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A brief survey of the cays of Arrecife Alacran,

a Mexican atoll

by

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It has long seemed desirable to make comparisons of atolls, atoll-like reefs, and islands between the three different oceans where such phenomena occur. A talk by J. T. Conover, Jr. before an AAAS Section G audience in 1960 on his investigations on Arrecife Alacran, Yucatan, indicated some features of the reefs that seemed vastly different from any I had observed on the Pacific Atolls. On his invitation I made a short visit to Alacran during his second visit there, in July 1961. This trip was made possible by a grant of funds from the Office of Naval Research through the Pacific Science Board. Eight days were spent on the Reef, during which it was possible to visit all six of the cays.

My sincere thanks are extended to Mr. Charles Hoskin and Dr. Conover, in charge, respectively, of the University of Texas and the University of Rhode Island-Duke University parties that were working on Alacran (and to Sr. Cabanas, lighthouse keeper on Alacran), for their kind hospitality and invaluable assistance in enabling me to visit the cays, as well as for freely sharing their knowledge of the Reef, making it possible to develop some familiarity with it, in spite of the shortness of the time I spent there. I can only hope that our discussions were as stimulating to them as they were to me. A brief notice of their investigations, as well as those of Professor F. Bonet, and his associates, may be found in Atoll Research Bulletin 84.

Until recently, Alacran was one of the least known of atolls, although it was described as early as 1699 by William Dampier, the English privateer-writer, in whose work is found some of the earliest carefully recorded field natural history. Descriptions were again made by Alexander Agassiz in 1888, and by C. F. Millspaugh, in 1916. During the last few years much investigation has been accomplished (see ARB 84), but rather little of it has been published as yet. In terms, at least, of observations in manuscript, Alacran has now become one of the best known of atolls. It has even joined the select company of atolls that have been investigated in depth by core drilling.

Arrecife Alacran has been described and a small-scale map of it published by Kornicker and associates (1959), and some of the fauna listed from their collections made in 1959. Also a detailed study of the reefs and especially of the roles of the various reef organisms has just been published by Kornicker and Boyd (1962). The emphasis of both these papers is mainly on the reefs and the marine aspects. The map shows Alacran as an intricate network of reefs, roughly oval in shape, with an arcuate, practically uninterrupted windward reef. Accumulated boulders on this break the water surface at low tide. The cays or islets are on the leeward side, mostly toward the north and south ends of this reef, and together they do not aggregate more than 0.5 sq. km in area.

The largest cay is Perez, with the lighthouse and weather station. Southeast of this are Pajaros and Chica, near the south end of the reef. About a third of the way up the west side is Desertora (Allison Cay) and at the north end the Desterrada (Utowana) cays, until recently one islet which a storm cut in two by removing the middle part, leaving the two ends separate.

### Physiography

The cays are all very low, probably nowhere more than between 3 and 4 m, mostly much lower than this. On each cay, dune ridges and beach ridges account for all land above a general level between 1 and 2 m. No boulder ridges were seen, nor any gravel above pebble-gravel size, except for the piles of Strombus shells mentioned below. A very few scattered boulders, 50 cm or more in largest dimension occur. These are mostly compact, fine-grained limestone, but one or two are pegmatite. In all probability these were brought to Alacran as ballast. Large brain corals are abundant on the reefs, but surprisingly few are thrown up on land, where actually none of any large size were seen. A special search was made for beach rock and emerged reef conglomerate but no consolidated rock of any sort was seen, and it is thought that none exists on any of the cays. Loose lime-sand and "finger gravel" of broken Acropora cervicornis are the most common materials. The sand, in places where birds are especially abundant, is of a dark yellowish brown color, elsewhere white to pale gray-brown. Most of it would correspond either to the Shioya Soil Series of the Pacific islands or to what has been termed Unaltered Sand and Gravel in the Marshall Islands (Fosberg 1959).

The following profile was encountered in a pit, dug for the purpose on Perez Islet just north of the lighthouse buildings, about 90 paces from the seaward beach, 68 paces from the lagoon beach, on ground very gently sloping from a dune ridge toward the lagoon, in a small opening in open Suriana scrub, thickly populated by sooty terns:

- 0-2 cm: loose dry sand mixed with Suriana litter.
- 2-3 cm: somewhat caked sand.
- 3-10 cm: fine sand, thinly and irregularly bedded light and dark gray-brown.
- 10-35 cm: medium-fine sand, irregularly mottled pale brown and yellow brown, first traces of moisture visible at about 25 cm, Suriana roots common in this layer; they are up to 1 cm thick.
- 35-65 cm: coarser pale sand with fine roots scattered through it.
- 65-105 cm: coarse sharp very pale sand.
- 105-140 cm: coarse sharp white sand with scattered, rather rotten coral fragments.

Water level, at 12:10 p.m., 133 cm, at 3:30 p.m., 133 cm, at 6:00 p.m., 150 cm.

The water in this pit tasted quite salty. A sample, analyzed by S. Rettig, of the U. S. Geological Survey, showed Cl 15,500 ppm., NO<sub>2</sub> 1,420 ppm., P as PO<sub>4</sub>, 1.2 ppm., HCO<sub>3</sub> 437 ppm., pH 7.1, and specific conductance at 25°C 41,700 micromhos. The high nitrate content is doubtless from the excrement of sea birds.

Along the beaches on several of the cays, especially Perez, Chica and Pajaros, are conspicuous ridges or hillocks as much as 1 or 1.5 m high of the large shells of Strombus gigas. These shells are thrown there

by fishermen after they have removed the animals to use as bait. Each shell has a hole broken in the smaller whorls. Another curious feature is the frequent occurrence of what appear to be leafless skeletons of a somewhat thorny irregularly branched shrub with a woody enlargement at the base. These are washed-up skeletons of large gorgonians commonly called sea-whips that are very common on the reefs. Purple sea-fans, also common in the beach sediments, are likewise abundant components of the reef community.

### Climate

Records kept by the Mexican government weather station on Alacran between January 1959 and the time of my visit, were made available through the courtesy of the personnel of the station, to whom I am very grateful; these show several interesting features, though the period covered is far too short for adequate generalization. Time was only available to study and copy certain features of these records, so wind direction and rainfall distribution were chosen as having the most influence on other features studied, namely physiography and vegetation. Data on wind strength have been compiled from the same set of records by J. T. Conover, and kindly made available to me.

The records of wind direction that are generalized in the accompanying graphs were made three times daily.\* The bars on the graphs simply represent the total number of observations of wind from each direction, the bottom bar indicating observations recorded as calm. It is clear that there is a prevailing wind from the east, commonly ranging to northeast or southeast, rarely to north or even northwest. The only months that were notable exceptions, during the 2½ years of record, were November 1959, when the preponderant direction was north with only a moderate easterly component, and September 1960, when the winds were fairly well distributed as to direction. From April through August, the southerly to westerly components are negligible and during the rest of the year almost so. The data assembled by Conover (unpublished) indicate that wind exceeds 20 knots on half or more of the days in 8 months of the year.

The rainfall regime indicated by the station records is so remarkable that it seems necessary to present the actual figures,\* generalized only to the extent of adding together the amounts shown by three daily observations into daily totals. The three enormously high figures, 999 mm on each day, on Sept. 11, 1959, Dec. 26, 1960, and Jan. 9, 1961, each represent single readings of the gauge (1 meter), thus being the record for 12 hours or less. It was said that on each of these occasions the gauge overflowed in a storm, so the record should be more than a meter for each of these readings. As the regime indicated by these records is so unusual that it may possibly not be accepted by climatologists, it will not be discussed here, other than to say that the sparseness of the vegetation, its poverty in species, and the extremely xeromorphic character of the plants seem generally consistent with extreme drought.

In the soil pit dug on Perez Islet, the first traces of moisture were encountered at about 25 cm, the sand became wet at 105 cm, and the water was salty. According to the record there had been no rain for 20 days, then only 3 mm, and before that none for 105 days.

\* Graphs and rainfall figures will be found at end of Bulletin.

## Vegetation

The vegetation of Alacran has been described in some detail by Bonet and Rzedowski (in press), whose observations agree in most respects with mine. Therefore only a summary need be given here. The vegetation is all of an extremely pioneer character, is composed of few species and shows a strong tendency to form recognizable communities, as well as a tendency toward almost pure stands of single species. Nowhere is the dynamic nature of vegetation better shown. While on the basis of such a brief survey a detailed successional pattern could not be worked out, certain dynamic relationships may be indicated.

Early records of the vegetation of Alacran are meager, indeed. William Dampier, who visited the atoll in 1675, says in the account of his voyage (1931 ed., p. 143) "The Alacranes are 5 or 6 low sandy Islands... On some there are a few low bushes of Burton-wood, but they are mostly barren and sandy, bearing nothing but only a little Chicken-weed; neither have they any fresh water."

Doubtless by "Burton-wood" he means Conocarpus (button wood), now almost lacking on Alacran. What "Chicken-weed" might be is not so clear, though possibly it may be Portulaca oleracea.

T. Smith (1838, pp. 804-805) is perhaps the next to mention the vegetation of Alacran. He says that "these sand bores soon get covered with grass, samphire, and various kinds of herbs." The grass was doubtless Sporobolus virginicus and the samphire must have been Sesuvium. The lack of any mention of shrubs suggests that between Dampier's visit in 1675, and 1838 the atoll may have been swept by a storm of unusual violence and the vegetation removed. However, the West India Pilot (p. 371) says that the three cays at the southeast extreme of the reef were "clothed with grass and brushwood." This is most likely based on a report by T. Smith or by Captain Barnett who surveyed Alacran in the 1840's. Marion (1884) says that in 1865, on Perez there was not a tree, only short grass and sea-fennel (fenouil marin) and one hut.

In 1899 C. F. Millspaugh visited Alacran on the Utowana Expedition and prepared a detailed description and maps of the vegetation of most islets (Millspaugh 1916). The islets were principally covered by Sesuvium, with considerable areas of Sporobolus, and a scattering of other herbs and shrubs.

Since Millspaugh's visit profound changes have occurred. It was evident to Millspaugh that the vegetation of the cays was all of an early pioneer character and he regarded most of it as no more than 57 years old, as, according to him, Pajaros and Chica had been described in 1842 as "bare sand spits devoid of vegetation" and Perez and Allison (Desertora) as having "grass and samphire only." Although he nowhere says so in so many words, Millspaugh apparently regarded the youthfulness of the vegetation as indicating that the islets, themselves, were very young, as he said "The discovery, on these islets, of three species new to science, with the proof that they have evolved within the known and definite period of 57 years, is a fact impressive as it is important." The species

he referred to were Cakile alacranensis Millsp. (apparently a form of C. lanceolata, though the taxonomy of Cakile still leaves much to be desired), Tribulus alacranensis Millsp. (a form of the variable T. cis-toides) and Cenchrus insularis Scribn. (C. pilosus H.B.K.). All of these seem to be merely forms or synonyms of more widely distributed, previously described species.

There is, of course, no way of proving that the islets of Alacran either are or are not of such recent origin. It does seem probable that in 1838 and 1842 there was little vegetation. Whether this was a primitive condition is questionable in view of the statements of Dampier and Smith (1838), and since the violence of storms in the region is such that complete denudation of the islets is easily possible and may have taken place not long before the visit of the British survey party in the 1840's. In any event, the report of nothing but grass (Sporobolus) and samphire (Sesuvium) on Perez and Desertora and nothing at all on Pajaros and Chica in 1842 provides an important reference point for estimating the rate of colonization of bare sand cays by plants and of the development of their vegetation.

The possibility that between 1675 and 1838 the woody vegetation may have been entirely destroyed by sealers who would have used it for firewood in trying out seal oil cannot be ignored. However, constant use of Suriana for firewood by the inhabitants of Perez Islet since the light-house was established over 40 years ago has not prevented this shrub from becoming the dominant vegetation on the islet. Also, on the similar Pedro Cays, south of Jamaica, annual clearing of woody vegetation to facilitate egg gathering, has not, in many years, eliminated this vegetation. The woody plants concerned sprout readily from the root crowns, and these crowns are not easily pulled out by such ordinary means as would likely be employed by firewood gatherers.

The discernible plant communities or vegetation types are listed below and briefly characterized; their relations with substratum variations, something of their patterns of arrangement, and historical changes, where known, are discussed. It is hard to be sure that some of the primary pioneer communities listed are not just fortuitous aggregations of plants with no significance, except where a definite relation with substratum or topographic variations is discernible. A detailed map of these communities would be desirable, but time to make such maps at all carefully was not available. The arrangement followed is arrived at purely subjectively, starting with the most extreme pioneer situations and ending with the most advanced vegetation, in a successional sense. It should not, however, be assumed that there is any regular or linear successional series of communities intended. To establish actual dynamic relationships between these communities would take long and detailed study, with repeated visits over a period of years.

1. Cyperus colonies. Occasionally, on gravel bars, at the tops of beaches, and more rarely on interior sand flats, are small groups of usually widely separated tufts of the spreading culms and rather harsh leaves of Cyperus planifolius. That this is a primary community is shown by stands of tiny seedlings on otherwise bare areas. Locally, as on the sand flat at the top of the beach at the north end of Perez, dead tufts

of this sedge were seen. No apparent reason for the dead condition was noted, but perhaps with the extreme drought prevalent here, only slight differences in porosity may result in desiccation of the roots. Colonies of Cyperus are now much more widely distributed than indicated by Mills-paugh, who mapped it only from the south end of Perez, where it is still present.

2. Atriplex colonies. At the tops of beaches of fine gravel and sand, and on sand flats in the interior of islets are small rather open patches of Atriplex pentandra, a gray-green bushy herb, clearly tolerant, as are most of its congeners (generally called salt-bush), of high salt concentrations. It seems a bit more widely distributed than indicated by Mills-paugh, being abundant on Desertora (Allison) Islet, where he does not show it.

3. Euphorbia mesembrianthemifolia dwarf scrub. One of the most widespread vegetation types is an open dwarf scrub of Euphorbia mesembrianthemifolia, with various, usually minor, admixtures of other plants, especially such herbs as Cenchrus, Portulaca, Cakile, and, occasionally, Atriplex. The substratum is usually small gravel or a mixture of sand and gravel, high enough to be well drained. In places the Euphorbia is largely dead or in poor condition, but mixed with dead or dying plants are occasional healthy green ones. Millspaugh shows this type to be more confined to the peripheries of the islets than it is now, though it is still more commonly found there. There seems to be no indication that this community follows or replaces any other, and it has every appearance of a primary community that would, in an undisturbed situation, be readily replaced by Suriana, or possibly even by Sesuvium or Sporobolus.

4. Portulaca oleracea stands. Locally, on sand and gravel flats, both at the tops of beaches and in the interiors of islets, are open, more or less pure, stands of Portulaca oleracea. This fleshy herb forms depressed circular mats, each made up of one plant, up to 25 or even 30 to 40 cm across. There is no apparent difference between the situations occupied by Portulaca and those of the Euphorbia described above. This is certainly a primary community, probably very short-lived. Millspaugh records only a few individuals of Portulaca scattered among Sesuvium (and Sporobolus). It is much more abundant now.

5. Cakile stands. On beaches, beach ridges, and sand flats just back of beaches are occasional areas of sparse stands of Cakile lanceolata, a somewhat fleshy annual. Almost all mature plants were dead, but shedding mature fruits in July. A few were green and flowering, and locally small seedlings were abundant. This also seems to be a primary pioneer community, confined to substrata of sand or gravelly sand.

6. Open Tournefortia scrub. On Desterrada Islet and on the northwest part of Perez, also on a small sand lobe on the east side of Perez, is a community largely made up of low round dome-like bushes of Tournefortia gnaphalodes, with some admixture of Euphorbia, Cenchrus, Portulaca, and Cakile. This community occupies sandy terraces, dune ridges, and dune fields, and, at least on Perez Islet, seems to indicate land that has recently been added to the islet by deposition of sand. It is not unlikely that the relation with dunes may be the reverse of what might be expected,

that is, that the dunes result from the accumulation of sand by the Tournefortia plants which act as sand traps. These bushes are commonly growing up through a low mound of sand of about the same shape as the bush, with the stems originating at the original ground level beneath the mound. Examination of Perez Islet from the top of the lighthouse shows that the former outline of the islet, that shown on Millspaugh's map, is largely preserved by the present area of Suriana scrub (see below) and the areas occupied by Tournefortia scrub appear to have been added subsequently, as they are clearly outside the periphery of the islet as mapped by Millspaugh. Ground examination of this area shows some indication of invasion by Suriana, suggesting that Suriana will eventually replace the Tournefortia. On Desterrada Islets, this is the principal community, except in peripheral situations. Much of the area is an irregular field of low dunes largely occupied by Tournefortia.

7. Sesuvium mat. On most of the islets are areas, usually not very extensive, covered by closed mats of prostrate, fleshy Sesuvium portulacastrum. These areas are mostly low and very saline, sometimes actually wet at high tide. This vegetation type was, at the time of Millspaugh's visit, by far the most prevalent, covering the larger part of all the islets he mapped. Other plants indicated by him as growing in the areas mapped as Sesuvium suggest invasion. However, in most places the closed Sesuvium community is replaced by open types, so some other factor than invasion and ordinary succession must be involved, as a succession from a closed to an open vegetation would be most unusual. The fact that the areas concerned are now occupied by large bird populations may be of significance. Another fact may be added here. On Desertora (Allison) Islet, some areas of Sesuvium mat are in a very unhealthy condition, and some are completely dead, but with the dead plants mostly still there and intact. These areas are in some cases occupied by nesting frigate birds, but the nests are fairly widely spaced. No other reason for this condition suggests itself, since there seems to be no topographic or other differences between these areas and those where the Sesuvium is healthy and flourishing. On Perez Islet the former extensive Sesuvium area is now completely occupied by open Suriana scrub is the site of an enormous sooty tern rookery.

8. Avicennia swamps. On Pajaros and Perez islets are very small salt-water ponds, cut off from the sea by sand spits, in which Avicennia germinans forms tiny mangrove swamps. The shrubs are at most several meters tall, mostly much smaller, and very young ones and seedlings are plentiful. No other species grow with them, and no such swamps were indicated by Millspaugh, who did not find Avicennia at all. These swamps, though very small, are so conspicuous that they could not have been missed by earlier investigators if they had been present. The local people said that they brought the plants from the swamp on Pajaros Islet to the pond on Perez, but gave no indication of the origin of those on Pajaros. In all probability a single plantlet was washed ashore on Pajaros while the pond was still partly open, or may have been washed into the pond on a high wave, in very recent times, since Millspaugh's visit, giving rise to this vegetation.



9. Tribulus flats. In the interior of the Pajaros and Desertora islets, which serve as rookeries for large numbers of blue-faced boobies, on rather hard packed sand, is a sparse very depressed vegetation of large very open mats of Tribulus cistoides, with locally, scattered small mats of Portulaca. This occupies areas indicated on Millspaugh's map as Sesuvium. Its presence is doubtless in some way related to the birds.

10. Sporobolus virginicus sod. On Pajaros, Chica, and Desertora are areas covered by a closed stand of harsh, wiry salt-grass, Sporobolus virginicus. This is generally fairly luxuriant where present at all, usually 20-30 cm tall. Nothing was seen to be invading it. However, its area is now much smaller than indicated by Millspaugh, and it is altogether lacking on Perez Islet, where he showed a large area on the south end and smaller patches in the center. Now these places are entirely covered by Suriana scrub. This, however, is open, and how it supplanted the dense grass sod so completely is not clear.

11. Suriana scrub. The dominant vegetation on most of Perez Islet is an open scrub about 1.5 to 2 m tall of Suriana maritima. The densely branched, bright green bushes are widely enough spaced that in most places it is easy to walk at will among them. The sand between them is absolutely bare of vegetation. Innumerable sooty terns, adults and feathered out young, occupy the spaces between the plants and roost in large numbers on the bushes themselves. In 1899, according to Millspaugh's map, Suriana formed a narrow fringe along the seaward side of the islet, somewhat as it does now on some of the other islets. The position of this fringe is marked now by a sand ridge covered by Suriana, that separates the Suriana scrub from open sand and gravel flats apparently added to the islet since 1899 and characterized by other vegetation. The curious fact that an open Suriana scrub has replaced two types of closed herbaceous vegetation has been alluded to above. It is apparent that, whatever the mechanism, Suriana is able to replace all the other natural vegetation types except possibly the Opuntia. The ground occupied is mostly sand.

12. Opuntia scrub. Millspaugh indicates a single small patch of what he calls Opuntia toona, or O. tuna, growing on a small pile of coral heads north of the center of Perez Islet. Now there are two patches, much larger than indicated by Millspaugh, one is approximately the same place, one south of the lighthouse; there is also one patch on the south end of Desertora Islet. The plants seem to be Opuntia dillenii rather than O. tuna. These fleshy, leafless, very spiny plants form a solid stand about 1 m or less tall, and seem clearly to be spreading at the expense of the Suriana. If left to themselves they may eventually occupy the entire islet. The patch on Desertora is a bit less solid, and is the site of a considerable number of Frigate bird nests. The presence of the birds seem to have a bad effect on the Opuntia. How the birds go about starting a nest in such an unpleasant situation is not clear, but the nests are dense and substantial enough so that the young birds are not bothered by the spines so long as they stay in the nest.

13. Casuarina groves. Around the lighthouse on Perez, and extending a short distance to the north and south of it, Casuarina equisetifolia trees have been planted, and have reached a considerable size, perhaps 10 meters. Smaller numbers of Cordia subcordata and Coccoloba uvifera shrubs have also been planted and seem to thrive. None of them, however, are reproducing themselves to any extent by seed, and this vegetation type seems to be dependent for its spread, if not for its persistence, on human intervention. The trees are fairly widely spaced and the intervening spaces are occupied by the Suriana scrub that covers most of the rest of the islet. Numbers of frigate birds use for roosts some of the Casuarina trees that are a little distance from the houses around the lighthouse.

Vascular Flora

The tabular arrangement of the plant species gives an idea of the floristic changes that have taken place, with perhaps more reliability than such figures usually have, since the Millspaugh survey was a careful one, as was that by Bonet. It is seen that species have disappeared as well as become established. Water, birds, and people are the principal agencies of dispersal, and most of the plants are well adapted to utilize one or more of these means. Why some species have disappeared is not so readily apparent. Some may have been crowded out as succession progressed. Others, such as Scaevola, may never have been present in sufficient numbers to preclude their disappearance because of accidental elimination of one or two plants. Storms may also have swept certain species away. Finally, some may not have been able to endure the extraordinary droughts that seem characteristic of this island.

In the following tables, E stands for records earlier than Millspaugh's; M for Millspaugh; B, Bonet; F, Fosberg; C. W., Conover, and Welch. 1 indicates that only a single individual was seen on an islet, X, more than one.



List of species	Perez					Desertora			Pajaros			Chica			WD	ED*
	E	M	B	F	C.W.	M	B	F	M	B	F	M	B	F	F	F
<i>Tournefortia gnaphalodes</i>		X	X	X	X			X	1	1	X			1	X	X
<i>Avicennia germinans</i>			X	X						X	X					
<i>Scaevola plumieri</i>		1														
<i>Flaveria linearis</i>		X														
<i>Crinum</i> sp.				X												
<i>Casuarina equisetifolia</i>			X	X												
<i>Cocoloba uvifera</i>			X	X												
<i>Chenopodium ambrosioides</i> (pot)				X												
<i>Portulaca grandiflora</i> (pot)				1												
<i>Jatropha urens</i> (pot)				1												
<i>Terminalia catappa</i> (pot)				1												
<i>Nopalea cochinellifera</i>			1	X												
<i>Cordia sebastena</i>			X	X												
<i>Mentha spicata?</i> (pot)				1												
<i>Capsicum annuum</i> 1 (pot)				1												
<i>Capsicum annuum</i> 2 (pot)				1												
<i>Solanum lycopersicum</i> (pot)				X												
<i>Sesamum indicum</i> (pot)				1												

\*WD and ED are West Desterrada and East Desterrada

List of Flowering Plants

The following list includes all the species known to exist on Alacran in July 1961, listed under the names believed to be correct, with citations of specimens seen by me. My own collections have not yet been distributed to herbaria, nor have those of Mr. Bruce Welch. A number of the names used differ from those used for the same species by Millspaugh (1900a, 1900b, 1916). Where Millspaugh's names are regarded as synonyms of those used here, they are listed as such, under the correct names. Where they are considered as misidentifications, they are referred to in the comments, so as not to confuse the reader. An asterisk (\*) precedes the names of planted species.

Diplanthera wrightii (Asch.) Asch.

Perez, F 41873.

Submerged marine aquatic, locally common in shallow areas in lagoon and around islets, forming a sod alone or with Thalassia.

Syringodium filiforme Klitz.

(Cymodocea manatarum Asch.)

Perez, F 41913.

Submerged marine aquatic with terete leaves, local in Thalassia sod near islets.

Thalassia testudinorum Koen. et Sims

Perez, F 41872.

Submerged marine aquatic, abundant generally in shallow water on sandy bottoms, forming a dense sod which is the predominant marine vegetation on large parts of the reef.

Cenchrus gracillimus Nash

Desertora, F 41929.

Common locally along lagoon beach ridge and somewhat inland. Differs only slightly from C. pauciflorus.

Cenchrus pauciflorus Benth.

Desterrada, F 41919.

Occasional on low sand dunes. This may be the plant reported by Millspaugh (1900) as C. tribuloides L. and (1916) as C. carolinianus Walt. but it could as well have been the preceding. It now seems to have disappeared completely from Perez Islet, where Millspaugh's collection was made.

Cenchrus pilosus H.B.K.

(Cenchrus alacranensis Millsp.)

Pajaros, F 41894; Desterrada, F 41914; Desertora, F 41930.  
Local on sand flats and dunes.

Sporobolus virginicus L.

Chica, F 41905; Pajaros, F 41901; Desertora, F 41926.

Forming dense sod on sand flats. In Millspaugh's time this species covered much larger areas than now. On Perez Islet, where it then formed a large part of the vegetation it has disappeared completely.

Cyperus planifolius L.C.Rich.

(Cyperus brunneus Sw.; Cyperus brizaeus Vahl; Cyperus ottonis Boeckl.)  
Perez, F 41863, Welch in 1961; Pajaros, F 41895.

Occasional and local on sand flats and at tops of beaches.

\*Crinum sp.

Perez, F 41891.

Planted around dwellings; not sufficiently developed for identification, but probably C. asiaticum L.

\*Casuarina equisetifolia L.

Perez, F 41876.

Planted in considerable numbers around lighthouse and in central parts of Perez Islet, where they have reached a considerable size but do not seem to establish themselves spontaneously from seed.

\*Coccoloba uvifera L.

Perez, F 41878.

Planted near lighthouse.

Atriplex pentandra (Jacq.) Standl.

(Atriplex cristata H. & B. ex Willd.)

Perez, F 41870, 41871, Welch in 1961; Desertora, F 41924.

Local, as scattered individuals, more usually open patches, in sandy and gravelly places.

Sesuvium portulacastrum (L.) L.

Perez, F 41874, Welch in 1961; Pajaros, F 41903; Chica, 41908;  
Desertora, F 41925.

Abundant locally, forming mats, sometimes very large ones, in low saline places; on Desertora in some areas these mats are dead or apparently dying.

Portulaca oleracea L.

Perez, F 41867, Welch in 1961; Pajaros, F 41902; Chica, F 41909,  
41912; Desterrada, F 41917; Desertora, F 41922.

Common to abundant generally in open areas; a form with flowers very large for this species.

Cakile lanceolata (Willd.) Schulz

(Cakile alacranensis Millsp.; C. edentula var. alacranensis (Millsp.) Schulz; C. aequalis L'Her.; C. lanceolata var. alacranensis (Millsp.) Schulz).

Perez, F 41864, 41868; Pajaros, F 41900; Chica F 41910; Desterrada, F 41920; Desertora, F 41932.

Common on upper parts of beaches, beach ridges, and on other open sandy or gravelly areas; our material is all of var. alacranensis, with greatly swollen distal segments to the fruits, but Millspaugh (1900a, b) reported var. lanceolata, first as C. maritima Scop., then as C. aequalis L'Her. This has narrowed merely terete distal segments. The detailed taxonomy of these forms is not yet in a satisfactory condition, so the whole complex is here referred to C. lanceolata.

Suriana maritima L.

Perez, F 41875, Welch in 1961; Pajaros, F 41898; Chica, F 41906; Desertora, F 41928.

Locally forming an open scrub, especially on Perez Islet, where it dominates most of the undisturbed part of the island.

Tribulus cistoides L.

(Tribulus alacranensis Millsp.)

Pajaros, F 41898; Desterrada, F 41916; Desertora, F 41923.

Common on open flats of hard ground, especially where boobies are nesting. The Alacran plants are of a small-flowered form, but since forms with such small flowers may be seen locally in other parts of the world, and since the species is a variable pantropical one, it does not seem advisable to maintain this local population as a distinct species. If a careful study of the variation of T. cistoides were made, there would doubtless be a number of varieties distinguished.

Euphorbia mesembrianthemifolia Jacq.

(Chamaesyce buxifolia (Lam.) Small; Euphorbia buxifolia Lam.)

Perez, F 41862, 41865; Pajaros, F 41899; Chica F 41911; Desterrada, F 41915; Desertora F 41931.

Conocarpus erecta L.

Perez, F 41893.

There seems to be only one bush of this species remaining here, a depauperate specimen with small leaves that so resembles the dominant Suriana that it was missed entirely until Professor F. Bonet called my attention to it. Several are shown in the same locality on Millspaugh's map.

\*Nopalea cochinellifera (L.) Salm-Dyck

Perez, F 41879.

Planted, but only one or two individuals, near dwellings.



Opuntia dillenii (Ker-Gawler) Haw.

Perez, F 41892, Welch in 1961; seen also on Desertora.  
Forming dense patches, but very local; reported by Millspaugh  
(1900a, 1916) as O. tuna (L.) Mill.

\*Cordia sebestena L.

Perez, F 41877.  
A number of trees of various sizes planted near the lighthouse and  
dwellings, abundantly flowering but almost completely leafless  
in July.

Tournefortia gnaphalodes (L.) R. Br.

(Mallotonia gnaphalodes (L.) Britton).

Perez, F 41869, 41890, Welch in 1961; Pajaros, F 41897; Chica,  
F 41907; Desterrada F 41918; Desertora, F 41927.

Abundant in sandy areas on Perez and Desterrada Islets, very rare on  
Desertora, Pajaros and Chica, only one tiny seedling seen on  
the latter islet. Millspaugh found one plant on Pajaros and  
none on Desertora or Chica. Because of the floating mechanism  
on the fruits, this species and its Indo-Pacific counterpart,  
T. argentea, are often segregated as a separate genus, called  
either Messerschmidia or Mallotonia, depending on whether or  
not the Siberian Messerschmidia sibirica is regarded as also  
in the same genus.

Avicennia germinans (L.) L.

Perez, F 41866; Pajaros, F 41904.  
Locally abundant around two small ponds, said to have been brought to  
Perez from Pajaros; undoubtedly absent from both islets at the  
time of Millspaugh's visit.

In addition to the 24 species listed above, the following were  
growing in enclosures protected from the wind and spray, as well as from  
chickens, by bamboo fences:

- \*Setcreasea purpurea Boom (F 41886)
- \*Chenopodium ambrosioides L. (F 41887)
- \*Portulaca grandiflora Hook. (F 41885)
- \*Jatropha (Cnidoscolus) urens L. (F 41882)
- \*Terminalia catappa L. (F 41883)
- \*Mentha spicata L. (F 41884)
- \*Capsicum annuum L. (F 41888, 41889, two forms)
- \*Solanum lycopersicum L. (F 41921)
- \*Sesamum indicum L. (F 41881)

It is practically certain that none of these would survive exposure to  
salt and drought on Alacran without special protection and watering.

Plants previously reported from Alacran by Millspaugh, but apparently  
not found there at present, are Boerhavia repens L., Philoxerus vermicularis  
(L.) R. Br., Scaevola plumieri (L.) L. (reported as S. lobelia Murr.),  
and Flaveria linearis Lag.

## Terrestrial Vertebrates

July is a poor month to see a large variety of birds on Alacran, though a few species are present in large numbers and several nest at this season or just before. In all, only 13 species of birds were seen during a visit of over a week. These all seemed to be resident birds. Doubtless a much longer list could be observed during migration seasons.

The following birds and reptiles were all seen during the first week in July 1961. A few of the species had been recorded earlier by Kornicker and associates (1959), and several by Dampier (1699). Birds are also listed by Kennedy (1917) and Paynter (1953, 1955) but their records will not be discussed here. The two mammal records are included as they may represent the entire mammal fauna in pre-lighthouse days.

### Mammals

Rattus sp.

"large rats"

Dampier (1699, 1931 ed. p. 143) records "large rats, which are in great plenty." No rats were seen in 1961 on any of the islets. They may have been eliminated by the dogs and cats of the lighthouse staff, but this does not seem likely. Other evidence suggests that a severe storm may have swept the islets, eliminating the vegetation, subsequent to Dampier's visit. The rats may well have been eliminated also.

Monachus tropicalis (Gray)

West Indian Seal, West Indian Monk Seal

Alacran was formerly an important habitat of this tropical seal. Dampier (l.c., pp. 145-146) speaks of the abundance of seals on Alacran and gives an account of an expedition from Jamaica to prepare seal oil. In recent years, no seals have been seen on the atoll, and it is feared that these interesting creatures may now be extinct. Raymond Gilmore made a search for them over their former range a few years ago but failed to find any. However, he told Gordon Gunter (1954) that they had been reportedly seen on Alacran as late as 1948.

### Birds

Sula dactylatra Lesson

Blue-faced booby

Two were seen flying by Perez Islet on first day, but none were nesting or even roosting on Perez. On July 4, 8 or 10 were seen on Chica Islet, mostly with downy to partly feathered out young, one parent staying with each bird. Two of the young seemed newly hatched, scarcely even downy yet. One bird had two eggs. One hundred or more were seen on Pajaros Islet, mostly with young in various stages from newly hatched to almost grown. Two were seen with eggs, one with one, and one with two. An enormous number were seen on Desertora Islet, from the lagoon; later many hundreds were examined on the ground, with eggs and young in all stages. Nests were about 2 m apart.

From Dampier's account (1699, 1931 ed., pp.143-144) boobies must have been more numerous in 1675 than now, though their behavior and the fact that they occupy definite territories on the islets have not changed.

Sula leucogaster (Boddaert) Brown booby

Six were seen flying north of Desertora in forenoon of July 5. In afternoon, 50-60 were in air over Desertora Cay. It is not clear where they live. One was seen on the ground on Desertora on July 6.

Fregata magnificens Mathews Frigate bird

Hundreds of these great birds roost on the Casuarina trees on Perez Islet during the daytime. On July 5, a large number were on the ground and on some old pilings off the lagoon beach of Desertora Islet. Many were nesting on the ground there; the nests are very low mounds of twigs, in thin, dead, or half dead Sesuvium mats. The young were fully feathered out but not yet flying. Many dead young frigate birds were seen. About 75 nests were in a cactus patch near the southeast corner of the cay.

Dampier (l.c., p. 144) gives an excellent account of "Men-of-War-Birds" on Alacran, reporting them in great numbers and recording their habit of piracy, robbing the boobies both young and old, of their already swallowed fish. Possibly this is the earliest account of this phenomenon.

Florida caerulea L.? Little blue heron

A small dark heron, seen on one of the lagoon bars toward the south end of Perez Islet, may have been this species. Its behavior resembled that of the reef heron (Demigretta sacra) on Pacific coral islands.

Arenaria interpres L. Ruddy turnstone

A small flock of turnstones were observed on Perez Islet, 5 birds on Chica, and 2 on Desertora, running and flying along the beaches, their habits much the same as on Pacific atoll beaches.

Castrophorus semipalmatus Gmelin Willet

One was seen on the lagoon beach of Pajaros and another on the lagoon beach at East Desterrada Islet.

Larus atricilla L. Laughing gull

On July 4, 20-30 were seen on Chica Islet. A small nest, of Euphorbia mesembrianthemifolia, in a mat of Portulaca oleracea, about 15-18 cm across and containing a dull gray egg with irregular blackish-brown spots, probably belonged to a pair of these, as they flew around making much noise when it was approached.

One gull was seen on Pajaros Islet, several were with a flock of royal terns on East Desterrada, and several were flying over Desertora Islet.

Thalasseus maximus (Boddaert)

Royal tern

One was seen flying near Perez Islet, none were resting or nesting there. On July 4, 20 or 25 were seen sitting on a small sand horn on Chica Islet. On July 5, a number were over the lagoon north of Desertora Islet, all flying toward Desterrada. An enormous flock, of perhaps several thousand birds, were sitting on the sand on a low beach ridge on the north east side of East Desterrada, protesting when scared up, mostly not wanting to leave. Eleven large gray eggs with black spots, in slight depressions in sand on the berm at the top of the seaward beach, probably belonged to some of these birds, as they made a tremendous commotion when the eggs were approached.

Sterna hirundo L.

Common tern

A considerable number of light backed terns with black bills, which must have been this species, were seen on East Desterrada, mixed with the large flock of royal terns described above.

Sterna fuscata L.

Sooty tern

An enormous colony of these graceful birds occupies the greater part of Perez Islet outside the portion immediately around the lighthouse and weather station buildings. Almost full grown young, fully feathered out but not quite able to fly, were seen in great numbers. These young had dark breasts, pale gray anal parts, black backs barred with buff to white on feather tips. When a person walked through the area these young birds scrambled frantically to get away through and under the bushes, and clouds of adults flew up. The sooty terns rest in hundreds on the Suriana bushes, but in tens of thousands on the ground between them. One egg was seen on the sand on a seaward sparsely vegetated sand terrace near the south end of the islet. At night the sooty terns were still roosting on the ground and in the Suriana bushes, making less noise than during the day. A strong light scares them up but they fly with much less sureness than in daytime. On July 3, clouds blew over and a very few drops of rain fell, not enough to be registered by the rain gauges. This occasioned a terrific clamor among the sooty terns, far more than the normal level of noise, and great numbers of the birds left the ground and flew around in great confusion and excitement. Some immature birds, with varying amounts of gray on under parts, were seen flying over the lagoon north of Perez Islet and adults were common in the air around Perez. None were observed on the ground anywhere except on Perez Islet. People resident on Perez say the terns leave the island in September and return in February.

The "Egg-Birds" recorded by Dampier (l.c., pp.143-144) were probably sooty terns. He says: "The Egg-Birds, tho' they are many, yet being but small take up little room to the rest. Yet in that little part which they inhabit they are sole Masters, and not disturbed by their Neighbours." This does not correspond well with the present situation, where the sooty terns are "sole masters" of almost the entire Perez Islet and far more numerous than any other bird on the atoll. The difference may of course be due to a difference in season, as Dampier was there in the fall, probably October.

Sterna anatheta Scopoli

Bridled tern

Many of these were seen on July 5 in a mixed flock with black terns sitting on the east spit of West Desterrada Islet.

Chlidonias nigra (L.)

Black tern

Many were seen in a mixed flock with bridled terns sitting on the east sand spit of West Desterrada Islet.

Anous stolidus L.?

Common noddy?

Many noddies were seen on Perez Islet, apparently the common noddy but rather light colored (compared to Pacific birds), nesting in Suriana bushes (some in Casuarina). The nests were of Suriana twigs, very bulky and poorly formed, but some fully 1 meter tall and standing on the ground. Some of the nests were ornamented by as many as 25-30 bivalve shell halves, most had none. This seems to be a matter of individual taste on the part of the birds. A few had eggs or newly hatched young, while some had fully feathered out young. The large nests are in striking contrast to the small flimsy collections of twigs that serve as nests for the common noddy of the Pacific, as seen in the Northern Marshalls. The noddies on Perez mingle freely with the sooty terns in the same area. Neither noddies nor their nests were seen on the other islets.

#### Reptiles

Mabuya mabuya (Lacepede)

Skink

This lizard is apparently rare, as it was only seen twice, both times on Perez Islet. A mature specimen was collected on a coral gravel ridge just back of the beach on the north end of the islet. It was identified by Drs. Doris Cochran and Walter Brown, and is deposited in the U. S. National Museum. A small specimen of what is probably the same species was found in a building near the lighthouse by Professor F. Bonet. Mr. Hoskin stated that he had seen these lizards occasionally during his earlier visits to Alacran.

Chelone mydas (L.)

Green turtle

Two egg pits were seen on a sand lobe on south end of Perez Islet, a number of others on the west sand ridge of Pajaros near the north end, and several more on Desertora along the seaward terrace back of the beach. Six great turtles had been captured and were on their backs in a shed on West Desterrada Islet on July 5.

Terrestrial invertebrates: Insects

The following list of insect identifications was furnished by the U. S. National Museum.

- Formicidae  
Paratrechina longicornis (Latr.), det. M. R. Smith
- Coccinellidae  
Naemia seriata (Melch.), det. E. A. Chapin
- Tenebrionidae  
Blapstinus sp., det. T. J. Spilman
- Curculionidae  
Dryotribus mimeticus Horn  
First record from Mexico, Yucatan, det. R. E. Warner
- Tethinidae  
Rhicnoessa sp.
- Muscidae  
?Lispocephala sp.
- Sarcophagidae  
Tricharaea femoralis (Schin.), det. C. W. Sabrosky
- Hippoboscidae  
Olfersia spinifera (Leach), det. A. Stone
- Pentatomidae  
Murgantia histrionica (Hahn)  
Microporus obliquus Uhler
- Lygaeidae  
Exptochiomera sp.?  
Nysius sp., det. R. C. Froeschner
- Myrmeleontidae  
Psammoleon cf. bistictus (Hag.), det. O. S. Flint
- Coccoidea  
Phenacoccus sp., on cultivated pot plant. Det. H. Morrison
- Acrididae  
Trimerotropis pallidipennis Burm.
- Blattidae  
Periplaneta americana (L)  
Panchlora sp.
- Gryllidae  
Cycloptilum sp., det. A. B. Gurney
- The collection also included Histeridae, Sarcophagidae, Thysanura and spiders which were not identified.

### Comparison between Alacran and Pokak Atolls

One of the principal purposes of visiting Alacran was to compare it with the Pacific atolls with which I am familiar. It was soon evident that the Pacific atoll in my experience most comparable with Alacran is Pokak (Taongi), the northernmost of the Marshall Archipelago (Fosberg 1955, 1956, 1957). They are both completely in the trade wind belt, not exposed to doldrum influence to any significant extent. Alacran is at 22°30'N latitude, Pokak 14°35'N. Both are dry, though adequate rainfall records are not available for comparison.

Detailed lists of species are not available either except for vascular plants and land vertebrates, and the bird lists cannot be compared profitably because they were collected at different seasons. Nor are analyses, either chemical or mechanical, of the soils and sediments available for Alacran. It would perhaps be profitable to have some made for comparison with those on hand from Pokak and other Marshall Islands. It would be of great interest to study the Pokak marine biota to determine the role of the various species in the reef community, as Kornicker and Boyd (1962) have recently done for that of Alacran.

The following tabular comparison is mostly of very general features. Some of these are single items, others may be regarded as integrations of many components. The list may only be regarded as a start toward a definitive comparison, but may be indicative of the degree of similarity or dissimilarity.

ALACRAN

POKAK

Reef and lagoon features

Orientation north-south	Same
Total length, 25 km	Total length, 18 km
Total width, 13 km	Total width, 8 km
Maximum depth of lagoon, 23 m	Maximum depth of lagoon, 15 m
Lagoon open on a large part of leeward side	Lagoon closed except for a tiny leeward channel
Lagoon level changing with tides	Lagoon level almost constant
Windward reef crescent-shaped	Same
Algal ridge none	Algal ridge well developed
Niggerheads none	Niggerheads abundant
Reef platform sandy, evident only on windward side, where it is covered by an incomplete pavement of slabby boulders, an accumulation of these on the windward edge exposed at lowest tides	Reef platform flat, a completely consolidated algal pavement, probably a planation surface enamelled by calcareous red algae
Outer slope of leeward reef gradual, shelving	Outer slope of leeward reef abrupt, steep
Lagoon reefs abundant, forming a network extending through most of the lagoon	Lagoon reefs few, mostly parallel to main reef, concentric to it
Alcyonarians abundant on reefs	Alcyonarians rare or absent
Calcareous red algae not making up a large proportion of reef community	Calcareous red algae abundant



ALACRAN

POKAK

Islets

Islets all on leeward side of atoll, well distributed from end to end

Islets all on southeast quadrant, on windward side

Islets with no evident reef-rock platform

Reef-rock platform prominent, mostly somewhat under 2 m above mean low tide, few humps to 3 m or more

No consolidated rock on islets, neither reef-rock nor beachrock

Reef-rock and beachrock abundant

Sediments on islets mostly sand and small gravel

Sediments from sand to boulders, mostly coarse

Boulder ridges none, low sand beach ridges and dune ridges general

Boulder ridges on most windward coasts, locally on lagoon side, sand ridges and dune ridges only very local

Large boulders on islets none (except a few from ballast)

Large boulders on islets common

Ground water saline

Same

Vegetation

Thalassia beds abundant on sandy bottoms

Thalassia or other sea-grasses absent

Algal crusts on sand none except where wet by salt water

Algal crusts general on dry open sand

Algal discoloration of dry coral rocks almost none

Algal discoloration of dry coral rocks general and conspicuous

Native vegetation low, semi-arid in aspect, maximum height about 2.5 m.

Same, but maximum height 5-7 m

Principal native vegetation types:  
1. Open scrub of Suriana; 2. open scrub of Tournefortia; 3. Mangrove swamp; 4. open dwarf scrub of Euphorbia; 5. closed Sporobolus sod; 6. Sesuvium mat

Principal native vegetation types:  
1. Open scrub forest of Tournefortia; 2. closed scrub forest of Pisonia; 3. closed scrub of Scaevola; 4. open scrub of Sida; 5. shrub-savanna of Lepturus with Sida; 6. Lepturus bunch grass.

ALACRAN

POKAK

Land Biota

Birds (resident)

6 terns  
1 gull  
2 boobies  
1 frigate bird  
1 heron  
2 shore birds  
(occasionally resident)

Birds (resident)

7 terns  
3 boobies  
2 tropic birds  
1 frigate bird  
1 heron  
4 shore birds  
(occasionally resident)  
1 shearwater

Mammals

1 rat (formerly)  
1 seal (formerly)

Mammals

1 rat

Reptiles

1 lizard  
1 turtle

Reptiles

1 lizard

Vascular plants

19 native species  
3 introduced species established  
2 others perhaps able to persist  
without protection

Vascular plants

9 native species  
No exotics (coconut was  
introduced but did not live)

Perusal of this table shows that, except for features that characterize all atolls, and which are not included, the differences between these two atolls are perhaps more important than the similarities. If Alacran were compared with atolls in wetter climate belts, the differences would be even more impressive. However, Alacran is only one of the Caribbean atolls, and no generalization is possible until a substantial sampling of others have been compared with Pacific atolls in similar climatic situations. Also comparisons of much more detailed and exact features are needed.

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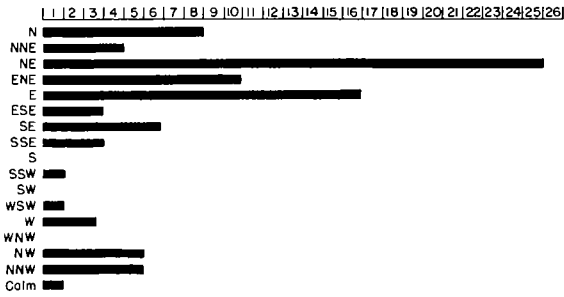
The following paper, delimiting marine plant communities in the vicinity of Perez Islet has just come to our attention:

Huerta, M. L.

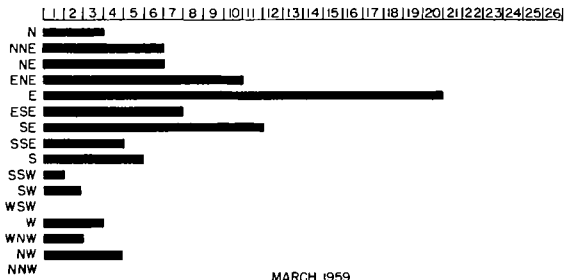
Flora marina de los alrededores de la isla Perez, Arrecife Alacranes, sonda de Campeche, Mexico.  
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# WIND GRAPHS

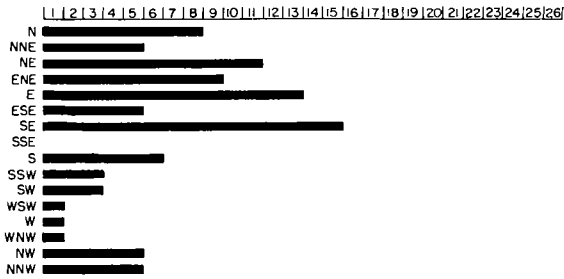
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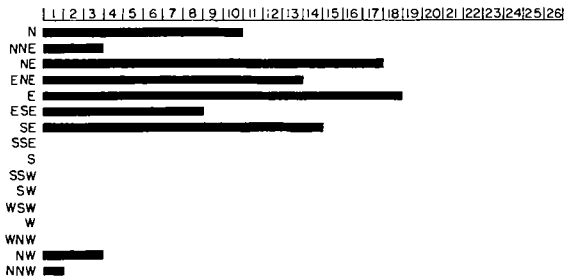
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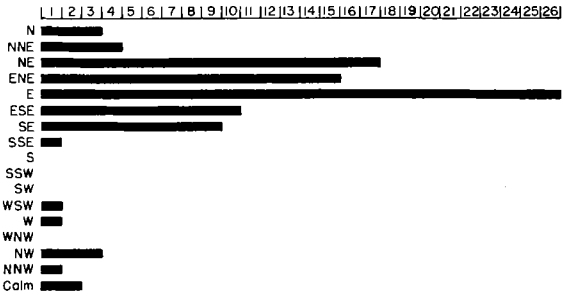
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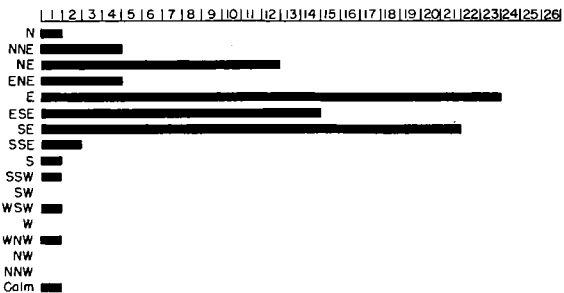
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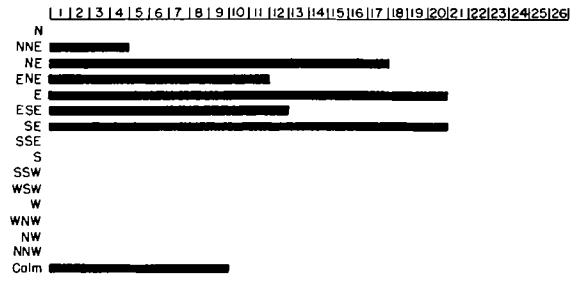
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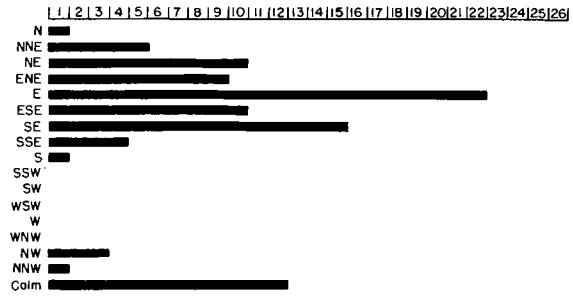
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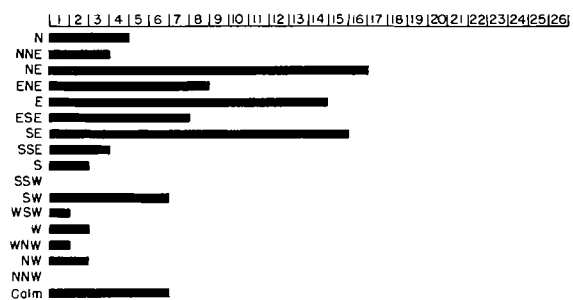
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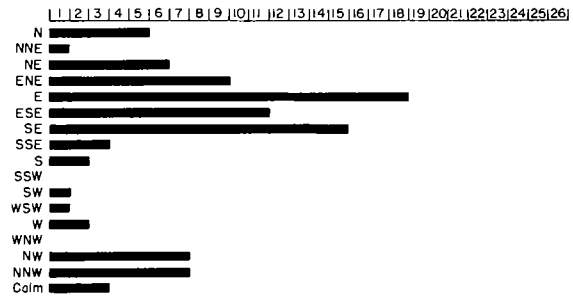
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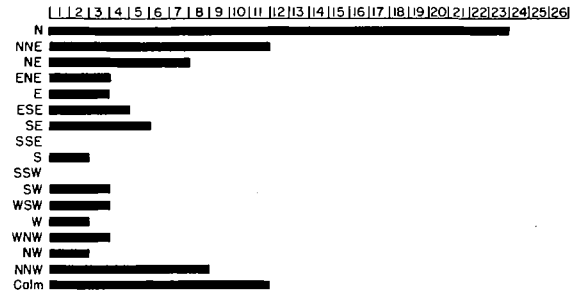
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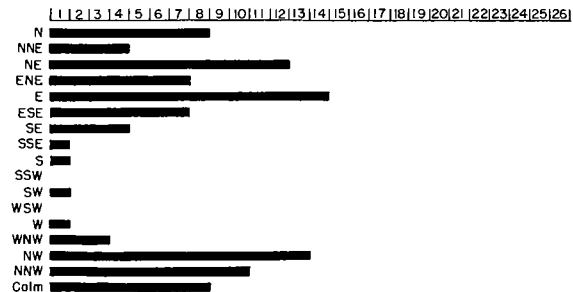
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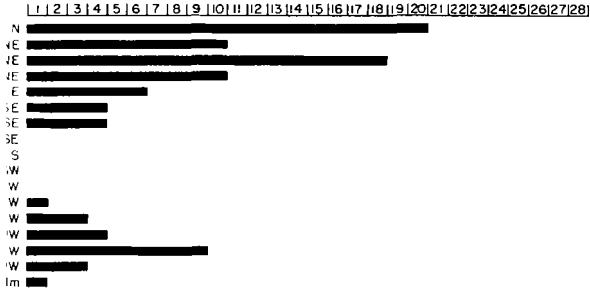
DECEMBER 1959



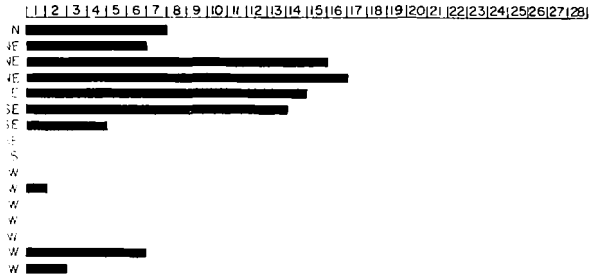


# WIND GRAPHS

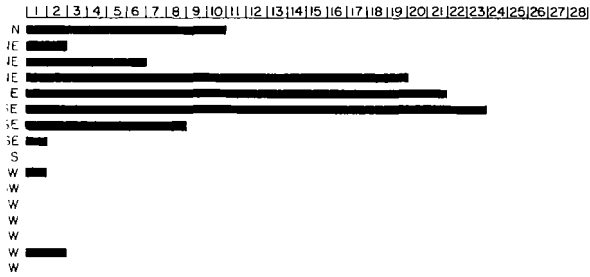
JANUARY 1961



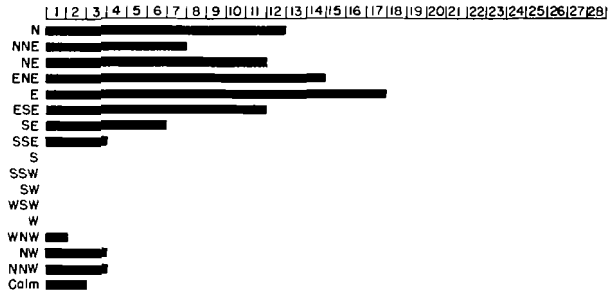
FEBRUARY 1961



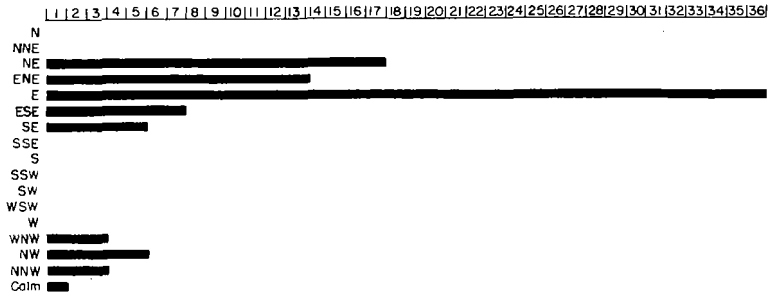
MARCH 1961



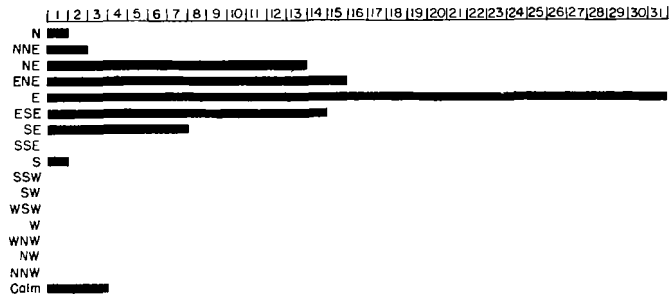
APRIL 1961



MAY 1961



JUNE 1961



Daily Rainfall (in millimeters)

1959	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	20	0	5	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	21	0	0	0	0	0	0	0	0	0	0	0
6	8	1	8	0	0	0	0	0	0	9	0	0
7	0	0	0	0	0	0	0	0	0	0	3	0
8	18	0	2	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	9	0	0
10	0	0	0	0	0	0	0	0	6	0	0	0
11	0	1	0	0	0	0	0	0	999*	1	0	0
12	0	0	0	2	0	0	0	0	0	0	9	0
13	0	0	0	1	0	0	0	0	0	0	0	0
14	0	0	0	0	4	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	2	0	0	0
16	0	0	0	0	0	16	0	0	0	0	0	0
17	0	0	0	4	0	0	0	0	0	0	0	0
18	0	0	0	0	0	18	0	0	7	3	4	0
19	0	0	5	0	6	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	22	0
21	0	20	0	0	0	0	0	0	0	0	3	0
22	7	0	0	0	0	0	0	0	8	0	0	0
23	0	0	0	0	0	0	0	0	0	1	0	5
24	0	0	0	0	0	0	0	0	20	0	0	0
25	1	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	1	0	0	0	0	0	0	0
28	0	4	0	0	0	0	0	0	0	0	0	0
29	5	0	0	0	0	0	0	5	1	0	0	0
30	0	0	0	0	2	0	0	0	0	0	0	0
31	0	0	0	0	0	0	1	0	0	0	0	0

\* The gauge overflowed



Daily rainfall (in millimeters)

1960	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	0	0	0	0	0	0	0	0	0	1	0	0
2	0	0	0	0	6	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	2	8	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	1	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0
7	1	0	0	0	0	0	3	0	0	0	1	0
8	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	25	0	0
10	0	0	0	0	0	0	40	0	0	3	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	3	0	0	0	0
13	0	0	0	0	0	4	0	6	0	0	0	0
14	0	0	0	0	0	0	0	0	3	0	0	0
15	0	0	0	0	0	0	4	0	0	0	0	6
16	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	6	0	0	2
19	0	0	0	0	0	2	0	9	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	20	0
23	0	0	0	0	0	0	0	0	1	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	999*
27	0	0	0	40	1	0	0	0	21	1	0	0
28	0	0	0	0	0	0	0	0	28	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	7	0	0	0
31	0	0	0	0	0	0	0	0	0	19	0	0

\* The gauge overflowed.

Daily Rainfall (in millimeters)

1961	Jan.	Feb.	Mar.	Apr.	May	June	July
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	1	0	0	0	0	0
4	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0
7	0	9	0	0	0	0	
8	0	0	0	0	0	0	
9	999*	0	0	0	0	0	
10	0	0	0	0	0	0	
11	0	0	0	0	0	0	
12	0	0	0	0	0	3	
13	0	0	0	0	0	0	
14	0	0	0	0	0	0	
15	0	0	0	0	0	0	
16	0	0	0	0	0	0	
17	0	0	0	0	0	0	
18	0	0	0	0	0	0	
19	0	0	0	0	0	0	
20	0	0	0	0	0	0	
21	0	0	0	0	0	0	
22	0	0	0	0	0	0	
23	0	0	0	0	0	0	
24	0	0	0	0	0	0	
25	0	29	0	0	0	0	
26	0	0	0	0	0	0	
27	0	0	0	0	0	0	
28	0	0	0	0	0	0	
29	3		0	0	0	0	
30	0		0	0	0	0	
31	0		0	0	0	0	

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 \* The gauge overflowed