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IS IT DEVELOPMENT OR DESTRUCTION? THE IMPACT OF PHYSICAL INNOVATIONS ON ATOLLS. ATOLL ENVIRONMENT: BIOLOGICAL AND ECOLOGICAL IMPLICATIONS.

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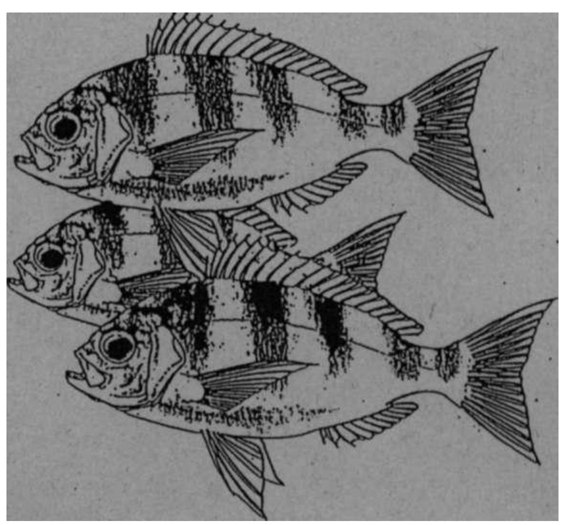

IS IT DEVELOPMENT OR DESTRUCTION?
IMPACT OF PHYSICAL INNOVATIONS ON ATOLLS
BIOLOGICAL AND ECOLOGICAL IMPLICATIONS

by

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AUTHORS' NOTE

This document is anecdotal and is being interpreted and related to scientific knowledge on the impact of development on the biological and ecological environment of atolls. In some cases predictions are made on the basis of knowledge of atoll ecosystems. The predictions should not in any way be looked at as a threat but should be considered with an open mind. It is hoped that future development plans do not only look at immediate social benefits but also the long term adverse effects that will affect us economically, culturally, intellectually and environmentally. Our destiny is our environment with all the resources it provides. It is therefore our responsibility to protect and manage them to the best of our ability. This is not a political but rather an educational document. Constructive criticism is welcome. Should any organisation or agency be embarrassed, it is very much regretted.

Temakei Tebano

INTRODUCTION

I have been intrigued by the rapid "developments" being pursued by the small island nations in the Pacific region. Millions of dollars have been poured into projects which one could not have dreamed of becoming a reality. Some of these development projects as often referred to definitely have more adverse than positive impacts on the communities they were designed to help. Moreover, changes that have been created are often irreversible and destructive to the fragile and unique atoll ecosystems that nature provided and natures.

I cast my particular interest on atoll ecosystems with particular reference to Kiribati because I am more familiar with and I have been working and visiting them during the last couple of years. Dramatic changes have been noted particularly on the islands where these so called "development projects" have been initiated. Although the social benefits are being enjoyed, the biological and ecological aspects are poorly understood. Some people at a village level are beginning to question what is happening with this and that, in particular, our marine food sources. The cases will be drawn from my own experience in the Gilbert Islands, Kiribati. Responses to questionnaires sent to each island council, which specifically asks for any effects or problems as probably resulted from causeway/bridges and reef passage construction, are also included.

The focus will be centred on human innovations such as causeways, bridges and boat channels. The sole purpose of this document is to relate such innovations to facts based on scientific knowledge and understanding of atoll environments prone to both natural and human induced disasters. The more we fiddle with the fragile atolls the more we are going to suffer.

ATOLL ENVIRONMENT AND DEVELOPMENT

Physical characteristics

Coral atolls are scattered over a large part of the tropical seas of the world. There is some disagreement over the exact number of atolls but it is estimated to be around 309 atolls in the Pacific. This probably includes a few that do not have lagoons, and hence are table reefs. Generally, atolls are ring-shaped coral reefs that enclose lagoons.

Primary atoll characteristics which should be noted include outer slope, reef, islet, lagoon, reef structures within the lagoon, channels and passages between lagoon and open sea (Fig. 1). (Refer to Atoll Environment In Kiribati, Atoll Research Unit, University of the South Pacific, 1984a; for more detail).

Origin of atolls

The origin of atolls is still an area of scientific dispute. Two distinct theories proposed are Subsidence and Glacial Control. The former was first promulgated by Charles Darwin following his five-year voyage on the Beagle, during which time he had the apportunity to study reefs in several areas (Nybakken, 1982). He claimed that atolls are formed when an island with fringing or barrier reef is submerged. The reef continues to grow upward to maintain the living organisms at the necessary depth. When submergence has gone far enough the original volcanic island is covered by water, leaving the coral limestone atoll. Daly and Penck, supporters of the Glacial Control Theory advanced the theory in the early twentieth century. They reasoned that during the Pleistocene (about 1 million years ago) when sea level was over 100 metres lower than it is now, the ocean was cooler than at present and thus less favourable for coral growth. As sea level dropped, islands and their fringing reefs were exposed above sea level.

Corals could not grow around the margins of the islands fast enough to protect the island from wave erosion. Thus the islands were levelled off to form platforms. When the sea began to warm up, new reefs formed near the margins of the platforms and maintained their positions during further rises in sea level when the ice sheets melted at the end of the Pleistocene, thus creating the atolls with their flat bottomed lagoons.

The formation or origin of atolls is important to understand as most people living on these islands have never realised how fragile and delicate the atolls are, and that they need a never ending protection from all sorts of disturbances particularly artificial ones.

Coral growth conditions

Coral reefs occur around the world in warm subtropical or tropical oceans particularly on the eastern sides of continents e.g. the Great Barrier Reef, Australia, East Coast of Africa, and from Melanesia to Polynesia and Micronesia in the western Pacific Ocean. Two important factors, temperature and sunlight, are required for coral growth.

For coral growth, the water temperature range should fall between 20°C and 30°C. This requirement limits reef formation to latitudes between 30°N and 30°S. Sunlight is required in sufficient amount to support the algae (zooxanthellae) which live in symbiotic relationship with the coral. This means that the flourishing coral growth is only found in clear, shallow water down to a depth of approximately 15 m with decreasing growth to about 70 m. Both requirements also explain why reefs are generally found in shallow areas on continental shelves associated with islands or atolls.

Corals are animals which either live solitarily or as a colony. They do not depend entirely on zooxanthellae. They are carnivorous (prey on other animals) and feed on plankton in the water column. Fish eggs and larvae as well as other microorganisms that spend part of their early life in the planktonic stage may fall prey.

Currents and waves

Ocean currents form an amazing mechanism which one cannot deny. They maintain lifeform in the most unpredictable and harsh environments like the two Poles. Though low temperatures persist in these regions, lifeforms flourish. The currents transport warm water from the equator and tropics either northward or southward to the temperate and polar regions. When warm water reaches these cooler regions it slowly displaces the denser cool water which sinks and moves toward the tropics. Cool water brings in nutrients and oxygen to the tropics. This is a long process which takes hundreds of years to accomplish.

Currents also play a major role in seed dispersal around the world. Most indigenous higher plants that have colonized the Pacific were dispersed by ocean currents. Pandanus trees, mangroves and many others are the result of this efficient mechanism. Other marine organisms in planktonic form have reached these islands by way of ocean currents.

Local currents and waves around an island or between islands play significant roles in the maintenance of marine life. They provide a medium for fertilisation, a medium for bringing up the young, a medium for transport, and a medium for other multiple processes. Currents, waves and wind continuously reshape and maintain atoll ecosystems.

Localised currents and waves around an island are the main agents in bringing about changes that may occur within the ecosystem. As an ecosystem, an island or atoll is made up of communities of animal and plant species that form a complex web. Each community within this ecosystem plays a role in sustaining and maintaining existence and continuity. If one community is disturbed the currents and waves will eventually transmit the disturbance to other communities which may also be affected. The effect may be serious or minor depending on the relationships between given communities. If the atoll landscape is altered in such a way that it interferes with current flow and wave directions then there will definitely be changes within both the lagoon and reef communities. As Nikolsky (1963) put it 'the interrelationships between the fish and the elements of its abiotic and biotic environment are not isolated; they are interdependent, and any changes in one system of relationships inevitably produce changes in the other'.

The Concept of "Development" in an island context

The definition of "development" has been centred around concepts based on frameworks which suit the big countries whose foreign trade and other activities are measured in the economic terms. It is a grave mistake to compare, United States of America with a country like Kiribati, Tuvalu or Tokelau or with other small island states in the Pacific region. If one looks at development in terms of the number of cars, skyscrapers, or luxury hotels, for example, we are no match to any of the so called "developing" or so called "developed" countries. If one measures "development" in terms of poverty and unemployment, or in terms of material wealth and resource distribution then we may fall within a "developing" or "developed" category.

Small island nations are caught up with the wrong definition of "development". We look at development in countries with vast (but finite) deposits of natural resources as relevant to us because of the priviledges that they enjoy. As Thaman (1990) put it, 'Perhaps the most frightening sign of environmental stress and breakdown, that Pacific Island societies should take note of, is that imported "modern development" strategies are not even working in the environment they were designed for'. We ought to look for development that fits in with our own set up.

Sustainable development which stresses the importance of utilising our resources while maintaining them through proper management may be a kind of development which we should be looking at. Our islands have scarce and finite resources, and that we cannot go beyond what they can provide. Our resources, both marine and terrestrial, need to be utilised on a sustainable basis. They need to be protected and managed wisely. We cannot afford to fiddle around as the costs may be too great and irreversible, thus endangering the "health of our environment". So we should measure atoll development in terms of environmental and resource protection and management and not just in cash or material terms.

CASE HISTORIES - Causeway and bridge

Introduction

Kiribati is one of the small island nations in the Pacific Ocean. It is also one of the poorest countries in the world in terms of cash and material wealth and one of the most needy nations in terms of aid for "development projects". A never ending list of projects includes telecommunication, energy, education, marine resource development and many others. Some projects were viewed as more urgent than others, some were viewed as ongoing, short or long term. Priorities were also determined on the basis of relevance and financial support that could be obtained from aid donors. Among such projects causeways and bridges **were** a priority. This is clearly shown in the **1970-1972** development plan **for** the then former Gilbert and Ellice Islands Colony. This plan was carried through (1973-1976) and modified to include channel construction and reef blasting for fishing boats and canoes. Most of these projects were initiated during this period and continued after the two states separated in 1987. Gilbert is now known as Kiribati and Ellice Islands as Tuvalu.

There has been an increasing demand for causeways/bridges and boat/canoe channels in the Gilberts, Kiribati. The main reasons are i) to make travelling easier and faster, ii) to make services more accessible to rural people in fragmented atoll islets, iii) to allow larger vessels to bring in supplies to outer islands, and iv) to help fishermen have better access to fishing grounds. Specific examples are discussed below.

Makin Island

Makin Island is one the smallest islands in the Gilbert chain. At the northern end of Makin village there is a small lagoon which separates Tenaa (a strip of land from the extreme north) from Makin village during high tide (Fig. 2). Getting across during high tide has to be done by canoe or by wading through. The deepest pool is where the shortest route can be made. The causeway was built here in the late 1970s. The people of Makin enjoyed easy access to the other side of the lagoon.

Several years later, drastic changes became apparent. The mangrove swamp and other saltwater vegetation started disappearing. Edible land crab and shellfish populations dwindled and there were mass die-offs of several species. The islanders wondered what was happening.

Biological and Ecological aspects

The mangroves and other saltwater vegetation were dying or died afterwards because they were denied access to sufficient supply of oxygen and nutrients brought in by the incoming tide. The causeway inhibits adequate supply required by this vegetations. At the same time, the swamps were turned into a waste dump of decaying and waste matter some of which may be toxic to the plants themselves. The outgoing tide removes an adequate quantity of decaying matter thus preventing plants from getting intoxicated.

Some of them re-enter the organic cycle (Meadows and Campbell, 1978).

The people of Makin have noticed a dramatic reduction in the edible land crab "manai" *(Cardisoma sp.)*. It is believed recruitment into the population must have been very poor. Crabs like other marine or terrestial creatures migrate to certain grounds to spawn. On a particular night, probably during full moon and when the tide reaches its highest level, they would proceed to the seashore to spawn. The eggs and sperm are shed in the water, at the highest tide, where fertilisation takes place. These are then carried away by the outgoing tide. No one knows where they are being carried to but several studies show that while the larvae are at the mercy of current and prone to high predation they develop into miniature larvae before they are brought back to where they originated or dispersed to other habitats where they may continue their life cycle once again, if the conditions are favourable. This is the recruitment process which if interfered with will have a serious effect on the size of a population. The causeway surely had prevented most of the eggs, if not all, from being taken away and transported back. Spawning, in many cases, is restricted to particular tidal or current conditions, often in a lunar rhythm and limited to a few days each month, apparently to ensure that the young are released into the most favourable current patterns for return to the reef at the end of the plankton phase (Johannes, 1978; Lobel, 1978; Lobel, 1978 and Kamiura, 1958). This process is very similar to that just described above. It supports a claim that recruitment into a crab or other sedentary and benthic organisms' populations has been and is being jeopardized.

With increasing pressure from human consumption of the crab, the population was on the verge of being wiped out completely. The meat of the animal is one of the best and craved by both young and old. The animal is still being sought after but the number caught has always been very low.

Marine organisms that inhabit a mangrove swamp and a mudflat beyond were seriously affected. Certain bivalves and other shellfish such as *Gafarium tumidum "koumara"*, *Asaphis violascens "koikoi"*, which used to be in great abundance died in hundreds and thousands. They must have been denied adequate oxygen and food supply brought in by the tide. The water which may either become brackish during the rainy season, or too high in salt content during dry season could adversely affect the osmoregulatory process of these animals. The causeway had probably contributed to greater variation in salinity. Some fishes can adapt to fluctuating salinity while others can not and if subjected to even narrow changes they would die rapidly (Nikolsky, 1963). This could have happened to the mudflat bivalves and other communities.

Variation in salt water content could also be unsuitable for fertilisation required for recruitment into the population. The fertilised eggs (if fertilisation took place) which develop and hatch into the young may not find enough food normally brought in by the tide or they may not be able to access some environmental conditions required for their further development. These conditions may include planktonic phase in the water column, larval settlement and so forth. The unfertilised eggs, and the unused semen and even the dead larvae may produce toxins or anoxic conditions upon decay. This may foul the water and environment that the shellfish and other marine organisms inhabit. A causeway is the contributing factor. It interferes with natural processes and creates changes at both the ecosystem and community levels.

Butaritari Island

At Butaritari Island there was a natural cut-through waterway "te rawa" separating the two villages, Tanimainiku and Keuea, at the northern portion of the island (Fig. 3). During the late eighties a causeway was built across this passageway.

Biological and Ecological Aspects

A notable change along the coastline around the two villages and at the vicinity of the massive construction is evident. On the lagoon or western side sand had been deposited in some areas and removed from others. A similar process was also witnessed on the ocean side (respondent to a questionaire, pers. comm.). Some land owners are lucky while others are not. But there is more than this. The large and small coral boulders with which the causeway was built each offers a favourable marine habitat. These habitats provide shelter and feeding grounds for both diurnal and nocturnal organisms. On a larger scale, both lagoon, reef and pelagic organisms were affected. Spawning and migration are interfered with or hindered. There is very little mixing of oceanic and lagoonal waters. Wave and current patterns were also probably affected. All other processes that take place at this particular location are interupted.

Some fish species like bonefish "ikarii" (*Albula neoguinaica)* and mullet "aua" *(Valamugil seheli or Liza vaigiensis)* migrate to certain spawning grounds at a certain time of the month or the year. Some mullet species have been observed for their spawning patterns. Some migrate to specific spawning grounds, though the location of these spawning areas varies widely both within and between species (Laevastu, 1987; Johannes, 1981 and Moe, 1969). One species in Kiribati, probably *Valamugil seheli,* migrate to the ocean side to spawn. They are often sighted first forming small schools in the lagoon before migrating to the windward side of the island via passages then aggregate off the beach or rocky shores during high tide. The spawning patterns have not been documented, but in other species individuals have been observed swimming rapidly in counter-clockwise close to the surface in shallow waters. The splashing of the water surface was assumed to be the climax whereby eggs and sperms are released into the water surface (Thresher, 1984 and Nakai, 1959). A bonefish "ikarii", *Albula neoguinaica,* also migrates to the windward side, in some instances they share the same spawning ground, but not the spawning season, with mullets (Tebano, unpubl. work).

After spawning the currents carry away the fertilised eggs into the open sea where they undergo various developmental stages before metamorphosing into young juveniles. The waves and currents, to a certain extent, provide protection to the fertilised eggs and juveniles by reducing predation from other predatory species. They also provide transport back to where they originated to complete a cycle. Oceanic cool water provides nourishment and dissolved oxygen during the planktonic period.

Lagoonal water needs to be replenished with oceanic nutrient-rich/oxygen-rich water. Not only migratory fish species or sedentary organisms are affected by the construction of a causeway but also other processes and forms of marine life.

Wave and current patterns may change due to a water blockade by the causeway. Observations on the effect of groynes and harbour breakwaters on wave and current patterns were reported by Meadows and Campbell (1978). These changes in pattern and direction not only interfere with sediment and sand particles (Meadows and Campbell, 1978) but with the return of juveniles to where they originated.

The fishermen and local populace of this island are aware of the significant reduction in the number of fish being caught, that is, the effect of a causeway on marine food sources. Information was obtained either through interview or from response to questionaires sent to the Island Council. Solid data need to be collected on the impact of this "development".

Marakei Island

This is a land of fish (Aban te ika) as people often say. It is no longer true. Fish is scarce. Pelagic fishes like flying fish, tuna and garfish are the main species being exploited. Reef fishes are toxic and the lagoon which was once full of life can now be described as a "dead lagoon".

Ciguatera fish poisoning compounded the problem. Most, if not all, of the reef fish are potentially toxic but the people of Marakei occasionally test them if they are still toxic. In most cases they are not successful.

Marakei Island is one of the unique islands in the Gilbert group. A lagoon is enclosed with only two narrow openings one on the eastern side and the other is on the western side, adjacent to each other (Fig. 4).

In the early 80s a causeway-bridge was constructed across the western passage (Baretoa Passage). The people of Marakei were very proud of this project until several years later the passage was blocked. Fish populations in the lagoon declined and most of them disappeared (pers. comm.). Dead corals (mainly *Porites and Acropora spp.),* millions of black sea-urchins (probably *Arbacia punctulata)* and filamentous-green algae now predominate. Apart from introduced tilapia which now inhabit the lagoon other species of fish (*Lethrinus, Gerres)* and shellfish *(Anadara maculosa "te Bun")* are rarely found (Tebano and Lewis, 1990).

Biological and Ecological aspects

Water analysis in late 1989 (Tebano, 1990) shows a high level of turbdity as compared to other islands in the same group; there is high level of phosphorous, nitrate, nitrite and other nutrients but the oxygen level was far below the minimum level acceptable to most marine organisms. Salinity was slightly higher than mean salinity of the group (Tebano and Lewis, 1990). During rainy periods salinity drops dramatically.

Water exchange between the lagoon and the open sea is probably reduced and now insufficient to support some biological processes. Reduction in water exchange could mean poor oxygen supply and the accumulation of nutrients being brought in by the cooler oceanic water from the windward side via the eastern passage. The nutrients and other domestic wastes washed into the lagoon during heavy rains accumulate and provide nutrient-rich water for algae and sea urchins, a good sign of pollution. Recruitment into populations of fish species like striped emperorfish "okaoka" (Lethrinidae), silver biddy "ninimai" (Gerreidae) and other organisms has been reduced or cut off. Migrations, spawning cycles, developmental stages and a host of other processes were either interrupted or hindered.

As fishing pressure continued each existing population was exploited beyond what they can sustain, resulting in a dramatic decline and disappearance. Several models claim that there is a certain point whereby a stock is able to replace what is removed from the population either through predation, natural mortality or fishing mortality; the stock may not recover if this limit is exceeded (Everhart *et al, 1975).* Some animals and even plants may have become extinct but this needs further research.

The blockage of the western passage must have brought about all these changes; the causeway-bridge being to blame. The eastern passage has got shallower than it used to be. Sand is being deposited down stream towards the lagoon. The bridge pillars must have slowed the current down or changed the normal current flow thus affecting the physical nature of the passage. Meadows and Campbell (1978) describe how a change in current and wave patterns created by the construction of a breakwater, in Santa Barbara, resulted in sand deposition. It can, therefore, be predicted from the present observation that this passage may be blocked around the year 2000.

Tarawa Island

Tarawa is made up of two portions, North (Rural) and South (Urban). The latter is the capital of the Republic of Kiribati. Many development projects have been and are still carried out. Causeway and bridge construction is one of the priorities given to both North and South Tarawa (Fig. 5).

North Tarawa had a number of causeways constructed from the late seventies through early eighties. Some more are being planned for 1992. The effect of causeways in North Tarawa is being realised. There are problems with land ownership regarding newly formed or disappearing land. This is compounded by increasing population and easier access to rural areas, meaning that the marine food sources are getting scarce. The same biological and ecological problems discussed above apply.

South Tarawa has an even worse situation. The three causeways built during the early seventies namely, Bairiki-Naanikaai, Naanikaai-Teaoraereke and Ambo-Taborio, have definitely obstructed a bonefish spawning migration from the lagoon to the ocean side. Some of the islets on the ocean side either have disappeared or are disappearing.

Before the sewerage system was in full operation and effective, there was a cholera epidemic in 1977 (Naidu, *et al,* 1991). This is due to increases in feacal choliform concentrations in the lagoon. The principal cause is inadequate flushing of polluted and contaminated lagoonal water by fresh oceanic water. A survey conducted in 1987 shows that nutrient levels have increased indicating that problems such as water-borne diseases and pollution are most likely to occur in the near future (Naidu, *et al,* 1991). The causeways that were built must have slowed lagoon flushing.

A gigantic and modern causeway (Nippon) was completed two years ago. This joins the islet of Betio, the main battle ground during World War 2, to the rest of South Tarawa. It is about 3.4 km long, 13 m wide and 6 m high forming a partition between lagoonal and oceanic waters leaving only a narrow channel Nei Tebaa which now barely enables the boatmen and fishermen to gain access to both sides of the reef (Tebano and Lewis, 1990). Several months later the islet of Bikemaan (also known as Te Aba-n-Uea or Land of King) seems to be disappearing. At the same time coral sand has been deposited on all sides of the causeway in particular on both sides of the channel and around the bridge. Late last year the channel had to be excavated as the boats coming back from fishing trips could not go through during low tide. How often has this to be done? Nei Tebaa, a small beautiful islet on the ocean side, has disappeared.

At Santa Barbara, California, USA, a dredger works continuously to remove sand from inside the breakwater and to deposit it back into the normal longshore current system (Meadows and Campbell, 1978). This shows that any interference with current flow or wave patterns will create problems such as erosion, sand deposition and above all the distribution of sand dwelling animals.

It was estimated that 108,000 m^3 beach sediment was deposited adjacent to the causeway on the lagoon side. After four months of completion 16,000 m^3 accumulated with a rate of 43,000 m^3/yr (Harper, 1989). During my recent visit to Tarawa in October this year I witnessed huge deposits of sand on both the ocean and lagoon sides. Sand deposition, particularly on both sides of the channel has been dramatic. I watched the fishermen trying to make their way through the channel during low tide with not much success.

Some biological and ecological damage has been realised. The coastlines of Betio and Bairiki are undergoing dramatic changes. In some areas erosion and sand deposition have taken place and obviously are continuing. The nearby villages particularly those in close proximity to the construction have also been or are being affected. Sea walls have been and are still being built on both the ocean and lagoon sides of villages to counter this. But would these sea walls solve the problem?

Undoubtedly, the whole current system of Tarawa lagoon and the inshore wave patterns particularly on the ocean side must have been altered. The effect of these changes must be immense thus research is needed to monitor the biological, ecological and environmental damages.

The rate of pollution in the lagoon is expected to increase (Naidu *et al,* 1991) and many more marine plant and animal forms should be affected. The formation of new passages are quite possible and flooding and coastline erosion cannot be ignored.

Kuria Island

A causeway was built on the island of Kuria in the early 1980s. The village of Oneeke is now connected to Buariki village, the latter is where the Island Council Office is located (Fig. 6).

The people of the island could now travel easily back and forth between the two villages. On my visit to the island in 1984 I was surprised by the rapid change in the coastline around this part of the island. Vast volumes of sand have been deposited at both ends of the causeway. In response to the questionaire sent to the Island Council the clerk said beach erosion and reduction in the number of reef fish caught have been felt.

Biological and Ecological aspects

Coral boulders were collected from both the western and the eastern sides of the island as well as from inside and around the passageway. Countless numbers of animal (fish, crab, bivalves, etc.) and plant communities (mangrove, iron-wood, etc.) perished in the act and biological and ecological processes mentioned earlier were adversely affected. The people of Kuria enjoy uninterrupted road travel from one end of the island to the other, but they resent the declining number of fish that they normally catch at night using coconut leaf torch or pressure lamps. Who is to blame?

Abemama Island

This island was known to be the land of the bonefish "ikarii" *(Albula neoguinaica).* According to the people of Abemama this fish is netted as they make their way through various passages or at both ends of the island, to the ocean side. The migratory pattern and spawning cycle occur three of four times a year, however, the exact times remain a secret as often the case in Kiribati tradition. At a certain phase of the moon, the fishermen set up camps at either ends of the island. The nets are cast as to form a barrier about 0.4 km long right from the beach and out into the sea. In some cases the nets are cast parallel to each other where the migration appeared to be most concentrated. It has been reported that in most cases almost none of the fishes escaped the nets. Up and until now no one has heard of such heavy landings.

Three passages have been built between 1970 and 1989, two between Kabangaki and Manoku village and one between Manoku and Tebanga village. One bridge (built in 1973) connected Tebanga and Tabontebike, the latter is the headquarter of the island (Fig. 7).

Biological and Ecological aspects

Since the construction of these causeways there has been no more bonefish migration through the passages except at both ends of the island. But this also soon vanished. Although the migration route and spawning period are both well known to the old fishermen who mastermind group fishing activities, such events now rarely or have not happened.

Two things stand out very clearly: a blockade of migration routes and a dwindling population size. These are the results of causeway construction and heavy landings during migrations to or from spawning grounds, respectively. Other factors such as reduced mixing of both oceanic and lagoonal waters, a probable change in local current systems and others definitely affect and influence this marine food source and other numerous marine food sources, plants and animals alike, in one way or another. The effects and influence of these factors have been discussed above and some are presented in more detail later in the text.

Beach erosion and sand deposition around the causeway areas have been very significant. At times severe damage was inflicted on the causeways particularly during heavy seas and rough weather. Maintenance work provided by the Island Council will be required as long as the causeways still exist but at what price to the existing ecosystem and environment!

Nonouti Island

There are numerous passages on this island particularly at the northern portion (Fig. 8). The only passage at the southern portion between Temotu (south-western end) and Tenanoraoi villages was blocked with a causeway during the late 70s. The other four at the northern portion followed with one of them just completed in 1984. There are more being planned for 1992 and the following years.

Biological and Ecological aspects

Notable changes have been observed. Shore erosion and sand deposition in many areas have been witnessed. This was confirmed by the clerk to the Island Council (from response to a questionnaire). Maintenance is increasingly costly to the island council as wave and current actions constantly try to push their way through. Bonefish "ikarii" and mullet "aua migration and spawning activities are no longer witnessed. Common coral reed fish species such as goatfish "tewe" (Mullidae), cod "kuau" (Serranidae), cardinal fish "nikatang" (Apogonidae) particularly the territorial species are no longer found in the passages as all available coral boulder and even massive living corals were used for the construction of the causeways. The once rich environments are now like deserts. The reef platform which was previously crowded with broken off coral boulders (large and small) looks deserted. Night fishing with dry coconut leaf torches or pressure lamps is now more of a hobby rather than an engaged fishing method. A sipunculid mudflat worm locally known as "ibo" is getting scarce and can now only be found in certain areas.

A lot of biological and ecological damage have been done. The impact of these so called "development projects" are felt and realised. The diversion of current flow and wave patterns, the interference with mixing of two water masses (ocean and lagoon), the destruction of communities and other forms of interruption contribute to a great impact on the environment, biological and ecological processes.

One of the causeways which had not been completed may be changed into a bridge. I warned the two nearby villages that there is more than enough destruction done to the biota from the latest causeways. They were advised either to stop or opt for a more expensive alternative, a bridge. Of course this will still have some effect but a properly designed structure can minimise any alteration in all aspects of the environment, biological and ecological processes.

Tabiteuea Island

This is one of the longest islands in the group. There are numerous passages which separate the two Tabiteueas, North and South (Fig. 9). But recently, there was a move to unify the two. There are causeways already built in the late 60s, two at Tabiteuea North and three at Tabiteuea South. More are being planned.

Biological and ecological aspects

The impact of these causeways is being felt and realised by the people of the island. The biological and ecological implications discussed above also apply here. One prediction that should be borne in mind is that if those numerous passages in the middle are blocked then the clam population on the lagoon side will eventually decline and disappear. The luxurious coral growth in the same area will also be endangered. The most obvious reason is non mixing of oceanic water from the ocean side (eastern side) with lagoonal water (western side). This mixing regulates temperature, dissolved oxygen levels, nutrient levels and many other biological and ecological processes discussed earlier. The clam will be denied of clear, oxygen rich oceanic water which is one of the basic requirements for healthy growth. Of course other organisms will also be affected in terms of unavailability of plankton as a food source or in their migratory or spawning activities.

Onotoa Island

The northern and southern parts of the island have been separated since its very existence until 1989 when a causeway joined the two together (Fig. 100., The causeway is approximately half the length of Dai Nippon Causeway in South Tarawa. No channels were created to allow some water to pass through.

Biological and ecological aspects

During the period that I worked on Onotoa (1989), I witnessed a lot of changes. The most obvious were coastline erosion, shifting and deposition of sand in many areas. Every now and then the eastern side of the structure would be dismantled by high wave and strong current actions. Special walls were erected in the worst hit areas to weaken the force generated by the waves during the incoming tide. At this stage maintenance work had already begun and the causeway had never been declared complete.

Dredging and excavations on the reef platform have caused a lot of damage to many marine organisms not to mention what will still be affected.

On the lagoon side life is abundant. Healthy coral growth and other life forms can be witnessed. The clams "vere" (*Tridacna crocea)* bore their way through dead coral and flourish. On the mud flat are other edible mollusks and mudworm "ibo" in great abundance. Will they ever sustain their present population? The obvious answer is "No", they will eventually decline and probably disappear within the next five years unless something is done.

Boat channels and reef passages

There are a number of boat channels being constructed through reef crests or around naturally existing ones across the Gilbert group, notably Makin, Marakei, Maiana, Kuria, Abemama, Nikunau, Tamana and Arorae. A similar project has also been carried out in another seven Pacific nations. In Tuvalu most islands have newly constructed boat channels and reef passages. Usually naturally existing channels are not accessible by larger boats, these have to be enlarged or made deeper. New channels were constructed where needed.

Biological and ecological aspects

Coral and other marine communities within the immediate surrounding areas are destroyed. The extent of the damage within some unknown radius has not been assessed. But evidence of the severity of the damage can be witnessed with the number of dead fish floating around the blasted area. Short term, long term and permanent effects are expected to follow. There is a great need to make assessments on the impact of these activities.

The current pattern within the lagoon and around an island may change. The presence of channels or wider and deeper channels may help improve the supply of fresh nutrients around the area but at the same time any change in current pattern may also alter present patterns of deposition and erosion to unconsolidated areas of reef as well as to the island itself.

Coral fragments may provide new surfaces for algal settlement. It has been found that coral damage and dredging may trigger the onset of ciguatera fish poisoning (Tebano, 1984b; Tebano and McCarthy, 1991). This type of poisoning was not known in Maiana till after a channel was constructed at the western side of the island. This was witnessed in early 1988. On the islands of Marakei and Nikunau where ciguatera fish poisoning is a daily tale, this got worse and even spread out to the neighbouring villages.

SUMMARY AND RECOMMENDATIONS

Atoll environments are fragile and deserve to be protected. The effect of causeway and bridge construction obstructs water flow and affect inshore currents which may lead to both biological and ecological damage. In a similar way, reef passages can also create problems which in most cases cannot be controlled.

The water needs to flow freely so that adequate mixing of oxygen-rich and oxygen-depleted waters can take place in order to sustain life in the marine environment. The water also needs to flow freely so that dirt and other waste products can be efficiently washed out from endangered areas thus reducing pollution and the spread of diseases.

The quality of water is very important to both marine and terrestrial organisms. Nutrients required for healthy growth and other processes are obtained from seawater. Most marine organisms spend part of their life cycle in the planktonic stage and therefore water quality can be the determining factor.

Fish migration and spawning seasons are part of a life cycle and can affect the size of a population if severely interfered with. The blockade of migratory paths which is obviously the result of causeway and bridge construction can contribute to dramatic reduction in population size and extinction.

The change in inshore wave and current patterns can be caused by both causeway/bridge and reef channel construction. Some animal species depend on these agents as their guide and means of transportation. Some fish species rely on current direction and flow which guide them to their spawning or feeding grounds. Some also rely on them for their return home after undergoing various developmental stages in the planktonic stage.

The physical nature of an atoll can be transformed within months by wave and current actions. Erosion and sand deposition are very obvious but the fate of numerous organisms that inhabit sandy beaches and rocky shores are often neglected or unheard of.

We are facing problems which have resulted from development projects thought to bring us good. Although there are benefits that we enjoy, the costs in terms of our marine food resources, in particular, will be very high. Some of the projects can be modified to minimise both biological and ecological damage. In this regard, careful planning should involve expertise in all areas that are involved.

Having experienced these difficulties, the Kiribati Government has taken positive steps to contain all environmental problems with particular emphasis on pre-assessment and post assessment of the effect of causeways and bridges (KOIDP, 1990). A team of environmental scientists and engineers has commenced studying the likely major problems that are involved in causeway construction.

The only causeway/bridge which has caused little damage to biological/ecological processes and physical land formation is Mamankaburara Causeway on the island of Abemama. A modern and expensive bridge between Tanaea and Buota villages in Tarawa is another structure which may also prove that such designs are probably the best for our islands. The costs of constructing them may be phenomenal but their impact on marine food sources and the environment will be very minimal.

It will never be too late to restructure the present causeways in light of the adverse impacts which have been felt. Multiple waterways through the solid structures and the dredging of sand-filled passages could tremendously revive the disappearing communities and ecosystems. This step may be very costly in monetary terms but the long term investment in our marine food sources and environment will offer enduring social, economic and cultural prosperity.

Public education is one of the means of getting the people to understand the need to protect our environment which is tied up with our marine resources on which we depend so much upon for our day-to-day living.

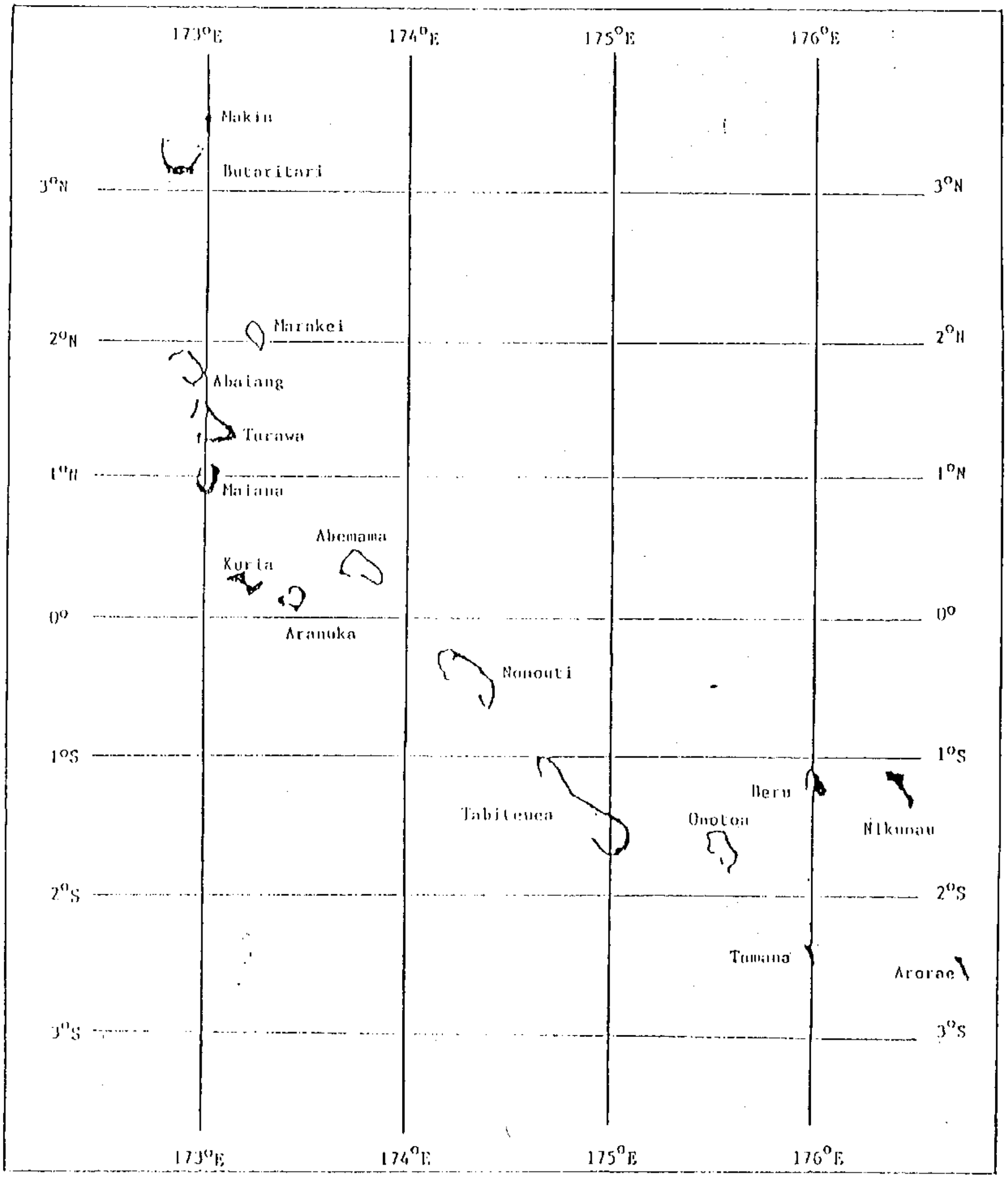

Figure 1. Map of the Gilbert Islands, Kiribati.

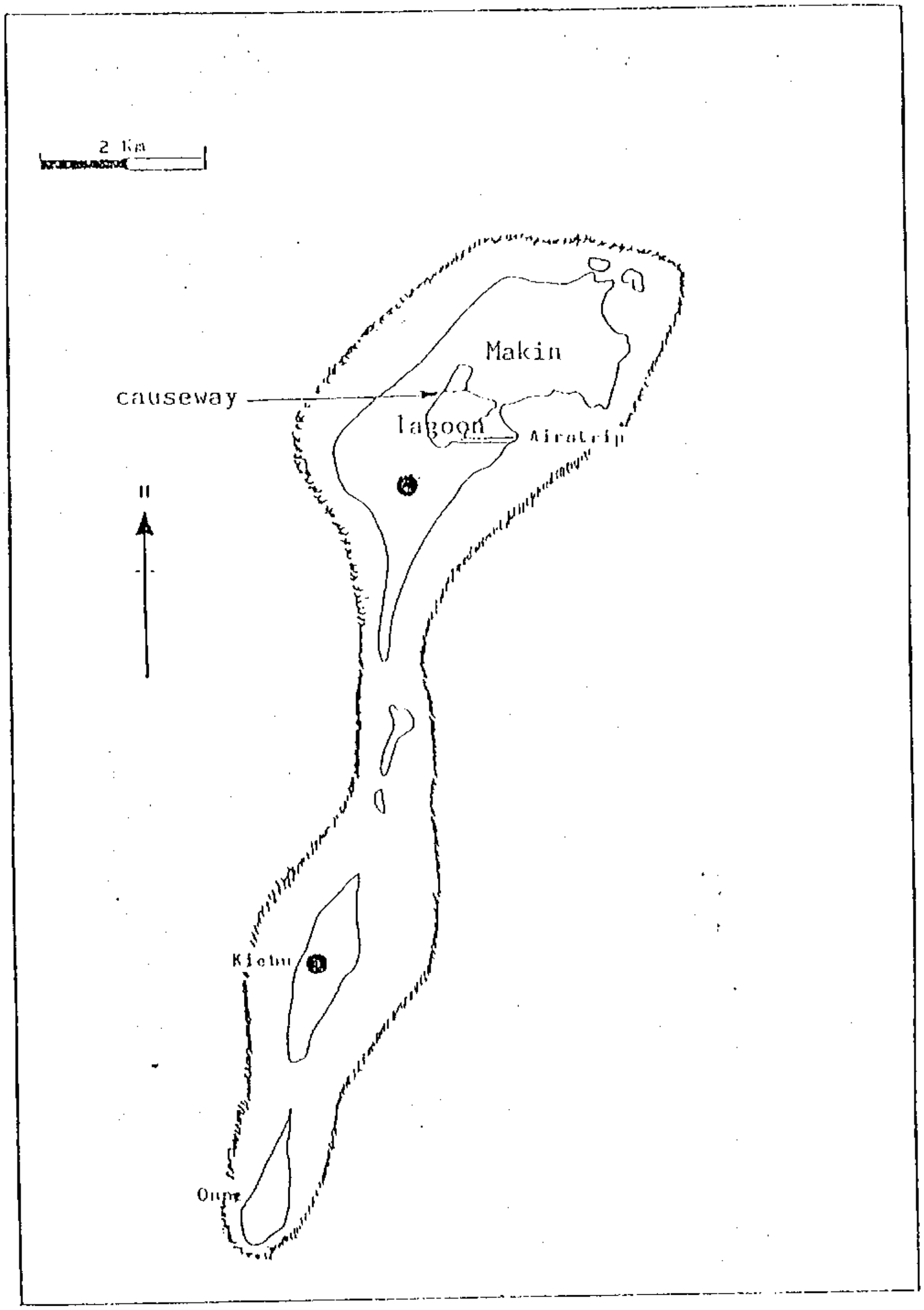

Figure 2. Map of Makin Island.

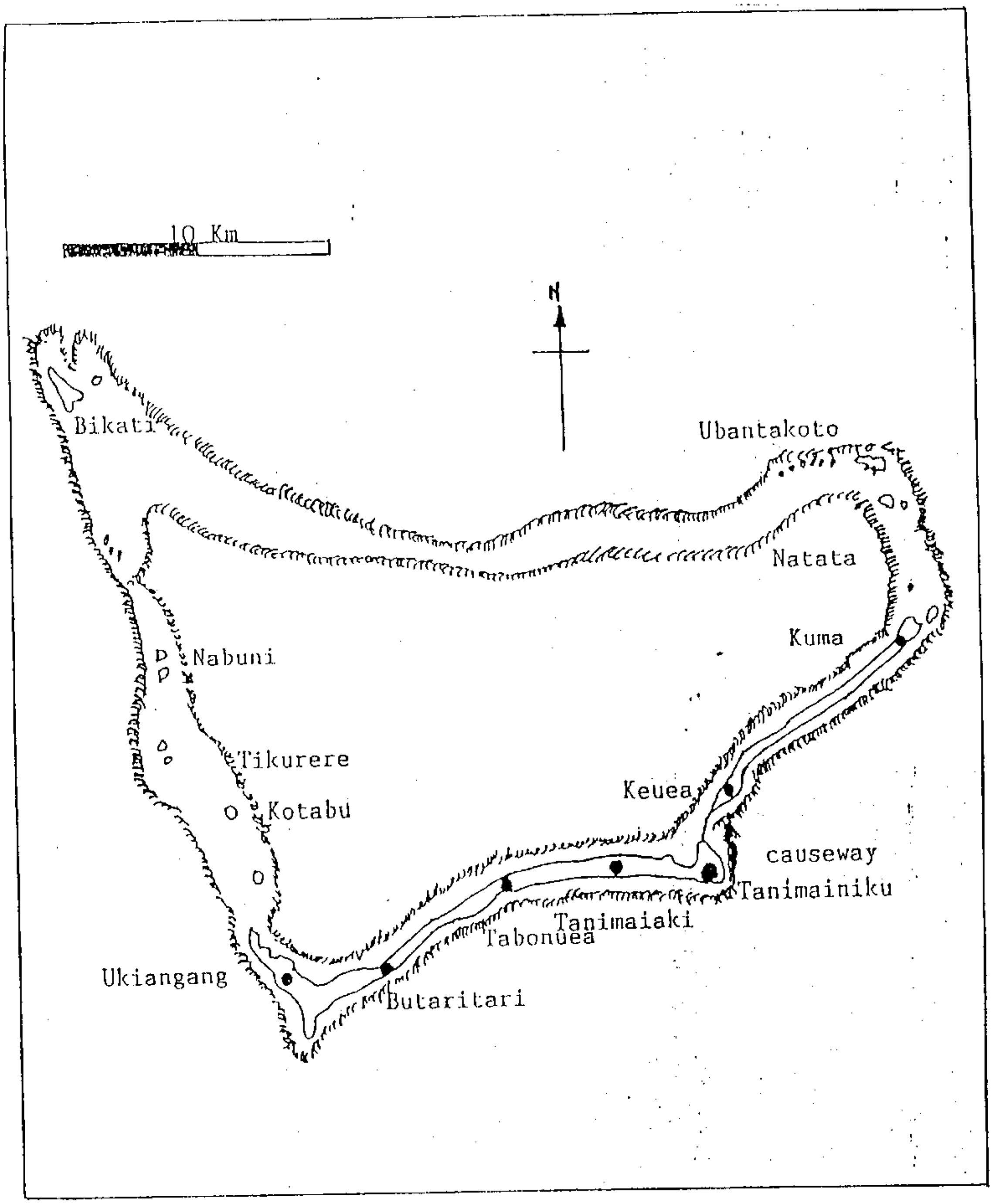

Figure 3. Map of Butaritari Island.

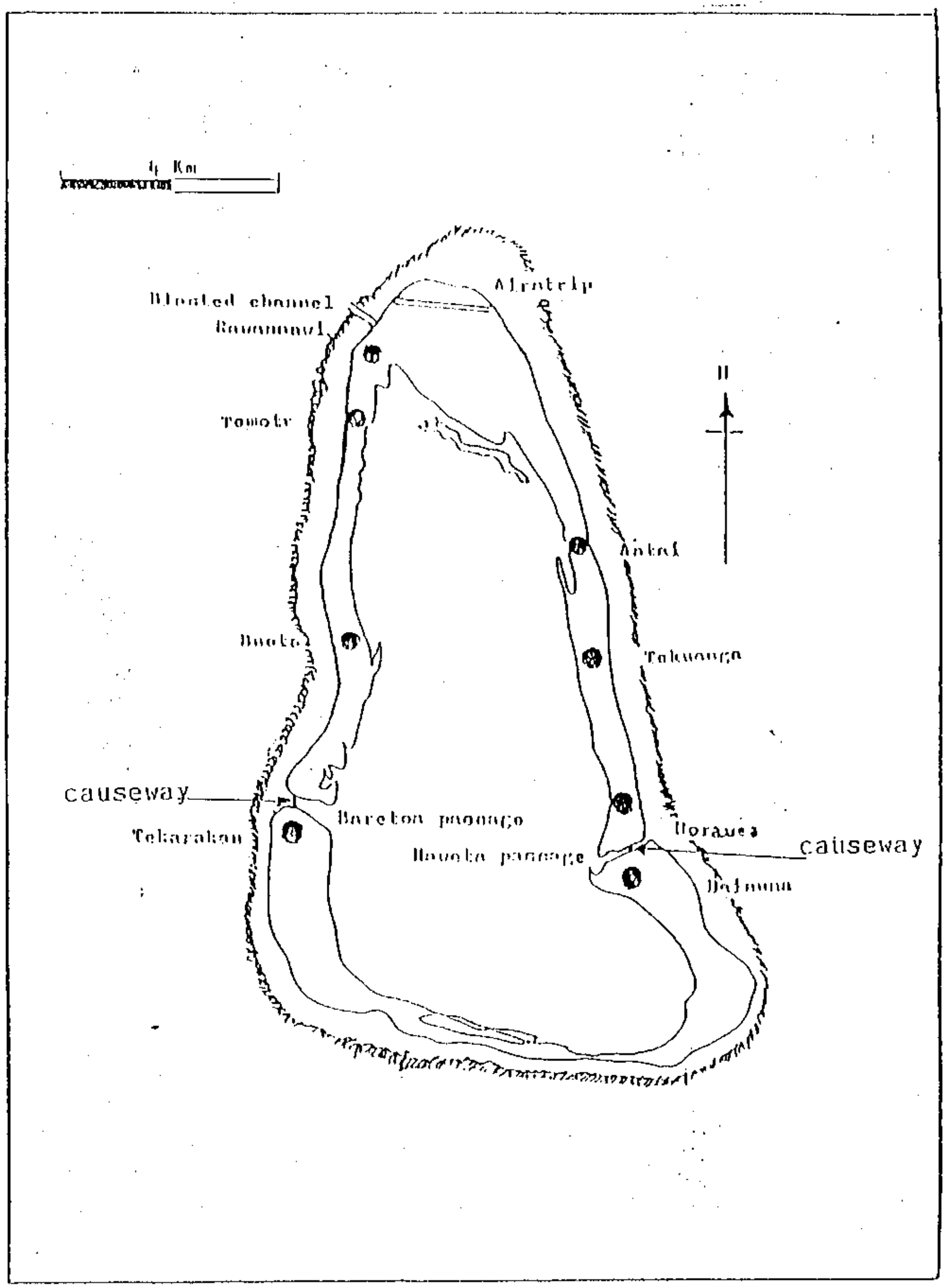

Figure 4. Map of Marakei Island.

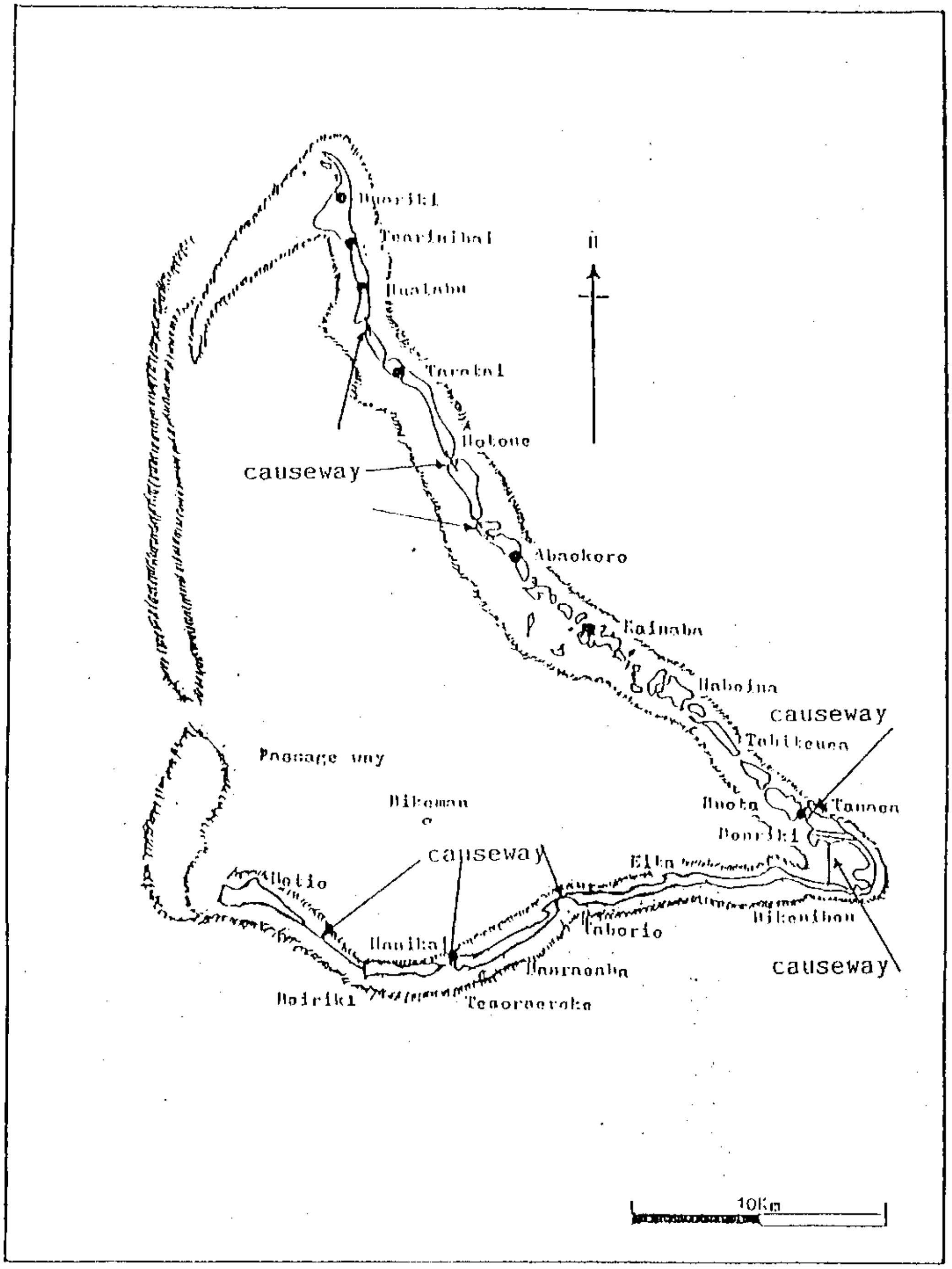

Figure 5. Map of Tarawa Island.

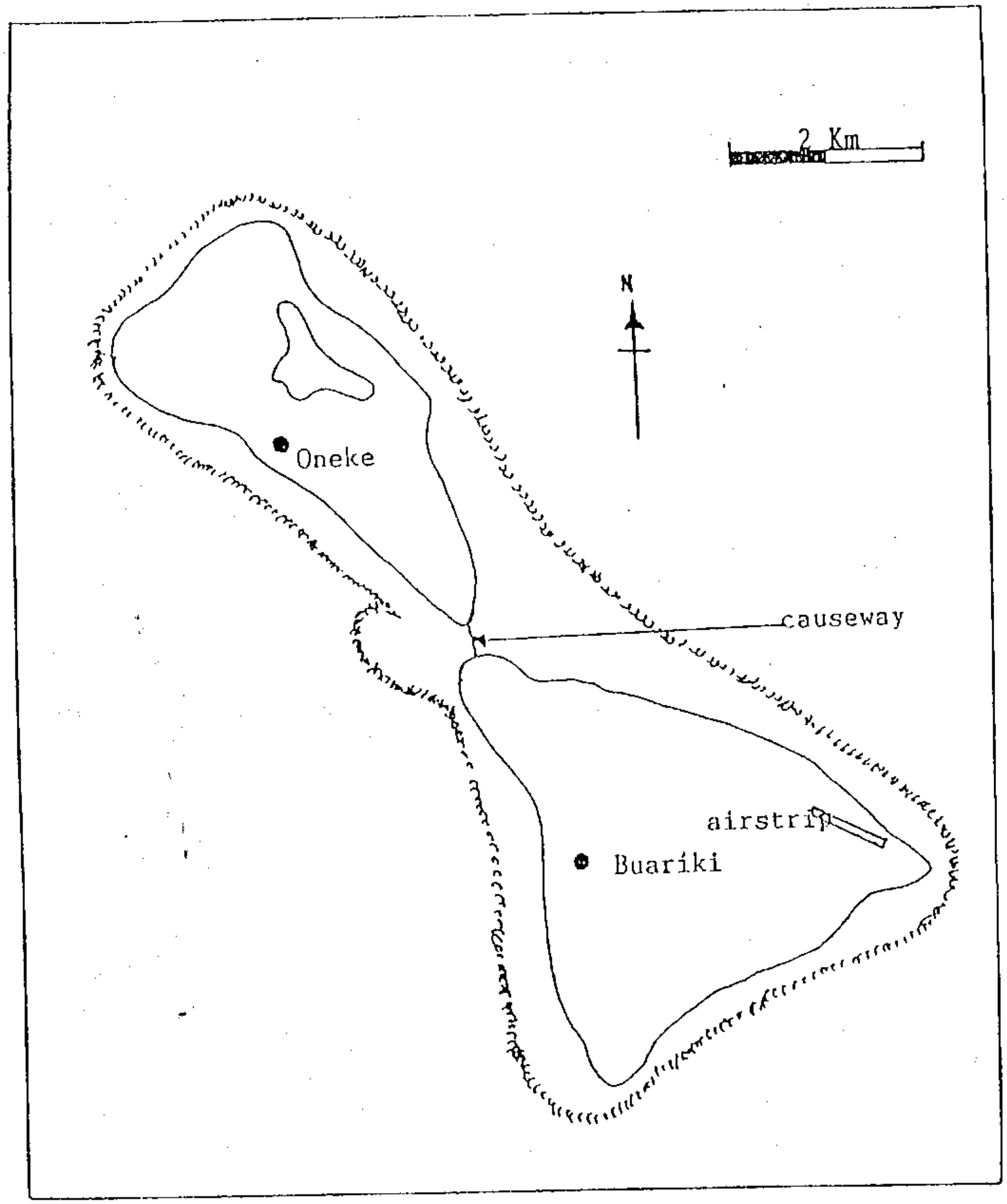

Figure 6. Map of Kuria Island.

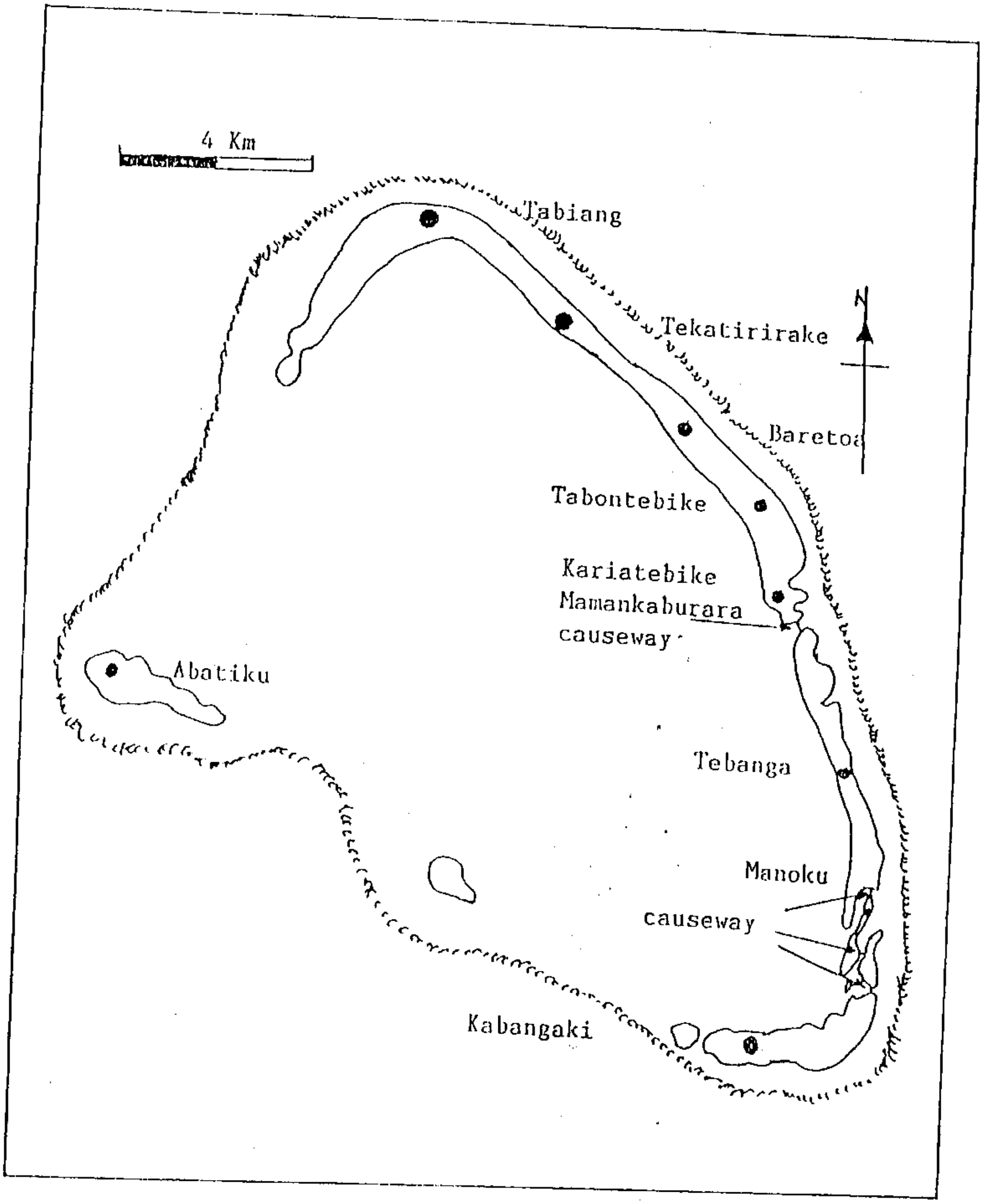

Figure 7. Map of Abemama Island.

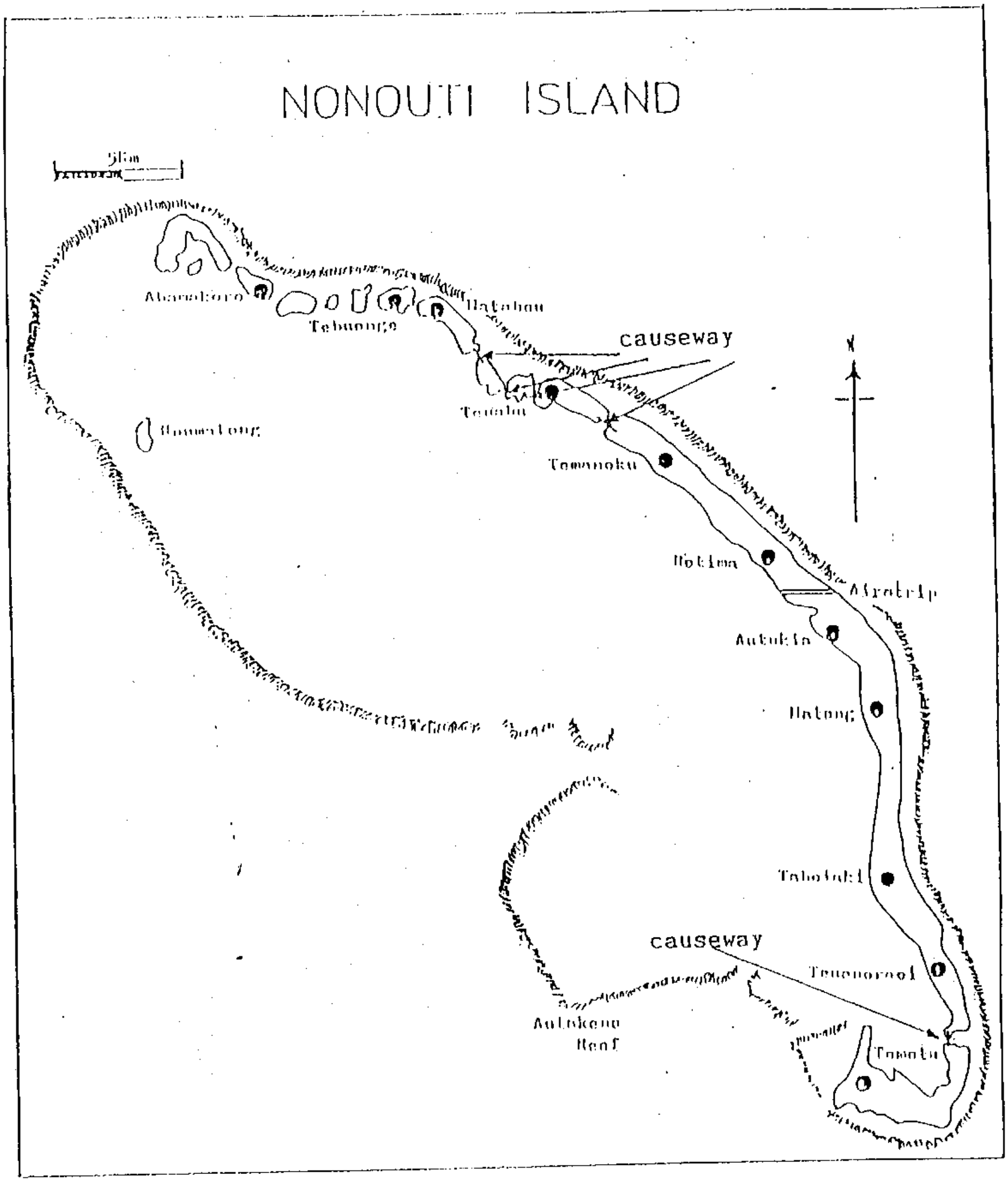

Figure 8. Map of Nonouti Island.

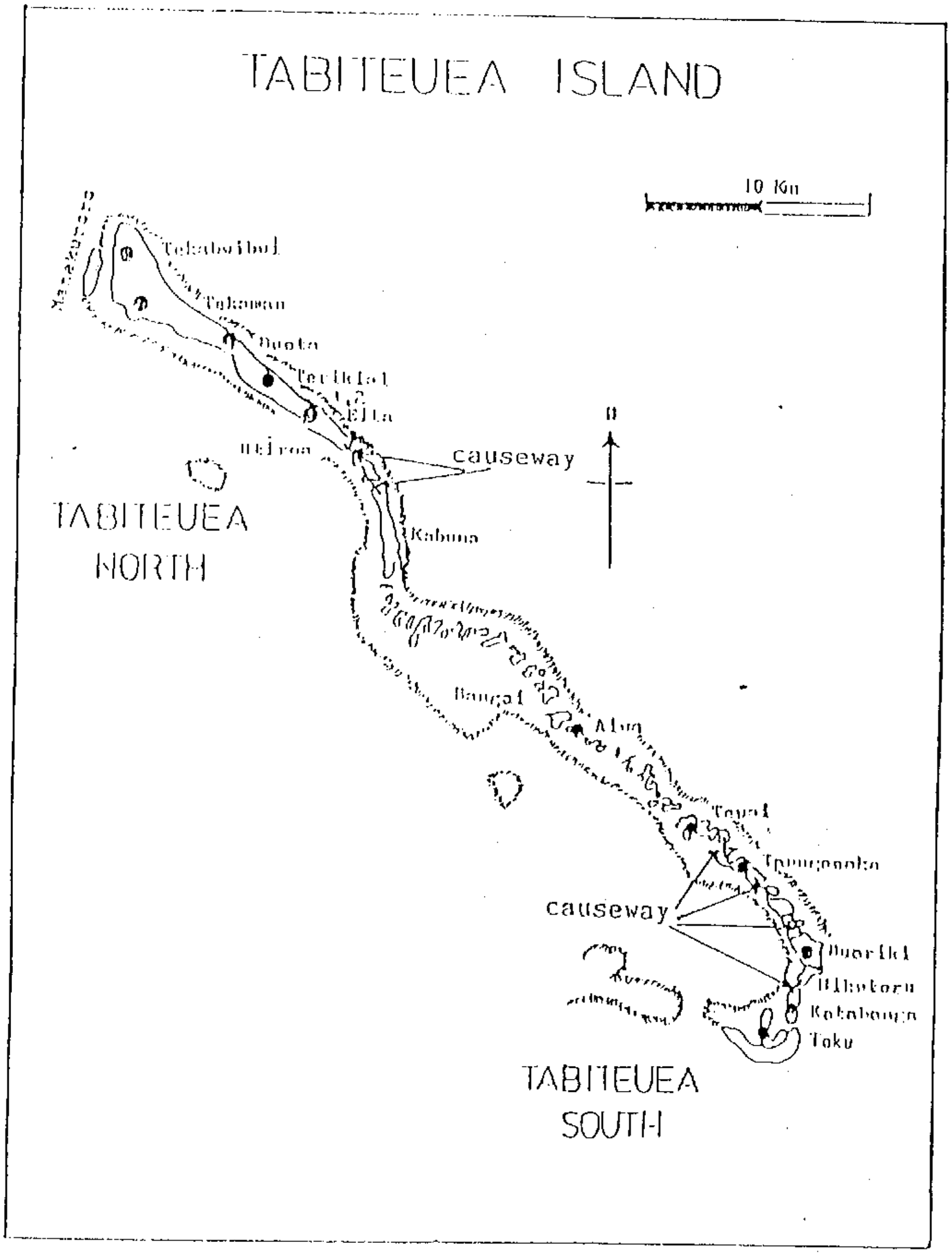

Figure 9. Map of Tabiteuea Island.

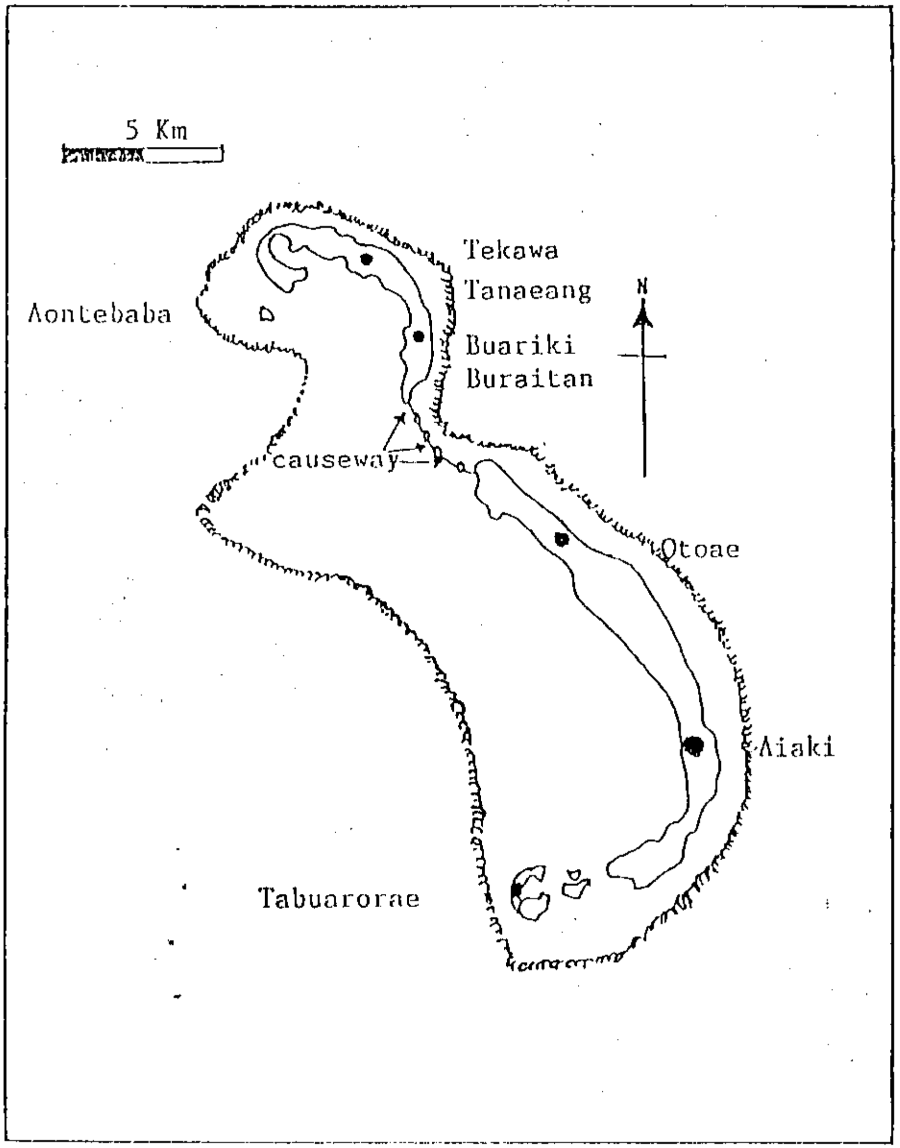

Figure 10. Map of Onotoa Island.

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