U S ARMY NATICK LABORATORIES

SPECIAL REPORT

S-3

VISIBILITY IN A TROPICAL FOREST

EARTH SCIENCES DIVISION

AUGUST 1963

NATICK, MASSACHUSETTS

U. S. ARMY NATICK LABORATORIES
Natick, Massachusetts

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Special Report
S-3

VISIBILITY IN A TROPICAL FOREST

Robert L. Anstey
Geographer

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August 1963

FOREWORD

This is the first quantitative study ever made of visibility in a Central American tropical forest. It extends experience gained in earlier research on visibility in temperate forests by the U. S. Army Natick Laboratories.

In view of the serious operational problems resulting from poor visibility in tropical forests, it seems surprising that this subject has been neglected. One of the first sensations experienced by a person on foot or in a vehicle plunging into the tropical forest is an oppressive feeling of smothering confinement within the dense surrounding foliage. Hidden, unknown dangers may lurk within a few yards in any direction. The present study showed that in some areas a man could not be seen at distances greater than five feet. Under such conditions an enemy can be concealed close at hand, weapons are useful only for very close ranges, contact with friendly forces is hard to maintain, and navigation is difficult. At the same time, the low visibility favors defensive concealment.

Although there has been abundant research on tropical forests from a taxonomic, physiognomic, and ecologic viewpoint, visibility distances cannot be derived from this type of analytical research. Quantitative measures of visibility depend upon direct observation of a target: a method that automatically synthesizes the effects of the entire vegetation complex — stem, leaf, vine, and undergrowth.

The field work for this report was carried out by Dr. Anstey, ably supported by Mr. Giarratana, in Panama in October 1962, during such time as could be spared from other activities of the Swamp Fox II exercise. The study contributes to our basic knowledge of a little-studied aspect of vegetation significant from a scientific and a military viewpoint. The author has brought us some quantitative concept of visibility in deciduous tropical forests, both in full foliage and in a theoretically denuded state. In addition, he has assessed the relative validity of different methods of measuring visibility in the forest. As in most pioneering research, as many questions have been raised as answered, and it is clear that further research would be highly interesting and fruitful, both on methodology and on other vegetation types. Such research is currently underway by this Division in subarctic and Mediterranean-type vegetation.

PEVERIL MEIGS, Ph.D.
Chief
Earth Sciences Division

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ABSTRACT

Horizontal visibility in a tropical deciduous forest in Eastern Panama was measured in October 1962 in the course of Project Swamp Fox II. The total of 360 observations consisted of 4 observations at each of 90 sites. The maximum distance at which a camouflaged object moving away from the observer could be identified in this type of forest was 100 feet; the average distance, approximately 50 feet. The maximum distance that a pre-positioned camouflaged object could be identified was 60 feet; the median distance was approximately 22 feet. A study of the spacing of tree trunk diameters disclosed that an observer standing in the center of randomly selected circles with a 15-foot radius would find that an average of 30 percent of the peripheries would be obstructed to view by tree trunks without foliage, and 66 to 88 percent of the peripheries of quadrats measured at 90 feet on a side would be obstructed to the viewer from central points. It was also found that some unobstructed sight lines of 100 to 300 feet could be obtained in this type of forest if the foliage were removed.

VISIBILITY IN A TROPICAL FOREST

1. Introduction

Army personnel deployed in forested areas in the tropics usually find it critically important to know how far away men can see each other or a target through the vegetation cover. For many years there were incidental, qualitative references in the literature to visibility in forest stands (1). Rare quantitative references have been made. We read, for example, a passing remark that near Kuala Lumpur in Malaya the flat land was "covered with dense primary jungle, giving a (visibility) range of only twenty yards in any direction" (2). During the last decade, a planned quantitative study of this problem has been conducted by the Natick Laboratories. In 1952 a pioneering systematic survey of visibility in temperate forests was initiated under Quartermaster contract with the American Geographical Society. Dr. Robert Drummond, Duke University, carried out the field work, and the results were published in 1956 (3). Visibility problems in tropical forests were investigated in 1961 by contract with Indiana University (4), though this investigation was concerned with atmospheric visibility restrictions in tropical forest clearings rather than the restriction of visibility due to the vegetation.*

Project Swamp Fox II furnished an opportunity for a study of horizontal visibility within a tropical deciduous forest in the vicinity of El Llano (Provincia de Panama) between the Rio Bayano and the Pan American Highway approximately 60 miles east of Panama City (Figs. 1, 2). This forest was designated as vehicle evaluation Area B; a tropical gallery or riparian strand forest was selected for vehicle evaluation Area C. Area A is a cleared, planted pasture with only scattered trees.

2. Site Overview

The vegetation in Area "A" consisted of Heliconia, para grass (Panicum Purpuracens), and cabezona grass (Paspalum Virgatum) in dense stands 1 to 2 meters in height. This type of clearing is common in Eastern Panama. Comparative visibility measurements were taken in this area, but were not included with those obtained in the forests.

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*As this study goes to press, a copy has been received of a study by USA Engineer Waterways Experiment Station: Environmental Factors Affecting Ground Mobility in Thailand, Preliminary Survey, Appendix D, Vegetation, Tech. Rept. 5-625, May 1963, including measurements of visibility made according to the first technique described by Dr. Anstey on page 5.

Few large areas of untouched forest remain in the tropics today; most have been affected in some degree and much has been completely cut over or replanted to tree crops, such as rubber, coffee, tung oil, citrus, etc. Area B was the most extensive forest remaining adjacent to the Pan American Highway, between Chepo and El Llano (Fig. 2). A tropical deciduous forest, thinned by selective logging, this area still contained many huge trees at the time of the investigation and, according to James A. Duke of the Missouri Botanical Gardens (5), it maintained a primeval appearance (Fig. 9). Because of the selective logging, this forest may be considered to be representative of many of the forested areas in the tropical regions of the world, particularly those in Malaya, Thailand, Burma, the Philippines, and adjacent areas. The forests in the Fort Sherman Military Reservation, cleared about 50 years ago, exhibit similar vegetative formations to those in the study area. Significant differences in height of trees, density, and number of big trees, however, were noted between Area B and the forest about 30 miles east, adjacent to the Rio Silugandi camp. During the dry season immediately following Project Swamp Fox II vehicle tests, most of the forest of Area B was cleared for agricultural use by the owner, which precludes further studies in this location.

This forest is dominated by cuipos (Cavanillesia platanifolia), espinosos (Bombax quinatum), and espaves (Anacardium excelsum), the typical tropical deciduous vegetation of the Pacific-facing slopes of Eastern Panama. These trees reach 100 to 150 feet in height. The espave is the most common canopy tree in this area and is indicative of a distinctly dry-season area. The big trees are generally from 20 to 50 feet apart, but appear to be much closer because of their buttressed root systems. Most of these trees do not branch except near their crowns (30 to 50 feet from the top of the tree). Their crowns appear to form a continuous canopy; only an occasional tall tree rises above the general level (Fig. 8). Below the upper, or main canopy, there is, in some places, a second story canopy which is more widely spaced and consists of smaller immature cativos, cuipos, trumpet trees, and small black palms. Most of these trees are less than 30 feet tall and the majority have trunks only a few inches in diameter. The trunk of the black palm is ringed with long, sharp thorns and needle-like barbs. Its wood is heavy and so difficult to cut that it is frequently left standing when other trees are cleared. Many of the larger trees have horizontal surface roots which extend from 10 to 50 feet away from the main trunk. Many of these roots are 3 to 4 feet above the ground lying over other surface roots, and some are buttressed to heights of from 12 to 20 feet above the ground on the main trunk of the tree. The buttressed trees are 2 to 3 times as restrictive to visibility at eye level as non-buttressed trees with the same trunk diameter. These trees may support as many as 20 vines 3 to 6 inches in diameter. The foliage of the vines forms a considerable part of the canopy, closing gaps and lowering visibility. Surface roots, vines, and branches of the trees support numerous orchids, wild pineapple, and other parasitic

plants. The total vegetative mass is truly restrictive to both observation and movement required to conduct a study of visibility in this type of forest.

This area had a per-acre average of 150 trees (from 120 to 180) with minimum trunk diameter of 4 inches at eye level (5 feet above the ground). There is great diversity of tree species even within the small areas used as study sites for the present investigation. Approximately 3 percent of the matured trees exceeded 150 feet in height, including Cavanillesia platanifolia and Bombax quinatum; approximately 12 percent of mature trees were more than 100 feet high, including Ficus spp., Sapium spp., Tabebuia pentaphylla, and Anacordium excelsum; more than 75 percent of the trees were less than 100 feet high and less than 8 inches in diameter, representing both the immature large trees and mature undergrowth.

Vines, lianas, orchids, vanilla, philodendron, and other parasitic plants grow on the trunks and branches of trees. The flora of the forest floor is limited to species such as lichens, moss, and ferns requiring a minimum of light, soil nutrients, and root space. In the openings and clearings where sunlight penetrates to the forest floor, there are thickets of heliconia, various palms, coarse grasses, and herbaceous plants. This condition prevails near roads and in slightly drier environments. It causes the forest to appear impenetrable. Near the Pan American Highway dense clumps of Trema micrantha, a tall weed, limited visibility to less than 10 feet (Fig. 10).

The courses of vegetative succession on old clearings begin with grasses, sedges, and a variety of broad-leaved herbs. However, most of these pioneer types are short-lived. Plants such as the heliconias and the Panama-Hat palm appear after a year, together with numerous seedlings of the trees that will dominate later. Also, thorny lianas become established, making this vegetation an impenetrable tangle. Trees become dominant after 2 years, forming a young secondary forest. Additional species invade the area and the vegetation takes on the aspect of a typical deciduous forest. In succeeding years this vegetation becomes more dense and more difficult to penetrate than the primary forest, until the undergrowth and smaller trees are shaded out.

Area C is bisected by the Rio Mamoni, which is broad enough to create a wide opening in the canopy (Fig. 12). A well-developed gallery forest lines both banks of the river, and can be located from the air by its slightly taller trees. This forest is characterized by ant trees (Cecropia spp.), fig (Ficus glabrata), and pichinde (Pithecolobium longifolium). Of these the fig or "higo" grows to the greatest height, 80 to 100 feet. On the banks of the river and in open areas between the trees are clumps of tall grasses and shrubs from 6 to 10 feet high. These clumps include volunteer sugar cane and several grasses such as

para grass, zocote grass, and guirea grass. In the vicinity of visibility sites 4, 5, and 6 in Area C, there was a thick stand of cane, banana, and lime trees, relics of previous cultivation. Visibility in this "cultivated" area was restricted to less than 20 feet.

The present investigation was conducted during the rainy season (which normally occurs between April and December) and during one of the rainiest months of the year (October). However, October 1962 was approximately 10 percent drier than the average October (6). High relative humidities (90 to 100 percent) in the early morning hours (daylight to 0700 hrs LST) resulted in mist and "jungle steam" in the air, which became more limiting to visibility than the vegetation. This is especially true if rain falls during the night or early morning hours. Water drips from the canopy for several hours after a rain. Small clouds may form under the canopy. Rain during the day reduces visibility, both because of the darkening of the sub-canopy forest due to cloudiness and the rain itself which seems to fall in sheets between the trees. During a heavy shower, targets cannot be identified more than 10 feet from the observer. However, specific studies were not made of the actual distances an object could be identified with these reduced natural lighting conditions, and measurements during rainstorms were not included in the summaries of this report. It was noted that the abrupt darkening of the forest at sunset obviated further visibility studies after 1800 hrs LST.

Animal life is also a hindrance to efficient conduct of visibility studies. These are also factors that would add to the difficulty of concealment of personnel. While standing motionless in a tropical forest, a man is usually harassed by ants and several types of flying insects, such as gnats, hornets, mosquitoes, and flies. In several instances during the second series the man was located by his movements while brushing off insects. Men resting on fallen trees and stumps are bothered by chiggers, ticks, scorpions, and tarantulas. Snakes are common.

3. Visibility Measurements

This investigation consisted of measuring the distance over which a camouflaged target can be seen at various horizontal distances in a tropical deciduous forest*. The camouflaged target used in this investigation was a man wearing the standard US Army utility uniform, shade OG 107, including tropical DMS boots and the standard field cap. The man was standing erect at all times during the observations. In a tropical deciduous forest, leaf, vine, and tree-bark colors are sufficiently varied so that a man's shaded face is not particularly noticeable as a locating factor. The direction that the target faced did not appear to

*A camouflaged target under a tropical forest canopy is generally not visible from above the canopy.

be significant; however, this aspect was not fully checked in the field. In the first series of observations the target was facing away from the observer; in the second, he was facing toward the observer.

A green object absorbs much of the natural light which impinges upon it. For example, chrome green reflects less than 40 percent of visible light at a wave length of 510 millimicrons; titanium dioxide white reflects 92 percent of received light at the same wave length. Where natural light is indirect, or subdued, the reflectance is even less; at wave lengths of 460 millimicrons and below, or above 660 millimicrons, the reflectance of visible light by chrome green is 10 percent or less (8).

A total of 360 observations of visibility was made, consisting of 4 observations (1 in each of the cardinal compass directions) at each of 90 sites. The use of standard compass directions was merely for uniformity and comparability in sampling, rather than an attempt to detect possible increased visibility in any direction. The original plan of field work provided for observations at 50 sites approximately 100 feet apart within Area B of the Swamp Fox II vehicle evaluation test course area (Fig. 3). At given paced distances, i.e., 10 feet, 25 feet, 50 feet, 75 feet, photographs were taken of the target (Figs. 10, 11). This was usually done at a spot just before the point where the target became completely blocked from the observer's view due to intervening vegetation (leaves, vines, and other underbrush), and usually it required the target to move back into view.

The first 50 series of observations were made of the camouflaged target moving away from the observer to the given distances, or until the target moved out of sight. It became apparent that this technique was faulty inasmuch as the observer could see parts of the target moving from point to point, even though the target was generally obscured from view. Also, the observer's eyes were focused on the exact location of the target; he could hear the target moving through the vegetation, or see the movement of vegetation being pushed aside. Greater distances were observed and recorded, therefore, than would have been obtained without these locating events. A second technique was then employed in which the camouflaged target was pre-positioned in each site prior to the arrival of the observer. Positions were selected at random in this series; no attempt was made to observe at each cardinal direction. In this series the observer was unable to see the target at distances as great as those in the same sites when the observer was able to see the target moving. In fact, in many instances the observer came within 10 feet of the target before seeing any part of the target, and on two occasions the identification was made at a distance of only 5 feet. The greatest distance at which positive identification could be made of a pre-positioned target was 60 feet. Only 2 percent of the observations located the target at distances of 50 feet or more with pre-positioning; the median distance was 21.5 feet. In the previous series of observations, where the target moved away from the observer, the median distance

of the observation series was 48.5 feet. In this series, the range of observations was from 10 feet to a maximum of 100 feet (one identification). Over 60 percent of all observations with this technique showed that the maximum distances over which a camouflaged target could be identified in a tropical deciduous forest were between 35 and 55 feet (Fig. 5).

Both visual acuity and the experience factor must be considered in observing targets in a particular environment. It was noted that the camouflaged object could be identified at much greater distances (increases of 20 to 30 feet) on second check measurements of the first series of observations. A significant aspect of the first series of observations was excessive perspiration, which limited the visual acuity of the observer. With acclimatization perspiration ceased to be a problem. However, a professional hunter with many years experience in similar environments was able to locate the pre-positioned target during the second series of observations at much greater distances and more rapidly than the regular observer. Only once did the regular observer and the hunter sight the location of the target at the same distance; this, however, was due to the observation of smoke from the target's cigarette rather than sighting the target himself. It became necessary to avoid smoking during the visibility study.

The greatest obstruction to vision in a tropical deciduous forest is due to leaves, palm fronds and epiphytes, and aerial roots of the latter. A study was made of the obstruction to horizontal visibility due only to trunk diameters, branches and vines, including spine and barb clusters, to determine the maximum visibility in a long dry season when the leaf-fall would be greatest (Figs. 6, 7). The sites selected (Nos. 19 and 21) were in the southern section of the study area, and they were in the least cutover portion of the forest. This area was more open than the lower areas, i.e., it contained less underbrush, and was more representative of the forests farther to the east where clearings are less common. It was found that an average of 30 percent of the peripheries of randomly selected circles with 15-foot radii from the observer would be obstructed by tree trunks and vines, and on the periphery of randomly selected 90-foot quadrats (8100 sq ft) horizontal visibility was 66 to 88 percent obstructed. It was also found that occasional unobstructed horizontal sight lines of 100 to 300 feet could be obtained in this forest if the foliage were removed. The density of underbrush, hanging vines, low-branching palms, and small immature trees, however, is too great to permit long lines of sight.

The close spacing of study sites was an attempt to sample visibility in as many of the different vegetative stands in this forest as possible. It is recognized that not all of the various vegetative formations in the forest were studied, or included in the test, and it is quite possible that a different selection of study sites, particularly in the higher elevations, would yield different results. In order to

check the findings in Area B a series of observations was made at 10 sites on the west bank of the Rio Mamoni in Area C, a type of riverine vegetation or gallery forest (Fig. 4). The latter area was thickly overgrown with underbrush, containing several giant fig trees (Ficus glabrata) and ant trees (Cecropia sp.) as well as rattan and volunteer growth of the bananas and limes which were planted when the area had been cleared approximately 10 years ago. In addition there was a thick growth of grass higher than a man.

In general, visibility was much more restricted in Area C than in Area B, due to the increase in density of undergrowth. Also, the irregular terrain in Area C, especially the steep bank above the lower floodplain, placed the observer above or below the target and therefore prevented him from identifying a recognizable item at eye level. In this area no identification could be made at distances greater than 60 feet, and these were generally adjacent to the machete trail made by the visibility party. The median distance that targets could be identified in this type of forest was 20.7 feet. At each of the 10 sites in Area C at least two observations failed to locate a pre-positioned target at distances greater than 20 feet from the observer.

No attempt was made to conduct a systematic study of visibility in Area A. The tall grass obscured most of the target from view. In this area visibility was localized only by movement, sharply contrasting colors, or reflection of sunlight on metal surfaces (7). At distances beyond 50 yards small motionless objects near the top of the grass, such as a standard field cap, became blurred and unrecognizable due to heat shimmer. A crouching man would be invisible to an observer more than 10 feet distant.

4. Conclusions

Most of the obstruction to visibility in a tropical, deciduous forest is due to undergrowth, vines, epiphytes, and exposed buttress roots or fallen trees lying over other logs above the ground surface. This is especially true in areas that have been partially cleared. Additional studies should be conducted to discover more complete information on the density and spacing characteristics of tropical forests, both deciduous and evergreen, under various climatic and edaphic conditions. Further investigations of the climate in tropical forests and grasslands, particularly humidity and temperature conditions relating to visibility, should be conducted to give meaning to present limitations in sighting.

Highly contrasting colors, reflection of metal objects in the sun, or movement, are the most common means of locating objects in the types of environment used in this study. A camouflaged target moving away from the observer can be seen much further from the observer than a pre-positioned camouflaged target standing motionless.

It is imperative that personnel engaged in these studies be protected against insects. Smoking should not be permitted if a man is used as the camouflaged target. Future observers should be fully acclimatized and each observer should be given training in observing under the environmental conditions peculiar to the area, prior to the initiation of the field study.

Normal search for object identification is at or near eye level. A special observation technique is required in order to locate a camouflaged target above or below the normal line of sight at eye level, such as in forests over irregular terrain.

Search for a camouflaged target and identification of it is a time-consuming process and requires new techniques for maximum efficiency. At the present time, identification is based on contrast in color or shape if the target is standing erect and motionless. Other identification factors are required. Straight line or geometrical shaped camouflaged targets should not be used in future studies. A man wearing the standard utility uniform, or a cylindrical shaped target such as was used in the temperate forest study, are easily identified by their form, especially by straight lines.

Maximum visibility is achieved during the period of greatest light intensity, i.e., during the middle of the day, when skies are relatively free of clouds. Rain, early morning mists, increased shadows late in the day, and "jungle steam" are conditions which require special attention in future investigations.

Supplemental studies are required to provide military equipment design personnel with information on visibility in tropical forests. These studies include additional work in similar forests, as well as in other types of forests and tropical vegetative conditions, using different camouflage colors or white targets, with improved techniques of observation. Research in observation techniques should be conducted, employing the so-called "rules of thumb" of the professional hunter or naturalist as a point of departure. A standard technique of observation should be developed. Several shades and hues of green should be tried as the camouflage color in these visibility studies to discover which shade or hue blends most effectively with the background colors in these environments. Also, these studies should be repeated, employing a white target to be identified at various distances in the same areas, for comparative purposes with the present study.

5. References

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6. Acknowledgments

Sincere appreciation is extended to Mr. Angelo Giarratana, Research Analysis Corporation, for assistance in the field work and provision of photographs for this study. Lt. Gordon K. Nishimoto of this Laboratory, and enlisted personnel of the Transportation Board, provided valuable aid in the latter part of the field investigation. Miss Pernel Leuvelink drafted the maps and diagrams used in this report.

LIST OF ILLUSTRATIONS

Maps and Graphs:

Photographs:

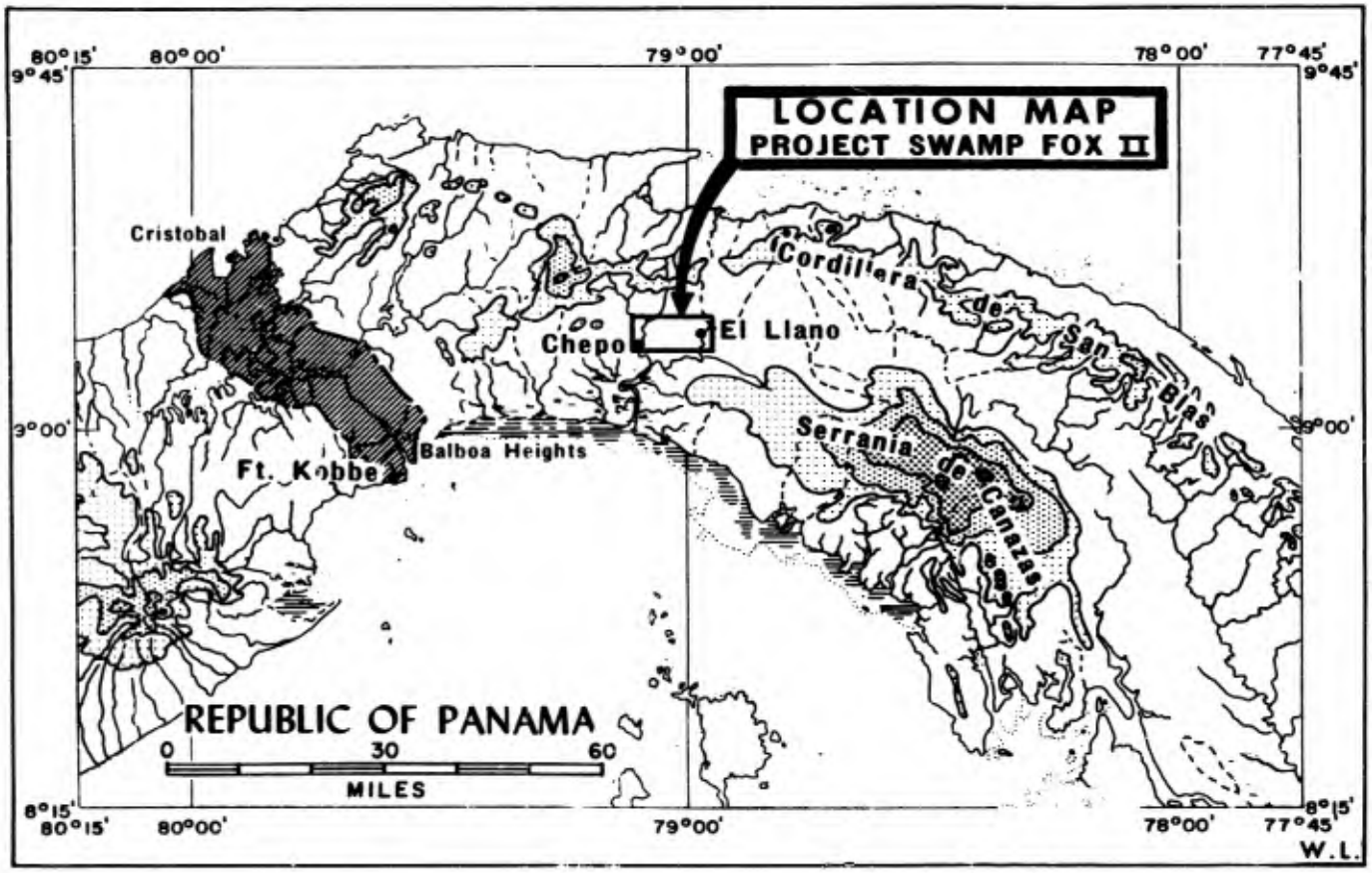

LOCATION MAP
PROJECT SWAMP FOX II
80°15'
80°00'
79°00'
78°00'
77°45'
9°45'
8°15'
Cristobal
Chepo
El Llano
Cordillera de San Blas
Serrania de Canazas
Balboa Heights
Ft. Kobbe
REPUBLIC OF PANAMA
0
30
60
MILES
W.L.

Figure 1

LOCATION MAP - PROJECT SWAMP FOX II

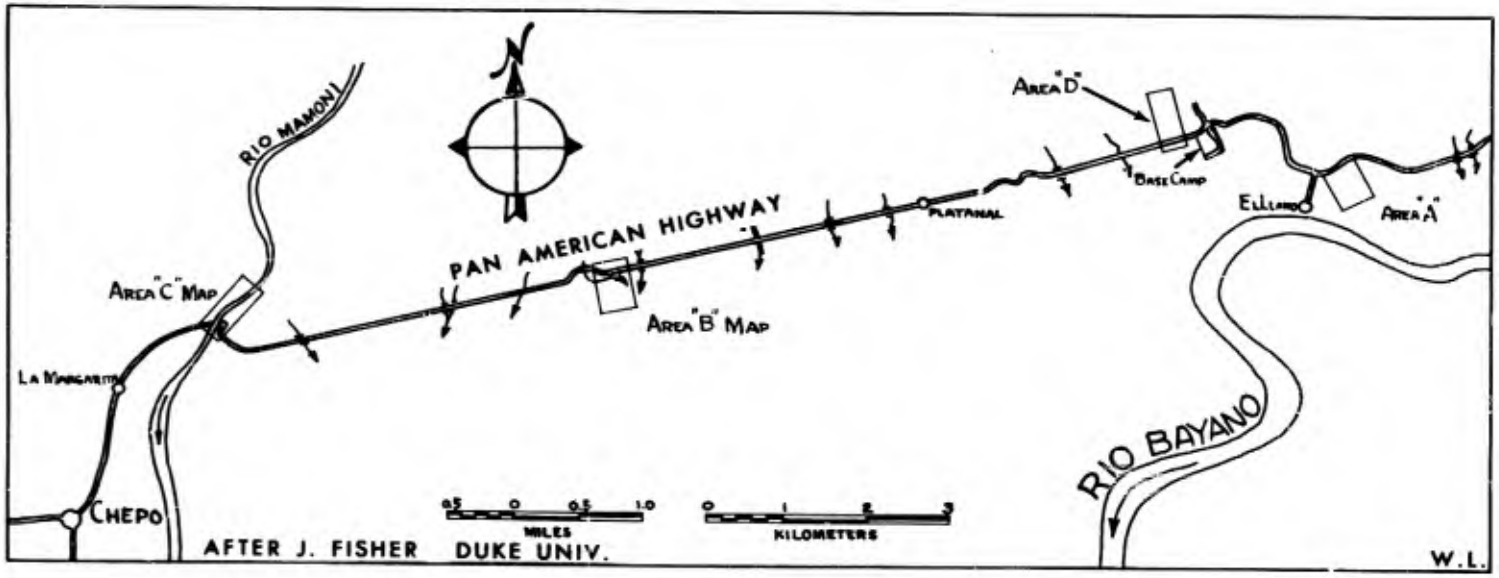


Figure 2

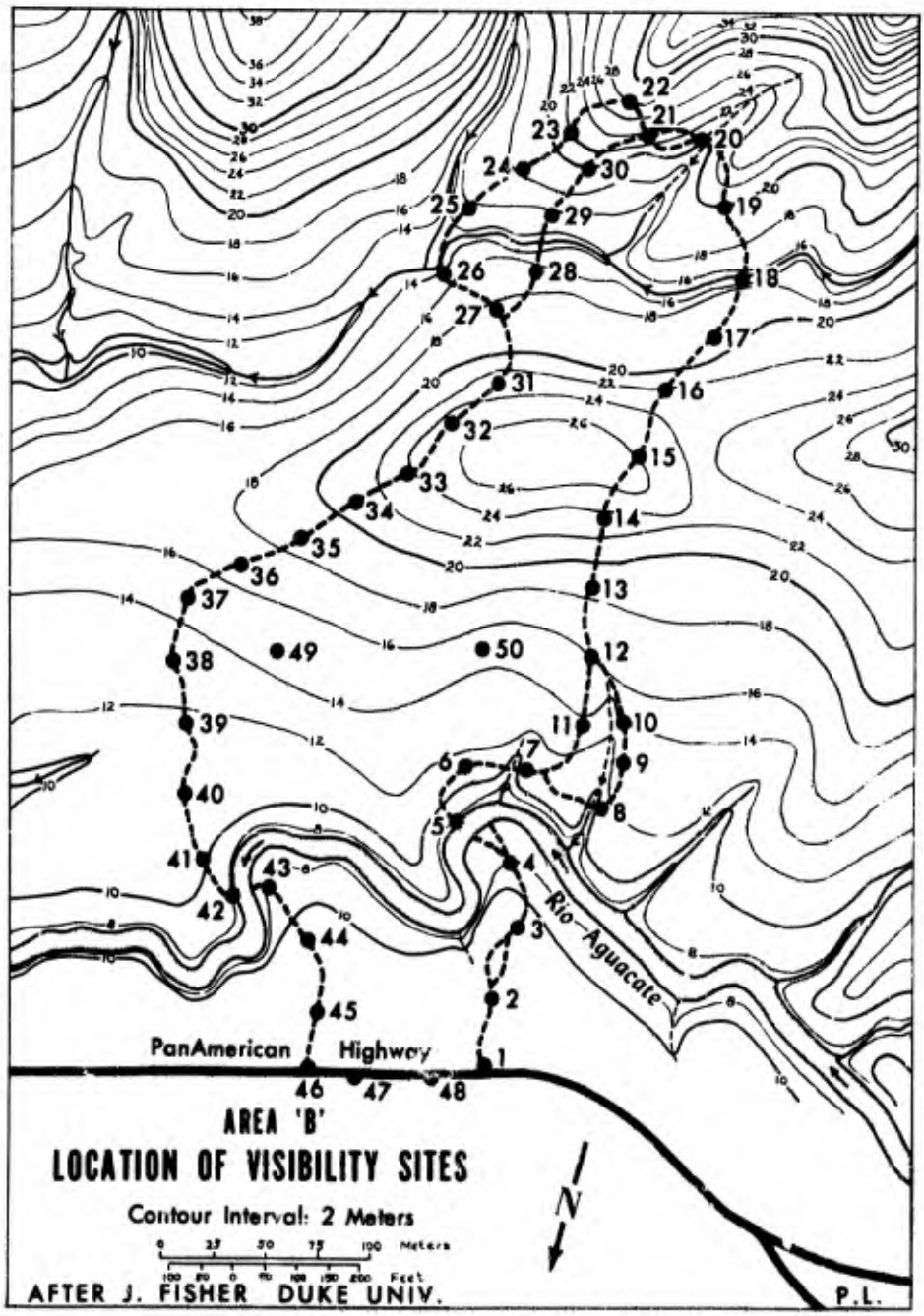

PanAmerican Highway
Rio Aguacate
AREA 'B'
LOCATION OF VISIBILITY SITES
Contour Interval: 2 Meters
N
AFTER J. FISHER DUKE UNIV.
P.L.

Figure 3

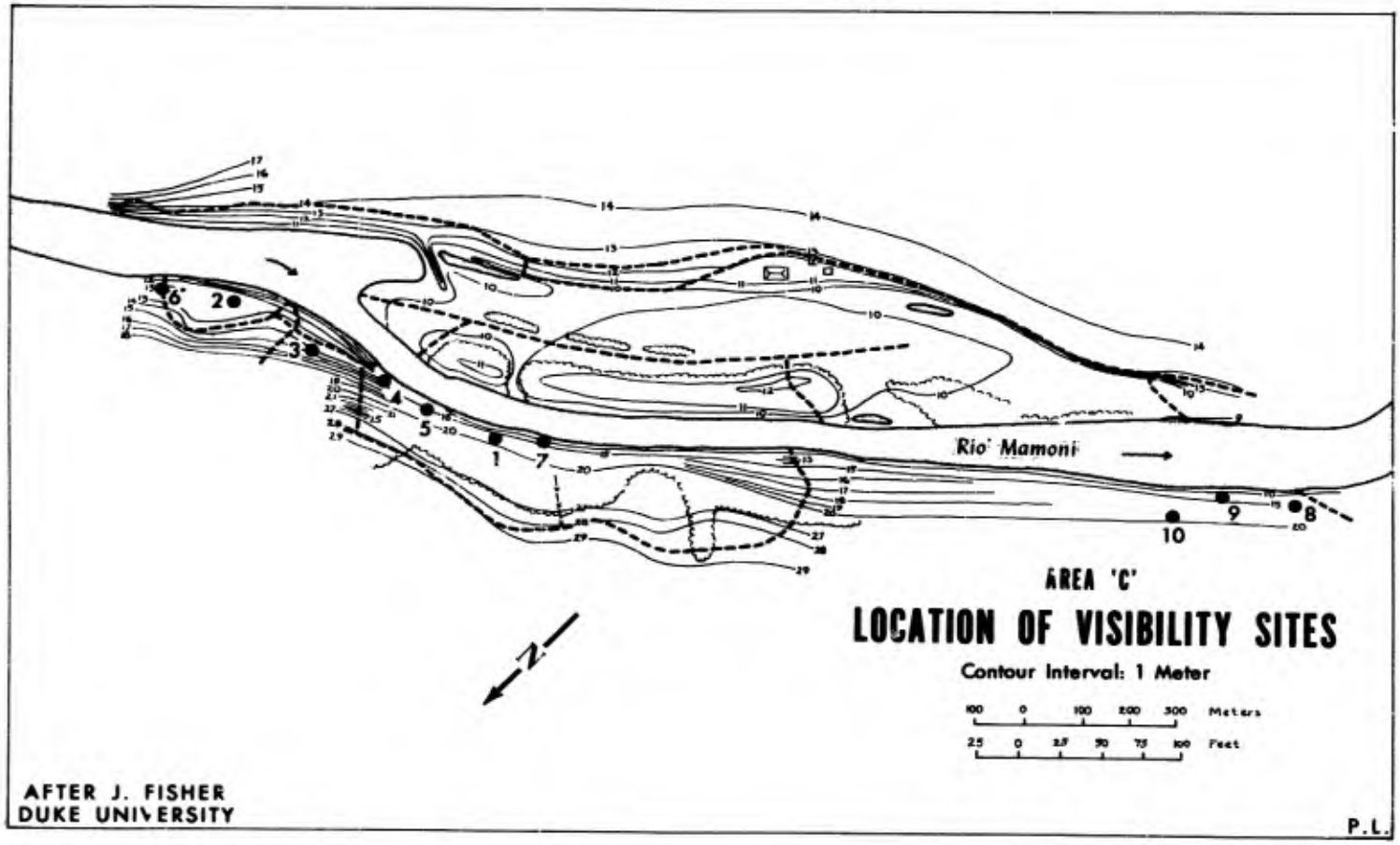

Rio Mamoni
AREA 'C'
LOCATION OF VISIBILITY SITES
Contour Interval: 1 Meter
100 0 100 200 300 Meters
25 0 25 50 75 100 Feet
AFTER J. FISHER
DUKE UNIVERSITY
P.L.

Figure 4

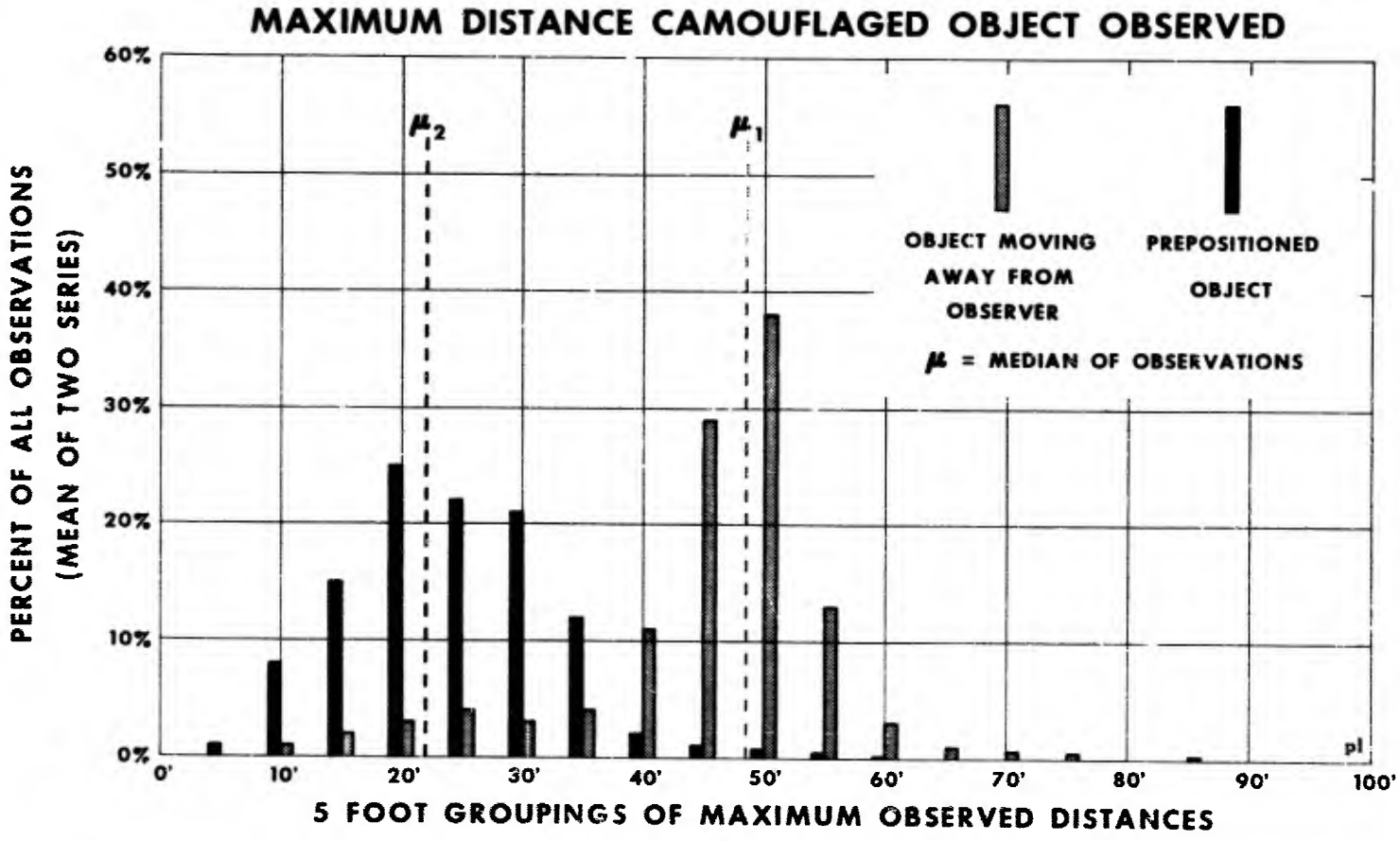
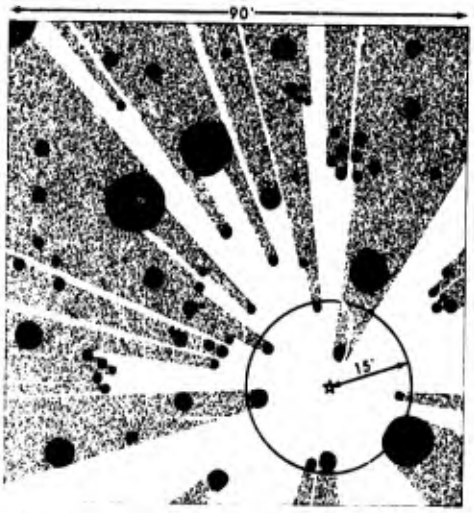
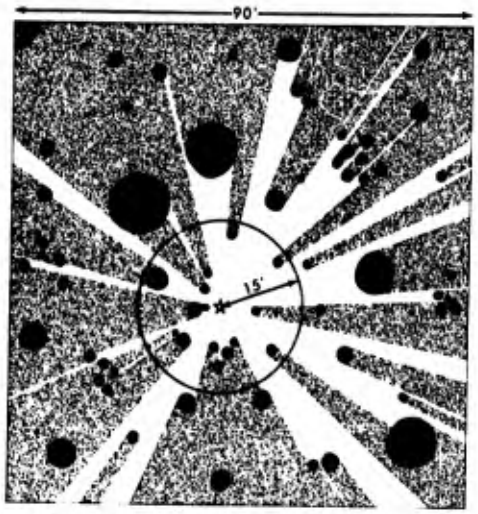

MAXIMUM DISTANCE CAMOUFLAGED OBJECT OBSERVED
PERCENT OF ALL OBSERVATIONS
(MEAN OF TWO SERIES)
60%
50%
40%
30%
20%
10%
0%
μ_2
μ_1
OBJECT MOVING AWAY FROM OBSERVER
PREPOSITIONED OBJECT
μ = MEDIAN OF OBSERVATIONS
0'
10'
20'
30'
40'
50'
60'
70'
80'
90'
100'
5 FOOT GROUPINGS OF MAXIMUM OBSERVED DISTANCES

Figure 5



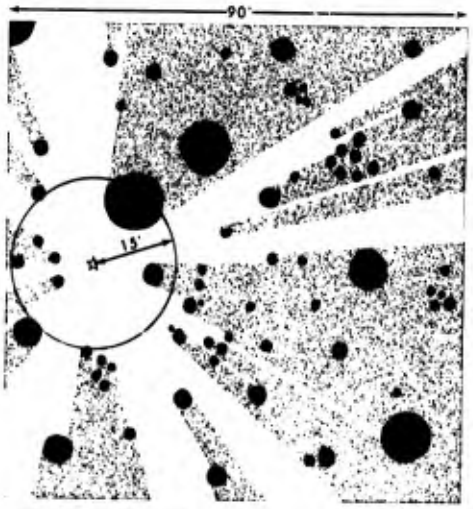
OBSCURED CIRCUMFERENTIAL VISIBILITY AT HEIGHT OF 5 FEET MEASURED 15 FEET FROM OBSERVER = 33%

OBSCURED VISIBILITY ALONG 360 FOOT QUADRANTAL PERIPHERY = 66%



OBSERVED CIRCUMFERENTIAL VISIBILITY AT HEIGHT OF 5 FEET MEASURED 15 FEET FROM OBSERVER = 42%

OBSCURED VISIBILITY ALONG 360 FOOT QUADRANTAL PERIPHERY =88%



OBSCURED CIRCUMFERENTIAL VISIBILITY AT HEIGHT OF 5 FEET MEASURED 15 FEET FROM OBSERVER = 34%

OBSCURED VISIBILITY ALONG 360 FOOT QUADRANTAL PERIPHERY = 76%

HORIZONTAL VISIBILITY OBSCURED BY TREE TRUNKS

PLATANAL, PANAMA - SEPT-OCT, 1962

Represents Maximum Dry Condition Of Deciduous Forest

I

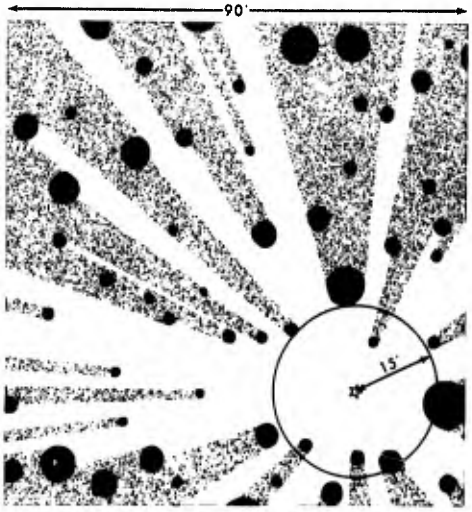
TREE DIAMETER AT 5 FEET ABOVE THE GROUND Includes Spines, Vines And Branches, But Not Palm Fronds, Leaves Or Epiphytes

☆ OBSERVER

AREA OBSCURED FROM HORIZONTAL VIEW BY TREE TRUNKS

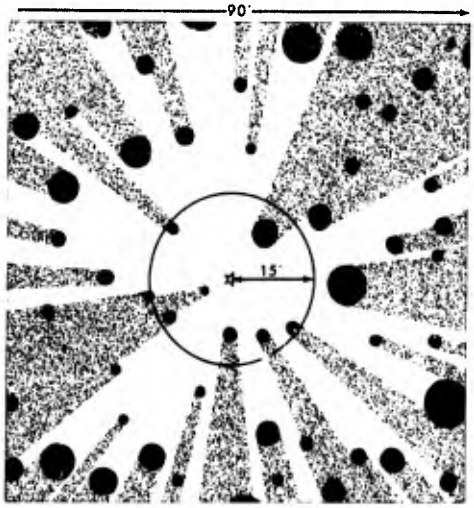
PL

Figure 6



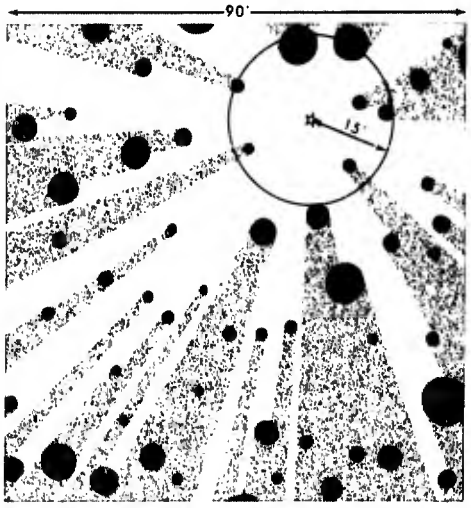
OBSCURED CIRCUMFERENTIAL VISIBILITY AT HEIGHT OF 5 FEET MEASURED 15 FEET FROM OBSERVER = 22%

OBSCURED VISIBILITY ALONG 360 FOOT QUADRANTAL PERIPHERY = 72%



OBSCURED CIRCUMFERENTIAL VISIBILITY AT HEIGHT OF 5 FEET MEASURED 15 FEET FROM OBSERVER = 25%

OBSCURED VISIBILITY ALONG 360 FOOT QUADRANTAL PERIPHERY = 84%



OBSCURED CIRCUMFERENTIAL VISIBILITY AT HEIGHT OF 5 FEET MEASURED 15 FEET FROM OBSERVER = 29%

OBSCURED VISIBILITY ALONG 360 FOOT QUADRANTAL PERIPHERY = 74%

HORIZONTAL VISIBILITY OBSCURED BY TREE TRUNKS

PLATANAL, PANAMA - SEPT-OCT, 1962

Represents Maximum Dry Condition Of Deciduous Forest

II

TREE DIAMETER AT 5 FEET ABOVE THE GROUND Includes Spines, Vines And Branches, But Not Palm Fronds, Leaves Or Epiphytes

OBSERVER

AREA OBSCURED FROM HORIZONTAL VIEW BY TREE TRUNKS

PL

Figure 7

Figure 8. Area B from the air, showing the entrance to the vehicle evaluation course adjacent to the Pan American Highway. Transportation Board photograph.

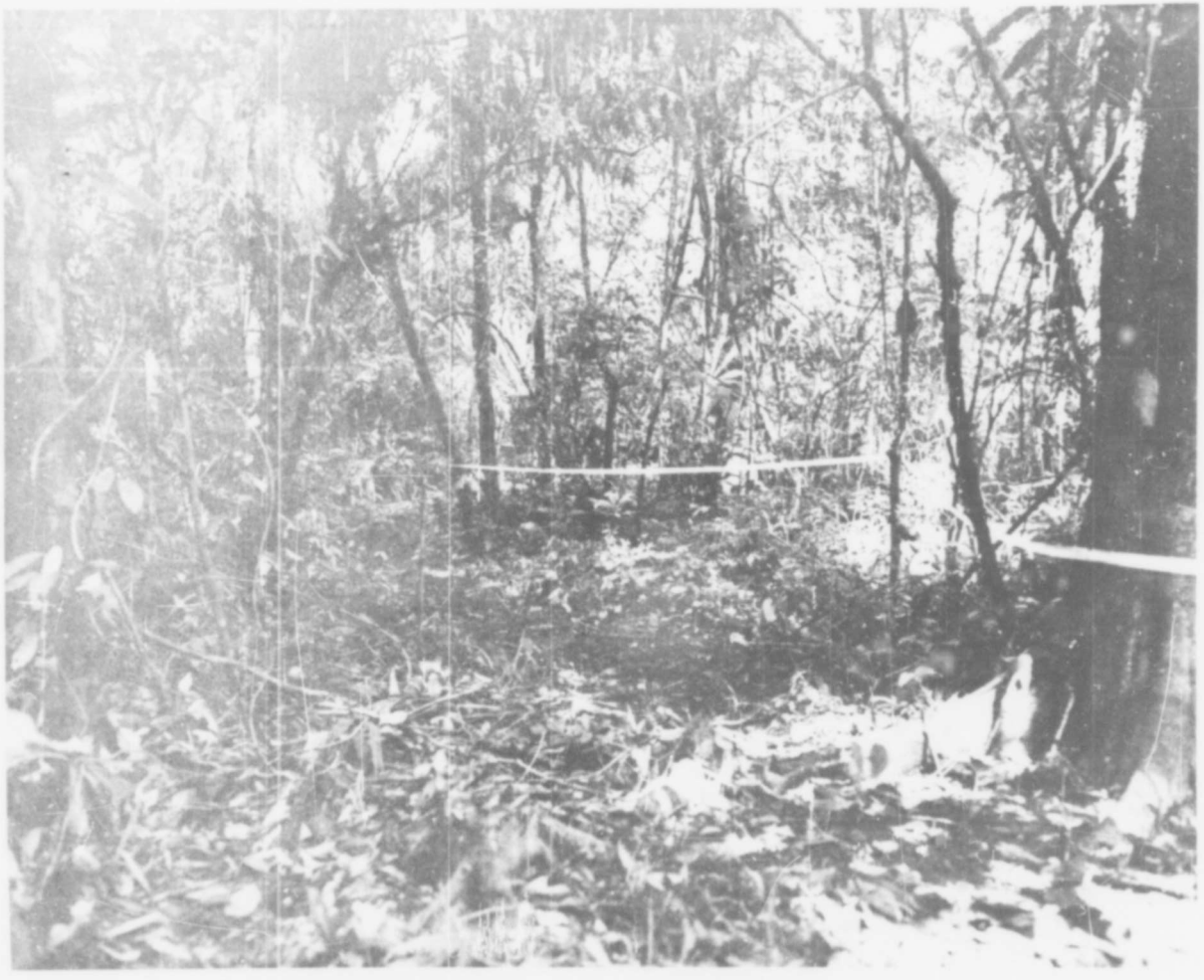


Figure 9. A recent clearing in Area B. The white tape marks the route of the vehicle evaluation course, which was cleared to a width of 15 feet. Transportation Board photograph.

Figure 10. A stand of Trema micrantha in a clearing in Area B. Visibility is limited to less than 10 feet in such clearings. Research Analysis Corporation photograph.

Figure 11. A stand of Heliconia in a clearing in Area C. Visibility is limited to less than 20 feet in such clearings. Research Analysis Corporation photograph.

Figure 12. Area C from the Rio Mamoni. Visibility observation site No. 4 is directly behind the Mil4 in the center of the photograph. Transportation Board photograph.

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