Morrison-Saunders, A. and Bailey, J. (2003) ***Practitioner perspectives on the role of science in environmental impact assessment.*** **Environmental Management, 31 (6). pp. 683-695.**

Practitioner Perspectives on the Role of Science in Environmental Impact Assessment

Short Title: *Science and Environmental Assessment*

*__Angus Morrison-Saunders__

Lecturer in Environmental Assessment

Division of Science

Murdoch University, Murdoch WA

6150 Australia

Tel: 61 8 9360 6125

Fax: 61 8 9360 6787

E-mail: A.Morrison-Saunders@murdoch.edu.au

John Bailey

Associate Professor in Environmental Assessment

Division of Science

Murdoch University, Murdoch WA

6150 Australia

Tel: 61 8 9360 2375

Fax: 61 8 9360 6787

E-mail: J.Bailey@murdoch.edu.au

*Author to whom correspondence should be addressed.

Practitioner Perspectives on the Role of Science in Environmental Impact Assessment

ABSTRACT / A large body of literature addresses the role of science in environmental impact assessment (EIA) but less attention has been given to the views of practitioners themselves. In this research a survey of 31 EIA practitioners in Western Australia was undertaken to determine their perceptions of the quality and importance of science in EIA. The survey results are compared with previous theoretical, empirical and survey studies of the role of science in EIA. Interview questions addressed the role of science in impact prediction, monitoring activities, mitigation and management, and EIA decision-making. It was clear from the interviews that many practitioners are satisfied with the quality of science currently used in EIA, but do not believe that it is given sufficient importance in the process. The quality and importance of science in the pre-decisions stages of EIA was rated higher than in the post-decision stages. While science was perceived to provide the basis for baseline data collection, impact prediction and mitigation design, it was seen to be less important during decision-making and ongoing project management. Science was seen to be just one input to decision-makers along with other factors such as socio-political and economic considerations. While time and budget constraints were seen to limit the scientific integrity of EIA activities, pressure from the public and regulatory authorities increased it. Improving the scientific component of EIA will require consideration of all these factors, not just the technical issues.

KEY WORDS: science, environmental impact assessment, professional practice, monitoring, impact prediction, mitigation, decision-making

A considerable amount of interest and attention has been focussed on the role of science in environmental impact assessment (EIA) and a substantial body of literature has addressed this topic. This paper reviews this literature briefly before presenting the results of a survey of 31 EIA practitioners in Western Australia. The principal aim of the survey was to determine what practitioners perceived that the role of science in EIA should be and to compare this with the positions established in the literature. The results of a survey of EIA practitioners in Western Australia are presented and compared with previous theoretical, empirical and survey studies of the role of science in EIA. The study provides valuable insights concerning the practice of EIA and what can be expected of the process. As the hypotheses underlying the study were derived from the literature on the role of science in EIA, it is useful to start with an overview of this body of work.

Much of the literature can be classified into two main types:

- studies of the theory and practice of EIA with respect to the role that science can or should play (eg. Beanlands and Duinker 1984, Shrader-Frechette 1985, Lemons 1994); and
- empirical studies which have examined the scientific content of EIA documents and products in a systematic and rigorous way (eg. Culhane and others 1987, Bailey and others 1992, Malik and Bartlett 1993).

There have been fewer studies which have focussed on the perceptions of practitioners themselves on the role of science in EIA; Caldwell and others (1982, Chapter 4) and Sadler (1996, Section 4.1.3) are two notable exceptions. Overall there is a general feeling in the literature that the level of science is wanting. However, perceptions and findings appear to vary according to particular stages and tasks in EIA.

A generic approach to EIA has been described by Sadler (1996, p18) which can be applied to any proposal put forward by a proponent. It commences with screening of proposed developments to determine the need for EIA, includes preparation of environmental impact statements (EIS) by proponents and their review by the public, decision-making and setting of approval conditions and extends into project implementation and follow-up. Previously Morrison-Saunders and Bailey (1999) found it useful to differentiate between pre-decision and post-decision stages of EIA. In this study, the focus was on four main tasks which are utilised at various times during EIA: monitoring, impact prediction, mitigation and decision-making.

During the pre-decision stages of EIA, monitoring activities may be undertaken to collect baseline information. Impact prediction is derived from baseline data collection activities and comprises an important component of EIS. Mitigation measures are proposed in EIS as well as by decision-makers during the review process that will avoid, minimise or compensate for predicted adverse impacts. Decision-making generally refers to the principal or consent decision when it is determined whether a proposed proposal should be permitted to proceed and under what terms or conditions. However, other important decision points occur during the early stages of the process, such as screening and scoping to determine the need for EIA and the terms of reference of subsequent EIS.

During the post-decision stages of EIA, the project is implemented and environmental impacts occur. Further monitoring should be conducted to determine the extent of impacts and compliance with approval conditions. Mitigation measures should be implemented by proponents, ideally in an ongoing adaptive fashion in response to the findings of impact monitoring programs.

For the purposes of brevity the post-decision monitoring and ongoing adaptive management activities are combined with their pre-decision counterparts in the following discussion. The role of science in the four EIA tasks is examined in turn before considering its role in the overall EIA process.

Environmental Monitoring

There have been numerous criticisms of the quality of science utilised in EIA monitoring programs. (eg., Preston 1985, Duinker 1989, Fairweather 1989, Underwood 1991, Antcliffe 1999, Benkendorff 1999, Ecological Society of Australia Inc. 2002). These commentators have all expressed dissatisfaction with the application of science in monitoring activities in practice compared to their expectations as scientists. Similarly, in an international survey of 324 EIA practitioners, 48% of participants rated the extent to which the state of the science limited the ability of practitioners to establish monitoring schemes that are able to detect significant development-induced effects as 'somewhat limiting', and 19% rated this factor as 'very limiting' (Sadler 1996, p81). In an earlier survey of approximately 400 EIA practitioners Caldwell and others (1982, pp345-348) asked participants to rate the availability and quality of scientific data and the state-of-the-art of specific studies and systems modelling with respect to how much these four factors limited their ability to respond to EIA requirements in the US. While this study did not single out monitoring programs as such, the results are broadly comparable as the information or data referred to would come predominantly from baseline data collection activities and supporting literature studies. For each question, responses ranged from 10.6% – 25.2% as 'very limiting' and 53.0% – 68.7% as 'somewhat limiting'. Each of these studies suggests that monitoring is an area of EIA that could be greatly improved with respect to its scientific integrity.

The finding is also supported by recent empirical research into the scientific integrity of monitoring programs for six case studies that had undergone EIA in Western Australia. In this study Morrison-Saunders (1997) classified EIA monitoring activities with respect to the use of formal scientific techniques such as before/after control/impact (BACI) monitoring in the manner advocated by Green (1979) ranging down to programs based upon ad hoc sampling and observation only. For two of the case studies there were no examples of BACI monitoring and the best level recorded was 38% for an ocean wastewater outfall project and this was substantially higher than the other projects (Morrison-Saunders 1997). But even in this project, numerous problems with the integrity of monitoring were recorded for the key issue of water quality monitoring including; unsuitable spatial distribution of sampling sites, a five year period when sampling was conducted on a single annual basis only, no replication of sampling and contamination of a so-called 'control' site located in the impact zone of the outfall (Morrison-Saunders 1996). Combined with various other deficiencies of environmental monitoring programs for these six case studies, Morrison-Saunders and Bailey (1999) concluded that the monitoring programs largely failed to meet scientific expectations of the EIA process.

Apart from deficiencies in design, a key reason why EIA monitoring programs are considered to fail scientific expectations relates to cost. For example, the Ecological Society of Australia Inc. (2002) note that constraints in time and cost may restrict the ability of consultants to conduct comprehensive ecological studies for EIA while Lemons and Brown (1990) and Antcliffe (1999) give examples of monitoring programs being designed according to the available budget which negatively impacts on their scientific integrity.

Impact prediction

A perceived shortfall in the scientific integrity of EIA predictions has often been highlighted with many commentators arguing that impact predictions should be derived in a scientifically rigorous manner and presented as testable hypotheses (eg. Beanlands and Duinker 1984, Environmental Resources Limited 1985, Duinker and Baskerville 1986, Clark 1994, Epp 1995). Duinker (1985) maintains that decision-makers are more likely to pay attention to and use impact predictions when they are derived in a scientifically rigorous manner, are stated quantitatively and are measurable. Empirical research both in Western Australia (Bailey and others 1992, Morrison-Saunders 1999) and internationally (eg. Bisset 1984, Culhane and others 1987, Bernard and others 1993, Eddlemon and others 1993) has confirmed that the scientific integrity of impact predictions could be substantially improved. Finally 53% of EIA practitioners surveyed by Sadler (1996, p81) rated the extent to which the state of the relevant science limits the ability of practitioners to make accurate predictions 'somewhat limiting' and 24% rated it as 'very limiting'.

Mitigation and Ongoing Adaptive Environmental Management

It would appear that mitigation and management activities in EIA are prone to similar deficiencies in scientific integrity as monitoring and impact prediction. For example, the extent to which the state of science limits the ability of practitioners to custom-design successful mitigation measures was rated as 'somewhat limiting' by 58% of participants in Sadler's (1996, p81) international survey and 'very limiting' by 12%. These findings are largely supported by the work of Bailey and others (1992), Bailey (1997) and Morrison-Saunders and Bailey (1999) who similarly found relatively low levels of science evident in mitigation and environmental management activities in EIA compared to international expectations.

Decision-Making

The perceived role that science should play in monitoring, impact prediction and mitigation aspects of EIA appears to be greater than that expected of decision-making. Here, the influence of non-scientific factors on EIA decision-making is frequently acknowledged in the EIA literature. Morgan (1998, p80) argues that while there has traditionally been an expectation and emphasis in the scientific literature that the EIA process is, or ought to be, primarily a scientific process for making and testing predictions about human impacts on the natural environment, this view of EIA is one-sided and ignores the socio-political aspects of EIA. Freudenburg (1989) recognises the political dimension of EIA and suggests that political factors typically outweigh scientific ones in the decision-making process. Sadler (1996, p16) notes that decision-making requires striking a balance between economic, environmental, social and other criteria, and thus it is a political process involving trade-offs rather than a purely scientific undertaking.

Role of science in EIA overall

EIA commentators would appear to fall into main two camps with respect to the role of science in EIA. On the one hand, there are those that suggest that EIA should be predominantly a scientific exercise based around rigorous monitoring programs, testable impact hypotheses and informed environmental mitigation and management (eg. Beanlands and Duinker 1984, Duinker and Baskerville 1986, Fairweather 1989, Ecological Society of Australia Inc. 2002).

In contrast, there are some people who suggest that it is appropriate that the EIA process is actively informed from sources other than science alone. For example, many researchers have pointed out that there is a subjective component of EIA based on value judgements and which constitutes the ‘art’ of EIA (eg. Eversley 1976, Orians 1986, Hyman and Stiftel 1988, Lemons and Brown 1990, Caldwell 1991, Hellstrom and Merle 1996). Robinson (1989) suggests that EIA comprises three parts: politics, public and science, and implies that successful EIA requires that all three be in balance. Malik and Bartlett (1993) go further to suggest that 'the EIA process is not a technical one that employs a science-based interdisciplinary policy analysis approach; rather, it is a political process involving science'.

A further issue to consider regarding the role of science in EIA concerns the quality and quantity of science necessary for effective impact assessment and management to occur. The extent to which the state of science in EIA limits or enhances environmental outcomes is not clear. For example, participants in Sadler's (1996, p81) international survey indicated that the state of science limited the ability of practitioners to custom-design successful mitigation measures. In contrast, in previous empirical studies in which we analysed the scientific integrity of various components of the EIA process in Western Australia (eg. Bailey and others 1992, Bailey 1997, Morrison-Saunders and Bailey 1999) we concluded that effective mitigation and environmental management could arise in the absence of rigorous science. We analysed the scientific integrity of EIA in terms of conformance with accepted scientific procedures for collecting and analysing information (eg. the use of BACI monitoring in EIA). Our focus in these studies was in terms of environmental outcomes for projects that had undergone EIA. We recorded relatively low levels of science evident in EIA compared to international expectations, but provided evidence that effective environmental management could arise in the absence of scientific rigor in EIA. We concluded that neither scientific rigor in impact prediction nor prediction accuracy had any bearing on the implementation of environmental management activities (Morrison-Saunders and Bailey 1999), and suggested that simple issue identification during EIA may be more important than rigorous impact prediction as it would be sufficient to alert managers to issues requiring environmental management attention. We also found that environmental management activities may result in the absence of ideal rational-scientific monitoring programs. The implication here is that it is possible to protect and manage the environment without recourse to formal scientific studies or procedures.

Our research findings appeared to be at odds with the portion of the literature advocating a scientific model of EIA. To explore this issue further, and to address an apparent gap in the existing literature, we were interested in finding out how EIA practitioners viewed this issue themselves.

We derived several hypotheses to test:

- based on the predominate view in the EIA literature, practitioners perceive the role of science in EIA to be more important than it currently is in practice;

- the importance of science would be perceived to be lowest for EIA decision-making as this stage of the process is made at a political level and involves tradeoffs with social and economic considerations; and
- the current quality of science varies at different stages of the EIA process.

Before proceeding further, some characteristics of the EIA process in Western Australia require explanation (a full account of the process is made in Wood and Bailey 1994). Responsibility for EIA rests with the Environmental Protection Authority (EPA), a small independent statutory authority which determines EIA procedures and the level of assessment of proposals. It is also a key recommendatory body that makes recommendations to the Minister for the Environment on whether proposals are environmentally acceptable. The final approval decision and the establishment of legally binding approval conditions is the responsibility of the Minister. Whilst the EPA plays an important figure-head and decision-making role in the EIA process, day to day administration rests with the Department of Environment, Water and Catchment Protection. Other government agencies also get involved in the process. They are invited to comment on EIA proposals during the public review of EIS, and in some cases they may issue regulatory approvals to proponents and monitor their compliance that are separate to the formal EIA process itself. In Western Australia, an approval from another government agency cannot be issued, though, until environmental approval under the EIA process has been granted.

METHODOLOGY

A total of 31 EIA practitioners were interviewed in the study representing proponents, consultants, EIA regulators and other government agencies. Interviews were conducted in two major resource development centres in Western Australia (mining and mineral processing operations) located some 500km and 1,500km from the capital city, as well as in the capital itself, to ensure that people with experience in both remote and urban settings were included. These two centres were selected on the basis of the number of nearby post-EIA projects and the presence of a regional office of the EIA regulator and other government agencies. An opportunistic sampling approach was utilised in the remote areas based upon personnel availability at the time of the visit. Proponents and government agencies were selected mainly on the basis of their activities in the two remote development areas visited, although representatives of each based in the capital city were also included. Consultants and EIA regulators were mainly based in the capital city and were identified through their respective organization staff lists.

The EIA process was divided into the four main tasks described previously. Environmental monitoring tasks were divided into two sub-categories to distinguish between pre-decision baseline data collection and post-decision impact monitoring activities. Similarly, mitigation and ongoing adaptive management were split into two categories to distinguish between pre-decision and post-decision phases of EIA. Hence the EIA process was divided into six individual stages for some of the survey questions and these are presented in chronological sequence to mimic a generic linear EIA process (i.e. baseline monitoring, impact prediction, mitigation design, decision-making, impact monitoring and ongoing adaptive environmental management).

Practitioner perceptions were sought in this research, using a similar approach to that of Boyd and others (1993) and Starbuck and Mezias (1996). A questionnaire was prepared and presented to current EIA practitioners in an interview setting. The interview questions sought both quantitative and qualitative answers in relation to EIA practice in Western Australia.

For the quantitative responses interviewees were asked to rate on a 7-point Likert scale answers to a series of questions concerning the current quality, current importance, expected importance and change in quality of science for the six stages in the EIA process identified previously (questions 1-4 in Table 1). Towards the end of the interview, participants were asked to rate the extent to which the current quality of science in EIA overall in Western Australia met their expectations of the process on a similar Likert scale (question 5).

With respect to the questions concerning the 'quality of science' in EIA, interviewees were directed to freely interpret the phrase for themselves, but to explain their answer. With respect to the questions concerning the importance of the role of science in EIA, interviewees were asked to consider how much weight was given to scientific factors in comparison to other factors (eg. socio-political) for each particular stage of EIA.

To test the hypothesis that: practitioners perceive the role of science in EIA to be more important than it currently is, the results of Questions 2 and 3 in Table 1 were analysed. To test the hypothesis that the importance of science would be perceived to be lowest for EIA decision-making, the rankings for Question 3 in Table 1 were analysed by comparing the result recorded for decision-making with the other five stages of EIA. To test the hypothesis that the current quality of science varies at different stages of the EIA process, the rankings of the interviewees for Question 1 in Table 1 were compared across the six stages of EIA. Non-parametric statistical tests were used to analyse the data from these Likert scale questions, as the response to each question was a rating and not of a continuous data format. Furthermore, the samples were dependent, and as such a related-samples test was needed. The Wilcoxon signed-rank test (Hinkle and others 1979), was used to compare individual responses to two different questions.

Qualitative information was obtained from the interviewees by asking them to justify their responses to the quantitative questions and to provide examples. Interviews were taped and subsequently transcribed so that qualitative answers could be accurately recorded. Two open-ended questions were asked towards the end of the interview:

- What factors do you believe have determined the level of science utilised in EIA?

- How would you improve the scientific integrity of EIA (if at all)?

Here the expressions 'level of science' and 'scientific integrity' were used to encapsulate both the quality of science and the level of importance attached to it in EIA. Interviewees were encouraged to answer these two questions in this context.

RESULTS

For each of the six stages of EIA, the answer to the question: how important currently is the role of science? was rated significantly lower to the question: how important should be the role of science? (Table 2). Furthermore, the perceived difference between the current importance of the role of science in mitigation design and that for ongoing adaptive management was statistically significant ($P=0.020$).

Perceptions of the importance of science in EIA decision-making compared with the other five stages of EIA are shown in Table 3.

Statistically significant variations in the perceived current quality of science between different stages of the EIA process are presented in Table 4.

Practitioner perceptions on the changes in quality of science utilised in the six stages of EIA is presented in Figure 1.

Overall satisfaction with quality of science in EIA is shown in Figure 2.

The most frequent responses to the two open ended questions at the end of the survey are summarised in Table 5.

DISCUSSION

In the following sections the results are discussed in conjunction with the qualitative data collected and compared with previous theoretical, empirical and survey studies of the role of science in EIA.

Importance of the role of science in EIA

As seen in Table 2, the EIA practitioners perceived the role of science to be significantly more important than it currently is for every stage of the process, supporting our first hypothesis. This perception is consistent with the view of numerous EIA commentators (e.g. Beanlands and Duinker 1984, Duinker and Baskerville 1986, Fairweather 1989, Ecological Society of Australia Inc. 2002) as well as the findings of previous empirical studies (e.g. Culhane and others 1987, Bailey and others 1992, Malik and Bartlett 1993, Morrison-Saunders and Bailey 1999). The following section outlines in greater detail, practitioner perspectives on specific stages of EIA.

Importance of the role of science in EIA decision-making

The perceived importance of science in EIA decision-making was found to be lower than the perceived importance of science in baseline data collection, impact prediction, mitigation design, impact monitoring and ongoing adaptive management (Table 3). Qualitative responses frequently indicated that science was only one of several factors that EIA decisions should be based upon, whereas science should form the basis of the other stages of EIA.

Participants were asked to identify the other factors that influence EIA decision-making. In Western Australia the ultimate responsibility for decision-making and issue of project approvals rests with the Minister for the Environment. Consequently social, economic and political considerations influence the decision-making process along with the environmental considerations and these were frequently identified by participants. Additionally, several participants suggested that other factors such as precedent, experience, intuition, common sense, anecdotal information and emotions all influence EIA decision-making processes.

While the survey participants acknowledged the realities of non-scientific influences on EIA decision-making, it did not mean that they necessarily agreed that it should be this way. Some participants believed it was wrong that socio-political factors should be included in EIA decision-making and one even suggested that a scientifically based decision-making process drawing solely on 'objective' data should be developed and utilised. Most of these comments came from consultants or proponents.

Others were more accepting. EIA regulators and other government regulators were more likely to be accepting of the socio-political aspects of EIA decision-making with several advocating an explicit role for economic and other social factors be incorporated into the process (a recent ruling in a legal case in Western Australia prevents the EPA from taking economic and certain social considerations into account when assessing a proposal; Bache and others 1996).

Current quality of science at different stages in the EIA process

Table 4 demonstrates that practitioner perceptions of the quality of science in different stages of the EIA process varies as hypothesised. Discussion of the results is divided into the four main tasks in EIA identified previously.

Environmental Monitoring

The current quality of science utilised in impact monitoring was rated the lowest of the six stages of EIA and was significantly poorer than that used in mitigation design and EIA decision-making (Table 4). Though not statistically significant, baseline data collection was generally considered to be better than impact monitoring. It appears that the post-decision stage of EIA as far as monitoring is concerned, is not as strong as the pre-decision stages with respect to the quality of scientific input. Many participants perceived impact monitoring to be poorly conducted. Reasons suggested to explain this was that proponents were keen to win approvals for their projects and so were more likely to engage in baseline data collection to satisfy the public and regulatory agencies in the lead up to decision-making, but subsequently neglect these activities once the project was operational. This finding is similar to Lemons' (1994) observation that one of the reasons why use of more adequate scientific knowledge has been constrained in EIA in the US is because little attention is given to post-EIS monitoring.

Several participants suggested that monitoring, fundamentally, was a scientific activity, although it was often noted that it could be done a lot better. A frequent comment was that money and time constraints place limitations on the scientific integrity of monitoring programs; an observation that has previously been noted by Lemons and Brown (1990), Antcliffe (1999) and the Ecological Society of Australia Inc. (2002).

It is clear from Table 2 and from the comments received that EIA practitioners have higher expectations for the role of science in environmental monitoring programs than is apparent in practice. A similar viewpoint has been well articulated by many other commentators (eg. Preston 1985, Fairweather 1989 and Benkendorff 1999), supported by the practitioner surveys of Caldwell and others (1982, pp345-348) and Sadler (1996, p81) and is consistent with our earlier empirical research (eg. Morrison-Saunders and Bailey 1999).

Impact Prediction

Ratings of the current quality of science utilised in impact prediction were similar to those for impact monitoring and it was rated significantly poorer than that used in mitigation design and EIA decision-making (Table 4). Practitioner comments indicated that much of the information required for making impact predictions came from baseline data collection programs and suffered similar time and money constraints which prohibited high quality scientific studies from being undertaken.

As with the case for environmental monitoring, EIA practitioners in Western Australia believe that greater emphasis should be placed on scientific methods and approaches during impact prediction than is currently the case (Table 2). This finding is consistent with the views of many EIA commentators, empirical studies in both Western Australia and internationally and practitioner surveys mentioned previously.

Mitigation and Ongoing Adaptive Environmental Management

Mean ratings of the current quality of science utilised in mitigation design (3.2, Table 4) were higher than those for ongoing adaptive environmental management (3.5) but this was not statistically significant. With respect to perceived importance, it can be seen from Table 2 that mitigation design received the highest importance ratings for the current role of science (mean 3.0) and ongoing adaptive management received the lowest importance ratings (mean 3.4) and this difference was statistically significant (P=0.020). Again, the pre-decision stages of EIA appear to command greater attention with respect to scientific input than the post-decision stages for comparable activities. In previous empirical research, Morrison-Saunders and Bailey (1999) found that the majority of environmental management actions (ranging from 71% to 91% of all management activities recorded for six case studies) originated during the pre-decision stages of EIA, suggesting that a higher level of scientific focus may be warranted during this stage of the process.

In the current research, two explanations for this finding were provided by practitioners in their supporting qualitative responses. Firstly many practitioners suggest that the key focus for most proponents in EIA is to obtain approvals (as mentioned previously). Consequently they are more likely to devote time and resources to project design, investigative studies and the preparation of EIA documentation prior to the approval decision rather than the post-decision stages of a project unless a significant environmental problem is encountered or they are prevailed upon by regulators or public pressure (eg. Morrison-Saunders 1998, Morrison-Saunders and others 2001).

Similarly several participants suggested that regulatory agencies paid less attention to projects in the post-decision stages of projects. These practitioners advocated a greater role for project auditing and follow-up of impact monitoring and management activities. Secondly, for major resource development projects (eg. mining and mineral processing) it is difficult to make modifications to fixed plant even if there were good environmental reasons to do so due to the costs involved. Hence greater investigation and planning is likely to be initially invested in the engineering design stages of projects compared to ongoing project operations. The emphasis on engineering design aspects of projects was seen by participants to be grounded in scientific method.

Decision-Making

Ratings of the current quality of science utilised in decision-making were relatively high giving it the strongest rating of the six stages of EIA and this difference was statistically higher than that for impact prediction and impact monitoring (Table 4). Similarly, the ratings of the current importance of science in EIA decision-making were rated highly (Table 2). By way of explanation of these findings, it was frequently pointed out by practitioners that the current EPA places a high emphasis on science in its decision-making. This is supported by the recent description of EIA decision-making in Western Australia by Morrison-Saunders and Bailey (2000) which is consistent with rational-scientific expectations of the process.

Changes in the quality of science in EIA over time

There was almost unanimous agreement amongst the practitioners interviewed that the quality of science utilised in all six stages of EIA had increased over time (Figure 1). The relatively high number of 'neutral' category responses recorded for EIA 'decision-making' was because many of the proponent representatives and consultants, particularly those with less years of experience did not feel confident to make a judgement about this factor.

In comparison, in response to a question concerning the extent to which the scientific and empirical basis for various EIA tasks had been strengthened in the previous five years Sadler (1996, p80) reported figures of 0-8% 'have been strengthened', 23-46% 'little/no change', 38-50% 'moderately strengthened' and 5-23% 'significantly weakened'. There are no empirical studies to demonstrate that the quality of science utilised in EIA has improved over time, although it might be expected as learning from experience occurs.

Overall expectations of the science in EIA

It can be seen from Figure 2 that the majority of participants indicated that the current quality of science in EIA met with their expectations of the process with 68% expressing satisfaction. Given the previously discussed misgivings many interviewees had with the quality of science and the level of importance placed on it during EIA, this apparent contrary finding implies that practitioners' expectations are tempered by the realities of what they know to be current EIA practice. For example, all interviewees indicated that the quality of science in EIA could be improved and that it should play a more important role in the process, but many clearly did not expect this to eventuate in practice due to the influence of other factors (eg. economic, available time, socio-political reasons etc.). There was no evidence that EIA practitioners in any one of the four roles were any more satisfied or dissatisfied in terms of their expectations of the current quality of science in EIA than the others. This finding is consistent with Sadler's (1996, p106) conclusion that the scientific and methodological basis for EIA is 'considered to be satisfactory'.

Factors determining the level of science in EIA

In response to the question: What factors do you believe have determined the level of science utilised in EIA in Western Australia? the most frequent response was increased public knowledge or expectation for environmental performance and the subsequent pressure this placed on proponents, consultants and regulators alike to improve accountability and the quality of information used to justify approval decisions (Table 5). All four types of EIA practitioners identified this factor. This perception is generally supported by surveys of Australians' level of concern for the environment which show an increase in concern over time in recent years (Lothian 1994 and Environmental Protection Authority 1997, p21). Previously, Morrison-Saunders (1998) found that public pressure also had a major effect on environmental management outcomes in each of six case study projects examined in Western Australia and Morrison-Saunders and others (2001) found that public pressure was an important driver for the quality of proponent's EIA documents. This finding highlights the importance of having an EIA process which is transparent and accountable to the public (Commonwealth Environmental Protection Agency undated, p15; Wood and Bailey 1994, Sadler 1996, p95; Morrison-Saunders and Bailey 2000).

Despite the apparent public pressure in EIA, remoteness may reduce this influence. Five of the respondents (16%) stated that there was generally less public pressure on projects located in remote parts of the state, including offshore oil and gas projects, compared to those in well populated areas. This is partly due to the vast scale of the 'outback' regions of Western Australia which are scarcely populated. It is also partly because most of the population living near major resource development projects are those that are employed in the industry themselves and they are likely to be advocates for that industry or operation. For example, one proponent working on a remote mining project stated that they get practically no pressure from community groups because the mining lease area is so large (i.e. mining operations are not visible from the boundaries) and no-one can enter the area without permission. Another industry representative highlighted the importance of having legislative controls for areas where public pressure is not strong.

Other frequently identified factors believed to have determined the level of science utilised in EIA by all four practitioner groups were:

- the requirements of EIA regulators (17 or 55%), including published guideline documents, as well as the leadership provided by key personnel within the EPA and the Department of Environment, Water and Catchment Protection. These were generally seen to have had a favorable impact on the quality of scientific studies during EIA and to be a positive initiative. However, some participants felt that these guidelines were inadequate and one suggested that they reduce the flexibility of the EIA process by focussing effort onto narrowly defined issues, a concern similarly raised by Morrison-Saunders and Bailey (2000) in regard to current EIA practice in Western Australia;
- political expectations (15 or 48%) which were seen to reduce the importance placed on scientific factors as decisions were seen to be largely influenced by socio-economic and political considerations; and
- financial resources provided by proponents (14 or 45%). The cost of undertaking scientific studies during EIA was seen to be a major problem with insufficient funding being available to permit appropriate work to be carried out (eg. baseline data collection) in many circumstances.

Budget restrictions were identified by 61% of participants in Sadler's (1996, p82) international survey as being very limiting on 'best practice' EIA.

Company size was also frequently identified as a factor determining the level of science in EIA in Western Australia (12 or 39%). This factor was identified primarily by consultants and regulatory agencies only. It also relates to the financial resources provided by proponents whereby larger operators tend to have more resources available to undertake EIA studies as well as more experience in the process. However, several interviewees gave examples of small companies with minimal financial resources engaging in high quality scientific investigations during EIA.

Improving the scientific integrity of EIA

In response to the question: How would you improve the scientific integrity of EIA in Western Australia (if at all)?, respondents typically referred to or built upon their answers for the previous question. Three additional suggestions were frequently offered too, and they were common to all four types of EIA practitioner (Table 5).

The first was to increase the resources available to the Department of Environment, Water and Catchment Protection. Problems identified here included overworking/understaffing of the department combined with inadequate levels of experience or training of the staff employed. It was frequently pointed out that many of the 'best' environmental professionals end up working for proponents and consultants (i.e. in the 'private sector') as the pay and work conditions are more attractive here. Furthermore, people with experience in the department appear to be highly sought after by the private sector, presumably because they 'know the system' and may be able to more readily obtain project approvals for proponents. It was believed that a reduced individual workload and increased expertise of staff in the department would increase the scientific integrity in EIA via provision of better advice to proponents and more opportunity to prepare guidance documents outlining the expectations of regulators.

The second suggestion for improving scientific integrity in EIA was for increased consultation with all stakeholders early in the EIA process; for example, one proponent identified consultation with stakeholders as being 'first and foremost' a critical ingredient for effective EIA. This was seen to be mainly the responsibility of proponents. Early consultation would enable regulators and the public to provide feedback on proposals before EIS documents were prepared and formal public review procedures commenced. In this way the feedback could be construed as constructive criticism rather than negative feedback as it would enable project design to be modified during the planning stages. It was believed that early public consultation would improve the scientific integrity of EIA through improved scoping and demand for greater rigor in EIA studies. It was pointed out that once proponents had invested in the preparation of an EIS document, they tended to be locked into a particular project design which they would only reluctantly change if forced to by regulators.

The third suggestion was to subject EIA documents to peer assessment and review (9 or 29%). Similar to having early public consultation, it was felt that peer review would generally improve scientific methods and techniques used in EIA studies as well as the quality of information and reporting. For example if monitoring programs were subject to peer review, it was believed that better programs would subsequently be designed. Similarly it was suggested that peer review of EISs would overcome the tendency for consultants to prepare documents of advocacy on behalf of proponents by requiring a more objective rational or scientific basis to EIA reporting. Peer review in EIA has previously been recommended by various authors (eg. Dickerson and Montgomery 1993, Lemons 1994, Morgan 1998, p83; Benkendorff 1999, Ecological Society of Australia Inc. 2002) as a means of improving the scientific component of monitoring programs and EISs in particular.

CONCLUSION

The results have shown that EIA practitioners perceive the current importance of the role of science in each stage of the process to be significantly lower in practice than it should be; a finding that is echoed in the literature. However, they see that the importance of role of science in decision-making should be less than for the other stages of EIA. The current importance of science in ongoing adaptive environmental management was seen to be particularly low and significantly less than that of mitigation design.

Practitioners consistently indicated that the quality of science in EIA has increased over time for all EIA stages and that they are generally satisfied with the overall current quality of science in EIA; a finding that is contrary to most commentators and empirical studies, but is consistent with the results of Sadler's (1996) survey of practitioners internationally. It would appear to be the case that EIA practitioners in Western Australia are happy with the quality of the science available for use in EIA, but dissatisfied with the importance placed on it in terms of the extent to which it is actually used in practice. Caldwell and others (1982, p390) recorded a similar finding noting that '...it was the ways in which scientific information and methods were used, rather than the intrinsic quality of science that drew criticism' from practitioners in their survey. Practitioner perceptions of the quality of science in pre-decision baseline data collection and impact prediction was lower than that for mitigation design and decision-making.

Although participants suggested that the quality of science in EIA is improving over time for all stages of the process, the results of the survey have clearly indicated that practitioners believe there is room for improvement. It appears that the quality of science in the post-decision stages of the process is particularly wanting; a similar finding was reported by Sadler (1996, p82). That the quality of science in the pre-decision stages of EIA is generally perceived to be better than that in the post-decision stages suggests that desire to win a project approval remains a key driving force in EIA, rather than to maximise environmental protection.

It seems that factors other than knowledge and technical capability affect the role of science in EIA. Quality and availability of science to practitioners form only part of the equation and there are other factors that influence the scientific integrity of EIA outcomes. Foremost among these are time and budget constraints to engage in scientific studies, particularly baseline data collection upon which all other stages of EIA depend to some extent.

Socio-political factors clearly have a bearing on the scientific integrity of EIA, particularly during the principal decision-making stage. It is clear that science provides only one input to decision-making along with other considerations (i.e. social, economic, political etc.). Socio-political factors also affect the quality and use of science in the other stages of EIA. To advance the scientific integrity of EIA may not require more sophisticated scientific studies and development of scientific techniques so much as better integration with these other factors. Tapping into public pressure interests and encouraging regulators to adopt more stringent guidelines and expectations for EIA practice are promising avenues to explore.

There are clearly a variety of factors that determine the scientific integrity of EIA practices. Looking to science alone to improve EIA performance may be misleading. As Bisset (1988) cautioned: 'the literature concerned with the new 'scientific' thinking has a certain missionary, proselytising tone which it is necessary to treat with a degree of circumspection'. Practitioners need to look beyond advances in scientific methods alone to improve EIA practice.

Acknowledgments

Research was funded by a small Australian Research Council grant. Statistical analysis of results was performed by Karen Joesbury. The cooperation of the practitioners who participated in this study and the detailed feedback received from Dr Kirsten Benkendorff plus two other (anonymous) reviewers on a previous version of this paper is gratefully acknowledged.

Literature Cited

Antcliffe, B.L. 1999. Environmental Impact Assessment and Monitoring: the Role of Statistical Power Analysis. *Impact Assessment and Project Appraisal* 17: 33-43.

Bache, S., J. Bailey, and N. Evans. 1996. Interpreting the Environmental Protection Act 1986 (WA): Social Impacts and the Environment Redefined. *Environmental and Planning Law Journal*, 13: 487-492.

Bailey, J. 1997. Environmental Impact Assessment and Management: An Under-Explored Relationship. *Environmental Management* 21: 317-327.

Bailey, J., V. Hobbs, and A. Saunders. 1992. Environmental Auditing: Artificial Waterway Developments in Western Australia. *Journal of Environmental Management* 34: 1-13.

Beanlands, G. E., and P. N. Duinker. 1984. An Ecological Framework for EIA. *Journal of Environmental Management* 18: 267-277.

Benkendorff, K. 1999. The Need for More Stringent Requirements in Environmental Impact Assessment: Shell Cove Marine Case Study. *Pacific Conservation Biology* 5: 214-223.

Bernard, D.P., D.B. Hunsaker Jr., and D.R. Marmorek. 1993. Tools for Improving Predictive Capabilities of Environmental Impact Assessments: Structured Hypotheses, Audits and Monitoring. Pages. 547-564 *in* S.G. Hildebrand and J.B. Cannon (eds.) Environmental Analysis: The NEPA Experience. Lewis Publishers, Florida.

Bisset, R. 1984. Post-Development Audits to Investigate the Accuracy of Environmental Impact Predictions. *Umweltpolitik* 4: 463-484.

Bisset, R. 1988. Developments in EIA Methods. Pages 47-61 *in* P. Wathern (ed.) *Environmental Impact Assessment: Theory and Practice*. Unwin Hyman. London.

Boyd, B.K., G.G. Dess, and A.M.A. Rasheed. 1993. Divergence Between Archival and Perceptual Measures of the Environment: Causes and Consequences. *Academy of Management Review* 18: 204-226.

Brown, A.L., and G.T. McDonald. 1995. From Environmental Impact Assessment to Environmental Design and Planning. *Australian Journal of Environmental Management* 2: 65-77.

Caldwell, L.K. 1991. Analysis - Assessment - Decision: The Anatomy of Rational Policymaking. *Impact Assessment Bulletin* 9: 81-92.

Caldwell, L.K., D.E. Bartlett, D.E. Parker, and D.L. Keys 1982, A Study of Ways to Improve the Scientific Content and Methodology of Environmental Impact Analysis. Advanced Studies in Science, Technology and Public Affairs. School of Public and Environmental Affairs, Indiana University, Bloomington, USA.

Clark, B.D. 1994. Introduction to Environmental Assessment, Environmental Management and Sustainable Development. Presented at the 15th International Seminar on Environmental Assessment and Management, CEMP, University of Aberdeen, 26 June-9 July, 1994.

Clark, B.D., R. Bisset, and P. Tomlinson. 1987. Environmental Assessment Audits in the United Kingdom: Scope, Results and Lessons for Future Practice. Pages 519-540 *in* B. Sadler (ed.), Audit and Evaluation in Environmental Assessment and Management. Canadian and International Experience Volume II Supporting Studies. Beauregard Press Ltd, Canada.

Commonwealth Environmental Protection Agency. undated. Public Review of the Commonwealth Environmental Impact Assessment Process: Initial Discussion Paper: Setting the Direction. Commonwealth Environmental Protection Agency, Canberra.

Culhane, P.J., H.P. Friesema, and J.A. Beecher. 1987. Forecasts and Environmental Decision-Making: The Content and Predictive Accuracy of Environmental Impact Statements. Westview Press, Boulder, Colorado.

Dickerson, W., and J. Montomery. 1993. Substantive Scientific and Technical Guidance for NEPA Analysis: Pitfalls in the Real World. *The Environmental Professional* 15: 7-11.

Duinker, P.N. 1985. Forecasting environmental impacts: better quantitative and wrong than qualitative and untestable! Pages 399-407 *in* B. Sadler (ed.) Proceedings of the Conference on Follow-up/Audit of EIA Results. Environment Canada and Banff Centre, School of Management, Canada.

Duinker, P.N. 1989. Ecological Effects Monitoring in Environmental Impact Assessment: What Can It Accomplish? *Environmental Management* 13: 797-805.

Duinker, P.N., and G.L. Baskerville. 1986. A Systematic Approach to Forecasting in Environmental Impact Assessment. *Journal of Environmental Management* 23: 271-290.

Ecological Society of Australia Inc. 2002. Ecological Factors In Environmental Impact Assessment. Position statement by the Ecological Society of Australia. Available online: http://life.csu.edu.au/esa/esaPSeia.html [last accessed 4 October 2002]

Eddlemon, G.K., J.W. Webb, D.B. Hunsaker Jr., and R.L. Miller. 1993. Actual Versus Predicted Impacts of Three Ethanol Plants on Aquatic and Terrestrial Resources. Pages 272-287 *in* National Association of Environmental Professionals (Ed.), *NEPA Symposium*, NAEP Publications, Washington DC.

Environmental Protection Authority. 1997. Who Cares About the Environment in 1997? EPA Social Research Series. Environmental Protection Authority (New South Wales), Chatswood, Australia.

Environmental Resources Limited. 1985. Handling Uncertainty in EIA. Volume 18 Handling Uncertainty in Prediction. Environmental Resources Limited, London.

Epp, H.T. 1995. Application of Science to Environmental Impact Assessment in Boreal Forest Management: The Saskatchewan Example. *Water, Air and Soil Pollution* 82: 179-188.

Eversley, D. 1976. Some Social and Economic Implications of Environmental Impact Assessment. Pages 126-141 *in* T. O'Riordan and R. Ley (eds.) Environmental Impact Assessment. Saxon House, Westmead, UK.

Fairweather, P.G. 1989. Environmental Impact Assessment: Where is the Science in EIA? *Search* 20: 141-145.

Freudenburg, W.R. 1989. Social Scientists' Contributions to Environmental Management. *Journal of Social Issues* 45: 133-152.

Green, R.H. 1979. Sampling Design and Statistical Methods for Environmental Biologists. John Wiley and Sons, USA. 257pp.

Hellstrom, T., and J. Merle 1996. Uncertainty and Values: The Case of Environmental Impact Assessment. *Knowledge & Policy* 9: 70-85.

Hinkle, D.E., W. Wiersma and S.G. Jurs. 1979. Applied Statistics for the Behavioral Sciences. Rand McNally College Publishing Company, Chicago, USA, 489pp.

Hyman, E.L., and B. Stiftel. 1988. Combining Facts and Values in Environmental Impact Assessment: Theories and Techniques. Westview Press, Boulder, USA, 304pp.

Lemons, J. 1994. The Use of Science in Environmental Impact Assessment. *Journal of Ecology and Environmental Sciences* 20: 303-315.

Lemons, J. and D. Brown. 1990. The Role of Science in the Decision to Site a High-Level Nuclear Waste Repository at Yucca Mountain, Nevada, USA. *The Environmentalist* 10: 3-24.

Lothian, J. 1994. Attitudes of Australians Towards the Environment: 1975 to 1994. Australian *Journal of Environmental Management* 1: 78-99.

Malik, M., and R.V. Bartlett. 1993. Formal Guidance for the Use of Science in EIA: Analysis of Agency Procedures for Implementing NEPA. *The Environmental Professional* 15: 34-45.

Morgan, R.K. 1998. Environmental Impact Assessment: A Methodological Perspective. Kluwer Academic Publishers, Dordrecht, The Netherlands, 307pp.

Morrison-Saunders, A. 1996. Environmental Impact Assessment as a Tool for Ongoing Environmental Management. *Project Appraisal* 11: 95-104.

Morrison-Saunders, A. 1997. The Influence of EIA on Environmental Management in Western Australia. PhD Thesis, School of Biological and Environmental Sciences, Murdoch University, Western Australia.

Morrison-Saunders, A. 1998. The effect of public pressure during environmental impact assessment on environmental management outcomes. Presented at: IAIA'98 Sustainability and the Role of Impact Assessment in the Global Economy. 18th Annual Meeting of the International Association for Impact Assessment, 19-24 April 1998, The Convention Centre, Christchurch, New Zealand.

Morrison-Saunders, A., and J. Bailey 1999. Exploring the EIA/Environmental Management Relationship. *Environmental Management* 24: 281-295.

Morrison-Saunders, A., and J. Bailey 2000. Transparency in EIA Decision-Making: Recent Developments in Western Australia. *Impact Assessment and Project Appraisal* 18: 260-270.

Morrison-Saunders, A., D. Annandale and J. Cappelluti 2001. Practitioner Perspectives on What Influences EIA Quality. *Impact Assessment and Project Appraisal*, 19: 321-325.

Orians, G.H. 1986. The Place of Science in Environmental Problem Solving. *Environment* 28: 12-17 and 38-41.

Preston, B.J. 1985. Monitoring - The Neglected Aspect of Environmental Impact Assessment. *Habitat Australia* 13: 6-7.

Robinson, R.M. 1989. Environmental Impact Assessment: The Growing Importance of Science in Government Decision Making. *Hydrobiologia* 188/189: 137-142.

Sadler, B. 1996. International Study of the Effectiveness of Environmental Assessment, Final Report, Environmental Assessment in a Changing World: Evaluating Practice to Improve Performance. Minister of Supply and Services, Canada, 248pp.

Shrader-Frechette, K.S. 1985. Science Policy, Ethics, and Economic Methodology: Some Problems of Technology Assessment and Environmental-Impact Analysis. D. Reidel Publishing Company, Dordrecht, The Netherlands, 321pp.

Starbuck, W.H., and Mezias, J.H. 1996. Opening Pandora's Box: Studying the Accuracy of Manager's Perceptions. *Journal of Organizational Behaviour* 17: 99-117.

Underwood, A.J. 1991. Beyond BACI: Experimental Designs for Detecting Human Environmental Impacts on Temporal Variations in Natural Populations. *Australian Journal of Marine and Freshwater Research* 42: 569-587.

Wood, C., and J. Bailey. 1994. Predominance and Independence in Environmental Impact Assessment: The Western Australian Model. *Environmental Impact Assessment Review* 14: 37-59.

Table 1. Interview Questions With Numerical Responses on a Likert Scale

Question	**Range on Likert Scale#**
1. How good is the current quality of science…*?	very good (1) - very poor (7)
2. How important is the role of science…*?	very important (1) - not at all important (7)
3. How important should be the role of science…*?	very important (1) - not at all important (7)
4. How has the quality of science changed over time…*?	increased (1) - decreased (7)
5. To what extent does the current quality of science in EIA overall meet your expectations of the process?	highly satisfied (1) - highly unsatisfied (7)

* i.e. in each of (i) baseline data collection; (ii) impact prediction; (iii) mitigation design; (iv) decision-making; (v) impact monitoring; and (vi) ongoing adaptive management

On the Likert scale the number 1 position always represented the most positive rating declining to a neutral position in the number 4 position. Numbers 5-7 represented a negative rating gradient with the 7 position representing the most negative rating.

Table 2: Wilcoxon Test comparisons for the importance of the role of science in EIA

EIA Stage	How important currently is the role of science? [mean (SD)]	How important should be the role of science? [mean (SD)]	Z score	*P* value (two tailed)
Baseline data collection	3.2 (1.3)	1.7 (0.8)	-4.03	<0.001
Impact prediction	3.2 (1.3)	1.7 (0.7)	-4.11	<0.001
Mitigation design	3.0 (1.0)	1.7 (0.6)	-4.10	<0.001
Decision-making	3.1 (1.2)	2.0 (0.9)	-3.54	<0.001
Impact monitoring	3.2 (1.2)	1.6 (0.7)	-4.06	<0.001
Ongoing adaptive management	3.4 (0.9)	1.7 (0.6)	-4.52	<0.001

Table 3: Perceived importance of the role that science should play in decision-making compared to the other stages of EIA.

How important should be the role of science in…	[mean (SD)]	How important should be the role of science in …	[mean (SD)]	Z score	*P* value (two tailed)
Decision making	2.0 (0.9)	Baseline data collection	1.7 (0.8)	-2.65	0.008
Decision making	2.0 (0.9)	Impact prediction	1.7 (0.7)	-2.23	0.026
Decision making	2.0 (0.9)	Mitigation design	1.7 (0.6)	-2.18	0.029
Decision making	2.0 (0.9)	Impact monitoring	1.6 (0.7)	-3.28	0.001
Decision making	2.0 (0.9)	Ongoing adaptive management	1.7 (0.6)	-2.07	0.038

Table 4: Statistically significant Wilcoxon Test comparisons for the current quality of science in EIA

How good is the current quality of science utilised in…	[mean (SD)]	How good is the current quality of science utilised in…	[mean (SD)]	Z score	*P* value (two tailed)
Mitigation design	3.2 (1.0)	Impact prediction	3.7 (1.2)	-2.40	0.016
Decision making	3.1 (1.0)	Impact prediction	3.7 (1.2)	-2.24	0.025
Mitigation design	3.2 (1.0)	Impact monitoring	3.9 (1.3)	-2.60	0.009
Decision making	3.1 (1.0)	Impact monitoring	3.9 (1.3)	-2.52	0.012

Table 5: Interviewee perceptions on factors influencing the use of science in EIA

Question	Response	Frequency
1. What factors do you believe have determined the level of science utilised in EIA?	Increased public knowledge or expectation for environmental performance.	19 (61%)
	The requirements of EIA regulators.	17 (55%)
	Political expectations.	15 (48%)
	Financial resources provided by proponents.	14 (45%)
	Company size (of proponents)	12 (39%)
2. How would you improve the scientific integrity of EIA (if at all)?*	Increase resources available to the EIA regulator.	10 (32%)
	Increased consultation with all stakeholders early in the EIA process.	10 (32%)
	Subject EIA documents to peer assessment and review.	9 (29%)

*Note: respondents typically referred to or built upon their answers for the previous question; only new answers are recorded here.

How has the current quality of science utilised in EIA changed over time?

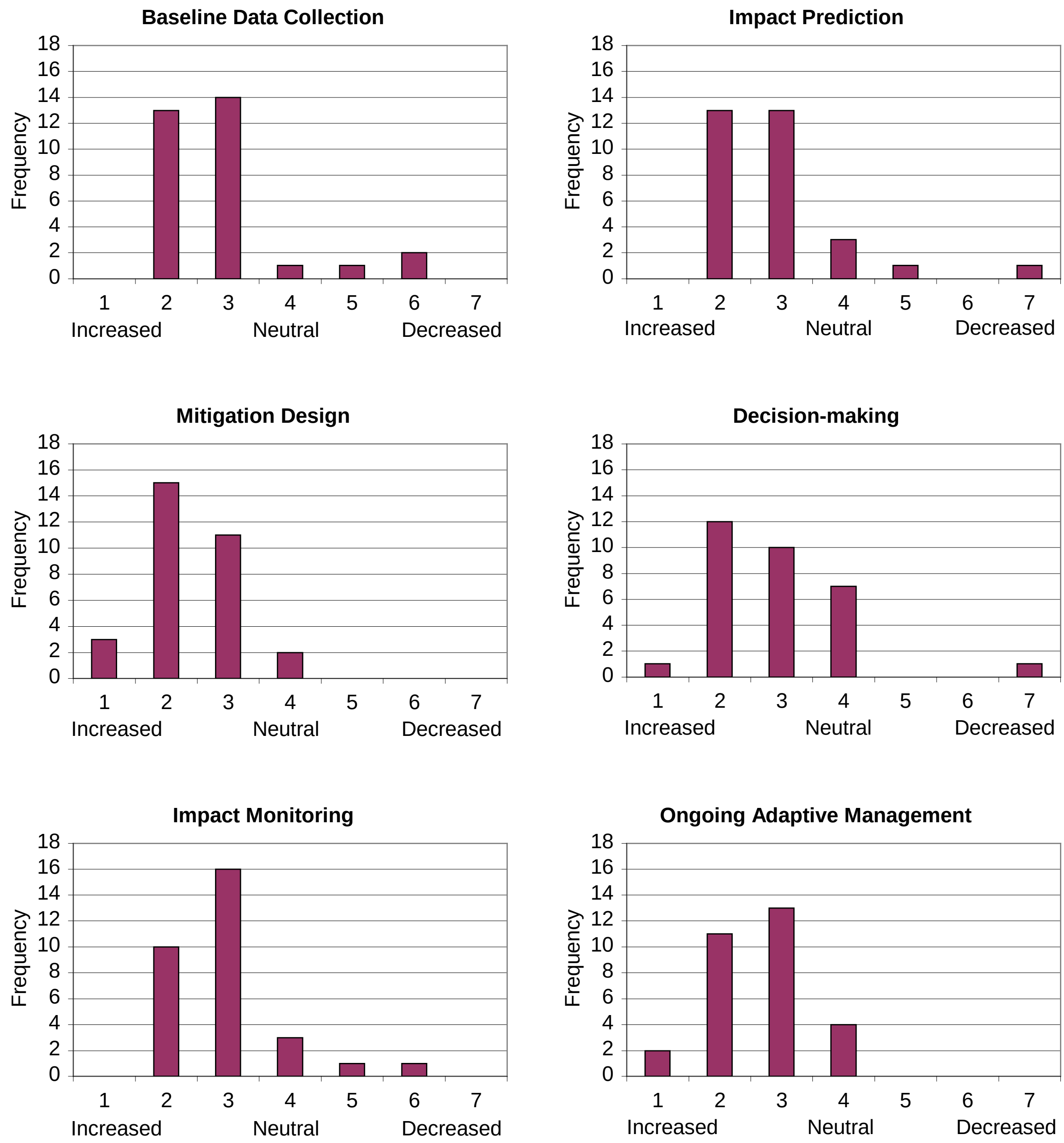

Figure 1: Perceived Change in Quality of Science In EIA Over Time

To what extent does the current quality of science in EIA overall meet your expectations of the process?

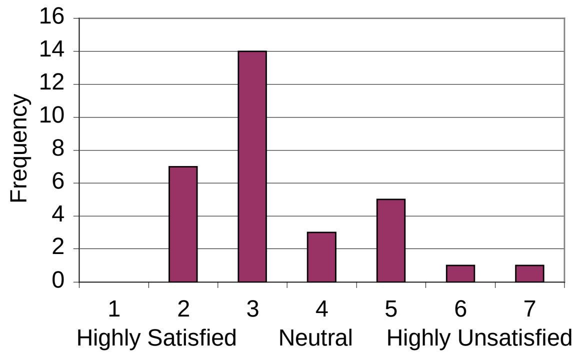

Figure 2: Extent to which the current quality of science in EIA overall meets with practitioner expectations of the process