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Research Report No. 8

JUNGLE VISION VII:

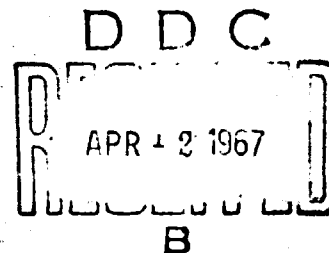
Seasonal Variations in Personnel Detectability
In a Semideciduous Tropical Forest

by

D. A. Dobbins, R. Ah Chu, and C. M. Kindick

January 1967

U.S. ARMY
TROPIC TEST CENTER
Fort Clayton, Canal Zone

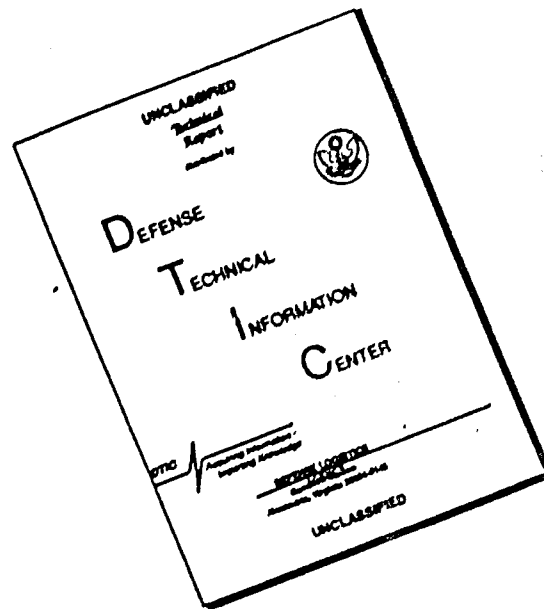


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(An In-House Laboratory Independent Research Project)

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ABSTRACT

The U.S. Army Tropic Test Center conducted a study to determine the effects of the tropical wet and dry seasons on the horizontal detectability of human targets in a semideciduous forest. Testing was conducted on three jungle sites in the Canal Zone in July, 1966.

Thirty infantry EM observed standing, motionless human targets appear randomly within a 180° field of search at distances ranging from 30 to 115 ft. Target detections, detection cues, search times, and distance estimates were recorded. Results of the present study were compared to those of an earlier dry season study conducted on the same sites.

Visibility was significantly lower during the wet season. Total target detections dropped by 44% during the period. Most of the change occurred on two of the three sites and was apparently caused by a single type of vine that loses its leaves during the dry season. Visibility gradients were of the same shape, though different levels, for both seasons. Illumination levels, search times, and distance estimates were significantly different from season to season.

Visual cues contributing most to target detection were the symmetrical outlines of target's trunk and legs against jungle foliage. The lines and color of the OG-107 fatigue uniform also contributed, particularly at farther distances.

FOREWORD

This is the seventh report in the Tropic Test Center series dealing with personnel detection in tropical forests. The research is supported by the US Army In-House Laboratory Independent Research Program.

The primary purpose of these studies is to make available, for the first time, a baseline of quantitatively sound data concerning the visual capabilities of the soldier in the jungle. From the standpoint of the test and evaluation mission of the Center, these data afford quantitative standards for evaluating the effectiveness of various types of target detection aids through jungle foliage. To date, the reports have dealt with visual capabilities in different types of tropical forests, with the effects of seasonal variations, with evaluations of potential performance aids, and the use of standard visibility objects. The present study examines the influence of tropical dry and wet seasons on visibility in a semideciduous forest site.

The Tropic Test Center, because of its geographical location, is ideally situated to collect these basic data and thus help close the gap in present knowledge.

Beyond the test and evaluation mission, these reports may have implications for tactics, training, and operations. For these reasons, the reports are widely distributed.

All observers were provided by the Commanding Officer, 3d Battalion, (Airborne) 508th Infantry, through the assistance of the Chief, Combat Developments Office, US Army Forces Southern Command.

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BRIEF OF RESULTS

The purpose of the present study was to determine the effects of the tropical wet and dry seasons on horizontal detectability of targets in a semideciduous forest.

Thirty enlisted men from an infantry unit in the Canal Zone, pre-selected for normal visual acuity, were each presented 45 standing human targets. Observers were tested in the wet season on the same three jungle sites where 30 different observers had been tested in an earlier dry season. Targets appeared at nine distances--30 to 115 ft--and were randomly presented along five radii separated at 30° intervals across a horizontal search area of 180°. By comparing results of the present study with those of the earlier dry season study, the following seasonal variations were noted:

1. Visibility was significantly higher in the dry season than in the wet season. The total number of detections dropped by 44% from dry to wet season. Average 50% detection thresholds dropped from 60 ft in dry season to 45 ft in wet season for all sites combined.
2. Of the three sites used, visibility was very much reduced in the wet season on two sites but did not change for the third. The two sites most affected by season differed from the third by the presence of a particular species of vine of eye-level height that loses its leaves in the dry season and also, by the presence of a larger proportion of deciduous trees.
3. Even though the level of the visibility gradients was much lower in wet season than in dry season, the familiar reverse "S" slope emerged again. Both dry and wet season distance gradients were well-fitted to a normal ogive.
4. The search time required to detect targets was from one and one-third to two and one half times higher during the wet season than the dry season, depending on target distance.
5. Horizontal luminance levels on the detection sites were approximately four times higher during dry season than in wet season. Mean levels in dry and wet seasons were approximately 165 and 45 foot-candles respectively. This difference is attributed both to canopy leaf loss and cloud cover differences between seasons. Low wet season light levels are not believed to have had a significant effect on visual detections for reasons discussed in detail in the report.
6. Distance estimates to detected targets differed substantially from one season to another. However, the evidence strongly indicates that the effect was neither seasonal nor perceptual, rather the effect seems to depend on whether the observer makes his estimates using the metric system or the English system.

7. At the conclusion of the report, data are shown comparing the relatively greater effects of season on visibility in the semideciduous forest with the lesser effects found in the evergreen forest. Systematic differences between the two types of forests are noted in thresholds, visibility gradients, luminance levels, and the extent of seasonal effects.

The following results do not pertain to seasonal effects:

8. The visual cues most important in the detection of human targets in the jungle were recorded. Overall, the vertical lines of the human trunk and legs were the more important cues (44%). However, the symmetry of head, face and shoulders--a small area of the body--accounted for 38% of all cues. The symmetry of lines on the OG-107 fatigue uniform and to a lesser extent, color contrast, resulted in the uniform being an important detection cue, particularly at farther target distances.

9. Individual differences in detection scores were stable, resulting in a reliability coefficient of .82. The coefficient is surprisingly high considering the narrow range of detection scores found on the task and restriction of range.

10. Regardless of season, individual observer variation was minimal. Standard deviations of individual 50% detection thresholds on the same sites ranged from only three to six ft.

11. No relationship was found between either observer age or experience and detection proficiency.

INTRODUCTION

The U.S. Army Tropic Test Center has initiated a series of studies to establish normative visibility data of unaided human vision in tropical forests. These studies provide baseline data against which gains resulting from technological detection aids may be evaluated.

The present study is the seventh of this series. It deals with the effects of the tropical dry and wet seasons on target detectability in a semideciduous tropical forest.

BACKGROUND

A previous study was conducted on the effects of seasonal variation on visual detections of single, standing human targets in a tropical evergreen forest (3)*. The results indicated that despite much higher dry season illumination levels and noticeable changes in vegetation, target detectability was no better in the dry than in the rainy season. Neither the 50% detection thresholds nor the visibility gradients were affected by season. The farthest distance at which any targets could be detected was between 100 and 115 feet from the observer.

The present study was conducted in the semideciduous forest on the Pacific slope of the Canal Zone. The dry season lasts longer and is more severe than in the evergreen forest of the Atlantic slope. Furthermore, a greater amount of sunlight filters through the more ragged canopy of the semideciduous forest. The dry season sunlight reaches the tangled mass of vines and undergrowth, and in the absence of the usual amount of rain, withers the leaf mass to a much greater extent than in the evergreen forest. Because of these characteristic differences in dry season severity and canopy cover between the two types of forests, the present study was initiated.

The dry season portion of the present study was conducted in March, 1964 (1). Thirty infantry observers were each presented 40 randomly appearing human targets at three semideciduous sites. For a single site, the targets appeared at eight distances, from 30 to 100 ft, along five radii within a 180° field of search. The 50% detection thresholds ranged from 52 to 70 ft for the three sites and averaged 60 ft for the combined sites. Percentage detections decreased gradually up to 55 ft, then dropped sharply up to 75 ft, at which distance they leveled off again. These inflections resulted in an ogive-shaped visibility gradient which has been reproduced since that time on other sites with different observers (5). This gradient appears characteristic of semideciduous vegetation and is distinctly different from the linear gradient found in tropical evergreen vegetation (2, 3, 4, 6).

* See Literature Cited

The present wet season study was conducted in July, 1966 on the identical sites as the dry season, using the same test procedures and different observers.

OBJECTIVES

a. To determine the effects of seasonal variations in climate and vegetation on horizontal detectability in a tropical semideciduous forest. Comparisons are made between the results of the present rainy season study with those obtained at the same sites during a previous dry season.

b. To continue accumulation of normative data on target detectability in jungle areas. Each study adds to the reliability of the base line.

METHOD

Observers. Thirty observers (Os) were tested. Observers were members of the 3rd Battalion, (Airborne) 508th Infantry, Fort Kobbe, Canal Zone. All Os were in combat MOS. Observers' ages ranged from 18 to 27 years; their mean age was 20.3 years. Grades ranged from E-3 to E-6; most were in grade E-4. Length of service ranged from 11 to 92 months; the average time was 44.5 months. Each O was pretested with an Ortho-Rater vision tester to insure normal far and near visual acuity.

Targets. Targets were two persons dressed in the standard fatigue (O.G.-107) uniforms including jacket (not tucked in), cap, and bloused trousers, without insignia. No web equipment or firearms were worn. Targets ranged in height from 5'7" to 5'11", and ranged in weight from 130 lbs. to 190 lbs. Targets always stood motionless on fixed distance markers facing O.

Experimenter. One experimenter (E) controlled all testing. He gave instructions to Os, scored detection, and recorded distance estimates, detection times, and detection cues.

Independent variables. Only one independent variable was of interest in the present study, wet season vs. dry season. However, target distance, horizontal placement, and site were also varied as experimental procedures.

(1) Target distance. Nine distances were used: 30, 40, 50, 55, 60, 65, 75, 100, and 115 ft. These were the same target distances used in Jungle Vision I except for 115 ft, which was added as a check to the detection limits (See Fig. 1).

(2) Horizontal target placement. The Os field of search was 180°. All targets actually appeared within a 120° field, but Os were not aware of this. Five 115-ft radii extended outward from the Os fixed

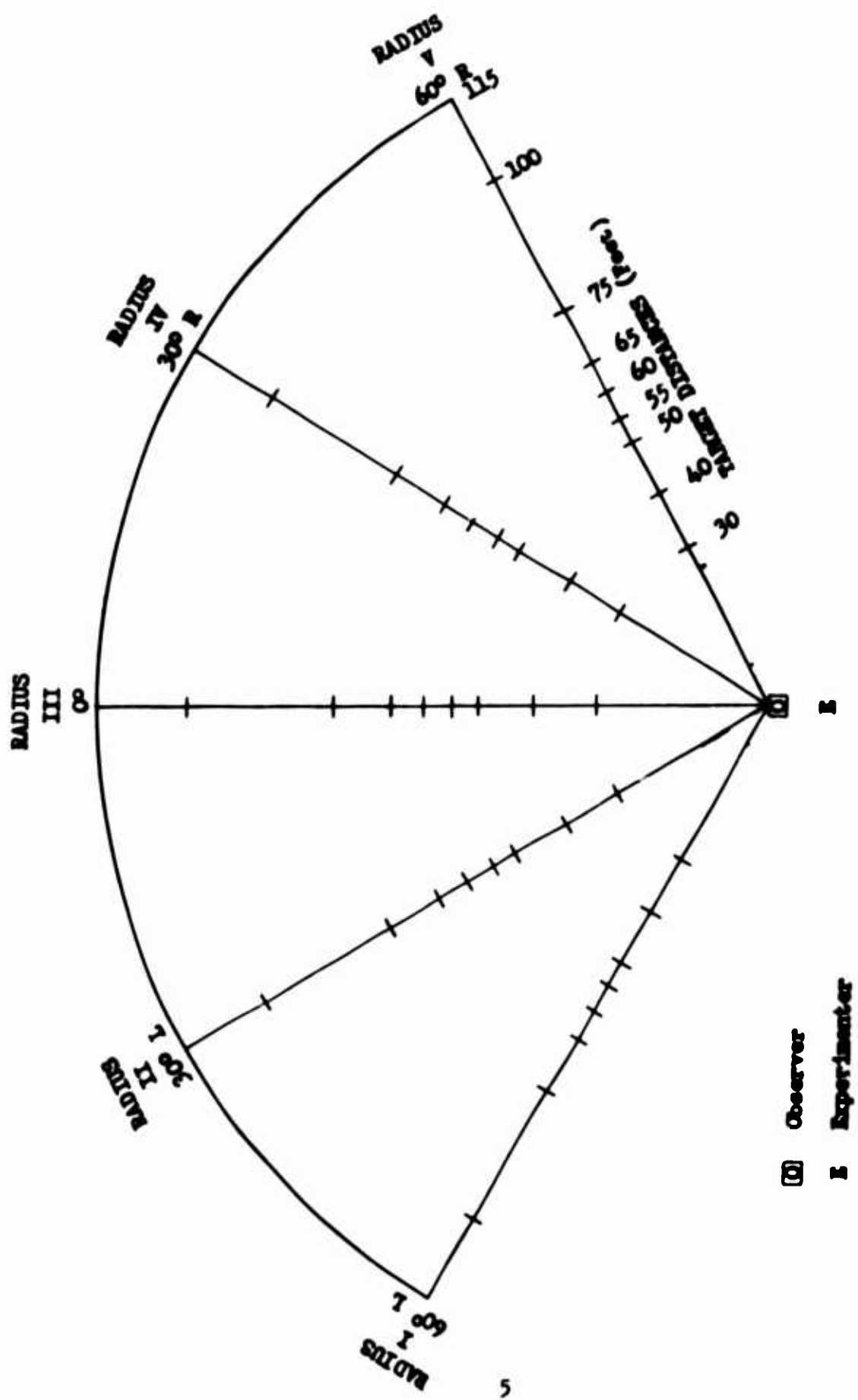


Fig. 1. Sketch of test site showing target distances and placement.

position. Radius I was 60° to the left of O's line of sight, III was directly in line of sight (12 o'clock), and V was 60° right of line of sight.

(3) Site selection. The same sites used in Jungle Vision I were used again in the present study.¹ Site A was located at grid coordinates 17P-FV-581961, site B at 17P-FV-600958, and site C at 17P-FV-521929 (see Appendix E for site locations).

Sites had been selected originally to meet the following criteria:

(a) To be apparently representative of vegetative variations found in the semideciduous forest belt of Panama's Pacific slope.

(b) To be relatively level to prevent physical terrain features from obscuring targets.

(c) To prevent complete obstruction of any target by large tree trunks along the sighting radii.

The present study was conducted on the same site as the earlier dry season study; however, the work was done two and one-third years later. Thus, an uncontrolled variable is vegetative growth during this rather long interval. The authors cannot be certain the extent to which new growth affected visibility. Only photographs and memory of the sites as they existed earlier are available. Since the sites were thick and uncut in 1964, and had not been cut over since, it is felt that sheer growth of underbrush played a relatively minor role. However, this is impossible to demonstrate conclusively.

The detailed botanical descriptions of these sites that were given in the earlier publication remain essentially valid and will not be repeated here. The primary differences in sites noticeable to several persons who participated in both studies were (a) the lower light levels in the present study due to wet season cloud cover and fuller wet season canopies, and (b) the fullness and greenness of the vegetation compared to its somewhat withered and brownish appearance during the dry season study.

¹ Sites in the present study and Jungle Vision I correspond as follows:

<u>Jungle Vision I</u>	<u>Present Study</u>
Clayton	"A"
Albrook	"B"
Empire	"C"

Sites A and B appeared particularly thicker in certain areas due to the "climbing bamboo"¹ vines. This vine, which predominates from ground to eye-level, loses most of its leaves entirely during the dry season and replaces them during the wet season. Most of the vegetation that grows at eye-level heights in this type of jungle do not shed their leaves as does the climbing bamboo. By far, most of the leaf droppage occurs from the larger trees comprising the middle and upper portions of the forest canopy. Photographs of sites appear in Fig. 2 in back of text.

The climbing bamboo vines were particularly thick on radii I and II of site B which helps explain the drastic drops in visibility between dry and wet seasons (see Table IV and Appendix F).

Dependent variables. Four performance measures were used. The three usually employed in this series, detection threshold, distance estimation, and detection time, were repeated. One additional measure, not previously employed, was added--detection cue.

The 50% detection threshold is that distance at which a target has a 50-50 chance of being detected. This measure is usually calculated by linear interpolation between two target distances; if detection data are asymmetrical, it is computed by least squares.

For those targets that were detected, each O was asked to estimate the distance. The purpose of this measure is to explore accuracy of depth perception as influenced by the jungle.

For those targets that were detected, search time was recorded with a stopwatch. Of interest is the relationship between search time and target distance.

An additional measure, detection cues, was added. When a target was detected, O was asked to tell what portion(s) of the target was detectable. This information was gathered in an attempt to draw inferences concerning the underlying stimulus characteristics of the detected signal.

Research design. The research design is summarized in Table I. The 30 Os were assigned randomly to one of three subgroups of 10 Os each. Each subgroup was comparable in visual acuity. Each O was presented 40 targets which appeared randomly with respect to distance and horizontal placement (an additional five targets at 115 ft for check purposes were not randomized; they were added at the last of the test).

¹ The climbing bamboo is identified botanically as either Chusquea simpliflora or Arthrostylidium racemiflorum; the two plants are very similar and are differentiated primarily by width of leaflets. J. W. Duke. Personal communication, 3 January 1967.

TABLE I
Research Design of Jungle Vision VII

Site	Number Observers	Radius					TOTAL
		<u>I</u>	<u>II</u>	<u>III</u>	<u>IV</u>	<u>V</u>	
A	N = 10	90*	90	90	90	90	450
B	N = 10	90	90	90	90	90	450
C	N = 10	<u>90</u>	<u>90</u>	<u>90</u>	<u>90</u>	<u>90</u>	<u>450</u>
Total	N = 30	270	270	270	270	270	1350

* Number of observations.

Each of the 9 distances was represented on all five radii. Each of the 10 Os was presented nine targets per radius, making a total of 450 observations per site, or 1350 observations in all. Target sequence was randomized across radii and distance by a table of random numbers (Appendix A).

Testing was systematically randomized across the three sites to insure that no two pairs of Os were tested consecutively on the same site, and, also, that each site was used equally often (Appendix B).

Procedure. Test sites were laid out according to Fig. 1. Horizontal luminance measures were taken at the Os eye and at the midpoint of each radius with a GE-type 213 light meter before and after testing.

The Os were tested one at a time (see Fig. 3). Two Os were tested daily, one in early morning, one in late morning. The O was told by the experimenter (E) that this was a test of his ability to spot targets in the jungle. Target EM were visible to O before the test for familiarization purposes. The O was informed that targets would appear anywhere within a horizontal 180° field of search, that he had two minutes to locate the target; and to guess even when he was not quite sure the target was present. The O was fitted with HEARGUARD model 1200 ear protectors to prevent responding to noises made by targets moving through the underbrush. (See detailed instructions to Os in Appendix C).

Before the appearance of the first target, E turned O around, facing away from the course. The first target took his position on a given radius at a pre-emplaced distance marker and stood immobile, facing O. The target signalled by whistle, informing E that he was in position. The O was confined to a marked three-foot square. He was allowed to bend,



Figure 3. Experimenter and Observer.

twist, crouch or even lie down in searching for targets, but was not allowed to move his head outside the marked square. O was required to point and give a distance estimate and a detection cue when he detected a target. O was not informed as to the correctness of his detection. After the first trial, E again turned O around, calling out the number of the next position. One of the targets stayed out of sight while the other assumed the assigned position. The above sequence was repeated until O completed 45 observations. Total testing time for one O averaged one and one-half hours. The first O of the day was tested from approximately 0800 - 1000 hours; the second from approximately 1000 - 1200 hours. Four three-minute rest pauses were allowed, following the 10th, 20th, and 30th target observations.

RESULTS

In each of the following tables, the results of the present study will be labelled "wet season" and will be compared to the 1964 study, labelled "dry season", when comparisons are possible.

Effects of season on detection thresholds. Table II shows thresholds for the three sites by season. The 75% detection threshold is the distance in ft at which 75% of all targets are detected; the 25% threshold is the distance at which only 25% of all targets are detected.

For all sites combined, it is obvious that visibility was very much more restricted during the wet season. Wet season 50% detection thresholds were approximately 14 ft less than dry season. A total of 660 target detections were made during dry season; only 371 detections, representing a 44% decrease, were made in the wet season. However, there were great differences from one site to another.

Visibility on site C remained unchanged. Visibility on sites A and B, as measured by 50% detection thresholds, dropped by 15 and 31 ft respectively from dry to wet seasons. Site C, which had been originally the most difficult site, became the easiest site in the wet season study. Conversely, Site B, the easiest site during the dry season, became the most difficult during the wet season.

A factorial analysis of variance was performed on the number of detections for the 60 Os in the dry and wet season studies. Seasons, as a source of variance, were highly significant ($F = 155.4$; $P < 0.1\%$; $df = 1/54$). This means that, regardless of season, Site B averages out as the easiest site, followed by Site A and Site C, respectively. However, the interaction between seasons and sites was also highly significant ($F = 51.6$; $P < 0.1\%$; $df = 2/54$). This means that the ease of seeing on any given site depends on the season in which the observation is made; that is, the interaction was caused by the seasonal reversals discussed in the preceding paragraph.

The most probable reason for the change in two sites and lack of change in the third is the nature of the vegetation. The vegetation at Site C was predominantly palm, with a minimum of deciduous trees. Thus, from dry to wet seasons, one would expect less change in the amount of sun falling on targets and the amount of leaf loss and leaf withering. The illumination comparisons in a subsequent section support these contentions. Sites A and B, as discussed earlier, were characterized by large amounts of climbing bamboo vines, one of the few types of eye-level vegetation that loses its leaves during the dry season.

TABLE II

75%, 50%, and 25% Detection Thresholds for Three
Semideciduous Forest Sites in Two Seasons

Site	75% Detections (feet)		50% Detections (feet)		25% Detections (feet)	
	<u>Season</u> <u>Dry</u>	<u>Wet</u>	<u>Season</u> <u>Dry</u>	<u>Wet</u>	<u>Season</u> <u>Dry</u>	<u>Wet</u>
A	54.6	42.5	61.0	45.7	71.1	49.8
B	61.0	*23.2	70.3	39.2	84.8	61.8
C	30.0	33.4	52.5	51.1	58.2	58.1
All Sites	51.5	34.9	59.6	45.8	71.5	55.3

* Least Squares Solution

An interesting finding is that the distance between the 25% and 75% thresholds was approximately 20 ft in both seasons, even though both thresholds were much lower during the wet season. This finding means that the level of the visibility gradient dropped during the dry season but that

the slope remained approximately the same. This will be confirmed by graphs that appear in the subsequent section.

Effects of season on visibility gradients. Table III shows the percent of targets detected at each distance by site and season. Fig. 4 shows the combined gradients for the three sites by season. For sites A and B, there were large reductions in detections at all target distances. There was very little difference in the comparative number of detections on site C.

TABLE III

Percent of targets detected at each distance for three semideciduous forest sites in two seasons.

Distance (feet)	SITE						Mean (All Sites)*	
	A		B		C		Dry Season	Wet Season
	Dry Season	Wet Season	Dry Season	Wet Season	Dry Season	Wet Season		
	%	%	%	%	%	%	%	%
30	100	88	100	70	74	86	91	81
40	96	84	100	48	68	74	88	69
50	86	24	96	32	49	54	77	37
55	74	8	96	32	40	36	70	25
60	52	10	76	30	16	18	48	19
65	42	12	70	16	14	8	42	12
75	14	4	32	4	2	4	18	4
100	0	0	14	0	0	0	4	0
All Distances	58	29	73	29	33	35	55	31

* 150 Total Observations Per Distance Each Season.

NOTE: No detections made at 115 ft during wet season study; those observations have been eliminated.

Fig. 4 shows that the characteristic reverse "S" visibility gradient previously found in semideciduous forests was still evident in the present study (1, 2, 5). The primary effect of the wet season was only to lower the general level of the curve while retaining its characteristic shape. These curves resemble a normal ogive. The results were plotted on normal probability paper in Fig. 5. Data for both seasons were well described empirically by a normal ogive as shown by the linearity of the gradient when plotted on normal probability paper. Detection data, linearly

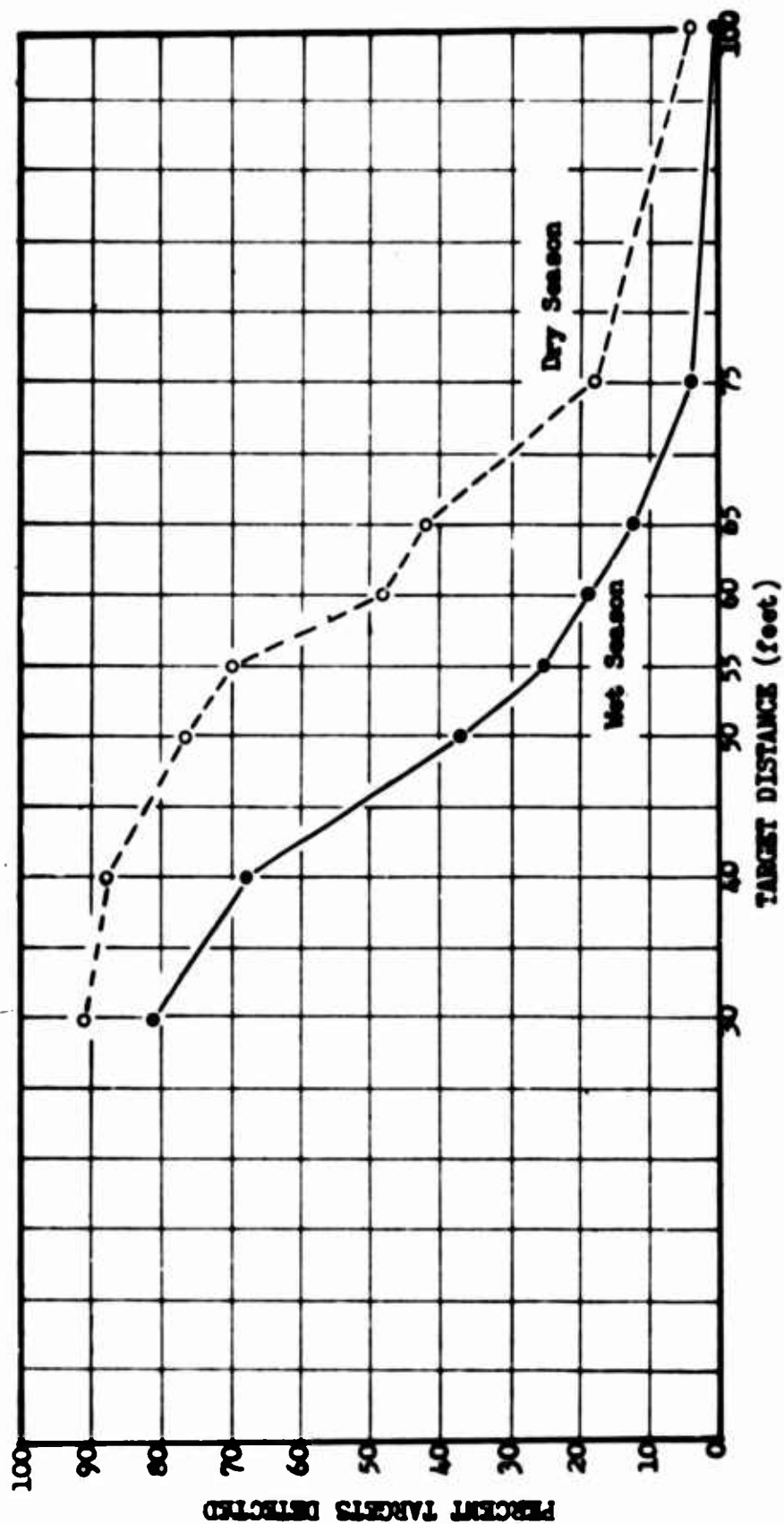


Fig. 4 Comparison of visibility gradients in dry and wet seasons on the same three semideciduous forest sites.

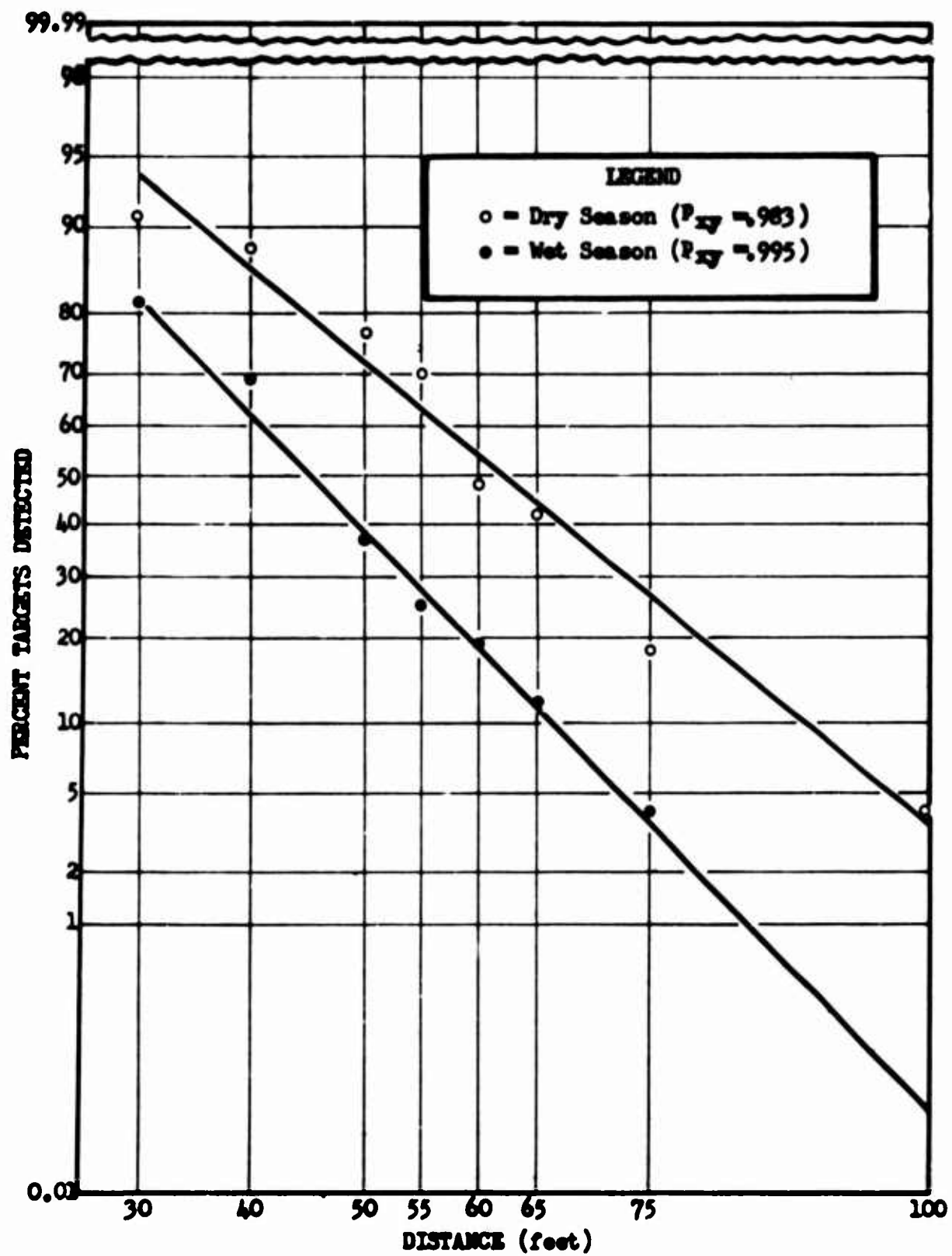


Fig. 5 Comparison of regression lines for wet and dry season on normal probability ordinate.

transformed to normal probability terms, resulted in correlation indexes (p_{xy}) of .995 and .983 for wet and dry seasons respectively.¹

Effects of horizontal target placement. Table IV compares 50% detection thresholds for the 15 individual sighting radii during the two seasons. These data are routinely shown in this series of studies to demonstrate variations in visibility that can be expected even when the observer is in a fixed position looking in different directions on one site.

The dry and wet season values show no systematic relationship. In fact, the thresholds for the first three radii of Site B were grossly different from season to season. As discussed earlier, this is believed to be caused primarily by the leafing pattern of the climbing bamboo vine which is nearly bare of leaves and dormant in dry season but has a heavy leaf mass during the wet season (Appendix F).

It should also be pointed out that the exact azimuths of original radii were never recorded. Therefore, the radii locations in the two studies were close but not exact. This could have caused some variance. The observer positions in the two studies were identical.

Extent of individual differences. It has been customary in jungle vision studies to show data on the variability from one observer to another when tested under as nearly the same conditions as possible--i.e., same site, same experimental procedures, same targets, etc. Indeed, in one respect, the standard deviation of an array of scores taken on the same site may be regarded as an interval of "error" around a given site threshold (mean). That is, a second, similar group of observers, tested on the same site under the same conditions would probably (68% chance) yield an average threshold within one standard deviation above or below the average of the first group tested. Means and standard deviations for both seasons are shown in Table V.

Fortunately, the relatively large number of observations and the nature of the visual task seems to stabilize individual observer variation, such that there is a relatively narrow band of variability (3-6 ft) around a site mean derived from 10 Os with 40-45 observations each.

¹ No theoretical significance is attached to this finding. An attempt was made to find a good empirical "fit" only; no claim is made for a rational relationship. In fact, the normal probability model allows neither 100% nor 0% detections which obviously can and do occur.

50% detection thresholds for each radius at three semideciduous forests sites during wet and dry seasons

SITES	RADII																	
	I			II			III			IV			V			All Radii		
	Season			Season			Season			Season			Season			Season		
	Dry	Wet		Dry	Wet		Dry	Wet		Dry	Wet		Dry	Wet		Dry	Wet	
A	58.7	50.0		57.5	43.3		58.3	50.0		65.0	41.7		63.7	49.4		61.0	45.7	
B	70.0	46.4		72.5	49.0		87.5	34.3		70.0	65.0		60.0	61.2		70.3	38.3	
C	57.3	36.7		32.5	55.0		55.0	56.0		53.3	48.0		52.5	51.9		52.5	51.1	

Least Squares Solution.

No threshold available; estimated graphically.

TABLE V

Means and standard deviations of 50% detection thresholds for individual observers for three semideciduous forest sites during wet and dry seasons.

	<u>SITE A</u>		<u>SITE B</u>		<u>SITE C</u>	
	Season		Season		Season	
	<u>Dry</u>	<u>Wet</u>	<u>Dry</u>	<u>Wet</u>	<u>Dry</u>	<u>Wet</u>
Mean (ft)	61.4	47.4	70.7	41.2	50.2	50.4
Standard Deviation (ft)	4.8	2.8	4.5	4.8	6.1	5.8

Reliability of individual differences. For the first time in these studies, an estimate of the reliability of the visual task itself was made. The task was divided into two parts, equal in difficulty. This was done by scoring detections for the same distances, with two radii equally represented in each score. The scores, for each of two parts of one task, are analogous to the "split-half" reliability coefficient employed in mental testing. When such part scores were obtained for all thirty Os, the split-half reliability coefficient was .82.¹ Thus, individual observer differences are relatively stable. The coefficient is considered high considering (a) field conditions, (b) relatively small range of individual difference in detections (seemingly characteristic of the task), and (c) restriction of range due to preselection by visual acuity tests. No "corrections" were made for the conditions (b) and (c), above, in the reliability coefficient.

Effects of observer age and experience. In the original dry season study, Pearson product-moment correlation coefficients were computed between both age of O and Os length of time in service versus individual O detection thresholds. The coefficients were .18 and .27 respectively, neither of which approached statistical significance. Parallel coefficients were computed in the present study; the coefficients were only .05 and .04 (df = 29) for age and experience respectively. As stated in earlier reports, the reasons for these findings are believed to be (1) that the task is highly saturated with visual acuity factors that are not learnable, and (2) the Os are a statistically restricted (homogeneous) group

¹ For the full task of 45 observations as determined by the Spearman-Brown formula.

in age, experience, and thresholds, strongly reducing the likelihood of high correlation coefficients.

Distance estimation. Observers were asked to estimate the distances to detected targets. The purpose of such estimates is to examine the data for "constant" errors of over or under estimation. From the presence or absence of such errors, one can make inferences about the influence of the jungle on depth perception. However, with an increasing amount of research data, it seems clear that these estimates reflect the system of distance estimation employed by the observer to a greater extent than human perception.

It has been found that Os who use the English system of measures tend to underestimate actual distance (1, 2) while those who use the metric system tend to overestimate actual distance (3).

Table VI illustrates these results once again. In the first study (dry season) 80% of all Os used feet in their estimates while in the present study 87% of all Os used meters in their estimates. The average estimate in the first study was a six to twelve ft underestimate, whereas overestimates up to 17 ft were found in the present study. The metric estimates tend to decrease in accuracy with target distance while the English system estimates tend to stay relatively constant.

Using either method, the statistic Q indicates that variability of the estimates tends to increase with target distance.

The more parsimonious explanation of these data is that they represent neither seasonal effects nor perceptual effects, rather they represent the human errors implicit in judging distance by feet and yards versus judgments by meters. These Os judged meters to be shorter and feet to be longer than they truly are.

Effects of Season on target search time. In addition to reducing the total number of detections, the wet season vegetation luxuriance also increased the amount of search time required to detect targets. The comparison is shown for all sites combined in Table VII. Wet season search times were generally from one and one-third to two and one-half times higher during the wet season, depending on distance. For either season, search time was from three to four times greater at 75 ft than at 30 ft.

Effects of Season on horizontal luminance. Tables VIII and IX compare wet and dry season illumination levels at Os eye level and at the 50 ft radius markers, respectively. These measurements were taken at approximately the same time of day and are directly comparable. (Appendix D shows additional illumination data gathered in the two studies that were measured at times of day that do not permit seasonal comparisons).

TABLE VI

Actual distances compared with observer distance estimates for detected targets in a semideciduous tropical forest during two separate studies.

Actual Distance (D) (feet)	Estimated Distance (E) (Median)		Diff (E) - (D)		Semi- Interquartile Range (Q)	
	First Study	Present Study	First Study	Present Study	First Study	Present Study
30	19.7	33.3	-10.3	3.3	8.7	6.2
40	27.5	45.8	-12.5	5.8	11.0	8.3
50	39.0	50.2	-11.0	0.2	13.3	10.6
55	49.2	66.7	- 5.8	11.7	25.8	16.3
60	49.8	72.5	-10.2	12.5	21.8	16.4
65	52.5	82.2	-12.5	17.2	28.5	16.0
N	628	365				

NOTE: Insufficient cases to compare medians beyond 65 ft.

TABLE VII

Mean search time in seconds for detected targets in a semideciduous tropical forest (combined sites)

	Target Distance (ft.)						
	<u>30</u> Sec.	<u>40</u> Sec.	<u>50</u> Sec.	<u>55</u> Sec.	<u>60</u> Sec.	<u>65</u> Sec.	<u>75</u> Sec.
Dry Season	13	18	20	28	35	31	48
Wet Season	32	37	38	49	44	37	67

TABLE VIII

Mean horizontal luminance in foot-candle taken at eye level of observers before and after testing on same site during wet and dry seasons.

	SITE A	
	<u>Dry Season</u> (N = 7)	<u>Wet Season</u> (N = 5)
Start (0900)	190	(0815) 40
End (1030)	534	(1000) 76
Mean	363	58

	SITE B	
	<u>Dry Season</u> (N = 5)	<u>Wet Season</u> (N = 5)
Start (0900)	83	(0815) 50
End (1030)	198	(1000) 97
Mean	139	73

	SITE C	
	<u>Dry Season</u> (N = 3)	<u>Wet Season</u> (N = 5)
Start (0900)	50	(0815) 15
End (1030)	112	(1000) 33
Mean	81	24

Total Range:	30 - 1500 fc	11 - 1000 fc
--------------	--------------	--------------

TABLE IX

Mean horizontal luminance in foot-candles taken at midpoint of each radius before and after testing (mean of five radii).

SITE A			
	<u>Dry Season</u> (N = 70)		<u>Wet Season</u> (N = 50)
Start (0900)	81	(0815)	14
End (1030)	154	(1000)	27
Mean	117		20

SITE B			
	<u>Dry Season</u> (N = 50)		<u>Wet Season</u> (N = 50)
Start (0900)	88	(0815)	37
End (1000)	161	(1000)	75
Mean	124		56

SITE C			
	<u>Dry Season</u> (N = 30)		<u>Wet Season</u> (N = 50)
Start (0900)	114	(0815)	14
End (1000)	208	(1000)	37
Mean	161		26

Total Range:	11 - 1000 fc		4 - 400 fc
--------------	--------------	--	------------

Considering wet season comparisons only, there was no systematic relationship between target detection difficulty and illumination levels from one site to another. For example, Site B with the lowest number of detections, had higher average illumination levels than the two easier sites. This finding has been a common one in many of the jungle vision studies--and was also true in the dry season study. The decrease in mean illumination levels from wet to dry season, on the same sites, however, was marked and significant ($t = 2.99$; $df = 22$; $P < 1\%$). For all sites, morning dry season levels averaged 164 foot-candles (fc) while corresponding wet season levels were only 43 fc. This represents nearly a fourfold

increase from wet to dry seasons. The two major reasons for the higher dry season light levels are, first, the leaf-fall of the dry season deciduous trees that allows a greater amount of sunlight to penetrate to the ground--and, second, the virtual absence of cloud cover during the dry season, which usually insures maximum light levels above the forest canopy.

The decreases from dry to wet seasons from site to site were proportional to a moderate degree. That is, a site with low dry season light levels tended also to have relatively low wet season levels¹ ($\rho = .63$; $df = 10$; $P < 5\%$).

Even though lower illumination levels in the wet season paralleled increased difficulty in detecting targets, it is felt that the decreased light played a minor role, if any, in decreasing target detections. This opinion is based on evidence from the present and five previous studies in which the prevailing luminance levels on individual sites were not proportional to detection levels on the same site (1, 3, 4, 5, 6). In one earlier study, such a relationship appeared valid, but "washed out" in later studies (2). Also, when observers are tested on the same sites, but at different times of the day, light levels typically change significantly, while detection levels do not (1, 2, 4, 5, 6). This lack of relationship has held up for all past studies as well as the present. In the present study, the mean 50% detection thresholds for Os tested earlier in the morning (0830-1000 hours) was 46.5 ft; for Os tested later in the morning (1015-1200 hours) the mean threshold was 45.1 ft ($t = 0.173$; $df = 28$; $P > 80\%$).

One additional type of analysis has been performed - this is to compute Pearson product-moment correlation coefficients between the number of detections of individual Os and the mean level of illumination on the site while the detections were being made. This analysis thus takes into account day to day light variations on the same site. These coefficients have been computed in four studies including the present one. Only one moderately significant coefficient ($r = .44$) was found (2); in the present and two other studies coefficients were not significantly different from zero (1, 3).

Thus, the bulk of evidence to date indicates that daytime illumination levels--in the ranges encountered in Panama forests--have little if any effect on the visual detection of human targets. It is felt that vegetation so effectively obscures vision as to nullify variations in illumination. If the vegetation were less dense, illumination would perhaps exert more effect.

¹ For those investigators who use light intensity as a measure of canopy density, this result might be encouraging since it indicates a measure of reproducibility, or at least regularity, of light measures taken at the same geographic location over a considerable time span. (ρ = Spearman rho correlation)

Practice Effects. Table X shows the mean number of detections per observer for each consecutive block of 10 trials (between rest pauses) by season. Also shown are the mean actual distances, or approximate difficulty level of four blocks. (For equivalent comparisons, detections must be divided through by difficulty.) There was some suggestion of an "end-spurt" during the last block of trials for both studies; however, there was no progressive tendency for performance to increase or decrease prior to the last block of trials.

An examination of data from three past studies shows evidence of and end-spurt in one study and none in the remaining two. End-spurts in performance are sometimes found in monotonous tasks such as the present one; however, the existence of end-spurts is not considered conclusive since some hint of their presence has been found in only half of the studies.

TABLE X

Comparison of practice effects between studies
carried out in dry and wet seasons.

		<u>1st 10</u>	<u>2nd 10</u>	<u>3rd 10</u>	<u>4th 10</u>
		<u>Trials</u>	<u>Trials</u>	<u>Trials</u>	<u>Trials</u>
Average Number Detections:	First Study	4.9	4.9	5.2	6.8
	Present Study	2.8	2.8	2.4	4.4
Average Actual Distance (ft):	First Study	58.0	63.0	64.0	52.5
	Present Study	58.0	62.5	67.0	50.0

Visual Target Detection Cues. The following section was done only in the wet season and is thus independent of seasonal effects. The purpose was to attempt to identify those portions of the human body and uniform which visually "give away" the standing target in jungle vegetation. Each O, when a detection was made, was simply asked to tell E what he saw. Of the 371 targets detected, 443 detection cues were given (multiple cues were allowed, e.g., "boot and cap"). These responses were categorized and appear in Table XI. The distribution of cues is broken down into targets detected at near distances and at further distances to determine whether cues change with distance.

TABLE XI

Summary of detection cues
by distance from target (wet season).

Cue	Target Distance (ft)				Total	
	30-40		50-75		N	%
	N	%	N	%		
Trunk	81	27.8	39	25.9	120	27.1
Legs	47	16.1	28	18.5	75	16.9
Face	49	16.8	21	13.9	70	15.8
Head	37	12.7	17	11.3	54	12.2
Shoulders	34	11.6	12	7.9	46	10.4
Arms	7	2.4	5	3.3	12	2.7
Boots	8	2.7	4	2.6	12	2.7
Clothing	21	7.2	25	16.6	46	10.4
Entire Person	8	2.7	0	0.0	8	1.8
TOTAL	292	100.0	151	100.0	443	100.0

A chi-square test between the two distance distributions was not significant ($\chi^2 = 11.321$; $df = 6$; $P > 5\%$). The reason that the chi-square was this large, however, was due primarily to the "clothing" cue which was the only cue of greater numerical importance at the farther than at the near target distances. Analysis of the individual responses showed that the major "clothing" cue was the horizontal line formed by the bottom of the fatigue jacket which served to visually "cut" the human silhouette in half. Another cue cited was the outline of the pocket of the fatigue jacket. Another cue cited frequently was that the O.D. uniform did not "blend in" with the jungle. This statement is true; the OG-107 uniform is (a) much less reflective and (b) darker-hued than the jungle surroundings--it therefore appears darker and serves as a detection cue.

Further inspection of Table XI reveals that, over all distances, vertical lines of the human trunk and legs were the two most frequent single cues (44% combined). However, face, head and shoulders combined accounted for 38% of total detections--a figure disproportionately high for the small amount of body area involved.

It is inferred from these data and personal observations that the underlying dimension that best explains the great majority of visual detections through jungle foliage can best be labelled "symmetry". The

visual panorama reaching the eye of the jungle observer is one characterized by (a) a fine-grained chaos of form, (high asymmetry), (b) greenness--dappled only with occasional sun flecks and shadows. (The foldouts in the reverse of the report--fig. 2--give a general, but somewhat deficient impression). Any symmetry, whether linear (trunk, legs, bottom of fatigue jacket, pockets) or curved (head, shoulder, face), appears to break the chaotic nature of the visual background and results in detection. If the symmetrical form is also discriminably larger than the fine-grained background, the cue appears even more conspicuous. Color and brightness contrast of target with surroundings undoubtedly play a role, although probably less important than form and size, under the conditions of this experiment.

As suggested in an earlier experiment (6) and confirmed in the present, color and brightness-contrast of the OG-107 uniform seems to become a relatively more important (relative to form and size) cue as target distance is increased.

Breaking the symmetry of the target has always been the guiding principle of camouflage. However, it appears that any future efforts in jungle camouflage might well consider (a) better obscuration of the head and shoulder regions (b) reducing the size of individual pattern elements (in consonance with vegetation) and (c) increasing brightness of some pattern elements (also in consonance with vegetation).

(NOT USED)

COMPARISONS WITH EVERGREEN FOREST

With the completion of the present study, the last portion of a preplanned design was completed. The design may be shown in a fourfold table:

Type of Forest	Season	
	Wet	Dry
Semideciduous:	Jungle Vision VII	Jungle Vision I
Evergreen:	Jungle Vision II	Jungle Vision III

These four studies thus complete that part of the programmed series concerned with seasonal variations in visibility.

The tropical evergreen forest is located in the Atlantic slope of Panama in an area characterized by greater rainfall, higher humidity, slightly lower temperatures, and shorter dry season than found in the semideciduous vegetation on the Pacific slope of Panama. The effect of these climatic disparities is to produce an evergreen forest¹ characterized by higher trees, thicker canopies, fewer leaf-losing trees, a different mix of species, less sunlight filtering to the jungle floor, and thinner undergrowth at eye level than found in the semideciduous forest. Both types of tropical forests are prevalent in varying mixtures in tropical regions of the world and thus merit separate study.

A summary of selected aspects of the four studies is shown in Table XII. In general, results of these investigations indicate that visual detection data support viewing the two types of forests as separate entities. Systematic differences may be seen in thresholds, visibility gradients, seasonal effects, and light levels.

Items 1 and 2 of Table XII show that, for the four studies combined, a total of 4,560 separate target observations has been made by 108 U.S. Army enlisted observers, all with normal visual acuity.

Item 3 indicates that 50% detection thresholds for specific sites may vary considerably from season to season. However, overall thresholds decreased by 23.2% from dry to wet season in the semideciduous forest, but did not change in the evergreen forest.

¹ In earlier studies, the forest on the Atlantic slope was referred to as a "rainforest". Some vegetation specialists hold that the Fort Sherman forest does not meet the criteria for a "true" rainforest. Although this label appears to depend on whose criteria one accepts, the term "rainforest" has not been used in the present study in deference to greater erudition.

TABLE

Selected summary of results for two types of

		SEMIDECIDUOUS FOREST	
		(Dry Season)	(Wet Season)
1. Total Observations		1200	1350
2. Number Observers		30	30
3. 50% Detection Thresholds:			
	Site A	61.0 ft	45.7 ft
	Site B	70.3 ft	39.2 ft
	Site C	52.5 ft	51.1 ft
	All Sites	59.6 ft	45.8 ft
4. Percent Detections:	Feet	%	%
	30	91	81
	40	88	69
	50	77	37
	55	70	25
	60	48	19
	65	42	12
	75	18	4
	100	4	0
	115	-	0
5. Goodness of fit and shape of visibility gradient		$P_{xy} = .983(\text{ogive})$ $P_{xy} = .995(\text{ogive})$	
6. Ambient horizontal luminance:			
a. Mean fc at 0 (0800-1030)		194 fc	52 fc
b. Mean fc on Radii (0800-1030)		134 fc	34 fc
c. Correlations-Illumination vs detections		$r = .04$	$r = .11$
7. Target Search Time: (all distances)		26 sec	43 sec
8. Observer Attributes			
a. Correlation-Os age vs 50% threshold:		$r = .18$	$r = .05$
b. Correlation-Length of Service vs 50% Threshold:		$r = .27$	$r = .04$
c. Observer variability (standard deviations-thresholds)		$\sigma = 5.2$ ft	$\sigma = 4.6$ ft
d. Mean Age of Os		21.0 yrs	20.3 yrs

XII

tropical forests during wet and dry seasons

	EVERGREEN FOREST	
	(Dry Season)	(Wet Season)
	810	1200
	18	30
	74.0 ft	62.5 ft
	71.1 ft	80.0 ft
	75.0 ft	76.3 ft
	73.9 ft	72.6 ft
<u>Feet</u>	<u>1</u>	<u>1</u>
40	90	95
50	84	80
55	82	77
60	63	67
70	60	53
80	34	41
90	28	-
100	14	10
115	3	-
$r_{xy} = .985$ (linear) $r_{xy} = .993$ (linear)		

31 fc	12 fc
25 fc	10 fc
$r = -.29$	$r = .44$ (Sig)

30 sec	34 sec
--------	--------

$r = .05$	$r = .04$
$r = -.02$	$r = .08$

8.7 ft	8.0 ft
22.2 yrs	22.4 yrs

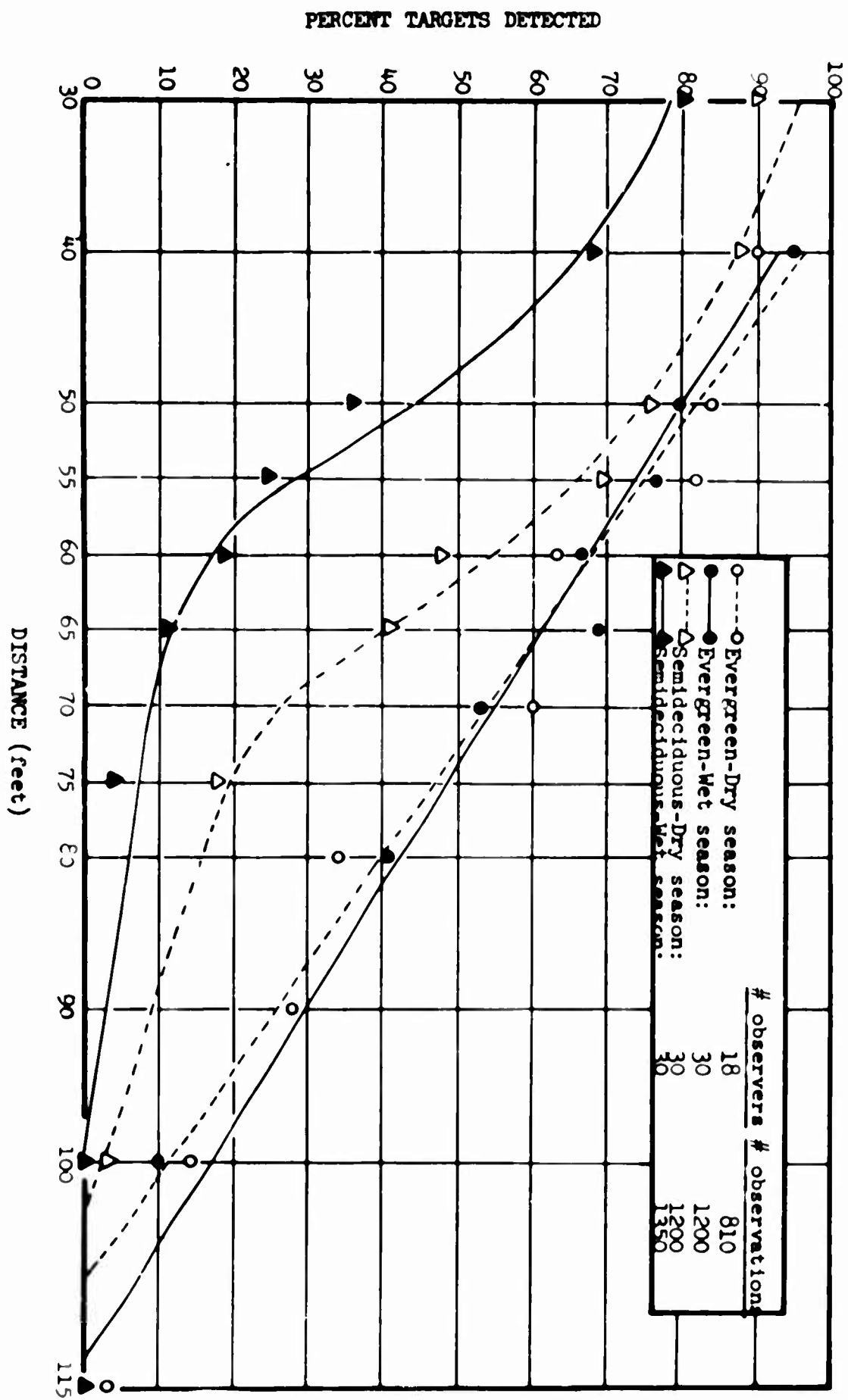


Fig. 6 Visibility gradients for single, standing human target on the same evergreen and semideciduous tropical forest sites during dry and wet seasons.

Items 4 and 5 and Fig. 6 compare the visibility gradients for the four studies. Regardless of the season, each type of forest repeatedly yields a unique visibility gradient under the experimental conditions employed in this series. Season, however, drastically influences the level of visibility gradients of the semideciduous but not those of the evergreen forest.

In general, targets are better detected in the evergreen forests; 50% detection thresholds average from 14 to 28 ft higher than on semideciduous sites regardless of the season. However, the maximum distances at which targets can be detected is only slightly higher in the evergreen forest; typically, targets are completely obscured by 100-115 feet in either type forest. At distances from approximately 60-80 ft, there is the greatest difference in detection difficulty between the two types of forests.

Item 6 summarizes mean horizontal luminance measured during the morning hours. Semideciduous light levels are consistently three and one-half to six and one-half times higher than evergreen levels, regardless of season. The difference represents the relatively greater density of the evergreen forest canopy.

Dry season light levels are nearly four times greater than wet season levels in the semideciduous forest; dry season levels are two and one-half times greater than wet season levels in the evergreen forest. The variance in seasonal effects reflects the less severe dry season and less leaf fall in the evergreen forest.

Item 8 summarizes various aspects of individual observer differences. Regardless of season or type of forest, no relationship has been found between age or experience and target detection proficiency.

The average standard deviation per site of individual observer 50% detection thresholds is also shown in Table XII. Observer variability is greater in the evergreen sites. This difference may be statistical, i.e., because the target detection task is more difficult in semideciduous vegetation, individual detection scores cannot vary within as wide a range as in the evergreen forest. Whatever the reason, site thresholds should be regarded only as estimates of visibility within ranges defined by inter-observer variability. This is a point that seems to get ignored frequently in visibility work.

The average age of Os is presented only to emphasize that these data have been derived from a very select and homogeneous group of men--young and pretested for normal vision. If the tests had been made with older or less visually acute observers, detection thresholds would have probably decreased in magnitude while observer variability increased.

(NOT USED)

25a

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APPENDIX A

Order of Target Presentation

<u>Distance (feet)</u>	<u>I</u>	<u>II</u>	<u>III</u>	<u>IV</u>	<u>V</u>
30	37	1	21	34	16
40	5	39	20	6	19
50	7	28	32	29	25
55	2	35	23	33	38
60	10	17	24	36	40
65	4	14	31	9	15
75	18	26	12	8	11
100	22	3	13	27	30
*115	41	43	42	44	45

* 115 ft distances were purposely not randomized among other distances.

APPENDIX B

Sequence of Observers Tested at Three Different Sites

<u>SITE A</u>	<u>SITE B</u>	<u>SITE C</u>
1	5	3
2	6	4
7	11	9
8	12	10
13	15	17
14	16	18
21	19	23
22	20	24
29	25	27
30	26	28

APPENDIX C

Instructions given to O by E prior to the start of each 45 trials at each site.

"THIS IS A RESEARCH TEST OF THE US ARMY TROPIC TEST CENTER. WE ARE TRYING TO FIND OUT HOW WELL YOU CAN DETECT TARGETS THROUGH THE FOLIAGE. YOU WILL SEE ONE OF THESE MEN (demonstrate) STANDING UP FACING YOU BETWEEN 9 O'CLOCK (point) and 3 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 WITHIN 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. ALSO TELL ME WHAT PORTION OF THE MAN YOU FIRST RECOGNIZED - HEAD, SHOULDER, TRUNK, LEG, OR BOOT. YOU WILL HAVE TWO MINUTES TO FIND HIM. IF YOU DON'T SPOT HIM WITHIN 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 45 TRIALS IN ALL, AND THE TEST WILL LAST ABOUT AN HOUR AND A HALF. ARE THERE ANY QUESTIONS?"

APPENDIX D

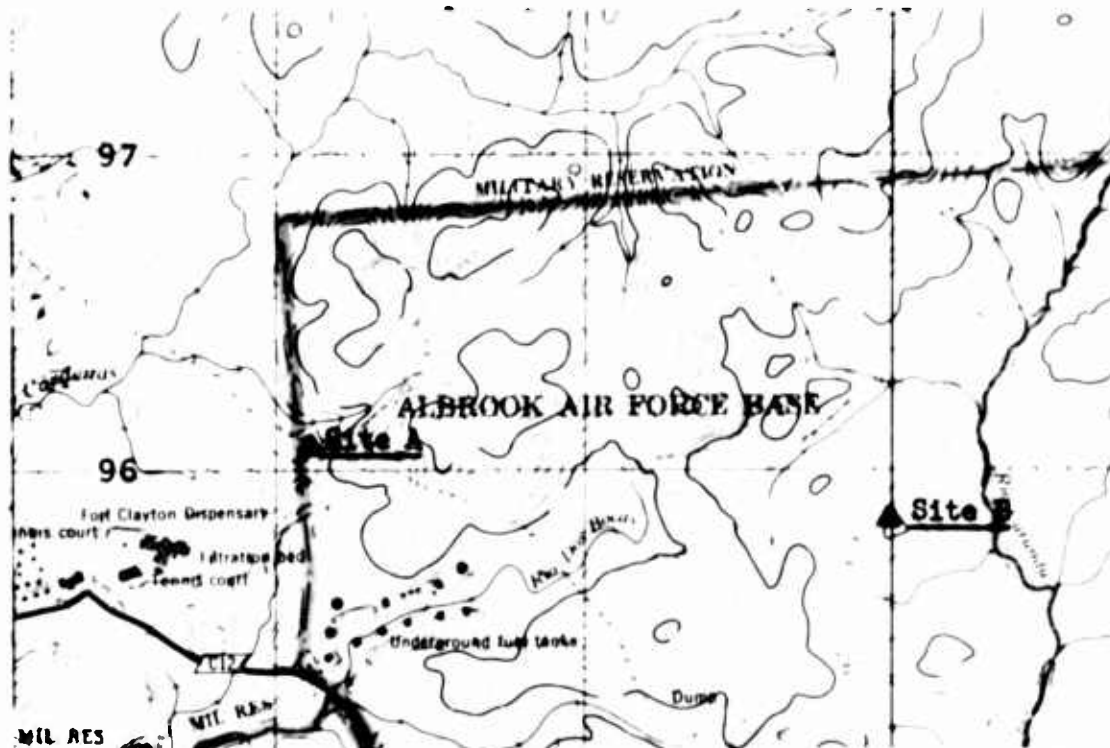
Average horizontal luminance in foot-candles taken before and after testing in two seasons at different times of day (same sites).

SITE A							
	Midpoint of Radii		Eye-Level				
	Wet Season (N=50)	Dry Season (N=30)	Wet Season (N=5)	Dry Season (N=3)		Wet Season (N=5)	Dry Season (N=3)
Start (1015)	24	(1330)	113	(1015)	87	(1330)	323
End (1200)	30	(1500)	167	(1200)	125	(1500)	525
Mean	27		140		106		424

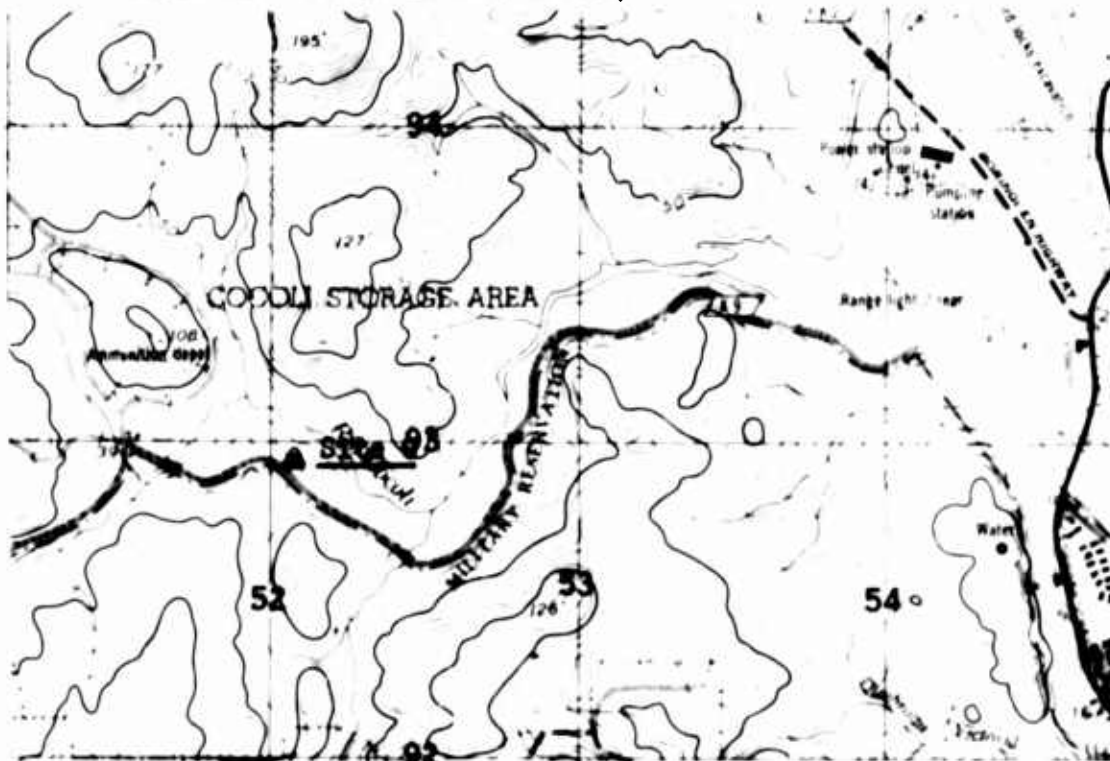
SITE B							
	(N=50)		(N=50)			(N=5)	
	(N=50)	(1330)	(N=50)	(1015)		(N=5)	(N=5)
Start (1015)	92	(1330)	112	(1015)	87	(1330)	117
End (1200)	99	(1500)	146	(1200)	122	(1500)	340
Mean	95		127		104		229

SITE C							
	(N=50)		(N=70)			(N=5)	
	(N=50)	(1330)	(N=70)	(1015)		(N=5)	(N=7)
Start (1015)	38	(1330)	141	(1015)	31	(1330)	132
End (1200)	49	(1500)	101	(1200)	44	(1500)	83
Mean	43		112		38		110

APPENDIX E



SITE LOCATION (Fort Clayton, Panama, Canal Zone, Series E866 Sheet 4243 II SE Edition 1-AMS)



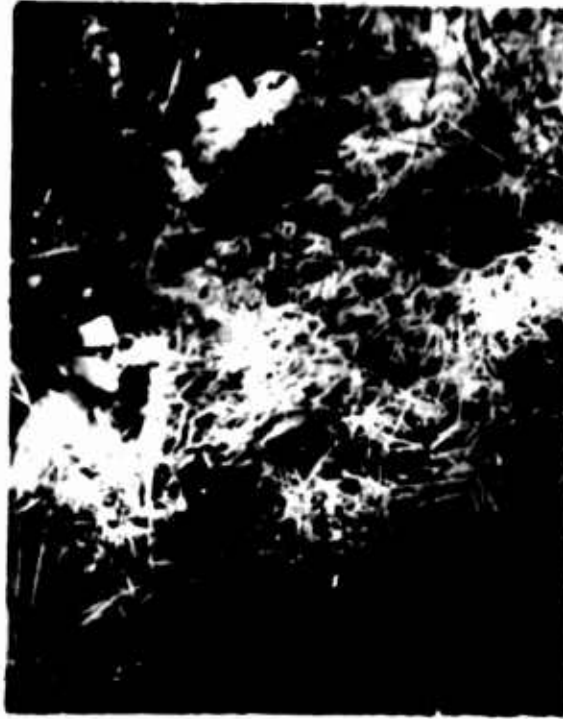
Scale 1:25,000



SITE LOCATION (Panama, Panama, Series E866, Sheet 4242 I NE Edition 1-AMS)

APPENDIX F

Photographs of Climbing Bamboo Vines



Climbing bamboo vines growing in jungle



Close-up view of climbing bamboo vines

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R&D		
<small>(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)</small>		
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5 AUTHOR(S) (Last name, first name, initial)		
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Data collection only done by contract --this is In-House Research.		US Army Tropic Test Center Fort Clayton, Canal Zone
13 ABSTRACT		
<p>The U.S. Army Tropic Test Center conducted a study to determine the effects of the tropical wet and dry seasons on the horizontal detectability of human targets in a semideciduous forest. Testing was conducted on three jungle sites in the Canal Zone in July, 1966.</p> <p>Thirty infantry EM observed standing, motionless human targets appear randomly within a 180° field of search at distances ranging from 30 to 115 ft. Target detections, detection cues, search times, and distance estimates were recorded. Results of the present study were compared to those of an earlier dry season study conducted on the same sites.</p> <p>Visibility was significantly lower during the wet season. Total target detections dropped by 44% during the period. Most of the change occurred on two of the three sites and was apparently caused by a single type of vine that loses its leaves during the dry season. Visibility gradients were of the same shape, though different levels, for both seasons. Illumination levels, search times, and distance estimates were significantly different from season to season.</p> <p>Visual cues contributing most to target detection were the symmetrical outlines of target's trunk and legs against jungle foliage. The lines and color of the OG-107 fatigue uniform also contributed, particularly at farther distances.</p>		

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KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Military Personnel, Detection Human Detection Target Detection Tropical Regions Ambient Illumination Vision Test Methodology Jungles Performance, Human Tropical Seasons						

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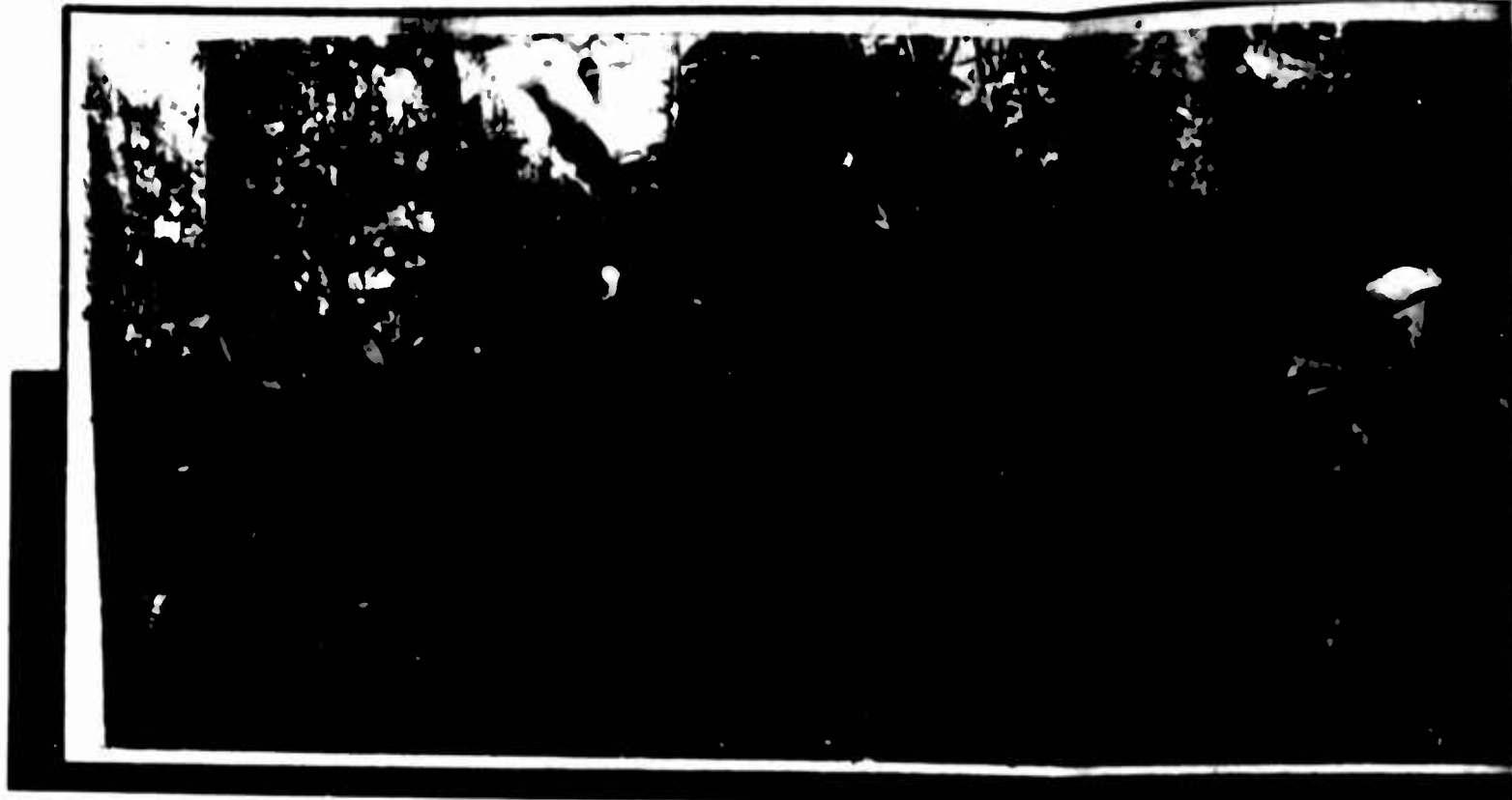
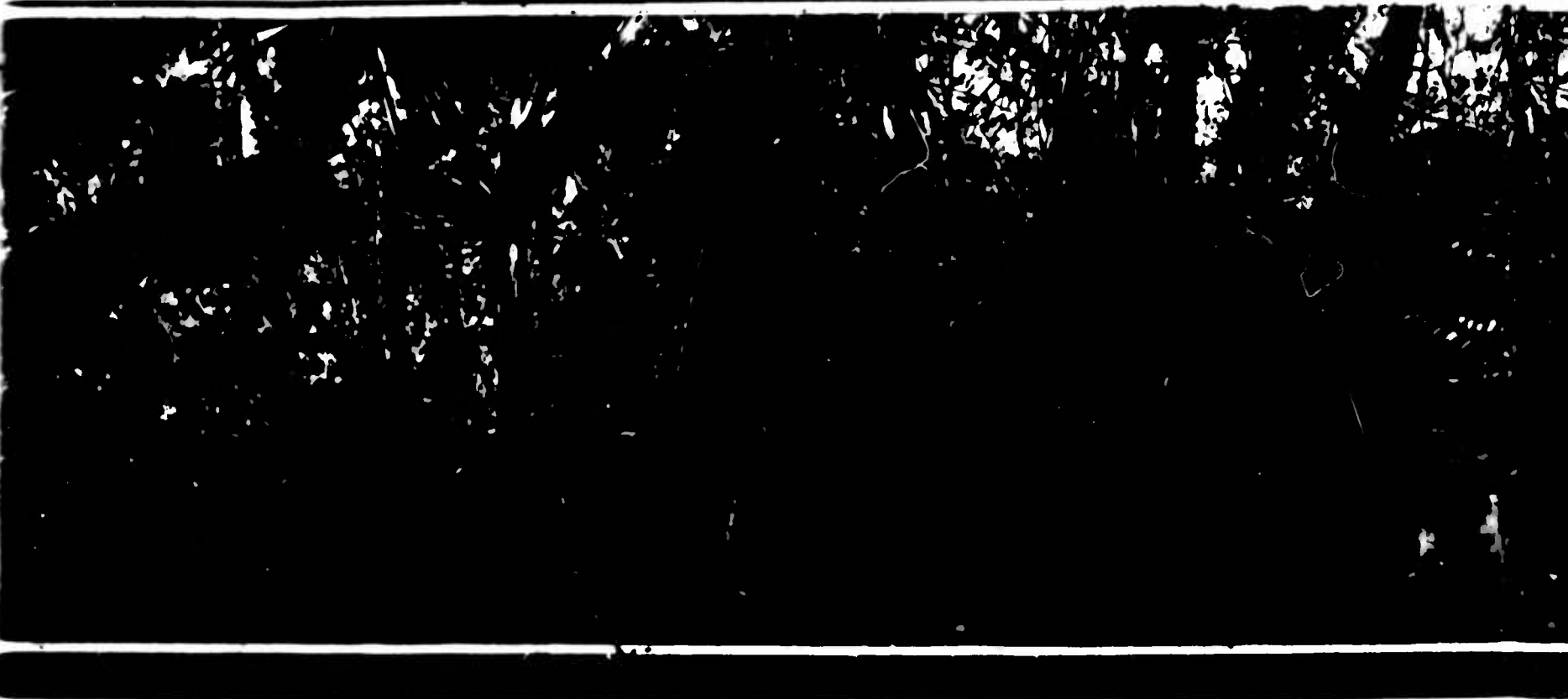


Figure 2 (a) Site A



Figure 2 (b) Site B

A



B



C/

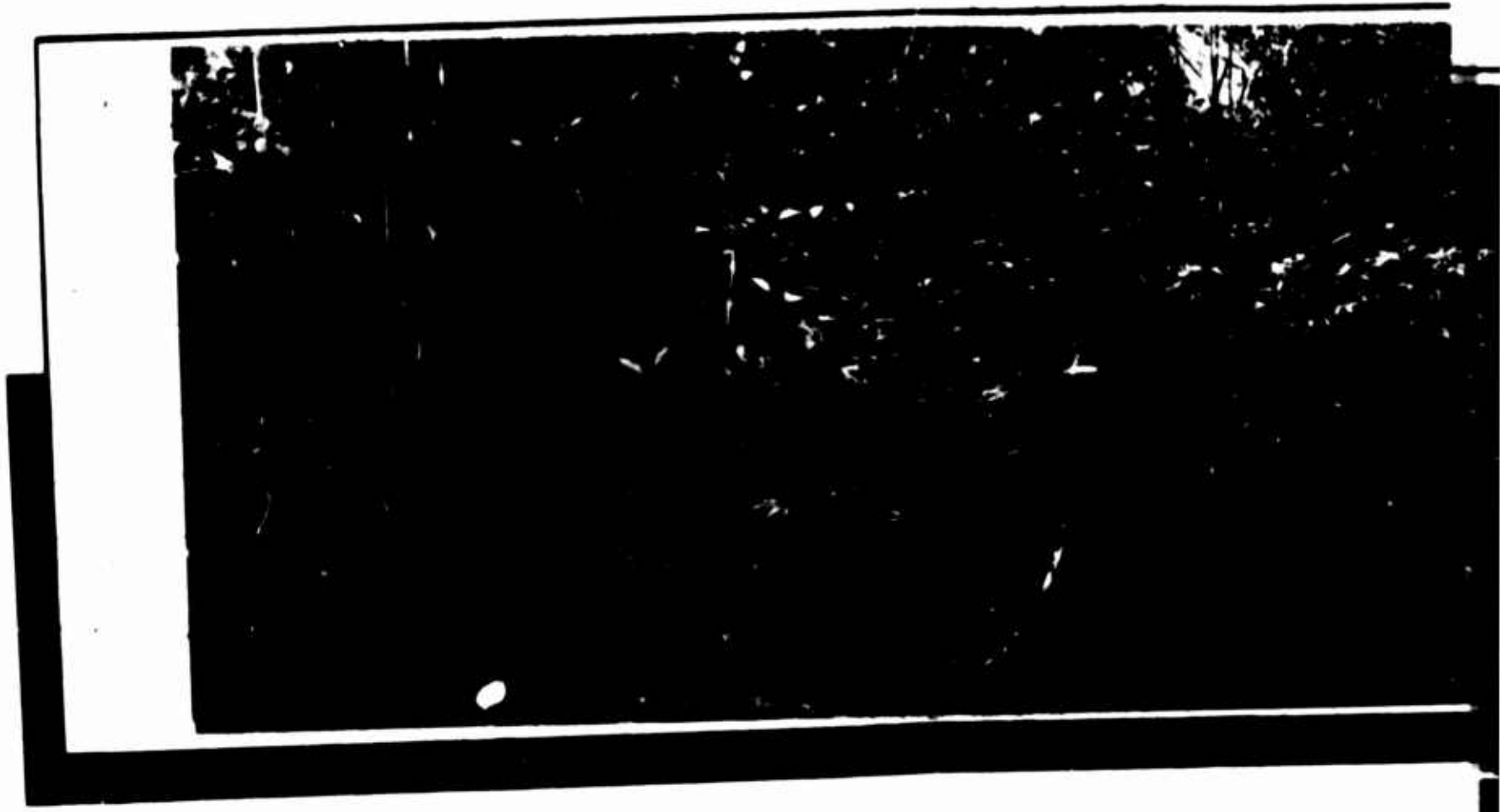
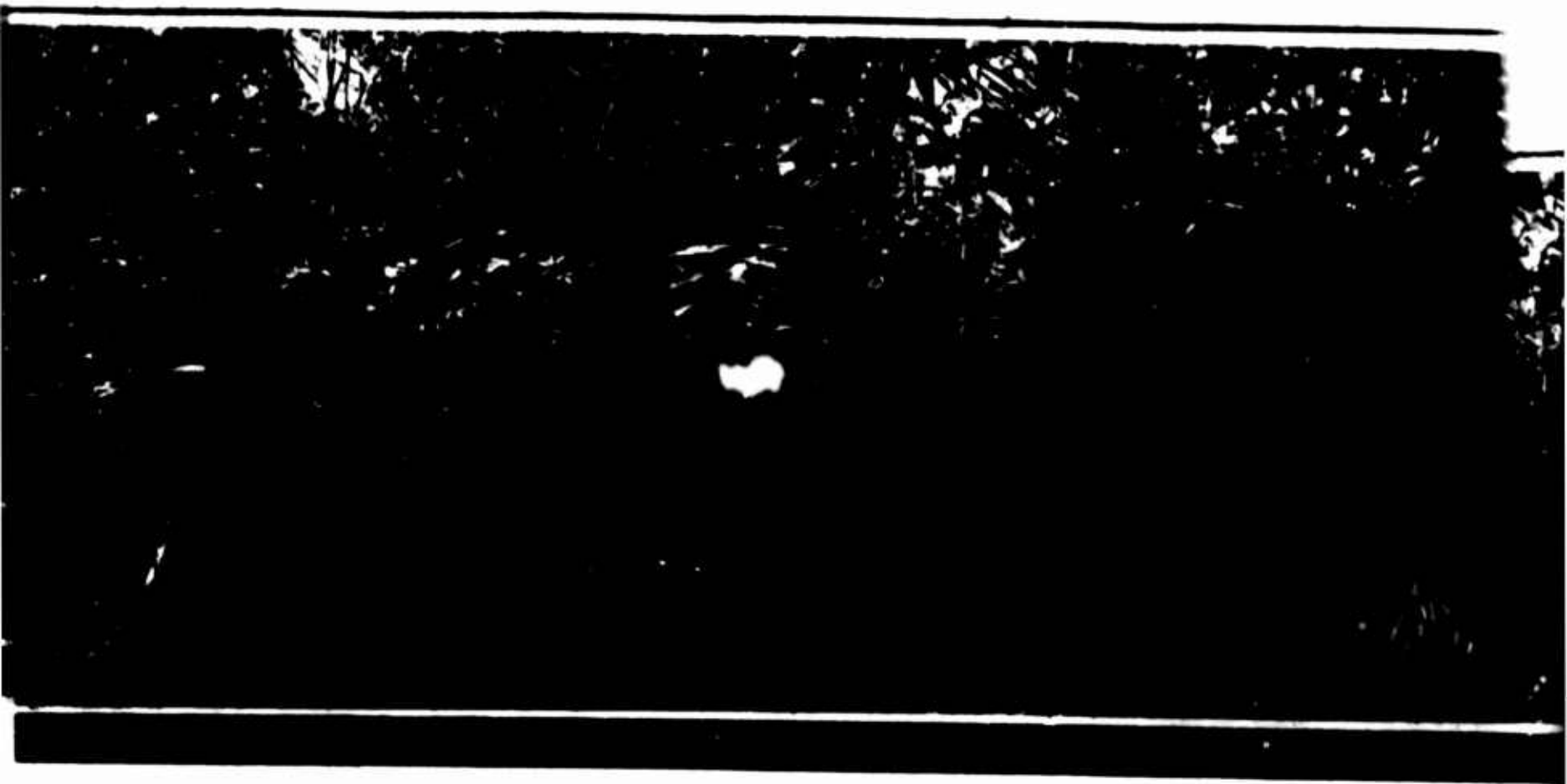


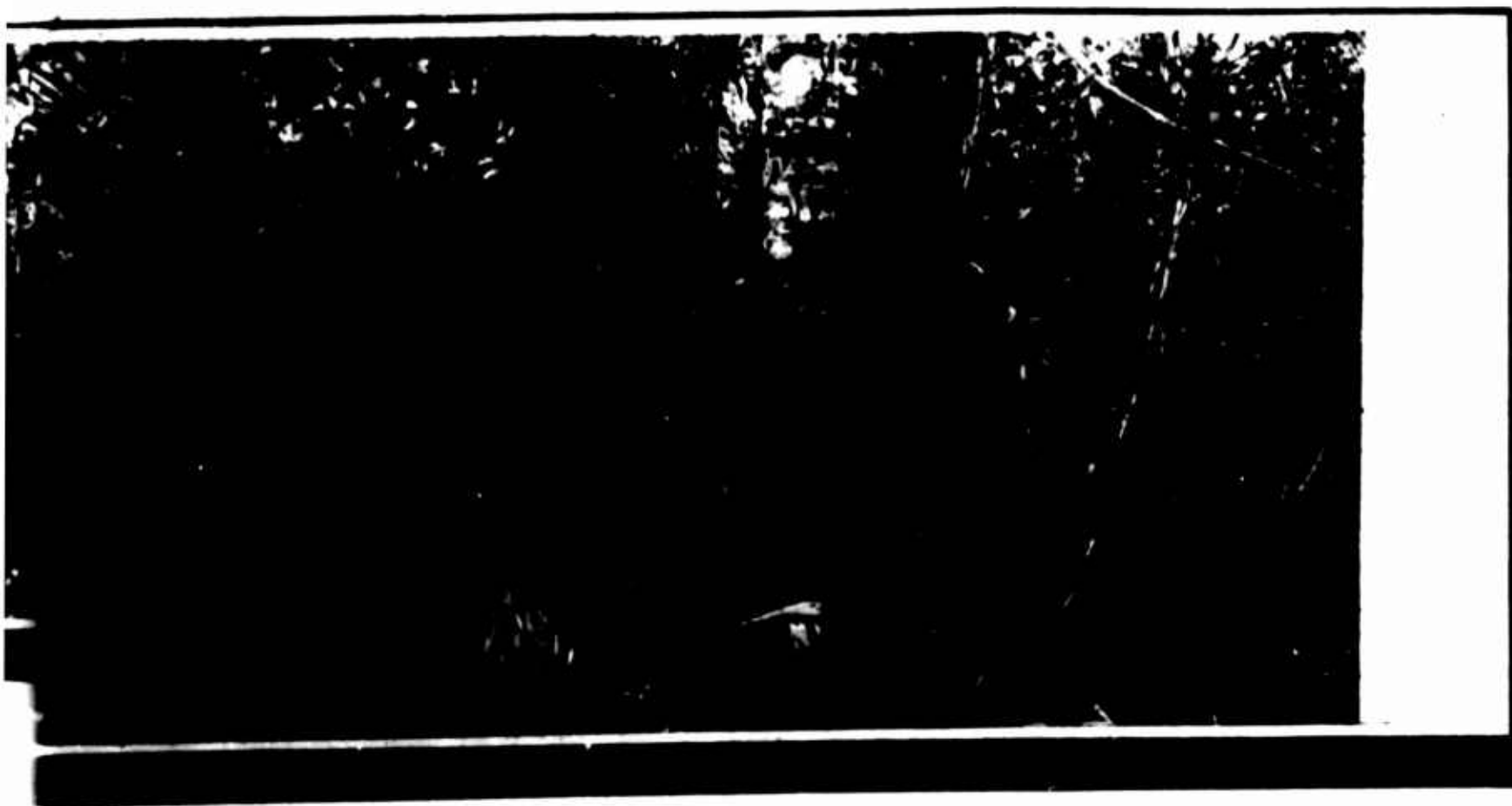
Figure 2 (c) Site C

c/

Figure 2. VIEWS OF THREE SEMIDECIDUOUS SITES (WET SEASON)



Q



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M