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Is Validation of Indigenous Ecological Knowledge a Disrespectful Process? A Case Study of Traditional Fishing Poisons and Invasive Fish Management from the Wet Tropics, Australia

Monica Gratani [1], James R. A. Butler [2], Frank Royee [3], Peter Valentine [1], Damien Burrows [4], Warren I. Canendo [5], and Alex S. Anderson [6]

ABSTRACT. Despite the growing recognition of the contribution that indigenous ecological knowledge (IEK) can make to contemporary 'western' science-based natural resource management (NRM), integration of the two knowledge systems has not reached its full potential in Australia. One explanation is that there is an implicit requirement for IEK to be validated by western scientific knowledge (SK), which has stalled its application and perpetuated the primacy of SK over IEK. Consequently, there is little experience of IEK validation, indigenous peoples' perspectives of the process, and no formal frameworks to achieve mutual and equitable validation of both IEK and SK. In this paper we assess the opportunities and limitations of validation processes using a case study of traditional fishing poisons for invasive fish management in the Wet Tropics World Heritage Area of Australia. The study was conducted within a coresearch approach between the Aboriginal holders of the IEK, who are among the paper's authors, and science-based biologists. We jointly carried out scientific laboratory trials that demonstrated that fishing poisons are effective at immobilizing invasive tilapia. Retrospective interviews with indigenous coresearchers showed that they did not find the experience of validation disrespectful, but instead empowering and necessary for their IEK to be understood and appreciated by scientists and included in NRM. Based on our experiences and knowledge of socialization theory we present a framework for the potential future design of collaborative validation processes to facilitate the integration of IEK into mainstream NRM, and the acceptance of SK within indigenous communities in Australia.

Key Words: *comanagement; fishing poisons; indigenous ecological knowledge; invasive fish; knowledge socialization; livelihoods; poisonous plants; social-ecological systems: tilapia; traditional ecological knowledge; validation*

INTRODUCTION

Turnbull (2009:2) states that "if there is to be a future for us all, it depends on treating the planet and the totality of its environmental and cultural resources as a commons to be shared and sustained. Recent re-conceptualisations of the commons consider them as complex adaptive systems whose sustainability and resilience depends upon diversity and interactive feedback between autonomous and distributed agents (Ostrom 1999). This raises the question that if the commons are also considered to include the diversity of knowledges, then how can they be productively shared and allowed to interact?" This is an important issue for Australia, where Cork (2009:64) points out that "humans have dampened the processes of disturbances on both the natural and human-made environments, causing loss of diversity of form and function among non-human species and loss of diversity in thought, skills and outlook among humans." Hence, there remains a challenge to both recognize and respect diverse knowledge systems, while simultaneously allowing the 'healthy disturbance' of established epistemologies to promote diversity of thought and resilience of social-ecological systems.

[1]School of Earth and Environmental Sciences, James Cook University, [2]CSIRO Ecosystem Sciences, EcoSciences Precinct, [3]Malanbarra Yidinji Elder, [4]Australian Centre for Tropical Freshwater Research, James Cook University, [5]CSIRO Sustainable Ecosystems and Sustainable Agriculture Flagship, ATFI, [6]Centre for Tropical Biodiversity and Climate Change, School of Marine and Tropical Biology, James Cook University

In Australia natural resource management (NRM) based on western scientific knowledge (SK) has been imposed through colonialism over a landscape that had previously been managed by systems of indigenous ecological knowledge (IEK; Ross and Pickering 2002), defined as a cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down over generations by cultural transmission, about the relationships between living beings and their environment (Berkes et al. 2000). Although the situation is changing, IEK in Australia plays a limited role in NRM (Carter and Hill 2007), and western scientific epistemology maintains intellectual primacy over IEK (Nursey-Bray 2009). This might be because, as summarized by Stephenson and Moller (2009:142), "when control and decision-making authority rests... with government management agencies, negotiation needs to occur and new institutions must be created to ensure indigenous groups have a substantive role in environmental management." There is also a general expectation that IEK must first be validated against science to be valued and adopted, and this may stall negotiation of a role for IEK in the comanagement of natural resources (Nakashima and Roué 2002). As a consequence, even though Australian federal and state government policies encourage the inclusion of IEK in NRM, integration through local NRM plans has not achieved its recognized potential.

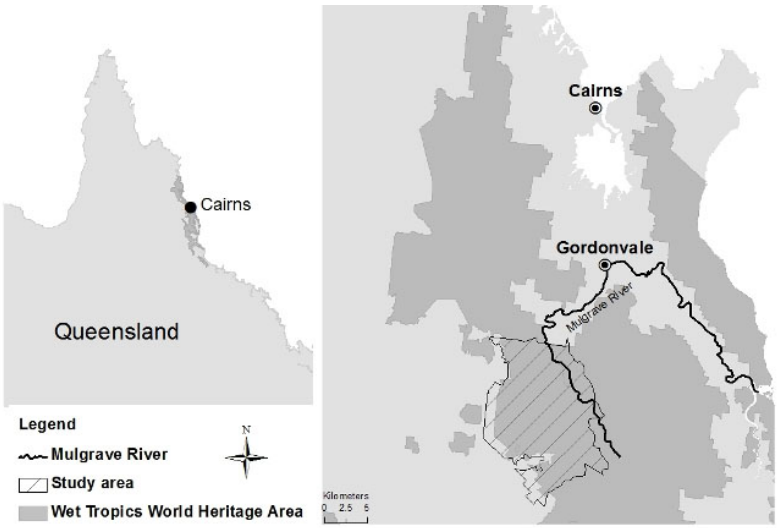
The Oxford Dictionary (www.oxforddictionaries.com) defines validation as "to check or prove the validity or accuracy of..." or "to demonstrate or support the truth or value of..." That the validity of one knowledge system must be confirmed by another raises issues over the equity of such an approach. The risk is that the superiority currently held by SK is perpetuated if validation of IEK is achieved by either adopting SK as the standard against which IEK must be measured, or by accepting only scientific evidence to support IEK (Shiva 2000). Many authors suggest that the primacy of SK is justified by the positive record of science in empirical, real-world problem solving (Dickison 2009), and therefore IEK should be validated against SK (Gilchrist et al. 2005, Gilchrist and Mallory 2007). However, others warn against the unilateral validation of IEK by SK, because it might be disempowering and disrespectful for local communities (Brook and McLachlan 2005).

For others, however, indigenous knowledge systems need no validation by western knowledge systems because they have proved their validity by supporting communities for thousands of years (Michell 2005). Indigenous peoples also adopt their own indigenous knowledge as the benchmark against which to validate other knowledge systems. As Williams (2009:168) notes: "indigenous people worldwide ... commonly believe that their traditional knowledge is superior to scientific knowledge because it is meaningful to them and it works." Hence, the relative positions of knowledge holders toward alternative knowledge systems may further inhibit the dialogue necessary for the integration of SK and IEK in NRM. Consequently, there is a need to develop spaces where holders of different knowledge systems can develop a respectful and equitable dialogue on how to mutually validate and integrate their knowledge for effective NRM (Davidson-Hunt and O'Flaherty 2007, Robson et al. 2009).

We contribute to the debate on what validation is, and how it can support integration of IEK and SK with a case study that tested traditional fishing poisons for the control of tilapia, invasive fish that are spreading through the rivers of the Wet Tropics of Queensland, Australia. Fishing poisons are toxic plants that affect fish but not people who consume the fish, and continue to be used in traditional societies all over the world, especially in developing countries (Neuwinger 2004). There is a widespread interest in including fishing poisons in modern pest management because they are effective on many aquatic pest species, and are usually less expensive (Bagalwa and Chifundera 2007) and perceived as more environmentally friendly than chemical pesticides (Ramanujam and Ratha 1980). Scientific validation has previously been applied to assess the effect of traditional fishing poisons on target pest species (Ramanujam and Ratha 1980, Ibrahim et al. 2000, Luitgards-Moura et al. 2002, Kalita et al. 2007) and nontarget species (Wei et al. 2002, Singh and Singh, 2005, Bagalwa and Chifundera 2007) in Africa, India, South America, and China. However, none of these studies evaluated the validation process in terms of communities of learning, equity, and respect. Furthermore, scientific validation of traditional fishing poisons for invasive fish has never, to our knowledge, been undertaken in a collaborative fashion in Australia.

Our study was initiated by the elders of a community who wanted their knowledge to be validated in scientific terms, because they hoped that this would raise awareness of IEK among the nonindigenous community and governmental agencies, and its

Fig. 1. The study area in the Mulgrave River valley, in the Wet Tropics Worls Heritage Area, Queensland, Australia.



potential to contribute to contemporary NRM. The scientific validation in our study was conducted by a mixed team of indigenous and nonindigenous researchers. The team's ultimate aim was to promote the integration of IEK and SK to improve local NRM, and to explore potential linked livelihood opportunities for the indigenous community. However, during the project different perspectives of the validation process emerged and this provided an opportunity to reflect on our experience. Hence, the research questions we address in this paper are: (1) what were the characteristics of the validation process, and (2) is validation of IEK by SK intrinsically a disrespectful process? To answer these questions we retrospectively interviewed indigenous team members who took part in the validation process, and related emerging themes to published literature on validation processes and knowledge production.

Currently there is no framework in Australia for governments and their environmental agencies to validate IEK prior to its adoption in NRM. Internationally there is only one published example of a framework for the validation of IEK, in which ethnopharmacopeias were validated in ethnoveterinary practice (Lans et al. 2007). In this framework Lans et al. accepted reviews of similar IEK applied elsewhere and published validation of similar plants as nonexperimental evidence, but acknowledged that this was inferior to scientific validation. Hence, based on our findings we also developed a framework for the potential future design of collaborative validation processes and knowledge integration in Australian NRM.

STUDY AREA

The study was carried out with the collaboration of elders from the Malanbarra Yidinji clan, traditional owners of the Mulgrave River valley in the Wet Tropics World Heritage Area of Queensland (Fig. 1). Malanbarra means 'people of the stony river bed' (Nungabana 1996), and this community has a traditional and ongoing dependence and cultural knowledge of the Wet Tropics rainforest and the Mulgrave River (Sangha et al. 2011). As traditional owners, the Malanbarra are involved in the comanagement of the World Heritage Area surrounding the Mulgrave River, but they are not satisfied with their role. They perceive that decisions made by Queensland and Australian government agencies responsible for NRM based on western scientific paradigms are disconnected from their aspirations and do not respect their cultural values or IEK. Therefore, they approached one of the authors to explore the potential for their

IEK to contribute to the management of the Mulgrave River, and the control of tilapia through the integration of IEK and SK.

Tilapia species' tolerance for a wide range of environmental conditions and their reproductive strategy enables them to be highly successful colonizers, and severe declines of native fish species have been related to their presence in Colombia, Nicaragua, Madagascar, and Nevada (Canonico et al. 2005). In Australia two species of tilapia, *Tilapia mariae* and *Oreochromis mossambicus*, have been introduced as ornamental species, and they are established in Queensland (Webb 2003, Lintermans 2004) where they are listed as noxious species, and considerable resources are devoted to managing their spread (Queensland Fisheries Service 2001). *T. mariae* has established self-sustaining populations in the Mulgrave River (Webb 2007, Burrows 2009).

Piscicides and mechanical removal are methods adopted by NRM agencies for controlling tilapia in Queensland (Ovenden 1998). Rotenone is most commonly used because of its low toxicity for nontarget animals, rapid decomposition in the environment, and relatively low cost. Despite these advantages the use of rotenone is controversial because of its side effects on nontarget species and the toxicity of solvents used in its preparation (Ling 2002). Hence, indigenous fishing poisons are a possible alternative source of environmentally friendly bioactive molecules.

The presence of tilapia in the Mulgrave River therefore presented an opportunity to test the Malanbarra Yidinji's traditional fishing poisons as a possible alternative tool for their control. We developed an experimental procedure to scientifically validate the efficacy of Malanbarra fishing poisons for tilapia.

METHODS

Community engagement

The engagement of the Malanbarra Yidinji community throughout the study was conducted within a culturally appropriate coresearch framework designed for the region (Cullen et al. 2008, Cullen-Unsworth et al. 2010). The team consisted of two male Malanbarra Yidinji elders, nonindigenous scientists from James Cook University (JCU), the Commonwealth Scientific and Industrial Research Organization (CSIRO), the Australian Centre for Tropical Freshwater Research (ACTFR), and an indigenous cultural broker. The male elders were appointed by the Malanbarra Yidinji community as their representatives because of their expertise in fishing poisons, and they conferred with the community throughout the study. The elders provided their free and prior informed consent for all phases of the project. It was agreed that the identity of the two plants traditionally used as fish poisons was the intellectual property of the community and should remain confidential. Instead, we have named them 'W' (white) and 'R' (red), which referred to the color of their sap.

Samples of the plants were collected by the elders during participatory field trips in the study area. Plants were prepared by cutting a 30-50 cm section from the basal stem and storing it in a plastic bag in a refrigerator. In the laboratory these sections were pulverized using a pestle and mortar to produce a paste of woody material and sap. The mixture was then added to laboratory tap water (86% oxygen saturation, 24-28°C and filtered to eliminate chlorine) to obtain a mother solution. This was then diluted to achieve two concentrations typically used in the field for both W and R, equivalent to 1.8 g/l (low concentration) and 3.8 g/l (high concentration).

Laboratory tests

A pilot experiment was conducted in April 2009, and the main research study was conducted during three experimental sessions in May, July, and December 2009. Overall, 48 individual *O. mossambicus* tilapia of 12-14 cm total length were tested, in multifactorial tank experiments at the ACTFR. Each was placed in an individual plastic basket, and four batches of 12 fish were treated in a 250 l experimental tank. The low and high concentrations of W and R were added to the tank water, with one treatment per batch of fish. A stopwatch was used to measure the onset of response in each fish ('onset time') in seconds. Immediately after each fish showed the onset of effects, and having recorded the onset time, a team member removed the fish and allowed it to recover in an adjacent clean water tank. Three control fish were kept in plastic baskets in clean water for the entire duration of each treatment. Mean onset times for fish in each batch were compared using t-tests.

Table 1. Mean onset time for the two treatment concentrations of W and R.

	Onset time (seconds)			
	Low (1.8 g/l)		High (3.8 g/l)	
Plant	Mean	SE	Mean	SE
W	625.0	91.5	345.0	23.5
R	262.5	25.1	180.0	12.8

Reflections on the validation process

The indigenous coresearchers' reflections on the validation process were derived from retrospective semistructured interviews (after Bernard 2006). Interviews were undertaken by the lead author after the tank experiments had been completed in December 2009, and were video and/or audio recorded. The interviews covered the following topics:

- Whether and why they supported the validation process
- Whether they felt disrespected by the process
- Their suggestions for a future IEK validation framework

RESULTS AND DISCUSSION

Laboratory tests

All fish showed obvious effects from the treatments. Symptoms differed for the two plants: W induced agitation, spasmodic breathing, and immobilization, and R induced paralysis. Fish used as controls did not show any change in behavior. Symptoms conformed with stunning and reversibility effects observed by the indigenous coresearchers when the two fishing poisons were traditionally applied in the Mulgrave River.

The mean onset time for W was significantly greater for the low concentration than for the high concentration (t-test, $t = 2.96$, $p < 0.05$; Table 1). The mean onset time for R was significantly greater for the low concentration than for the high concentration (t-test, $t = 2.93$, $p < 0.05$). The mean onset time for the low concentration of R was significantly less than that for the same concentration of W ($t = 3.82$, $p < 0.05$). Similarly, the mean onset time for the high concentration of R was significantly less than that for the same concentration of W ($t = 6.17$, $p < 0.05$).

These results show that W and R were highly effective when applied to *O. mossambicus*. Different active chemical components are usually responsible for the bioactivity of fish toxicants, but their isolation and characterization requires complex chemical analysis (Ibrahim et al. 2000). We did not investigate the biochemistry of W and R to protect the community's intellectual property rights. However, our observations reflect published literature on the typical observed effects of saponins, alkaloids, and rotenone/rotenoids.

Plant W induced respiratory stress, with fish becoming agitated and their breathing spasmodic. Similar symptoms have been observed when *T. nilotica*, *O. machrochi*, and *Haplochromis* spp. were tested with *Maesa lanceolata*, a saponin plant used for traditional fishing in the Congo (Bagalwa and Chifundera 2007). Climbing perch, *Anabas testudineus*, show similar symptoms when exposed to saponins of *Quillaja saponaria* (Roy and Munshi 1989). Roy et al. (1990) ascribe such respiratory stress to the impact of saponins on fishes' respiratory epithelia, whereas Wickens (2001) attributes it to the alteration of water tension, whereby uptake of oxygen from water is impossible. Although extended exposure to saponins can be lethal (Bagalwa and Chifundera 2007), we observed only temporary effects perhaps because in our experiment fish were removed and revived after the onset of symptoms.

Plant R induced muscle paralysis, which is typical of toxic alkaloids (Wickens 2001). These are the active chemical components of the families Loganiaceae, Solanaceae, and Umbelliferae, which contain species of toxic plants used as fishing poisons worldwide by indigenous cultures (Singh and Singh 2005). Alkaloids disrupt the calcium homeostasis of the cell and induce depolarization in neurons, and are used by some reef sponges of the genus *Agelas* to deter predatory fish (Bickmeyer et al. 2004). Muscular paralysis is also induced by rotenone and rotenoids, which are isoflavonoids occurring in different genera of tropical Leguminosae (Luitgards-Moura et al. 2002).

Our results suggest that the effect of both plants is dose-dependent. This was observed also by Bagalwa and Chifundera (2007), who tested saponin extracts of *M. lanceolata* on *T. nilotica* and by Ibrahim et al. (2000) for rotenone plants tested on *T. nilotica*. The experiments also indicate that plant R affected fish more quickly than plant W.

Reflections on the validation process

Extracts from interviews are presented with text in plain font inserted to help contextualize them.

Whether and why indigenous coresearchers supported the validation process:

Indigenous coresearchers supported the validation process because they believed that results from the experiments provided proof to scientists and government environmental agencies of the legitimacy of their IEK. As such the results built confidence among the elders about their own knowledge, and empowered them in negotiations with government about their involvement in the comanagement of their traditional estates:

> *Well the experiment put us out there, it did... brought it right to the point that yes this thing* [the plants that affected tilapia] *does work...otherwise I do believe that this thing a lot of our people would have kept this quiet and would have said "no we are not going to put this thing out there" or otherwise "maybe the older people don't agree", whereas we have spoken with our elder and we said "well look, you know, somebody has to take the initiative and do this and prove to other people that it can be done and that we can help other people with this. It can be done, we can eradicate this fish"* [tilapia].

The coresearchers also supported the scientific validation of their IEK as a tool to gain attention from government agencies and nonindigenous communities. In their opinion, the validation experiment produced evidence that supported the integration of their IEK into the established NRM system. Elders were aware that many scientists and government agencies believe that only data collected in a scientific fashion can support sound NRM. They supported the scrutiny of their knowledge in scientific terms to challenge the inertia of established environmental practices, as also noted by Huntington (2000) in Canadian First Nation communities. However, they believed that the mainstream SK system still does not recognize alternative knowledge systems and their holders, as also observed by Shiva (2000) and Denzin et al. (2008) in North America and India, and consequently they continue to demand a more equitable involvement of their IEK in current NRM:

> *Without it* [the experiment] *they* [government agencies] *wouldn't believe you for starters, I don't believe they would, you could tell them about it and unless it's actually shown to them and they can actually see this thing for themselves as what they did during that experiment I don't believe they would. They tend to do things their own way more times than often, but they haven't got anything else that will do this job* [the effect plants had on tilapia].

> *The western society doesn't really want to take on board our indigenous knowledge and respect our values and how we do business on country and how we are as one with nature, and we live and we breathe country, you know, we can read country and I knew this experiment would work as we have a similar plant up home, where I come from in the Tablelands, but it was just good to get it out there* [through the experiment] *and get it into the scientists' ears to let them*

> *know that this can happen and it's just a stronger voice for us traditional owners so that we can get the things rolling because we're sick of being put behind all the time, you know we need to be working together instead of one up front and one behind.*

> [With the experiment we got] *more attention now than what we did in the past, because it was so hard to, government bodies would never listen to you, they would say "yeah, yeah, yeah" but it was all falling out here* [out of their ears], *nothing was remaining in here* [in their head], *you know, because when we come back to this thing again, then we are going through the whole process again and reinventing the wheel if you like.*

Whether indigenous coresearchers felt disrespected by the process:

The coresearchers did not indicate that they were dissatisfied or had been disrespected by the process. Instead they emphasized the importance of appropriate engagement and the adoption of a collaborative approach for the successful running of the experiment. The acknowledgement of the elders' expertise and their involvement in all phases of the research project is strongly advocated by indigenous and nonindigenous scholars as conferring legitimacy and validity to research projects on indigenous matters (Cadet-James 2001). Therefore, we engaged Malanbarra Yidinji elders in a collaborative research approach that allowed the necessary time to develop mutual understanding, trust, and a positive relationship. The process was time-consuming, and this may partly explain why government agencies often do not engage appropriate community members in planning activities, as also observed by Denzin et al. (2008). However it was crucial for the process of validation to be perceived by the elders as respectful:

> *Usually when scientists come and want to do studies they don't come and see the traditional owners or see the main people like the elders who are the decision makers, they usually just see anyone and by that they don't really get the 110% out of that project or whatever they are doing because they're not seeing the proper people. Even though they are seeing the people that belong to country but* [it might be they] *see a younger generation, where they don't have much of an idea only hear what a couple of people have said and then try and add that together. But really to get the best benefit out of it* [you have] *to come and see the elders, because it is coming from them* [who are the people the knowledge] *has been passed down to.*

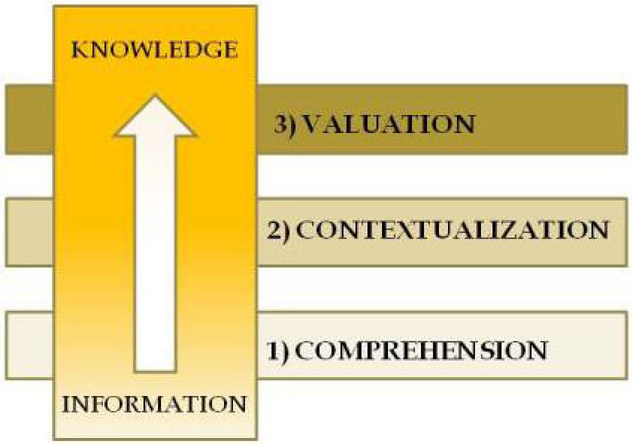
> [In this project I saw] *western and indigenous knowledge together. Scientists respecting and appreciating traditional knowledge and ways, earning trust, value and respect not just one hit wonder come in and fly out again but earning that trust, well becoming a friend like we have over the last year and a half, at the start it was a bit edgy but since you come up and then you started being a part of a bigger picture with the traditional owners they accepted you because they trusted you and just working with scientists and that and telling them that we do have ways that date back for 40,000 years that we need to put on the table for you to understand with your western ways.*

Indeed, the involvement of elders was essential to gain accurate information on Malanbarra Yidinji knowledge of fishing poisons, as was also observed by Chalmers and Fabricius (2007) when studying land cover change within the Nqabara community of South Africa, and by Gilchrist et al. (2005) for knowledge of migratory birds held by the Inuktitut of the Eastern Arctic. Our study therefore further corroborates the prerequisite for collaborative approaches if positive integration of IEK and SK is to be achieved (Cullen et al. 2008, Moller et al. 2009, Cullen-Unsworth et al. 2010, Mercer et al. 2010).

Indigenous coresearchers' suggestions on future engagement frameworks for the validation of IEK:

The coresearchers found the discussion about developing a framework for future validation of IEK challenging because they were not familiar with the language relating to frameworks and conceptual models. Therefore the question was rephrased in terms more familiar to them, and they were asked what they would do if they had a similar plant to propose for a different application. They stated that they would apply scientific validation in the same way:

Fig. 2. The three step transformational process of knowledge production from new information, modified from Diemers (1999).



> [If I had another plant to use for another application] *I would bring* [people to be convinced] *back out to the country, talk to them about this thing and then show them, give them a bit of an experiment so we'll show you that it actually does work.*

TOWARD A FRAMEWORK FOR KNOWLEDGE VALIDATION

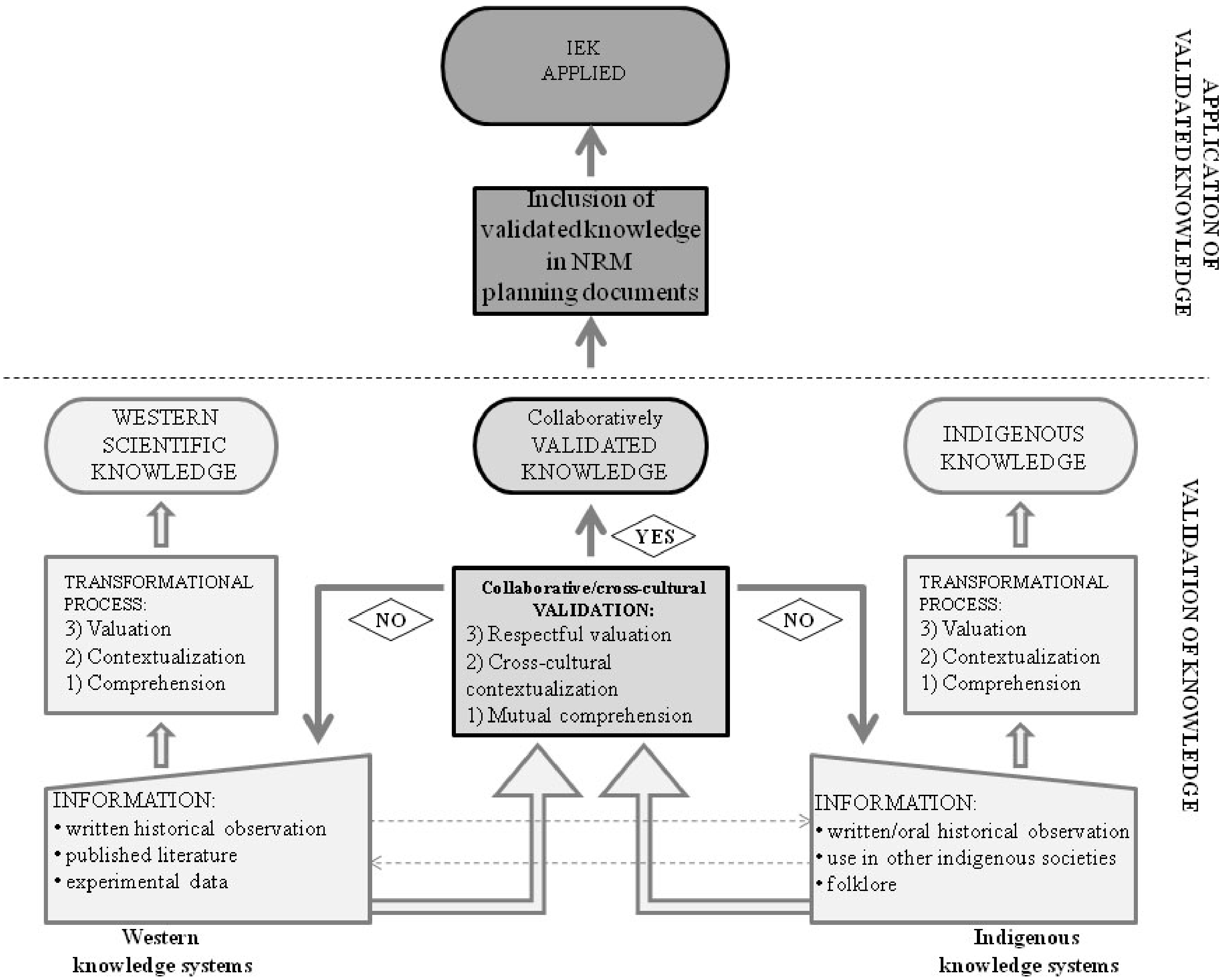
We found parallels between our experiences of the validation process and the theory of knowledge socialization (Berger and Luckmann 1966). The theory proposes that when processing new information, individuals and institutions attempt to internalize the information into existing knowledge. Diemers (1999) modeled a three step transformational process whereby an individual who encounters information decides if it is worth retaining as part of his/her established knowledge. The steps are: (1) 'comprehension', whereby the individual needs to understand the new information and hence it has to be expressed in a known language; (2) 'contextualization', whereby the individual tries to make sense of the new information by relating it to his/her pre-existing knowledge or benchmark; and (3) 'valuation', whereby the new information is valued as useful for application, and is then retained and established as new knowledge (Fig. 2). However, if it clashes with the pre-existing knowledge or is considered not useful, it is rejected.

We suggest that the IEK validation exercise followed a similar transformational process, whereby the efficacy of fish poisons was new information that the coresearch team jointly passed through the comprehension, contextualization, and valuation steps. Based on this parallel we adapted Diemer's (1999) model to create a cross-cultural validation framework (Fig. 3).

Our initial assumption is that IEK and SK are two different domains of knowledge with a similar underlying process of knowledge production through socialization. In both cultures the quality of new knowledge is checked by a panel of experts, through the peer review process in the western knowledge system and by endorsement by councils of elders in indigenous knowledge systems. Our understanding is that the main difference between indigenous and nonindigenous knowledge systems is that knowledge produced on either side of the cultural divide can reflect different social values and can be encoded in different forms, such as scientific publications in western societies, and a story, ritual, or history in indigenous societies.

In our framework (Fig. 3) five categories of IEK and SK information are accepted as of equal weight for the production of validated knowledge: historical observation in both western and indigenous societies, including written or oral; published literature; experimental data; similar indigenous knowledge used in other indigenous

Fig. 3. A framework for collaborative validation of indigenous ecological knowledge (IEK). In the diagram trapezoid shapes represent 'inputs' to processes, squares represent 'processes' and rounded shapes represent 'outputs.' Dashed arrows represent potential independent accessing of information by western and indigenous knowledge systems outside a collaborative validation process.



cultures; and folklore developed to maintain indigenous knowledge. These categories of information are evaluated by a collaborative and cross-cultural 'validation team,' composed of indigenous elders, western scientists, and NRM managers. This team is analogous to the 'communities of learning' defined by Robson et al. (2009) and 'place-based learning communities' proposed by Davidson-Hunt and O'Flaherty (2007) to facilitate convergence of IEK and SK.

To achieve collaborative validation, the team must proceed through the three steps of Diemer's (1999) transformational process of knowledge production:

1. mutual comprehension: by presenting information in a language and medium intelligible to all team members;

2. cross-cultural contextualization: by finding analogies within each team member's pre-

existing knowledge system, which is supported by the mutual comprehension achieved in the first step;

3. respectful valuation: by valuing information against a common values framework representing all of the team members involved.

If all three steps are successfully achieved, the information becomes collaboratively validated knowledge. This can then be included in NRM planning documents and is available for application (Fig. 3), subject to the local institutional context and process. If one of the three steps fails, however, the information remains confined to the knowledge system where it had been produced and cannot become validated knowledge. In that case, the process can be started again following appropriate reflection on the cause of the failure.

It should be noted, however, that there are other alternative processes for the coproduction of knowledge not represented in our framework. For example, we do not explicitly consider joint hypothesis formulation and data collection (Moller et al. 2009), or how appropriate institutions are established within which power is shared and adaptive learning can occur (Davidson-Hunt and O'Flaherty 2007, Robson et al. 2009). Such processes may vary in Australian environmental planning, potentially presenting differing prospects for knowledge integration (R. Hill, C. Grant, M. George, C. Robinson, S. Jackson, N. Abel *unpublished manuscript*), and therefore validation exercises. Instead, our framework focuses on the process of collaborative validation of information that has been independently produced within one or other knowledge system, rather than the enabling institutional environment. It should also be highlighted that knowledge holders in the two systems can independently access and utilize information produced by the other system (Fig. 3).

Implications for the adoption of collaborative validation in NRM

Berkes et al. (2000) and Moller et al. (2009) suggest that the integration of SK and IEK should occur at the level of 'process' rather than of 'content' so as to avoid the appropriation of information from one knowledge system by another. We support this view by proposing that integration can be equitably achieved through an adaptation of the transformational process within knowledge socialization. Our framework proposes a collaborative, cross-cultural approach to support the mutual validation of knowledge systems and, consequently, knowledge integration through process.

To date the assumption that IEK should be tested against SK before being adopted may have presented a major obstacle to the application of IEK in NRM. Scientific experimental validation is time consuming, expensive, and may be disrespectful of indigenous cultures when not conducted in a collaborative fashion. In addition, cultural and spiritual components of indigenous knowledge systems are usually disregarded by western knowledge systems (Casimirri 2003). This is particularly likely if the validation of IEK is undertaken by scientists and/or government agencies unilaterally, with little or no involvement of legitimate holders of IEK. In this case the validation of IEK weakens indigenous knowledge systems and cultures (Casimirri 2003, Turnbull 2009), and is often unsuccessful because without considering the social and spiritual dimension of IEK systems it fails to harmonize incompatible worldviews (Casimirri 2003, Brook and McLachlan 2005, Aikenhead and Ogawa 2007). The adoption of our framework by Australian environmental agencies would allow indigenous communities to actively enter the validation process as an equal partner, and would enable them to present their own information without risking disempowerment and disrespect.

From our study's results we suggest that validation is not an intrinsically disrespectful process. Instead, it can be seen as a fundamental human process of internalizing new information within an established knowledge system. This already occurs within indigenous and nonindigenous people and institutions, and we advocate that it should be extended to the integration of IEK and SK, rather than being avoided on the grounds that integration may be disrespectful to IEK. However, in promoting this approach we are not advocating that IEK should always be validated by SK, or vice versa; rather, we propose that cross-cultural validation exercises must consider all knowledge domains as equal to achieve an equitable and mutually respectful process. In advocating our framework we are sharing the pragmatic attitude of our indigenous coresearchers who embraced validation as a way to challenge the current worldview in Australian

NRM. However, we are aware that power dynamics implicit in different comanagement contexts within which validation and knowledge integration take place will have a major influence on the nature of the process and its outcomes (Newman and Moller 2005, Moller et al. 2009).

It could be argued that our conclusions are based on biased results because the indigenous knowledge holders initiated the validation process and therefore were less likely to feel marginalized than in a situation where the initial challenge was made by scientists. This is possible, and more empirical evidence and testing of our framework in different contexts is required, particularly where the initiative is taken by parties other than the knowledge holders. To minimize the chance of adverse outcomes we would recommend instead that collaborative validation should only proceed after sufficient trust has been generated through a comanagement process, and validation begins after multilateral consensus has been reached.

The integration of IEK and SK requires a change of social values if NRM is to accommodate indigenous perspectives and worldviews, and the development of community-based decision making for more effective NRM and resilient social-ecological systems (Casimirri 2003). In Australia, we suggest that the 'healthy disturbance' required to generate diversity of thought and outlook and hence resilience of social-ecological systems is also relevant to NRM. In this context IEK should be promoted in NRM to challenge the conventional wisdom of SK-based management, and introduce a more holistic paradigm wherein humankind is part of the natural world rather than superior to it (C. Royal, *unpublished manuscript*). The integration of indigenous ecological knolwedge and western scientific knowledge is particularly needed at the local scale where rapid detection and response to environmental change is required to promote resilience of social-ecological systems. In Australia we believe that it is time to provide government and other environmental agencies with tools to implement this change, including our collaborative validation framework.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/vol16/iss3/art25/responses/

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