FISHING STRATEGY OF THE INDONESIAN TUNA LONGLINERS IN INDIAN OCEAN

Lilis Sadiyah and Budi Iskandar Prisantoso

Researcher at Research Center for Fisheries Management and Conservation, Ancol-Jakarta

Received September 27-2010; Received in revised form December 28-2010; Accepted January 7-2011

ABSTRACT

Information on fishing strategy is essential to manage the Indonesian tuna fishery. Therefore, it is important to attempt to characterise the fishing strategies of the fishery. This paper attempts to classify longline sets recorded by the Indonesian Indian Ocean Trial Observer Program based on similarity of their tuna catch composition to characterise fishing strategy of the fishery. Cluster analysis was applied to identify longline sets to be targeting each of the four tuna species (big eye tuna-*Thunnus obesus*, yellow fin tuna-*Thunnus albacores*, albacore-*Thunnus alalunga*, and southern blue fin tuna-*Thunnus maccoyii*) based on their relative contribution to the tuna catch composition. Seven main clusters were identified. Big eye were predominantly caught (31.68%), followed by albacore (25.31%), yellow fin tuna (25.09%), and southern blue fin tuna (17.92%). Big eye tuna and a combination of big eye and yellow fin tuna were predominantly targeted in the Indian Ocean above 20°S, whereas albacore and southern blue fin tuna were targeted in the Indian Ocean below 20°S. In addition, big eye tuna were targeted in the northern part by using deep longlines and predominantly using sardines (*Sardinella* spp.) as bait. Albacore were apparently also targeted in the southern part using deep longlines, by using sardines and gizzard shad (*Anodontostoma chacunda*) as bait.

KEYWORDS: **fishing strategy, cluster analysis, longline, Indian Ocean**

INTRODUCTION

Longlining was introduced to Indonesia by Japan in the 1930s, when test fishing was conducted by Japanese longline vessels in Indonesian waters. However, Indonesia commenced its commercial tuna longline fishing in the 1960s (Simorangkir, 1982; Proctor *et al.*, 2003). Currently, Indonesia has the largest fleet of commercial tuna longline vessels in the Indian Ocean i.e. 1782 active vessels in 2003 (Anonymous, 2006). The Indian Ocean Tuna Commission estimated that Indonesian longline catches between 1996 and 2000 were the highest in the Eastern Indian Ocean (Campbell, 2003). The high catches were due to both the re-flagging of many longliners from Taiwan, China to Indonesia and the increase in the number of longliners built in Indonesian shipyards. However, Indonesia has not been able to manage its tuna longline fishery. In order to be able to manage the fishery, it is essential to understand fishing strategies in terms of species target, fishing position, and gear type i.e. deep or surface longline and bait species. It is therefore important to attempt to characterise the fishing strategies of this fishery.

Benoa Port situated in Bali is one of the most important landing ports for tuna caught by the Indonesian industrial fleet operating in the Indian Ocean. The tuna species most commonly caught by Indonesian tuna longline vessels were big eye tuna (*Thunnus obesus*), yellow fin tuna (*Thunnus albacares*), albacore (*Thunnus alalunga*) and southern blue fin tuna (*Thunnus maccoyii*) (Proctor *et al.*, 2003). Southern blue fin tuna were caught by Indonesian longline vessels targeting yellow fin tuna and big eye tuna in the South of Java and around the Lesser Sunda Islands (DGCF *et al.*, 2005), but it was found that few vessels were targeting southern blue fin tuna south of the southern blue fin tuna spawning grounds i.e. south of 20°S (Davis *et al.*, 2005; Proctor *et al.*, 2007).

Within a multi species fishery, fishing strategies are commonly changed to target different species, and this in turn, may change the extent to which catch rates reflect stock abundance, as the effectiveness of effort in catching different species relies on the fishing strategy (He *et al.*, 1997). At one extreme, these targeting practices may result in numerous zero catch sets for tuna species that may not be targeted. In the Benoa based longline fishery, fishers sometimes switched target species between fishing trips or between sets within a fishing trip. In fact, this is common in most other longline fisheries, such as in the Hawaii based longline fishery (He *et al.*, 1997) and the Japanese longline fishery off Western Australia (Dowling & Campbell, 2001).

Corresponding author:
Jl. Pasir Putih I, Ancol Timur-Jakarta 14430, E-mail: rccf_office@indo.net.id

The Benoa based longline vessels change their target species not only by modifying a specific fishing technique, but also frequently a combination of fishing techniques for instance changing number of hooks and/or bait species used. It is therefore difficult to characterise the targeting practices based on only an individual fishing practice. Moreover, He *et al.* (1997) stated that catch composition reflects the final output of fishing that contains information that can be used to identify fishing strategies. It has been further argued that catch composition can be used as an indicator of actual target species (Salthaug & Godø, 2001). Specifically, a unique catch composition of tuna is presumed to be equivalent to a unique targeting strategy. In order to identify different fishing strategies, cluster analysis has been used in other fisheries as an effective quantitative method (He *et al.*, 1997; Rogers & Pikitch, 1992; Lewy & Vinther, 1994).

This research is aimed to classify longline sets recorded by the Indonesian Indian Ocean Trial Observer Program based on similarity of their tuna catch composition. Furthermore, it is also aimed to characterise, to the extent possible, the fishing strategies of the Indonesia's Indian Ocean industrial tuna longline fishery operated from Benoa Port.

MATERIALS AND METHODS

Data Overview

Set by set data were obtained from Indonesia's Indian Ocean Trial Observer Program on industrial tuna longline vessels based at Benoa Port, Bali. The Trial Observer Program data from 2005-2007 were available for this research. This data set comprised a total of 793 records of number of longline sets. However, there were 32 sets (4% of the 793 sets) with no tuna reported, and these were eliminated before the cluster analysis.

Catch and effort data were recorded as the number of fish and the number of hooks recorded per set, respectively. The tuna catch for this fishery consists of four species, big eye tuna, yellow fin tuna, albacore, and southern blue fin tuna, and other byproduct species. However, the analysis in this study is only concerned with the four tuna species. The proportion of each tuna species in the tuna catch was used in the cluster analysis.

Information on fishing strategies was also recorded by the observers for each set. This includes fishing area by latitude and longitude, number of hooks between floats and bait type. There were six bait species used, i.e. sardines (*Sardinella* spp.), milkfish (*Chanos chanos*), scad mackerel (*Decapterus* spp.), gizzard shad (*Anodontostoma chacunda*), frigate tuna (*Auxis thazard*), and squid (*Loligo* spp.).

In term of gear type, longline gears were arbitrarily classified, based on the number of hooks between floats or branch lines (Suzuki *et al.*, 1977). Deep longlines were defined as having at least 10 branch lines, whereas surface longlines were defined as having 4-6 branch lines.

Analysis

Cluster analysis was used to identify sets considered to be targeting each of the four tuna species based on their relative contribution to the tuna catch composition. Specifically the cluster analysis is aimed to classify the 761 sets based on their similarity of tuna catch composition and to combine the most similar sets into one group. Further, for each set, the catch composition was calculated and expressed as proportions relative to the total of the four tuna species yellow fin tuna, big eye tuna, albacore, and southern blue fin tuna. In order to meet the statistical property of normality, the proportions were arcsine square root transformed to normalise their distribution (Snedecor & Cochran, 1980).

Hierarchical cluster analysis is impractical for a large data set i.e. of more than 100 entities (Schonlau, 2003). As 761 sets were used, clusters were developed in two stages. Firstly, a non hierarchical cluster analysis (K-means method) was used to group all records into 100 clusters using the Clara procedure (cluster package) of the R software using euclidean distance. Secondly, an agglomerative hierarchical cluster analysis i.e. ward method was applied to the 100 medoids resulting from the non hierarchical analysis. A dendrogram showing the degree of relatedness between the 100 medoids was produced, and the main groups of clusters were chosen to form the main cluster categories. The selection of the main clusters was based on a consideration that the selected clusters reflect the nature of the fishery.

Subsequently, a qualitative judgment was employed on each of the main clusters selected to identify which species was being targeted by each cluster. If the average relative proportion of a species of tuna was less than 20% of the tuna catch, then this species was not considered to be a target species. The main clusters were plotted into individual fishing tactics.

RESULTS AND DISCUSSION

Seven main clusters have beed identified. There were clear differences in catch composition among those clusters. However, based on the Euclidean distance between cluster centroids, clusters 1 and 2 as well as clusters 4 and 5 were found to be closely related (Figure 1). Clusters 1 and 2 predominantly caught yellow fin tuna, whereas clusters 4 and 5 mostly caught big eye tuna (Table 1). Clearly, there are three clusters targeting a single tuna species. Cluster 3, the largest with 306 sets, obviously targeted big eye tuna (with big eye tuna comprising 91% of the tuna catch in this cluster), while clusters 6 and 7 consisted of sets predominantly catching albacore (88%) and southern blue fin tuna (84%), respectively. On the other hand, the remaining clusters seemed to target mixed tuna species. Cluster 1 consists of sets targeting yellow fin tuna (75%) but also big eye tuna (21%), while cluster 2, the smallest with 5 sets, contain sets that seem to target yellow fin tuna (57%) and southern blue fin tuna (34%). Cluster 4 contains sets apparently targeting big eye tuna (36%), albacore (34%) and yellow fin tuna (30%). Sets belonging to cluster 5 caught mostly both big eye tuna (56%) and albacore (41%).

The average of tuna proportion across all cluster showed that big eye tuna were predominantly caught (32.68%), followed by albacore and yellow fin tuna (25.31 and 25.09%, respectively). Southern blue fin tuna had the lowest proportion (17.92%).

A clear separation was revealed by the spatial distribution of effort (number of sets) by cluster (Figure 2). Clusters 1 (yellow fin tuna/big eye tuna), 2 (yellow fin tuna/southern blue fin tuna), 3 (big eye tuna), 4 (big eye tuna/albacore/yellow fin tuna), and 5 (big eye tuna/albacore) were associated with sets concentrated in the Indian Ocean above 20°S. Sets from clusters 1 and 3 occurred in the Banda Sea, and several sets belonging to clusters 3, 4, and 5 occurred in the Indian Ocean below 20°S (exceeding 30°S for both clusters 4 and 5). Sets from clusters 6 and 7 largely occurred in the Indian Ocean below 20°S, with cluster 7 concentrated in the area between 115°-120°E and 20°-25°S and between 80°-85°E and 30°-35°S.

Table 1. Tuna catch composition for each cluster

Species	YFT/BET	YFT/SBT	BET	BET/ALB/YFT	BET/ALB	SBT	ALB	Average of tuna proportion
Cluster	1	2	3	4	5	6	7	
BET	21.28	9.00	91.00	35.74	56.07	5.71	3.02	31.68
YFT	75.02	57.33	7.23	29.85	0.78	0.00	5.40	25.09
ALB	3.64	0.00	1.04	33.54	40.91	10.08	87.96	25.31
SBT	0.06	33.67	0.73	0.87	2.24	84.21	3.62	17.92
No.sets	**132**	**5**	**306**	**64**	**70**	**36**	**148**	

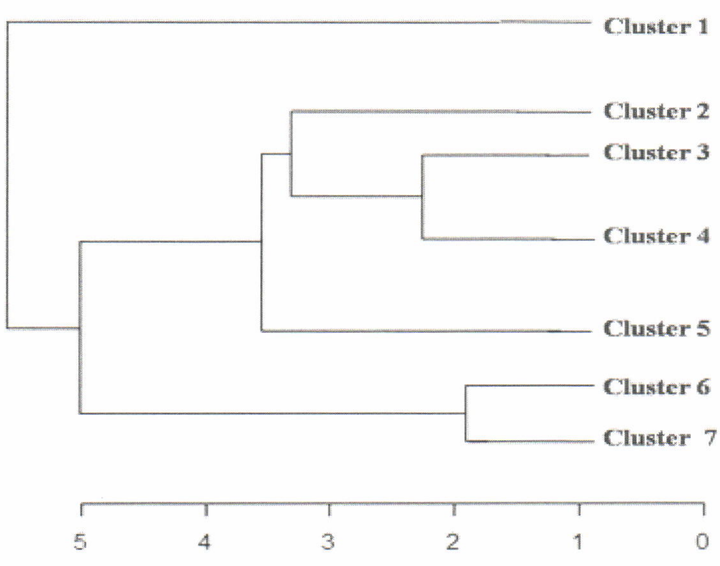

Figure 1. Dendrogram of the cluster analysis showing the relative separation of the individual clusters.

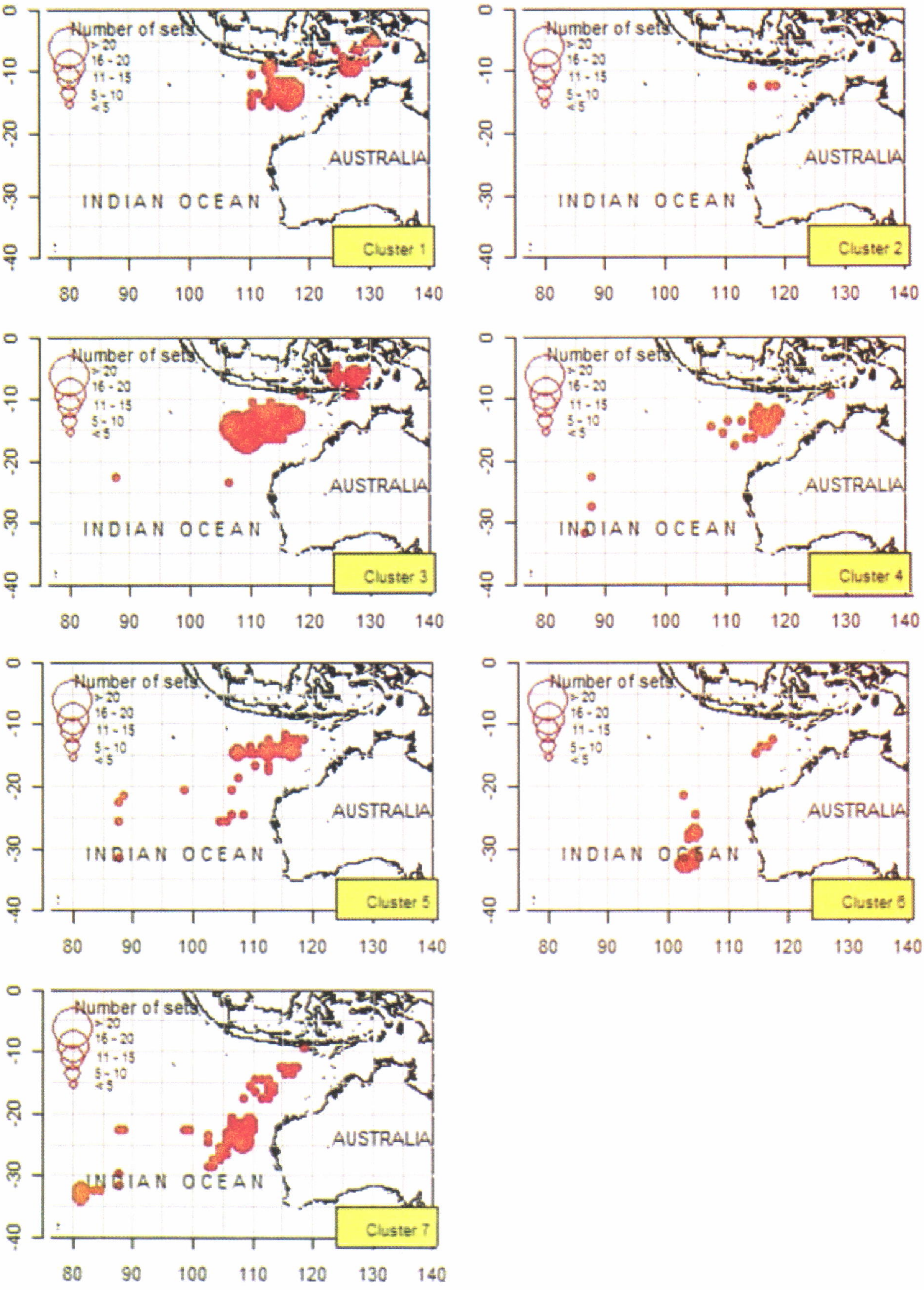

Figure 2. Spatial distribution of effort (number of sets) for each cluster.

The distribution of sets by cluster and quarter showed that there is no quarterly pattern, however, clusters 1 (yellow fin tuna/big eye tuna), 3 (big eye tuna), and 7 (albacore) were the most predominant over the studied period (Figure 3a). The highest percentage of cluster 3 sets occurred in quarters 3 and 4 of 2005, quarter 1 of 2006, and quarter 3 of 2007. Nevertheless, the number of recorded sets in quarter 4 of 2005 was low (less than 20 sets) (Figure 3b). On the other hand, sets from clusters 1 and 7 were highest in quarter 4 of 2007 and of 2006, respectively.

The percentage of sets by fishing month varied between clusters (Figure 4a). Cluster 1 generally comprised between 20 and 30 sets each month. Sets from cluster 2 all occurred in September. Cluster 3 sets peaked in January and also between July and August, whilst cluster 4 sets were most frequent between March and June. Sets from clusters 5 and 7 were predominant in February, whilst cluster 6 sets peaked in November.

The average number of hooks between floats varied slightly between clusters (Figure 4b), although the distribution of number of hooks per basket overlapped between clusters. Cluster 2 contained sets with the lowest hooks between floats (5 hooks), while cluster 3 comprised sets with the highest (~16 hooks) average of hooks per basket. The average hooks between floats for clusters 1, 4, 6, and 7 ranged between 10 and 12 hooks, and were 4, 16, and 14 for clusters 2, 3, and 5, respectively.

In addition, bait composition for each cluster was different. Cluster 1 predominantly used milkfish, sardines, and scad mackerel, and Clusters 2, 3, 5, 6, and 7 mostly used sardines, and comprised at least gizzard shad, milkfish, and sardines (Figure 4c) whereas Cluster 4 largely used milkfish.

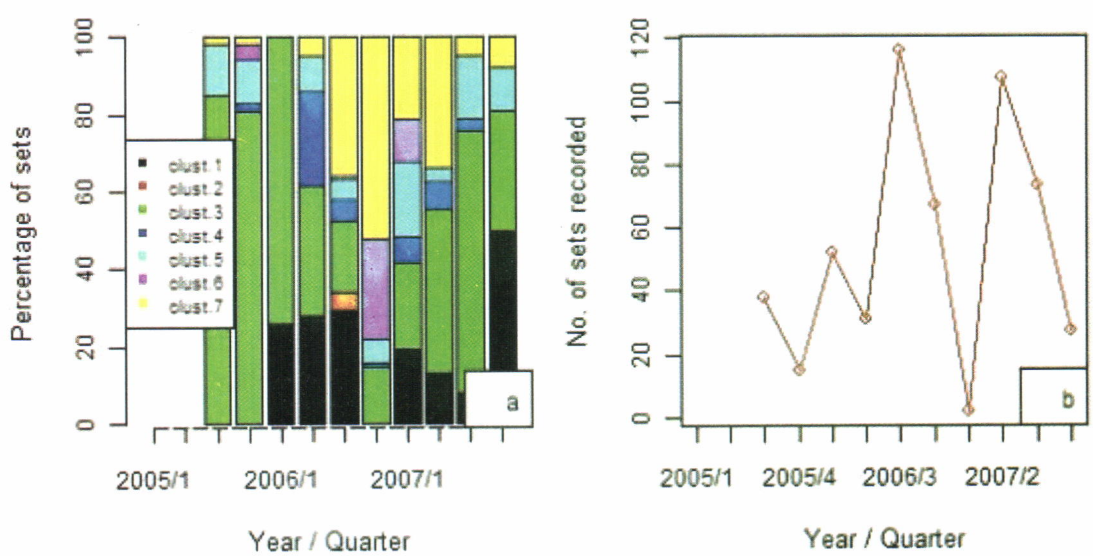

Figure 3. Percentage of sets associated with each cluster as a function of year and quarter (a) and number of sets by year and quarter (b).

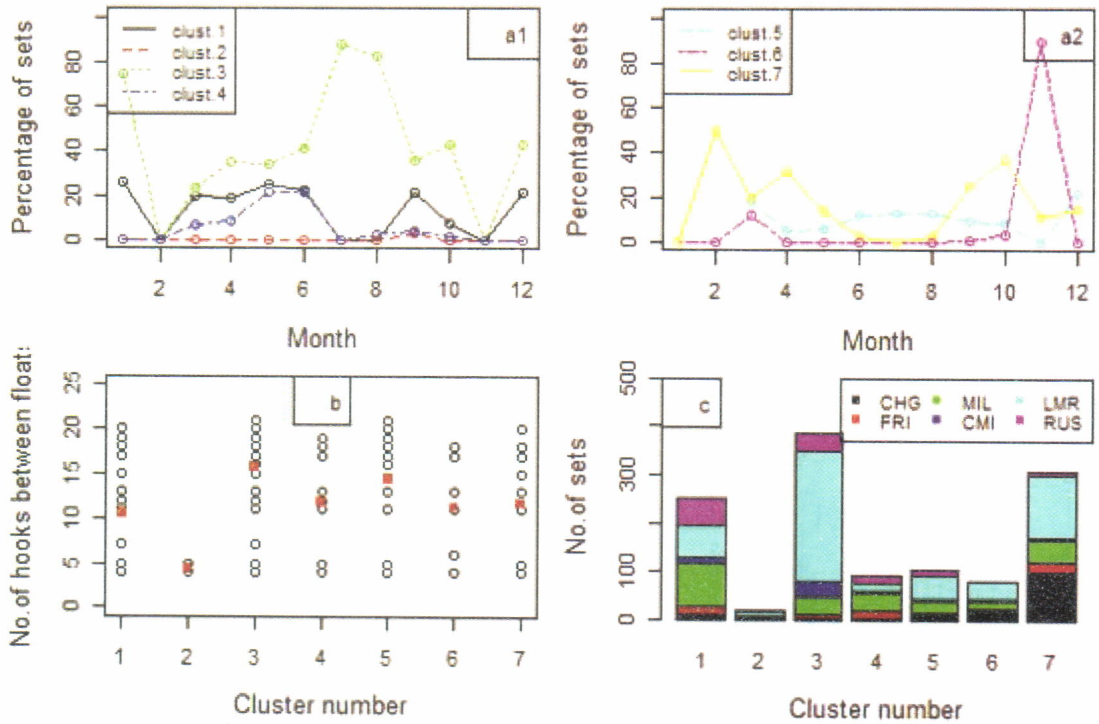

Figure 4. Percentage of sets for each month (a1-a2), distribution of number of hooks between floats (b) and number of sets by bait type for each cluster (c).

A useful outcome of the cluster analysis was that the differences observed between clusters can be used to attempt to characterise the fishery. Fishing techniques and targeting practices suggest that the fishery is targeting more than one species and using different targeting practices. Tuna catch proportions of the main seven selected clusters suggested that there was single species and mixed species targeting of tuna in this fishery, with the majority of sets targeting big eye tuna, albacore or a combination of yellow fin tuna and big eye tuna. Few of the observed sets seem to target southern blue fin tuna. Those that did occurred mostly south of 20°S, consistent with the finding that southern blue fin tuna were targeted by some vessels fishing south of 20°S (Simorangkir, 1982; Proctor *et al.*, 2003). There was clear spatial separation between clusters. big eye tuna and a combination of big eye tuna and yellow fin tuna were targeted mainly in the Indian Ocean above 20°S, while albacore and southern blue fin tuna were targeted in the Indian Ocean below 20°S. Spatial segregation between clusters has also been observed in the Japanese longline fishery off Western Australia (Campbell, 2003). In addition, there were differences between clusters in terms of fishing month and fishing techniques (including hooks between floats and bait used).

The results showed that spatial differences observed between catch composition clusters give insight to the attempt to characterise the fishery. However, these interpretations are coarse as the cluster analysis was undertaken on data from only the five companies (out of 30 tuna fishing companies operating out of Benoa Fishing Port) which currently participate in the trial observer program. Therefore, to be able to draw more reliable interpretations on the target species and targeting practices across the whole fleet, more companies need to be encouraged to participate in the program to achieve better coverage of the fleet.

CONCLUSION

Seven main clusters were identified. Those clusters suggested that there were single species and mixed species targeting of tuna in this fishery. The fishery seems to predominantly catch big eye tuna (31.68%), followed by albacore and yellow fin tuna (25.31 and 25.09%, respectively). Southern blue fin tuna had the lowest proportion (17.92%). Big eye tuna and a combination of big eye tuna and yellow fin tuna were predominantly targeted in the Indian Ocean above 20°S, whereas albacore and southern blue fin tuna were targeted in the Indian Ocean below 20°S. In addition, big eye tuna were targeted in the northern part by using deep longlines and predominantly using sardines as bait. Albacore were apparently targeted in the southern part using deep longlines and using sardines and gizzard shad as bait.

ACKNOWLEDGEMENTS

The authors wish to thank Indonesia's tuna fishing companies and the Bali Office for Control and Surveillance of Fisheries Vessels for their cooperation, assistance, and support for the trial observer program. We also would like to thank Australian Centre for International Agricultural Research and Research Centre for Capture Fisheries for their funding through research collaboration in the project FIS/2002/074: Capacity development to monitor, analyse, and report on Indonesian tuna fisheries. Last but not least, the observer team, without whom this research would not been possible, we are extremely grateful.

REFERENCES

Anonymous. 2006. *Indian Ocean Tuna Fisheries Data Summary, 1994-2003*. Indian Ocean Tuna Commission Data Summary No.25. 112 pp.

Campbell, R. A. 2003. Overview of longlining in the Indian Ocean. *International Technical Expert Workshop on Marine Turtle Bycatch in Longline Fisheries*. Seattle. Washington. USA. 11-13 February.

Dowling, N. & R. Campbell. 2001. Assessment of the Japanese longline fishery off Western Australia: 1980-1996. *1st Meeting of the Stock Assessment Group for the Southern and Western Tuna and Billfish Fishery*. Fremantle. Western Australia. 26-28 February.

Davis, T. L. O., J. Farley, R. Andamari, & C. H. Proctor. 2005. Monitoring the longline catch of southern blue fin tuna landed in Indonesia 2004-2005. *Final Report*. Commonwealth Scientific and Research Organization Marine Research. Hobart. Tasmania. 13 pp.

DGCF, RCCF, IOTC, OFCF, CSIRO, ACIAR, & DAFF. 2005. Preliminary results of the multilateral catch monitoring programme on fresh tuna longliners operating from ports in Indonesia. *Seventh Session of the IOTC Working Party on Tropical Tunas, Phuket, Thailand, 18-22 July, 2005*. IOTC-2005-WPTT-06.

He, X., K. A. Bigelow, & C. H. Boggs. 1997. Cluster analysis of longline sets and fishing strategies within the Hawaii based fishery. *Fisheries Research*. 31: 147-158.

Lewy, P. & M. Vinther. 1994. Identification of Danish North Sea trawl fisheries. *ICES J. Mar. Sci.* 51: 263-272.

Proctor, C. H., I G. S. Merta, M. F. A. Sondita, R. I. Wahju, T. L. O. Davis, J. S. Gunn, & R. Andamari. 2003. A review of Indonesia's Indian Ocean tuna fisheries. *Australian Centre for International Agricultural Research Country Status Report*. 106 pp.

Proctor, C. H., R. Andamari, D. Retnowati, B. I. Prisantoso, F. Poisson, M. Herrera, & S. Fujiwara. 2007. The catch of southern blue fin tuna by the Indonesian longline fishery operating out of Benoa, Bali in 2006. *Commission for the Conservation of Southern Blue Fin Tuna 8th Meeting of the Stock Assessment Group and the 12th Meeting of the Extended Scientific Committee*. Hobart. Australia. 4-8 September and 10-14 September.

Rogers, J. B. & E. K. Pikitch. 1992. Numerical definition of groundfish assemblages caught off the coasts of Oregon and Washington using commercial fishing strategies. *Canadian Journal of Fisheries and Aquatic Sciences*. 49: 2,648-2,656.

Suzuki, Z., Y. Warashina, & M. Kishida. 1977. The comparison of catches by regular and deep tuna longline gears in the western and central Equatorial Pacific. *Bull. Far Seas Fish. Res. Lab.* 15: 51-89.

Snedecor, G. W. & W. G. Cochran. 1980. *Statistical Methods*. Iowa State Univ. Press. Ames. 507 pp.

Simorangkir, S. 1982. Perikanan tuna longline di Indonesia. *Dalam* Simorangkir, S. (Ed.). *Perikanan Indonesia*. Bali Post. Bali. 17-28.

Salthaug, A. & O. R. Godø. 2001. Standardisation of commercial catch per unit of effort. *Fisheries Research*. 49: 271-281.

Schonlau, M. 2003. Visualizing non hierarchical and hierarchical cluster analyses with clustergrams. *Computational Statistics*. 19: 95-111.