Analysis of catch size differences between longtail tuna and other commercial fish species by set-net fishing off Futaoi Island (western Sea of Japan) using cluster analysis

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Abstract

The differences in catch sizes between longtail tuna and other commercial fish species by set-net fishing off Futaoi Island (western Sea of Japan) was examined using cluster analysis. According to the results of this study, barracuda and greater amberjack were close in Euclidean distance. Therefore, a cluster is formed between barracuda and greater amberjack. Furthermore, the Euclidean distance between longtail tuna and this cluster (barracuda and greater amberjack) was also close. Among feed species for longtail tuna (horse mackerel, sardine and mackerel), horse mackerel was closest in Euclidean distance to longtail tuna. The cluster of barracuda and greater amberjack were far from longtail tuna in Euclidean distance in 2007. Because recorded water temperatures were significantly warmer than average this year, 2007 was an unusual year.

1 Introduction

Longtail tuna (*Thunnus tonggol*), with an adult body length of only 1 meter approximately, are distributed in the Indian Ocean, western and eastern Australia [1], and the western Sea of Japan [2]. Studies of the species so far have been conducted on their larval shape [3][4] and developmental process [5][6]. However, the studies are limited, compared to those on the other main tuna species: bluefin tuna (*Thunnus thynnus*), southern bluefin tuna (*T. maccoyii*), albacore (*T. alalunga*), bigeye tuna (*T. obesus*) and yellowfin tuna (*T. albacares*).

Because of insufficient information on longtail tuna, the species is often mistaken for bluefin tuna around the western Sea of Japan [7]. To avoid this mistake, a report was issued identifying longtail tuna as being 27 - 30 cm [8], or 16 - 30 cm [9]in fork length from a morphological perspective. Another report using DNA analysis classified longtail tuna as those tuna with a fork length between 125-166 mm [10].

Adult longtail tuna are mainly caught on the coasts of the Sea of Japan [5][11]. To avoid the above-mentioned mistake, previous studies between 1995 and 2000 examined the relationship between catch sizes of juvenile fish species by set-net fishing and monthly differences in the water temperature of fishing grounds, as observed by the American NOAA satellite [10]. Further studies in 2001 also examined the relationship between catch sizes of juvenile fish species and the water temperature of the fishing grounds [11]. However, these past studies did not include other commercial fish species besides longtail tuna data.

Accordingly, the purpose of this study is to understand the ecology (in particular, habitat segregation and food chain) of longtail tuna off Futaoi Island (Shimonoseki City, Yamaguchi Prefecture) in the Sea of Japan. Especially, this paper aims to clarify the inter-specific relationship between longtail tuna and other commercial fish species using cluster analysis.

2 Materials and methods

2.1 Materials

The Futaoi Island branch office of the Fisheries Cooperative Association of Yamaguchi Prefecture recorded the data on adult longtail tuna caught with set nets during the period from 1998 to 2008. We used this daily catch data for our calculations. The top ten commercially fished species during the longtail tuna fishing season were chosen for this study.

2.2 Items analyzed

We analyzed the following items.

First, we calculated the T-score for yearly and monthly catches of longtail tuna and other commercial fish species, and the relationship was examined by using cluster analysis. The reason why we calculated the T-score was as follows:

With set- net fishing, several longtail tuna are caught in the same nets with many other commercial fish species. In this situation, we could not calculate the Euclidean distance necessary for cluster analysis. So we used the monthly T-score to effectively perform this analysis.

2.3 Cluster analysis

Cluster analysis includes several methods. So we comparatively examined the four following methods of analysis [12].

1. Shortest distance method

Among objects belonging to two clusters, this method defines the distance between the nearest objects as the cluster distance.

2. Longest distance method

Among objects belonging to two clusters, this method defines the distance between the farthest objects as the cluster distance.

3. Group average method

Distances of all combinations of objects belonging to two clusters are examined. Subsequently, the average distance is defined as the cluster distance.

4. Barycentre method

The barycentre, or centre of mass, is set as the measurement point for the cluster. The cluster distance is defined as the distance between these barycentric points.

Of the four methods stated above, the group average method is used by field of biology because of its effectiveness when variables within the group are clear. Related dendrograms have a high level of consistency and results are easy to interpret.

In this study, we used the group average method. Using this method, we were able to examine the fishing season and diet of the subject fish species, even when schools of different species were mixed with each other. Furthermore, using early results for clusters distances (Euclidean distance) we were able to determine the composition of the diet of longtail tuna. Euclidean distances were obtained with the following equation [12]:

$$d_{ij} = \sqrt{(x_{i1} - x_{j1})^2 + (x_{i2} - x_{j2})^2} \quad (1)$$

where x_{i1} = number of the T-score catches for monthly fish species i of the first calculation target, x_{i2} = number of the T-score catches for monthly fish species i of the second calculation target, x_{j1} = number of the T-score catches for monthly fish species j of the first calculation target, x_{i2} = number of the T-score catches for monthly fish species j of the second calculation target, (x_{i1}, x_{i2}) = i -th data and (x_{j1}, x_{j2}) = j -th data.

In group average method, the degree of dissimilarity d_{XY} (Euclidean distance) is computed from the combined cluster x and combined cluster y [13]:

$$d_{XY} = \frac{1}{n_X n_Y} \sum_{i \in Cx} \sum_{j \in Cy} d_{ij} \quad (2)$$

where C_X = cluster x, C_Y = cluster y, n_X = number of objects belonging to C_X, n_Y = number of objects belonging to C_Y, $i \in C_X$ = object i belonging to C_X, $j \in C_Y$ = object j belonging to C_Y, d_{ij} = the degree of dissimilarity computed from the object i and object j.

2.4 Process of cluster analysis

First, we measured the distance between each target, and obtained the distance for a case combining a cluster. All distances between individual targets were calculated, and we decided the first cluster based on the smallest distance between targets. We calculated all the distances between a cluster and newly formed targets, and combined the smallest distance between targets. The process explained above was continued until all clusters were combined.

Second, we drew a dendrogram to show the processes for combined clusters, and divided it into groups by cutting it at a suitable distance. We examined the target that included each group and identified the characteristics of groups.

3 Results

Fig.1 shows the location of Futaoi Island and the position of the set-net. Futaoi Island is located at 34° 06′ N 130° 47′ E and the set- net is placed in the area northeast of the island.

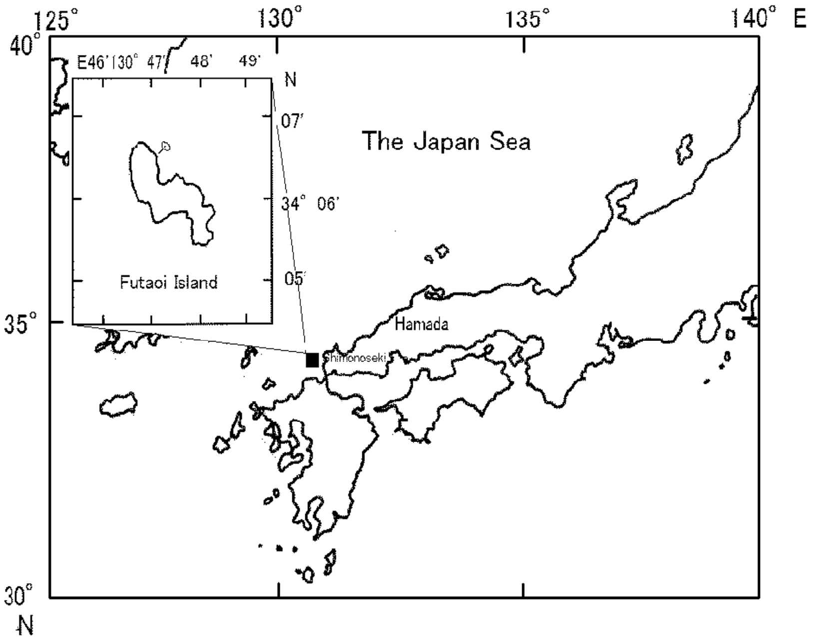

Fig.1 Location of Futaoi Island and set net position.

Table 1 gives the matrix of Euclidean distances among fish species from data provided from 1998 to 2008. In this table, we selected the top ten commercially fished species (horse mackerel, sardine etc. (sardine, anchovy and red-eye round herring), barracuda, greater amberjack, mackerel, J.S.mackerel (Japanese Spanish mackerel), longtail tuna, yellowtail amberjack, Japanese amberjack, juvenile b. tuna (juvenile bluefin tuna)) with a fishing season coinciding with longtail tuna [14]. Among longtail tuna and the species they feed on (horse mackerel, sardine and mackerel), it was horse mackerel that had a Euclidean distance (30.685) nearest to longtail tuna.

Table 1 Matrix of Euclidean distance among fish species.

	horse mackerel	sardine etc.	barracuda	greater amberjac	mackerel	J.S. mackerel	longtail tuna	amberjac k	amberjac k	juvenile b. tuna
horse mackerel	0.000	51.803	42.281	41.159	55.985	54.794	30.685	35.685	50.459	48.972
sardine etc.	51.803	0.000	52.821	53.568	55.589	55.626	54.430	48.203	44.848	48.482
barracuda	42.281	52.821	0.000	4.883	45.705	39.260	17.575	26.893	54.603	47.127
greater amberjack	41.159	53.568	4.883	0.000	47.336	40.800	16.734	26.705	54.023	46.969
mackerel	55.985	55.589	45.705	47.336	0.000	24.401	51.048	51.396	54.632	47.371
J.S.mackerel	54.794	55.626	39.260	40.800	24.401	0.000	45.661	51.432	56.331	31.237
longtail tuna	30.685	54.430	17.575	16.734	51.048	45.661	0.000	20.460	54.595	47.649
yellowtail amberjack	35.685	48.203	26.893	26.705	51.396	51.432	20.460	0.000	56.723	51.738
Japanese amberjack	50.459	44.848	54.603	54.023	54.632	56.331	54.595	56.723	0.000	52.544
juvenile b. tuna	48.972	48.482	47.127	46.969	47.371	31.237	47.649	51.738	52.544	0.000

Fig. 2 shows the tree diagram of Euclidean distances among fish species (1998-2008). The horizontal and vertical axes represent the fish species and distances. From this figure, we can determine that barracuda and greater amberjack are close in Euclidean distance. So a cluster is formed between these two species. Furthermore, this cluster (barracuda and greater amberjack) and longtail tuna are also close in Euclidean distance. Accordingly, a cluster is formed between barracuda, greater amberjack and longtail tuna. Similarly, further clusters are later formed among other fish species with a close Euclidean distance.

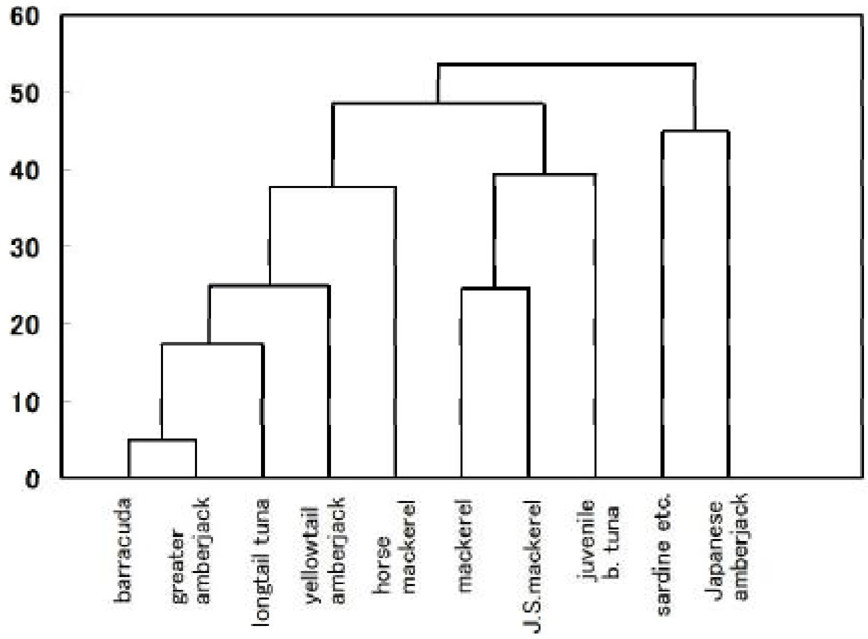

Fig. 2 Tree diagram of Euclidean distance among fish species (1998-2008).

Fig. 3, 4 and 5 represent the tree diagrams of Euclidean distance among fish species in 2003, 2004 and 2005 (years when the recorded water temperature did not vary greatly from the average [15]) respectively. From these figures, we can determine the fish species of barracuda, greater amberjack and longtail tuna were close in Euclidean distance.

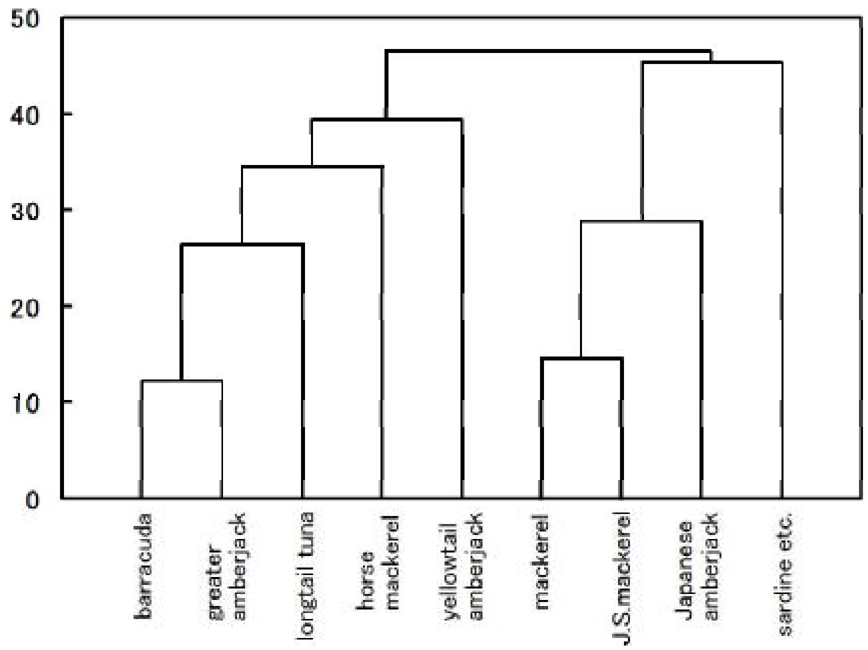

Fig. 3 Tree diagram of Euclidean distance among fish species (2003).

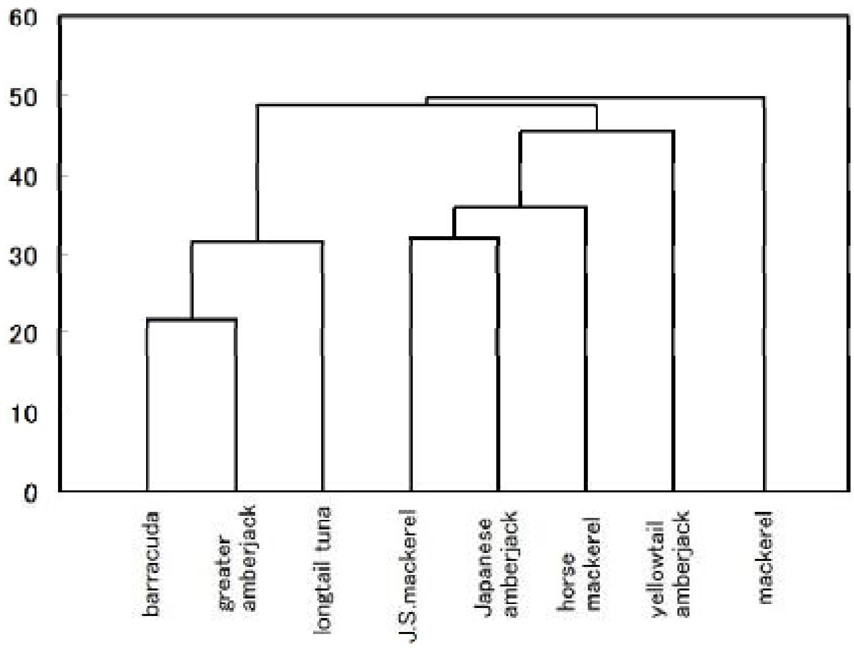

Fig. 4 Tree diagram of Euclidean distance among fish species (2004).

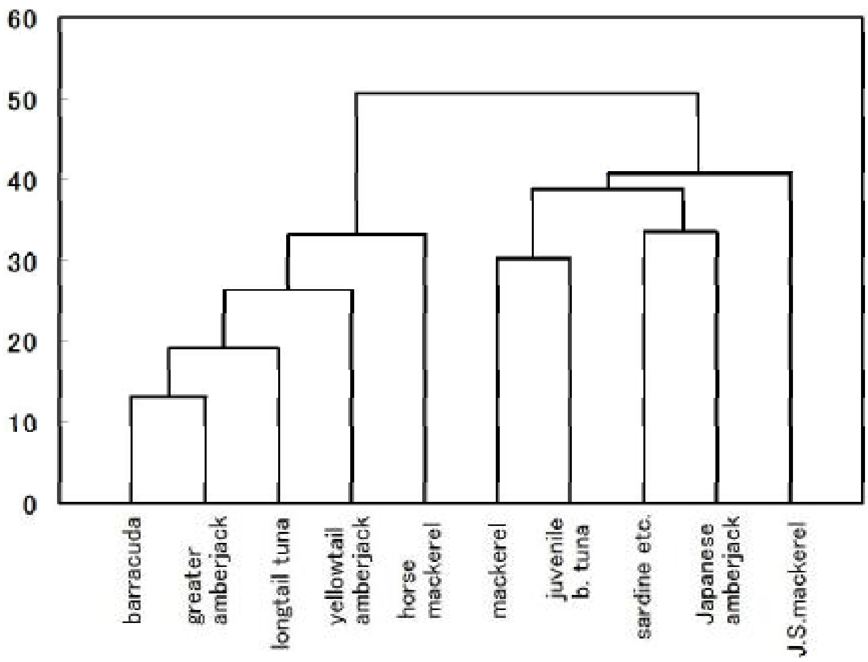

Fig. 5 Tree diagram of Euclidean distance among fish species (2005).

Fig.6 is the tree diagram of Euclidean distance among fish species in 2007 (the year when recorded water temperatures were significantly warmer than average [15]).

Looking at this tree diagram, we can see the cluster of barracuda and greater amberjack were far from longtail tuna in Euclidean distance.

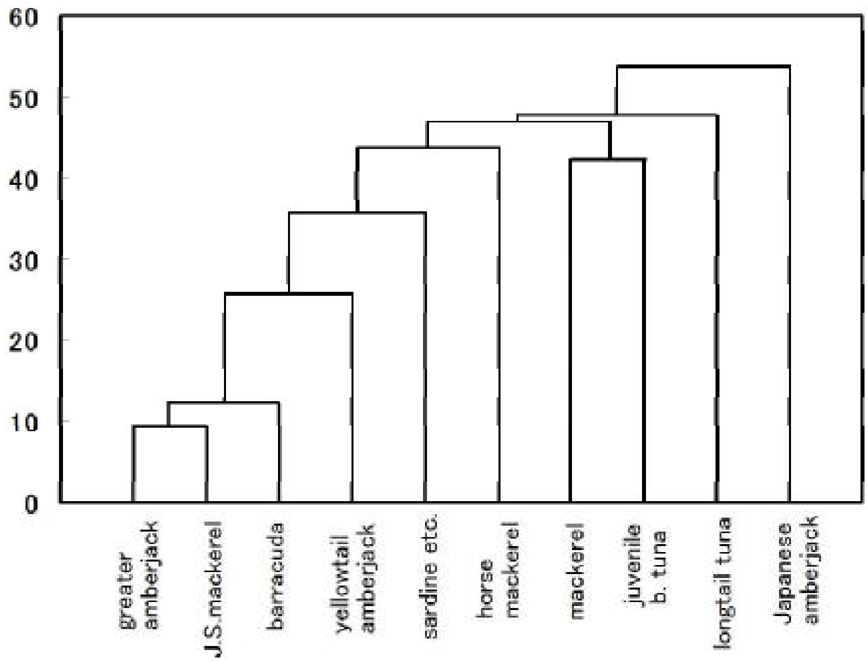

Fig. 6 Tree diagram of Euclidean distance among fish species (2007).

4 Conclusion

From the tree diagram of Euclidean distance among fish species (1998-2008), we determined that barracuda and greater amberjack were close in Euclidean distance. Therefore, a cluster is formed between them. Furthermore, this cluster (barracuda and greater amberjack) and longtail tuna are close in Euclidean distance. So we concluded that the main fishing season (from July to September) of these three fish species was close. This quantitative result differed from a qualitative study by Mohri *et al*. [15] (determining that the fish species of barracuda, yellowtail amberjack and longtail tuna were qualitatively close in distance).

Regarding the relationship between longtail tuna and the fish species they feed on (horse mackerel, sardine and mackerel), it was horse mackerel that had the Euclidean distance nearest to longtail tuna. This quantitative result was the same as the qualitative study by Mohri *et al*. [15]

The cluster of barracuda and greater amberjack were far from longtail tuna in Euclidean distance in 2007. Because 2007 was an unusual year of particularly high recorded water temperatures, the main fishing season of longtail tuna was different from usual years, occurring in the later months of September and October.

5 Future prospects for study

In this study, we examined the "monthly catch relationship between longtail tuna and other commercial fish species" by cluster analysis only using the number of fish caught. As a result, this relationship in 2007 (the year of significantly higher than average recorded water temperatures) differed from standard years. In future, we need to study the relationship between longtail tuna and other commercial fish species after consideration of other additional factors such as water temperature.

6 Acknowledgements

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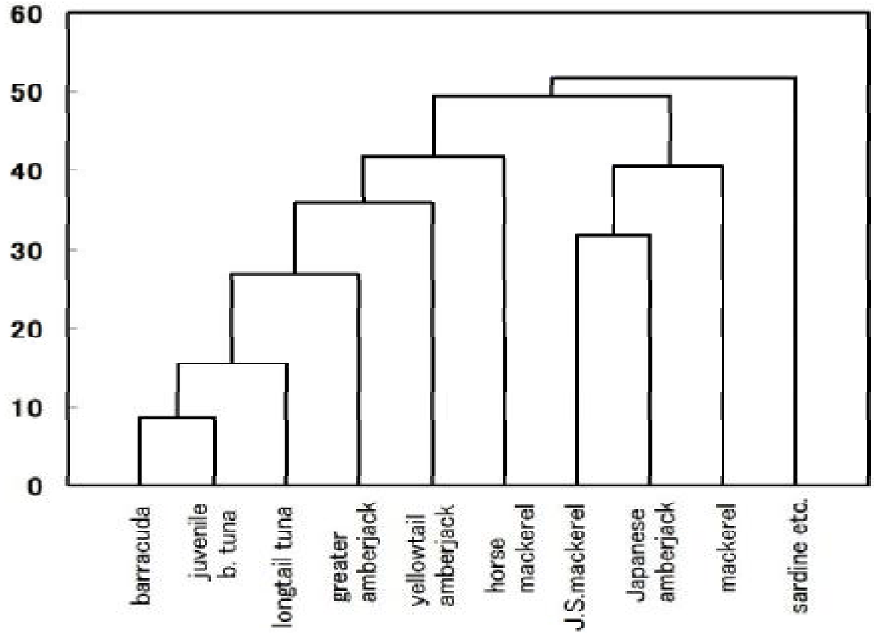
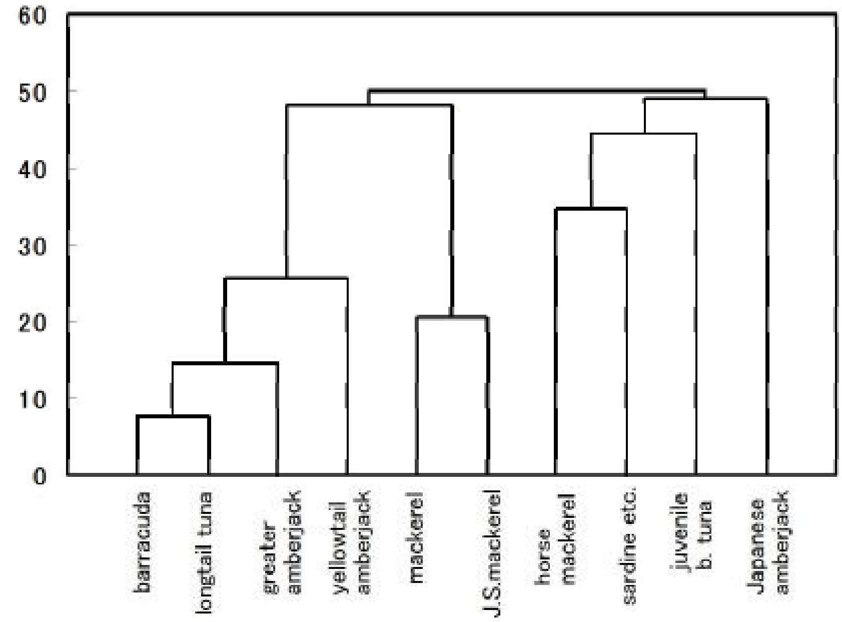
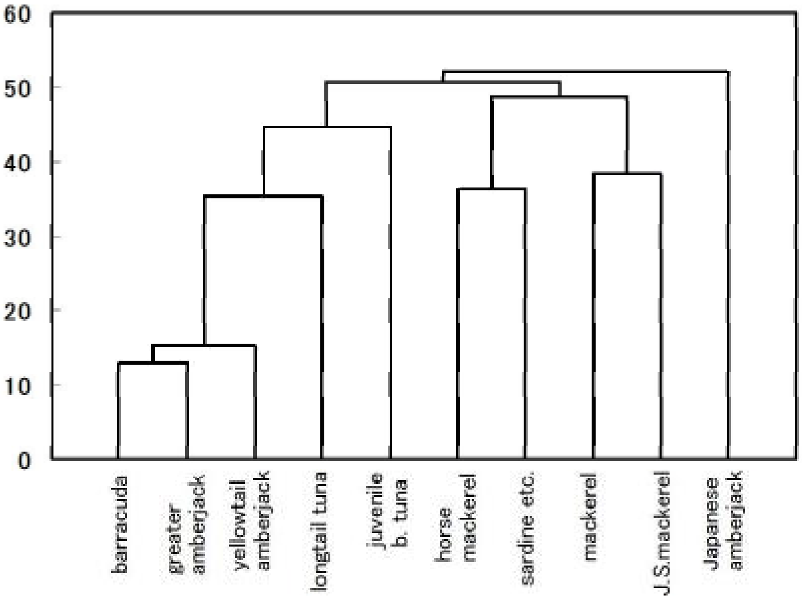
Appendix



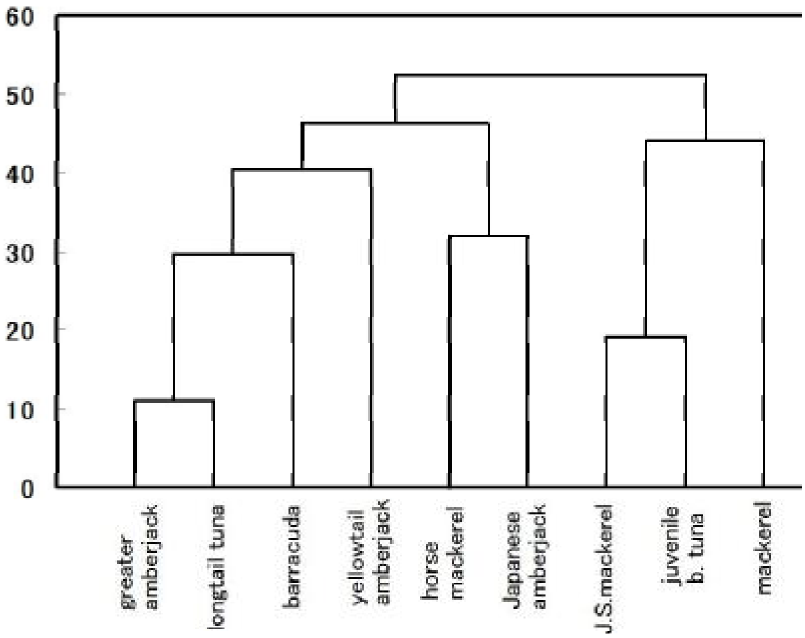
Appendix Fig. 1 Tree diagram of Euclidean distance among fish species (1998).



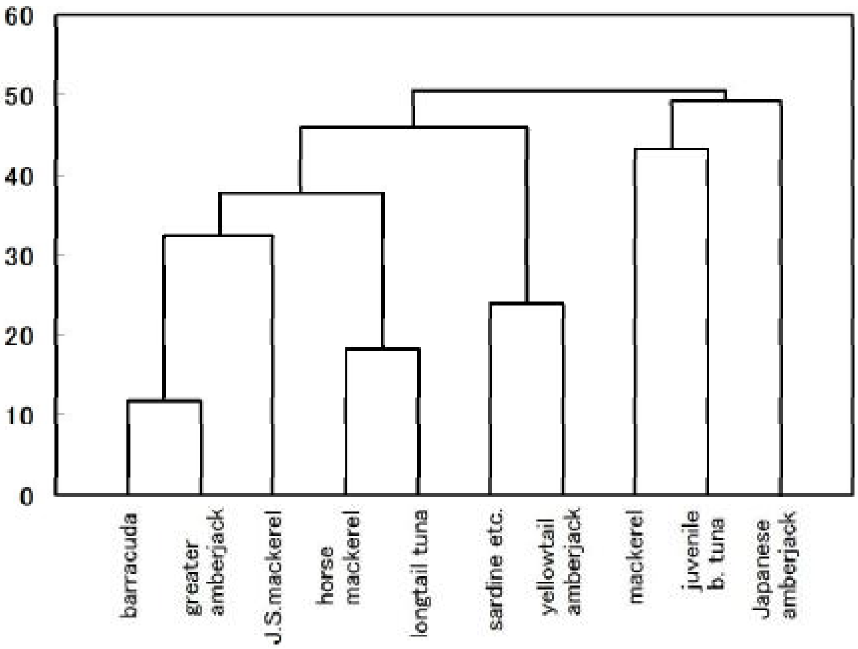
Appendix Fig. 2 Tree diagram of Euclidean distance among fish species (1999).



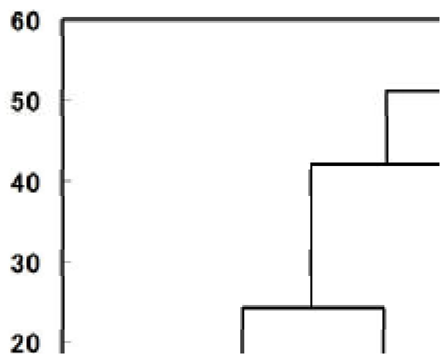
Appendix Fig. 3　Tree diagram of Euclidean distance among fish species (2000).



Appendix Fig. 4　Tree diagram of Euclidean distance among fish species (2001).



Appendix Fig. 5 Tree diagram of Euclidean distance among fish species (2002).



Appendix Fig. 6 Tree diagram of Euclidean distance among fish species (2008).