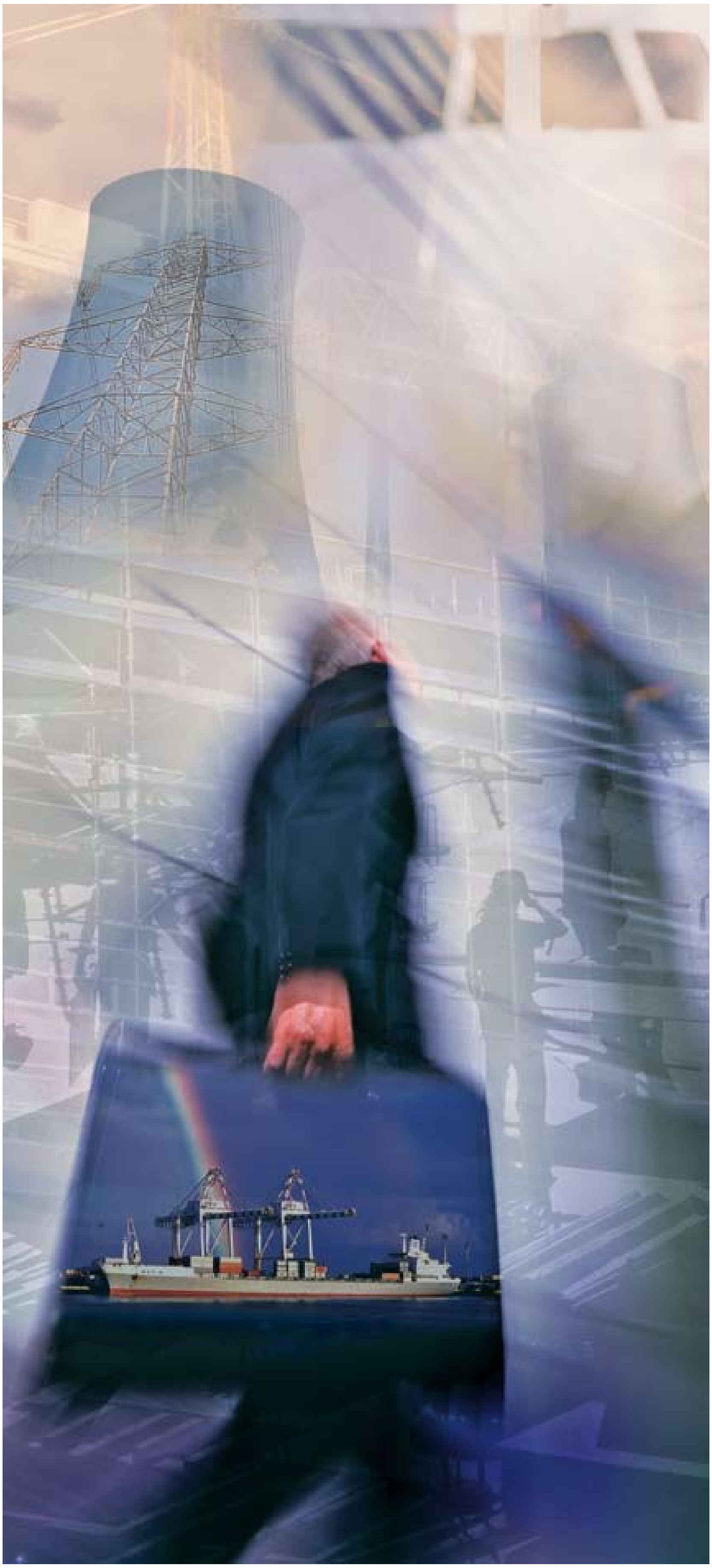

Queensland

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Papers delivered at ACE 08

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The Economic Society of Australia warmly welcomes you to the Gold Coast, Queensland, Australia for the 37th Australian Conference of Economists.

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The Paper following forms part of - *Proceedings of the 37th Australian Conference of Economists*
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Managing impact reduction in fisheries: A multi-criteria assessment of objective priorities

James Innes

Abstract

When attempting to mitigate the environmental impacts of fishing gears there are typically multiple criteria against which the performance of any measures can be assessed. If the gains are non-commercial (i.e. non-market) in nature, formally determining how well measures perform becomes more difficult.

This study uses the analytic hierarchy process (AHP) to quantify the relative preferences of stakeholder groups for one impact reduction objective over another in the context of European mobile demersal fisheries. An advantage of this methodology is that it allows for the inclusion of non-commercial benefits.

Preferences are quantified and allow ranked group-specific weights relating to the reduction of discarding and other *in situ* impacts to be derived. The relative weights placed on the sub-objectives within each of the two objectives are also determined. The variability of preferences at both the intra- and inter-group level is considered and the potential implications with regard to perceptions of success discussed.

Establishing a measured order of preference for individual criteria allows the significance of reductions in any impacts (essentially non-market gains) to be determined. It should also facilitate more targeted and efficient approaches to the process of impact alleviation within these fisheries.

1 Introduction

1.1 Multiple objectives

In the presence of multiple management objectives it is often not possible to fully satisfy all simultaneously. Fishery policy problems and the national and international legislation that aim to tackle these are typically characterised as such (Mardle *et al.,* 2002; Leung *et al.* 2006). Differences in perspective at both the individual and/or group level also tend to result in disparity between the relative priority those involved (i.e. stakeholders) attach to the management objectives. Fisheries typically have multiple stakeholder groups, each with their own interests, so opinions as to how the fishery should be managed tend to differ by group. In instances where the industry is having a significant impact on the environment such differences, and therefore the perceived effectiveness of any management measures, tend to be all the more pronounced. By formally determining the priority stakeholders attach to certain objectives it is then possible to explicitly state the perceived effectiveness of any management measures.

1.2 Fishery Impacts

In addition to the removal of their target species fisheries often have a number of additional impacts on the environment in which they operate. These can be broadly classified into effects on the biota and effects on the habitat/physical environment. Impacts on the biota include; the mortality associated with bycatch i.e. from discards, retained non-target species, and lethal contact with the gear not resulting in capture. Habitat impacts consist of; long/short term changes to the physical structure of the sea bed, or increased turbidity/particulate matter in the water. Last, it is possible all of these may alter predator/prey relationships or the suitability of local habitat and ultimately contribute to longer term shifts in species composition.

Such negative impacts are an ongoing matter of concern in Europe and particularly within the towed demersal fisheries. A desire to reduce fisheries environmental impacts has facilitated a number of research projects[1] and contributed to the understanding and literature surrounding this matter. Much of the work has been aimed at reducing problems associated with bycatch and tends to focus on the use of technical measures (REFS?? General or specific?? Catchpole *et al*, 2008; or Innes and Pascoe 200?). Whilst the problems of bycatch are immediately visible the effects of other impacts are generally less obvious, harder to observe and significantly more problematic to account for.

To fully measure the effectiveness of any management measures all the benefits they generate must be considered. Calculating the potential future economic value of commercial organisms saved by a reduction in discarding has been done in a number of studies (some examples being: Hendrickson *et al.,* 1993; Revill *et al.,* 1999; Pascoe and Revill, 2004; Macher *et al.,* 2008 ?? (this is only for the Nephrops though)), however, determining the non-market benefits of reductions in other impacts such as habitat change or the mortality of infauna on the seabed is not so easy (has not been done?? Need to search lit..). Furthermore, as the value attached to each benefit is likely to vary by stakeholder group this also needs to be accounted for.

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[1] Projects such as; ECODISC, DISCRAN, REDUCE, NECESSITY.

This study applies the analytic hierarchy process (AHP) (Saaty 1977, 1980) to a number of stakeholder groups involved in European mobile demersal fisheries in order to determine the relative priorities they attach to reducing their environmental impacts. The resultant sets of priority scores not only give insight into the relative significance stakeholder groups attach to differing impact reductions, they also provide group specific weights.

1.3 The Analytic Hierarchy Process (AHP)

The AHP is a method for structuring, measurement, and synthesis, and allows individual preferences to be converted into ratio-scale weights (Forman and Gass, 2001), it is one of several multi-criteria decision making techniques (MCDM) available. It provides a relatively simple yet powerful means of deriving individuals' preferences for one objective over another and can incorporate qualitative/value judgements. It allows the inclusion of any non-commercial benefits modified gears may achieve. It is a flexible, structured, methodology that enables either an individual or groups of individuals to define a specific problem based on their own experience of the problem. Additionally, as the AHP is not a statistical exercise it does not require probabilistic assumptions about the decision alternatives. In this instance the goal is to quantify the relative importance different groups attach to reducing certain fishing related impacts (creating a ranking). AHP surveys have not been widely applied in the field of environmental economics and even less so in fisheries management. Reviews of the AHP and other MCDM techniques being applied in the fisheries arena can be found in Mardle and Pascoe (1999) and Leng (2006).

The derived ranking is an indication of the relative weights the respondents place on reducing in-situ impacts and reducing discards. Furthermore it indicates the relative weights the respondents place on the sub-objectives within each of the two objectives (i.e. In-situ impacts: reduce mortality of infaunal invertebrates in the seabed, reduce mortality of epifaunal invertebrates on the seabed, reduce habitat change. Discards: Reduce commercial fish discards, reduce non-commercial fish discards, reduce commercial invertebrate discards, reduce non-commercial discards).

Saaty (1994) defines the AHP as having three basic principals; decomposition, comparative judgement, and hierarchic composition/synthesis of priorities. Following previous studies (such as: Mardle et al., 2004; Leung et al., 1998; Himes, 2007) the process was undertaken in four main steps;

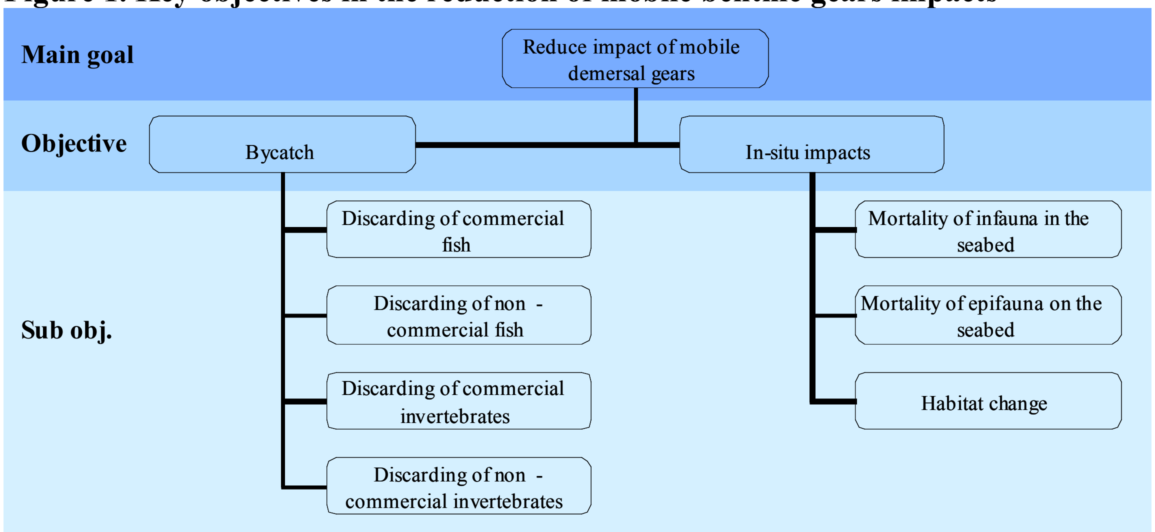
1. develop a hierarchy of the factors important in that decision;
2. survey the associated participants to elicit judgements based on pairwise comparisons of the identified criteria;
3. calculate the individuals relative weights of the factors under consideration;
4. determine homogeneous group weights

2 Method

2.1 Hierarchy of key objectives (step one)

The first step when performing an AHP analysis is to develop a hierarchy of the objectives and attributes. It is essential that at this stage the problem is fully described to ensure validity. Figure 1 gives the main goal, major impacts (objectives), and specific impacts (sub-objectives).

Figure 1. Key objectives in the reduction of mobile benthic gears impacts



(* for the purposes of this study it was assumed all bycatch has 100% mortality)
Objective set determined within the DEGREE project based on the potentially mitigatable impacts (i.e. reductions in impacts)

2.2 Survey of preferences (step two)

The majority of AHP surveys are mail-based. However, concerns that these do not allow for sufficient interaction between participants has led a number of studies undertake their surveys on a face-to-face basis (Leung et al, 1998; Mardle and Pascoe, 2003; Himes, 2007; Parra-López *et al.,* 2008). The pan-European nature of this study meant a face-to-face survey was not feasible. However, in recognition of the concerns raised above and in order to facilitate a level of interaction greater than mail can practically allow, the survey was primarily conducted via e-mail[2].

Valid results also depend on respondents being sufficiently knowledgeable about the matter under consideration, in this case; mobile demersal fisheries and the issues surrounding them. A database of suitable ecologists, biologists, economists, gear technologists, industry and fisheries managers from across Europe was constructed in order to facilitate this.

The survey itself was preceded by; a short introductory paragraph explaining its subject and purpose, an explanation of the scale choices were to be ranked under, and an example and explanation of a completed pairwise choice. The importance of a clear and careful explanation illustrating how to complete the survey is obvious when not being undertaken on a face-to-face basis. Furthermore, respondents were also asked to make it known if they had any doubts with regard to their understanding of how to complete the survey so

[2] In a small number of instances surveys were either conducted or completed by phone.

that further clarification may be provided. A series of pairwise choices were then presented and respondents asked to state, from their perspective, the importance of one objective relative to another. The pairwise choices were presented in a top-down order; i.e. general objectives first followed by those of greater detail. Whilst there has been some debate as to what the optimal order of presentation is, i.e. top-down or bottom-up, Webber *et al,* (1996) found no strong or consistent difference in responses under either (CHECK FOR MORE RECENT WORK ON THIS).

The scale of importance against which preferences are compared must be consistent for each pairwise choice. A nine point scale was used (figure?) and whilst others can be used (e.g. Whitmarsh and Palmieri, 2007…FIND MORE e.g's..) this is the most commonly applied and has been validated for effectiveness through theoretical comparisons with a number of other scales (Saaty, 1990). The fundamental 9-point scale is outlined below in table 1. Choosing a value of 1 (middle of range) indicated the respondent considered the elements to be of equal importance. Choosing a higher value, from 2 to 9, indicated that one element was believed to be more important than the other and additionally to what extent.

Table 1. Scale used for pairwise comparisons

Importance	Definition	Explanation
1	Equal importance	Reducing both impacts is of equal importance
3	Moderate importance (one over another)	Experience and judgement favour the reduction of one impact over another
5	Strong importance	Experience and judgement strongly favour the reduction of one impact over another
7	Very strong importance	Experience and judgement very strongly favour the reduction of one impact over another
9	Absolute importance	Opinion favouring the reduction of one impact over another is of the highest possible order
2,4,6,8	Intermediate values	When opinion falls between the levels of importance stated above

The hierarchy tree illustrated in figure 1 resulted in three sets of pairwise comparisons; one between the two primary objectives, then; a further two sets comparing the sub-objectives within each objective. The number of pairwise comparisons is dependent on the number of elements (say *n*) to be compared on each occasion, the total number of comparisons is then $\left[\frac{n}{2}\right]$ (Mardle and Pascoe, 2003). This resulted in a total of ten pairwise comparisons.

The survey was undertaken during the last quarter of 2007. A total of 137 survey forms were distributed; 40 were ultimately considered usable. The non statistical nature of the method means it is not uncommon for AHP surveys to solicit the opinions of relatively small groups of experts or stakeholders. For example 18 respondents in Mawapanga and

Debertin (1996), 12 in Nielsen and Mathiesen (2006), 9 in Utne (2008), 39 in Himes (2007), 31 in Mardle et al, (2004).

2.3 Calculating the relative weights (steps three and four)

Determining priority weights

Priorities were determined for each goal
A pairwise comparison matrix [A] was constructed for each set of comparisons (three, one each of the dimensions: 1x2, 3x3 and 4x4) and assumed the following form:

$$A = \begin{bmatrix} w_1/w_1 & w_1/w_2 & \cdots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \cdots & w_2/w_n \\ \vdots & \vdots & \ddots & \vdots \\ w_n/w_1 & w_n/w_2 & \cdots & w_n/w_n \end{bmatrix}$$

where A is a square (w*w) positive reciprocal matrix where the vector w (i.e. w_1, w_2, .., w_n) represents the importance weights for the given set of objectives. Each element in the lower left triangle is the inverse of its counterpart in the upper right triangle ($w$ij = x then $w$ji = 1/x, where x is not 0), and elements in the diagonal equal 1 ($w$ii = 1 for all i). As such *wi / wj* indicates the relative preference of element *i* in relation to element *j* in a direct comparison. Its reciprocal property means only n(n-1)/2 pairwise comparisons are required for an n x n comparison matrix. AHP scores are commonly calculated using either the eigenvalue method as proposed by Saaty (1977, 1980), or the geometric mean advocated by Crawford and Williams (1985). It has been demonstrated that both methods are comparable (Budescu *et al.,*1986; Choo and Wedley, 2004; Whitmarsh and Wattage 2006??). Priority weights were derived for each respondents using Expert Choice (v?), widely applied software that utilises the right eigenvalue method of Saaty (1977, 1980).

The subjectivity of making pairwise choices means there will naturally tend to be a certain degree of inconsistency in respondents' choices. For example; if a respondent indicates that B is twice as important as A and C is three times as important as B then, in order to be consistent, C should be six times as important as A. However, in practice it is common that responses do not display such neat preferences and demonstrate either inconsistency in; the relative scale of importance between objectives, their rank order or both. Such intransitive relationships are not permissible in alternative methods (such as Multi-Attribute Utility Theory). The AHP allows for this and the right eigenvalue method proposed by Saaty (1977, 1980):

$$Aw \underset{\max}{=} \lambda w$$

where λ is the largest eigenvalue of matrix A, and w the principal eigenvector enables the consistency of respondents choices to be formally tested. The derived weights are normalised so they sum to one.

The consistency index is calculated following $CI = (\lambda_{max}-n)/(n-1)$ and compared to standard tables (Saaty, 1980) denoting the average consistency for n objects. Perfect consistency occurs where $\lambda = n$ so the closer λ is to n the more consistent the responses. A consistency ratio ($CR = CI$/table value) of no more than 10% is generally considered acceptable; however, there are examples of studies where ratios of up to 20% have been included (Mardle and Pascoe, 1999; Himes, 2007).

Group analysis

Where individuals consistency ratio scores were in excess of 10% the areas of highest inconsistency in their responses were identified and respondents asked to confirm their choices. Cases in which the consistency ratio could not be reduced below 10% were subsequently excluded when calculating the group scores.

Assumptions relating to how the groups under consideration act affect the stage at which they should be created and the most appropriate form of mean to derive. A decision should be made *a priori* and rests on whether to group individual judgements (A_{IJ}) or priorities (A_{IP}) as each method has different underlying assumptions (Mardle et al, 2004). Aggregating A_{IJ} implies the group essentially 'thinks as one'; whereas, aggregating A_{IP} assumes increased autonomy at the individual level allowing for within group differences of opinion (Forman and Peniwati, 1998). As opinions relating to fisheries management tend to demonstrate heterogeneity at both the group and individual level we follow Mardle *et al,* (2004) in applying the latter method. When aggregating A_{IP} either the arithmetic or geometric mean can be used as both have been shown to satisfy the AHPs reciprocal property requirement[3] (Forman and Peniwati, 1998). Respondents were grouped (A_{IP}) by area of expertise (as indicated in the survey response i.e. ecology, biology, economics, gear technology, industry and fisheries management) and the arithmetic mean used to determined group level priorities.

3 Priority weights (results)

The derived ratio-scale measures can be interpreted as final ranking priorities (weights). Group priorities and the associated standard deviation at every level (i.e. Objective, sub-objective, and global) are presented in table 2 where the global (i.e. overall) weights for each group are shown in bold text.

Generally the results conformed to prior expectation. Highest priority is attached to the reduction of commercial fish discards by all groups except management, for whom it ranked second. Reducing habitat change and commercial invertebrate bycatch are the objectives of next greatest concern. Group preferences at the global level are presented in figure 2.

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[3] If aggregating A_{IJ} only the geometric mean is appropriate (Aczel and Saaty, 1983; Forman and Peniwati, 1998).

Table 2. Group level priority scores

		Ecologists			*Biologists*			*Economists*			*Gear Technologists*			*Industry*			*Management*		
		Obj.	Subobj.	Overall	Obj.	Subobj.	Overall	Obj.	Subobj.	Overall	Obj.	Subobj.	Overall	Obj.	Subobj.	Overall	Obj.	Subobj.	Overall
Obj.	Sub obj.																		
In situ impacts		0.445			0.495			0.376			0.262			0.143			0.520		
	Std. dev.	*0.235*			*0.397*			*0.269*			*0.188*			*0.000*			*0.367*		
	Mortality of infaunal inverts		0.184	**0.082**		0.208	**0.103**		0.195	**0.073**		0.256	**0.067**		0.297	**0.042**		0.137	**0.071**
	Std. dev.		*0.191*			*0.180*			*0.114*			*0.179*			*0.052*			*0.098*	
	Mortality of epifaunal inverts		0.293	**0.130**		0.371	**0.183**		0.296	**0.111**		0.441	**0.115**		0.373	**0.053**		0.289	**0.150**
	Std. dev.		*0.171*			*0.192*			*0.132*			*0.243*			*0.056*			*0.131*	
	Habitat change		0.524	**0.233**		0.421	**0.208**		0.510	**0.192**		0.302	**0.079**		0.330	**0.047**		0.574	**0.298**
	Std. dev.		*0.217*			*0.345*			*0.205*			*0.203*			*0.004*			*0.139*	
Bycatch		0.555			0.505			0.624			0.738			0.857			0.480		
	Std. dev.	*0.235*			*0.397*			*0.269*			*0.188*			*0.000*			*0.367*		
	Comm. Fish discards		0.338	**0.188**		0.401	**0.203**		0.315	**0.196**		0.496	**0.367**		0.643	**0.551**		0.228	**0.110**
	Std. dev.		*0.194*			*0.216*			*0.165*			*0.151*			*0.044*			*0.155*	
	Non-comm. Fish discards		0.194	**0.107**		0.255	**0.129**		0.164	**0.102**		0.138	**0.102**		0.087	**0.074**		0.165	**0.079**
	Std. dev.		*0.082*			*0.088*			*0.088*			*0.077*			*0.038*			*0.102*	
	Comm. Invert. Discards		0.229	**0.127**		0.220	**0.111**		0.312	**0.194**		0.235	**0.173**		0.219	**0.188**		0.352	**0.169**
	Std. dev.		*0.081*			*0.115*			*0.146*			*0.116*			*0.011*			*0.095*	
	Non-comm. Invert discards		0.239	**0.132**		0.124	**0.063**		0.210	**0.131**		0.131	**0.096**		0.051	**0.044**		0.255	**0.122**
	Std. dev.		*0.174*			*0.078*			*0.183*			*0.102*			*0.006*			*0.171*	
	No. of respondents:	14			4			9			8			2			3		

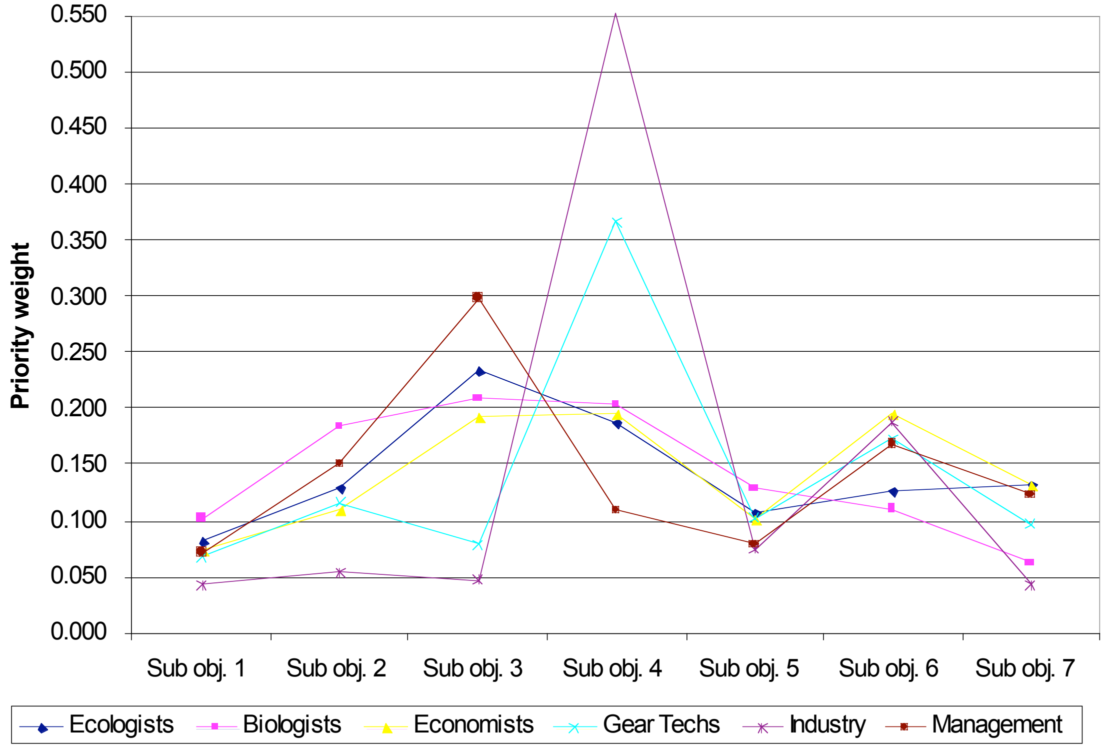
3 Group level priorities

The fishing industry indicated a very strong preference for the objective of reducing of bycatch (0.857) over that of reducing *in situ* impacts (0.143). Reducing the discards of commercial fish and invertebrates were clear priorities, with global weights of 0.551 and 0.188, respectively. In fact, the reduction of commercial fish discards was indicated to be over twice as important to industry when compared to any group other than technologists. Gear technologists ranked the abovementioned impacts in the same relative positions and order but the absolute priority values they attached were more moderate; indicating a preference for reducing bycatch (0.738) over *in situ* impacts (0.262), the top two global preferences were reducing commercial fish (0.367) and then invertebrate (0.173) discards.

Biologists, ecologists, and management attached almost even priorities to the main objectives of reducing bycatch and reducing *in situ* impacts whilst economists erred slightly more towards that of reducing bycatch. Globally, commercial fish discards and habitat change were most important for both biologists and ecologists but the absolute size of these priorities were not nearly as large as those observed with industry and technologists. Reducing habitat change was ranked third by economists who favoured first reducing commercial fish (0.196) and second commercial invertebrate discards (0.194), the main impacts on revenue. Management had the same top three but in this instance reducing habitat changes was the main priority, followed by commercial invertebrates and then commercial fish. Overall, however, the preferences indicated by all four of these groups were much more evenly spread over the seven impacts.

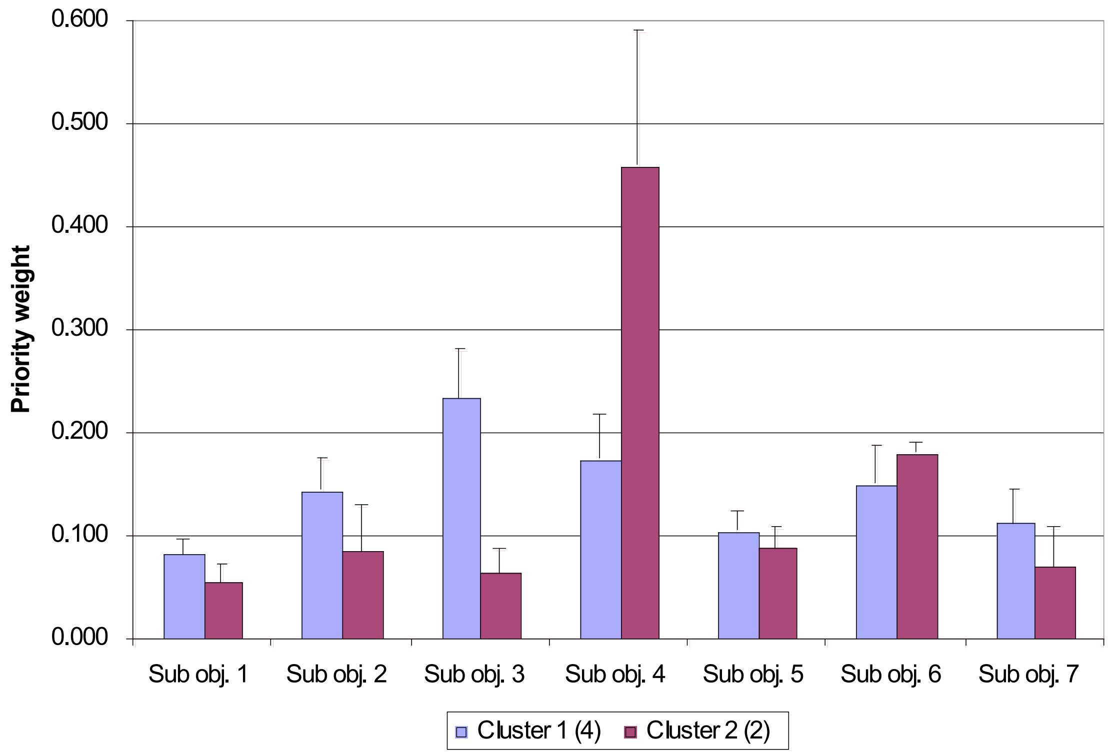
All groups demonstrated a relatively high level of standard deviation at the individual indicator level. This is symptomatic of diverse within group opinion, typical of fisheries, and observed within many other studies (Himes, 2007; Mardle et al, 2004; Wattage and Mardle, 2005; Whitmarsh and Wattage, 2006).

Figure 2. Priorities aggregated by stakeholder group



Cluster analysis based on the *k*-means algorithm (minimising intra-cluster variance) (method? Use Zahir method?) was performed at the global level in order to clarify and more formally analyse any similarities in the preferences expressed by the groups. This identified two natural groups or clusters; one contained ecologists, biologists, economists and management; the other contained gear technologists and the fishing industry. The greatest point of separation between these clusters arose from differences in opinion over the priority of reducing habitat change and reducing commercial fish discards. Figure 3 illustrates the far greater level of priority group two placed upon reducing commercial fish discards.

Figure 3. Group priorities clustered by similarity of preferences



The results of correlation analysis between the individual groups are given in table 3 and indicate the strength of underlying similarities. The groupings identified through cluster analysis can be seen again here. (POSSIBLY REMOVE THIS?)

Table 3. Between stakeholder group correlation

	Ecologists	*Biologists*	*Economists*	*Gear Techs*	*Industry*	*Management*
Ecologists	1					
Biologists	0.721	1				
Economists	**0.783***	0.456	1			
Gear Techs	0.334	0.413	0.589	1		
Industry	0.342	0.414	0.582	**0.991****	1	
Management	**0.799***	0.505	0.626	-0.162	-0.166	1

* correlation significant at the 0.05 level, ** 0.01 level.
Number of observations = 7.
THIS SHOULD PROBABLY NOT BE INCLUDED!

Also:
What about the extra stuff like perceived level of familiarity/understanding of the issues? Correlation with level of inconsistency seen (in initial answers..)? Very mixed results with no clear correlation between the believed level of knowledge/familiarity and the level of inconsistency observed in responses. (looking at initial levels of inconsistency may be more valid??)

4 Discussion and conclusions

Preferences are subjective by nature so a certain level of correlation with respondents familiarity of the issues under consideration should be expected (e.g. as seen in Piet et al, XXXX). The fact fishermen are primarily concerned by, and consequently attach high priority to reducing the level of commercial discards is understandable. This is not to say the industry is unconcerned by the other impacts but, as financially orientated operations, aspiring to maximise profits by reducing any loss of potential revenue is a natural priority. The level of discard related mortality varies by species and fishery but can be high and is often significant (FAO, 1994; Lindeboom and de Groot, 1998; Jennings and Kaiser, 1998). This means that when vessels bring aboard commercial species they, for whatever reason, cannot land the subsequent discarding and associated mortality imposes negatively on the resource upon which they (or other fishers) depend.

The similitude of opinion observed between the industry and gear technologists is believed to be an artefact of the way Europe has concentrated on reducing bycatch through the development of technical measures. As a result gear technologists (and economists) tend to be very familiar with the issues of bycatch whereas attempts to reduce other environmental impacts are a more recent development. Furthermore, gear technologists commonly operate in close connection with the industry so a certain similarity between perspectives may be expected. The more moderate priorities of ecologists, biologists and managers are believed to result from viewing the fishery in a more holistic manner. Ecologists and biologists are likely to take more of an ecosystem perspective where everything is interlinked and changes to both habitat and organism mortality considered significant. Managers are typically required to consider the demands of all involved in the fishery and results in them also having a somewhat more moderate and balanced set of preferences.

Time preferences were not considered in the survey but will also influence preferences, i.e. the industry may be less concerned by impacts such as habitat change because the immediate benefits are possibly less well understood, smaller or harder to see. Confidence that investing in the long term health of the environment offers a good chance of financial returns is necessary if the benefits will not be felt in the relatively short term. The situation currently facing many trawler fisheries is at best uncertain as; if not limited by stock constraints the sustained rises in fuel prices have the potential to make these fisheries economically unviable before any of the environmental impacts they may generating will. Also, if impacts such as habitat change do not (or at least are not perceived to) directly affect the species they target the mere existence value is likely to be low when compared to potential revenue.

As each group attaches different levels of importance to the individual sub-objectives the benefit of any management measures (e.g. modifying gears) will be judged accordingly. By quantifying these preferences into weights the resultant trade-offs of any subsequent and related management decisions can be made explicit and compared with alternatives. For example; if a selection of impact reducing gears were available, each resulting in an alternative combination of reductions, application of the weights would allow the perceived success of each to be derived for each stakeholder group. When stakeholder groups believe measures are tackling issues they deem to be of importance there is a much higher likelihood of acceptance, or compliance in the case of legislation. A significant problem with some technical measures is the ease with which they can be circumvented without a significant risk of detection. If the likely level of acceptance can be determined prior to final policy decisions being made it is possible greater levels of compliance may be achieved whilst also reducing the burden of enforcing the final policy.

The goal of this work was to derive sets of weights at the stakeholder group level that quantify the priorities each place on reducing the environmental impacts mobile demersal fisheries can have. Appling the AHP has revealed the individual importance of each contributory objective and sub-objective to various interest groups. Further analysis of the group level results has also indicated opinions tend to follow two patterns; the majority have relatively moderate preferences and value the reduction of all impacts, the remainder are seen to place far greater priority on reducing the immediately visible commercial impacts.

The derived preference weights have a potential application in any situation where measurable changes in the impacts of mobile demersal gears are known or can be anticipated. One natural application would be in determining the cost-effectiveness of certain modified demersal gears; the weights applied to estimates of absolute changes in impacts and then combined with changes in costs.

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