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?August 1979

COLONIZATION OF THE COMMUNITIES

ASSOCIATED WITH

RHIZOPHORA MANGLE ROOTS

By

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CENTER FOR ENERGY

AND ENVIRONMENT RESEARCH.

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TERRESTRIAL ECOLOGY DIVISION

AUGUST, 1979

CENTER FOR

NERGY AND ENVIRONMENT RESEARCH OPERATED BY

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ABSTRACT

The colonization, succession and equilibrial state of the communities associated with Rhizophora mangle roots were assesed by of artificial substrates placed in eight preselected sites in Laguna Grande, Fajardo.

Data was collicted by randomized harvesting on a logarithmic time scale

of one, two, four,

?ight, sixteen and thirty two weeks. Other aspects of this study involved using one of the stations (IX) to test if any sea~ sonality occured and an additional part where the first microscopic stages of colonization were followed for a period of four weeks using glass slides. Colonization curves were constructed closer inspection of these indicate a long term equilibrium. The turnover rate for this study was 1.11 and no seasonal variation was detected either in species composition nor in number of organisms.

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DEDICATORY

To my mother for her support and understanding.

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?RODUCTION

tn biogeography. the smallest unit that can be studied is an island,

Not only because of the variations it presents in area, shape and degree

of isolation, but because it provides the necessary replications in natural

experiments by which evolutionary theories can be tested

Islands offer other advantages as well, They contain a smaller num-

ber of species present on them. In addition, one can remove one or more elements of blots or the

ire biota itself and monitor the process of

recolonization (Wilson § Simberlo?f, 1980).

Gotenization of an istand is a dynamic process. Pianka (1966) has described the colonization process as having four stages: 1, the non-interactive phase, where there is no competition involved, 1, the interactive phase, where there is competition and habitat partitioning, U1, the assortative phase, where new adjustments are made by the Species present and, IV, the evolutionary phase, which occurs when genetic adaptations to local environment takes place.

Mac Arthur and Wileon (1963, 1967) have suggested that the number of species on an island is the net result of the interaction of two oppos-

ing processes: immigration, or the arrival of new species to a habitat,

extinction, or the dissappearence of already existing species, Over

tim

. the resultant number should approach an equilibrium value,

This equilibrium hypothesis has motivated several attempts to

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determine whether in fact island species are in equilibrium, (Diamond, 1968, 1971).

Experimentally there are two ways of testing this hypothesis. First, the number of species can be followed from the time the colonization begins, then a colonization curve can be computed which would indicate whether species numbers level off. This technique has been used by several investigators (Maguire 1963, 1971; Cairne et al. 1969; Simberloft

and Wilson 1969, 1970; Sch

er 1974), all of whom found convex cotoni-

zation curves which suggest an initially rapid increase of species which later levels off.

?The second method involves the comparison of the immigration and

extinction rate curves, which theoretically should meet at one point,

which corresponds to equilibrium value (Mac Arthur & Wilson, 1968).
The immigration rate curve (the number of species arriving per unit
time plotted against time after initiation) should in a decreasing curve,
whereas, the extinction rate curve (the number of species going extinct
per unit time plotted against tine from initiation) should result in an

increasing curve.
Mac Arthur and Wilson (1964) have noted in their theory of Insular
Biogeography that actual measurements of immigration-extinction rate

curve are difficult to make because t would involve knowing the exact

time (which specific date 1

er arrived or left) and all the

immigrations and extinctions of the species colonizing.

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Furthermore, there is no procise definition of what an immigrant species is or whether a species that leaves it for a time or never to return, should be considered extinct.

Contrary to the difficulty of the immigration-extinction rate curves, approximation of the colonization rate curves (Cairns et al, 1969).

As defaunated islands are not easily found and certainly not in enough numbers for experimental replicas, the use of artificial substrates as islands has been extensively used. Cairns et al. (1969) used plastic substrates, while Schoener (1974) used plastic sponges.

For an excellent review of earlier literature in this field, see Cooke,

(1956).

?An initial experiment was carried out to test which kind of substrate was more suitable for this study. Wood, PVC pipes uncoated, cement coated PVC pipes and real R. mangle roots were tested. The difficulties of using wood was that a weight had to be added to matain the substrate under water, and where water was shallow this presented a drawback, ?The use of real mangrove roots was soon discarded because of the dif- fioulty in cutting them. Also the problem of the weights was present. In the PVC alone the same problem was also present adding to it that it was disticult to recover organisms that attached to it. The cement covered PVC pipes did not present any of these problems, also when placed in the water there was no apparent discri

tion on part of the colonizers.

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When these substrates were examined in the laboratory. all organisms found on them were the same. Thus, the cement-covered PVC pipes were chosen for this study.

Just as islands emerge from the ocean and provide habitats to be colonized by all kinds of organisms, the roots of Rhizophora mangle create additiona! habitats for colonization upon entering the water. Like

islands, they provide habitats for marine or brackish water organisms that

constitute the communities associated wit

? Rhizophora mangle roots

The communitie:

hat live on the roo!

of Rhizophora mangle have

been studied before by Koiehmainen et a? (1973) and Bacon (1973). Studies regarding specific organisms associated with the red mangrove roots have been done by Jelder (1973), Robertson (1959) among others. To date, no studies have boon done on the actus! colonization process on mangrove

roots.

?The site selected for this work was Laguna Grande, located at Las

Cabezas de San Juan, Fajardo in the North-Eastern part of Puerto Rico.

?This lagoon covers an area of 4.88 x 10° square meters with an average

depth of 1.42 m. and a volume of 719,800 cubie meters. (Candelas, 1968). The lagoon is closed except for one channel connecting it to the sea

at Las Croabas (Fig. 1). There are four mangrove species present in the

system: Rhizophora mangle, Avicennia germinans, Laguncularia racemosa, and Gonocarpus erecta, Rhizophora mangle borde

?the lagoon. (Candelas

---Page Break---

et al., 1988). Rich communities grow on the roots of the red mangrove, Rhizophora mangle.

?The objectives of this study were:

1, Determine the rate of colonization on the roots of Rhizophora mangle.

2, Determine the successional patterns of this colonization.

3. To test the applicability of the Mac Arthur and Wilson

equilibrium theory,

MATERIALS AND METHOD:

Eight stations were chosen arbitrarily using @ map of the area and dividing it into eight sections utilizing the cardinal points of the

compass. (Figure 2).

At each station 21 artificial roots were placed. These artificial roots were made of {" wide x 15" Jong PVC pipes, covered with a thin layer of

ready mix cement. Cement was placed in a 20001 graduated eylinder and

the PVC already cut to size with one end filled with newspaper was

introduced in the cylinder with the cement and placed in the sun to dry,

?then @ second coat was applied in the same way,

Each root was numbered, and suspended by a 100 pound test mono-

?lament Line, from a supporting structure made of 3" steel reinforcement

rods tied togethe

with galvanized wire,

---Page Break---

?Two of these supporting structures were placed under water at each

site, one containing 11 roots, the other 10, spaced five inches from each

other. (Figure 2).

To establish colonization patterns, three roots from each station were randomly harvested at pre-determined dates. Randomized harvesting of the artificial roots was done by enumerating the roots from one to twenty cone and using a random table selecting three numbers per harvesting date

per station. Scheduled harvesting was cone at one, two, four

eight.

sixteen, and thirty two weeks aft

the placement of the artificial roots.

Harvesting of the artificial roots was done by placing 2 plastic bag over

the root to prevent the loss of material and placed in an ice chest until all

harvesting was through and then taken to the laboratory to be examined.

Im the laboratory, the roots were examined carefully under a disse

?ion mieroscope and organisms found on the roots were detached and grouped

together according to species. Specimens were placed in vials, preserved

with ethanol and labeled with museum tags.

Organisms were collected using a pair of fine forceps, placed in vials

already prepared with 708 alcohol and them labeled with museum tags.

For those organisms that were difficu't to detach such as the tunicate

Botryllus planus, and the Arthropod Balanus, and algae, a method was

Gevised for their counting.

A strip of paper 1" wide and 11-1" long was cut and squares of 1 cm?

---Page Break---

were drawn and then cut at 1? intervals, to make 10 squares of 1 cm

squared.

?This strip was wrapped in spiral fashion around the root. Organisms

were identified and then counted in each of the squares. A mean was

then calculated and that mean multiplied by the area of the root

(111,68 em*). Numbers of individuals per species are expressed in total

The number of individusls per species per harvesting date was

recorded. Photographs wore taken for more detailed taxonomical

igentification

?To determine any seasonal variation in the first four weeks of

exposure a ninth station was established between stations six and seven.

(Figure 2). The procedure followed with this ninth station w.

to place

three roots previously numbered at the begining of each month and left

in the water for a period of four weeks. Harvesting and examination of

the roots and specimens on this station was done as described before.

?Those roots that could not be processed the same day because of the

Jarge number of roots harvested were kept in a fri jer until processed.

As these artificial roots have a cement surface, the early microscopic

stages occuring on these roots would have been difficult $f not impossible

to asses. For this purpose, sanded and marked 75 x 25 mm glass slides

---Page Break---

attached in sets of three, were placed at the eight stations and harvest-

ed in one, two, and four weeks after being placed in the water.

?These slides followed the same harvesting as described for the

roots. In addition they were fixed in 4§ Formalin and mounted with

Permount. They were examined under a phase microscope using @ Baush

and Lomb micrometer disk and randomly selecting 10 areas on the slide and averaging for total species and individuals per unit area.

The colonization an¢ succession of organisms on artificial roots in a

?coastal lagoon were followed over a thirty:

wo week pei

dA total of

51 species, representing twelve phyla were found to colonize the artificial roots during the period observed. See species list Appendix 1. In the second part of this work, which was the colonization on glass slides, 47 genera representing 11 phyla were found to colonize the slides during 8 period of four weeks. Appendix Il. The detailed isting of species colonizing the artificial roots and glass slides are presented in Appendix tables III and IV respectively.

Colonization curves were constructed for each of the eight stations by plotting the number of species present at each harvesting date. These curves are presented in Graph 1.

The colonization curves for al! eight stations show =

they follow

feneral pattern. In the first four weeks there is an increase in the

number of species colonizing the roots. From harvesting dates of eight

---Page Break---

to thirty-two there is a leveling off or e'ther a decrwase in the number

of species present at those harvesting éates.

In the graph of station VI there is ¢ nesled diy tu the number of

species present at the thirty-second werk. This was due to the fact

that for this harvesting date the roots left on the slution disappeared:

probably someone took them out of the water or bunaped into them with a bost causing the roots to sink into the nud. Only one replicate was found, and when it was examined under the mic oscope, oly two species were present.

N

vertheless, all stations on simple sbservation behaved very much the same, at least for the first four wee'.s of harvesting. It was decided to test for similarity of slopes. Linear rogressions were run for this seg- mont of the colonization curves and thelr slopes determined for all stations. After the slopes were calculat:4 a Student + test was run to ?establish if there was any significant di?fexence between the b coefficients. ?The difference between the slopes of the first segment of the colonization curves for all eight stations was not sig? ificant for amy cf the stations. Based on observation and on the results obtained on the t test, we grouped all the data and plotted a comp: shensive colonizstion curve presented on Graph 2,

As can be seen in this graph, it follow s the sue pattera as the individual colonization curves. This colvrizatiou cv.ve as well as the

colonization curves for all eight stations can be civided into the three

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phases described by Pianka (1966). Graph 3. The first phase or the nonineteractive phase would correspond to the section of the graph, A, Between one and four weeks of exposure. The interactive phase indicated as B corresponds to that section between four and eight weeks, and the assortative phase C corresponds to the section between harvesting dates of sixteen and thirty-two weeks. Pianka (1966), mentions a fourth phase but as the duration of this study was only of thirty-two weeks, this phase could not be ascertained,

Colonization curves were also constructed for the glass slides, though,

the time span for these eur

4s only of four weeks. Graph 4.

As cen be observed, they

under the colonization pattern discussed before for the artificial roots. In al! eight stations, there is an increase in

?the number of species present in the four week period.

Linear regression was calculated for these colonization curves and a 1 Test was run, Slopes were significantly different from zero and t factors were not significantly different from each other. A comprehensive

colonization curve was plotted for the data on the glass slides Graph 5,

As done previously for the roots, this colonization curve was analized to see if it conformed to the general colonization pattern and if it followed.

Planka's colonization phases:

On closer inspection, this comprehensive colonization curve behaves much like the other colonization curves, There is an increase in

the number of species from the first week to the fourth.

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As far as Pianka's distribution of phases, we found correspondance roughly with only one of the phases and that is the noninteractive phase.

There is not enough information because of the short period of time.

For the ninth station, a total of 21 species were found in a period of six months. Appendix V, The colonization curve for this station Graph 6 shows litte or no variation from harvesting date to harvesting date in species composition and in the number of species present. Thus,

it can be concluded that from April to Sentomber, there is no significant

variation in

fer species composition or species numbers with time

It appears that the colonization process in this lagoon is not deter-

mined by the amount of organic matter flowing through the system. The

lagoon also has a direct exchange of nutrients and inorganic matter

?through the channel that connects the lagoon with the sea. Figure 1,

?The daily tidal fluctuation Nushes the system renovating oxygen, etc.

Light doos not constitute itself a limiting factor in this system. Average

depth in this lagoon is one meter. water is more or less clear letting light

pass through the water column. Algze grows on the bottom substrate to @

depth of three meters. Good circulation is also present, although it has

not been documented, Salinity is more or less constant through out the

year, being more or less 35 parts per thousand.

[As the factors mentioned above are not limiting colonization, the only

factor that cou'd be observed is the lack of area to be colonized. This

area is provided by the aerial roots of the red mangrove when they go

into the water

aie

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After the colonization process begins, succession takes over on the roots as shown on Table 1.

?Some organisms an present in only one harvesting date, like in the ?case of the tunicate Ascidia nigra at eight weeks; other species are present through-out all harvesting dates as in the case with six species out of ten of the first as is the case with six species out of ten of the first colonizers, and that some species come and go between harvesting dates.

If @ compariscn is made of how many species are present and the

number of species are absent at

vesting dates we will find that these numbers will tell us the immigration - extinction for each harvesting

date. Table 11,

?The number of extinctions is fairly constant, the only drastic change is between harvesting dates of one and two weeks where there is no loss.

meanwhile for the fourth week the number of species lost amounts to six.

The number of immigrations varies also in the first two weeks of exposure from a gain of ten species in the first week to thirteen species fn the second week to a eight species gain in the fourth week. From the fourth week on the gain and loss in the number of species is more or

less stable.

From the Table 1 it can be seen that some species are in a particular harvesting date, while other species are common throughout all harvesting

dates, Table 111,

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As far as the glass slides immigration and extinction analysis, the extinction is higher than that on the roots, probably due to the limitation in space. Table IV.

{As available space is a limiting factor in the colonization process. resource partitioning should be taken into account. It should be noted that there is no zonation on these artificial substrates nor in the natural roots.

We made a relation of the spe

present at each harvesting date and

their feeding modes to establish if there is a relation in feeding modes and

their position in the succession. Table V

In general, we classsified the species present in three feeding mode:

I sedentary filter feeders, which are organisms that obtain their nutrients

by filtering the water that passes by and trapping the particles, II Raptorial

feeding which are active searchers and obtain the!

food either by scraping

such as Molluscs, or by eating other organisms, III, the photosynthetic mode, which produce their own food.

Out of 81 species found for the thirty-two week period of experimenta~ tion a total of 30 species are secundary raptorial feeders, 10 are primary consumers (scrapers) and 20 are secondary consumers (predators), 15 are filter feeders and four species are phtosynthetic. In Table V we will find that there is an increase in the number of predator species as tine increases becoming stable through harvesting weeks eight, sixteen and

thirty-two. Filter feeding species increase from three species in harvesting

a1

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weok one to ten species in harvesting week two, becoming stable through- out subsequent harvesting dates. The other two feeding divisions have

sentatives present in harvesting week two, throughout the thirty

second week of experimentation.

Filter feeding species are more stable probably because as these species are sessile, they noed area to colonize and live on. This is not

?the case with the raptorial species which are usually found between

sessile colonizing species as e.g. of Ampithoe (raptorial) with Bra:

idontes

or the tunicate Eoteinascidia (both filter feeders). These sessile organisns,

provide shelter for the non-sessile organisms,

Sessile species usually had a higher number of individuals per species

than the raptorial species. See Appendix III, 1V.

Using the same relation with the data obtained from the glass slides
as presented in Table VI. We obtained that from a total of 49 species,
37 species are photosynthetic, being in their majority Diatomacea (33 genera)
and Rhodophyta (2 genera), Chlorophyta (1 genera) and unidentified
germinating algae.

Both raptoria! and filter feeding species in this study are present in

low numbers, There is litle variation in these numbers between harvesting

dates. Filter feeding species are present in higher number than raptorial

species. This could be accounted for by the shape and position of the

slides which are not too enticing

non sessile colonizers. But there is

ot enough data to conclude anything of that nature. In order to do that,

?this study should be structured so that the slides are left in the water for

the same period of time as the artificial roots.

a1

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As st can be observed from the tables of succession discussed before

and from the data presented in Appendix 111, IV, V, this system has a

very high diversity and that the species found throughout this study

are a fair representative of animals and plants.

?Species diversity Index was calculated for the roots using the Shenon-

Weaver Diversity Index.

The results obtained from this test are presented in Table VII. The

species é

srsity Indes gave very high values when we had very few

species e.g. in haversting date of one week for stetion IV, with four

species present, Brachidontes exustus (1 individual), Bugula neritina

(29 individuals), Ampithoe (10 individuals), Balanus with 16,927 and
Pachygrapsus with two individua's present gave a diversity index of 2.15.
(On the other hand, this diversity Index does not take into account

?those species with only one individual present at one haversting date
which is a common situation in this type of study.

For these reasons, the Shanon-Weaver Index, was just taken as a

rough estimate of the diversity at haversting dates on this stucy.

For @ real measure of the diversity present at haversting times it was decided to use the number of species present.

Also, the Simpson Similarity Index was calculated for all stations at Gifferent dates to establish if similarity between the populations present

at the stations was significant or not, Table VIII.

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Similarity is significant between the first two harvesting dates, decreasing in value as time passed for all stations. Also significant are the similarities between the populations present at harvesting dates of four and eight weeks and between sixteen and thirty-two weeks in stations 1, V, Vi and vin,

Trellis diagrams for Simpson's Similarity Index were also constructed for the data obtained from the glass slides, Table IX.

?The Treilis diagram shows that al! populations in harvesting dates

in all stations w

nificantly similar except for station UIT

In this station, atl populations in hervasting dates of one and two

?weeks and two and four wecks, wore significantly similar. In station IV

similarity between the populations present was not significant between

harvesting dates one and two and between one and four.

One of the objectives of this study, was to test the applicability of

the Mac Arthur and Wilson equilibrium theory proposed in 1964

In order to ascertain if it was applicable to the cotonization of this

artificial substrates the method described by Schoener 1974 was used.

and divided into two segments. The first segment being the line described

by the points corresponding to harvesting dates one, two and four wees,

and segment two including harvesting dates of eight. sixteen and thirty two weeks.

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Line

regressions for each segment were calculated. The early

portion of the colonization curve had a slope of 5.57 significantly

a

srent from zero and the second segment had a slope of -0.04 not

significantly different from zero. This also applies to the slopes of each

individual graph.

?A student t Test was run then to test whether the probability that the two slopes making the colonization curve were significantly different

from each other (Sokal § Rohiph, 1988).

?This analysis i

dicated that there were significant differences between the slopes of the two parts making the colonization curve.

If we examine the colonization curve in Graph 2 it can be observed that it follows an increasing relationship reaching an asymptote, suggesting that equilibrium is approached. This is further evidenced by the fact that an average of 29 species is mantained over a period of eight, sixteen and thirty two weeks.

Furthe

evidence is thet immigration and extinction rates should be equal at equilibrium. Table Il. Here the number of extinctions and immigrations stay more or less stable throughout the last four harvesting dates. For this system equilibria! conditions are present from the fourth

?week of experimentation.

Thus, turnover rates (the extincti

rate, equal to the immigration

rate at equilibrium) is calculated from the Mac Arthur and Wilson

<7

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prediction of 1.15 x S/ty gg) where S is the average equilibrial number

of species and ty gp 1s the time In days needed to reach $08 of the

equilibrial species number. Even though this formula was derived for

the noninteractive equilibrium, it is used in this study for the long term

equilibrium because the experimental results do not show any different

equilibrium number at the noninteractive phase.

Schoener suggests 1

t both equilibria may be close and covered by

the same equation,

Substituting the equation 1.15 x S/ty gp for 28 species in thirty days

times 1.

irty days times 2.15, we obtain a

?we obtain a species in

turnover rate of 1.11 species per day.

SUMMARY {CLUSIONS:

Artificial substrates made of cement covered PVC pipes were used to study the colonization and succession of the organisms associated with ?the Rhizophora mangle roots.

Conclusions on this study are based on 120 species representing 15 phyla.

Colonization curves wore constructed for each station for the

artificial roots and for the glass slides.

Inspection of these curves indicate a long term equilibrial condition, which is confirmed statistically by the significant decrease in the slope that occurs in the second segment of the curve. This is supported also

by the immigration and extinction rates on Table II. This is evidence

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?that the equilibrium theory proposed by Mac Arthur and Wilson applies

?to the colonization taking place

Contrary to what Schoener 1974 found based on the trophic structure

in the first stages of colonization raptorial species as well as filter feed-

ing species are present.

Successional changes were followed for both artificial substrates,

cement and glass slide:

?There was no seasonal variation in species

composition or in species numbers.

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FIGURE 1

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FIGURE 2

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TABLE 11

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?TABLE IV

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?Loss of Species: 7 ? 1

{Total Number of Species

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TABLE VI

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RELATION OF FEEDING MODES OF SPECIES

PRESENT IN GLASS SLIDES.

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APPENDIX 1

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SPECIES LIST

Phy

um Protozoa

Foraminifera

Phylum Porifera

Family Clionidae

Cyone sp.

Family Dysidetdae

Disidea sp.

Family Halisarca

Halisarca sp.

Family Mycalidae

Mycale sp.

Tethyidae

Tethya sp.

Phylum Coelenterata

Family Zoanthidea

Parazoanthus parasiticus

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Phylum Platyhelmintes

Family Pscudoceridae

Pseudoceros crozleri

Phylum Molluscs

Family Atyidae

Haminoea elegans

Family Bullidae

Bulla striata

Family Calyptractd

Crepidula glauca

Family Cerithitdse

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Family Mytilidae

Brachidontes exustus

Family Neritidae

?Neritina virgines

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Family Tonnidae

Family Triphoridae

?Triphora nigrocineta

Family Vitrinellidae

Parviturboid

comptus

Family Isognomonid:

Tsognomus

Phylum Annelida

Family Maldanidae

Family Nereidae

Family Serpuligee

Family Terebellidae

Phylum Bryozoe

Family Bugulidae

Bugula neritina

Family Membraniporidae

Membranipora sp.

Phylum Artropoda

Family Ampitholde

?Ampithoe sp.

Family Anthurida

?Apanthura sp.

Fomily Balanidae

?Balanus sp.

Family Grapsidae

Pachygrapsus grace

Genera Cumacea

Genera Hyperoche

Genera Neomysis

Phylum Chordata

Subphylum Urochordata

Family Ascidiida

Ectetnascidia turbinata

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Ascidla nigra

Family Botrylida

Botrylus planus

Class - Osteichtyos

Family Gobbidee

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sp.

Kingdom Plantes

Class ~ Clorophyta

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APPENDIX 11

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SPECIES LISTS

Phylum Protozoa

Foraminifera

Dinoflagellata

Phylum Coelenterata

?Obelia sp.

Phylum Annelida

Family Maldanidee

Family Serpulidae

Bydroides sp.

Phylum Bryozoa

Family Bugulidae

?Bugula neritina

Family Membraniporida

Membranipora sp.

Kingdom Plantae

Class - Clorophyta

Enteromorpha sp.

Class - Rhodophyta

Folysiphonia sp.

Caranfum 3p.

Diatomacea

?Amphora sp.

Biddutphia =p

Centrate sp.

Cocconeis sp.

Torsinodiscus sp.

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Diptonets sp.

Geasmatophore ep.

Gerosigas 3p

Homocladia =p.

Elomophora sp.

Ntosta vp.

Navicula sp.

Nitzschia sp.

Faralia sp.

Flourseige

Binnularia sp.

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Rhabdonema sp.

alla sp.

?Trachyneis sp.

Unknown (8 species unidentified)

Phylum Arthropoda

Family Balanidae

Balanus sp.

Genera Copepoda

Phylum Chordata

?Subphylum Urochordata

Family Botryliidae

Botryllus planus

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APPENDIX IT

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DATA ON STATION 3

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APPENDIX IV

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APPENDIX V

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