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Race Rocks

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EXTENDED ESSAY TITLE PAGE

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SCHOOL: LESTER B. PEARSON COLLEGE **SCHOOL CODE:** 0034

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EXTENDED ESSAY TITLE:

A Study of a Biological System on an Introduced Substrate in the High Current Zone of the Race Rocks Ecological Reserve.

IB SUBJECT: Biology
BEST LANGUAGE[S]: English, Danish
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LANGUAGE B: English B
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Table of Contents

Abstract

An almost 1 m^3 submersed concrete block in a high current area was studied in 5 dives. The frequencies of 8 indicator species on the four vertical faces of the block were recorded. The number of individuals of each species on each face were then compared to see if any conclusions about correlations could be drawn.

To explain the correlations and differences in the number of individuals of each indicator species, various factors such as current and sunlight, were studied closer.

Acknowledgement

For making me so interested in this subject as a whole, and for being so helpful with, and interested in this essay, I want to thank mr. Garry Fletcher, who gave me his advise and concerns.

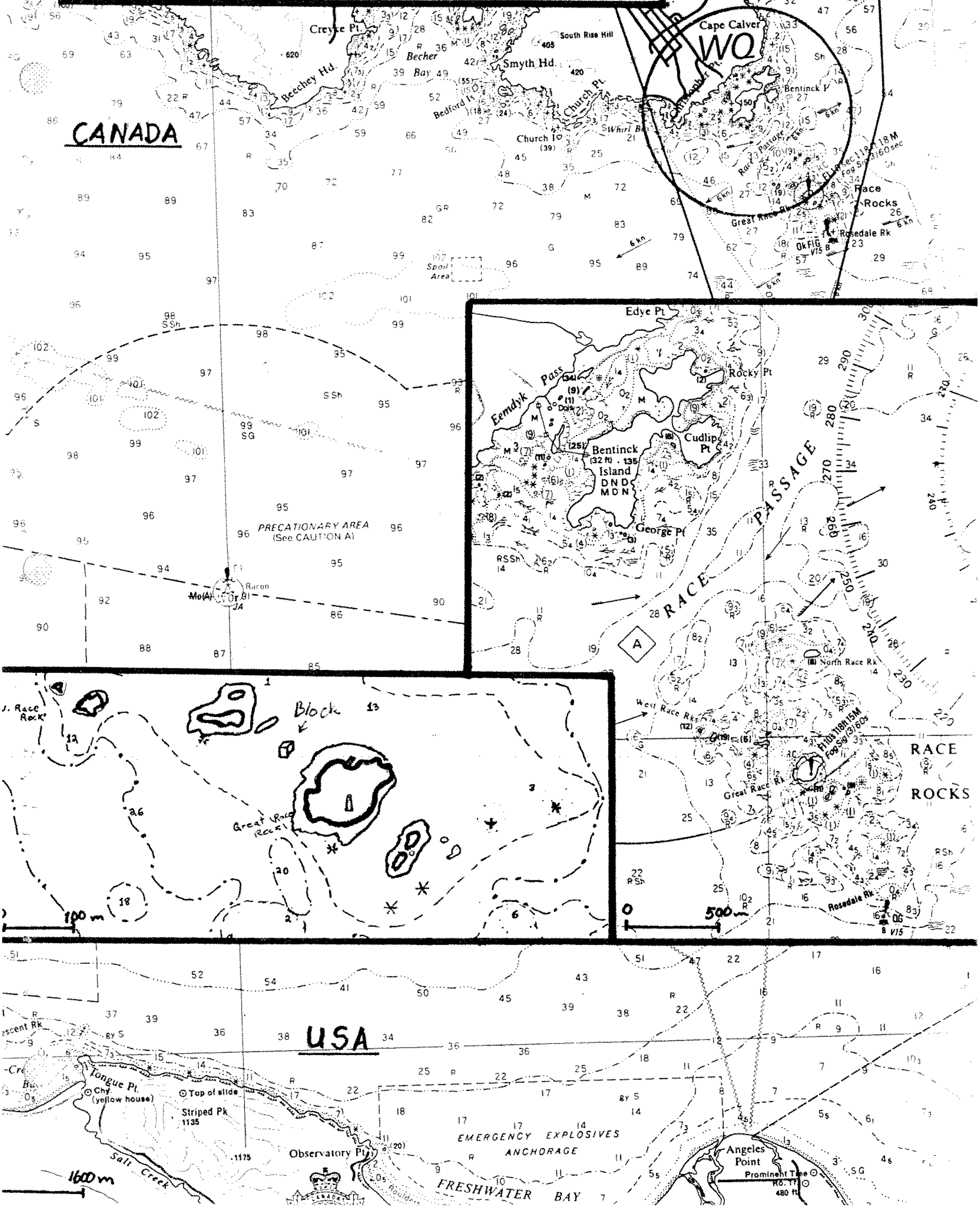
I would also like to thank Dr. Anita Brinkmann-Voss for her help in identifying species, and for sharing some of her knowledge about the marine environment around this area.

Introduction

In 1980, a concrete block was lowered the 10m down to the bottom of Inner Race Passage, Race Rocks, Vancouver Island, Canada. The purpose was to install a current meter on a line between a float and the block. This was done over one year, and the results were analyzed in a computer, which then made current-table predictions for the future. (Woodward,M.J,1980)

This concrete block has undergone ecological succession over the past 10 years. The block forms the substrate of an ecological system that is investigated in this study.

Map #1 : Location of Race Rocks and the concrete block.



Hypotheses

One general hypothesis involving all 8 indicator species was made up, and from this general hypothesis, three sub-hypotheses concerning specific species were developed:

General hypothesis concerning all 8 indicator species:
There is no significant difference and relation in the number of organisms of each species between the four vertical faces of the block.

Sub hypothesis concerning the distribution of Epiactis prolifera:
There is no significant difference in the number of individuals in the Epiactis prolifera populations living on any two faces of the block.

Sub hypothesis concerning the distribution of Garveia annulata:
There is no significant difference in the number of individuals in the Garveia annulata populations living on any two faces of the block.

Sub hypothesis concerning the Tonicella lineata, Lithothamnion sp. relationship:
There is no significant correlation between the number of Tonicella lineata in a specific square, and the surface area covered by Lithothamnion sp. in that same square.

Assumptions

1. It is assumed that in the 5 days of recording, there were no significant changes in the biotic factors of the system, such as predation, grazing, nutrient flow, salinity, and temperature, so that all the data are comparable.

2. It is also assumed that the system has not been disturbed by any abiotic factors such as ships, humans or passing marine mammals.

3. The divers collecting data did so accurately and in an unbiased fashion.

4. This block is representative of a newly introduced natural substrate in high current zones of equivalent depth.

Delimitations

This preliminary study is only intended to analyze a very specific area, as specified in Map #1. Applying conclusions from this essay to a block anywhere else than at the one at Race Rocks would therefore not be correct, and it might lead to some wrong results. This study was done during May, 1990 and might have changed since then.

Limitations

The use of mathematical models as basis for considering a correlation for being significant or not, can be questionable because no mathematical model can describe nature. However, mathematical analyses give us very precise results since these models have been developed and improved over many years. This problem is mentioned later in "Analysis of Tonicella lineata and Lithothamnion sp. correlation".

Choosing 8 indicator species as representatives for the whole population on the block, instead of counting every individual in each species population on the block, also give some limitations. However, it would be almost impossible to recognize and count every single species. As many indicator species as allowed by the divers knowledge would have been the most reliable and the best representation, but the physical conditions the divers and the researcher had, limited this number to 8.

Background

The reason why I chose a topic involving both energy input into a system and taking transects was my big interest in both physics and the environment. Also the excellent conditions for studying high energy input (caused by extreme exposure), and marine life with high species diversity here on the southern tip of Vancouver Island.

Purpose

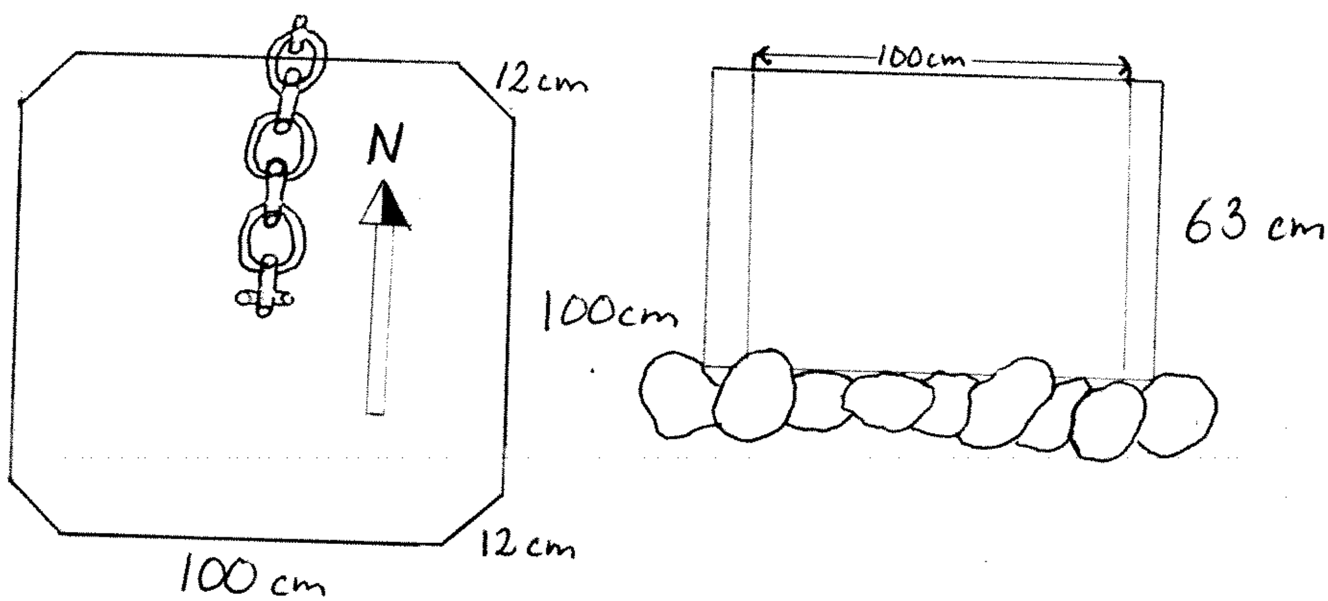
My aim for this essay was to explore a complex ecosystem to see how different factors would affect different populations, but it was also meant as a succession study, to see which populations would dominate the block, after having been submerged for 10 years.

My aim was also to test the four null-hypotheses described in "Hypotheses". If these hypotheses were rejected by using statistical analysis my aim was to make an alternative hypothesis based on qualitative measurements of the environmental conditions around the block to explain this population diversity.

Method

The research and the measurements were all carried out at 10m depth, so SCUBA diving equipment was used. On the first SCUBA dive to the block, the measurements of the block, and the compass bearings of each face, were recorded. As seen on Figure #1, the sides of the block are oriented in perfect North, South, East and West direction, and the block is 100cm long on each side, and 63cm high everywhere.

Figure # 1: The block studied closer.

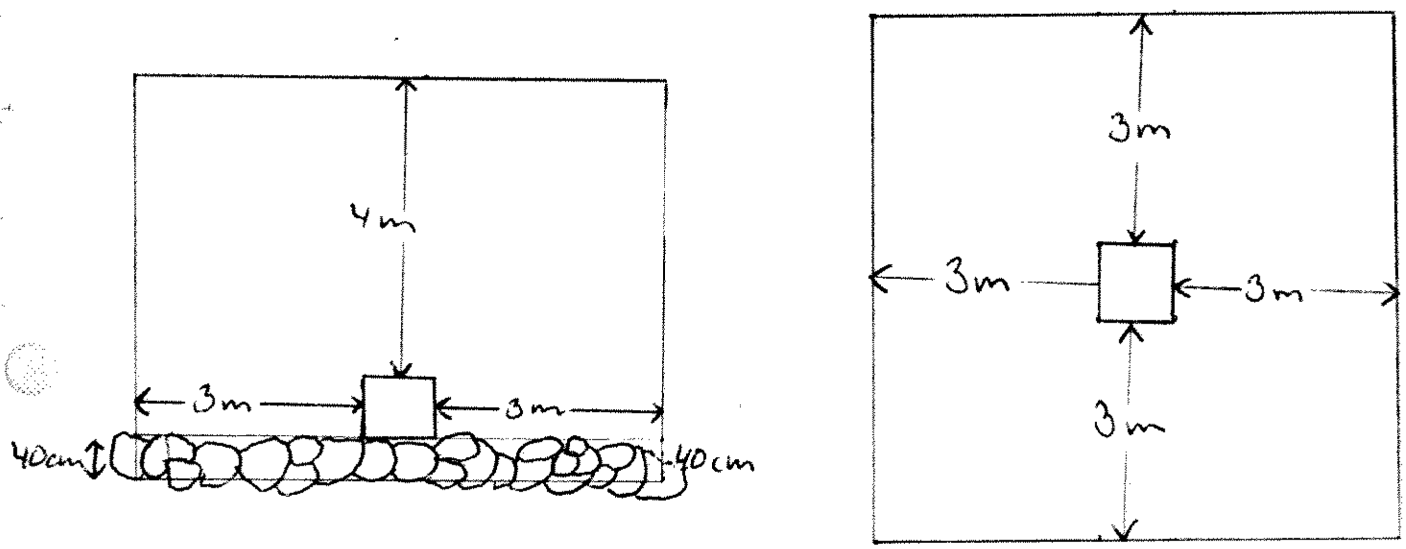


Furthermore, four 12cm long sides with angles of 45° to the 100cm long sides were on the block. To make all further calculations easier, I made a "simplification" of the block: I neglected the four 12cm corners, assuming that these did not have an area big enough to make significant and reliable data. Also, the current running over the block hits the East and the West side in a right angle, and is parallel to the North and the South side. As the angles between the 12cm sides and the 100cm sides each are 45°, the current flowing over the block will hit all 12cm-sides in the same angle, and therefore one of the most important abiotic factors, the current, will be equal on all of the four 12cm sides, not creating a possible species and population diversity between these four 12cm sides.

As shown on Figure#1, there is a chain hanging down over the North side. This shouldn't have any significant role in the species distribution. The bottom around the block mainly consists of stones with an average diameter of 30cm, overgrown with red algae, hydroids, mussels (Mytilus californianus), barnacles (Balanus balanoids) and brooding anemones (Epiactis prolifera). After having done these bottom observations, and therefore gained some knowledge about the environment around the block, I assumed that the block with the following boundaries was a system. I defined the boundaries as being 3m beside the block, and 4m over it, containing the upper 40cm of the bottom layer also in a distance of 3m from the concrete block. The explanations of this choice of boundaries are as follows: The reason for including the upper 40cm in a radius of 3m of the bottom layer is that these attached, benthic organisms have an impact on the organisms living on the block. Spores from the red algae can as an example settle on the block and grow there. Other kinds of reproduction, such as medusae from hydroids on the bottom can settle on the block and therefore change the biotic structure of the life on the block. In fact, as described later in "Experiment #1", the possibility of neutrally buoyant particles settling on the block is higher than anywhere else inside the defined boundaries, because of the eddy flows around the block.

The 3m from the sides of the block to the boundaries were mainly chosen to follow the 3m boundary that was chosen for the bottom layer.

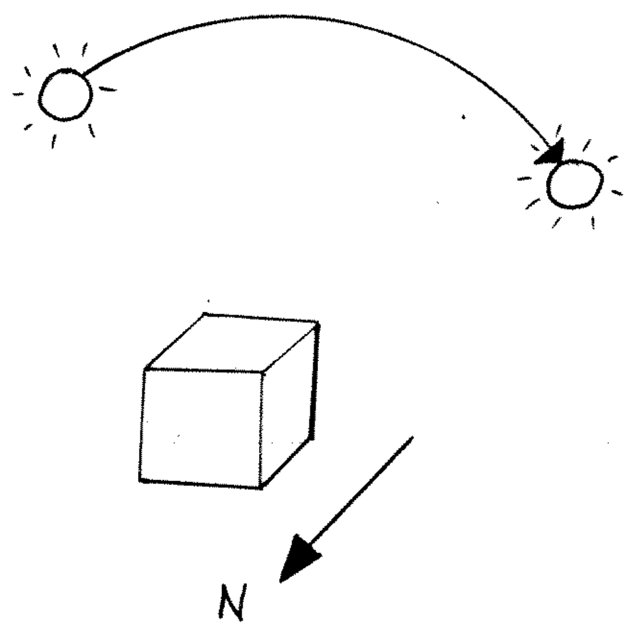
Figure # 2: Boundaries of the system.



The distance of 4m from the block to the upper boundary is there to include the brown algae, Nereocystis luetkeana, (also called bull kelp) which was growing on the top of the block. This algae was about 4m long when my recordings found place, but during the summer months, some bull kelp reach a length of 15m. Defining a systems boundaries involves a lot of assumptions, and give many limitations. In a very current swept area, like Inner Race Passage, where my block is situated, it is extremely hard to fit a system into boundaries, because no matter how the boundaries are defined, the current will always give an extremely high input of energy to the system. In this case, the energy is mainly in form of nutrients and detritus. This is certainly the case with a flood at Race Rocks where all the nutrients from the nutrient-rich Pacific Ocean are pushed into the Juan de Fuca Strait by the tide.

Wave motion, which is a very important factor affecting exposed rocky shore populations, is not a very important condition on the block because the waves do not make water movement at 10m depth where the block is situated. Another important factor giving energy to the system is the sun.

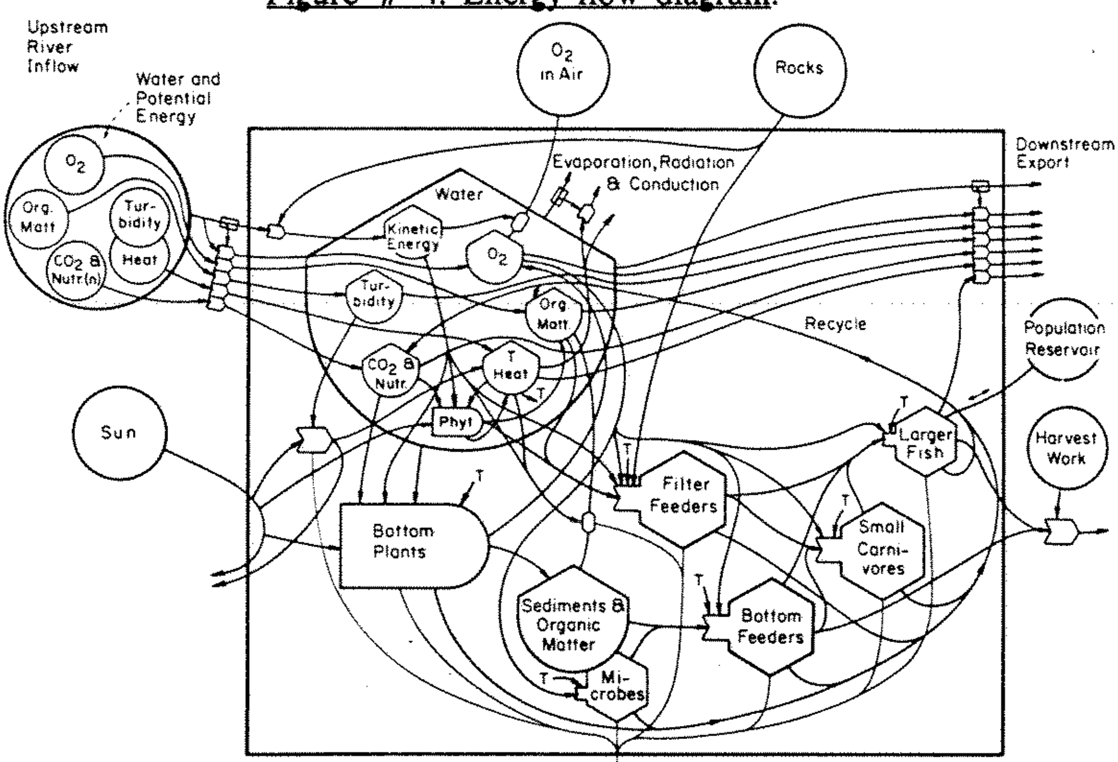
Figure # 3: The sun falling on the block.



However, this input is only a fraction of what it would have been on a sunny spot on land because the light that hits the water gets absorbed and reflected. Several factors such as water turbidity, sea surface condition (calm or waves), angle between the sun and the sea surface and light intensity affect the distance of which the different wavelengths of light reach down towards the bottom before getting absorbed.

The big wave motion, and the high turbidity due to plankton and nutrients in the water at Race Rocks, cause the light to be absorbed very fast. In some very silt and nutrient filled coastal waters, 2/3 of the available surface light is absorbed within the upper 10m.(Sumich, Dudley, 1976). However, after having had many dives around Race Rocks, my impression is that at least 50% of the available surface light penetrates through the 10m of water, so this input is certainly not negligible.

Figure # 4: Energy flow diagram.



The intensity of the sun changes the temperature of the water running over the block. This temperature is a very crucial factor for determining the species living on the block. (Pickett, White, 1985)

The salinity and the pH of the water interacting with the block are also very important when an attempt to "break down" the abiotic factors interacting within the populations of the block is made. (Sumich, 1976)

All of these factors together with biotic factors such as grazing, pollution, and diseases interact with the different populations on the block with different results. These interactions and results will be studied and analyzed closer in the part called "Analyses".

Data recording procedure

To make the recording of species as convenient as possible, since air and heat loss limited the divers time under water, a list containing 8 indicator species was worked out from the qualitative observations that were done when the divers had their first dive at the block. On this first dive, samples of species from the block were selected, put in sampling bottles, and brought back to a saltwater tank with circulating water. Here Dr. Anita Brinkman-Voss helped identifying the different species so that the divers would be able to recognize these species underwater. Also a rectangular grid which measures 100cm x 13cm was made of PVC pipes, and split into 10 smaller rectangles. The grid was used by the divers to put over one side of the block, and the frequencies of the species, sometimes containing more than the 8 indicator species, were recorded from the smaller 20cm x 31.5cm rectangles, which were numbered according to Figure#5.

Figure # 5: Grid size and numbering.

5	4	3	2	1
10	9	8	7	6

63 cm

100 cm

The frequencies were recorded on a plastic slate carried by the divers (Holme, McIntyre, 1984), and when returned to the college, they were transferred to a computer to do calculations and graphs.

Four more dives were made from May 17th to May 22nd. Each time the divers went down to record the frequencies of organisms living on one side, so that the amount of data I had from each side was sufficient enough to provide reliable data for analysis, and so that no wrong trends and correlations were drawn.

Recording the data over 5 days also made it more reliable than if it had been recorded over a month, because no system remains in equilibrium.

Data

As mentioned before, the frequencies of 8 indicator species were recorded from each side of the block and analyzed in a computer.

Table # 1: Data from the north face.

Species	Quadrat number 1	2	3	4	5	6	7	8	9	10
Epiactis prolifera	10	11	6	11	10	11	9	9	15	15
Tubularia marina	6	5	4	3	5	5	3	10	2	6
Calliostoma ligatum	3	1	0	0	1	0	2	1	0	3
Aglaophenia latirostis	10	20	15	10	0	20	15	10	25	15
Tonicella lineata	3	2	1	1	1	2	1	1	1	2
Garveia annulata	20	15	20	20	30	0	15	10	25	25
Distaplia occidentalis*	20	25	15	30	15	30	10	30	55	10
Lithothamnion sp.*	70	50	60	40	30	60	50	30	20	50

*) In percentage cover

Table # 2 : Data from the south face.

Species	Quadrat number 1	2	3	4	5	6	7	8	9	10
Epiactis prolifera	10	13	15	12	10	8	9	13	8	10
Tubularia marina	3	5	6	4	4	0	3	7	5	4
Calliostoma ligatum	1	2	1	0	2	0	0	1	0	0
Aglaophenia latirostis	10	5	20	10	80	10	15	10	15	60
Tonicella lineata	1	0	1	0	1	0	1	2	0	1
Garveia annulata	1	3	0	5	0	3	1	1	0	2
Distaplia occidentalis*	0	5	0	10	0	0	5	0	10	0
Lithothamnion sp.*	15	5	10	0	10	5	10	15	0	5

*) In percentage cover

Table # 3: Data from the east face.

Species	Quadrat number 1	2	3	4	5	6	7	8	9	10
Epiactis prolifera	2	1	7	4	5	5	3	0	10	3
Tubularia marina	3	2	2	1	1	4	3	1	4	2
Calliostoma ligatum	2	1	3	1	0	0	0	0	1	0
Aglaophenia latirostis	10	25	15	10	10	10	20	15	10	5
Tonicella lineata	1	1	2	0	0	0	2	0	1	0
Garveia annulata	1	0	2	5	5	0	8	5	0	3
Distaplia occidentalis*	10	5	5	5	0	5	5	10	0	5
Lithothamnion sp.*	10	5	15	5	0	5	10	5	10	5

*) In percentage cover

Table # 4: Data from the west face.

Species	Quadrat number 1	2	3	4	5	6	7	8	9	10
Epiactis prolifera	6	5	2	8	7	5	9	5	0	7
Tubularia marina	5	1	1	4	15	6	3	7	4	2
Calliostoma ligatum	1	0	1	3	0	1	2	0	3	1
Aglaophenia latirostis	15	10	15	5	10	5	10	15	10	15
Tonicella lineata	2	0	2	1	1	0	1	2	1	2
Garveia annulata	3	5	6	0	10	7	0	0	1	25
Distaplia occidentalis*	10	5	10	15	15	10	5	0	10	5
Lithothamnion sp.*	60	10	20	50	30	40	20	60	30	40

*) In percentage cover

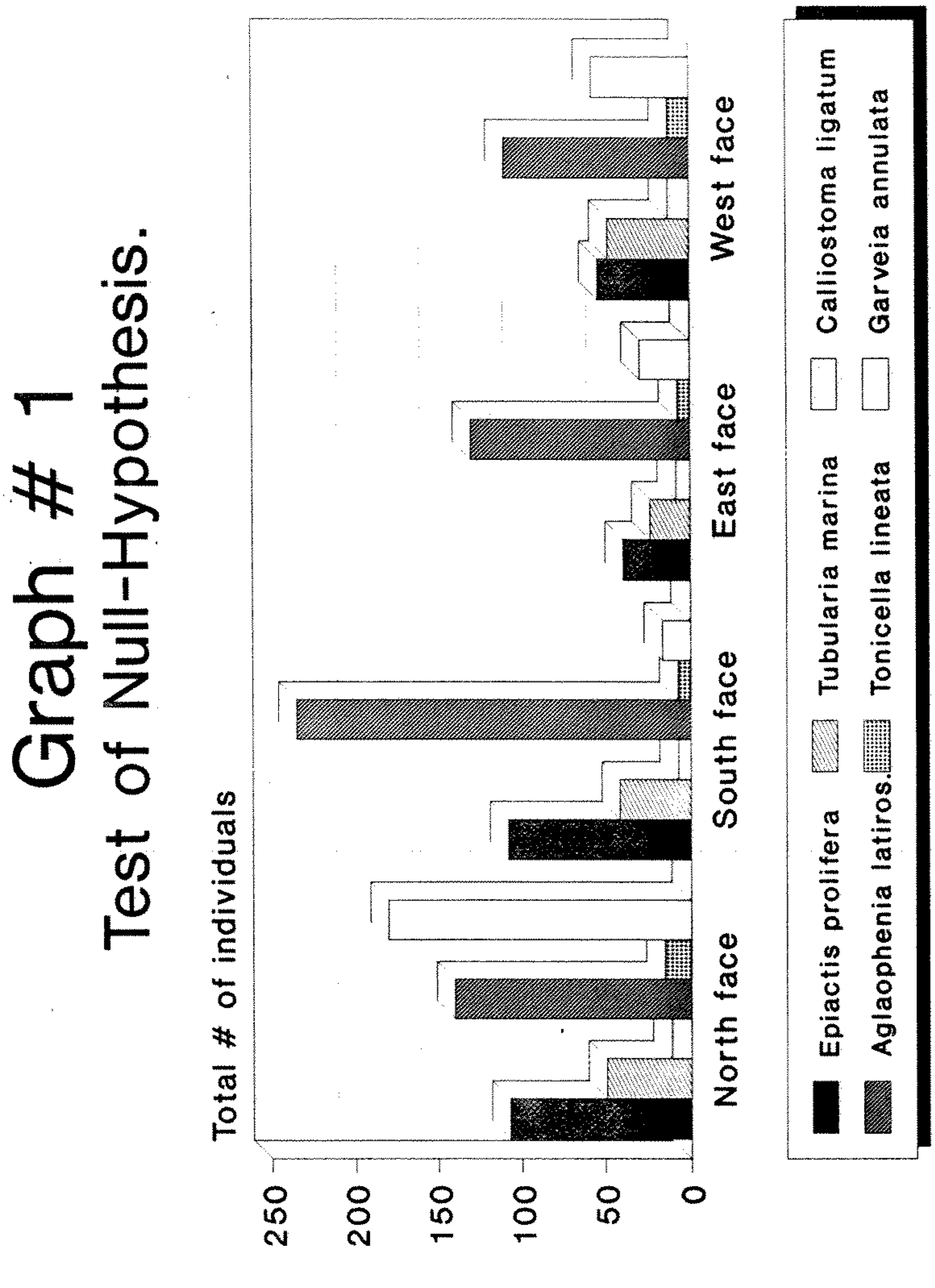
As shown in table 1, 2, 3 and 4, Distaplia occidentalis and Lithothamnion sp. are shown as percentage coverage. The reasons for doing this instead of a count of individuals, as the other 6 indicator species, was that it would be much easier to analyze to see if there was any connection and competition between the two populations of encrusting organisms. It was also much easier than to count the number of individuals in the colonial populations.

Analyses

From the frequency of species on the four different faces a variety of correlations, comparisons, graphs and probability tests can be done.

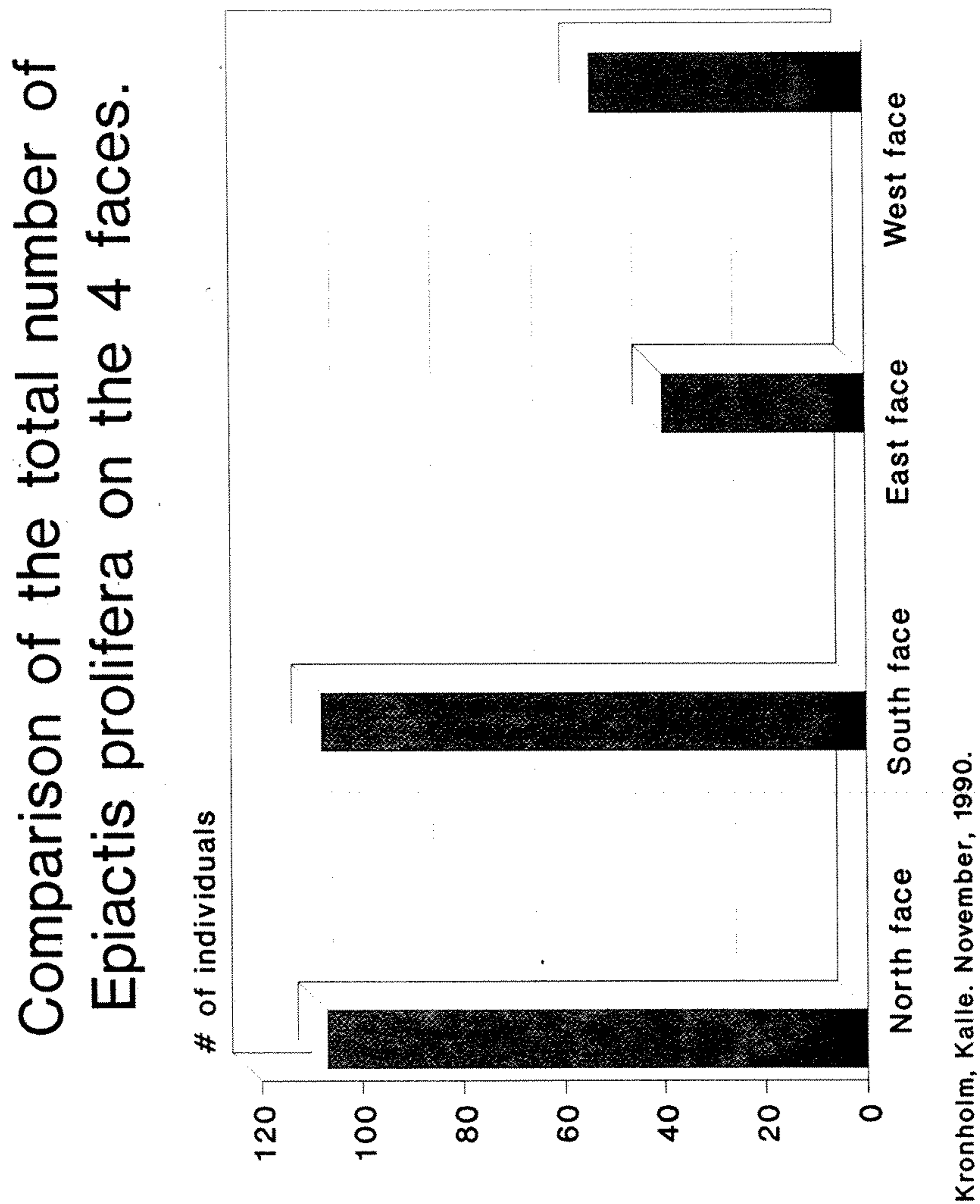
First a histogram, Graph#1, comparing the total number of individuals of each populations on the four faces of the block was plotted, to get a rough idea about the population size and distribution.

Graph#1 gives the idea that the distribution of Epiactis prolifera, Tubularia marina, Calliostoma ligatum, Aglaophenia latirostis, Tonicella lineata, Garveia annulata, Distaplia occidentalis and Lithothamnion sp. is related to which face the population grows on.



Kronholm, Kalle. February, 1991.

Graph # 2



Comparison of the total number of Epiactis prolifera on the 4 faces.
# of individuals
120
100
80
60
40
20
0
North face
South face
East face
West face
Kronholm, Kalle. November, 1990.

Analysis of the Epiactis prolifera population

From graph #2, it looks like there are many more individuals of Epiactis prolifera on the north and the south faces, than on the east and west faces. However, to be certain, we use a non parametric mathematical test to see if the null-hypothesis holds, or if it should be rejected and therefore the alternative hypothesis, which tries to explain why there is a difference in the number of individuals, should be used.

The reason for using a non-parametric test is that the data from the block is not assumed to be normally distributed , for example are there many zero's that could disturb the output of a parametric test, and therefore, results might be wrong.

Various non-parametric tests were considered, but finally the Mann-Whitney test was chosen for it's very fast and convenient calculation methods, which are reliable at the same time. The only problem with this specific test is that many tied ranks will give us some misleading results.

Example of calculation:

Using the Mann-Whitney test to compare the number of Epiactis prolifera living on the north face to the number living on the south face.

Table # 5

North	South	Rank	
Plants/quadrat	Plants/quadrat	North	South
10	10	9	9
11	13	13	16.5
6	15	1	19
11	12	13	15
10	10	9	9
11	8	13	2.5
9	9	5	5
9	13	5	16.5
15	8	19	2.5
15	10	19	9
	Total	106	104

1. Arrange the data sets as in Table#6. The values are listed so that the smallest value gets the smallest rank, and the largest value recorded gets the highest rank. If two or more values are equal, they are ranked according to their average rank. This is called tied ranks.

Table # 6

Value	6	8	8	9	9	9	10	10	10	10	10	11	11	11	12	13	13	15	15	15
Rank	1	2.5		5			9					13			15	16.5		19		

2. The rank for each value is now put into the spaces under Rank in table # 5, and the total of the ranks are calculated for each face, and the smallest sum of the ranks is now called T_1 and we have $T_1 = 104$.

3. After this, the table in appendix A showing "Significance level for Mann-Whitney test" is consulted. n is the number of samples on each face of the block. In this case, n is equal to 10, and the percent level that the test is wanted to be

is 5, we get the number 79 for T_1. If our value for T_1 is higher than this number, we have no statistical base to reject the null-hypothesis on, but if our value for T_1 is less than, in this case 79, we have a reason to reject the null-hypothesis.

In this case it means that, because $T_1 = 104 > 79$, we can not reject our hypothesis about Epiactis prolifera stating that: "There is no significant difference in the number of individuals in the Epiactis prolifera populations living on any two faces the block."

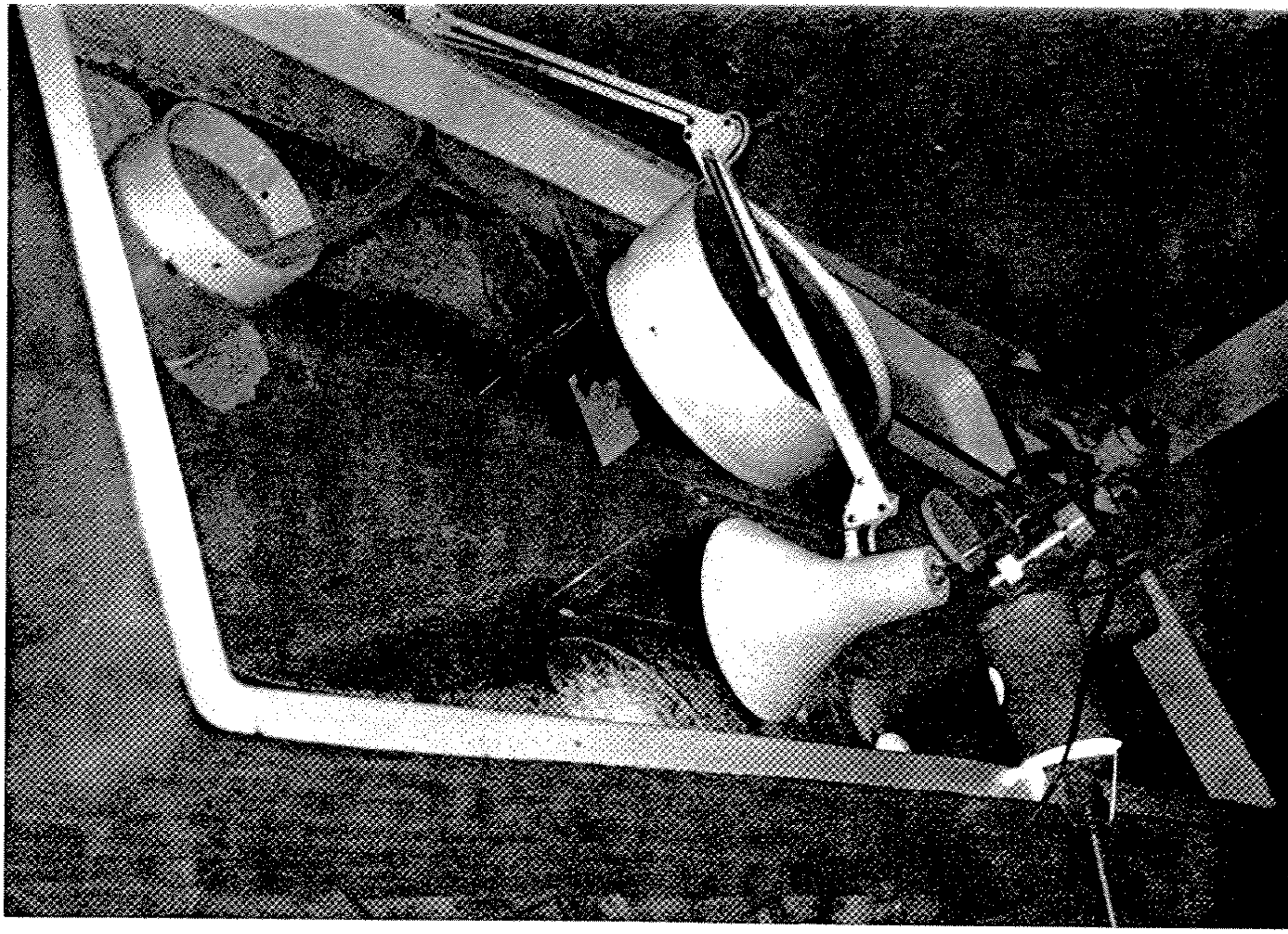
Before we tested the north side against the south side, and we found that the null-hypothesis held. Using the Mann-Whitney test again, but now comparing the east face and the west face, we get $T_1 = 108$, which (with $n = 10$, and percent level = 5) is greater than the appendix A obtained 79. Also here we conclude that the null-hypothesis was not disproved, so we are able to accept it. However, if the Mann-Whitney test is used to compare the other four possible combinations of faces (north-east, north-west, south-east and south-west), the calculated T_1 is smaller than 79, which means that we have to reject the null-hypothesis, and therefore try to explain the significant difference in the number of Epiactis prolifera between the faces.

The reason for this significant difference in the number of Epiactis prolifera living on the north and on the south face compared to the number living on the east and west faces now have to be described by the factors which were described in "Method"(p.9).

The only important factor can not be the sun, unless brooding anemones act to sunlight in such a way that much sunlight and very little sunlight give the best living conditions, and a medium amount of sunlight does not give nearly as good living conditions (Figure#1). This could be the case to a certain extent, but it could not possibly be the only factor causing this very high difference in the total amount of Brooding anemones on the different faces. Therefore more research was done on current flow around a block. The sources on current flow over a cubic shaped block are very few, so I had to make my own experiment to get more knowledge about eddies and settling.

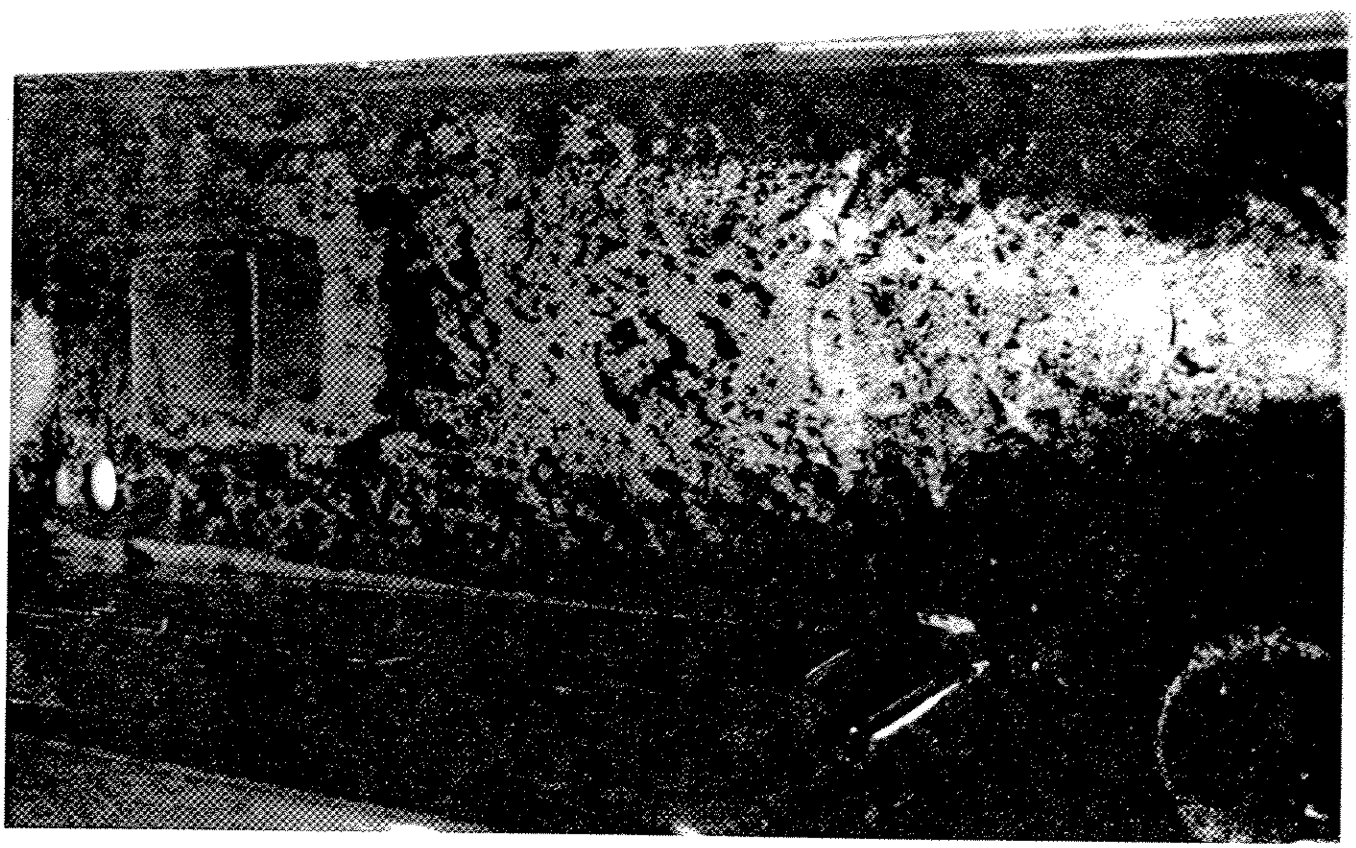
Current Experiment

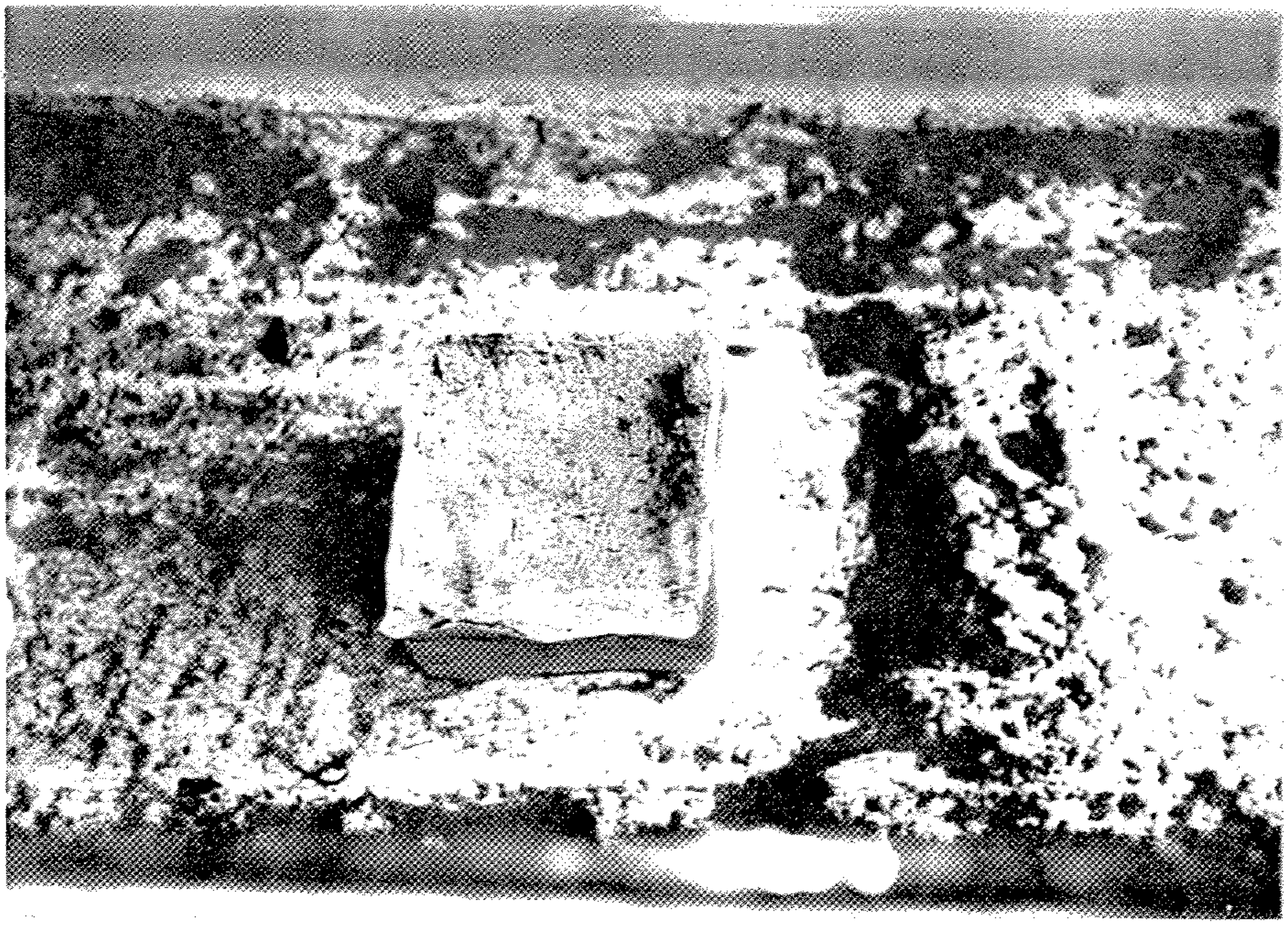
The purpose of this experiment was to get more knowledge about how water current flows over a block. (Michell, 1970), (Shapiro, 1961), (Bradshaw, 1964). A current was created in a 200 x 100 x 400cm tank full of saltwater by placing an obstacle in the middle of the tank, and letting a hose accelerate the water around in the tank. The hose was placed 50cm from a 5 x 5 x 5cm clay block, pointing towards the block to create the fastest and straightest current here (in the rest of the tank it was going in a circle). Then a glass of mud was dropped in the water, and patience was needed until the mud particles had settled. The particles from the mud had distributed themselves unequally, with many particles where the current was weak, and where there were back eddies, and fewer where the current was strong, because they got washed away. As can be seen on the pictures on page 25, the faces parallel to the current flow have a lot of sediments piled up in front, whereas the side facing the current has none. The side facing away from the current a "tail" of settlements in the direction away from the current. This "tail" however would not be present if the direction of the current suddenly changes, and therefore at Race Rocks, this tail would only occur 50% of the time.



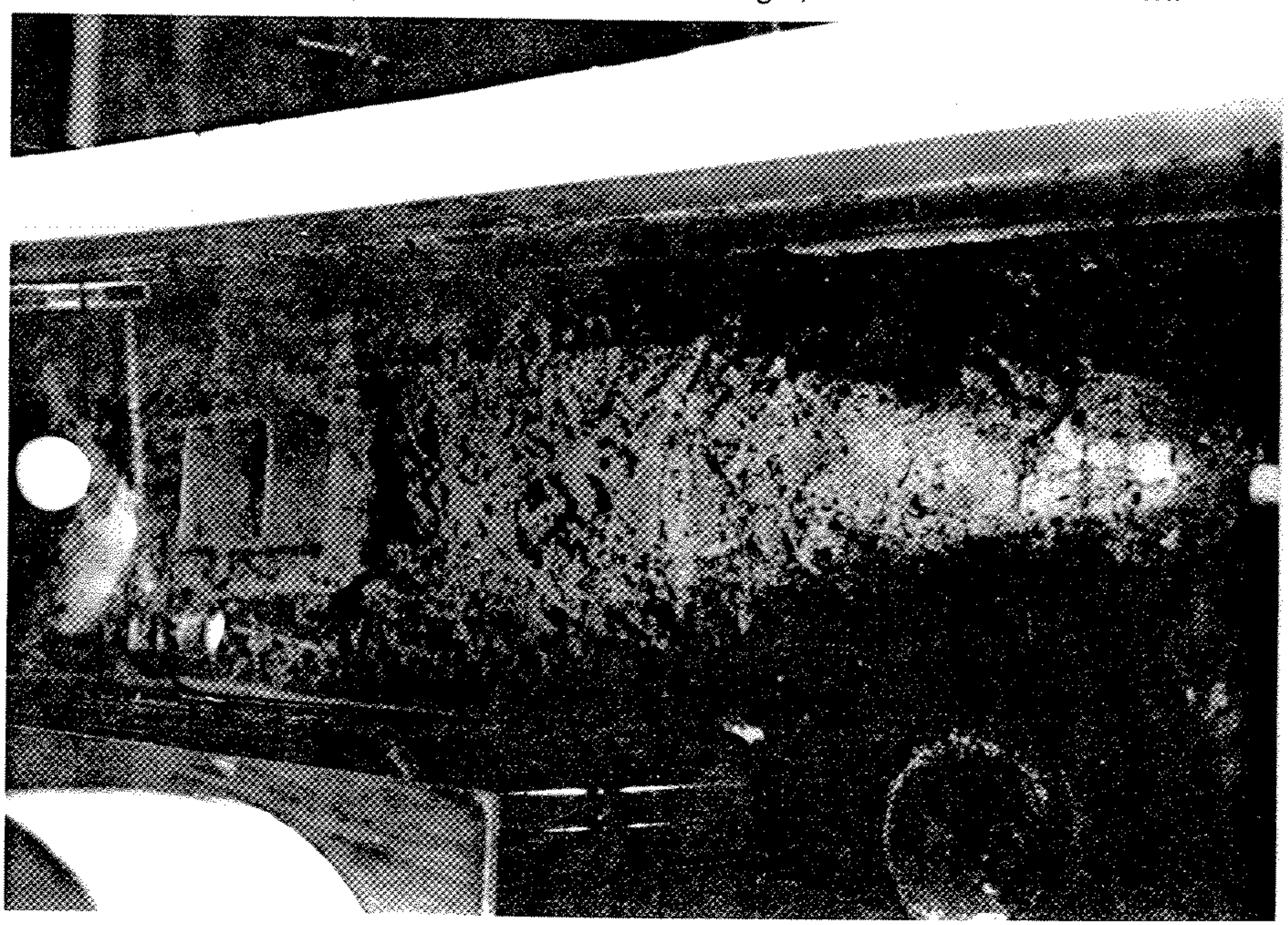
The Current Experiment set-up, with water running around the box in the middle.

The white areas are the places where no sediments have build up. The block is to the left.





The settling of sediments can be seen in front of, on the top front of, on the sides of, and in a tail behind the block.
Below, the accelerating hose can be seen to the right, and the block to the left.



From this experiment we can conclude that the areas parallel to the current would always be more covered than the two other faces, with nutrients, crustaceans, detritus, etc., that were trapped by the back eddies, and therefore were forced to settle on the block, or flow very slowly close to the sides. This could be a very important factor explaining the unequal distribution of Epiactis prolifera between the four faces.

As Epiactis prolifera feed mainly on small crustaceans (Morris, Abbott, Haderlie, 1980), the best living conditions possible would be a place where there are many crustaceans. A very reasonable guess to where there would be more food for the anemone, would be the same places as where the mud from the current experiment settled down. This is assuming that crustaceans and other mobile organisms that the anemone feed on can not swim against the current. This assumption seems very reasonable because even bigger fish would have difficulty swimming against a 3 knot current without using the back eddies created by the stones on the bottom to hide behind.

Our alternative hypothesis saying that: "The less current running over the block at a certain area, the more Epiactis prolifera live on that area", can now be compared to the frequency data of Epiactis prolifera on the four faces, and to the qualitative observations from the current experiment, describing the eddies around the block. These observations seem to agree with the alternative hypothesis.

Another very possible explanation for the very significant amount of Epiactis prolifera on the sides could be that this species holdfast is not strong enough to hold on to the surface of the block when very strong currents are present. The very special reproducing manner that Epiactis prolifera has, will probably make this explanation more valid for Epiactis prolifera, than for any other anemone.

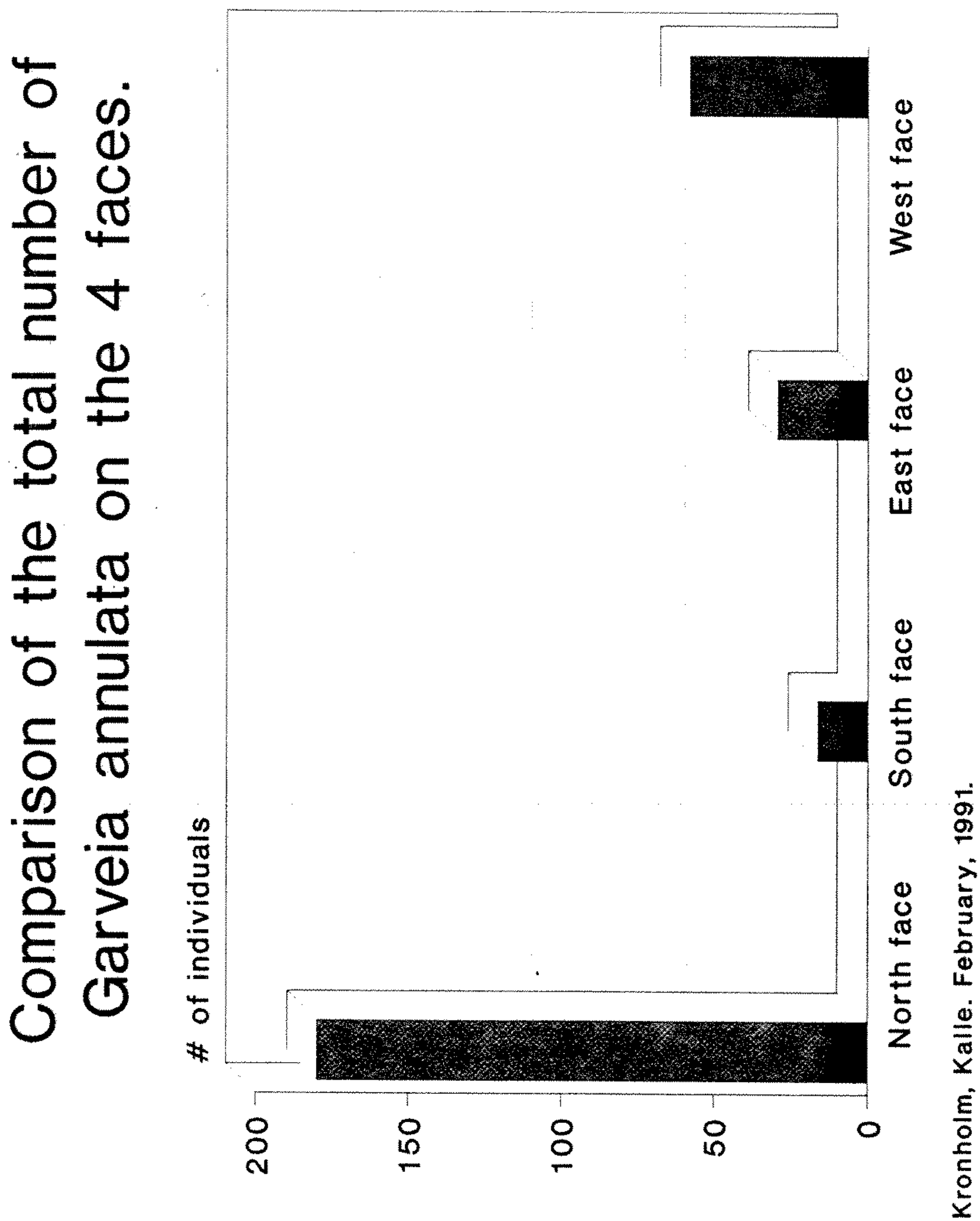
Analysis of Garveia annulata distribution

From graph #1 we also see that there might be a significant difference in the number of individuals of the hydroid Garveia annulata between the 4 faces of the block. To test this statement we need to prove it statistically. For the same reasons as before, we use the Mann-Whitney test: Comparison of the number of individuals in the Garveia annulata population on the north side, to the population on the west side. With the Mann-Whitney test we calculate that $T_1 = 71$, which is smaller than 79, and we therefore conclude that the difference in number of individuals of Garveia annulata from the west face compared to the north face is significant at the 5 percent level. The reason for comparing the north face to the west face is that the difference in the number of individuals here is smaller than the difference from the number on the north face to any other face. Therefore if the null-hypothesis is rejected when the west and the north face are compared, it will be rejected if the north face is compared to any other face.

Now the west and the south faces are compared using the Mann-Whitney test, for if the null-hypothesis is not rejected, it will not be rejected when the east and west faces are compared, or when the south and west faces are compared because the difference in the number of individuals between the south and the west face is bigger than any of the other combinations. This is assuming that not too many values share a common rank, in which case the sensitivity of the test would be reduced.

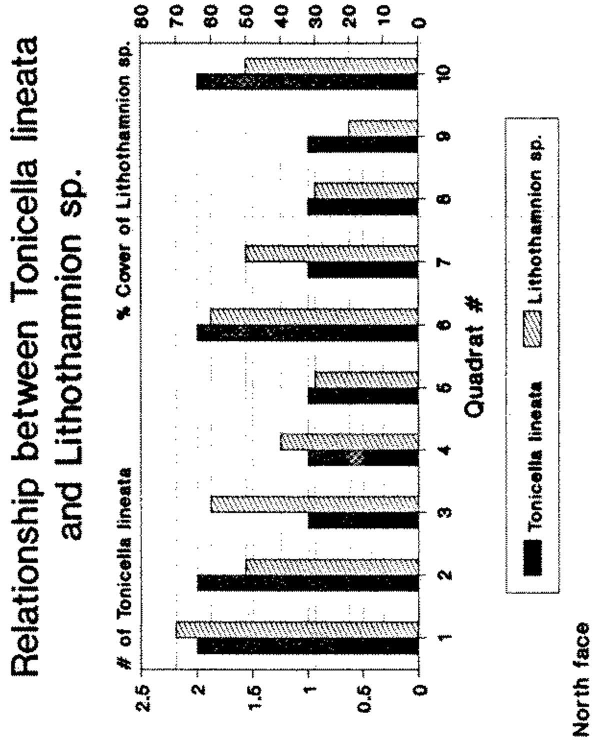
For the south against west face comparison we get $T_1 = 85.5$, which is

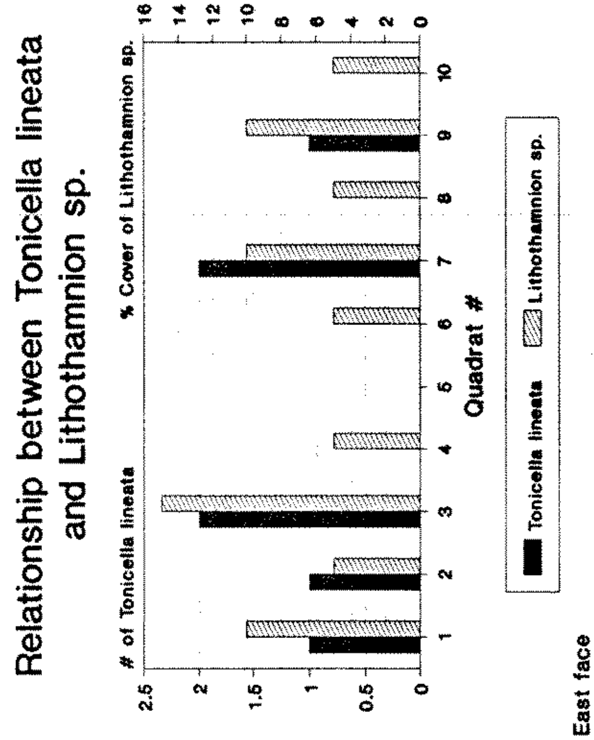
Graph # 3

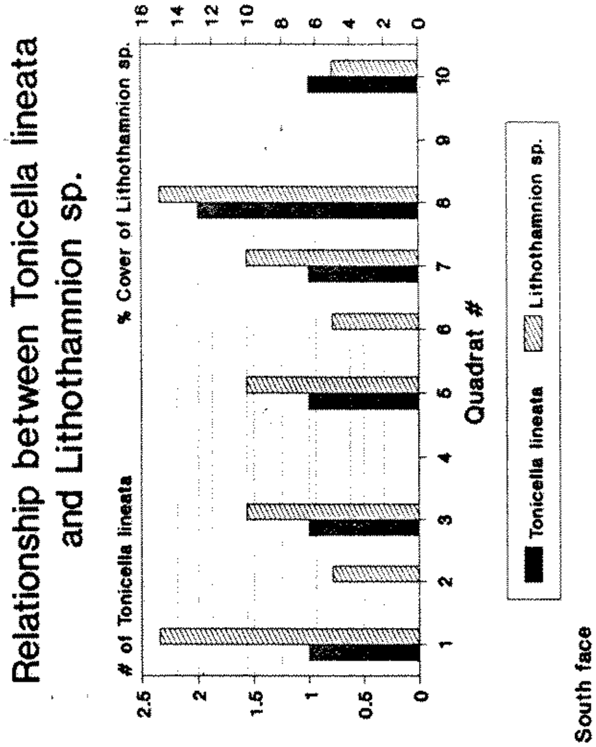


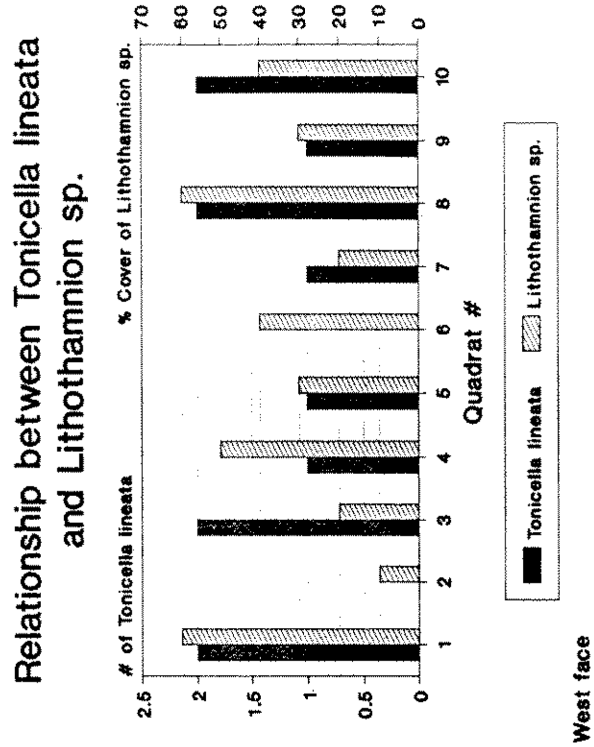
Comparison of the total number of Garveia annulata on the 4 faces.
# of individuals
200
150
100
50
0
North face
South face
East face
West face
Kronholm, Kalle. February, 1991.

Graph # 4


Relationship between Tonicella lineata and Lithothamnion sp.
# of Tonicella lineata
% Cover of Lithothamnion sp.
Quadrat #
Tonicella lineata
Lithothamnion sp.
North face


Relationship between Tonicella lineata and Lithothamnion sp.
# of Tonicella lineata
% Cover of Lithothamnion sp.
Quadrat #
Tonicella lineata
Lithothamnion sp.
East face


Relationship between Tonicella lineata and Lithothamnion sp.
# of Tonicella lineata
% Cover of Lithothamnion sp.
Quadrat #
Tonicella lineata
Lithothamnion sp.
South face


Relationship between Tonicella lineata and Lithothamnion sp.
# of Tonicella lineata
% Cover of Lithothamnion sp.
Quadrat #
Tonicella lineata
Lithothamnion sp.
West face

larger than 79, and therefore we cannot reject the hypothesis for the south-west face comparison. This means that some factors have a role to play in the distribution of the hydroid species Garveia annulata: "Common seasonally in shaded areas on open or semi-protected rocky shores" (Morris, Abbott, Haderlie, 1980). Also we see from graph#3, that the biggest difference in total number of individuals is from the north face to the south face: the two faces with the most extreme sun exposures. In the case of Garveia annulata, the sun exposure is probably the most important factor since we cannot us the argument that the less current the higher the number of individuals. If the current was a factor, the number of Garveia annulata individuals could not have been so low on the south side, but, in theory, around the number of individuals on the north face.

From this we agree that the hydroid Garveia annulata, as stated in Intertidal Invertebrates of California, prefers spots where there is shadow, but at the same time is exposed, like at Race Rocks.

Analysis of Tonicella lineata vs. Lithothamnion sp.

If a histogram, Graph#4, displaying the number of Tonicella lineata and the encrusting algae Lithothamnion sp., is plotted for each quadrat on each side, there seem to be a possible connection between these two populations. To see a correlation from a graph, however, is not to justify that there actually is a correlation. Some kind of mathematical/statistical proof has to be made. The test used here; the Spearman's Rank Correlation Coefficient, use the same principle as the Mann-Whitney test: Ranking the data from different quadrants. The important difference between the two tests is that the Mann-Whitney test compares the same species, but living in two different areas, whereas the Spearman's Rank test compares two different species populations to each other, or it could compare physical factors with species, which could have been done in this case by comparing current measurements to the populations of Epiactis prolifera. However, this could only have been done if quantitative current data had been available.

Example of the Spearman's Rank test:

Because the two sets of results that we are comparing are so different (they are two different species; one is a producer and the other is a consumer),it is not possible to rank the recorded values together, and they therefore have to be ranked separately as in table#7.

Table # 7

Lithothamnion sp.	rank	T.lineata	rank	d	d^2
15	9.5	1	7	1.5	2.25
5	4	0	2.5	1.5	2.25
10	7	1	7	0	0
0	1.5	0	2.5	1	1
10	7	1	7	0	0
5	4	0	2.5	1.5	2.25
10	7	1	7	0	0
15	9.5	2	10	0.5	0.25
0	1.5	0	2.5	1	1
5	4	1	7	3	9
					18.1

1. Rank the values so that the higher the value, the higher the rank. If two or more values are equal, they are all ranked according to the average rank.

2. The difference (d) in the ranks for the two species should be taken, and then squared (d^2). Then the sum of all the squares of the differences should be found, giving $\Sigma(d^2)$. Now using the formula for Spearman's Rank Correlation Coefficient: $r_s = 1 - \frac{6[\Sigma(d^2)]}{n(n^2-1)}$ we get that $r_s = 1 - \frac{6(18.1)}{10(10^2-1)} = 0.890$, since $n = 10$ and $\Sigma(d^2) = 18.1$. In the Spearman's Rank Correlation Coefficient table in Appendix B, we find that with $n = 10$; the degrees of freedom are $10-2=8$ and for a 5 percent significance level, our value of r_s has to be greater than 0.648 for there to be a significant correlation between Tonicella lineata and Lithothamnion sp. Our calculated value for r_s is indeed greater than 0.648, which means that there is a significant correlation between the area in a quadrat covered by Lithothamnion sp. and the number of Tonicella lineata observed in that specific quadrat. This correlation example was done on the data from the south side, but following the same methods as described above, we get that r_s (north) = 0.689, r_s (east) = 0.870 and r_s (west) = 0.491. With each of the data sets having 10 pieces of data, they all have 8 degrees of freedom, an therefore the r_s of each side should be greater than 0.648 for there to be a significant correlation, for a 5 percent level of significance. This is the case for the north, south, and east face, but not for the west face. The reason for the significant correlation between the two species can be explained by looking at the diet of Tonicella lineata: According to most studies (Morris, Abbott, Haderlie, 1980), the lined chiton feed on algae; Tonicella lineata especially feeds on encrusting algae, which are scraped off the rocks with a "tongue-like organ, the ranula"(Sumich, 1981). The study that was done on the concrete block at Race Rocks, partly agrees with this correlation between the presence at an encrusting algae, and Tonicella lineata. Only partly because only in 3 out of 4 data sets there was shown to be this correlation.

One thing we have to remember about Spearman's Rank Correlation

Coefficient is that the more tied ranks there are, the less reliable this test is. Having 10 data sets with values ranging from Zero to two (as for Tonicella lineata), there will inevitably be many tied ranks, so the Spearman's Rank Correlation Coefficient value might not be very exact in these four cases, but the test is nevertheless the best one to use in this occasion.

Conclusion

After having done studies of the possible physical and biological factors affecting the distributions of the populations on the block: and after having collected and analyzed data, and combined the results of the investigation of the factors mentioned above, an extremely small part of the life around the block has been investigated and explored.

Even though this exploration is small, this study has lead to some conclusions, partly involving the whole ecosystem studied, and partly involving single species.

The general hypothesis concerning the 8 indicator species has been rejected, and so we conclude that an alternative hypothesis, saying that factors, such as the ones studied in this paper, have an impact on the whole ecosystem.

The sub-hypothesis concerning the distribution of Epiactis prolifera was also rejected and so we conclude that, as for the general hypothesis, factors such as current and possibly sunlight affect the distribution of individuals on the different sides. However, here having to deal with a single species, it is easier to pinpoint factors that affect the distribution.

Epiactis prolifera feed on small crustaceans (Hewlett, 1976), (Morris, Abbott, Haderlie, 1980) Which due to the back eddies around the block (Current Experiment) gets trapped on the north and the south side, causing a greater number of individuals of brooding anemones on these two sides than on the east and the west side.

The alternative hypothesis used to replace the sub-hypothesis concerning Garveia annulata, describes how much sun exposure on a side decreases the number of individual Garveia annulata on that side.(Morris, Abbot, Haderlie, 1980).

The system with the boundaries that I defined should be seen as a subsystem of high current ecosystems of the worlds ecosystem.

For further study

1. In a preliminary study like this, where some conclusions concerning correlations between populations and environmental conditions are drawn, it would have been ideal if a test experiment could have been set up. In this experiment all the factors described here (current, sunshine, salinity, temperature, pH, grazing, pollution, and diseases) should have been controllable, so that by changing are factor at a time, the result on the different populations could have been observed and recorded so that a better understanding of the populations action to these factors would have been reached. Knowing this would bring us much more knowledge about the system around the block as a whole. However, setting up such a control block would not be a very easy project.

2. Samples from such a control block should have been recorded over a whole year.

3. Instead of doing the current experiment, or maybe in addition to it, a nontoxic dye such as Fluorescein could by divers have been used to see the eddies around the block.

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Appendix B: Spearman's Rank Correlation Coefficients.

Degrees of freedom (n – 2)	*5 per cent*	*1 per cent*	*Degrees of freedom (n – 2)*	*5 per cent*	*1 per cent*
2*	none	none	24	0.388	0.496
3*	1.000	none	25	0.381	0.487
4*	0.886	1.00	26	0.374	0.478
5*	0.750	0.893	27	0.367	0.470
6*	0.714	0.857	28	0.361	0.463
7*	0.683	0.833	29	0.355	0.456
8*	0.648	0.794	30	0.349	0.449
9	0.602	0.735	35	0.325	0.418
10	0.576	0.708	40	0.304	0.393
11	0.553	0.684	45	0.288	0.372
12	0.532	0.661	50	0.273	0.354
13	0.514	0.641	60	0.250	0.325
14	0.497	0.623	70	0.232	0.302
15	0.482	0.606	80	0.217	0.283
16	0.468	0.590	90	0.205	0.267
17	0.456	0.575	100	0.195	0.254
18	0.444	0.561	125	0.174	0.228
19	0.433	0 549	150	0.159	0.208
20	0.423	0.537	200	0.138	0.181
21	0.413	0.526	300	0.113	0.148
22	0.404	0.515	400	0.098	0.128
23	0.396	0.505	500	0.088	0.155

n = the number of pieces of data in *EACH* dataset.

To be significant, the calculated value for r_S must be greater than the tabled value.

*Values for degrees of freedom 2 to 8 (inclusive) are specific to the Spearman's Rank procedure (calculated by Kendall). The rest are as used for the ordinary parametric (2.5) correlation coefficient (r).

(Slingsby, Cook, 1986)