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6. The Agriculture of Arno Atoll, Marshall Islands

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THE AGRICULTURE OF ARNO ATOLL,

MARSHALL ISLANDS

C O N T E N T S

To the ecologically minded the low islands appear as a unique habitat for man, an environment not harsh but marked by lack of diversity and, in many respects, by monotony. Here is a climate so equable that the average temperature for any month departs not more than a degree from the yearly mean, a land restricted in size and relief, dominated by the sea, and made up almost entirely of one material -- calcium carbonate. Upon this are soils uniformly calcareous and differing chiefly in texture and degree of maturity. Distance, soils and the sea salt have sharply restricted the number of land dwelling plants and animals, and so limited man's choice of foods and materials.

THE GENERAL AGRICULTURAL SCENE

Physical Setting

The climate, hydrology and soils of Arno Atoll are described in other reports but may be summarized as background thus: The mean annual temperature presumably is almost identical with that of Jaluit, that is 80° F., with monthly means deviating about ± 1°. Rainfall is some 120 inches, possibly higher, rather well distributed but with a tendency for a dry period between January and March. High humidity and high degree of cloud coverage augments the effects of rainfall, whereas the more or less constant winds, coarse textured soils and short term (e.g. one week) periods of dry weather sometimes lead to a moisture stress in plants. Since the ground water commonly occurs three to six feet below the soil surface its salinity is a major factor controlling the distribution of deep rooted vegetation. Shallow rooted plants, however, draw upon the rainwater held in the soil.

Agriculture

Like other aspects of the Atoll, the agriculture is marked by simplicity. There is no sharp separation between agriculture and non-agricultural plants and, to Western eyes, culture is a somewhat casual affair at best. At first glance the coconut dominates the agriculture as it does the landscape but there are other components to both. A shrub belt lines the seaward shores and takes possession of lands too salty or too new for other vegetation. In the interiors of the wider islands are breadfruit, sometimes in groves or often scattered, with a variety of other plants beneath. In this zone, too, are the old excavations made to provide suitable growing conditions for taro for here the groundwater is largely free of salt. Mixed with the breadfruit are tall coconut palms and these form extensive groves around the zone and along the narrow lands adjoining.

Various writers have described the agriculture of the atolls as consisting of tree and root crops -- coconuts, breadfruit, pandanus and bananas, together with taro and Polynesian arrowroot. In a general sense this is true but on Arno the taro has lost most of its former importance. Sweet potatoes are a rarity and other tropical root crops absent. Further, poultry and, to a limited extent, pigs are part of the casual husbandry. Fish and seafoods provide the protein the land does not. Over the years copra traders, missionaries and former German and Japanese residents have introduced a large number of plants but of these the weeds and ornamentals have been most persistent.

Although the introduced plants have not greatly influenced the basic agriculture, the prolonged emphasis on copra production has. Well before the beginning of "German times," traders made copra a commodity of value; under German and, later, Japanese administrations people were "encouraged"

to continually increase the area of coconuts. Ultimately this extension eliminated the native forest that once covered the unused lands and reduced the number of breadfruit and pandanus.

Other changes occurred during the early period of missionary activity and German contact: Old men now living say that the population diminished greatly then, although this is unsupported by other evidence. Certainly a population shift occurred, with people moving to lagoon shore and abandoning the less desirable house sites on the seaside and island center. The culture of taro, once a staple, diminished, very probably because the introduced hogs became very abundant and devastated the taro pits. The copra brought goods from the outside world and these gradually became essentials. Under the influence of trade, outside authority, and religion the established culture changed, and the transition from old ways to new is still in progress.

PLANTS AND THEIR UTILIZATION

Coconut, "Ni"

Although waving palms are almost synonymous with atolls, the extensive coconut groves are as artificial as orchards and will not persist without man's care. Under the influence of the copra trade, "native" vegetation gave way to palm plantations wherever growth conditions were suitable; much of this occurred within the memory of men still living.

Culture

There has been little varietal selection and most of the palms bear nuts of mediocre size, although the people recognize differences such as nut color and edibility of the mature meat. Under Japanese instruction "diseased" trees -- presumably scale infested -- were cut, possibly reducing the number of susceptibles. A large fruited coconut has been introduced and is found in small numbers but there seems to be no concerted attempt to

increase this variety.

The culture of the coconut is simple but continuous. Planting consists of removing a square of sod or the loose rocks if necessary and placing the sprouting nut. The large amount of stored material in the nut gives rise to a large seedling and even in deep rubble the roots reach down to establish contact with soil moisture. Competing vegetation is kept down and trees are said to reach bearing age in about five years. Present planting is largely a matter of filling in occasional openings but in several areas the palms are over-mature and replacements should be considered. The coconut, of course, tolerates considerable salt, possibly even benefiting from it, and palms have been planted over the entire salinity range, from the wide island interiors to areas too salty for normal growth.

The groves require continual weeding for a large variety of woody species soon spring up beneath the palms and if unchecked compete with them, as well as making nut gathering almost impossible. Near the coasts and on narrow lands Scaevola, Messerschmidia, Guettarda, Ochrosia and "wild" pandanus are aggressive invaders whereas inland Allophyllus, Morinda, Pipturus, Pandanus, as well as some of the above fill in beneath the palms. In plantations left unharvested, particularly those of the interiors, sprouting nuts soon make a solid mass of undergrowth. Periodic cutting is the only means of controlling this vegetation. Once well cleared an area can readily be maintained but when abandoned for a long period, as many plantations were in the later stages of the war, strenuous efforts are required. Often the coarse herbaceous vegetation, such as Wedelia, is also cleared. Usually the brush is burned, together with the fallen fronds. Sometimes the piles for burning are placed over stumps or against undesirable trees so fire supplements the machete. Quite frequently, however, palms and

other useful trees are scarred by careless burning. When the emptied husks and fallen fronds are heaped together burning is often incomplete and the lightly charred heaps decay naturally. Except for these, the signs of fire disappear rapidly; woody and herbaceous sprouts soon mantle the soil and the profound effects of the clearing may go largely unappreciated by the casual observer.

Copra Production

The major export product, of course, is copra. According to Lajiblok, who has largely transported the crop, the monthly production for the atoll is about 53 tons but sometimes drops to only 30-40 tons. These figures should be reliable but have not been otherwise verified. So far as could be learned the variation in production is not seasonal. At the current price of $80 per ton the atoll income from outside sources is much greater than might at first appear.

Supposing the average monthly production to be 50 tons and estimating that this is produced from 2,000 acres (roughly 5/8 of the total atoll area) of coconuts worked for copra, the average yield would then be 0.3 tons per acre per year, not a high figure. Further, if we assume that 2,500 acres is the maximum average available for palm groves and 0.5 tons per acre per year is the maximum average yield likely to be obtained, we find that an annual production of 1,200-1,300 tons of copra is about the maximum expected output of the entire atoll under foreseeable cultural practices.

Copra production is slow and tedious business but less so when made a group activity as it often is. The fallen nuts are thrown into heaps, often using a sharp tipped "pickup stick," and husked on a flat pointed husking stake. This is of any hard wood, sometimes shod with a Japanese-made hollow steel tip, and set firmly in the ground. Later the nut is

cracked into pieces and the meat pried from the shell. All the copra manufacture observed involved artificial drying, at least in the initial stages. The shells are excellent charcoal source and this is somewhat inefficiently made by burning off the volatile matter, often in an oil drum. The charcoal is then burned beneath the rack containing the thinly spread coconut meat, the entire rack being more or less closed to conserve heat and regulate the draft to the fire. With skill, little scorching of the copra occurs. Further drying is generally by exposures to the sun, either in racks or on mats, etc. spread on the ground. The sacked copra is transported to concentration points for later shipment.

There is a wide variation in the efficiency with which different individuals produce copra but the average is low. Some of the measures for improvement are obvious: (1) As a rough estimate, perhaps one-fourth of the area now in bearing age palms is too thickly vegetated for effective nut collection. Examples of this may be seen on L'angar, Bikareij and the western portion of Ine Island as well as on Ül-en' and Namwi Islands where reclearing is now going on. On an additional area the vegetation is dense enough to interfere to some degree. The population shifts and disturbances caused by the war are at least in part responsible for this but reclamation has been slow. The pattern of land "ownership" also leads to neglect of the areas remote from the major "operator." Bringing all suitable areas into normal production could easily increase the atoll's copra output by one-third. (2) Although the better producers are aware that sprouted nuts yield less copra, the majority seem untroubled by a high percentage of sprouting. The succulent tissue filling the cavity of the sprouting nut, "iu," is eaten but it is an expensive food in terms of copra. The mass and respiration of the external sprout itself represent sheer waste of copra without any reduction in the amount of labor

necessary to extract the remainder. Periodic gathering of the nuts and storage on sheltered racks to allow absorption of the milk and prevent sprouting is a practice long recommended elsewhere. By this means alone an increase of perhaps 10% in copra could be obtained without proportionate increase in labor. (3) A few producers have drying sheds, i.e., roofed buildings housing the dry racks, but the majority get along with cruder and often impromptu arrangements. It is undoubtedly effective to spread copra on the mat in the sun for curing or re-drying but chickens, pigs and sudden showers are attendant hazards. Widespread adoption of the best drying practice already in use in the atoll would not increase the production greatly but would reduce the labor involved and contribute to a higher quality product.

The above comments on increasing production concern only practices already known to the Arnoese and accepted, in large part, by some of them.

Uses as Food

The mature meat and dried copra are less used for food than might be thought. Since the fruiting occurs throughout the year the oily nut is an excellent emergency food and apparently has its greatest use in between the pandanus and breadfruit season. In many cases copra for eating is made of nuts from particular trees, apparently selected for tenderness and sweetness of the flesh. The "iu" from the sprouting nut cavity is eaten out of the hand and also baked; it is eaten in quantity when copra is being made. Coconut "cream" squeezed from the grated mature nut is widely used in cooking, particularly of the more elaborate dishes, but is of only minor importance in terms of average consumption per person. Although methods of extracting oil from copra are known, they are tedious and it appears that very little is made, despite the general demand for cooking fats and hair pomade.

The immature nuts are used in quantity for drinking, and the soft sweet

flesh is commonly eaten as well. It would be difficult to fairly estimate average consumption over the atoll, for drinking nuts are usually proffered the visitor as routine courtesy; furthermore, the use away from the villages, particularly by men working in the groves, is greater than within the populated areas. Nevertheless, the total is great and perhaps is limited chiefly by the necessity of climbing the tree and of husking the nuts if they are to be carried.

Another widely known beverage from the coconut is the palm sap, obtained from the "flower stalk." Before the flowers emerge from the large elongate bud the tip is cut off and the juice flow observed. If satisfactory the leafy covering (spathe) is wrapped with twine to prevent opening except near the tip where it is cut away, exposing the spadix within. This is also wrapped and bent downward into a container; the sap flows from the cut surface, which is renewed by cutting each time the sap is collected. To facilitate collection, palms regularly "tapped" are notched with shallow steps the length of the trunk. On Arno the fresh sugary liquid, "jekara," is drunk fresh or occasionally boiled down to a syrup having a characteristic flavor. In the latter form it can be kept for long periods, by occasionally reheating, and serves as a sweetening. According to Spoehr, on Majuro jekara is consumed in quantity but casual observations on Arno suggest that the average consumption here is quite low. The sap ferments very rapidly and, of course, provides one of the principal alcoholic drinks throughout the range of the palm. The Arnoese, although they may jest about this product "jemanin," are reluctant to concede that it might be produced by anyone on the atoll. This is understandable, if not altogether credible, for both the missionary influence and the Mandate terms have worked against demon rum.

Other Uses

The meat from both copra and drinking nuts is often fed to chickens and pigs, either as scrap or as supplementary feeds. Surplus "iu" from copra making is also fed to pigs.

Both the husks and the large leaves of the coconut rate as major products. The dried husks, convenient in size and in abundance, are the major fuel particularly in the well settled places or where the groves are kept free of other vegetation. The husks are also the source of twine (sennet) and rope. The long vascular fibers are freed by retting the husks for at least one or two months. If let stand for only the minimum time the husks must be pounded to free the fibers whereas with longer retting the fibers can be rubbed free of the decomposed husks in seawater. The retting apparently takes place satisfactorily in salt, brackish, or fresh water for all three are used. Husks may be buried near the high tide level on stable beaches usually along the lagoon side. Inland are retting pits, "tou," dug below the groundwater level, either fresh or brackish. Often the tou is located in a natural depression and it may be only a muddy spot in an old taro pit or brackish swamp although, according to legend, a tou on Ül-en' Island was conveniently excavated by a star.

The washed and dried fiber or coir is made into a two strand twine, sennet. Each strand is formed endlessly by repeatedly adding groups (15 to 25) of the long parallel fibers to its untwisted end, each addition and its juncture being twisted by rolling between palm and thigh. The additions are made alternately to the two strands and between additions the strands in turn are rolled together to form the twine. The product is a tough cord that may be used for lashing, as on canoes and houses, or braided into a strong and durable rope.

The palm leaves likewise provide a fiber although of much less importance than sennet. The epidermal layers of the flat upper surface of the frond midrib are stripped free of the coarse tissues below to give a strong, somewhat brittle, strap several feet long. This is chiefly used on the spot, rather than as a permanent rope, but finds considerable use. Epidermis peeled from the individual leaflets twists into long flexible fibers used chiefly for fine weaving.

The flat leaflets of the frond are readily woven and from a palm leaf an Arno resident of any age can usually produce a basket of almost any proportions. The leaflets are left attached to the portion of the midrib which serves as a rim of the basket. Although considered much inferior to the pandanus, coconut fronds and stripped leaflets can be quickly woven into matting or panels for temporary house construction. The dry matured midribs are stiff and are sometimes used as rafters in house construction. The trunk is only occasionally used in house construction. It was once common to chop a cavity in the palm base to catch water flowing down the stem. This "emmak" was further enlarged by decay and ultimately contributed to the destruction of the tree. Although these cavities are still found on older palms they have long since been supplanted by cisterns and oil drums. The juice squeezed from the green husks is considered of value in reducing the irritating properties (presumably caused by calcium oxalate crystals) in the prepared roots of Alocasia. If the juice is indeed effective this cannot be due to its acidity, for samples tested were above pH 5.5.

Factors Affecting Production

As mentioned, the red coconut scale is present as well as a leaf spot but we saw no severe infestations of either. More serious pests, such as the rhinoceros beetle, are absent. Effective quarantines would minimize the likelihood of introducing major pests found elsewhere in the Pacific, but it is

doubtful that native shipping can ever be well inspected.

Areas of "poor" coconuts are found on the islands of Namwi, Ül-en', L'angar and Arno. On Ül-en' a portion of the affected area is adjacent to an inland salty pool, and is said to be flooded by the highest tides. Excessive salinity also probably accounts for similar symptoms observed on the younger portions of Namwi. On L'angar a malady locally attributed to the presence of demons causes yellowing, poor fruiting and early mortality on a tract of perhaps five acres in the interior. The presence of excessive salinity is perhaps as likely as that of demons but the soil samples have not yet been analyzed for either. In traveling, small areas of yellow palm foliage have been noticed on other islands but, on the whole, salinity is only a minor problem in the coconut groves and certainly one not readily remedied.

A tract of several acres in the interior of Arno Island is characterized by early barrenness and gradual death of the palms. According to the Headman of the village this condition has always existed in the same area, the coconuts being maintained only by continuous planting. There are no visible evidences of insects or pathogens and the characteristic leaf symptoms differ from those observed in saline areas. Breadfruit trees growing among the dying palms appear to be unaffected. The appearance and depth of sandy soils do not differ from adjacent areas where palms are normal but the long persistence of the malady within definite boundaries suggests some soil relationship. These soils are relatively removed from the shore and seem to be among the oldest on the atoll; nutrient deficiency is at least a possibility and forthcoming analyses of soil samples may help clarify this problem. The exact acreage affected cannot be well estimated because of interspersions of breadfruit groves and secondary forest; these, however, are said to be so abundant because of failure of the palms. The loss in coconut production is to some degree compensated for by

growth of such other species and the simplest solution is to give up trying to grow coconuts within this area. Attempts to discover the cause of the malady would be worthwhile, however, for it may well be found on other atolls, and its amelioration may not prove difficult.

Some comments on copra production have already been made. A further need is a replacement program to eliminate older trees past the peak of bearing. If varieties superior to those now in use can be found, their establishment would logically be coupled with such a replacement program. The introduction of large fruited strains might help reduce the labor involved in copra manufacture even though no yield increase resulted. The possibility of finding higher yielding varieties is worth exploring fully but the limitations of the atoll soils and their dissimilarity from those of most commercial planting areas should be borne in mind.

Breadfruit, "Mā"

Wherever its origin, the breadfruit, like the coconut, is well adapted to the atoll habitat. The breadfruit is characteristic of the interiors of the wider lands although it may grow almost to the beach when conditions are suitable. It is the common tree along walks and settled areas. Its distribution is almost certainly related to the salinity of the groundwater (see report of Hydrologist) and it is not found in the narrow lands or obviously salty areas.

Culture

At least six well-recognized varieties are grown on this atoll. Fruit characteristics seem to be most dependable criteria for identification although leaf form is indicative except for occasional inconsistencies. No differences in tree form are associated with variety, according to the Arnoese, and there are only minor differences in season of fruiting. Two or three varieties have seeds; the remainder are seedless. Examples of varieties with seeds are the Mattata,

which has leaves cut almost to the midribs, and the Mājwan (Mijwan) with large, 3-5 lobed leaves, the lobes limited to the distal half of the leaves. Another type of the Mājwan has entire leaves. The Bātaktak is the preferred seedless variety with a large, solid fruit. It has large 5-lobed leaves, the lower lobes extending for perhaps two-thirds the length of the leaf. By contrast, the Mākinono is named for the resemblance of the 7-9 narrowly lobed leaves to those of the kino fern. Its fruit is globose and regular, turning light yellow when ready.

Around the older trees young breadfruit arise from seeds and root suckers so replacement planting is often unnecessary. Trees blown over usually sprout vigorously from the root crown and stem. The idea of vegetative reproduction is understood and suckers from desirable varieties are taken to establish new trees. Despite this, varieties said to be less desirable are still abundant.

The culture of the breadfruit is even more simple than that of the coconut. Vegetation directly competing with the young trees is cut although the plant tolerates a fair amount of side shade from taller trees and is often started in small openings. The tree grows rapidly, particularly if a sprout from an existing root system, and its own dense shade soon eliminates much of the vegetation below. Thereafter no care is given except as the expanding crown comes into competition with less desirable trees which may, in the course of time, be removed.

Tree form is greatly influenced by density. In the open or with continuous removal of side competition breadfruit tends to branch low and form a massive crown. When crowded in youth the lower branches shade off and the tree has a smaller, often ragged crown and a tall columnar trunk. Such differences in older trees have interpretive value in revealing growth conditions at an

earlier period.

The peak of the breadfruit season is from May to July but the trees continue to bear in decreasing amounts until December. Individual trees vary in duration of yield but there is little varietal difference. As might be expected the large crowned trees tend to be more fruitful but are not necessarily more easily harvested. To "pick" the fruit a man climbs the tree, often using a rope to reach the first branch. Most of the fruit is reached with a picking pole some 20 ft. long, having a Y-shaped end to thrust against the fruit. With it, or by hand, the fruit is detached and falls to the ground. In narrow crowned trees most of the fruit is readily seen and can be reached with the pole from the central trunk, whereas in large spreading trees much of the fruit can be reached only from more hazardous positions midway out on the larger limbs. The fruits suffer much less than might be expected from the 30 to 60 foot fall but some are marred by exudation of the gummy latex into bruised areas. Needless to say, when the trees overhanging walks are being picked the local traffic either halts or detours.

Used as Food

During the season of fruiting breadfruit is the single most important food on the atoll. For most purposes the green fruit is preferred and the most common means of preparation, particularly for the preferred Bātaktak variety, is baking over charcoal. After cooking the pineapple-sized fruit is scraped clean and is then ready to be eaten or carried. The fruit may be cooked in a large number of other ways, suggesting the use of both potatoes and bread. Ripe breadfruit is somewhat sweeter and has a definite fruity taste; it is prepared somewhat as a delicacy. The rather large (3/4 - 1") seeds of the seeded forms are eaten with the cooked fruit but are not usually gathered for that purpose when freed by natural decay of the fruit.

Although the breadfruit is perishable it is preserved by methods analogous to ensiling. The green latex-containing epidermis is scraped away, the fruit sliced and soaked in seawater. Upon removal the material is packed tightly into leaf-lined pits and covered with leaves which are changed regularly. Before use the starchy paste is thoroughly washed in seawater to remove the fermented taste, considered undesirable by the Marshallese. Although the method produces an acceptable foodstuff and is recognized as a means for preparing for the lean months before the next breadfruit season, it does not seem that very large quantities are stored in this way.

Other Uses

Near the houses the freshly fallen breadfruit leaves are often gathered for wrapping fish, breadfruit paste, etc., prior to baking. The milky latex that flows abundantly from bark wounds was once used, after hardening, as calking for canoes; it is now used only when prepared materials are not available. The latex can also serve as a bird lime although this is of little consequence to present-day people. The wood of the breadfruit is moderately soft, durable and withstands alternate wetting and drying. Further, it occurs in long pieces of relatively large diameter and so is the universal choice for canoe construction. Smaller diameter pieces and, occasionally, hand worked timbers are used for house construction.

Factors Affecting Production

So far as observed the tree itself is free of major pests. Only occasional instances of heart rot were observed and the few dead trees seen were all past maturity. A malady affecting the fruit, resulting in a partial decay and premature drop, was reported on Arno, Ine, and L'angar Islands, but not on Ül-en'. According to Kotiel of Arno and Loban of L'angar, the malady was first observed about 1948 and affected a large number of fruits during the

following two years, becoming less severe in 1950. Examination of fallen fruit shows a portion of the surface blackened with rot extending inward. When the stem or the central axis is weakened the fruit falls prematurely. The nature of this malady and its seriousness require a thorough investigation (see report of the Entomologist).

As mentioned, the distribution of breadfruit is certainly related to ground water salinity although little is actually known concerning depth of rooting. Generally the tree reaches maximum development in the sheltered interior of wider islands but large open-grown trees are found in settled areas and occasionally very close to the beaches. It is evident that salinity in the rooting zone will be affected by permeability of the underlying materials, depth of soil above the ground water and conditions controlling the outward flow of ground water, as well as by mere distance from the beach. In some areas (e.g. the southern part of Bikareij village) the trees reach fair diameters but appear stunted in height and show dead wood in the tops. Their appearance and location suggest salinity as a cause, perhaps acting through recurring injury or root restriction during dry periods rather than by continuous exposure. In this connection breadfruit on the lower rainfall islands of the northern Marshalls is said to be much shorter than in the south. Salinity problems are generally beyond man's control and affected areas can only be avoided.

The quantity of breadfruit in the atoll appears to be more than adequate for average needs during the seasonal peak, although additional vigorous trees would increase the late season supply. In addition to establishing more trees, replacement of less desirable varieties with better, and judicious thinning in crowded groves, as on Arno Island, would augment production. Young trees not required for food production, however, might well be kept in somewhat crowded stands to improve stem form for later utilization.

In any comprehensive work with breadfruit selection for fruit characteristics and season of fruiting would be as important as for total productivity. Introduction of other varieties of Artocarpus altilis, as well as other species of the genus is certainly worth trying. The present method of harvesting the fruit appears satisfactory to all concerned but small experiments in pruning young trees to a low spreading shape would not be altogether out of place. Artificial fertilization will probably be out of the question for a long time except with locally available phosphate.

As is true also for other crop plants, the native culture of the breadfruit includes no fertilization practice. Among the store of local medicine are at least three procedures for increasing the yield of breadfruit but, whatever their effectiveness, the materials used are in much too small quantities to affect soil fertility. The course of civilization has apparently eliminated one threat to the breadfruit for black magic is no longer considered an effective means of destroying the tree, although our informant believed it was successful in the past.

Pandanus, "Böp"

Culture

Anderson considered all of the pandanus on the atoll to be varietal selections of P. tectorius and listed 16 varieties. Of these one, Böp in Kabiliñ, with white margined leaves was reputedly introduced from the Carolines (Kabiliñ) and is found only as an ornamental. Another, Edrwan, apparently includes the straight-stemmed, small-fruited "wild" types rather than being a definite variety. The remainder are recognized as established varieties, distinguished principally by fruit characteristics which the writer never mastered. Fruit shape and, particularly, the shape of the nutlets and their aggregates seem to be the significant features. Fruit size, other than Edrwan

is not; the largest fruit is borne on young trees. Likewise leaf characteristics change with age. Certain varieties, such as Anberia and Joibeb, are recognized as outstanding for eating out of hand but our informants seemed uncertain about other specific choices among the varieties.

The pandanus season begins in October, attains its peak in November and December, and falls off after January but a few fruits mature throughout the year. There seem to be no certain varietal differences in time of maturity. The varieties are reproduced vegetatively, using the long prop roots as stock. Seedling clusters from fallen or discarded nuts are common weeds in coconut groves. These volunteer pandanus are hacked down in clearing groves although larger straight stemmed trees are often left. Plantings of the pandanus are scattered as isolated trees and small groups along paths and near houses as well as on the lagoon shore or dune, as in the interior.

The pandanus seem to have a considerable tolerance for salinity and the wild form is often found in abundance on the beach rampart of the windward coasts between the Scaevola-Messerschmidia scrub and the coconuts. The wild forms are also common on dunes and back of sandy shores bordering the lagoon but here as elsewhere they are often replaced with cultivated varieties. Culture of the latter consists of removing competing vegetation.

Uses as Food

Among the more colorful sights of the atoll are brown-faced youngsters chewing on chrome-yellow pandanus segments. In the uncooked form these serve as does sugar cane elsewhere in the tropics, albeit more flavorful. Upon baking the flavor tends to change but the non-fibrous portion is more readily extracted. This somewhat mucilaginous material is also scraped free and dried; in this form it can be stored without spoilage as an emergency food. The small nuts can be extracted and cracked for the contents although this is not a very

rewarding task. The pandanus season follows upon that of the breadfruit and during its seasonal peak it is the major food but its over-all importance is considerably less than that of the breadfruit.

Other Uses

The leaves of the pandanus were once perhaps fully as important in the native economy as the fruit. The plain mats used as bedding, floor covering, etc., as well as decorative mats and items almost forgotten by the present generation are woven principally from pandanus leaves. The long leaves are stripped or are gathered from the ground, trimmed, rolled so the recurved cross section will be flat and stored indoors. Later the spiny midrib is removed and the blade split into segments of desired width. Color contrasts are obtained by using leaves that have cured to various degrees, by dying, and by introducing other fibers that are colored or readily dyed.

Pandanus leaves also provide the thatching material for roofs and sides of the traditional house, although to an extent this has been superceded by introduction of corrugated iron roofing under the Japanese and, temporarily, by discarded American construction materials brought from Majuro. For use the pandanus leaves are assembled into panels made by folding the leaves over a long slender support, usually a split pandanus prop root, and stitching them in place. These units, often 5 or 6 feet in width, are overlapped as shingles and tied to the house framework. Such thatching makes a satisfactory roof for about three years or so but lasts much longer as walls. According to a legend this method of using pandanus was brought to the Marshalls long ago by wandering Gilbertese; before this, the Marshallese had used the flat leaves of the fern, Asplenium nidus.

The wild pandanus, Edrwan, is also valued for its tall straight trunks, sometimes used as supports in house construction.

Factors Affecting Production

No major pests were observed. A great many varieties of this fruit are found throughout the Pacific and it is possible that varieties superior in some respect to those now present on the atoll may be found. Production can easily be increased simply by planting more trees, however, so the objectives of any introduction should be longer bearing period and additional fruit characteristics.

Taro and Other Araceous Plants

The native taro of the Marshallese is Cyrtosperma chamissonis, Iaraj. The more widely known Colocasia esculenta was apparently introduced by the missionaries and its native name, Kötak, came from Kusaie, probably with the plant; it is also called Hawaiian taro. Both green-stemmed and purple-stemmed colocasias are present and there probably are other varieties not observed by the writer. Two other araceous plants are here considered with the taros although definitely not included under that name: Wöt in Kabilin is a species of Xanthosoma recently introduced and is of little significance to the present agriculture. The native Wöt is Alocasia and, according to Anderson's check list, another species may be included with A. macrorhiza under this name.

Colocasia

The introduced Hawaiian taro is valued only for its starchy "root" which by some is considered superior to the native cyrtosperma. In keeping with the Marshallese disinterest in leafy foods the edible leaves and stems are not utilized at all. In general the culture and use of colocasia are similar to those of the native taro discussed below but a few plants, possibly an upland variety, were observed growing on the well-drained soils of the island interiors.

Cyrtosperma

No varietal differences are known. The entire plant increases in size with age, however, and the huge leaves, 8-10 ft. tall of old plants may not be

immediately identified with those of the more common smaller plants.

At one time, Iarej (Iaraj) ranked with, or perhaps exceeded breadfruit and pandanus. Today the evidence of its declining importance is clear for perhaps less than one-tenth of the pits prepared for its culture are growing significant amounts of taro. These pits were excavated to the ground water level in the sandy island interiors where the water is free of salt. The pits vary in size and shape but are commonly oval or oblong with flat bottoms 20-40 ft. long and 10-20 ft. wide. Presumably the builders made use of such natural depressions as existed but it is apparent that the pits were largely man-made. Although weathering has softened the outlines, the outer rims of the pits are commonly raised somewhat above the surrounding land, marking where the excavated material was dumped. Soil profiles on these rims are shallower and younger than those adjacent. On Ül-en' Is. taro is grown in the mucky margin of a large natural depression but cannot be extended over the somewhat brackish peat that occupies most of the basin.[1/] Elsewhere the pits are concentrated in the interiors of the wider lands such as parts of Arno, L'angar and Ine Is. where constant fresh water was assured. Within these areas some pits are immediately adjacent so the spoil forms a high wall between; others are well separated. The separate pits and such random occurrence suggest no orderly construction. Certainly each pit was an undertaking of considerable magnitude, involving the excavation of one- to several hundred tons of sand with crude tools and baskets. Labon, a very old man of Arno Is., recalls that a pit was dug in the early 1900's but it seems probable that this was the last or among the last constructed on the atoll. No one else has any recollection of excavation and the condition of all observed suggests very considerable age. According to Lijömmar the pits on his land at Ine village were there at the time of his grandparents. A legend states that the pits on Arno Is. are the footprints of a man who walked across

1/Later analysis (Part I, Table II) shows the Ül-en' Island peat to be free of salt.

the land.

Elsewhere in the Pacific newly excavated taro pits are prepared for use by placing quantities of organic matter in the bottom. Presumably this was also true on Arno and organic debris is still added to the pits in use. In consequence the bottom soils are calcareous mucks with the water level lying close to the surface. After heavy rains the water may stand to the depth of several inches in the pit for at least a few days. Other than planting and harvesting the principle culture of taro is weeding. Such plants as the vigorous Wedelia extend outward from the pit margins and woody species spring there also. There are relatively few plants, such as Cyperus, the fine-like Clerodendrum and Hibiscus tiliaceus, that grow directly in the wet muck. The principle reason given for not growing taro now is that its culture involves too much work, although the prepared food is preferred to rice by some.

Use as Food

During the breadfruit season taro is rarely eaten but is saved for the months after the pandanus peak. The larger corms are harvested as needed and boiled or baked. Other preparations (Jukjuk) are made by baking mixtures of the cooked root with sugar and coconut cream or banana. At the present level of cultivation the Cyrtosperma and colocasia together rate as a rather minor component of the diet, although important to a few families and as a general reserve.

Factors Affecting Growth

No major pests were noted. The typhoons of 1905 and 1918 were said to have killed taro by flooding the pits with salt water but such storms are rare. Young taro (Cyrtosperma) in pits on Arno Is. is reported to have been killed by immersion, probably complete, in fresh water following heavy rains.

Without observation elsewhere on the Marshalls it is somewhat hazardous to speculate on the reasons for the decline of taro from its former position as a major food crop. Dr. Mason has pointed out that with a decrease in the absolute powers of the Iroij, brought about by missionary and German influences, went a gradual lessening of the landholders' responsibility to his rulers. This may well have led to the neglect of the more difficult or less rewarding tasks. It was during the same period, however, that extension of the coconut groves took place; under the stimulus of the copra trade land clearing, care of coconuts and copra manufacture required much more labor than previously. Yet another factor was involved, perhaps the decisive one: the pigs introduced by the missionaries thrived and multiplied until on Arno Is., according to Labon, taro and arrowroot were almost eliminated and new coconut plantings were damaged. Probably urged by the Germans the residents in "about 1900" declared an open season on all pigs at large, an action that reduced the depredations. Nevertheless, the taro crop had been wiped out for a period. A similar story is told by Lijömmar; pigs ruined the taro near Ine and the pits were abandoned and remain largely so to this day. The destruction of taro by pigs at a time when the native agriculture was already changing may well account for the conditions noted, apart from other factors.

Elsewhere in the Marshalls taro continues to be an important food and its culture might well be encouraged on Arno, particularly since it is already well accepted and the pits are present.

Alocasia

Although sometimes found with the Iarej this plant is more common on protected and fertile well-drained soils. Cultivation is largely negative, consisting of not destroying it when other plants are cut. The Wöt is an emergency food, used when others are not available, as following the pandanus

season. The corm is peeled and baked a few hours but even then may be too irritating to eat because of the minute calcium oxalate crystals. Juice of the green husks of the drinking nuts is believed to lessen the irritating principle but even after treatment the root may still be inedible. There is a belief that some people know what part of the root is responsible for the irritation and hence have more success in its preparation, but there is no botanical reason to suppose this is true. Since Wŏt provides an acceptable food when free of the irritating principle, some attention might be given to taxonomic and varietal differences and to methods of preparation for elsewhere in the world some highly irritating plants of this group are rendered edible by sufficient treatment. Substitution of introduced Xanthosoma may be much simpler.

The large leaves of Wŏt and probably of Iarej as well are used for wrapping fish and other foods for baking. The flowers of Wŏt have been used for perfuming oil.

Polynesian Arrowroot, "Makmŏk"

Tacca leontepetaloides, the "arrowroot" of the region, exists as a semi-domesticated plant, flourishing with little care wherever the soil is salt free and only moderately shaded. It is spared when other vegetation is slashed in the groves and benefits from this weeding. In densely shaded areas, such as the interior of Arno and the wartime abandoned groves on L'angar, tacca is soon eliminated as a crop; this was well recognized by the people of L'angar in explaining the small amount of tacca now found there.

Propagation scarcely offers any problems. The small rootstocks are left when the larger ones are harvested; moreover, the plant fruits abundantly. The potato-like rootstocks are sometimes stored for a short time in the pits along the beach but soon sprout. Although it is possible to eat them baked,

usually the starch is extracted. For this the clean roots are grated raw and placed in a coarse cloth bag. Water is poured through as the mixture is stirred, thus washing out the starch and leaving the fiber in the bag. The starch is collected and dried, yielding a white high quality product that can be stored.

Although not present in quantity on all islands the makmök is sufficiently abundant on the atoll to constitute an important emergency food source in addition to its normal use. Observations suggest that the latter use is limited more by the labor involved in harvesting and preparation rather than by available supply. Inasmuch as this plant is adapted, productive, and can be successfully grown beneath the coconuts, at least in the better soils, some attention might be given to devising simple equipment that would facilitate starch extraction.

Bananas

On L'angar there is a legend of how once during a period of starvation a man in chase of a rat carrying away a pandanus nut discovered a grove of bananas. This is reputedly the origin of a variety, Jorukwor, regarded as indigenous, and the exact spot is marked by the sleeping man -- a massive piece of protruding beachrock. There are other versions of the story but discovery of this banana is common to all. The deep moist soil of this spot is regarded as the best for bananas, and probably is, but very few grow there now. Nowhere on the atoll does the banana grow wild and it is probable that even the Jorukwor was an ancient introduction. Most of the present bananas are known to have been introduced and often the circumstances attached to the introduction are remembered, as on Arno Is. where two weeds were reputedly brought in with the soil attached to bananas introduced by German Catholic missionaries early in the century.

Culture

The varieties of bananas now present on the atoll were not catalouged but they seem to be few. One or two cooking bananas are grown as well as one or more edible sorts; presumably all of these can be classed as varieties or sub-species of Musa paradisiaca. The Chinese banana, M. nana, is recognized as desirable because the dwarf plants are much less subject to wind injury and it would be more widely planted if seedstocks were more abundant.

The banana is propagated by means of the large offshoots. Since the number of these is usually not great under Arno conditions and one or two are often left as replacements, multiplications of seedstocks is slow. Its growth, of course, is limited to the salt free, somewhat more fertile areas protected from the wind. Bananas seem to be planted in three general areas: (1) In the house courtyards, (2) in the groves adjacent to the house, and (3) on the sides and bottoms of the taro pits.

The graveled courtyards are kept free of organic matter and leaves of the bananas are generally chlorotic because of a deficiency of available iron. Young plants, particularly, are occasionally almost completely yellow but usually survive and become greener, generally accumulating iron during wet periods when the saturated soils favors its availability. Severe deficiency increases the time required for fruiting and, of course, reduces yield. For optimum growth and yield the banana also requires moderately high levels of soil nitrogen, ordinarily not found in the courtyard locations. Occasional plants are vigorous with large dark green leaves but these exceptions suggest only that the family sanitation does not comply with the Marshallese standards.

Planting sites in the second group are only arbitrarily separated from those in the first but in general have greater shading and somewhat better soils. Acute iron deficiency is rare, although sub-acute symptoms are often

seen. Commonly pits are dug and filled with organic refuse before the shoots are planted; similarly, sand pits dug for the maintenance of walks are often filled with household rubbish, then closed and a banana planted above. Several of our soil profile pits were left open upon request for the same purpose. Such preparation is considered good practice by the more alert growers and obviously is an excellent, albeit laborious, means of providing the fertility needed by this crop. The method is used in probably no more than 25% of the plantings made. In some soils no marked benefits would be expected and in one instance detrimental effects from this method were reported.

On planting sites of the third class, bananas usually grow well with occasional weeding as the only culture. On the lower slopes and mucky bottoms of the taro pits nutrients are in fair supply and moisture abundant but most of these areas are too heavily shaded for a maximum growth.

Use

Writing of conditions on nearby Majuro atoll, Spoehr suggested that perhaps bananas figured more as food gifts for visiting Americans than in the local diet. On Arno the banana seems to be a well-liked fruit and is sufficiently well-regarded that many people, though not all, are willing to give it the necessary minimum culture. Though children and honored visitors occasionally monopolize the available supply, this seems to be due more to generosity and a desire to please rather than to indifference towards the fruit. The present plant numbers and yields do not seem great enough for the fruit to be of much nutritional significance for the average person but it does provide some variety in the diet.

Factors Affecting Production

No major insects or diseases were evident. The fruit is usually gathered green to avoid theft and damage by rats.

The effects of iron and nitrogen deficiencies have been mentioned but there is no doubt that these could be avoided or overcome. Applications of soluble iron to very yellow leaves in Ine village produced a rapid greening but such treatments are neither feasible nor necessary. Maintenance of a deep surface mulch of organic matter would eliminate deficiency of iron, as well as supplying the nitrogen and other nutrient elements required in quantity for rapid growth. Such a mulch, if composed largely of low-nitrogen material like coconut husks, might lead to temporary nitrogen deficiency through microbial tie-up of this element but the condition would be only temporary. If herbaceou or leguminous material were included in the mulch even such temporary tie-ups would be unlikely.

Production of bananas could be increased many fold simply by further plantings on the soils known to be most favorable, such as the phosphate areas, taro pits, etc., and on other soils using mulch fertilization. The principal limitation to such mulching is the labor involved in carrying the material; by scattering the plantings throughout suitable areas, rather than concentrating them, the distance to available materials can be kept very low. Around the house areas, where surface organic matter often shelters centipedes and scorpions, pits filled with organic matter would continue to be the best insurance of satisfactory growth.

Papaya and Lime

It is probable that the papaya was introduced on the atoll very early in the century but it is nowhere abundant. It is usually found as a somewhat neglected tree near the dwelling places and persists as much by reason of its heavy seeding as by deliberate planting. The tree often suffers from a sub-acute iron deficiency. The only variety observed has a mediocre fruit and the plant is usually allowed to grow too tall. Unless picked green the fruit is

damaged by rats. There are occasional exceptions but generally the fruit is of very minor importance.

Present interest in the fruit does not warrant much attention to it. Introduction of better varieties and provision of knowledge about their culture and vegetative propagation are the obvious needs and might bring about further acceptance of the fruit.

Large lime trees are relatively scarce but numerous younger plants were observed. The common planting site is in the shaded interiors or on taro pit slopes. Trees planted near the houses often suffer from a severe chlorosis caused by iron deficiency. The quantity of fruit produced is much too small for any significant effects on the vitamin C intake of the average individual but the lime ranks with the kino fern as the major flavoring agents used on the atoll.

Mulching or incorporation of organic matter beneath the young trees as suggested for the banana are the obvious cultural recommendations. The single variety is of good quality and apparently propagated by seed. Introduction of additional varieties is much less important than introduction of other citrus adapted to the atoll habitat.

Other Introduced Food Plants

The Chile pepper (Capsicum frutescens) is commonly grown near houses for its fruits which are used, though sparsely, in cooking. In a few areas (e.g. the phosphatic soil on Tak-lib Is.) an introduced pumpkin grows as a semi-wild plant; its occasional fruits are eaten. Two varieties of sweet potatoes, "Bitato", were observed but this crop is grown only rarely and is of no significance in the general diet. A small clump of sugar cane, To'o, was found growing in an old taro pit near Ine but apparently no effort is being made to increase this despite a general liking for sweets. The presence of the yautia,

Xanthosoma, was noted under the discussion of taro. A small-fruited fig, Tōbro (Ficus tinctoria) introduced from Jaluit, is found occasionally on the atoll and does not appear to have spread beyond the original planting some years ago. The firm marble-sized fruits are boiled, mashed and mixed with grated coconut; thus it provides occasional variety for few individuals. A single tree of Kūrak (Inocarpus fagiferus) grows and fruits in the garden of King Tobo in Ine village and a single mango tree was planted on Arno Island after the war.

Other Introduced Plants

Neglecting horticultural varieties, roughly 40% of the species now recorded on the atoll have been introduced in historic times. In addition to the introduced food plants mentioned previously and a few weeds of foreign origin, several of the other exotics have some importance for the people of Arno. With their fondness for flowers they have welcomed ornamentals and here, as throughout the Pacific tropics, hibiscus and frangipangi (Plumeria) are conspicuous. Oleander, Croton, and Bougainvillea are present but rare, the latter represented by a single plant on Arno Is. Acalypha and species of Polyscias are hedge plants in Ine village, presumably by reason of Japanese introduction. Much more widely distributed are two species of Pseuderanthemum; they are used as hedge plants and the fleshy leaves of P. atropurpureum, Tirosbin (= pink tearose), are gathered as pig feed. The herb Ocimum sanctum is used for scenting coconut oil. The small pink fairy lily, Zephyranthes, blooms periodically in the graveled yards where it seems to thrive. The much larger Hymenocallis littoralis, Kiop wau (= Lily of Oahu) was presumably brought by Hawaiian missionaries but is now naturalized in the open groves. Several other garden flowers are found in smaller numbers, presumably the hardy remnants of successive waves of introductions. Similarly, a few plants of cotton, Gossypium barbadense persist though uncultivated. Another plant called "Kotin"

is the kapok tree, Ceiba pentandra; its floss is occasionally used for pillows. According to Felix, seedlings were sent to him in 1915 by a German living on Ponape. Planted on the fertile phosphatic soil of Tak-lïb Isl. they have flourished and spread but the tree is not found elsewhere on the atoll.

Seeds of tomato and watermelon as well as those of a number of garden flowers were brought to the atoll as a gift to the people from Mr. Anderson. Observations on these plantings, as well as on a small garden established by the writer, indicate a very high percentage of failure. The use of artificial fertilizers, composts or mulches will be necessary for successful growth of most common garden crops. In this connection, the shallow fresh water peats of old taro pits may be used to surface small garden spots for a few preferred plants such as the tomato.

Indigenous Plants of Value

Virtually all the indigenous plants figured in the native materia medica and many had other uses. The loo, Hibiscus tiliaceus, is a fiber plant of value. In habit it resembles a gigantic bush and is found singly or in very small groups in moist soil and abandoned taro pits. Although here considered indigenous, its limited occurrence and lack of aggressiveness suggest that very possibly it, too, is an ancient introduction. The tall straight poles arising from the old horizontal branches are stripped for their tough inner bark. This is used as cordage or as an easily dyed fiber for mat weaving, etc.. The inner bark of arme, Pipturus argenteus, was relied upon for fish lines and is still used when imported lines are not available. The bark of Triumfetta provides a colored fiber for weaving.

The grasses, Thuarea, Elusine and Paspalum, and especially the ubiquitous legume, Vigna marina, provide much of the feed consumed by chickens. The leaves of Ipomoea tuba are gathered for pigs. In addition to the uses of its tough

wood, the fruits of the mangrove, Joñ, Bruguiera conjugata, is a source of the black dye used for decorating mat fibers. Likewise, roots of Morinda provide a yellow dye. The fronds of a fern, Kino, Polypodium scolopendria, are widely used for the flavor imparted to fowl, etc., baked in its leaves. The nuts from the two species of Terminalia are used occasionally but the supply is very limited. Barringtonia fruits are used as fish poison but only by children. The wood of Guttarda was used for fire plows, not much in demand at present. Prior to cooking, octopus is covered with leaves of Messerschmidia and pounded. Tests of the dried leaves (by J. B. Sumner, Cornell University), however, show no appreciable amounts of protein-decomposing enzymes.

LIVESTOCK

Other than dogs and cats and occasional pet pigeons and reef herons, the only domesticated animals now on the atoll are pigs and chickens, first introduced by the Germans and missionaries. Turkeys and ducks are said to have been present prior to the war.

Poultry

Old men still remember that before the missionaries came the jungle fowl lived in quasi-domestication on these islands; they were valued for the cockpit. Itself an ancient immigrant, brought in some forgotten canoe, the jungle fowl was absorbed by the introduced chickens although some of the plumage characteristics are still seen. The present population has resulted from a mixture of breeds, mostly now unrecognizable except for the feather pattern of the Frizzles, said to have been introduced by the Japanese. The Arnoese do not eat eggs and the chickens are kept only for meat. Body size is usually quite small and the merits of the stock are largely hardiness and the ability to forage. The chickens are kept penned only rarely and their food consist of grasses, seeds (particularly of Vigna), insects, etc., discarded coconuts and the meager

household scraps. Young chicks are sometimes fed grated coconut or coconut and chopped grass. The hens "steal" their nests; they are good mothers and commonly bring off broods of from 12 to 15 chicks. Subsequent mortality is high and three-week-old broods seldom number more than 6 to 9. Food, weather and disease doubtlessly account for many of these losses but predation by cats is probably much greater than the people concede.

Despite these hazards the chickens are abundant and of some importance as a protein source, although the use seems to be limited to special occasions. They could be more important for there is additional poultry range outside of the well populated areas. Improvement of the existing stock and practices is quite possible but only within certain limits: (1) There is no reason to emphasize egg production until the time when people accept eggs in their diet. (2) Feed supplies will continue to be much as described above, with an ample native range and only limited supplemental feeding. Additional coconut could be fed as in the Philippines, but other supplements are not in sight. Hence, feed will probably continue to limit growth. (3) Early mortality could be decidedly decreased by confinement and supplemental feeding of the chicks. Other changes in present practice cannot be expected, except possibly within the villages, for the chickens must range widely to feed. The hardiness, disease resistance and foraging ability of the present stock are necessary attributes. Thus, the only practical recommendation is introduction of males of some vigorous, fertile, medium-weight breed such as the meat-type New Hampshire to upgrade the native stock.

The Civil Administration native school at Majuro has recently imported ducks. Various breeds, including the Muscovy, should be tried for ducks are worthy of thorough trial in view of their previous presence and the possible food supply of the shallow beaches.

Swine

The rapid increase in numbers following introduction and the consequent disastrous effects on agriculture early in the century have been mentioned in connection with taro culture. In the more populated areas pigs at large are still prohibited, although enforcement is not always strict, and there an occasional family pig is kept in a stone walled pen. In a few areas pigs range at will with consequent destruction of all edible plants.

A very rough estimate of the total number of pigs in the atoll would be between 100 and 150. Their numbers were greatly reduced during the war and some of the Guam breed were brought in during post-war rehabilitation efforts. Crosses of this adapted breed with the runty local animals have resulted in some upgrading but the effects do not seem very marked. In two instances second and third generation animals, still with 25 or 50% Guam blood, approached the local breed in size.

This directs attention to the nutritional status of the animal. Confined animals almost certainly receive a very low energy ration, unless deliberately fattened, for leaves, household scraps, etc., can seldom be fed as sufficient quantities. Coconut is virtually the only concentrate and it is not usually fed in quantity except to pigs fattened for lard production. Pigs at large appear to fare somewhat better but unless their numbers are small in relation to area ranged they soon wipe out the plants that supply their feed. It is obvious that protein intake must be minimal. Of the minerals, calcium should be adequate because of the leafy feeds and incidental ingestion of soil. The sources of phosphorus are limited although they may suffice for the low energy ration.

Thus it appears that both animal numbers and attempts to improve the breed will be restricted by the nature and amount of food available. Increasing

the area of "open range" would provide more food but would eliminate the possibility of growing tacca, bananas, taro, etc., there. Pork is a highly desirable food, providing animal protein and adding much needed variety to the diet, and the lard is valued as well. A moderate increase in the swine population is feasible but under present conditions any considerable increase would be at the expense of other foodstuffs.

WOOD SUPPLIES AND REQUIREMENTS

As pointed out, much of the extension of the coconut groves was at the expense of the original forested area. Thus the Pisonias which Agassis commented on when he visited the atoll in 1900 are nowhere abundant now. Today there is little to show the nature of that forest at its best; the "jungle" areas in the interior of Arno and L'angar Is. are clearly secondary forest. The only wooded area that may have some affinities with the original forest is on the atypical soils of Tak-lib Is. Here are a few large Pisonia, Cordia, Intsia (Afzelia) together with other species, but the introduced Ceiba suggests a very considerable disturbance.

Forest Situations

Apart from the above it is convenient to recognize four "forest situations," although these are not valid ecological units. (1) On exposed shores and recent lands the shoreline brush is composed largely of the sprawling Scaevola with a variable amount of Messerschmidia. On sandy lagoon shores and interior saline flats Pemphis, or rarely Suriana, is more likely to dominate. This type is of value as a windbreak and some of the woody stems are used.

(2) Merging with the above is the mixed brush, consisting of Scaevola and Messerschmidia together with tree species, such as Pandanus, Guettarda, Ochrosia, Ochrocarpus, Terminalia, Morinda, Intsia and occasionally, Barringtonia and Calophyllum. The trees are young and the species present depend on the

degree of salinity and seed supply. Such mixtures often represent stages in the vegetational succession following disturbance by storms or clearing. Thus, without periodic cutting the trees would eventually dominate. Occasionally one finds small stands of older Ochrosia, Soulamea, Guettarda, or various mixtures where this has occurred. Elsewhere the mixed brush areas are transition zones; a mixture with Pandanus predominating is often found on the beach rampart, tapering in height from the outer shore brush to groves inland. The mixed brush types are widely distributed and provide a variety of different woods and shapes for local use.

(3) Secondary forests on the dark salt-free soils of the interior consist of Allophyllus, Premna, Morinda, Pipturia and Guettarda, together with the wild Pandanus and sometimes Intsia or young Artocarpus. Ixora is locally abundant on Arno Island, and Hibiscus tiliaceus may occur in moist spots. All of the areas of such forests are relatively young and usually they have originated as an understory in abandoned coconut or breadfruit groves. A high proportion of stems tend to be rather crooked but the stands are sufficiently dense to largely overcome this. The relatively long, small diameter poles are well suited for framing thatched houses and are readily cut and handled. Hence this forest is of value but its occurrence is limited to a few islands and there largely owes its existence to neglect. Several of these species are good timber trees elsewhere in the Pacific but on Arno the crooked stems of young trees and the sprawling form of older relics suggests this is not true on the atoll habitats. Breadfruit (Artocarpus) is the noteworthy exception.

(4) Several small areas of mangrove swamp occur, chiefly in inland depressions. Bruguiera is the principal species, forming dense pure stands on the shallow brackish peats and rocky depressions of L'angar, Tinak and other islands. Elsewhere it occurs with Lumnitzera in small brackish basins. The

young poles are straight but the older trees tend to be crooked and seldom exceed ten inches in diameter. On Bikareij and Namwi Is. Bruguiera forms small pure stands along the margins of saline flats and inlets as well as mixing with Sonneratia. The inland mangrove areas are nearly valueless for agriculture but are of decided importance to nearby residents as a source of tough poles and durable wood.

Other sources of small diameter poles are the woody invaders of coconut and breadfruit groves but their abundance is in proportion to the intensity of clearing. Large trees of Pandanus, Calophyllum, Ochrosia, Terminalia and Intsia are occasionally found as isolated individuals along protected shores or in door yards. These are usually too large to be utilized with available tools. From time to time the large breadfruit die and decay without utilization for the same reason. Root suckers of breadfruit may form colonies that occasionally, as on the Arno Is., take on the aspects of a forest stand and are excellent sources of straight workable trunks.

Species and Uses

A list of woody species used by the Marshallese would simply be a catalog of those occurring for almost all are utilized. The durability of Bruguiera, Lumnitzera and Intsia in contact with the soil, as well as the toughness of these, Ochrocarpus and Calophyllum are known. The wide use of breadfruit for canoes has been mentioned and it is worked in many other ways. Although less abundant than now formerly, Cordia, workable and tough, serves for the end-pieces of small canoes, and is made into paddles, platform boards, pounding bowls, hatblocks and for similar incidental carving. In addition to the breadfruit Soulamea provides support beams for canoe outriggers and curved pieces of it, as well as the stems of Scaevola, are used for the arched braces to the outrigger float. The very hard Pemphis is spliced on as mast tips and

onto sail poles as a bearing frog against the mast; it is also used as the protective keel. Pemphis, Randia and Ixora are made into cage-type fishtraps and Premna, Allophyllus and Lumnitzera are the preferred woods for fishing poles. Net floats have been made of the very light wood of Hibiscus tiliaceus. Straight poles or posts of almost any species are of value for house building but differences are recognized, thus Barringtonia is considered a very poor wood. Coconut is occasionally used for heavy posts but is not durable in contact with the soil.

Construction Requirements

The discontinuance of the wartime base on Majuro provided a bonanza of construction materials that still has its effect on the architecture and construction of Arno. The abundance of frame and frame-thatched hybrid dwellings tends to obscure the fact that housing of sawn lumber is simply not compatible with the present average income of the Arnoese. Barring other bonanzas, most of the people will go back to living in thatched houses as decay and obsolescence claim the present shanties. The few pre-war frame buildings were largely Japanese houses or stores and copra sheds. It is easy to calculate that at present-day prices there will be very little construction, even of Marshallese-size houses, with purchased lumber. Hence the need for pandanus thatch and small diameter poles for framing is likely to increase in the future. Since rainfall stored in cisterns provides the main fresh water source for the village areas, the demand for metal roofing is a reasonable one and will continue strong. Boat construction will continue to require wood, either solid breadfruit logs for outrigger canoes or sawn lumber for the more conventional small boats.

Because of the considerable difficulties of transporting wood some individuals or groups may lack but, at present, there are ample supplies of wood and thatch for building on the atoll. Continued clearing and

better maintenance of the groves will automatically reduce wood supply. Future prospects are for diminishing supplies and somewhat higher demands.

Future Measures

Suggested measures for improving wood supply depend to some degree on education or supervision and hence are not practicable under existing circumstances. They are: (1) Education in and encouragement of simple care of woodland areas not in conflict with agricultural use. Thus the productivity of the mangrove swamps, in terms of useful material, could be increased by simply cutting or girdling oversized and crooked trees. Breadfruit is potentially the most valuable timber tree and its planting should be encouraged beyond the need for the fruit.

(2) It is doubtful that any introduced species would be superior to breadfruit in rate of growth or general utility but Casuarina and the bamboos have special merits. The Casuarina is a strand tree, occurring on coral shores elsewhere in the Pacific and might succeed in the beach zone. The form of the tree is fair to good and the wood hard but subject to splitting. The bamboos are so generally useful elsewhere that they are worthy of extensive trials. Mr. Kessel of the Civil Government School at Majuro reported that a planting of bamboo made there has failed. There are several genera and species of bamboos, however, and these should be tried on a variety of planting sites, especially the old taro pits and, moist soils of the interiors, and on the three areas of phosphatic soils.

(3) The possibility of a small portable sawmill serving one or more atolls should not be overlooked, although admittedly a project of the future. Presumably this would entail cooperative ownership, and operation would require mechanical skills but these problems have already been met with some success in the acquisition of atoll-owned ships. The capital investment required would

amount to, say, one-fourth to one-half of the sum represented by the atoll's copra production for a single month and hence is by no means prohibitive. The real problems involved are satisfactory transport of the mill from place to place and of the logs to the mill, as well as rigorous control of cutting. The source of logs would be very largely breadfruit and coconut, the latter yielding "porcupine wood," suitable for use if kept dry. Obviously such cutting could not be permitted to reduce production of food or copra and it need not. A replacement program for overage palms and removal of over-mature or crowded breadfruit would provide a continuous supply of sawn lumber from material now largely wasted.

FOOD SUPPLIES AND NUTRITION

The appraisal of food supply and nutritional significance can be in only the most general terms for the writer has no estimates of productivity and consumption, nor are there nutritional data for many components of the diet. Further, our observations were for a limited period in the season of abundant food. Nevertheless, there are ample signs that at present this atoll is well supplied with food, so far as total quantity is concerned. The sustained production of copra is an obvious guarantee against near-starvation levels. The unused supplies of arrowroot, breadfruit and alocasia, the decrease in fishing and taro culture, and the rather minor attention to food storage suggest that such food shortages as occur are far from critical. There may well be times when the diet is limited to the less desirable foods or those obtained more laboriously -- to "fish, crabs and copra" as was said on L'angar -- but the actual calorie intake can be maintained. Further than this, some food is imported, although primarily for the high income families.

Nutrition is one of the fads of our time as well as a subject for sober investigation, and some of the recent reports on the Pacific areas contain

facile judgments on the adequacy of native diets. Without clinical evidence of deficiency or detailed appraisal of diet, supplemented with analyses, such judgments can scarcely be more than opinion. To begin with, from all accounts the Marshallese thrived fairly well on their original island diet which contained no leafy vegetables, only pandanus and possibly bananas as fruit, and certainly no milk. Rather than the original diet it is the subsequent modification of it that provides cause for concern.

From considerations in other paragraphs it is evident that the agricultural production of the atoll in terms of calories far exceeds present dietary needs, although large percentage of this is in the form of copra. Thus it may readily be calculated that about one-third (ca. 15 to 16 tons per month) of the present copra production would alone fully supply the energy requirements (2500 calories per person per day) of the entire population (1200). Although the idea of such a diet is fantastic the figure demonstrates the importance of the coconut as a reserve and points out that the amount actually consumed is only a fraction of that prepared for export. In fact the contribution of coconut to the average calorie intake is probably greater than commonly realized, for although the mature nut is scarcely eaten when other foods are available the consumption of the soft flesh of drinking nuts and of iu (cavity tissue) is very appreciable. Much of this is eaten outside of the regular meals and often away from the dwellings. It seems likely that coconut ranks near breadfruit and pandanus as major calorie sources, with the protein foods, tacca, taro, etc., and imported foodstuffs ranking well below.

There is reason to believe that fishing is carried on to a lesser extent than formerly but the principal protein sources are still fish and seafood. Pork and poultry can make but a small contribution to the average requirement. Breadfruit and taro are considered low protein foods but, according to available

analyses, if eaten in sufficient quantity to satisfy the daily calorie requirement they supply from one-fourth to one-half the established protein requirements of the normal adult, although the quality of this protein is unknown. Analyses of dried pandanus flour and preserved breadfruit from Kapingamarangi (kindly supplied by C. D. Miller, H. Denning and A. Bauer of the University of Hawaii) show the dried pandanus, and hence presumably the original fruit, to be a poor protein source. Flesh of the immature coconut may have a much higher protein-calorie ratio than the mature nutmeat.

Although concern has been expressed over the starchy diet of breadfruit and taro the Hawaiian workers have demonstrated that these foods are, in fact, much superior to white flour and rice in respect to the B vitamins and calcium. The high calcium content in araceous plants may be of no value, however, because of the presence of oxalates. Breadfruit is considered a fair source of vitamin C, even when cooked, and this may be of considerable significance in view of the quantity consumed. Assays of the two Kapingamarangi foods bear out these results and suggest that the pandanus is a fair source of vitamin A. Although fluid from the drinking nut contains relatively small amounts of accessory substances, the quantity consumed must be considered in evaluating its contribution. Fish, crabs and other seafood provide minerals and several of the vitamins, as well as proteins, in proportion to the quantity consumed. Vitamin D is presumably of little concern except for infants and some women continuously sheltered from the sun.

These considerations suggest that the adequacy of the native diet may have been maligned unduly, although estimates of the calcium, phosphorus and vitamin C status are weak. But two unhealthy trends in the dietary habits are appearing: The substitution in part of white flour, sugar and rice for the local carbohydrate sources, and the reputed reduction in fishing. Both of these

tendencies are most marked in the Ine village area because of the higher income and greater foreign contacts, and are of lesser importance in the more remote portions of the atoll. Extension of these tendencies will inevitably lead to deterioration in quality of the diet for the lack of leafy foods, fruits, and additional protein sources leaves but little margin for safety. Yet increase in purchasing power encourages such extension and it probably cannot be avoided, barring actual controls. Suggested positive measures are mandatory enrichment of flour, at such time when its potential use is sufficient to warrant this, improved fishing methods (see report of the Marine Biologist) and diversification of the present subsistence agriculture, adding new foods while encouraging use of the old to provide both variety and nutritional quality in the modified diet.

It must be pointed out that the foregoing estimate is largely based on impressions and a few analyses. Data on the actual consumption of food, both local and imported, as well as nutritional assays and related evidence, are necessary for accurate evaluation and prediction.

SUMMARY OF THE AGRICULTURAL SITUATION

The agriculture of the atoll is thus seen to have two aspects, subsistence and export. The present subsistence agriculture is derivative and still rests largely upon the original food plants, cultural methods and uses of native vegetation. Introduced plants have had only minor effects on the subsistence agriculture and diet. Originally, agriculture and fishing were complementary subsistence activities and to a large extent still are. The relatively small contribution of introduced animals to the diet arises from their limited number rather than local acceptance. Some of the changes occurring in the past half century or so are displacement of taro as a major food, a great increase in the cultivated area and consequent elimination of the original vegetation, greater dependence on imported goods, and the beginnings of substitution of imported for

local foods. The pattern of land holding (see report of the Anthropologist) does not always favor fullest use of the land, particularly for subsistence crops. None the less, the subsistence agriculture is largely adequate and capable of expanding to support a considerable increase in population.

The export agriculture is concerned wholly with copra, which is the product of an indigenous tree cultivated with practices that are only modifications of those employed in the native agriculture. By those concerned with the economics of such areas, increases in export agricultural values are often looked upon as the most promising means of providing the goods and services necessary for material improvement of the people. We have already estimated very grossly that for Arno about a two-fold increase in copra production is about the most that can be hoped for under existing practices. Such an increase is a worthwhile objective but a limited one, even when combined with moderate increases in quality and production efficiency. Further, prices for copra in the world markets have been subject to wide fluctuations in the past and may be in the future.

Such considerations lead to the question of producing other export crops in order to increase the total income of the area and minimize the risks inherent in a single-crop agriculture. Unfortunately the present prospect of any considerable gains by such means is exceedingly dim. In the entire Marshalls the total area of protected land suitable for such crops is small and it is scattered piecemeal, precluding any large single developments or mechanization, and complicating production and shipment. Taking Arno as representative, even in favorable rainfall regions the inherent productivity of the soils for most such crops is very low. The calcareous soils preclude some crops and without measures for maintaining or increasing fertility the success of others would be foredoomed. Finally, were a crop decided upon, discovering varieties and

cultural methods adapted to the area, the almost certain likelihood of pest control and fertility problems, and the considerable task of adapting the people's folk ways to the new crop would together require sustained skilled effort and supervision.

These and additional causes for pessimism are set forth by J. C. Ripperton in his 1946 report on Some Agricultural Aspects of Micronesia, vol. 17 of the USCC. Economics Survey of Micronesia. They are also implicit in the perceptive statement of Project No. E. 6, "Economic Development of Coral Islands" prepared for the South Pacific Commission Research Council. The one possible exception, suggested by Ripperton, is the production of fruits, truck crops, etc. on areas near American bases to supply garrison forces. Although localized in importance such markets are lucrative and this possibility should be developed fully. The price incentives, if combined with production guidance, would accelerate agricultural change in the areas influenced.

In the subsistence agriculture it is clear that many gains can readily be made and that, in addition, there are many possibilities that offer enough prospect of success to warrant some investigation. Improvement of the existing crops and crop types, cultural methods and utilization, are realizable objectives. Introduction of additional useful plants, of which there are many in the tropics, is an obvious and attractive prospect. The same considerations mentioned for new export crops apply to such introductions, however, and numerous failures are to be expected. Yet the choice is great, the investment involved is small, and a number have already been tested in part by former introductions of low islands. But even though successful, mere introduction is without value unless the plant with its culture is accepted by the people and fills an existing or created need. Moreover, plant introduction should be looked upon largely as a means of supplementing, not making over, the present adapted agriculture.

The limitations of agriculture have been mentioned. Some general and specific changes in the export and subsistence aspects have been suggested. Yet what is clearly needed for substantial improvement in this region is a long time program of on-the-ground investigation linked with education and demonstration. Both activities can be on a small scale if properly supported and staffed. At this stage, by making use of relevant information accumulated elsewhere in the tropics, well conceived emperical investigations could pay off handsomely for a time. The results will be of little value, though, without demonstration and education to bring about acceptance. Such extension activities necessarily reach beyond the questions of production to influence utilization and consumption. Thus, they might well be fitted into a larger program of education and assistance, embracing other aspects of native industry and welfare, but this is a question of administrative policy.

The people of Arno are extremely receptive to new ideas, even though subsequent retention and execution are rather less than outstanding. American technical capacity is highly regarded because of the war-time contacts, the Bikini tests and the medical successes against yaws, venereal diseases, etc. People would readily accept an extension program modeled after the familiar agricultural extension and home demonstration activities of the U. S.; but adapted to their needs and level. Yet all extension work is presumptuous to some degree, implying the greater wisdom of the newer knowledge, and if such a program is not to disturb the values and the sense of security in the existing order it must be guided by anthropological as well as technical considerations.

Summarizing, for Arno Atoll we find that productive capacity in terms of value of agricultural exports is below maximum at present but this maximum is definitely limited. In terms of subsistence agriculture, the land, supplemented by the sea, is capable of sustaining a considerably higher population than is now present, provided the meager resources are used fully and intelligently.