A Study of the Effects of a Wave Gradient on Intertidal Zonation at Yaquina Head, Lincoln County, Oregon

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ABSTRACT

A study of the effect of wave exposure was made on the outer rocky coast of Oregon. We found a definate effect on intertidal zonation produced by the wave gradient. This suggests that waves are a determining force in the intertidal habitat of the outer rocky coast.

INTRODUCTION

Intertidal zonation is a common theme among marine ecologists of the world. The Stephensons (1949,1972) outlined the universal features of intertidal zonation in a comparative review, although the first definative work on intertidal zonation is attributable to Lorenz(1863).

Intertidal zonation of British shores was described by Lewis(1955,1964) and a scheme of three major zones was postulated to be the Littoral, Eulittoral, and Sublittoral zones, as defined by dominant organisms. Many such schemes have been proposed(eg. Ricketts et al., 1968; Carefoot, 1977 for review). All such schemes are subject to limited generality due to the unique nature of intertidal sites as well as their heterogeneity.

Intertidal zonation is determined primarily by the tidal environment, as modified by: 1)wave action; 2) topography and substrate; 3) climatic factors; 4) period of immersion; and 5) biotic factors(Lewis, 1964). In this study we have chosen to investigate the effect of wave action on intertidal zonation, assuming that all other factors are held constant(Southward and Orton,1954). Two study sites were chosen which satisfied this assumption for the most part. These sites differed primarily in the degree of wave action and were described as strong and moderate wave action respectively.

DESCRIPTION OF STUDY AREA

The area of this study was Yaquina Head, a prominant basaltic headland on the open coast located four miles north of Newport, Oregon. The specific study sites were on the eastern surface of a point which receives a great deal of winter wave action(Figures 1 and 2). We chose a long, near vertical rock surface with a compass bearing of 30°N by 210°S along its length. It has an exposed southeastern face that is

parallel to the direction of wave travel and boardered by a surge channel. The seaward end is the most exposed to wave action. The shoreward end, with a shallow surge channel and tidal shelf receives less wave action.

The two study sites were chosen with respect to the wave gradient; site one at the seaward end and site two at the shoreward end. Both sites were similar as to slope, compass direction, degree of shading, amount of wind exposure, and substrate type. A comparison of transect heights and tidal heights is given in Figure 2b, as determined by methods below.

MATERIALS AND METHODS

At each site a vertical line transect with one foot intervals was established by measuring from the low low tide level with a stadia rod and hand level. Sampling quadrats were established by randomly placing a thirty centimeter square grid in each interval along the transect. From within the grid, samples were taken to determine the species encountered and counts were made of number of individuals and the percent cover of each species. Drawings were made depicting the types and arrangement of organisms within the grid area(Figure 3). Photographs were also taken at the location and study sites.

Sampled organisms were identified to species when possible, using taxonomic keys of the eastern Pacific coast(Light,1975;and Ricketts et al., 1968). The data were recorded and tabulated to determine the species composition and widths of visually observed zones. Because of the many factors affecting organisms existing together as associations,(as in the mussel community) and because many organisms were found only rarely and in small quantities, only the dominant organisms encountered were considered for determining zonation. We considered organisms to be dominant if they occured as greater than two percent of the

cover in any one interval.

RESULTS

Relative abundance expressed as percent cover for flora and fauna found in our two transect areas are given in Figures 4-7. Common organisms found in the more wave-exposed transect were; crustose coralline algae, Anthopleura xanthogrammica, Strongylocentrotus purpuratus, Corallina vancouveriensis, Plocamium violacium, Mytilus californianus, Pollicipes polymerus, Balanus cariosus, B. glanula , Chthamalus dalli, Acmaea digitalis, and Littorina sp. C. dalli was not recorded in the first transect due to taxonomic confusion, but was present. C. dalli was recorded on the second transect after proper identification was made.

On the second transect common organisms were A. xanthogrammica, S. purpuratus, crustose coralline algae, Endocladia muricata, M. californianus, B. cariosus, B. glandula , A. digitalis, C. dalli, and Littorina sp.

On the basis of visual observation we determined that the study sites had three major zones of organisms present. These zones were also apparent in our quantitative data. The zones are summarized in Figure 8.

Greater Wave Exposure - The transect with more wave exposure had a lower zone(zone 1)composed primarily of exposed rock, crustose coralline algae, A. xanthogrammica, S. purpuratus, and in the upper regions, a subzone of C. vancouveriensis and P. violacium. A middle zone(zone 2)was composed almost exclusively of M. californianus and associated P. polymerus. This large mussel dominated the area of zone two and had many species of animals associated with the cracks between the shells as they grew out from the rock substrate. This community would make an excellent place to study on the micro-habitat level, something outside of the scope of this study. Pisaster ochraceus was also

found here and is a predator of small M. californianus(Dayton, 1975). An upper zone(zone 3)was composed primarily of Balanus spp., C. dalli, A. digitalis, and Littorina sp. This community is dominated by prostrate organisms adapted to high wave action.

Lesser Wave Action - The transect with less wave exposure had modifications of the above zonation structure. Zone one was similar to the higher wave action site but did not include the upper subzone of coralline red algae. The abundance of A. xanthogrammica and S. purpuratus was greater in this transect of lower wave exposure. Zone two was very disimilar, having a predominance of E. muricata, with a high subzone of M. californianus in low abundance which did not form an extensive micro-habitat as described above. The third zone was similar to the more wave exposed transect, although we noted that the characteristic organisms had a generally lower range of distribution along tidal height. This zone was dominated by B. glandula, A. digitalis, and C. dalli.

A comparison of ranges of flora and fauna was made over the two transects(Figures 9,10). Inspection shows that distribution of plants and animals is generally lower in transect two, the moderate wave exposed site. Exceptions are found in the M. californianus-E. muricata interactions of zone two, where E. muricata tends to displace M. californianus in the moderate wave exposed site. A. xanthogrammica also occurs higher up in the moderate wave exposed site, displacing the coralline red algae subzone found in zone one of the strong wave exposed site.

DISCUSSION

Intertidal zonation was influenced by a wave gradient. From our scheme of zonation, we noted that a wave gradient was typified by a change of either: dominant organisms(eg. M. californianus-P. polymerus to E. muricata in zone two); relative abundance of organisms(eg. A. xanthogrammica in zone one); or

relative tidal height occurance of organisms(eg. Barnacles-A. digitalis in zone three).

It is apparent from the above possible changes in intertidal zonation that many factors are involved in the observed changes of intertidal zonation along a wave gradient. Physical factors are paramount in the intertidal habitat(Lewis,1964; Stephenson, 1949). Our study sites were chosen to minimize the inter-study site variation of slope, substrate, temperature, light, dessication, wind, and food availability, ie. two sites along a rock wall boardered by a connecting surge channel. Thus we addressed ourselves to the effect of wave exposure and its two components, surge and shock. The surge and shock of wave action affect the organisms through physical damage and wetting (EifionJones and Demetropoulos,1968). Organisms have developed adaptations to cope with wave action and we have assumed that the presence or absence of these adaptations has determined their relative distributions along the wave gradient.

The semi-diurnal tide creates the basic milieu of conditions in the intertidal. Wave action modifies these conditions and thus creates further habitat pattern which we observed in our study. The observed zonation of intertidal organisms is a direct result of the physical and biological factors in which these organisms must live(Lewis,1964).

Biological factors have been found to be of importance in determining the zonation of intertidal organisms. We have no way of testing these factors in this study, but merely suggest them as interesting alternatives and modifications of the effect of wave action. Organisms have specific physiological adaptations which allow them to live in specific environments. For example P. polymerus is adapted to high wave shock, by clinging to rocks or mussels, with a hydrodynamic morphology and feeds with cirri modified for wave surge. The crustose red algae are adapted with a prostrate morphology and are incrusted with $CaCO_3$ in order to resist grazing and high wave exposure on steep intertidal

areas.

Organisms may also be coadapted. We note that in the case of M. californianus, a concurrent micro-community is established. Thus once one type of organism colonizes an area, others will move in, which are adapted to live with the original colonizer in its modified environment. These events are modified during succession until a stable community is reached in time and space (Dayton,1975; Margalef,1968). Predation, both herbivory and carnivory as well as competition for space and food, have been found to also be significant factors determining intertidal zonation(Connell, 1961a,1961b; Dayton,1975; Paine,1974).

In this study it is interesting to note the large change in zone two between the strong wave action and the moderate wave action(transects one and two respectively). M. californianus dominated transect one whereas E. muricata dominated transect two. We hypothesize that there is an important biologically determined exclusion occuring here. However the importance of wave action cannot be overlooked in the exclusion of E. muricata from the exposed site versus the exclusion of M. californianus from the less exposed site. Perhaps the mussels cannot settle properly in the E. muricata community, or there is a specific predator effect of Pisaster ochraceus(Dayton,1975).

Specific experiments have been designed and are applicable to the biological causes of intertidal zonation relative to physical factors(Dayton,1975; Menge,1976). The scope of this study was limited to the evaluation of wave exposure effects upon intertidal zonation, hence cannot answer the above vital question.

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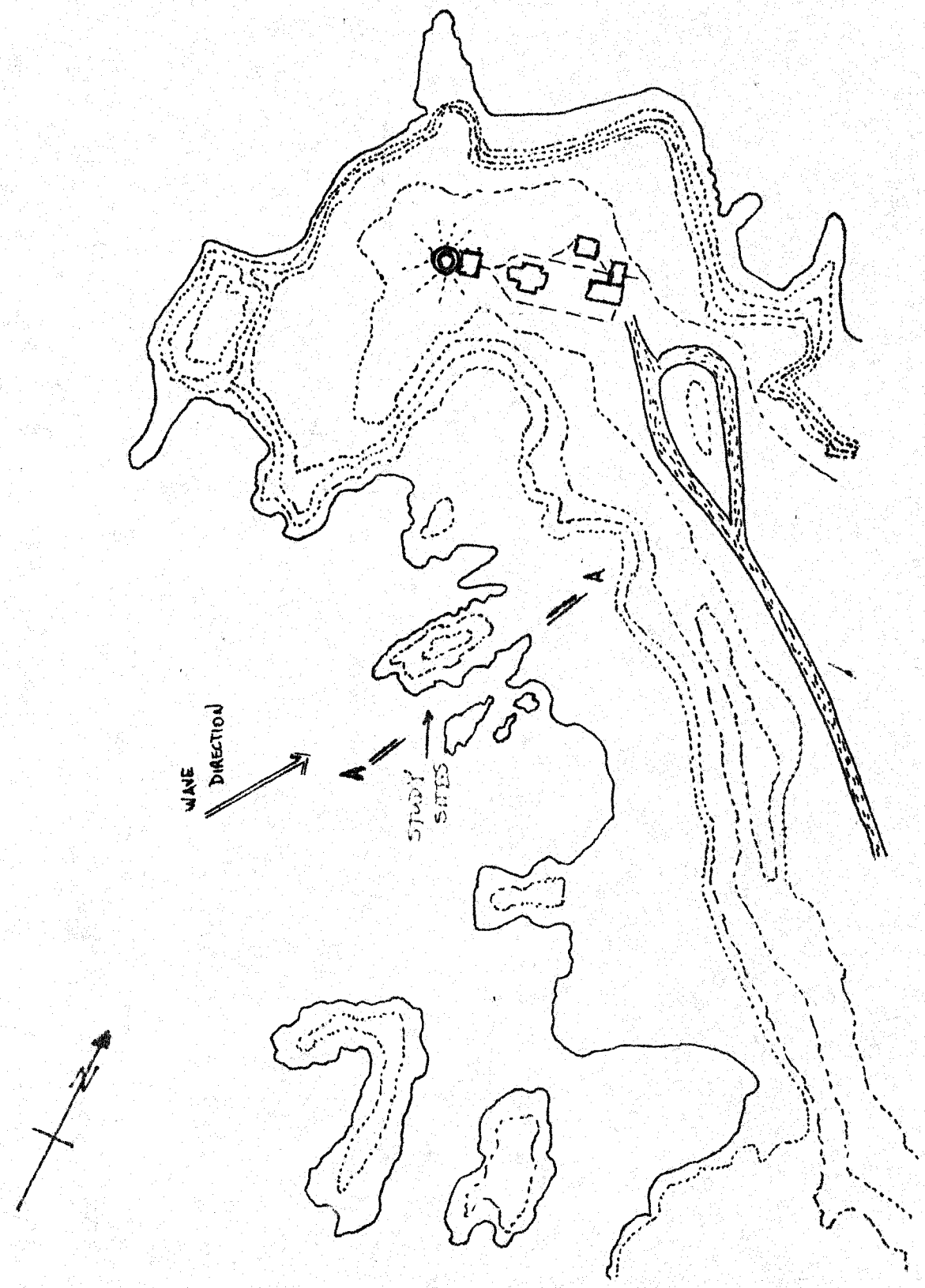
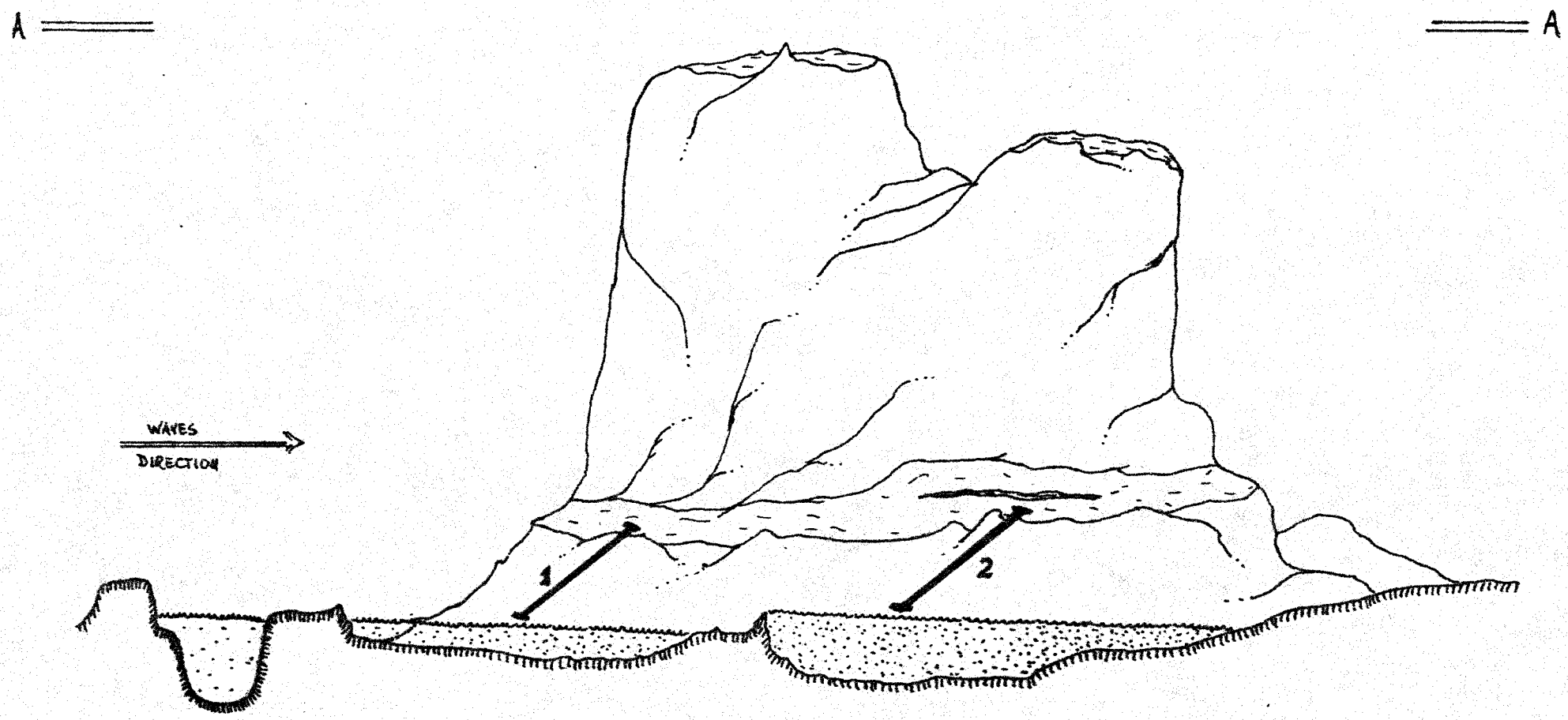


Figure 1. Map of Yaquina Head, Lincoln County, Oregon.



pa. Figure 2. Location of wave gradient study sites at Yaquina Head.

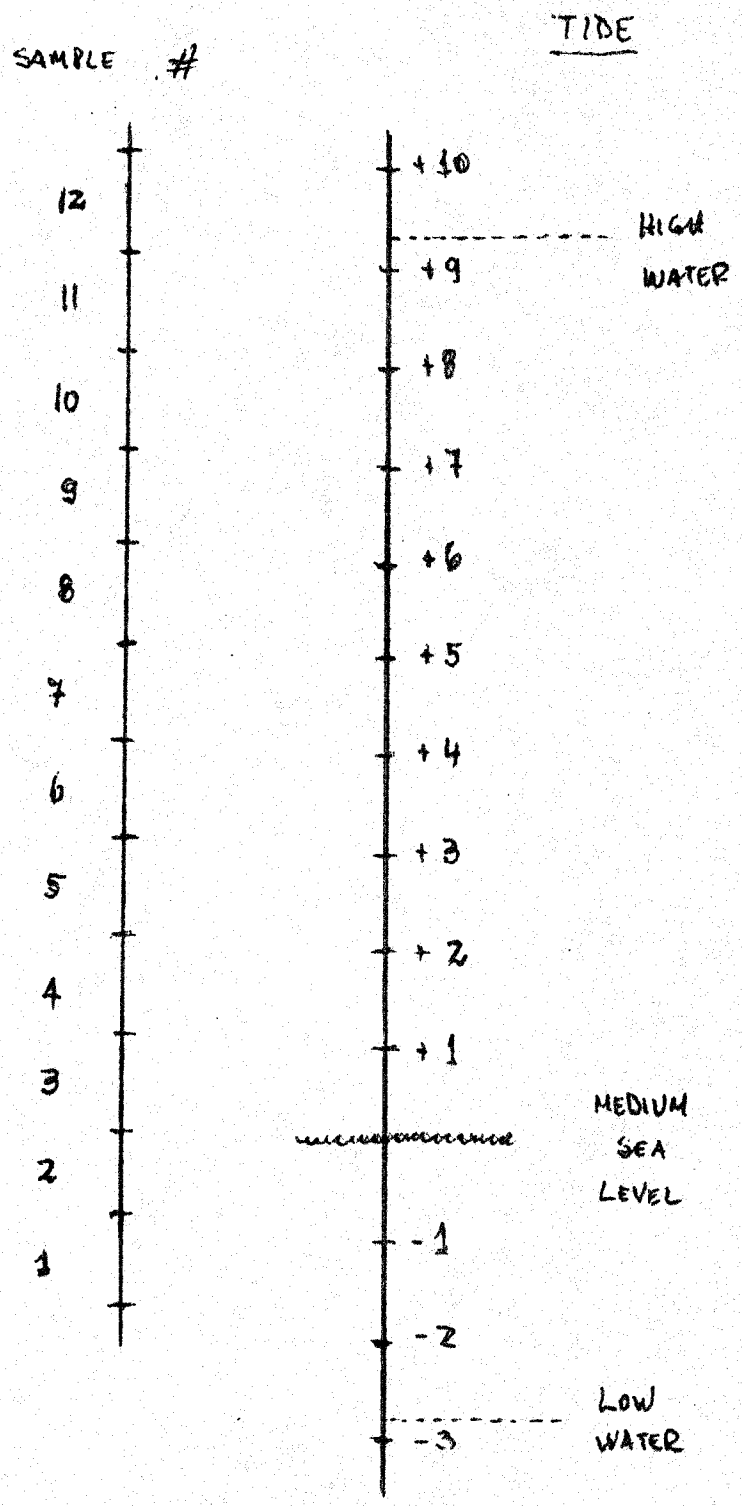


Figure 2b. Levels of transect intervals in relation to tidal height at Yaquina Head. 21/VI/78-22/VI/78.

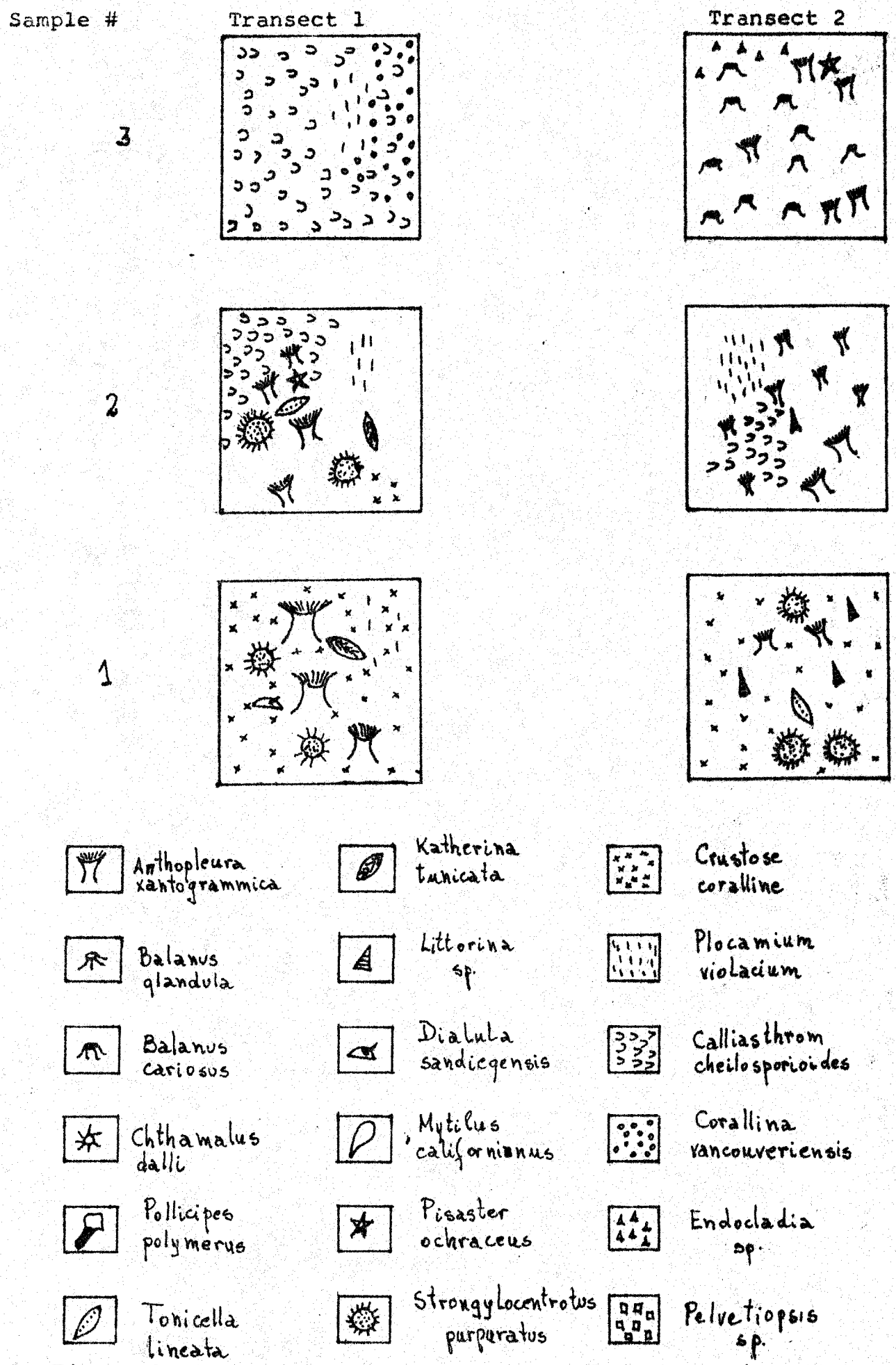


Figure 3. Diagrams of the quadrats sampled at Yaquina Head.

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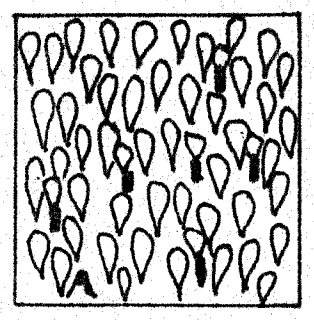

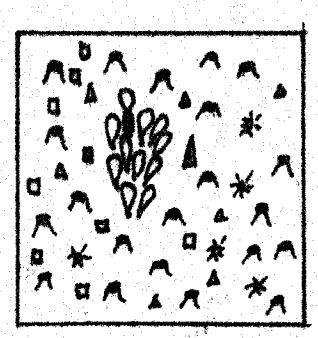

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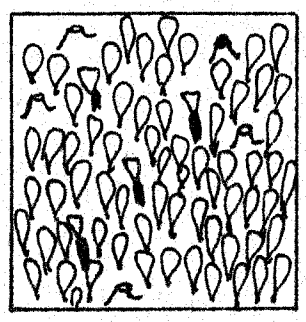

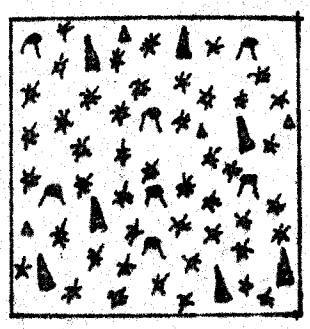

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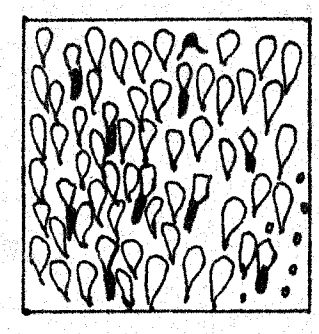

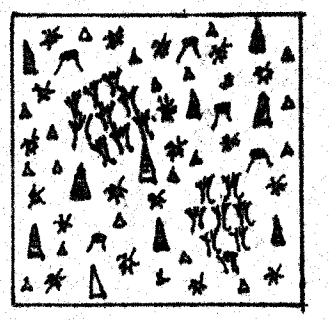

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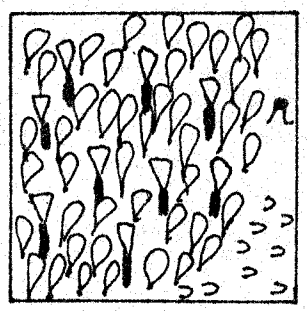

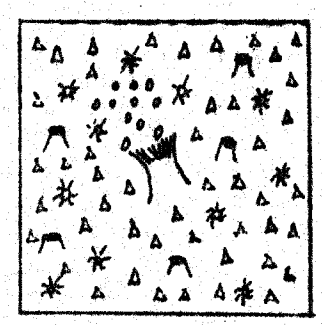

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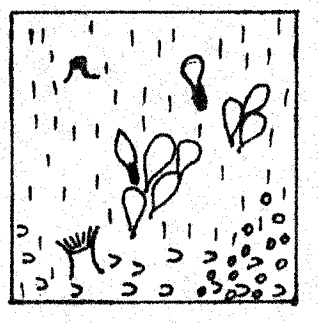

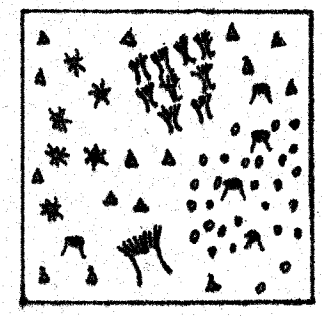

Figure 3. Continued.

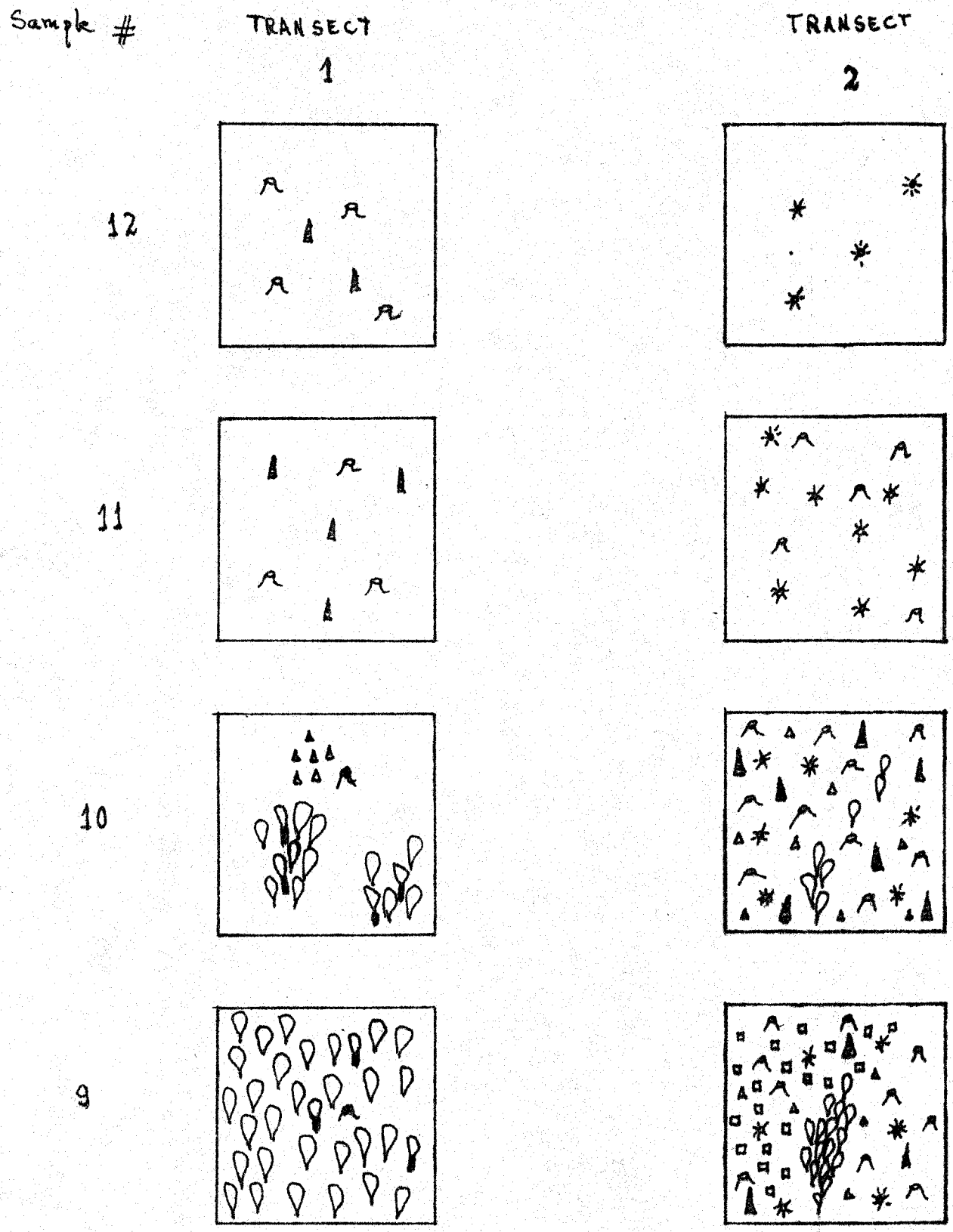

Figure 3. Continued.

Figure 4. Percent cover of animals at the strong wave exposure transect.

Figure 5. Percent cover of animals at the moderate wave exposure transect.

Figure 6. Percent cover of plants at the strong wave exposure transect.

Figure 7. Percent cover of plants at the moderate wave exposure transect.

Figure 9. Comparison of the animals at transect one and transect two.

Figure 10. Comparison of the plants at transect one and transect two.

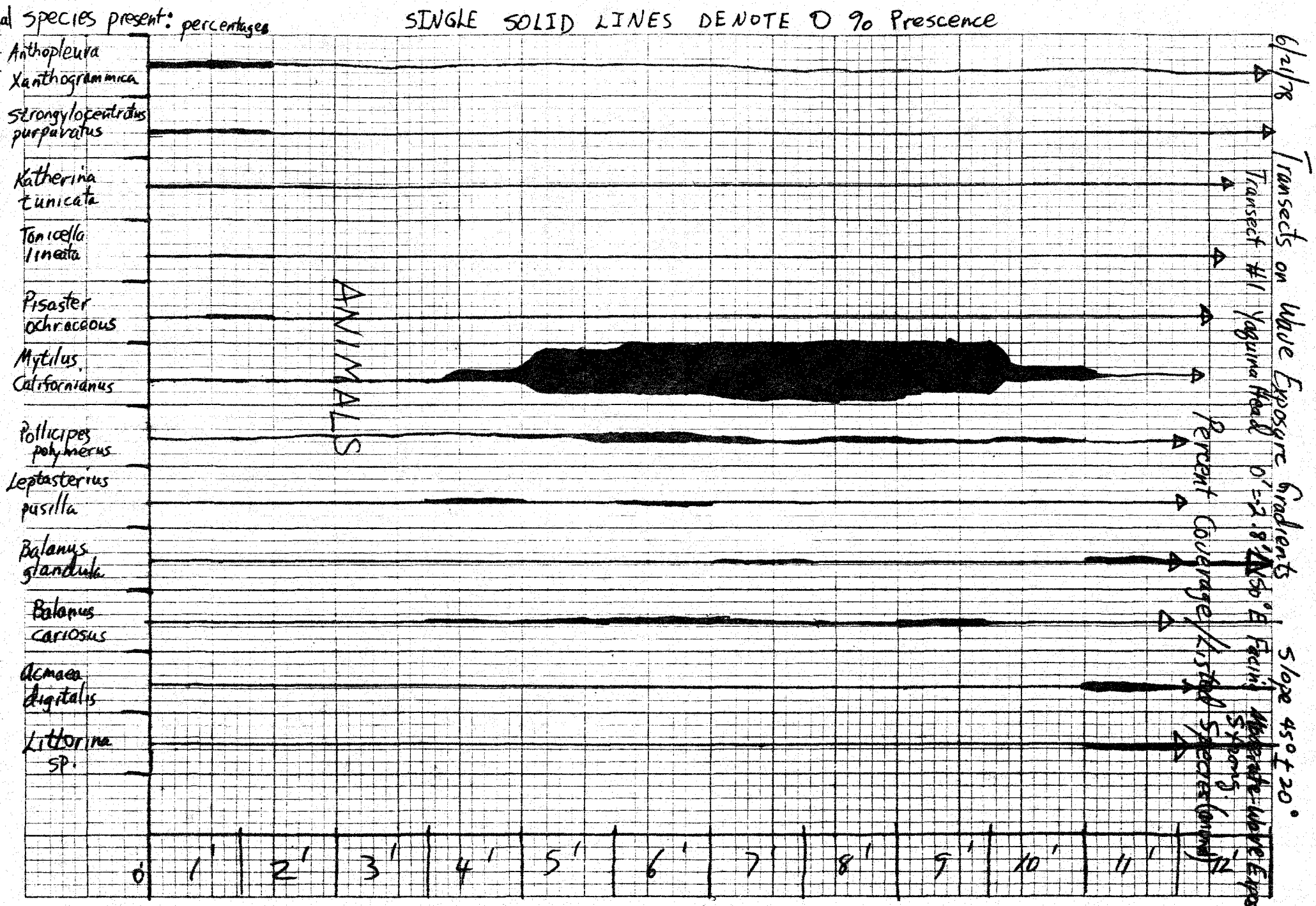

Figure 4. Moderate waves, Animals

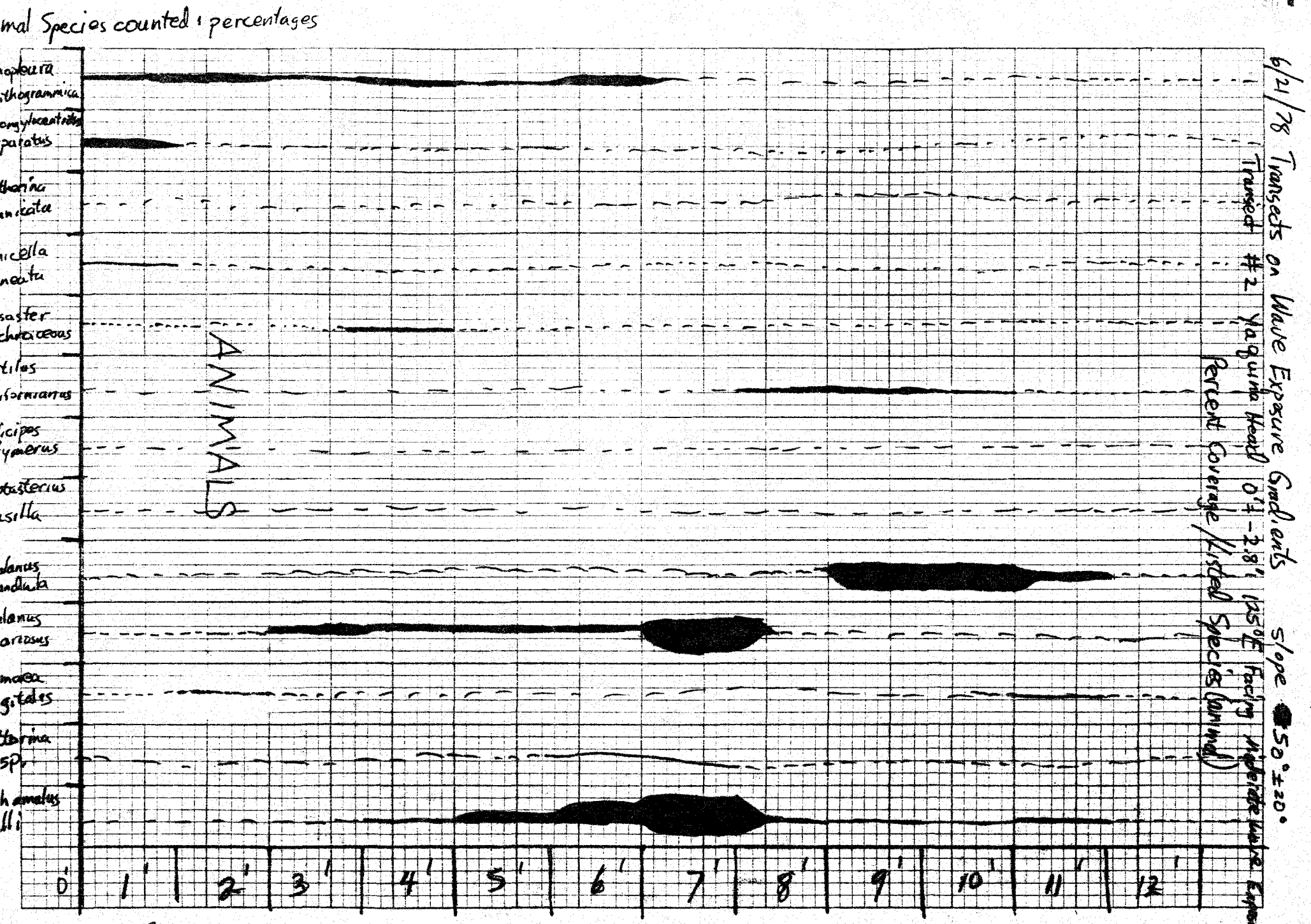

Figure 45. Moderate waves, Animals.

Transects on Wave Exposure Gradients Slope 45° ± 20°

6/29/78 Transect #1 Yaguina Head 0' = -2.8' 150° E Facing ~~moderate~~ Strong wave exposure

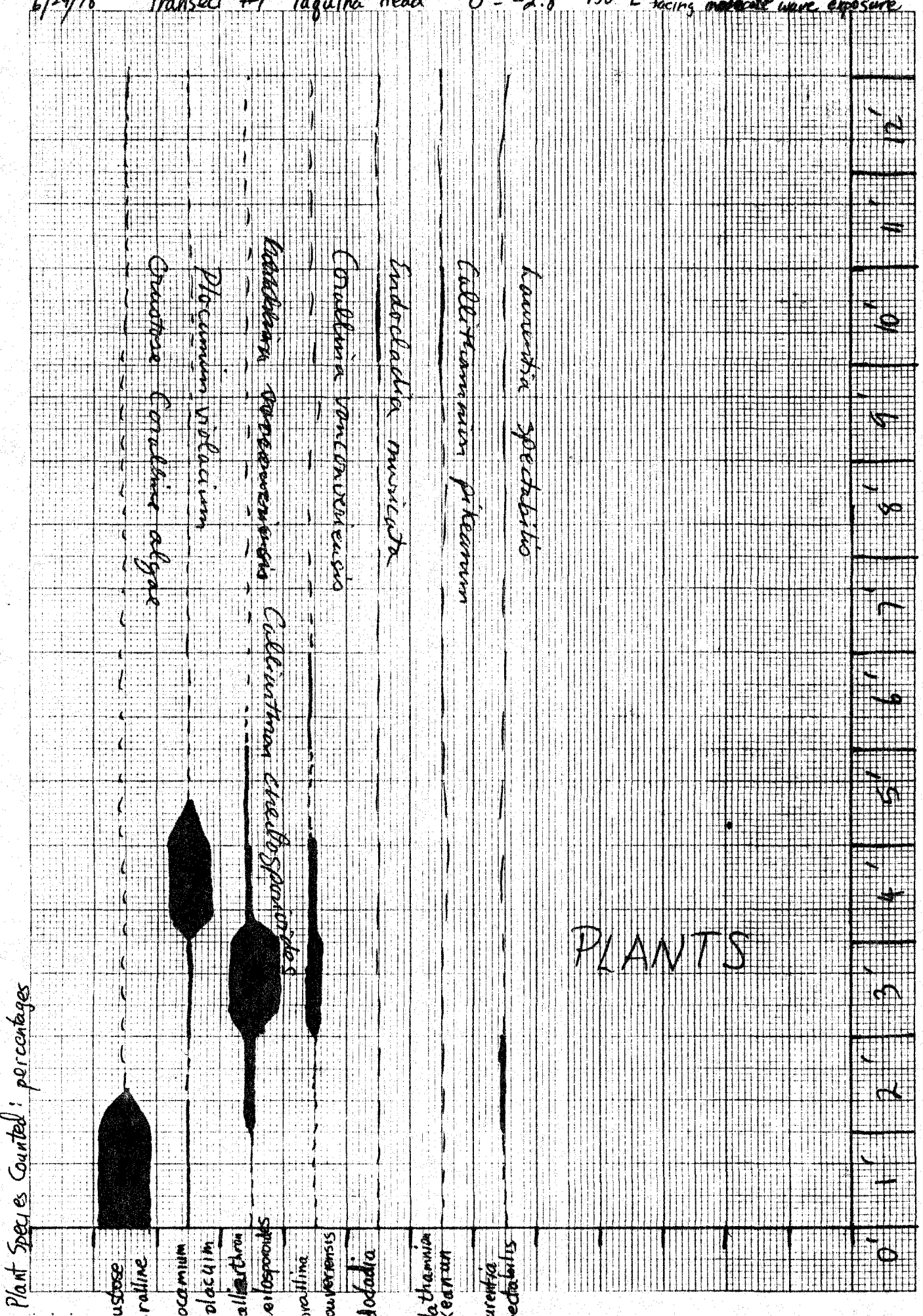

Figure #6 Strong waves, Plants

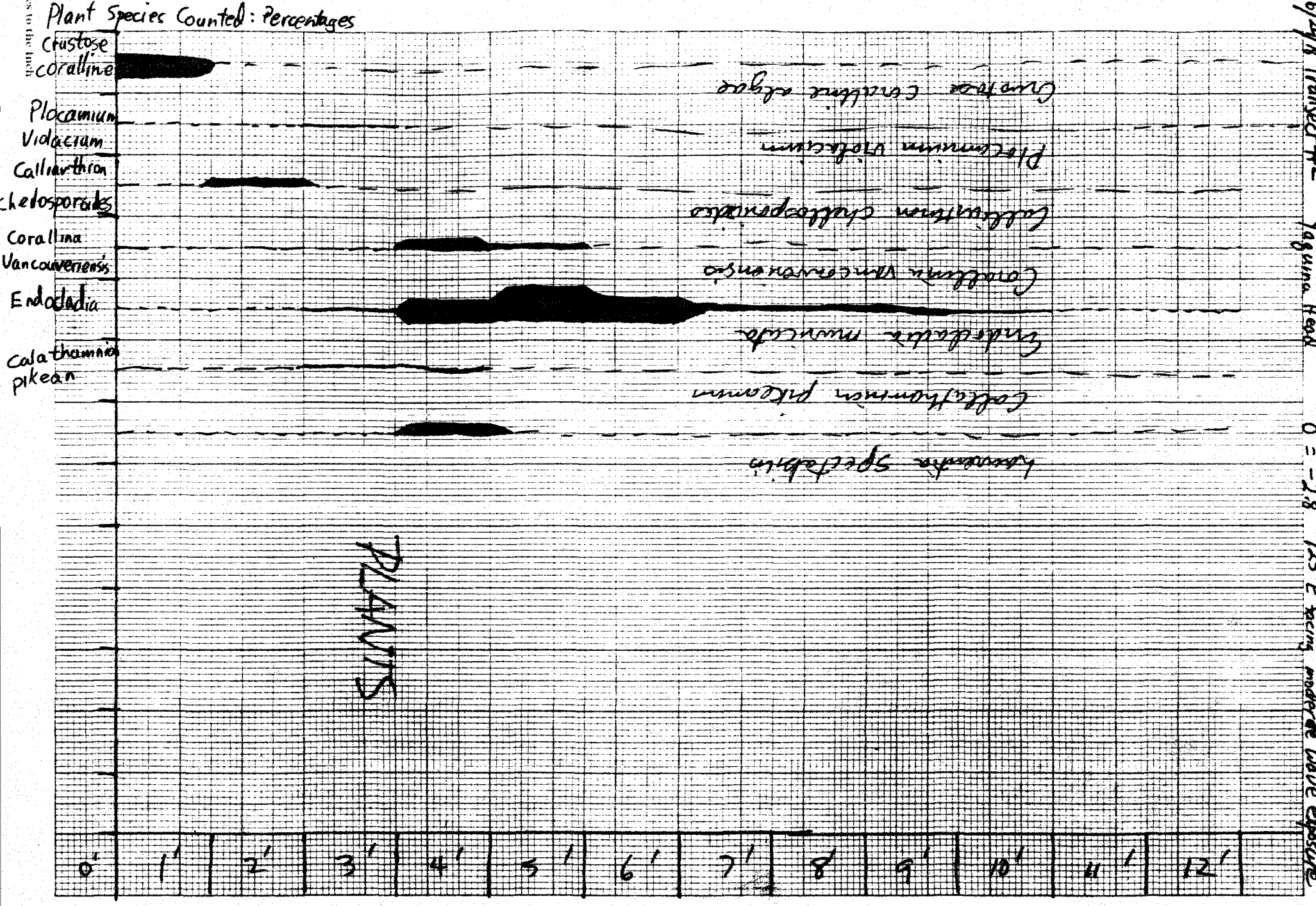

Figure 47. Moderate Waves, Plants

Transect #2 Yaquina Head 0' = -2.8' 125°E facing moderate wave exposure Slope 50 ± 20

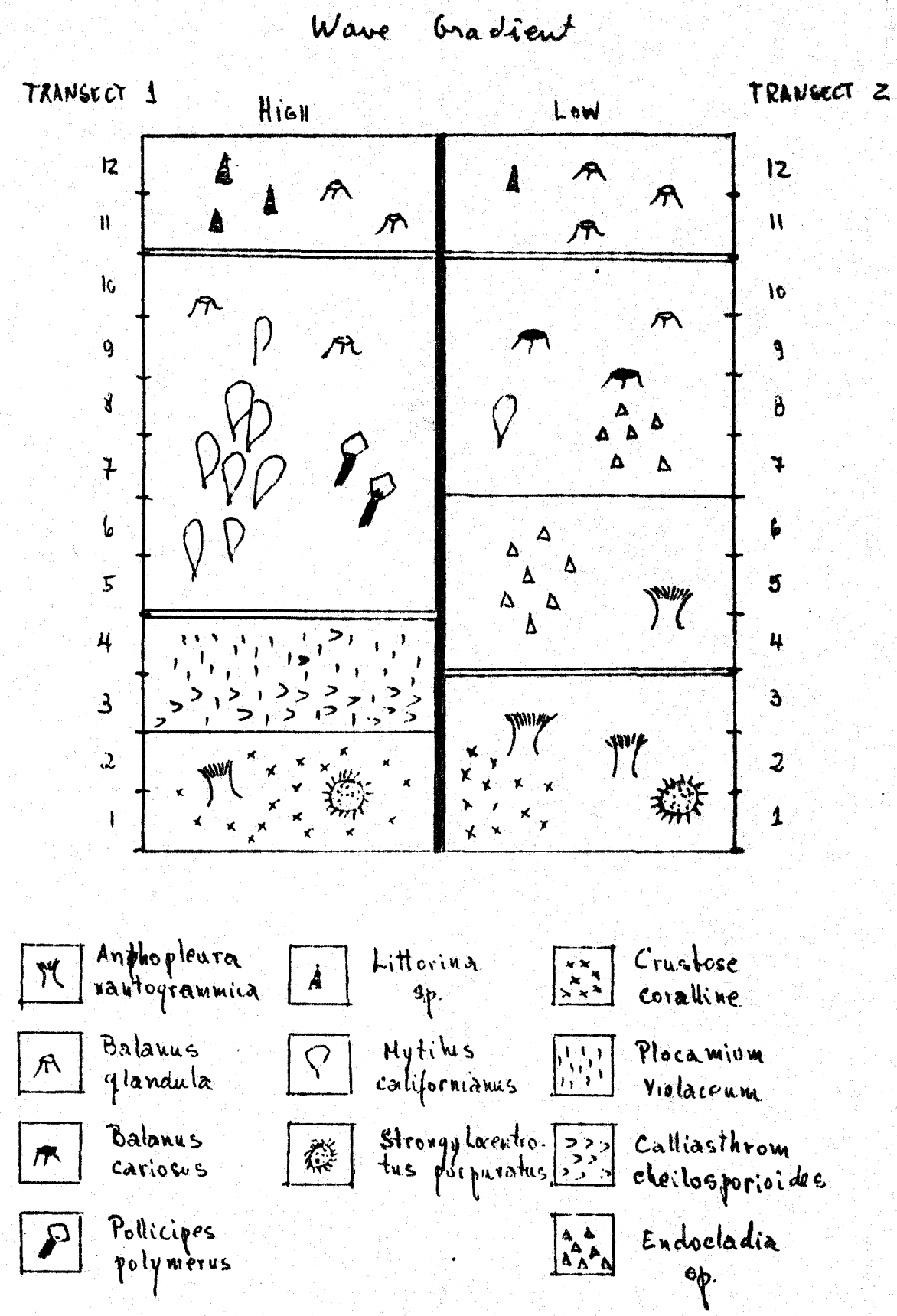

Figure 8. Diagram of the dominant species and their zones along a wave gradient at Yaquina Head.

6/29/78 Transects on Wave Exposure Gradients
Yaquina Head

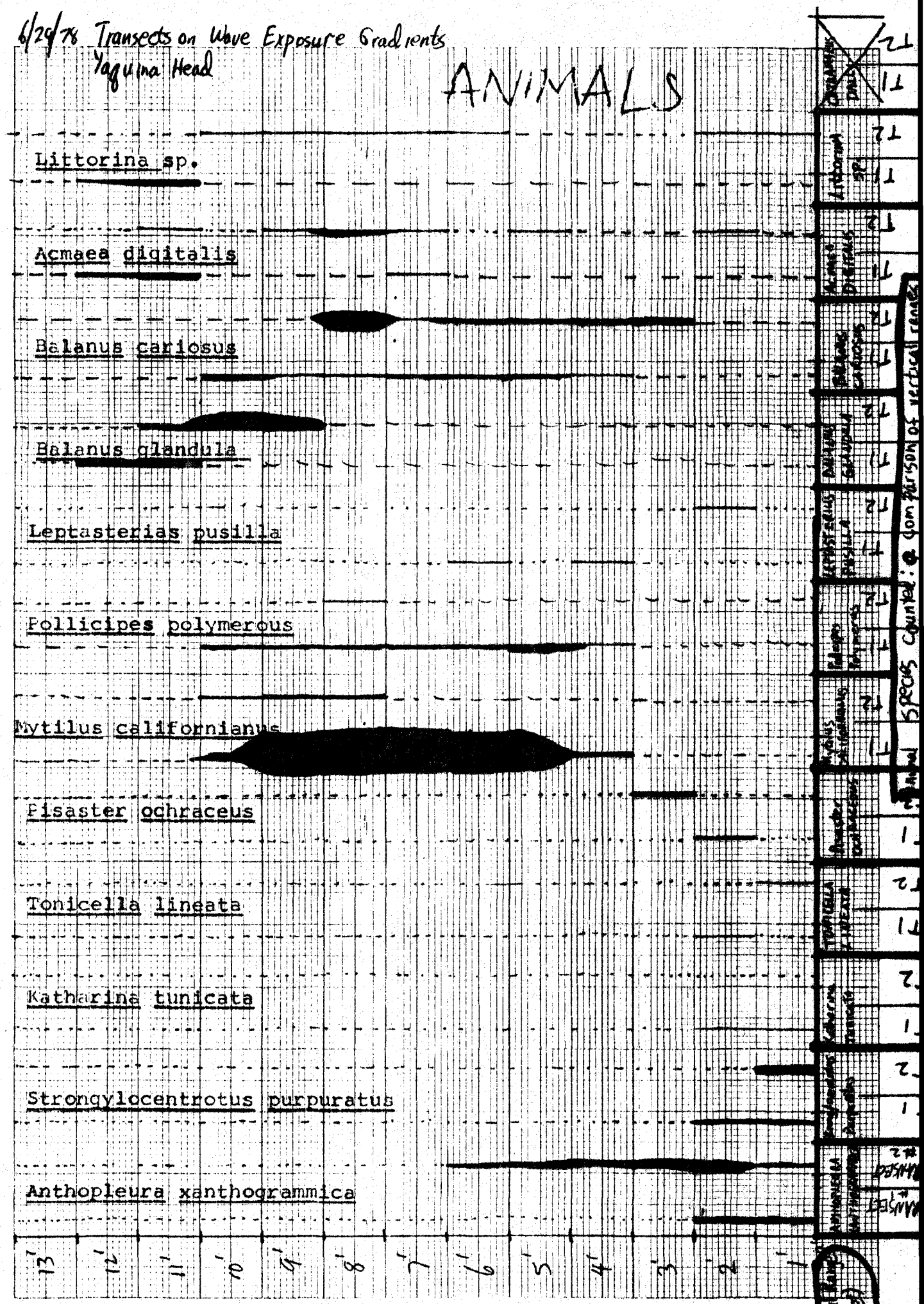

Figure 29. Comparison of animal ranges Transect 1+2

6/29/78 TRANSECTS ON WAVE EXPOSURE GRADIENTS

Yaquina Head

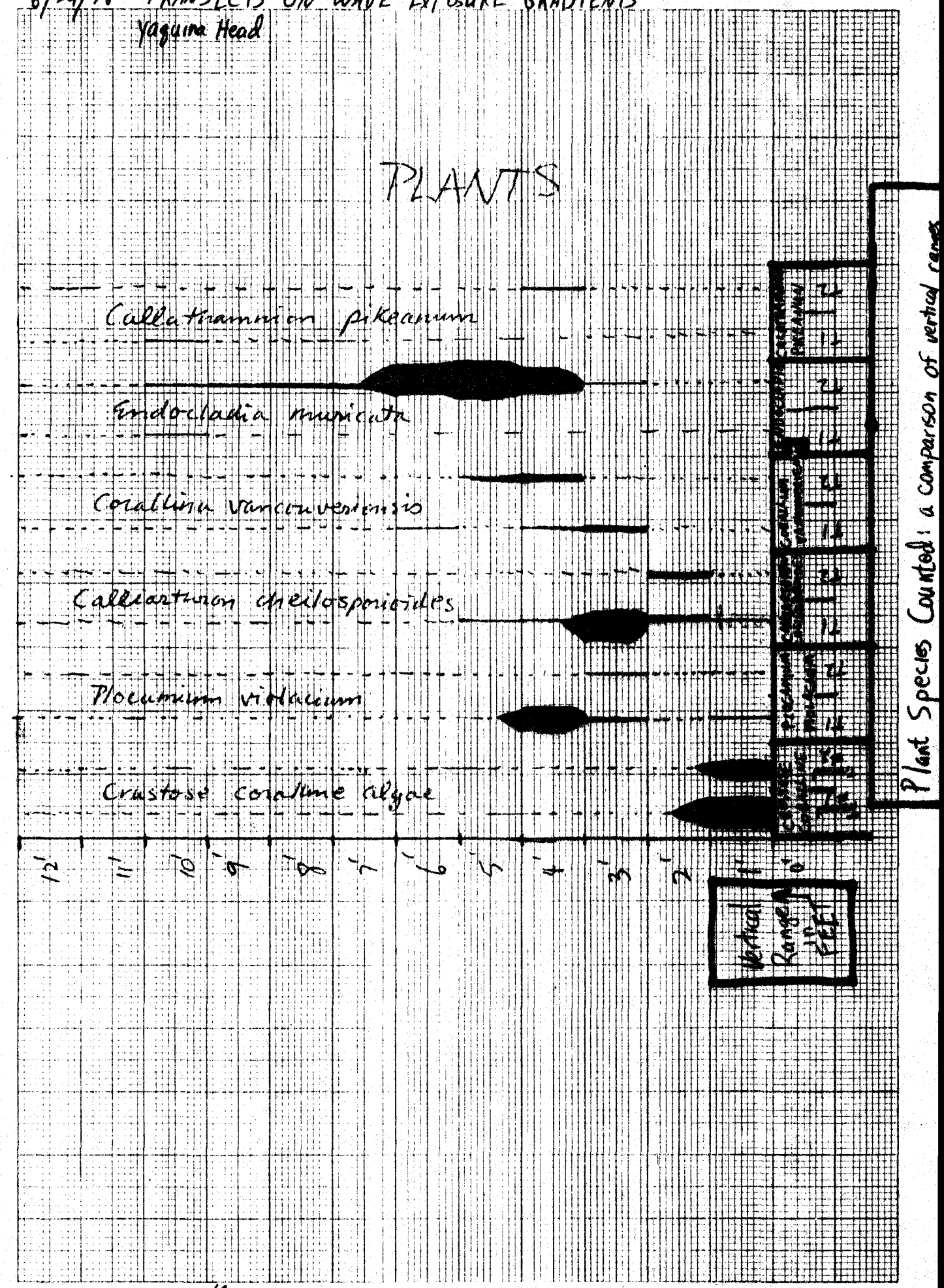

Figure 10 Comparison of Plant Ranges Transect 1+2

Transects on wave exposure gradients.

Transect #1, Yaquina Head 21/VI/78

Raw Data

0' = -2.5 ft. 150° T facing. Moderate wave exp. slope 95° ± 20°

#/%

	2	3	4	5	6	7	8	9	10	11	12	13	
Anthopleura xantho	12/10	8/10	1/<1	1/<1									★
Strongylocentrotus	2/3	2/3											★
Katharina tunicata	1/<1	1/<1											★
Diaulula sandiegensis	1/<1												
Tonicella lineata		1/<1											★
Pisaster ochraceus		1/3											★
Mytilus californianus			8/15	120/70	116/80	270/90	200/50	118/80	80/20				★
Pollicipes polymerus			26/2	75/15	100/10	20/3	10/5	20/2	45/5				★
Leptasterias pusilla			1/<1		1/<1								★
Chthamalus dalli													
Balanus glandula						12/<1				150/10	100/7		★
Balanus cariosus			1/<1	10/2	20/3	70/5	100/2	110/2	70/10				★
Tube polychaete	2												
Acmaea digitalis						24/1				40/10	20/5		★
Littorina sp.								1/10		100/10	75/7		→ mussel cover.
			★						★				→ mussel size decr

	2	3	4	5	6	7	8	9	10	11	12	13	
Crustose coralline	83/2												★
Microcosmus violaceum	2		5/65										★
Laminaria spectabilis		1/5											★ do la
Callianthron cheilosporioides	2/15	2/75	7/4										★
Gallina vancouveriensis		20/7		2									★
Iridea cordata				2									
Cladophora								1					
Endocladia								15					★
Calothamnion pikeanum								1					★

#/%

Transects on wave exposure gradients.

Transect #2 Yuquina Head 22/VI/78

Raw Data

Slope. 50° ± 20° 0' = 2.88'. 125° E Facing.

	1	2	3	4	5	6	7	8	9	10	11	12	13	
1 Anthopleura xanthogrammica	2/7	9/16	5/4	11/10	1/3	19/15								★ –
2 Mytilus californianus	3/10													★ –
3 Katharina tunicata														–
4 Tegula funebralis sanctiegensis														
5 Tonicella lineata	1/1													★ –
6 Pisaster ochraceus			1/4											★ –
7 Nucella emarginata								10/5	21/5	6/2				★ –
8 Pollicipes polymerus								1						★ –
9 Septastrea pusilla		2												★ –
10 Chthamalus dalli				5	15	30	80	5	4	4/1	5			★ –
11 Balanus glandula									40	40	10			★ –
12 Balanus cariosus			10	5	5	5	7	50						★ –
13 Gigartina prolifera	1			5	15/5									★
14 Littorina sp.	4	1				10/1	10/1	1	3	7				★ –
polycheate worms	4	5												
16 Mitrichondria pericea				1/5										
17 Acmaea digitalis		2			1		5	10	5		10/3			★ –
18 Cancellare coralline	35													★ –
19 Ceramium violacium			1/1											★ –
20 Laurencia spectabilis														
21 Calliarthron chilosporidioides		10												★ –
22 Corallina vancouveriensis				16	5									★ –
23 Iridea cordata														
24 Cladophora														
25 Endocladia			1/2	35/1	55	40	15/5	8/4	6	2				★ –
26 Microcladia pikianum				3										★ –
27 Ulva latuca		1/1												
28 Rhodymenia palmata		1/1	5/2											
29 Red #2		9												
30 Red #3			5											
31 Hedophyllum				2/15										★ dolost
32 Petrocelis								11/3	10	Pollusia 5%				