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Methodological considerations when using local knowledge to infer spatial patterns of resource exploitation in an Irish Sea fishery

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A B S T R A C T

Despite the potential of local knowledge (LK) to provide reliable, quick, and low cost data, its use has been limited due to the lack of understanding of the accuracy and biases. We compared fishers' spatial LK data and fishery independent data from vessel monitoring systems (VMS) to analyse the concurrence between fisher derived and independently derived information. We examined the effect of sample size and scale on the match, to indicate the most appropriate approaches for future studies. Whilst LK provided a reasonable estimate of fishing extent, the estimated intensity of fishing was less well correlated with the VMS data. The agreement between LK and VMS data was significantly affected by the sample size from which LK knowledge was derived. There can be considerable variation in the accuracy of individual LK samples, therefore the sample size must be maximised to buffer for unreliable LK samples. A finer grid provided a more accurate representation of fishing extent; however, fishing intensity was more accurate when a coarser grid resolution was used. The use of a larger grid could also buffer some of the inaccuracy of a small sample size when determining intensity. Local knowledge can provide data of a similar accuracy to conventional scientific data, which is of particular use in data poor situations, e.g. in developing countries and for inshore fisheries that have no current mandatory VMS recording systems. However, the proportion of the community sampled should be maximised to minimise inaccuracy between individual fishers.

1. Introduction

The communities of people who live and interact with species, habitats and resources are increasingly considered as a valuable source of quantitative data (Danielsen et al., 2005; Gilchrist et al., 2005; Hill et al., 2010; Jones et al., 2008; Moreno et al., 2007; O'Donnell et al., 2012). Participatory monitoring (PM) and local ecological knowledge (LEK) are forms of community derived data that are gaining recognition. PM generally incorporates prior planning and the use of a sampling regime (Danielsen et al., 2009). LEK tends to be retrospective, referring more to a body of knowledge accumulated over time and transformed into an individual's perception of the resource, which is then presented as the communities' collective knowledge (Bundy and Davis, 2013). LEK can be considered similar to traditional ecological knowledge (TEK). However, while LEK could be accumulated over just an individual's lifetime, TEK assumes knowledge accumulation over multiple generations and refers more to indigenous populations (Berkes, 1993). Extensive LEK can be collected on a range of topics such as species distribution, behaviour or population trends (E.g. Drew, 2005; Hallwass et al., 2012; Moreno et al., 2007), or habitats and environments (e.g. Chalmers and Fabricius, 2007; Teixeira et al., 2013), and has the potential to aid in management planning (Bergmann et al., 2004; Leite and Gasalla, 2013; Rist et al., 2010).

1.1. The accuracy of local knowledge

Although PM has been implemented in a range of situations (Danielsen et al., 2009), LEK is less often incorporated into management planning (Gasalla and Diegues, 2011). Despite its potential to provide reliable, quick, and low cost data, LEK remains underutilised due to the lack of understanding of the accuracy, reliability, and biases in such data (Teixeira et al., 2013). More recently, researchers have sought to establish sources of bias and error in LEK but they remain poorly understood, and its use has therefore

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been challenged (Folke, 2004; Gilchrist et al., 2005; Hill et al., 2010; Leite and Gasalla, 2013; O'Donnell et al., 2012; Teixeira et al., 2013; Zukowski et al., 2011). Decisions made through the interpretation of inaccurate data could lead to flawed management strategies (Ludwig et al., 1993), therefore there is a pressing need to understand more fully the reliability of LEK and its value to management (Folke, 2004). The present study is centred on LEK; however, the issues of spatial accuracy are also relevant to PM research.

Criticisms of LEK focus on the lack of a standardised rigorous survey approach (Hill et al., 2010). Some studies have considered interview protocol (Brook and Mclachlan, 2005; Forbes and Stammler, 2009). However, aside from sourcing the most experienced and therefore most 'expert' members of the community (Moreno et al., 2007), and ensuring an un-quantified 'adequate' sample size (Gilchrist et al., 2005), little attention has been given to individual and sample size effects. The collection of LEK data must integrate a shared system of knowledge, incorporating individual knowledge claims into a broader consensual and representative body of community knowledge (Bundy and Davis, 2013).

Previous studies have required fishers to attend workshops to collaboratively collate their knowledge, and follow a process of discussion and revision of maps (Leite and Gasalla, 2013). However, in the presence of a group, fishers may feel they should respond in a certain way, or may not want to reveal fishing spots, losing their competitive advantage; this response is known as social desirability bias (see review, Nederhof, 1985). In addition, groups can show a psychological preference for cohesion, and quickly establish a consensus without fully discussing or disagreeing with suggestions ('groupthink'; Janis, 1982); the effects of groupthink can differ depending on the makeup of the group, and how many dominant individuals are present (Callaway et al., 1985). Integrating multiple individual fishers' data in a GIS to provide a consensus map, without the need for group meetings and workshops as used in other studies (Leite and Gasalla, 2013), could provide a more cost-effective method, and remove some of the bias which may be associated with group dynamics.

Averaging multiple estimates can be remarkably robust when compared to variable individual estimates (Galton, 1907); nevertheless, through only recording a subset of the community, without consideration given to how to select the sample, a potential bias may be introduced (Hill et al., 2010). As yet no attempt has been made to define what constitutes a sufficient sample size, or sufficient proportion of the community that should be sampled to obtain reliable and representative LEK data. A better understanding of the potential impacts of sample size could help refine sampling methodology and increase the integrity of LEK data. There does remain debate within the scientific community of how, and indeed whether, it is appropriate to 'test' LEK against scientific criteria (Brook and Mclachlan, 2005; Holm, 2003), with some stressing that differences do not necessarily constitute error on either part (Zukowski et al., 2011). However, without this understanding of how best to use LEK data, its use in management may continue to be met with scepticism (Bundy and Davis, 2013).

1.2. Aims

There is a need for further study into the reliability of data collected from a local community, and how the methods of data collection and analysis can affect its accuracy, to allow more informed decisions concerning its incorporation into resource management. Here we compare two complete spatial datasets of fishing extent and intensity in a GIS, one set derived from local knowledge (LK) and one from conventional scientific vessel monitoring system (VMS) data, to investigate the spatial accuracy of fishers' self-drawn maps of fishing locations. There exists no standard method or grid size to analyse spatial LEK data or compare it with conventional scientific data. Specifically the study sought to test the hypothesis that the sample size used to derive the local knowledge (i.e. the number of people, or the proportion of the community interviewed) can affect the accuracy of, and conclusions drawn from, the data, and that the analysis grid size can confound these effects. In addition, we were in a rare position to compare individual LK polygons directly with their own VMS points.

2. Material and methods

2.1. Study area

The Isle of Man, located in the northern Irish Sea, has a territorial sea that extends 12 nautical miles (nm) (22.2 km) from the land and encompasses an area of 3965 km^2 (Murray et al., 2011). There are four primary fishing ports (Fig. 1). Fisheries control of the 12 nm sea is shared with the UK; however, the Isle of Man government has exclusive fishing control of the 3 nm closest to the shoreline. The territorial waters have supported an important scallop fishery since the 1930s. King scallops (*Pecten maximus*) are the primary target species, with queen scallops (*Aequipecten opercularis*) generally targeted primarily during the *P. maximus* scallop closed season (1st June–31st October) (Jenkins et al., 2003).

2.2. Vessel monitoring systems

Whilst VMS monitoring was originally introduced for enforcement purposes, it is now used as a standard tool for investigating patterns in fishing activity (Lambert et al., 2011, 2012; Mills et al., 2007; Murray et al., 2013). VMS data for the period 2008–2010 were extracted for all Manx vessels fishing for scallops. Each point displayed latitude, longitude, vessel course, and speed of vessels at 2 hourly intervals. Whilst VMS data does not specifically indicate if a vessel is fishing or not, fishing activity can be inferred by selecting only data points with a speed between 1.2 and 3.4 knots, identified from vessel speed-frequency distributions (Murray et al., 2011). In addition, logbook records were linked to each VMS record, indicating if they were targeting king or queen scallops, and the area of seabed swept determined from the towing speed and gear width, as described in Murray et al. (2013).

Spatial analysis was undertaken using ArcGIS 10.1 (ESRI, 2014). Points close to port were removed, as the slow speed may not be due to fishing activity. Points representing fishing activity were selected and exported, and clipped to the 12 nm territorial zone. VMS data points were recorded and extracted for 30 different vessels, between 01/11/2008 and 16/11/2010. A total of 36,619 data points were recorded (19,204 points = king scallop fishing, 4747 points = queen scallop fishing).

A continuous raster of fishing effort was created, representing the density of point features around each raster output cell. This was created according to area of seabed swept per point, using a 100 m output cell size and a search radius of 2 km. Separate rasters were created for the king and queen fisheries. Vector analysis grids of cell size 1 km, 3 km and 5 km were created using ET Geowizards, as grids commonly used in VMS research (Hinz et al., 2013; Lambert et al., 2011; Mills et al., 2007). As grid size was defined at constant km units, longitude and latitude VMS position records were projected to the British National Grid. Using Geospatial Modelling Environment (GME; Beyer, 2012), the point density rasters were joined to the analysis grids, attributing each grid cell a mean point density from the section of raster bound by the cell.

2.3. Fishing intensity derived from local knowledge

Face-to-face semi-structured questionnaires were carried out with 20 scallop fishers in the Isle of Man between July and August