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AD

RESEARCH REPORT NO. 3

JUNGLE VISION III:
Effects of Seasonal Variation on Personnel Detection in an Evergreen Rainforest.

by

D. A. Dobbins, M. Gast, and C. M. Kindick

May 1965

DA Project 1L013001A91A 00 001
(An In-House Laboratory Independent Research Project)

US ARMY
TROPIC TEST CENTER
Fort Clayton, Canal Zone

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ABSTRACT

The study was conducted to determine whether there are sufficient changes in evergreen rainforest vegetation during the dry season to enable US soldiers to detect human targets more readily than is possible during the wet season. The determination was made by comparing the results of the present study with a similar one conducted at the same sites during the wet season.

Eighteen US Infantry soldiers, all with normal vision, each were presented 45 randomly appearing human targets dressed in standard Army field clothes. The observers, who had a 180° field of search, attempted to detect each target and estimate the distance to the target. Noise arresters were used to eliminate auditory cues.

In spite of higher illumination levels, observable qualitative changes in vegetation, and a severe dry season, there were no significant differences in target detectability between the two seasons. In fact, the results of the present study could have been predicted from the previous study. Reliability of the methodology is indicated by the reproducibility of results.

The near limit of target detectability in an evergreen rainforest was between 100 and 115 feet. Eye-level vegetation appears to be the principal deterrent to target detection regardless of the season.

FOREWORD

This is the third 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 (DA Project 1L013001A91A 00 001).

The primary purpose of these studies is to provide 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 measures for use in evaluating the results of tests involving various types of visual aids. Moreover, the techniques used for measuring visual thresholds in the field are also applicable for testing equipment designed to enhance visual capabilities. The Tropic Test Center, because of its geographic location, is ideally situated to collect these basic data and thus help close the gap in our present knowledge.

Beyond the Test and Evaluation mission, however, these reports may have implications for tactics, training, and operations. For these reasons, the reports are given a wide distribution.

The authors acknowledge the technical assistance provided by Mr. Ricardo Ah Chu.

TABLE OF CONTENTS

Page

Title Page
Abstract
Foreword

Brief of Results 1
Introduction 3
Background 3
Objectives 4
Method 4
  Observers 4
  Targets 5
  Experimenters 5
  Independent Variables 5
    Target Distance 5
    Horizontal Target Placement 5
    Site Selection 5
  Description of Sites 7
  Dependent Variables 8
  Research Design 8
  Procedure 8
Results - Part I; Dry Season Results 11
  Detection Thresholds 11
  Effects of Target Distance 11
  Effects of Horizontal Target Placement 13
  Distance Estimation 14
  Individual Differences 15
  Detection Time 15
  Effects of Illumination 15
  Effects of Observer Age and Experience 18
  Practice Effects 18
Results - Part II; Effects of Season 19
  Detection Thresholds 19
  Effects of Distance 19
  Illumination 21
  Distance Estimation 23
  Detection Time 25
  Observer Attributes 25
  Practice Effects 25
Distribution List 27

APPENDIXES

A: Order of Target Presentation 33
B: Sequence of Observers Tested at Three Different Sites 35

		Page
C:	Instructions given to the O by E prior to the start of each test session	37
D:	Definitions of Statistical Symbols	39

LIST OF TABLES

Table I.	Research Design of Jungle Vision III	9
Table II.	25%, 50%, and 75% detection thresholds for each of three evergreen rainforest sites (dry season)	11
Table III.	Percent of targets detected at each of nine distances at three evergreen rainforest sites (dry season)	13
Table IV.	Detection thresholds (50%) for each radius at three evergreen rainforest sites (dry season)	13
Table V.	Actual distances compared with observer distance estimates for detected targets at three evergreen rainforest sites (dry season)	14
Table VI.	Detection thresholds (50%) for individual observers at three evergreen rainforest sites (dry season)	15
Table VII.	Time in seconds for target detection at three evergreen rainforest sites (dry season)	16
Table VIII.	Illumination in foot-candles taken at eye level of observers before testing, at mid-test, and after testing (dry season)	17
Table IX.	Illumination in foot-candles taken at 50-feet marker of each radius before and after testing (dry season) (average of five radii)	18
Table X.	Comparative summary of the results of Jungle Vision studies II and III	20

LIST OF FIGURES

Figure 1.	Sketch of test site showing target distances and placement	6
Figure 2.	Views of three evergreen rainforest sites	(inside back cover)
Figure 3.	Experimenter and observer	10
Figure 4.	Percent of targets detected at three evergreen rainforest sites (dry season)	12
Figure 5.	Regression lines and empirical data relating target detection to target distance in wet and dry seasons	22

Page

Figure 6. Comparison of the accuracy of distance estimates for observers using Metric and English systems. (Data obtained during Jungle Vision I study in March 1964.) 24

BRIEF OF RESULTS

The major purpose of the present study was to determine the effects of seasonal variations in vegetation on personnel detection in an evergreen rainforest. A secondary purpose was to continue accumulation of quantitatively stated visual thresholds in tropical forests.

Eighteen enlisted men from an Infantry unit in the Canal Zone, preselected for normal vision, were each presented forty-five uniformed human targets (stationary, standing, and facing the observer) at three evergreen rainforest sites on the north side of the Canal Zone during April 1965, the latter part of the dry season. The study was conducted at the same sites as a previous study conducted during the wet season. The targets appeared at nine distances--40 to 115 feet--and were randomly presented along five radii separated at 30° intervals across a horizontal search area of 180°. The observer, denied the aid of auditory cues, pointed to the target when he detected it and estimated its distance. Levels of illumination and time to detect targets were also recorded.

When the results of the present study were compared with those of a similar study conducted in the wet season, the following findings emerged:

1. Detection times, practice effects, and relationship between individual detection thresholds versus both age and experience did not change significantly from wet season to dry season.

2. Ambient illumination during the dry season was from two to three times higher than during the wet season at the same geographic sites. The average increase was statistically significant.

3. In spite of the large difference in illumination, a severe dry season, and observable qualitative changes in vegetation, neither the 50% detection thresholds nor the linear target detection functions were affected by season. To the contrary, the wet season data accurately predicted the dry season data even though the latter data were obtained from different observers who were tested seven months later. New information afforded by these comparisons suggests that eye-level vegetation inhibits visibility much more than ambient illumination.

4. Regression lines computed for wet and dry season results indicated that a drop of 13% to 14% in target detectability may be accurately predicted for every 10-feet increment in distance past 40 feet. The absolute limit of target detectability in typical rainforest vegetation lies between 100 and 115 feet regardless of season.

5. The high reproducibility of results from wet season to dry season suggests that the basic methodology employed in the current series of studies is reliable.

For the present study only--disregarding effects of season--the following additional results were obtained:

6. The overall detection threshold (point of 50% detectability) for the three sites combined was 73.9 feet. The three sites did not differ significantly with respect to overall threshold values. Horizontal target placement did not affect target detectability within the 120° angle encompassed by the five radii. The greatest deterrent to vision appeared to be the eye-level vegetation typical of the undergrowth of the evergreen rainforest.

7. Ninety percent of the targets presented at the 40-feet distance were detected; only three percent of the targets presented at the 115-feet distance were detected. The function relating detection probability to target distances was linear.

8. Observers overestimated true target distances beyond 55 feet by from 2 to 13 feet. Distance estimates became much more variable from observer to observer as true target distance increased. Analysis of data from a previous study indicated that the tendency to overestimate was greater for observers using the Metric system. Observers using the English system tended to underestimate slightly. Overall, observers using the English system were more accurate in their estimates.

9. All sites were characterized by moderate illumination levels--typically ranging from 9 to 67 foot-candles. No significant relationship was found between detection thresholds of individual observers and illumination levels at their test sites. Furthermore, no increase in target detectability was found between observers tested early in the morning and those tested at midmorning, despite the fact that ambient illumination approximately doubled during this interval.

10. Individual observer thresholds within each site did not vary greatly. Variation from observer to observer tested on the same site was greater than the variation in average thresholds from one site to another site.

11. Detection thresholds of individual observers were statistically independent of the age of observer or length of service in the Army within the ranges of the present study.

12. There was no evidence that detection performance improved through practice during the course of 45 observations per observer.

INTRODUCTION

Little quantitative data are available on visual thresholds in tropical forests. Even though a series of personnel surveillance aids have been developed or are under development for use in remote area operations, quantitative statements concerning unaided personnel detection are sparse. To fill in the gaps, the US Army Tropic Test Center has initiated a series of studies to establish visual thresholds in different types of tropical forests, using the most probable jungle targets (uniformed soldiers), representative observers 1/, unpredictable target locations, coupled with strict experimental control over procedure. The present report is the third of this series. The first report established thresholds in a semideciduous tropical forest during the dry season. The second study reported results from an evergreen rainforest during the wet season. The present study is a partial replication of the second, accomplished in an evergreen rainforest during the dry season.

BACKGROUND

Prior to the Tropic Test Center studies, only one quantitative determination of target detectability in tropical forests was found in the scientific literature 2/.

In the Tropic Test Center's first study, Jungle Vision I 3/, conducted in March 1964, 30 Infantry observers were presented 40 targets in a 180-degree field of search at three different sites. The study was conducted during the dry season in a semideciduous forest. Detection thresholds averaged approximately 60 feet. There was little absolute variation in target detectability among the three sites or among individual observers tested on the same site. One hundred feet approximated the limits of target detectability. The primary deterrent to visibility was the dense network of low hanging small vines and lower shrubs. Within the ranges investigated, horizontal target placement, age of observer, length of military service, immediate practice, and prevailing levels of ambient illumination had little or no effect on target detection.

1/ Troop observers were provided for Jungle Vision III through the assistance of the Chief, Combat Developments Office, US Army Forces Southern Command, and the Commanding Officer, 4th Battalion, 10th Infantry.

2/ Anstey, R.L., and G.L. Stiles. Target acquisition, Swamp Fox II, Vol. VIII, US Army Materiel Command, Washington, D. C., Apr 1964.

3/ Dobbins, D.A., and M. Gast. Jungle Vision I: Effects of distance, horizontal placement, and site on personnel detection in a semideciduous tropical forest, US Army Tropic Test Center Report, Fort Clayton, Canal Zone, Apr 1964.

In the Center's second study, Jungle Vision II 4/, conducted from September to November 1964, 30 Artillery observers with normal vision were presented 40 randomly appearing targets in a 180-degree of search at three different sites. The study was conducted in an evergreen rainforest during the rainiest part of the wet season. Detection thresholds averaged approximately 73 feet. Again, little variation in target detectability was found among the three sites or among individual observers tested on the same site. Horizontal target placement, age of observers, length of military service, and immediate practice had no significant effects on target detection. A moderate but statistically significant relationship was found between detection thresholds of individual observers and illumination levels at their test sites. The main problem in target detection appeared to be related to extremely low levels of illumination and the eye-level, low-branching vegetation found in abundance in the evergreen rainforest.

OBJECTIVES

The objectives of the present study were as follows:

a. To determine the effects of seasonal variations in vegetation on target detectability in the evergreen rainforest by comparing the results of the present study with those of a study performed at the same sites during the preceding wet season. These comparisons are made in Part II of the "Results" section of this report.

b. To continue accumulation of data useful as control information for the evaluation of technological aids to jungle vision. These results are shown in Part I of the "Results" section of this report.

METHOD

Observers. Eighteen observers (Os) were tested. Observers were obtained from the 4th Battalion, 10th Infantry, stationed at Fort Davis in the Canal Zone. All Os were in Combat MOS. Observers' ages ranged from 19 to 28 years; the mean age was 22.2 years. Grades ranged from E2 to E5; most were in grades E4. Length of service ranged from 10 to 84 months; the average time was 32.7 months. Each O was pretested with an Ortho-Rater 5/ vision tester to insure normal close, distance, and color vision, as well as normal depth perception. From the initially selected pool of eighteen Os, three subgroups, comparable in visual acuity, were randomly assigned to one of the three different sites for testing.

4/ Dobbins, D.A., and M. Gast. Jungle Vision II: Effects of distance, horizontal placement, and site on personnel detection in an evergreen rainforest, US Army Tropic Test Center Report, Fort Clayton, Canal Zone, Nov 1964.

5/ The mention of any trade name in this study is for information only and does not constitute an official indorsement of the product.

Targets. Two field teams conducted tests simultaneously at different sites. Targets for each team were two US Army soldiers dressed in standard utility (fatigue OG-107) uniform without insignia, including jacket, cap, bloused trousers, and jungle boots. Targets ranged in height from 5' 8" to 5' 11" and ranged in weight from 142 to 170 lbs. No web equipment or firearms were worn. The targets, their faces blackened with charcoal, stood motionless on predetermined marked positions facing the O. The same targets were used throughout the experiment.

Experimenters. Two experimenters (Es) were present during testing; each controlling one field team. The Es followed identical, standardized procedures during all aspects of testing. The Es gave all instructions to the Os, scored detections, and recorded distance estimations and detection times.

Independent Variables. Three independent variables were investigated: target distance, horizontal target placement in O's field of search, and test site. In Part II of this report, the effect of wet versus dry season is introduced as a fourth independent variable.

(1) Target Distance. Nine distances were used: 40, 50, 55, 60, 70, 80, 90, 100, and 115 feet. These distances were selected on the basis of statistical data from Jungle Vision II. The 115-feet targets were added because of the possibility that the limit to visibility might have been extended due to seasonal changes in vegetation.

(2) Horizontal Target Placement. The O's field of search was 180°. All targets were actually within a 120° field, but Os were not aware of this. Five 115-feet radii extended outward from the O's fixed position (Figure 1). Radius I was 60° to the left of the 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. There was one deviation from this fixed pattern in the present study. On Site X, Radius I was 45° left rather than 60° to avoid terrain irregularities.

(3) Site Selection. The same sites used in Jungle Vision II were used again in the present study. All sites adjoined road number S-1 within the Fort Sherman Military Reservation. Sites X and Y were situated near to each other, approximately five miles northwest of the intersection of roads S-10 and S-1. Site Z was situated approximately 100 yards southeast of the intersections of roads S-8 and S-1.

Sites had been selected originally to meet the following criteria:

a. To be apparently representative of the vegetation of the larger evergreen rainforest of which they were a part.

b. To be relatively level to prevent physical terrain features from hindering vision.

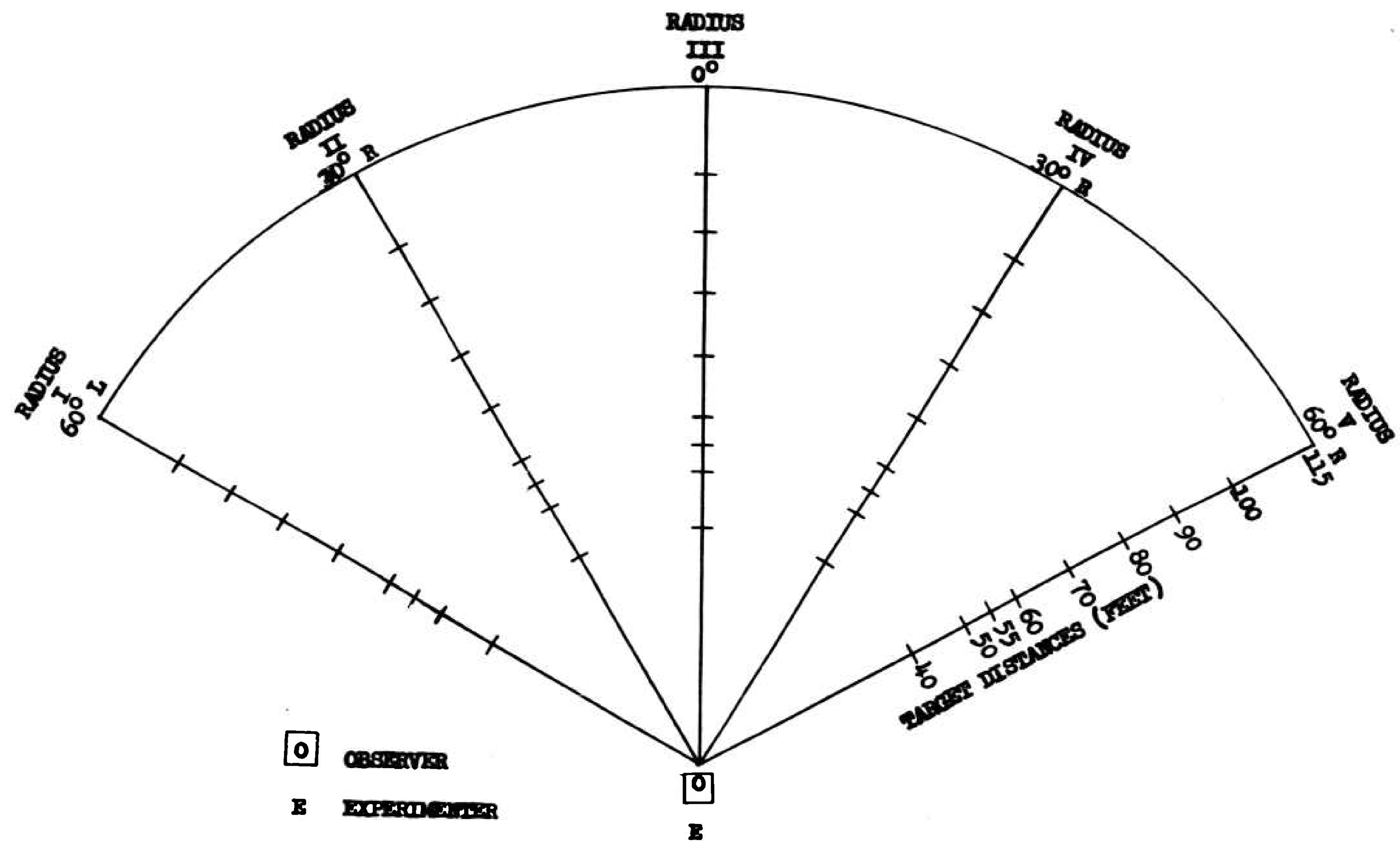

FIGURE 1. SKETCH OF TEST SITE SHOWING TARGET DISTANCES AND PLACEMENT.

c. To allow the radii to be laid out in such a manner that targets would not be hidden behind large tree trunks. (This criterion was not difficult to meet since the O was not altogether limited in mobility--see "Procedure" section.)

To describe the present study as an exact replication of Jungle Vision II would be misleading. The observer posts at all three sites were identically located in both studies. However, the placement of radii was only approximate for the two studies. This inexactness was caused by failure to keep records of compass points of radii from Jungle Vision II. Thus, it is more correct to say that observer sites were replicated and radii were only approximated between Jungle Vision studies II and III.

The objective of site replication was to obtain an additional estimate of intraforest variability with respect to target detectability. Use of the same sites as used in the previous study afforded a direct comparison of the effects of season on visual thresholds.

Description of Sites. The sites used for this study represent a fairly mature evergreen rainforest, with the upper stories generally ranging from 100 to 125 feet in height. *Geonoma decurrens* (wide leaf palm), *Oenocarpus panamanus* (maquengue palm), and *Stromanthe lutea* (a big leaf herbaceous plant) comprised the most significant vegetation in the undergrowth with respect to horizontal visibility. These plants are illustrated on Figure 2 (see end of report), which is composed of photomosaics of the sites as they appeared while the field work was being conducted. A detailed description of the sites is contained in the Jungle Vision II report and will not be repeated here.

If any significant seasonal changes occur in the eye-level vegetation of the evergreen rainforest, they could have been expected during the December 1964 - April 1965 period, which was exceptionally dry. The preceding 55-year average dry season rainfall for this area was 22.6 inches; only 10.6 inches of rain were recorded during the recent dry season [6].

Although the vegetation did change qualitatively from the end of the wet season to the end of the dry season, the most significant differences were in the upper stories. None of the trees was bare; however, considerable leaf fall was evident. As a result, the general illumination levels were higher and many more shafts of light reached the ground than during the wet season. Moreover, gusts of wind of sufficient velocity to cause some movement of the leaves in the undergrowth were noted during the present study. There had been almost complete calm at ground level during the wet season study.

6/ Climatological data furnished by the Meteorological and Hydrographic Branch, Panama Canal Company.

Eye-level vegetation, spaced to form overlapping patterns, remained the principal deterrent to horizontal target detection. While the leaves on some plants became dry, brittle, and brownish, and some leaves either disintegrated or fell to the forest floor, the general aspect was still dark green. In fact, many plants appeared to be equally as robust during the dry season as during the wet season. As will be seen later in the report, it seems safe to state that the shade tolerant plants that live on the floor of the evergreen rainforest undergo qualitative changes during the dry season, but these changes are not of sufficient extent to influence horizontal visibility.

Dependent Variables. Three performance measures were used. The first measure was the detection threshold. The threshold is defined as that distance at which a target is detected 50% of the time.

The method used to establish detection thresholds in the present study was an adaptation of laboratory psychophysical techniques. The primary features of the method include unpredictable sequences of both target location and target distance from trial to trial, making it unlikely that Os would build up systematic biases of expectation or habituation.

The second performance measure was distance estimation. For those targets which were detected, each O was asked to estimate the distance. The purpose of this measure was to determine the accuracy of estimating target distances and, more specifically, to determine whether there is a constant error involved in distance estimation in the evergreen rainforest.

The third performance measure was detection time. For those targets that were detected, search time was recorded with a stopwatch.

Research Design. The research design is summarized in Table I. Three separate subgroups of 6 Os each, comparable in visual acuity, were assigned randomly to each of the three sites. Each O was presented 45 targets which appeared randomly with respect to distance and horizontal placement. Each of the nine distances appeared an equal number of times across all five radii. Each of the 6 Os was presented nine targets per radius, making a total of 270 observations per site, or 810 observations in all. Target sequence was randomized across radii and distance by a table of random numbers (Appendix A).

Procedure. Test sites were laid out according to Figure 1. Illumination measures were taken at the O's eye and at the midpoint of each radius with a GE 7/ type 213 light meter before and after testing. All sites were laid out approximately north-south to minimize the effect of

7/ The mention of any trade name in this study is for information only and does not constitute an official indorsement of the product.

TABLE I

Research Design of Jungle Vision III

Site	Number Observers	Radius I	II	III	IV	V	Total (n)
		Number Observations (n)					
X	N= 6	54	54	54	54	54	270
Y	N= 6	54	54	54	54	54	270
Z	N= 6	54	54	54	54	54	270
Total	N=18	162	162	162	162	162	810

sunlight on O's vision. Four Os were tested, one at a time, each morning (see Figure 3). Two Os were tested by one field team while the remaining two Os were tested by the second field team. The O was informed by E, reading from a standardized set of instructions, that this was a test of his ability to spot targets in a jungle environment. 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 nondetection. The O was fitted with HEAR-GUARD 8/ model 1200 ear protectors to reduce the possibility of responding to auditory cues caused by movements of the targets through the vegetation. The O was urged to guess when he was unsure of the location of the target. (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 place on a given radius at a pre-emplaced distance marker and stood immobile, facing the O. The target gave a whistle signal informing E that he was in position.

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

The O was required to point and give a distance estimate when he detected a target. O was not informed as to the correctness of his detection. After the first trial, E again turned the O around and announced the number of the next position. One of the targets stayed out of sight

8/ The mention of any trade name in this study is for information only and does not constitute an official indorsement of the product.

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. One rest pause of five minutes was allowed after the 23rd observation.

Figure 3. Experimenter and Observer.

RESULTS - PART I; DRY SEASON RESULTS

Detection Thresholds. Table II shows detection thresholds for each of the three sites. Thresholds were computed by linear interpolation between those two distances at which 50% of the targets would have been detected.

For all three sites, the overall 50% detection threshold was 73.9 feet. By linear interpolation, it is estimated that at the distance of 56.9 feet, 75% of targets would be detected; at the distance of 92.0 feet, only 25% of the targets would be detected.

TABLE II

25%, 50%, and 75% detection thresholds for each of three evergreen rainforest sites (dry season).

Site	25% Detections (feet)	Detection Thresholds (50%) (feet)	75% Detections (feet)	n*
X	91.3	74.0	58.4	270
Y	79.4	71.1	53.7	270
Z	95.0	75.0	57.2	270
All Sites	92.0	73.9	56.9	810

* Number of observations.

Effects of Target Distance. Table III shows the percent of targets detected at each of the nine distances. The distances adequately sampled the range of visual acuity for human targets. Overall, ninety percent of targets at the 40-feet distance and only three percent at the 115-feet distance were detected. (Only three detections out of a total of 90 opportunities were made at the 115-feet mark. All three detections were made at one site: Z.)

Figure 4 shows the same data in graphic form. The relationship between detection probabilities for all sites and target distance was essentially linear. The combined data for all sites were fitted by a straight line with a correlation coefficient 9/ of -.985 (df=7; $P < 1\%$). With this very high correlation, the standard error of estimate (σ yX) reduces to 5.24% detections.

9/ See Appendix D for definitions of statistical terms.

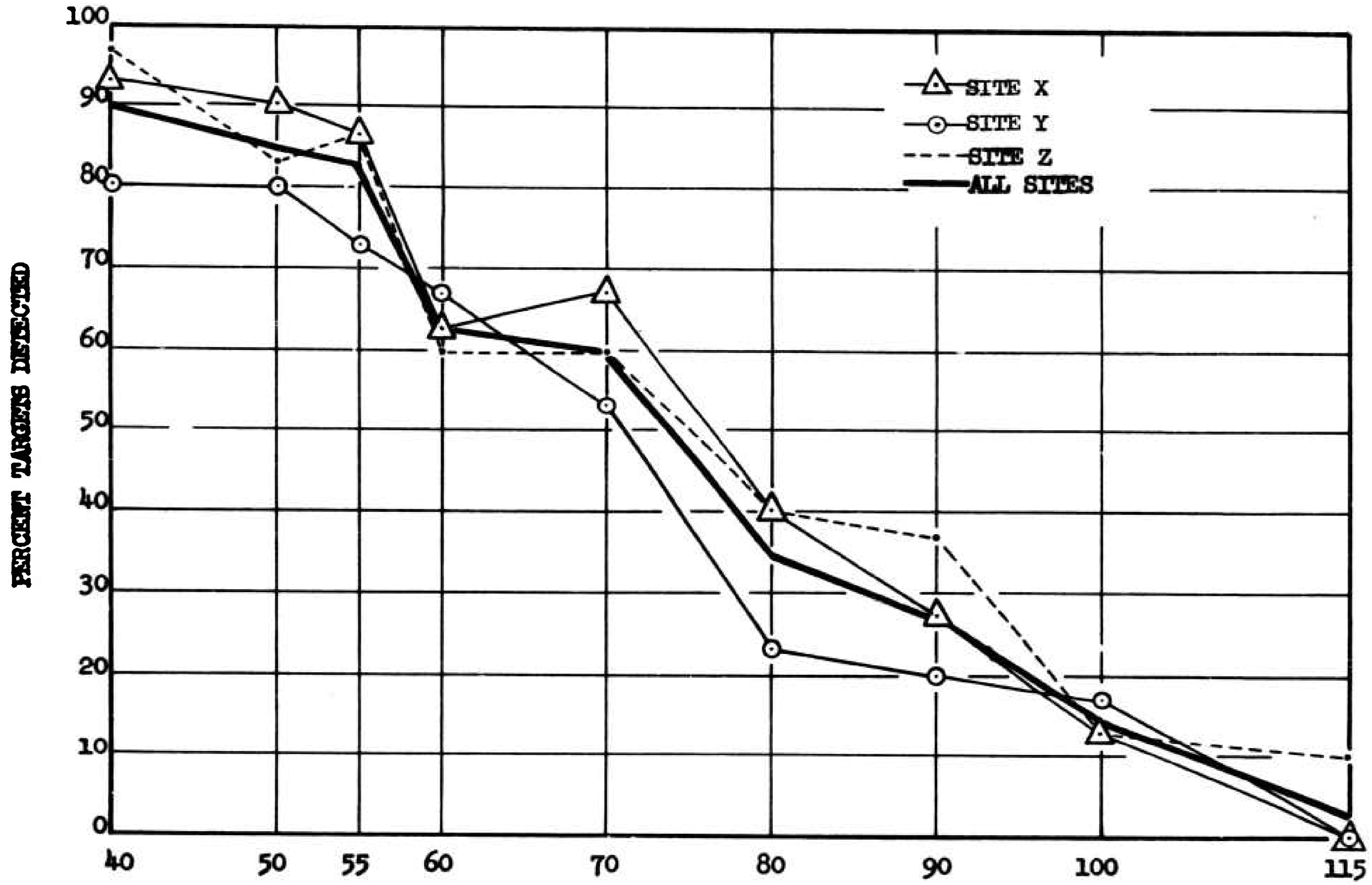

FIGURE 4. PERCENT OF TARGETS DETECTED AT THREE EVERGREEN RAINFOREST SITES (DRY SEASON).

TABLE III

Percent of targets detected at each of nine distances at three evergreen rainforest sites (dry season)

DISTANCE (feet)	SITE X %	SITE Y %	SITE Z %	ALL SITES* %
40	93.3	80.0	96.7	90.0
50	90.0	80.0	83.3	84.4
55	86.6	73.3	86.7	82.2
60	63.3	66.7	60.0	63.3
70	66.7	53.3	60.0	60.0
80	40.0	23.3	40.0	34.4
90	26.7	20.0	36.7	27.8
100	13.3	16.7	13.3	14.4
115	0.0	0.0	10.0	3.3
All distances	53.3	45.9	54.0	51.1

* 90 total observations for each distance.

Effects of Horizontal Target Placement. Table IV compares detection thresholds for each of the five radii at each site. In those cases where there were no clearly defined thresholds, a least squares approximation was made from the function relating detection probability to distance. In one instance, at Site Y on Radius IV, it was necessary to estimate the threshold point at less than the nearest actual marker (40 feet) because less than 50% of the targets were detected at all distances.

TABLE IV

Detection thresholds (50%) for each radius at three evergreen rainforest sites (dry season)

SITES	RADII I	RADII II	RADII III	RADII IV	RADII V	Mean (each site)
X	70.6*	57.5	85.0	95.0	74.2*	76.4
Y	70.0	70.0	107.0	32.2*	57.5	67.5
Z	67.1*	80.0	100.0	95.0	55.0	79.4
Mean (each radius)	69.2	69.1	97.3	74.0	62.2	74.3

* Threshold estimated by least squares.

The purpose of these comparisons was to determine whether the three sites differed significantly with respect to the 50% threshold values and to determine whether there was a significant tendency for thresholds to vary as a function of horizontal target placement (radii). A repeated measures analysis of variance was performed on the data in Table IV. The analysis showed that the three sites did not differ significantly with respect to average 50% detections ($F=0.53$; $df=2/8$; $P > 20\%$). Thus, the differences among the means for the three sites could have resulted from random sampling. The analysis also indicated no statistically reliable differences due to horizontal placement ($F=1.47$; $df=4/8$; $P > 20\%$). The radii variations could also have occurred by chance.

Distance Estimation. In Table V, observer distance estimates of 398 detected targets are compared with the actual distances. Estimates are shown in terms of medians. Distance overestimation errors occurred beyond the 55-feet distance. Variability of distance estimates increased with true distance. These data are not consistent with past studies which have shown small but constant errors of underestimation for all target distances. One difference between Os used in the present study and those of past studies is that most (88%) of the Jungle Vision III Os estimated by meters--consistent with current US Army training doctrine. However, during the field testing for Jungle Vision I 10/, most (80%) of the Os estimated by the more familiar English system of feet and yards. Thus, the present data seem to represent a lack of familiarity with and competence in estimating distance in terms of meters. This topic is discussed further in Part II of the present report.

TABLE V

Actual distances compared with observer distance estimates for detected targets at three evergreen rainforest sites (dry season).

Actual Distance (D) (feet)	Estimated Distance (E) (median feet)	Diff. (E)-(D) (feet)	Semi-interquartile Range (Q) (feet)	No. of Estimates
40	32.8	- 7.2	9.7	81
50	48.0	- 2.0	16.5	76
55	49.5	- 5.5	17.3	74
60	65.7	+ 5.7	17.7	57
70	77.5	+ 7.5	20.4	54
80	93.0	+13.0	40.4	31
90*	92.0	+ 2.0	42.1	25

* Insufficient data cases past 90 feet.

10/ Adequate records of the type of metric used were not kept for Jungle Vision II.

Individual Differences. The extent to which 50% detection thresholds for sites may be relied on as relatively fixed quantities depends on the variation from O to O when tested at the same site under comparable conditions. Table VI shows thresholds for each O tested. The means and standard deviations are shown for each group of 10 Os. In general, there was little variation within sites considering the range of values possible.

Variability estimates based on these data apply to groups of Os similar to those tested in the present study. If extended to a larger military population, including those with visual defects, older, or less well motivated, the average threshold probably would decrease and the standard deviation increase.

TABLE VI

Detection thresholds (50% for individual observers at three evergreen rainforest sites (dry season).

Site X		Site Y		Site Z	
Observer Number	Threshold (feet)	Observer Number	Threshold (feet)	Observer Number	Threshold (feet)
1	77.5	3	78.4	6	95.0
2	77.5	4	75.0	7	77.5
5	85.0	8	57.5	10	73.4*
12	72.6*	9	72.5	11	62.5
13	65.0	14	58.7	16	78.5*
18	72.5	15	67.5	17	71.1*
Mean	75.0		68.2		76.3
Standard Deviation	6.1		7.9		11.2

* Threshold estimated by least squares.

Detection Time. A stopwatch was used to record the time necessary to make a detection. These data are shown in Table VII.

For the three sites combined, mean search times increased only gradually with distance from 40 feet to 70 feet. At 80 feet, however, there was a sharp rise. For example, it took nearly three times as long to detect targets at 80 feet than at 40 feet.

Effects of Illumination. Measures of illumination were taken immediately before and after each test. Readings were taken at the O's eye level and at the 50-feet marker on each of the five radii. Since two Os

TABLE VII

Time in seconds for target detection at three evergreen rainforest sites (dry season).

	TARGET DISTANCE								
	40	50	55	60	70	80	90	100	115
SITE X	14.4	32.3	35.3	31.3	23.8	54.2	30.0	61.7	--
SITE Y	19.1	20.1	21.8	23.1	47.9	33.8	13.8	26.0	--
SITE Z	14.8	21.8	20.9	27.2	19.8	37.8	46.0	46.0	*
Weighted Mean (sec)	15.9	25.0	26.2	27.1	29.6	43.2	33.2	43.1	*
Number Detections per Distance	81	76	74	57	54	31	25	13	3=414

* Insufficient cases to compute reliable mean.

were tested consecutively on each test day, Table VIII and IX show three rows of data. From "Start" to "Mid-test" represents the average increase in illumination for the Os tested first; from "Mid-test" to "End" represents the average increase in illumination for Os tested last. Because 50% site thresholds were nearly identical, there can be no close relationship between target detectability and ambient illumination. For example, average eye-level illumination (Table VIII) was much higher on Site Z. However, the detection threshold for Site Z was only one foot higher than Site X, and four feet higher than Site Y. The average 50-feet ambient illumination (Table IX) was highest for Site Y even though Site Y had the lowest target detectability. These results obviously do not support any claim for a lawful relationship between average 50% detections and average illumination on a site-to-site basis.

Moderate illumination levels were found at all sites during the dry season. At the O, illumination ranged from a mean of 12 foot-candles to 67 foot-candles. The lowest single level recorded was 4 foot-candles; the highest single level recorded was 500 foot-candles.

Without exception, average ambient illumination increased on all sites from the start to the end of the tests. The average increase was from 24.2 to 40.6 foot-candles at the Os, and from 19.7 to 46.6 foot-candles at the 50-feet distance. This approximate doubling of illumination from early morning to mid-day suggested the possibility of increased target detectability as light increased. However, the data show that the average detection threshold for the Os tested first in the morning was 73.7 feet, for the Os tested last (when illumination was higher) was only

71.4 feet. The difference between the total number of detections of those Os tested first and those tested last, regardless of site, was not statistically significant (χ^2=0.783; df=2; P > 50%).

TABLE VIII

Illumination in foot-candles taken at eye level of observers before testing, at mid-test, and after testing (dry season).

	Site		Site		Site		Mean (All sites)	N*
	X	N	Y	N	Z	N		
Start (0815 hrs) (1st O tested)	12.0	(3)	13.0	(3)	47.7	(3)	24.2	(9)
Mid-test (1000 hrs) (2nd O tested)	22.0	(3)	23.7	(3)	61.3	(3)	35.6	(9)
End (1145 hrs)	29.6	(3)	25.3	(3)	67.0	(3)	40.6	(9)
Mean (each site)	21.1	(9)	20.7	(9)	58.8	(9)	33.4	(27)

* N refers to number of illumination measures taken.

Another type of analysis was made concerning illumination. The detection threshold for each O was correlated (Pearson product-moment) with the average level of illumination (average of five radii levels present on the site before and after his test). The correlation coefficient of -.28 (df=16; P > 5%) was not statistically significant.

The point has been made several times in this series of studies that the illumination measures taken are both gross and deficient. The point merits repetition. Measures of ambient light taken only before and after testing and only at six positions in a large area are both temporally and spatially deficient. These measures offer inadequate descriptions of the patterns reaching the Os' eyes and certainly do not reflect such subtleties as shafts of light filtering through the canopy, a pinpoint of brightness seen by O only when in a certain physical posture, or the continuous march of sunflecks across vegetation as the sun rises. A continuously recording illuminometer will be used in future studies. Although this instrument will allow a better description of temporal variation during a given test session, illumination measurements will be spatially deficient because only one sensor will be active.

Effects of Observer Age and Experience. To assess the effects of experience, both the age of the O and length of Army service were correlated (Pearson product-moment) with detection thresholds. Detection thresholds were first statistically adjusted to rule out mean differences in difficulty among the three sites. The coefficient between age and thresholds was -.05 (df=16; P > 5%), which was not statistically significant. The coefficient between length of Army service and thresholds was -.02 (df=16; P > 5%), which was not statistically significant. The relatively restricted range of detection thresholds makes it very unlikely that any reliable associations with any external variables would be found.

TABLE IX

Illumination in foot-candles taken at 50-feet marker of each radius before and after testing (dry season) (average of five radii).

	Site		Site		Site		Mean	
	X	N*	Y	N*	Z	N*	(All sites)	N*
Start (0815 hrs) (1st O tested)	8.6	(15)	20.8	(15)	29.8	(15)	19.7	(45)
Mid-test (1000 hrs) (2nd O tested)	17.3	(15)	41.3	(15)	29.8	(15)	29.4	(45)
End (1145 hrs)	22.8	(15)	64.8	(15)	52.3	(15)	46.6	(45)
Mean (each site)	16.2	(45)	42.3	(45)	37.3	(45)	31.9	(135)

* N refers to the number of illumination measures taken.

Practice Effects. Practice effects were investigated. Individual detections were grouped into five blocks of nine trials. The mean number of detections per observer for each consecutive block was computed. Since the mean actual distances within each block of nine trials differed due to randomized distances, this fact also must be considered.

	1st 9 Trials	2nd 9 Trials	3rd 9 Trials	4th 9 Trials	5th 9 Trials
Mean Number Detections	3.1	5.0	4.0	6.4	4.4
Mean Actual Distance (feet)	75.6	69.4	75.6	66.7	79.4

No evidence of a practice effect exists when task difficulty (actual distance) is considered.

PART II - EFFECTS OF SEASON

This portion of the report deals with the influence of seasonal variations on target detectability. Selected comparisons are made between data gathered seven months previously (Jungle Vision II) on the same sites, using different Os and conducted during the wet season.

The procedural differences between the present study and Jungle Vision II are as follows:

a. Thirty Artillery Os were used in Jungle Vision II; 18 Infantry Os 11/ were used in the present study.

b. Eight target distances ranging from 40 to 100 feet were used in Jungle Vision II; nine target distances ranging from 40 to 115 feet were used in the present study.

c. The placement of radii was only approximate, not exact, between the two studies even though the same sites and observer positions were used.

d. Different data collection crews were used. Four Os were tested daily in the present study; only one O was tested daily in Jungle Vision II.

Otherwise, research design, methodology, and detailed procedures were identical. The results are thus considered comparable.

Detection Thresholds. Table X compares selected results of the two studies. Item 2 shows that the 50% detection thresholds for all sites differed by only 1.3 feet from season to season. This difference was not statistically significant ($t=0.213$; $df=46$; $P > 10\%$). Individual sites, however, differed by factors of 1 to 13 feet from season to season.

It is concluded that seasonal variations had no significant effect on the overall 50% detection thresholds and that the overall site thresholds were well reproduced between the two studies.

Effects of Distance. Item 3 of Table X compares percent detections on a distance-by-distance basis (for those seven distances which were comparable between the two studies). An analysis of variance performed on the percent of detections 12/ at discrete target distances between the wet

11/ Actually, 30 Os were tested during Jungle Vision III; however, 12 were equipped with special goggles designed to selectively filter out the short rays of the visible spectrum. The results will be presented in a separate report.

12/ Percent detections subjected to inverse sine transformation prior to analysis of variance.

TABLE X

Comparative summary of the results of Jungle Vision studies II and III.

	II Evergreen Rainforest (rainy season)	III Evergreen Rainforest (dry season)
1. Total observations:	1200	810
2. Detection thresholds (50%):	X - 62.5 ft Y - 80.0 ft Z - 76.3 ft All sites 72.6 ft	X - 76.2 ft Y - 71.1 ft Z - 75.0 ft All sites 73.9 ft
3. Percent detections (ft): 40:	95%	90%
50:	80%	84%
55:	77%	82%
60:	67%	63%
70:	63%	60%
80:	41%	34%
100:	10%	14%
4. Detection probability and target distance:	r_{xy}=-.993 (linear)	r_{xy}=-.985 (linear)
5. Ambient illumination:		
a. Mean ft-candles at O. Midmorning only:	12 fc	31 fc
b. Mean ft-candles at radii. Midmorning only:	10 fc	25 fc
c. Correlation--illumination vs detection thresholds:	r=.44 (Sig)	r=-.29
6. Intraforest (site) variability (σ):	7.5 ft	2.2 ft
7. Distance estimation:	Underestimate	Overestimate (beyond 55 feet)
8. Detection time (average):	34.1 sec	30.0 sec
9. Observer attributes:		
a. Correlation--O's age vs thresholds:	r=.04	r=.05
b. Correlation--O's length of service vs thresholds:	r=.08	r=-.02
10. Practice effects:	None	None

season and the dry season revealed no statistically significant differences due to season ($F=.00$; $df=1/4$; $P > 20\%$). The overall effect of target distances for both seasons combined was, as expected, highly significant ($F=126.8$; $df=6/24$; $P < 0.1\%$). The interaction between seasons and distances was also non-significant ($F=1.86$; $df=6/24$; $P > 24\%$). The lack of interaction was due to almost identical detection probability functions between seasons; this subject is discussed in greater detail in the next paragraph. It is thus concluded that season had no effect on target detection at any of the distances from 40 to 100 feet. Most of the variation in the data is accounted for by the rapid drop-off of detections as distance from the observer increased.

Figure 5 compares the slopes of the detection probabilities of the wet and dry season. The continuous lines are the computed regression lines of "best fit." The spread of the empirical data around the lines is shown by discrete symbols. The close juxtaposition of the regression lines indicates the following:

a. First, there is little difference between either the slopes or the levels of the lines--the average deviation of predicted points from one another on a distance-by-distance basis is only 4.3% detections.

b. Second, the almost identical slopes show that during the wet season, a drop of 14% in target detectability may be expected for every 10-feet increment in target distance beyond 40 feet. Likewise, during the dry season, a drop of 13% in target detectability may be expected for every 10-feet increment in target distance beyond 40 feet.

c. Third, the high similarity of the lines reaffirms the conclusions already reached that seasonal variation in vegetation did not affect target detectability in the evergreen rainforest.

d. Fourth, the most probable absolute limit of target detectability in typical rainforest vegetation lies between 100 and 115 feet, regardless of season.

e. Finally, and perhaps most important, the similarity of the lines indicates that the methodology employed to date in this series of studies has yielded reproducible results, i.e., wet season data accurately predicted dry season data even though different Os and fewer Os were tested during the dry season, and the two studies were separated in time by approximately seven months.

Illumination. Item 5 of Table X deals with illumination levels. Inspection of the data shows that dry season levels were roughly two to three times higher than wet season levels at the same geographic locations. Statistical analysis between midmorning levels--combining data taken at the Os' eye levels and on the 50-feet points of radii--from wet season to dry season indicated that the differences were highly significant ($t=3.37$; $df=10$; $P < 1\%$). As discussed earlier, this difference

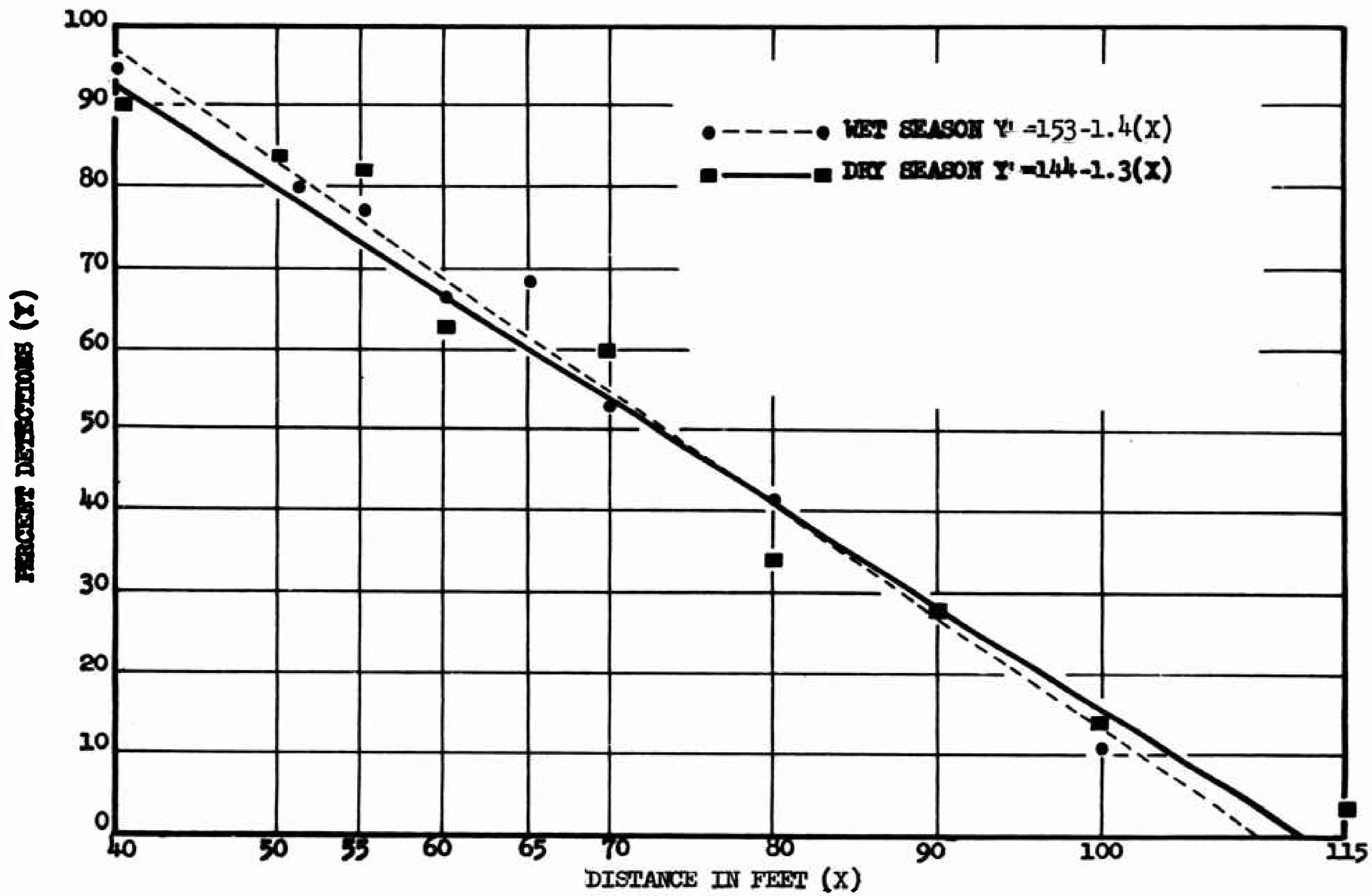

FIGURE 5. REGRESSION LINES AND EMPIRICAL DATA RELATING TARGET DETECTIONS TO TARGET DISTANCES IN WET AND DRY SEASONS.

can be attributed to two factors. First, there was more cloud cover during wet season tests, resulting in less light reaching the canopy. Second, the canopy during the dry season was not as dense as it was during the wet season, consequently, more of the light reaching the canopy was able to filter through.

In the earlier wet season study, a moderate (r=.44) but statistically significant correlation coefficient was found between 50% detection thresholds of individual Os and average radii illumination. No significant correlation was found in the present study. Two possible explanations come to mind. First, it is possible that small increases in illumination affect target detection only at the critically low levels found in the wet season forest. During the wet season, the increase from 1 to 10 foot-candles could make a significant difference in visibility. During the dry season, the increase from around 20 to 47 foot-candles on the radii would not increase visibility proportionately. Second, the significant coefficient of Jungle Vision II may have been a chance occurrence. Future wet season studies will confirm or negate the latter hypothesis.

It is concluded that doubling the illuminance in the rainforest at the same geographic sites did not enhance target detectability. In the Jungle Vision II report, the difficulties of parceling out the relative influences of low illumination and thick vegetation as they bear on target detection were discussed. The new information given by the present comparisons suggests that, of the two, eye-level vegetation may well be the greater deterrent to target detection, contrary to the investigators' previously stated hunches.

Distance Estimation. Item 7 of Table X deals with the estimation of distance to the detected targets. In preceding studies, an average underestimate of around 10 to 15 feet was found over all the target distances. In the present study, median overestimates ranging from 2 to 13 feet were found at distances past 55 feet. However, as was noted earlier in the report, most of the Os in prior studies used the English system of measures (feet and yards), while most of the Os in the present study used the Metric system (meters). The procedure followed in all studies has been to allow Os to estimate by the measuring system each selected. During data reduction, all estimates were converted to feet for comparability.

The best records on the particular metric system employed by Os were made during the first study in the series (Jungle Vision I). Therefore, Jungle Vision I data were retrieved and rearranged to further investigate the relative accuracy of estimation using the two systems. Figure 6 shows the results. The top line shows the median estimates given by all Os who used the Metric system; the lower line shows the same information for those using the English system. The data show that those using the Metric system tended to overestimate true distance (average overestimate equaled 27.2 feet), while those using the English system underestimated target distance (average underestimate equaled 14.9 feet). Furthermore, those

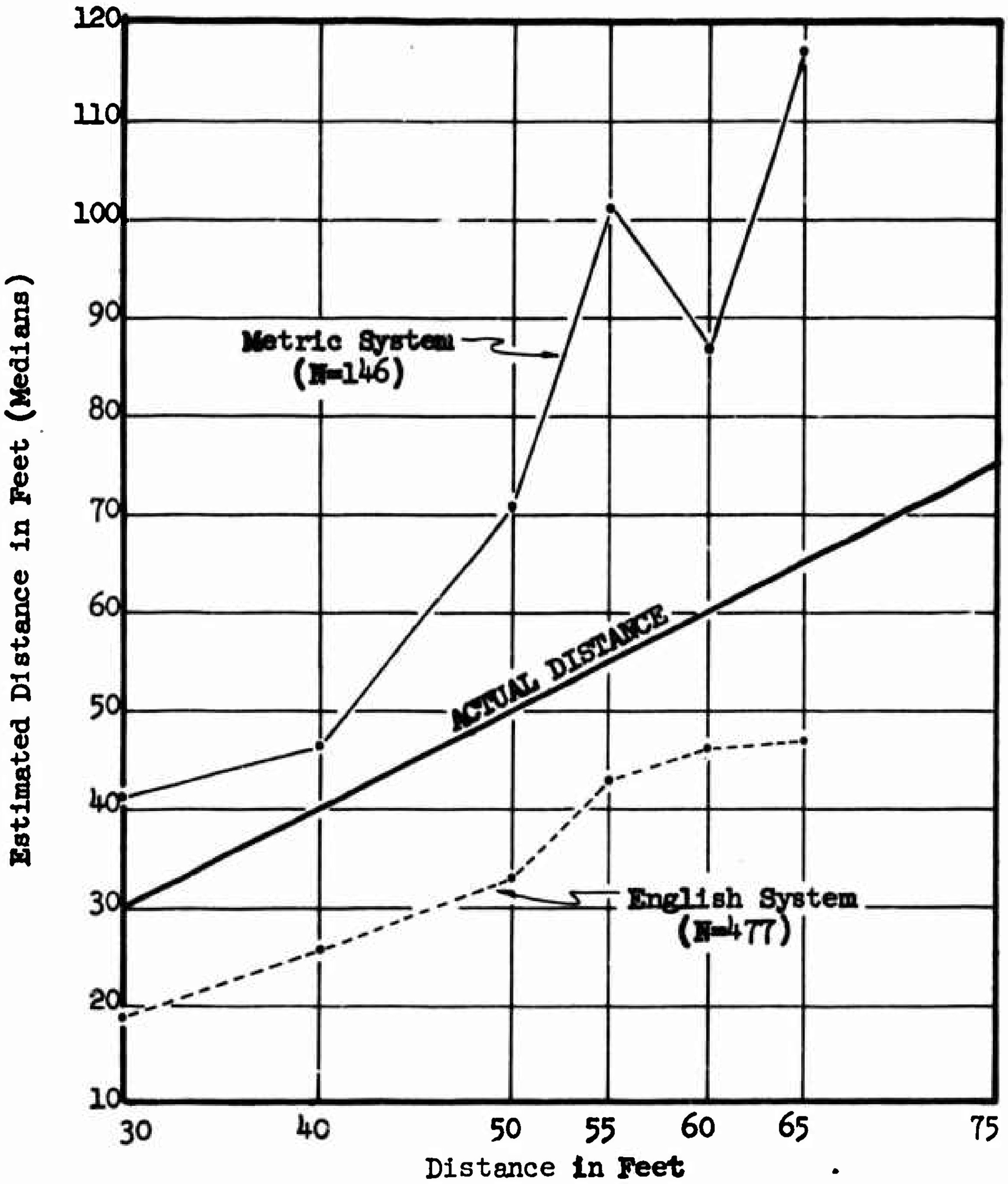

FIGURE 6. COMPARISON OF THE ACCURACY OF DISTANCE ESTIMATES FOR OBSERVERS USING METRIC AND ENGLISH SYSTEMS. (Data obtained during Jungle Vision I study in March 1964.)

using the Metric system tended to make increasingly larger errors as distance increased. Those Os using the English system, on the other hand, made approximately the same degree of error for all target distances.

The overestimation found in the present study, then, probably resulted from the fact that most Os used the Metric system--whereas those using the Metric system were in the minority in past studies. In future studies, accurate records will be kept of the particular metric used by Os to estimate distances.

These data suggest that the tendency to overestimate or underestimate jungle distances is influenced more by the particular metric employed than by environmental factors. Furthermore, distance estimates in the English system were more accurate and more consistent than estimates made in the Metric system.

Detection Time. Table X, Item 8, shows that the average time to make a detection for all distances was 34.1 seconds during the wet season, and 30.0 seconds during the dry season. This difference was not statistically significant ($t=0.20$; $df=12$; $P > 40\%$). Thus, seasonal variations had no influence on the time required to detect targets.

Observer Attributes. Item 9 of Table X shows a comparison of correlation coefficients between individual observer thresholds versus age and versus length of service for both studies. No significant relationships were found in either season. None of the four coefficients is significantly different from zero correlation.

Practice Effects. No within-test improvement in performance was found in either study. These data do not, however, preclude the possibility of learning effects from one test to another test if the same Os were tested repeatedly on different occasions. Neither do the data preclude the possibility of improving target detection in the jungle through a systematic and formalized training course.

a. View of Site X from Observer's Position

b. View of Site Y from Observer's Position

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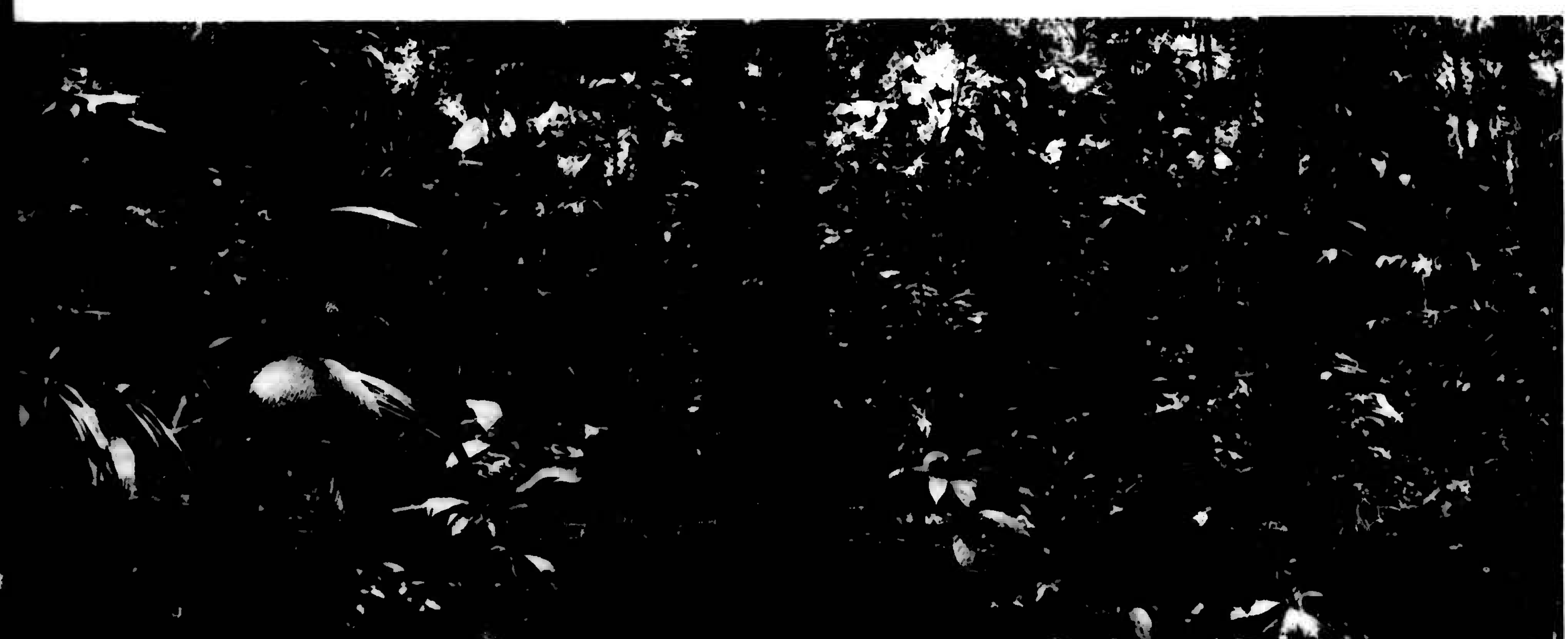
b. View of Site Y from Observer's Position

c. View of Site Z from Observer's Position

FIGURE 2. VIEWS OF THREE EVERGREEN RAINFOREST SITES. 3



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APPENDIX A

Order of Target Presentation

Distance (feet)	Radius				
	I	II	III	IV	V
40	15	10	19	5	31
50	34	14	3	40	21
55	39	43	45	9	36
60	28	32	11	25	24
70	17	13	30	27	1
80	8	23	35	4	18
90	2	38	41	33	44
100	26	12	29	22	7
115	37	6	42	16	20

APPENDIX B

Sequence of Observers Tested
at Three Different Sites*

Observer Number	Site	Test Day
1	X	1
2	X	1
3	Y	1
4	Y	1
5	X	2
6	Z	2
7	Z	2
8	Y	3
9	Y	3
10	Z	3
11	Z	3
12	X	4
13	X	4
14	Y	5
15	Y	5
16	Z	6
17	Z	6
18	X	7

* Four observers were tested daily, however, some observers were wearing specially equipped glasses--the results of which will appear in a subsequent report.

APPENDIX C

Instructions given to the O by E prior to the start of each test session.

"We are trying to find out how well you can detect targets through the foliage. You will see one of these fellows (demonstrate) 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 45 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-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 random sampling from a common, normally distributed population.
Probability (P):	This symbol refers to the level of confidence which may be placed in the statistical significance of values derived from many different types of statistical tests and measures.
Degrees of Freedom (df):	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.
Semi-interquartile range (Q):	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 (σ):	This is a measure of the variability of individual values in a frequency distribution around the mean value.
Standard error of estimate (σ yX):	A measure of the goodness of fit of empirical data around a predicted function such as a regression line.
Coefficient of correlation (r_{xy}):	The Pearson Product-Moment correlation coefficient is a measure of the extent to which 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.
Regression line ($y'=a+bX$):	This is a predicted function of line which yields the best average fit of empirical

Regression line (cont'd) data to the line. In a two-variable linear equation, there are two parameters involved--the level ("a" coefficient) and the slope ("b" coefficient).

Chi square (χ^2): This test of significance is frequently used when data are in terms of discrete frequencies of occurrence rather than in terms of measurements. Chi-square tests the statistical independence of two or more empirically derived sets of frequencies.

Median: The midpoint of a series of numerical values; it represents a point on a continuum rather than an algebraic average.

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.

Inverse sine transformation: A transformation frequently applied to percentage values prior to analysis of variance to reduce correlation between means and variances.

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13. ABSTRACT The study was conducted to determine whether there are sufficient changes in evergreen rainforest vegetation during the dry season to enable US soldiers to detect human targets more readily than is possible during the wet season. The determination was made by comparing the results of the present study with a similar one conducted at the same sites during the wet season.

Eighteen US Infantry soldiers, all with normal vision, each were presented 45 randomly appearing human targets dressed in standard Army field clothes. The observers, who had a 180° field of search, attempted to detect each target and estimate the distance to the target. Noise arresters were used to eliminate auditory cues.

In spite of higher illumination levels, observable qualitative changes in vegetation, and a severe dry season, there were no significant differences in target detectability between the two seasons. In fact, the results of the present study could have been predicted from the previous study. Reliability of the methodology is indicated by the reproducibility of results.

The near limit of target detectability in an evergreen rainforest was between 100 and 115 feet. Eye-level vegetation appears to be the principal deterrent to target detection regardless of the season.

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14. KEY WORDS	LINK A		LINK B		LINK C	
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