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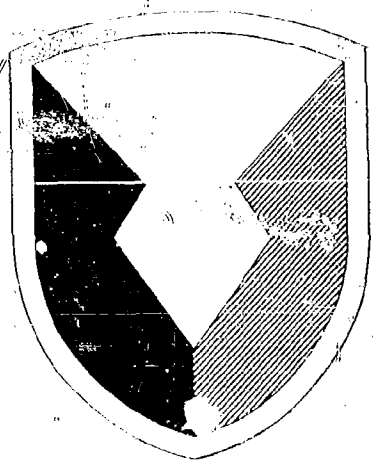
US ARMY
TEST & EVALUATION COMMAND



JUNGLE VISION

I: Effects of Distance, Horizontal Placement, and Site on Personnel Detection in a Semideciduous Tropical Forest.

US ARMY
TROPIC TEST CENTER
FORT CLAYTON, CANAL ZONE

JUNGLE VISION

I: Effects of Distance, Horizontal Placement, and Site on Personnel Detection in a Semideciduous Tropical Forest.

by

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US Army Tropic Test Center
Fort Clayton, Canal Zone
JUNGLE VISION - I. EFFECTS OF DISTANCE, HORIZONTAL PLACEMENT AND SITE ON PERSONNEL DETECTION IN A SEMIDECIDUOUS TROPICAL FOREST
D. A. Dobbins and M. Gast April 1964
Unclassified

To furnish control data for future tests of visual performance aids in the Canal Zone, detection thresholds for uniformed human targets were established in the semideciduous tropical forest near the end of the dry season. Thirty infantry observers, with normal or better vision, were presented 40 randomly appearing targets in a 120-degree field of search at three different sites. Overall detection thresholds (point of 50% detectability) averaged approximately 60 feet with significant differences found among sites. One hundred feet described the near-limit of target detectability. Tropical vegetation, consisting primarily of small vines, lianas, and shrubs, was the predominant deterrent to target detection. Horizontal target placement, individual differences among observers, past experience, immediate practice, and prevailing levels of ambient illumination had little or no effect on target detectability within the ranges investigated.

1. Personnel Detection
2. Target Detection
3. Visual Threshold
4. Tropics
5. Human Factors Engineering

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AVAILABILITY NOTE

Qualified requestors may obtain copies of this report from the Defense Documentation Center.

SECTION 1. GENERAL

1.0 AUTHORITY

USATECOM Regulation 10-20, par. f, dtd 17 March 1964.

1.1 OBJECTIVES

The objective of this study was to determine detectability of uniformed human targets in the semideciduous tropical forest during the dry season. The study utilized the most probable targets for remote area operations, representative observers*, and typical vegetation, with strict experimental control over procedure.

1.2 BACKGROUND

An increasing amount of military research and development is being devoted to the detection of personnel in remote areas through various technological extensions of the human senses -- including aural, olfactory, and visual. The Tropic Test Center is charged with conducting the tropical tests of Night Observation Device (MR), Night Vision Weaponsight (Ind.), Night Observation Device (LR), Night Vision Weaponsight (crew served), and the Laser Rangefinder. Tests of weapons systems such as TOW now scheduled require the evaluation of sighting devices in the tropical environment. Several sub-tests of other larger systems require both visual and auditory observations to assess the detectability of the system through dense vegetation.

Little information, however, exists on detection thresholds in tropical forests without the benefit of magnification devices, night vision aids, and rangefinders. The present study is the first of a series planned by the Tropic Test Center to provide quantitative information on jungle vision. The data will provide (a) control information for the evaluation of technological aids to jungle vision and (b) the beginnings of a data bank to meet future requirements as yet unspecified.

1.3 SUMMARY

Thirty Infantry enlisted men, preselected for normal vision, were each presented forty uniformed human targets

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*Troop support necessary to conduct this study was made possible through the assistance of the Chief, Combat Developments Office, US Army Forces Southern Command, and the Commanding Officer, 4th Battalion (Mechanized), 20th Infantry.

(stationary, standing, and facing the observer) at three semideciduous tropical forest sites during March 1964, which was near the end of the dry season. The targets appeared at eight distances -- 30 to 100 feet -- and were randomly exposed along five radii separated at 30° intervals across a search span of 120°. The observer, without the aid of auditory cues, pointed to the target when detected and estimated its distance. Time to detect targets was also recorded. The results were as follows:

a. The overall detection threshold (point of 50% detectability) for three sites combined was 59.6 feet. The three sites differed significantly with respect to average threshold values obtained even though the curves relating detections to distance were similar. Horizontal target placement did not affect target detections within the 120° range. The greatest deterrent to vision appeared to be the smaller vines, lianas, and shrubs, which rapidly destroy the outline of a target as distance increases.

b. Ninety-one percent of all targets were detected at a distance of 30 feet; only four percent were detected at 100 feet. Thus, a distance of only 70 feet made the difference between nearly perfect and nearly impossible detectability in the jungle vegetation. Average detections decreased sharply beyond a distance of 55 feet.

c. Observers consistently underestimated true target distances on the average of 10 feet. Range estimates became more variable from observer to observer as true target distance increased. These effects may result from reduced cues for depth perception in the visually homogenous tropical forest.

d. Detection time increased as target distance increased. Target detection required nearly four times longer at 75 feet (48 seconds) than at 30 feet (13 seconds).

e. Within the ranges of illumination recorded in the present study, there was no apparent relationship with ease of target detection. Ambient illumination during the dry season was at high average levels throughout the test. The analysis was gross, however, and is not considered definitive.

f. Individual observer thresholds within any given site did not vary greatly. Individual thresholds varied less than the average thresholds among the three different site

g. Detection thresholds were not related to age of observer or length of experience in the infantry.

h. There was no evidence that detection performance improved through practice during the course of 40 observations per observer.

1.4 CONCLUSIONS

1.4.1. Visual thresholds may be stated quantitatively for a given tropical forest site with relatively little observer variation. The methodology used in the present study was found satisfactory for future studies. In the dry season, the best estimates possible from the present study of a generalized threshold for personnel detection in the semideciduous tropical forest is around 60 feet. The best estimate possible for the normal range of thresholds is from 45 to 75 feet, depending on the particular site. A distance of only 70 feet separated near perfect target detectability from undetectability. This threshold is applicable when observers are actively searching for a known target on relatively level sites. The threshold would, in all likelihood, be lower when the observer is unaware of the target's presence and nature.

1.4.2. Variations in detection thresholds appear to be due primarily to tropical vegetation differences and not horizontal target placement, individual differences among observers, past experience, immediate practice in target acquisition, or prevailing levels of ambient illumination.

1.4.3. The vegetative classification "semideciduous tropical forest" may not be a useful classification with respect to target detection. Extensions of the present study to other major forest types will more definitively affirm or deny this conclusion.

SECTION 2. DETAILS AND RESULTS OF STUDY

2.0 INTRODUCTION

Little quantitative data have been accumulated on visual thresholds in tropical forests. Most popular descriptions of the jungle consist of adjectives such as "murky," "gloomy," "dark," and "dense." In fact, the US Army's Field Manual 31-30, "Jungle Operations" -- the Army's official body of knowledge and doctrine -- contains only the following statements: "The jungle offers so much concealment and limits visibility to such an extent that surprise in the attack and defense may be exploited to an unusual degree." **(p.5)**"The terrain and the poor visibility cause the establishment of observation posts with desirable characteristics to be extremely difficult." **(p.55)**; and "Forward observer teams are seriously handicapped by restricted visibility, and suitable observation posts are difficult to find." **(p.77)**. Neither the general statements in FM 31-30 nor the journalistic adjectives are erroneous; however, they offer little assistance to the developers and testers of night vision aids, military magnification devices, rangefinders, and other equipment scheduled for tropical use. Neither do qualitative comments offer much assistance to tacticians and troop commanders interested in day-to-day operational problems such as target detection, target recognition, range estimation, and troop training.

On the basis of available literature, it appears the US Army Natick Laboratories (formerly Quartermaster Research and Engineering Command) have performed the bulk of the US Army's work in terrain visibility. For example, the land areas of the world have been classified according to predominant colors (4)*. This information concerns camouflage criteria but does not deal directly with problems of target detection in the tropics.

Drummond and Lackey (5) made visibility measurements in deciduous and coniferous stands in the United States. "Continuous visibility" was defined as the maximum distance at which a stationary target could be detected as the observer withdrew. They found that (a) visibility was about 40% greater in winter deciduous forest, (b) season made no appreciable difference in coniferous visibility, (c) vines reduced visibility by about 36%, and (d) nearly half of all stands investigated had visibilities between 90 and 180 feet.

*See par. 2.3 BIBLIOGRAPHY

A 1963 report of the US Army Natick Laboratories categorically states that it is "the first quantitative study ever made of visibility in a Central American tropical forest" (1). The report further states that "In view of serious operational problems resulting from poor visibility in the tropical forest, it seems surprising that this subject has been neglected." In the Natick study, three hundred and sixty observations of a uniformed person were made, consisting of four observations made at cardinal compass points at each of 90 sites. The report does not make clear the number of observers used or the manner in which they were selected.

The Engineer Waterways Experiment Station (WES) has issued a generally excellent plan for visibility tests. (8). The WES plan calls for the use of both dot targets and pattern recognition targets. The plan also includes a detailed method for identifying and classifying vegetation. The WES plan does not indicate where or when the plan will be implemented, nor does it mention the tropics specifically.

Ashton (2), Carter (3), and Evans, Whitmore, and Wong (6, 7) have measured ambient illumination in the Brazilian, British Guianan, and Singapore and Nigerian rainforests. The purpose of these studies, however, was to investigate patterns of light intensity. None of the reports dealt directly with problems of target detection.

2.1. METHOD

2.1.1. OBSERVERS. Thirty observers (O's) were used. They were drawn from the 4th Battalion (Mechanized), 20th Infantry, in the Canal Zone. All O's were in Combat MOS. Observers' ages ranged from 17 to 32 years; the mean age was 21 years. Grades ranged from E-2 to E-5; the majority were in grades E-2 and E-3. Amount of time in the infantry ranged from one to 144 months; the average time was 24 months. Each O was pretested with an Ortho-Rater vision tester to insure normal or better close, distance, color, and depth vision. From the initially selected pool of thirty O's, three sub-groups, comparable in visual acuity, were randomly assigned to one of three different sites for testing.

2.1.2. TARGETS. Targets were two US Army soldiers dressed in standard utility (fatigue) uniform, without insignia, OG-107, including jacket, cap, trousers bloused, and jungle boots. Both targets were 6'1" in height; one weighed 185 lbs.; the other weighed 160 lbs. No web equipment or firearms were used. The targets stood motionless

facing the O, and their faces were blackened with charcoal (See Figure 1). The same targets were used throughout the experiment.

2.1.3. EXPERIMENTERS. Two experimenters (E's) were present during all testing. E_1 gave instructions to the O and scored the test. E_2 supervised the deployment of targets among the preselected target positions.

2.1.4. INDEPENDENT VARIABLES. Three independent variables were investigated: target distance, horizontal target placement in O's field of search, and test site.

Figure 1. Close-up view of target.

2.1.4.1. TARGET DISTANCE. Eight distances were used: 30, 40, 50, 55, 60, 65, 75, and 100 feet. These distances were selected on the basis of rough exploratory studies which indicated that most targets were seen at 30 feet and few were seen at 100 feet. Five-feet increments were used between the 50 to 65 feet distances because the exploratory studies suggested that the average threshold was more likely to fall within this range. Smaller increments were needed within this range to assure sensitive threshold measures (See Figure 2).

2.1.4.2. HORIZONTAL TARGET PLACEMENT. The O's field of search was a 180° arc. All targets were actually within a 120° field, but O's were not aware of this. Five 100-feet radii extended outward from O's fixed position (Figure 2). Radius I was 60° to the left of O's line of sight, II was 30° left, III was in the direct line of sight (12 O'clock), IV was 30° to the right, and V was 60° to the right.

2.1.4.3. SITE SELECTION. Three sites were selected: one near Fort Clayton at UTM Grid coordinates 17P-PV-581961, one near Albrook Air Force Base at coordinates 17P-PV-600958, and a third approximately five miles distant in the Empire Range area at coordinates 17P-PV-521929.

Selection of sites was not random. Sites were selected to meet the following three criteria:

a. To be apparently representative of the semideciduous tropical forest of Panama in the opinions of the two authors and a Panamanian vegetation specialist. There are at present no known objective criteria by which representative sites may be selected because tropical vegetation has not been adequately inventoried.

b. To be relatively level to prevent physical terrain features from hindering vision. Determining the detection threshold as a function of vegetation was of primary interest in the present investigation. This criterion somewhat limits the generality of the results.

c. To be unobstructed by a large tree trunk along any radius so that the observer "had a chance" on each target.

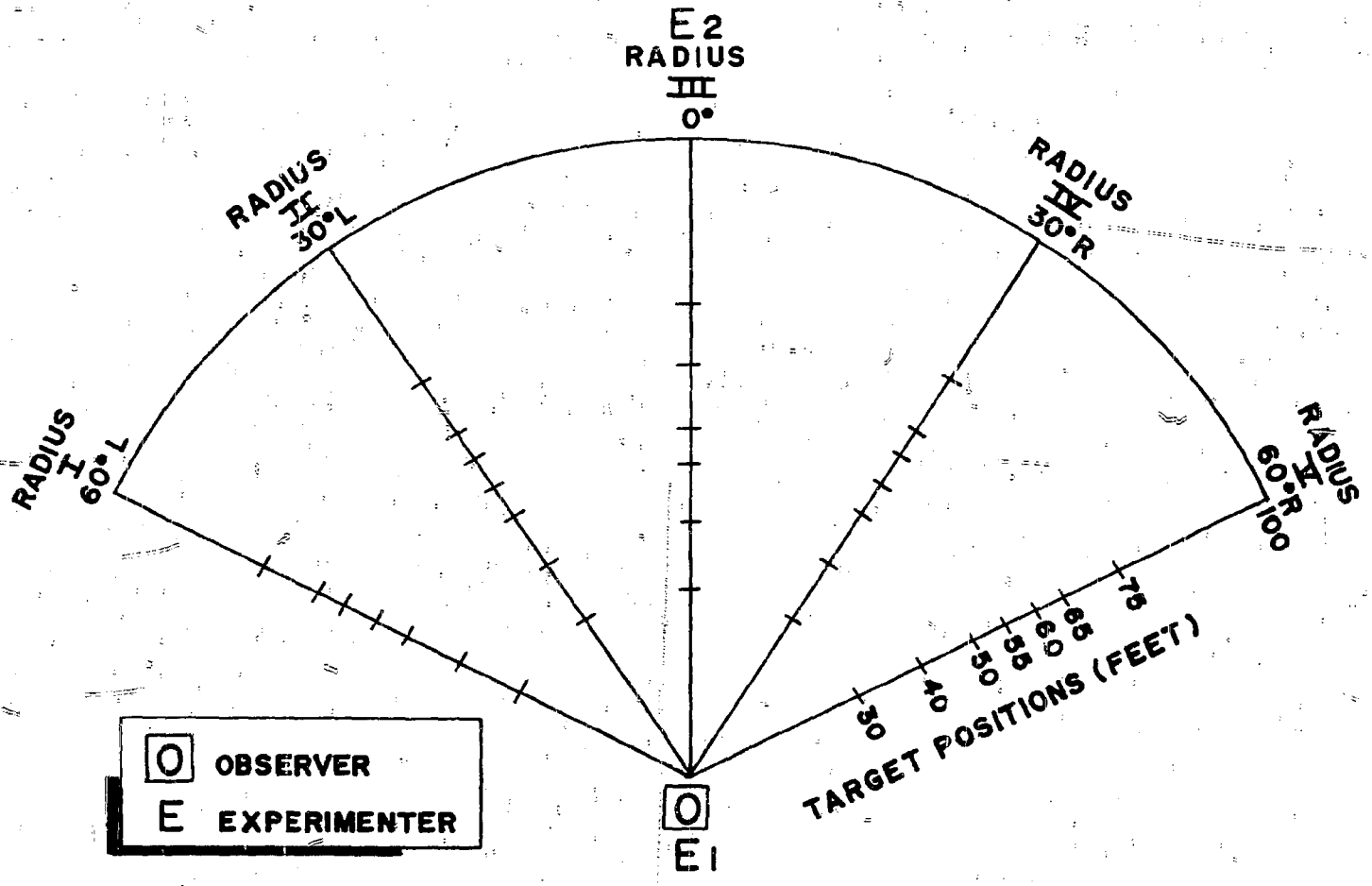

FIGURE 2. SKETCH OF THE THREE TEST SITES SHOWING TARGET DISTANCE AND PLACEMENT.

To prevent undue trampling of the underbrush on the radii, four narrow lanes, not visible to O's, were cut at each site between radii I and II, II and III, III and IV, and IV and V. A narrow semicircular lane was cut at the 100-feet arc to facilitate target deployment.

The primary objective of using three different sites within one major environment was to obtain an estimate of intraenvironmental variability with respect to target detectability. When the present study is extended to cover other environments of the humid tropics -- tropical evergreen, savanna, and reed swamp, for example -- the intra- and inter-environmental variations may be compared to test the validity of environmental classifications with respect to target detectability.

2.1.5. DESCRIPTION OF SITES. Each of the three sites described below represents a common variation of the semi-deciduous forest belt of the Pacific side of the Isthmus of Panama. The principal differences among the sites can be traced to two major factors: the influence of man and the height of the water table level. Since the test was performed in March, which is near the end of the dry season, the vegetative cover was at a minimum (See Figure 3 in back of text). In spite of the fact that much of the overhead canopy was sparse and brownish in color, the lower shrubs and vines retained their green hues and furnished effective camouflage for the fatigue uniform.

2.1.5.1. FORT CLAYTON SITE. This site was a relatively flat area broken in several places by shallow depressions (See Figure 3A). The brownish clay soil, which was dry and cracked, was covered by a mat of dry leaves about two inches thick. Most of these leaves came from the upper of the two stories that formed the principal canopy layers. Although none of the trees on the site was completely bare, some had only a few leaves. Melostomaceae, espave, and carate were the principal types of trees represented. The trees forming the upper story were from 60 to 75 feet tall with trunk diameters from 10 to 15 inches. Crowns overlapped in many places, but they did not form a complete canopy. Epiphytes were abundant on upper branches. Below the top story, at heights of 25 to 40 feet, the second story was composed of such trees as cedro, guarumo, strangling fig, and Jacaranda copaia, which have very shallow crowns. The most conspicuous types of vegetation were the small diameter vines, which hung from the branches in a tangled mesh. The larger lianas were close to the trunks of supporting trees and formed loose coils around the base of the thicker trunks.

The undergrowth, though not particularly dense, formed a complex pattern. Woody shrubs up to six feet tall were interspersed throughout the site. Most of these shrubs were covered with many fairly small leaves. Filling the gaps between the shrubs were such herbaceous plants as platanillo, which has a leaf about six inches wide and more than a foot long, and panama hat palm, which has leaves that are closely spaced on branches about two feet long. These plants were as much as eight feet tall. Climbing sedge, with its razor-sharp stems and leaves, presented hazards to both targets and observers alike. Tying all of the various plants together and forming the most difficult obstacle to both movement and observation were the myriad of tiny vines, such as pica pica, climbing bamboo, and inga. Forming a broad latticework across the site, the vines and their hundreds of leaves served to break the outline of the targets, which became more indistinct with distance from the observer. Near the margins of the site were several corozo palms. Long, stiff fronds branch directly from the stem of the corozo and bend until they touch the ground, forming an umbrellalike formation. The stems are from 10 to 15 inches in diameter and 15 to 20 feet tall. Unlike the trees of the upper story, the vegetation in the undergrowth had its full complement of leaves.

2.1.5.2. ALBROOK AIR FORCE BASE SITE. (See Figure 3B). This area was uniformly flat. One to one and one-half inches of dried leaves covered the hard, reddish brown, clay soil which was unmarred by cracks. The top canopy of vegetation was relatively low, with most trees between 35 and 50 feet tall. A few trees reached about 70 feet. Although the crowns of some of the trees overlapped, the general appearance was quite broken because many of the trees were nearly bare of foliage. This was especially true of the monkey comb (most common of the defoliated types), the carate, and indio encuero. The most prevalent tree type in the area was the melostomaceae, which, with the caimito and coccoloba, retained most of its leaves, though many were dry and brittle. As an indication of the youth of this forest, the trunks of the trees forming the upper story were mainly between four and eight inches in diameter, with a few of the larger ones reaching ten inches.

Beneath the upper story was a confused mass of undergrowth. Although there were some young trees that were 12 to 15 feet tall, they were so well scattered that they did not form a distinct second story. The most complete ground cover was formed by the smaller shrubs and herbaceous plants, which generally

were between four and eight feet high. By far the most prevalent were the platanillos, whose long thick leaves shaded about 25% of the ground. Piperaceae and rubiceae were other common types. Wild pineapple, four to six feet tall, was quite evident, although not very prevalent. Interspersed among the plants previously named were the panama hat palm and several other palms.

As at the Fort Clayton site, however, the greatest hindrances to visibility in this area were the numerous vines and lianas. Hanging from the trees and shrubs, these features formed a web throughout the entire site. Some of the lianas were up to five inches thick, but most of the vines were less than one-half inch in diameter. Many of the smaller vines presented hazards in the form of long spines and needles. All of them had many leaves, most of which were green. The light that reflected into the eyes of the observers when the sun shone on the moving leaves provided the best camouflage available at the site.

2.1.5.3. EMPIRE RANGE SITE. (See Figure 3C). The principal relief feature at this site was a depression about five feet wide and two feet deep that extended across lanes IV and V between 40 and 50 feet from the observer. Since none of the distance markers was in the depression, it had no effect on the conduct of the test. The rest of the site was nearly level. A carpet of leaves about one inch thick covered the brownish light clay soil, which, though dry, was not as hard as the soil at the other two sites. The top canopy was broken and uneven, but it provided coverage over approximately 75% of the site. A variety of palm, Scheelea zonensis, dominated the average level, which was at a height of 70 to 85 feet. Also included in this layer were the caimito and melostomaceae. Reaching above the main level to heights of approximately 100 to 115 feet were a number of espave trees; these contributed to the uneven appearance of the upper story. Only the crowns of the taller trees were relatively bare, and the canopy retained an aspect of fullness. Trunk diameters ranged from eight to 10 inches for the melostomaceae, 10 to 12 inches for the espave and Scheelea zonensis, to 12 to 15 inches for the caimito. The trunks of many of the palms were embraced by strangling fig; and lianas, two to four inches in diameter, hung like cables fro numerous trees. Ferns and mosses covering the trunks indicated the exceptionally high humidity at the site. Forming a pronounced second story at a height of 15 to 25 feet were young scheelea zonensis palms, panama hat palms, and black palms. The leaves of the low scheelea zonensis were major obstacles to visibility. Growing from the trunk in a circular pattern,

the stiff leaves were from 10 to 14 feet long. In addition to hampering observation, the leaves also made walking difficult. Black palms were also hazards; each four to six inch trunk was covered by ringlets of three-inch barbed thorns, which also circled each branch. The panama hat palms, which had leaves only at the top of their thin stems, had the least effect on observation.

Undergrowth at this site was extremely dense. The principal bushes, represented by rubiceae, piperaceae, and lugum-inaceae, were from four to 10 feet tall, but many of them started branching at their bases. Countless small vines, a number of which had sharp spines hidden among their leaves, were interspersed through the bushes. In addition, the fallen remnants of small trees, fallen decayed branches, and dried palm leaves provided bulk to the living vegetation. Ferns, sedges, and grasses with thick leaves filled in the spaces at the lowest level.

2.1.6. DEPENDENT VARIABLES. Three measures of performance were taken. The first measure was the detection threshold. The threshold is defined as that distance at which a target is detectable only 50% of the time.

The method used to establish stimulus thresholds in the present study has no exact counterpart in the classical psychophysical methods of the laboratory. It could be described as a modified "limits" technique. The difference is that the stimuli used in the limits technique are progressively varied in magnitude from small to large and large to small values. In the present study, the stimulus magnitudes (target distances) were randomized to minimize errors of habituation and expectation and to make target location unpredictable on any given trial.

The second performance measure was range estimation. For those targets which were detected, O was asked to estimate the distance. The purpose of this measure was to determine whether there is a constant error involved in range estimation in the semideciduous forest.

The third performance measure, detection time, was introduced shortly after the beginning of the experiment.

2.1.7. RESEARCH DESIGN. The research design is summarized in Table I. Three separate, but visually comparable, sub-groups of 10 O's each were assigned randomly to each of the three sites. Each O observed 40 targets appearing randomly with respect to distance and location. Each of the

eight distances appeared an equal number of times across all five radii. Each of 10 O's observed eight targets per radius, making a total of 400 observations per site, or 1200 observations in all. Target sequence was randomized across radii and distance by a table of random numbers (Appendix A).

Testing sequence was systematically randomized across three sites to insure that no two O's were tested consecutively on the same site and, also, that each site was used equally often after blocks of three O's were tested (Appendix B). The latter control was used to minimize collusion among O's and maximize time for vegetation to recover.

TABLE I

Research Design of Jungle Vision I

		Radius					
		I	II	III	IV	V	
Site	Number Observers	Number Observations (n)					Total (n)
Clayton	N=10	80	80	80	80	80	400
Albrook	N=10	80	80	80	80	80	400
Empire	N=10	80	80	80	80	80	400
Total	N=30	240	240	240	240	240	1200

2.1.8. PROCEDURE. Test sites were laid out according to Figure 2. Illumination measures were taken at the O's eye and at the midpoint of each radius with a GE type 213 light meter before and after testing. All sites were laid out north-south to minimize the effect of sunlight on O's vision, since both morning and afternoon testing was scheduled.

The O's were tested one at a time (See Figure 4) O was informed by E_1, reading from a standardized set of instructions, that this was a test of his ability to spot targets in a jungle environment. The target EM were initially visible for familiarization. The O was informed that targets would appear at any point from nine O'clock to three O'clock (180°). The O was informed that he had two minutes to make a detection; if at the end of that time he had not detected a target, it was scored as a non-detection. The O was fitted with Clark 372-9A ear protectors to reduce the possibility of responding to auditory cues caused by movements of the targets through the

Figure 4. Experimenter ($\underline{E}_1$) and Observer

vegetation. The $\underline{O}$ was urged to guess when he was unsure of the location of the target. (See detailed instructions in Appendix C.)

Before the appearance of the first target, $\underline{E}_1$ turned $\underline{O}$ around facing away from the course. $\underline{E}_1$ blew a whistle signalling $\underline{E}_2$ to deploy one of the targets into the first position. The target took his place on a given radius at a pre-emplaced distance marker and stood immobile, facing the $\underline{O}$. $\underline{E}_2$ returned a whistle signal informing $\underline{E}_1$ that the target was ready.

The $\underline{O}$ was confined to a marked three-feet square. He was allowed to bend, twist, crouch, or lie down in searching for targets, but he was not allowed to move his head outside the marked square.

The $\underline{O}$ was required to point and give a distance estimate when he detected a target (See Figure 5 for an observer's view of targets at varying distances). $\underline{O}$ was not informed as to the correctness of his detection. The $\underline{E}_1$ again turned the $\underline{O}$ around and signalled $\underline{E}_2$ to return the target EM to the 100-feet distance (out of sight) and to deploy the other

target EM into the next position. The above sequence was repeated until the O completed 40 observations. Total testing time for one O ranged from one and one-half to two hours. Rest pauses of three minutes each were allowed after each tenth trial.

Two men were tested each day. The morning test began each day at 0830 hours and the afternoon tests at 1330 hours. No test was conducted during rain or overcast conditions; however, overcast conditions occurred twice while the tests were already in progress. Out of the desired 1200 observations, 1198 were actually obtained. One O was not allowed to complete his final two observations because of the onset of rain near the end of an afternoon session.

2.2 RESULTS

2.2.1. DETECTION THRESHOLDS. Table II shows detection thresholds for each of the three sites. Thresholds were computed by interpolating between those two distances between which 50% of the targets were detected. The average thresholds ranged from 52.5 feet at the most difficult site (Empire) to 70.3 feet at the easiest site (Albrook).

Combining the results for all three sites, the detection threshold was 59.6 feet. At distances less than 51.5 feet 75% of all targets were detected; at distances over 71.5 feet, only 25% of all targets were detected.

TABLE II

Average detection thresholds and 25-75% range at each of three semideciduous tropical forest sites.

Site	25% Detections (feet)	Detection Thresholds (50%) (feet)	75% Detections (feet)	n*
Clayton	71.1	61.0	54.6	400
Albrook	84.8	70.3	61.0	400
Empire	58.2	52.5	30.0	398
Average (all sites)	71.5	59.6	51.5	1198

*Number of observations

If these thresholds seem high to those with jungle experience, several factors must be remembered:

a. It is well known that a person deliberately concealing himself in the jungle can effectively hide at a distance of only two to three feet from the observer; however, targets in the present study were not hiding or crouching, commensurate with the study's purpose of providing typical rather than extreme data.

b. The measurements were made during the latter part of the dry season, when certain types of foliage was at a minimum, illumination at a maximum, and detectability thereby supposedly at a maximum. (A later study will provide empirical data on this point.)

Table III shows the percentage of targets detected at each of the eight distances used. With slight variation from site to site, the eight distances efficiently sampled the range of visual acuity for human targets in the semideciduous sites. Overall, ninety-one percent of all targets were detected at 30 feet and only four percent at 100 feet. Another index of the accuracy of course "calibration" is the fact that there were 660 detections (55%) made from 1198 opportunities.

TABLE III

Percentage of targets detected at each of eight distances at three semideciduous tropical forest sites.

DISTANCE (feet)	SITE			Average (all sites)*
	Clayton %	Albrook %	Empire %	%
30	100	100	74	91
40	96	100	68	88
50	86	96	49	77
55	74	96	40	70
60	52	76	16	48
65	42	70	14	42
75	14	32	2	18
100	0	14	0	4

*150 total observations for each distance except 50 and 60 feet, which had 149 each.

Figure 6 shows the same data in graph form. The general conformation of the three curves is similar regardless of the intrinsic differences in detection difficulty among them. Average detections decreased little as a function of distance up to 55 feet, then dropped off sharply. Passed 65 feet, detection dropped off rapidly up to 100 feet where only seven detections out of 150 opportunities were made -- and all these seven were made at one site (Albrook).

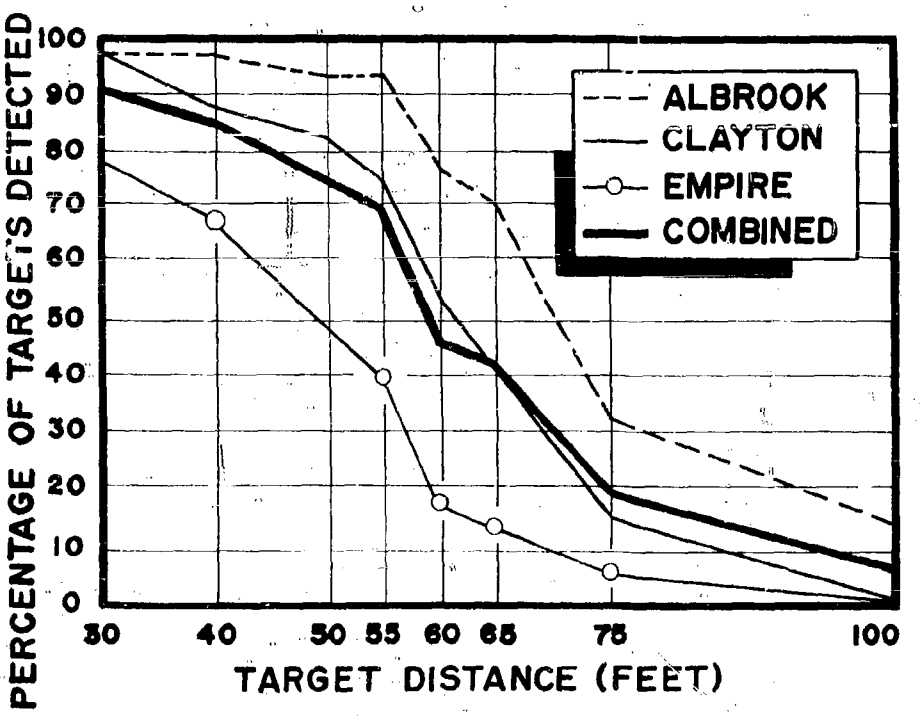

FIGURE 6. PERCENTAGE OF TARGETS DETECTED AT 3 SEMIDECIDUOUS TROPICAL FOREST SITES.

TABLE IV

Average detection thresholds for each radius at three semi-deciduous tropical forest sites.

	RADII					
SITES	I	II	III	IV	V	Average (all sites)
Clayton	58.7	57.5	58.3	65.0	63.7	61.0
Albrook	70.0	72.5	87.5	70.0	60.0	70.3
Empire	57.3	32.5	55.0	53.3	52.5	52.5
Average (each radius)	62.0	54.2	66.9	62.8	58.7	59.6

Table IV shows detection thresholds for each of the five radii at each site. The purpose of this analysis was to determine whether the three sites differed significantly with respect to the average threshold values and to determine whether there was any significant tendency for thresholds to vary as a function of horizontal target placement. More specifically, did detections drop off systematically when targets appeared at the site peripheries (Radii I and V) as opposed to the central radii? A repeated measures analysis of variance was performed on the data in Table IV. The analysis showed that the three sites differed significantly with respect to average detections ($F=8.43$; $df=2/8$; $P<5\%$)*. There were less than five chances in 100 that differences among the three site means resulted from random sampling from a common distribution (two-tailed test). The analysis also showed that there were no statistically reliable differences due to horizontal target placement (radii). ($F=0.96$; $df=4/8$; $P>50\%$.)

2.2.2. RANGE ESTIMATION. In Table V observer range estimates of 27 detected targets are compared with actual distances. Estimates are shown in terms of medians because the means were distorted by a few "wild guessers." A constant error of approximately 10 feet in the direction of underestimation was made for all distances. The median estimates are also plotted in Figure 7. This effect is believed to be due to reduced cues for depth perception in the visually homogeneous tropical forest.

* See Appendix D for definitions of statistical symbols.

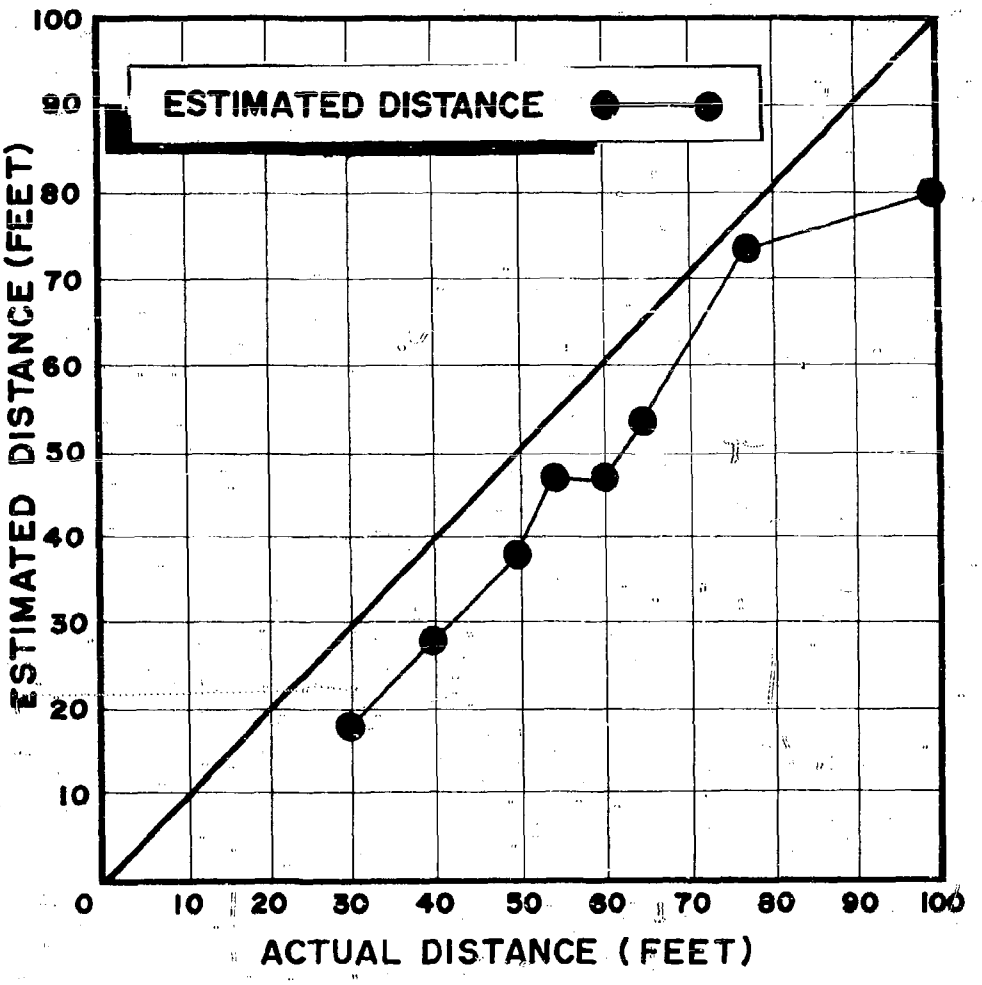

FIGURE 7. MEDIAN DISTANCE ESTIMATES OF 30 OBSERVERS AT 3 SEMIDECIDUOUS TROPICAL FOREST SITES.

Also shown in Table V are the semi-interquartile range of distance estimates. This statistic indicates that observer range estimates became increasingly more variable as actual target distance increased even though the constant error remained.

TABLE V

Actual distances compared with observer distance estimates for detected targets at three semideciduous tropical forest sites.

Actual Distance (D) (feet)	Estimated Distance (E) (Median)	Diff (E)-(D)	Semi-interquartile Range (Q)	No. of Estimates
30	19.7	-10.3	8.7	136
40	27.5	-12.5	11.0	132
50	39.0	-11.0	13.3	113
55	49.2	- 5.8	25.8	105
60	49.8	-10.2	21.8	75
65	52.5	-12.5	28.5	67
75	72.0	- 3.0	49.7	25
100	84.0	-16.0	*	7

*Insufficient cases to compute Q.

2.2.3. INDIVIDUAL DIFFERENCES. The extent to which average detection thresholds may be relied on as relatively constant quantities depends, of course, on the variation from $\underline{0}$ to $\underline{0}$ when tested at the same site under comparable conditions. Table VI shows thresholds for each $\underline{0}$ tested. The means and standard deviations are shown for each group of 10 $\underline{0}$'s. In general, there was very little variation within a given site. There was relatively greater variation on the more difficult course (Empire) and less variation on the least difficult course (Albrook).

Two standard deviations on either side of the mean account for 68% of all cases in a normal distribution. It may be estimated, then, that in an extension of studies in sites comparable to Clayton, the middle 68% of detection thresholds would fall between 56-67 feet; for Albrook-type sites, between 66 and 75 feet; for Empire-type sites, between 44 and 56 feet.

TABLE VI

Detection thresholds for individual observers at three semi-deciduous tropical forest sites.

Clayton		Albrook		Empire	
Observer Number	Threshold (feet)	Observer Number	Threshold (feet)	Observer Number	Threshold (feet)
1	52.5	3	70.0	2	45.0
4	57.5	6	70.0	5	45.0
9	62.5	8	68.5	7	51.3
11	57.5	10	62.5	12	53.8
15	61.2	13	72.5	14	57.5
18	66.7	17	81.2	16	50.0
21	63.3	19	72.5	20	38.3
23	58.8	22	67.5	24	52.5
25	70.0	27	72.5	26	58.7
28	63.8	30	70.0	29	*
Mean	61.4		70.7		50.2
Standard Deviation	5.4		4.4		6.1

*Unable to compute threshold because of insufficient detections.

These estimates apply to groups of O's similar to those tested in the present study and assume normality of distribution. If extended to a larger military population, including those with visual defects, older, or less well motivated, the average thresholds would probably decrease and the standard deviations increase.

2.2.4. DETECTION TIME. Shortly after the beginning of the present study, it became apparent that it was possible for E$_1$ to measure the time necessary to make a detection in addition to his other duties. A stopwatch was subsequently used to record these measurements for the last 507 of the 660 detections. These data are shown in Table VII. Detection times were generally shorter for the easiest site (Albrook) and correspondingly longer for the sites of intermediate (Clayton) and greatest difficulty (Empire).

Means for the three sites combined showed a sharp increase in detection time as a function of actual target distance. For

example, it took nearly four times as long to detect targets at 75 feet than at 30 feet. Increased detection times were probably caused both by the decrease in apparent target size as well as increased vegetative camouflage as target distances were increased.

TABLE VTT

Average time in seconds for target detection at three semi-deciduous tropical forest sites.

	Target Distance (feet)							
	30	40	50	55	60	65	75	100
Clayton	9.4	15.8	25.4	28.8	38.5	25.8	65.7	*
Albrook	4.5	6.1	10.1	18.0	29.6	35.2	40.5	*
Empire	27.9	36.7	25.8	46.6	50.3	31.4	*	*
Weighted Mean	12.9	18.3	19.7	28.3	35.2	30.9	47.8	*
Number Observations	107	103	90	74	62	48	20	3=507

*Insufficient cases to compute mean.

2.2.5. EFFECTS OF ILLUMINATION. Measures of illumination were taken immediately before and after each testing. Readings were taken at the observer's eye and at the 50 feet (midpoint) distance of each of the five radii. These measures are summarized in Tables VIII and IX. No relationship is apparent between the relative amount of illumination and the relative ease (average detection threshold) of target detectability among the three sites, i.e. the Clayton site, of intermediate detection difficulty, had the highest average ambient illumination at eye level. There was little difference among the three sites in illumination taken along the radii.

TABLE VIII

Average illumination in foot candles taken at eye level of observers before and after testing (average of five radii).

	Clayton		
	Morning (n=7)	Afternoon (n=3)	Weighted Mean
Start (0900)	190	(1330) 323	231
End (1030)	534	(1500) 525	532
Weighted Mean	363	424	381

	Albrook		
	Morning (n=5)	Afternoon (n=5)	Weighted Mean
Start (0900)	83	(1330) 117	100
End (1030)	198	(1500) 340	268
Weighted Mean	139	229	184

	Empire		
	Morning (n=3)	Afternoon (n=7)	Weighted Mean
Start (0900)	50	(1330) 132	113
End (1030)	112	(1500) 83	93
Weighted Mean	81	110	101

Average illumination tended to be higher in the afternoon tests. The mean "morning" threshold for all sites was 64 feet; the mean "afternoon" threshold was 59 feet. An analysis of data revealed that these differences could have arisen from random sampling ($t=0.35$; $df=27$; $P>60\%$).

TABLE IX

Average illumination in foot candles taken at midpoint of each radius before and after testing (average of five radii).

	Clayton				
	Morning (n=7)		Afternoon (n=3)		Weighted Mean
Start (0900)	81	(1330)	113		91
End (1030)	154	(1500)	167		158
Weighted Mean	117		140		124

	Albrook				
	Morning (n=5)		Afternoon (n=5)		Weighted Mean
Start (0900)	88	(1330)	112		100
End (1030)	161	(1550)	146		154
Weighted Mean	124		127		127

	Empire				
	Morning (n=3)		Afternoon (n=7)		Weighted Mean
Start (0900)	114	(1330)	141		119
End (1030)	208	(1550)	101		137
Weighted Mean	161		112		127

Another analysis was made concerning illumination. The detection threshold for each $\bar{0}$ was correlated (Pearson product moment) with the average level of illumination present on the site before and after his testing. The coefficient of .04 (df=27; P>5%) indicated no reliable association between illumination and threshold. It seems apparent that within the restricted range of thresholds found in the present study, no strong statistical relationship could exist. Even at the lowest level of illumination recorded, all test days were sufficiently bright so as not to hinder vision. The intense sunlight did not appear to make a target more visible; rather, the sun flecks dappled the fatigue uniform and appeared to break up the figure-ground relationship between uniform and surrounding vegetation. It must be remembered, however, that

no continuous measures of illumination were available, thus no detection-by-detection or "fine-grained" comparison with illumination levels were possible. The present analyses are gross and do not rule out a more definitive relationship between ambient illumination and target detection in future studies.

2.2.6. EFFECTS OF OBSERVER AGE AND EXPERIENCE. Correlation coefficients (Pearson product) were computed between two observer attributes and detection thresholds. Detection thresholds were first statistically adjusted to rule out mean differences in difficulty among the three sites. In an attempt to assess the effects of experience in target detection, both the age of the observer and time in the infantry were correlated with detection thresholds. The coefficient between age and thresholds was .18 (df=27; P>5%), which was not statistically significant. The coefficient between infantry experience and thresholds was .11 (df=27; P>5%), which was not statistically significant. (Many of the O's had received prior training in jungle target detection.) As stated previously, the restricted range of detection thresholds makes it very unlikely that any reliable associations with any external variables would be found.

2.2.7. PRACTICE EFFECTS. Finally, an analysis was made of practice effects. Individual detections were grouped into four blocks of 10 trials representing the first, second, third, and fourth groups of trials between rest pauses. The mean number of detections for each consecutive block was computed. This analysis was not altogether legitimate since the mean actual distances within each block of ten trials differed due to target distance randomization. The data are as follows:

	1st 10 Trials	2nd 10 Trials	3rd 10 Trials	4th 10 Trials
Average Number Detections	14.8	14.7	15.5	20.5
Average Actual Distance (feet)	58.0	63.0	64.0	52.5

No systematic evidence of a practice effect exists when the difficulty (actual distance) of the fourth block is taken into account.

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SECTION 3. APPENDIXES

APPENDIX A

Order of Target Presentation

Distance (feet)	Radius				
	I	II	III	IV	V
30	14	9	17	5	28
40	31	13	3	36	33
50	35	38	40	8	18
55	25	29	10	22	21
60	2	34	37	30	39
65	15	12	27	24	1
75	7	20	32	4	16
100	23	11	26	19	6

APPENDIX B

Sequence of Observers Tested at Three Different Sites

Clayton Site	Albrook Site	Empire Site
1	3	2
4	6	5
9	8	7
11	10	12
15	13	14
18	17	16
21	19	20
23	22	24
25	27	26
28	30	29

APPENDIX C

Instructions given to the $\underline{O}$ by $\underline{E}_1$ prior to the start of each 40 trials at each site.

"We are trying to find out how well you can detect targets through the foliage. You will see one of these fellows (demonstrates) standing up facing you between nine o'clock (point) and three o'clock (point) at different distances from you. There will be only one target at a time. When I give you the signal, you are to stand up in this marked box (point) and search for the target. You may crouch, kneel, or even lie down, providing you don't move your head out of the box (demonstrate). If you spot him, point in his direction and tell me how far away you think he is. You will have two minutes to find him. If you don't spot him in the time limit, I will turn you around and score a miss. If you think you see him, but are doubtful, go ahead and guess. There will be 40 trials in all, and the test will last about an hour and a half. Are there any questions?"

APPENDIX D

DEFINITIONS OF STATISTICAL SYMBOLS

F = F-ratio. This ratio is derived from the analysis of variance. The analysis of variance yields the probability that the variation in a set of means may be attributed to chance.

t = t-test. This test yields the probability that variation between a pair of means may be attributed to chance.

P = Probability. This symbol refers to the level of confidence which may be placed in the statistical significance of values derived from many different types of tests.

df = degrees of freedom. Degrees of freedom are related to the number of observations entering into a particular test of significance. To some extent, the degrees of freedom determine the level of confidence placed in the results of the analysis.

Q = Semi-interquartile range. This is a measure of variation which includes one-half of the middle 50% of a normal frequency distribution. It is ordinarily employed as a measure of variation when the median is used as the measure of central tendency.

Standard deviation = This is a measure of the variability of individual values in a frequency distribution around the mean value.

Coefficient of Correlation = The Pearson Product Moment correlation coefficient is a measure of the extent to which two variables tend to vary together. A coefficient of ".00" indicates the variables fluctuate independently of each other. A coefficient of "1.00" indicates that the variables are perfectly related.

Weighted Mean = This is the grand mean of a series of individual means weighted by the total number of observations entering into the computation of the individual means.

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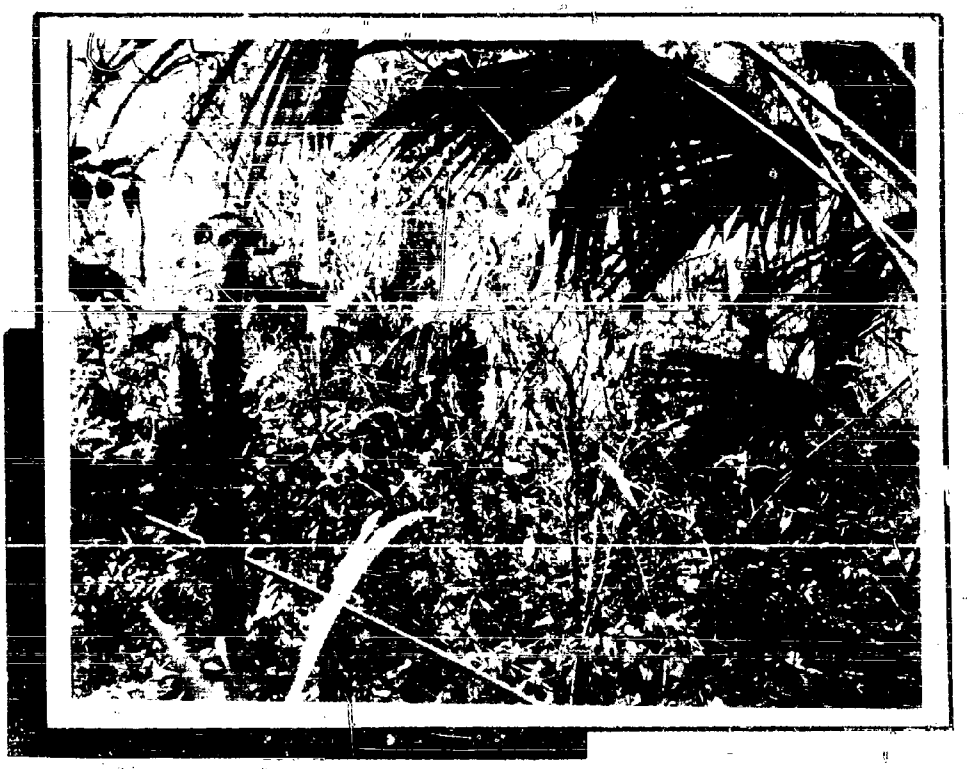
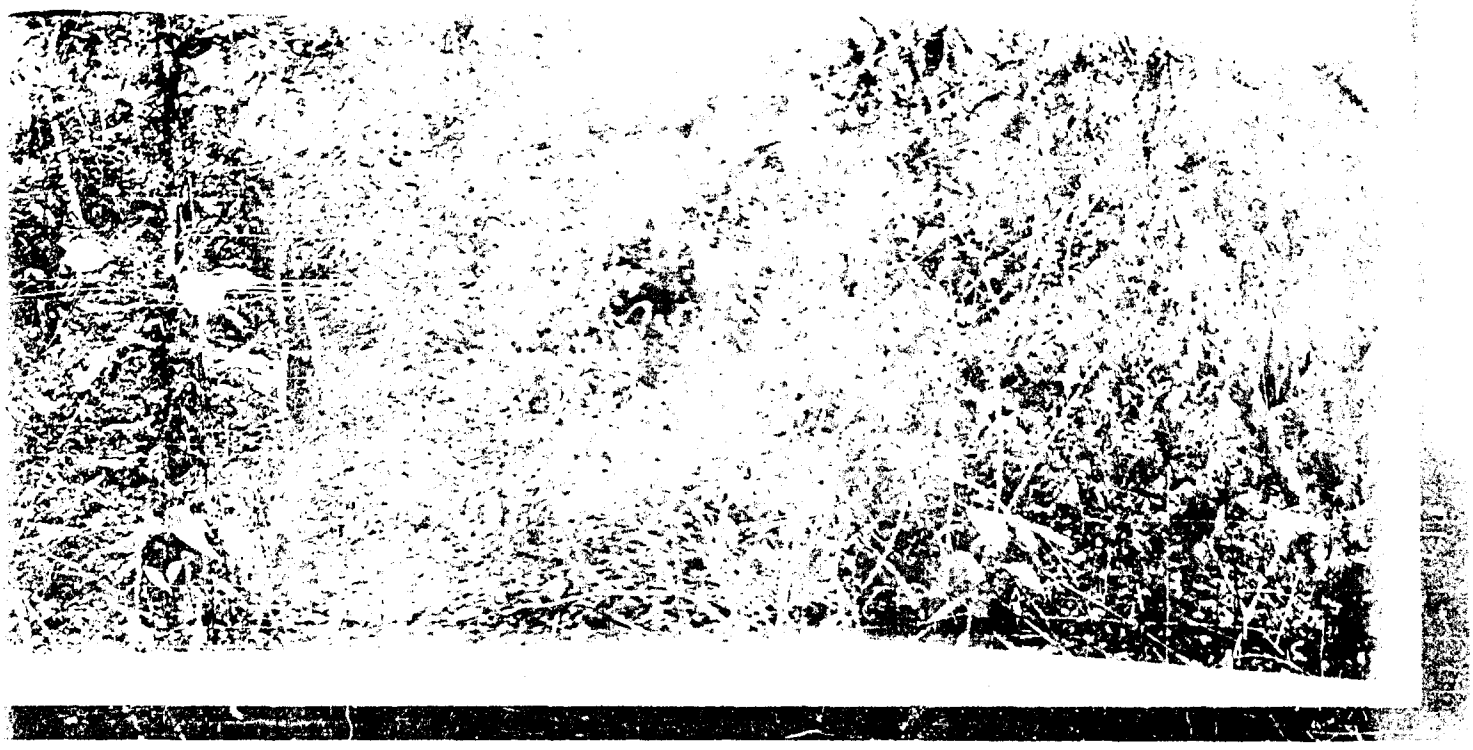


Figure 5 Targets at 30, 40, and 60 Feet, respectively From Top To Bottom At Albrook Air Force Base Site

Figure 3a. Fort Clayton S



Fort Clayton Site

Figure 3b. Albrook Air Force Base Si

Figure 3c. Empire Range Site

Figure 3. Views Of Three Semideciduous T

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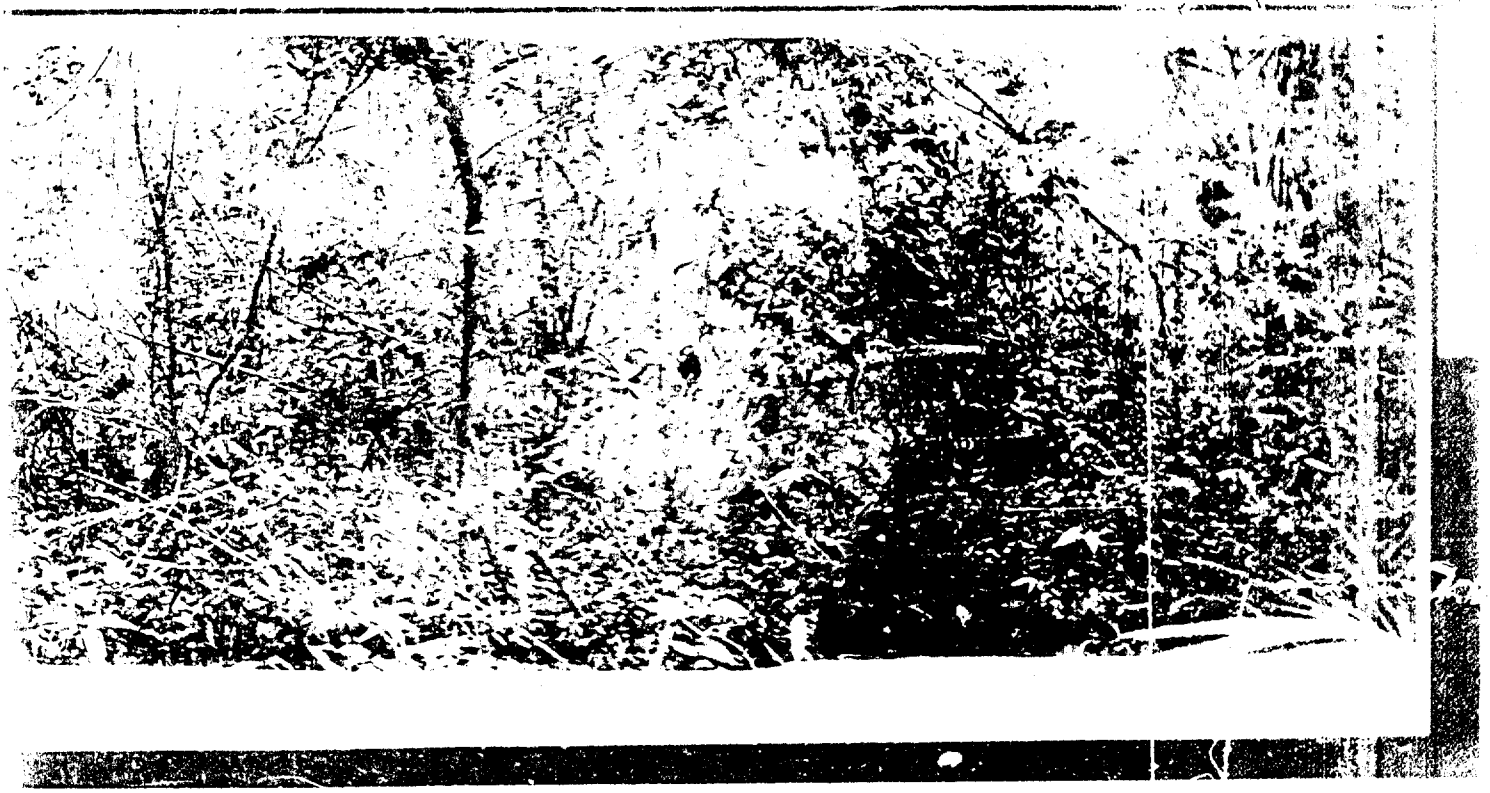

Empire Range Site

Three Semideciduous Tropical Forest Sites

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