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A GIS-based protocol for the collection and use of local knowledge in fisheries management planning

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Abstract

Despite a heavy reliance on scientific knowledge as the primary source of information in resource management, many resources are in decline, particularly in fisheries. To try and combat this trend, researchers have drawn upon the knowledge of local resource users as an important supplement to scientific knowledge in designing and implementing management strategies. The integration of local knowledge with scientific knowledge for marine species management, however, is problematic stemming primarily from conflicting data types. This paper considers the use of spatial information technology as a medium to integrate and visualise spatial distributions of both quantitative scientific data and qualitative local knowledge for the purposes of producing valid and locally relevant fisheries management plans. In this context, the paper presents a detailed protocol for the collection and subsequent use of local knowledge in fisheries management planning using geographic information systems (GIS). Particular attention is paid to the use of local knowledge in resource management, accuracy issues associated with the incorporation of qualitative data into a quantitative environment, base map selection and construction, and map bias or errors associated with the accuracy of recording harvest locations on paper map sheets, given the complications of map scale.

Keywords: GIS; Local knowledge; Fisheries management; Map bias

1. Introduction

In recent years, increasing evidence has been assembled to support the view that local fishermens' knowledge is fundamental to the management of fish species (Berkes et al., 2001; Berkes, 1993; Neis and Felt, 2000; Johannes, 1989; Wavey, 1993; Johnson, 1992; Maurstad, 2002). However, this knowledge has tended to be neglected in management plans due to the notion that local knowledge is fragmented and subjective, and thus lacking in scientific merit. This view is currently undergoing re-evaluation as the importance of local knowledge is being increasingly recognized, especially in light of the failures of management policies derived solely from the use of scientific knowledge.

Fishermen, because they are on the water most days of the week, depending on season and weather, experience patterns in climate, water currents, fish migration patterns and species' behaviour first hand that may not be fully represented during the times when a scientific study takes place (Johannes, 1989). Hence, they tend to have better local and temporal knowledge than scientific data gathering can capture unless data are captured over substantial time periods. A striking example of such behavioural knowledge concerns the Giant Squid (*Architeuthis dux*) that live off the coasts of Australia, Tasmania and New Zealand. Very little is known about this creature, with less than 50 sightings over the last century. What is known was anecdotal from fishermen describing whales in 'fierce battles' with these creatures. These claims went unrecognized by the scientific community until whales where caught with large tentacle marks on their bodies and large squid 'beaks' in their stomachs (CNN, 2002).

One reason such local knowledge is important as an information source for researchers and fisheries resource managers is its inherent spatial component (Johannes, 1993). Fishermen tend to perceive the environment as

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a non-linear representation of space, often orientating themselves based on place, such as how far a fishing spot is from a particular island or where a location is along a riverbank (Brodnig and Mayer-Schönbergerm, 2000; St. Martin, 1999). These types of spatial interactions represent features at a finer, or more localised scale than other types of information. In effect, fishermen identify where they fish by a series of environmental cues. In this context, local knowledge has the potential to be very effective if integrated successfully with quantitative data on numbers of, for example, species harvested or total gross weight. In addition, if collected over a multi-year period, this knowledge can illustrate a temporal representation of the population and health of fish stocks.

Spatial information technologies (SIT), specifically geographical information systems (GIS) and remote sensing (RS), are increasingly being used by fisheries scientists (Meaden, 2001). However, SIT in fisheries science have been slow to evolve relative to terrestrial applications, largely due to the fluid nature of aquatic systems (Nishida et al., 2001). Further complicating this inherent property is the fact that GIS software is typically designed to process hard, quantitative data rather than the soft or subjective qualitative data that characterize local knowledge systems. In the latter case locational representation by species harvesters is much more subjective than, for example, the use of global positioning systems to identify the location of fishing grounds. Given this, there is a conceptual and operational challenge in integrating these two knowledge systems, especially since scientists and fishermen tend to view the world differently.

A scientist's view of the world is primarily Cartesian, or humans above and separate from nature, where reality is ordered and explored through a quantitative scientific method. In contrast, local knowledge tends to be a more qualitative, informal world-view of humans co-existing with and being an intricate part of the natural world, where respect for nature may often lead to a more sustainable relationship (Berkes, 1993; Gadgil et al., 1993; Kalland, 2000; Raedeke and Rikoon, 1997)

Recognizing the dichotomy between scientific and informal or local world-views, this paper argues that local knowledge is an important element in the future success of fisheries management and that through visualization of spatial distributions of data from both traditional science and local knowledge perspectives, GIS can serve as a common ground where both views converge to produce scientifically valid and locally relevant fisheries management planning. The paper presents a protocol for the collection and use of local knowledge beside traditional scientific data in fisheries management planning using GIS. Specifically, procedures are identified to select and interview key informants, to collect data, and to represent the inherent local knowledge that is embodied in harvester activities.

2. Local knowledge in resource management

Before presenting the local knowledge assembly protocol, the resource knowledge bases and resource management decisions that exist within a general resource management framework must be considered. Resource management decisions are influenced directly by the quality and quantity of information available in relevant resource knowledge bases, hence knowledge and resource decision-making are intrinsically connected. However, scientific knowledge (SK) is at best patchy in many resource areas in terms of information on species biology and on their distribution relative to associated environmental characteristics (Berkes et al., 2001; Neis and Felt, 2000).

To alleviate this problem, scientists have begun to consider seriously the knowledge and activities of local resource harvesters. This knowledge source has gained increasing prominence in the resource management field and is generally referred to as local knowledge (LK). Rather than regarding LK merely as a supplement to scientific knowledge, it is generally agreed that it is, in and of itself, of equal importance to SK in understanding harvester and species interaction. There are a variety of problems, however, when dealing with local resource users, not only in terms of understanding their knowledge, but more importantly, in collecting and assembling it into useable formats that resource managers can read and decipher for the purpose of implementation into management decisions.

There are four main factors that impede the collection and integration of LK into resource management knowledgebases and decision-making, namely (1) the acceptability, and for some, the validity of LK and the treatment of local resource users as equals, (2) conflicting and often incomplete data types, specifically qualitative versus quantitative data, (3) differences in world-views, and (4) socially sensitive and/or confidentiality issues that limit the ability to share data and information derived from LK sources. While each of these impediments contributes to the problem of knowledge integration, this paper focuses primarily on points 2, 3 and 4. Within these, GIS are proposed and used as a medium to facilitate the integration of qualitative and quantitative source data within the resource management framework of a small-scale, artisanal fishery.

The relationships between resource management knowledge and decisions, SK, LK and the use of GIS as a unifying and facilitatory mechanism are portrayed in a general conceptual framework shown in Fig. 1. This framework suggests that resource knowledge can originate from two disparate, yet related sources (LK and SK) that implicitly (within the context of Fig. 1) commence with the collection of data, transformation of these data into information and then into knowledge that fills the knowledge base both directly and indirectly, as illustrated in the diagram. LK and SK pass through a spatial information translator that takes both data sources and unifies them into a common

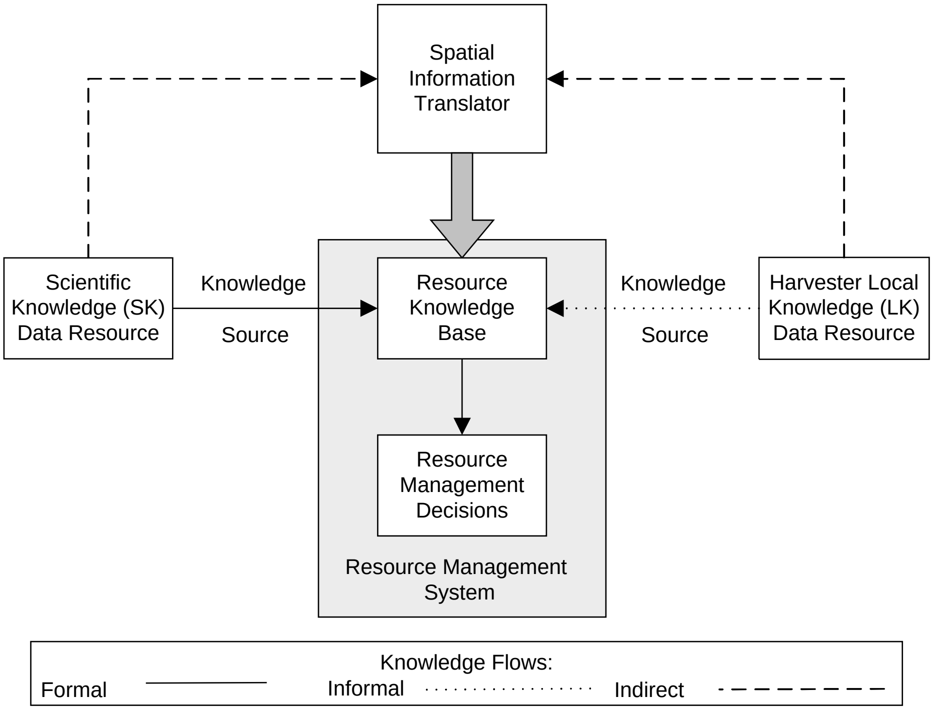


Fig. 1. Conceptual framework for the integration of scientific and local knowledge into a resource management system.

representational and analysis environment before supplementing the resource knowledge base. The knowledge base itself is multi-faceted and multi-sourced and can be difficult to manage, especially when components are uncertain or incomplete, as they often are within a marine environment (Ames et al., 2000). Moreover, construction and maintenance of the knowledge base can be costly and difficult to achieve in the context of fisheries, particularly those that are small-scale (Berkes et al., 2001).

The framework presented in Fig. 1 presents an approach that allows resource managers to utilize both qualitative and quantitative information to support resource decision-making. Further, it is important to note that Fig. 1 can be used to characterise different types of resources (for example, agriculture, fisheries, and forestry). Thus, the final outcome of resource management decisions illustrates actions based on knowledge extracted from local harvesters, scientific data gathering, and their integration into a relevant knowledge base.

The interpretation of the collected and integrated data is influenced by the resource management approach within a specific resource management system. Hence, the solid line in Fig. 1 from SK to the Resource Knowledge Base indicates the flow of formal scientific data, information and knowledge. The dotted line represents the flow of informal local knowledge that is not processed through a GIS-based knowledge translator.

The approach to knowledge integration in Fig. 1 provides a means by which both qualitative and quantitative data can be viewed and manipulated in tandem, thus constructing a hybrid knowledge source. Once LK and SK are unified in a GIS environment, resource managers will be better equipped to utilize the untapped knowledge of local resource harvesters in partnership with traditional scientific knowledge for improved management decision making. For example, a species distribution map derived from SK can be compared with a species distribution surface constructed from LK for the same species. Results can illustrate differences and/or similarities that exist between the two systems of knowledge and inferences may be drawn ultimately to provide a more robust base for decision-making.

3. Local knowledge protocol

Fig. 2 describes the components of a local knowledge collection protocol and as such, complements Fig. 1 by expanding the SIT knowledge translator component, specifically the approaches that fisheries managers and planners can use to collect and incorporate LK into their resource knowledge base. This knowledge is derived from data collected primarily through map-based interviews with local harvesters, where an interviewer and informant use hard copy maps of proximal offshore marine areas to record harvest activities. Such activities can be in the form of harvest locations, number and species of fish harvested at given locations, known or expected bottom-types at harvest locations, and/or approximate depths of water by location. Once these data are transformed from paper into digital form and integrated into a GIS, they can be contrasted with SK derived from bottom-types identified from aerial

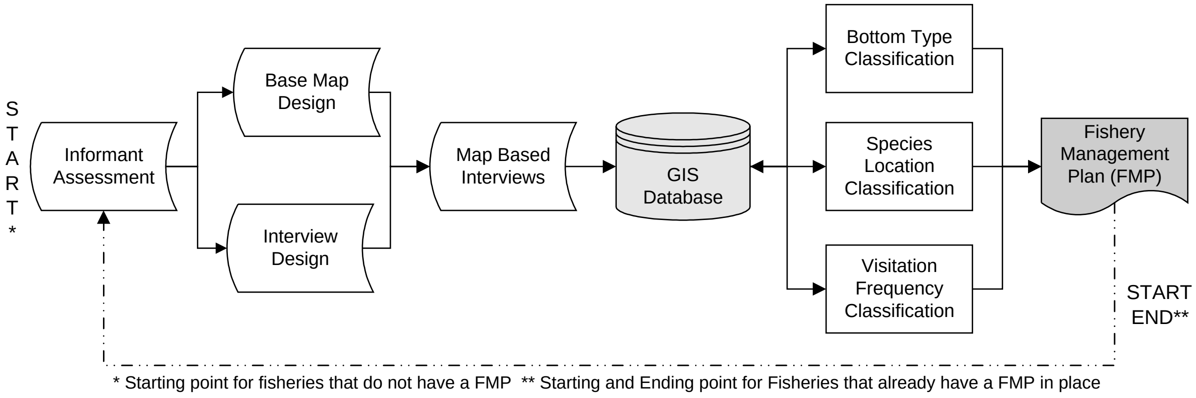


Fig. 2. Knowledge collection and utilization protocol for small-scale fisheries.

photography or remotely sensed data and depths generated from GPS-based bathymetric mapping to help develop an integrated fisheries management plan.

The protocol treats knowledge provided by local harvesters equally with traditional scientific forms of spatial data. The key divergences between the two knowledge sources are their nature and origin. The local knowledge gathering process presented in Fig. 2 is broken down into two components, specifically the Interview Preparation and Methods, and GIS use. Only the former considerations are discussed in detail in this paper. GIS-based methods of integrated data analysis with the locally collected data are discussed in Close and Hall (2005).

Fig. 2 begins with the Interview Preparation procedures where questionnaires and related interview materials are organized and created and the tactics to use during the interview process are established. Next, the GIS components (database and rectangular boxes) allow the researcher to take the assembled local knowledge revealed by harvest activities of local harvesters on hard copy maps, and translate them into a number of new digital map layers (e.g. bottom-type (habitat classification), species location, and visitation frequencies (fishing pressure maps). In terms of the knowledge inputs for the framework, LK inputs are provided by the harvesters who live in the study area and are focused on areas where the harvesters catch the species of interest. SK is based on stock assessments obtained from measurable criteria used by traditional science (water temperature data, water depth, catch logs, etc). Each of the components of Fig. 2 are now discussed in detail.

3.1. Interview preparation and methods component

The interview preparation components of Fig. 2 occur prior to the collection of any data. These include the production of questions and maps to be used during interviews with individual harvesters. The importance of assessing the harvesters themselves and the culture of the community from which the LK is to be obtained needs to be considered prior to any actual data collection. Methods for constructing base maps and formulating specific questions for harvesters can then be explored, followed by establishing techniques and tactics for conducting individual map-based interviews. The data collected from the combination of these four components provide the main input for a LK generated GIS database. Before discussing the operational framework in detail, it is important first to consider the characteristics of the informants and how they may respond to map-based data collection.

3.1.1. Informant assessment

The foundation of the data collection protocol lies in the ability to translate fishing areas marked by informants on paper maps into a digital GIS database. Working with local harvesters involves numerous considerations, most of which relate to the sensitivity of the data that are collected. In this context, LK that seeks to identify harvest locations can be construed as a form of intellectual property or a trade secret, as harvesters are being asked to reveal information that is confidential and central to the successful outcome of their labours. Moreover, researchers/fisheries planners must understand the culture and characteristics of their informants and how these characteristics may affect their ability to interpret information and locations represented on hard-copy maps. This is of particular importance in small-scale fisheries where the education levels of harvesters can vary substantially.

Hence, there are numerous important issues that the interviewer must understand before conducting harvester interviews. This information includes considerations such as type of informant, their education level and cognitive abilities, familiarity with using maps, and how this information may influence possible map bias, or the accuracy of recording harvest locations on paper map sheets, given complications that concern legibility of maps as well as the daunting influence of map scale. Issues of data confidentiality must also be considered.

Informants can be categorised initially as regular or key. Regular informants are individuals who can provide information about the subject matter in question. Key informants are those ‘who know a lot about the rules of a culture, are highly articulate and are, for whatever reason of their own, ready and willing to walk you through their culture and show you the ropes' (Bernard, 2002; 187). These informants may direct the interviewer to regular informants who may have pertinent information and can serve to help facilitate the smooth passage of data gathering within the local community. This, however, does not guarantee that all data collected will be accurate and valid. Informants may provide false or biased information in order to protect their favoured harvesting locations and there is no easy way to protect against this, other than doing repeat interviews at a later point in time to verify the veracity of the original data.

Education levels among local harvesters may affect their ability to engage effectively with an interviewer who may pose academic questions, forgetting that not all people can understand academic language (Mitchell, 1997). As such, it is important to pose questions in a language, even using local vernacular, that can be easily understood by locals, and that are sensitive to local culture and customs. Education levels may also affect the ability of informants to provide written answers. This is important in map-based interviews where the purpose is for the informant to provide written information about harvest locations on paper maps. In these cases, the interviewer may have to translate this information onto the map for the informant. However, this involves an additional series of considerations related to data accuracy.

Informant spatial cognition or how he/she constructs space should also be considered. Cognition in this context refers to the experiential process of knowing about something through perception of and reasoning about it (Lefrancois, 1983). Thus, an informant's spatial cognition both influences and reflects how they perceive and interact with the world around them. This is of particular importance with reference to the disparity in worldviews between local harvesters and the scientific community, as noted in the introduction. Thus, in order to understand harvester activities better, the first components of data collection must consider how harvester cognition affects their use of maps, specifically related to distance perception in the context of actual versus perceived locations and spatial references used while on the water.

Perhaps the largest problem in the collection of LK through the use of map-based interviews is the nature of maps themselves. Many resource harvesters, especially from developing countries, have never seen topographic maps, nor do they have any real understanding of the nuances of map scale. Formally, map scale can be defined as the ratio between the distance in maps units between two points and the distance in ground units between the same two points (Campbell, 1993). For artisanal fishermen features of significance, such as coral heads that break the surface of the water, may not be visible at smaller scales. At a scale of 1:20,000 or smaller, even some very small islands may not be visible. In contrast, the physical distances that harvester's travel every day may be best represented not by distance, but by time or some combination of time and distance travelled on the water. Hence, travel time may be a more relevant spatial reference than distance, especially when translated into time-distance on a base map. The interviewer must be aware of this issue when interviewing local harvesters and factor it in accordingly. Solutions for dealing with map scale are discussed below.

The degree of feature generalization in the maps used for the interviews may further hinder the translation of harvester activities into a format that is consistent with traditional SK. As suggested above, map scale is directly related to the level of map feature generalization. The larger the scale of a map (i.e. 1:20,000 or less), the more detail is present; the smaller the scale (i.e. more than 1:20,000) the more generalized (less detail) the map features are (Campbell, 1993). Generalization of features is of particular importance to local marine harvesters as they use landmarks, island points, shoals, and other shore-based and aquatic features as reference points for locating harvest areas. At a large scale, areas of relevance to a harvester may be obscured because the area covered by the map is too small. These reference points can change slightly depending on the species being harvested. For example, if a species is harvested in shallow water close to shore, weed lines, bottom-types or sand bars could be used as reference. For species harvested in deeper water, islands, coral heads, or reef edges could be used. This is discussed further in Section 3.1.3.

The issues discussed above all contribute to potential data errors that are referred to generically as map bias. Map bias represents the levels of absolute and relative error that can occur through identifying harvest locations revealed by harvesters on hard-copy maps. An informant can identify his/her harvest locations as either a point, a line, or line that circumscribes a closed polygon (an area). If the informant draws the harvest locations him/herself, error can occur based on informant interpretation of map scale, generalization, and the general condition of the map itself. If the interviewer draws the harvest locations, error is potentially greater because the interviewer must estimate locations based on the informant's instructions, which are themselves affected by problems noted above.

Map bias is explained in more detail in Section 3.2.2. However, an additional issue related to informant assessment is the information on the species being harvested. Here it is important for the interviewer to be familiar with the biological characteristics of the species in addition to the fishing technology and techniques used within the fishery being studied.

This section has outlined some of the key issues that need to be explored and understood if LK collection and integration into a combined knowledge base is to be successful. These issues should be carefully thought out in advance of any fieldwork, however room should be left for improvisation in the field. All instruments and interview procedures to be used should be thoroughly pilot-tested and refined prior to actual use in harvester interviews. These issues are explored further in the following sections.

3.1.2. Interview design

Prior to initiating the interview procedure, the researcher must design a set of questions that will satisfy the data requirements and objectives of his/her research. Data collection should be prefaced by an examination of prior fisheries management plans, or from a fishery sector review of the study area and associated fisheries organization(s). The recommendations of these plans should be considered in framing the nature and purpose of the data collection process. Since the identification of harvest areas and harvest activities from different knowledge sources is of primary interest, the use of paper maps provides a common reference framework that harvesters can use to mark out their fishing locations. Other important information that can be collected from harvesters include, estimated average number and weight of fish caught per day, depth and bottom-type at harvest sites, estimated current patterns, and typical weather conditions present during successful harvests. Points to remember when designing questions, in addition to informant literacy levels, include significance and simplicity of questions and researcher flexibility. These are now discussed.

During an open fishing season, artisanal harvesters typically have relatively little free time, thus questions should be designed to get the required information in as short a time period as possible. Second, in order for an analysis to have merit, there must be a representative sample consisting of complete data sets. If too many peripheral questions are asked, the data sets may not be complete enough in terms of quality and quantity to draw any reasonable conclusions. Hence, questions must be simple, straightforward, and asked in order of most importance to least importance (Mitchell, 1997; Conway and McCracken, 1990; Chambers, 1994).

As suggested above, the interviewer must be able to improvise, while not deviating from the protocol, depending upon an informant's responses. In instances where it is apparent that informants are losing interest in the interview, it is important for the interviewer to ensure that focus is retained. This can be achieved primarily through simplification of questions and/or removing questions that are deemed to be less important or not applicable. Thus, in order to ensure that the most pertinent information is collected, the number of questions asked should be kept to a minimum. In addition, what is expected prior to arrival in the field can change quickly once a few interviews have been completed. In this regard, a visit to the study area and informal discussions with potential informants prior to data collection is a preferred strategy.

A common approach that can serve to alleviate many of the above concerns is to use a combination of the common sense and/or interdisciplinary management approaches (Maurstad, 2000) where study participants (including researchers and local harvesters) can work in tandem with one another on an equal and mutually self-reinforcing footing.

3.1.3. Base map design

To facilitate base map design, local knowledge data collectors and fisheries managers need to create base maps of the study area(s) or find maps at appropriate scales suitable for the local marine environments. This requires maps that show large areas of water that include shore-based reference points such as coastlines and shallow water shoals. Harvesters can use these maps either to sketch or point out their fishing locations. Elements to consider in base map design are map detail (small islands and, in the tropics, coral heads must be visible), scale, direction, and a grid overlay reference system.

As noted above, the rationale for maintaining map detail is that harvesters may use these details as reference points for locating their harvest areas. Unlike terrestrial environments, there are very few reference points on the water to locate fishing locations, especially if they are out of sight of land. Closer to land, harvesters may use submerged structures in the water that can be seen from the surface as reference points (for example coral, plant growth, etc). However, these structures typically will not be illustrated on a paper map.

Fig. 3 illustrates examples of errors that can occur through map generalization. The black outlines depict a generalized shoreline extracted from a remotely sensed Landsat Thematic Mapper satellite image (ground spatial resolution of 30 m per pixel) of the Turks and Caicos Islands. The grey shaded area represents a more detailed version of the coastlines of the same land digitized from low level (27 cm ground spatial resolution) digital orthophotography flown in 2001. Letters A, D, E, and G represent examples of small islands that are not visible in the Landsat image. These islands are of particular importance when dealing with harvesters who may use them as reference points in locating their fishing grounds. Removing these islands from paper maps could result in harvesters becoming confused and disorientated during an interview, possibly leading to inaccurate locations of fishing areas. Letters B, F, and H illustrate the removal or misrepresentation of island points, that again may be used as reference markers by the harvesters. Finally, letter C represents a section of land that was removed during map generalization.

Since water cannot provide ground control points from which to orientate aircraft-based positioning systems and photographic equipment, most topographic maps only show marine areas that extend to a maximum of 1.5–2 km from land (as illustrated in the index map series of the Turks and Caicos Islands shown in Fig. 4). Indeed, the inclusion of marine areas on topographic maps is only co-incidental as the primary subject of topographic mapping interest is the land. The absence of areas of stretches of water may prove to be important if a harvester fishes outside the mapped zone. For this reason, a smaller scale map must be used, but not too small as to obscure locally important features. This then presents the problem of 'unreferenced areas' on a map, where there will be expanses of open water, such as

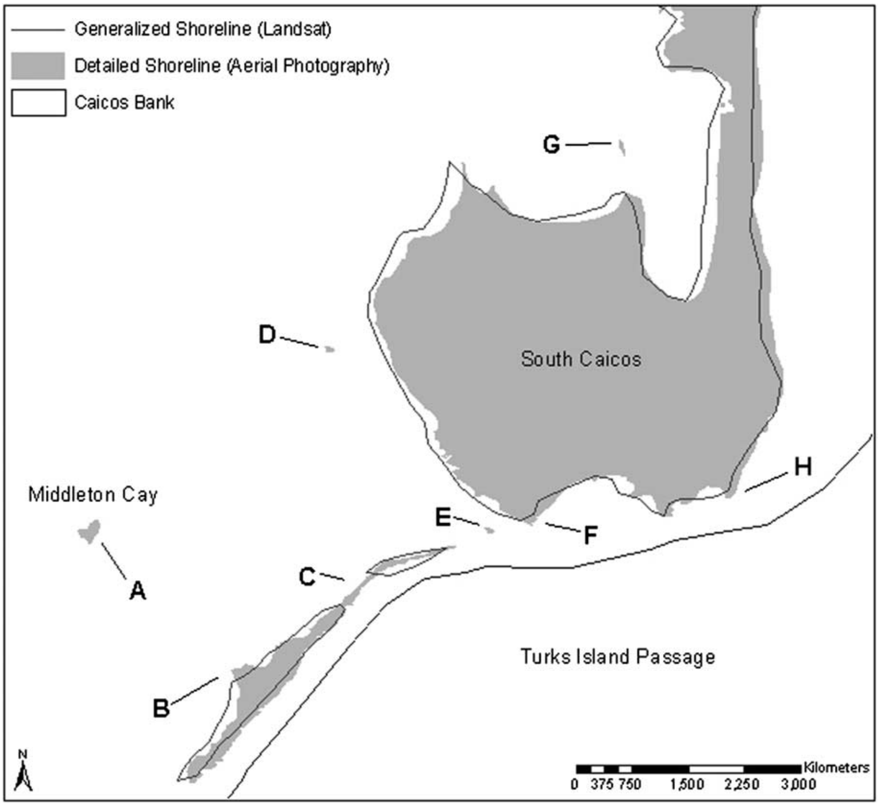


Fig. 3. Difference between a detailed and generalized shoreline in the vicinity of South Caicos, Turks and Caicos Islands.

the middle of the Caicos Bank shown in Fig. 4, that are beyond the extent of available maps.

To compensate for these ‘unmapped areas,’ a good referencing technique to use is the application of a map grid or series of map tiles for the study area. This approach not only compensates for unmapped areas, but it also allows the harvesters to reference larger areas of interest during the interview and for the researcher to use the same grid during data input to the GIS database. Moreover, it allows maps of appropriate scale to be used for the entire study area. A sample reference grid used in the Turks and Caicos Banks is shown in Fig. 5.

3.1.4. Map-based interviews: LK collection techniques and interview tactics

The final component of the interview procedure involves the map-based interviews themselves (Fig. 2). The foundation of the techniques used to collect LK should follow the Participatory Local Appraisal (PRA) and Rapid Rural Appraisal (RRA) approaches to data collection as described by Mitchell (1997); Conway and McCracken (1990), and Chambers (1994). Here, the success of LK collection will largely depend on support from the host community, including participation of local fisheries officials. Inclusion of fisheries officers may increase the likelihood of getting the cooperation of harvesters. However, this could act negatively as there may be a history of conflict between local harvesters and fisheries officers and this could adversely influence the success of the data gathering exercise. Hence, some discretion and sensitivity should be used. In terms of creating a meaningful GIS database, clearly the more data that are collected, the more representative the final database will be of local harvest activities.

Independent of, but related to, data collection in the protocol for LK collection is the integration of data into a GIS database. The procedures used to operationalise this aspect of the protocol are explained in the following section.

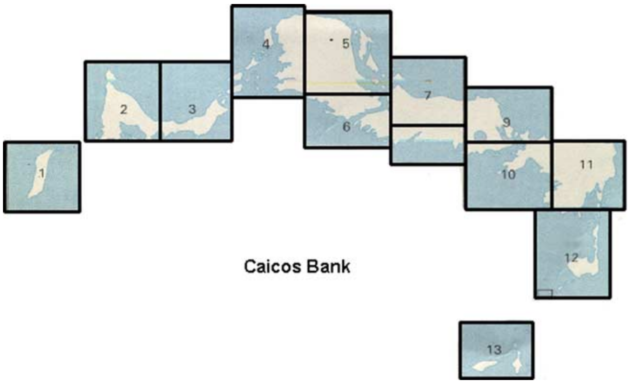


Fig. 4. Map Index for the topographic map series of the Turks and Caicos Islands illustrating the water extent around each island (Source: Land Registration & Survey Department, Grand Turk, Turks and Caicos Islands Map Sheet 14, Series E8112 (DOS 309P), Ed 2-OSD 1985).

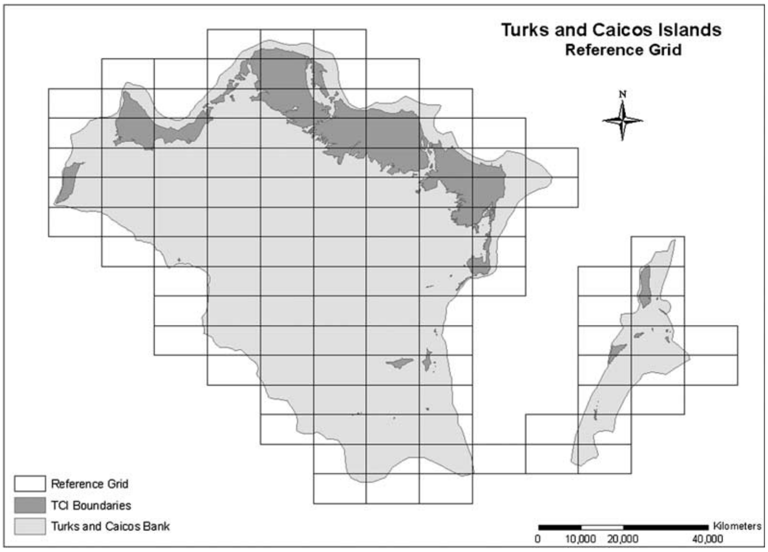


Fig. 5. Representation of the index map and grid for the base maps.

3.2. GIS component

The purpose of the second stage of the extraction and utilization protocol outlined in Fig. 2 is to outline elements in the design of the GIS database and to facilitate data input. Once data are input, they can be used to create a number of harvest classification surfaces including, but not limited to species location, visitation frequency, and bottom-type. These classifications apply equally well to single or multi-species fisheries and can be used to determine areas that receive high degrees of fishing pressure and thus require specific management or further research. The specific GIS-based classification procedures are discussed further in Close and Hall (2005).

3.2.1. GIS database

The GIS database comprises an integrated set of spatially referenced data including harvest locations and their characteristics. The level of detail and size of the database is determined by the size and location of the fishery under consideration. Although it is possible to use various spatial data formats, a vector-based LK collection approach (points, lines and areas as described by harvesters) is suggested here with supplemental scientific data and analysis coming from raster-based RS imagery. The primary reasons for this are: (i) the data storage requirements of each GIS model, (ii) the similarity between vector data and conventional topographic map features, and (iii) the use of attribute tables that can be attached to map features in the vector data model. The vector model stores data as a series of x, y coordinate pairs that can represent single points and strings of coordinates that can form lines or polygons that define the location of harvest activities. This information, along with any additional data is stored in associated attribute tables that describe the conditions found at specific locations.

Fig. 6 illustrates an example of the data layers that would be included in a typical vector-based LK sourced GIS database. On-screen digitizing of features from paper maps is the preferred method of data input because it is difficult to extract precise coordinates from the paper maps that the harvesters draw on. This type of digitizing can be performed manually, where points are input by tracing using a background image or vector layer that is registered using real world ground coordinates.

General harvester data that are collected during the interview, for example number of years the harvester has fished, weight of fish harvested on a given day, or general comments on conditions of the fishery, can be input into an external database while map-based data are input directly into the GIS database. Using a key field that identifies each harvester uniquely, the external database tables and the GIS database tables can be easily linked together.

Since there is potentially a large number of harvesters who could fish in the same area, the overlap of locational information can be significant. This overlap is important in utilizing qualitative knowledge for determining the classification surfaces listed in Fig. 2. Thus, at least one separate digital map ‘layer’ and associated attribute table can be created for each harvester to depict his/her fishing locations, depending on the manner in which they describe their fishing locations and activities. It is possible for each harvester to have a maximum of three separate ‘layers’, one for points, one for lines, and one for polygon features per species depending upon how they have described their harvesting activities. Line and point layers represent specific fishing locations as reported by the harvester, whereas

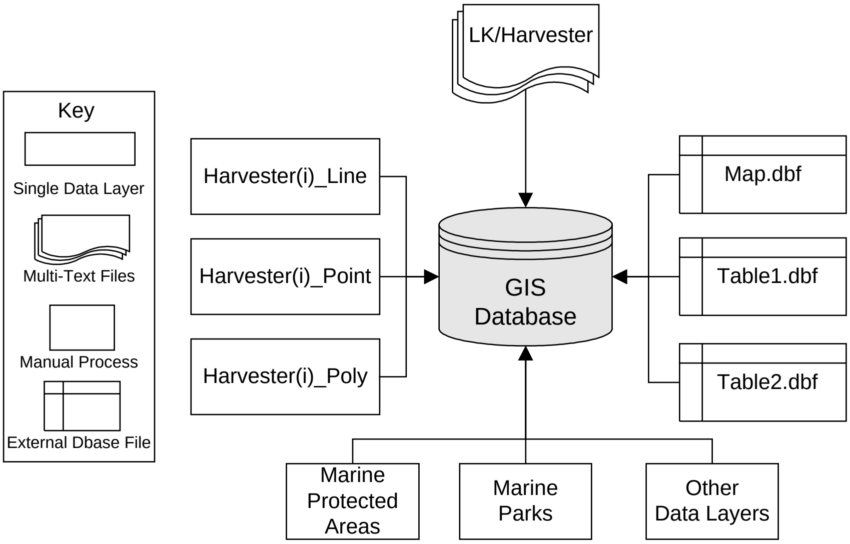


Fig. 6. Data input layers for the GIS database.

polygon features represent more generalized species-specific fishing areas.

3.2.2. *GIS classification surfaces*

This section describes two examples of the different types of classifications that can be produced using LK-based data collected from local harvesters, namely species location classifications and visitation frequency classifications. These classifications are determined from LK data on harvest locations within a local fishery. Classifications are created using a combination of GIS-based map overlaying and buffering of features on individual harvester map layers.

The concept of buffering involves using GIS functions that build one or more new polygons around an original input feature (point, line or polygon) according to user-defined distances. Single or multiple buffers may be defined with the latter describing a target-like configuration around the original feature (concentric circles around a point, for example). In contrast, a union is a procedure that merges two or more map layers into a single layer. During a union, all original features from two input map layers are preserved in the output layer. Where two features overlap, the intersections between them are calculated and recorded, resulting in additional features being constructed in the output layer (ESRI, 1996). Only two input layers can be unioned at any given time, thus if more than two data layers are to be unioned together, the output of the first union is used as one of the inputs to the second union. Fig. 7 illustrates the graphical results of a three data layer union. Input map layers 1 and 2 together form union 1, which serves as the input union for map layer 3 to produce the second union layer.

In a typical vector GIS database, each map layer has two parts, the graphic view (as shown in Fig. 7) and an associated attribute (database) table. Each record or row within the attribute table represents a single feature in the graphical view. Columns in the table represent specific attributes associated with each feature. Thus, attribute tables associated with each of the three input layers in Fig. 7 would resemble those shown in Fig. 8. Each harvester has a unique identifier and each feature has a unique identifier recorded under the ID field in the tables and the letter that represents each feature is recorded in the associated table based on the record-ID number for that feature. For example, the letter ‘a’ represents the feature in input 1. Since the corresponding ID number is 2, the letter ‘a’ is recorded in the second row of the table. This holds true for each of the three input layers. Where two features overlap, intersections are constructed resulting in additional records as shown in union 1 and 2 in Fig. 8. Similarly, attribute data tables from each of the input

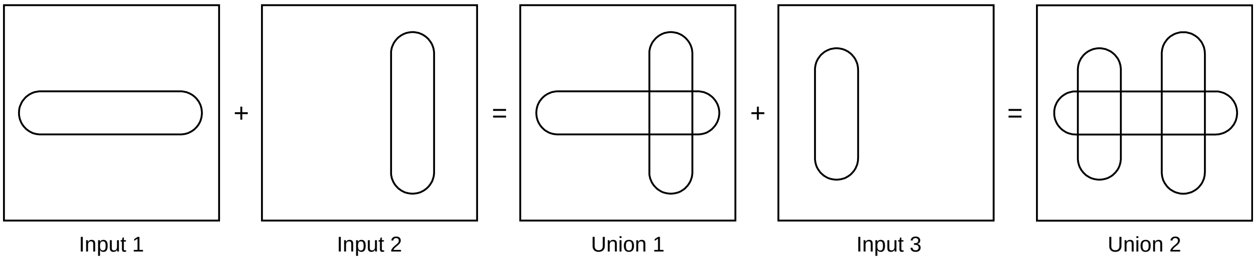


Fig. 7. Graphical illustration of input and output layers for a three-layer union.

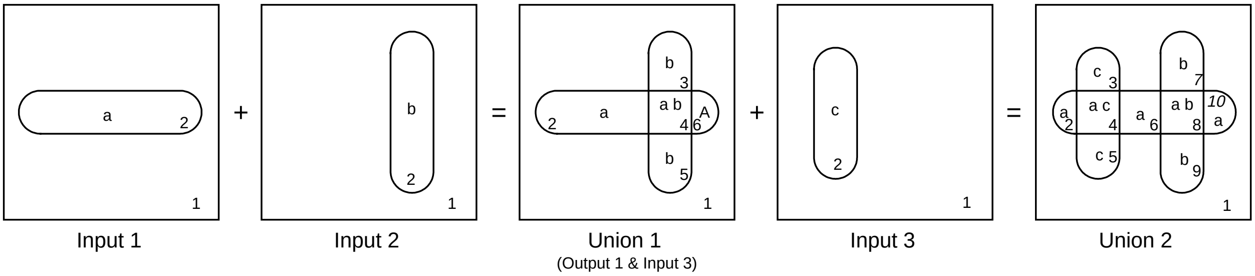


Table 1: Input 1

ID	Input1
1	
2	a

Table 2: Input 2

ID	Input2
1	
2	b

Table 3: Union 1

ID	Input1	Input2
1		
2	a	
3		b
4	a	b
5		b
6	a	

Table 4: Input 3

ID	Input3
1	
2	c

Table 4: Union 2

ID	Input1	Input2	Input3
1			
2	a		
3			c
4	a		c
5			c
6	a		
7		b	
8	a	b	
9		b	
10	a		

Fig. 8. Input and output for three-layer union with attribute tables.

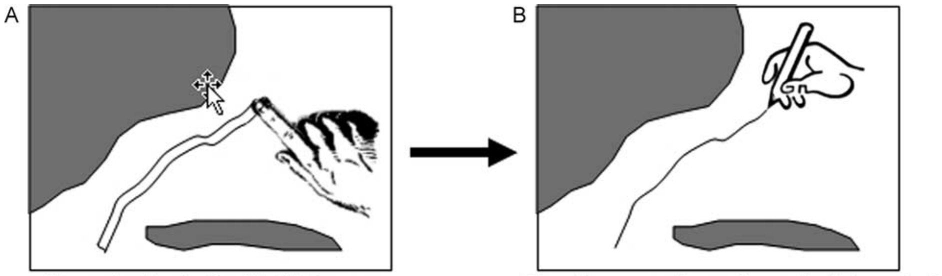
layers are joined in the output layer based on a common field, in this case the ID field.

The initial preparation steps associated with the species location classification analysis can also be used with a visitation frequency classification, thus the two are explained together. The purpose of the species location classification surface derived from harvester input is to illustrate the range of fish species in the study area, as indicated by each harvester's description of the locations of their fishing grounds. The purpose of the visitation frequency classification is to determine the sites in the study area that receive a high degree of fishing pressure, illustrated by the number of harvesters fishing in the same area over a specific time period. Since each harvester has his/her own data layer associated with each species, as well as a specific data type (point, line or area fishing) a method to combine all of the harvesters into one cumulative data surface is required. One method that satisfies this need is a multiple binary union (Close and Hall, 2005).

Before considering the overlay procedure, some preliminary map layer preparation is required. As noted above, one of the issues in working with LK in a GIS environment is map bias. When a harvester indicates a fishing location on a map the location is, by definition, both discrete and an approximation. This idea is illustrated in Fig. 9. The grey areas represent landmasses and the white area within the box represents water. Fig. 9(A) shows a fishing location as indicated by a harvester. Fig. 9(B) illustrates the same fishing area as interpreted by the interviewer. In cases where harvesters sketch their own fishing areas, only Fig. 9(B) applies. Regardless of who draws the harvest area, the accuracy is still generalised due to the effects of map bias.

In essence, the locations marked by the harvester's finger are merely a representation of reality, while the drawn line in Fig. 9 is a generalization of reality. To put this into perspective, if a harvester's finger width is one centimetre, this equates to approximately 100 m on a 1:10,000 scale map, 250 m on a 1:25,000 scale map, and 500 m on a 1:50,000 scale map. Similarly, if the width of a drawn line is approximately 0.5 mm, this equates to roughly 50 m on a 1:10,000 scale map, 125 m on a 1:25,000, and 250 m on a 1:50,000 scale map.

Since neither the drawn line nor the generalization caused by the harvester's finger are true representations of reality, a method is required to accommodate these two sources of potential representational error. Two solutions can address this problem, namely single and multiple buffers constructed around the original feature. A single-ringed



Harvester illustrating his fishing area

How the researcher or harvester interprets it

Fig. 9. Fishing area as illustrated by the harvester and interpreted by the researcher.

buffer approach provides a generalised idea of harvest activities while the use of a multi-ringed buffer acts as a transition zone, providing the analyst with a more realistic idea of harvest activities within the study area. It should be noted that these solutions should be used for line and point features only. Polygon features are already generalized, thus they are less likely to be affected by the same sources of potential error. A harvester's drawn points or lines (or the interviewer's approximation of a harvester's fishing area) can be interpreted as the centre or location of highest likelihood of a fish being at a particular location with the likelihood of fish being caught decreasing with distance from the centreline.

Utilizing the above approach, the single buffer exaggerates the line drawn by a harvester (or drawn by an interviewer under the direction of a harvester) to include a more representative area fished without going to the extreme generalization dictated by the width of the harvester's finger. The distance used to buffer the original line will differ based on the study area, scale of the map used, weather conditions, size of fishing vessel and species harvested. For example, in a small-scale fishery, such as that in the Turks and Caicos Islands, using a small 14 ft boat and where weather conditions are fairly calm, a buffer distance of 50 m (on either side of the fished line—for a total of 100 m) was found to be a realistic representation of a harvest area. Furthermore, the 100 m total distance allows adjustment for map bias, boat drift, and fish movement.

4. Conclusion

This paper has outlined a methodology or protocol for the collection and incorporation of LK into the fisheries management planning process using a simple GIS framework. Operational procedures were explained for collecting, storing, analysing and visualizing LK with the aim of integrating LK into a data storage and analysis environment that can accommodate SK and allow fishery management plans to be generated using relatively cheap and effective procedures.

Through use of this protocol, a fisheries manager or representative group from a harvester collective can see, for example, the extent of the collective harvest areas, species distributions across the study area, frequency of harvester visits per day, and areas that are under varying degrees of fishing pressure per day. These classifications could be used alone or in conjunction with classifications of similar data derived from traditional SK and their associated data collection methods.

By adding a spatial component to LK, the protocol presented in this paper allows LK to be visualised in map form and analyses to be performed much like other GIS data sources. The major difference when dealing with local resource users, however, is the error associated with potential map bias. In this context, the use of the single and multiple buffers discussed in the paper address map bias and divergent data types. Given that each harvester's knowledge reflected in fishing activity is inherently qualitative, inputting and analysing the data within a GIS transforms this LK into quantitative data and facilitates integration with traditional scientific fisheries data.

Giving LK a spatial context provides LK-based classifications measurable meaning in that decision makers can reference harvest areas on a map and thus compare these with other quantitative data. Through this ability to view LK in a visual and quantitative manner, resource managers have the option of using a well-rounded, unified SK-LK knowledge base. Further, since only basic GIS functionality is utilized, the protocol can be used equally well regardless of a country's economic status and extent of modernization.

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