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# Application of Analytic Hyerarchy Process Method in Capture Fisheries: Fringe Scale Sardine (*Sardinella fimbriata*) Fishery at Madura Strait, East Java Indonesia

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# ABSTRACT

The aim of this research was to identify the hierarchy priority of fishing gears in exploiting the fringe scale sardine resource at Madura Strait based on recommendation of some experts by using AHP method. Exploitation of fringe scale sardine resource at Madura Strait is a complex activity. A lot of sectors is involved. AHP is an applicable method in many field of applied science to solve big and complex problem. Four hierarchy levels were used in this research that was focus, condition, criteria, and alternative. Focus of thee research was on decision of proper fishing gear used based on assessment of three higher levels above. There were four groups of respondent involved. They were fisheries province and regency officials, senior fisheries lecturers, researchers, and experience fishermen. Result showed that although change I was the first priority of respondents in second hierarchy (condition) with number of 0.2781, the differences with the second, third, and fourth priority was not so high. The priority number of change II, east and west was 0.2506, 0.2420, and 0.229, respectively. In third hierarchy (criteria), the first priority is social with number of 0.3561. This was followed by economy in the second priority with tight number of 0.3252. Then the third and fourth priority was technical (0.1707) and biology (0.1479). In contrast, the first priority in the last levels of hierarchy was due to purse seine with number of 0.4120. This was a great different number toward the second, third, and fourth places which were occupied by payang, drift gillnet, and fixed gillnet with respectively number of 0.2569, 0.2191, and 0.1120 Keywords: decision, experts, complex, purse seine, payang, gillnet, sardine.

## **INTRODUCTION**

Madura Strait is a semi closed waters located in between two islands, Java and Madura. This waters stretched from east to west of north of East Java province with area of 2.700 km<sup>2</sup>. Having had close relation with Java Sea in both side, it has very narrow area in west side and wide area in east side [1]. It also has an important role in East Java Province because a lot of fishermen engage in fishing activities in this area. Totally there were about 65,321 fishermen in this area. It was about 30.4% of total fishermen of East Java Province. They were spreaded in 10 Regencies and Cities, namely Bangkalan (863), Sampang (6,621), Pamekasan (6,967), Sumenep (6,278), Sidoarjo (1,043), Pasuruan (12,306), Probolinggo (8,765), Pasuruan City (1,380), Probolinggo City (8,765), and Situbondo (17,332) [2].

Fringe scale sardine was the second species landed in north coast of East Java, included Madura Strait. While the first species landed in East Java was bali sardine (*Sardinella lemuru*) which was mainly caught in Bali Strait [3]. Main fishing gear used to exploit the fringe scale sardine resource in Madura Strait of East Java was purse seine. There were also four fishing gears able to catch the fish, namely payang, drift gill net, fixed gill net, and set lift net. All these five gears were able to catch not only fringe scale sardine but also other small pelagic fishes such as little tuna, skipjack, and mackerel. Four fishing gears which exploit the fringe scale sardine at least 10% of total catch in Madura Strait were purse seine, payang, drift gillnet, and fixed gillnet.

Analytic hierarchy process (AHP) is a model of decision maker which uses functional hierarchy as the main instrument for analysis by means of human perception [4]. This method was introduced by Saaty since 1970 [5]. Application method of AHP is simplicity of complicated, strategic, and dynamic problem in a hierarchy procedure [6]. Although it is not too much theory to be used, the AHP is applicable in many field of applied science to solve big and complex problem [7]. Several researchers have adopted the AHP in many field of study. They were Tomboelu *et al.* [8], Sugiarti [9], Vargas [10], Zahedi [11], and Leung *et al.* [7].

Fishing actifity at the sea is a complex bisnis. It is influenced by a lot of sectors. They are fishing season, status of the stock, fishing gear technology, and social condition of fishermen. Due to its complexity of fringe sardine fisheries in Madura Strait of East Java, the AHP is therefore an appopriate method to identify kind of proper fishing gear to exploit this resource.

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#### Bintoro et al, 2012

#### MATERIALS AND METHODS

Four steps were done in AHP application to solve a complex problem as mentioned by Saaty [5], Leung *et al.* [7], Tomboelu *et al.* [8], and Zahedi [11], were (1) Identification and solving problem needed; (2) Justification of hierarchy decision by elaborating the decision problem. The elaboration problem was divided into two sections, above and bottom. The former would be used as decision elements which consisted of all purposes while the later contained several criteria and sub criteria of the problem; (3) Collection of data input by constructing pairs of comparison of decision elements; and (4) Determination of Eigen value and Eigen vector, examination of consistency, and identification of hierarchy decision alternative.

Effect of each element toward other elements in the same level of hierarchy was identified before decision was made by arranging pair's comparison and giving value to each element. Then analysis of value assessment was done in order to identify main priority of element in each level of hierarchy. Pairing comparison method above could be simplified by arranging each comparison element into matrix. If C1, C2, ......Cn are the set element, pairs quality comparison of each element toward other element can be formed as matrix A with the size of n x n. If Ci is an element matrix in right direction and Cj is an element matrix in down direction, the comparison between Ci and Cj will be aij which represents the omportance level of Ci toward Cj. Value of matrix aji inverses value of aij, that is 1/aij, thus aij x aji = 1 [12]. So that shape of matrix A with the size of n x n which its element is C1, C2... Cn for i, j = 1, 2 ....n can be performed as follow:

A = (aij) =	C1	C2	Cn
	C1	a11	a12 a1n
	C2	a21	a22 a 2n
	 Cn	 1/a1n	1/a2nann

Number used to illustrate the degree of importance of element toward other elements in a matrix pairs comparison is 1 to 9 (Table 1). Next step will be to examine respondent consistency. By using equation consistency index (CI) =  $(\alpha - n)/(n-1)$ , Value of CI should be below 0.1 (10%) where  $\alpha$  = sum of value assessed, and n = number of variable.

Level of Importance	Definition
1	Equal important toward another
3	Moderate important toward another
5	Strong important toward another
7	Very strong important toward another
9	Extremely strong toward another
2, 4, 6, 8	Value in between of two nearest values
Reciprocal	If element i has one of values above compare to element j, then element j has an inverse value compare to element i

Table 1 Comparison scale in pairs of inter element used in AHP analysis [5]

Four levels of hierarchy were used in this research, namely: Level I: Focus (decision of proper fishing gear); Level II: Condition (season): (1) West, (2) Change I, (3) East, and (4) Change II; Level III: Criteria: (1) Biology, (2) Technical, (3) Economy, and (4) Social; Level IV: alternative. Four fishing gears were (1) Purse seine, (2) Payang, (3) Drift gill net, and (4) Fixed gill net (Figure 1).

The number of respondents involved in the research was 70 experts. Their entire job is dealing with fisheries activities around Madura Strait of East Java Province. They were divided into four groups, namely fisheries province and regency officials (43 respondents), senior fisheries lecturers (6 respondents), researchers (9 respondents), and experience fishermen (12 respondents). The first group consisted of eight sub groups. They are fisheries official of East Java Province (8 respondents), and five respondents each of seven sub groups of fisheries official regencies around Madura Strait (Sampang, Pamekasan, Sumenep, Pasuruan, Probolinggo, Pasuruan City, and Probolinggo City). Whilst member the last group, experience fishermen, are for those who have many years dealt with fishing activities in Madura Strait such as fishing masters, ship owners, and captains.



Figure 1 Decision Hierarchy of Proper Fishing Gear for Exploitation of Fringe Scale Sardine in Madura Strait of East Java.

## **RESULTS AND DISCUSSION**

Data below is questionnaire example of fishing season filled in by respondent 01 from Sampang Regency which is tabulated in table 1.

West	9	8	7	6	5	4	3	2	1	2	(3	)4	5	6	7	8	9	Change I
West	9	8	7	6	5	4	3	(2)	)1	2	3	4	5	6	7	8	9	East
West	9	8	7	6	5	4	3	(2)	)1	2	3	4	5	6	7	8	9	Change II
Change I	9	8	7	6 (	5	4	3	2	1	2	3	4	5	6	7	8	9	East
Change I	9	8	7	6 (	5	4	3	2	1	2	3	4	5	6	7	8	9	Change II
East	9	8	7	6	5	4	3	2	(1)	2	3	4	5	6	7	8	9	Change II

Table 1 illustrates degree comparison amongst four fishing season, namely West, Change I, East, and Change II. The degree comparison of Change I is three times more important than West or the degree comparison of West is one third less important than Change I. The number of the degree comparison was then transformed in order to obtain priority number of each element (Table 2). Priority number of each element was calculated from average value of total number of each element in row. Table 2 informs that with priority number of 0.5720, Change I is the first priority of fishing season which is followed by West in the second priority with priority number of 0.2920. While the third, and the fourth priority is occupied together East and Change II with same priority number of 0.1094. Examination of respondent in filling questionnaire informs that respondent 01 from Sampang Regency has high consistency (CI = 0.0014) (Table 2).

Although value of season priority scale of respondents highly varied, the average priority scale of season illustrated that there was no big different amongst them. The first priority of season was due to change I with value of 0.2781. It was then followed by second, third, and fourth places by Change II, East, and West with value of 0.2506, 0.2420, and 0.2293 respectively. All respondents had high consistency in deciding priority of season with average value of CI of 0.0053 (Table 3). In contrast, priority scale of criteria was dominated by social and economy sectors. In general their values were much higher than other two criteria, biology and technical. The average criteria priority scale illustrated that social and economy sectors were the first and second priority with value of 0.3561 and 0.3252, respectively. On the other side, value of priority scale of technical and biology was only 0.1707 and 0.1479 respectively. They were in the third and fourth places of priority (Table 4).

Fishing Season	West	Change I	East	Change II
West	1	0.3333	2	2
Change I	3	1	5	5
East	0.5	0.2	1	1
Change II	0.5	0.2	1	1
	5	1.7333	9	9

 Table 1 Degree Comparison by respondent 01 Sampang Regency Based on Fishing Season Criteria toward

 Fringe Scale Sardine S. fimbriata) Resource Condition in Madura Strait

 Table 2 Priority Scale of Each Criteria by respondent 01 Sampang Regency Based On Fishing Season

 Toward Fringe Scale Sardine (S. fimbriata) Resource

 Condition in Madura Strait

Fishing Season	West	Change I	East	Change II	PRIORITY
West	0.2	0.1923	0.2222	0.2222	0.2092
Change I	0.6	0.5769	0.5556	0.5556	0.5720
East	0.1	0.1154	0.1111	0.1111	0.1094
Change II	01	0.1154	0.1111	0.1111	0.1094
				Total	1.0000
				CI	0.0014

Table 3 Season Priority Scales of All Sub Groups of Respondent Toward Fringe Scale Sardine (*S. fimbriata*) Resource in Madura Strait

Thige Seale Salatile (S. Junoritata) Resource in Madula Stati								
Respondent	West	Change I	East	Change II	CI			
Pasuruan	0.4243	0.1811	0.2135	0.1811	0.0030			
Pasuruan City	0.1867	0.2428	0.3947	0.1757	0.0093			
Probolinggo	0.1872	0.3933	0.1762	0.2433	0.0040			
Probolinggo City	0.1807	0.3024	0.2492	0.2677	0.0041			
Sampang	0.1954	0.4720	0.0993	0.2333	0.0036			
Pamekasan	0.1525	0.1923	0.3673	0.2878	0.0068			
Sumenep	0.0996	0.2356	0.3595	0.3053	0.0048			
Province	0.1652	0.2250	0.2831	0.3267	0.0085			
Fishemen	0.2588	0.3154	0.1884	0.2374	0.0046			
Researchers	0.3463	0.162	0.1828	0.3088	0.0036			
Lecturers	0.3255	0.3369	0.1477	0.1899	0.0063			
Average	0.2293	0.2781	0.2420	0.2506	0.0053			

Whilst priority scales of fishing gear based on sub groups of respondent strongly suggested that purse seine was the prime choice of most respondent. Eight sub groups of respondents gave highest value of priority to purse seine. They are respondents from Sampang, Pamekasan, Probolinggo, Probolinggo City, Province, fishermen, researchers, and lecturers. The three sub groups of respondent who does not place purse seine as the first priority are fisheries official from three regency, namely Sumenep, Pasuruan, and Pasuruan City. All of them choose payang as the first priority (Table 5).

Fringe Scale Sardine (S. fimbriata) Resource in Madura Strait								
Respondent	Biology	Technical	Economy	Social	CI			
Pasuruan	0.1388	0.1822	0.3467	0.3323	0.0060			
Pasuruan City	0.1629	0.1726	0.3014	0.3630	0.0045			
Probolinggo	0.1422	0.1457	0.3716	0.3405	0.0049			
Probolinggo City	0.1367	0.1242	0.3923	0.3468	0.0075			
Sampang	0.0961	0.2399	0.3503	0.3137	0.0080			
Pamekasan	0.1547	0.1865	0.2874	0.3714	0.0061			
Sumenep	0.1789	0.1571	0.2720	0.3920	0.0060			
Province	0.1510	0.1958	0.2558	0.3975	0.0057			
Fishermen	0.1655	0.1471	0.3104	0.3769	0.0048			
Researchers	0.1424	0.1761	0.3456	0.3358	0.0046			
Lecturers	0.1574	0.1509	0.3440	0.3477	0.0049			
Average	0.1479	0.1707	0.3252	0.3561	0.0057			

Table 4 Criteria Priority Scales of All Sub Groups of Respondent Toward Fringe Scale Sardine (*S. fimbriata*) Resource in Madura Strait

U		,			
Respondent	Purse seine	Payang	Drift Gillnet	Fixed Gillnet	CI
Pasuruan	0.1511	0.3897	0.3219	0.1373	0.0064
Pasuruan City	0.3209	0.3861	0.1828	0.1102	0.0066
Probolinggo	0.4757	0.2377	0.1956	0.0910	0.0054
Probolinggo City	0.5086	0.2261	0.1744	0.0909	0.0048
Sampang	0.4624	0.1829	0.2140	0.1408	0.0074
Pamekasan	0.4459	0.1893	0.2603	0.1046	0.0071
Sumenep	0.1303	0.4150	0.2817	0.1730	0.0059
Province	0.4733	0.2168	0.2006	0.1093	0.0049
Fishemen	0.5080	0.1826	0.2175	0.0918	0.0046
Researchers	0.5046	0.2038	0.1955	0.0961	0.0043
Lecturers	0.5510	0.1962	0.1655	0.0873	0.0040
Average	0.4120	0.2569	0.2191	0.1120	0.0056

Table 5 Fishing Gear Priority Scales of All Sub Groups of Respondent Toward Fringe Scale Sardine (*S. fimbriata*) Resource in Madura Strait

Average priority scale of all respondents toward fishing gear illustrated that purse seine was the prime priority with value of 0.4120 which was followed by payang, drift gillnet, and fixed gillnet in second, third, and fourth priority with value of 0.2569, 0.2191, and 0.1120, respectively. In general all respondents had good consistency toward fishing gear with value of CI of 0,0056 (Figure 2).

It was found that four fisheries official's regencies, namely Sampang, Pamekasan, Probolinggo and Probolinggo City placed purse seine as the first choice due to dominancy of the gear in their area. In contrast, respondents from other three fisheries officials' regencies of Sumenep, Pasuruan, and Pasuruan City did not choose purse seine as the first priority because purse seine is not dominant fishing gear in their area. Whilst the rest of four sub groups, fisheries officials Province, experience fishermen, senior lecturers, and researchers gave purse seine as the first choice to be developed due to as mentioned before, dominancy of the gear in Madura Strait to exploit the fringe scale sardine resource.

There were only two dominant choices of criteria, social (six sub groups), and economy (five sub groups). While other two criteria, biology and technical had very low value of priority. Moreover, seven sub groups chose biology criterion as the least important as other. This phenomenon may be caused by high number of fishermen operated in Madura Strait [2]. They think that better income and employment are much more important than sustainability of the stock due to the high number of fishermen operated as stated above. Although social was the first priority, other criteria economy, technical, and biology also played important role to manage fisheries resources in Madura Strait. As stated by previous researcher that ecosystem based management had to include all sectors related to fisheries resources [13]. It is the Government responsibility that exploitation of fisheries resource activity should pay more attention to sustainability of the stock. Therefore responsible fishing should be applied in Madura Strait. The stock will be overfished otherwise. Moreover the stocks could be collapse such as bluefin tuna in Western Atlantic [14]. Many previous researchers also stated that marine and capture fisheries resources in Indonesia tended to be either fully or over exploited [15][16]. While toward season, there was no dominant choice among them. This phenomenon may be influenced by different fishing season in one area to another.



Figure 2 Priority Scales of Each Criterion by All Respondents toward Fringe Scale Sardine (*S. fimbriata*) Resource in Madura Strait

Analysis of AHP illustrated that in fringe scale sardine fishery point of view, purse seine is the prime priority to be developed in Madura Strait. Government of East Java Province together with seven Regencies and Cities around Madura Strait had therefore to elaborate efficiency of purse seine to exploit fisheries resource in order to sustain the stock in Madura Strait. Local government (Province) now plays an important role to manage fisheries resources due to rapid change in governance system in Indonesia from centralized system to decentralized system since early 2000 [13]. As long as managed properly and supported by local government and stake holders, development of purse seine will be safe for fringe scale sardine and other fisheries stocks in Madura Strait. As it occured in Peruvian anchovy fishery in Peru. The stock was highly vulnerable to drastic natural stock fluctuation. Moreover it was overfished and nearly collapse in several years. Through applying tight management toward anchovy fishery in Peru waters, such as quota limitation to purse seiners, closed area, and closed season, the stocks become healthy in several years later hence sustainability of the stock could be maintained [17]. Several researchers stated further that multi discipline areas and all stake holders has to be involved if we need to sustain the fisheries resources [18][19][20][21].

### CONCLUSION

Purse seine was the first priority fishing gear in exploiting the fringe scale sardine resource in Madura Strait based on AHP analysis with value of 0.4120. It was then followed by payang, drift gillnet, and fixed gillnet with value of 0.2569, 0.2191, and 0.1120 consecutively. There were four sub groups of fisheries official regencies which placed purse seine as the first priority, namely Sampang, Pamekasan, Probolinggo Regency, and Probolinggo City.

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