way. To access to the SPC Coastal Fisheries Programme menu, go to:

http://www.spc.org.nc/coastfish/

Then scroll down to the bottom of that menu and open 'Newsletters'. Within that, select the title of this InfoBull: *Traditional Marine Resources Management and Knowledge*.

Kenneth Ruddle

Erratum

In the last issue (#9) of this bulletin a typo occurred in the article by Shankar Aswani (p. 19–26). The equation given by the author on page 23 should have read:

$$R = \sum_{i=1}^{n} (E_a - E_e)/(t)(n)$$

A methodology for incorporating traditional ecological knowledge with geographic information systems for marine resource management in the Pacific[1]

by Mark A. Calamia[2]

Introduction

In this article I describe a general methodology for documenting indigenous knowledge of Pacific Island coral reef biogeography, and for developing a conceptual framework on how to adapt this information to a Geographic Information System (GIS) database. In many parts of the Pacific, *de jure* control of marine resources is now vested in government agencies although *de facto* control of resources continues to reside with many local groups that manage resources through traditional means. As we shall see, local input is critical for effective GIS resource management applications.

Throughout Micronesia, Melanesia and Polynesia local traditional fishing strategies have been lost as result of acculturation, development, commercial fishing, and population growth. In some areas, attempts have been made to use many strategies that remain strategies to complement more contemporary management approaches. Results, such as those of the Hawaiian Coral Reef Initiative assessment of coral reef health, suggest that some coral reef habitats in Hawaii show evidence of degradation. The coral reef habitats there, as well as in other parts of the Pacific, may be adversely affected by commercial and recreational fisheries, SCUBA diving, snorkelling, aquarium fish collection, and onshore development. Suspected causes of coral reef impacts include an increase in use by rising numbers of residents and tourists as well as such natural factors as hurricanes. Pacific peoples have an opportunity to contribute traditional ecological knowledge that may be of direct benefit to scientists and nonscientists alike in the protection of reefs from some of these impacts. Opportunities for such involvement include the development of a geographic information database system, thereby offering islanders an active role in the ongoing management of these fragile marine ecosystems.

Traditional ecological knowledge (TEK) and geographic information technology for resource management

The practical importance of TEK

Although the preservation of TEK is important for social and cultural reasons as well as for resource conservation ones, there are also practical reasons why TEK is very important, apart from the ethical imperative of preserving cultural diversity. The International Union for Conservation of Nature and Natural Resources (IUCN) Program on Traditional Knowledge for Conservation (IUCN, 1986) summarises five practical and tangible benefits of TEK:

1. This article has been adapted from a longer work entitled 'Traditional Ecological Knowledge and Geographic Information Systems in the Use and Management of Hawaii's Coral Reefs and Fishponds' High Plains Applied Anthropologist 1996, 16(2): 144–164.

2. Mark A. Calamia, 6036 Bel Mar, El Paso, Texas, 79912 U.S.A.
E-mail: calamia_m@student.usp.ac.fj

- Traditional knowledge may be useful for new biological and ecological insights. New scientific knowledge is sometimes derived from perceptive studies of traditional environmental knowledge systems;

- Traditional knowledge for resource management is of great value. Much traditional knowledge is useful for contemporary natural resource management in areas such as tropical fisheries. In particular, rules and rote procedures developed by ancient resource managers and enforced by social and cultural means are often just as good as Western scientific prescriptions.

- Traditional knowledge is often used for protected areas and for conservation education. Protected areas may be designed to allow resident communities to continue their traditional lifestyles while enjoying the benefits of conservation. Where the local community is jointly involved in the protection of an area, the use of traditional knowledge for conservation education may be especially effective.

- With respect to development planning, traditional knowledge may benefit development agencies in providing more realistic evaluations of environment, natural resources, and production systems. Involving local people in the planning process improves the chances of successful development.

- Fifth, traditional knowledge is useful for environmental assessment. Local people who depend on local resources for their livelihood are in good positions to assess the true costs and benefits of development better than outside researchers. Their knowledge of the local area is a crucial aspect of any impact assessment.

Johannes (1993) presents a methodology for using ethnoscientific information for environmental impact assessment: traditional ecological knowledge and management system (TEKMS). In his approach, he recommends that four frames of reference be thoroughly considered during field work: taxonomic, spatial, temporal, and social. He notes that for the spatial frame of reference in environmental impact assessments, it is important to record the spatial distribution of living and non-living resources and amenities through detailed mapping.

The knowledge of local users is valuable in this context, especially in places where there is little recorded knowledge of local environments. Thus, the integration of information from sources such as satellite imagery, aerial photography or digital images, and TEKMS allows for an important opportunity to apply traditional ecological knowledge to environmental impact assessment (Johannes, 1993:34).

The social frame of reference also deserves some comment. This frame of reference refers to the manner in which local residents perceive, use, allocate, transfer, and manage their resources. TEK must be viewed within the social and political structure in which it is found. As such, environmental impact assessments should address the direct environmental impacts of a project as well as the impacts of altered human access to natural resources. The latter is contingent upon the nature or the absence of a traditional conservation ethic among indigenous people (Johannes, 1993:35).

By using TEK in management practices, Western societies may enhance their appreciation of the cultures that hold this knowledge. Furthermore, the documentation of such knowledge may be useful as a means for stimulating social change through policy development.

Indigenous peoples do have an enormous contribution to make in each of the five areas outlined above. However, it should be kept in mind that traditional knowledge is complementary to western science, not a replacement of it (Knudtson & Suzuki, 1992).

As discussed below, TEK can contribute to the conservation of coral reefs in Hawaii once the information has been converted to an automated information format that is spatially referenced. Because of different cognitive models and differences in access to economic resources, attempts at integrating TEK and scientific knowledge inevitably brings up the question of power-sharing in decision-making, a point that will be addressed at the end of this paper.

TEK, maps and GIS

Traditional peoples have also used TEK to represent the spatial dimension of important geographic features on the landscape and seascape. For thousands of years either hand-drawn or oral maps have been used for defining boundaries of homes as well as for depicting the location of important resource zones and sacred sites.

Bruno Adler, an early twentieth-century Russian cartographer, compiled or acquired 55 maps drawn on skin, wood, and paper by native peoples prior to contact with European explorers (de Hutorowicz, 1911). Gladwin (1970) and Lewis (1972) note that Micronesians created stick charts that showed complex representations of ocean tides and currents. Australian aborigines have developed songlines to sing their land into existence. These songlines also draw mental maps of historical events, significant places, and claims to territory (Chatwin, 1987).

More recently, spatial information has been used for understanding interrelationships between traditional human societies and ecological processes. In Manitoba, Canada, elders teach skills and maintain continuity and links to community resource areas by transferring highly detailed 'oral maps' and inventories of resource values and land use to their younger members. These individual and family maps also complement one another in such a way that they provide integrated knowledge of the ecosystems within the village's traditional resource area (Wavey, 1993:13).

In a study of mapping customary land in East Kalimantan, Indonesia, Sirait et al. (1994), found that the combined use of oral histories, sketch maps, and Geographic Information Systems (GIS) and Global Positioning Systems (GPS), is a useful methodology for mapping customary land tenure and comparing villagers' perceptions of land ownership and land use to those of the state.

A GIS is an organised collection of computer hardware, software, and geographic data designed to efficiently capture, store, update, retrieve, organise, manipulate, analyse, and display spatial information (Burrough, 1986).

As a computer tool, GIS allows for the integration of many 'layers' or overlays of spatial information, the development of dynamic models, the analysis of trends over time, the simulation of scenarios, and the development of predictive models. An important capability of GIS is to link, relate, and analyse spatial and attribute data. Because a GIS handles natural resource data as automated spatial features, it is possible to develop resource inventories which can be rapidly accessed and updated. The GIS can also be used to perform spatial queries on automated resource data such as determining where natural or cultural resources are located with respect to other resources, impacts, or hazards.

High tech mapping tools, resource management and ethnography

Some recent examples of high tech mapping applications for traditional and applied research show how cultural anthropologists have used GIS for regional data management and analysis (Stonich, 1996; McGwire et al., 1996). Using concepts of ecological anthropology, these studies addressed the problem of effectively integrating data from disparate sources, such as informant interviews, remotely sensed images, and participant observation. This was crucial for those researchers who were attempting to find ways to integrate the results of traditional anthropological investigation which is usually personal and small-scale with information obtained from regional-scale phenomena. Another concern was to develop an approach to effectively operationalise the ecosystem concept rather than simply use it as a general paradigm (Winterhalder & Evans, 1991).

In the field of development anthropology, there is the need to manage regional-scale data within anthropological inquiry (Aldenderfer, 1996). The spatial scale of the cultural entity affected by rapid change is often much larger than that dealt with in more traditional anthropological contexts.

Development anthropologists, on the other hand, must address changes taking place across regions and larger geographic spaces. Thus, more traditional forms of investigation, such as participant observation, must be supplemented by other types of survey instruments such as questionnaires.

GIS may serve as another approach to augment traditional anthropological work by automating spatial data that can be related directly to problems of anthropological inquiry. It also provides a common basis for sharing data across scientific disciplines. For example, in her study of a Honduran society, Stonich (1996) exchanged data with agronomists and other natural scientists who had different perspectives on data collection and field research. GIS, in this case, served to develop a broader basis for cooperation among scientists from different disciplines.

In an interesting mapping study of coastal Nicaragua that applies traditional knowledge of a marine environment with GIS and other high tech mapping tools, Nietschmann (1995) showed how the Miskito Indian 'captains'—the traditional sea knowledge specialists—are assisting invited marine scientists, Miskito environmentalists and lobster divers to map Miskito reefs and inshore waters. Since its initiation in 1994, the Miskito Reef Mapping Project has been carried out by 13 communities in order to:

- Document that the vast system of waters and reefs belongs to them,
- Justify community defence of their sea territory against industrial fishing fleets, drug traffickers and international lobster 'pirates,' and
- Develop baseline biogeographic data for future comparison of coral reef change and health.

Cartographic and spatial modelling applications using GIS technology

The development of GIS 'layers' or overlays of coral reefs and man-made features, such as fishponds, that represent aspects of Pacific Islander TEK can eventually be used with other data digital overlays for modelling management alternatives to produce acceptable management scenarios. The dynamic 'what if' modelling process requires the manipulation of spatial information and input from the decision maker.

Using the cartographic modelling capabilities of a GIS, the 'what if' modelling of management alternatives can be operationalised (Berry, 1995). The potential to digitally combine overlays, determine feature proximity, generate buffers and reclassify maps allows Pacific Islanders to analyse the interrelationships between spatial features.

For example, cartographic modelling capabilities of a GIS can be used to assist a local group to identify the most optimal location for an onshore construction project based upon a specific distance from groundwater, soil type, avoidance of coral reefs and coastal runoff, and presence or absence of threatened or endangered marine species. In this example, GIS serves as an important tool in the development of management scenarios because of its potential to integrate a variety of spatial data.

Another possible application of GIS technology to resource management includes 'data mining.' In this application, the GIS is used to discover relationships among mapped variables (Berry, 1995).

For example, a map of a dead and dying fringing reef can be statistically compared to maps of independent variables such as water quality, slope, depth, substrate type, and effective sunlight penetration. If a strong spatial coincidence is identified for a certain combination of driving variables, this information can then be used for management action.

In a predictive modelling application, most of the modelling is nonspatial. Data are collected by sampling large areas, then reducing the set of measurements to a single arithmetic value. The averages of several variables are then used to solve a mathematical model such as a regression equation (Berry, 1995).

For example, a prediction equation for the amount of coral reef breakage during heavy diving activity may be defined in terms of number of visits to a site, the depth of the reef, the relative tensile strength of the corals, reef volume, percent defect, age of reef, and steepness of slope.

The nonspatial approach ignores the inherent spatial information collected and substitutes the average of each variable into the equation to solve for a single estimate of breakage for an entire area. A GIS approach, on the other hand, spatially interpolates the field data into mapped variables, then solves the equation for all locations in space. The result is a map of predicted reef breakage with 'loci' of unusual breakage levels clearly identified. A variant of this modelling is dynamic modelling which allows the user to interact with a spatial model. Model behaviour can be investigated by systematically altering the model's parameters and documenting the results. In a sense, this type of analysis allows for the identification of the relative importance of each mapped variable within its unique geographic context (Berry, 1995).

Cognitive maps

Ancient cognitive or oral maps undoubtedly reflected Pacific Islanders' worldview of how the land and seascapes were organised and utilised. Lexical categories for identifying water ecozones reflect the local inhabitants' intimate connection with nature. Their kinship to their natural environment was often based on a strong spiritual connection with their ancestors and the land where their ancestors were buried as well as on subsistence needs. The oral maps presented by contemporary local peoples may be seen, in other words, as an indigenous ethnographic model of their cultural code. The maps may reflect social behaviour and aspects of marine resource use and conservation.

Oral maps serve as a framework from which to operationalise local lexical items that may serve as part of the cultural code for aspects of biogeographic categories. Because the very nature of many societies' lexical items is spatial in nature, it allows for the mapping of terms (through a Western technology) to form a graphic representation of oral (cultural) maps of various marine ecozones (including reef locations) and associated man-made features.

Finally, a few words should be said about past TEK in relation to contemporary environmental management contexts. Prior to large-scale development, TEK was sufficient for supporting the indigenous decision-making process. Today, however, many Pacific Islanders recognise that resource management and planning for their future must address the fact that their natural environment has been substantially modified by agricultural and onshore construction projects, overexploitation of reef areas, increased siltation in bays and estuaries, and the other impacts of growing resident and tourist populations.

Using traditional knowledge for resource management planning and the development of spatial models

When used by Pacific Islanders, it may seem that the automated process of database development could replace TEK in the local decision-making process. However, unless resource-management decisions are developed through a method of environmental assessment and modelling that includes traditional cultural values, such as tenure rights, GIS technology cannot replace TEK.

An opportunity for incorporating TEK into the resource planning process for coral reef management is through 'sensitive area analysis.' This analysis is a step in management planning that allows for the identification of areas or marine eco-zones and cultural sites, such as fishponds, of particular concern to local peoples.

Reef sites and associated features that are environmentally sensitive, as well as reef areas and lagoons that are significant in a traditional cultural context can be designated as sensitive areas. These must be considered when local inhabitants determine suitability or capability of a land or water management unit for development. Sensitive areas may include the following: disputed areas, traditional religious sites, shrines, restricted areas off-limits to non-Islanders, marine eco-zones containing traditionally used marine resources (fishing areas or fishing holes), and endangered species habitat.

The ancient fishing sites of Hawaiians serve as an example. According to Hawaiian religion, *ko'a* are sacred spots decreed by the gods where certain fish will be found. It is believed that over time the fish return to these sacred spots, which are often blessed by natural food sources or currents. Hawaiians take care of these spots through offerings of sweet potatoes and taro, thereby encouraging the fish to return and training them so they can be harvested when the time is right. Most of these *ko'a* have been digitised as cultural features.

Another important opportunity for including TEK during resource planning and management is through GIS database development. Owing to the spatial nature of the traditional cultural and ecological knowledge of water eco-zones, TEK can benefit GIS technology in the development of a local Islander decision support system.

However, to effectively utilise the GIS for incorporating TEK into the community decision-making process, the GIS must include direct input from the local resource users. For example, development of a GIS database using Hawaiian terms requires mapping *ahupua'a* (traditional tracts of land) and marine eco-zones from the local perspective. *Ahupua'a* have been mapped from historical landmarks using archaeological records and oral records from Hawaiian history.

The purpose of mapping and ultimately developing GIS databases from the Islander perspective is that spatial cognition often differs from one culture to another, which is exemplified in the different linguistic categories of the water eco-zone. Historically, Euro-American and many Pacific peoples represented space differently. This difference may be observed in the geometry and information content of their maps.

The information content (geographic feature attributes) in early maps used by Euro-Americans is of two basic types: (1) a general mixture of diverse geographic features or (2) a thematic representation of a single phenomenon. In the Euro-American cognitive model, the perception of space tends to standardise and categorise features while placing boundaries around the features. In terms of geometry, the map models are two dimensional and use projections that 'fit' the mapped features to the curvature of the earth (Marozas, 1995:6). Marine features mapped by contemporary Hawaiians may not be amenable to standardisation since perceptions of the *ahupua'a* marine eco-zone boundaries may vary according to tidal stages, currents, seasonality, and other natural phenomena.

In historic times, Pacific Islanders created maps. And, as mentioned above, the oral culture utilised and was dependent upon spatial references. Ancient Pacific Islander spatial knowledge was communicated through an oral process, and maps may have been used in conjunction with oral information. Tangible evidence of these ancient maps is difficult to find since most of them were probably relayed through chants based on known landmarks. It is also possible that directions were drawn on tapa or, in the Hawaiian case, presented in steps as part of the traditional *hula*. In expressive culture, such as the hula, movements are carried out which serve to embody experiences and events (Wood, 1992:14).

Marozas describes historic maps made by Native Americans: Historic maps produced by Indian people modelled the complexity of space in a way that was relevant and functional by first the purpose and second the cultural importance of geographic features. Rather than standardising geographic features, the map creator selected geographic features that helped communicate the purpose of the map. The geometry of the maps distorted distance and angles (scale and direction) but preserved topology (connectivity) between features. For example, the size of a lake on an Ojibway birchbark map was not determined by the actual size of the lake; rather, the size of the lake depicted on the map was based upon the importance of the lake for the purpose of the map (Marozas, 1995:6).

Although the view presented here is speculative, it is possible that prehistoric Islanders also emphasized the most important geographic features. Cultural importance may have been placed on such geographic features as the *ahupua'a,* including the marine eco-zones and subzones. Likewise, it is possible that in historic times, emphasis was also placed on geographic feature names for man-made features (e.g., fishponds) which also suggests the cultural importance of these features.

An important point to keep in mind is that in emphasising the development of automated map 'layers' from the Islander perspective, the Euro-American uniform model of spatial reality contains a cultural bias or a perspective of spatial reality that is different and possibly inappropriate for the local decision-making process.

Modern mapping is based on a Western perspective, and ancient Islanders may never have used drawn cartographic products, relying instead on oral and expressive maps, such as the hula. In terms of traditional Pacific peoples' values, especially respect for other peoples' knowledge, the Euro-American spatial model may be somewhat foreign to indigenous peoples attempting to implement traditional values in a contemporary resource decision-making context. The cultural bias that exists in Euro-American models of spatial reality needs to be considered when attempting to utilise spatial information, which may be needed to incorporate TEK in the local decision-making process. Hence, in order to properly include TEK in community-based resource management plans and decision-making processes, contemporary Islanders will have to play an integral part in the development of geographic databases that reflect their own perspectives and values of space, usage, and land and marine tenure.

A method for mapping TEK of coral reefs

One of the most effective methods for mapping coral reef, fishpond and the other marine biogeographic features from an Islander perspective is mapping traditional marine use. Traditional marine-use activities are usually subsistence-related and include fishing and marine-related resource gathering activities. For example, in Hawaii many people, and especially women, are involved in fishing in nearshore waters.

> 'Every day saw many people, women in the majority, out on the reefs for hours, searching, collecting all that was edible and desirable. Calabashes tied to their persons floated along and held the catch' (Titcomb, 1972:4).

Another effective method for this mapping involves input from community experts and resource users. For example, local fishermen and other experts in marine resources can draft traditional sea use onto manuscript maps. A good starting point would be to apply local knowledge of marine eco-zones along with terrestrial topographic features.

Because marine eco-zone names may vary considerably, emphasis should be first on obtaining ethnographically derived information from local fishermen and marine experts for the boundaries of reefs and local fishponds. And because marine eco-zones may be region-specific, it would be inappropriate to generalise these eco-zones to all islands, or even to one island in an archipelago.

Local knowledge is critical for developing GIS databases that will not only reflect local TEK but, most importantly, will be meaningful and useful to Pacific peoples concerned with the impact of natural and anthropogenic forces on their use of marine resources, especially for subsistence-related activities. Informants should be screened prior to both structured and open-ended interviews to insure that they possess traditional knowledge of their culture's biogeography and marine resources. A list of marine eco-zone terms could serve both as a means for initiating discussion of local names and boundaries and as a screening aid.

Individuals residing or working on islands might be good sources of local information. To illustrate, residents could be asked about names of numerous ocean gathering sites showing scattered habitat areas. Traditional place names and locational information could be sought for fringing and barrier reefs. Finally, the coincidence of contemporary subsistence sites with important prehistoric archaeological and modern cultural sites could be investigated by asking local informants about their knowledge of these sites and the meaning and value they ascribe to them.

Interviews of residents could also be undertaken using the base maps as a starting point for specific areas. Local experts may be asked to give their own perspective on substrate distributions (e.g. sand, mud, reef and rubble) and habitat distributions (e.g. marine eco-zones, coral reef types, mangroves, or anchialine ponds). These people might point out discrepancies between the digital base map features or attributes and those that are locally known. In essence, this information would reflect local cultural values and meaning pertaining to the biogeographic features shown on the maps, as well as serving as an accuracy check.

Similarly, GIS maps of coral reefs could be used to elicit information from local informants on the boundaries of the reefs as well as the reef types themselves. The reef types could then be compared with the coral reef typology. For example, many typologies consist of definitions for reef forms found throughout many Pacific Islands: fringing reef, barrier reef, patch and pinnacle reefs, lagoon floor, and coral community. A comparison of local names with the scientific names could reveal differences in geographic perceptions that may elucidate cultural variation in the boundaries of these marine features, as well as the values and meanings placed on them.

In many indigenous societies boundaries are dynamic and not static. It is likely that many marine eco-zone boundaries have shifted, depending on criteria that may have more to do with the purpose and cultural importance of the geographic features than with the need for geometric accuracy. In other words, rather than using standard symbols for geographic features, such as reefs and fishponds, these may have been selected on the basis of communicating the purpose of the map layer. These are some of the problems involving GIS mapping of ecological systems from the local perspective.

Once an appropriate GIS database is developed using a local Islander cognitive model, the database can be used to incorporate elements of TEK into the decision-making process for the planning and management of marine resource use.

A hypothetical application

An example of how local participation in resource management decision-making may be enhanced through the integration of TEK with GIS technology follows. A group of Pacific Islanders may set a priority on exploitation of particular subsistence fish species known to congregate at a local fringing reef. However, local assessments by expert fishermen reveal that fish production seems to have decreased over successive years. To understand this situation (and the basis for diverging viewpoints) it is necessary to first quantify the loss and to identify the causes of the decline. For this participatory approach to be successful, there must also be an explicit requirement for independent monitoring of resources.

The measurement of temporal change in particular species of reef fish populations requires mapping and monitoring of specific reef locations over a period of time. First, the fringing coral reef must be delineated by field surveys, Global Positioning System (GPS), remote sensed digital imagery, and underwater photos, to accurately demarcate the boundaries and depth ranges of the reef. The boundaries of the reef delineated by digital imagery could be transferred onto a base map, and polygons could be coded by image date along with other attributes and finally automated into the GIS. (See Friel & Haddad 1992 for a discussion of this methodology.)

Local fishermen's TEK of reef characteristics relating to productivity of particular fish species can be added to the feature attribute tables of the reef polygons. The attribute items can be identified by interviewing those local fishers knowledgeable about customary conservation practices and who can determine when and where reef areas should be 'rested.' These individuals possess knowledge about coral reefs and related changes in fish productivity that can be synthesised into descriptive attributes for portions of the fringing reef.

The resulting GIS layer would be an inventory of the fringing reef through time. The GIS could then be used to select and display monitored reef sites by specific dates. Comparative viewing of the displays with underwater photographs, identified by date, would indicate whether portions of the reef were changing in size and, indirectly, if particular species of fish also were declining.

The areas of the fringing reef could also be quantified by date to support the argument that the reef was diminishing. In addition, the fringing reef layer could be overlaid with sediment flow and water quality features, as well as known contaminant source points, to detect causes for variable reef productivity. The cartographic modelling capabilities of the GIS could allow users to identify variables contributing to injury of fragile reefs and to the decline of dependent fish species.

The development of traditional resource use GIS databases, such as fringing coral reefs, for inclusion in the management of marine resources facilitates reef ecosystem conservation and management. The inclusion of traditional marine use activities in the planning and management process is most valuable when modelled with other geographic data to aid in decision making on potential impacts to the resource or customary practices.

Conclusions and recommendations

As already stated, GIS affords Pacific peoples an opportunity to map their marine resources or activities from their own perspective. When local people engage in mapping traditional marine use, they are, in effect, documenting how a portion of the ecosystem has been used within the community's traditional or customary resource area (Wavey, 1993). The resulting maps may reflect a significant amount of information about the local group's technology, economy and resource values.

As Pacific Islanders develop their own GIS community base maps they can begin to change the names of bio-geographic features on copies of existing digital maps to local names. These digital maps can also be annotated or altered to show landmarks and sacred sites. These annotations ultimately will reflect the values and perspectives of the local culture.

In using GIS, however, some of the rules of database development may need to be modified. For example, in GIS database development it is important to identify appropriate existing spatial data. This rule may not always be applicable to local groups that wish to incorporate TEK of coral reefs into marine resource management.

These local communities will have to develop maps from their own spatial reference points, since appropriate spatial data may not be available because of differences in cognitive models (spatial paradigms). Such layers as elevation, watershed, stream, vegetation, reef, land and sea tenure may serve as a good starting point for developing maps representative of local values and concerns. The resulting maps can then be used to teach children about local geography, GIS technology, marine resource management, and most importantly, the indigenous language. The involvement of knowledgeable community members in the mapping process ensures that marine use is mapped from a local perspective.

GIS databases that are designed to include traditional marine use in the community decision-making process are not in themselves a substitute for the power of TEK. More importantly, these traditional marine-use databases offer a framework into which TEK can be incorporated and then applied to solve specific resource management problems.

As seen in the above examples, GIS attributes for each geographic feature represented by a point, line, or polygon are found in a relational database that utilises a feature identification number to link the attributes to the cartographic feature. For example, every polygon in a GIS layer representing fishponds also has associated attributes in a relational database, which identify the type, owner, size, condition, approximate size, and cultural affiliation. In a similar manner, aspects of TEK can be associated with biogeographic features that are mapped from the Islander cognitive model. The ability to associate TEK with geographic features is not unlike the way in which oral maps linked vast amounts of cultural information to culturally important spatial reference points, including events and sacred sites, important landmarks, and resource harvesting areas (Goes in Center 1994, as cited in Marozas 1995).

Through the use of lookup tables and related databases, feature attribute tables for automated geographic features can hold large amounts of traditional knowledge. The automation process requires identifying and adding attributes and then filling the attributes with codes or actual data. Database design is a requirement prior to data entry to ensure that the attribute data are consistent and adequately integrated to meet the requirements of different applications.

Along with accuracy, there is the issue of using TEK in a GIS environment that ensures adequate security. In the Pacific, security is crucial because the information contained in these databases is very valuable intellectual property of the local people. Intellectual property is specialised secular knowledge that is potentially exploitable for profit by outsiders. Sacred knowledge, on the other hand, is knowledge that is of religious origin and not often revealed to outsiders. This knowledge, together with intellectual property, could be contained in databases to which only designated individuals have access, thereby offering some assurance against outside manipulation of the database.

Since the most important purpose of including TEK in the GIS is to encourage local participation and to support the local decision-making process, the data should be made available only to researchers with whom local groups wish to share it. The rationale for this caveat is that some researchers may wish to use the ecological databases that contain TEK to promulgate more laws and regulations on the use of resources by indigenous peoples (Wavey 1993).

Pacific peoples could contribute to and develop their own local databases through the development of onsite GIS workstations. Such local GIS sites could be set up in individual communities utilising databases and copies of base maps and thematic layers from the State government GIS for local management needs. These databases could then be used to create locally significant cartographic models and maps of geographic features with associated attributes containing TEK.

Conceivably, these new layers would remain the sole property of the community user group. Access would be licensed to designated groups or individuals involved in using local knowledge to enhance resource management.

In such a scenario, not only would local Islanders take an active role in the management of their own resources, but they would also be empowering themselves by making local decisions that could augment government resource management efforts. In these times of dwindling funds for implementing resource management programs, this could serve as an alternative strategy for agencies in carrying out their mandates for environmental protection and marine resource development.

On another practical level, there is good reason to include local TEK in the planning and management of marine resources: by having a better understanding of what the local ecosystems have provided Islanders in the past, it may be possible to assess the magnitude of problems in the regional marine ecosystem created by modern anthropogenic practices.

This understanding could be acquired through archaeological investigations to reconstruct prehistoric environments and identify the resources exploited by early indigenous peoples in areas currently subject to environmental impacts.

A number of recommendations follow for integrating TEK of biogeography and cultural values with GIS technology and existing databases, to enhance participation in the planning and decision-making process for local marine resource management.

1. Government agencies could organise a team of trained local ethnographers to conduct interviews with focal groups of Islanders to elicit information on locally available marine resources, such as coral reefs and associated fish populations. With permission of the informants and their relatives this information could then be used to augment feature attribute tables in the State government GIS or create new layers, as appropriate. In addition, community awareness and conflict resolution could be mobilised through the use of Participatory Rural Appraisal (PRA). The products of PRA might include a set of maps that could reveal as much about the people's minds and attitudes as about their marine resources.

2. GIS maps of coral reef layers from prior studies could be copied and annotated with information from local fishers on the boundaries of the reefs, as well as the reef types themselves. The reef types could then be compared with the reef typology used in other studies. By comparing local terms with the scientific names, differences in geographic perceptions may clarify cultural variation in values and meanings placed on marine features.

3. Methodologies could be developed that allow for more ethnoscientific descriptions of local marine biogeography. Further, questionnaires could include questions on values and spatial paradigms regarding the use and management of coral reefs and fishponds. The answers could then be linked to biogeographic feature attribute tables in the GIS.

4. Because of cultural differences in perception and value systems, questionnaires should be developed by Pacific Islanders using a methodology that identifies perceived threats and stresses to the marine ecosystems from a local perspective. For example, a separate question that allows people to comment on the threats to traditional access to fishing areas or coral reefs could be coded to the same geographic feature that the other user groups address in their questionnaire.

5. State government could fund and organise pilot programs to train interested Islanders in the use of GIS at onsite workstations that have modem access to the government GIS marine resources and cultural site databases. Although access to archaeological and sacred sites would be limited to certain individuals, locally designated fishers could have access to data on fishponds, fishing areas, and other marine-related resources in their areas.

6. An educational program could be initiated that encourages participation of local youth and their parents and grandparents to learn more about their native language, place names, and local biogeography, as well as about GIS and its applications to planning and resource management.

7. The State government GIS database on marine resources could be modified so that copies of data layers and related databases could be remotely accessed for local marine resource and planning purposes. At the same time, users could be encouraged to build their own databases and annotate their resource layers with local terms and names. Nonproprietary/noncontroversial GIS layers also could be placed on an Internet website, thereby allowing users to develop their own applications and annotated databases as needed.

8. Once remote GIS stations have been established and security measures implemented,

local TEK and other types of traditional knowledge may be shared, but only to facilitate planning and management for marine resource protection.

Finally, several concerns should be mentioned involving the use of GIS for the types of applications discussed here. These are that:

- Many indigenous categories of management are not static, but dynamic. Some cultural specialists would argue that once an indigenous management system is formalised it runs some risk of being severed from the culture that spawned it. This same argument is valid for the codification of traditional laws, rules, practices, etc. However, others would be quick to point out that some codification is essential to allow for government assistance in enforcement, monitoring, compensation, and so on;

- GIS has sometimes been 'sold' within regions as a panacea for all management problems. GIS is only another tool that still needs a specialist to optimise analysis of the results and interpret what they mean for management; and

- The analytical results from integrating TEK with GIS need to be funneled through an appropriate decision support system. GIS is not just for making elegant maps, but is also capable of highly sophisticated cartographic and predictive modelling and spatial analysis important in decision-making. There is a place for GIS applications in the Pacific using TEK; however, it needs to be appropriately integrated into existing local management systems, not portrayed as a replacement. If this is done, then GIS can enhance participation and representation in the local decision-making process.

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Notes

Mark A. Calamia is a graduate student in cultural anthropology (emphasis human ecology) at the University of Colorado at Boulder, where he is currently working toward his doctoral degree. His doctoral research is on variability of customary marine tenure and the establishment of marine reserves in Fiji.

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