DREADING THE NEXT WAVE

Nontraditional Settlement Patterns and Typhoon Threats on Contemporary Majuro Atoll

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PREFACE

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SUMMARY

Low-lying islands and atolls are particularly prone to the impact of storm surges created by tropical depressions and typhoons. This paper reviews the contemporary settlement pattern of Majuro, the capital of the Republic of the Marshall Islands, and its vulnerability to such storm surges. The paper shows that defiance of traditional wisdom, as expressed in pre-World War II settlement patterns, exposes urban development to increased flood hazards, a risk which may exact a price too high to pay.

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INTRODUCTION

Unpleasant at best, devastating at worst, tropical, circular high-speed wind systems ("typhoons", "cyclones", "hurricanes") are a fact of life in many parts of the world. Living on a low-lying and narrow island, however, exposes residents to a substantially increased risk of destruction and personal peril; when a typhoon comes, there is nowhere to go. While the occurrence of a typhoon cannot be prevented, its impact can be mitigated or compounded by the choice of settlement location. This paper argues that traditional, pre-World War II settlement patterns on the atolls making up the Republic of the Marshall Islands (RMI) provided for a maximum of protection given the prevalent environmental conditions. It also argues that the present location of RMI's two population centers, Ebeye on Kwajalein Atoll, and Delap-Uliga-Djarrit on Majuro Atoll, defeats traditional wisdom and unnecessarily exposes the residents to typhoon risk.

In this paper, I first provide background for the Marshall Islands and Majuro Atoll in particular. An overview of the demographic history of Majuro Atoll and the history of pre- and post-World War II development on Majuro Atoll follows, outlining past and present trends of settlement patterns. In the second part of the paper I look at the frequency and impact of typhoons and the implications these observations have with regard to the current settlement patterns.

TRADITIONAL VERSUS MODERN MANAGEMENT

Modern technology is capable of sustaining human life in remote and adverse conditions, and modern international development has been technology oriented. In the last few years, however, concepts such as sustainable development have become increasingly dominant in the literature, even though confusion in nomenclature reigns (Lélé, 1991). This change in perspective notwithstanding, much has been said and written about economic development in the Pacific area and the pitfalls connected with superimposing modern western economic concepts onto Pacific societies with social and economic norms substantially different from those of the western world (Connell, 1991).

In the last decade it has also been gradually accepted that traditional communities have an intimate relationship, based on the cumulative experiences of past generations, with their environment. There is a growing body of literature showing that traditional technology and knowledge, because of its appropriateness, has a place in modern development.

The traditional skills available in the Pacific Islands are based on a long history of proven technology, perfected to the tasks at hand with the raw materials and resources available. In numerous cases traditional technology is suitable to the demands posited, while at the same time it is more cost efficient than modern counterparts (for example, see Spennemann, 1989). Thus, traditional technology can play an important role in the economic development of Pacific nations (Spennemann, 1987).

In his ground-breaking study, *Words of the Lagoon*, R.E. Johannes (1986) shows that the body of knowledge of fish biology among the Palauan traditional fishermen rivals that of modern science. A similar study of traditional fishing in the Torres Strait Islands has comparable results (Johannes and MacFarlane, 1991).

In the recent past, traditional tenure systems both of terrestrial (Crocombe, 1988; Dahl, 1985; Pulea and Associates, 1985; Utanga, 1988) and marine resources (Dahl, 1988) have been recognized by regional organizations as fostering environmental conservation and thus prolonging the life of resources.

A number of studies focusing on the Marshall Islands have been conducted in the last few years. Alessio (1991a) has shown the economic potential of traditionally constructed outrigger canoes over imported fiberglass boats and has gone on to show that such technology can be used to build ocean-going canoes, while Spennemann has shown the potential of using traditionally procured arrowroot starch as a substitute for imported corn starches (Spennemann, 1992c; 1994, in press). All these studies show the relevance of traditional skills for modern society and often document that the renewed or continued use of these technologies may in fact be economically beneficial. In many cases traditional skills and technologies have already been abandoned, but as the reintroduction of wet taro horticulture on Aneytum (Spriggs, 1981; 1984) and the reintroduction of traditional food storage technologies (Parkinson, 1984; 1986) have shown, there is a chance for revival.

The following case study shows that modern urban planning can learn from the body of knowledge embodied in traditional settlement patterns. These patterns were developed in response to both environmental threats and opportunities. A shift away from a subsistence economy may well have obviated the need to choose settlement locations according to environmental opportunities. As will be shown, however, it is dangerous to assume that environmental opportunities were the only reason for settlement patterns and that, today, we can ignore them. While the opportunities provided by the environment may no longer matter, the threats have not diminished, and it may well be disastrous to ignore them.

GEOGRAPHICAL BACKGROUND

The Marshall Islands (*Aelon Kein Ad*) (Figures 1 and 2), comprising 29 atolls and 5 islands, are located in the northwest equatorial Pacific, about 3,790 km west of Honolulu, about 2,700 km north of Fiji and 1,500 km east of Pohnpei. With the exception of the two northwestern atolls, Enewetak and Ujelang, the Marshall Islands are arranged in two island chains running roughly north-northwest to south-southeast—the western Ralik Chain and the eastern Ratak Chain. Majuro Atoll, with its close neighbor, Arno Atoll, is located on the northern margin of the southern group of atolls of the Ratak Chain (*Ratak-rak*). Not counting the five islands, Jemo, Jabwat, Kili, Lib and Mejit, the atolls of the Marshall Islands range from very small—less than 3.5 km^2, such as Nadikdik (Knox) Atoll—to very large, with up to 2,173 km^2 lagoonal area. Kwajalein Atoll has the distinction of being the atoll with the world's largest lagoon (U.S. Army Corps of Engineers, 1989; Spennemann, 1992a).

The Marshall Islands consist of atolls and raised islands. However, bathymetric maps show that there is also an abundance of seamounts (guyots), some of which reach almost to the surface, such as Keats Bank east of Arno Atoll. Most of these guyots are aligned along the same axes as the Ralik and Ratak chains, so that these bathymetric features as a whole have recently been termed Ralik Ridge and Ratak Ridge. The reefs in the Marshall Islands consist of fully developed atolls, such as Majuro; almost table reefs, such as Wake/Eneen-Kio; and table reefs, such as Mejit.

At no point in the Republic of the Marshall Islands is volcanic or sedimentary rock, other than limestone or beachrock (cemented sand), accessible at the surface. In addition, no sources of obsidian or other flakeable material exist on the islands.

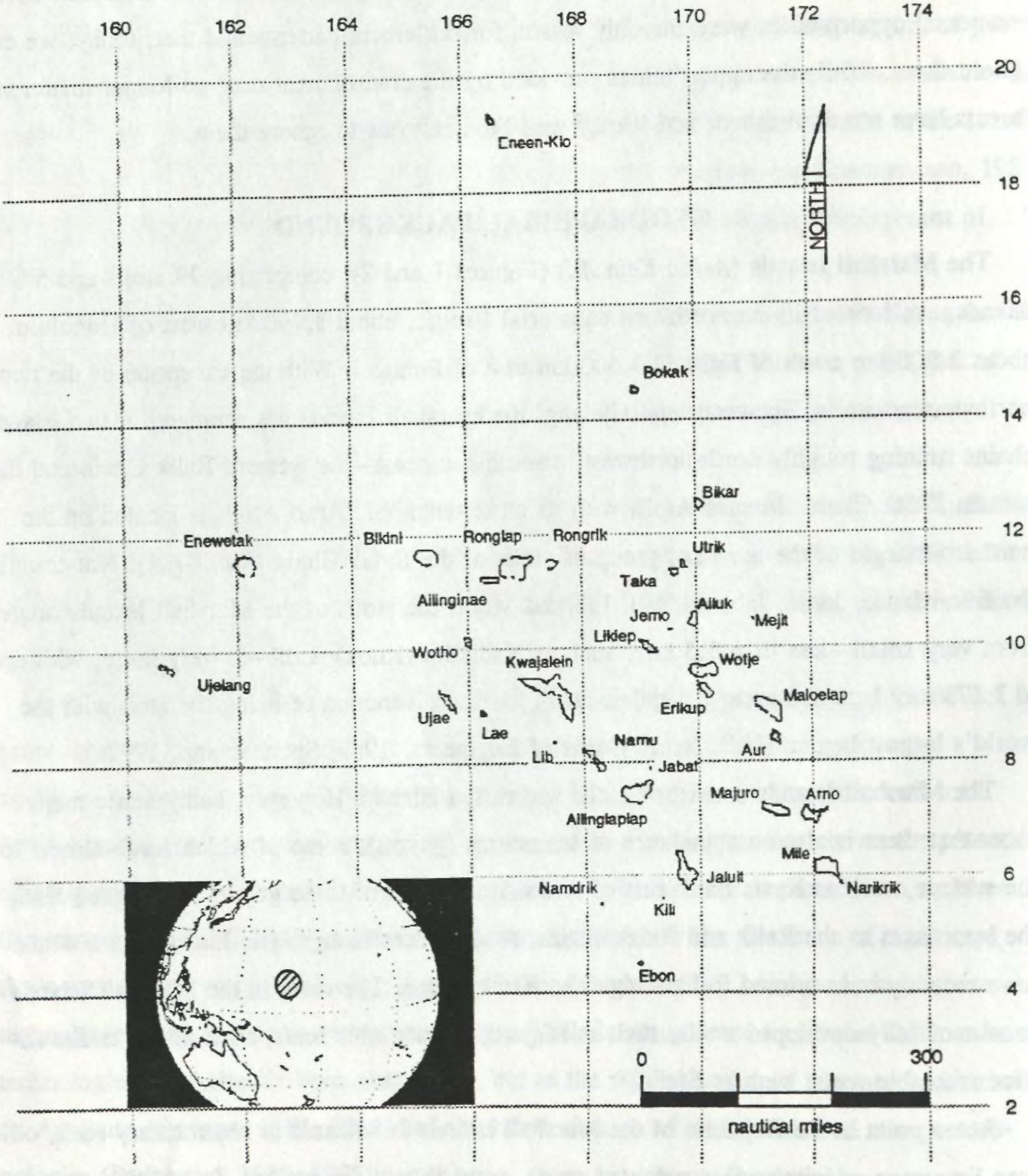

Figure 1
The Marshall Islands

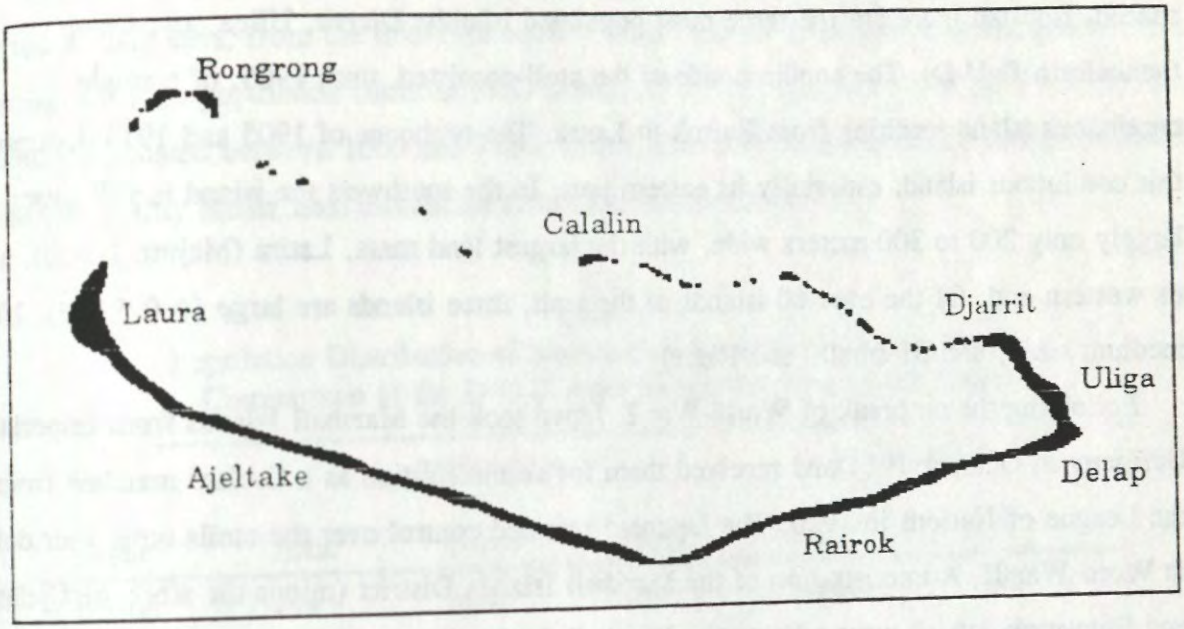

Figure 2
Majuro Atoll and Locations Studied

Coral growth, and, correspondingly, reef width, is most vigorous in areas in the general direction of prevailing winds, currents, and waves. Since the Marshall Islands are in the zone of the northeastern trade winds, with predominant wind and swell direction from the south-east, the zone of most reef growth is the southern and eastern side. Conversely, deep passes through the reef platform occur most frequently on the leeward side of the atolls. Thus on most atolls there are several passes, which are located on the west and northwest sides.

Majuro Atoll

Majuro Atoll, situated at 7°03'–7°13'N and 171°02–171°23'E, is oriented east-northeast to west-southwest and covers a total lagoon area of 295 km², with a total land area of only 9.17 km². The atoll can be split into a northwestern, windward side and a southeastern, leeward side. The northwestern part is characterized by large, extended reef flats with very few islands, save for the distinct Enyagin Group, which is located at the very northwestern tip of the atoll and which consists of two reasonably large islands (Jelte and Rongrong). To the east, the islands on the northern side become more numerous and are relatively closely spaced. Located there are the three most populated islands: Djarrit, Uliga, and Delap (henceforth D-U-D). The southern side of the atoll consisted, until 1905, of a single continuous island reaching from Rairok to Laura. The typhoons of 1905 and 1918 disrupted this continuous island, especially its eastern part. In the southwest the island is still intact, largely only 200 to 300 meters wide, with the largest land mass, Laura (Majuro Island), at its western end. Of the over 60 islands of the atoll, three islands are large (>0.5 km^2), 10 medium sized, and 51 small (≤ 0.1 km^2).

Following the outbreak of World War I, Japan took the Marshall Islands from Imperial Germany in October 1914 and received them for administration as a C-class mandate from the League of Nations in 1920. The Japanese retained control over the atolls until their defeat in Word War II. Administration of the Marshall Islands District (minus the atolls of Ujelang and Enewetok, which were administered from Pohnpei) was maintained on Jaluit Atoll. Majuro Atoll saw little base development during World War II compared to other atolls such as Maloelap or Kwajalein. This changed in February 1944 when, after a successful and unopposed landing, U.S. forces transformed Majuro Atoll. Following the establishment of a U.S. Navy base and airfield in the D-U-D area, elaborate facilities were constructed for the U.S. wartime administration. Since Jaluit was held by a bypassed Japanese garrison until August 1945, and since large-scale destruction of Jaluit had occurred because of continued and prolonged U.S. bombing, the administrative center first for the southern and later for all of the Marshall Islands was shifted to Majuro Atoll. It remained there during the period of the U.S. military government, particularly in the D-U-D area, and has remained there ever since.

After World War II the United Nations awarded the atolls to the United States as a strategic trust and the U.S. continued to develop Majuro, in favor of bombed-out Jaluit, into the new center of the Marshall Islands District. In 1986, with the signing of the Compact of Free Association, the atolls became once more independent as the Republic of the Marshall Islands. The Republic was finally released into independence by the Security Council of the United Nations in 1991 and was shortly thereafter accepted as a new U.N. member.

Demographic History

The demographic history of the Marshall Islands can be split into two main phases: the period of estimates, from the mid-19th century until 1900, and the period of censuses, starting with the population count in 1910 (Merz, 1910). The population of 19th century Majuro fluctuated between 1000 and 1500, which, given the mobility of the people, is likely to reflect reality rather than estimation errors (Spennemann, 1992b).

Table 1
Population Distribution of Marshallese Citizens on Majuro Atoll:
Comparison of the D-U-D Area Versus the Rest of the Atoll

	Population			Percentage	
Year	Total	D-U-D	Rest	D-U-D	Rest
1930	753	199	554	26.43	73.57
1935	782	179	603	22.89	77.11
1947	837	0 *	837	0.00	100.00
1958	3415	2387	1028	69.90	30.10
1967	5249	4149	1100	79.04	20.96
1973	9961	7506	2155	77.69	22.31
1980	11791	8583	3208	72.79	27.21
1988	19695	14707	4988	74.67	25.33

* U.S. military only

Majuro's population appears to have been increasing steadily up to a maximum of 1,600 or 1,800 people, if the late 19th and early 20th century estimates are to be believed. The census for 1910 provides a reliable figure of 1,400 people for Majuro Atoll, with a dramatic decrease to 1,089 in 1912 (Merz, 1910; 1912). Epidemics at the turn of the century, as well as the effects of the typhoon of 1905 on the subsistence economy of Majuro, cannot be underrated and may well be responsible for a decrease in the population by nearly 400 people. A low percentage of children ages 15-19 and 20-24 in the 1930 census reflects high infant mortality from 1905 to 1915, confirming recent observations (Spennemann, 1992b).

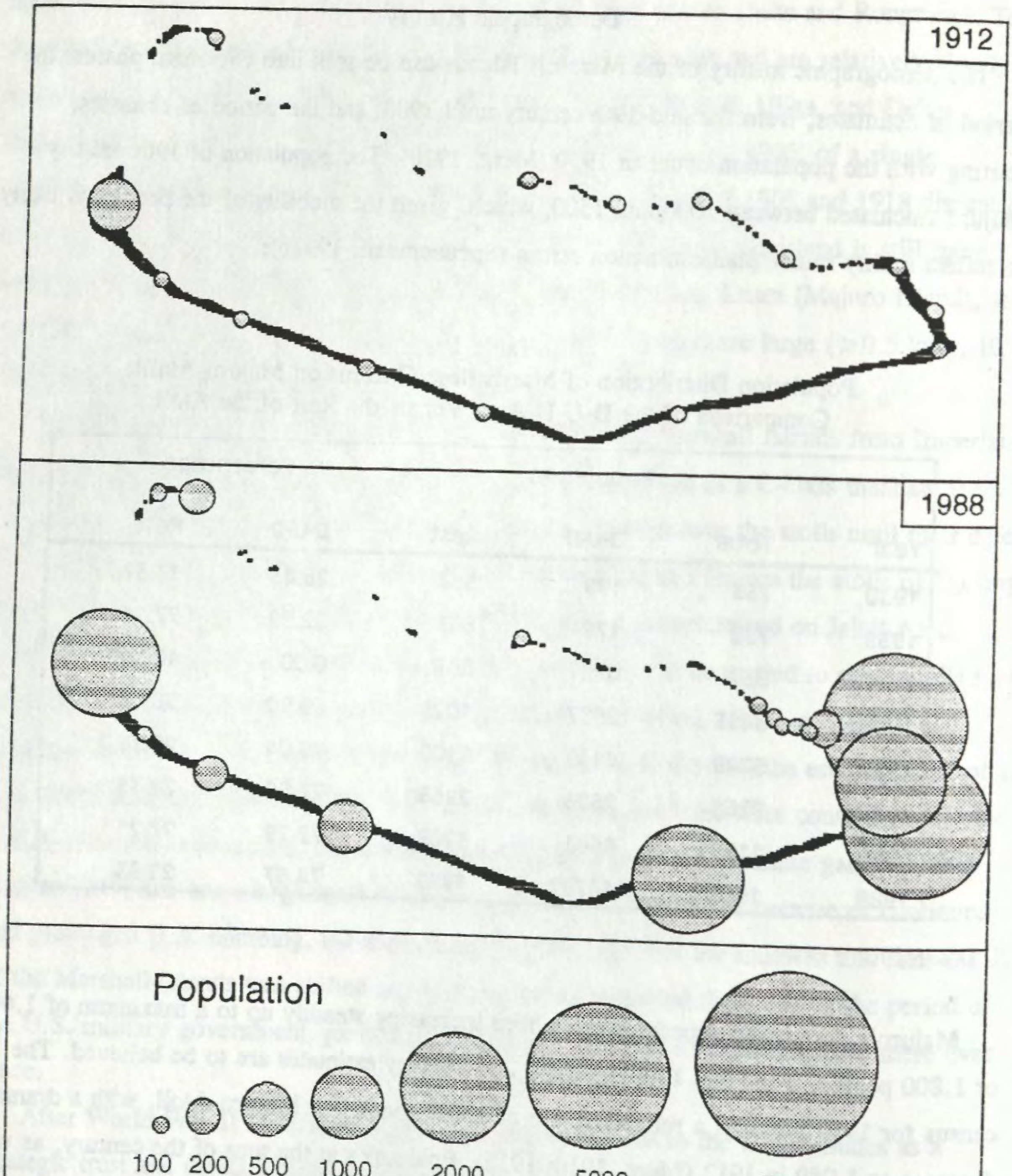

Figure 3
Demographic Development of the Population of Majuro, 1912 to 1988.

A dramatic change took place after the Pacific War (Table 1, Figure 3). During the period from 1935 to 1947 the nationwide population remained approximately stable with a 0.44 annual decrease—most likely as an effect of the war—whereas the population of Majuro Atoll increased at a rate of 4.6% annually. Part of this increase was due to the influx of non-Majuro people to the atoll during the closing days of the Pacific War, while further increase may have been the result of a population still recovering from the effects of the 1918 typhoon. After the war, however, the population increased nationwide at a rate of only 3.7% annually, while that of Majuro increased at a rate of 16.5%—clearly reflecting the increased importance of post-war Majuro as an administrative and commercial center (Spennemann, 1992b).

The population increased from 837 in 1947 to 3,415 in 1958 (Nucker, 1959) and 19,695 in 1988 (OPS, 1989). The uneven distribution of the population meant that in 1988, population density ranged from 46 persons/km² on Enumanet to 17,325 persons/km² on Djarrit.

MODERN SETTLEMENT PATTERNS

Archaeological data indicate that Majuro was settled as early as the middle of the first millennium B.C. (Riley, 1987; Spennemann, 1992a). A scatter of radiocarbon dates tends to suggest that human habitation, at least on the major island, Majuro ("Laura") was continuous to the present (Spennemann, 1992c). The English captains Gilbert and Marshall, passing through in 1789 without stopping, were the first Europeans to see the atoll (Gilbert, 1789). Before the establishment of the German colony of the Marshall Islands in 1885, the center of power was where the most powerful chiefs (*irooj*) resided and any suitably located atoll could attract the attention of traders. Majuro Atoll had a small but steady influx of foreign vessels and a couple of trading stations (Witt, 1881; Hager, 1886). Beginning with German colonial times, the center of administration and port of entry was Jaluit Atoll, while Majuro was a "backwater" that held several small trade stores, a major trading post on Ejit Island, a mission training center on Rongrong Island, and several churches.

Following their takeover at the beginning of World War I, the Japanese utilized the German facilities on Jaluit Atoll, which became the center of administration for the Marshall Islands District of the League of Nations' Mandated Territory of the North Pacific Islands.

On Majuro little changed, except that a small Japanese administration was established with a trader as the resident officer. The effects of a devastating typhoon in 1918 on copra production, the economic base of Majuro Atoll, however, curtailed any development of the atoll and led to a temporary withdrawal of the Japanese traders and a closure of the Japanese administration. Trading, and hence administrative interests, awakened again in the late 1930s, when the coconut plantations had recovered and began to produce. Neither during German nor during Japanese times was there any centralized planning and settlement, and plantations were erected wherever the people decided.

Centralized planning on Majuro began about 1939 or 1940, when the atoll was resurveyed by the Japanese navy and development of a seaplane base was planned on the eastern, leeward part of the island, chiefly the island of Djarrit. The choice of location was governed by both the protected nature of the lagoonal waters leeward of the windward islands and the fact that the western part of the lagoon was studded with patch reefs making seaplane activity hazardous. The main population center of Majuro was located on the other end of the atoll, away from the Japanese base, which made base security easier. The Japanese military development was then focussed on Djarrit Island, where they built the seaplane base, complete with pier facilities, warehouses, barracks, buildings, and the like. The development mainly occupied the lagoon side of the island and was dispersed, with numerous palms and local buildings left standing. The relocation of the remaining local population from Djarrit did not occur until well into the Pacific War, possibly early 1942. By late 1942 the base was abandoned in favor of base development on Mile Atoll.

Development 1944 to 1947

Immediately after their landing on January 31, 1944, the U.S. troops began constructing a forward military naval and air base on the eastern part of Majuro Atoll. The criteria for the choice of location were the same as those of the Japanese: base security and lagoonal conditions favorable for ships and seaplanes. The U.S. troops basically moved into an existing base and commenced building an airstrip on Delap Island. They connected the islands of Djarrit and Delap and the islands in between by a series of causeways. Afterward, these causeways were extended to include the island of Rairok, where an additional fighter strip was built. Until the end of the war, the base on Majuro was further developed with a pier, seaplane ramp, barracks, and other facilities. The sparse Marshallese population on Delap was forcibly moved to Laura, at the western end of the atoll (Richard, 1957).

During the Pacific War, the old capital of the Marshall Islands, Jaluit, had a substantial Japanese garrison and thus was severely bombed in consecutive bombing raids from November 1943 until the Japanese surrender in August 1945. Given the level of destruction of Jaluit, the enormous amount of unexploded ordnance spread about, and given that a functioning U.S. base had been erected relatively nearby, the U.S. administration of the fledgling U.N. Trust Territory of the Pacific Islands (TTPI) decided to leave the administrative center on Majuro Atoll and not to relocate to Jaluit.

Development 1947 to 1955

The transition to peacetime administration facilitated rapid change. It created job opportunities in the territorial administration as well as in private business, well-stocked trade stores, and the like. With these changes, a significant shift in the settlement patterns began.

Rapid development of housing occurred on Delap, Uliga, and especially on Djarrit. No organized development took place on the islands other than in the D-U-D area, with the exception of Rongrong, where a U.S. Coast Guard base was established.

Development 1956 to 1965

By 1967 most modern development had taken place with most buildings erected on the lagoon side of the islands, simply because the road ran there. In addition, this location is away from the destructive salt spray and the prevailing winds, which also made it favorable (U.S. Army Corps of Engineers, 1969, p. 4). However, a land-use map shows that while Uliga was quite densely developed, both Delap and Djarrit still had substantial portions of land used for gardening (Hawaii Architects & Engineers, 1968b, plate 17). The islands from Rairok to Laura had been connected by a 4-5 meter-wide unpaved road and a series of single-lane "earthen" causeways by 1960, all of which were in dire need of repair by 1967 (U.S. Army Corps of Engineers, 1969).

The 1967 Development Plan

In the mid-1960s, following a change in policy regarding the TTPI under the Kennedy administration, several development plans were initiated (McHenry, 1975). The Trust Territory Development Program activities in the Marshall Islands focused on Ebeye and Carlson Islands, Kwajalein Atoll (Hawaii Architects & Engineers, 1968c) and Majuro Atoll (Hawaii Architects & Engineers, 1967; 1968a; 1968b). In addition, plans for the development of Wotje as a district center had been drawn up (Hawaii Architects & Engineers, 1972a; 1972b).

The Majuro development plan proposed a development centered on the D-U-D area and included Western/European-style design concepts, such as zoning and the establishment of recreational areas and parks, which run not only contrary to Marshallese custom, but also show little understanding of the realities of Marshallese land use and land ownership. While the establishment of the parks failed, the recommendation to move an agricultural station, where pigs and chicken were raised, out of the fledgling central business district (CBD) to Laura was taken up. The proposed general zoning trends—to develop Djarrit into a predominantly housing area and to develop Uliga into the administrative and commercial district—were largely implemented, although the individual microzones did not eventuate.

The plan also proposed substantial landfill on the ocean side of the causeway between Djarrit and Uliga, merging Delap, Enileggere, Biggariat, and Uliga into a single long island, as well as the relocation of the airport (Hawaii Architects & Engineers, 1968b; U.S. Army Corps of Engineers, 1969). Both moves were designed to create more residential and industrial areas in the D-U-D area to accommodate existing and anticipated population increases. Further, the plan recommended the location of cemeteries near the ocean side of the islands, as this was considered to be the least habitable area. The plan, however, also contained references to the increased risk of erosion of such cemeteries and the need for a coastal zone protection.

The 1981 Development Plan

Following the 1979 tidal wave, which inundated large parts of the D-U-D area (discussed below), a development plan was drafted, which included precautions to prevent similar situations developing in the future. By the mid-1960s the refurbishment of the 1944 military airstrip on Delap Island had become a necessity. Since the advent of jet air services would have required the extension of the existing strip, it was decided to relocate the airport to an area west of Rairok and to utilize the area on Delap for industrial, commercial, and residential development.

The 1981 development plan, more detailed than the 1968 plan, pushed for a planning system to be set up and stressed the need for zoning regulations (McCoy, 1981). It also included a very strong environmental component and a detailed discussion of the atoll environment and its vegetational zonation. Heavily concentrating on proposals for the development of Delap and the area of the now redundant airfield, it included only a brief section on the development of Laura (McCoy, 1981, p. 35), mainly in the form of a general zoning sketch.

The period from 1981 to 1993 has seen an increased intensification of residential housing in the D-U-D area with the exception of the old Delap airstrip, where commercial buildings, as well as a hospital and the capitol building have been erected. In addition, the development of the airport has created an artificial boundary on the atoll, whereby everything west of the airport is perceived as remote, while the area between the D-U-D area and the airport is seen as close and has experienced increased development of residential housing from 1989 to 1993. Even though the land is less than 250 meters wide for most of the distance, there is an almost continuous line of houses both along the lagoon and the ocean side of the main road from the airport to the D-U-D area. In many instances a second row of houses has been developed between these house and the lagoon, as well as the ocean shore.

Development Trends

In summing up, the period since the end of World War II has seen commercial and administrative developments focused on the D-U-D area of the atoll, with residential housing following suit. While much of the land was open space in 1945, either in the form of gardening land or runways, planned and unplanned development has seen such space diminish. Only the very fringe of the ocean shore, often less than five meters from the high tide line, is left unutilized (though on Djarrit a number of sea walls have been constructed, pushing out the habitable area onto the reef platform). Over time, not only the islands of Djarrit and

Delap have seen increased residential development, but also the narrow stretch of land between the CBD and the airport. The increase in population, due to both births and inward migration, has led to incredibly high population densities (see Table 1).

To put these observations into perspective, one must first examine the settlement patterns that prevailed before the military base development of the Pacific War. That analysis is undertaken below.

Demographic Predictions

The past decades have shown a dramatic increase in population on Majuro Atoll, and various scenarios on the future increase of the population have been presented (OPS, 1989; 1990). Based on conservative projections, the population of Majuro Atoll is predicted to increase to 26,000 by the year 1995, 31,500 by the year 2000, and over 47,000 by the year 2010 (OPS, 1990).

As discussed above, the population in 1988 was mainly concentrated in the D-U-D area (see Table 2). It is predicted that this area will see most of the future population increase. In the following section, we will look at how this concentration in the D-U-D area developed.

TRADITIONAL SETTLEMENT PATTERNS

The available land mass on Majuro Atoll, as on all other atolls of the Marshall Islands, is very limited. Atolls are chains of sand islands on a coral reef platform of varied shape, forming a doughnut-shaped ring surrounded by water. The width of the islands is limited by the width of the supporting reef platform and determined by current conditions. On any given atoll, the majority of islands are less than 200 meters wide and 500 meters long. Settlement space, that is land suitable for human habitation is even more limited. Stretches of the ocean shore of the atoll are so exposed to wind-driven salt spray, generated in the breaker zone of the reef, that they are all but uninhabitable. In fact, today they are preferred locations for cemeteries.

The choice of the prime settlement locations is basically governed by environmental considerations (such as wind, wave action, protection from storms, etc.), which have changed only little, if at all, since the beginning of human habitation in the Marshall Islands

Table 2
Distribution of Population and Population Density (Persons per km²)
on Majuro Atoll in 1988

District	Population	Area (km²)	Population Density
Jelter	24	0.233	102.96
Rongrong	245	0.355	690.47
Calalen	19	0.259	73.36
Biken	8	0.052	154.44
Enemonet	6	0.130	46.33
Denmeo	7	0.052	135.14
Bokrej	14	0.041	337.84
Drirej	16	0.130	123.55
Garra	9	0.034	267.30
Ejit	170	0.049	3,454.58
Enarau	3	0.016	193.05
Djarrit	6813	0.389	17,536.68
Uliga	2144	0.293	7,325.66
Dalap	5692	0.648	8,790.73
Rairok	2021	0.622	3,251.29
Ajeltake	556		
Woja	224		
Arrak	118	5.180	477.41
Laura	1575		

(Data from OPS,1989)

some 2500 years ago. Traditionally, human habitation was restricted to the strip of land along the lagoonal shore of the large leeward islands protected from storm surges and typhoon effects. The remainder of the islands would be utilized for agroforestry of some kind or the other.

Drinkable groundwater, a prerequisite for ongoing human habitation, but also for the success of vegetation, is restricted to rainfall-recharged groundwater lenses suspended within the permeable coral reef platform and floating upon the heavier salt water. The volume of these lenses is determined by the width of the island and are, as a rule, the thickest in an island's center. Wind and ocean swell conditions vary on an atoll, with those islands on the windward side being smaller and comprised of coarser soil, ranging from coarse sand to rubble. Given frequent inundation during storm events, the groundwater lenses of these islands are shallow and not supportive of salt-sensitive plants, which in turn diminished these island's agricultural value.

Human habitation on atolls occurs predominately on the large, leeward islands, which possess a fine-grained soil and a durable thick groundwater lens, which supports an abundance of plants, the decomposition products of which, in turn, provide fertile soils conducive to plant growth. For early inhabitants these islands were sheltered from storm events, had a secure drinking water supply, secure food resources and, usually, sheltered sand beaches to land canoes. Small islands on the windward side possessed none of these characteristics and were thus avoided except to serve as temporary fishing camps and the like. In fact, the large islands were so important compared to the remaining islands on the atolls that the names of these islands were used synonymously with the name of the entire atoll. The only exception for this is Maloelap Atoll, where due to ocean current conditions there are three large islands

Traditional Patterns Defied

The modern settlement pattern described earlier, with the high concentration of people in the eastern part of the atoll and often very close to the ocean shore, defies traditional settlement patterns and hence traditional wisdom. The question arises whether this change in settlement patterns should be of any concern to modern urban planners, or whether the modern pattern merely reflects the technological advantage of being able to support a population in an otherwise adverse environment.

There is room for very serious concern that the defiance of traditional wisdom may in the future exact a price too high to pay. The key factor in the equation is the typhoons.

ENVIRONMENTAL CONSTRAINTS

The passing of the tropical storm "Zelda" in late November 1991 and of typhoon "Axel" in early January 1992 has once more shown that the islands of the atolls of the RMI are very vulnerable to typhoon impacts. The overall damage incurred comprised wind damage to structures, direct inundation of the low-lying areas including structures erected thereon, wind damage to food trees, and especially damage to food and utility trees caused by wind-driven salt spray.

The detailed extent of the damage incurred is beyond the scope of this paper. It is sufficient to say that on Majuro Atoll, the capital of the RMI, most of the southern and eastern reef platform and the islands thereon were affected by storm-driven waves and wind damage, while destruction in the western section of the atoll was confined to wind damage. In the southeast, inundation of low-lying areas occurred in a number of locations, temporarily merging ocean and lagoon and making the road impassable. In addition, areas not impacted by flooding saw the destruction of fruit trees by wind breakage of fronds, leaves, and small branches. Some trees, chiefly breadfruit trees, were exposed to the salt spray generated at the breaker zone and driven inland by the high velocity winds; these trees shed their leaves within a week after the typhoon. In addition, some of the coconuts experienced such high levels of salt spray that they showed a (temporary) shut-down reaction by shedding their immature and mature nuts to conserve energy to push new leaves.

The above is a summary of the damages resulting from a low-impact typhoon. The potential damages wrought by a strong typhoon passing directly over atolls in the Marshall Islands are several magnitudes worse. Depending on the strength of such a storm, whole islands could be depopulated and, in the extreme, even washed away entirely.

Typhoons in the Marshalls

Historic references to typhoons speak of human tragedy of vast proportions. Some low points include:

- The first typhoon recorded for the Marshall Islands happened in the 1840s. It devastated Likiep Atoll and cost the lives of the greatest part of the population (Goetze, 1914).
- A typhoon in about 1850 affected the northern Marshalls and decimated or completely

wiped out the population of Rongelap and Rongerik Atolls (Krämer and Nevermann, 1938, p. 51).

• Erdland (1914, p. 18) mentions that as a child his informant Benjamin had heard about a typhoon which destroyed much of Ebon and devastated all coconut and breadfruit trees there, leading to widespread starvation.

• In 1864 a typhoon struck Ebon Atoll and devastated the island. The resident missionary, Snow noted: "You would hardly know the end of the island. Every green bush and shrub is gone. The water tore everything before it" (Snow, 1864). Houses, coconut palms, and breadfruit trees had been washed off the island. In addition, canoes and a boat had been destroyed.

• The most devastating effects of typhoons known occurred on Ujelang. Gulick (1862) estimated the population of that island in 1860 to be about 1000 people. A severe cyclone hit the island in 1870, and all but 20 people perished. Most of these 20 people moved at least temporarily to Jaluit, so that in 1878 the total population had shrunk to 6 (Witt, 1881).

• In 1874 Ailinglaplap was badly hit by a cyclone coming from the southwest (Witt, 1881, p. 528) and had not yet recovered by 1880. The population given by Witt (1881, p. 529) was 220 in 1880, from an estimated high of 500 or 600 in the early 1870s.

• Young, a trader on Ebon Atoll, reports a typhoon which struck the northern islands:

> At 3:30 am a very heavy squall came suddenly from W. which lasted for half an hour; the heaviest squall I have seen in the islands; it blew with perfect hurricane force and was reinforced with thunder and lightening. The natives think this is the beginning of a hurricane. Not a pleasant prospect when one considers that a rise of a hurricane wave of 8 feet would sweep this islet bare as it did Kwajelen Island in 1875, drowning the inhabitants. (Young 1877, p. 153; entry for July 17, 1877)

The most complete data exist for the effects of the 1905 and 1918 typhoons, both of which affected Majuro Atoll.

The Typhoon of 1905

On June 30th, 1905, a strong typhoon passed over the southern Marshall Islands, severely affecting Nadikdik (Knox), Mile, Arno, Majuro, and Jaluit Atolls. Other atolls, namely Aur, Maloelap, and Ujelang were affected to a lesser degree (Jeschke, 1905, 1906; Erdland, 1905;

1914; Erdland in Linckens, 1912, p. 22-24; Rife, 1905, 1906; Schwabe 1905a, 1905b).

Over 227 Marshallese lost their lives on that day on the affected atolls of the Marshall Islands, most of them on Nadikdik and Mile (Treue 1940, p. 198). Many more were injured. Because of the destruction of all food stocks and fruit on the islands' trees, approximately 90 other people died in the following months due to starvation. The lagoon of Mile, and to a lesser extent of Jaluit, was reported to be completely full of floating debris: trees, bushes, houses, broken canoes, wooden utensils, and corpses. The concentration of drift material in the waters of the Marshalls during July and August 1905 was so high that it constituted a serious shipping hazard, making the limited relief operations even more difficult. Flooding by salt water killed many fruit trees and contaminated the freshwater lens.

On Mile, heavy seas washed across the islets, the storm surge being compounded by a high tide. According to eyewitnesses, waves were as high as the tops of the coconut trees. Even if one takes exaggeration into account and allows for the crest of the waves to consist of wind-driven foam, a wave height of some five to seven meters (16-23 feet) can be estimated. Jeschke (1905) assumes a wave-height of 12 to 15 meters. On Mile three small islands on the southern coast were completely washed away, and some other narrow islands in the southern part of the atoll were breached in many places. Only the islands closest to and in the lee of Nadikdik Atoll were reported to have survived well (Jeschke, 1905). Neighboring Nadikdik Atoll was completely washed over, several inhabited islands reduced to the bare reef platform, and the human population of that atoll (70 people) completely extinguished, save for two boys who survived a 24-hour voyage drifting on a breadfruit tree to the southern coast of Mile.

Similar to the inhabitants of Mile, the people of Arno Atoll mentioned that the seas reached to the tops of coconut palms. Waves breached some islands and washed away three-quarters of the narrow southeastern strip of land. The people on Arno living on the exposed southern islands had sufficient warning to flee across the lagoon to the larger western islands and seek shelter there, resulting in only eight fatalities.

On Majuro the waves breached the narrow continuous strip of land in two places on the southeastern coast resulting in a loss of land three miles length.

When the typhoon passed over Jaluit it was low tide and so the impact was substantially less. Nonetheless, flooding occurred, several ships sunk in the lagoon and the entire European settlement was completely flattened. Schwabe (1905a), an eyewitness to the scene, mentions that the island's center was awash to a height of about 3 meters. Flying debris, such as sheets of corrugated iron, torn loose, caused further damage, acting like guillotines and slicing through coconut trees and wooden walls (Schwabe 1905a). Canoes had been washed to the interior of Jabor Island. The ground was strewn with parts of buildings, toppled trees, and branches.

Casualty figures for Jaluit vary between 72 and 78 killed (Schwabe, 1905a). In addition, on Jaluit alone, some 60 people died of starvation and other typhoon-induced illnesses after the event. Seventy to eighty percent of all coconut palms, breadfruit, and Pandanus trees were destroyed, while all other palms lost their immature nuts and flowers. On many islands the humus layer was partially washed away by the waves and heavy rainfall, making the regrowth of replanted coconut plantations a slow process (Treue, 1940, p. 198).

Atolls north of Arno, such as Aur (Islands Aur and Tabal), Maloelap (Taroa), and Ailinglaplap (all eastern islets from Jih to Airik) experienced flooding. No loss of lives was reported from these atolls.

The Typhoon of 1918

The typhoon of 1918 was devastating for Majuro Atoll. A tidal wave washed across the entire southern part of the atoll flooding an area over 20 miles in length. The wave impact was not sufficient to reduce the entire island to the bare reef platform, but it was powerful enough to breach the narrow island in many locations in the southeastern corner of the atoll. The islands devastated or ravaged by this typhoon range from the western end of Delap to Woja. Until 1905 there had been a narrow but continuous land connection between Delap and Majuro Island (Laura). The typhoon of 1905 breached this in two places, and the 1918 event smashed it in numerous other locations between Delap and Ajeltake. The most serious breaches were along the southeastern corner, between Delap and Rairok, leaving only little bits of land behind, such as the tiny islets of Utwe or Enirak, now all rejoined by the causeway. In the southwestern areas the wave power was insufficient to breach the island, but strong enough to bombard it with coral boulders torn loose from the reef's edge. Trees, small vegetation and houses were washed into the lagoon.

On the other islands of Majuro damage seems to have been mainly restricted to wind damage to houses and trees and salt spray damage to vegetation. All churches and thatch stores were destroyed as were most of the thatch houses. Fruit trees were uprooted, coconut palms felled, taro plants broken, and Pandanus trees defoliated.

The *Missionary Herald* reported on the destruction:

> Mejuro looks like a wilderness and the food prospect for the Marshalls looks not too cheerful. About 129 died in the storm, a small fraction, perhaps, from the immediate effects of the typhoon, many deaths being caused by the waves.
>
> The islands have so little elevation above the sea that the tidal wave, which usually follows the wind, does much injury to life and land. The wave did not go over mission property, either at Mejuro or at Roritori [Rongrong], but the wind carried the salt water in sufficient quantities to make everything pretty salt. (*Missionary Herald* 1919, p. 389)

There seems to have been little forewarning of the impending disaster, and according to Japanese casualty figures over 200 people drowned on Majuro Atoll alone. The census for 1912 provides a reliable figure of 1089 people for Majuro Atoll (Merz, 1912a). In the years following the typhoon, the population decreased substantially and sank as low as 526 people on 1920 (Hawaii Architects & Engineers, 1968b), caused by both the direct effect of the typhoon, and after effects in the form of food shortages and inadequate health and housing. It appears that the population of Majuro Atoll did not recover to pre-cyclone strength until close to the Pacific War in 1941 (Spennemann 1992b).

After-effects on vegetation were severe, as inundation with salt water or exposure to wind-driven salt spray had caused the die-back of inundated trees and the temporary shut down of fruit growth due to salt scorching of roots. Lightly damaged plants eventually recovered, but little food was available for the year following the typhoon. On a commercial basis, it took over 15 years for the copra production on this stretch of Majuro to recover. This was particularly problematic since copra was the tax base for the island.

Exceptional High Tides

It has been argued that the southern Marshall islands do not experience serious typhoons, and that Majuro Atoll is relatively "safe." The 1905 and 1918 typhoons are seen by many in the RMI as "freak" exceptions, rather than as a standard threat.

However, the direct hit of a typhoon of 1905 or 1918 strength is not necessary to create havoc and cause substantial loss in property. Stable high pressure systems northeast of Wake or east of the Marshall Islands create higher-than-normal sea levels that will cause flooding of low-lying areas if they coincide with a spring tide or with high wave action. Such high pressure systems are common and have affected the atolls of the Marshall Islands on numerous occasions (the 1979, 1989, 1990, and 1991 floods on Majuro Atoll for example).

There is some historic information on such occurrences, although the data are scattered and sparse. In October 1909 an extreme high tide swept over parts of Jabor, Jaluit Atoll (Merz, 1910). A similar high tide occurred on Wake on January 24, 1947, washing away the recently built causeway connecting Wilkes and Wake Islands.

The extent to which drift material, logs, tree stumps, small floating debris, and the like is deposited along the shore and in the interior of the islands does give unequivocal evidence of the extent of the inundation during average storm surges. The lighter and smaller the material, the farther it is carried onto the land and through the fringing vegetation. Although the material is concentrated in a zone reaching about five to ten meters from the high-tide mark of both lagoonal and ocean shore, it can be encountered on the ocean shore up to 40 meters inland, readily testifying to the degree of water washing the island's interior can experience (personal observation of the author).

The 1979 Flooding (D-U-D Area)

In late November 1979 a subtropical high pressure system ("Alice") had formed some 2000 miles east of the Marshall Islands, creating higher than normal sea level at its perimeter, as well as a storm surge sent out as a swell with a wave amplitude of over 20 feet. The first set of waves inundated parts of the D-U-D area on the morning of November 26, 1979 (Ginoza, 1979a). Since the weather forecast came too late, there was no warning and a many personal belongings were devastated. During the night of November 27-28, a second inundation occurred (Ginoza 1979b), and a third inundation took place on December 4, when a third storm hit Majuro, this time accompanied by gale-force winds and a 20-foot surf (Hovertsen, 1979). Before the second tidal surge hit the atoll, some 4,000 residents of the already devastated D-U-D area had been warned well ahead and had relocated to Laura

(Wagner, 1979). On the morning of November 28, some 80% of the affected area was still covered by sea water (Ginoza, 1979b). This high tide and flooding was made worse where the waters pushed by the strong winds had been channeled and funneled into the embayments of the former inlets now barred by causeways and had washed over the causeways and adjacent reclaimed areas (see McCoy, 1981).

The entire flooding went by without loss of life, although several people were injured. The effects of the inundations were destruction of housing and personal belongings, as well as the inundation of septic tanks and subsequent spread of raw sewerage. Majuro was declared a disaster area, with quarantine measures enforced to prevent the spread of diseases. Some 5,000 people were relocated into tent cities on Rairok Island, a narrow strip of land in the south of the atoll.

The 1979 flooding was the worst in memory. The total damage to housing and belongings was estimated to be $26 million during the first set of waves, and another $4 million as a result of the second set of inundations.

Frequency of Typhoon Events

The waters of the southeastern equatorial Pacific undergo a quasi-cyclic phenomenon with a variable time interval of three to five years. During these events, which have been termed El Niño/Southern Oscillations (ENSOs), global atmospheric disturbances develop. A rise in the atmospheric temperature and the sea surface temperature generates climatic conditions favorable to more frequent, and also more severe, storms (Holland et al., 1988). Because the sea surface temperature stands in direct correlation with the minimum sustainable pressure and hence intensity of tropical typhoons (Emanuel, 1987), an increase in sea surface temperature, either during ENSO events or as a result of greenhouse-gas-induced global warming, is likely to a) facilitate the occurrence of typhoons in areas hitherto not previously affected; b) shift the area of typhoon generation further eastward into the central Pacific; c) increase the frequency of storms and typhoons; and d) increase the severity of typhoons in areas already affected by typhoons (Wendland, 1977).

In preparation for a publication on prehistoric settlement patterns in the Marshall Islands, the effects of the 1905 and 1918 typhoons were studied in detail (Spennemann, in prep.). An analysis of the historic record of typhoons in the Marshall Islands identified a significant association between the occurrence of ENSO events and the occurrence of typhoons in the Marshall Islands (Spennemann and Marschner, 1994). While typhoons normally occur further to the west, the warming of the ocean waters around the Marshall Islands, as part of the ENSO phenomenon, generates typhoons further to the east. Statistical analysis suggests that typhoons are 2.6 times more likely to occur during ENSO years, with a 71% chance of a typhoon striking during an ENSO year, and only a 26% chance of one happening during a non-ENSO year. The observed association between ENSO events and the historic occurrence of typhoons (Spennemann and Marschner, 1994) fits well with the expectation of typhoon genesis and sea surface temperature developments during ENSO phenomena. Further, the observed ratio of 2.6 times higher likelihood of typhoons during ENSO years fits well the frequency postulated by Wendland (1977).

OPTIONS FOR PLANNERS

The association between changes in typhoon location, frequency, and strength on the one hand and sea surface temperature anomalies on the other as implied by both theoretical modeling and the analysis of historic data has a number of implications. Typhoons are not freak events, but regularly recurring disasters that need to be considered in planning decisions. With an average elevation of 1.8 meters (six feet) above high water, the atolls of the Marshall Islands are so low lying that there is little margin for extremes. Any sizable typhoon will cause the inundation of parts of an atoll, with the eastern (windward) parts being more vulnerable.

The historic records quoted earlier, show that some typhoons were so violent that entire islands were washed away, leading to casualties of up to 80% of an atoll's population. In 1979, inundation of the CBD of the capital on Majuro Atoll left 5,000 homeless. Should a typhoon like the one in 1918 recur, casualties are likely to be in the thousands, with many thousands more homeless.

Very obviously, such prospects have implications for planning and public safety, which the relevant authorities should note:

- step up public education programs if a new occurrence of the El Niño is detected;
- review housing policy to assure that all new buildings, public and private, are adequate to resist typhoons;
- review the increasing destruction of coastal broadleaf forest and resulting reduction of wind breaks; and, most importantly,
- review the policy of sustaining population concentrations on islands traditionally only sparsely settled, such as Ebeye and Guegue on Kwajalein, and the D-U-D area on Majuro Atoll; and, in conjunction,
- consider shifting the development focus to the safe islands, following traditional wisdom.

Public education to alleviate or reduce future typhoon impacts is needed. There are several traditional low-cost technologies available that can be used to alleviate some of the salt-spray and wind effects in future typhoon or tropical storms. These include, but are not limited to:

- the re-creation of salt spray barriers in the form of traditionally used plants, preferably species that have additional uses. A very suitable plant would be pandanus;
- creation of natural wind breaks to protect banana plants and the like;
- creation of natural wind breaks to protect houses;
- use of historically proven low-technology methods to strengthen roofs and walls of dwellings against wind impact.

There are also side benefits to the traditional methods of land management:

- Apart from guarding against meteorological extremes, such as tropical storms and typhoons, the re-creation of natural salt spray filters benefits house owners, since it cuts down on salt levels in the air, thereby prolonging the life of electrical appliances, especially outside mounted air conditioners.
- If the vegetation to be planted are pandanus, these plants will also produce fruit, thereby providing additional nutrition to the people. In the 1992 RMI National Nutrition Survey, vitamin A deficiency was cited as wide-spread in the community,

especially among young children. Of all traditional fruit in the RMI, pandanus has the highest natural Vitamin A content.

CONCLUSIONS

Physical development, coupled with the extraordinary population increase on Majuro Atoll, has resulted in a departure from the traditional settlement patterns. Over time settlement on the islands in the D-U-D area extended from the protected lagoonal shore to the ocean shore. This trend is continuing with additional houses being erected ever closer to the shoreline. In the meantime settlement is rapidly extending on the islands between Delap and the airport—locations very vulnerable to typhoon-generated wave action, as the typhoons of 1905 and 1918, and typhoon "Axel" have shown. As part of the development process, coastal vegetation, as little as there is left in many areas, is becoming increasingly sparse.

Traditional methods of land management have been abandoned and the land has been increasingly modified to suit individual short-term needs. Eroding land is not stabilized to the degree feasible, nor is care given in the inland areas to preserve the fragile layer of topsoil upon which plant growth relies.

The long-term perspective which the Marshallese traditionally had is being rapidly forgotten. In addition, a large number of people are "squatting" on Majuro Atoll and on Ebeye (Kwajalein) without hereditary rights to the land and without proper lease agreements affording them rights or security of tenure. Understandably, therefore, there is little, if any, personal commitment to the land. This is well reflected in the homes that have been erected, which often can be pulled down at a moments notice and thus are of inferior structural quality well below what economic necessity dictates. Moreover, few if any plants are being planted to improve the immediate environment. Plants of no immediate commercial value are not planted at all.

In traditional settlement patterns, populations were concentrated on the safest island on an atoll, which, in the southern Marshall Islands is located on its western fringe. Today, Majuro's population is concentrated on the exposed eastern islands. Environmentally, the present spatial organization of urban Majuro is clearly unsuitable, as it unnecessarily exposes the residents to storm surge hazards. In a modern planning framework there is no need to perpetuate this concept, which was created by war-time expediency, driven by short-term perspectives and planned obsolescence. That the D-U-D area remained the focus of Majuro, and in fact the entire RMI, is an accident of history, rather than the result of careful planning.

As the past 75 years have shown, not all typhoons need to be as destructive as those of 1905 and 1918 to cause significant damage, but it may be too costly to underestimate the potential of a recurrence of a typhoon of such magnitude. Again, one of the potential impacts of global climate change is the limited increase of the sea surface temperature, which in turn is likely to increase typhoon frequency and intensity. The variations in typhoon occurrence as a result of the cyclic ocean warming caused by the El Niño/Southern Oscillation are ample proof of the impacts of limited temperature variations. Thus, a repeat of the 1918 disaster may take a long time to come—or it may just be round the corner.

The past has much wisdom to offer for present and future development. Many skills were developed over the more than 2000 years the Marshallese settled the atolls now named the Marshall Islands. This period allowed the people to fine tune their technologies and their techniques for managing and exploiting the natural environment within their technological constraints. In this case, previous experience, in the literal sense of the word, taught the Marshallese where to settle, which islands on an atoll to choose. Traditionally the windward islets were only used for temporary settlement or supported only a very small scattered population, while the larger islands on the leeward side were inhabited. Concentrating the population on these islands not only ensured protection from extreme natural events such as typhoons and tidal waves, but also ensured a reliable groundwater and food supply for daily life.

The post-World War II settlements on Ebeye and in the D-U-D area on Majuro Atoll have departed from that traditional wisdom; both are erected on the exposed windward side of the atolls, and both islands paid a price during typhoon Axel. In the Marshall Islands, technological development may have moved ahead at a dramatic rate, yet people remain at the whim of nature's unharnessed ire; the typhoon experiences of the past are still valid today. Let us hope the price to ignore the lessons of the past will not, one day, be too high to pay.

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