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Evaluating fisheries management options in Hawaii using analytic hierarchy process (AHP)[1]

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Abstract

Fisheries management is typically characterized by multiple and often conflicting objectives. The Western Pacific Regional Fishery Management Council (WPRFMC) is the authority for managing exclusive economic zone (EEZ) fisheries in Hawaii. The array of multiple objectives coupled with the heterogeneous composition of WPRFMC creates a complex decision-making environment for fishery management in Hawaii. In this paper, we applied the analytic hierarchy process (AHP) to evaluate four alternatives for limiting entry of longliners into the Hawaii pelagic fishery. We first elicited the factors deemed to be important for a sustainable pelagic fishery using a questionnaire survey, followed by another questionnaire to elicit judgments from all of the individuals involved in the decision-making process of WPRFMC. While there is considerable variation among individuals, the overall weighting of objectives and ranking of alternatives is robust in the sense of being consistent across all four bodies of the WPRFMC. There was no statistical difference in mean results among the WPRFMC bodies at the 5% level. This experience demonstrated an application of the AHP process in fishery management. The results of the present evaluation of the alternatives for limiting entry of longliners are comparable to earlier decisions. As compared to conventional decision making, this process has the advantages of timeliness, quantification, and documentation. It may also provide policy analysts with insights into potential conflicts and tradeoffs before the decision-making process unfolds. © 1998 Elsevier Science B.V. All rights reserved.

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1. Introduction

Fishery management is typically characterized by multiple and often conflicting objectives. The Western Pacific Regional Fishery Management Council (WPRFMC) is the authority for managing exclusive economic zone (EEZ) fisheries in Hawaii. WPRFMC's organizational structure consists of four main bodies: the Council itself; a Scientific and Statistical Committee (SSC); a fishing industry Advisory Panel (AP); and fishery management Plan Teams (PTs). These bodies bring together federal, state, and private fishing interests to participate in the policy

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and decision-making process, and consist of around 70 individuals with different backgrounds and interests in pelagic fishery. The array of multiple objectives coupled with the fishery management council's structure creates a complex decision-making environment for fishery management. Decision analysis (DA), a branch of operations research and management science, can be a valuable addition to the existing tools of fishery management to assist the Council in tackling the increasingly complex fishery situations.

DA provides a logical and systematic process for making better decisions particularly in complex decision situation with conflicting objectives, uncertainty, and different perspectives. It should be noted, however, that DA does not replace decision making; it simply provides a conceptual framework for systematic thinking about difficult problems along with a set of analytical tools to make the thinking easier. DA has been applied widely in the business world but very few applications can be found in fishery management. Rothschild and Heimbuch (1983) presented a decision-theoretic foundation for the design of a fishery management system and demonstrated how various sampling schemes can improve the management process. Following Thibodeau's (1983) approach, Maguire (1986) demonstrated the application of formal methods of decision analysis under uncertainty to integrate ecological theory, objective data, subjective judgments and financial concerns in the management of endangered species populations. Recently, Tam et al. (1996) applied formal decision analysis to evaluate the consequences of effort variations in the sea snail fishery on the central-northern coast of Chile.

A recent addition to the DA literature, analytical hierarchy process (AHP), has been applied extensively in many diverse areas with complex decision and evaluation problems involving tradeoffs of multiple objectives. While the authors believe that there are possibly many applications of AHP in fishery management, only one published article and a conference paper can be found in the literature. DiNardo et al. (1989) demonstrated the applicability of the AHP to fishery management and provided an illustrative example involving Maryland's river herring fishery. Merritt (in a paper presented at the TIMS XXXII Conference) used AHP to evaluate the suitability of

selected Alaskan streams as a habitat for rainbow trout.[2]

In this paper, we applied the AHP to evaluate four alternatives for limiting the entry of longliners into the Hawaii pelagic fishery. We first elicited the factors deemed to be important for a sustainable pelagic fishery using a questionnaire survey, followed by another questionnaire to elicit judgments from all of the individuals involved in the decision-making process of WPRFMC.

2. Hawaii's fishery management structure

The WPRFMC is one of the eight regional councils created by the US Fishery Conservation and Management Act of 1976 (Magnuson Act). WPRFMC is responsible for bringing together the various federal, state and local fishing interests to participate in the policy/decision-making process. The Magnuson Act also provided detailed instructions regarding the organizational structure of the councils. WPRFMC has 13 voting members in all, with two representatives from American Samoa, one each from Guam and the Northern Mariana Islands, four from Hawaii, the regional director of National Marine Fisheries Service (NMFS), and four additional designated state officials. In addition, there are several non-voting members including the regional director of the US Fish and Wildlife Service, the commander of the designated Coast Guard district, the Executive Director of the Marine Fisheries Commission, and a representative of the Department of State.

Also by direction of the Magnuson Act, each council must establish an SSC, a fishing AP, and any other committee that is necessary to aid in the development and amendment of the FMPs. In addition to the mandatory SSC and AP, the WPRFMC has two other committees: the fishery management plan teams (PTs)

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[2]Meritt mentioned that despite initial resistance, AHP is gradually gaining wider acceptance as a useful process for the Alaska Fish and Game Department's decision making which often involves multiple parties, and social and environmental values combined with physical and biological parameters. Source: Merritt, M.F. Ranking selected streams in interior Alaska on the basis of suitability for sustaining an introduced Rainbow Trout population. Paper presented at the TIMS XXXII conference, June 1994, Anchorage, Alaska.

and the standing committees (SCs). The types of interests that are represented within the groups vary greatly with the PTs being the most diverse and the SCs the most homogenous. Some individuals serve on more than one group.

There are four PTs corresponding to each of the four fishery management plans – pelagic, bottomfish and seamount groundfish, crustaceans, and precious coral. The pelagic PT consists of 15 members. The main functions of the PTs are to review and organize issues provided by the Council for incorporation into a fishery management plan (FMP) or an amendment to the FMP and to produce annual reports for each fishery. Furthermore, the PTs also provide recommendations for research and data required to analyze fishery issues and evaluate possible policy alternatives.

Like the PTs, the industry AP is divided into four sub-panels. These sub-panels are further broken down by geographic location. By far the largest group among the Council's subcommittees, the AP has as many as 50 members representing marketing interests as well as both full and part time commercial and recreational and sports fishing interests. Of these sub-panels, the Hawaii pelagics group is the largest with 24 members in 1995. The main objective of the AP is to incorporate local fishing industry interests into the decision-making process. In fact, the AP is the main channel of information flow between the fishing community at large and the policy makers.

The SSC is a single entity consisting of 15 members with its main function being to follow up with scientific and statistical review of the research recommended and commissioned by the plan team for the development of a fishery management plan or an amendment. As a purely scientific advisory body, the SSC's recommendations generally hold quite a bit of weight.

There are nine SCs consisting of Council members to aid the Council in digesting the volumes of information they are responsible for at each meeting. The nine SCs are: executive; bottomfish and seamount groundfish; budget and program; fishery rights of indigenous people; precious corals; ecosystems and habitat; crustaceans; enforcement; and pelagics.

Finally, the WPRFMC has an administrative staff headed by an executive director with several professional and secretarial staff members. The administrative staff is responsible for organizing and drafting fishery management plans along with other administrative duties such as setting up council and subcommittee meetings and their agendas. In addition, the staff serves as an information broker by gathering, organizing and interpreting information for the council.

The WPRFMC is a complicated but balanced bureaucratic system. The organization of the various subcommittees is depicted in Fig. 1.

3. The Hawaii pelagic fishery

Pelagic species dominate Hawaii's commercial fisheries. In 1994, the commercial catch of all pelagic species totaled 21.7 million pounds, or 90% of all reported commercial landings, with an ex-vessel value of $58 million (DBED&T, 1995). Tunas and swordfish make up the bulk of the pelagic catch, which also includes marlins, mahimahi, wahoo, and opah
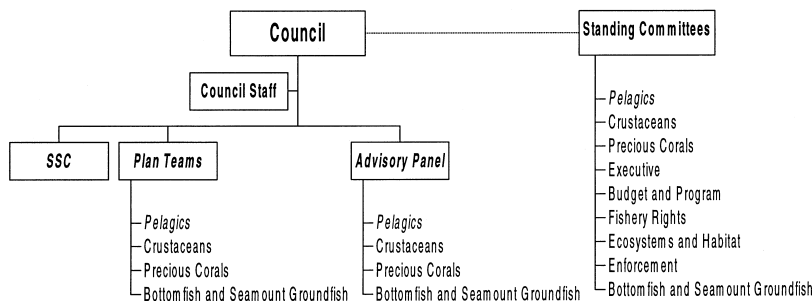

Fig. 1. Organization of council family.

Table 1
Commercial fish catch in Hawaii, year ending June 30, 1994

Species	Catch in million lbs	Value in $ million
Tunas	11.212	26.899
Bigeye	3.812	14.015
Yellowfin	3.741	8.368
Billfish	8.880	22.505
Swordfish	6.302	19.839
Blue Marlin	1.360	1.245
Striped Marlin	1.026	0.989
Miscellaneous pelagic	1.584	1.481
Mahimahi	0.702	1.492
Wahoo	0.370	0.954
Opah (sunfish)	0.408	0.407
Total pelagic species	21.676	50.885
Total all species	24.029	57.999

(Table 1). In comparison, the commercial catch was 9–11 million pounds annually for the early and mid-eighties, and started increasing with the entry of modern longliners associated with the development of local and export markets for fresh tuna, and new swordfish fishing methods (Pooley, 1993). No current recreational catch information is available.

These species are targeted by commercial, recreational, and part-time commercial ('expense' boat) vessels. Large (35–40 feet and longer in length) commercial vessels include pole-and-line boats targeting skipjack tuna and longliners targeting bigeye tuna, yellowfin and swordfish. The smaller commercial vessels as well as recreational and 'expense' boats include handliners and trollers mostly in the 12–25 ft range, many of which are trailered boats. These typically operate well within 20–30 miles from the shore. Charter boats up to ca. 60' in length also operate out of several ports and usually sell their catch. Boggs and Ito (1993) describe the longline, troll, and handline fleets over the history of their existence as well as trends in fishery landings.

The pelagics FMP was adopted by WPRFMC in 1987 and, among other changes, subsequently amended in 1991 to establish a three-year moratorium on new longliners entering the fishery. Upon its expiration in 1994, a longline limited entry program with a size restriction on vessel upgrades was adopted in Amendment 7 of the FMP. Six formal alternatives were considered by the Council for Amendment 7. The discarded alternatives included:

1. limited entry program with harvest capacity restriction on vessel upgrade,
2. limited entry with no harvest capacity restriction on vessel upgrade,
3. dual permit system,
4. extension of the limited entry stipulations of the moratorium, and
5. open access (WPFRMC, 1994).

The objective of the present study is to evaluate, using the AHP technique, four of the alternatives as if the amendment was to be updated for the 1996 fishery. The four alternatives are:

1. *Restricted vessel size*: Limited entry program with permits issued to existing permit holders. Transferability of permits is subject only to a size restriction on vessel upgrades. Upgrade (replacement) of current vessel is possible only up to 93 feet in length.
2. *Unrestricted upgrade*: Limited entry program with transferable permits issued to existing permit holders. Unrestricted vessel upgrading.
3. *Dual permit*: Limited entry program with two types of permits: 'Class A' to existing permit holders and 'Class B' to new entrants into the fishery. 'Class A' boats would be allowed to fish within the EEZ in Hawaiian waters, while 'Class B' boats would be allowed to fish only outside of the EEZ and also be required to carry VMS equipment aboard. No restrictions on vessel upgrading is stipulated.
4. *Open access*: No limit on the number of permits available to longline fishing and no restrictions on the harvest capacity of vessels.

4. The analytic hierarchy process (AHP)

The AHP is an approach to multiple criteria decision making developed by Thomas Saaty in the early 1970s. Although not firmly rooted in utility theory, the practical nature of AHP has led to many diverse applications in the last two decades in solving large, complex and elusive decision problems. There are many books and articles documenting the technique

(e.g. Zahedi, 1986; Saaty, 1988, 1990; Vargas, 1990; Saaty, 1994). Saaty and Vargas (1994) provide a diverse collection of AHP applications. Expert Choice, Inc. provides a comprehensive AHP bibliography up to 1993 containing some 1000 citations. After two decades of struggle, the debate is still ongoing as to the validity of the AHP in solving multiple criteria problems as compared to the long-standing multiple attribute utility theory (MAUT) (Winkler, 1990). While we will not go into the many arguments of the debate, we would like to mention that the AHP provides a simple and yet powerful analytical framework for the fishery management problem at hand.

Following Zahedi (1986), four steps are identified in using the AHP to solve a decision problem. They are:

1. setting up the decision hierarchy by breaking down the decision problem into a hierarchy of interrelated decision elements, as a tree containing the overall goal at the top with many levels of criteria and subcriteria in between and the alternatives at the bottom;
2. collecting input data by pairwise comparisons of decision elements;
3. using the eigenvalue method to estimate the relative weights of decision elements; and
4. aggregating the relative weights of decision elements to arrive at a set of ratings for the decision alternatives.

Like any other decision analytic approach, AHP has its strengths and weaknesses. Carlsson and Walden (1995) pointed out five strengths and four weaknesses of the AHP as a decision-support system in particular reference to group decision making. The strengths are:

1. AHP permits collection of all relevant elements of a decision problem into one model to work out their interdependencies and their perceived consequences interactively.
2. The use of pairwise comparisons forces AHP users to articulate the relative importance of criteria and then to decide the relative contributions of the alternatives to the criteria.
3. The sophistication and user-friendliness of Expert Choice software (Expert Choice, Inc., 1996) allows AHP users to quickly build and solve a multiple criteria decision problem.

4. The hierarchical feature of AHP allows easy and natural structuring of a decision problem.
5. The inconsistency measure allows AHP users to be aware of the seriousness of any inconsistent judgments.

The weaknesses noted by Carlsson and Walden are:

1. AHP users almost never use the 7 (very strong importance) and the 9 (extreme importance) scale because they do not perceive them to be much different from 5 (essential or strong importance). However, we do not find that to be the case in our study where the entire scale of measurement was used.
2. AHP users must rely too heavily on their experience and intuitive judgment.
3. An arbitrary starting reference point is needed in pairwise comparison that may change perceptions of a multiple criteria problem.
4. Pairwise comparisons eliminate the longer chains of interdependence which the users perceive during an AHP evaluation.

5. Development of the AHP tree

The Council's management goals were determined using a two-step process from January to November of 1995. First, a tentative list of management goals with their definitions was compiled by combining information from the pelagic FMP with interviews of representatives from the Council's various subcommittees. This tentative list was then incorporated into a mail-out survey sent to selected members of the Council's pelagics PT, SSC, AP (pelagics), and Council staff for their comments.

The revised list of identified management goals and sub-goals was then arranged into a decision tree using the Analytical Hierarchy Process (AHP). The initial tree was tested and refined by a selected group of NMFS researchers. The final structure of the decision hierarchy was presented to WPRFMC for their feedback at a council meeting. Fig. 2 shows the final AHP tree. Since the four alternatives are evaluated at the lowest level for all the criteria, they are presented at the bottom of the tree.

Sustaining a viable pelagic fishery

| Biological 0.526 | Economic 0.191 | Social 0.200 | Political 0.083 |

Biological 0.526
- MSY 0.078
- Overfishing 0.268
- Bycatch 0.073
- PSI 0.107

Economic 0.191
- Employment 0.100
- Profit 0.091
  - Longliners 0.029
    - Revenue 0.017
    - Cost 0.012
  - Small Boats 0.037
    - Revenue 0.022
    - Cost 0.016
  - Support Industries 0.025
    - Revenue 0.015
    - Cost 0.010

Social 0.200
- Community 0.051
  - Society 0.018
  - Local 0.033
- Access 0.042
  - Commercial 0.016
  - Noncommercial 0.026
    - Native 0.015
    - Recreational 0.011
- Bycatch 0.032
  - Competition 0.009
  - Waste 0.023
- Social PSI 0.044
- Gear Conflict 0.031

Political 0.083
- Public Acceptance 0.038
- Resistance 0.045
  - Longliners 0.015
  - Small Boats 0.031

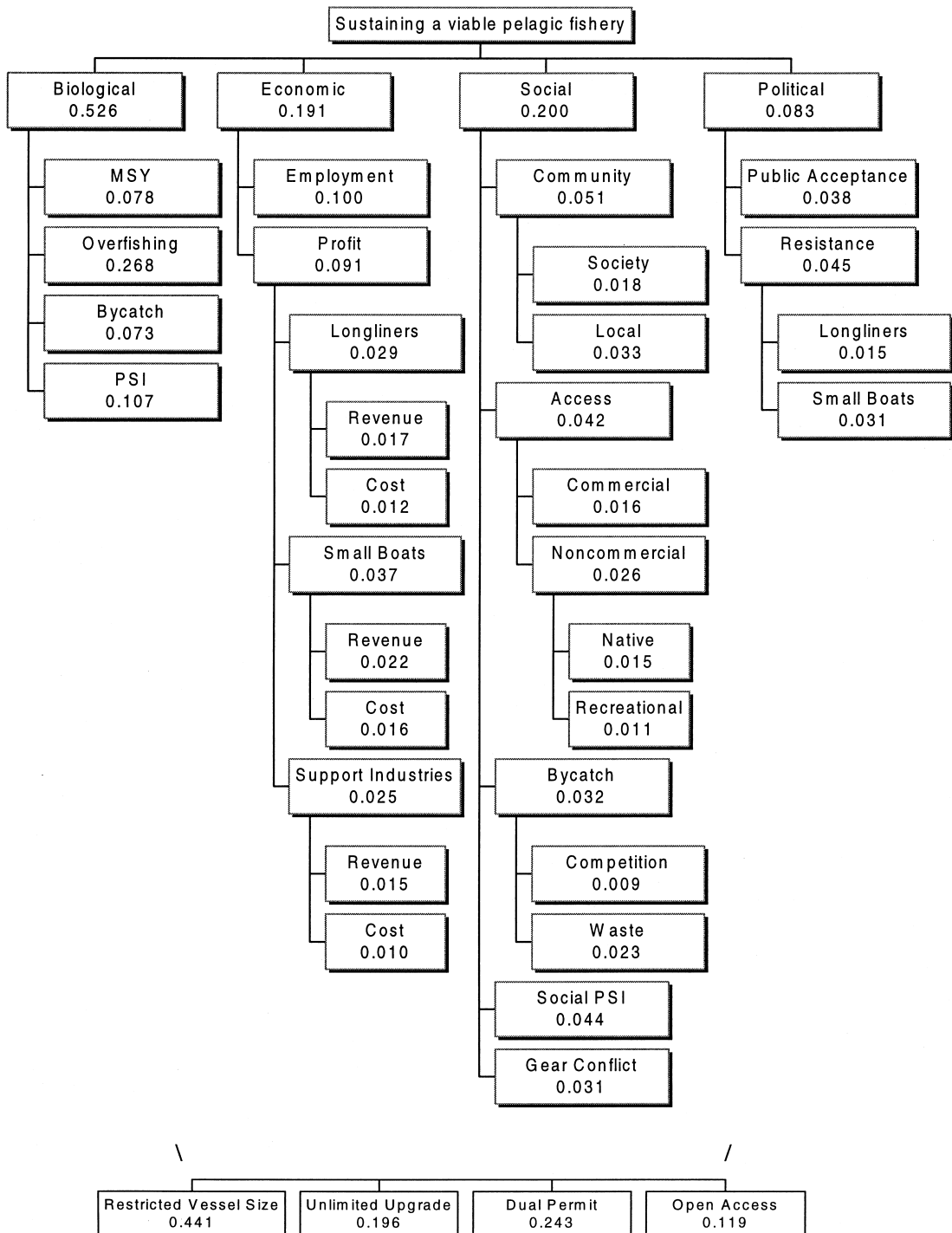| Restricted Vessel Size 0.441 | Unlimited Upgrade 0.196 | Dual Permit 0.243 | Open Access 0.119 |

Fig. 2. AHP tree – Hawaii pelagic fishery management objectives (numbers are priorities of the overall group).

At the top of the tree is the overall goal of sustaining a viable pelagic fishery in the long run. Four criteria are identified as essential for achieving the overall goal: biological; economic; social; and political. The biological criterion is further divided into four sub-criteria: achieve maximum sustainable yield (MSY); avoid overfishing; reduce bycatch; and minimize protected species interactions (PSI). MSY is the largest possible yield or catch rate year after year where the fish stock will remain viable or 'healthy' in the long run. The objective is to reach and maintain the fishery at MSY. Overfishing occurs as a result of fishing activity that reduces the target species' spawning stock below the NMFS-determined spawning potential ratio (SPR). Thus, we wish to minimize overfishing by regulating harvest levels to prevent the target species spawning stock from dropping below the SPR. Bycatch can best be described as fish mortality and potential reduction in recruitment of non-targeted species that are caught and not utilized. In the biological definition of bycatch, non-targeted species that are utilized are not considered bycatch. The only consideration of bycatch as a biological objective is to ensure long term stock viability of the non-targeted species by minimizing their incidental bycatch. PSI, or the interactions with protected species, refers to minimizing physical and ecological interactions with protected species such as sea turtles, sea birds and marine mammals. As with bycatch, only the viability of the protected species' stocks is taken into consideration, e.g. the bycatch of sea turtles has detrimental effects on their stocks that could have a long term negative impact on the viability of the species.

There are two main economic considerations, which are employment and profit. The profit category is further broken down into cost and revenue considerations for the three interest groups: longline fishermen; small boat fishermen; and support industries. Employment refers to the number of jobs in the fishing industry, including fishermen as well as marketers, suppliers, etc. The goal is to maximize employment in the fishing industry. Profit refers to the industrywide profit that we wish to maximize. Revenue is the income derived from the sale of a good (e.g. bait, fishing supplies) or a service (e.g. boat repair). We wish to maximize revenue. The cost category includes all expenses incurred from fishing related activities.

We wish to minimize costs for a given level of operations as well as any additional costs. The longline fisher group includes the 'large' vessel, full time fishermen who use the longline fishing technique. Small boats include all full time and part time commercial fishermen who do not use the longline method of fishing (i.e. troll, handline, etc.). Recreational fishermen are addressed under the social criterion. Support industries include businesses such as marketing, fueling, suppliers, shippers, handlers, bait dealers, etc. In other words, the support industries group includes all business whose operations are linked to the fishing industry.

The social criterion includes community lifestyle and values, access, bycatch, PSI and gear conflict. Community lifestyle and values refer to both the overall community or 'society' and the subset of the overall community consisting of the 'local fishermen' and their families for whom fishing is an integral part of their lifestyle. In other words, the long run viability of fishing is important to both society – who values the continued existence of a traditional occupation and recreational activity – and fishing families who value fishing because it is a way of life. Access refers to access for the fishermen to areas and targeted species. This criteria is further broken down into commercial and non-commercial considerations. Access issues in both the commercial and non-commercial sectors can be described as the distribution and allocation of the resource between various fisheries. The non-commercial access criterion is further divided into provisions for native rights and recreational fishing opportunities. Native rights refer to providing special access provisions for the individuals who practice 'traditional' native Hawaiian fishing techniques and thus constitute a fishery with specific interests at stake. Recreational fishing opportunities refer to maximizing opportunities for individuals to partake in fishing for pure pleasure seeking motives. Social bycatch as a social consideration can be split into two components. The first, refers to society's disdain for waste. For example, sharks that are finned but whose carcasses are not landed would be considered waste. The second component, competition, refers to the catch of a non-targeted species in one fishery that is valued and targeted by another fishery (regardless if the species is utilized or not by the fishery with the bycatch). For example, blue marlins

are often considered to be a longline bycatch. In this section, bycatch does not refer to the implications that incidental landings of a species have on the viability of its stock. We seek to minimize both the waste and competition components of bycatch. Protected species interactions (social PSI) as a social consideration refer to society's disapproval of the injury or killing of sea turtles, sea birds, marine mammals, etc. As a social objective, we wish to minimize PSI to avoid the negative publicity generated when protected species are injured or killed. In addition, PSI must be minimized to conform to the Endangered Species Act and the Marine Mammal Protection Act. Long term preservation of the stock is taken into consideration as a biological objective. Gear conflict is the interaction between various gear types in the different fisheries that share the same fishing areas. We wish to minimize gear conflict.

There are two political considerations: public acceptance and resistance by fishers. The Council would presumably like to maximize the public's acceptance of an adopted policy, as well as minimize the resistance by fishers to an adopted policy. The less likely that the fishers will resist, the more attractive the policy alternative. Again, fishers consists of longliners and small boats.

6. Eliciting weights of the management goals and the four alternatives

Since the group of decision-makers is large and diverse, another survey was conducted to elicit the weights of the fishery management goals, then to evaluate the four alternatives as if the 1994 Amendment to the pelagics FMP was to be updated. This survey was sent out to all 66 Council members and pelagic subcommittee members where the respondents were asked to evaluate a series of paired comparisons regarding the identified goals. Appendix A shows part of the survey instrument used. A scale of −9 to 9 was given to the respondents to state their preferences with −9 favoring the left goal and 9 favoring the right goal presented in each pair. Along with this survey, the participants were also asked to evaluate four alternatives for limiting entry of longliners into the fishery. The same scale was used to pairwise evaluate the four alternatives.

Table 2
Survey response rates by group

	Participants surveyed	Number of usable surveys	Response percentage (%)
AP	24	12	50
PT	15	8	53
SSC	15	12	80
Council	16	4	25
Total individuals [a]	66	34	52

[a] Groups do not sum up to total because some individuals belong to two groups. An additional 10 surveys were returned incomplete.

The response rates with respect to each of the decision-making groups are summarized in Table 2. Overall, a little more than half of the participants returned usable surveys. Response rates were highest for the SSC and lowest for Council members. Judging from comments on unusable surveys and experiences during the process of conducting the mail survey, the latter partly reflects the fact that half of the Council members are from out of state (the majority of individuals in other groups are in-state) and partly that most members' primary professions are more removed from fisheries than in other groups. These factors magnify the weaknesses of using a mail survey and a procedure that is unfamiliar to participants.

The response of each participant was analyzed using Expert Choice (EC), a microcomputer implementation of the AHP, to arrive at the individual priorities of management goals and the four alternatives. Similarly, geometric means of the judgments from all 34 respondents were used to derive the overall and the respective groups' priorities. The overall priorities for the group are listed in the AHP tree in Fig. 2. Table 3 compares the priorities of the 36 specific criteria and sub-criteria for the four groups. Of the four major criteria (level 2 in the AHP tree) for sustaining a viable pelagic fishery in Hawaii, the biological criterion has the highest priority for all groups (0.526), particularly for the Council members (CM) whose average weight is 0.714. The economic and social criteria are of roughly equal weights (0.191 and 0.200) with the AP showing a relatively higher priority and the Council members the lowest priority for these two criteria. The political criterion shows the lowest priority consistently for all four groups (0.083).

Table 3
Priorities of the management criteria and sub-criteria by group

Level	Criteria and sub-criteria	AP	CM	PT	SSC	Overall
2	Biological	0.435	0.714	0.555	0.539	0.526
3	MSY	0.058	0.059	0.047	0.133	0.078
3	Overfishing	0.231	0.421	0.220	0.259	0.268
3	Bycatch	0.071	0.088	0.080	0.069	0.073
3	PSI	0.076	0.146	0.209	0.078	0.107
2	Economic	0.238	0.090	0.171	0.206	0.191
3	Employment	0.139	0.027	0.074	0.086	0.100
3	Profit	0.099	0.063	0.097	0.120	0.091
4	Support	0.024	0.012	0.029	0.035	0.025
5	Revenue	0.017	0.005	0.020	0.016	0.015
5	Cost	0.008	0.007	0.009	0.019	0.010
4	Small Boats	0.042	0.030	0.038	0.046	0.037
5	Revenue	0.030	0.012	0.020	0.025	0.022
5	Cost	0.012	0.018	0.018	0.021	0.016
4	Longliners	0.033	0.021	0.030	0.039	0.029
5	Revenue	0.019	0.012	0.020	0.024	0.017
5	Cost	0.014	0.009	0.010	0.015	0.012
2	Social	0.241	0.136	0.206	0.166	0.200
3	Community	0.082	0.042	0.045	0.029	0.051
4	Society	0.031	0.006	0.017	0.010	0.018
4	Local	0.052	0.036	0.028	0.019	0.033
3	Access	0.057	0.015	0.028	0.040	0.042
4	Commercial	0.019	0.012	0.010	0.018	0.016
4	Non-commercial	0.038	0.002	0.017	0.022	0.026
5	Native	0.020	0.002	0.011	0.012	0.015
5	Recreation	0.018	0.001	0.006	0.010	0.011
3	Bycatch	0.035	0.031	0.025	0.023	0.032
4	Competition	0.008	0.016	0.008	0.008	0.009
4	Waste	0.027	0.015	0.016	0.016	0.023
3	PSI	0.041	0.038	0.073	0.035	0.044
3	Gear conflict	0.026	0.011	0.036	0.038	0.031
2	Political	0.086	0.060	0.068	0.089	0.083
3	Public acceptance	0.039	0.038	0.026	0.033	0.038
3	Resistance	0.047	0.022	0.042	0.056	0.045
4	Longliners	0.012	0.009	0.016	0.023	0.015
4	Small boats	0.035	0.013	0.026	0.034	0.031

The priority ranking and magnitudes of the four criteria are quite similar to the illustrative AHP exercise conducted by DiNardo et al. (1989) for the river herring fishery in Maryland in which the priorities were derived as a consensus of the three authors of that paper. Both cases reveal the utmost importance of biological factors in fishery management.

At the 3rd level sub-criteria comparison under the biological criterion, overfishing ranks the highest for all four groups with CM showing as high as 0.421. MSY was lowest except for the SSC. This may be due to the relative vagueness or misinterpretation of the MSY concept to the non-scientific community or the over-belief in analytical constructs by the scientists.

It is interesting to note that under the economic criterion, the AP, which represents the interests of the fishing industry, indicated a higher priority for employment than profit while the rest of the groups

showed the reverse. At the 4th level comparison under profit, all four groups consistently favored small boat, then the longliners followed by the support industries. The 5th level comparison showed that revenue is more important than cost for both small boats and longliners for all groups. However, the importance of revenue and cost for the support industries varies across the four groups.

The level 3 sub-criteria, under the social criterion, display the most disagreement among the four decision groups. On the average, the entire group rated community the highest (0.051), followed by PSI (0.044) and access (0.042), then bycatch (0.032) and gear conflict (0.031). The order of importance for the AP is community, access, PSI, bycatch and gear conflict. For the CM, the order is community, PSI, bycatch, access and gear conflict. The PT ranks PSI first followed by community, gear conflict, access and bycatch. The SSC shows the order of importance as access, gear conflict, PSI, community and then bycatch. At the 4th level comparison under community, local (fishers) is rated consistently higher than society in general for all four groups. While the other three groups rank non-commercial access more impor-

tant than commercial access, CM shows the reverse. As for non-commercial access, native rights is more important than recreational opportunities for all groups. Under bycatch, the AP, PT, and SSC all reveal a higher priority for waste over competition but the CM shows a roughly equal weight.

Unlike the other level 3 criteria, the social criterion is less structured in terms of scientific or generally accepted definitions and importance of lower-level subcriteria. Instead, definitions and importance are open to interpretation and subjective judgment of individuals. Thus, the general diversity of weightings reflects the diversity within and among the groups.

With respect to the political criterion, while the AP, PT, and SSC express the importance of resistance to an adopted policy by the fishers over public acceptance, the CM thinks otherwise. This is understandable as the CM are accountable to a broader constituency. With respect to the resistance by fishers, all groups place more importance on small boats than on longliners.

While there is considerable variation among individuals, the weightings of the four 2nd level criteria are not statistically different among the four decision

Table 4
Comparison of priorities of second level criteria by group

	Biological	Economic	Social	Political
AP	0.435	0.238	0.241	0.086
CM	0.714	0.090	0.136	0.060
PT	0.555	0.171	0.206	0.068
SSC	0.539	0.206	0.166	0.089
Overall	0.526	0.191	0.200	0.083
F-value	1.878	1.266	0.396	0.293
p	0.153	0.303	0.757	0.830

Table 5
Comparison of alternative priorities by group

	Restricted vessel size	Unrestricted upgrade	Dual permit	Open access	Inconsistency ratio
AP	0.507	0.185	0.205	0.104	0.018
CM	0.539	0.194	0.176	0.091	0.092
PT	0.444	0.207	0.233	0.116	0.028
SSC	0.351	0.193	0.326	0.130	0.014
Overall	0.441	0.196	0.243	0.119	0.012
F-value	2.430	0.349	2.435	0.485	
p	0.083	0.790	0.083	0.695	

Table 6
Comparison of alternative priorities (for overall group) by second level criteria

	Restricted vessel size	Unrestricted upgrade	Dual permit	Open access
Biological	0.502	0.170	0.252	0.076
Economic	0.267	0.239	0.249	0.245
Social	0.442	0.212	0.226	0.120
Political	0.451	0.231	0.215	0.102
Overall goal	0.441	0.196	0.243	0.119

groups as shown in Table 4. Lower-level subcriteria similarly do not have statistically different weightings.

Table 5 shows the overall synthesis as to the priorities of the four alternatives for the four decision groups. The ranking of the four alternatives is similar for the AP, PT, and SSC in the following order: restricted vessel size; dual permit; unrestricted upgrade; and open access. The CM's order is slightly different where unrestricted upgrade is preferred to dual permit. All groups consistently choose restricted vessel size as the most preferred alternative and open access as the least preferred. While the overall priority for vessel size (0.441) almost doubles that of the second choice of dual permit (0.243), the SSC's priorities of these two alternatives are quite close (0.351 vs. 0.326). The overall inconsistency ratio for the entire analysis is well within the acceptable range (<0.1) for all groups, indicating consistent judgments by the participants.

Table 6 shows the priorities of the four alternatives for the overall group with respect to each of the 2nd level criteria. While the restricted vessel size alternative displays the highest priority for biological (0.502), social (0.422), and political (0.451) criteria, the priorities of the four alternatives are quite close with respect to the economic criterion. Thus, it is very important to test the sensitivity of the decision with respect to the changes in the weighting of the criteria, particularly that of the economic criterion.

The robustness of the weighting of the four alternatives is tested using the sensitivity analysis feature of EC. The sensitivity analyses indicated that the restricted vessel size alternative has the highest priority for all possible weights of all four criteria, thus confirming the robustness of the preferred choice. With respect to the biological and social criteria, the ranking of the four alternatives stays the same

for all possible weights of the two criteria. For the political criterion, unlimited upgrade becomes a more preferred alternative than dual permit when the weight of the political criteria exceeds 0.75. However, restricted vessel size remains the most preferred and open access the least preferred throughout. For the economic criterion, even though the priorities for the four alternatives are very close, restricted vessel size is still the preferred choice throughout but the ranking of the other three alternatives do change place at different weights of the economic criterion.

These results clearly demonstrate that the preferred choice is rather robust in this exercise. The resulting choice of the restricted vessel size alternative coincides with the real-world choices made in 1991 and 1994.

7. Concluding remarks

This experience demonstrated an application of the AHP as a decision-support system in fisheries management. The results of the present evaluation of the alternatives for limiting entry of longliners are comparable to the decision made in 1994. As compared to conventional decision making, the AHP process has the advantages of timeliness, quantification, and documentation.

Ideally, we would have run an AHP session for each subcommittee of WPRFMC since the largest group consists of only 22 individuals. However, the logistics and cost of scheduling all these busy individuals precluded such a possibility, given the large numbers of individuals involved in the decision-making process, their geographical dispersion, and the diverse interests vested in each group. We found the mail-out surveys to be an acceptable alternative. Mail surveys

have led to lower than desirable response rates, primarily due to a lack of interaction between the respondents and surveyors especially for introducing and explaining the survey, and as a consequence, the length of the questionnaire. Comments on returned surveys, including those that were not usable, as well as other communication with participants confirm these observations. In addition, the synergism from interaction among the members of each group is lost in a mail-out survey particularly in the development of the AHP tree.

Even with these limitations, we feel that the AHP administered via a mail survey has great potential in serving as a decision-support system for the WPRFMC although any decision-support system will never replace actual decision making, particularly in political decisions. In fact, many are doubtful that a decision-support system could have any influence on actual political decision making. Carlsson and Walden (1995) stated that "Rationality, logical consistency, and optimality – not to mention systematic evaluations with multiple criteria – carry little weight in the political arena."

While we agree with Carlsson and Walden, our experience with this exercise suggests that the AHP can be a valuable tool for the WPRFMC in handling many of the tough fishery management decisions. In particular, we feel that the current AHP tree structure and the assessed priorities of the criteria and sub-criteria can readily be applied in other decision situations facing the pelagic fishery of Hawaii, and could be readily adapted to other fisheries as well. It will certainly take many attempts and refinements before the Council family becomes more comfortable with the technique. We are hopeful that this will eventually happen.

Appendix A. Part of the survey instrument

A.1 Evaluation of management criteria and sub-criteria

Please evaluate the five categories of objectives keeping in mind the overall fishery management goal – to sustain viable fisheries in the *long run*. The tables are read horizontally where each row is a single comparison for you to evaluate. The value of one means that both criteria are equivalent, while selecting a value along the scale means that a particular criteria is more important than the other. Higher numbers correspond with increasing importance, i.e. 3=moderately important, 6=strongly important, 9=extremely more important.

For example, if I am indifferent between MSY and Overfishing as a Biological subcriteria, I would encircle '1' on the scale between the two. However, if I feel that MSY is *very strongly more important* than Overfishing, I would encircle '8' on the side closest to MSY.

Importance with respect to biological criterion:

MSY	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Overfishing
MSY	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ByCatch
MSY	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	PSI
Overfishing	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ByCatch
Overfishing	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	PSI
ByCatch	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	PSI

1=indifferent, 3=moderately important, 6=strongly important and 9=extremely more important

A.2. Evaluation of alternatives

Considering what is going on in the industry today and using your current knowledge and beliefs, please evaluate each pair of alternatives in the following tables. The procedure is the same as in part I, but in this section we are comparing relative *preference* of the alternatives with respect to each objective, i.e. 1=equally preferred, 3=moderately preferred, 6=strongly preferred and 9=extremely preferred.

For example, if I *strongly preferred* the alternative of a limited entry program with a vessel size upgrade restriction as opposed an open access policy, I would encircle '6' closer to the side of 'vessel size'.

Preference with respect to maximizing MSY: (Biological: MSY)

Vessel size	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Unlimited upgrade
Vessel size	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Dual permit
Vessel size	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Open access
Unlimited upgrade	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Dual permit
Unlimited upgrade	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Open access
Dual permit	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Open access

1=equally preferred, 3=moderately preferred, 6=strongly preferred, and 9=extremely preferred

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