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Research

Accurate Mental Maps as an Aspect of Local Ecological Knowledge (LEK): a Case Study from Lough Neagh, Northern Ireland

John McKenna [1], *Rory J. Quinn* [2], *Daniel J. Donnelly, and J. Andrew G. Cooper* [3]

ABSTRACT. A mental map of the substrate of Lough Neagh, Northern Ireland, compiled from interviews with local fishermen, is compared with maps produced by science-based techniques. The comparison reveals that the mental map is highly accurate. This finding contrasts with the spatial distortion characteristic of the classic mental map. The accuracy of the Lough Neagh map is attributed to the fact that it is a compendium of the knowledge of several generations, rather than an individual perception. Individual distortions are filtered out, and accuracy is promoted by economic self-interest. High accuracy may be characteristic of the mental maps held by artisanal exploiters of natural resources.

Key Words: *Geophysical survey; LEK; local environmental knowledge; Lough Neagh; mental maps; Northern Ireland; traditional fishery*

INTRODUCTION

In recent decades, there has been an increasing interest in, and respect for, traditional systems of resource exploitation (Folke et al. 2007). In the area of common property resources, for example, many workers have emphasized the fact that traditional methods of exploitation have produced long-term sustainability—in some cases over millennia (Berkes and Farvar 1989, Larson and Bromley 1990, Ostrom et al. 1999). This shift in attitude is also well illustrated in the case of fishing (Acheson 1989, Ruddle 1989). The long-term sustainability of some traditional fisheries is contrasted with the ecological, economic, and social misfortunes caused by non-sustainable "industrial" exploitation, e.g., the catastrophic collapse of important fisheries such as those in the North Sea and on the Grand Banks off Newfoundland (Finlayson and McCay 1998). Interest in traditional systems of resource use is also evident in other fields, e.g., Shipman and Stojanovic (2007) criticize an over-reliance on technical approaches in coastal management. They believe that this ignores the value of indigenous knowledge, both "traditional" as in the case of fishermen, and also empirical, local knowledge held by modern commercial and recreational users of coastal resources.

As part of this interest in indigenous resource use, an extensive literature has built up debating the merits of using the (typically) qualitative anecdotal knowledge of resource users alongside scientifically acquired data in the management of natural resources. Some are strongly in favor of this approach, but resistance comes both from those who fear that indigenous knowledge is simply being exploited by the dominant "western" culture (e.g., in the pharmaceutical industry), and those in the science community who are unconvinced that its quality is high enough to be consistently useful. Debate is hampered by tortuous agonizing over terminology and nomenclature, with some researchers insisting that terms such as "traditional," "indigenous," "folk," and "native" are ambiguous at best, and culturally loaded at worst. (See, e.g., the discussions on terminology in Woodward and Lewis (1998, page 2), and Ellen and Harris (2000, pages 2–3). The most commonly used terms and their acronyms are "indigenous environmental knowledge" (IEK or IK), "local environmental knowledge" (LEK), and "traditional environmental knowledge" (TEK). (Some writers prefer to use the word "ecological" rather than "environmental".) In this paper, we have chosen to use LEK as it seems to be the most neutral term, and has fewer external connotations. Local, of course,

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does not necessarily mean traditional. For example, surfers and recreational divers have local and empirically derived knowledge of inshore bedforms and currents (one of the co-authors of this paper has used this local knowledge in a coastal research context). However, we continue to use the term "traditional" when it seems appropriate to the context. Woodward and Lewis (1998, page 2) discuss the problems with this descriptor, but on balance they judge that it can be useful in discussion.

The paper looks at the communal knowledge bank of the fishermen in a traditional fishery in Lough Neagh, Northern Ireland. The paper explicitly sets out to rigorously assess the objective accuracy of one aspect of the fishermen's LEK, their mental (cognitive) map of the geography of the habitat. This map does not have a hardcopy graphical representation, but it represents the accumulated knowledge of generations of fishermen and is passed down to new generations as they learn the fishermen's craft.

The genesis of the paper owes little to either fishing or LEK. In 1996–1997, three of the four authors were part of a University of Ulster team commissioned by a government department to carry out a side-scan sonar survey of the bed of Lough Neagh. This information was required because of concerns that the scale of ongoing sand extraction by licensed suction dredges might be negatively impacting the lough.

Almost 10 years later, the University team became aware of the existence of a mental map of the lough's substrate in a book by a social geographer, D. J. Donnelly, published a decade before the side-scan sonar survey was carried out. The close resemblance between the mental map and the side-scan sonar map prompted us to check the accuracy of the mental image against two technically acquired images—the sonograph described above and a published Admiralty chart. This seemed to us the logical approach to take, as we were already familiar with the accuracy standards of the technical sources, but did not have equivalent information for the mental map. In the latter case, we had no more than a general qualitative impression of accuracy.

The claim to originality and innovation in this paper lies in the comparison of existing sources of data. The side-scan sonar map of Lough Neagh is our own work and has not previously been published, but we do not regard that as the significant contribution of the paper. What is new is the semi-quantitative comparison of a "traditional" mental map with two science-based maps, after careful assessment of the error margins of the latter. To our knowledge this has not been done before in such an objective manner.

THE LOUGH NEAGH FISHERY

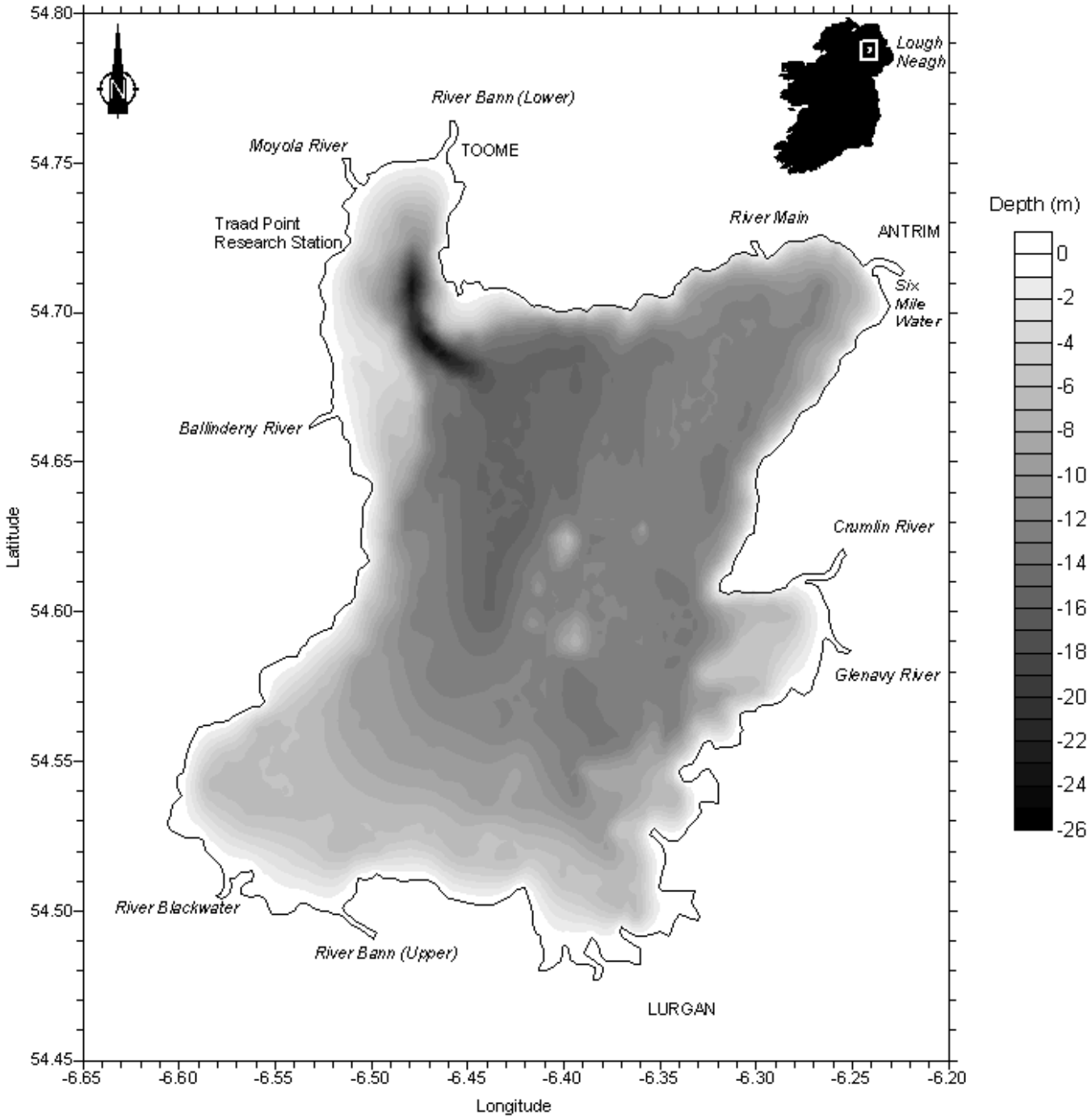
Lough Neagh is the largest freshwater lake in the British Isles (Fig.1). Its physical, hydrological, and ecological characteristics are described in detail in the text edited by Wood and Smith (1993). The lough is aligned in a general north–south direction, and has an almost rectangular plan. Maximum length is ca. 30 km along a SW to NE axis, whereas width varies from ca. 12 km to 16 km west to east. The lough has a maximum depth of just over 30 m in the northwest corner, but only 3% is below 20 m and the average depth is only ca. 9 m.

The fishery is centuries old, and is carried on by a distinctive community. Donnelly (1986) gives a detailed description of the fishery as it was around 20 years ago. There were then around 250 fishing families, totalling approximately 1550 persons. There were 500 active fishermen, operating 226 fishing boats out of around 50 small inlets or "coves." Sixty percent of the fishermen worked from the western shore. In order of commercial importance, the main fisheries on Lough Neagh were eel (*Anguilla anguilla*), perch (*Perca fluviatilis*), pollan (*Coregonus pollan)* (a fresh water herring), and trout (*Salmo trutta*).

The main fishing methods used were draft net, trammel net, and long line. The most widely practiced method was draft netting, which was used to catch eels (the main catch), perch, and occasionally trout and pollan. The draft is a long, bag-shaped net pulled in a semi-circular sweep by a boat. The trammel net is a vertically orientated gill net about 2 m deep and about 40 m long, used variously as a floating surface net, in mid-water, or sunk to the bottom. It was used to catch perch, trout, and pollan. Baited long lines extending for ca. 10 km, with up to 2000 hooks on the line and weighted to lie on the bed of the lough, have been traditionally used for catching eels.

Currently (2008), the fishery shows significant changes from the situation in the mid 1980s. There are now just 80 boats fishing the lough. Of these,

Fig. 1. Location map and two-dimensional contour plot (bathymetric variation) of Lough Neagh, located in the north of Ireland. Place names and geographical features cited in the main text are plotted around the shoreline of the lough.



65 fish for eels, still the principal fishery, whereas the remaining 15 fish for pollan, trout, perch, bream (*Abramis brama*), and roach (*Rutilus rutilus*). The latter two species were not commercially significant in the 1980s. Many younger fishermen now fish only with draft nets, but older men alternate between lines and nets depending on the success rate in various parts of the lough. Drafting, once a very strenuous activity, has recently been greatly assisted by the introduction of winching gear.

The Importance of Substrate Characteristics to Lough Neagh Fishermen

Detailed knowledge of the lough's bathymetry and surficial sediments was, and is, essential for the fishermen. For reasons relating to food supply and life cycle, species migrate to different bottom types and water depths at different times (Crozier and Ferguson 1993, Wilson 1993, Winfield et al. 1993). Drafting is effective on the muddy bottom (the net is often drawn through the surface layer of bottom mud) and along the sloping sandy shores of the lough's larger embayments, but it is relatively less successful along the western and northern shores, which have a stony or rocky bottom. In the latter areas, it is still used, but only by experienced, highly skilled fishermen with detailed local knowledge of selected areas.

Long-line fishing demands detailed bottom knowledge over long distances. In places, shallow stony or rocky "flats" interrupt the uniformly flat muds that characterize about 75% of the lough bed. The wide muddy corridors between the flats are known as "gulfs," and they are prime long-line fishing sites for eel. However, the proximity of the hazardous stony bottom that might snag lines demands precise knowledge of the bed. Bottom relief and substrate also have an important influence on the direction and velocity of the "swimmeries," i.e., the bottom currents. Knowledge of these is fundamental to the use of both nets and lines.

THE FISHERMEN'S MENTAL MAP OF THE BED OF LOUGH NEAGH

Mental maps are perceptual constructs in which subjects produce a personal graphical representation of a known environment. Once completed, the map is assessed for its congruence with the objective plan of the environment based on a published scale map or a georeferenced aerial photograph. Variations from objective accuracy can then be analyzed, and attempts made to identify reasons both for these individual variations, and inter-subject variations. Typically, inaccuracies and distortions are attributed to factors operative at the individual level (see, e.g., Appleyard 1970). Virtually all work done in the field of mental maps has been in urban environments (e.g., Ley 1983, pages 104–114) or inside very large buildings. Very little investigation has been carried out in a natural, or even predominantly rural, setting.

In a master's thesis (Donnelly 1981), and in a subsequent book based on the thesis (Donnelly 1986), the author included a mental map captioned "The bed of the lough as perceived by local fishermen." This map is reproduced here in Fig. 2 (page 7 in the 1986 book). The mental map is, in essence, a substrate map, that is a portrayal of the lateral variation of surficial sediment type on the lake bed. The map identifies seven bottom types, augmented by spot depths in feet. Specific areas of the lough bed are named. The mental map exercise was carried out over the period October 1980 to March 1981, and was compiled using the collective perceptions of 12 experienced fishermen. Details of its construction can be found in Appendix 1.

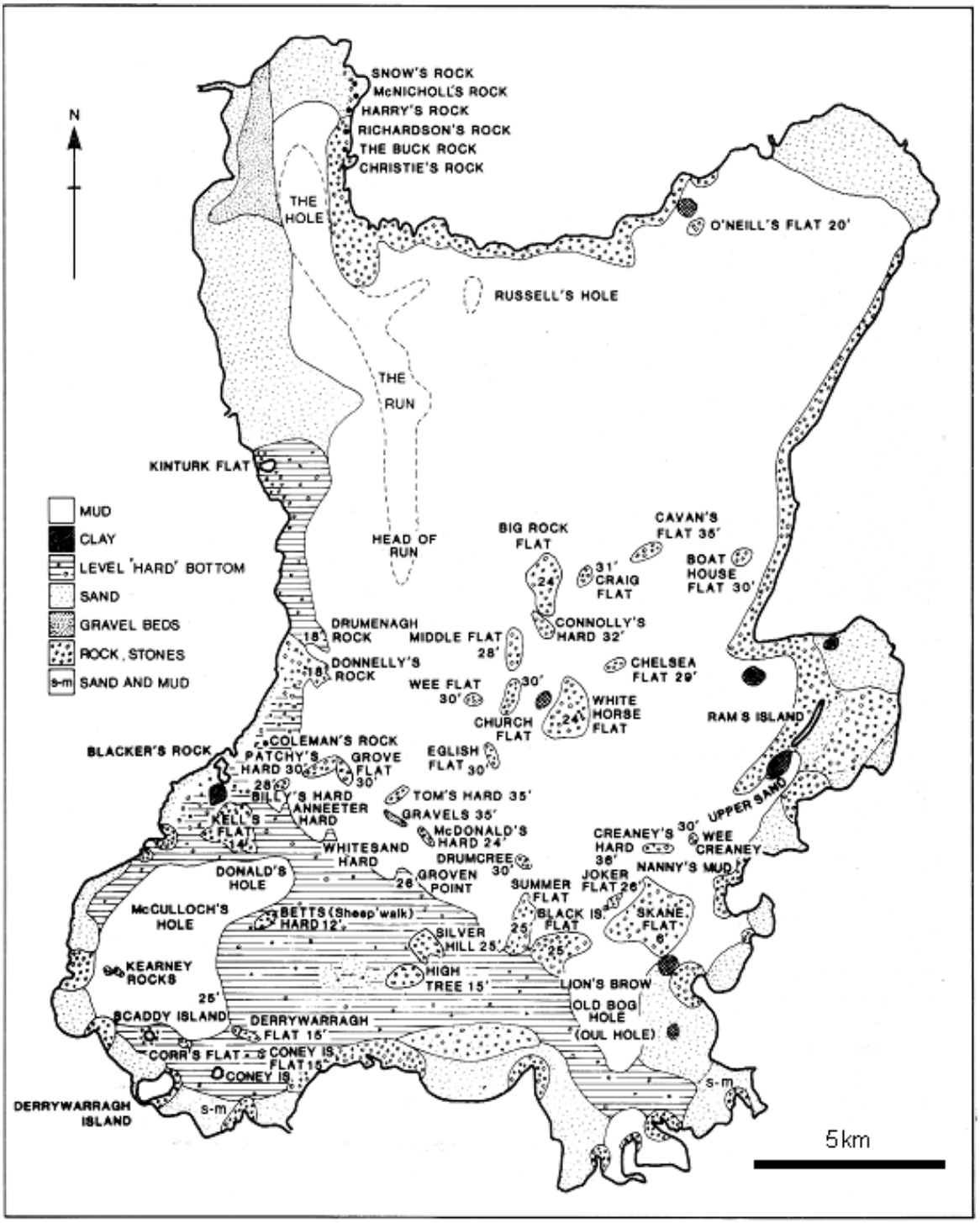
Accuracy of the Mental Map

An initial qualitative visual comparison of the mental map with a side-scan sonar map surveyed in 1996–1997 (see below) suggested that the mental map is highly accurate. Consequently, this paper set out to establish the accuracy standard of the mental map more rigorously by making a semi-quantitative comparison with two technically acquired sources of spatially referenced data. These are the side-scan sonar survey and the revised Admiralty Chart of 1983 (No. 2163).

Admiralty Chart No. 2163 (1983)

Chart No. 2163 was surveyed in 1981 and published in 1983 at a scale of 1:40 000. The close inshore areas and the embayments in the northwest and southeast corners (Fig.1) were not resurveyed, so the data for these areas are still those of an earlier 1835 chart. The 1983 chart has a latitude/longitude graticule with positions and shore topography taken from Ordnance Survey maps. Depths were acquired

Fig. 2. Mental map of the substrate of Lough Neagh as perceived by local fishermen (after Donnelly 1986).



by single-beam echosounder, and are given in meters contoured at 5-m intervals. A standard system of abbreviations similar to that used on the 1835 chart is used to denote spot samples of substrate type, although in practice there is no indication made of rocky bottom.

Side-scan Sonar Survey of Lough Neagh

In 1996–1997, a series of side-scan sonar surveys were conducted in Lough Neagh as part of a contract carried out by the Coastal and Marine Research Group of the University of Ulster for the Department of the Environment, Northern Ireland (Quinn et al. 2001). The survey methodology is described in Appendix 2. The output substrate map is given in Fig. 3.

Results

Details of the accuracy comparison are given in Appendix 3. This exercise confirms the initial visual impression that the mental map is strikingly accurate. There is a very high degree of correspondence and correlation between it and the two science-based comparators, both in terms of bathymetric value and position, and substrate type and location. Although comparison with the sonar data concentrates on a small central section of the lough, the strong correlation exhibited between the mental map and side-scan sonar data is evident throughout.

Possible Influence of Other Maps and Surveys

It is necessary to assess the extent to which the fishermen's perceptions of the lough's bathymetry and substrate may have been influenced by exposure to maps, charts, and surveys of Lough Neagh that predated the mental mapping exercise. These sources consisted of the 1835 British Admiralty chart, and three pieces of academic work carried out by researchers based at the University of Ulster's Freshwater Biology Research Station at Traad Point on the western shore of the lough. Two of these have substrate maps, and the third presents a set of seismic profiles. The issue is discussed in detail in Appendix 4. It is concluded that fishermen had little to learn from an Admiralty Chart with sparse substrate information and without a position graticule. Similarly, experienced fishermen would learn nothing from the generalized, non-georeferenced maps and figures in the academic studies. Donnelly's presentation of an accurate outline of Lough Neagh (based on a 1:63 360 Ordnance Survey map) arguably constrained the potential inaccuracy of the mental map as the map elements must necessarily be drawn inside the outline. To this extent, it may be claimed that the mental map is "influenced" by the map outline, but it is a somewhat strained point.

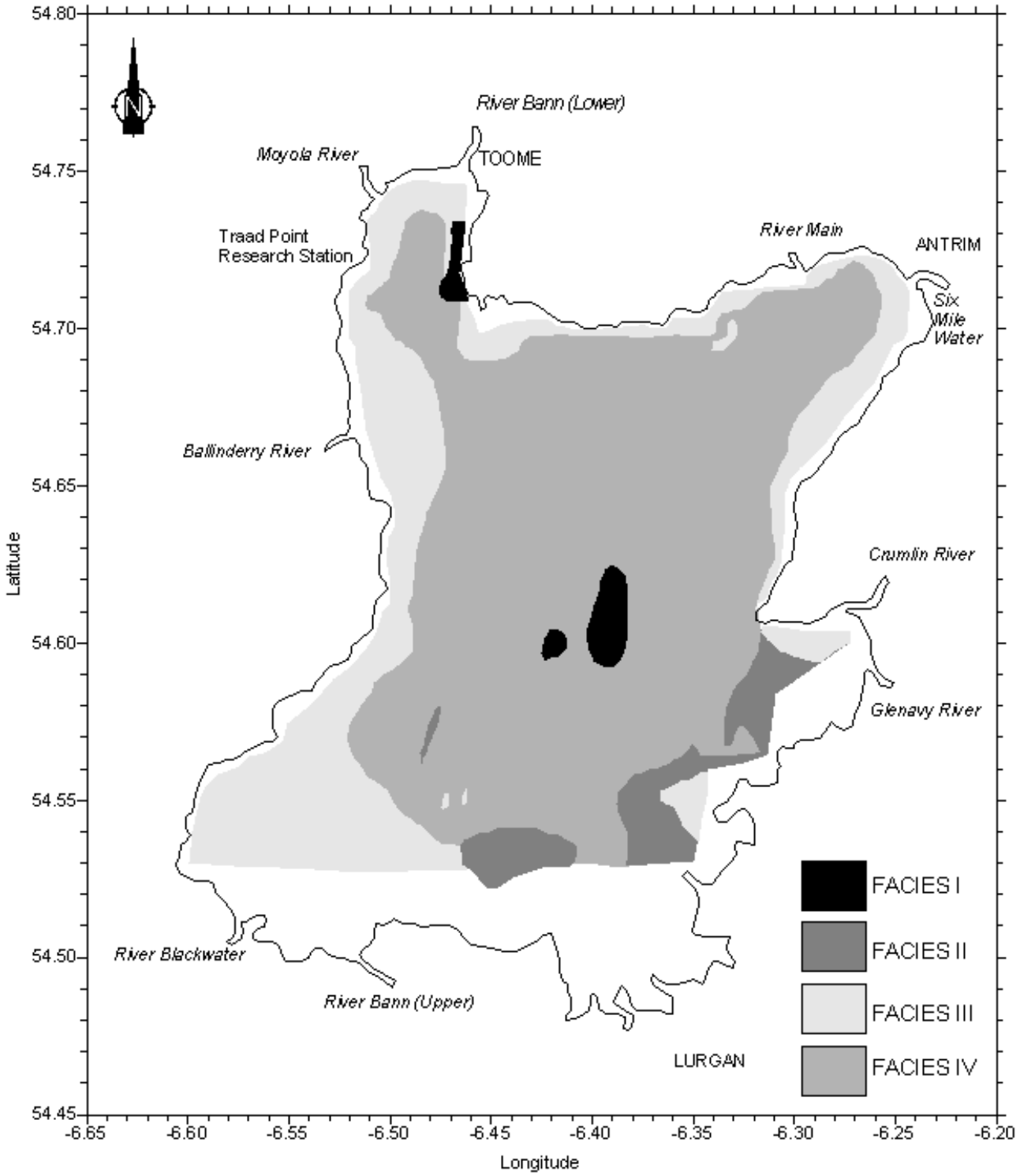
DISCUSSION

The Mental Map of Lough Neagh

Comparison with the science-based sources confirms that the mental maps held by Lough Neagh fishermen are highly accurate. The accuracy standards are even more impressive in light of the fact that the interviewees were asked only to produce a map at the scale of the entire lough. They could have easily produced highly accurate and detailed substrate maps of much smaller areas, at nested scales, with correspondingly enhanced definition. The broad pattern is that, on all shores, fishermen with many years of experience have a comprehensive knowledge of the lough. Younger long-line fishermen also demonstrate impressive familiarity. However, in general, fishermen from the western shore tend to have the most complete knowledge, because traditionally they travelled further across Lough Neagh than fishermen from the other shores. The main reason for this was that western shore fishermen specialized in long-line fishing for eels, and the best eel fishing grounds lie near the eastern shore. Another factor was that the greater concentration of fishermen on the western shore made it necessary for some to travel longer distances to find fishing space. The technique itself demands detailed knowledge of bottom characteristics over long distances.

At the time the mental map exercise was carried out, the fishermen used no position-fixing equipment, nor did they use echosounders to ascertain water depth. Indeed, most boats did not even have compasses. Echosounders appeared for the first time in the early 1980s, but none of the elderly men asked to compile the mental map would ever have used one. GPS technology was introduced in the late 1990s, but even now it is used only to fix the positions of buoys, not for general point-to-point navigation. The mental map is a product of an era when fishermen established locational fixes for water depth and substrate type using various shore

Fig. 3. Facies map of Lough Neagh generated from side-scan sonar surveys (after Quinn et al. 2001)



landmarks such as isolated trees, distinctive houses, hills, woodland, and high buildings such as church spires. The conjunction of two easily identifiable features on the shore would indicate that the boat had reached a known point. In the early years of the 20th century, fishermen used a method akin to leadline soundings, but to establish substrate character rather than water depth. A stone tied to a line was dropped over the side, and when the stone hit bottom the nature of the tension transmitted up the line enabled the experienced man holding it to distinguish the full range of bottom types. This method was used as a precaution where a sandy area suitable for drafting was surrounded by gravelly flats that would "rag" nets and lines.

In discussing location, fishermen describe the lough bed as a farmer might describe individual fields, with each area given a specific name. They do use the cardinal compass points, but they also make extensive use of a "secular" terminology using expressions such as "beside," "beyond," "over beyond," and so on. Donnelly (1981, 1986) also noted that the fishermen have little sense of scale in the conventional sense. He had to precede the mental map exercise by carefully explaining the 1:63 360 scale of the outline map at a very basic conceptual level. As they have no tradition of using hardcopy maps, the fishermen's mental world is experienced essentially at a 1:1 ratio.

The accuracy of the Lough Neagh mental map stands in sharp contrast to the characteristic distortion of the classic mental map, developed almost exclusively in urban environments. For example, Bell et al. (1978, page 267) state that "compared to 'reality' the cognitive map is sketchy, incomplete and distorted. In a sense, it is highly impressionistic..." Indeed, it is this very divergence from reality that gives the mental map its general and academic interest, as researchers try to elucidate the personal cognitive, emotional, and lifestyle factors that lie behind errors and distortion. For example, one common characteristic is the tendency to exaggerate the areas of those spatial elements that lie closest to home.

The level of accuracy in the Lough Neagh mental map also contrasts with the findings of Miller (2003), who carried out one of the very few mental mapping exercises located in a natural setting. Her study was set in a closed forest with few outlooks or vistas that would enable participants to gain a broad overview of the environment. She noted that there are many similarities in the mental maps created by participants in natural settings with those carried out in urban settings. However, she considered that the specific location of features on mental maps in natural settings may be less accurate, because there are so few locational cues. Even more so than hikers in a forest, fishermen could not obtain an overview of the lough bed in an era predating echosounders and side-scan sonar. The accuracy of the Lough Neagh map is even more noteworthy because, in this environment, there can be no question of "inferential structuring," a term that describes the anticipation or prediction of the spatial organization of a given environment from experience elsewhere. For example, urban dwellers can anticipate elements of city structure from previous experience of block patterns in another city.

The environment presented by the bed of Lough Neagh is a huge challenge to accurate mental mapping because it scores so low on "legibility," a concept introduced by Kevin Lynch (1960, pages 2–6) in his groundbreaking work on the mental maps of American cities. Legibility describes the ease with which a subject can form a cognitive map of an environment. It is promoted where an environment has elements that enhance human ability to impose a pattern, an organizing structure that assists learning. Lynch identified five groups of such elements: paths, edges, districts, nodes, and landmarks. A high degree of visual access to these various elements improves legibility. Although equivalents of Lynch's elements do exist on the bed of Lough Neagh, they are visually inaccessible from the surface. The lough bed is much more difficult to visualize than its closest urban "equivalent," the city subway, an environment regarded by Bell et al. (1978, page 275) as particularly challenging to accurate mental mapping because of its lack of visual cues and overview opportunities.

There are a number of factors that, taken together, may explain why the fishermen's mental map of Lough Neagh is so remarkably free of distortion. In the literature, the mental maps under discussion are invariably those of individuals rather than groups. Indeed, Gould and White (1974) see individuality as fundamental to the very concept of the mental map. However, they go on to outline communal or group concepts that help to throw light on the genesis of the Lough Neagh map, "While every view is unique...there may be considerable overlap between the mental maps of people. The more

homogeneous the group in terms of age and experience, the more overlap we might expect between the mental images“ (page 52). This leads them to the concept of the “homomorphic map,” which is a single, representative mental map constructed from the many individual viewpoints of people in a group.

Even though each Lough Neagh fisherman has his own mental map, the map is a communal rather than an individual construct, because it is a compendium of the knowledge of many individual fishermen from several generations. At various times in the past, individual distortions undoubtedly existed because relative inexperience, or an untypical or chance event, may well skew a given fisherman’s perception of his working environment. However, the process of mental map construction is self-correcting, as in the event of disagreement between the accepted version and a new perception, it is almost inevitable that the traditional perception will prevail. Thus, the essential conservatism of the process acts to filter out errors by laying the onus of persuasion overwhelmingly on those advocating change. (This process has analogies in other fields notable for their reluctance to change accepted viewpoints, e.g., the legal principle, “The burden of proving this lies on whoever asserts it,” and the theological maxim, “In dubio pro traditio,” i.e., where a matter is in doubt side with the tradition.)

It could be argued that conservatism should militate against improvement of accuracy, because it prevents acceptance of corrections and additions to the communal knowledge bank. However, economic self interest will serve to counterbalance conservatism by acting continuously to prevent errors from becoming institutionalized. Even at the individual level, economic interest acts as a constraint on distortion, and emotional factors are unlikely to play much part. This contrasts with the urban mental maps portrayed in Lynch’s study (Lynch 1960). A change in the accepted view will be gradually incorporated in the fishermen’s collective perception of their environment, but only when the change has long-term sanction by majority opinion, and in particular where it has the authority of the most experienced and most respected fishermen. Over time, individual distortions are counterbalanced and corrected by other influences, and significant inaccuracies are filtered out of the folk record. This process of gradual adjustment and refinement may be greatly aided by the fact that the map is a mental map, rather than a hardcopy chart. The latter is a fixed “official” representation, and accordingly is more likely to be defended against change. On this point, Turnbull (2003, page 148) observes that “arguably there is a greater requirement for conservatism in an oral tradition to ensure effective transmission, but that conservatism or closedness does not of necessity preclude change any more than it does in Western science.”

The Lough Neagh mental map may be seen as the ultimate homomorphic map generated by the combined perceptions of a relatively homogeneous community reliant on a specific resource, but with a vital additional self-correcting dimension created by economic self interest acting over a long period of time. It should be noted here that self interest in a more immediate sense is also served by accuracy. The lough is dangerous, and over the years, many lives have been lost in boating accidents. The transmission of this collective knowledge through the medium of the relatively few fishermen interviewed in depth by Donnelly brings no risk of distortion, because to these fishermen the communal knowledge bank of their community and their own personal knowledge are identical.

The notion that this knowledge is communal, rather than personal, property is illustrated by the fact that the fishermen exhibit no reluctance in sharing their knowledge of the lough. This is in sharp contrast to the attitudes of inshore fishermen on many open ocean coasts. In areas as far apart as the coast of Maine in the USA and the north Irish coast, lobster and crab fishermen zealously protect their specialist knowledge of areas that they regard as historically “theirs,” and they strongly resent any encroachment by others on their territory. Grant and Berkes (2007) note that long-line fishermen in Grenada, eastern Caribbean, try to keep fishing grounds secret by approaching the village from different directions. In contrast, in Lough Neagh, there is no sense that particular areas of the water body are the exclusive property of any individual or group.

Transmission of the Mental Map

It should be noted here that the mental map depicted in Fig. 2 forms only part of the geographical knowledge transmitted to future generations. The fishermen’s knowledge also includes the locations and names of 178 individual “drafts,” specific inshore areas used to deploy nets (Donnelly 1986, Appendix 2a, pages 260–262).

On Lough Neagh, fishing is very much a family affair, often with three generations represented. Kinship groupings are of central importance, e.g., the artificially excavated coves the boats use as bases were originally dug by family groupings. As the coves are still family owned, an unrelated outsider cannot break into the family-based fishing circle (and in any case a newcomer could not get a licence from the cooperative that controls the fishery). The fishermen themselves acknowledge that the vital key to transmission of all aspects of their fishing knowledge is the tradition of fishing in family groups. Fishermen usually operate in two-man partnerships with a friend or relation but there are also three-man partnerships. It is almost unheard of for two or three young (teenagers or twenties) men to form a fishing partnership. The usual mix is a younger man with his father, uncle, or even grandfather. This type of organization is ideal for the transmission of traditional oral knowledge.

Boys from their mid-teens upward are taken on the lough by their fathers, uncles, and other older male relatives and family friends. Donnelly (1986) noted that 65% of fishermen's families had at least one son fishing, in detail ranging from 50% on the western shore to 85% on the eastern shore. They learn the shoreline and substrate geography by a process of "osmosis" as they work alongside these older men, both on the water and during associated activities such as running (i.e., baiting) long lines and preparing boats. Indeed, even before going on the lough, a boy will know a lot about it simply because he lives in a family and in a community where Lough Neagh is central to everyday life and conversation. Both on the water and on land, boys will overhear adult men discuss fishing grounds, methods, and strategies. Older fishermen will sometimes keep up a running commentary on the day's activities for the benefit of the novices. They will also occasionally move into an explicit instructional mode where they instruct the younger boys on some aspect of the fishing trade such as line handling or bottom characteristics.

In the past, the importance of practical, workplace-based transmission of knowledge and skills was accentuated by the somewhat ambivalent attitude of the fishermen to formal education. Before the 1950s, educational opportunities for their families were very limited, and in any case education was always regarded as being of little importance for fishing. Many elderly fishermen say that they started to fish when they were only 12 years old, and so their school days were truncated. Occasionally, fishermen complain that their sons were never encouraged in the schools as it was considered that they would be "going to the lough anyway." (It may have been that boys who felt that they were destined for the lough had little incentive to study, and their fathers had little incentive to encourage them to do so.) For whatever reason, in the mid 1980s only 12% of fishermen's families were receiving a grammar school education, well below the then Northern Ireland average of ca. 30%. (Donnelly 1986, page 206). This sense that formal education was unimportant reinforced the status of orally transmitted and practically derived knowledge over the "book learning" of schooling. Pálsson (1998, page 53) describes similar attitudes in Iceland, where fishers are often dismissive of formal training, even when the subject is fishing: "Even a novice fisherman, skippers say, with minimal experience of fishing, is likely to know more about the practicalities of fishing than the teachers of the Marine Academy."

Transmission of the fishermen's knowledge is also facilitated by the fact that the fishing community is historically very closely knit. Donnelly (1986, page xx) observes that "The Lough Neagh fishing community is notoriously difficult to penetrate; its members do not communicate easily with outsiders." In 1986, 35% of west-shore marriages were within the local fishing families; in the early decades of the 20th century, the proportion was 55% or higher. Donnelly (1986, pages 171, 173) presents maps showing the alongshore and cross-lough marriage and kinship patterns that have developed over the years. Many of these were established in the days of sail when, up until about 1940, it was common for fishermen to spend at least one night and often up to a week on the opposite shore. Fishermen also migrated across and alongshore to live in new areas. In modern times, day-to-day contacts continue to take place across a wide range of age groups and fishing experience. Fishermen regularly meet out on the lough, and it is common for two boats to lie alongside for some time as the men talk and exchange opinions and news. Some fishermen are also small farmers, and they meet in that context, e.g., at markets and through cooperative farmwork. Fishermen have regular cross-generational contact at social occasions such as sporting events, where they habitually "talk shop."

The Influence of New Data from Technological Innovations

It may be asked if and how the fishermen's mental map has been modified by data from new technological aids such as echosounders and GPS instruments that have been introduced to Lough Neagh over the last quarter century. This question could be fully explored only by repeating the mental map exercise with younger fishermen, but even then there would be major difficulties in interpretation. If a new map revealed significant differences from the mid-1980s mental map published by Donnelly, it might be surmised that the differences are due to technological correction of earlier errors. However, it would be more logical to assume that the accuracy of the mental map had deteriorated rather than improved, because the comparison study in this paper (against state-of-the-art mapping sonar, superior in definition and areal coverage to any instruments used by the fishermen) has revealed no errors. A speculative explanation for the deterioration in mapping quality would then be that errors are induced by the breakdown of the traditional highly efficient knowledge transmission process, and its replacement by over-reliance on instrument-generated spot data. Such digital information is useful enough in real time, but because it is unrelated to shoreline landmarks, it is less likely to be internalized in the form of an accurate and comprehensive mental map of the lough.

However, even if a new study produced a mental map identical to the map published by Donnelly, the question could then be posed: which elements of the new map are derived from the use of technology, and which elements are derived from cross-generational transmission of local knowledge? In fact, there is little reason to believe that a new study would result in a significantly different mental map. There is some anecdotal evidence that technological aids actually have little influence on the mental construct. Recently (January 2008), one of the authors of this paper interviewed a group of fishermen, all of whom use echosounders and GPS. Perhaps surprisingly, they said that GPS is used solely to fix and locate fishing gear such as long-line buoys. It is not used to georeference water depths or other features in relation to the wider geographical context. Digital echosounders are used to give spot checks of water depth on fishing grounds, but the instruments in use do not give any information on substrate character. Some fishermen glance at their echosounder readout only when leaving or approaching a cove on the shore; in this case, it is principally a safety device. In summary, both GPS and echosounders are used to generate ephemeral spot data that are not contextualized, and so are not easily assimilated into a coherent cognitive image of the lough bed. The mental map transmitted from earlier generations has been so completely internalized by fishermen of all ages that they consider the morphology of the lough bed as a "known," factually accurate and complete. The evidence of our comparisons confirms that they are totally justified in making this assumption.

Accurate mental mapping in Lough Neagh is certainly a challenge because fishermen cannot see the bottom, but in the longer term, it is facilitated by the fact that the lough substrate, particularly in the gravel flats, which are analogous to "islands" in a sea of mud, is an essentially fixed morphology unlike, for example, the constantly changing bedforms often found in tidal estuaries and on some open coasts. The finer sediments, sand and mud, do move under the influence of currents, but the gross geometry of the bed remains unchanged. Importantly, Lough Neagh is small enough to be known in its entirety. Consequently, repeated fishing experience over many years will aggregate, confirm, correct, and refine environmental knowledge. This combination of substrate stability, relatively limited extent, and extended fishing experience over generations means that, in practice, the fishermen's mental map is already at optimal accuracy at the scale required for use, and so is not open to revision or "updating." (For example, in practical terms, there is no improvement when traditional knowledge of water depths in units of feet (30.5 cm) is replaced by echosounder data using units of 5 cm.) As indicated in Appendix 1, an individual fisherman will accept that his own knowledge has limitations, but the collective knowledge of the fishermen as a group is regarded as exhaustive. If a young fisherman using an echosounder calls out a water depth reading to his father, it merely confirms what the older man already knows. Indeed, older fishermen perceive their knowledge of the lough bed as the "gold standard" that can be used to confirm the accuracy of the echosounder, rather than vice versa.

There is a close parallel to the Lough Neagh mental map in the mental map of coral reefs held by fishermen in the Polynesian island of Anuta (Feinberg et al. 2003). There are many similarities:

the map was developed without scientific instruments and has been transmitted across generations without reliance on hardcopy representation. A very detailed graphical representation was produced by drawing on the knowledge of a group of experienced and respected fishermen (although Anuta differs from Lough Neagh in that just one of these men was the main source of most factual information). As in Lough Neagh, terrestrial landmarks were used to accurately line up marine features in relation to each other and the land. However, the Anutan seabed is more "legible" because the coral heads can be seen when hovering directly overhead in a boat or canoe. A further similarity lies in the methods of transmission. The Anutan map is also passed on both orally and through concrete demonstration, "the expert takes the novice to the fishing grounds and shows him how to find them by lining up with the appropriate land and sea marks." One expected difference is that, in contrast to Lough Neagh, which is small enough for the fishermen to acquire a detailed knowledge of the entire bed, Anuta lies in a vast ocean. Thus, the reef map is detailed only within a 2–3 mile (ca. 3–5 km) radius of the island, and for a greater distance in the direction of most frequent travel. Outside these limits, fishermen's knowledge of the seabed is sketchy and often inaccurate.

It is not suggested here that the Lough Neagh mental map is in some way "superior" to those produced by instrumented methods. We are not comparing like with like. The mental map of the lough took generations to evolve. Although highly accurate, it is subjective and specialized in that it contains only selected information perceived to be of value to the map user. (In this regard, it displays the characteristics of a standard mental map; it is its freedom from spatial distortion that sets it apart.) Ultimately, the limiting resolution of a fisherman's mental map will be established at the point where additional detail brings no practical or economic advantage. At this point, further detail, even if acquired, will not be retained or transmitted in the communal knowledge bank. In contrast, the science-based methodologies can acquire huge amounts of high-resolution data on a scale of hours, days, and weeks. The limits of data acquisition are set by technical specification, rather than by subjective interest. As these data are digital, they are open to further manipulation and analysis by sophisticated software that can add further value to the surveys.

LEK, Science, and Mental Maps

Many writers in the field of social anthropology have commented on the accuracy of the mental maps (later realized on hardcopy media) held by various indigenous peoples. Brody (1981) notes that hunting peoples have a preoccupation with literal truth, whereas Rundstrom (1990) states that modern cartographic research has established that "most Inuit maps....were extraordinarily accurate renderings of the landscape as sensually perceived" (page 155). Interestingly, Rundstrom suggests that accuracy is promoted by the Inuit tradition of free sharing of environmental information.

Despite such claims for accuracy, the use of traditional knowledge alongside scientific data is hindered by what Turnbull (2003, page 89) has described as the "great divide" between science and other knowledge traditions. The divide exists because traditional knowledge is embedded in epistemologies and ontologies that are distinctive and fundamentally different from those of science. (In many cases, this comment also applies to local knowledge, even though the descriptor "traditional" may be inappropriate.) Indeed, Ingold (2000, page 225) emphasizes the fact that all maps, including those produced by modern scientific methods, are strongly influenced by their social and cultural matrix.

The most frequently quoted example of a culturally embedded map is that of the Pacific navigational knowledge tradition, specifically the non-artefactual mental cartography of the island navigators of Micronesia, which is based on a sidereal compass (Akimichi 1996, Finney 1998, Ingold 2000, Turnbull 2003). Akimichi (1996) points out that some elements of the navigators' knowledge are empirically real (e.g., directions of rising and setting stars, bird and fish behavior) whereas others are metaphorical, but in combination they allow its users to create cognitive maps of the islands that make sense to them. Another example is provided by the Inuit of the North American Arctic. Fossett (2003, page 113) states that "scale, orientation, legend, relief and completeness in Inuit maps did not conform to the ideals of European scientific cartography." In relation to completeness, for example, she points out that European observers typically failed to understand that an Inuit map was never intended to stand alone, that there was an essential link between the graphical representation, whether held as a mental image, ephemeral (e.g.,

drawn on snow) or hardcopy, and the verbal instructions that accompanied it. Inuit mapping often used a straight-line topological technique, which included only those landscape features necessary for finding direction. This simplification is ideally suited to teaching a route along a coast or a river, provided that the map user is also following a list of detailed oral instructions.

Another common conceptual difference between scientific and traditional mapping concerns the representation of distance. Scientific maps are based on linear units of distance; in contrast, many traditional artefactual maps and mental maps use units of temporal duration, e.g., Micronesian navigators (Turnbull 2003), the Inuit (Jackson 2000, Fossett 2003) and the Maori (Barton 1998). Jackson (2000) describes the Inuit practice of measuring distance by the number of overnight "sleeps" (camps) necessary on a journey. As this number will vary with difficulty of terrain and other factors, two journeys of identical linear distance will often return quite different journey times. In context, the time taken recorded on an Inuit map is much more real and useful to the map user than the linear distance recorded on a science-based map. The Maori used an identical system of reckoning distances by nights spent in camp (Barton 1998, page 496).

Given these fundamental differences between the scientific and traditional knowledge systems, two linked questions arise: (a) can traditional and scientific knowledge be compared, and (b) can traditional knowledge be used alongside modern scientific data in resource management? (These questions apply equally to local knowledge.) Although Woodward and Lewis (1998, pages 8–9) broadly favor comparisons, later in the same volume Lewis (1998, page 176) points out the problems, "Without knowing a culture's underlying concepts of how space is ordered and represented, it is impossible for another culture using different spatial structures to interpret indigenous maps." Turnbull (2003, page 132), however, strongly advocates cross-cultural comparisons because he believes such comparisons would enhance the status of local/traditional knowledge systems, "if the full power of the knowledge is to be recognised it is not enough for it to be valued in its own right, it must also to be understood in a comparative context." Several workers have proposed methods and protocols to facilitate the integration of local knowledge into management. Both Mackinson and Nøttestad (1998) and Grant and Berkes (2007) advocate an expert system approach, with the former making the point that, without the insights of local knowledge, "not only are we missing half the picture, we are also in danger of reinventing the wheel." In Chesapeake Bay in the United States, Paolisso (2002) advocates use of a cultural model as a device to overcome watermen's distrust of science and regulation.

However, comparisons across the traditional–scientific divide can be a highly sensitive issue, particularly when debating the validity of testing the accuracy of traditional knowledge against scientific knowledge. Here, the consensus among anthropologists and ethnographers seems to be that science-based and traditional knowledge systems are truly incommensurable. Without a common standard of evaluation or assessment, traditional knowledge, of which maps both artefactual and mental form a part, can only be validly appraised "on its own terms," a phrase directing the user toward the full cultural context in which traditional knowledge is generated. On this argument, comparisons across the divide are invalid and futile as they would inevitably take place on the terms of science, resulting in an equally inevitable conclusion that science was superior. The LEK literature often exhibits an exaggerated sensitivity to the risk of exploitation of indigenous peoples and their environmental knowledge. In some cases, either the researchers themselves, or the organizations funding their research, seem to perceive any attempt to compare LEK with science as threatening the uniqueness, value, importance, or integrity of LEK. Brook and McLachlan (2005), for example, oppose even the suggestion that local/traditional knowledge be validated by science-based data, pointing out that the latter also has constraints on its accuracy. (No scientist would dispute this, hence the attempt in this paper to establish the accuracy standards of the scientific comparators.) Brook and McLachlan go on to express concerns that validation by science is in some way disrespectful and works to the disadvantage of marginalized communities. Even Turnbull (2003, page 20), a strong supporter of cross-cultural comparisons, is anxious to level the playing field as he insists that, "a necessary condition for fully equitable comparison is that Western contemporary technosciences, rather than being taken as definitional of knowledge, rationality or objectivity, should be treated as varieties of such knowledge systems." Turnbull's own motivation is hardly that of the disinterested facilitator (page 131), "Such comparisons constitute important political

strategies for the deflation of the dominant knowledge tradition of science."

The literature specifically dealing with LEK characteristically assumes its intrinsic value, presumably because the knowledge would not have been retained and transmitted if its users had not found it practically useful. No attempt is made to validate the accuracy of the knowledge because the cultural process is perceived as providing its own validation. This aversion to practical evaluation in favor of abstract high-level debate is well illustrated in the introduction by Ellen and Harris to the text edited by Ellen at al. (2000). Here it is stated (page 1), "In short, we take it for granted that IK (indigenous environmental knowledge) is useful in particular contexts, but seek to go beyond such demonstrations and statements of the obvious to ask what role it plays in 'green' arguments and scientific and political discourse more generally."

In the face of such attitudes, the resource manager, almost invariably trained in the scientific culture, is faced with a dilemma if he/she wishes to use local or traditional knowledge. Validation is central to the scientific paradigm, and scientists are reluctant to use information when they cannot assess its reliability and error margins. Although some scientists are enthusiastic about integrating LEK, a good deal of skepticism remains (not necessarily about the validity of local knowledge; perhaps more often about the practicalities of integrating it with science). Gilchrist and Mallory (2006) report that only two (0.1%) papers out of 1929 written on birds published in ornithological or wildlife journals between 2001 and 2005 incorporated LEK. Several studies have shown that some aspects of LEK are simply wrong (Gilchrist et al. 2005, Gilchrist and Mallory 2006). Although Feinberg has an undisguised admiration for the Anutans' "precise and detailed" mental map of coral reefs, he notes that it has inaccuracies (Feinberg et al. 2003, endnote 13).

At first sight, the work carried out in this paper would appear to fall foul of the LEK researchers' rejection of direct comparisons against a scientific standard. However, the science vs. traditional debate outlined above is largely irrelevant in the Lough Neagh case. The Lough Neagh mental map, although not produced by scientific methods, is accurate in scientific terms, e.g., fishermen's estimates of spot water depths coincide with those from bathymetric echosounders. Thus, the map is both traditional (e.g.,, the landmark-based method used to locate bottom features is very similar to that used by the Maori (Barton 1998, page 496) and the Anutans (Feinberg et al. 2003) and yet also embedded in the scientific knowledge tradition, e. g., linear scale (in plan and in depth) and compass points follow scientific conventions. This is not surprising because, in other aspects of their domestic lives and work, the fishermen routinely use standard scientific units to measure variables such as distance, weight, volume, and time.

The LEK literature typically concentrates on the LEK held by marginalized, traditional, pre-technological societies that are perceived as being under threat from Western values and economic systems. This bias in focus masks the fact that LEK is also a common feature of particular occupational and lifestyle groups in modern technological societies, e.g., farmers and fishers. The Lough Neagh fishermen certainly have a strong sense of separate identity. Historically, their relative isolation over long periods of time has produced a community of fisher families that kept much to themselves, e.g., marriage was predominantly within the community. These influences helped to produce what Donnelly (1986, page 243) calls "a remarkable homogeneity of cultural background." There was also a perception that the fishermen were socially inferior to the neighboring farmers, due to relatively poor economic returns from fishing during extended periods, such as the 1920s. However, their distinctiveness must not be overstated. The fisher families feel that they are part of a wider society, and share its prevailing cultural norms. All the fishing families have kinship relations and friends who have no fishing tradition. There have been periods, e.g., the 1980s, when good prices for their catches left them financially better off than neighboring non-fishing families. They are also pragmatic: they adopt new technologies perceived to be useful as and when they become available, and they welcome any innovation that makes their work easier. Their mental map was generated by experience and simple position-fixing methods, not because they valued this traditional approach, nor because they accorded it any spiritual significance, but simply because that was the optimum method available to them.

Agrawal (1995) has firmly rejected any attempt to make a fundamental distinction between indigenous and scientific knowledge. Kalland (2000) has warned against the tendency to romanticize and

idealize the behavior of indigenous peoples by considering it to be inherently conservationist. In line with this thinking, a central tenet of this paper is that LEK should be subject to the same searching scrutiny as any other type of knowledge. There is no convincing argument for it to be treated reverentially as a virtually sacrosanct "black box," so precious that it is above analysis or validation. Accuracy is an essential characteristic of any sort of knowledge relevant to sustainable resource management, and it is unrealistic to expect a scientifically trained resource manager to take the accuracy of traditional or local knowledge on trust. The government department that commissioned the side-scan sonar survey of Lough Neagh would have saved the taxpayer a lot of money if the fishermen's mental map had been regarded in this way. However, it would have been completely irresponsible to accord the mental map this status without any attempt to verify it (there may also be legal barriers if conservation legislation demands that monitoring and reporting be conducted using standard scientific protocols).

It is accepted that the "searching scrutiny" we refer to above will not always take the form of direct comparison with scientifically acquired data. Allowances will have to be made for the unique world view of those societies that produced the knowledge, and in some circumstances, comparison against a scientific standard will be inappropriate. In these cases, it may still be possible to use innovative approaches such as expert systems, fuzzy logic, and cultural models to integrate knowledge across the divide. However, where traditional or local knowledge is held in formats compatible with science, as in the Lough Neagh example, an essential and commonsense preliminary to its use in resource management must involve quality testing against whatever scientific comparators are available. It may be objected that this creates a "value hierarchy," with scientific knowledge at the top and local knowledge (and by association those who possess it) consigned to a subjugated position. In practice, it is just as likely that the validation exercise may demonstrate that LEK has advantages over the scientific method. Those who value LEK should have the confidence to believe that comparison studies will provide convincing evidence for its accuracy. Ultimately, our confidence in the Lough Neagh mental map is a result of a validation process that demonstrated that, where substrate and bathymetry are concerned, full integration of local and scientific information sources can be strongly recommended.

Emphasis on adjectives such as "traditional" or "indigenous" simply diverts attention from the central question: can this knowledge be trusted? The environmental knowledge of the Lough Neagh fishermen is local and empirical in that it was acquired by local people in a local environment going about the business of earning a living. Its "traditional" aspect is significant only because acquisition and testing of this knowledge by several generations over long periods of time provided the quality controls on its accuracy.

Elsewhere, validation followed by use of LEK in management could bring significant benefits and save large sums of money. In Belgium, for example, it has been suggested that the local knowledge of fishermen should be put to use in obtaining data on fish stocks and habitats (Frank Maes, *pers. comm.* 2007). Scientific monitoring can only be carried out in relatively few places, and the need to build extended time series demands that the same locations be used again and again. Inevitably, this concentration of effort means that most areas are not monitored. The development of a robust protocol to integrate quantitative scientific data with the usually qualitative (and often intuitive) knowledge of those who make a living from fishing is put forward as a means to monitor habitats more widely. It will often be a considerable challenge to find modes of integration that respect both knowledge traditions. For example, Pálsson (1998) describes the so-called "trawling rally" of Iceland, which is an explicit attempt to inculcate cooperation between scientists and fishers by involving the latter in the collaborative collection of detailed ecological data. However, this collaboration has been criticized as superficial, because fishermen are merely acting as assistants in a science-designed experiment; their own practical and intuitive knowledge is still effectively disregarded.

Our validation of the Lough Neagh mental map, and consideration of the reported accuracy of indigenous mental maps, leads us to speculate that the Lough Neagh case may be a local illustration of a "universal" principle that can be applied to many different cultures and many different natural resources, e.g., fisheries, forest products, and pasture. The principle is that, where LEK is held as a mental map, this map will be highly accurate when the following conditions are present: (1) a relatively homogeneous community, (2) local use or exploitation of a natural resource, (3) generation-to-generation transmission of knowledge, (4) economic dependence on the resource, and (5)

sufficient time for the self-correcting process to produce accuracy.

The literature contains contrary indications, e.g., Sáenz-Arroyo et al. (2005) point out that knowledge of the past conditions of a fishery is lost very quickly between generations. Fishermen under 30 had quite different perceptions of the resource baseline than those over 55, even though both lived in the same communities and indeed often in the same families. In the Lough Neagh study, however, the bathymetric and substrate characteristics of the lough bed form a relatively "fixed" subject matter (in historic time at any rate) that lacks the rapid change potential of fish stocks.

CONCLUSION

This paper is one of very few that has attempted to compare LEK with scientifically acquired data. It involves "retro-comparison" of three quite separate pieces of work; the side-scan sonar survey was not carried out with the explicit intention of comparing the results with the mental map published ca. 10 years earlier. It may even be the case that it is fundamentally inappropriate to assess the accuracy standards of the mental map against the two comparators used here, because the mental map may, in fact, be the most accurate of the three. This claim could be tested only by future survey work using high-resolution sensors, high-precision DGPS fixes, and information from a detailed bottom-sampling program.

Nevertheless, although a more thorough assessment of the accuracy of the Lough Neagh mental map is work for the future, the available evidence indicates that the map is strikingly accurate. If such accuracy is indeed typical of the mental maps held by other resource users, the lesson for academic researchers and resource managers may be that they should reconsider any scepticism about the value of so-called anecdotal knowledge. It is unwise to disregard LEK just because it is not acquired by high-technology, scientific methods. The process by which mental maps of a resource are generated may not be "scientific" in the usual sense, but it has an inherent rigor and quality control at least equal in efficiency to those associated with technology.

The outlook for the Lough Neagh fishery and the unique local knowledge of its fishermen is not encouraging. Eel yields are steadily decreasing, despite the use of quotas as a conservation measure. Indeed, the boats are finding it increasingly difficult even to reach their quotas. There now appears to be a preponderance of smaller eels in the lough. Reasons advanced for declining stocks include pollution (the lough has a significant eutrophication problem) and overfishing. Recruitment is a major problem. Educational and employment opportunities in the loughside communities are now better and more varied, and lifestyle expectations deter young men from continuing family traditions of fishing. There is a wide range of ages represented among current fishermen, ranging from early 20s to over 80, but older men dominate. There are only ten active fishermen under 35, and these younger men tend to have full-time jobs, particularly in the construction industry. They fish part-time in evenings and on weekends, particularly if the fishing is reported good. A pessimistic scenario is that continuing failure to recruit young men will ultimately lead to the end of the fishery, and with it the mental map of the lough that has been transmitted down through the generations. This outlook may be unnecessarily gloomy. The mental map will survive as long as the occupation it serves survives. Although numbers of fishermen may decline still further, there will probably always be a market for eels, and consequently fishing will continue on Lough Neagh. It seems likely that for the foreseeable future the fishermen will continue to rely heavily on the mental map of the lough handed down to them from the past.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/vol13/iss1/art13/responses/

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Appendix 1. Construction of the mental map of Lough Neagh

Please click here to download file 'appendix1.pdf'.

Appendix 2. Side-scan sonar survey of Lough Neagh

Please click here to download file 'appendix2.pdf'.

Appendix 3. Accuracy comparison of the mental map with the technical sources

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Appendix 4. Possible influence by other maps and surveys

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