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Acoustics Seminar AKUSTIKAN 2

CONTENTS

SPATIAL DISTRIBUTION OF FISH DENSITY IN RELATION TO ENVIRONMENTAL FACTORS IN MAKASSAR STRAIT WATERS

D. MANURUNG, D. SIMBOLON

ABSTRACT

The biomass or abundance of fish varies, due to environmental factors such as physical, chemical and biological. The seawater temperature and salinity as physical factors, at least, are very important when evaluating the fish density distribution.

An acoustic survey was conducted in the Makassar Strait, especially on Kalimantan Shelf during January and February 1995. The environmental data, i.e., temperature and salinity collected during the survey, were analyzed and the results are presented in this paper.

The temperature and salinity distributions indicate the presence of three water types, as coastal, transitional and oceanic water types. The fish density is in higher concentration in the Java Sea coastal waters than in the transitional and Pacific ones. The highest fish density concentration is found at the edge of coastal waters near the transitional waters area. It is considered that this situation is caused by the movement of Pacific water masses southward, to the Java Sea.

KEYWORDS : acoustic, density, pelagic fish, environment, Makassar Strait.

ABSTRAK

Perubahan besarnya biomassa atau kelimpahan ikan disebabkan oleh adanya perubahan lingkungan seperti halnya faktor-faktor fisika, kimia dan biologis. Salinitas dan suhu merupakan faktor fisika yang memegang peranan penting dalam penentuan penyebaran ikan.

Survey akustik yang dilaksanakan di perairan Selat Makasar terutama pada paparan Kalimantan pada bulan Januari dan Februari 1995, yang didukung oleh pengumpulan data parameter lingkungan yaitu salinitas dan suhu merupakan data dasar analisis dalam tulisan ini.

Sebaran salinitas dan suhu menunjukkan adanya 3 jenis massa air, yaitu jenis kostal, transisional dan oseanik. Konsentrasi kepadatan ikan yang lebih tinggi terdapat pada massa air kostal laut Jawa dibandingkan jenis masa perairan transisional dan Pasifik. Sedangkan konsentrasi tertinggi ditemukan pada tepian perairan kostal sekitar wilayah perairan transisional. Diduga hal ini berhubungan dengan pergerakan massa air Samudra Pasifik ke arah selatan menuju Laut Jawa.

KATA KUNCI : akustik, kepadatan, penyebaran spasial, faktor lingkungan, Selat Makasar.

Background

The acoustic method for fish stock assessment has been progressed, especially during the last two decades. The advantages of this method are to give accurate results and real-time field operations. Dual-Beam acoustic system, for measuring fish target strength in situ, was first proposed by Ehrenberg (1974). Recently, the Dual-Beam acoustic system was applied for fish stock assessment in Java Sea and Makassar Strait.

It is commonly understood that the biomass or abundance of fish varies due to the environmental factors such as physical, chemical and biological (Laevastu and Hela, 1970). On the other hand, the environmental data were rarely harvested during fish stock assessment surveys, in Indonesia. Fortunately, the environmental data, *i.e.,* temperature and salinity, were taken during acoustic surveys in the Java Sea and the Makassar Strait. In this paper, the interest is focused on the relationship between physical environmental factors and fish density.

Research objectives

The research objectives are :

- to study the vertical section of temperature and salinity distribution,
- to study the relationship between physical environmental factors and fish density.

METHOD

The acoustic survey was conducted in Makassar Strait during January 26th to February 5th, 1995 in collaboration with the Java Sea Pelagic Fishery Assessment Project, Research Institute for Marine Fisheries. Conductivity, temperature and depth (CTD) were measured on 15 stations set up on the cruise tracks. Geographical positions of the stations and times of CTD profiles are shown in Table 1. The numbering of the stations followed the series of cruise direction from North to South (0-11), and from South to North (12-15).

Table 1 Location and time of the oceanographic stations.
Tabel 1 Lokasi dan waktu stasiun oseanografi.

No. Station	Geographical Station	Dt/Mth/Y	Local Time	Day/Night
1	00° 26 S-117° 38 E	26-01-95	19.22	Night
2	01° 56 S-117° 14 E	27-01-95	02.30	Night
3	01° 56 S-116° 48 E	27-01-95	07.14	Day
4	02° 40 S-117° 00 E	27-01-95	13.26	Day
5	02° 40 S-118° 00 E	27-01-95	21.18	Night
6	03° 20 S-118° 13 E	28-01-95	02.52	Night
7	03° 20 S-116° 40 E	28-01-95	18.53	Night
8	04° 00 S-116° 27 E	29-01-95	01.27	Night
9	04° 00 S-117° 23 E	29-01-95	11.02	Day
10	04° 40 S-117° 7 E	29-01-95	17.08	Day
11	04° 40 S-116° 00 E	30-01-95	05.47	Day
12	04° 40 S-116° 39 E	30-01-95	11.59	Day
13	03° 25 S-117° 24 E	31-01-95	11.59	Day
14	02° 56 S-117° 56 E	01-02-95	12.15	Day
15	02° 40 S-117° 46 E	03-02-95	12.00	Day

Descriptions of meridional vertical section of temperature and salinity distribution were made by lining two transactions. The first transect covered the station number of 11, 8, 7, 4, 2, 1; and the second covered the station number of 10, 9, 13, 15. These two transects were not precisely meridional, but forming the angle of about 22.5° eastward.

On the same purpose, the longitudinal vertical section was made on four transects. The station number of each transect is shown in Table 2.

The fish density was obtained by using Dual-Beam acoustic system. The fish densities, taken into consideration for analysis in relation to temperature and salinity distribution, were the fish densities detected in every stratum of one nautical mile before and after CTD stations.

The formula for calculating fish densities per unit volume (Midttun and Naken, 1971; Burczynski and Johnson, 1986), is :

$$d = M.C$$

where,

d = fish density (fish/m^3)

M = echo integrator output (V^2, Volt squared)

C = integrator scaling factor ($V^2\ m^3$/fish)

The integrator scaling factor (C) can be calculated as following :

$$C = \sigma_{bs}.c.\pi.\tau.P_o^2.g_x^2.b_{av}^2(\phi)$$

where,

σ_{bs} = backscattering cross section (m^2/fish)

c = sound velocity in water (m/s)

τ = pulse duration (s)

P_o^2 = transmitted squared pressure at 1 m from transducer

g_x^2 = squared fixed through system gain for the equipment

$b_{av}^2(\phi)$ = mean square beam pattern factor of the transducer

Table 2 Station number of each transect.
Tabel 2 Jumlah stasiun pada setiap jalur pelayaran.

No	Transect Code	Station No.	Number	Direction of Section
1	M-1	11, 8, 7, 4, 2, 1	6	Meridional
2	M-2	10, 9, 13, 15	4	Meridional
3	L-1	11, 12, 10	3	Longitudinal
4	L-2	8, 9	2	Longitudinal
5	L-3	7, 13, 6	3	Longitudinal
6	L-4	4, 15, 5	3	Longitudinal

Temperature and salinity distribution

The distributions of temperature and salinity along the transect M-1, are shown in Figure 1. In general, the isotherms indicate that the more southern the warmer the water is, whereas the isohalines do reversibly. The temperature range in the shallow waters of the southern part is from 28.30°C to 28.50°C, and the upper layer of the northern part is covered by temperature range from 28.10°C to 28.30°C. The temperature difference is not so big in the upper layer, only about 0.70°C.

However, there is an important phenomenon to point out that between Station 7 and 4, the isotherm lies vertically with difference of 0.40°C, or a gradient of about 0.02°C/mile, in the depth of 20 metres. The salinity distribution also indicates vertical isohalines of 32.25 to 32.50‰, with a gradient of about 0.6‰/mile. The other phenomenon is the occurrence of low salinity water, which is less than 31.50‰ up to 10 metres depth in the South.

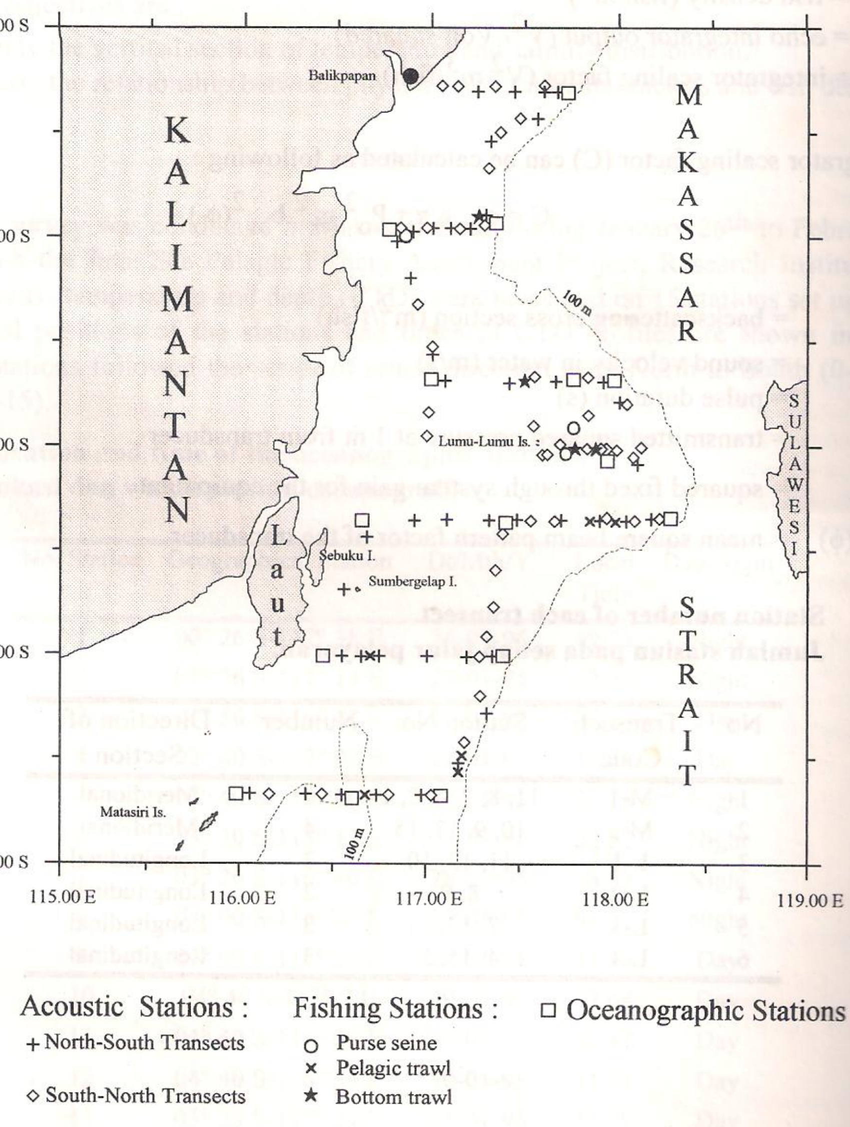

Figure 1 Transects of the survey and position of the oceanographic stations.
Gambar 1 Jalur pelayaran survey dan posisi stasion oseanografi.

In the northern part of the area, the temperature of layers deeper than 10 metres is less than 28.10°C. The isotherms show the development of horizontal layer and form a sharp temperature gradient which is about 0.13°C/metre in the layer near the bottom. But the salinity of the whole water column is nearly homogenous.

The vertical section of temperature and salinity of the eastern transect M-2 is illustrated in Figure 2. Considering the bathymetry, it shows that the southern part of the area is deeper than the northern part. This is in contrast to the condition on transect M-1.

The water temperature from the surface to 10 metres depth is less than 28.80°C until about 40 miles northward. The salinity range in this layer is 31.40 to 32.40‰. The isohalines, below it, tend to form horizontal stratification, *emerge to the surface, and form the isohaline vertical layers* with a gradient of 0.04‰ by mile at the surface, at nearly the same latitude range as the transect M-1.

Distribution pattern of temperature and salinity, along the transect L-1, are shown in Figure 3 (left side). The temperatures are nearly homogenous up to 50 metres depth. It seems that warmer water intrudes into water column with 28.80°C isotherm. The thermocline is formed at 60 metres depth in the eastern part of the area.

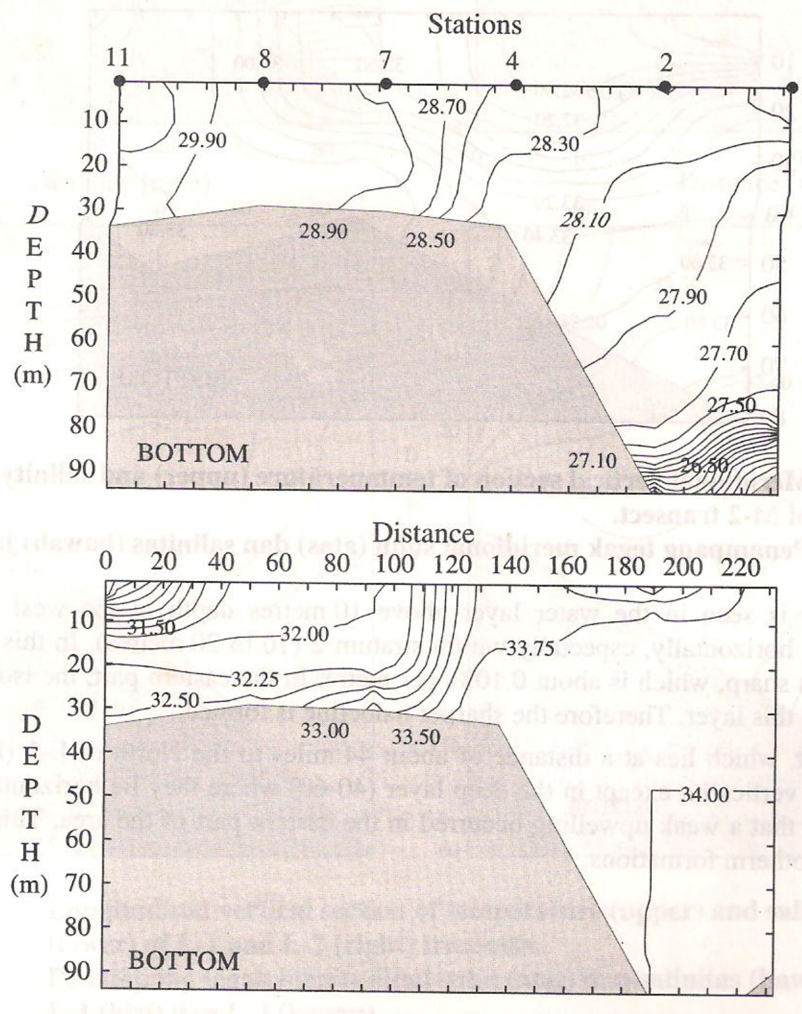

Figure 2 **Meridional vertical section of temperature (upper) and salinity (lower) of M-1 transect.**

Gambar 2 **Penampang tegak meridional suhu (atas) dan salinitas (bawah) jalur M-1.**

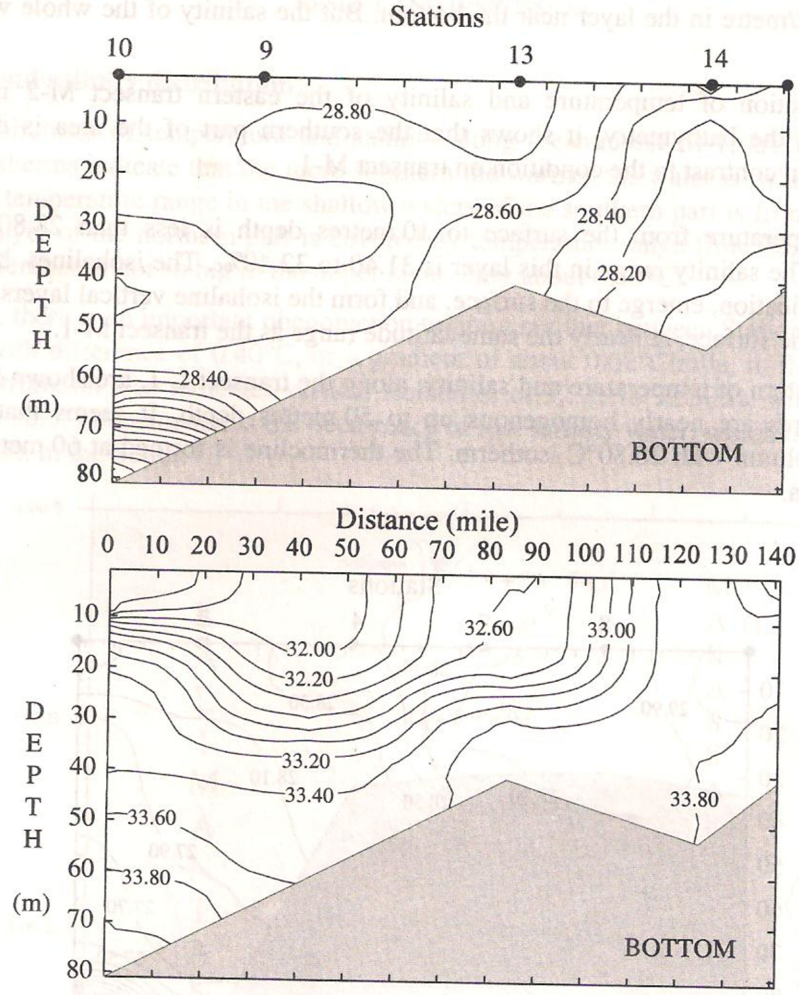

Figure 3 **Meridional vertical section of temmperature (upper) and salinity (lower) of M-2 transect.**

Gambar 3 **Penampang tegak meridional suhu (atas) dan salinitas (bawah) jalur M-2.**

The exception is seen in the water layer above 10 metres depth in the west side, where the isohalines tend to lie horizontally, especially within stratum 2 (10 to 20 metres). In this water layer, the gradient of salinity is sharp, which is about 0.10‰ per metre. In the eastern part, the isohalines of 32.50 to 33.00‰ emerge in this layer. Therefore the sharper halocline is formed.

In L-2 transect, which lies at a distance of about 44 miles to the North of L-1 (fig. 4, right), the isotherms tend to lie vertically, except in the deep layer (40-60) where they lie horizontally. Although it is not clear, it seems that a weak upwelling occurred in the eastern part of the area. This is indicated by both isohaline and isotherm formations.

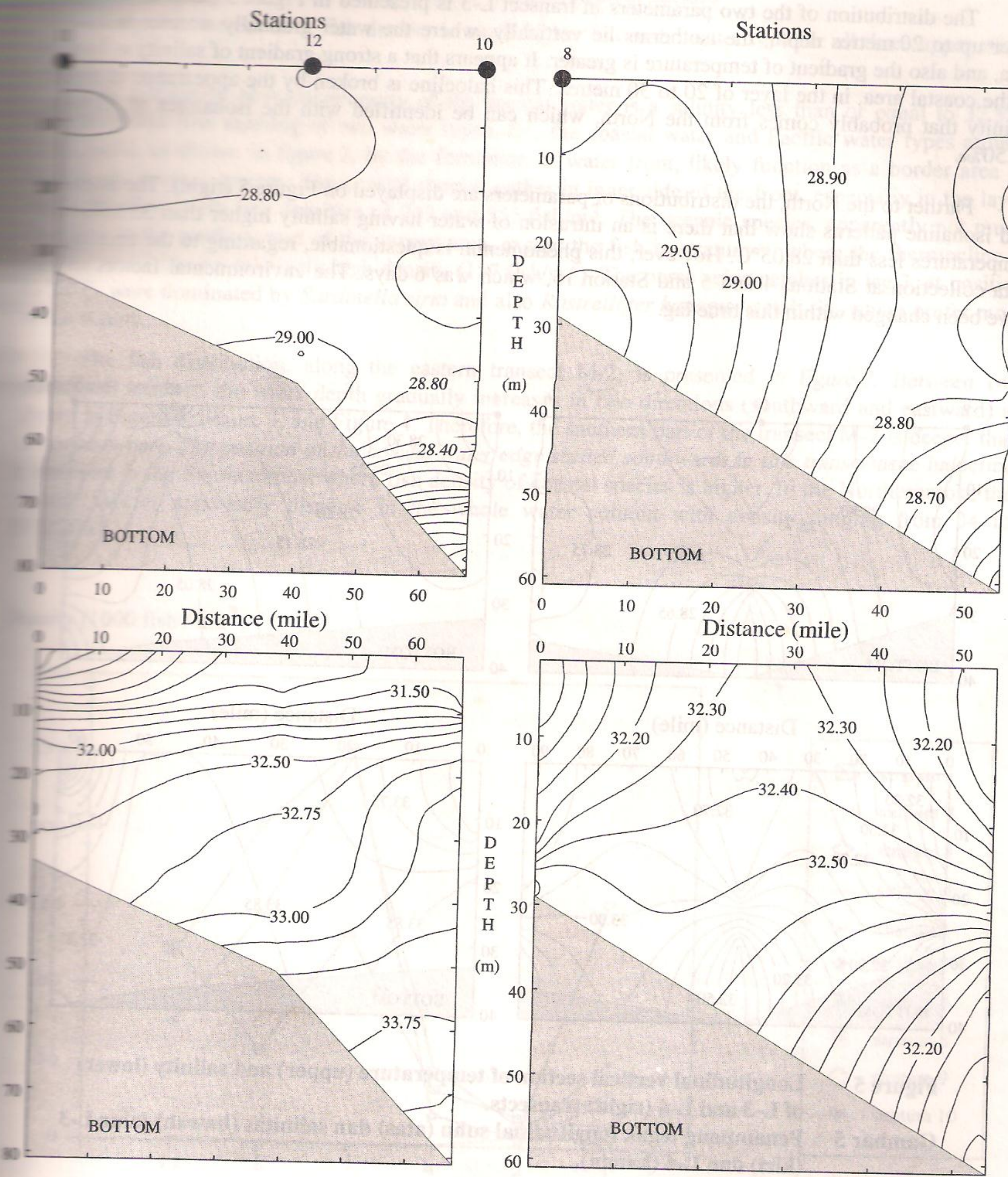

Figure 4 **Longitudinal vertical section of temperature (upper) and salinity (lower) of L-1 and L-2 (right) transects.**

Gambar 4 **Penampang tegak longitudinal suhu (atas) dan salinitas (bawah) jalur L-1 (kiri) dan L-2 (kanan).**

The distribution of the two parameters in transect L-3 is presented in Figure 5 (left). In the upper layer up to 20 metres depth, the isotherms lie vertically, where the water gradually warmer to coastal area, and also the gradient of temperature is greater. It appears that a strong gradient of salinity is formed in the coastal area, in the layer of 20 to 30 metres. This halocline is broken by the appearance of higher salinity that probably comes from the North, which can be identified with the isohalines of 33.10 to 33.50‰.

Farther to the North, the distributions of parameters are displayed on Figure 5 (right). The isotherm and isohaline patterns show that there is an intrusion of water having salinity higher than 33.85‰ and temperatures less than 28.05°C. However, this phenomenon is questionable, regarding to the time lag of data collection at Stations 4 and 5 and Station 15, which was 6 days. The environmental factors might have been changed within this time lag.

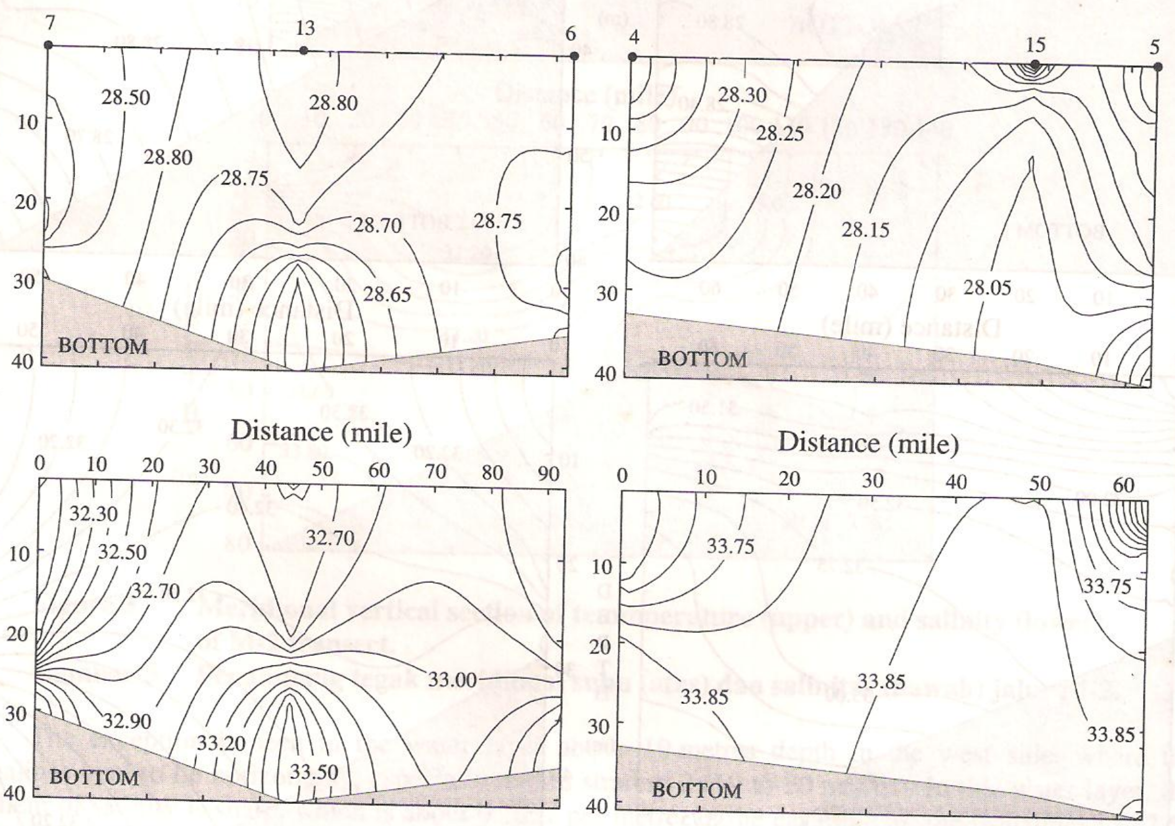

Figure 5 **Longitudinal vertical section of temperature (upper) and salinity (lower) of L-3 and L-4 (right) transects.**

Gambar 5 **Penampang tegak longitudinal suhu (atas) dan salinitas (bawah) jalur L-3 (kiri) dan L-4 (kanan).**

Spatial distribution of fish density in relation to environment factors

Along the transect M-1, fish density is much higher in coastal water type for all three upper strata (Fig. 6).

The distinctive physical property of the coastal water is a salinity less than or equal to 32.5‰ (Wyrtky,1961). The meeting of two water types, *i.e.,* the coastal water and Pacific water types around Lamu-lamu, as shown in figure 2, by the formation of water front, likely function as a border area of coastal and oceanic species. The coastal species gather in inner side of the front, especially in the layer within 12-42 m, with fish densities of 249 and 255 fish/m^3. The oceanic species, apparently not much abundant in the northern part of the survey area, except the fish in stratum-9, where the thermocline is likely formed, have a relatively high density (157 fish/m^3). The purse seine catches in leg 3, at position 117°56 E, were dominated by *Sardinella sirm* and also *Rastrelliger kanagurta* (tab. 3), which prefer more saline waters.

The fish distribution, along the eastern transect M-2, is presented in figure 7. Between two meridional transect, the water depth gradually increases in two directions (southward and eastward) as shown in Figure 2, Figure 3, and Figure 4. Therefore, the southern part of the transect M-2 is deeper than of northern part. The position of the coastal water edge shifted southward. In this transect, the halocline is narrower *in the Southernmost where fish density of coastal species is higher.* In the Northernmost, the oceanic species apparently disperse in the whole water column with density ranging from 34 to 89 fish/m^3.

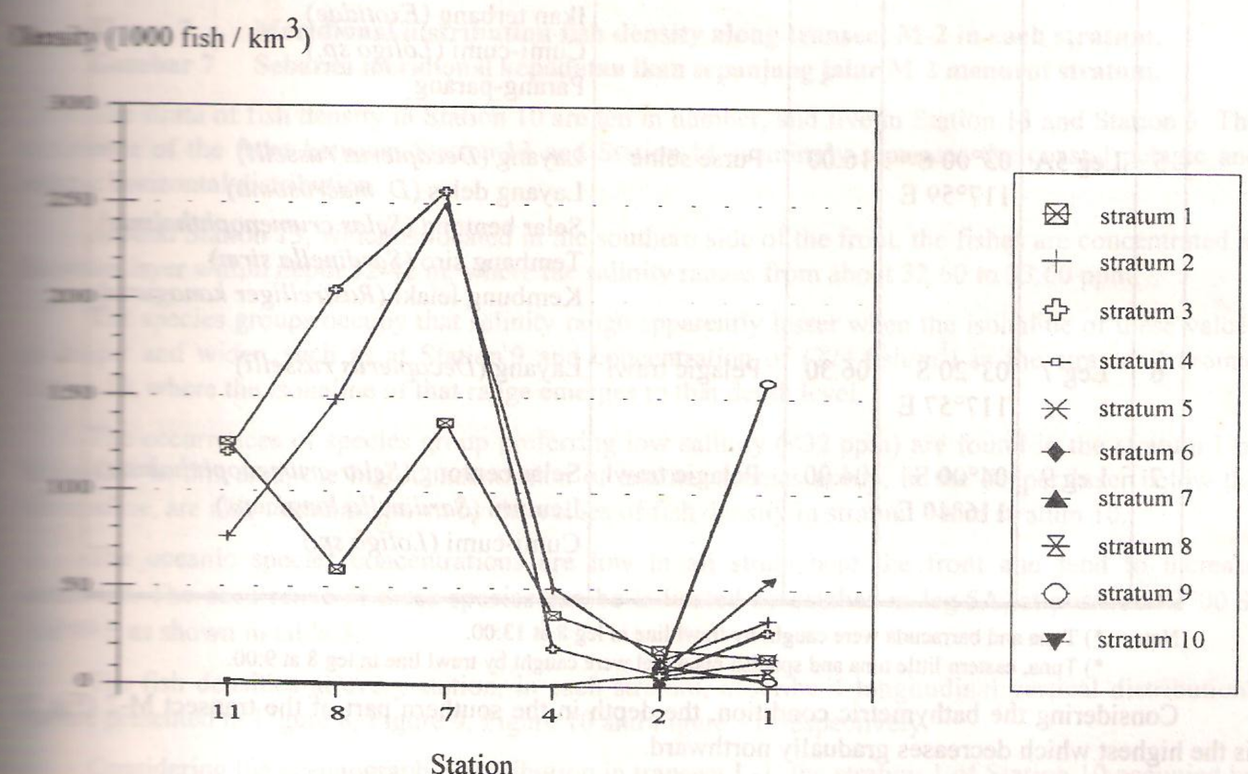

Figure 6 Meridional distribution fish density along transect M-1 in each stratum.
Gambar 6 Sebaran meridional kepadatan ikan sepanjang jalur M-1 menurut stratum.

Table 3 Position of fishing operation and catches.
Tabel 3 Posisi stasiun penangkapan dan hasil tangkapan.

No	Transect	Position	Time	Fishing gear	Local and scientific name of catch
1	Leg 3	01°56 S 116°56 E	16.00	Purse seine	Tembang siro (*Sardinella sirm*) Kembung lelaki (*Rastrelliger kanagurta*) Kembung perempuan (*R. neglectus*)
2	Leg 5	02°40 S 117°30 E	14.30	Bottom trawl	*Letrinus sp.* *Scolopsis* *Abalistes* Udang kipas Ikan sebelah
3	Leg 5	02°58 S 117°32 E	17.00	Purse seine	Layang (*Decapterus russelli*) Layang deles (*D. macrosoma*) Selar bentong (*Selar crumenophthalmus*) Tembang siro (*Sardinella sirm*) Kembung lelaki (*Rastrelliger kanagurta*)
4	Leg 5A	03°00 S 117°52 E	10.00	Bottom trawl	Tembang siro (*Sardinella sirm*) Teri (*Engraulidae*) Ikan terbang (*Exotidae*) Cumi-cumi (*Loligo sp.*) Parang-parang
5	Leg 5A	03°00 S 117°59 E	16.00	Purse seine	Layang (*Decapterus russelli*) Layang deles (*D. macrosoma*) Selar bentong (*Selar crumenophthalmus*) Tembang siro (*Sardinella sirm*) Kembung lelaki (*Rastrelliger kanagurta*)
6	Leg 7	03°20 S 117°57 E	06.30	Pelagic trawl	Layang (*Decapterus russelli*)
7	Leg 9	04°00 S 116°40 E	04.00	Pelagic trawl	Selar bentong (*Selar crumenophthalmus*) Lemuru (*Sardinella longiceps*) Cumi-cumi (*Loligo sp.)*

Note : *) Tuna and barracuda were caught by trawl line in leg 8 at 13:00.
*) Tuna, eastern little tuna and spanish mackerel were caught by trawl line in leg 8 at 9:00.

Considering the bathymetric condition, the depth in the southern part of the transect M-2 (Fig. 2) is the highest which decreases gradually northward.

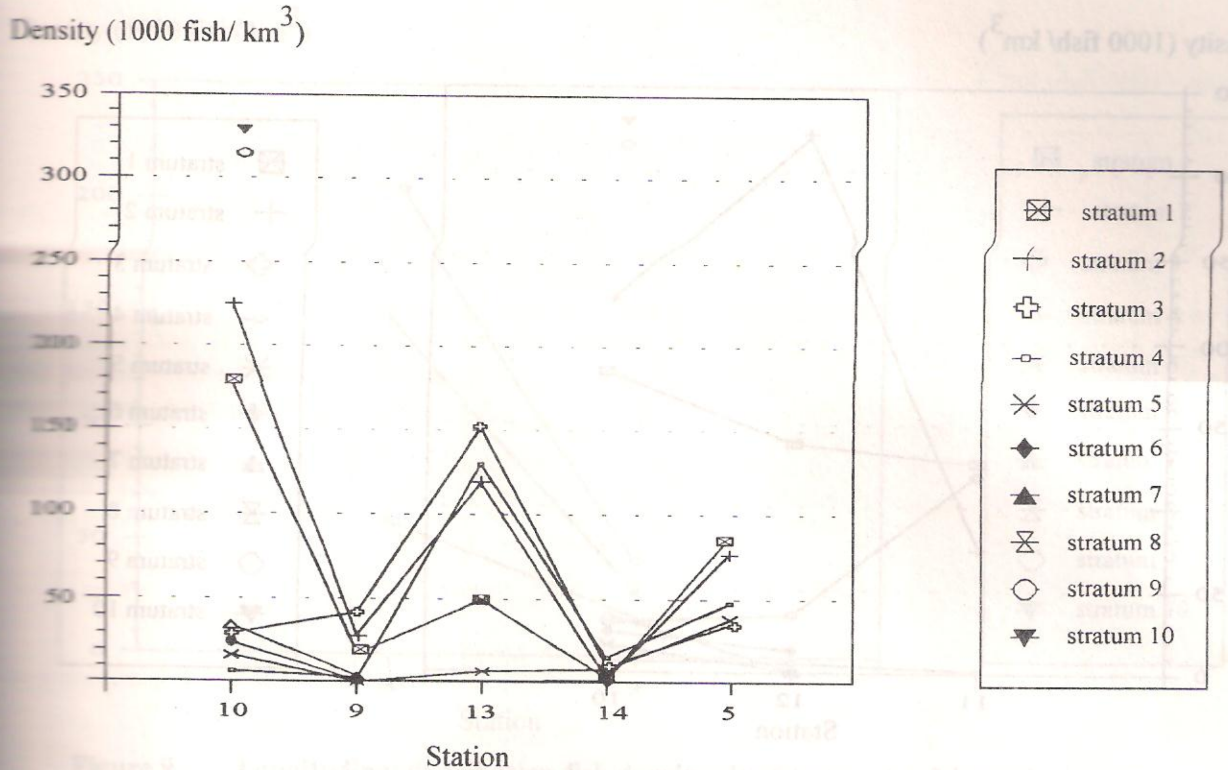

Figure 7 **Meridional distribution fish density along transect M-2 in each stratum.**
Gambar 7 **Sebaran meridional kepadatan ikan sepanjang jalur M-2 menurut stratum.**

The strata of fish density in Station 10 are ten in number, and five in Station 13 and Station 5. The occurrence of the front between Station 13 and Station 14 seemingly separates the coastal pelagic and oceanic horizontal distribution.

Around Station 13, which is located in the southern side of the front, the fishes are concentrated in the water layer within depth 12-42 m, where the salinity ranges from about 32.60 to 33.60 ppm.

The species groups occupy that salinity range apparently lesser when the isohaline of these values go deeper and wider, such as at Station 9 and concentration of (224 fish/m^3) in the stratum 2 around Station 10, where the isohaline of that range emerges to that depth level.

The occurrences of species group preferring low salinity (<32 ppm) are found in the stratum 1 of Station 10. In this area, the high concentration of another species group, in the deeper layer below the thermocline, are also found as shown by the values of fish density in stratum 9 and stratum 10.

The oceanic species concentrations are low in all strata near the front and tend to increase northward. The occurrence of these species can be indicated by catches in leg 5A, at position 03°00 S, 116°49 E as shown in table 3.

The fish densities at every station, in each stratum, describe 4 longitudinal vertical distributions and are presented in Figure 8, Figure 9, Figure 10 and Figure 11, respectively.

Considering the oceanographic distribution in transect L-1, the stratum 1 of Station 10 occupied by the species group of low salinity (<31.50 ppm), is probably different with the others. The fish density detected in stratum 2 and stratum 3 around the station can be more likely related to fish detected in stratum 1 and stratum 2 around Station 12, and stratum 1 around Station 3 as indicated by the running of isohaline 32.50 ppm. It means that fish density plotted in Figure 8, sounds differently. The species group, dense in stratum 2 of Station 12 are dispersed in stratum 2 and stratum 3 of Station 10. In the same way, we can delineate the other species group distribution due to salinity distribution.

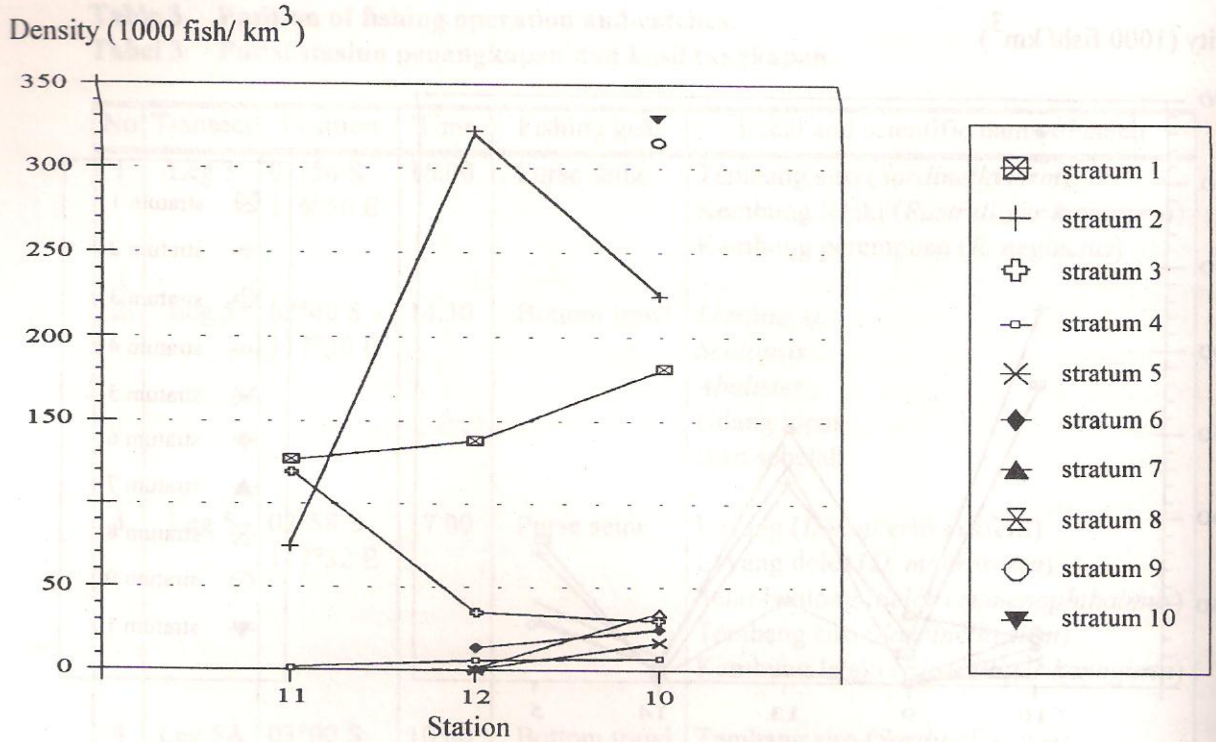

Figure 8 **Longitudinal distribution fish density along transect L-1 in each stratum.**
Gambar 8 **Sebaran longitudinal kepadatan ikan sepanjang jalur L-1 menurut stratum.**

Between Station 8 and Station 9, the isotherms tend to lie vertically, and the salinity from depth intrudes the upper layer waters and divides them into east and west low salinity (Fig. 4 night). This condition consequently separates coastal pelagic species in three strata, but the density was lower in the eastern side. The pelagic trawl operations at 03°20 S, 117°57 E obtained the catch of *D. russelli*.

Between Station 7 and Station 13 (Fig. 5), the isotherms and isohalines show the same condition with transect L-2 mentioned above, and also the fish density distribution of Station 6. The high density in stratum 3 of the Station 6 (572 fish/m^3) where the salinity ranged from about 32.80 tó 33.30 ppm, belongs to oceanic species.

The fish densities distribution along transect L-3, in Figure 10, indicated a similar pattern of stratum 1 and stratum 3, with the values for all three Stations, greater in the latter. Regarding to the distribution of salinity in Figure 5, the fish detected in the western part of stratum 1 might belong to the coastal group where the salinity is less than 32.20 ppm, while the other groups preferred the salinity around 32.70 ppm, at stratum the isohaline condensed in all stations and isohaline of 32.90 ppm situated in the mid of the stratum 1. The fishes in the west part of the stratum 2 of Station 1, seem to be of the same group as in stratum 1, and also the same as in stratum 2. The increasing of the density eastward at stratum 4, is related to the thickness of the stratum near the bottom.

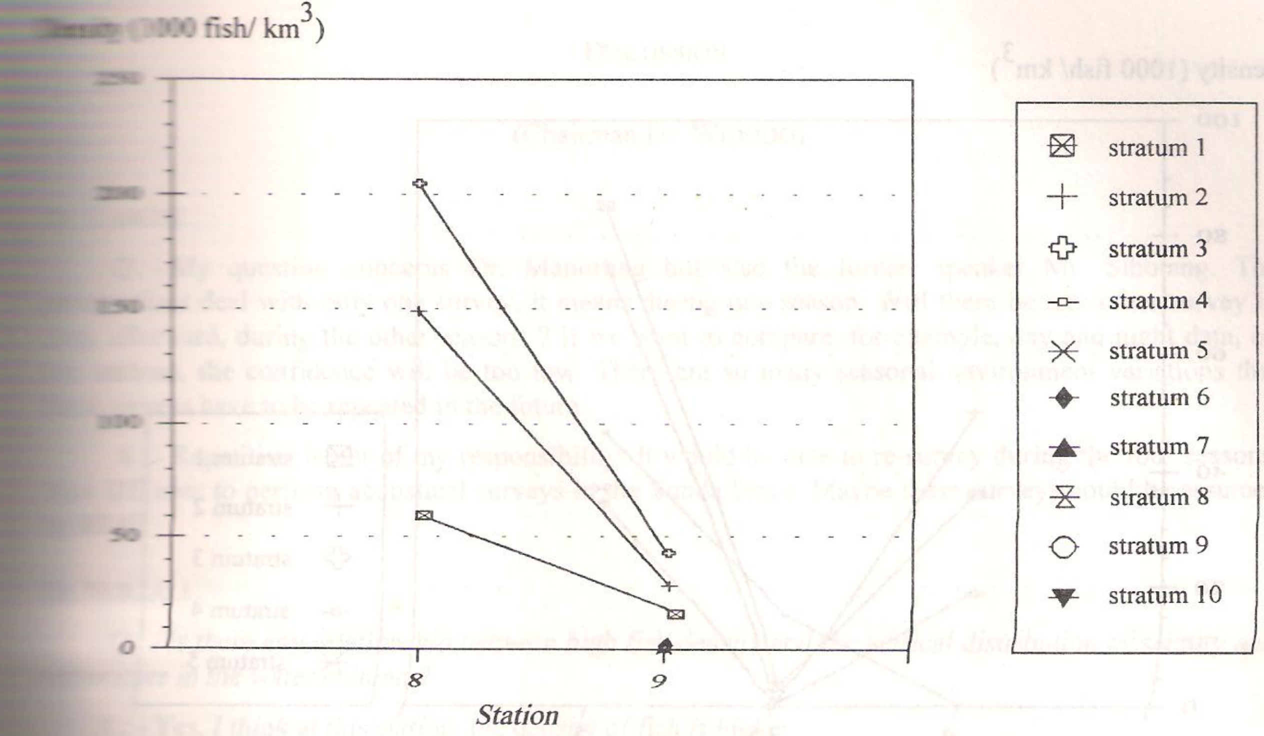

Figure 9 Longitudinal distribution fish density along transect L-2 in each stratum.
Gambar 9 Sebaran longitudinal kepadatan ikan sepanjang jalur L-2 menurut stratum.

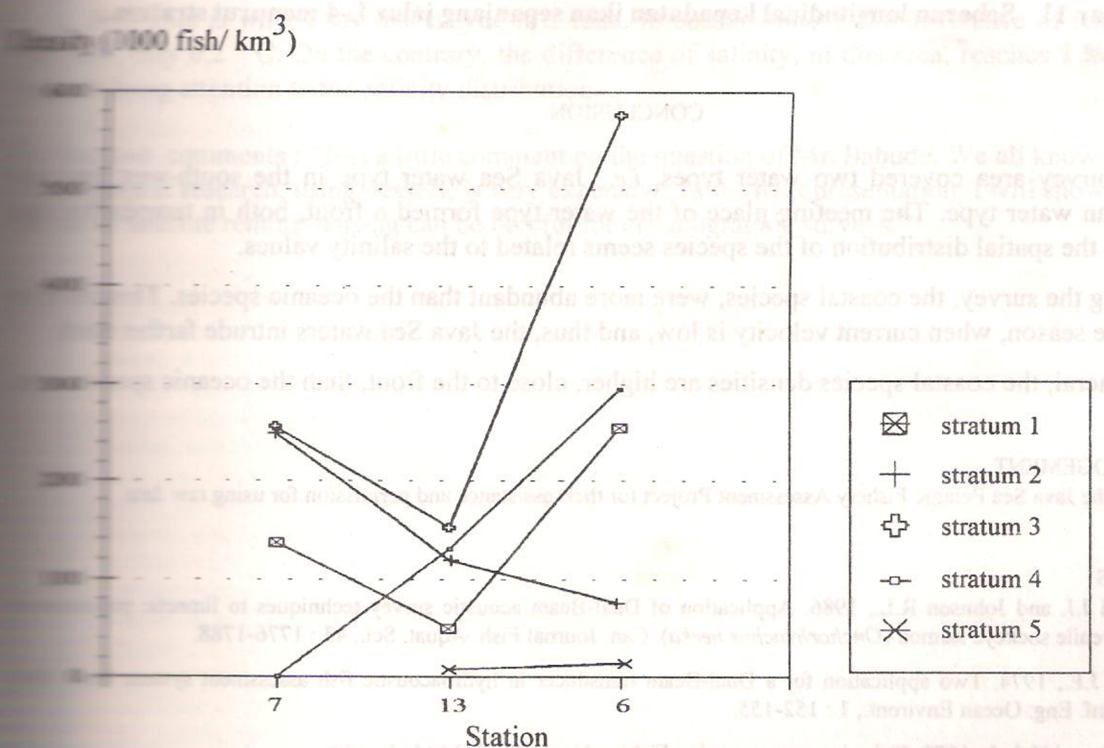

Figure 10 Longitudinal distribution fish density along transect L-3 in each stratum.
Gambar 10 Sebaran longitudinal kepadatan ikan sepanjang jalur L-3 menurut stratum.

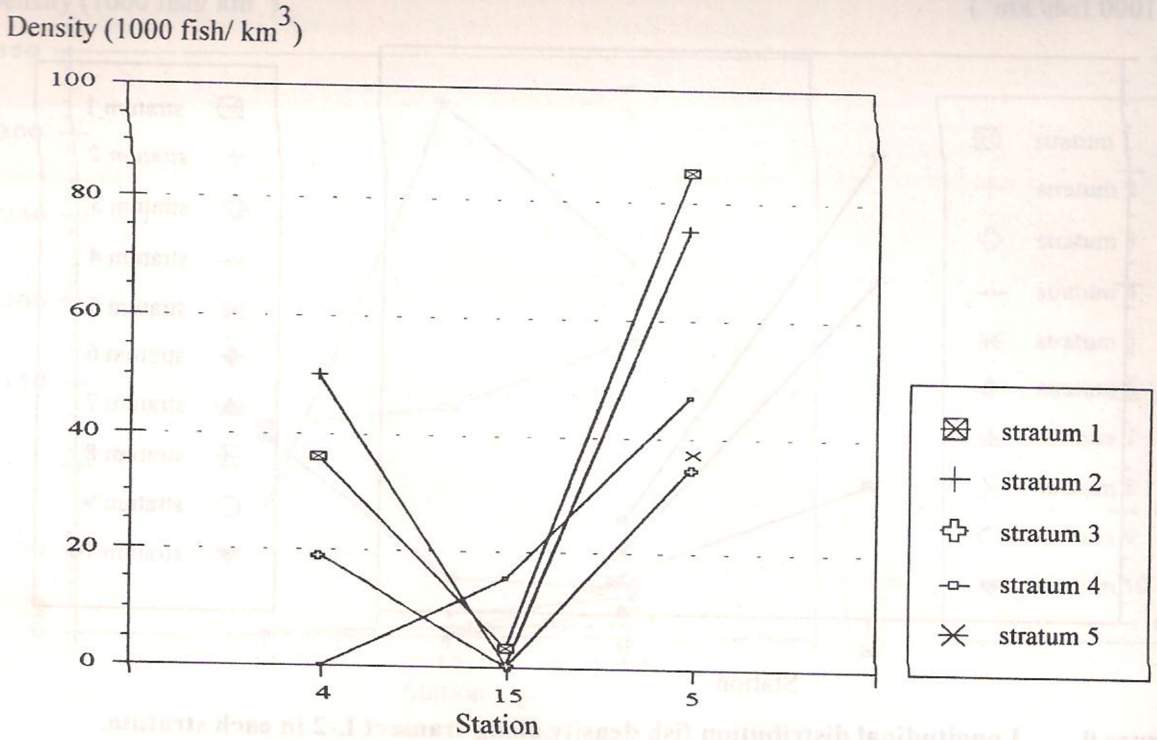

Figure 11 Longitudinal distribution fish density along transect L-4 in each stratum.
Gambar 11 Sebaran longitudinal kepadatan ikan sepanjang jalur L-4 menurut stratum.

CONCLUSION

The survey area covered two water types, *i.e.,* Java Sea water type in the south-west part and Pacific Ocean water type. The meeting place of the water type formed a front, both in temperature and salinity, and the spatial distribution of the species seems related to the salinity values.

During the survey, the coastal species, were more abundant than the oceanic species. This could be related to the season, when current velocity is low, and thus, the Java Sea waters intrude farther north.

In general, the coastal species densities are higher, close to the front, than the oceanic species ones.

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REFERENCES

Burczynski J.J. and Johnson R.L., 1986. Application of Dual-Beam acoustic survey techniques to limnetic population of juvenile sockeye salmon (*Onchorhynchus nerka*). Can. Journal Fish. Aquat. Sci., 43 : 1776-1788.

Ehrenberg J.E., 1974. Two application for a Dual-Beam transducer in hydroacoustic fish assessment system. Proc. IEEC Conf. Eng. Ocean Environt., 1 : 152-155.

Laevastu T. and Hela I., 1970. Fisheries oceanography. Fishing News (Books) Ltd., London.

Midttun L. and Nakken O., 1971. On acoustic identification, sizing and abundance estimation of fish. Fiskeridir. Skr. (Havunders), 16 : 36-48.

Wyrtki K., 1961. Physical oceanography of South-East Asia water. Naga Report, The University of California, La Jolla, California, 2 : 195 p.

DISCUSSION

(Chairman Dr. WIDODO)

Dr. ILAHUDE

Q : - My question concerns Dr. Manurung but also the former speaker Mr. Sihotang. The presentations deal with only one survey, it means during one season. Will there be any other survey in deep, afterward, during the other seasons ? If we want to compare, for example, day and night data, on two stations, the confidence will be too low. There are so many seasonal environment variations that these surveys have to be repeated in the future.

A : - Repetition is not of my responsibility. It would be nice to re-survey during the four seasons. Now IPB tries to perform acoustical surveys in the Sunda Strait. Maybe these surveys could be assumed by RIMF.

Dr. NURZALI

Q : - Is there any relationship between high fish density and the vertical distribution of salinity and temperature in the water column ?

A : - Yes, I think at this station, the density of fish is higher.

Q : - From your point of view, what is the predominant factor for high density ? Is it the salinity or the temperature ? Because for tuna, the temperature is the most important one.

A : - That is why, I say that maybe it is tuna. In coastal waters, the difference of temperatures is very low, only 0.2 ° C. On the contrary, the difference of salinity, in this area, reaches 1 ‰. Thus, it is better to bring attention to the salinity distribution.

Dr. SIREGAR comments : "Just a little comment on the question of Mr. Ilahude. We all know that oceanographic research, using vessels, is very expensive. In the next presentation, I will show you how the use of satellite remote sensing can be helpful for oceanographic surveys."