COGNITIVE MAPS: CARTOGRAPHY AND CONCEPTS FOR AN ECOSYSTEM-BASED FISHERIES POLICY

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The bellman himself they praised to the skies –
Such a carriage, such ease and such grace!
Such solemnity too! One could see he was wise,
The moment one looked in his face!

He had brought a large map representing the sea,
Without the least vestige of land:
And the crew were much pleased when they found it to be
A map they could all understand.

"What's the good of Mercator's North Poles and Equators,
Tropics, Zones, and Meridian Lines?"
So the Bellman would cry: and the crew would reply,
"They are merely conventional signs!"

"Other maps are such shapes with their islands and capes!
But we've got our Captain to thank"
(So the crew would protest) "that he's brought us the best –
A perfect and absolute blank!"

From Fit the Second in "The Hunting of the Snark: An Agony in Eight Fits" by Lewis Caroll, 1876. Illustration by Quentin Blake, Folio Society Edition, 1976.

ABSTRACT
Mental concepts of the health of a marine ecosystem and its fisheries can influence the goals and design of management policies. We discuss how such cognitive maps, held by individual humans, and deriving from an interplay of science, traditional and local knowledge, are fostered by the *Back to the Future* approach to fisheries policy. *Back to the Future* seeks to use the structure and abundance of past ecosystems to guide restoration policy, and engages all sectors in positive and remedial action.

A blank map is ideal for hunting a beast that no-one knows the form or whereabouts of. Lewis Carroll's Bellman and crew of snark-hunters neither needed nor desired much idea of where they were going. Later in the poem, the blank map seems to be there for them to sketch their own futures.

Henri Poincaré said that we all carry a map of the world in our heads (Figure 1), but our maps are not a perfect representation of the reality that surrounds us. Illusory and mistaken elements of the map may prompt erroneous behaviour, giving rise to all kinds of shocks and surprises. Using our mental map of the present to guide our steps to a better future is therefore an uncertain process. Present maps can at least be checked for errors against what we see in front of us now, but our mental maps of past times are subject to greater error from omissions, misconceptions, misinformation, and even disinformation from those who seek to rewrite history. Nevertheless, mental maps of the present and past are at least grounded in some kind of reality. In contrast, our mental maps of where the future might lead are imbued with dream, myth and wishful thinking. Such dreams of the future are the very stuff of humanity, but whilst they are pivotal to our spirituality and ethics, they rarely offer us much practical help in dealing with impacts on the natural world of which we are an integral, and in the case of marine ecosystems, very damaging, part.

The term 'cognitive map' was first defined by Tolman (1948) and used to denote a mental map of the actual spatial relationships in a rat's view of escaping from a maze. Since then the term has been used in a broader way to indicate mental maps of sets of conceptual relationships about environment, society, institutions, governance and human impacts on the natural world (Lazlo *et al.* 1996). In political science, cognitive maps have been used as a qualitative reasoning tool to try to analyse, predict and understand decisions, especially in the context of conflict and games theory (Axelrod 1976; Levi and Tetlock 1980). Mathematicians have taken the rather

Figure 1. Mathematician Henri Poincaré (1854-1912) said we all had maps of the world in our heads. Poincaré's mental world, however, was likely very different from yours and mine, populated as it was with the arcane equations of the Diophantine proposition and with Poincaré's conjecture, that has baffled all-comers since he died. Appropriately for someone concerned with maps, Poincaré invented topology.

inconsistent and imprecise concepts in the political science literature and formalised a theory of cognitive maps using algebra (e.g. Chaib-draa and Desharnais 1998), computational science (e.g. Park 1995) and fuzzy logic (e.g. Kosko 1986). Recently, fuzzy cognitive maps have become a part of artificial intelligence research in designing functional ways to represent human knowledge and causal inference, a way of programming the actors in a virtual world (e.g. Miao and Liu 2000). The overall success of these ventures in forecasting human social behaviour remains to be demonstrated.

In this paper we use the term 'cognitive map' in the broader sense to describe the totality of the way in which humans envisage natural marine ecosystems, with all their constituent organisms, fisheries, physical environment and modes of human intervention such as management, or lack of it. In fact, the term ecosystem itself implies a cognitive map of humans embedded in a natural world.

COGNITIVE MAPS OF ECOSYSTEMS AND *BACK TO THE FUTURE*

Before it reaches an 'adoption of policy' stage, our *Back to the Future* ecosystem modelling entails two stages: first, the construction of ecosystem models of past and present; and secondly, the choice of a desirable management goal from comparing the benefits and costs of restoring each past ecosystem from the present state. The scientific modelling of past ecosystems can help us improve our maps of the past. The design and analysis of sustainable and responsible future fisheries improves our perception of how a restored future might come to look like the past. So cognitive maps of marine ecosystems and the dynamics of how their status might be changed are integral to the Back to the Future policy agenda.

What might a cognitive map of an ecosystem look like? What elements are captured in the mind? Major features are the species, like valleys, coasts, lakes and rivers. We may imagine that the relative abundance and food web of animals and plants is captured in mountain chains, lake regions, watersheds and plains. Fisheries are perhaps like villages, town and cities. Clearly these representations of the features of natural ecosystems may take many different forms in different individuals, but given our recent evolutionary heritage as humans, it is reasonable to assume that we all have the ability to capture similar map features of the natural world in our heads. This forms the basis of the concept of human biophilia (Wilson 1984). To assume the contrary, that all cognitive maps are arbitrary and unrelated is at best solipsist, and at worst, postmodern.

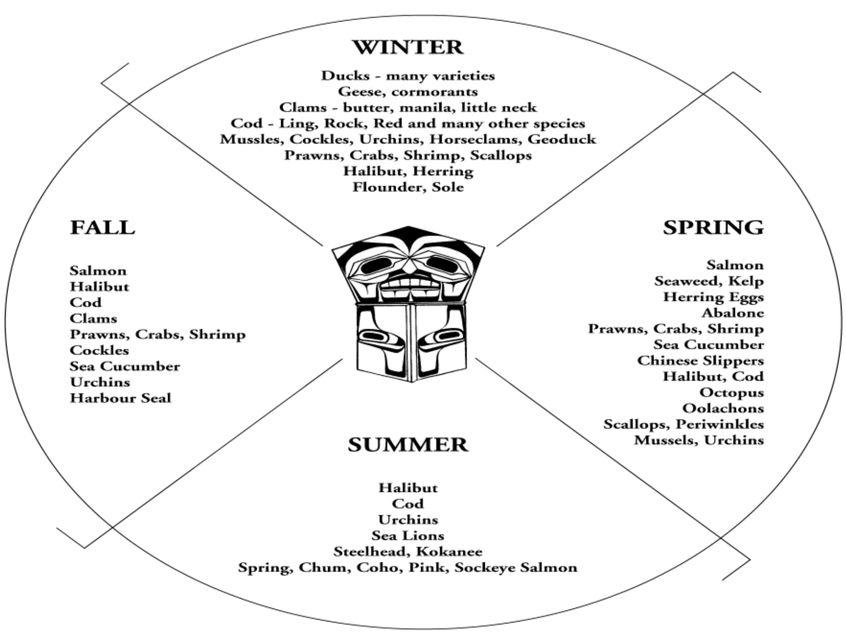

Figure 2: A seasonal cognitive map of traditional food gathering in the Heiltsuk Nation in central British Columbia. In Winter 19 items are named; spring 17; Summer 11; Fall 11 items (Brown *et al.* 1997). Chart prepared with the assistance of Cameron Brown, Beverly E. Brown and Cyril Carpenter.

Cognitive maps exist at different scales and units. That of an Aboriginal or traditional harvester links many species and natural assemblages, those sought and those associated to place, season, weather, ocean conditions and past experience (e.g. Figure 2). At a conceptual or spiritual level, the Canadian First Nation's ecosystem concept is of an ecological, environmental, human and spiritual whole. At the other extreme, the cognitive map of a stock assessment scientist tracks one or a very few fished species and their immediate ecosystem linkages over relatively vast distances. In the first case, the map relates species and abundance to geographic location. In the second, the primary 'geography' is a graph showing change in abundance over time. Figure 3 shows the catastrophic decline in abundance of Rivers Inlet, BC, sockeye salmon, representing an annual loss of $12 million to fishers and $65million in retail value, a foregone future for the Oweekeno Nation and serious consequences for forest and wildlife through the cutoff of marine phosphorous and nitrogen deriving form salmon carcasses. The graph tells us nothing about where or why the decline occurred, issues that would be an integral part of the equivalent cognitive map of the people concerned. There are good reasons to assume a large role for changed ocean conditions in the decline. However, 97% of the salmon fishing occurs in the Rivers Inlet watershed, even though looking at the watershed to the exclusion of the ocean is like looking beside the campfire for something you lost in the forest- it is easier to see, but there's little hope of finding what you seek (Haig-Brown and Archibald 1996).

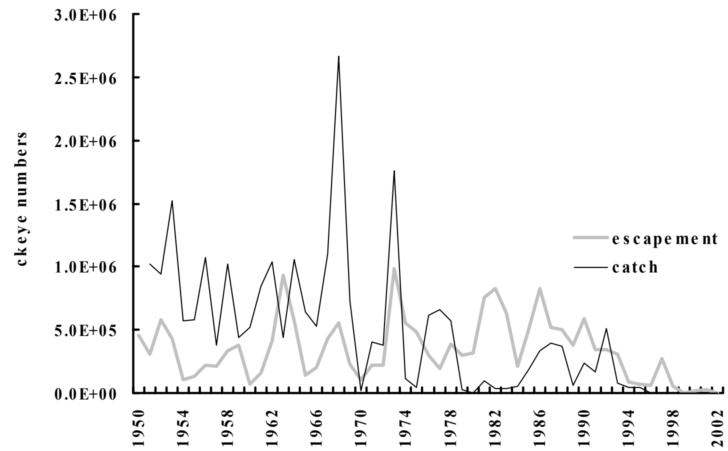

Figure 3. Estimated numbers of Rivers Inlet Sockeye caught and allowed to spawn (escapement) since 1980. Vertical axis in millions (Source: R&SPG 2003).

expressed in Aboriginal food gathering and illustrated in Figure 2. The concept of the adjacency principle (Pitcher and Power 2000; Coward *et al.* 2000; Pauly 1999) is embodied in this diagram. Traditional place-based economies have used traditional and local knowledge (T/LEK) and, from the early to mid 20th century, government agencies often employed local managers who used semi-quantitative ecological and locally-based management. This era has been replaced by large-scale corporate fisheries managed with highly quantitative single-species techniques run by a bureaucracy perceived as remote with no local roots. So a person in a local

Most scientific representations of ecosystems do not provide something equivalent to the powerful ownership and 'stewardship' relationship

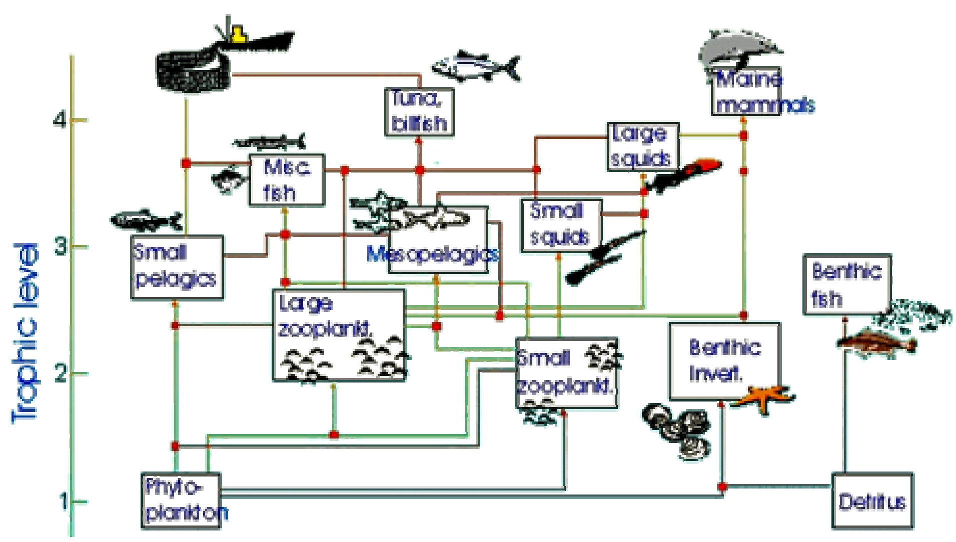

Figure 4. Schematic of a generic Ecopath mass-balance model of an ocean ecosystem showing trophic linkages against trophic level (plants are defined as trophic level 1). Actual models today often have over 50 compartments and many different fisheries (diagram courtesy V. Christensen).

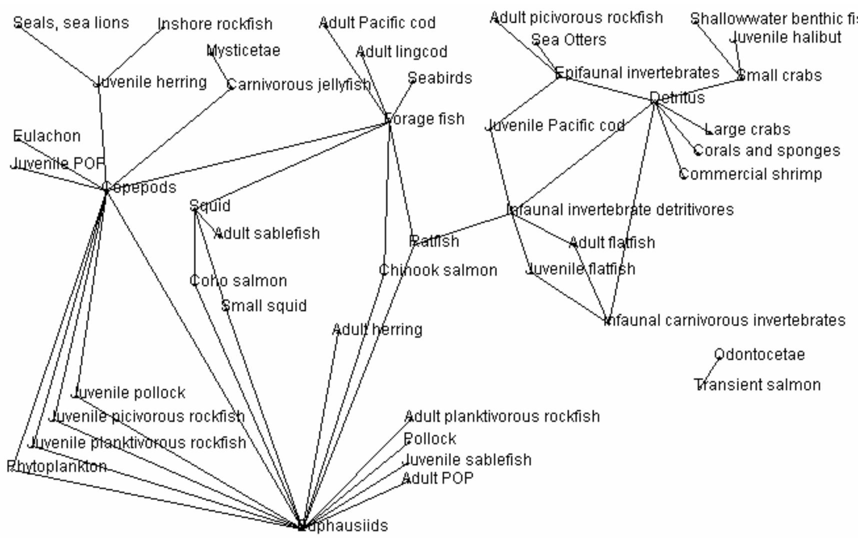

Figure 5. Important food web linkages (links >25% of diet) in the Northern British Columbia ecosystem, as drawn up by a mass-balance Ecopath model. (Ainsworth et al. 2002). The ecosystem scientist's cognitive map of the system is based on diagrams like this.

fishing community in the 1950s would have a very different cognitive map of the same fishery today. These trends have led to a fragmentation of knowledge (Haggan 2000).

The first challenge in creating a common cognitive map of the entire ecosystem is to make disparate maps mutually comprehensible. The progression from the holistic ecosystem knowledge of First Nations, through a stage of studying the bits and then trying to put them back together is, in the worst case, like Humpty Dumpty. At best, it is a 'Blake's progress', leading from the innocence of fisheries scientists in the 1950s and 60s, helping fishers to increase their catch, through the bitter experience of the failure of single species management epitomized by the Newfoundland cod, to, today an emerging informed knowledge of the whole, (Blake 1795, Haggan 2000).

The 'new ecosystem science' began with the development of a system to relate individual quantitative and scientific studies to each other using the 'Ecopath' mass balance approach (Christensen and Pauly 1992), an approach that tracks the trophic flows between predators and prey (Figure 4). This re-linking of separated components opened the door to the use of T/LEK information on presence /absence, relative abundance and trends to improve the models built by scientists (Pitcher 1998). The resulting new cognitive map has come a long way from the single species concept, in that it shows the relationship between species (Figure 4), but is imprecise, in that it smears biomass over the entire ecosystem in tonnes per square kilometre.

Ecosim, the dynamic version of Ecopath (Walters *et al.* 1997), allows modelers to explore the ecological and economic impacts of different fisheries, conservation and management strategies over time. The valuation methodology has been substantially expanded to include social benefits to present and future generations (Sumaila 2001, Sumaila *et al.* 2001) and to look for fisheries allocations that optimise specified objectives. Moreover, the spatial version, Ecospace (Walters *et al.* 1998), enables the assignation of species to their preferred habitat, thus opening the door to the possibility of transferring detailed spatial knowledge of species from scientific surveys,

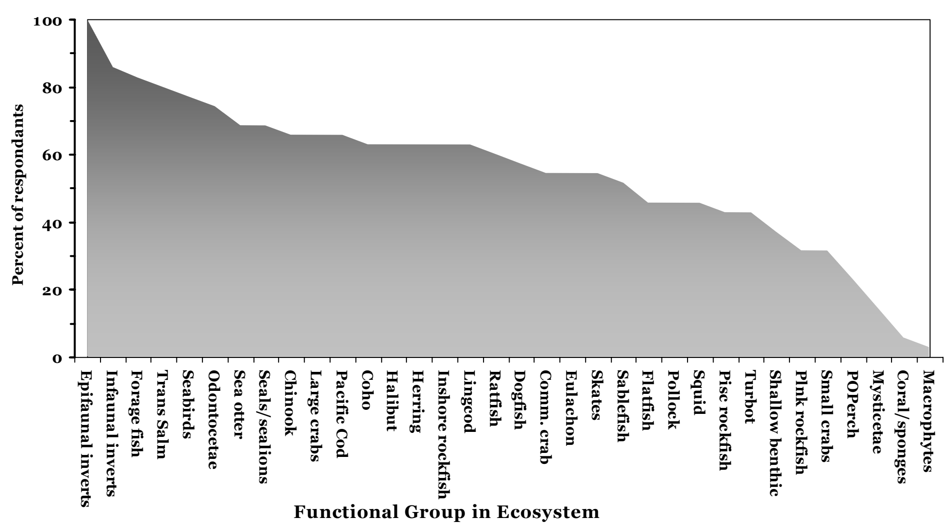

Figure 6. Diagram showing the percentage of respondents (total 35) mentioning as important each of the functional groups included in the mass-balance ecosystem model shown in Figure 5 (sorted from most-mentioned group the to the least). Respondents were from Prince Rupert, Northern British Columbia. Individual cognitive maps may contain only shadows for organisms held in full focus by scientists.

T/LEK, bathymetry and other sources. Spatial management plans, such as zones restricted to some fishing gears, or fully no-take areas, can also be explored and optimal fisheries searched for. The cognitive map delivered by Ecospace actually behaves rather like a real ecosystem and hence may engage the maritime community.

Alternative scientific representations of food web relationships, such as Multi-Species Virtual Population Analysis (MSVPA: Magnusson 1995) cover mainly the fishy portions of an ecosystem with greater rigour than ecosystem models. But MSVPA does not include most invertebrate, mammal and bird species, and does not address spatial distribution. Although these, and allied, models may be useful in fishery management, the MSVPA cognitive map is partial and is likely only to be understood by expert practitioners.

Figure 5 illustrates one aspect of the cognitive map of a scientist working on a trophic model of an ecosystem. The *Back to the Future* concept enhances this map by including perceptions of change in each of the main trophic linkages – change both from the past and for what might yet be. The cognitive map of the whole ecosystem implicit in Ecopath and *Back to the Future* analysis is perhaps closest to the concepts used in former times by pioneering ecologist/ naturalists such as Aldo Leopold (1933), Charles Elton (1926) and Alistair Hardy (1956). It reflects the classic division of ecology in autecology and synecology made in ecology textbooks (e.g. Krebs 2002).

Unsurprisingly, community members interviewed in Prince Rupert, a fishing town in northern British Columbia in the summer of 2000 (Pitcher *et al.* 2002b), revealed cognitive maps that differ from those of scientists. Figure 6 summarises an indication of those differences as reflected in the number and type of organisms mentioned as being important for the food web. Whilst high scores for salmon, crabs, seabirds and killer whales and low scores for small crabs and sponges are not surprising, baleen whales and kelp received unexpectedly low scores. The cognitive map of the ecosystem scientist, on the other hand, covers all organisms equally but weights organisms by the relative importance of trophic linkages as shown previously on Figure 5.

Differences in cognitive maps were also found among the interviewees. Figure 7 shows the percentage responses for ecosystem groups in four categories of respondent: commercial, recreational and aboriginal fishers, and conservationists. It is evident that conservationists put consistently high values on a patchy set of organisms, while they tend to almost ignore others. In contrast to our ecosystem scientist and naturalist mentioned above, a survey of a random set of traditional single-species ecologists, might be similar to this conservationist profile. Recreational and Aboriginal fishers have similar shaped profiles to each other, but recognize different organisms, while, at least in this data, commercial fishers have the most balanced set of scores.

It has to be emphasised that the conclusions made here are very preliminary, since the interviews were carried out by the snowball technique and were neither random, nor stratified by category. Some fishery sectors may be been missed from the survey. Moreover, the effects of scale and changes in fishing gear locations were not covered in the survey.

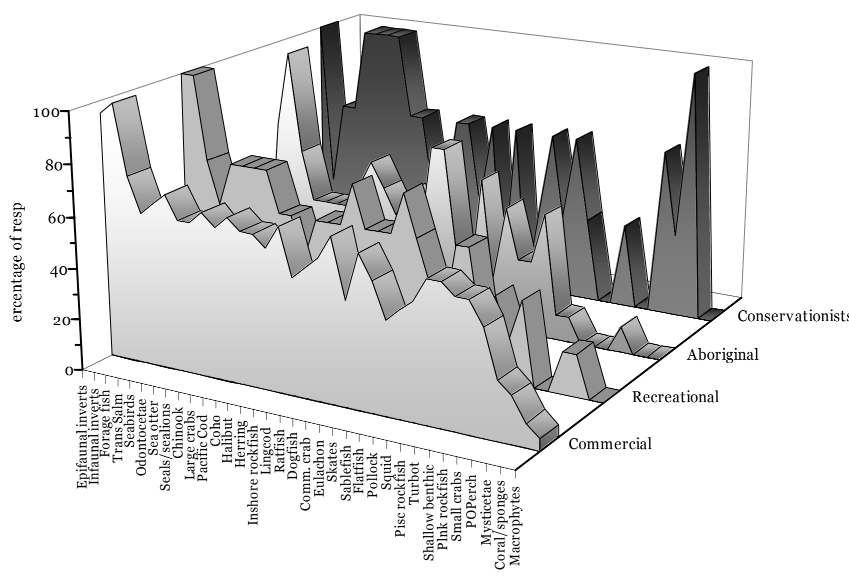

Figure 7. Diagram showing the percentage of respondents in four categories mentioning each of the functional groups included in the mass-balance ecosystem model shown in Figure 4. Respondents were from Prince Rupert, Northern British Columbia.

"THOSE WHO CANNOT REMEMBER THE PAST ARE CONDEMNED TO REPEAT IT"
(*George Santayana (1863-1952)*

The temporal dimension of a journey from TEK through single-species fishery science to an ecosystem science that *includes* T/LEK overlays the history of serial depletion of fisheries (Pauly *et al.* 1998). For example, recent work on the North Atlantic has demonstrated a ninefold reduction in table fish species between 1900 and the present (Christensen *et al.* 2003). Depletion like this has been driven by three ratchet-like processes (Pitcher 2001) that adversely affect ecology (Odum's ratchet), economics (Ludwig's ratchet), and the cognitive map of the system (Pauly's ratchet, = 'shifting baseline', Pauly 1995), the latter expressing how successive generations perceive abundance at the start of their careers as what 'ought' to be there. In response to this rather deep problem, the authors conceived the *Back To the Future* approach (Pitcher 1998, Pitcher *et al.* 1999) where different knowledge systems, history, archaeology and other sources are combined to reconstruct past abundance as a way to set restoration goals that relate to productive potential rather than present scarcity. The *Back To the Future* process draws up a set of cognitive maps of the entire system as it was, as it is, and what it might become if the wit and wisdom of the scientific and maritime community could be harnessed to restoration.

Back To the Future, is, in fact, a deliberate 'cognitive intervention' designed to expand knowledge of the system and the potential for restoration. The political drivers of change are intended to be public awareness of the extent of ecosystem depletion in relation to the past, coupled with re-kindled belief in the potential for restoration. The latter has been sadly eroded since Peter Larkin's 'stained-glass cathedral' era of the 1960s by a series of unexpected collapses, failures or fish stocks to rebuild and by a deep pessimism on the part of fisheries agencies, who these days are wont to portray themselves as helpless in the face of climate changes.

However, the future is not all black, since large area closures in US waters have shown that biomass of commercial fish stocks can rebuild, and that there is a future for fisheries provided that action is taken (Mace, pers comm.). Seeing positive results on their catches, artisanal fishers in the tropics have begun to ask for protected areas to be set up (Roberts *et al.* 2001). At the ecosystem scale, spatial models developed for marine protected areas in Hong Kong have shown the potential for restoring depleted fisheries through no-take areas, artificial reefs and other measures (Pitcher *et al.* 2002a). Cognitive maps engendered by these simulation models, coupled with consultations with fishers government and marine industry (e.g. Pitcher *et al.* 2002b), contribute to a better collective understanding of the marine ecosystem, the potential for restoration and the obstacles that have to be overcome. Such wide support, driven by a cognitive map that includes the past and the potential for restoration, encourages participation and commitment from all sectors (Pitcher 2000).

CONCLUSIONS

Is fisheries science drawn on a blank cognitive map, like Lewis Caroll's snark hunters, as some scientific practitioners would have you believe? We don't think that this has ever been the case. For example, Finlayson (1994) describes convincingly how misplaced confidence in models (Walters and Maguire 1966) and policies (Hutchings *et al.* 1997a, 1997b) led to the collapse of the Newfoundland cod stocks. Finlayson interprets this unhappy saga in terms of failed institutions, but underlying this in turn are the flawed mental maps of individuals who dealt with fisheries management policies.

Back to the Future encourages much more complete cognitive maps than hithertofore used in attempting to set goals for management. First, it embodies the widespread call for ecosystem-based management, or for an ecosystem approach to management (Cochrane FAO 2003). Questions that may appear purely the realm of policy using single species ecology, such as 'what is an acceptable degree of restriction on harvest?' (Healey 1997), turn out to have clearer answers if one evaluates the consequences for the rest of the ecosystem under a rebuilding policy.

Secondly, in *Back to the Future* the baseline relationship of the map's structure with the perceptions of the present state are integral, but changes in ecosystem structure may be rendered easier to conceive because the map already contains comparative elements of 'then and now' – rather like the geomorphological shadows of past coastlines or river beds on a landscape map. And major changes in peoples cognitive maps of ecosystems may be more easily accommodated than might at first sight be thought. For example, the dissonant image of a drowned landscape is conjured up by archaeologists retrieving stone tools from the present day sea bed, as has happened in Hecate Strait Northern British Columbia (Fedje and Christensen 1999). Hence, we think that the cognitive maps of humans are profound, subtle, complex and malleable enough to accommodate the possibility of major changes for the better, despite everyday miserable evidence to the contrary. At one extreme, the world's great religions would not work if this were not so, but in our case, BTF expresses a hope that a future may see healthier fisheries and ecosystems, in sharp contrast to the pessimism surrounding fisheries policy both globally and in Canada.

Modelling is imperfect, even when uncertainty is accounted for as explicitly as possible. The *Back to the Future* cognitive map, based on a linked series of past and future model representations, is only a representation of reality: "The map is not the territory" (Korzybski 1995). So we may ask what of our policy goal for the future, derived from modelling that is imperfect and flawed? Another saying by the originator of the cognitive map concept, Henri Poincaré is relevant here "It is far better to foresee even without certainty than not to foresee at all."

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