# A New Trial of Measuring the Habitat of the Seaweeds Quantitatively.※

By

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## Introduction

We have never heard up to date that any trial was made to measure quantitatively the habitat pattern of the seaweeds.

The author and others adopted the following method for such purpose when they carried out the surveys on the seaweeds in the Nomo and Nishisonogi peninsulas near Nagasaki during a period from June to August, 1949.

This method is a modification of usual photogrammetry, only the horizontal plane method of which S. Ishiguro, Nagasaki Marine Observatory, the author and others have applied in measuring current conditions at the Hirato and Inoura Straits.* In the survey of seaweeds it is necessary to follow both plane and vertical methods so as to measure the dimensions of those habitats.

The author wishes to report mainly the apparatus, principle of measuring method, procedure of analysis and some considerations on this method with some supplements of actual surveys, because the detail of biological results of those surveys will be reported later by other investigators.

## Apparatus

As shown in Fig. 1, a pin-hole-camera of a large type is so fixed on a common transit that the principal axis of the former lies as parallel and close as possible to that of the lens of the latter by adjusting the position of a duralumin plate attached to a wooden plate about 8 mm thick on which the camera is fixed. The whole body of the camera with its accessaries is mounted on the telescope of the transit.

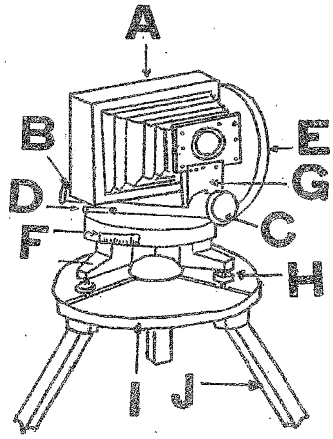


Fig. 1. Transit-camera.
Remarks : A ; camera, B ; telescope of transit, C ; lens of transit, D ; subsidiary telescope of transit, E ; graduator of depression angle of transit, F ; graduator of azimuth of transit, G ; supporter to camera, H ; adjusting screw, I ; top board of tripod, J ; tripod.

Next, a transparent glass plate is inserted in the place of the dryplate, and a piece of tracing paper is passed through the

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* These were presented at the Conversazione of Nagasaki Marine Observatory.

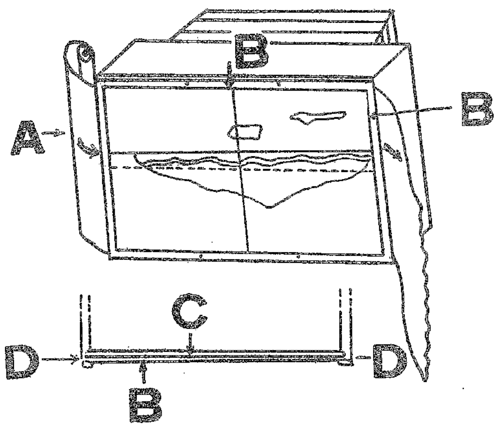


Fig. 2. Showing the tracing side of camera.
Remarks : A : tracing paper, B ; frame made of duralumin, C ; glass plate, D ; slit for inserting tracing paper.

narrow space between this plate and the frame fixed on it. We thus intended to get the upside-down real image of actual sight on this tracing paper (Fig. 2).

If the object to be traced were in a state of rest, common photograph plate or film would be permitted to be used, nevertheless in case of plate there are many technical difficulties in analysis, and film has to undergo subsequent enlargement. So usually it is recommended to use above-mentioned tracing paper.

## Principle

At first let MM′ and O denote the base surface (horizontal) and the centre of camera-lens respectively. Usually MM′ is determined to coincide with the mean sea level or sea surface at the time of observation. Though the centres of the transit-lens and the camera-lens seldom coincide with each other it may be permitted to neglect this uncoincidence as the distance between both positions is too small to compare with the distance between the camera-lens and the standard surface or the object.

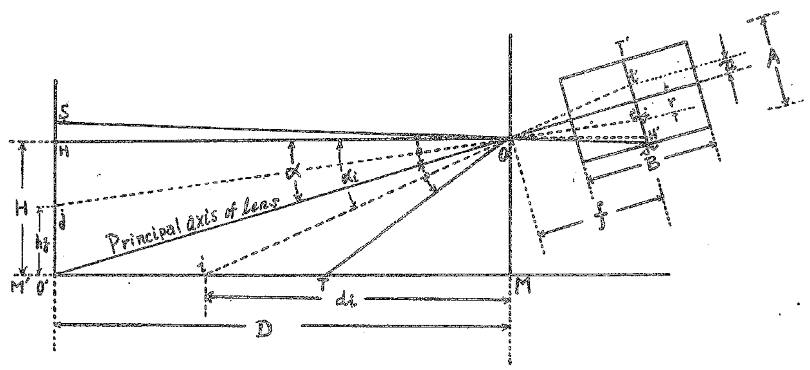


Fig. 3. Principle of the transit-camera (1).
Remarks : H ; height of lens above the standard surface,
D ; distance between lens and point of the principal axis of lens intersecting with the standard surface,
f ; focal length of camera-lens,
A ; vertical width of the tracing plane,
B ; horizontal width of the tracing plane,
C ; centre of the tracing plane,
O ; camera-lens,
$\overline{OS}$, $\overline{CT}$ ; upper and lower limits of the tracing plane.

Let O′ denote a point where the principal axis of camera-lens, $\overline{OO'}$, intersects with the standard surface, and the projected point intersecting lines produced by a horizontal plane through a point O and a plane perpendicular to plane OMO′ through O′ point, is called H. Then OC = f = focal distance of the camera-lens and A and B are the height and the width of the plate respectively.

Let

$$\overline{OM}=H,\ \overline{MO'}=D \text{ and } \angle TOS=2\theta,$$

θ is half of the angle of aperture. Therefore

$$\tan\theta = A/2f=\overline{OM}/\overline{OS'}=(H+\delta)/D.$$

And if $\angle HOH'=\alpha$,

$$\tan\alpha=\overline{OM}/\overline{OH}=H/D=\overline{CH'}/\overline{OC}=\tau/f.$$

Accordingly we obtain

$$D=fH/\tau. \qquad (1)$$

i ) Plane method :

We put arbitrary points 1, 2, 3 —— on $\overline{MO'}$ one point i of which makes a corresponding point image on the plate, and we call it i′. If $\overline{iM}=d_i$,

$$\overline{i'C}=\tau_i,$$

$$\overline{i'C}/\overline{OC}=\tau_i/f=\tan(\alpha_i-\alpha)$$

$$=(-\sin\alpha+H\cos\alpha/d_i)/(\cos\alpha+H\sin\alpha/d_i).$$

$$(\because\ H/d_i=\tan\alpha_i).$$

So

$$d_i=(f\cos\alpha=\tau_i\sin\alpha)H/(f\sin\alpha+\tau_i\cos\alpha), \qquad (2)$$

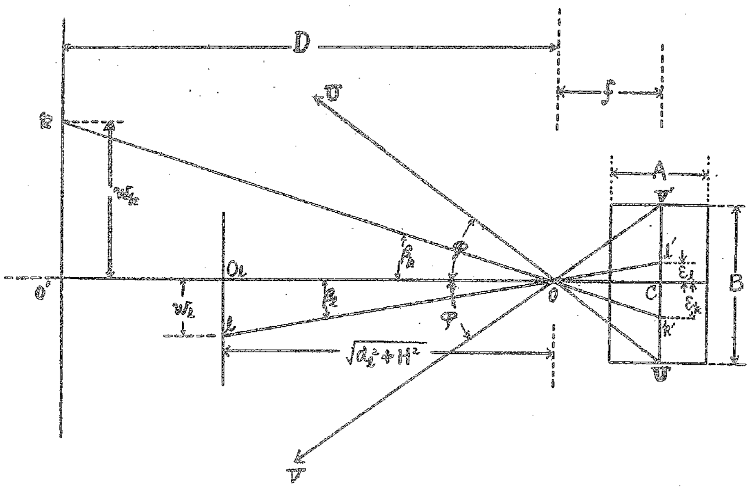


Fig. 4. Principle of transit-camera (2).
Remarks : U, V; right and left limits of the field of view, $\phi$ ; half aperture, $\beta_k, \beta_l$ ; horizontal angles of k and l measured from the principal axis of lens, $w_k$, $w_l$ ; horizontal distances perpendicular to the principal axis of lens.

And we put arbitrary points 1′, 2′, 3′ ——on $\overline{UV}$, a intersection formed by the standard surface and the plane through O′ perpendicular to $\overline{MO'}$, and let k′ denote an image point on the plate by a point k of those points on $\overline{UV}$. Let(Fig. 4),

$$\overline{O'k}=w_k, \qquad \overline{Ck}=\varepsilon_k.$$

Then

$$\overline{OO'} = \sqrt{D^2 + H^2},$$

so

$$\begin{aligned} w_k &= \overline{O'k} = \overline{OO'} \times \varepsilon_k / f \\ &= (\varepsilon_k \sqrt{H^2 + D^2})/f. \qquad (3) \\ &(\because \triangle OO'k \backsim \triangle OC'k). \end{aligned}$$

Consequently we can calculate a distance between the origin and an arbitrary point on $\overline{OO'}$, determining the position of O′ from equation (1) and using equations (2) and (3) after that (Fig. 5).

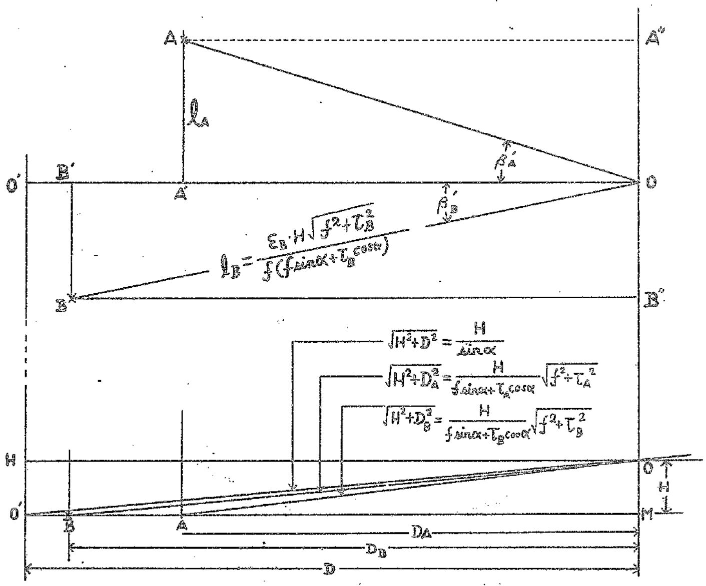


Fig. 5. Principle of the transit-camera (3).

ii) Vertical method :

As a special case we put an arbitrary point j on a plane perpendicular to the plane OMO′ through O′ in Fig. 3 and let j′ denote the image point of j on the plate. If we set (Fig. 6)

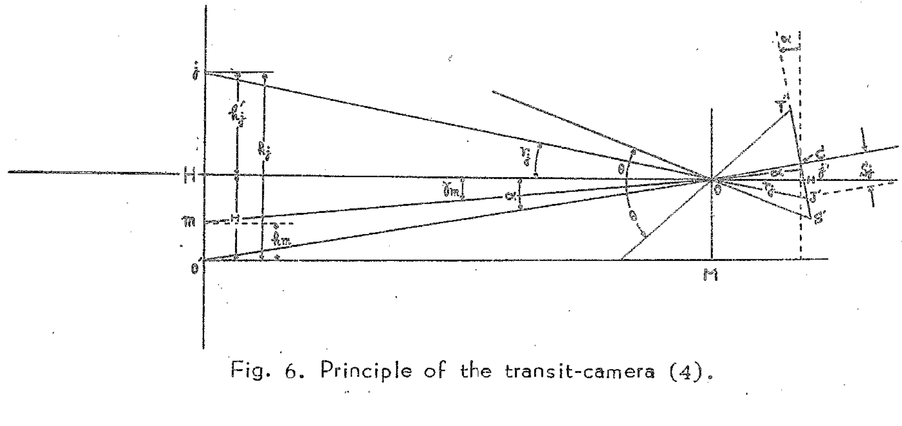


Fig. 6. Principle of the transit-camera (4).

$\overline{Hj} = h_j$ ; $\angle HOj = \gamma_j$,

we obtain

$$\overline{Oj'} = \overline{O'H} + \overline{Hj} = H + h_j, \qquad (4')$$

and

$$\overline{Cj'} = \overline{CO} \times \tan(\alpha + \gamma_j). \qquad (4'')$$

Yet

$$h_j = \overline{OH} \tan \gamma_j = D \tan \gamma_j, \qquad (4''')$$

so we obtain

$$h_j = D \tan\gamma_j = D (\sin\alpha - \xi_j \cos\alpha)/(\xi_j \sin\alpha - \cos\alpha), \qquad (4)$$

substituting

$$\tan\gamma_j = (\sin\gamma - \xi_j \cos\alpha)/(\xi_j \sin\alpha - \cos\alpha)$$

into $(4''')$, where $\overline{Cj} = \xi_i$ from equations $(4'')$ and $(4''')$. Therefore,

$$\overline{O'j} = H + D (\sin\alpha - \xi_j \cos\alpha)/(\xi_j \sin\alpha - \cos\alpha)$$
$$= H \{1 + f(\sin\alpha - \xi_j \cos\alpha)/\tau(\xi_j \sin\alpha - \cos\alpha)$$

gives a height of an arbitrary point above the standard horizontal surface.

In general case, we must at first seek A′, a position of vertical projection of an arbitrary point A. It becomes as follow;

(a) $$d_A = H \frac{f\cos\alpha - \tau_A \sin\alpha}{f\sin\alpha + \tau_A \cos\alpha}$$

And if we denote the projected position of point A on a line perpendicular to the plane OA′M through A′,

(b) $$\overline{A'A''} = \ell_A = \frac{\varepsilon_A . H}{f\,(f\sin\alpha + \tau_A \cos\alpha)} \cdot \sqrt{f^2 + \tau_A^2}.$$

Finally the height of A above the standard plane becomes

$$h_A = H + h'$$
$$= H + D_A \frac{f\sin\alpha - \xi_A \cos\alpha}{\xi_A \sin\alpha + f\cos\alpha}$$
$$= H + \left( 1 + \frac{f\cos\alpha - \tau_A \sin\alpha}{f\sin\alpha + \tau_A \cos\alpha} \cdot \frac{f\sin\alpha - \xi_A \cos\alpha}{\xi_A \sin\alpha + f\cos\alpha.} \right).$$

As above, we can determine the position of an arbitrary point on traced record

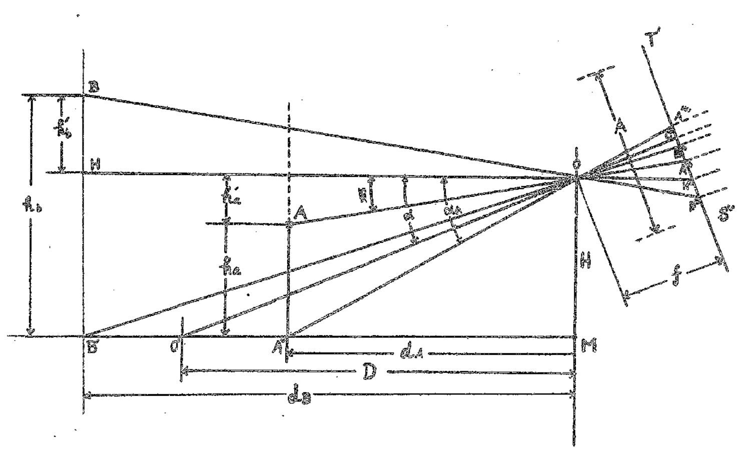


Fig. 7. Principle of the transit-camera (5).

by the vertical method.

## Method of Analysis

It is convenient to use the graphic method of analysis to diminish the trouble of calculation. So we set x—y coordinate with the origin O on a sheet of section paper of a large type and divide both axes into intervals of a unit of m, where x and y are horizontal and vertical axes respectively. Next, we draw a quadrant with a radius equivalent to the focal distance of the camera-lens f around the point O (Fig. 8).

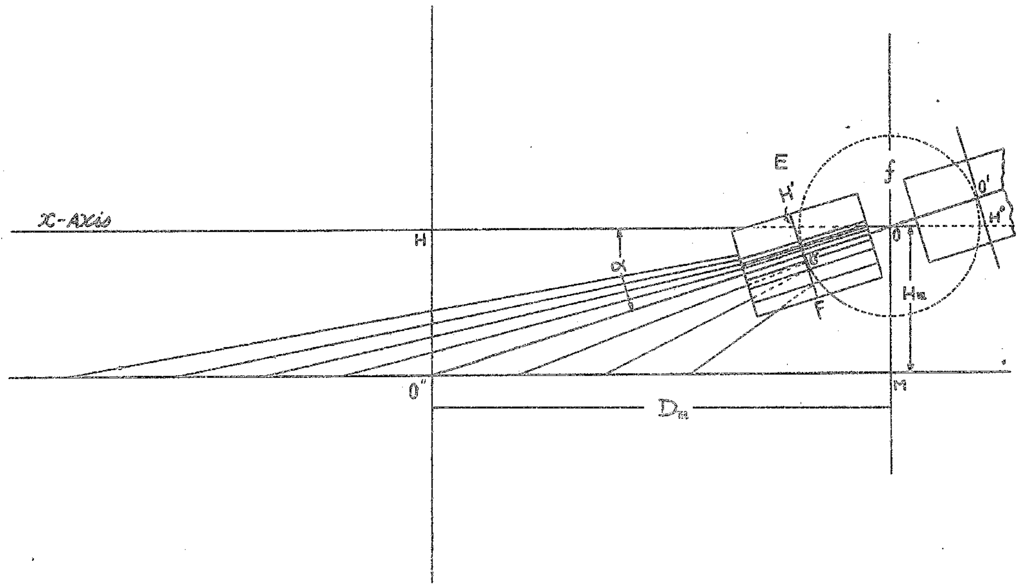


Fig. 8. a. Principle of analysis (1).
Remarks : f ; focal length of camera-lens (real magnitude, cm),
D ; horizontal length (reduced scale, m),
H ; height of camera (reduced scale, m),
α ; angle of depression,
H' ; height of eye.

i) Plane method of analysis :

First we mark the position of principal axis of lens (C in figures mentioned above) on a record paper, through which horizontal and vertical lines are drawn, and estimate the value of D (in m) from H and the angle of depression $a$.

In Fig. 8, let O″ denote the intersection of a line, having an angle $a$ with $\overline{Ox}$-axis, with the quadrant having a radius f, and let x-axis intersect at H′ with the tangent to this quadrant at O″, then $\overline{O''H}$ shows a length (on the record paper) equivalent to the height H of the camera. Accordingly we put the centre O′ of the record paper on H′ of the analysis paper and coincide the horizontal line of the record paper (H. L. ) on the $\overline{Ox}$-axis of the latter, and transcribe the position of O″ point on the vertical line (V. L. ) of the record paper, then H′ is a horizontal line

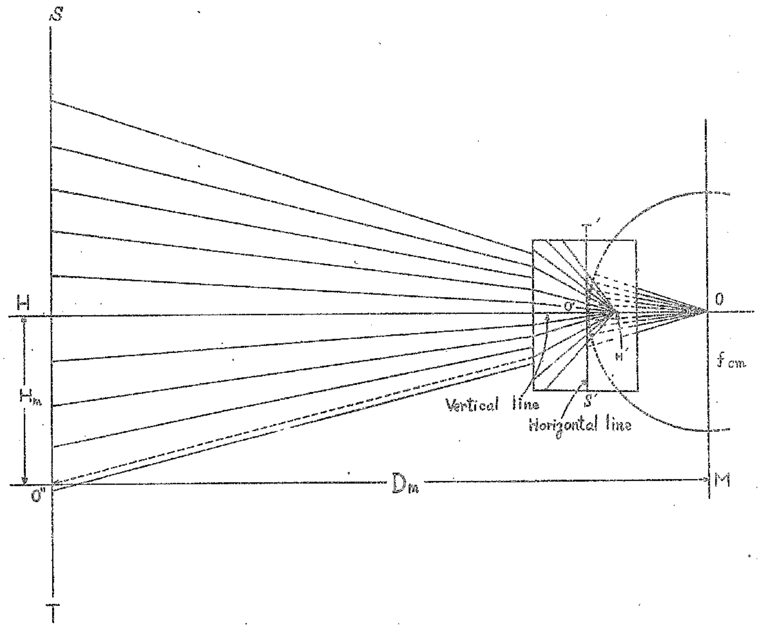


Fig. 8, b. Principle of analysis (2).
Remark : $\overline{ST}$ is a horizontal line perpendicular to $\overline{OH}$ at H.

through the centre of the camera-lens.*

Next, let $\overline{OO''}$ intersect at O' point with a line parallel to x-axis at a distance

* For reading of the height of camera from the record paper, it is convenient to use such a plane scale as shown in Fig. 19. This transparent paper has the same dimension as the photographic plate and various angles are marked on it according to the focal distance f of the camera-lens. Now we put this scale paper on the record paper so as V. L. and H. L. of this paper are superimposed on them of the record paper. If we mark $\alpha$, which is put on the record paper in case of image point stood normally, on the upper side of H. L. then the intersecting point of V. L. and H. L., then the point on which $\alpha$ lies shows a demanded image point on the record paper corresponding to the height of camera.

Also this paper scale may be used for test.

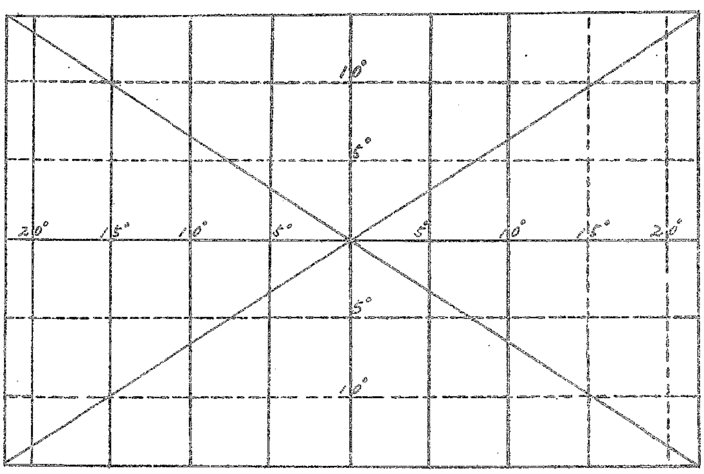


Fig. 19. (The reader is referred to the text for full account of the relation shown in this figure).

of H from O point, and mark the foot of the perpendicular to x-axis from O′, then

$$\overline{OH}=\overline{O'H}/\tan\angle HOC'=H\ \tan\ \alpha.$$

Therefore we obtain

$$\overline{OH}=D.$$

And we put the record paper on the analysis paper inversely so that the point O′ of the former coincides with O″ of the latter and V. L. of the former agrees with a tangential $\overline{EF}$ of that quadrant at O″. If we draw lines parallel to H. L. through the intersecting points of V. L. on the record paper with lines connecting the O point with points corresponding to several distances on $\overline{MO'}$, then those lines are equivalent to the above-mentioned distances on the projected line drawn on the standard surface by the principal axis of the camera-lens.

And, we superimpose the point O′ of the record paper on the H′ point of the analysis paper so that V. L. fall on x-axis and the upper part of the record paper lies on the same side as O.

Radical lines, connecting the point H′ on the record paper with cross points where H. L. on the record paper intersects with lines which connect the point O with points that represent distances on the line HO′, show the lines that afford us the distances frow the horizontally projected line of the principal axis of the camera. By two groups of these radical lines the record paper is divided into many squares. For example, a point B on the record paper lies at the point (40cm, 2.5cm left) to the centre of the camera-lens. Here notice that f is measured in real scale and D and H are measured in an optional reduced scale (Figs. 8-a and b). Fig. 9 shows an example of the record paper analysed by such method.

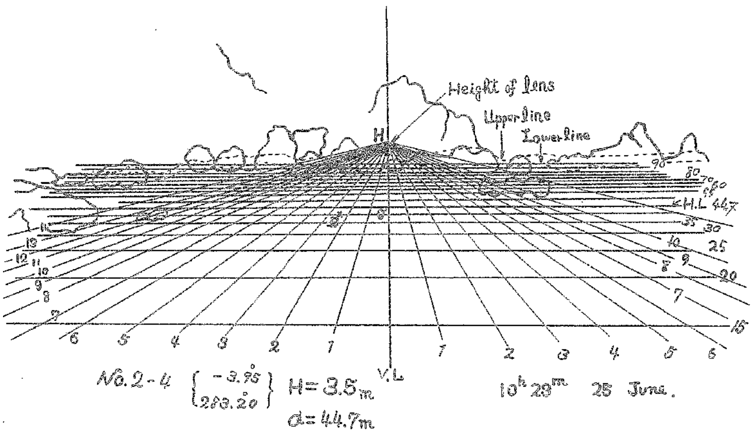


Fig. 9. An example of plane analysis.

ii) Vertical method of analysis :

Here we consider that this "vertical" method reveals the state in a vertical plane at an arbitrary point on the record paper as already written.

First, by the same operation as the plane method of analysis, we draw a horizontal line perpendicular to the principal axis of the camera at the specified point after obtaining V. L., H. L. and D. As Fig. 8-b, we draw perpendiculars to H. L. at points which stand at equal intervals from the origin on the horizontal line (Fig. 11-b). Next, we put the record paper on the analysis paper, by which the point O″ of the record paper coincides with the point O″ of the analysis paper and H. L. of the record paper is superimposed on $\overline{OO'}$ and H′ (height of lens) of

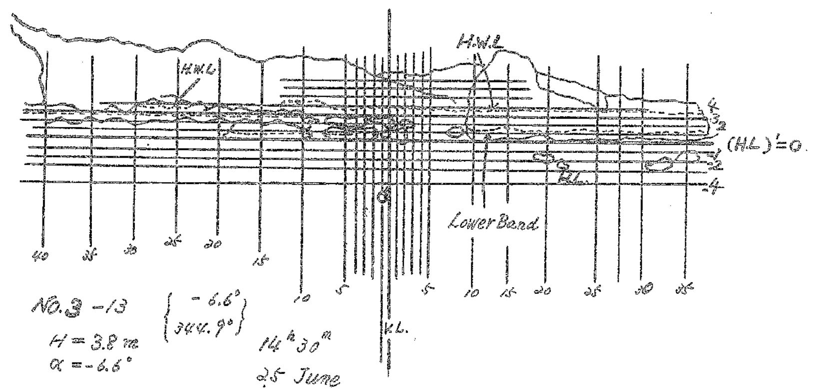


Fig. 10. An example of vertical analysis.
Remark : A and B correspond to the habitat of Barnacle and the habitat containing many species respectively.

the record paper lies on $\overline{OH}$, as shown in Fig. 11. If we draw lines perpendicular to V. L. through intersecting points which are made by V. L. of the record paper and lines connecting point O and points marked with equi-distance each other on a perpendicular to $\overline{OH}$ at an arbitrary point P, these lines show the heights of objects at point P. Therefore, from Figs. 11-a and b, we can complete the vertical analysis as Fig. 11-c. An example is shown in Fig. 10.

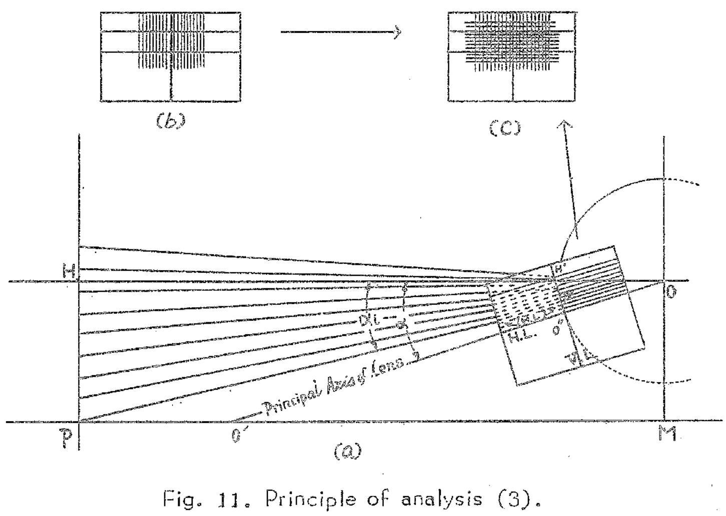


Fig. 11. Principle of analysis (3).

## Accuracy of analysis

Of several elements used in this analysis, H or the height of the camera-lens and $\alpha$ or the angle of depression can be directly measured and $\alpha_i$ or the angle of depression to a point lying at an arbitrary distance, hence $\tau_i$, $\xi_i$ and $\varepsilon_i$ are read from the record paper. H and $\alpha$ are the most fundamental elements among them. In the equation

$$\text{(a)} \qquad D = H/\tan\alpha,$$

$\alpha$ is about $0°-45°$ and it is usually inconvenient to analyse when $\alpha$ turns an angle of elevation, so we shoud set the camera as high as possible. Now if we denote the relative errors of two elements in the right side of (1) as $\delta H$ and $\delta(\tan\alpha)$ respectively, the relative error of D is obtained as follows ;

$$\frac{\delta D}{D}=\frac{\delta H}{H}+\frac{\delta(\tan\alpha)}{\tan\alpha}=\frac{\delta H}{H}+\frac{\tan(\alpha+\delta\alpha)-\tan\alpha}{\tan\alpha}.$$

If we put H=2, 5, and 10 m,

$$\delta H/H=0.025,\ 0.01 \text{ and } 0.005,$$

as we may take $\delta H \leqq 0.05$m. Therefore practically the maximum relative error may be considered as about 0.025.

Next, as $\delta\alpha=0.02°$, if we put $\alpha=1°$, $8°$ and $20°$, we obtain

$$\frac{\delta(\tan\alpha)}{\tan\alpha}=0.0057,\ 0.0028 \text{ and } 0.0011,$$

and thus it seems that the maximum relative error is practically 0.006. Accordingly it may be permitted to evaluate the maximum relative error as follows (Fig. 12);

$$\delta D/D = 0.025.$$

Thirdly, in case of

$$\text{(b)} \quad d_i=\frac{f\cos\alpha-\tau_i\sin\alpha}{f\sin\alpha+\tau_i\cos\alpha}\cdot H,$$

we obtain the following equation

$$\frac{\delta d_i}{d_i}=\frac{\delta(f\cos\alpha-\tau_i\sin\alpha)}{f\cos\alpha-\tau_i\sin\alpha}+\frac{\delta(\sin\alpha+\tau_i\cos\alpha)}{f\sin\alpha+\tau_i\cos\alpha}+\frac{\delta H}{H},$$

then

$$\frac{\delta(f\cos\alpha-\tau_i\sin\alpha)}{f\cos\alpha-\tau_i\sin\alpha}\leqq 0.00003,$$

$$\frac{\delta(f\sin\alpha+\tau_i\cos\alpha)}{f\sin\alpha+\tau_i\cos\alpha}\leqq 0.00002,$$

$$\frac{\delta H}{H} \leqq 0.025.$$

If we set $\delta\alpha=0.02°$ to $\alpha=1.0°$, $\delta\tau_i=2\times10^{-4}$ m to $\tau_i=10^{-3}$ m and $\delta H=0.05$ m to H= 2 m, because f=0.18m. Then

$$\frac{\delta D}{D}\leqq 0.025,$$

so the main factor affecting the maximum error may be regarded as $\delta H$.

In addition the maximum relative error based on errors of measures in evaluating the vertical and horizontal intervals at some optional distance $d_i$, are

$$\frac{\delta \ell_i}{\ell_i} \leqq 0.2, \qquad (\frac{\delta \varepsilon_i}{\varepsilon_i} \leqq 0.2),$$

$$\frac{\delta h_i}{h_i} \leqq 0.025. \qquad (\frac{\delta H}{H} \leqq 0.025),$$

from

$$\ell_i = \varepsilon_i \cdot H\sqrt{f^2+\tau_i^2}/f(f\sin\alpha+\tau_i\cos\alpha),$$

$$h_i = H\left(1+\frac{f\cos\alpha-\tau_i\sin\alpha}{f\sin\alpha+\tau_i\cos\alpha}\cdot\frac{f\sin\alpha-\xi_i\cos\alpha}{\xi_i\sin\alpha+f\cos\alpha}\right).$$

Or, in many case, the maximum relative error of observations affecting to $d_i$, $h_i$ and $l_i$ depends on terms concerned with H. Furthermore the reading of $\varepsilon_i$ exercises the considerable effect on the calculation of $\ell_i$. Accordingly, improving the accuracy of this reading is the first to be considered and yet actually difficult to attain.

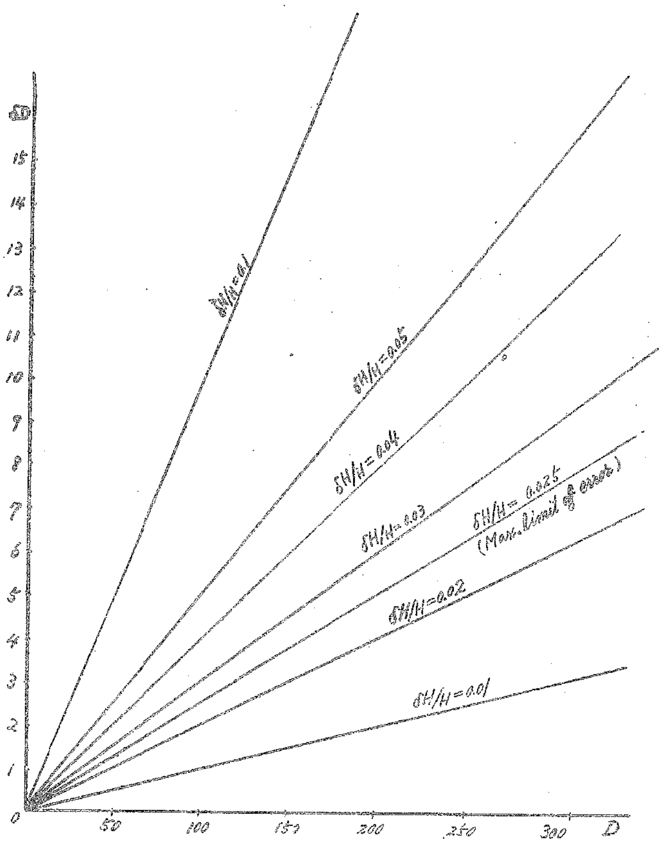


Fig. 12. Showing the degree of error of H due to the variation of D.

The above considerations are concerned with the calculation based on the actual value of f of our camera, generally we can hope that the degree of precision of $d_i$ should be increased by more accurate readig of H and that the error should be reduced by the enlarging of $\varepsilon_i$. But as regards $\varepsilon_i$, we must notice that even if $\frac{\delta\varepsilon_i}{\varepsilon_i}=0.2$, then $\frac{\delta\ell_i}{\ell_i}=0.2$, that is, the error amounts to 20 cm in case of the height of 1 m.

Moreover there is a problem by the variation of the sea surface as the standard surface at the time of observation, but considerably skilled observators may require only about ten minutes or less in tracing a sheet of record paper in the normal condition of habitat of the seaweeds. Then even in case when the rise and fall of tide is considerably conspicuous, the variation of the sea surface is at most only 10 cm or thereabout. So we may neglect that effect as compared with the vertical height of the object.

## Technical problems to be improved or heeded

There are some problems to be amended concerning with the apparatus, measurement and analysis;

1) To preserve the parallelism between the principal axes of the camera-lens and the transit-lens.

2) To use a camera-lens with a large resolving power.

3) To improve the accuracy in measuring the height of camera as great as possible.

4) To device some method by which we can analyse more simply and more accurately.

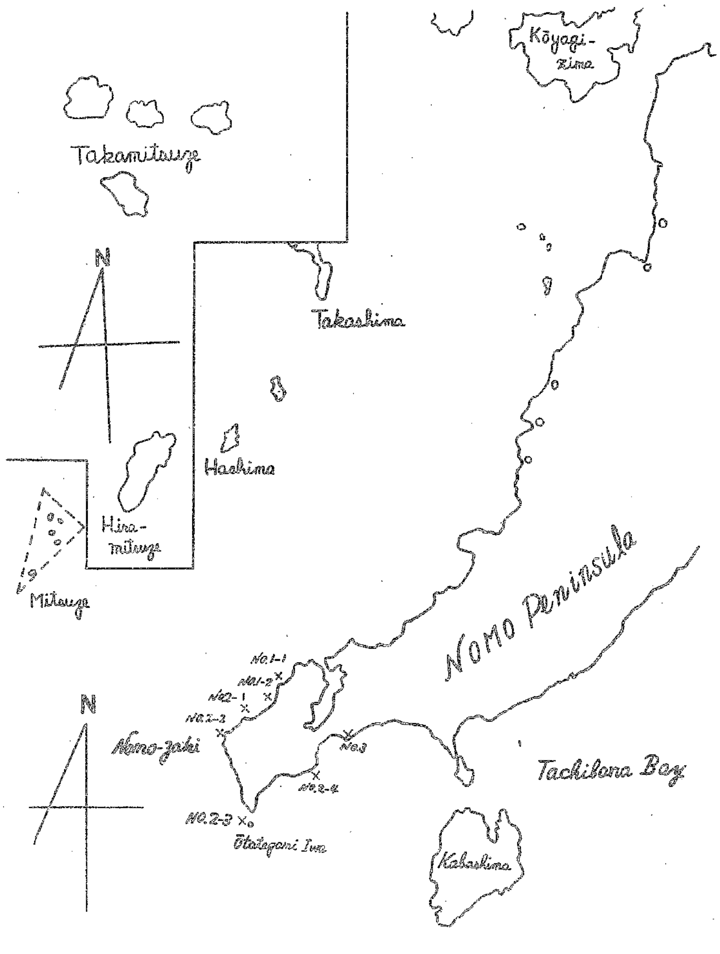


Fig. 13. Locality of observations.

## Actual example

The author and others carried out a survey on the habitat of the seaweeds for determining the degree of effect of barnacle to other seaweeds at the south projection of the Nomo Peninsula, Nagasaki Prefecture in June of 1949. We observed at 7 stations from that south projection of this peninsula and 4 stations at Mitsuze Is. off that projection, as shown in Fig. 13. As the times of observations are different from each other, we made the correction due to the tidal variations, assuming the lowest limit of the habitat of the gloiopeltis glue as the standard horizontal line, for that lowest limit forms almost horizontal straight line. Table 1

Table 1. Tidal time and its height at observations.

| Hour / Date | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 24 June | 216.9 | 170.7 | 120.8 | 78.2 | 52.1 | 48.5 | 68.1 | 107.7 | 158.6 | 210.5 | 252.4 |
| 25 〃 | 246.3 | 203.8 | 149.5 | 95.3 | 52.7 | 31.4 | 36.9 | 66.2 | 115.7 | 174.7 | 230.9 |

shows the times and heights of tide from the lowest surface on 24th and 25th of June. (Table 1 shows the same values as the port of Fukahori). And Tables 2 shows

Table 2. Details of observations.
Remarks : 1. V and H correspond to the vertical analysis and the plane analysis respectively.
2. Some data are used for measuring the waterrips or currents or mapping.
3. * corresponds to datum omitted because of its inadequacy.

| Date | Station number | Plate number | Hour | Height (H) | Direction of principal axis of lens ($\alpha$) | Horizontal direction of principal axis of lens | Diagram | Distance of vertical plane analysed(di) (m) | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| 24 June | 1 | 1 | 09h05m | 4.00m | 2.80° | 203.40 | * | * | * |
| | | 2 | 20 | 〃 | 0.90 | 59.85 | V | 190 | |
| | | 3 | 27 | 〃 | 1.70 | 354.05 | H | * | Water-rips |
| | 2 | 4 | 10 05 | 2.00 | 0.00 | 217.87 | V | 133 | |
| | | 5 | 12 | 〃 | 0.10 | 174.52 | * | * | * |
| | | 6 | 17 | 〃 | up 1.40 | 135.77 | * | * | * |
| | | 7 | 20 | 〃 | 0.10 | 189.57 | V | 40 | |
| | | 8 | 25 | 〃 | 1.40 | 54.87 | V | 40 | |
| | | 9 | 50 | 〃 | 1.22 | 359.47 | H | * | Current |
| | 3 | 10 | 12 20 | 4.50 | 4.70 | 281.60 | (4) V | 78, 58.5, 32.4, 17.8 | |
| | | 11 | 23 | 〃 | 9.00 | 128.35 | (2) V | 11.7, 284 | |
| | | 12 | 26 | 〃 | 6.00 | 249.70 | H | * | Current |
| | | 13 | 33 | 〃 | 10.50 | 266.00 | H | * | Map |
| | 4 | 14 | 13 25 | 3.80 | up 2.50 | 52.60 | V | 292 | |
| | | 15 | 30 | 〃 | 5.00 | 8.90 | V | 85 | |
| | | 16 | 35 | 〃 | 3.50 | 333.70 | V, H | 224 | Map |
| | 5 | 17 | 15 10 | 4.50 | 3.50 | 221.55 | H | * | 〃 |
| | | 18 | 13 | 〃 | 6.10 | 32.25 | H | * | 〃 |
| | 6 | 19 | 15 31 | 21.50 | 11.90 | 179.20 | H | * | 〃 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 25 June | 1 | 1 | 10 05 | 3.50 | 4.00 | 80.02 | H | * | 〃 |
| | | 2 | 12 | 〃 | 4.00 | 120.72 | V | 57.4 | |
| | | 3 | 18 | 〃 | 4.50 | 155.42 | V | 135 | |
| | | 4 | 23 | 〃 | 4.50 | 184.02 | V | 129 | |
| | | 5 | 30 | 〃 | 4.50 | 214.82 | V | 205 | |
| | 2 | 6 | 11 45 | 12.40 | up 1.00 | 359.65 | V | 103 | |
| | | 7 | 53 | 〃 | up 3.00 | 41.80 | * | * | * |
| | | 8 | 12 05 | 〃 | 13.10 | 76.10 | * | * | * |
| | | 9 | 19 | 〃 | 16.80 | 124.90 | H | * | Map |
| | | 10 | 28 | 〃 | 16.70 | 163.20 | H | * | Map |
| | 3 | 11 | 14 00 | 3.80 | 5.10 | 341.15 | V | 109 | |
| | | 12 | 07 | 〃 | 6.60 | 20.55 | V | 73 | |
| | | 13 | 30 | 〃 | 〃 | 48.90 | V | 91 | |
| | | 14 | 38 | 〃 | up 0.20 | 134.22 | V | 100 | |
| | 4 | 15 | 16 40 | 4.20 | 2.60 | 253.46 | * | * | * |
| | | 16 | 47 | 〃 | 3.50 | 293.24 | V | 108 | |
| | | 17 | 17 10 | 〃 | 〃 | 329.66 | V | 67 | |
| | | 18 | 20 | 〃 | 3.00 | 6.06 | H | * | * |
| | | 19 | 30 | 〃 | 〃 | 53.76 | * | * | * |
| | | 20 | 32 | 〃 | 8.00 | 140.09 | V | 90 | |
| 26 June | 1 | 1 | 09 40 | 44.00 | 6.80 | 185.45 | H | * | Map |
| | | 2 | 43 | 〃 | 〃 | 271.30 | H | * | 〃 |
| | | 3 | 49 | 〃 | 6.30 | 239.33 | H | * | 〃 |
| | | 4 | 52 | 〃 | 16.80 | 209.05 | H | * | 〃 |
| | | 5 | 56 | 〃 | 10.00 | 178.70 | H | * | 〃 |
| | | 6 | 10 00 | 〃 | 13.00 | 148.35 | H | * | 〃 |
| | | 7 | 09 | 〃 | 14.70 | 115.33 | H | * | 〃 |
| | | 8 | 12 | 〃 | 9.00 | 77.95 | H | * | 〃 |
| | | 9 | 18 | 〃 | 9.00 | 37.10 | H | * | 〃 |

the details of observed matters. The result is shown in Fig. 13′, omitting the data that could not be analysed, and the shaded portion contains many species, such as *Higikia fusiforme* (HARV.)OKAM., *Carpopeltis affinis* (HARV.) OKAM., *Corallina* and others, and the portion fringed by dotts corresponds to the band of barnacle.*

From Fig. 13′ we can consider that the vertical dimension of the lower

* Almost all surfaces of habitat incline to the vertical plane and are often not perpendicular to a horizontal plane containing the principal axis of lens, so in case of relatively short distance it shoud be noted that li and hi calculated from the record paper may have a small difference from the actual values. As at any rate there exists only the difference of direction, if let $\theta$ denote the angle of actual surface S with a surface S″ perpendicular to the principal axis or its projected line on the horizontal plane,

$$\ell' = \ell \cos \theta,$$

where $\ell'$ is obtained from measurement and $\ell$ is an actual length. Therefore it may be considered that when the distance between the camera and the measured plane is fairly long, unevenness becomes to be measured after being averaged to be almost uniform and over a considerable range we obtain an averaged value, notwithstanding the existence of differences of $\theta$. Accordingly it may be considered that the effect of the difference between $\ell$ and $\ell'$ is not so much.

Next, the distance of the measured plane from the camera was calculated on each record paper based upon the midpoint of each habitat band as shown in Fig. 15. It may be permitted to consider that by this procedure errors produced by the local

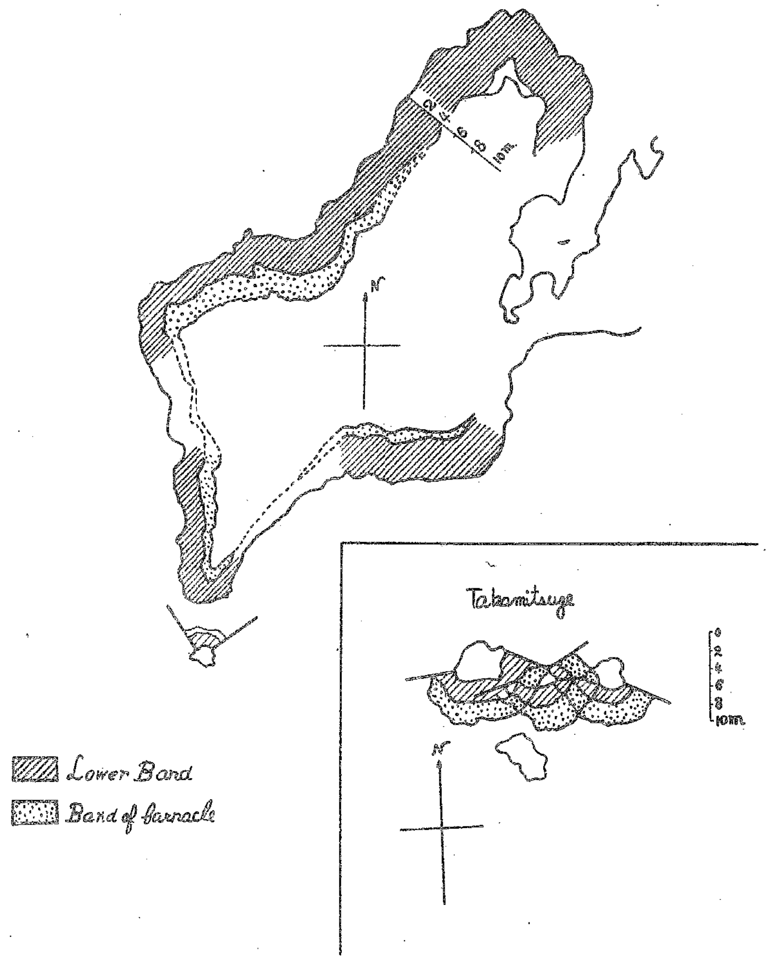


Fig. 13'. Results of observations.
Remarks : The shaded portion and dotted portion correspond to the lower band and the band of barnacle respectively.
In addition, in the direction normal to the coastline the vertical width of each band is measured.

band (shaped) is larger in the northern and south-eastern parts of this projection than in the western and southwestern parts, and the band of barnacle shows an opposite tendency. It happens to see the perfect absence of the band of barnacle in some part. Table 3 shows the maximum, minimum and average values of the

unevenness or the unequal inclination of the measured plane can be considerably offset before its calculation,

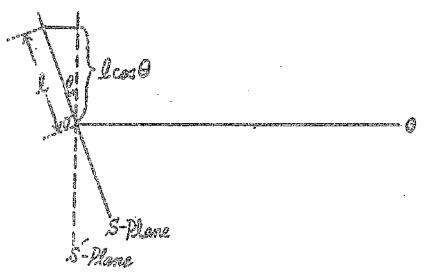


Fig. 14. (The reader is referred to the text for full account of the relation shown in this figure).

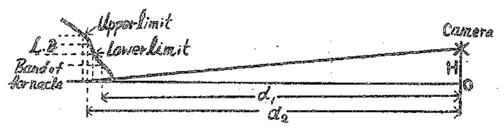


Fig. 15. (The reader is referred to the text for full account of the relation shown in this figure).

Table 3. Vertical widths of both bands(m).

| | Upper band | | | Lower band | | |
|---|---|---|---|---|---|---|
| | Max. | Min. | Mean | Max. | Min. | Mean |
| St. 1 — 1 | — | — | 3.80 | — | — | 1.00 |
| St. 1 — 2 | 2.50 | 1.60 | 2.05 | 1.25 | 0.75 | 0.90 |
| St. 2 — 1 | 3.80 | 2.00 | 2.50 | 2.75 | 1.00 | 1.60 |
| St. 2 — 2 | — | — | 2.75 | 2.85 | 1.25 | 2.05 |
| St. 2 — 3 | 1.80 | 1.10 | 1.40 | 2.35 | 0.50 | 1.30 |
| St. 2 — 4 | 2.50 | 1.50 | 2.10 | 1.80 | 0.80 | 1.20 |

vertical width of both bands. Because there is no record concerning with the inclination of the surface of each band, we can not evaluate the surface area of each band. From Table 3 and 4 we obtain the following equation of regression :

$$x=-3.12+4y, \text{ or } y=0.78+0.25\,x,$$

where x and y are the vertical width of each band respectively (Fig. 16). And if $x'=x+y$ and $y'=x/y$, obtain Fig. 17 and the following linear equation :

$$y'=0.98+0.15\,x'.$$

In Table 5 there is tabulated average values and the deviation of each value from the average of $x'$ and $y'$.

Finally from this actual survey we can conclude as follows:

1) Variations of the lower band and the band of barnacle are proportional and the rate of increase of the former is somewhat larger than that of the latter.

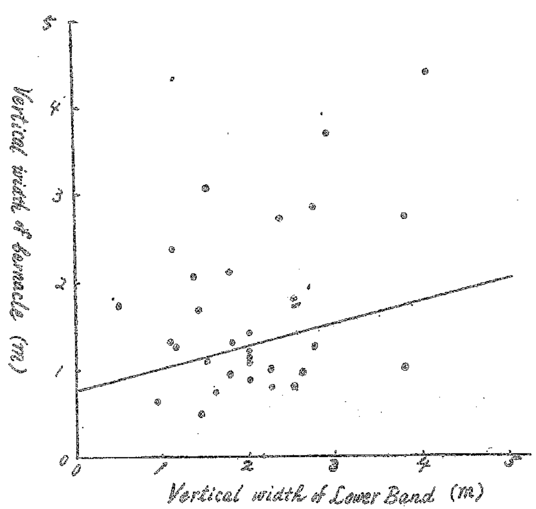


Fig. 16. Relation between the lower band and the band of barnacle.

Table 4. Details of analysis.
Remarks. : 1. m shows the value analysed on record paper.
2. C shows the height of the lower band above the standard surface.
3. V is composed from m and C.

| Date | Station number | Plate number | Hour | Direction of coastline | Vertical width of bands | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower band | | | Band of barnacle |
| | | | | | m | c | v | |
| 24 June | 1 | 2 | 09h20m | N N W | 3.03m | 1.54m | 3.80m | 1.00m |
| | 2 | 4 | 10 05 | N W | 1.00 | 1.20 | — | 0.75 |
| | 2 | 7 | 10 20 | N W W | 1.40—1.50 | 1.04 | 2.00 | 1.23 0.87 |
| | 2 | 8 | 10 25 | N W W | 1.98 | 1.00 | 2.50 | 0.83 |
| | 3 | 10— 1 | 12 20 | W | 3.80 | 0.48 | 4.05 | 4.40 |
| | 3 | 10— 2 | 〃 | W | 1.50 | 〃 | 1.75 | 0.95 |
| | 3 | 10— 3 | 〃 | W | 1.26 | 〃 | 1.50 | 3.10 |
| | 3 | 10— 4 | 〃 | W | 1.10 | 〃 | 1.35 | 2.07 |
| | 3 | 11— 1 | 12 23 | S S E | 1.80 | 0.47 | 2.00 | 1.10 |
| | 3 | 11— 2 | 〃 | S S E | 1.18 | 〃 | 1.40 | 21.65 |
| | 4 | 14 | 13 25 | W | 0.70 | 0.54 | 0.95 | 0.65 |
| | 4 | 15 | 13 30 | S W | 2.31 | 0.56 | 2.60 | 0.97 |
| | 4 | 16 | 13 35 | S | 1.45 | 0.58 | 1.75 | 2.08 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 25 June | 1 | 2 | 10 12 | N W | 1.32 | 1.36 | 2.00 | 1.16 |
| | 1 | 3 | 10 18 | N N W | 3.16<br>1.70 | 1.30 | 3.80<br>2.35 | 2.73 |
| | 1 | 4 | 10 23 | N | 1.40 | 1.25 | 2.00 | 1.42 |
| | 1 | 5 | 10 30 | N N W | 1.67 | 1.20 | 2.27 | 1.00 |
| | 2 | 6 | 11 45 | W | 2.47 | 0.60 | 2.75 | 1.25<br>2.87 |
| | 3 | 11 | 14 00 | W | 1.61 | 0.37 | 1.80 | 1.03 |
| | 3 | 12 | 14 07 | W | 1.26 | 0.38 | 1.45 | 0.50 |
| | 3 | 13 | 14 30 | S S W | 0.91 | 0.48 | 1.15 | 1.28<br>2.36 |
| | 3 | 14 | 14 38 | NW—NNE | 0.85 | 0.52 | 1.10 | 1.30 |
| | 4 | 15 | 16 40 | SSE—SSW | 1.75 | 1.56 | 2.50 | 1.80 |
| | 4 | 16 | 16 47 | S —SSW | 1.43 | 1.63 | 2.25 | 0.80 |
| | 4 | 17 | 17 10 | S S E | 1.25 | 1.80 | 2.15 | — |
| | 4 | 20 | 17 32 | N N W | 0.50 | 2.06 | 1.50 | 1.10 |

Table 5. Values of $(\bar{a}+\bar{b})$, $(\bar{a}/\bar{b})$ and their deviations from the mean value respectively.
Remark : Normal direction means a direction of normal line to the coastline at its middle point.

| Station | $\bar{a}+\bar{b}$ (m) | $\triangle(\bar{a}+\bar{b})$ (m) | $\bar{a}$ / $\bar{b}$ | $\triangle(\bar{a}$ / $\bar{b})$ | Remarks |
|---|---|---|---|---|---|
| 1 — 1 | 4.80 | + 1.15 | 3.80 | + 2.16 | Normal direction : NW |
| 1 — 2 | 2.95 | — 0.70 | 2.28 | + 0.64 | 〃 : NWW |
| 2 — 1 | 4.10 | + 0.45 | 1.57 | — 0.07 | 〃 : NEN |
| 2 — 2 | 4.80 | + 1.15 | 1.34 | — 0.20 | 〃 : WNW |
| 2 — 3 | 2.70 | — 0.95 | 1.08 | — 0.56 | 〃 : SSE |
| 2 — 4 | 3.30 | — 0.35 | 1.08 | — 0.56 | 〃 : SSE |
| Mean $(\bar{a}+\bar{b})$ =3.65m, | | | Mean $(\bar{a}$ / $\bar{b})$ =1.64 | | |

2) It can be considered that between the direction of the coast and the dimension of the habitat there is some relationship, or

$90° < r < 270°$ (mag. azimuth)··············$\triangle(\bar{x}+\bar{y})<0$ and $\triangle(x/y)<0$,

$0° \leqq r < 90°$ and $270° < r \leqq 360°$ ( 〃 )··············$\triangle(\bar{x}+\bar{y})>0$,

where r denotes the direction of the coast and $\triangle$ shows the deviation from the average value (Fig. 18).

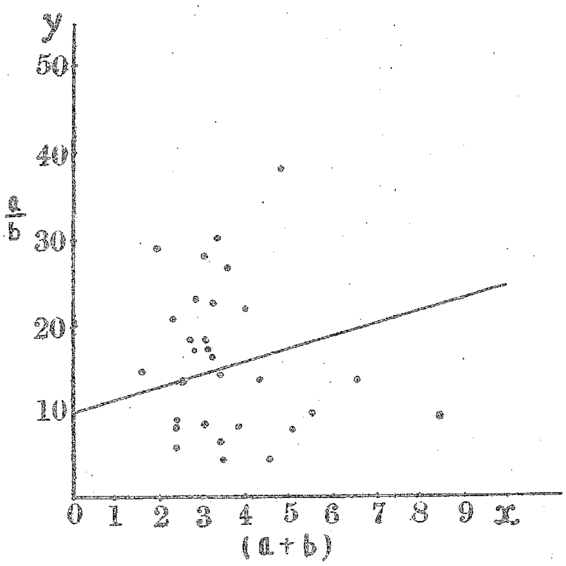


Fig. 17. Relation between $(\bar{a}+\bar{b})$ and $(\bar{a}/\bar{b})$.

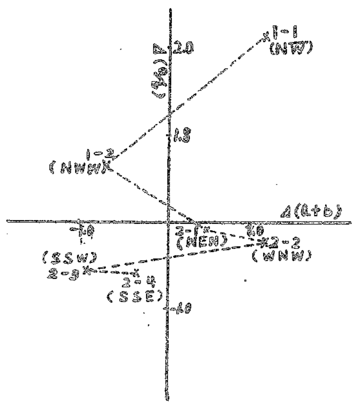


Fig. 18. Relation between the direction of normal line to the coastline and the vertical widths of both bands.

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