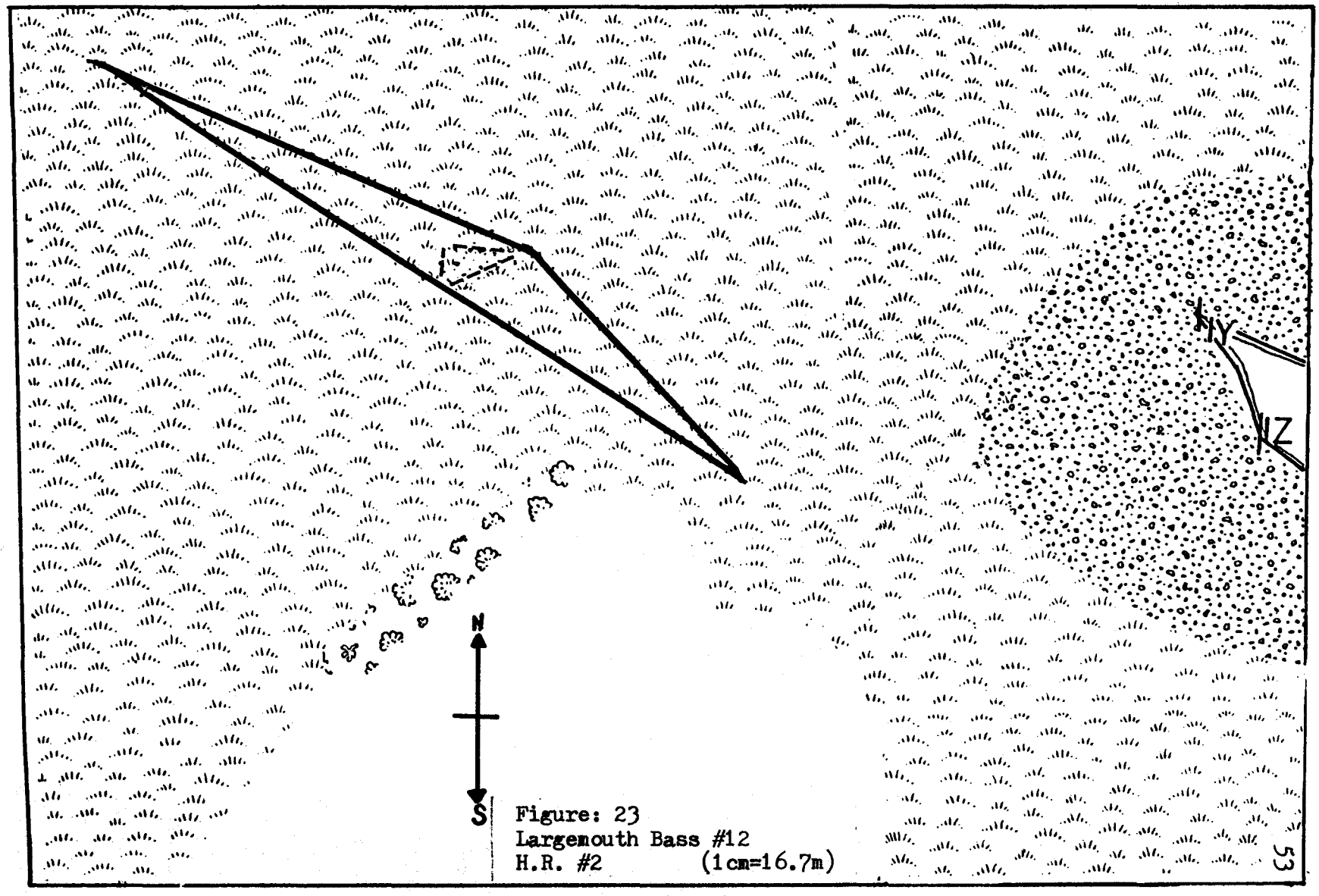


Figure: 23
Largemouth Bass #12
H.R. #2 (1cm=16.7m)

BLUEGILL HOME RANGE RESULTS

Nine Bluegills were studied to determine their home range and primary home range areas. Five of these fish namely, Bluegill #3, #4, #8, #9 and #10 each exhibited one home range and one primary home range area. Three other fish, Bluegill #6, #7 and #8 each exhibited a home range where the primary home range was of the same area. One other fish, Bluegill #1 established two home range areas.

The first bluegill that established one home range and one primary home range was Bluegill #3. Bluegill #3 established a home range that measured 0.48 hectares. This area was set up two days after the fish was released, 713 meters west southwest. This home range ran along stations K to L and at its furthest point from shore extended 121 meters outward. Bluegill #3's home range was entirely composed of sand (Figure 24).

Bluegill #3 established a primary home range that measured 0.23 hectares. This area encompassed the norhtern and center sections of the home range and was composed entirely of sand. The majority of triangulation on five minute data indicated this fish within the northern section of the home range.

Bluegill #4 established a home range that measured 0.72 hectares. This area was located along stations A to B and, at its farthest point from shore extended outward 213 meters. This home range was set up in the same area that the fish was caught and released (Figure 25).

Bluegill #4's home range encompassed a number of different habitats. The inshore section of the home range consisted of light weed bed #4, part of light weed bed #3 and the sand that surrounded and separated these areas. The outer section of the home range consisted of part of the heavy horseshoe shaped weed bed, heavy weed bed #3 and much of the offshore light weeds. This fish utilized ecotones extensively. Ecotone utilization was between light weed-heavy weeds and light weed-sand.

Bluegill #4 established a primary home range that measured 0.18 hectares. This area of primary utilization excluded the eastern and western most section of the home range. Within this area three different habitats were found namely the offshore light weeds, light weed bed #4 and the sand that separated these two areas. The majority of tracked locations indicated this fish within the inshore light weed bed and its ecotone. A number of other tracked locations indicated the fish within the outer light weeds. The sand that separated the inner and outer light weeds was only utilized by the fish as the fish moved from one weed bed to another.

Island Bluegill #8 established a home range that measured 0.74 hectares. This area was set up 140 meters south southeast from the area the fish was caught and released (Figure 26). This home range was composed entirely of offshore light weeds and sections of the heavy horseshoe shaped weed bed. The edge of the heavy hedgerow weed bed was also

found within this area.

Island Bluegill #8 established a primary home range that measured 0.52 hectares. This area encompassed the southern most section of the home range and was composed of the offshore light weeds and sections of the heavy horseshoe shaped weed bed. No one particular habitat of this primary home range was utilized more extensively.

Island Bluegill #9 established a home range that measured 0.61 hectares and was set up in the same area the fish was caught and released. This area was located off the southwest shore of the island along stations IY to IZ. At its farthest point from shore this home range extended outward 287 meters. This area consisted of the offshore island light weeds, island heavy weed bed #3, a sandy inshore section and a section of open water. Ecotones of heavy weed-open water, light weed-open water and light weed-sand were predominant in the home range (Figure 27).

Island Bluegill #9 estabilshed a primary home range that measured 0.27 hecatres. This area excluded the eastern and western most ends of the home range and was composed of the island offshore light weeds. Again no one particular area of this primary home range was utilized more extensively.

Island Bluegill #10 established a home range area that measureed 0.18 hectares. This area was set up 159 meters southeast from the area the fish was released. This home range was located off the southeast edge of the island and

included only a few habitats (Figure 28). The southern section of the home range contained the offshore island light weeds while the northern section contained the edge of the heavy hedgerow weed bed.

Island Bluegill #10 established a primary home range area that measured 0.11 hectares. This area encompassed the northern section of the home range and consisted of light weeds and a small section of the heavy hedgerow weed bed. The majority of data points indicated this fish within this light weed bed area. A few days of resectioning data indicated the fish within the heavy hedgerow weed bed and along the edge.

In determining the home range areas for bluegills it was noted that three of the fish established a home range and primary home range of equal areas. These fish utilized their entire home range areas equally, as no one data point indicated the fish more than 60.69 meters or 200 feet from any other data point. Therefore these primary home ranges were recorded as having the same area as their home range. These fish were Island Bluegill #5, #6 and #7.

Island Bluegill #5's home range and primary home range was found to measure 0.20 hectares. This area was set up 488 meters south southwest from the fish's point of release two days earlier. This home range area ran along stations N to O and at its furthest point from shore extended outward 110 meters (Figure 29).

Island Bluegill #5's home range and primary home range

contained part of heavy weed bed #1 and the sand that surrounded this area. The edge of the transition between sand and open water was also included. The majority of locations indicate this fish over sand.

Bluegill #6 established a home range and primary home range that measured 0.39 hectares. This area extended along stations Z to B and at its furthest point from shore extended 120 meters outward. The home range was established in the same area the fish was caught and released (Figure 30).

Bluegill #6's home range and primary home range consisted of light weed bed #3 and #4 and the sand that surrounded these two areas. The outer section of this area consisted of part of heavy weed bed #3 and the offshore light weeds. Ecotones were also prominent throughout the home range area. This was exhibited as the transition between light weeds and sand.

The majority of locations indicate the fish in and around the inshore light weeds. A few locations also indicated the fish within the outer light weed bed. From five minute data plottings the sandy area between these light weed beds appear only to be utilized by the fish as a means of getting from one weed bed to another. Not once during the course of the study was Bluegill #6 shown to spend more than five minutes solely over sand.

Bluegill #7's home range and primary home range areas were found to measure 0.20 hectares. This area was estab-

lished along stations A to B and at its furtherst point from shore extended 116 meters outward. This home range was established in the same area the fish was caught and released (Figure 31).

Bluegill #7's home range and primary home range consisted of light weed bed #4, the sand that surrounded the area, the offshore light weeds and part of heavy weed bed #3. Ecotones were prominent throughout this area as exhibited by the transition between light weeds and sand and heavy weeds and light weeds.

The majority of data points indicated the fish within the inner and outer light weeds and the sand that separated these areas. The ecotone of the light weeds-sand was also heavily utilized by the fish. Again the sandy area in this home range only appeared to be utilized as the fish moved along the edge of the light weeds or traveled from one weed bed to another.

Bluegill #1 was the only bluegill in the study to establish two home range areas. Home range #1 was found to measure 0.75 hectares. This area was set up along stations Y to A and at its farthest point from shore extended outward 122 meters. This home range was set up near the area where the fish was caught and released (Figure 32).

Bluegill #1's home range #1 was composed of an inshore sandy area and an offshore weedy area. The inshore section of this home range was composed of part of light weed bed #3 and sand. The outer section was composed of part of the

heavy horseshoe shaped weed bed and offshore light weeds. The edge effect was predominant in these areas.

Bluegill #1 established a primary home range within home range #1 that measured 0.60 hectares. This area eliminated part of the inshore sandy area. The majority of data locations indicate the fish within the outer weed beds.

Bluegill #1 remained in this first home range for two weeks after release. One week after leaving home range #1, Bluegill #1 established its second home range 171 meters east. Here the fish remained for the duration of the transmitter's life.

Home range #2 was found to measure 0.15 hectares. This area was located along stations E to F and at its farthest point from shore extended outward 73 meters. This home range was composed of light weed bed #6 and the sand that surrounded this weed bed forming the light weed-sand ecotone. No one particular area or habitat was utilized extensively by Bluegill #1.

Bluegill #1 did not establish a separate primary home range area. This was due to the fact that only a week's worth of data was collected before transmission was lost. Therefore Bluegill #1's primary home range was recorded as having the same area as the home range.

Bluegill Home Range Statistics

Linear correlations were performed on the home range and primary home range areas of bluegills. The correlations

correlated these areas with the number of days the fish were tracked and the size of the fish. Data for all correlations were handled in the same manner as previous tests.

A correlation coefficient was calculated between the area of the bluegill's home range and the number of days each fish was tracked. The null hypothesis stated that there is no correlation between the area of the home range and the number of tracked days. The null hypothesis was accepted; $r=-0.06$; $(p>0.05)$. This result was expected, as each bluegill was determined to have been tracked enough times to reveal an accurate home range area.

The second correlation coefficient calculated was between the area of the primary home range and the number of days tracked for each fish. The null hypothesis stated that there is no correlation between the area of the primary home range and the number of tracked days. This null hypothesis was accepted; $r=-0.01$; $(p>0.05)$. The result was expected, as each bluegill was tracked enough times to reveal an accurate primary home range area.

The third correlation correlated the home range area versus the size of the fish. This null hypothesis stated that there is no correlation between the home range area and the size of the bluegills. This null hypothesis was rejected; $r=-0.68$; $(p<0.05)$. A significant negative correlation was obtained indicating an inverse relationship. The result that larger fish are able to utilize a smaller area than smaller bluegills may possibly be due to larger blue-

gills establishing a social dominance. If this is true, then larger bluegills may efficiently utilize a smaller area than smaller fish.

It can also be noted that it is the larger bluegills that establish a home range and primary home range of the same area. This again can illustrate that the large bluegills are able to utilize a smaller area.

The fourth correlation coefficient calculated was between the size of the bluegills versus their primary home range areas. The null hypothesis stated that there was no correlation between the size of the fish and the area of their primary home ranges; $r=0.19$; $(p>0.05)$. All bluegills regardless of size were determined to utilize nearly identical primary home range areas.

TABLE 5

BLUEGILL HOME RANGE AND PRIMARY HOME RANGE RESULTS

BLUEGILL #	HOME RANGE (hectares)		PRIMARY HOME RANGE (hectares)		SIZE (cm)	DATES TRACKED
1	HR#1	0.75	PHR#1	0.60	17.8	6-17-80 6-28-80
	HR#2	0.15	PHR#2	0.15		7-12-80 7-22-80
3		0.48		0.23	17.0	6-24-80 7-6-80
4		0.72		0.18	15.5	7-8-80 7-22-80
5		0.20		0.20	17.0	7-11-80 7-27-80
6		0.39		0.39	18.0	8-14-80 9-5-80
7		0.20		0.20	19.0	9-14-80 10-11-80
I8		0.74		0.52	16.1	10-5-80 11-7-80
I9		0.61		0.27	17.0	5-3-81 5-26-81
I10		0.18		0.11	19.0	5-28-81 7-2-81

LEGEND EOR BLUEGILL ILLUSTRATIONS


Heavy Weeds


Light Weeds


Sand


Open Water


Home Range Line

Primary Home Range Line


Shoreline

Island or Mainland as Indicated

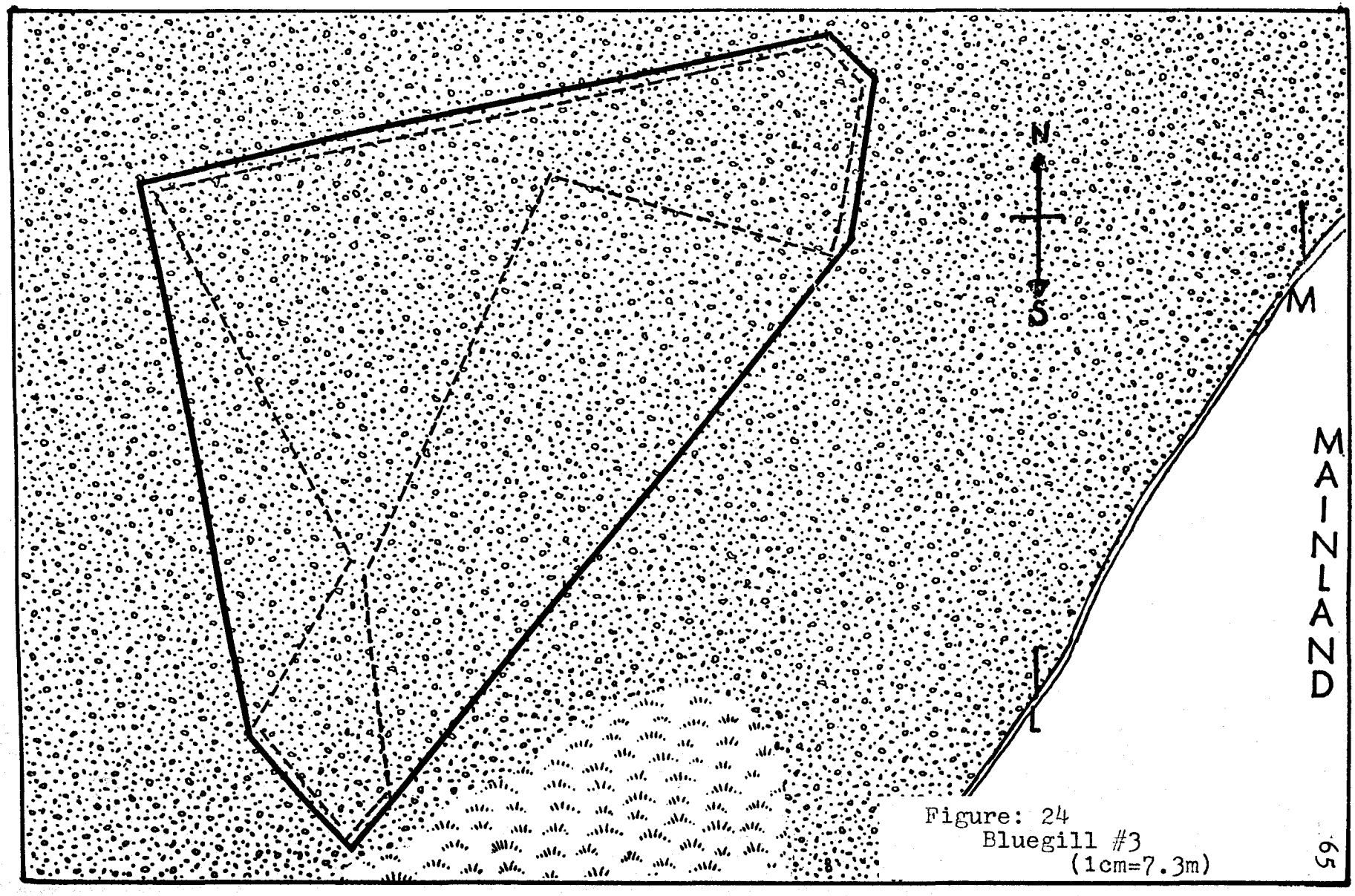


Figure: 24
Bluegill #3
(1cm=7.3m)

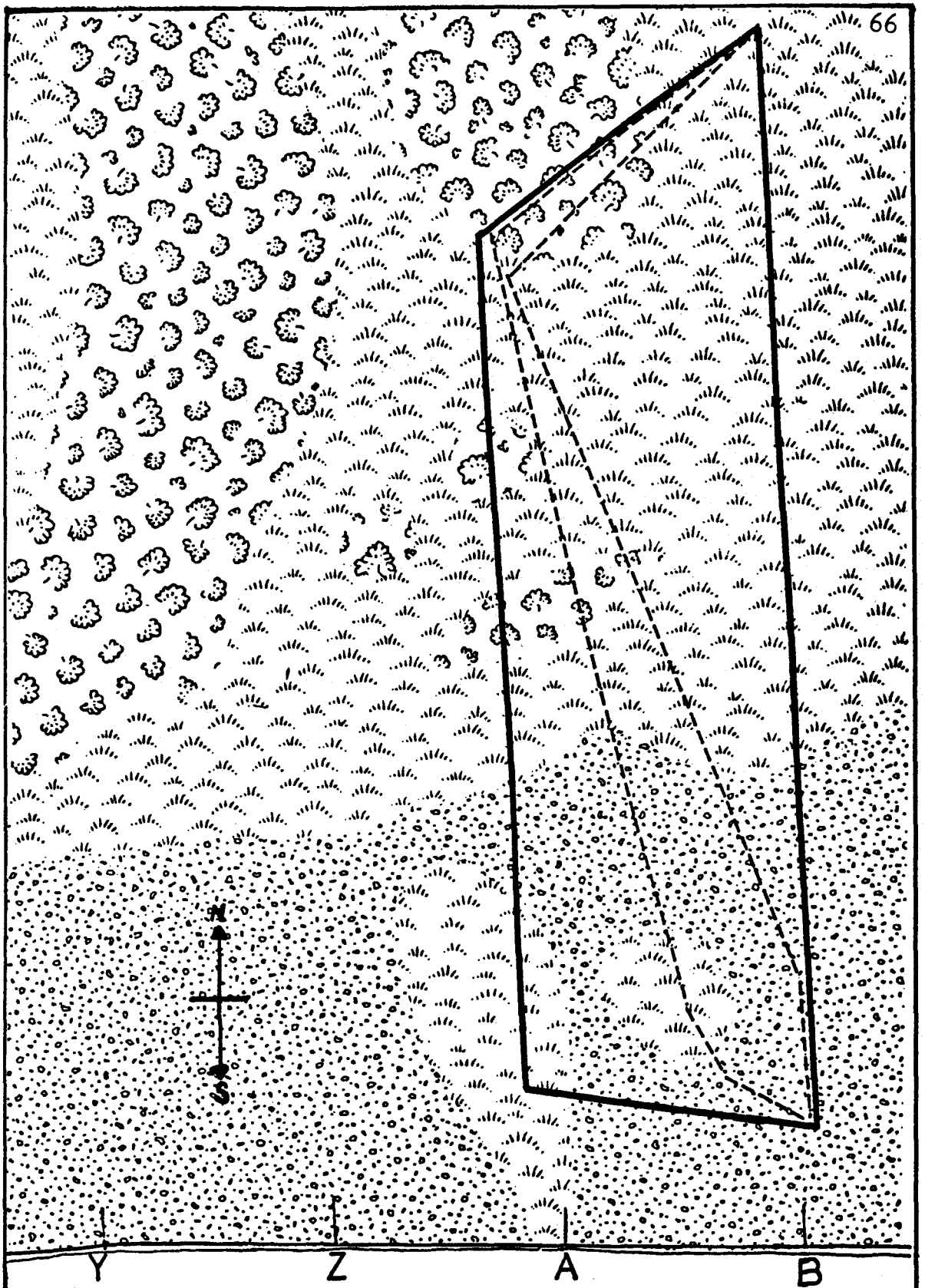


Figure: 25
Bluegill #4
(1cm=9.9m)

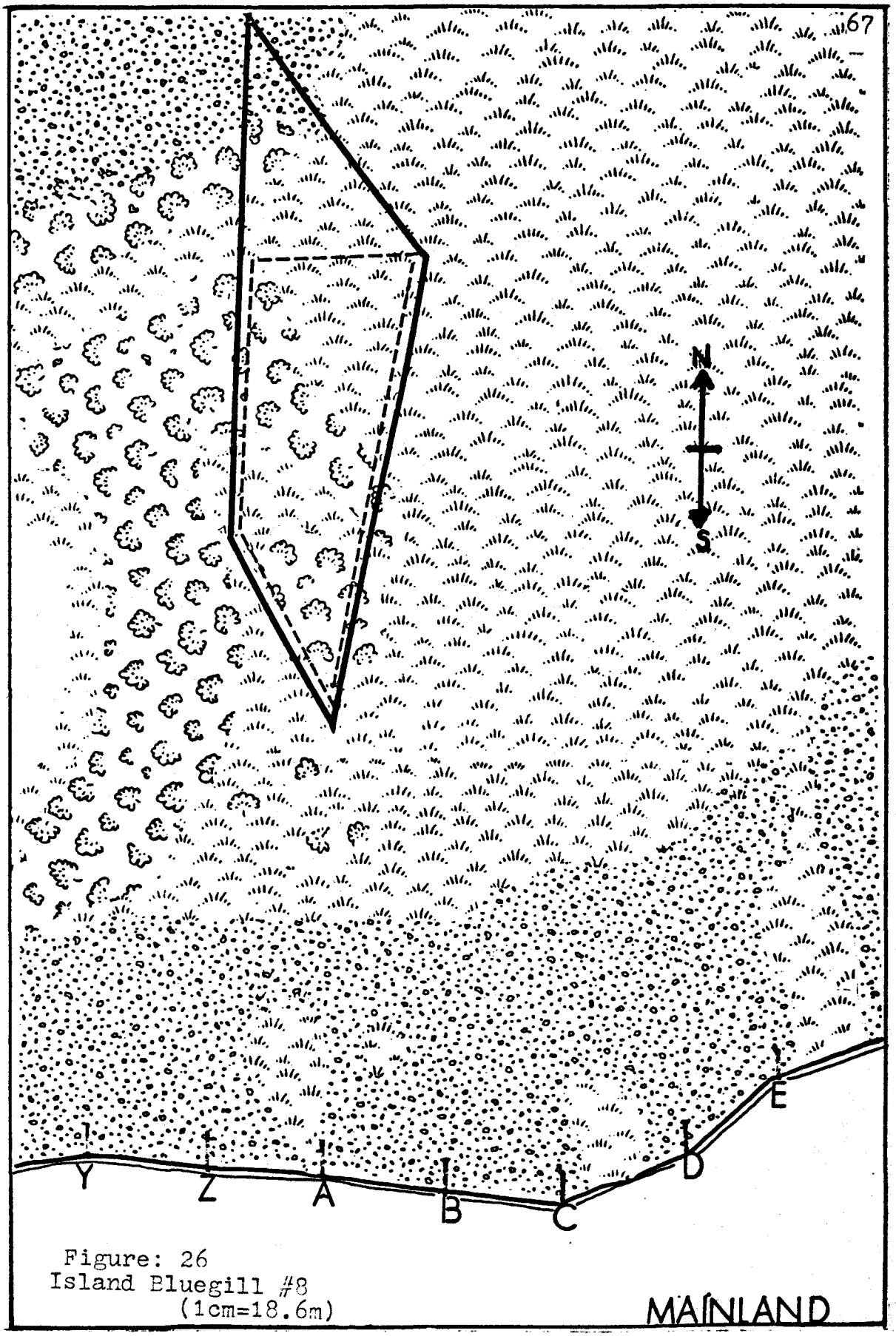


Figure: 26
Island Bluegill #8
(1cm=18.6m)

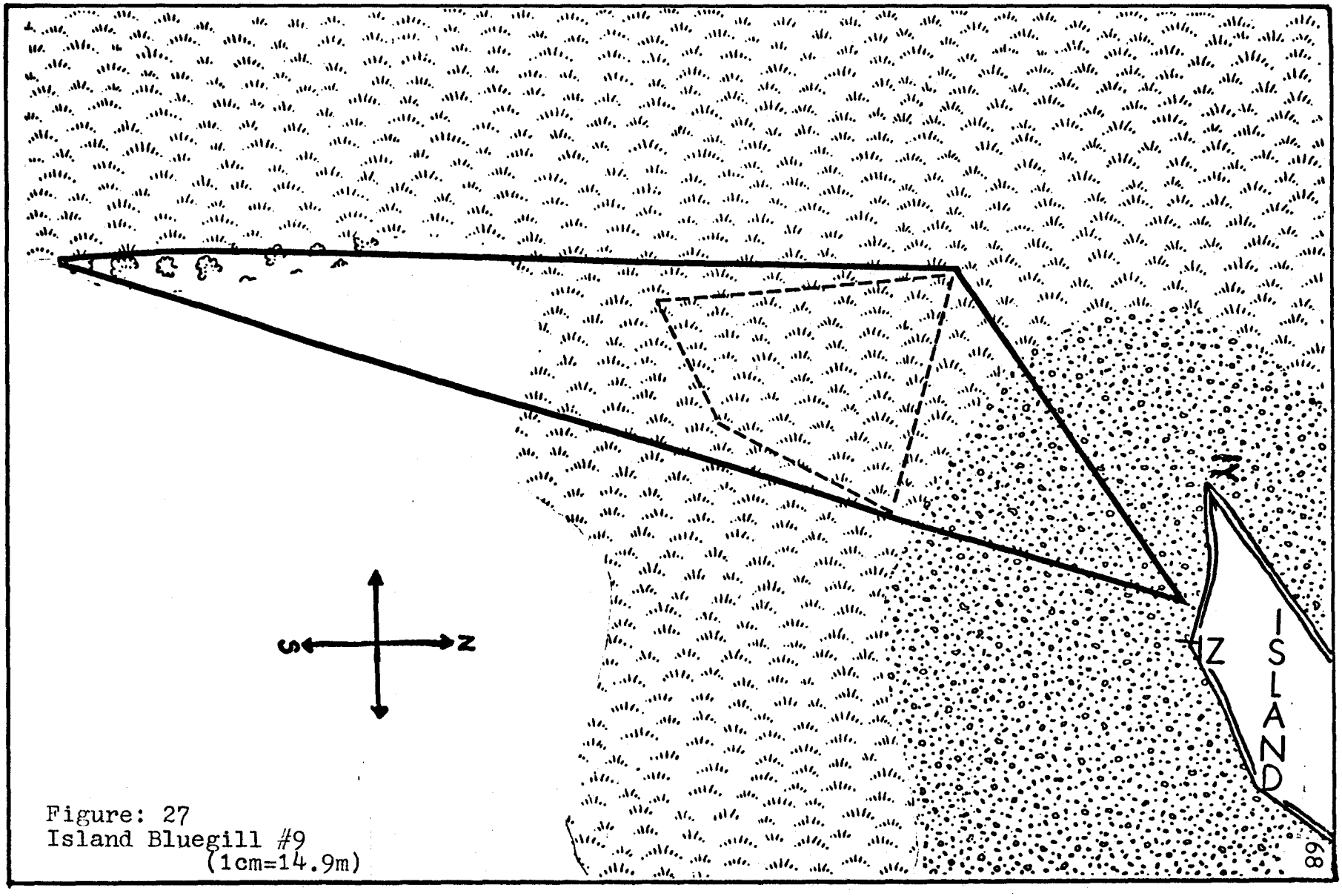


Figure: 27
Island Bluegill #9
(1cm=14.9m)

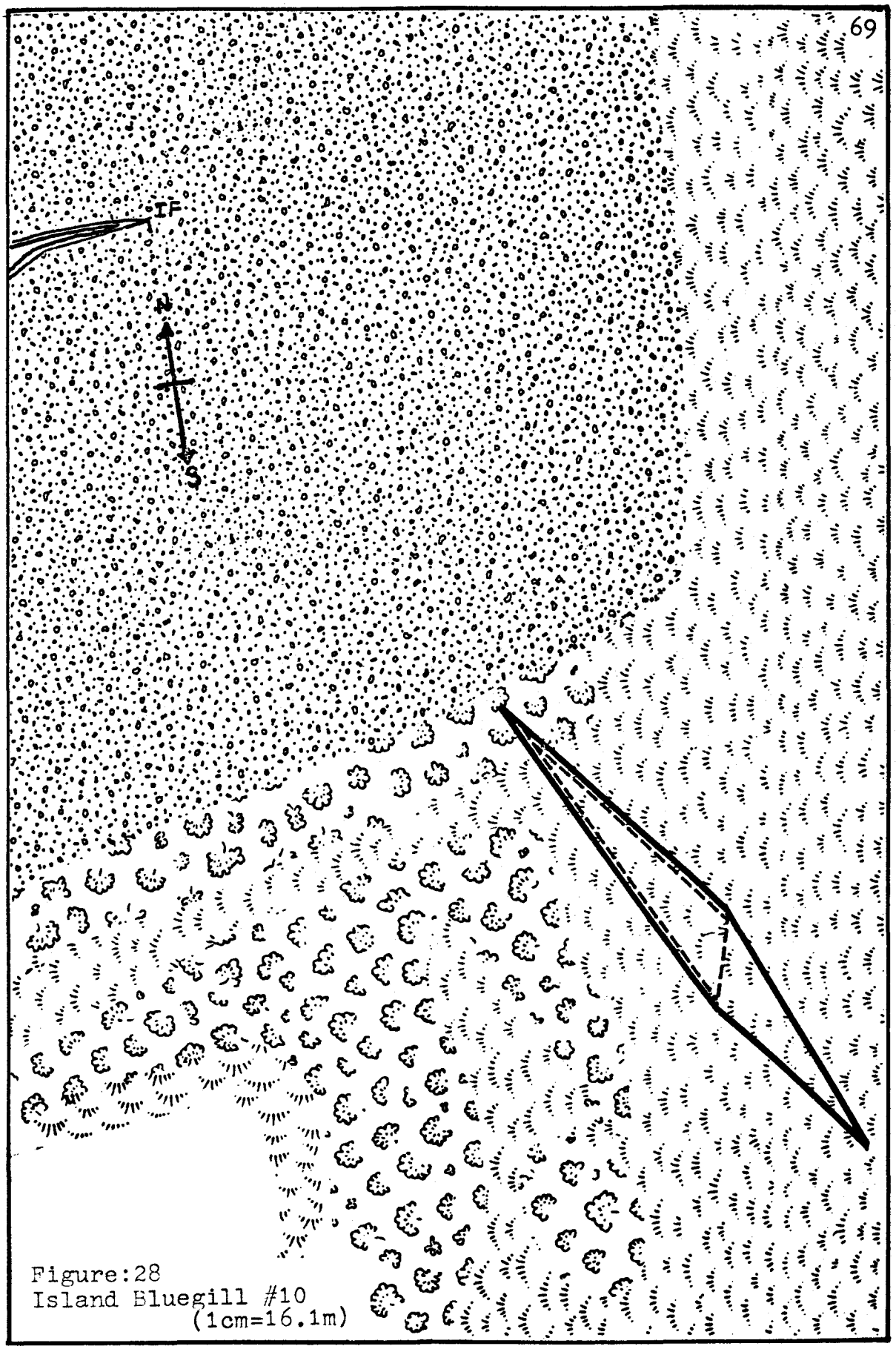


Figure:28
Island Bluegill #10
(1cm=16.1m)

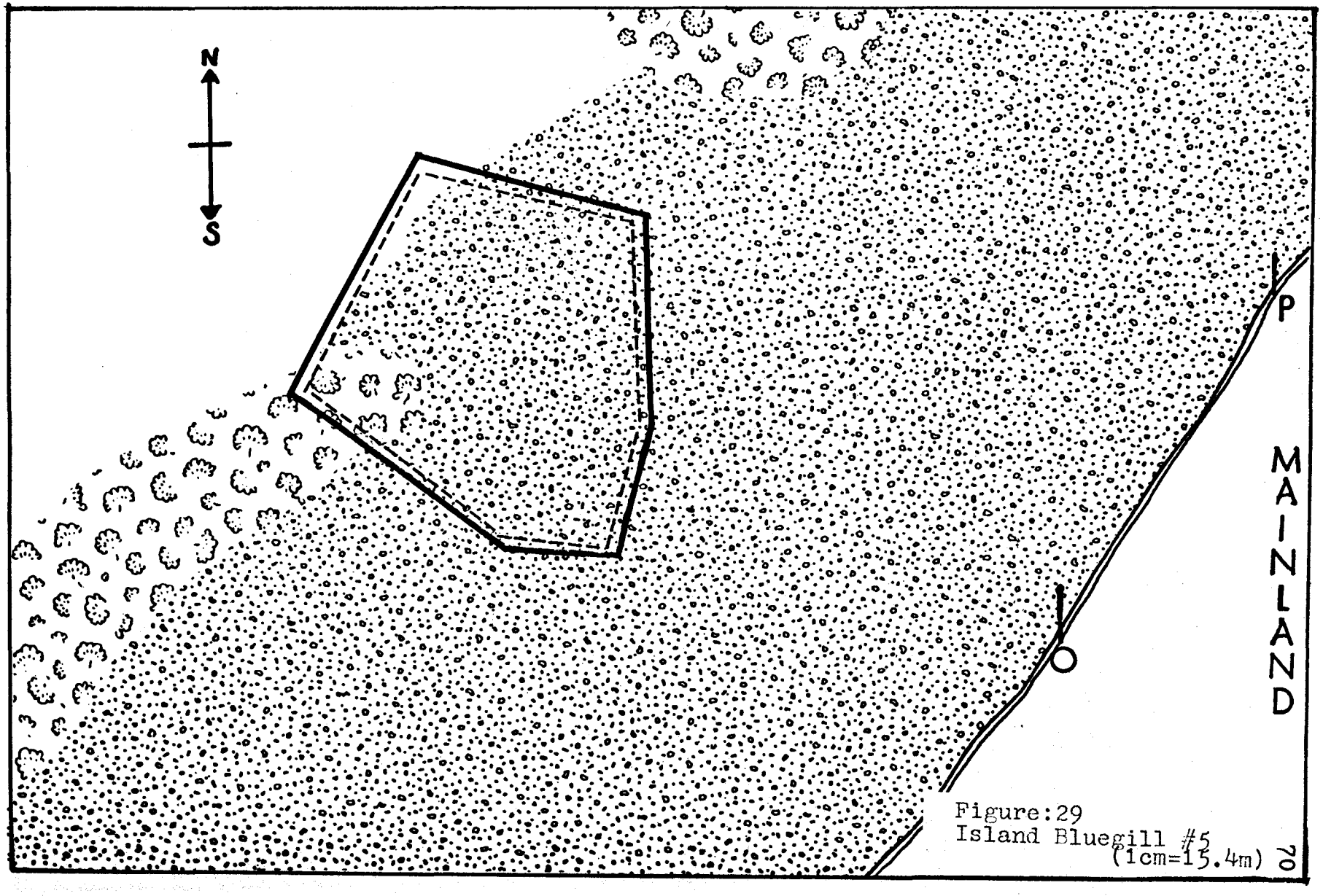


Figure:29
Island Bluegill #5
(1cm=15.4m)

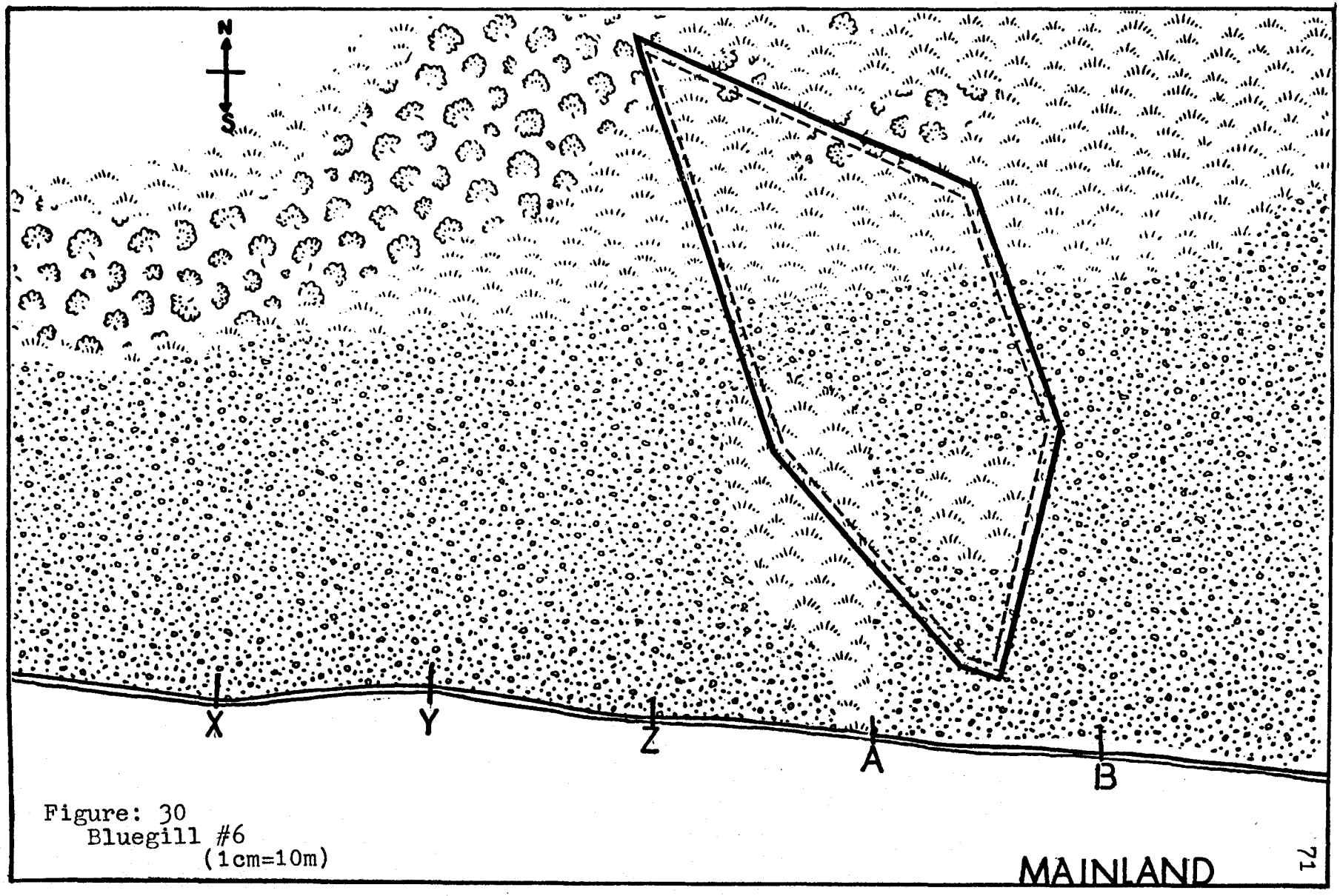


Figure: 30
Bluegill #6
(1cm=10m)

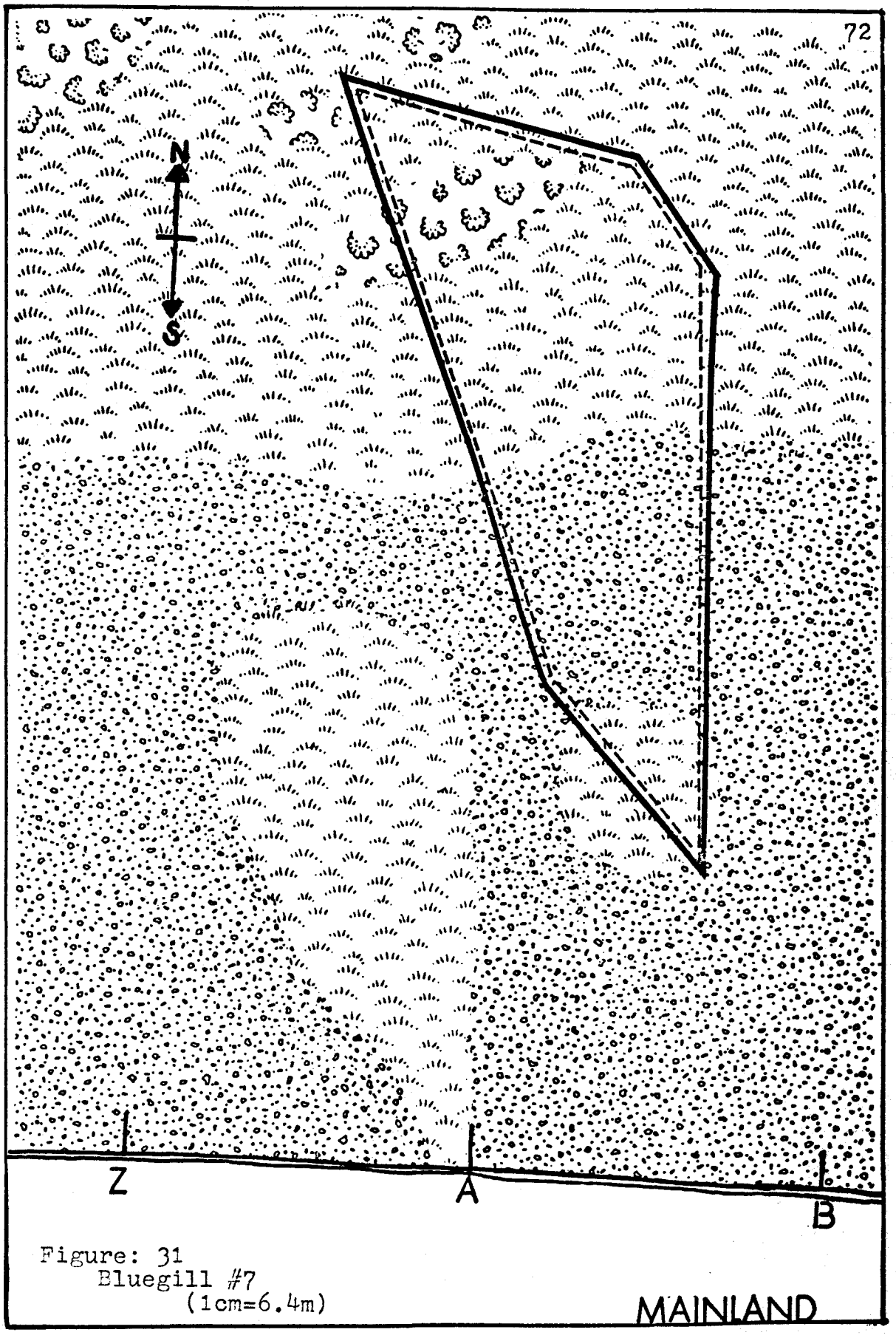


Figure: 31
Bluegill #7
(1cm=6.4m)

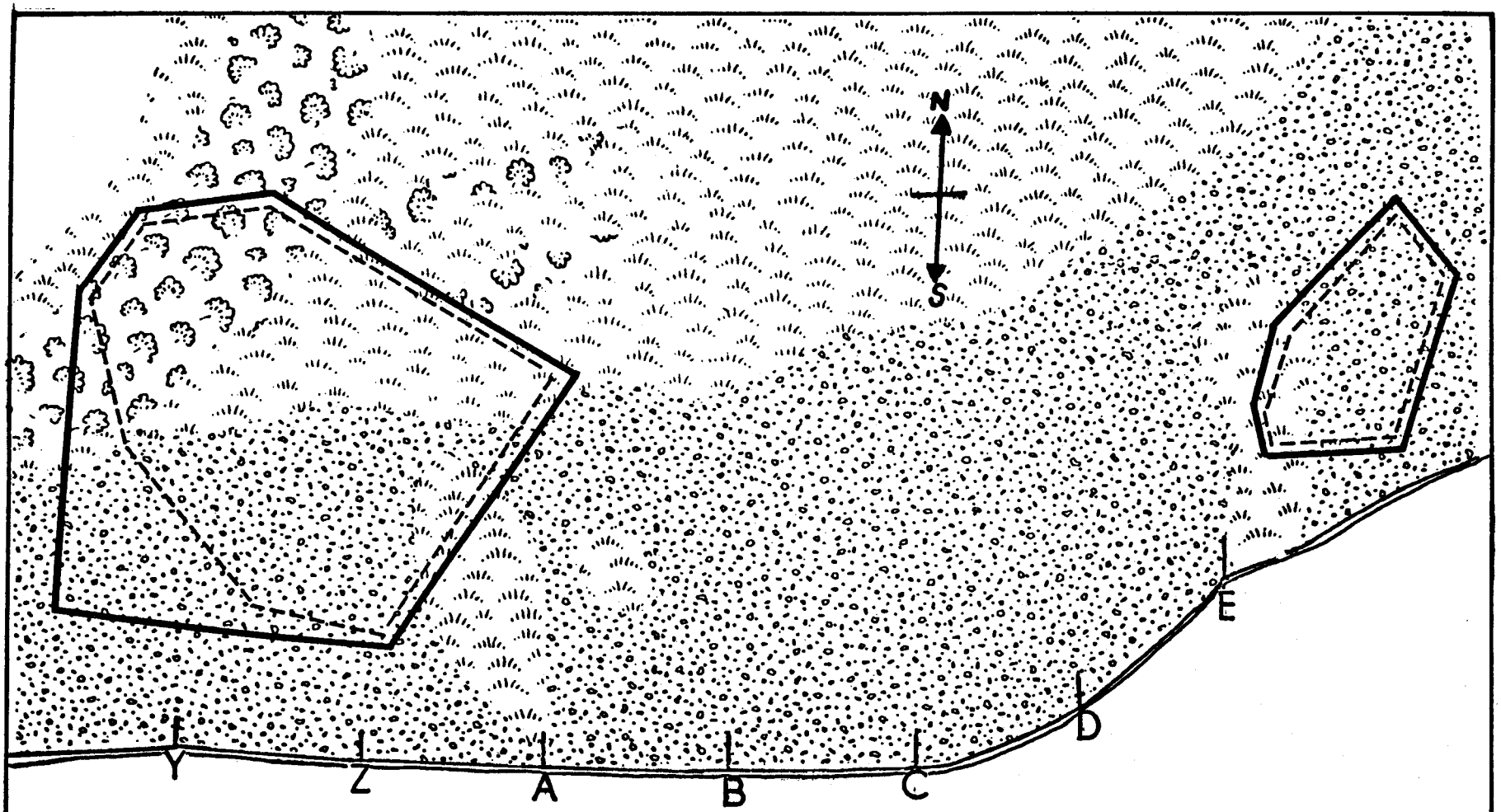


Figure: 32
Bluegill #1
(1cm=13.7m)

MAINLAND

YELLOW PERCH HOME RANGE RESULTS

Four yellow perch were studied to determine their home range and primary home range areas. Two of the yellow perch, Yellow Perch #3 and #5, each exhibited one home range and one primary home range area. The other two yellow perch, Yellow Perch #1 and #4, each exhibited one home range and two primary home ranges within each of these home range areas.

Yellow Perch #3 established a home range that measured 0.56 hectares. This area was betweeen stations A to C and extended 140 meters out from shore. This home range existed near the area where the fish was caught and released (Figure 33).

Yellow Perch #3's home range included a number of habitats. The inshore section contain light weed bed #4, the edge of light weed bed #3 and the sand that surrounded these areas. The outer section of the home range consisted of light weeds with portions of heavy weed bed #3 and an ecotone of light weeds-sand.

Yellow Perch #3 established a primary home range area of 0.38 hectares. This area included light weed bed #4, the offshore light weeds and the sand that separated these areas. The ecotone created by the light weed-sand transition was also included. The area excluded from the primary home range corresponded to some of the sandy inshore area and part of the offshore light weeds.

The majority of tracked locations for Yellow Perch #3

were found in and around light weed bed #4 and its ecotone. The offshore light weeds were also utilized by this fish although not as heavily as light weed bed #4. The sandy area that separated the inner and outer light weeds was again primarily used by the fish as a means of getting from one weed bed to another.

This fish also utilized the edge of light weed bed #3 as well as the edge of the heavy weed bed. Neither of these two areas were utilized as heavily as light weed bed #4 or its ecotone.

Yellow Perch #5 established a home range of 0.54 hectares. This area was found off the southwest shore of the island and extended along stations ID to IF. This area was located near the same place the fish was caught and released. Habitats within this home range included part of the light weed bed #I2 and the sand that surrounded this weed bed and extended along the shoreline (Figure 34).

Yellow Perch #5 established a primary home range of 0.05 hectares. This area excluded most of the sandy area that made up the home range as well as part of light weed bed #I2. The majority of data locations indicated the fish over sand and occasionally in light weed bed #I2.

It can be noted that Yellow Perch #5 was only tracked for eleven days due to premature transmitter failure. For this reason this primary home range may be under-estimated.

The other two yellow perch studied revealed one home range and two primary home ranges within each home range

area. As stated previously a fish may establish two primary home ranges if two distinctly separate areas of the home range are used exclusively and neither of these two primary home ranges were within 60.69 meters of one another. These two fish were Yellow Perch #1 and Yellow Perch #4.

Yellow Perch #1 established a home range that measured 1.39 hectares. This area extended along stations Z to D at its farthest point from shore extended outward 174 meters. This home range was set up in the same area the fish was caught and released (Figure 36).

Yellow Perch #1's home range included a number of different habitats. The inshore section of the home range was composed of light weed beds #3, #4 and #5 and the sandy area that surrounded these weed beds. The outer section of the home range consisted of part of heavy weed bed #3, the outer light weeds and the edge of the heavy horseshoe shaped weed bed. The ecotone created by the light weed-sand transition was also included in the home range.

From Figure 36, it can be seen that the eastern and western most regions of the home range was used exclusively. No known data locations indicated the fish within the center of the home range area. For this reason Yellow Perch #1 was considered to have established two primary home range areas.

Primary home range #1 measured 0.41 hectares and was the western most primary home range area. This area included heavy weed bed #3, the edge of the heavy horseshoe shaped weed bed and part of the offshore light weeds. Also

included was part of inshore light weed bed #3, the sand that surrounded this area, and the light weed-sand ecotone.

The majority of locations in the primary home range were found along the ecotone of light weed bed #3 and the sand that surrounded this weed bed. The fish was located only a few times within the outer light weed bed and only twice within heavy weed bed #3 or along the edge of the heavy horseshoe shaped weed bed.

The second primary home range measured 0.27 hectares and was located at the eastern end of the home range area. This area was composed mostly of sand with the ecotone of the offshore light weed bed also included. The majority of data locations within this primary home range reveal the fish over sand. Only twice was the fish positioned at the light weed-sand ecotone. It should be noted that both primary home ranges were utilized equally and alternately by the fish.

Yellow Perch #4 established a home range that measured 2.20 hectares. This area was set up along stations Y to F and extended outward 1.46 meters. This home range occurred in the same area the fish was caught and released (Figure 35).

The inshore portion of the home range consisted of light weed bed #6, sand and a light weed-sand ecotone. The offshore portion of this home range was composed of part of the heavy horseshoe shaped weed bed, heavy weed bed #3 and part of the offshore light weeds. A number of ecotones were

also prominent within this home range area.

As with Yellow Perch #1, Yellow Perch #4 utilized two areas of the home range exclusively. These areas corresponded to the eastern and western most sections of the home range, while the center area of the home range was never noted to have been utilized.

Primary home range #1 measured 0.17 hectares and corresponded to the western most area of the home range. Habitats within the area consisted of part of the heavy horseshoe shaped weed bed and the open water that borders it on the north and the offshore light weeds that border it on the south. A small section of sand near the edge of light weed bed #3 was also contained in the primary home range. No one habitat or area of this primary home range was utilized more extensively than others as Yellow Perch #4 was only located four times within this area. For this reason primary home range #1 may be underestimated.

Primary home range #2 measured 0.61 hectares. This area corresponded to the eastern most section of the home range. This area was composed of light weed bed #6, its ecotone and the offshore light weeds. The sandy area between these light weed beds was also included within the primary home range.

The majority of data points in primary home range #2 revealed the fish within the outer light weeds. The fish was only located three times over sand and twice within light weed bed #6. The light weed-sand ecotone of this pri-

mary home range did not appear to be utilized by the fish.

As with Yellow Perch #1 both primary home range areas were utilized alternately. It was noted however, that primary home range #2 was utilized more extensively.

Yellow Perch Home Range Statistics

The first correlation coefficient calculated was between the areas of the yellow perch home range and the number of days the fish were tracked. The null hypothesis was that there is no difference in the size of the home range and the number of tracked days. This null hypothesis was accepted, $r=-0.08$; $(p>0.05)$.

The second correlation coefficient was between the area of the primary home range and the number of days the fish was tracked. The null hypothesis was that there is no difference in areas of the primary home range and the number of days the yellow perch were tracked. This null hypothesis was accepted, $r=0.40$; $(p>0.05)$. This result was accepted as enough data was obtained to reveal an accurate representation of perch primary home range areas. No correlations were performed correlating the size of the fish to the area of their home range or primary home range area. This was due to the narrow range in the size of yellow perch (19.8cm - 22.5cm).

TABLE 6

YELLOW PERCH HOME RANGE AND PRIMARY HOME RANGE RESULTS

PERCH #	HOME RANGE (hectares)	PRIMARY HOME RANGE (hectares)		SIZE (cm)	DATES TRACKED
1	1.39	#1	0.41	21.3	6-10-80
		#2	0.27		7-4-80
3	0.56		0.38	20.5	9-14-80
					12-23-80
4	2.20	#1	0.17	22.5	5-13-81
					6-28-81
		#2	0.61		
5	0.54		0.05	19.8	5-21-81
					6-2-81

LEGEND FOR YELLOW PERCH ILLUSTRATIONS


Heavy Weeds


Light Weeds


Sand


Open Water


Home Range Line

Primary Home Range Line


Shoreline

Island or Mainland as Indicated

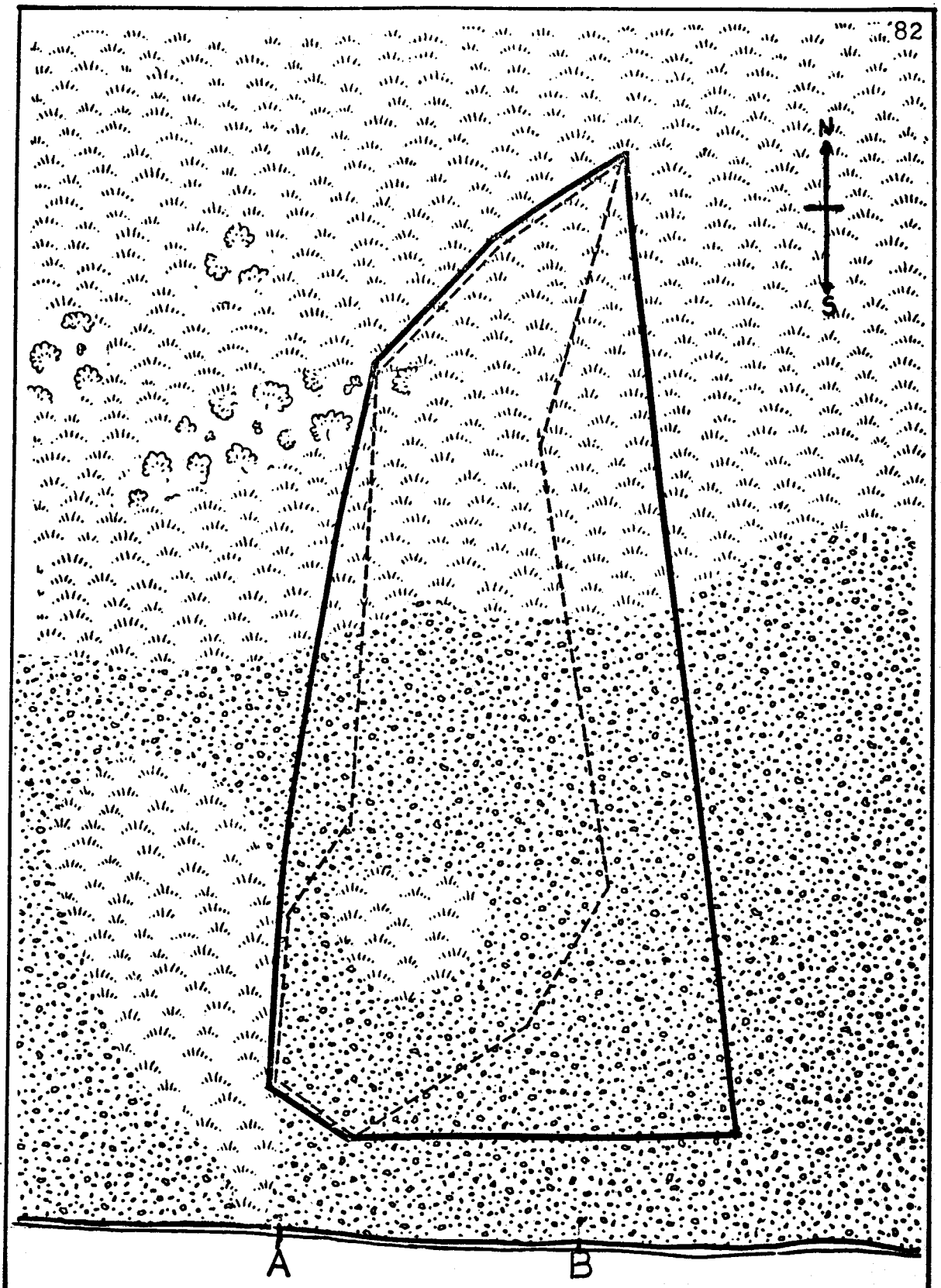


Figure: 33
Yellow Perch #3
(1cm=7.8m)

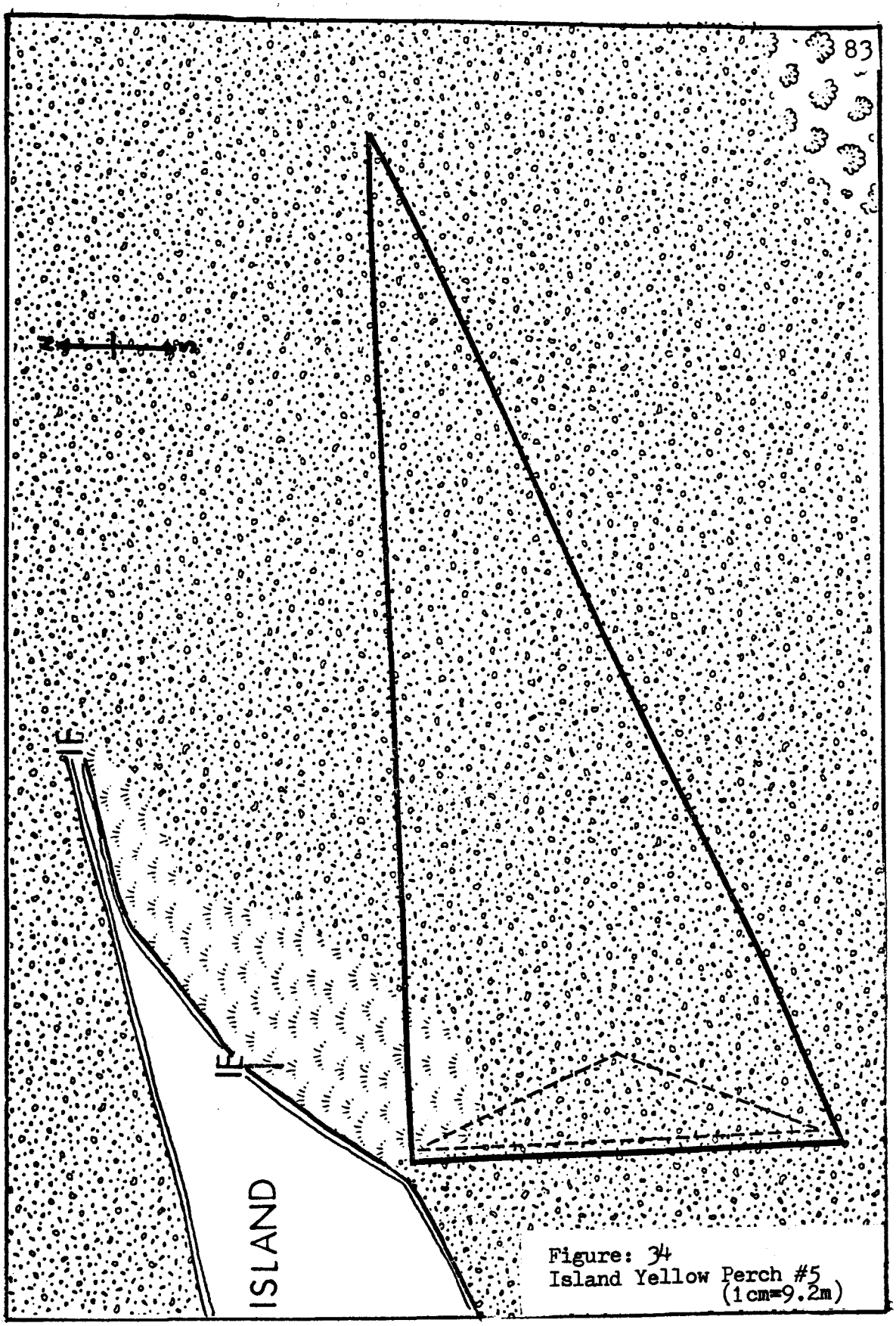


Figure: 34
Island Yellow Perch #5
(1cm=9.2m)

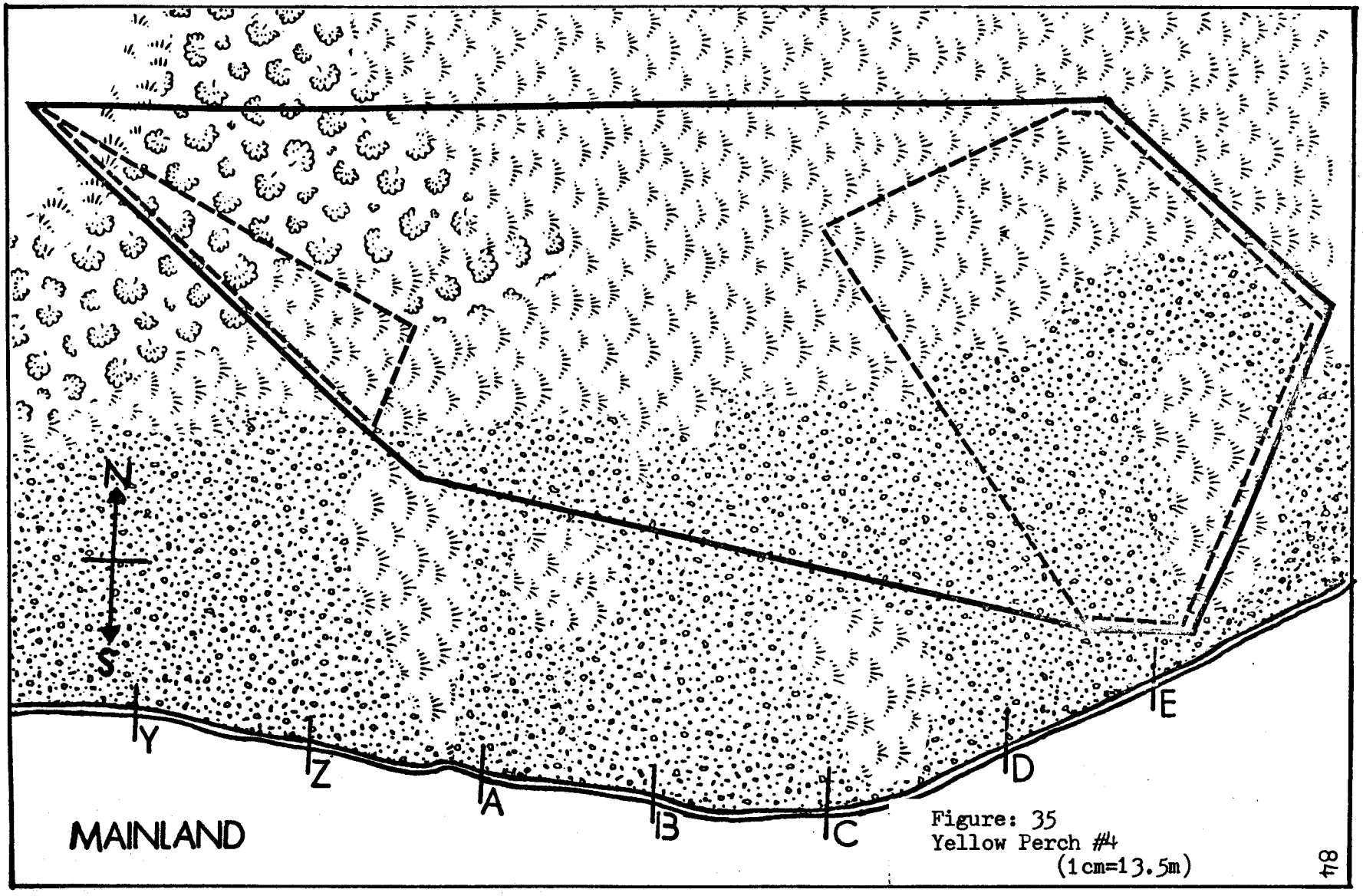


Figure: 35
Yellow Perch #4
(1cm=13.5m)

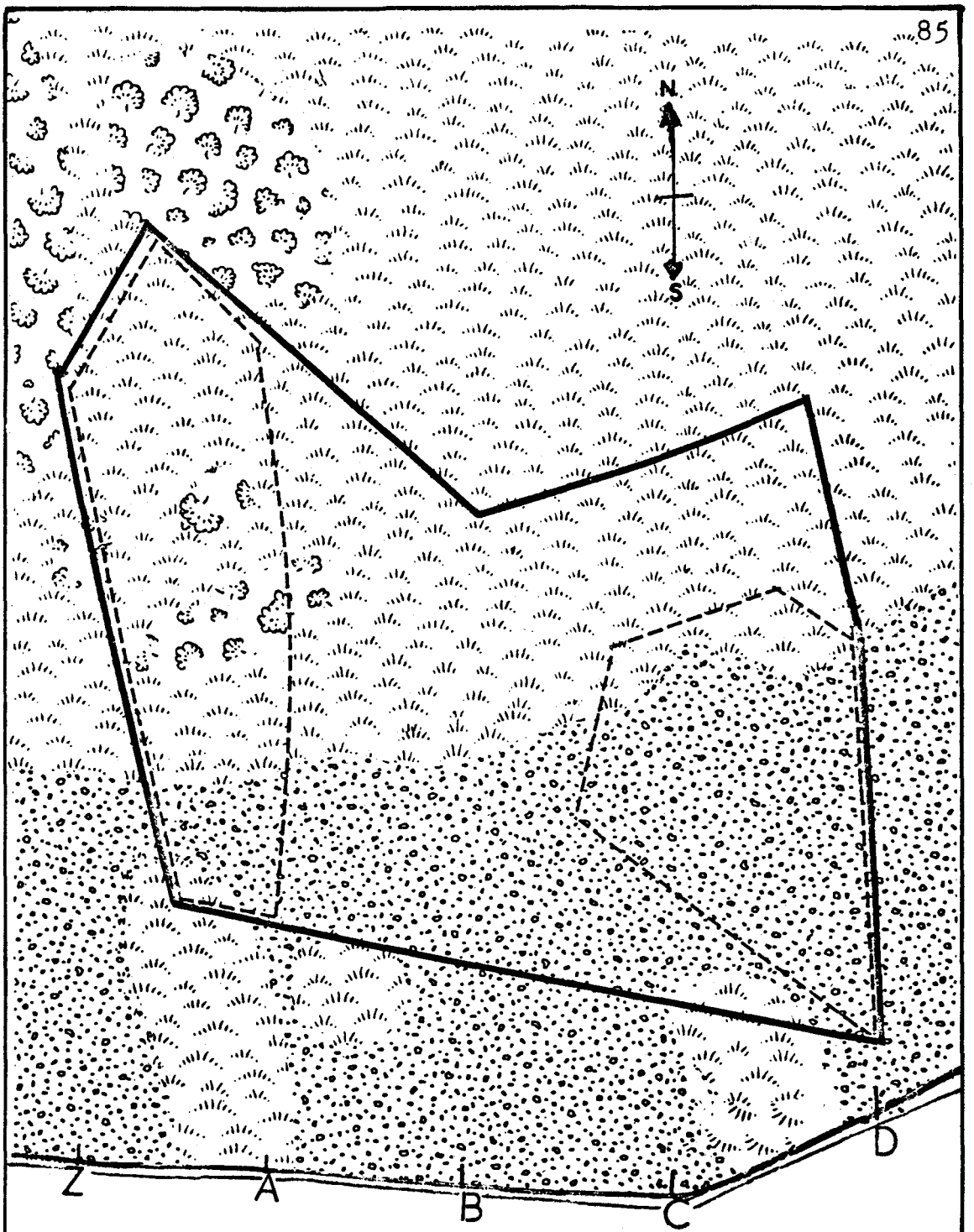


Figure:36
Yellow Perch #1
(1cm=12,6m)

MAINLAND

Pumpkinseed Home Range Results

Home range and primary home range areas of four pumpkinseed were examined. Two of these fish, Pumpkinseed #2 and #6, each exhibited one home range and one primary home range area. Two other fish, Pumpkinseed #4 and #5 each exhibited a home range and primary home range of the same area. .

Island Pumpkinseed #2's home range area measured 0.27 hectares. It was located off the southwest shore of the island along stations IA to IB and extended westward 104 meters. This home range was in the same area the fish was caught and released (Figure 37).

Pumpkinseed #2's home range consisted of light weeds and sand. The outer section of the home range contained the offshore island light weeds, while the inshore area was entirely composed of sand. The edge of the heavy hedgerow weed was also found within this home range area.

Island Pumpkinseed #2 established a primary home range that measured 0.11 hectares. This area contained a small section of the offshore light weeds, an inshore sand area and the light weed-sand ecotone. The edge of the heavy hedgerow weed bed was also included.

The majority of data locations for this fish were along the light weed-sand ecotone as well as the edge of the heavy hedgerow weed bed. Island Pumpkinseed #2 was never tracked solely over sand or within light weeds as each day's data indicated the fish at the sand-light weed ecotone.

Pumpkinseed #6 established a home range of 1.12 hectares. This area was located 85 meters north of the area the fish was caught and released. The majority of the home range was composed of the offshore light weeds although parts of the heavy hedgerow weed bed and heavy weed bed #3 were also included (Figure 38).

Pumpkinseed #6 established a primary home range that measured 0.23 hectares. This area of primary utilization contained sections of the heavy horseshoe shaped weed bed and the light weeds that border it on the east. The majority of tracked locations position the fish within the heavy horseshoe shaped weed bed. The fish was also located a few times within light weeds and only once positioned on the heavy weed-light weed ecotone.

Two of the other fish namely, Pumpkinseed #4 and #5, each exhibited a home range and primary home range of equal areas. All locations for both fish were never separated by more than 60.69 meters or 200 feet from any other data point. For this reason these fish were determined to have a primary home range that was the same area as their home range.

Pumpkinseed #4 established a home range and primary home range area of 0.36 hectares. This area was located off staions POINT to W and at its farthest data point from shore extended outward 122 meters. This home range existed in the same area the fish was caught and released (Figure 39).

Pumpkinseed #4's home range contained a number of dif-

ferent habitats. The inshore section of the home range was composed of light weed bed #2 and the sand that surrounded it. The outer section of the home range contained part of the heavy horseshoe shaped weed bed and the open water that bordered it on the north and the sand and light weed that bordered it on the south. The majority of tracked locations indicated the fish in and around the heavy horseshoe shaped weed bed and its ecotone. The sandy area inshore of this weed bed was also heavily utilized. Only once was this fish found utilizing light weed bed #2 or within open water.

Pumpkinseed #5 established a home range and primary home range that measured 0.23 hectares. This area was located between stations A to C and at its farthest point from shore extended outward 122 meters. The home range was located at the same area the fish was caught and released (Figure 40).

A number of habitats existed within Pumpkinseed #4's home range. The inshore section of the home range contained light weed bed #4 and the sand that surrounded and separated this weed bed from the offshore light weeds. The outer section of the home range contained the offshore light weeds and the ecotone of the light weed-sand transition. The majority of tracked locations for this fish were at the ecotone of light weed bed #4 and the sand that surrounded this area. Five minute data revealed the fish over sand for most of the tracking period yet also revealed the fish, every 15 minutes or so, to pass along the edge of light weed bed #4.

Pumpkinseed Home Range Statistics

Correlation coefficients were calculated between the size of home range and primary home range versus fish size and between size of these home ranges and days tracked. There was no significant correlation between the size of the home range ($r=-0.34$; $p>0.05$), or primary home range ($r=-0.652$; $p>0.05$) and the number of tracked days. A non-significant correlation was expected as each fish was tracked enough times to reveal an accurate representation of pumpkinseeds' home range and primary home range areas.

These correlations also indicated that home range areas did not change with time. This was also noticed in the actual plotting of the data as the home range and primary home range areas never increased or decreased in size as more data was gathered.

The third correlation correlated the size of the pumpkinseed to the size of their home ranges. The null hypothesis stated that there is no difference in the size of the primary home range and the size of the fish. This null hypothesis was accepted; $r=-0.284$; ($p>0.05$).

It should be noted that the range in sizes of the four pumpkinseeds (13.9 - 16.0 cm) may not be large enough for a meaningful analysis of the relations between body size and home range and primary range areas.

TABLE 7

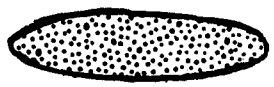
PUMPKINSEED HOME RANGE AND PRIMARY HOME RANGE RESULTS

FISH #	HOME RANGE (hectares)	PRIMARY HOME RANGE (hectares)	SIZE (cm)	DATES TRACKED
I2	0.27	0.11	14.5	8-6-80 8-20-80
4	0.36	0.36	13.8	9-1-80 10-26-80
5	0.23	0.23	16	9-14-80 11-5-81
6	1.12	0.23	16	9-24-80 10-10-80

LEGEND FOR PUMPKINSEED ILLUSTRATIONS

Heavy Weeds

Light Weeds

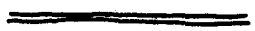


Sand

Open Water

Home Range Line

Primary Home Range Line



Shoreline

Island or Mainland as Indicated

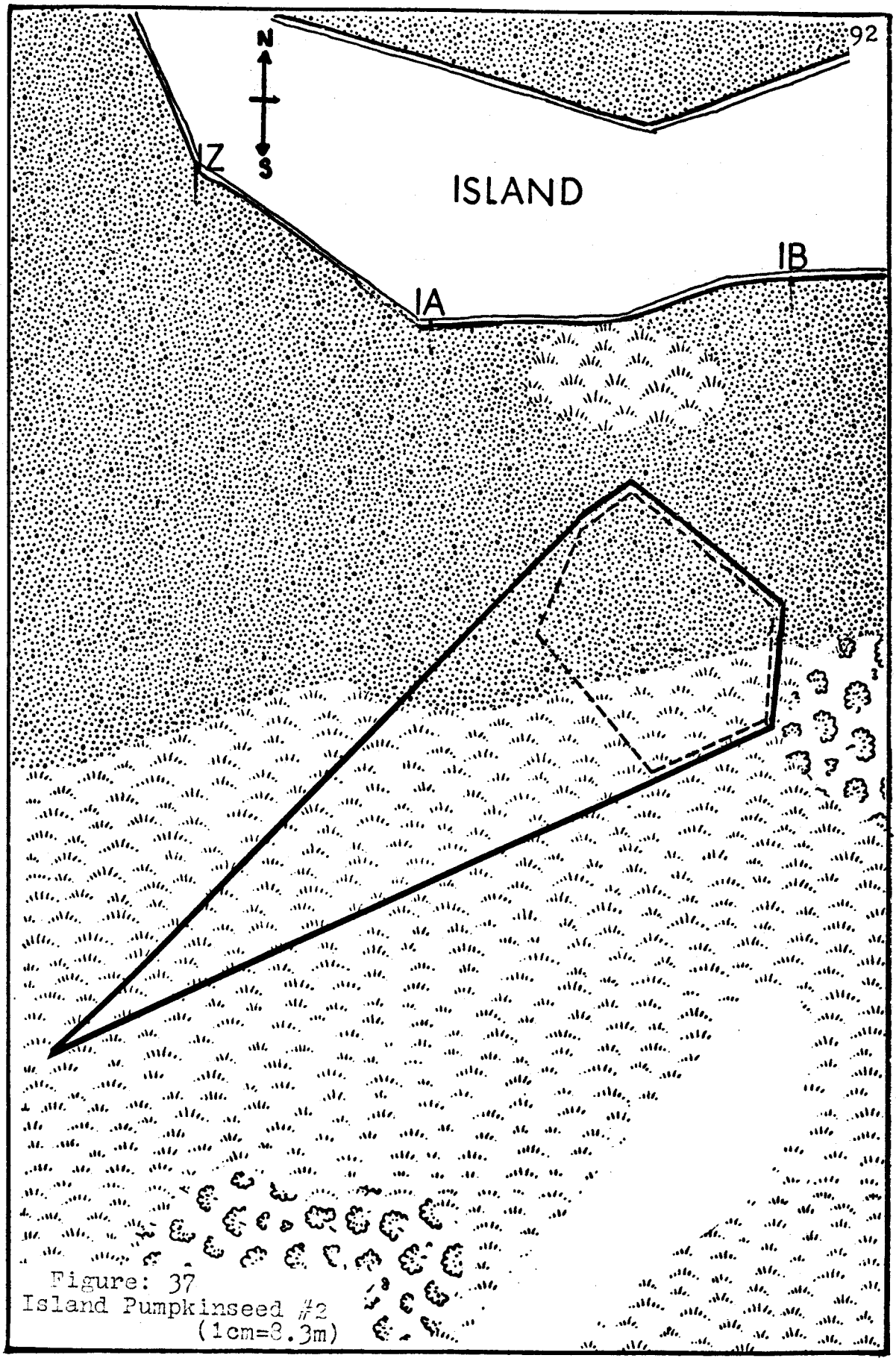


Figure: 37
Island Pumpkinseed #2
(1cm=8.3m)

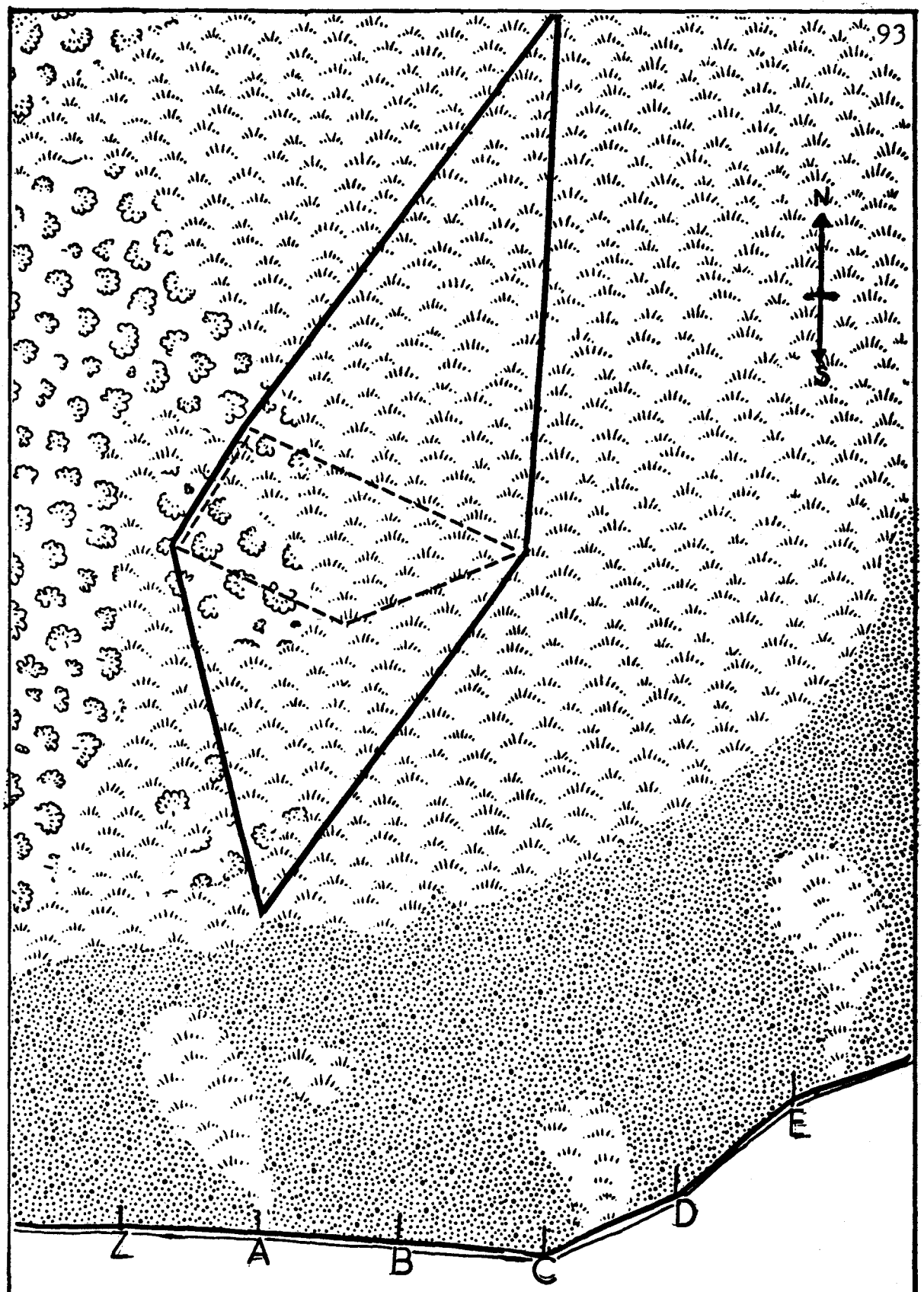


Figure: 38
Pumpkinseed #6
(1cm=16.6m)

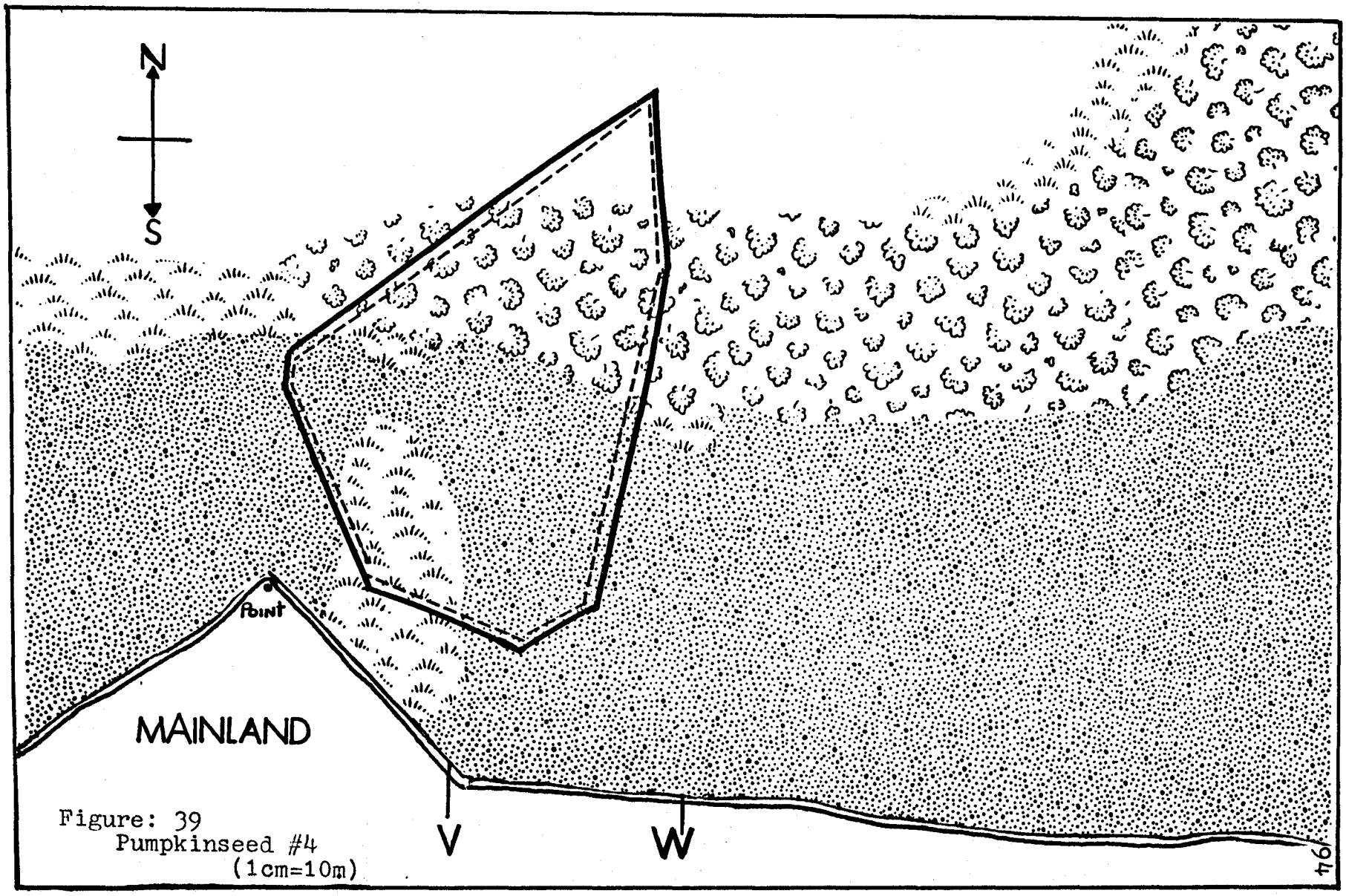


Figure: 39
Pumpkinseed #4
(1cm=10m)

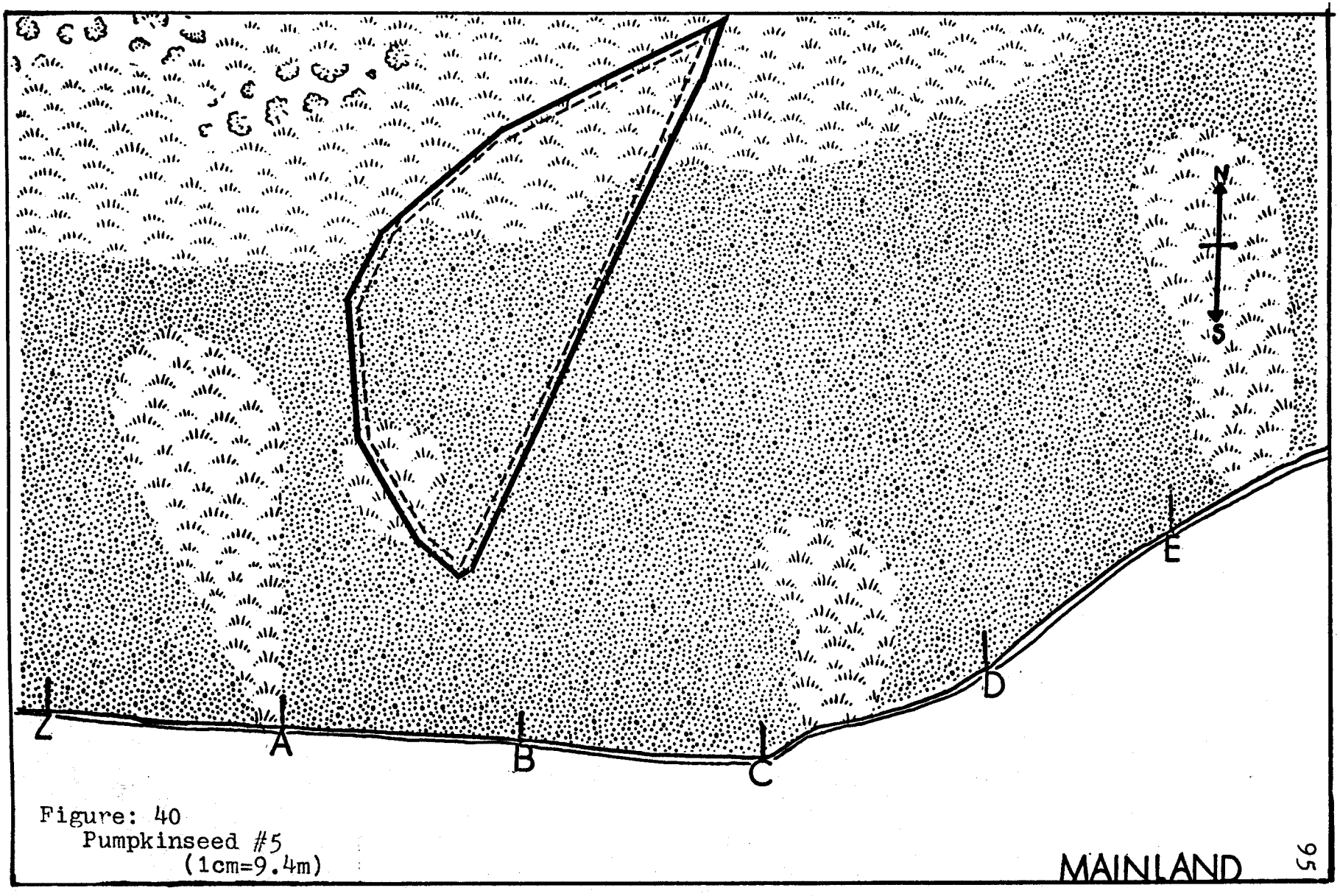


Figure: 40
Pumpkinseed #5
(1cm=9.4m)

HABITAT PREFERENCE RESULTS

Cedar Lake consists of five different habitats: heavy weeds, light weeds, sand, open water and edge of weeds. Heavy weeds were of the Myriophyllum sp. and occurred in large dense clumps that grew to the surface of the water. Light weeds were Potamogeton sp. and tended to be distributed uniformly and were usually submergent. An open water area is where the water was deeper than 5.5 meters and exhibited no visible macrophytes. The edge effect or ecotone is the area 1.5 meters on either side of the transition between heavy weeds and light weeds, sand or open water.

Areas of the five habitats were measured from the hydrographic map of Cedar Lake with a planimeter. The percent area of each habitat was determined. Heavy weeds composed 8.7% of the mapped area, light weeds 27.2%, sand 31.9%, open water 23.3% and edge 8.9%.

Time spent by the various fish in each habitat was determined by alloting one point for each tracking day. When a fish was tracked more than once during the day, or over an hour time, this alloted one point was divided among the various habitats based on how much time the fish spent in each habitat. Data points were then totaled in each habitat for each fish. These occurrence values were then divided by the percent of the habitat. This method was employed in order that each occurrence point would be weighted according to the amount of area that habitat encom-

passed.

A non-parametric randomized block analysis of variance by ranks (Friedman's test) was performed on the data. This stastical test determined if all habitats were perfered equally. This test also took into account effects by individual fishes' on the data. If the null hypothesis was rejected, a multiple comparison test for ranked data in a randomized block format was performed to determine among which habitats differences occurred.

Largemouth Bass Habitat Preference

Eleven largemouth bass were studied to determine their habitat preference. The Friedman's test revealed a $x^2=17.65$; $p>0.05$, revealing that the mean number of occurrences per area of habitat was not stastically similar in all five habitats. The non-parametric multiple comparison test revealed the following: E H L S O. This diagram reveals that edge and heavy weeds are preferred equally. Also heavy weeds, light weeds, sand, and open water are preferred equally yet edge is preferred over light weeds, sand and open water. This ambiguous result of overlapping similarities is not uncommon for this stastical test and usually occurs as a result of the test not being powerful enough to differentiate, in this case, which group heavy weeds belong to. This stastical test did reveal that the ecotone is preferred over light weeds, sand and open water by largemouth bass. This again substantiated the already stated heavy

utilization by largemouth bass of the ecotone habitats.

Bluegill Habitat Preference

Nine bluegills were studied to determine their habitat preference. The Friedman's test revealed a $x^2=17.67;p<0.05$, indicating that all habitats were not preferred equally. The non-parametric multiple comparison test differentiated the following habitats: H L S E O. This stastical test revealed that for bluegills heavy weeds are preferred equally to light weeds and sand. Also light weeds are preferred equally to sand, open water and edge yet heavy weeds are not preferred equally to open water or edge. Again ambiguous results were attained. It was found though that bluegills prefer heavy weeds over open water or edge. This was also observed in the actual data as bluegills were found to spend a great deal of time within heavy weeds.

Pumpkinseed Habitat Preference

Five pumpkinseeds were studied to determine their habitat preference. The Friedman's test revealed a $x^2=5.81;p>=0.05$, indicating that there was no significant habitat preference or: H=L=S=O=E. This result was expected as the actual raw data indicated pumpkinseeds utilizing all habitats except open water equally. The inability of this test to differentiate a low preference for open water may be a result of not enough data due to too few fish studied. It is apparent that open water was not preferred by pumpkin-

seeds as Pumpkinseed #4 was the only fish positioned within this habitat.

Yellow Perch Habitat Preference

Four yellow perch were studied to determine their habitat preference. The Friedman's test revealed a $x^2=6.16, p>0.05$, indicating there was no significant habitat preference: H=L=O=E=S. These results were expected as the raw data indicated perch utilizing all habitats except open water equally. The inability of this stastical test to reveal a low preference for open water was probably due to the small number of fish studied.

TABLE 8

LARGEMOUTH BASS HABITAT PREFERENCE

(occurrence / habitat proportion)

Largemouth Bass #	HEAVY	LIGHT	SAND	OPEN	EDGE
1	0	1.2	6.3	0	18.7
2	11.4	3.7	1587	10.3	124.8
3	24.9	3.7	3.2	4.3	41.2
4	0	3.7	7.9	0	28.1
5	17.2	0	0	0	16.8
6	0	18.4	5.3	8.5	14.9
7	0	3.7	11.1	0	28.1
8	2.3	1.8	11.1	0	67.4
10	0	18.4	31.6	0	78.6
11	11.5	3.7	6.3	0	11.2
12	80.4	36.7	0	0	11.2

TABLE 9

BLUEGILL HABITAT PREFERENCE

(occurrence / habitat proportion)

Bluegill #	HEAVY	LIGHT	SAND	OPEN	EDGE
1	23	7	17	0	7
3	0	4	13	0	0
4	34	5	2	0	0
5	11	2	8	4	0
6	11	4	2	0	6
7	21	7	6	0	82
8	46	11	0	0	34
9	23	18	3	0	0
10	34	18	0	0	0

TABLE 10

PUMPKINSEED HABITAT PREFERENCE

(occurrence / habitat proportion)

PUMPKINSEED #	HEAVY	LIGHT	SAND	OPEN	EDGE
2	0	5	1	0	26
3	11	0	3	0	0
4	96	4	21	6	26
5	0	22	11	0	39
6	29	13	0	0	11

TABLE 11

YELLOW PERCH HABITAT PREFERENCE

(occurrence / habitat proportion)

PERCH #	HEAVY	LIGHT	SAND	OPEN	EDGE
1	29	11	11	0	22
3	27	45	17	0	67
4	46	33	3	4	11
5	0	7	9	0	0

SWIMMING SPEEDS

Swimming speeds were measured for eight largemouth bass, seven bluegills, six pumpkinseeds and three yellow perch. This study was done to determine swimming speeds in different habitats.

Swimming speeds were determined by measuring the distance between two triangulation points. One assumption in measuring swimming speeds is that the distance between the two points is assumed to be covered by the fish in a continuous straight line swim. This assumption is similar to Diana's (1980) who measured swimming speeds of Northern Pike via radio telemetry.

The average swimming speed in the various habitats are listed for the largemouth bass, the bluegill, the yellow perch and the pumpkinseed in Tables 12, 13, 14 and 15 respectively. A single factor analysis of variance was performed on the four species data to determine if the swimming speed was similar in all five habitats: H=L=S=O=E. This null hypothesis was accepted for largemouth bass ($F=1.31, p>0.05$), bluegills ($f=2.48, p>0.05$) and yellow perch ($F=1.31$, $p>0.05$). This indicated that the swimming speeds did not vary as the fish swam thru different habitats. This also indicated that there is no correlation between habitat preference of the various species and swimming speed. One possible reason is that there is a great deal of variability in swimming speeds. This is exemplified thru the actual

range values listed in the tables. Also this method may not be sensitive enough to reveal any subtle changes between habitats. This could be due to the assumption that the distance covered between locations is a straight line. One may need to look at the patterns of movements in the various habitats as this may be more of an indication of how these fish forage for prey.

The analysis of variance performed on the pumpkinseed data was rejected, ($F=15.5$, $p<0.05$), indicating that the swimming speeds were not similar in all habitats; H=L=S=E. Open water was eliminated from the analysis as the fish were never tracked for five minutes solely within this habitat. The Newman-Keuls multiple range test was then performed on the data to determine in which habitats the swimming speed differed. This statistical test provided the following results: H≠L=S=E. This result was expected as the average pumpkinseed swimming speed in heavy weeds (5.1 m/minute) is twice its swimming speed in other habitats. This result could not be correlated to habitat preference as there was no significant habitat preference exhibited by the pumpkinseed.

Body lengths per minute were also determined for the four species of fish in each habitat. These results (Tables 12, 13, 14 and 15) do not indicate a great deal of difference either between habitats or between species. Again this method may not be sensitive enough to reveal subtle changes in various habitats.

TABLE 12

LARGEMOUTH BASS SWIMMING SPEEDS

(meters / minute)

	HEAVY	LIGHT	SAND	OPEN	EDGE
Bass #1	--	4.2	7.3	--	6.4
range	--	1.9-7.6	4.5-11.7	--	--
Bass #2	2.1	3.2	3.7	6.3	0.9
range	1.4-2.4	2.4-3.9	1.3-10.5	2.6-10.9	--
Bass #3	2.5	1.8	2.6	2.2	4.1
range	1.2-3.9	1.4-2.2	1.7-3.6	--	3.5-4.6
Bass #4	--	--	1.2	--	2.5
range	--	--	--	--	--
Bass #5	10.1	4.5	3.2	--	--
range	--	--	--	--	--
Bass #6	--	4.6	1.5	--	--
range	--	--	1.4-1.5	--	--
Bass #7	--	2.0	1.6	--	--
range	--	0.8	1.5-1.7	--	--
Bass #8	--	0.8	2.4	--	2.2
range	--	0.5-1.1	2.2-2.5	--	--
Average	4.8	3.0	2.9	4.3	3.2
Body Length/ minute	22.2	13.2	12.8	18.8	14.2

TABLE 13

BLUEGILL SWIMMING SPEEDS

(meters/minute)

	HEAVY	LIGHT	SAND	OPEN	EDGE
BLUEGILL #1	6.3	1.6	2.5	--	3.9
range	5.3-7.2	0.6-2.5	.49-5.7	--	0.5-9.26
BLUEGILL #2	--	2.9	0.89	--	--
range	--	--	--	--	--
BLUEGILL #3	--	3.7	4.9	--	--
range	--	--	2.7-8.4	--	--
BLUEGILL #4	--	3.4	6.0	--	3.6
range	--	--	--	--	--
BLUEGILL #5	--	2.7	4.4	--	--
range	--	--	2.9-5.7	--	--
BLUEGILL #6	--	1.8	3.5	--	1.8
range	--	--	--	--	--
BLUEGILL #7	1.4	1.0	2.6	--	1.4
range	.61-2.2	.34-2.0	1.2-4.1	--	0.45-2.4
Average	3.8	2.4	3.5	--	2.6
Body length/ minute	22.5	14.5	20.9	--	15.5

TABLE 14

YELLOW PERCH SWIMMING SPEEDS

(meters/minute)

	HEAVY	LIGHT	SAND	OPEN	EDGE
PERCH #1	1.8	2.7	4.9	--	5.0
range	--	--	3.6-7.3	--	--
PERCH #2	2.4	0.9	2.6	--	1.0
range	--	.04-1.5	2.0-3.4	--	.01-2.6
PERCH #4	--	8.8	2.3	--	--
range	--	--	1.6-3.1	--	--
Average	2.1	4.1	3.3	--	3.0
Body length/ minute	10.1	19.9	15.7	--	14.4

TABLE 15

PUMPKINSEED SWIMMING SPEEDS

(meters/minute)

	HEAVY	LIGHT	SAND	OPEN	EDGE
Pumpkinseed #1	--	--	0.9	--	--
range	--	--	--	--	--
Pumpkinseed #2	--	2.9	2.4	--	--
range	--	0.7-5.0	--	--	--
Pumpkinseed #3	--	0.9	--	--	--
range	--	--	--	--	--
Pumpkinseed #4	4.5	0.7	1.2	--	4.0
range	3.3-5.6	--	0.6-1.6	--	1.8-4.57
Pumpkinseed #5	--	1.1	1.0	--	0.6
range	--	0.4-2.8	0.6-2.2	--	0.5-0.6
Pumpkinseed #3	5.7	--	--	--	--
range	--	--	--	--	--
Total Average	5.1	1.4	1.4	--	2.7
Body length/ minute	33.8	9.3	9.3	--	17.9

ORIENTATION

During the course of the study it was observed that the four species of fish moved between the heavy weeds and the shoreline in directions that are almost perpendicular to these two areas. Because of this observation it was thought that theses two areas may be utilized by the fish as a means of orientating itself within its home range. Also we might be looking at a gross representation of these fishes' foraging patterns.

The direction these fish were heading during each of five minute intervals was determined. This entailed one assumption, namely that the direction the fish was heading was constant within each five minute interval. The percentage of directions headed by each fish species within four compass sectors was determined. These four compass sectors were divided depending upon the degree of the perpendicular line that connected the two parallel lines of the shoreline and the heavy weeds. In the eastern section of the lake this perpendicular line has a degree heading of 0^0 - 180^0. Therefore, if these fish utilize the heavy weeds and shoreline to orientate, the majority of directions the fish would swim whould be within $\pm 45^0$ of this perpendicular line. This revealed the following four compass sectors: 315^0 -45^0, 45^0 -135^0, 135^0 -225^0 and 225^0 -315^0.

In the southwest portion of the lake the perpendicular line that connects the parallel lines of the shoreline and

the heavy weeds had a degree heading of 135^0 - 315^0. Therefore, the majority of directions headed by the fish should be within $\pm 45^0$ of this perpendicular line. Thus the following four compass sectors for the southwest portion of the lake are: 0^0 - 90^0, 90^0 - 180^0, 180^0 - 270^0 and 270^0 - 360^0.

A heterogeneity chi-square was performed on each species data to determine if the data could be pooled. For all four species the chi-square was accepted; largemouth bass $x^2=17.74$, $p>0.50$, bluegill $x^2=8.10$, $p>0.90$, yellow perch $x^2=0.52$, $p>0.99$ and pumpkinseed $x^2=5.09$, $p>0.50$. This indicated that the data for each species could be pooled. A chi-square was then performed on each species data in both sections of the lake to determine if all direction headings were utilized equally.

For largemouth bass located in the eastern section of the lake the following percentage of directions headed in each of the four compass sectors (315^0 - 45^0, 45^0 - 135^0, 135^0 - 225^0 and 225^0 - 315^0) are as follows: 40%, 9.5%, 37.2%, 13.3% respectively. The chi-square was rejected ($x^2=62.04$, $p<0.001$), indicating that not all directions were utilized equally. The actual data reveals that 77.2% of the directions these fish were heading were within $\pm 45^0$ of the perpendicular line that connects the outer heavy weed beds and the shoreline.

In the southwest section of the lake the following percentage of direction headings in the four compass sectors

(0^0 - 90^0, 90^0 - 180^0, 180^0 - 270^0 and 270^0 - 360^0) were 16.7%, 31.7%, 12.7% and 38.9% respectively. The chi-square was rejected (x^2=23.14, $p<0.001$), again indicating that not all directions were utilized equally. Again the actual data reveals that 70.6% of the observed headings were within $\pm 45^0$ of the perpendicular line that connects the shoreline and heavy weed bed.

These results reveal that largemouth bass utilize, over 70% of the time, direction headings that are within $\pm 45^0$ of the perpendicular line between the shoreline and the heavy weed beds. Thus these fish seem to utilize these areas as a means of orientating within the home range.

All bluegills were tracked within the eastern section of the lake with exception of Bluegill #3 which was excluded from the analysis. This section of the lake reveals the following four compass sectors: 315^0 - 45^0, 45^0 - 135^0, 135^0 - 225^0 and 225^0 - 315^0. The percentage of directions headed by these fish within each sector respectively is as follows: 36%, 14%, 35% and 15%. The chi-square was rejected (x^2=23.14, $p<0.001$) indicating that not all directions were utilized equally. The actual data indicated that 71% of the directions that these fish were heading within within $\pm 45^0$ of the line that runs perpendicular to the heavy weeds and open water.

All yellow perch were tracked within the eastern section of the lake. The percent direction the fish were heading in the four compass sectors (315^0 - 45^0, 45^0 - 135^0,

135^0 - 225^0 and 225^0 - 315^0) are as follows: 39%, 12%, 39% and 10% respectively. This chi-square was also rejected (x^2=25.90, $p<0.001$) indicating that not all directions were utilized equally. Here the actual data indicated that 78% of the directions these yellow perch were heading were within $\pm 45^0$ of the perpendicular line.

All pumpkinseeds were tracked in the eastern section of the lake. The direction headings by these fish revealed the following percentages: 39%, 9%, 37% and 15% respectively. The chi-square was rejected (x^2=31.07, $p<0.001$). This reveals that 76% of the time these fish were moving in a direction $\pm 45^0$ of the perpendicular line that runs between the shoreline and heavy weed beds.

These results indicate that bluegill, yellow perch and pumpkinseeds like largemouth bass spend over 70% of the time moving between the heavy weeds and shoreline. This indicates that these species may be utilizing these areas as a means of orientating themselves within their home range areas.

Discussion

The largemouth bass established home ranges that ranged in size from 0.18 to 2.07 hectares. These home ranges were established in the same areas of the lake where the fish were caught and released. These results are in agreement with those founded by Lewis and Flickinger (1967) who demonstrated in 3.4 hectare lake, with mark and recapture techniques, that largemouth bass establish home ranges. A study by Ball (1947) in a 4.0 hectare lake revealed that the largemouth bass has no tendency to remain in a specific area. My results along with Winters (1976), who radio tracked largemouth bass and found the fish to establish home ranges between 0.33 to 1.4 hectares, do not agree with Balls' conclusions. I believe that Balls' results were not accurate because of his low number of recaptures and the nature of his technique. Also just because a fish leaves one area of the lake does not indicate that these fish did not establish a home range. For example during the course of the study two Largemouth Bass namely #2 and #12 each established two home ranges in different areas of the lake. This indicated that even though these fish left one area of the lake they still established a home range in the other area. Hasler and Wisby (1958) found that 68% of tagged largemouth bass remained in one part of the lake. This again does not indicate that the other 32% did not establish home ranges. What it does indicate is that they did not

establish a home range in the same area where they were released. This idea may also explain Balls' findings that largemouth bass do not remain in one section of the lake.

There are two possible reasons why Largemouth Bass #2 and #12 left their original home range areas. One posssible explanation is that Largemouth Bass #2's home range and primary home range were partially overlapped with Largemouth Bass #1 and #3's home range and primary home range during the same time period. This fish may have left this home range because of low prey availability due either to exploitative competition or limited prey resources.

Largemouth bass were found to establish primary home ranges within the home range area. These areas ranged from 0.01 to 1.64 hectares and are the areas where the fish is primarily found to utilize and reside.

One largemouth bass namely Largemouth Bass #10 was found to establish two primary home ranges within its home range area. This again may be a result of limited resources as the two areas that the fish primarily utilized were areas where the fish would be more likely to encounter prey items. The sandy area that separated these two primary utilized areas was not utilized by the fish and would probably not be an area with adequate forage.

The linear correlations on the size of the home range and primary home range areas vs. the number of tracked days were found to be nonsignificant. This indicated that these areas are not a function of time. Therefore, a fishes home

range or primary home range was never found to increase or decrease over time, yet the fish were found to leave one home range area and establish another. This was also observed in the actual plotting of the data as a fishes home range was usually established within 4-5 days. Only rarely was a point revealed after five days that enlarged the home range. Therefore once this home range was established the fish was found to remain within this area or totally change its home range for the duration of the study.

The linear correlation between size of the home range and fish size provided the possibility of obtaining a negative correlation. This result may be due to the 37.6cm largemouth bass in the study which established a small home range area of 0.18 hectares. In general home range sizes were variable. For example Largemouth Bass #2 established two home ranges, one that measured 0.80 hectares and a second that measured 2.07 hectares.

One explanation for the variation in home range size is that the size of the home range may be dependant upon the availability of food. When prey availability is high the fish has little need to forage extensively and therefore utilizes a smaller area. Conversely when prey availability is low the fish would need to utilize a larger area to forage. This possibility was observed with Largemouth Bass #10 which established a large home range yet only utilized two smaller areas of the home range that would yield high prey availability. This same idea can also explain why Large-

mouth Bass #2 and #12 each left one home ranage to establish another home range in a different part of the lake.

Habitat preference results indicate that largemouth bass prefer the edge of weed beds over all habitats except heavy weeds. This was also observed in the figures as a great deal of largemouth bass home ranges encompass a number of heavy weed beds and ecotones. This preference can be explained as it is in these areas the fish would encounter preferred prey items such as minnows and darters (Savitz 1982).

Swimming speeds were found to be similar in all five habitats. The swimming speeds in general were found to be highly variable ranging from 1.3 meters per minute to 10.4 meters per minute over sand alone. These results may be due to the technique not being sensitive enough to reveal subtile changes in swimming speeds between habitats.

Largmouth bass were also found to utilize the shoreline and heavy weed beds possibly as a means of orientating themselves within their home range.

Bluegills were found to establish home ranges that ranged in size from 0.15 to 0.75 hectares. Five of these fish established their home ranges in the same areas they were caught and released. The four other fish left the point of release and established home ranges within two days from 140 - 713 meters away from the point of release. This fact plus the point that Bluegill #1 established two home ranges during the course of the study can indicate that

bluegills may establish more than one home range in a single season. Gunning and Shoop (1963) also found that bluegills establish home ranges in streams. They believed that these home ranges were short termed because their number of recaptures decreased over time. These results are in agreement with our findings. These bluegills did not establish home ranges were released yet found other areas with adequate forage. The availability of prey at the original release point may be low due to predation by other fish as well as resource depression. For these reasons these fish may establish home ranges in other areas of the lake and probably establish a number of home ranges in a single season. The reason I believe that we only had one bluegill that established more than one home range was due to the transmitters having a theoretical life span of only 30 days. I believe if these fish were tracked longer that they would establish more than one home range in a single season.

Bluegills were also found to establish primary home ranges that ranged in size from 0.15 to 0.60 hectares. Four of these fish were found to establish primary home ranges that were of the same area as their home range. From linear correlations correlating size of fish vs size of home range it was found that the large bluegills utilized smaller areas than smaller bluegills. This can indicate that the larger bluegills establish a social dominance over the smaller fish and thus are able to utilize their primary home range and seldom forage outside of it. Thus the four larger bluegills

that established primary home ranges of the same area as their home ranges need not establish areas of different sizes as they are able to utilize a smaller area more effeciently.

Other correlations were found to be nonsignificant. This included the size of the home range and primary home range vs. the number of tracked days. This finding was also substantiated by the raw data as the majority of the home range was established within 3 to 4 tracking days. Only on rare occasions would a point occur 5 to 6 days into tracking that extended the home range.

Habitat preference results for bluegills revealed that heavy weeds were preferred over open water and edge yet were preferred equally with light weeds and sand. These preferred habitats specifically heavy weeds and light weeds correspond to the area these fish would encounter preferred prey items such as chironomids, caddisflies, and amphipods (Savitz 1982).

Swimming speeds were not significantly different in the five habitats and a wide range of variability in speeds was observed. Again, the technique may not be sensitive to reveal subtile changes in speeds as the fish swims through various habitats.

Bluegills were also found to utilize the shoreline and heavy weeds possibly as a means of orientating itself within its home range.

Yellow perch were found to establish home ranges that

ranged in size from 0.54 to 2.20 hectares. These results are in agreement with those of Ross and Winter (1981) who demonstrated via radio telemetry in a thermal plume that the yellow perch established a winter home range averaging 13.4 hectares. Although their study is not comparable to ours, as they dealt in a larger lake with different temperatures and with a seasonal difference, we both found that yellow perch establish home ranges.

Yellow perch were also found to establish primary home ranges that ranged in size from 0.05 to 0.61 hectares. Two of these fish, Perch #1 and #4 established two primary home ranges within each of their home range areas. Again a proposed reason these fish established two primary areas of utilization is due to low availibility of forage items or resource depression. Therefore in order to encounter more prey items these two yellow perch have established two areas of primary utilization in which they alternately forage in.

All linear correlations were non-significant indicating no relationship between the size of the home range and primary home range vs. number of tracked days. This was also substantiated by the actual data. It was found that within 3 to 4 days these home ranges were established and did not increase after this time.

No specific habitat was utilized by these fish as all areas excluding open water were utilized equally, although light weeds exhibited the largest number of occurrences (43.9%). This was not found to be the preferred habitat as

light weeds composed 27.2% of the lake. The fall data on Perch #3, indicating the fish extensively utilizing sand, was also non-significant although this fish moved inshore during this time period.

Swimming speeds were not significangly different in the five different habitats. In fact, swimming speeds were found to vary in all habitats from 0.3 meters per minute to 8.8 meters per minute. Although these results are inconclusive this is probably due to the small number of perch studied and their almost negligible range is size.

Pumpkinseeds were found to establish home ranges that ranged in size from 0.23 to 1.2 hectares. In all cases except one these fish established their home ranges in the same area they were caught and released. Pumpkinseed #6 established its home range 85 meters north of the area of release. This was not considered a highly significant change of areas.

Shoemaker (1952) revealed results for pumpkinseeds similar to ours. He found thru mark and recapture techniques in a 90-acre lake, that pumpkinseeds have tendencies to remain within one section of the lake. In this study we substantiated this tendency by revealing that pumpkinseed established defined home range areas.

Pumpkinseed were also found to establish primary home ranges that ranged in size from 0.11 to 0.36 hectares. Two of these fish, Pumpkinseed #4 and #5, each established primary home ranges of the same size as their home range.

All correlations were found to be nonsignificant. Correlations between home range and primary home range sizes versus size of the fish were considered nonsignificant as the range in size of the four pumpkinseeds was not large enough to reveal any meaningful analysis. The correlation between the size of these areas vs. the number of tracked days was also nonsignificant. The actual data plotting indicates that within 3 to 4 tracking days the home range limits were defined.

No significant results were found in determining these fishes' habitat preference. All five habitats except open water were utilized equally.

Swimming speeds were not found to be statistically different in all habitats except heavy weeds. Here it was found that these fish swims twice as fast through heavy weeds as in other habitats. This could not be correlated with habitat preference. These inconclusive results are probably due to the small number of fish studied and their similar size.

Summary

Largemouth bass, bluegill, yellow perch and pumpkinseed were found to establish well defined home range and primary home range areas. Residence time spent in home ranges was probably in response to food availability. Largemouth bass and perch may respond to this prey availability by utilizing two distinctly separate areas of the home range alternately where by increasing their chances of encountering available prey. Largemouth bass and bluegill left one area and set up other home ranges in different areas of the lake possible as a result of low prey availability in the original home range area. Bluegills are also thought to establish several home ranges in a single season in response to low or depressed resources in the area they were utilizing.

Although the habitat preference for these four species revealed inconclusive results for perch and pumpkinseed, but revealed that largemouth bass heavily utilized the edge of weed beds. It is in this area that these fish would encounter the largest number of prey items, namely minnows and darters. Bluegill were found to prefer heavy weeds over open water and edge but light weeds and sand were not significantly different from heavy weeds. These weedy areas contained the benthic prey item utilized by these fish.

Swimming speeds revealed inconclusive results for all species except pumpkinseeds. Here these fish were found to

swim twice as fast through heavy weeds although no correlation could be made between swimming speed and habitat preference. These inconclusive results were probably due to the technique not being sensitive enough to reveal subtle changes in foraging behavior between habitats.

All four species were found to predominantly move perpendicular to the shoreline and heavy weeds. For these reasons the fish may utilize these areas as a means of orientating themselves within the home range.

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APPROVAL SHEET

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The final copies have been examined by the director of the thesis and the signature which appears below verifies the fact that any necessary changes have been incorporated and that the thesis is now given final approval by the Committee with reference to content and form.

The thesis is therefore accepted in partial fulfillment of the requirements for the degree of Master of Science.

April 16, 1982
Date

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Director's Signature