SOLOMON ISLANDS

FINAL REPORT

Natural hazards and risk assessment

in the

Solomon Islands

R J Blong

DARadford

July 1991

MACQUARIE UNIVERSITY

EXECUTIVE SUMMARY

This study of natural hazards and. risk assessment in the Solomon Islands began with a detailed investigation of a wide variety of literature from scientific journals, newsparers, and other published material. Information on the consequences of tropica cyclones, earthquakes, storms, floods, landslides, tsunami, volcanic eruptions and droughts, were collected together in a data base format. These data focused on human deaths and the effects of natural hazards on traditional houses but a wide variety of information was also collected on other health and social effects, and on the consequences for other buildings and structures, agriculture, the economy and the physical environment. Volumes 1 and 2 of this report reproduce all the information collected.

The extent of damage was assessed using the Solomon Islands Damage Scale developed specifically for this project. This scale converts typical qualitative descriptions of disaster consequences into a quantitative scale using simple rules. The scale is similar in concept to the Modified Mercalli Earthquake Intensity scale, developed more than 50 years ago, except that it describes damage to individual structures as proportions of building replacement cost. This refinement allows the ready addition of damage of various severities and produced by a variety of agents to arrive at a total estimate of damage expressed as the number of equivalent houses destroyed.

The Solomon Islands have been divided into 146 polygons in this study based largely on census wards. On the basis of census and other data estimates of the number of houses in each polygon can be made at the time that a natural hazard occurred, so that damage can be expressed as the destruction of a proportion of the total housing stock in the polygon. In this way, estimates of damage are made independent of population density or population changes with time.

These data have been presented in Volume 3 in both spreadsheet and graphical form. Maps indicate 5 damage levels. The scale on composite maps, assembled to indicate the consequences of a number of events or all hazards, are based on different damagelevels to those used on individual maps.

More than two hundred events are considered in the database. The data show that damage from tropical cyclones have produced more damage than earthquakes by a factor of five, and that other hazards have produced less damage than earthquakes. In terms of deaths, tropical cyclones have killed 155 and earthquakes 106 but the greatest death tolls have resulted from 19th century eruptions of Tinakula arid Savo volcanoes. Other hazards are of lesser significance.

, The areas of the Solomon Islands that have suffered the most damage, when all hazards are considered are Guadalcanal, Makira and Malaita. If the past is an adequate guide to future hazardousness, then these areas are also likely to bear the brunt of future hazards. Similarly, tropical cyclones, earthquakes and volcanic hazards are likely to be the most significant hazards in the future. Consideration of the record from just the 20th century seriously underestimates the importance of volcanic hazards, particularly in producing deaths.

Although numerous models of global warming have now been produced it is not yet possible to determine the likely effects on the meteorological hazards occurring in the Solomon Islands regiqn, However, it seems likely from evidence assembled elsewhere in the world, that rainfall intensities are likely to increase, possibly leading to more frequent flooding or higher flood stages. While tropical cyclones may increase in intensity as a consequence of a rise in sea surface temperature and result in increased wind forces on structures this is by no means certain. Part of the problem in determining the consequences of global warming for the Solomons region lies in the fact that no modelling has yet been undertaken to determine the effects of warming on EI Nitro, the global phenomena that, *inter alia*, determines much of the pattern of tropical cyclones, rainfall and drought in the region.

When magnitude and frequency curves of past damage are used for the 1900-1990 period the available data suggests that a once in 10 year cyclone would destroy the equivalent of 400-500 houses and an earthquake with the same return period the equivalent of about 60-70 houses. A once in a hundred year tropical cyclone could be expected to destroy the equivalent of about 7000 houses and an earthquake with the same recurrence interval 2000-5000 houses.

Although it has been traditional amongst many of those concerned with disasters and disaster mitigation to consider only those events which recur more frequently than once in a hundred years, it must be recognised that higher magnitude, lower frequency events do occur and that they are likely to contribute a very large proportion of the total damage averaged over a long period. Some support for this assertion is gained when it is recognised that 26% of total cyclone damage resulted from Cyclone Namu and 29% of all earthquake damage from the 1931 earthquake.

The available data suggest that future efforts should focus on the development of houses and other structures that have greater resistance to wind and seismic forces and on the enhancement of tropical cyclone warning systems. Unfortunately, the data on destruction of houses does not provide an adequate picture of the actual agents producing damage but data on human deaths reveals that alternative strategies for disaster reduction should be investigated.

For those fatalities caused by tropical cyclones where the specific agent of death is known, 67% died as a result of landslides. Similarly, 20% of those killed in earthquakes died as a result of landslides and the remaining 80% were killed by tsunami. These data suggest that landslides and tsunamis have been the main agents of death from natural hazards in the Solomons this century, and it is possible that landslides and tsunamis are also major agents in producing damage to houses and other structures. Further investigation is required to check these suggestions.

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INTRODUCTION

The initial application for this project - *Natural hazards and risk assessment in the Solomon Islands* - indicated 6 major objectives:

a) the provision of maps of the Solomon Islands to show the distribution and intensity of geologic hazards, for example:

   1 volcanic hazards
   2) earthquake hazards
   3) tsunami hazards, and
   4) landslide hazards

b) the provision of maps of the Solomon Islands to show the distnbution and intensity of meteorologic hazards, for example:

   1) tropical cyclones
   2) floods
   3) droughts, and .
   4) other severe weather.

c) an analysis of the severity (judged on a range of scales) of past natural disasters in the Solomons with respect to human health, buildings, disruption to services, subsistence and cash crops, and the environment.

d) the provision of a readily update able data base containing the information listed above.

e) a method of combining the above risk maps into a single natural hazard map of the Solomon Islands.

f) an assessment of future relative risks, quantified where possible, offered by each of the above hazards, taking into account global climatic warming where appropriate.

g) an outline of the most cost-effective methods of natural disaster reduction in the Solomons based on the above risk assessments.

Achievement of objectives

There can be little doubt that the above objectives were overly ambitious given budget and time constraints, the unexpected wealth of information available, and the need to develop new methodologies to achieve the stated objectives.

The unexpected wealth of information available provided the most important limitation to completion of the project on schedule.

Despite these difficulties, most of the major objectives of the project have been achieved. However, analysis of the severity of events has been limited to deaths and damage to traditional buildings because of the wealth of information and time available. The damage scales provide a valuable surrogate for most of the other attributes except perhaps non-traditional buildings which have a different geographical distribution, and a differing resistance to geophysical forces.

METHODOLOGY

Data collection

The major islands of the Solomon Islands are shown in Figures 1, 2 and 3. Data was collected using typical library and archival search techniques, including a computerised search of international databases. The personal library of Dr J.C. Grover, longtime resident and Chief Geologist of the Solomon Islands, the Mitchell LIbrary and the Australian Archives were also utilised. Natural disaster files maintained by the Natural Hazards Research Group at Macquarie University from the *Sydney Morning Herald* and *Pacific Islands Monthly* were also examined. Other valuable sources of information on natural hazards and their impacts included a range of international and Australian scientific books and journals, publications of the British Solomon Islands Geological Survey and the Solomon Island Meteorological Service, the *BSIP News Sheet*, the *British Solomon Islands Reports for the Year*, Solomon Islands newspapers and a variety of Church and Missionary magazines. Australian and Fijian meteorological reports, some Fijian newspapers and a range of anthropological reports about the Solomon Islands were also examined.

A full list of the sources used has been presented in Volume 2 of this report.

Hazards considered

The major natural hazards considered were tropical cyclones, other storms, floods, droughts, earthquakes, volcanic eruptions, tsunami (often erroneously called tidal waves) and landslides. Some information about other hazards of lesser importance in the Solomon Islands - cold weather and sulphur fields - was also collected.

Emphasis of the study

Valuable compilations exist already on the incidence of earthquakes, tsunami, volcanic eruptions and tropical cyclones in the Solomon Islands. While some of the physical characteristics of the hazards have been recorded in the present study, the emphasis here is on the *consequences* of the hazard impacts.

Investigation of the hazard consequences has focussed on human health, the built environment and agriculture. Human health considerations have concentrated on deaths with less attention being paid to morbidity.

These foci have been determined by purely pragmatic considerations; simply, there is more information readily available about these aspects than about effects such as psychological morbidity, disruption to services or environmental consequences. Nonetheless, where such information has been identified, data have been added to the database.

Collation of data

For some of the hazard events recorded in the database limited information about consequences is available from a number of sources. Rarely is the information from one source complete, though sources frequently complement one another. Conflict between such sources is not uncommon. In order to evaluate multiple sources and to assess the total damage at a number of locations from the one event it has proved necessary to compile the various accounts into one document.

While this compilation has been very time-consuming it is the only method that allows satisfactory analysis of disparate, conflicting and incomplete materials to produce a considered view of the severity of the hazard consequences.

The various documentary items have been compiled in the present study using the database software NOTEBOOK II. The program is also relatively cheap and simple to use - the addition of material from time to time would not prove difficult. This software has the advantage that it allows almost unlimited text to be assembled into a variety of fields in free format. While fields can be searched for key words and/or sorted, mathematical manipulations characteristic of most databases are not possible.

The following fields were used to categorise information on each hazard impact:

Hazard type

Year, Month, Day
District, Island, Nearest town
Latitude, Longitude

Associated hazards
Other areas affected

Cost estimate
Health effects
Social effects
Built environment
Agricultural effects
Shipping effects
Economic effects

Physical environment
Biosystemslheritage

Physical characteristics

Illustrations
Sources

Other fields were established to allow comments on the quality of the sources, possible reasons for conflict in the information etc. For any individual event many of these might be left blank as information was not available.

The fields listed above formed the organisational framework for the database and for the information presented in Volumes 1 and 2 of this report.

Damage assessment

The database in Volumes 1 and 2 contains both qualitative and quantitative information about deaths and damage in natural hazards. One of the major achievements of the present study has been to develop a methodology which allows translation of the qualitative information into quantitative terms, taking into account the descriptions of deaths and damage, the contexts provided by the sources and estimates of the population in the affected area.

Semiquantitative scales have been developed by other workers previously. For example, the Modified Mercalli Scale, (developed in 1931 and modified several times since for use in specific countries), provides an estimate of the extent of damage to structures as a result of earthquakes and associated hazards. Similar scales have been developed to describe the consequences of tornadoes (the Fujita scale) and landslides (the Alexander scale).

These consequence scales have two major problems from the viewpoint of the present study:

(i) each scale relates to the damage produced by only **one** type of natural hazard; and

(ii) arithmetic operations cannot be performed on scale values; that is, it is not possible to say that Modified Mercalli (MM) VIII is equal to two times MM IV.

These limitations prevent:

(i) comparison of the damage from one type of hazard with that from another; and

(ii) addition of the damage from a number of events.

The scale developed here attempts to overcome these limitations. While a general version of the scale has been developed the present concern is largely with damage to houses constructed of traditional materials.

The Solomon Islands Damage Scale (SIDS)

SIDS is based primarily on a 8 point scale, I to VIII. This notation is based on the Modified Mercalli scale but here the scale refers to the damage inflicted on an individual traditional house. Values range from no damage (I) to total damage (VIII).

After consideration of housing styles and the relative costs of rebuilding damaged portions of European style houses in Australia each of the damage states, I to VIII, was assigned a numerical value indicating the proportion of the cost of total house replacement that the damage represents. Table 1 indicates the relationship between damage state and the proportion of the replacement cost.

Table 1: Damage states and associated proportions of replacement cost.

Damage State	Proportion of Replacement cost
I	0.0
II	0.01
III	0.05
IV	0.1
V	0.3
VI	0.6
VII	0.9
VIII	1.0

Both of these values are shown at the tops of Columns L to S in the damage spreadsheets in Volume 3 of this report.

Identification of the proportion of the replacement cost information means that damage amount can be totalled and expressed in equivalents of complete houses. For example:

5 houses damaged to VI = 5 x 0.6 = 3.0 house equivalents
9 houses damaged to IV = 9 x 0.1 = 0.9 house equivalents

Total damage is equivalent to the destruction of 3.9 houses.

Clearly, using this methodology it is also possible to combine, for example, building damage resulting from earthquakes and cyclones.

In practice, the extent of damage to individual houses is often not known but must be judged from qualitative statements in the source materials.

Table 2 sets out the types of qualitative information that relate to specific damage states for a number of natural hazards.

Table 2: Damage states and qualititative descriptions

I

No damage

II

General

If there is no specific information available but it is reasonable to assume that there was negligible damage, damage scale II has been assigned.

Cyclones

Area flooded.
Area affected.

Allocated to inner part of an island when both coasts are described as having suffered damage.

Landslides

Landslides occurred. [These may be on the hillslopes away from villages but there are usually houses close to gardens which are used during the gardening season].

Earthquakes

Small fissures in ground. [Where fissures are mentioned but there is no mention of their size or of the damage incurred].
Slight tectonic tremor.
Earthquake felt.

Tsunami

Minor tsunami which reaches up to 1 metre above high tide and does not go far inland; say 10 metres, affecting only those buildings very close to the shore.

III

No specific information available but it is reasonable to assume that some degree of light damage has occurred.

Tsunami

Tsunami which reaches about 2 metres above high tide in flat areas, or up to 100 metres inland.

Cyclones

Gardens buried in landslides. [Same reason as in II].
Gardens flooded.
Gardens destroyed.

These assume that some mud or debris from floods or landslides may have reached houses. Ships grounded. [Indicates there would be 'high seas' at the coast and therefore probably minor damage to coastal houses from storm surge]

Fallen trees on jungle paths. [Indicates high winds and/or landslides so there would be some damage to houses either from the fallen trees or other debris].
River flooded.
Airfield damaged.

Large amounts of rain in a short time. [e.g. 22 inches in 44 hours].
Serious damage to plantation trees.
Damage to overhead wires.

Earthquakes

House given a severe shaking.
Non-traditional houses 'damaged'.

Fissures so close to houses that people had to evacuate their homes.

IV

Cyclones

Houses damaged.
Houses badly hit.

Bridges damaged. [The bridges are usually damaged from trees and other debris carried by flooded rivers so any houses would also be damaged].

Houses next to an area where houses have been destroyed and this area is within the limits of gale force winds.

Villages flooded.

Earthquakes

Non-traditional buildings destroyed. An earthquake strong enough to destroy such buildings indicates that some damage would probably occur to trditional buildings.

Trees crashed down.

Land submerged up to about 3 metres.

Land emerged up to about 3 metres.

V

General

Considerable damage.

Cyclones

No mention of damage to houses but people have to be rescued or evacuated indicating some degree of damage.

Damage was bad.

Remaining percentage of houses not mentioned as having been damaged but the amount of houses assigned VII indicates that other damage would have occurred.

Tsunami

Tsunami which rises between 3 and 5 metres.
Tsunami which floods 'all the lowlands'.

Earthquakes

Considerable damage.

VI

Disaster struck.

Damaged houses when some described as some destroyed and some damaged.

Severe damage.

Badly damaged.

Cyclones

Remaining percentage of houses not mentioned as having been damaged, but the amount of houses assigned VIII indicates that other damage would have occurred.

Used if other information indicates that traditional houses may have been badly damaged. For example, Utupia, 1935 cyclone. "The cyclone practically stripped the island of Utupia of all vegetation". It is assumed that such a storm would have damaged most houses.

Damage from storm surge.

Floods

Heavy floods.

Earthquakes

Remaining percentage of houses not mentioned as having been damaged, but the number of houses assigned VIII indicates that other damage would have occurred.

Houses leaning at crazy angles.

VII

Cyclones

Traditional buildings ruined.

People homeless due to floods.

If European houses destroyed by floods or high wind then traditional houses assumed to have been destroyed.

Houses flattened.

Earthquakes

Houses knocked down.
Houses collapsed.

Tsunami

People drowned by the tsunami.

VIII

General

Houses wrecked.
Houses wiped out.
Houses totally blown down.
People made homeless.
Traditional huts destroyed.
Village razed.
Declaration of a disaster area.
Houses demolished.
Houses destroyed.

Tsunami and *Flood*

Houses swept away.

....

After a damage state, ranging from I to VIII has been assigned to an area from interpretation of the available qualitative information, it is still necessary, in most cases, to estimate the proportion of houses in the area that have been affected. Where better information is unavailable, it has been assumed that 25%, 50%, 75% or 100% of the houses in the area have been damaged.

The sorts of qualitative information listed in Table 3 were used to assign the values indicating the proportion of damage.

Table 3: Qualitative descriptions of the proportion or extent of damage in a defined area

....

25%

General

Very little damage.
People rescued.
Some places.
Many gardens flooded. (Some houses are in the same area and at the same height as the gardens). Buildings demolished.
Plantation damaged.
Plains flooded.
Damage not extensive.

Half houses in some areas.
Damage to one village in an area.
Several houses.

Damage to traditional houses not mentioned but damage assumed from other information.

Earthquakes

In those areas where 50% of the houses are destroyed then 25% of the remaining number are considered to have been damaged.

Fissures in ground through village where no damage mentioned.

Widespread damage.

Damage to traditional houses not mentioned but other buildings badly damaged or destroyed. Homes collapsed.

Slight tectonic tremor.

50%

General

Island half flattened.
Many houses.

If a number or percentage is described as damaged and/or destroyed then 50% is assigned to damaged and 50% to destroyed.

Several villages.

Severe damge.

A lot of damage.

Villages suffered badly.

Considerable damage.

Percentage of the remaining number of houses which have not been destroyed in a VIII event and where only the number/percentage of destroyed houses has been given.

Cyclone and Tsunami

Coastal villages. Used in those areas where most people do live on the coast. ego Weather coast of Guadalcanal, Savo.

75%

General

Most areas/houses affected.
Almost completely.
All gardens destroyed.
Extensive damage.
Nearly all.
Disaster struck.
Declaration of disaster area.

100%

General

All
Total
Whole area devastated.

Tsunami

Tsunami of sufficient size (eg, swept one mile inland) in a narrow coastal belt.

....

One of these four values can then be combined with the damage state to provide a shorthand description of the degree and extent of damage to houses in a specific area. These 28 shorthand values, originally used to place damage estimates in Column F of the spreadsheet are shown in Table 4. Assigning damage scales in this way maximises the consistency of interpretation of the damage recorded from any event, thus allowing the comparison of damage sustained from different types of hazards.

In summary, three types of information have been used in developing the Solomon Islands Damage Scale:

(1) Specific information is used when available; this includes the degree of damage to houses and the number or percent of houses damaged or destroyed.

(2) Descriptive information where specific information about the number of houses damaged or destroyed, the size of the area affected, or the degree of damage is generally not available, therefore use has been made of the descriptive information in the database. It is the phrases and sentences which describe damage to traditional buildings which forms the main body of the Solomon Islands Damage Scale.

(3) Non-traditional building damage information; knowledge of the damage to traditional buildings has been extended by referring to the damage which has occurred to engineered buildings and/or the environment.

In most instances, traditional buildings do not withstand damage as well as engineered buildings. For example, damage to or destruction of, a building such as western style houses, copra dryers, rice silos, wharves and bridges in a storm surge, tsunami, high wind or flood, suggests that traditional buildings would also have been damaged or destroyed. This may not be the case during ground shaking. The destruction of gardens in landslides or in floods, uprooted trees along paths or damage to plantations are further indicators that damage would have occurred to traditional houses.

Table 4: Shorthand estimates of damage states and extents for defined areas.

[A]	No location information, therefore no damage scale has been entered.
[B]	Specific information available. For example, the number or percent of houses destroyed. This may relate to particular polygons or an island or number or percent of people affected.
C]	25% at Damage State II
D]	50% at Damage State II
E]	75% at Damage State II
[F]	100% at Damage State II
[G]	25% at Damage State III
[H]	50% at Damage State III
[I]	75% at Damage State III
[J]	100% at Damage State III
[K]	25 % at Damage State IV
[L]	50% at Damage State IV
[M]	75% at Damage State IV
[N]	100% at Damage State IV
[0]	25% at Damage State V
[P]	50% at Damage State V
[Q]	75% at Damage State V
[R]	100% at Damage State V
[S]	25% at Damage State VI
[Tl	50% at Damage State VI
[U]	75% at Damage State VI
[V]	100% at Damage State VI
[W]	25% at Damage State VII
[X]	50% at Damage State VII
[Y]	75% at Damage State VII
[Z]	100% at Damage State VII
[AA]	25% at Damage State VIII
[BB]	50% at Damage State VIII
fCC]	75% at Damage State VIII
[DD]	100% at Damage State VIII

Population and household data

In most cases, in order to estimate the number of houses damaged, it was necessary to know the number of houses in an area or village.

Three types of information have been used:

(1) The number of households in an area

(2) For years other than a census year which contains the number of households, that number is increased or decreased by the percentage appropriate for that year. Table 5 sets out the average growth rates.

For the years 1923-1981, 1976 census information is used or earlier information where that is available and considered to be reasonably accurate.

For the years 1982-1990, 1986 census data are used. In the 1986 census there are growth rates for smaller areas which correspond with the polygons. These have been used when appropriate.

(3) Where no information is available about a village other than 'the village', 'some houses' or 'several houses' it is assumed that 10 houses are present.

Table 5: Average population growth rates and household sizes

Year	Average growth rate %	Average size of household
1931-59	1.0	
1959-70	2.6	
1970		5.1
1970-7	3.4	5.7
1976-86	3.5	6.4

Prior to 1970, census information for the Solomon Islands is incomplete. Table 1C in the 1970 census lists population data from 1917 to 1945 for selected areas from a variety of sources. A brief, partial census was carried out in some districts in 1931 but the information was gathered over a period of months and is not considered accurate. The population numbers for Choiseul are based on figures supplied by missionaries and on thejudgement of government officials [1970 Census p.2]. A sample census was carried out in 1959 which is considered accurate for the areas in the census.

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Complete censuses were held in the years 1970, 1976 and 1986; therefore, accurate household and population numbers are available for those years. The 1970 household or population numbers for the wards that have been used as polygons are not available so the population numbers are generally based on the 1976 census figures.

The term 'household' does not equate with the number of houses. It refers to all people who are considered part of a family unit who eat together but may not sleep m the same house [1976 census]. This indicates that there are more houses than households.

In the 1970 Census the mean size of settlements including labour-lines, missionary stations, boarding schools etc is 41 persons. The average size of a household = 5.1 people. The average size of a family unit = 4.6 people [p.20, 28].

As indicated in Table 5, between 1931 and 1959 the rate of growth was almost 1 percent per year. The annual growth rate 1959-1970 = 2.6% (1986 census).

Between 1970 and 1976 the population grew at a rate of 3.4% per year. Between 1976 and 1986 the growth rate was 3.5%.

The growth rate in Honiara and North Guadalcanal has been twice the national average, that is, 7% from 1976-1988. The annual growth rate 1976-1986 varies in different provinces and the average household size has increased from 5.7 in 1976, to 6.4 persons in 1986.

The numbers of houses in specific areas in the years that natural hazards occurred are given in Column C of the spreadsheets.

Mapping of data

For the purpose of mapping the damage, the Solomon Islands have been divided into 146 polygons which generally correspond with the wards as used in the 1976 census. Four polygons consist of divided wards and 11 polygons consist of combined wards. These variations produced polygons of a 'reasonable' size.

This method was adopted as reasonably accurate population numbers were required to estimate the percentage of houses damaged, destroyed or at risk from any event.

The distribution of the polygons and polygon numbers are shown on Figures 4 to 7. Polygon numbers are used in Column D of the Spreadsheets.

The Solomon Islands Damage Scale (SIDS) has been used to assign damage scales to each polygon which has suffered damage.

In the case where the track of a cyclone passed over a polygon, but no damage information was available, the lowest damage scale has been used to indicate that the area was affected by the cyclone.

Specific polygon areas may not be mentioned in the data but, for example, 'threequarters of the island affected' is described; in such cases the appropriate numbers of houses damaged or destroyed within the island are estimated.

As noted earlier, all the qualitative data has been presented in Volumes 1 and 2 using the NOTEBOOK II database format.

These data have then been 'quantified' using the methodology outlined above and entered into a QUATTRO PRO spreadsheet. The relevant portions of this spreadsheet for each natural hazard have been presented in Volume 3. A complete explanation of the spreadsheet columns is also contained in this volume.

The spreadsheet data have then been used to map the damage for each natural hazard impact where mappable data has been produced. The spreadsheet data has been exported to a Geographical Information Systems package called IDRISI, a grid-based geographical analysis system, specifically selected for this project as it is available for only a few hundred dollars from Clark University, Massachusetts, USA.

Information from the spreadsheet is then assigned to the relevant polygons where damage occurred and produced as a damage map after the screen image has been further massaged through DELUXEPAINT II which allows the appropriate scales to be included on the map. Maps have been produced as either grey scales or in colour.

Each map includes a damage index. This is limited to 5 categories as this seems to be the maximum number of grey scales that can be read easily. Two different scales have been used.

For individual damage maps, those illustrating damage from just one event, the following scale applies:

Damage Index	**Value**
5	< 100%
4	< 70%
3	< 30%
2	< 8%
1	< 0.3%
No damage	0.0%

This scale can be read in the following way; for example, a polygon with a Damage Index of 3 indicates that the equivalent number of houses destroyed in that polygon was equal to between 8 and 30% of the estimated total number of houses in the polygon at the time that the natural hazard struck.

The damage scale for composite maps, where the consequences of more than one event is being considered, is set out below.

Damage Index	**Value**
5	< 1000%
4	< 200%
3	< 100%
2	< 60%
1	< 10%
No damage	0%

This damage Index should be read in the following way; for example, a polygon with a Damage Index of 4 indicates that between 100 and 200% of the houses in the polygon were destroyed by the events considered. Event A may have destroyed the equivalent of 70% of the houses, Event B, 40% and Event C, 60% to give a total destruction of 170% of the housing stock in the polygon. Most of the damage maps in this Volume should be read in this way.

All the maps produced have been included together with the appropriate spreadsheet portions in Volume 3.

SUMMARY OF RESULTS

The purpose of the present summary is to highlight the major results of this survey of natural hazards in the Solomon Islands. Substantive details, on which the summary is based, are presented in the form of spreadsheets and maps in Volume 3 of this report.

Tropical cyclones

The tropical cyclone season in the Solomon Islands is generally considered to extend from November to April. However, Cyclone Namu occurred in mid-May, 1986 and Cyclone Ida in late May - early June, 1972.

The database in Volume 1 contains records of 45 tropical cyclones in the Solomon Islands area. The first of these was recorded in 1568, the second in 1788, and a total of only 8 cyclones are known to have occurred before 1900. Only 7 cyclones were reported in the first 50 years of this century. Until the late 1940s the annual reports stated that cyclones did not occur in the Solomons; it was thought that the islands were situated too close to the equator. The cyclones of 1951 and 1952 changed that belief.

Eighteen cyclones (39% of the total) were recorded in the period 1950-1969. Thirteen cyclones, 28% of the total, have been reported since 1970. At least 21 of the cyclones since 1950 have been damaging.

While the record is clearly very incomplete before 1900, and almost certainly incomplete until about 1950, it is not until the early 1950s that tropical cyclones are known to have caused considerable damage in the Solomon Islands. In 1951-1952 three cyclones occurred within weeks of each other. Two of these affected Tikopia which was also hit by a cyclone in 1953. Major damaging cyclones also occurred in 1966, 1967 (2 cyclones), 1979, and 1986. Cyclone Namu was the most damaging of these (Figure 8) but 24 of the 38 tropical cyclones recorded this century have produced damage in the Solomon Islands. For the total record extending back to 1568, 30 of the 45 cyclones produced damage. Although the tropical cyclones that produce no damage are almost certainly under-represented in the database, it seems likely that more than 60% of the cyclones which cross the Solomons produce at least some damage.

Figures 9-11 indicate the distribution of cyclone damage for all tropical cyclones for which mappable information exists. Damage is most severe on Guadalcanal, Malaita and San Cristobal. Santa Isabel and Choiseul have been less affected. The

New Georgia group of islands has been relatively little affected, at least so far. In general, it is the more southerly islands that have been more severely affected. The Santa Cruz Islands (Temotu Province) have suffered little damage except for the more southerly islands. Tikopia was badly damaged in a series of tropical cyclones in the early 1950s.

A colour composite of cyclone damage for the western Islands, 1900-1988 is presented in Figure 12. This map confirms the longer record shown on Figure 9 because both records are dominated by the influence of Cyclone Namu. Of the total 25,000 traditional houses destroyed by cyclones in the total period of record, about 6,000 (26%) were destroyed by Cyclone Namu; that is, one cyclone out of 30 damaging cyclones, produced one quarter of the total damage.

Cyclone damage is also summarised in Figure 13 as a histogram of the equivalent number of houses destroyed per tropical cyclone. For example, 4 tropical cyclones have destroyed between 30 and 100 traditional house equivalents. The diagram shows that small amounts of damage are most common, but that a surprisingly large number of events (15) have produced damage to more than 100 houses.

However, a smaller proportion of tropical cyclones in the region are known to have produced fatalities. This century only 10 cyclones (less than 25%) have resulted in fatalities. This record is likely to be a gross underestimate, but for most tropical cyclones the death tolls have been remarkably low.

The total death toll from all known tropical cyclones is 155, with 135 of these deaths occurring this century (Figures 14 and 15). Table 6 indicates the times and locations of known deaths. Cyclone Namu produced 111 of these deaths. While the death toll in this cyclone is sometimes reported as as much as 150 we have been able to positively identify only 111 fatalities. Thus, all other cyclones this century are only known to have killed 24 people. Again, this is likely to be a gross underestimate, but it is safe to conclude that most cyclones kill relatively few people. Figures 14 and 15 illustrate the relatively small number of deaths from tropical cyclones and the dominance of Cyclone Namu. Figures 16 and 17 indicate that virtually all the tropical cyclone related deaths have occurred on Guadalcanal.

While the popular perception is that most cyclone-related deaths result from collapse of structures in strong winds or from drowning as storm surges sweep inland, this has not been the experience in the Solomon Islands to date. Of the total of 155 deaths in the entire record, information about the method of death is available for 93 people. Of this total 61 have died as a result of landslides and 25 have died when boats have capsized or been lost at sea. Five more have drowned in rivers and two have been killed by falling trees.

Although this summary considers only direct damage and deaths resulting directly from tropical cyclones it is important to recognise that cyclones may produce a number of longer term consequences. This is implicit, for example, in the recognition that landslides are responsible for a significant proportion of deaths. Such events also destroy a number of food gardens; these gardens cannot be made again at the same sites for a generation or more as the topsoil has been stripped from the slopes. Similarly, on atolls and along coastal margins salt spray driven by cyclonic winds destroys the gardens (and crops) and it may take months for the gardens to recover. In both cases, tropical cyclones may lead to famine produced by the loss of both food crops and cash crops and to the migration of communities, or at least those of working age, to less-affected areas or to places offering labouring opportunities. Overturning of trees and the formation of new poorly-drained depressions in the landsurface increase the opportunities for the breeding of

SPREADSHEET FOR ALL CYCLONE DEATHS

HAZARD PRIMARY	HAZARD ASSOCIATED	LOCATION NO	LOCATION NAME	ISLAND	YEAR	MONTH	DAY	NO.DEATHS	REGIONAL TOTAL	COLOUR	FLAG
C	TR	49	WRE	REN	1979	FEB	17	1	1	3	1
C	TR	60	SNG	FLO	1972	MAY	30	1	1	3	1
C	S	72	LON	GUA	1972	MAY	30	3	3	3	1
C		73	KOK	GUA	1986	MAY	16	12	12	3	1
C		74	AOL	GUA	1986	MAY	16	1	1	5	1
C		75	PAP	GUA	1986	MAY	16	11	11	3	1
C		77	VUL	GUA	1986	MAY	16	12	12	5	1
C	R	78	WTA	GUA	1966	NOV	14	1	1	5	1
C	L	79	MAL	GUA	1986	MAY	16	61	61	3	1
C	S	80	HON	GUA	1972	JAN	11	1	1	12	1
C	R	82	AIM	MAL	1970	APR		2	2	3	1
C		87	FOO	MAL	1966	NOV	14	2	2	3	1
C		94	EIE	MAL	1986	MAY	16	3	3	3	1
C		95	ARE	MAL	1986	MAY	16	3	3	3	1
C		100	TAI	MAL	1986	MAY	16	1	1	3	1
C		101	KWA	MAL	1986	MAY	16	4	4	3	1
C		110	ARS	MAK	1986	MAY	16	1	1	3	1
C	R	113	ARO	MAK	1979	FEB	17	1	1	3	1
C	R	114	BAW	MAK	1979	FEB	17	1	1	3	1
C	S	115	BAC	MAK	1972	MAY	30	1	1	3	1
C	TR	122	CAT	MAK	1971	DEC	6	6	6	3	1
C		127	REE	TEM	1937	JAN		5	5	3	1
C		130	NEO	TEM	1986	MAY	16	2	2	3	1
C		137	UTU	TEM	1937	JAN		1	1	3	1
C	0	138	VAN	TEM	1788			20	20	5	1

mosquitoes and the spread of malaria, especially if control programs have been . interrupted in the aftermath of the cyclone.

Earthquakes

Seismic activity in the Solomon Islands is generally due to the underthrusting of the Solomon Sea Plate beneath the north western islands of the Solomons, but the tectonic system is complex and the distribution and intensity of earthquakes is varied. From Bougainville to Makira the tectonic trench is well developed and seismicity is high along the southern side of the island arc. Between Makira and the Santa Cruz Islands the area is of lower seismicity.

Earthquakes result in various types of damage. Direct damage results from ground shaking, ground subsidence and liquefaction, while secondary damage results from landslides on steeper slopes and by tsunami along coastlines. Subsequent damage may also be produced by damming of rivers by landslides and salt inundation where tsunami have swept inland, or where subsidence has occurred.

Earthquakes included in the database (Volume 1) are almost entirely confined to the 20th century with 60 of the 63 events recorded since 1900. In contrast to the record for tropical cyclones and volcanic activity where knowledge of events extends over several centuries, the earliest reported earthquake occurred in about 1870.

Exactly half of the earthquakes this century have produced damage about which we have found information. Undoubtedly, the most damaging of these was the October 3 1931 earthquake which reached 8.1 on the Richter scale with aftershocks on the 3rd and the 10th of October with Richter magnitudes of 7.0, 7.3, and 7.7. Most damage occurred on Makira, Malaita, Santa Isabel and Florida islands (Figure 18). Other major damaging earthquakes occurred in 1926 (Guada1canal and Savo), 1939 (Isabel, Central and Guada1canal Provinces), 1959 (Western Province), and 1977 (Guada1canal- see Figure 19). Numerous other earthquakes in the Solomon Islands have had Richter magnitudes greater than 7.0, but those listed above have produced the most serious or widespread damage.

Figure 20 indicates the distribution of damage from earthquakes in the Western Solomon Islands this century. The most damaged areas occur on Guada1canal and the eastern end of Makira. Notably, the western ends of both islands have experienced less damage, at least in this century. Cumulative damage from all earthquakes is portrayed in Figures 21 and 22. Not surprisingly, given the limited knowledge of earthquakes prior to 1900, the distribution of damage for the Western Solomons is similar to that shown on Figure 20. In fact, of the total 5500 house equivalents known to have been destroyed by earthquakes, $>$ 1600 (29%) were destroyed in the 1931 earthquake. However, the 1977 earthquake destroyed almost as many houses.

Figure 23 indicates that most historic earthquakes have produced damage to between 0.3 and 30 houses. Nonetheless, 10 earthquakes have produced damage to more than 30 (and up to 3000) equivalent houses.

Surprisingly, given the frequency of earthquakes with magnitudes of more than 7.0, only 4 earthquakes this century have produced fatalities (Figure 24, Table 7). Even more surprisingly, the total known death toll is only 106, of which 55 occurred in the 1931 earthquake. The distribution of these deaths is shown on Figure 26. Of the 106 fatalities, 78 can be ascribed to specific agents. A total of 62 people died in tsunami generated by earthquakes, 15 were killed by landslides produced by ground shaking,

SPREADSHEET FOR ALL EARTHQUAKE DEATHS

HAZARD PRIMARY	HAZARD ASSOCIATED	LOCATION NO	LOCATION NAME	ISLAND	YEAR	MONTH	DAY	NO.DEATHS	REGIONAL TOTAL	COLOUR	FLAG
E	TS	61	SAG	GUA	1939	APR	30	12	12	5	0
E		61	SAG	GUA	1926	JAN	25	5	17	5	1
E	L	65	NDU	GUA	1977	APR	21	5	5	3	1
E		67	TAL	GUA	1977	APR	21	6	6	3	1
E	ST	69	MOL	GUA	1977	APR	21	1	1	3	1
E		70	TET	GUA	1977	APR	21	5	5	3	1
E		73	KOL	GUA	1977	APR	21	5	5	3	1
E		75	PAP	GUA	1977	APR	21	5	5	3	1
E	L	77	VUL	GUA	1977	APR	21	5	5	3	1
E	L	97	AAB	MAL	1931	OCT	31	5	5	3	1
E	TS	117	WAE	MAK	1931	OCT	31	25	25	5	1
E	TS	118	WAE	MAK	1931	OCT	31	25	25	5	1

and one was killed by a rock falling on her head. Clearly, it is the associated hazards which are more important in producing fatalities than the earthquake induced by *groundshaking per see*

Storms and Floods

Only a few storms and floods are included in the database (Volume 2) as separate entities from tropical cyclones. Of the 21 storms and floods, 19 occurred this century; all except one of these occurred post-1950, suggesting that earlier events were simply not recorded. However, 18 of these events caused damage. The major areas affected by storms include central Guadalcanal, Gizo, the Florida Islands, and Tikopia. However, as shown on Figures 26- 28, none of this damage was particularly serious. Areas of Guadalcanal were the most seriously affected by storms.

Most of the reported flood damage occurred on Guadalcanal, Savo, western Santa Isabel, and part of Makira (Figure 29). In most cases, flood damage was more severe than storm damage (Figures 30 and 31).

Only two flood events and two storm events are known to have caused deaths (Figures 32 and 33), but this is likely to be a serious underestimate as individual deaths probably occur quite commonly as villagers attempt to cross flooded streams. The total known death toll from floods is only 3. On the other hand it is estimated that 28 people have perished in storms, 21 of these when several canoes were lost during a storm in 1984 near Ontong Java. The other deaths occurred in 1888 near Tikopia; again, a canoe was lost at sea. These deaths at sea are in addition to those recorded as occurring at sea during tropical cyclones.

Landslides

No doubt tens of thousands of landslides have occurred in the Solomon Islands this century, but most of these have been associated with earthquakes, tropical cyclones and storms. Only three landslides additional to those already discussed in association with other natural hazards are included in the database (Volume 2). Two of these occurred on Guadalcanal and one in the Florida Islands. Damage occurred to gardens in each case, but no deaths or injuries were reported.

Although there is little information in the database on landslides as a primary hazard, the evidence already presented in relation to earthquakes, storms and tropical cyclones indicates that landslides have been the most important single cause of death in natural hazards in the Solomon Islands this century. Damage to subsistence gardens and traditional houses is also very significant.

Tsunami

Tsunami experienced in the Solomon Islands have at least three source areas; locally, elsewhere in the Solomon Sea (principally near Bougainville), and other parts of the Pacific Rim. Most, but not necessarily all, of these tsunami, have been generated by submarine earthquakes. Only the damage from those tsunami that have not already been discussed under earthquakes are considered here.

Of the 19 primary tsunami in the database (Volume 2), 17 have occurred this century. The earliest tsunami considered here was reported in 1881 but this produced no damage. A tsunami in 1899 is reported as having washed away many beach houses but the area of the Solomons that was damaged is not known.

Of the 19 primary tsunami, 12 have produced damage that is recorded in the database. Figures 33 and 34 indicate primary tsunami damage in the western and eastern Solomons in this century. In the western Solomons primary tsunami damage is confined to the southern side of the more southerly islands, to the northern sides of Choiseul and Santa Isabel, and surrounds the coastlines of the more westerly islands of the New Georgia Group. Figure 35 shows that only three primary tsunami are known to have destroyed more than 30 equivalent houses.

Figures 37 and 38 indicate damage from tsunami associated with earthquakes. Figures 39 and 40 show combined primary and associated tsunami damage since 1900. Virtually all the damage reported has occurred in the Western Solomon Islands; the southern and western coasts of Guadalcanal have been the most seriously damaged areas, but tsunami damage is widespread, particularly in the westernmost islands.

Tsunami generated across the Pacific reached the Solomon Islands in 1952 (Kamchatka), 1960 (Chile), and 1978 (Mexico). None of these tsunami caused serious damage or deaths. In fact, none of the primary tsunami discussed here have resulted in fatalities in the Solomons.

Volcanic eruptions

Four volcanoes in the Solomon Islands have been active in the historic period Savo, Kavachi and Cook in the Western Islands, and Tinakula in the Eastern Islands. Kavachi is a submarine volcano which erupts frequently. Cook is also a submarine volcano but there is some doubt that it actually exists. Both Savo and Tinakula are island volcanoes that have erupted frequently in the historic period and have been responsible for considerable damage to surrounding areas of the islands and large death tolls.

The database (Volume 2) contains references to 53 eruptions. Sixteenth century eruptions of both Savo and Tinakula are reported. 42 of the eruptions have occurred this century. While the number of known eruptions is quite large only 4 eruptions have produced damage; the small number of damaging eruptions is a reflection of the fact that Kavachi is the most active volcano and that its isolated (and submarine) location limits the damage that can be produced.

While no fatalities have resulted from volcanic eruptions this century, two 19th century eruptions produced significant numbers of deaths. The 1827 eruption of Tinakula (Figure 41) probably killed more than 100 people. This eruption produced pyroclastic flows and it seems likely that the entire population of the island was killed. Similarly, in 1847 Savo erupted (Figure 42), also producing pyroclastic flows, and leaving few survivors. The death toll is estimated at about 500.

Droughts

Only three droughts have been recorded in the database (Volume 2), but undoubtedly there have been many more, particularly on the low islands. The most

Other natural hazards

Other natural hazards in the database include one incidence of cold weather on Nupani atoll in the Temotu Group which resulted in failure of food crops, malnutrition and migration of some of the population to Tinakula.

The only other natural hazard to be recorded are the sulphur fields on Vella Lavella where boiling mud has claimed lives on occasions.

Overview

More than 200 events are recorded in the two volumes of the database, with more than 180 of these occurring this century. There is no doubt that the quality of the natural hazard and damage record improves towards the present day. For some types of natural hazards the record is probably reasonably complete only for the period since 1950.

Table 8: Summary of natural hazard events and damaging events

	Number of events			**Number of damaging events**		
	1900-90	**pre-1900**	**Total**	**1900-90**	**pre-1900**	**Total**
Cyclones	38	8	45	24	5	29
Earthquakes	60	3	63	30	3	33
Floods	11	0	11	9	0	10
Storms	9	2	11	9	1	10
Landslides						
Tsunami*	17	2	19	11	1?	12
Volcanic eruptions	42	11	53	2	2	4
Droughts	2	1	3	2	1	3

*includes only primary tsunami

As Table 8 shows, almost half of the events recorded in the database have produced damage, with more than 80% of these damaging events occurring in the present century. More than half of the events that have produced damage have been tropical cyclones and earthquakes, indicating that, at least in terms of frequency of events, these are the most important natural hazards in the Solomon Islands.

The cumulative damage from all natural hazards from all events recorded in the database is presented in Figures 43 to 45. In the Eastern Solomons the most damaged islands are Utupia, Vanikolo and Tikopia. In the western Solomons the most heavily damaged areas are Guadalcanal, Makira and Malaita. Damage has been noticeably less in most of the New Georgia group and on Choiseul.

Figure 46 indicates the equivalent number of traditional houses destroyed for all natural hazards included in the data base. The diagram indicates that it is common for natural hazards to do little damage (12 events), but that 15 events have resulted in the destruction of the equivalent of more than 100 traditional houses and 6 events have resulted in the destruction of the equivalent of more than 1000 traditional houses. The modal event has destroyed the equivalent of between 3 and 10 houses. This range also includes the modal number of houses destroyed for tropical cyclones, earthquakes and storms.

By far the most damaging natural events in the Solomon islands are tropical cyclones. Although damaging earthquakes outnumber tropical cyclones, the total number of house equivalents destroyed by earthquakes is only about 22% of those destroyed by tropical cyclones. Similarly, the most damaging earthquake (1931) destroyed only 1600 house equivalents, just 25% of those destroyed by Cyclone Namu.

Only about 20% of the number of events that have produced damage have also resulted in human deaths. The total number of deaths recorded is more than 900, but only about 280 of these have occurred this century. Several important points arise from the record of deaths. The record of deaths from natural hazards in the Solomon Islands is summarised in Tables 9 and 10.

Just 4 events account for more than 80% of the known deaths. These events were the 1827 eruption of Tinakula, the 1847 eruption of Savo, the 1931 earthquake and Cyclone Namu in 1986. These data can also be interpreted to indicate that two thirds of the known deaths result from volcanic eruptions; in fact the Savo eruption of 1847 seems to have accounted for more than half of the known deaths from natural hazards in the last few hundred years. These results indicate that in terms of human deaths at least, an understanding of the natural hazards of the period since 1950 produces only a very incomplete understanding of risks from natural events.

The dominance of the the two volcanic eruptions in producing deaths is also evident on Figures 47 and 48. In the eastern Solomons some deaths have occurred in most island groups. In the western Solomons the majority of other deaths have occurred on GuadaIcanal, with some deaths also occurring in most of the other island groups on the eastern part of the map. There is a surprising absence of recorded deaths on the islands at the western end of the chain.

While the record of deaths implies that tropical cyclones and earthquakes are of secondary importance compared with volcanic eruptions, it must be remembered that many of the deaths in tropical cyclones, and a significant proportion of those produced by earthquakes, have occurred as a result of landslides. More than half of the deaths attributed to earthquakes have actually resulted from tsunami. Recognition of these facts has an important bearing on establishing future risks.

	Number of events			Number of deaths		
	1900-90	pre-1900	Total	1900-90	pre-1900	Total
Cyclones	10	1	11	135	20	155
Earthquakes	4	0	4	106	0	106
Floods	2	0	2	3	0	3
Storms	1	1	2	21	7	28
Landslides						
Tsunami*	0	0	0	0	0	0
Volcanic eruptions	0	2	2	0	600	600
Droughts	1	0	1	17	0	17

* includes only primary tsunami

FUTURE RISKS

In most studies of future risks from natural hazards it is reasonably safe to regard the past as the key to the future. In large part, that is also correct with regard to the Solomon Islands. However, several issues arise.

The first major issue concerns the length of the historic record. While it is clear from the comments above that the historic record is fairly complete for the post World War II period, that very completeness emphasises the paucity of information for much of the earlier period, in particular, the 19th century. In other words, the complete record is very short.

If estimates of the future risks from natural hazards are based on the post-war period, it seems clear that tropical cyclones and earthquakes are the major cause of death and destruction. When 19th century data are included as well the important contribution of volcanic eruptions in producing human deaths must be acknowledged, even though the proportion of damage produced by eruptions is relatively small.

A substantial proportion of the damage and deaths produced by natural hazards in the Solomon Islands results from just a few events. The dominance of Cyclone Namu, the 1931 and 1977 earthquakes and two volcanic eruptions has already been

SPREADSHEET FOR ALL DEATHS

HAZARD PRIMARY	HAZARD ASSOCIATED	LOCATION NO	LOCATION NAME	ISLAND	YEAR	MONTH	DAY	NO.DEATHS	REGIONAL TOTAL	COLOUR	FLAG
C	TR	49	WRE	REN	1979	FEB	17	1	1	3	1
V		55	SAV	SAV	1847			500	500	15	1
C	TR	60	SNG	FLO	1972	MAY	30	1	1	3	1
E	TS	61	SAG	GUA	1939	APR	30	12	12	5	0
E		61	SAG	GUA	1926	JAN	25	5	17	5	1
E	L	65	NDU	GUA	1977	APR	21	5	5	3	1
F		66	VAT	GUA	1965	JUN		2	2	3	1
E		67	TAL	GUA	1977	APR	21	6	6	3	1
F	R	69	MOL	GUA	1973	SEP		1	1	3	0
E	ST	69	MOL	GUA	1977	APR	21	1	2	3	1
E		70	TET	GUA	1977	APR	21	5	5	3	1
C	S	72	LON	GUA	1972	MAY	30	3	3	3	1
C		73	KOK	GUA	1986	MAY	16	12	12	5	0
E		73	KOL	GUA	1977	APR	21	5	17	5	1
C		74	AOL	GUA	1986	MAY	16	1	1	3	1
C		75	PAP	GUA	1986	MAY	16	11	11	5	0
E		75	PAP	GUA	1977	APR	21	5	16	5	1
E	L	77	VUL	GUA	1977	APR	21	5	5	3	0
C		77	VUL	GUA	1986	MAY	16	12	17	5	1
C	R	78	WTA	GUA	1966	NOV	14	1	1	3	1
C	L	79	MAL	GUA	1986	MAY	16	61	61	12	1
C	S	80	HON	GUA	1972	JAN	11	1	1	3	1
C	R	82	AIM	MAL	1970	APR		2	2	3	1
C		87	FOO	MAL	1966	NOV	14	2	2	3	1
C		94	EIE	MAL	1986	MAY	16	3	3	3	1
C		95	ARE	MAL	1986	MAY	16	3	3	3	1
E	L	97	AAB	MAL	1931	OCT	31	5	5	3	1
C		100	TAI	MAL	1986	MAY	16	1	1	3	1
C		101	KWA	MAL	1986	MAY	16	4	4	3	1
S	S	107	PEL	ONT	1984	DEC	23	21	21	5	1
C		110	ARS	MAK	1986	MAY	16	1	1	3	1
C	R	113	ARO	MAK	1979	FEB	17	1	1	3	1
C	R	114	BAW	MAK	1979	FEB	17	1	1	3	1
C	S	115	BAC	MAK	1972	MAY	30	1	1	3	1
E	TS	117	WAE	MAK	1931	OCT	31	25	25	5	1
E	TS	118	WAE	MAK	1931	OCT	31	25	25	5	1
C	TR	122	CAT	MAK	1971	DEC	6	6	6	3	1
C		127	REE	TEM	1937	JAN		5	5	3	1

SPREADSHEET FOR ALL DEATHS

HAZARD PRIMARY	HAZARD ASSOCIATED	LOCATION NO	LOCATION NAME	ISLAND	YEAR	MONTH	DAY	NO.DEATHS	REGIONAL TOTAL	COLOUR	FLAG
V		128	TIN	TEM	1827			100	100	12	1
C		130	NEO	TEM	1986	MAY	16	2	2	3	1
C		137	UTU	TEM	1937	JAN		1	1	3	1
C	S	138	VAN	TEM	1788			20	20	5	1
D		139	TIK	TEM	1952			17	17	5	0
S		139	TIK	TEM	1888			7	24	5	1

Table 10 (continue

mentioned. This pattern of dominance by a few larger events is not peculiar to the Solomons and it is extremely likely that such a pattern will continue in the future.

It is difficult to make sensible estimates of frequency for these major events from the short record available but Figures 50 and 51 provide magnitude - frequency curves for the 1900-1990 period. The figures suggest that a once in 10 year cyclone would destroy the equivalent of 400-500 houses and an earthquake with the same return period about 60-70 houses. Similarly, a once in a hundred year cyclone can be expected to destroy the equivalent of about 7000 houses, and an earthquake with the same recurrence interval 2000-5000 houses. In the latter case the shape of the curve is probably influenced by the occurrence of the 1931 earthquake when the population was significantly smaler than at present. It is probably reasonable to surmise that the recurrence interval for a volcanic eruption producing significant consequences, such as those of 1827 and 1847, is of the order of once in 100 years. The incidence of tropical cyclones and earthquakes producing severe consequences is probably more frequent than once in 50 years.

However, it should not be imagined that Cyclone Namu, the 1931 earthquake or the 1847 eruption of Savo are the most severe events that can occur in the Solomons. Cyclone Namu was only a Category 2 or 3 on the Cyclone Severity scale and a much more severe cyclone (Category 4 or 5) is possible, indeed likely. Similarly, while the 1931 earthquake was a severe earthquake with a Richter magnitude of 8.1, it did not severely affect the most densely populated areas. While the 1977 earthquake did affect Guadalcanal the magnitude of this earthquake was considerably less (Richter magnitude 7.5). In a great earthquake the amplitude of ground shaking could be 5 times more severe than it was in 1977. Finally, the Savo eruption in 1847 can be described as only a moderate eruption and much larger eruptions of volcanoes in the Solomons are possible.

In short, future risks should not be assessed solely on the basis of a relatively short record which probably includes only those events with consequences that can be expected to recur every 50 to 100 years or more frequently. Natural hazards which produce greater consequences, but which recur less frequently on average, can be expected some time in the future. As implied above, the most damaging such events are likely to be volcanic eruptions, earthquakes and tropical cyclones, but the possibility of large damaging tsunami should not be discounted.

Although it has been common policy for planners and designers to ignore the possibility of natural hazards with recurrence intervals less frequent than once in 100 years, in recent years considerable attention has been devoted to the consequences of extreme events for highly populated areas. In the case of Probable Maximum Floods, estimated return periods for such events are less than once in 10,000 years. The possibility of extreme floods, tsunami and volcanic eruptions in the Solomon Islands should not be entirely ignored.

The brief consideration of future risks set out above assumes that the present and the past are the key to the future. While this is probably correct when a record spanning hundreds, or preferably thousands of years, is available for consideration, global warming trends suggest that the past probably provides an imperfect record on which to assess the consequences of future meteorological hazards.

Many of the significant hazards facing the Solomon Islands are geological hazards; the incidence and severity of these hazards will not be affected by global warming. However, the incidence and severity of tropical cyclones and floods may well be affected.

Unfortunately, global climate models which have been used to generate possible future climates are not yet powerful enough to represent adequately meteorological conditions as "small" as a tropical cyclone. There is some evidence that increased sea surface temperatures will result in increased rainfall possibly leading to more prounced flooding under greenhouse conditions. Some preliminary results from models suggest that there will be little change in the areas of tropical cyclone genesis but this does not tell us about tropical cyclone frequency, intensity or track direction. Some studies suggest that raised sea surface temperatures will result in lowered central pressures and higher windspeeds in tropical cyclones but these possible changes may be counteracted by other (indeterminate) influences.

The changes to meteorological hazards postulated above refer specifically to the tropical portions of Australia; it is not known yet whether these postulated changes are correct or likely under greenhouse conditions and it is not known whether they might apply unaltered in the Solomon Islands region. Furthermore, no attempts have been made yet to model the possible consequences of global warming on the incidence or severity of EI Nino. This is of considerable importance to the Solomons because EI Nino has profound effects on the incidence of both tropical cyclones and droughts in the Solomons region.

At present it is not possible to state the effects of global warming on the incidence or severity of natural hazards in the Solomon Islands.

Future risks from natural hazards are largely indeterminate. Despite this it is possible to be fairly confident that the consequences of natural hazards in the Solomon islands will increase as a result of increased population and the drift towards towns. These influences and the consequences of natural hazards can be offset to some extent through efforts at risk reduction.

NATURAL DISASTER REDUCTION

Any attempt to reduce the impacts of natural disasters in the Solomon Islands must rest on a clear understanding of the nature of the problem. Our final aim in this report has been to provide some basis for such attempts.

Figures 43 to 45 indicate the areas of the Solomons where the highest proportions of traditional houses have been destroyed by natural hazards. These maps are risk maps, providing it is accepted that past risks are an adequate guide to future risks. Such maps, because they indicate the proportion of dwellings that have been destroyed by cumulative events, are independent of variations in population density. In these terms, the areas with the highest risks are Guada1canal, Makira and Malaita.

The natural hazards that have made the greatest contribution to risk are tropical cyclones and earthquakes. As explained previously, the contribution to past damage from tropical cyclones is about 5 times that from earthquakes. Given the greater frequency of damaging earthquakes, this relationship may imply that traditional dwellings have a greater resilience to ground shaking than to dynamic wind forces. Other natural hazards have made smaller contributions to total damage.

On this basis, attempts at disaster reduction should focus on increasing the resistance of traditional dwellings (and other structures) to cyclonic winds and ground shaking on the islands of Guadalcanal, Makira and Malaita, and on improved warning systems for tropical cyclones (warning systems for earthquakes are not yet practicable).

However, this view would seem to be too simplistic. As noted earlier, volcanic eruptions have the potential to produce significant damage in limited areas and other hazrds, not prominent in the short record available may also have considerable catastrophe potential.

More importantly, focussing on wind and seismic resistance may be misguided. Unfortunately, our damage data are of insufficient quality to determine the causes of house destruction but the available data on the agents of human deaths provides important clues. In the case of tropical cyclones, 67% of the deaths where the agent is known were killed by landslides, and a further 27% were lost at sea. These data suggest that increased wind resistance in traditional houses and other structures would have little positive effect on the death toll from tropical cyclones. While improved warning systems would probably reduce life loss at sea, it seems unlikely that better warnings would reduce life loss m landslides.

In the case of earthquakes, of the 78 deaths that can be ascribed to specific agents 80% resulted from tsunamis and the remainder were killed by landslides. These data also suggest that increased seismic resistance of structures is unlikely to result in a substantial reduction in the death toll. While an effective warning system would reduce the death toll from tsunami, the Pacific-wide warning system based in Hawaii is ineffective for locally generated tsunami as warning times are too short. Systems such as THRUST, designed for the Pacific Coast of South America can provide effective warning, but it is very dependent on high technology communications and is only suitable for urban areas. Educational programs are likely to be more cost effective and enduring.

The available data are not of sufficient quality to determine whether these tentative conclusions about reduction of loss of life also apply to reduction of damage to traditional houses and other structures. Nonetheless, these data suggest that the benefits to be gained from increased resilience of structures and improved warning systems may be rather marginal; the real problem may be loss of life and damage to structures caused by landsliding and tsunami rather than by tropical cyclones and earthquakes.

If the conclusions regarding the real importance of landslides and tsunami are correct, land use planning and educational programs are likely to provide the best basis for achieving a reduction in the consequences of natural hazards in the Solomon Islands.

Further investigation should be undertaken to determine the merit of these tentative conclusions.

ACKNOWLEDGEMENTS

We have become indebted to many people in the course of this lengthy project. Our initial debt is to Joe Barr from AIDAB and NDO for his early and continuing enthusiasm and encouragement. We have also received enormous support from Jocelyn Gardiner from the Library at Macquarie University and from John Grover for access to his considerable library on the Solomon Islands. More recently we have received continual assistance from Neil Flood who was ever ready to respond to our demands for yet more programming and fine tuning of numerous bits of software and hardware. Finally, Rosemary Saul provided valuable support in numerous ways.

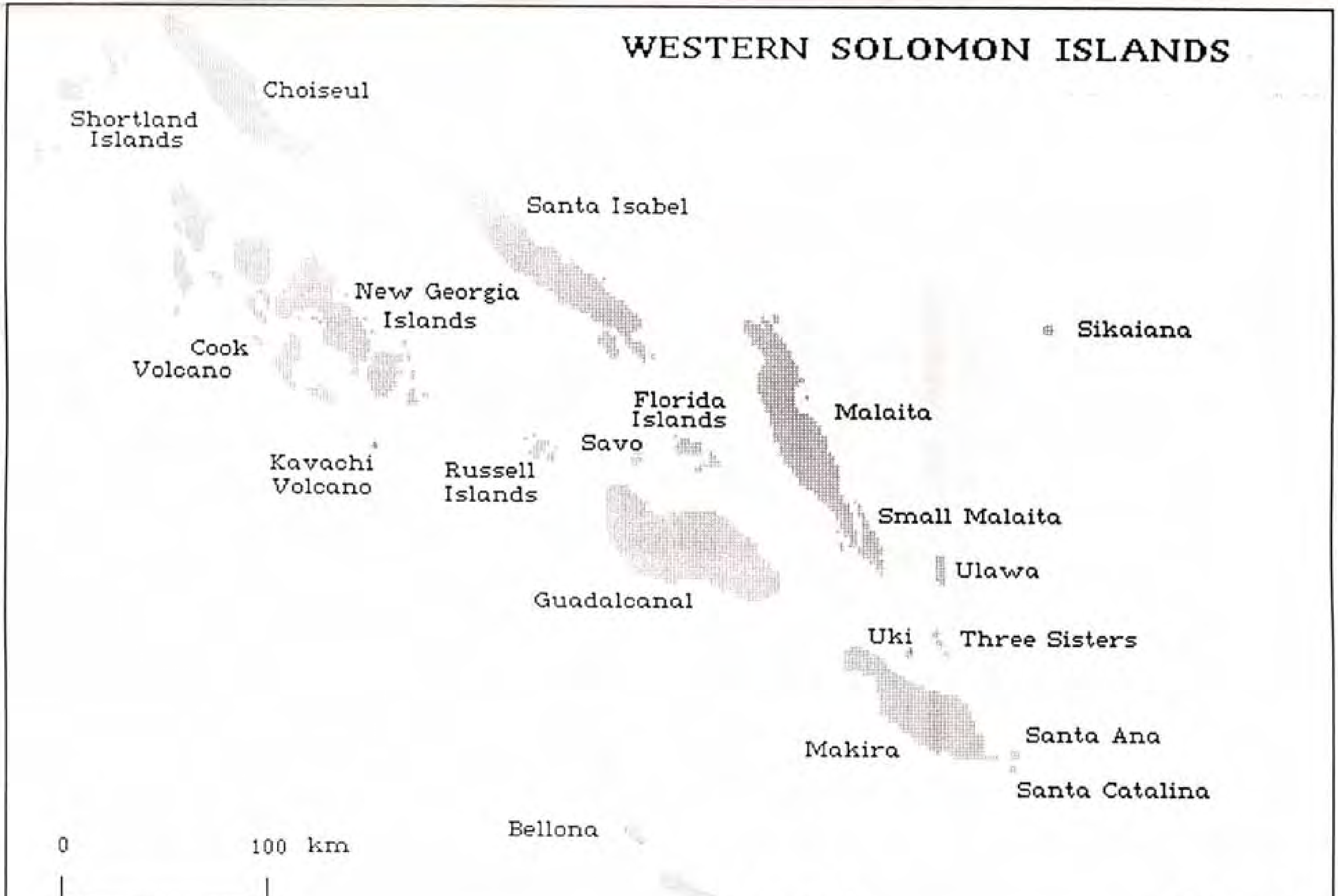

WESTERN SOLOMON ISLANDS
Choiseul
Shortland Islands
Santa Isabel
New Georgia Islands
Sikaiana
Cook Volcano
Florida Islands
Malaita
Savo
Kavachi Volcano
Russell Islands
Small Malaita
Ulawa
Guadalcanal
Uki
Three Sisters
Santa Ana
Makira
Santa Catalina
Bellona
0
100 km
Scale
Rennell

Figure 1

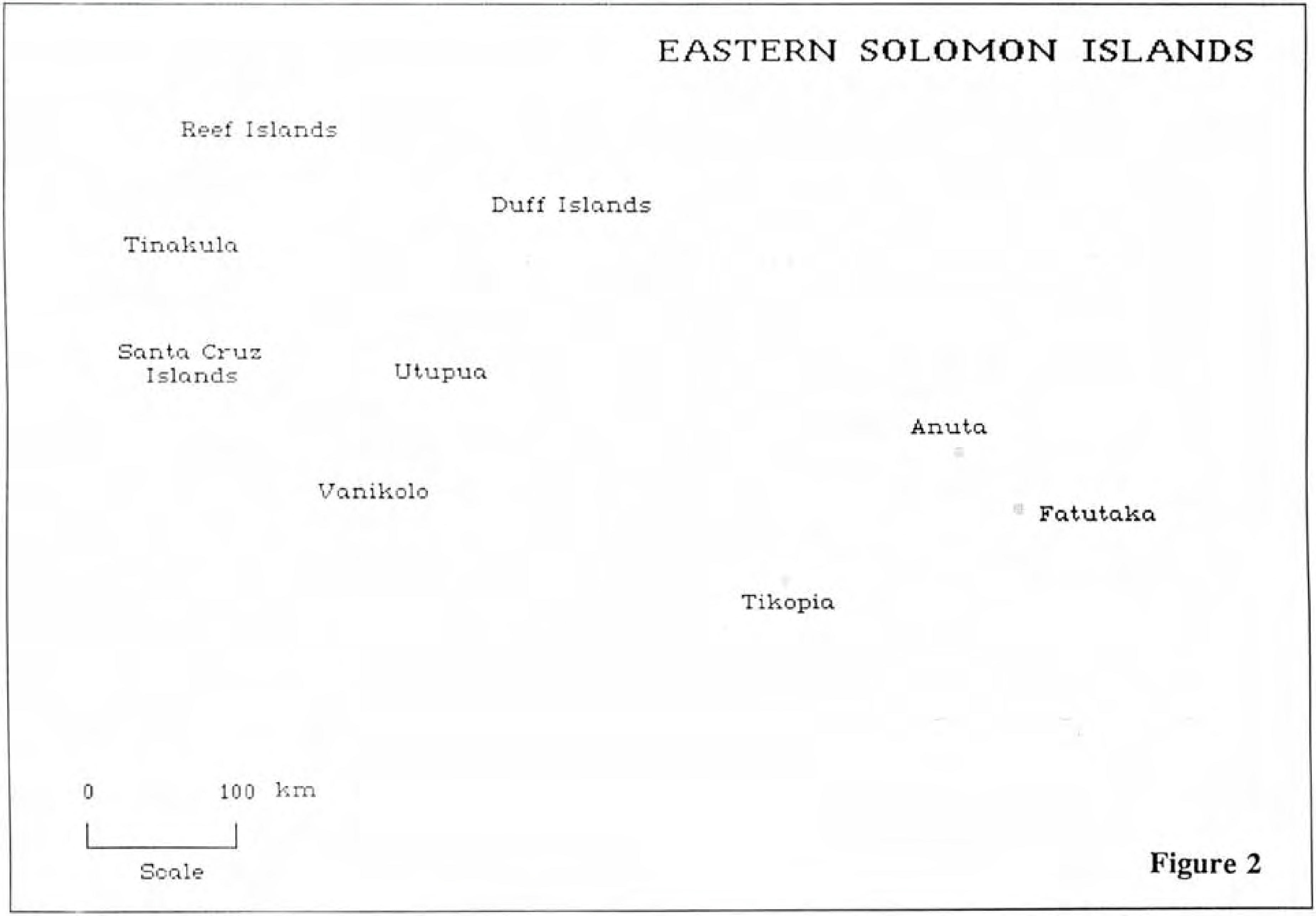

EASTERN SOLOMON ISLANDS
Reef Islands
Duff Islands
Tinakula
Santa Cruz Islands
Utupua
Anuta
Vanikolo
Fatutaka
Tikopia
0
100 km
Scale

Figure 2

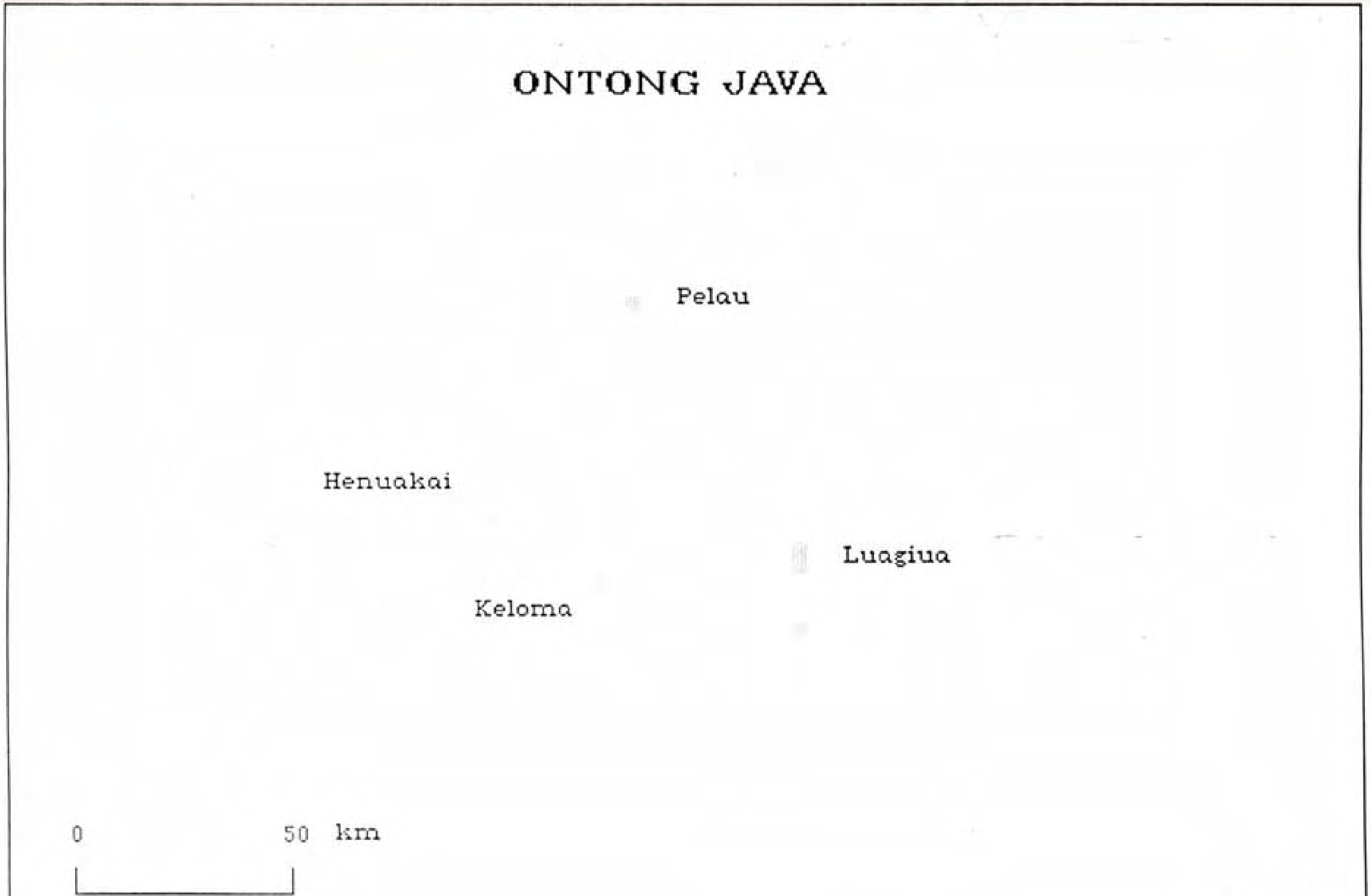


Figure 3

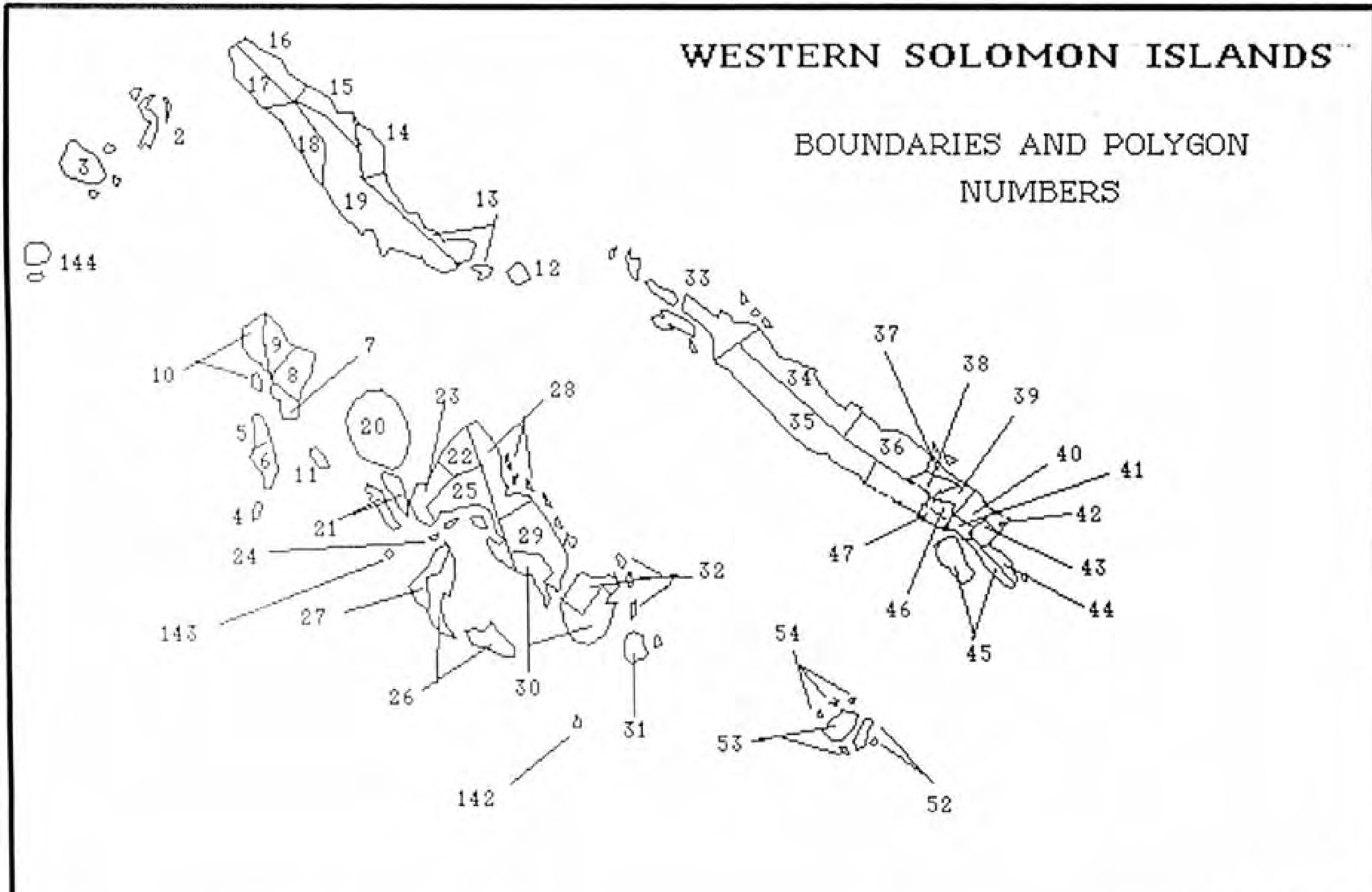
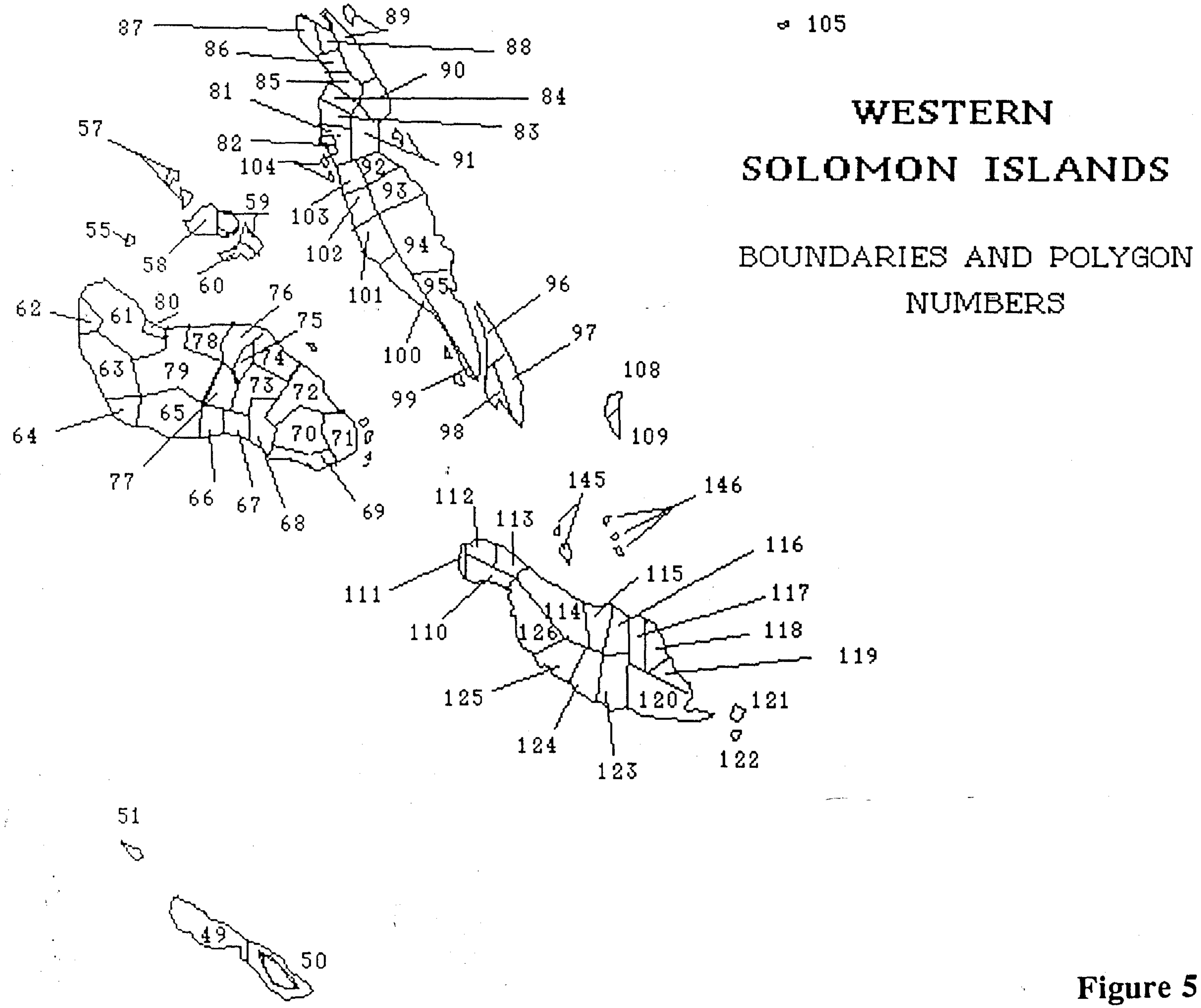

WESTERN SOLOMON ISLANDS
BOUNDARIES AND POLYGON NUMBERS
2
3
144
16
17
15
14
18
19
13
12
10
9
8
7
5
6
11
4
20
23
22
25
28
21
24
29
143
27
26
30
32
31
142
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
54
53
52

Figure 4



WESTERN
SOLOMON ISLANDS
BOUNDARIES AND POLYGON
NUMBERS
105
87
86
85
81
82
104
57
55
58
59
60
89
88
90
84
83
91
92
93
103
102
94
101
95
96
97
100
99
98
108
109
62
61
80
76
75
78
74
79
63
73
72
65
70
71
64
77
66
67
68
69
112
113
145
146
111
110
114
126
115
116
117
118
119
125
120
121
124
123
122
51
49
50

Figure 5

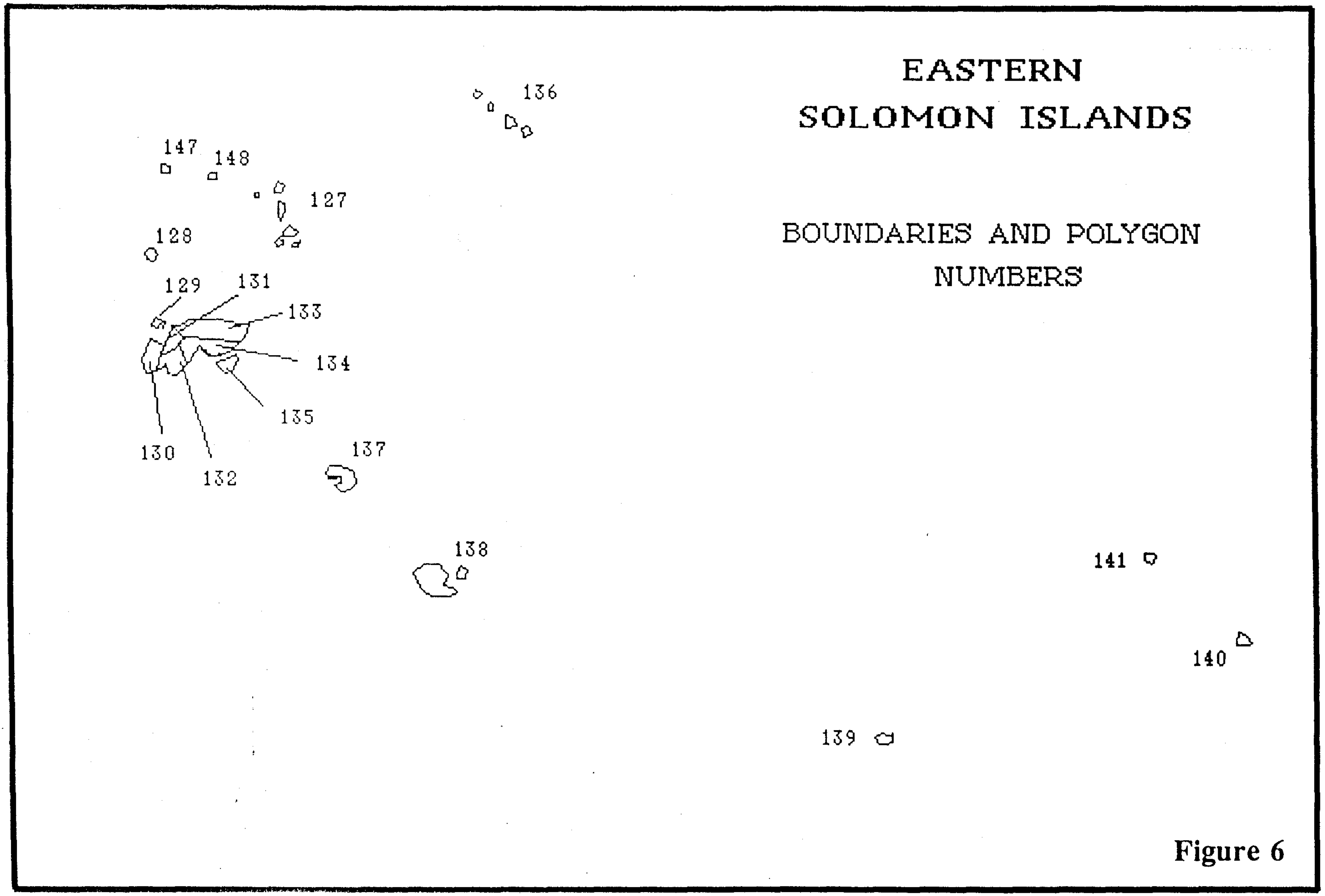

EASTERN
SOLOMON ISLANDS
BOUNDARIES AND POLYGON
NUMBERS
136
147
148
127
128
129
131
133
134
135
130
132
137
138
141
140
139

Figure 6

ONTONG JAVA

BOUNDARIES AND POLYGON NUMBERS

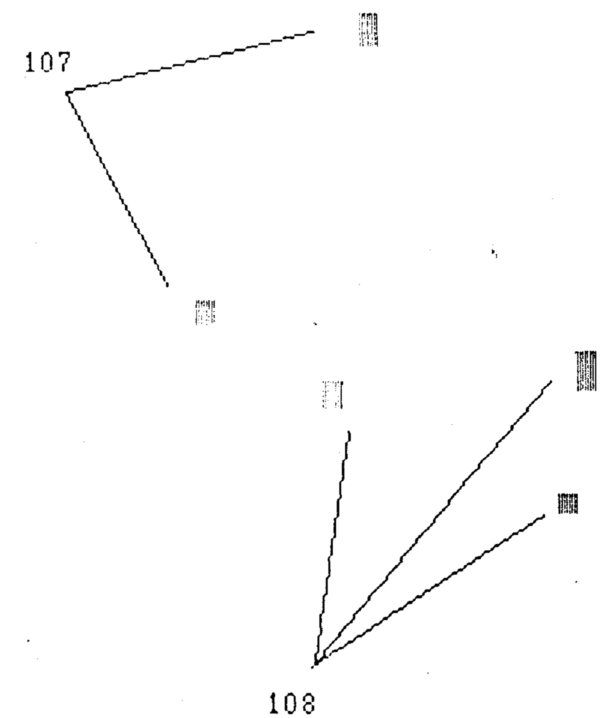


Figure 7

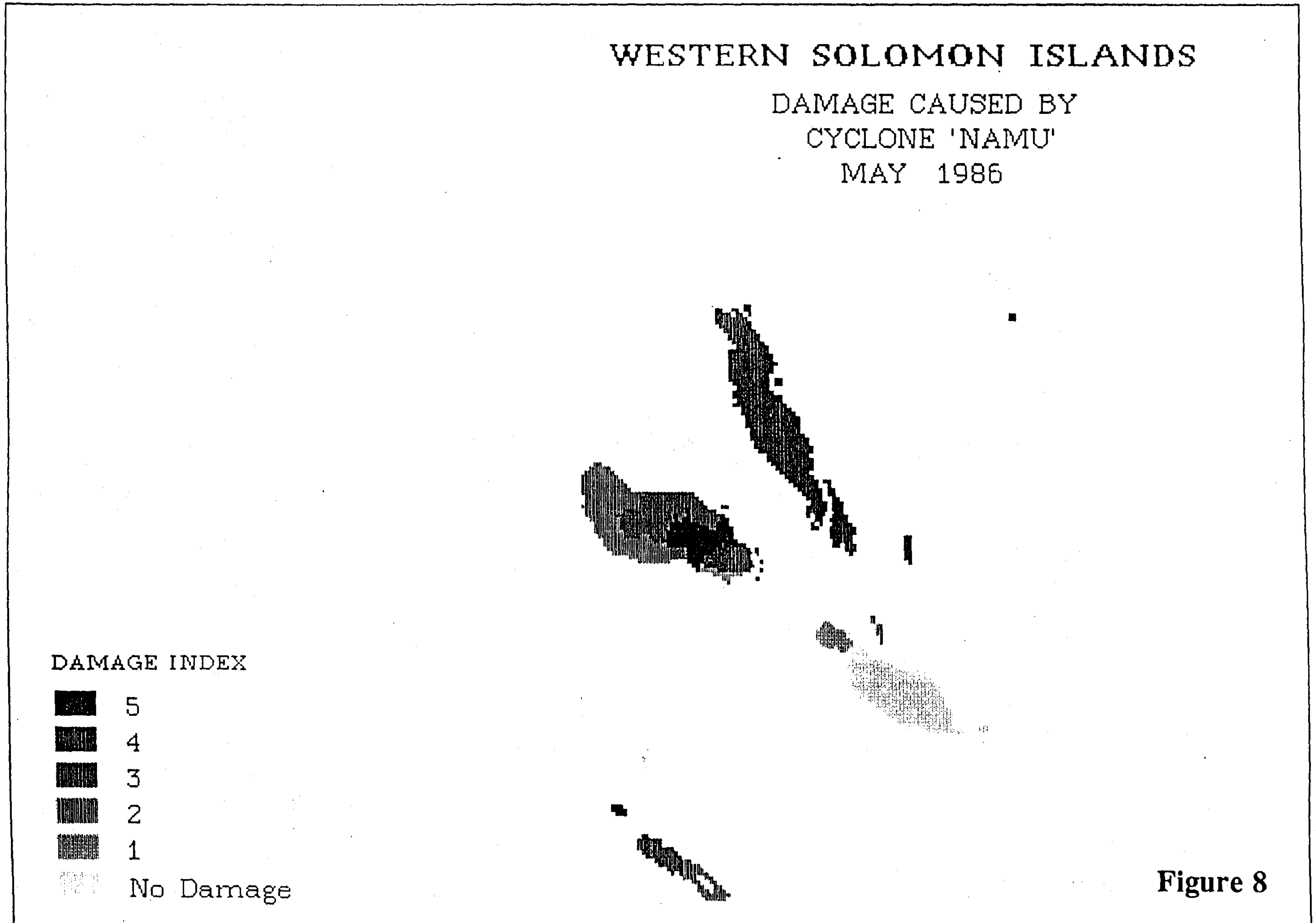

WESTERN SOLOMON ISLANDS
DAMAGE CAUSED BY
CYCLONE 'NAMU'
MAY 1986
DAMAGE INDEX
5
4
3
2
1
No Damage

Figure 8

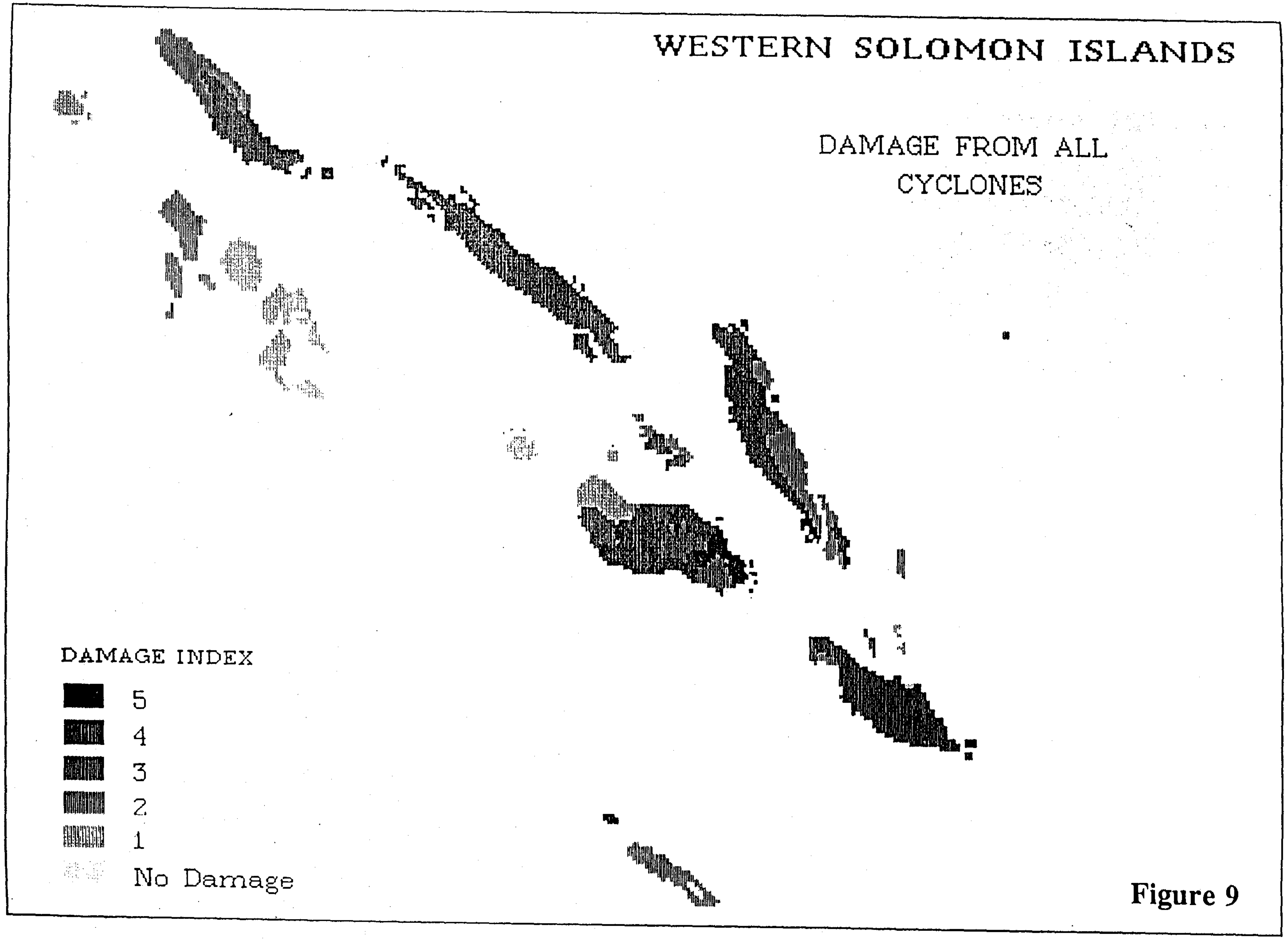

WESTERN SOLOMON ISLANDS
DAMAGE FROM ALL
CYCLONES
DAMAGE INDEX
5
4
3
2
1
No Damage

Figure 9

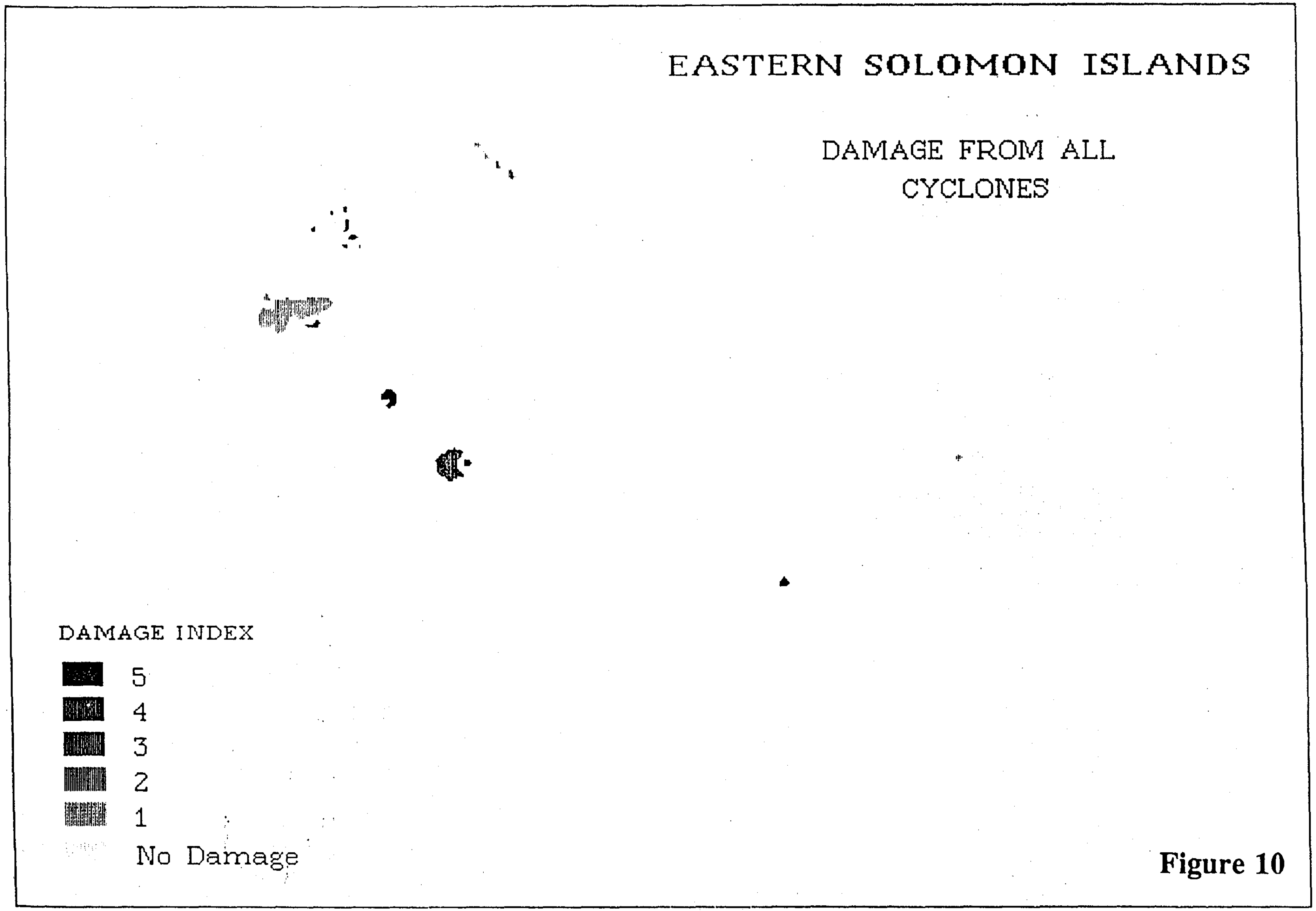

EASTERN SOLOMON ISLANDS
DAMAGE FROM ALL CYCLONES
DAMAGE INDEX
5
4
3
2
1
No Damage

Figure 10

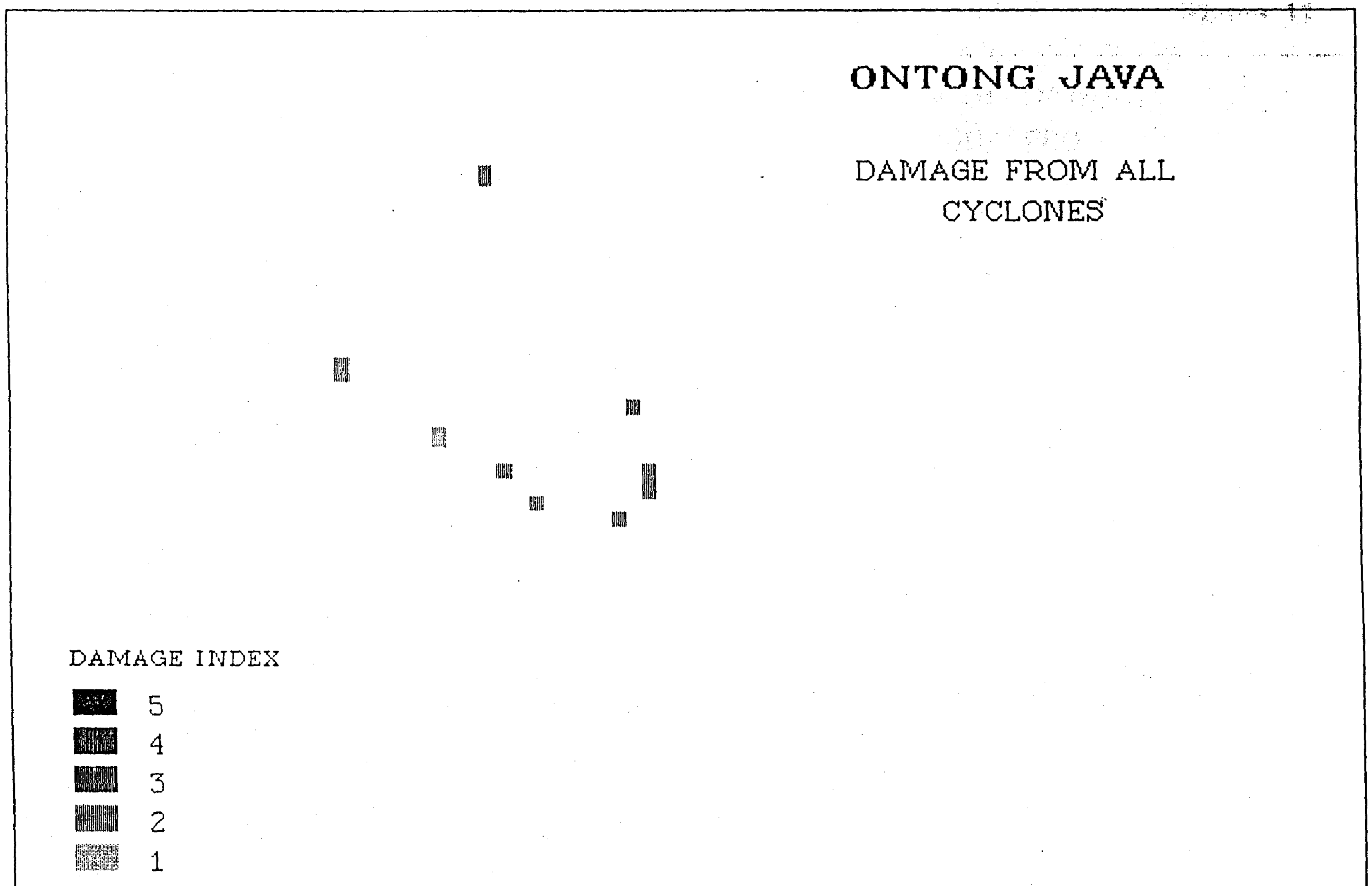

ONTONG JAVA
DAMAGE FROM ALL CYCLONES
DAMAGE INDEX
5
4
3
2
1
No Damage

Figure 11

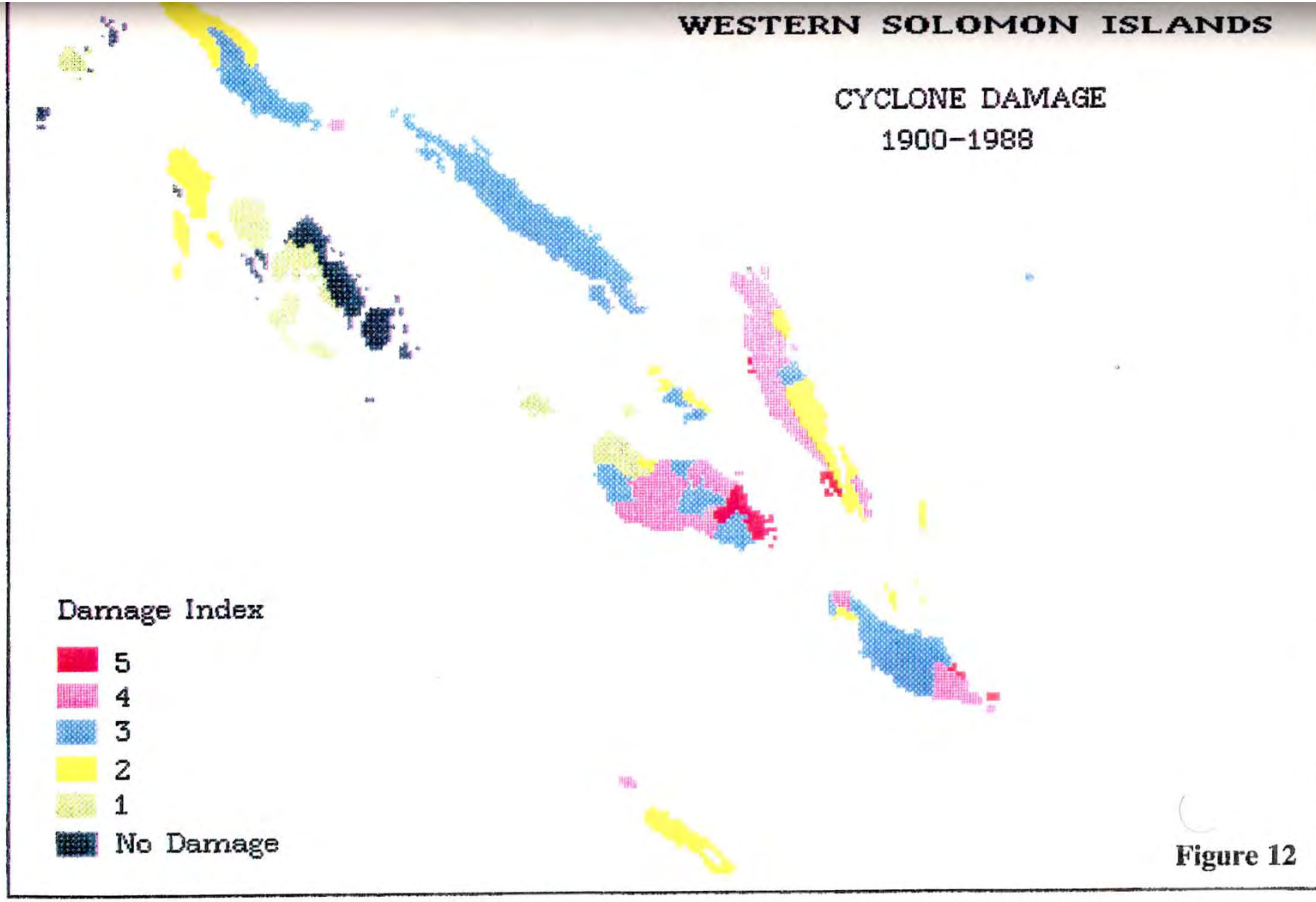

WESTERN SOLOMON ISLANDS
CYCLONE DAMAGE
1900-1988
Damage Index
5
4
3
2
1
No Damage

Figure 12

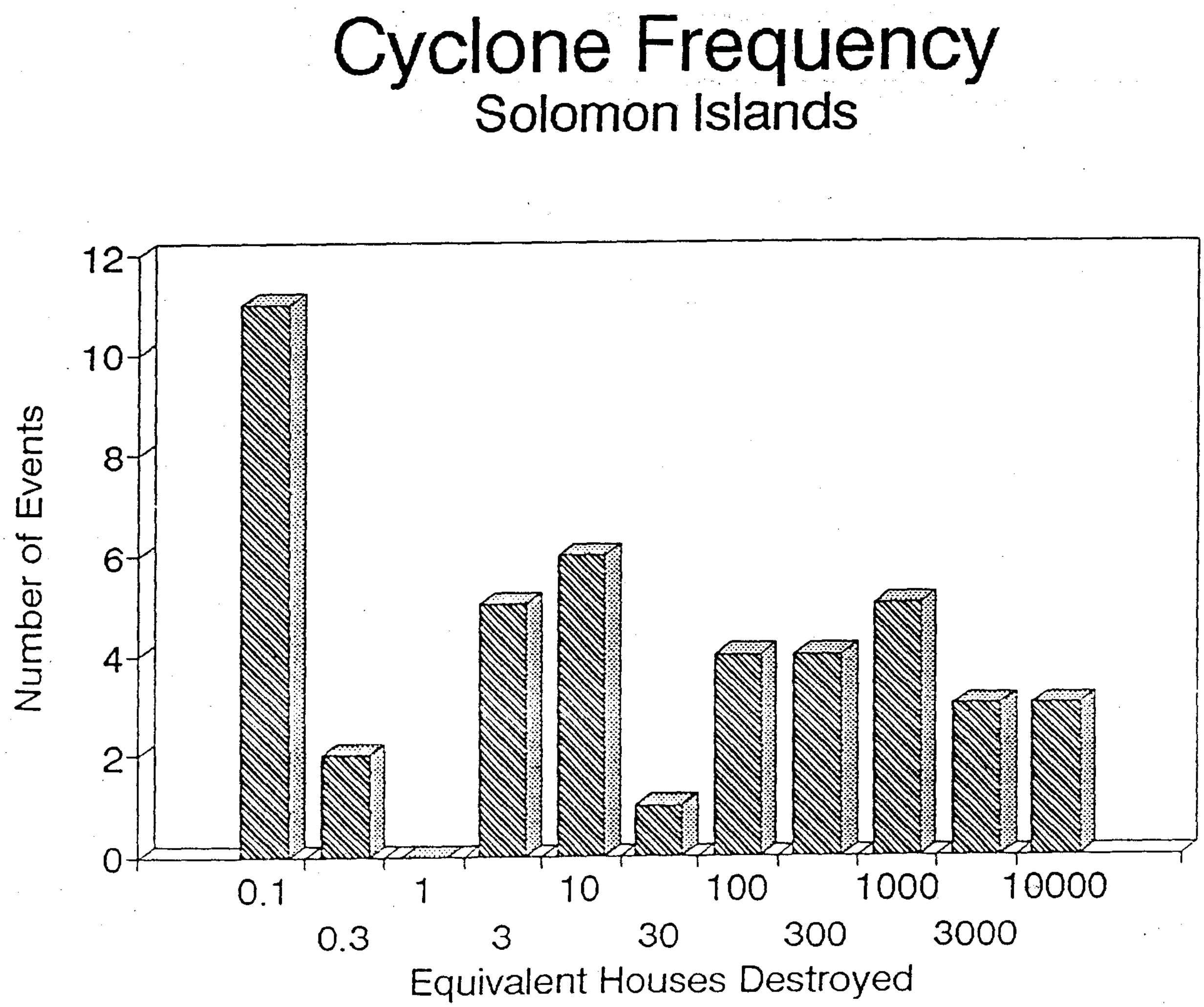

Cyclone Frequency
Solomon Islands
Number of Events
0
2
4
6
8
10
12
0.1
0.3
1
3
10
30
100
300
1000
3000
10000
Equivalent Houses Destroyed

Figure 13

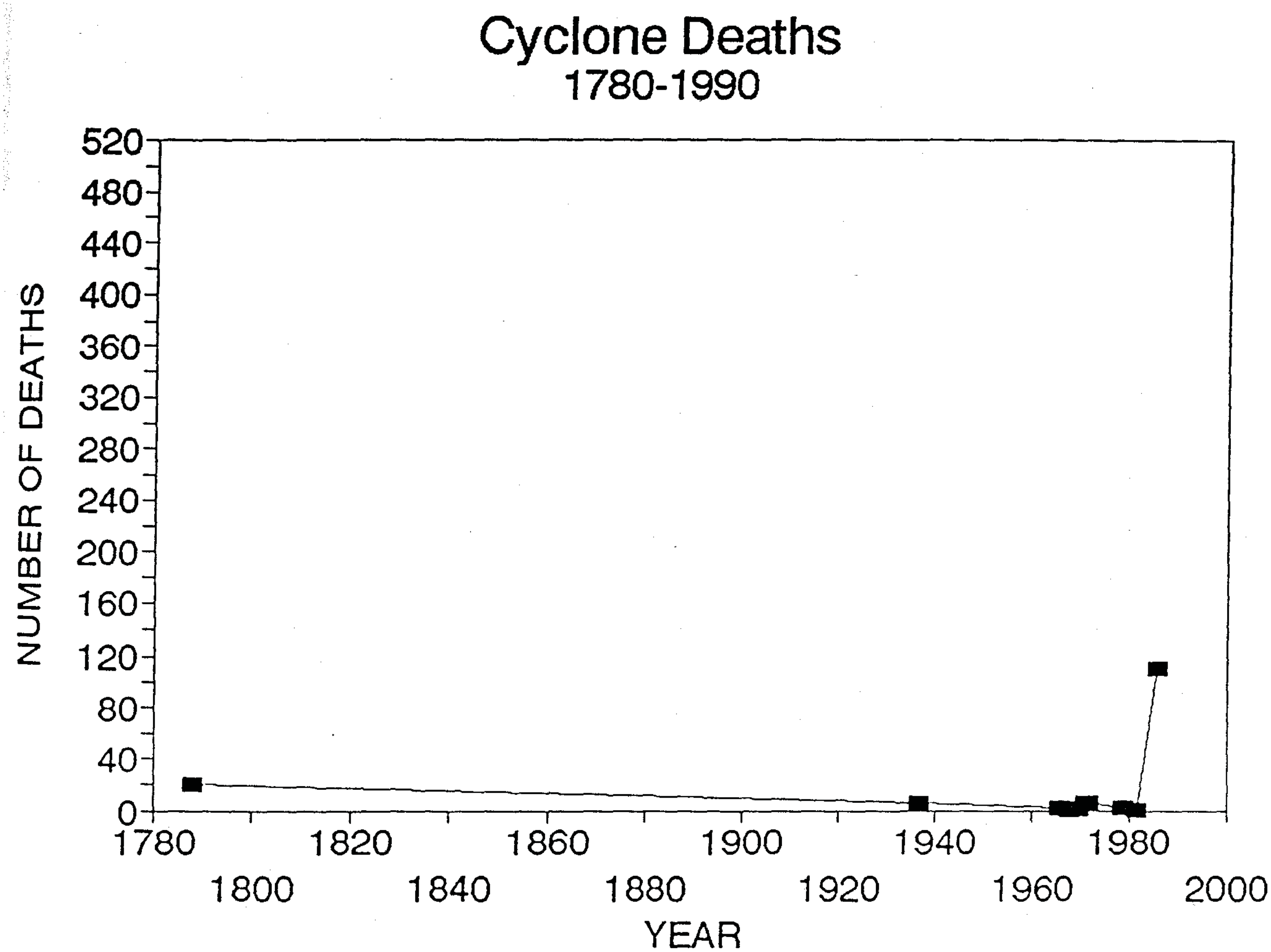

Cyclone Deaths
1780-1990
NUMBER OF DEATHS
520
480
440
400
360
320
280
240
200
160
120
80
40
0
1780
1800
1820
1840
1860
1880
1900
1920
1940
1960
1980
2000
YEAR

Figure 14

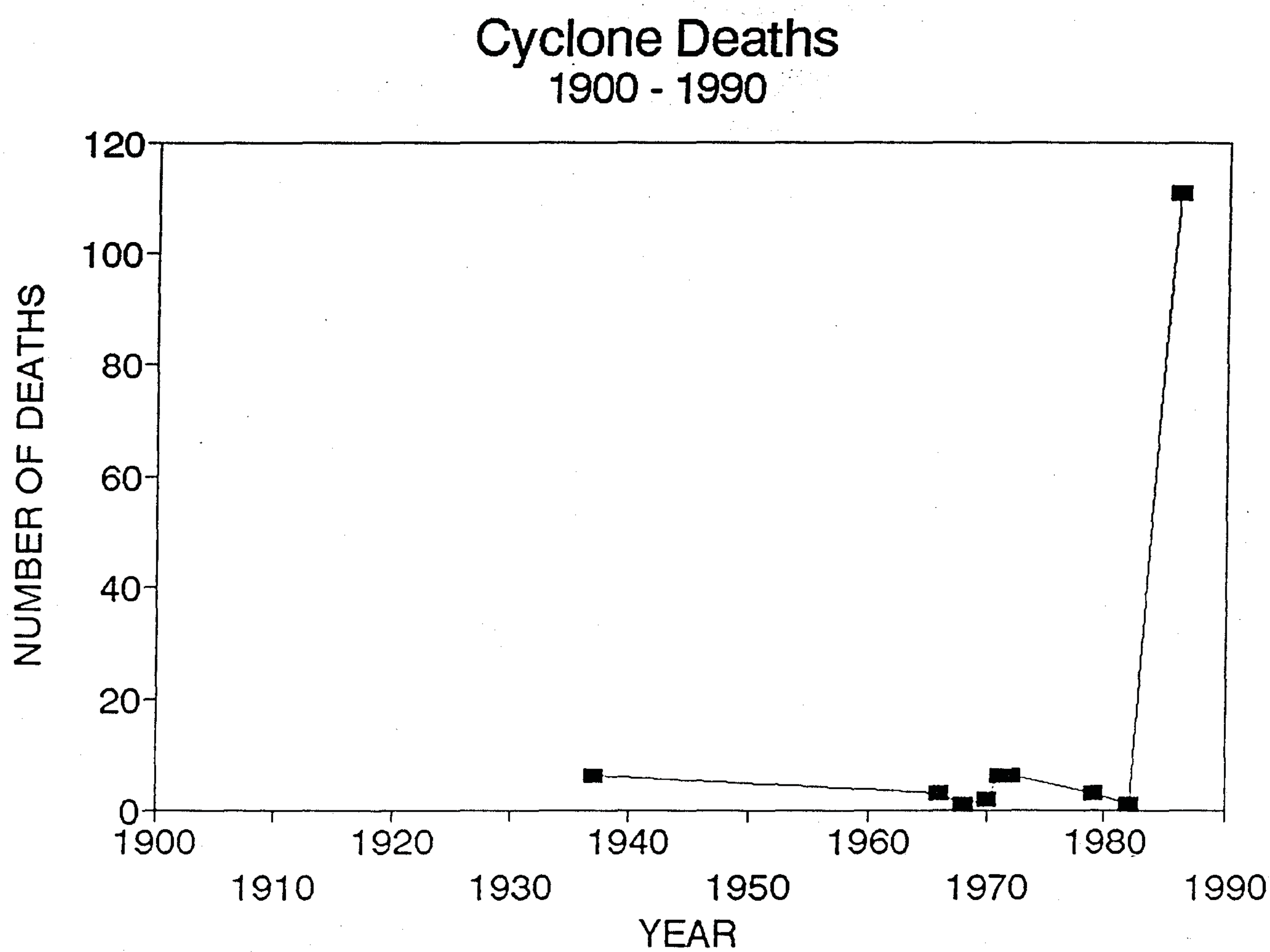

Cyclone Deaths
1900 - 1990
NUMBER OF DEATHS
120
100
80
60
40
20
0
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
YEAR

Figure 15

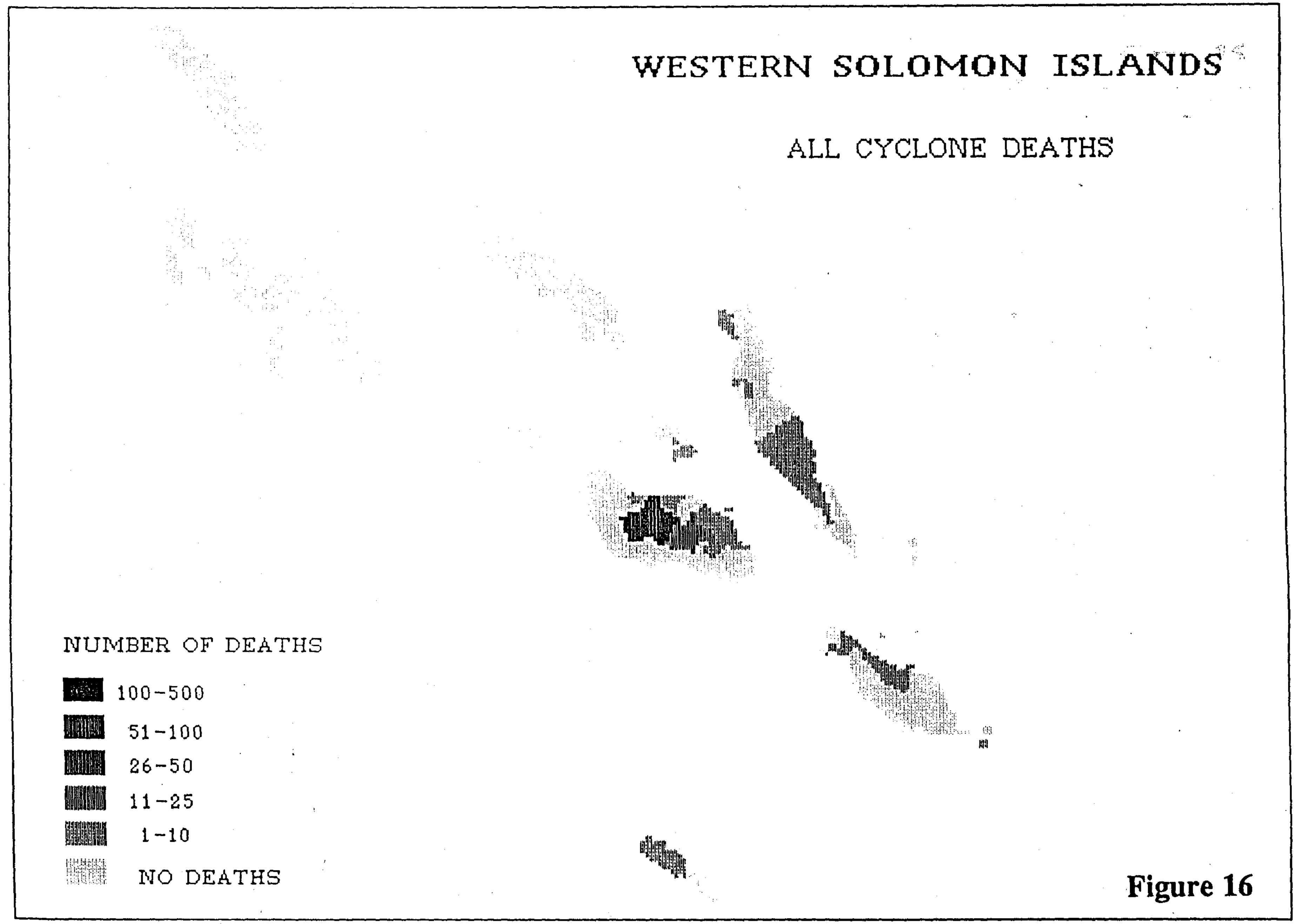

WESTERN SOLOMON ISLANDS
ALL CYCLONE DEATHS
NUMBER OF DEATHS
100-500
51-100
26-50
11-25
1-10
NO DEATHS

Figure 16

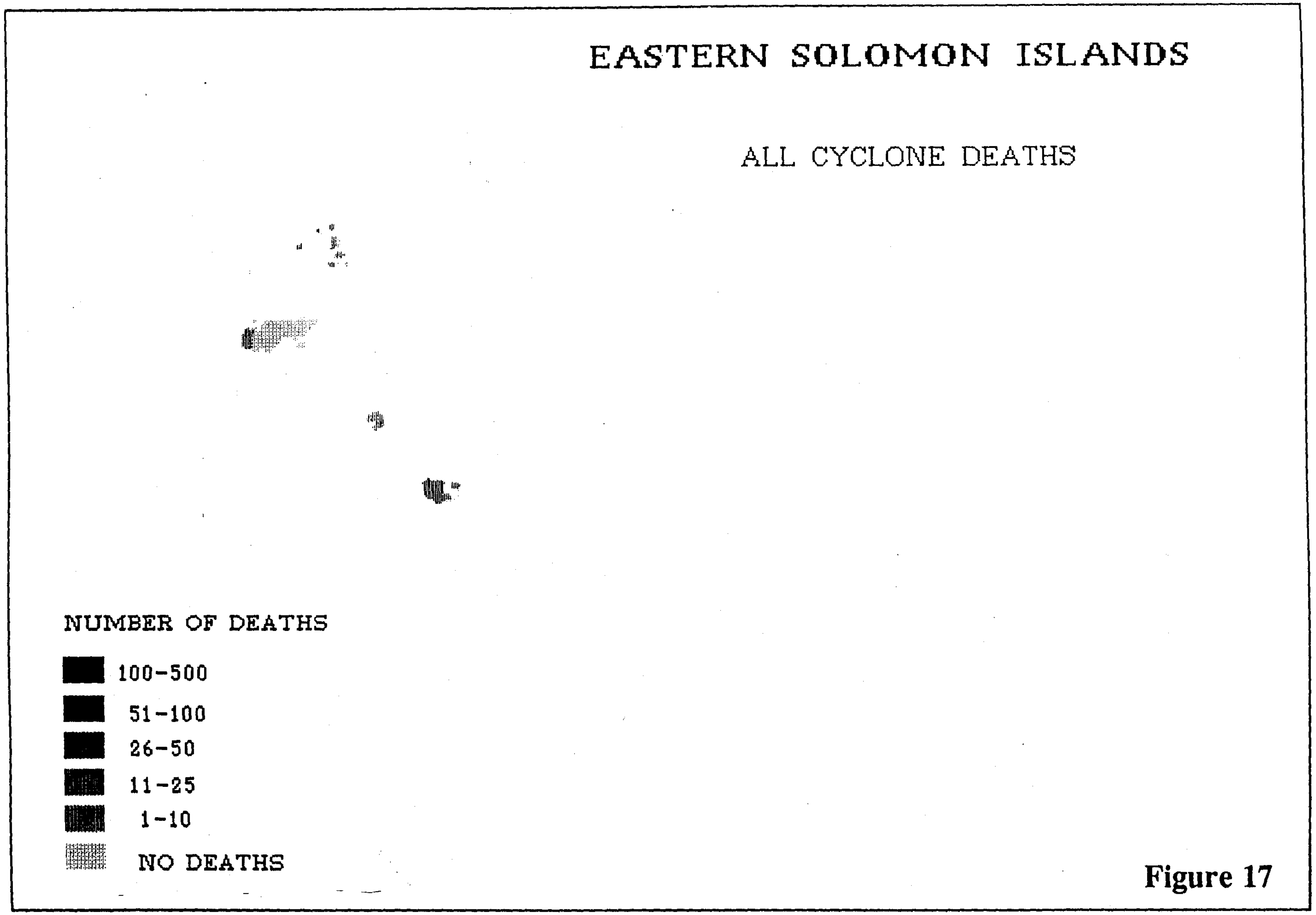

EASTERN SOLOMON ISLANDS
ALL CYCLONE DEATHS
NUMBER OF DEATHS
100-500
51-100
26-50
11-25
1-10
NO DEATHS

Figure 17

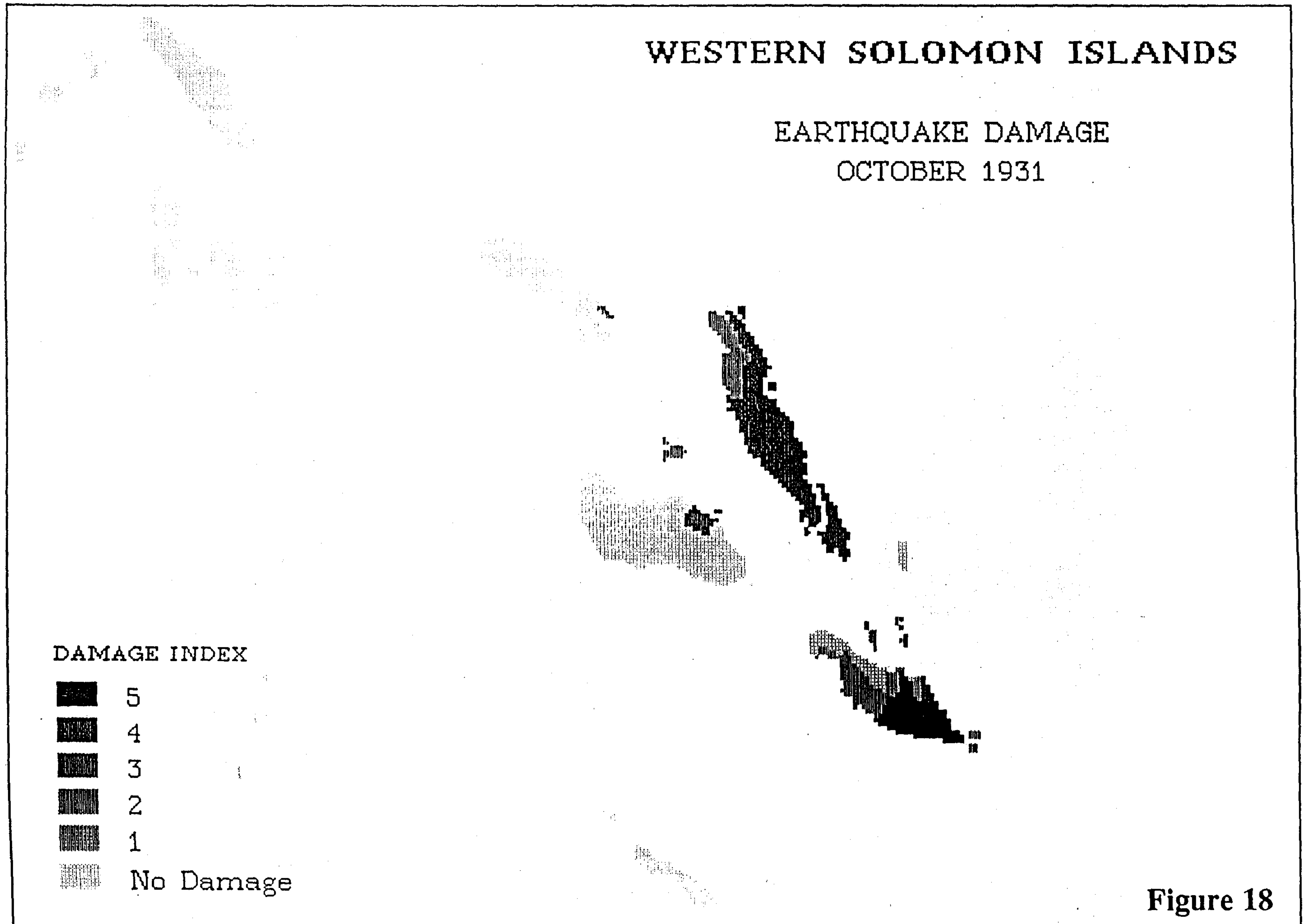

WESTERN SOLOMON ISLANDS
EARTHQUAKE DAMAGE
OCTOBER 1931
DAMAGE INDEX
5
4
3
2
1
No Damage

Figure 18

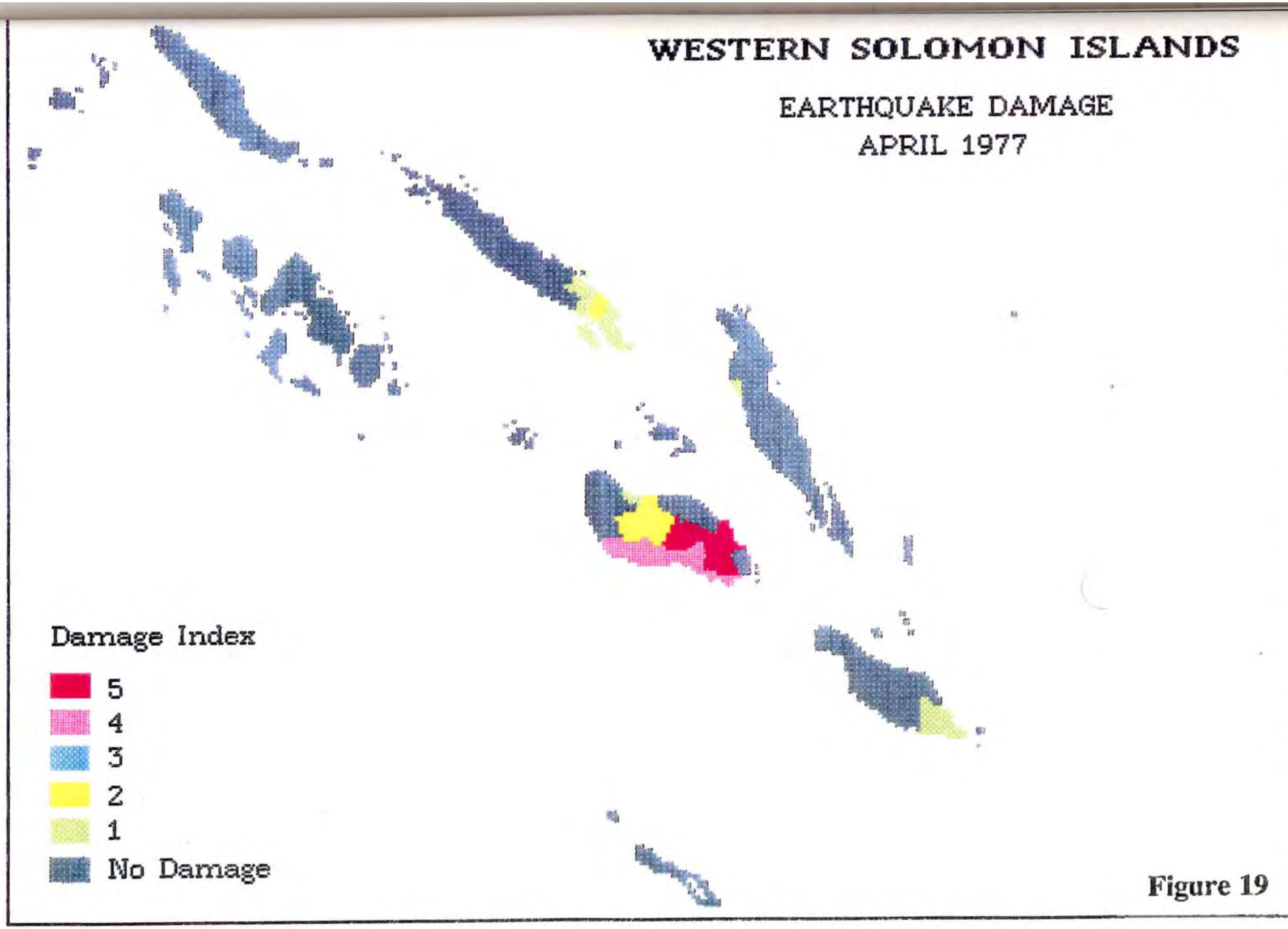

WESTERN SOLOMON ISLANDS
EARTHQUAKE DAMAGE
APRIL 1977
Damage Index
5
4
3
2
1
No Damage

Figure 19

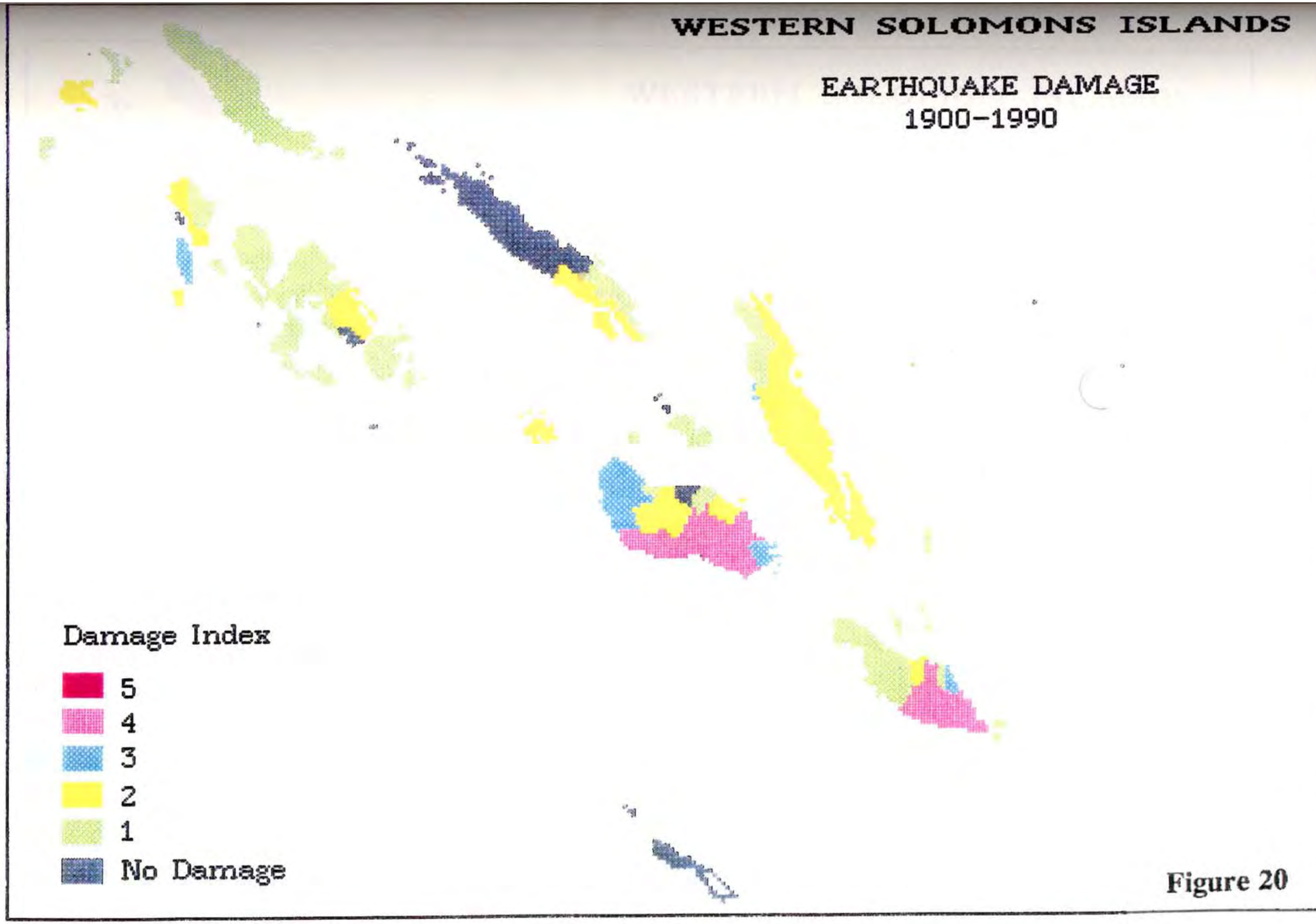

WESTERN SOLOMONS ISLANDS
EARTHQUAKE DAMAGE
1900-1990
Damage Index
5
4
3
2
1
No Damage

Figure 20

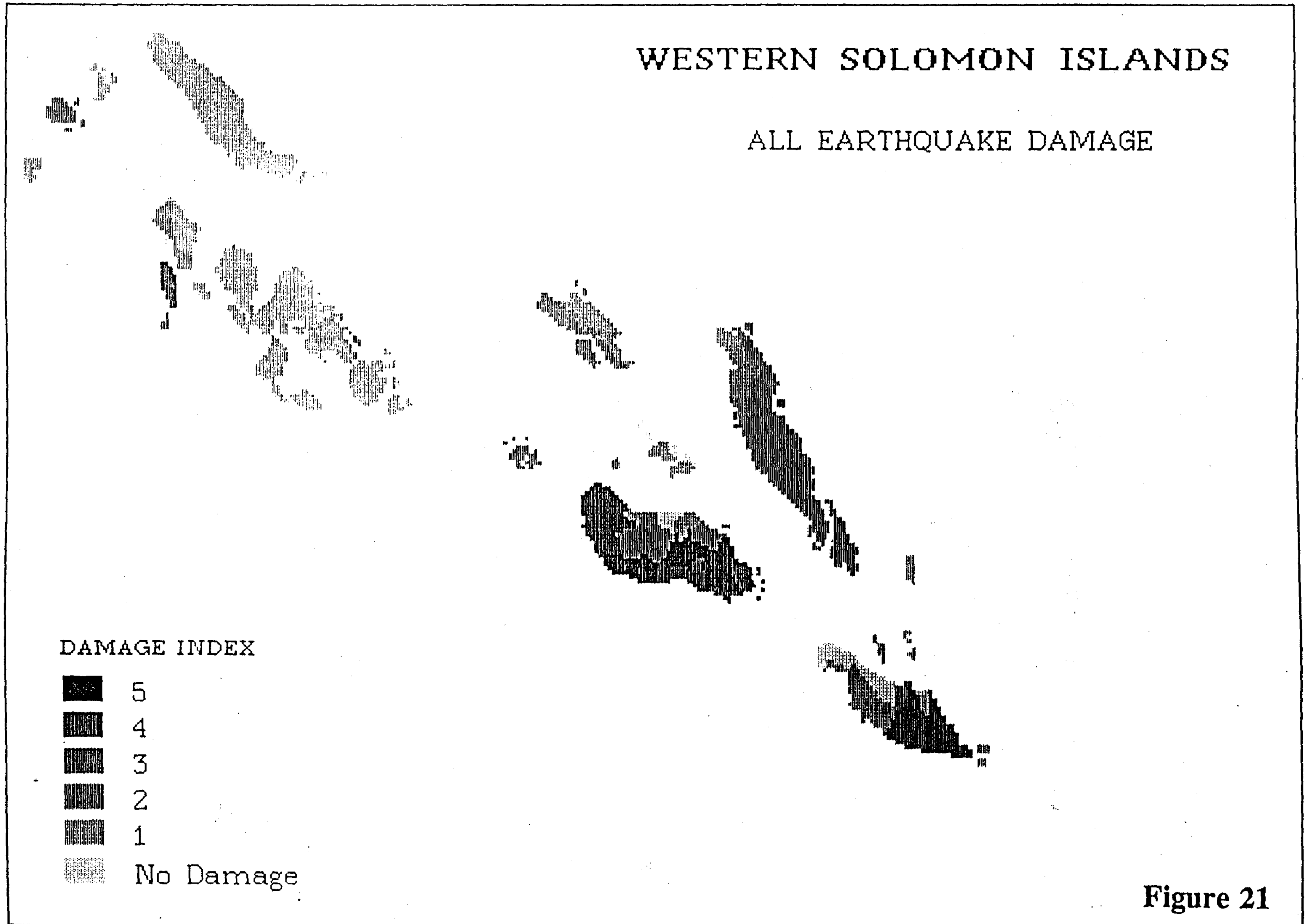

WESTERN SOLOMON ISLANDS
ALL EARTHQUAKE DAMAGE
DAMAGE INDEX
5
4
3
2
1
No Damage

Figure 21

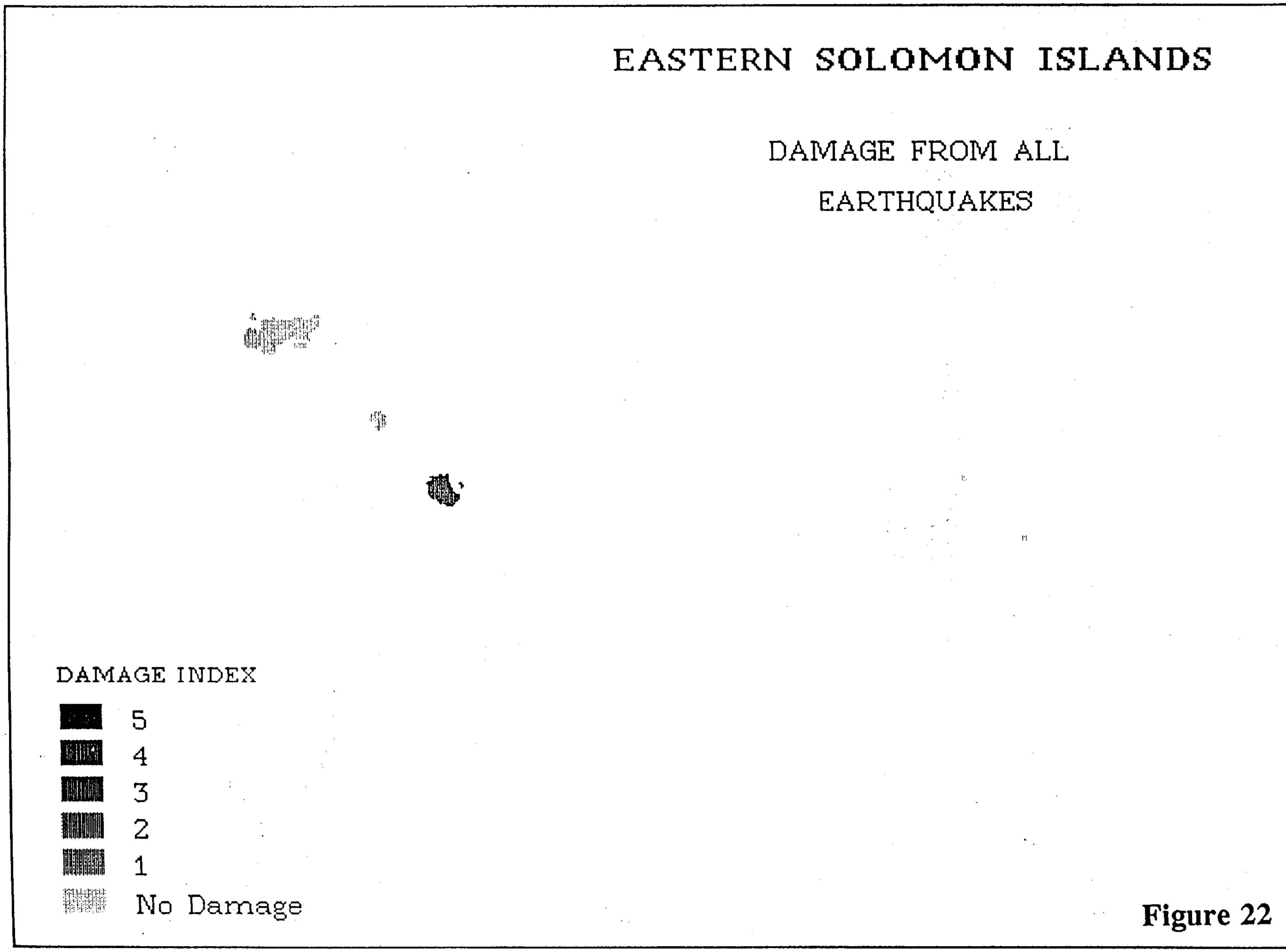
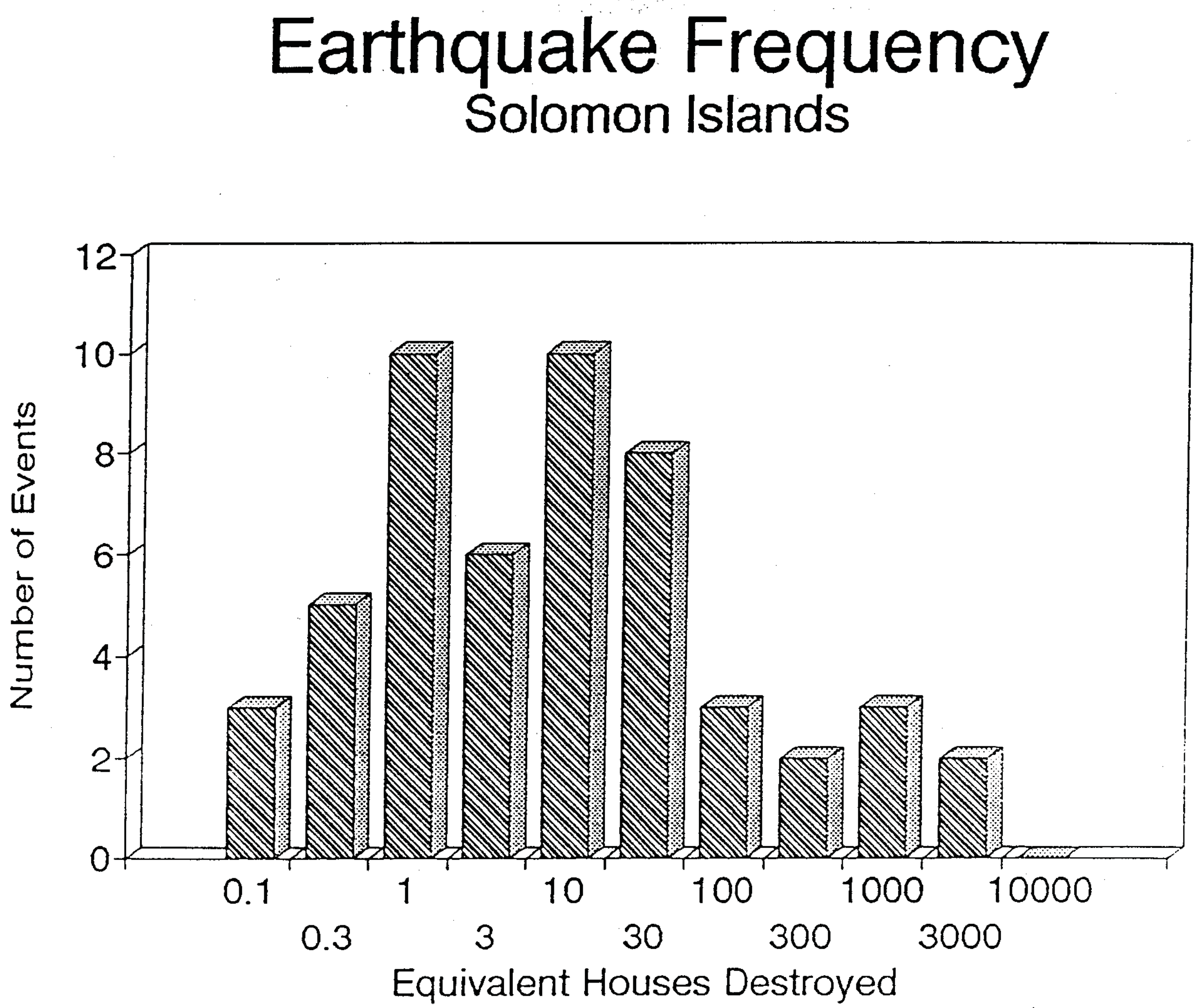
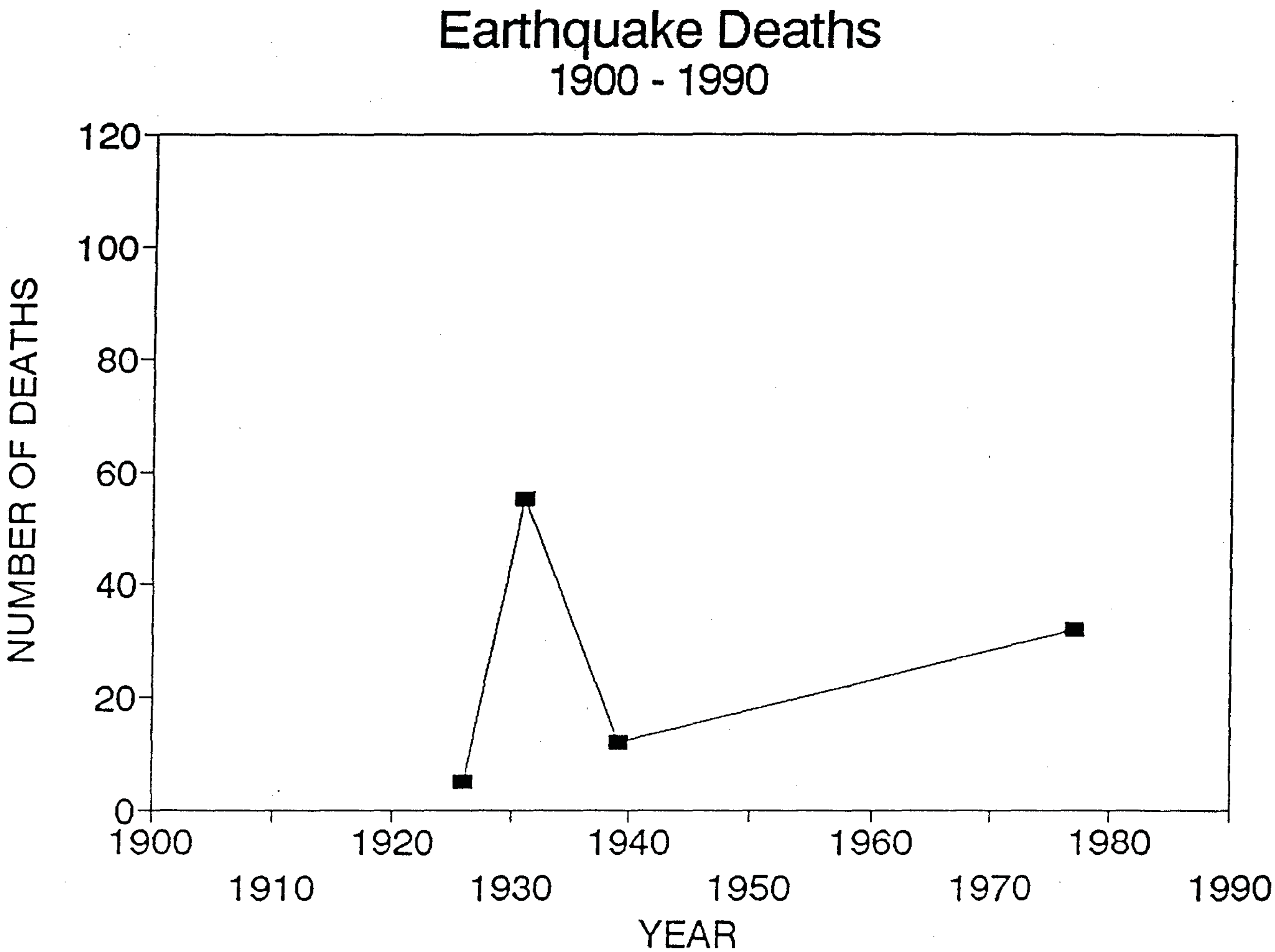

EASTERN SOLOMON ISLANDS
DAMAGE FROM ALL
EARTHQUAKES
DAMAGE INDEX
5
4
3
2
1
No Damage

Figure 22



Earthquake Frequency
Solomon Islands
Number of Events
0
2
4
6
8
10
12
0.1
0.3
1
3
10
30
100
300
1000
3000
10000
Equivalent Houses Destroyed

Figure 23



Earthquake Deaths
1900 - 1990
NUMBER OF DEATHS
0
20
40
60
80
100
120
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
YEAR

Figure 24

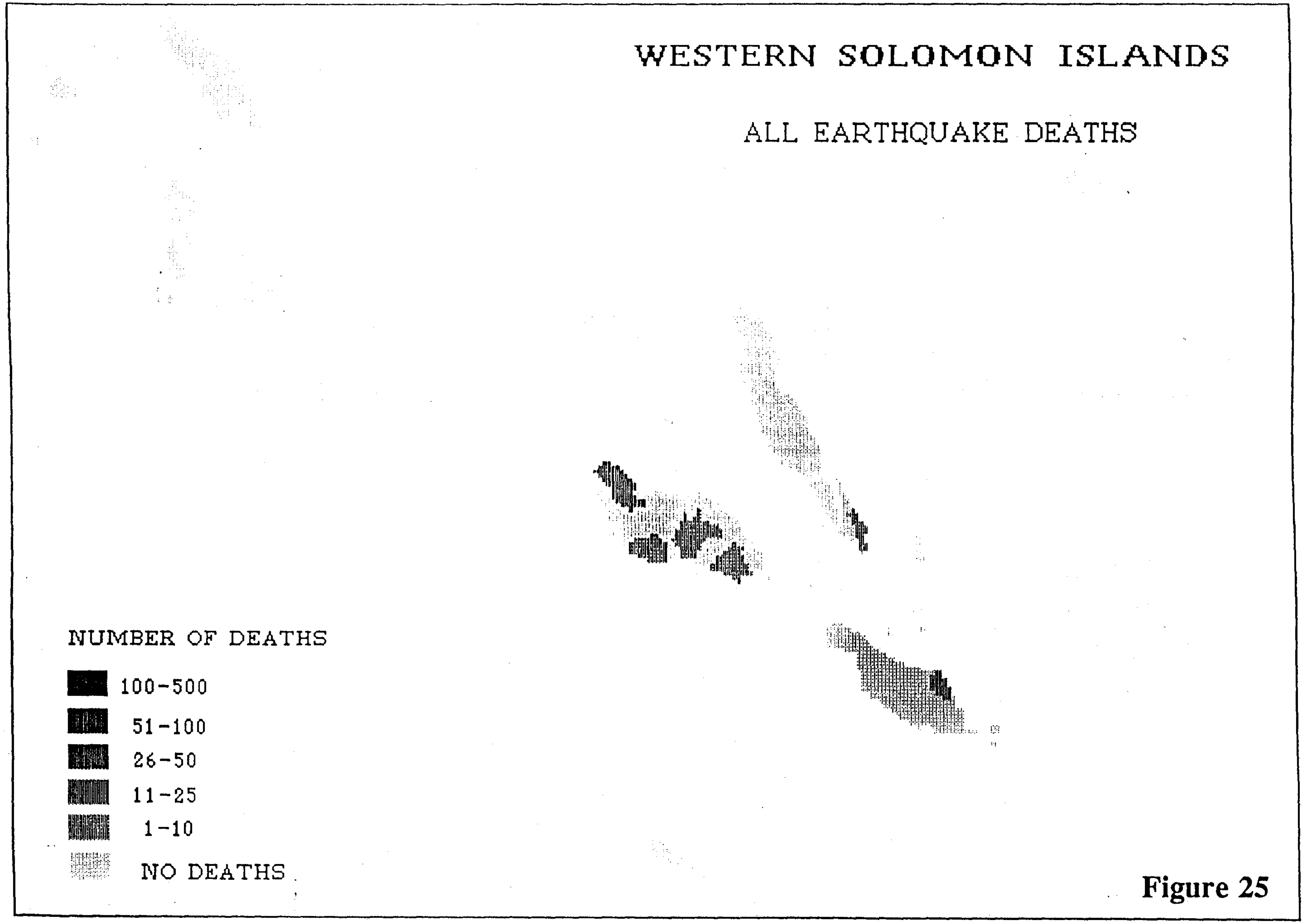
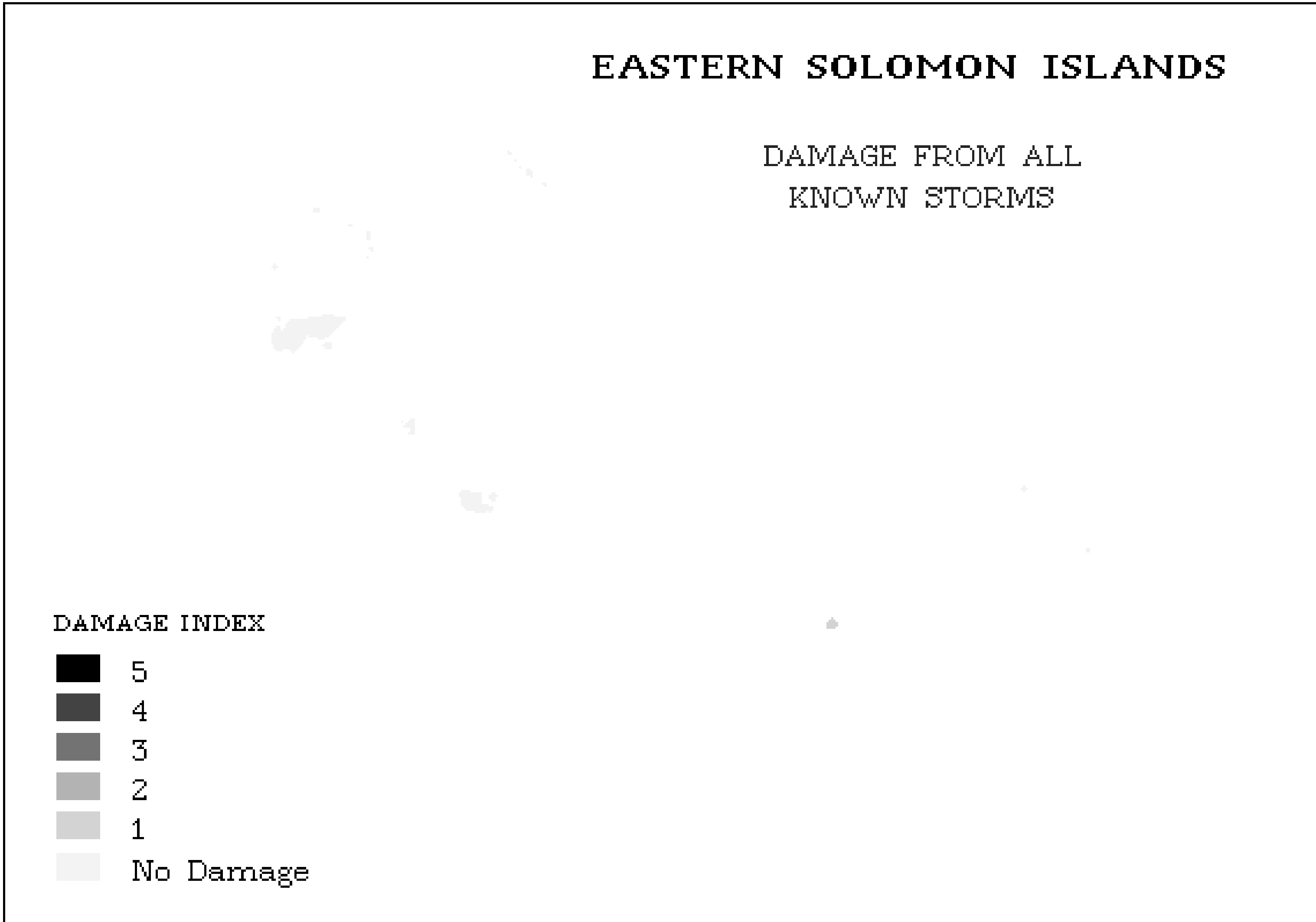

WESTERN SOLOMON ISLANDS
ALL EARTHQUAKE DEATHS
NUMBER OF DEATHS
100-500
51-100
26-50
11-25
1-10
NO DEATHS

Figure 25


WESTERN SOLOMON ISLANDS
DAMAGE FROM ALL
KNOWN STORMS
DAMAGE INDEX
5
4
3
2
1
No Damage


EASTERN SOLOMON ISLANDS
DAMAGE FROM ALL
KNOWN STORMS
DAMAGE INDEX
5
4
3
2
1
No Damage

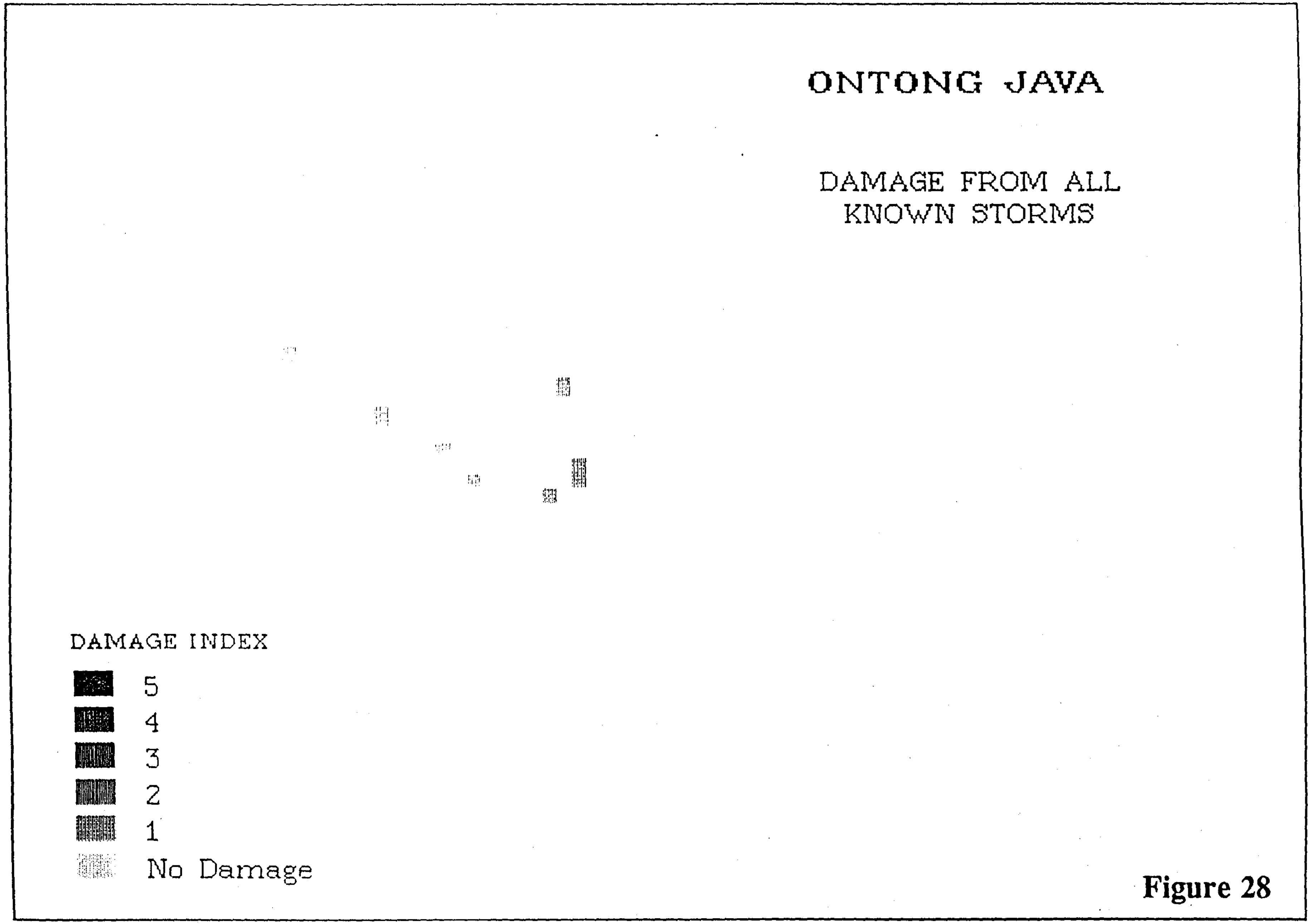

ONTONG JAVA
DAMAGE FROM ALL
KNOWN STORMS
DAMAGE INDEX
5
4
3
2
1
No Damage

Figure 28

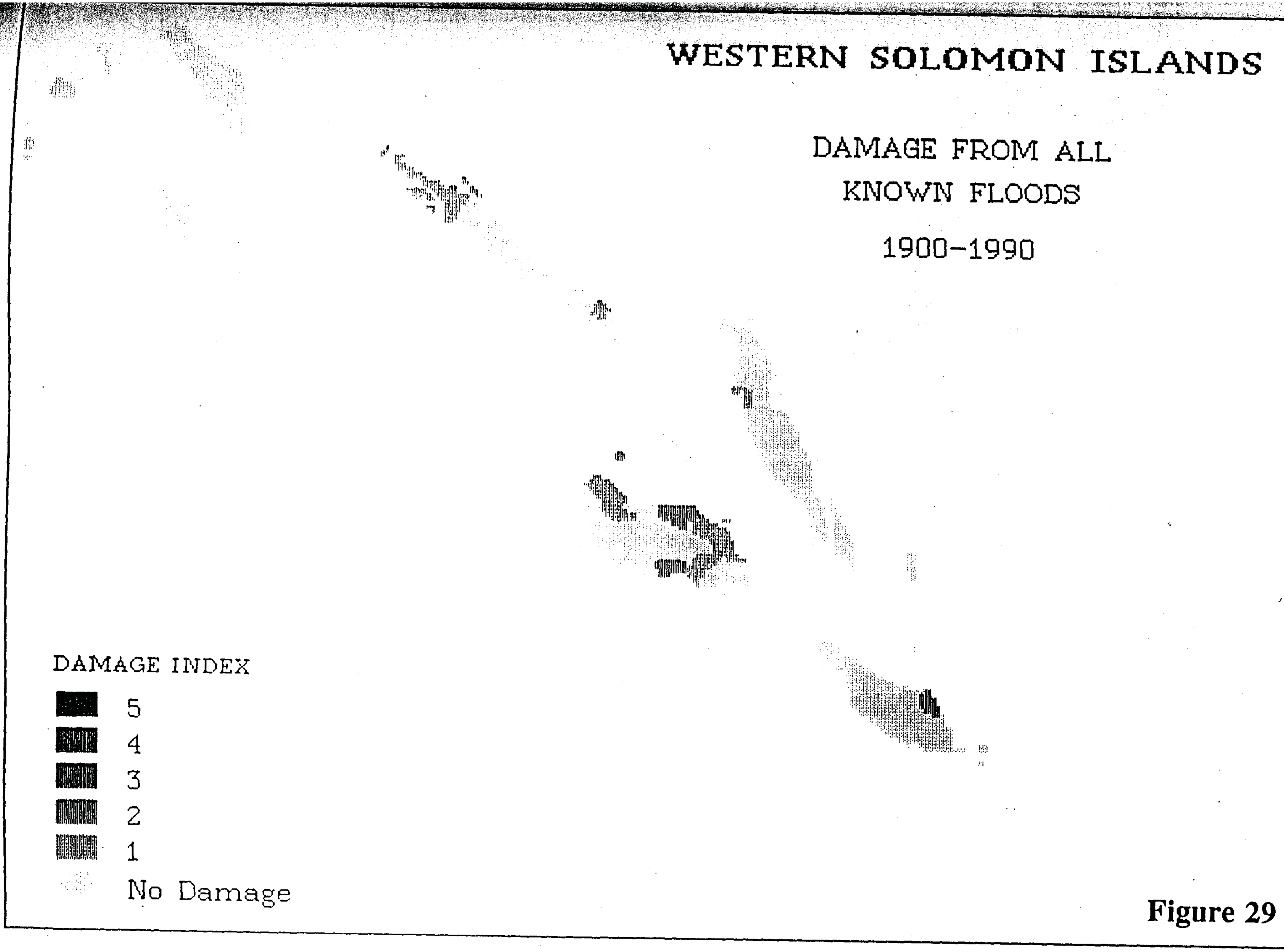

WESTERN SOLOMON ISLANDS
DAMAGE FROM ALL
KNOWN FLOODS
1900–1990
DAMAGE INDEX
5
4
3
2
1
No Damage

Figure 29

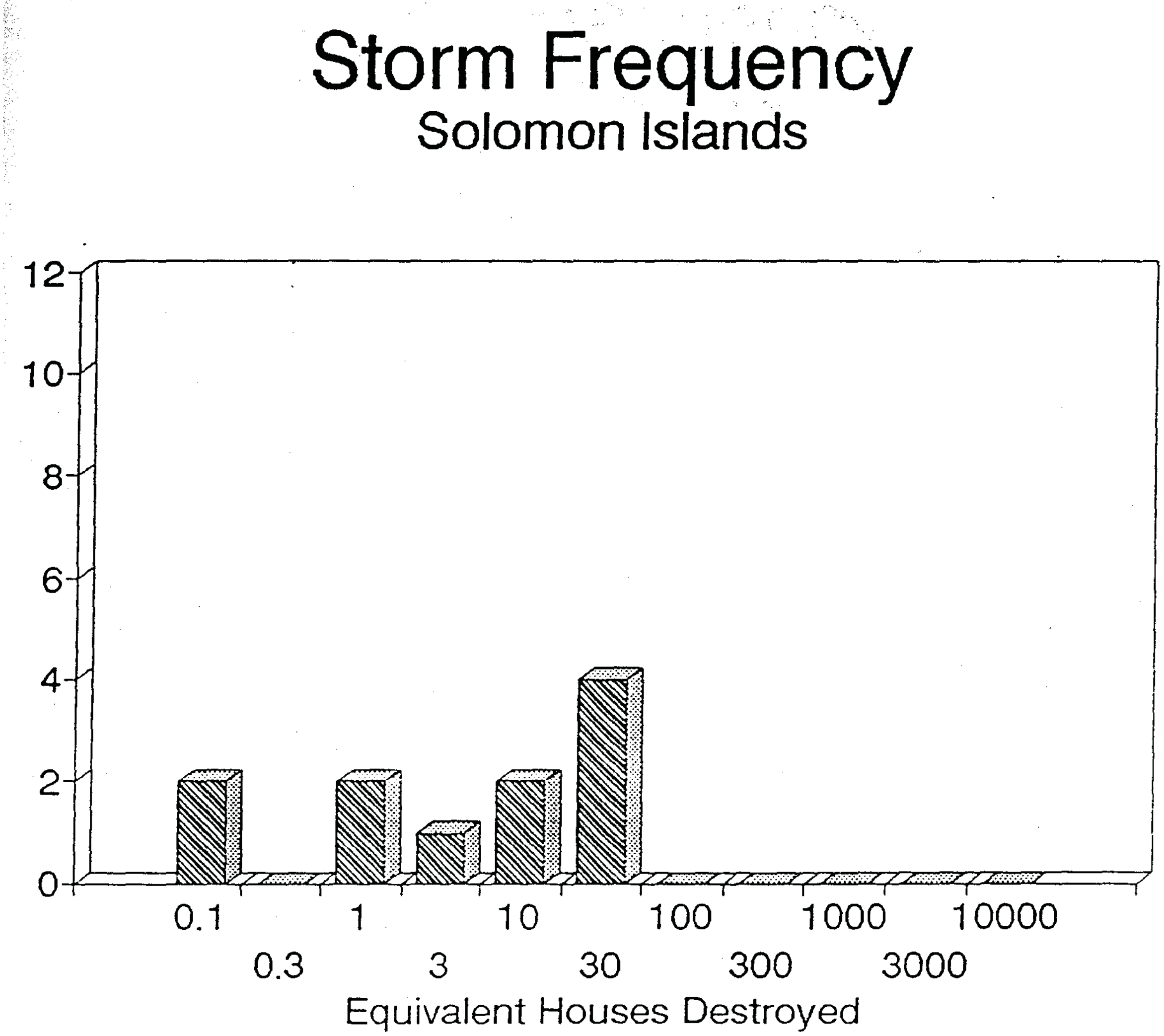
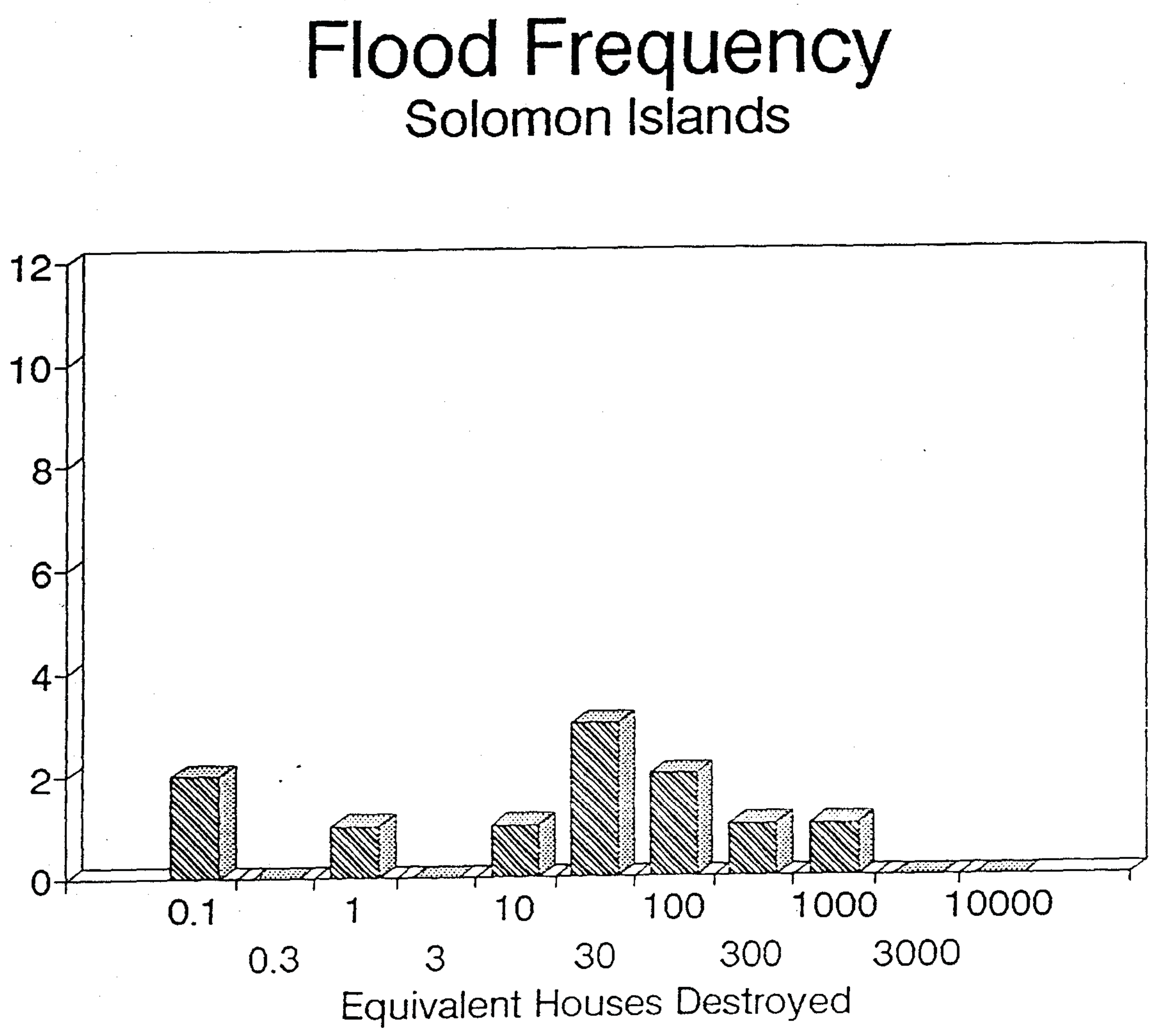

Storm Frequency
Solomon Islands
12
10
8
6
4
2
0
0.1
1
10
100
1000
10000
0.3
3
30
300
3000
Equivalent Houses Destroyed

Figure 30



Flood Frequency
Solomon Islands
12
10
8
6
4
2
0
0.1
1
10
100
1000
10000
0.3
3
30
300
3000
Equivalent Houses Destroyed

Figure 31

Storm Deaths
1780-1990

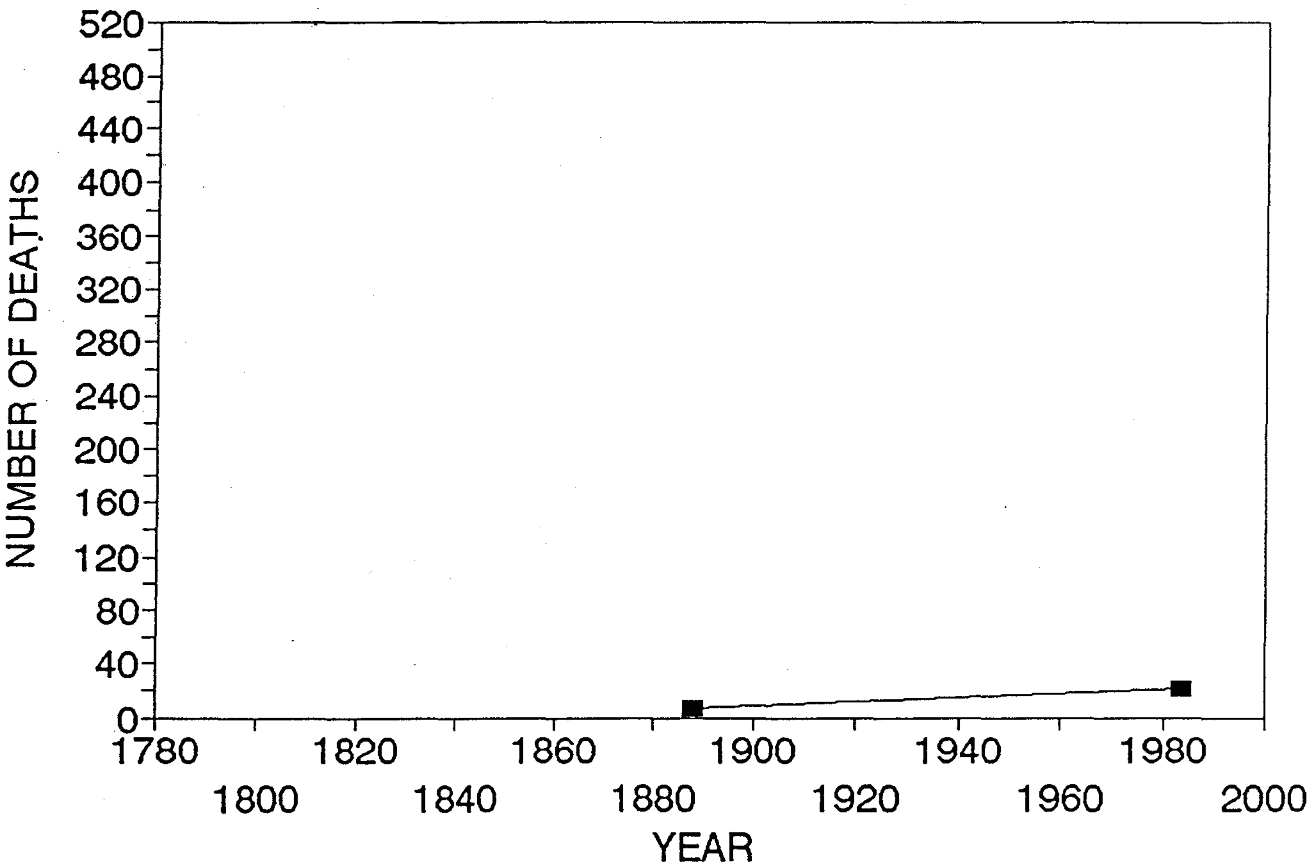
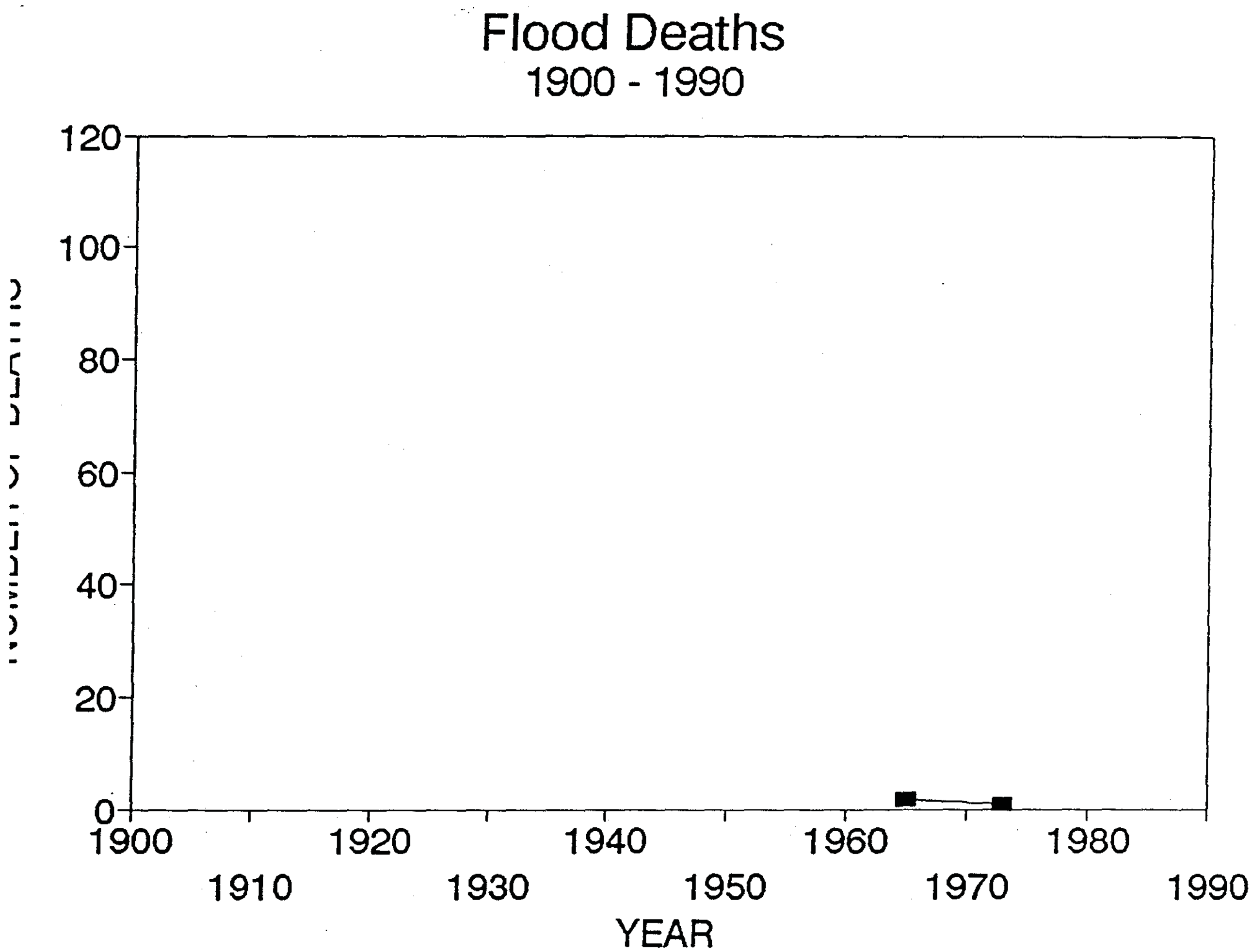


Figure [illegible]



Flood Deaths
1900 - 1990
120
100
80
60
40
20
0
1900
1920
1940
1960
1980
1910
1930
1950
1970
1990
YEAR

Figure 33

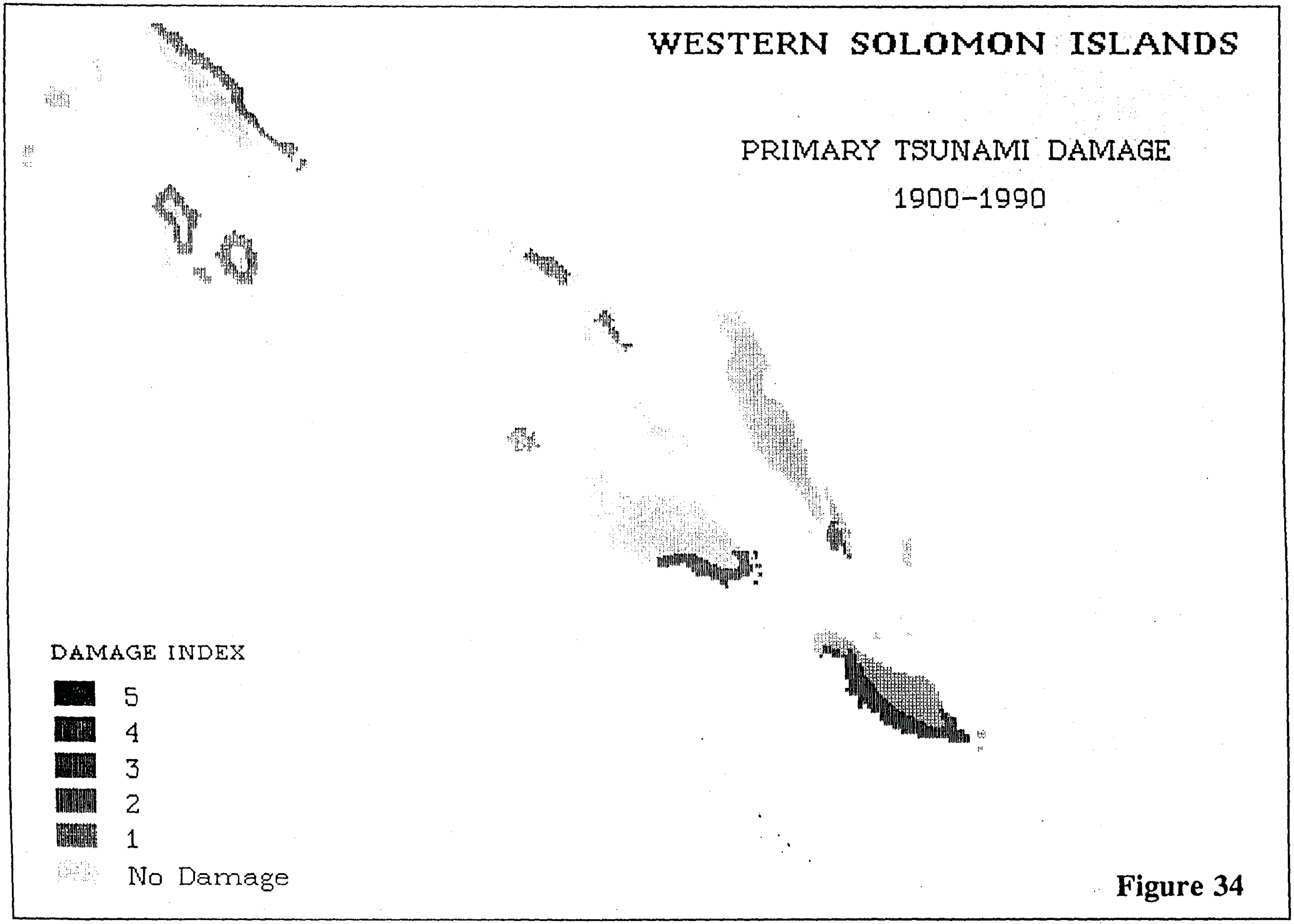

WESTERN SOLOMON ISLANDS
PRIMARY TSUNAMI DAMAGE
1900-1990
DAMAGE INDEX
5
4
3
2
1
No Damage

Figure 34

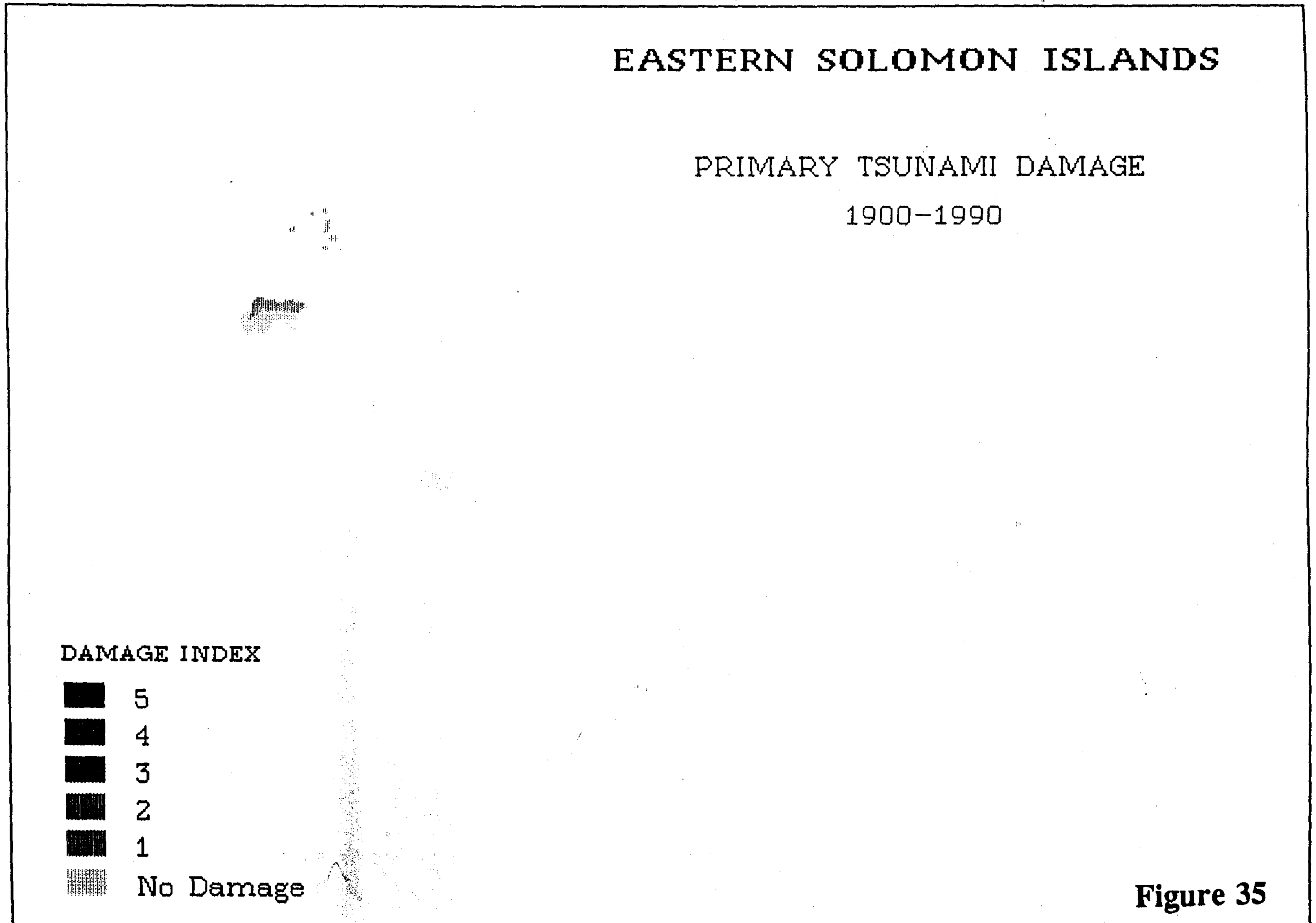

EASTERN SOLOMON ISLANDS
PRIMARY TSUNAMI DAMAGE
1900-1990
DAMAGE INDEX
5
4
3
2
1
No Damage

Figure 35

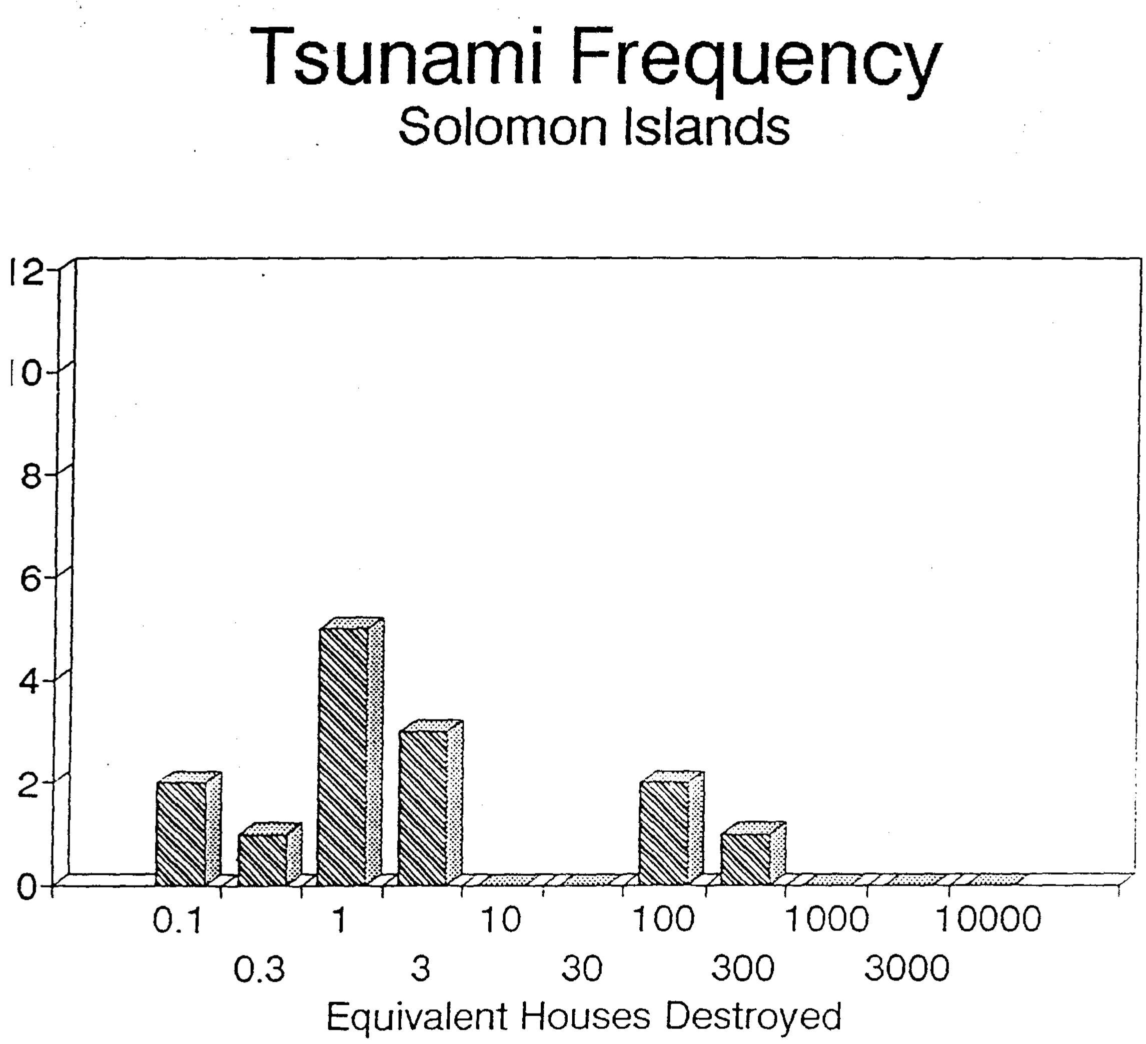
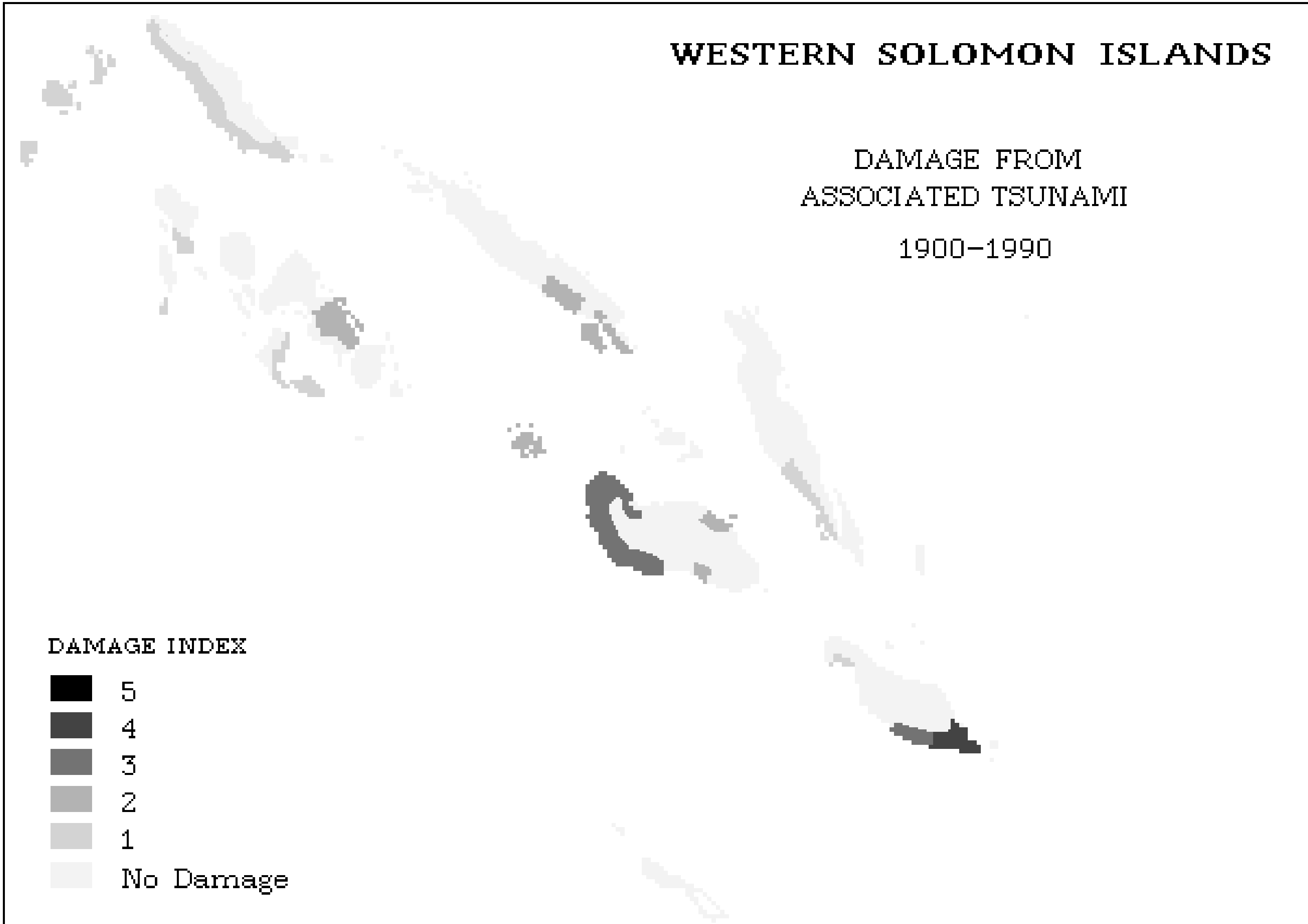
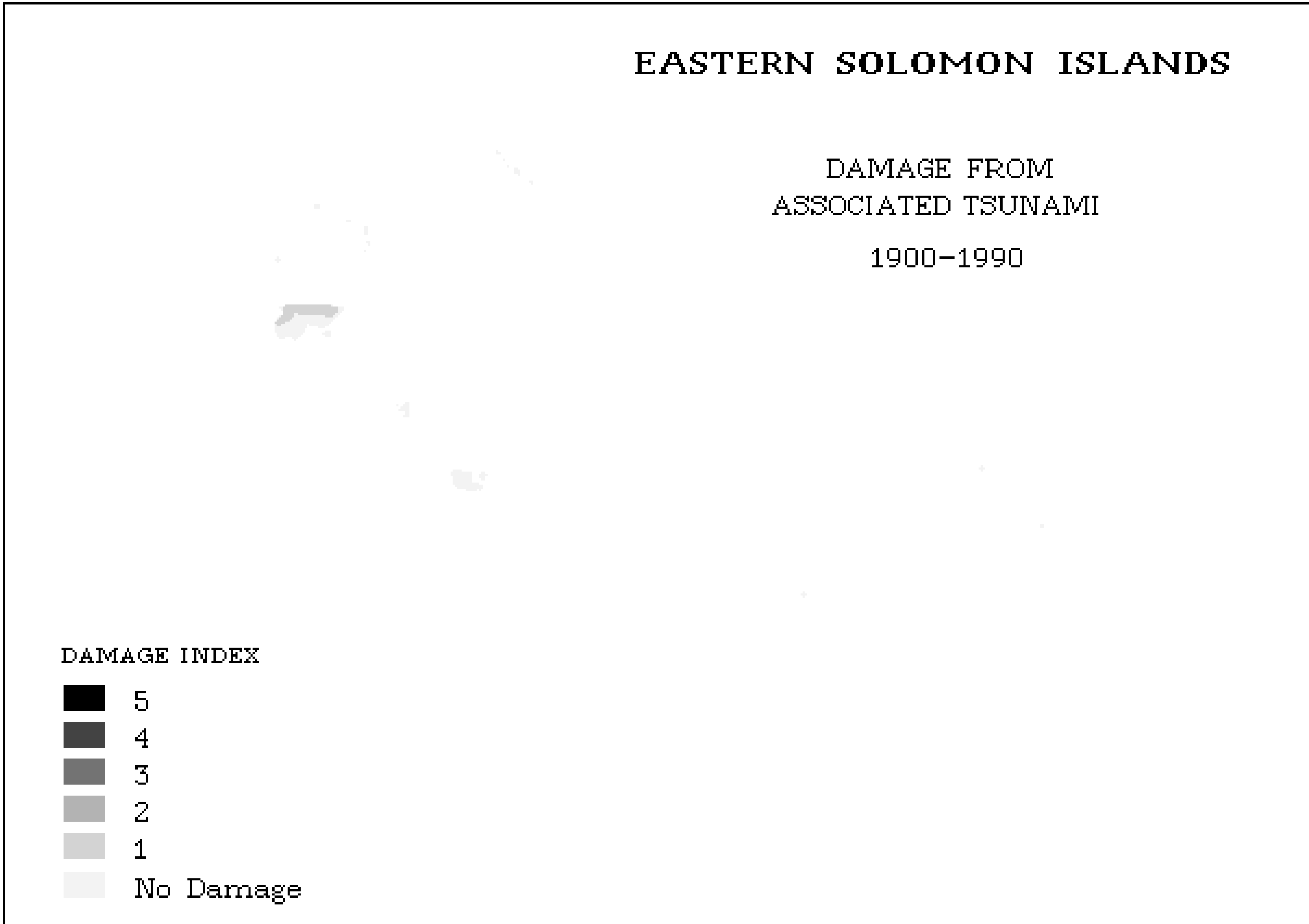

Tsunami Frequency
Solomon Islands
12
10
8
6
4
2
0
0.1
0.3
1
3
10
30
100
300
1000
3000
10000
Equivalent Houses Destroyed

Figure 36


WESTERN SOLOMON ISLANDS
DAMAGE FROM
ASSOCIATED TSUNAMI
1900–1990
DAMAGE INDEX
5
4
3
2
1
No Damage


EASTERN SOLOMON ISLANDS
DAMAGE FROM
ASSOCIATED TSUNAMI
1900–1990
DAMAGE INDEX
5
4
3
2
1
No Damage

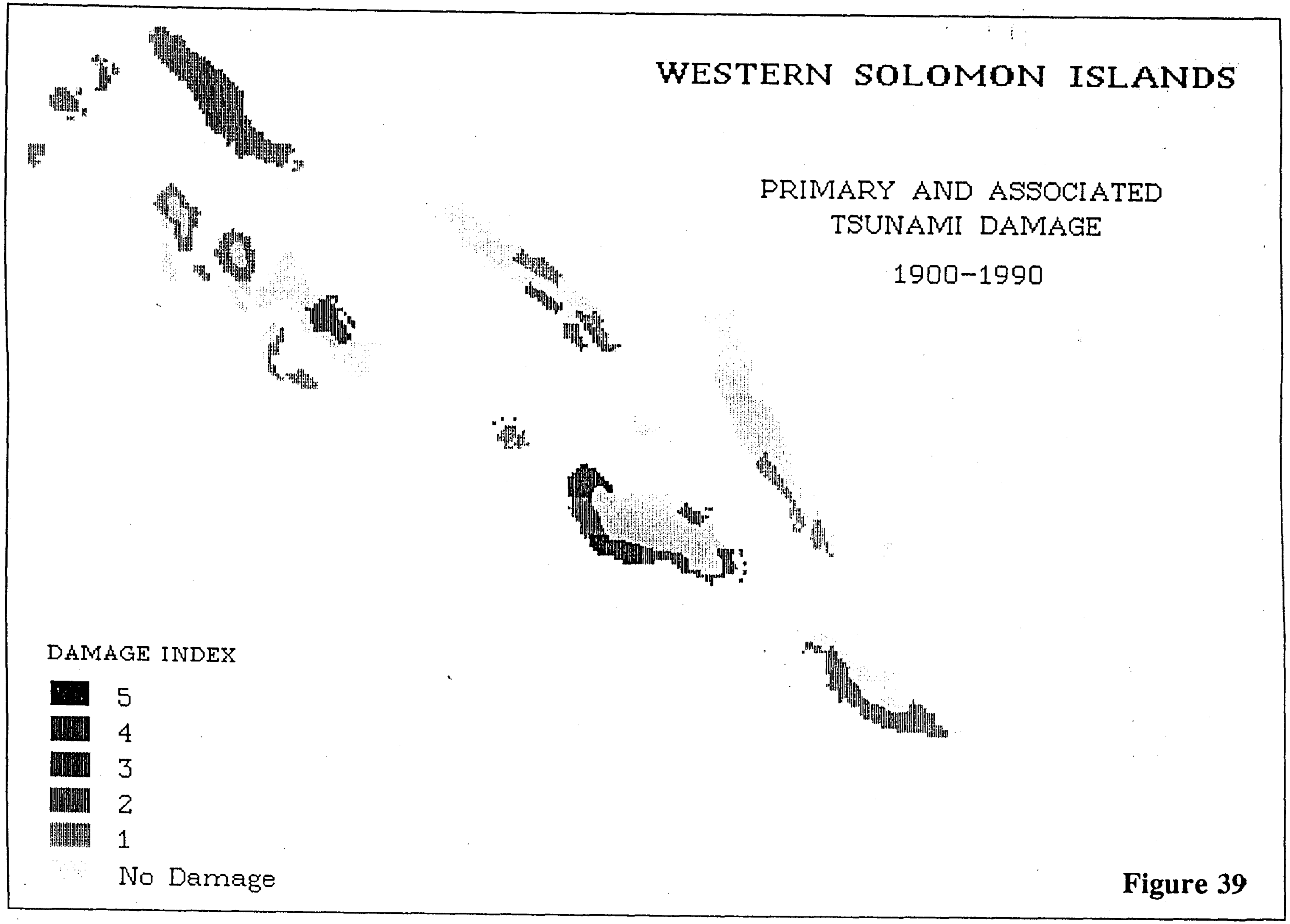

WESTERN SOLOMON ISLANDS
PRIMARY AND ASSOCIATED
TSUNAMI DAMAGE
1900-1990
DAMAGE INDEX
5
4
3
2
1
No Damage

Figure 39

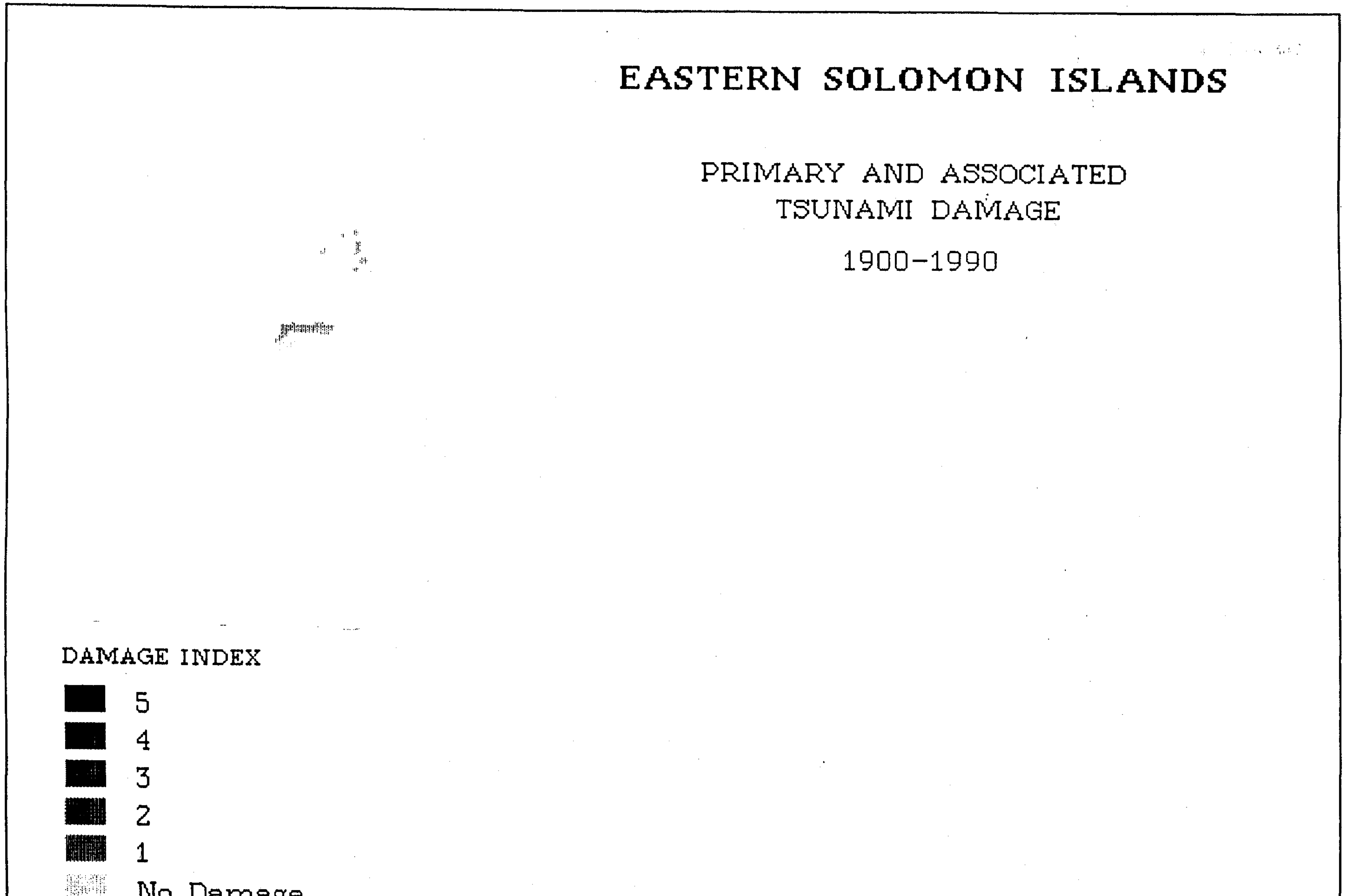
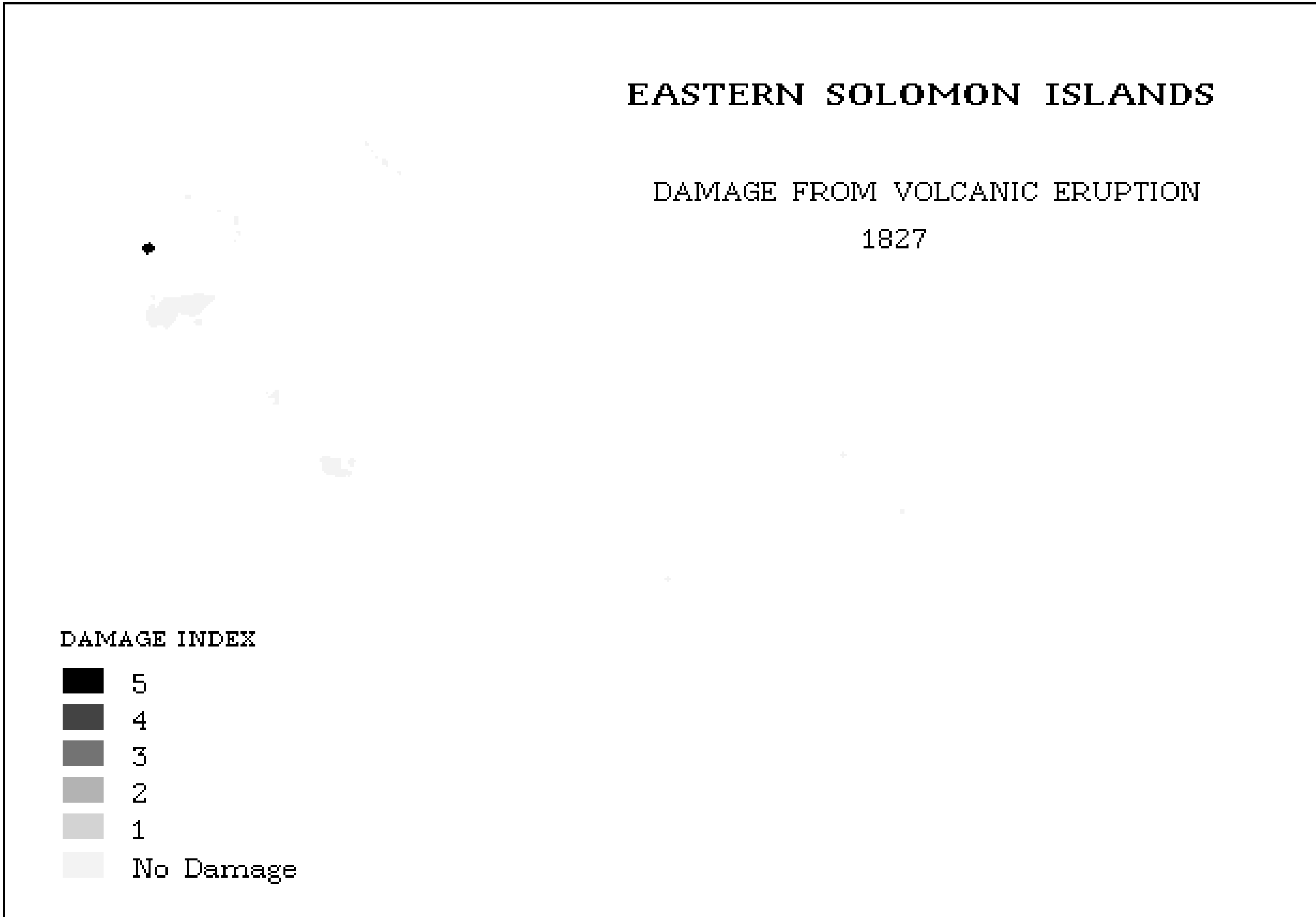
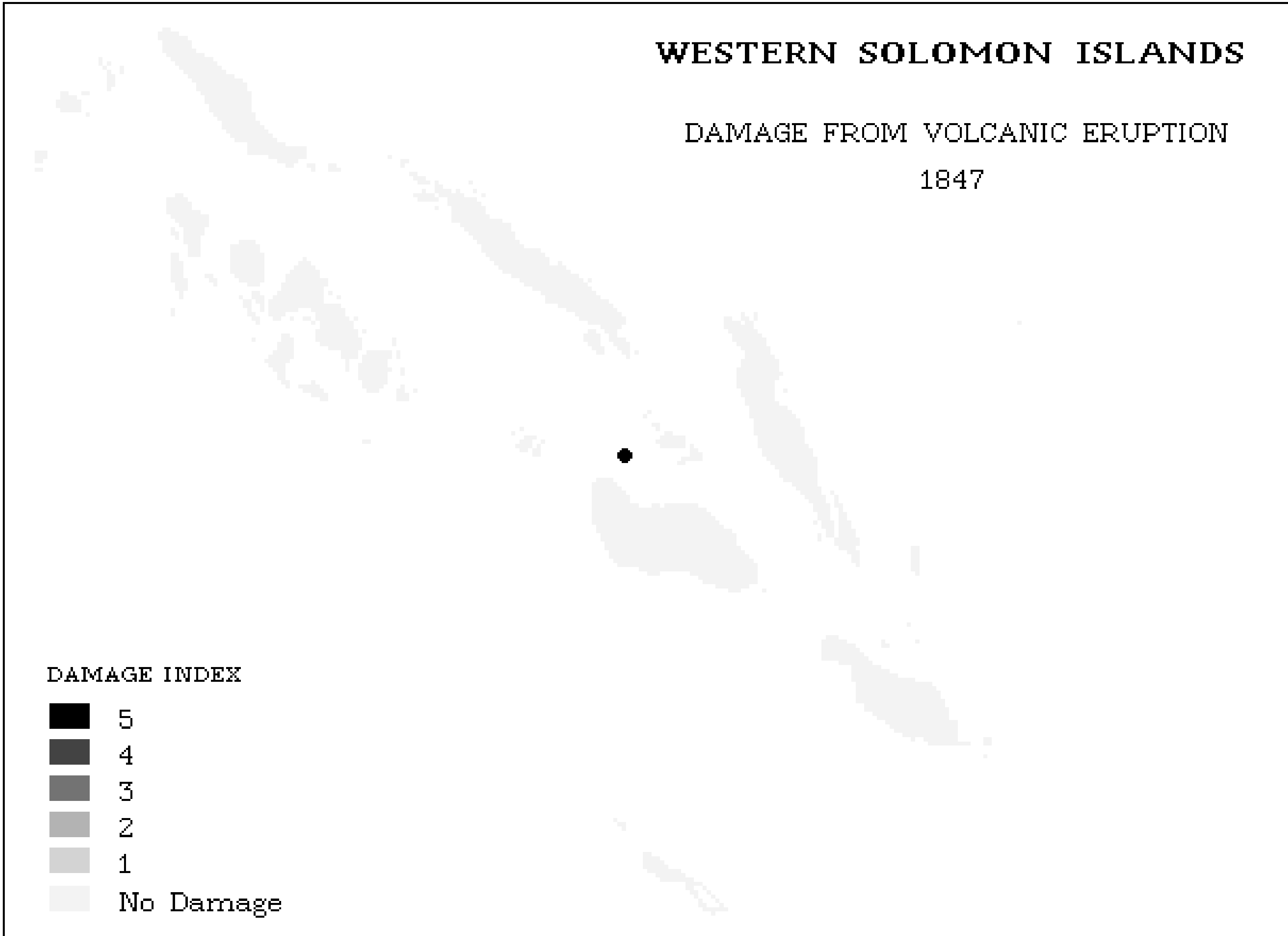

EASTERN SOLOMON ISLANDS
PRIMARY AND ASSOCIATED
TSUNAMI DAMAGE
1900-1990
DAMAGE INDEX
5
4
3
2
1
No Damage

Figure 40


EASTERN SOLOMON ISLANDS
DAMAGE FROM VOLCANIC ERUPTION
1827
DAMAGE INDEX
5
4
3
2
1
No Damage


WESTERN SOLOMON ISLANDS
DAMAGE FROM VOLCANIC ERUPTION
1847
DAMAGE INDEX
5
4
3
2
1
No Damage

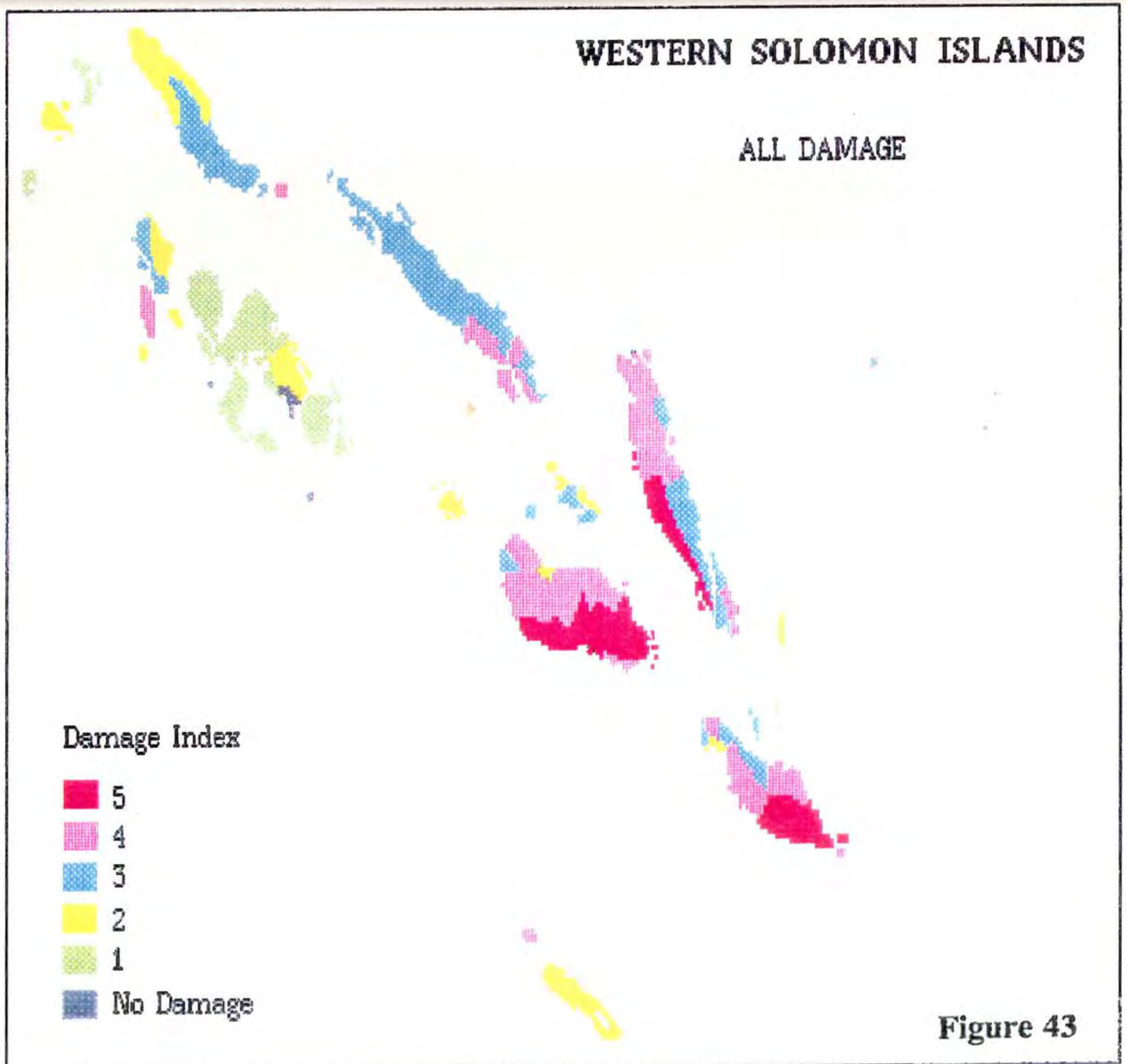

WESTERN SOLOMON ISLANDS
ALL DAMAGE
Damage Index
5
4
3
2
1
No Damage

Figure 43

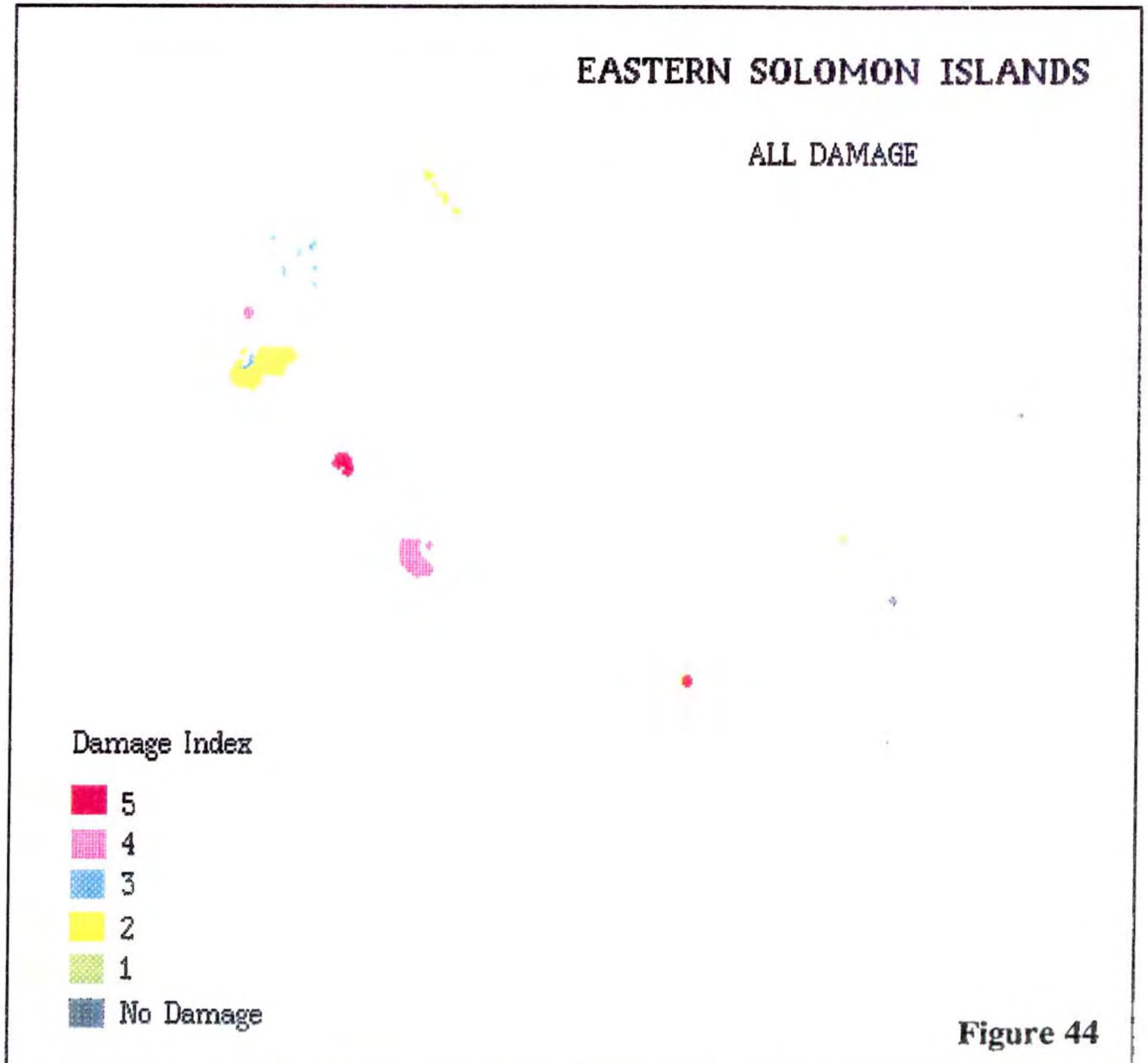

EASTERN SOLOMON ISLANDS
ALL DAMAGE
Damage Index
5
4
3
2
1
No Damage

Figure 44

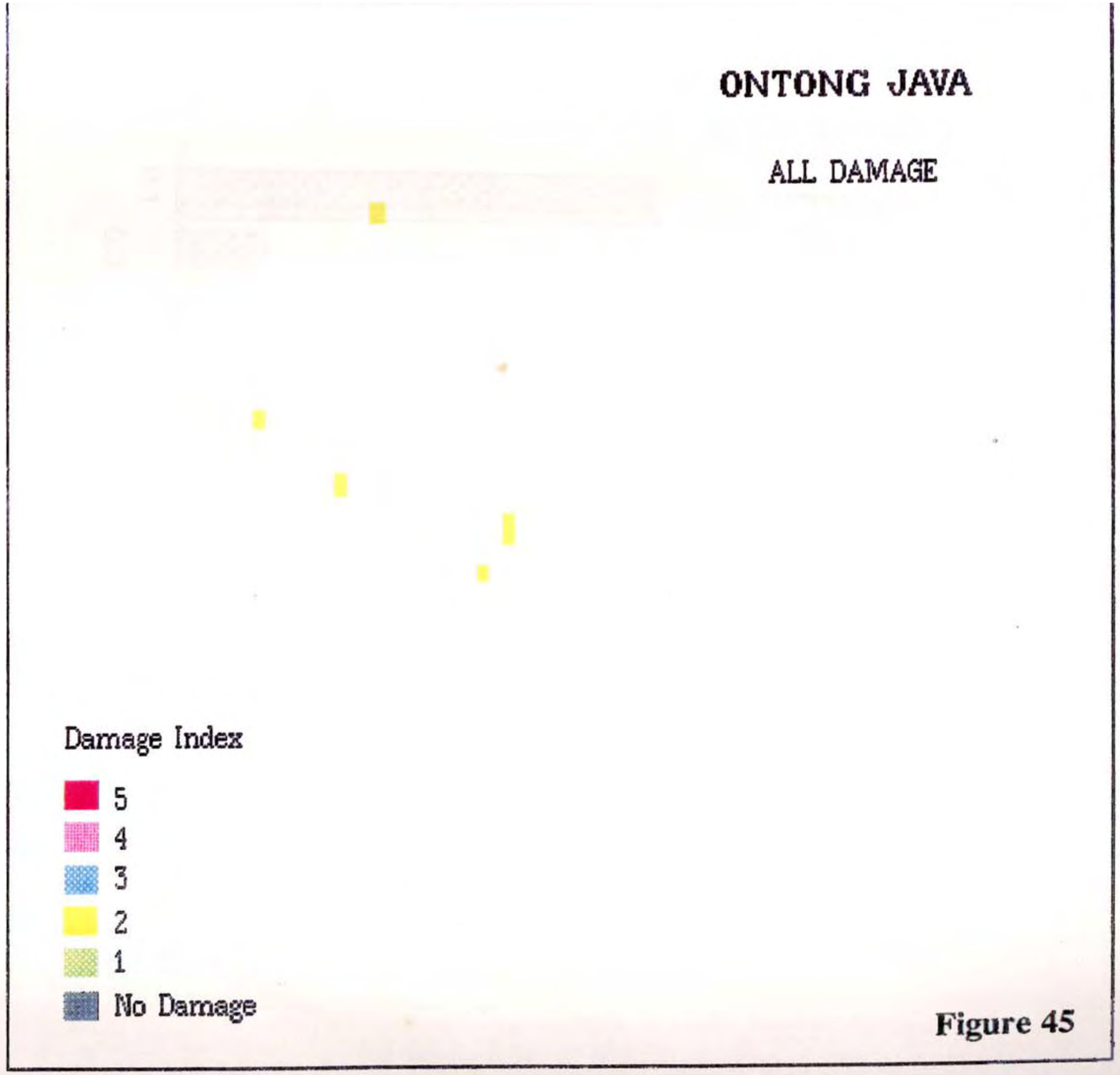


Figure 45

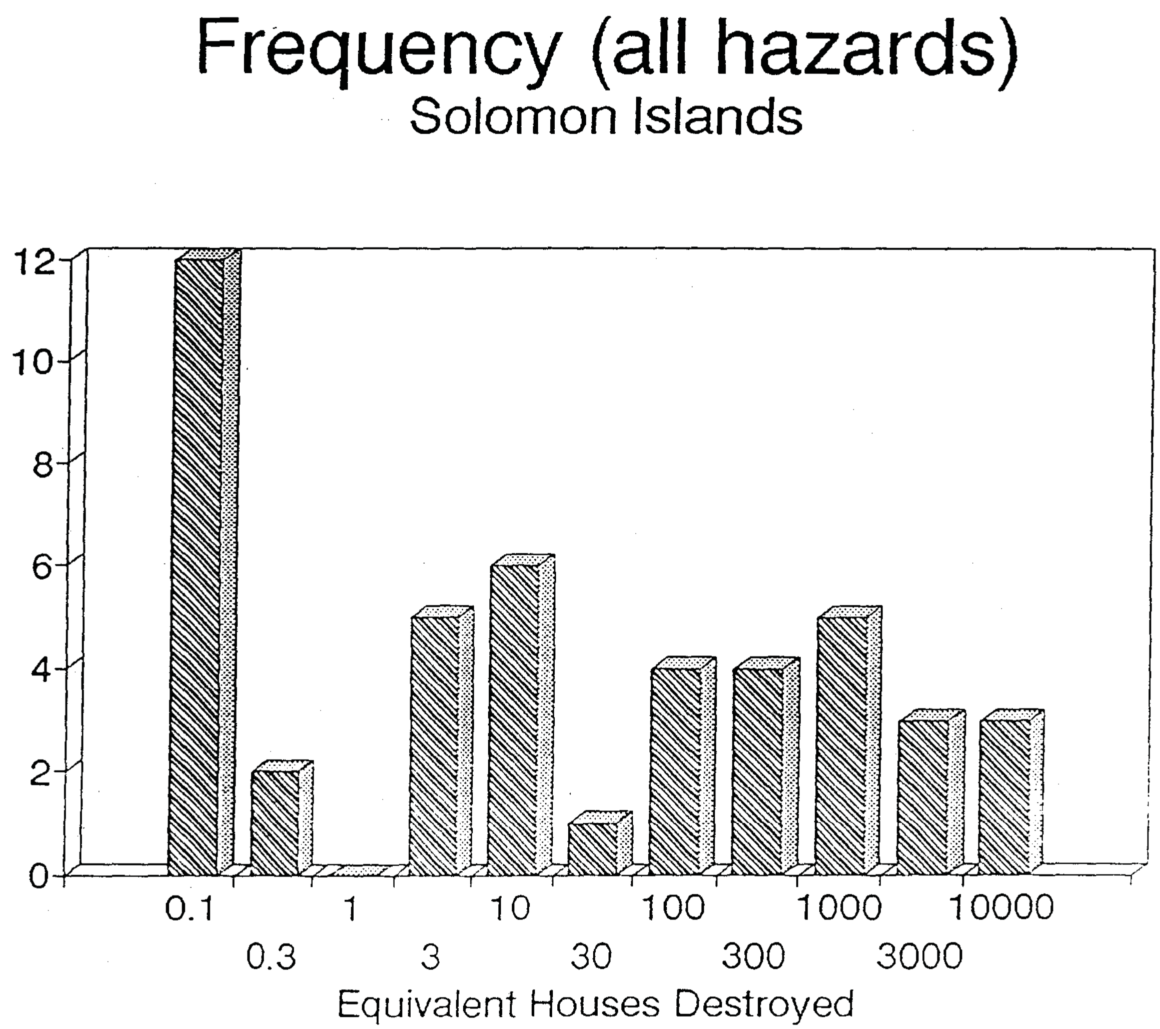

Frequency (all hazards)
Solomon Islands
12
10
8
6
4
2
0
0.1
0.3
1
3
10
30
100
300
1000
3000
10000
Equivalent Houses Destroyed

Figure 46

WESTERN SOLOMON ISLANDS

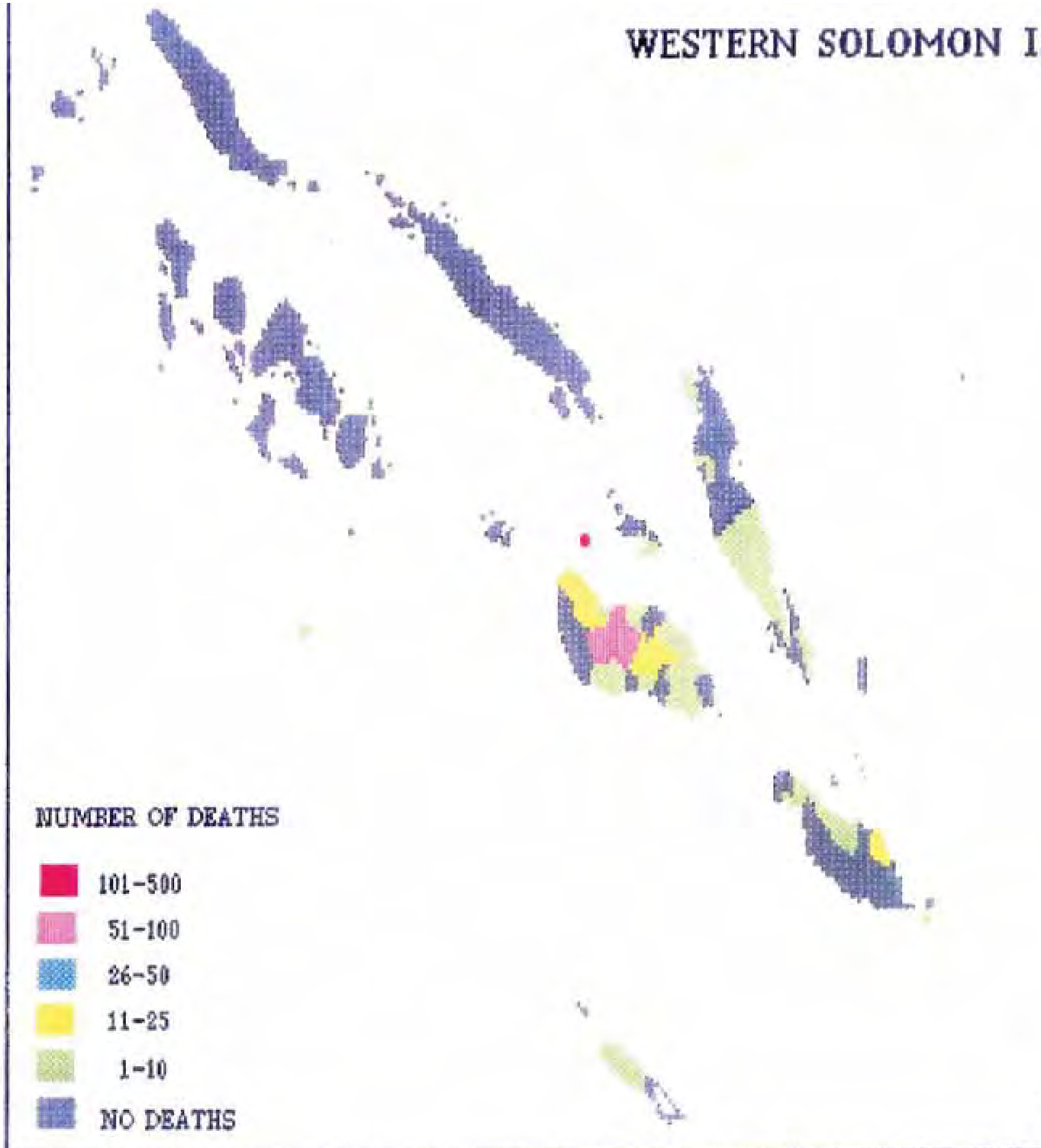


Figure 47

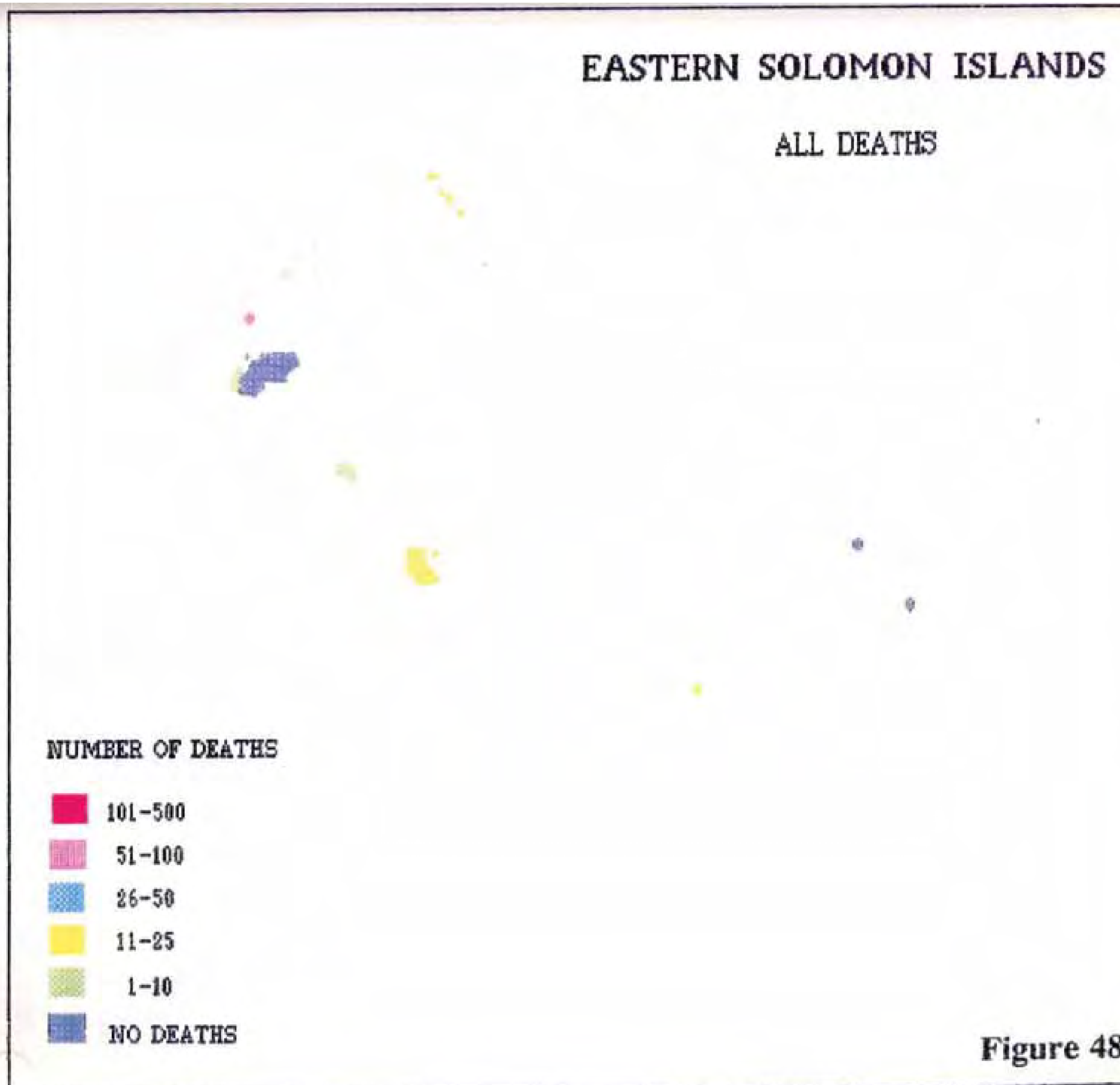
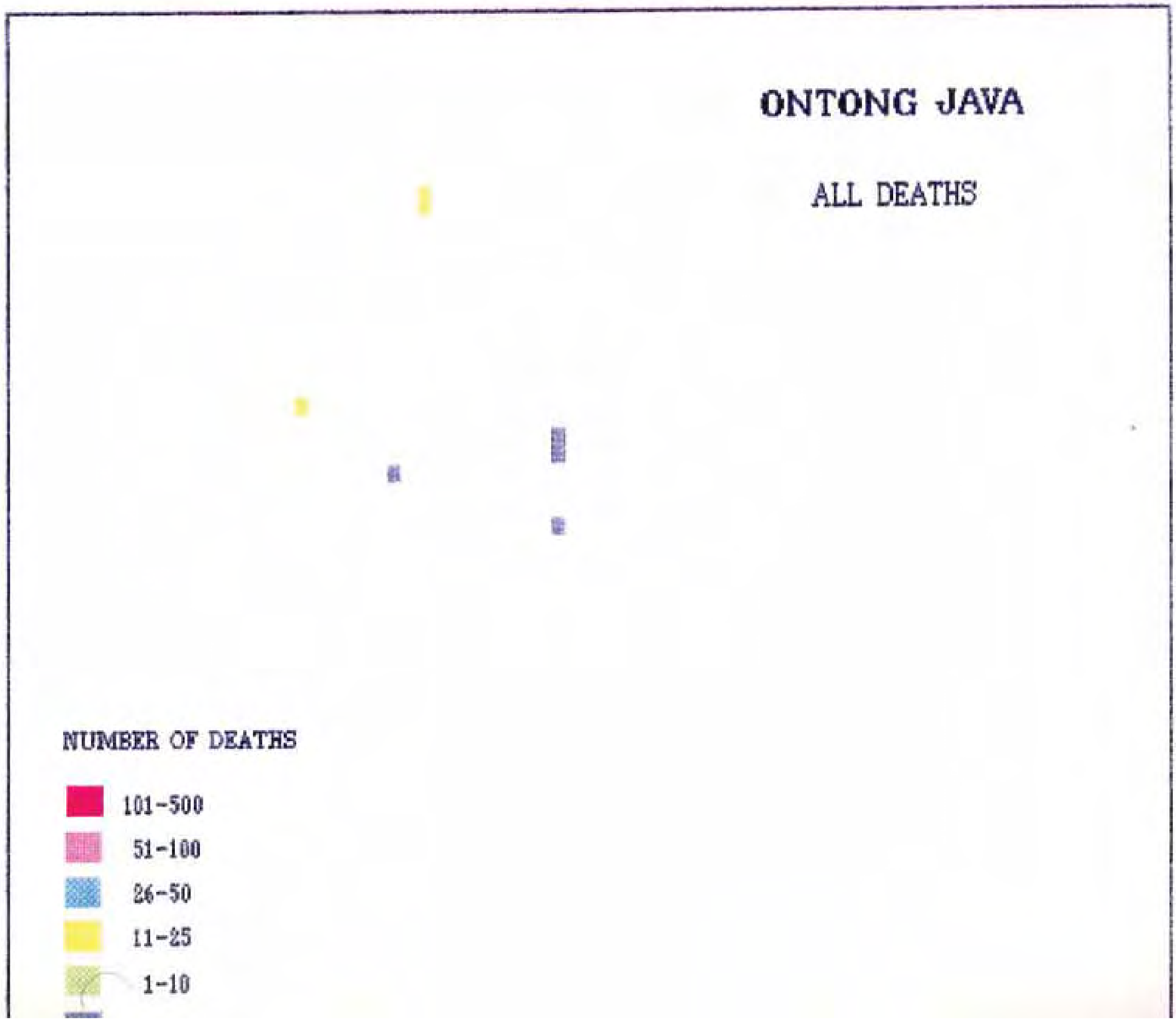
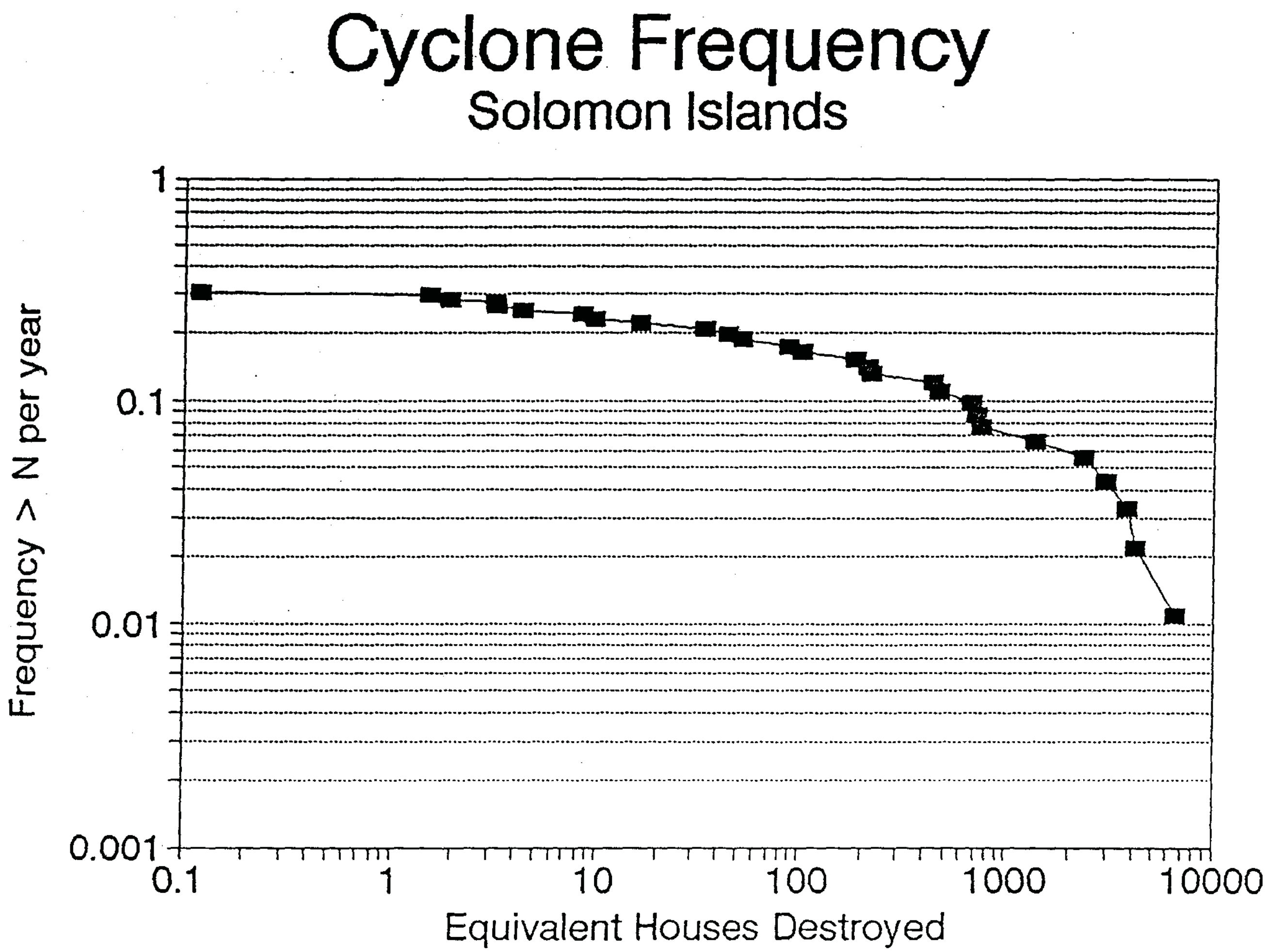

EASTERN SOLOMON ISLANDS
ALL DEATHS
NUMBER OF DEATHS
101-500
51-100
26-50
11-25
1-10
NO DEATHS

Figure 48


ONTONG JAVA
ALL DEATHS
NUMBER OF DEATHS
101-500
51-100
26-50
11-25
1-10



Cyclone Frequency
Solomon Islands
Frequency > N per year
1
0.1
0.01
0.001
0.1
1
10
100
1000
10000
Equivalent Houses Destroyed

Figure 50

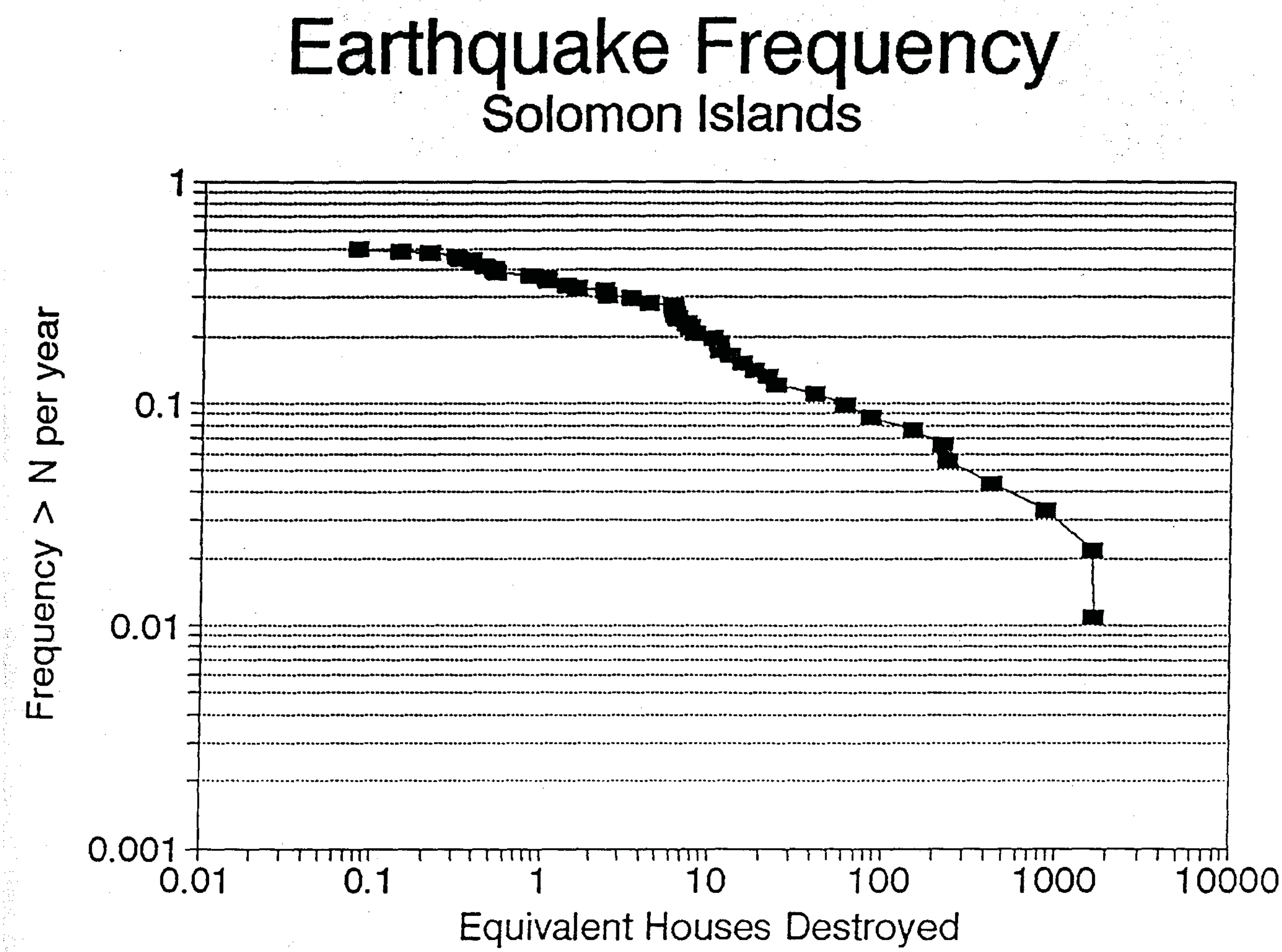

Earthquake Frequency
Solomon Islands
Frequency > N per year
1
0.1
0.01
0.001
0.01
0.1
1
10
100
1000
10000
Equivalent Houses Destroyed

Figure 51