UNUSUAL ARRIVAL OF CHUB MACKEREL **SCOMBER JAPONICUS** AT PUERTO CHACABUCO, SOUTHERN CHILE (PISCES: SCOMBRIDAE).

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ABSTRACT. Unusual arrival of chub mackerel **Scomber japonicus** at Puerto Chacabuco, Southern Chile (Pisces: Scombridae).

Chub mackerel, **Scomber japonicus**, migrated in schools to Puerto Chacabuco in the middle of January 1983 and mass mortality of the fish occurred. A morphological description of the chub mackerel is given. Total length, body weight, sex ratio, maturity, and stomach contents of 60 fish sampled are also studied. The chub mackerel showed an unimodal frequency distribution of total length ranging from 40.5 to 46.6 cm and body weight from 850 to 1305 g. In the fish collected there was no statistically significant difference in the sex ratio. All the fish had well-developed gonads, showing gonad indices between 5.6 and 18.6 in males and between 4.5 and 14.3 in females. Almost all fish had empty stomachs. The chub mackerel seem to have been lured into Fiordo Aysén by higher water temperature and to have died around Puerto Chacabuco due to a combined effect of low salinity above a halocline and low dissolved oxygen below it.

Key words: Fish, **Scomber japonicus**, mortality causes, morphology, biological data, environmental conditions.

RESUMEN. A mediados de enero de 1983, cardúmenes de caballa, **Scomber japonicus**, migraron a Puerto Chacabuco, produciéndose una mortandad masiva de los peces. Se hace una descripción morfológica de la caballa. De los 60 peces muestreados, se estudió el largo total, peso corporal, proporción entre ambos sexos, madurez sexual y contenido estomacal. Las caballas mostraron una distribución unimodal de la frecuencia de largo total, desde

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40,5 a 46,6 cm y peso corporal desde 850 a 1305 g. En los peces recolectados no hubo diferencias estadísticamente significativas en la proporción entre ambos sexos. Todos los peces tenían gónadas bien desarrolladas, alcanzando índices gonadales entre 5,6 y 18,6 en machos y entre 4,5 y 14,3 en hembras. Casi todos los peces tenían estómagos vacíos. Las caballas parecen haber sido atraídas al fiordo Aysén por la elevada temperatura del agua, muriendo alrededor de Puerto Chacabuco debido a un efecto combinado de baja salinidad sobre la haloclina y bajo oxígeno disuelto debajo de ella.

INTRODUCTION

In the Pacific Ocean chub mackerel, **Scomber japonicus** Houttuyn, is known along coasts of the North Pacific, Phillippines, Japan, Sakhalin and California, to the south-east Pacific, Peru and Chile (Hildebrand 1946, Matsui 1967, Kramer 1969, Miller & Lea 1972, Matsubara & Ochiai 1977, Pequeño 1979). In Chile the chub mackerel is one of the most important fishes for commercial fisheries, particularly in northern regions (Mann 1954, Boré et al. 1980). Although this mackerel have been reported from the water as far south as 45°41'S (Boré et al. 1980), the occurrence of the species in southern Chile is very rare (Pequeño 1979).

In the middle of January 1983, a great number of the chub mackerel unusually arrived at Puerto Chacabuco (45°28'S and 72°44'W) and mass mortality of the fish occurred. Little is known of the biology of chub mackerel in Chilean waters in spite of their commercial importance. This paper presents morphological description and some biological aspects of the chub mackerel sampled, and oceanographic conditions of Fiordo Aysén and Canal Moraleda. The causes of arrival at Puerto Chacabuco and mass mortality of the fish are also discussed.

MATERIAL AND METHODS

Sixty chub mackerel were sampled randomly from fish which were drifting along the shore of Ensenada Baja (Fig. 1) on January 15 and 16, 1983. Total length (TL), body weight and gonad weight of the fish collected were measured when fresh.

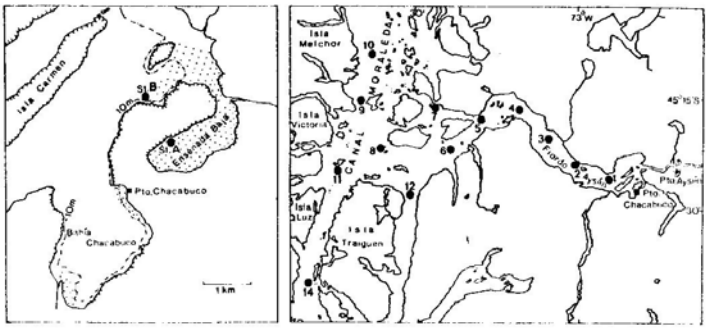

Fig. 1. Maps of Fiordo Aysén and Canal Moraleda (right) and the innermost part of Fiordo Aysén (left), showing stations of oceanographic observations and areas (dotted) where mass mortality of **S. japonicus** occurred.

Stomach contents of the fish were also examined. The gonad index (GI) was calculated with the following formula:

$$GI = \frac{\text{Gonad weight (g)}}{\text{Body weight (g)}} \times 100$$

The morphological description of the chub mackerel was based on only 10 specimens after preservation in formalin, except for gill raker counts which were made for all the fish collected, including rudimentary ones. Counts and measurements followed Hubbs & Lagler (1967).

The project of salmon introduction between Chile and Japan has carried out daily or periodically meteorological and oceanographic observations at stations fixed in Fiordo Aysén and Canal Moraleda. Most of meteorological and oceanographic data used in this study were obtained for the salmon propagation program at first. At station A of Ensenada Baja (Fig. 1), surface water temperature was taken almost every day between 10:00 and 17:30 and salinity was measured almost weekly at the surface and 5 m deep in December 1982 and January 1983. During these two months meteorological and oceanographic observations

were made several times at stations A and B, and once (January 13 to 15) at 13 stations of Fiordo Aysén and Canal Moraleda (Fig. 1). A specific gravimeter was used for the measurement of salinity. For the values obtained there is a probable error of ± 1.0‰.

RESULTS

Description of chub mackerel collected

Material examined: 10 specimens, 362.4 to 409.0 mm in standard length (SL) (415.0 to 465.0 mm TL), Ensenada Baja, drifted along shore, on January 15, 1983; 50, 354.0 mm SL (405.0 to 466.0 mm TL), Ensenada Baja, drifted along shore, on January 15 and 16, 1983, only for gill raker counts.

Description: Dorsal fin rays IX - I, 10 ~ 11 + 5 (finlets); anal fin rays I - I, 10 ~ 11 + 5 (finlets); pectoral fin rays 19 ~ 21; pelvic fin rays I, 5; vertical scale rows from upper end of gill opening to caudal base 211 ~ 219; gill rakers 12 ~ 15 + 25 ~ 29 = 38 ~ 43; vertebrae 14 + 17 = 31.

Proportional measurements expressed as a percentage of SL: Predorsal (1st) length 34.9 ~ 37.0; predorsal (2nd) length 64.9 ~ 67.4; preanal length 68.3 ~ 71.7; prepectoral length 26.8 ~ 29.3; prepelvic length 32.6 ~ 36.3; body depth 18.4 ~ 27.2; head length 26.5 ~ 31.6; snout length 8.6 ~ 9.5; eye diameter 5.1 ~ 5.9; upper jaw length 12.4 ~ 13.8; interorbital width 7.4 ~ 8.0; caudal peduncle depth 2.9 ~ 3.3; pectoral length 10.9 ~ 12.9; pelvic length 10.3 ~ 11.4; 3rd dorsal spine length 8.8 ~ 10.3; 1st dorsal base length 13.0 ~ 15.6; 2nd dorsal base length 10.2 ~ 11.6; anal base length 8.8 ~ 10.3.

Body stout, not greatly compressed, tapering to a slender caudal peduncle; head moderately compressed and somewhat flattened above; snout quite pointed; eye with adipose lid; mouth large, oblique; maxillary reaching below posterior margin of pupil. First dorsal fin depressible in a deep groove; 2nd dorsal and anal fins similar in shape, elevated anteriorly; pectoral fin short, but extending beyond 1st dorsal origin; pelvic fin inserted behind pectoral base; 1st anal spine small, separated from the 2nd one; caudal fin deeply forked. Minute teeth in a single row on each jaw; vomer with rudimentary

teeth in a band on each side; a few series of teeth on palatine; gill rakers long, closely spaced and each with bristles on posterior margin; lateral line rippled from upper end of gill opening to caudal base; body covered with small scales; head scaleless.

Color in life: Dorsal surface of body greenish-dark blue, with hook-shaped or rippled dark bands extending a little below lateral line, and ventral surface silver, with some dark spots below lateral line; distal half of dorsal fins blackfish and basal parts paler; pectoral base black, darkest on inner side; pelvic and anal fins transparent; caudal fin blackish, sometimes with a yellow tint.

Remarks: Among meristic characters special attention was paid to gill raker counts because Pequeño (1979) placed Chilean chub mackerel in the subspecies **S. japonicus peruanus** (Jordan and Hubbs) owing to its smaller number of gill rakers on the lower limb. As shown below, gill rakers of the fish presently examined ranged from 12 to 15 (with a mode of 14) on the upper limb and from 25 to 29 (27) on the lower.

Nº of gill rakers	Upper limb				Lower limb				
	12	13	14	15	25	26	27	28	29
Nº of fish	4	20	34	2	6	13	28	11	2

Mass mortality of chub mackerel

On January 13, 1983, chub mackerel began to die in and around Ensenada Baja and in Bahía Chacabuco (Fig. 1). It was unkown when the chub mackerel had migrated to Puerto Chacabuco. Although no attempt was made to count the dead fish, greater number of dead fish were observed in Ensenada Baja than in Bahía Chacabuco. The death of fish was found most frequently in both bays between January 14 and 17 and thereafter abruptly decreased, lasting until at least January 25. The areas of fish mortality were largely inside a 10 m isobath (Fig. 1). At the end of January chub mackerel have being caught by anglers at the pier at Puerto Chacabuco*.

* Personal communication of Mr. Delfin Vargas S., assistant of the Ensenada Baja Salmon Hatchery (Servicio Nacional de Pesca).

Total length and body weight

The fish sampled in this study ranged from 40.5 to 46.6 cm in total length, with the mode between 41.0 and 42.0 cm (Fig. 2). The body weight of fish was 850 to 1305 g, showing the mode between 1100 and 1150 g (Fig. 2). The frequency distributions of both total length and body weight were regarded as unimodal. The chub mackerel which came to Puerto Chacabuco appear to have consisted of fish falling into a single year-class.

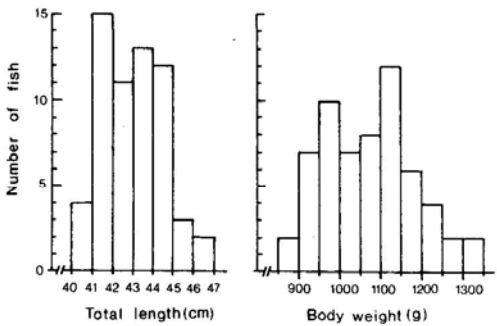

Fig. 2. Frequency distributions of total length and body weight of **S. japonicus** from Ensenada Baja in January 1983.

Sex ratio and maturity

Of the 60 fish examined 34 were males and 26 females. This is not significantly different from a sex ratio of 50% females at the 5% probability level by means of a Chi-square test. The gonad indices for males varied from 5.6 to 18.6 and for females from 4.5 to 14.3, less than in males (Fig. 3). All fish had well-developed gonads although completely-mature gonads were not found. In a few females the ovaries contained a number of transparent, mature eggs. These facts suggest that the chub mackerel presently studied were forming a spawning school and not long before to spawning.

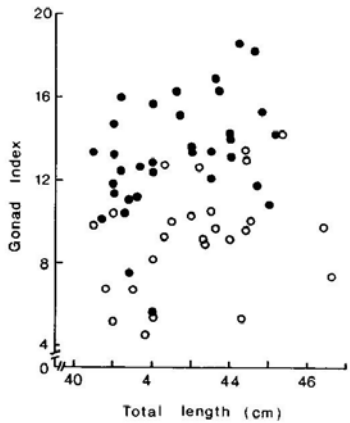

Fig. 3. Relationship between gonad index and total length for males (black circle) and females (white circle) of **S. japonicus** from Ensenada Baja in January 1983.

Stomach contents

Of the 60 fish 57 had empty stomachs; completely-digested material was found in two stomachs; two minute bivalves were found in one. Abundant small material, deposited along the shore, appeared in stomachs of 20 fish. However, these deposites as well as the bivalves were probably swallowed when the fish were dying.

Oceanographic conditions

Surface water temperature at station A rose to or above 16℃ in late December (1982) and early January (1983), and began to increase from about 17º to 20℃ in mid January when the chub mackerel appeared in Ensenada Baja and Bahía Chacabuco (Fig. 4). The days (January 14 to 17) during which there was the highest mortality of the fish coincided with a period of abruptly increasing water temperatures under fine weather (Fig. 4 and Tables 1 and 2). Ensenada Baja has a depth of 7 m at the station A during low tide, and a clear halocline was found between 5 m and bottom, showing low salinity less than 10‰ above the halocline and higher than 25‰ below it from January 15 to 25 (Table 1). At station B the halocline was distinct at a depth between 3 and 10 m (Table 1).

In mid January the surface water temperature of Fiordo Aysén (stations 1 to 6) was 15.6º to 18.2℃, higher than that

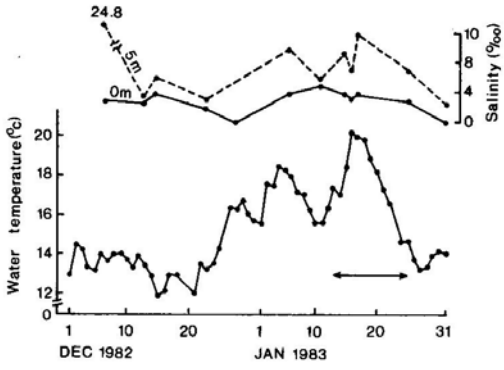

Fig. 4. Daily surface water temperature (bottom) and weekly salinity (top) at the surface and at 5 m deep in Ensenada Baja (Station A) in December 1982 and January 1983. An arrowed line showing a period during which the death of **S. japonicus** was observed; solid part for the highest mortality of the fish.

of Canal Moraleda (12.8º to 14.5℃). On the other hand, salinity of Canal Moraleda was higher and relatively stable vertically, between 28 and 31‰ (Table 2). The salinity at the surface layer decreased from station 8 toward 1, and in Fiordo Aysén the halocline was found between 3 and 10 m deep (Table 2). According to the salinity determinations on the stations 1, A and B, it can be said that the innermost part of Fiordo Aysén was covered with a layer of low salinity water (0.0 to 5.0‰) between mid December and late January.

DISCUSSION

There are only two reports of the occurrence of chub mackerel in southern Chile (south of 40°S). Boré **et al.** (1980) gave the range of Chilean chub mackerel southward to Darwin Bay

(45°41'S). Zama & Cárdenas (1983, MS) found a dead fish of this species which was stranded in Ensenada Baja in January 1982.

El Niño phenomena have had a great effect on oceanographic and biological conditions along the coasts of Peru and Chile (Nasu 1969). Ahumada & Arcos (1976) pointed out that mass mortality of fish and other organisms in Concepción Bay (36°40'S) during spring to summer are brought about by intensification and invasion of the Subequatorial Subsurface Water which has high water temperature and low oxygen content. Silva & Neshyba (1979/80) showed that the Subequatorial Subsurface Water reaches southward to 48°S as the Peru-Chile Undercurrent. From the end of 1982 to 1983, besides, there was a remarkable development of El Niño (Silva **et al.** 1983). It is likely, therefore, that the chub mackerel migrated to southern Chile under the influence of an intensified subsurface flow in the summer.

Pequeño (1979) reported that the chub mackerel from Curiñanco (39°41'S) have 10 to 13 upper gill rakers and 25 to 27 lower gill rakers, and Ojeda & Jaksić (1979) recorded average (?) number of gill rakers as 14 + 24 in Caleta Vitor (18°43'S) specimens. De Buen (1959) and Ojeda (1982) gave the gill raker counts as 27 and 24 to 25 on the lower limb, respectively. On the basis of the smaller number (25 to 27) of lower gill rakers, Pequeño (1979) considered the Chilean chub mackerel to be the subspecies **S. japonicus peruanus**, distinguishing it from the North Pacific populations which have 25 to 29 lower gill rakers. According to the original description of **S. peruanus** given by Jordan & Hubbs (1925), however, the lower gill rakers range from 26 to 29. In addition to the original description, the specimens presently examined had also 25 to 29 lower gill rakers with a mode of 27. We are in favor of Matsui (1967) who regarded the south-eastern Pacific **S. peruanus** as a synonym of **S. japonicus**.

Sex ratio of spawning males and females are equivalent or a little more females in the Japanese population of **S. japonicus** and they spawn in early summer (Matsubara & Ochiai 1977). According to Kramer (1969), the spawning season of California population occurs between March and October. Boré **et al.** (1980) noted that Peruvian **S. japonicus** appear to spawn during spring to summer. Ciechomski (1971) reported the Argentine population of this species spawn in spring and early summer (early November to December). On the other hand,

Berrien (1978) and Matsuura & Sato (1981) showed that the spawning of **S. japonicus** takes place during winter and spring in the west Atlantic (south of 33°N) and in southern Brazil waters, respectively. At any case, eggs or larvae of **S. japonicus** occur abundantly in waters with the temperature above 16°C and the salinity above 33‰ (Ciechomski 1971, Matsubara & Ochiai 1977, Berrien 1978, Matsuura & Sato 1981). No information is available of the spawning season of the species in Chilean waters. Judging from the gonad stage of the fish examined in this study, the spawning season of Chilean chub mackerel seems to be summer. Within the Chilean waters, of course, there must be variation of spawning season according to localities, particularly latitudal difference. Offshore surface water temperature of southern Chile seldom reach 14°C even in summer (Pequeño 1979, Silva & Neshyba 1979/80, Vargas et al. 1983). Although the summer water temperatures of channels and fiords sometimes rise above 16°C, the surface salinity does not exceed 32‰ (Table 2, Pickard 1971, Agencia de Cooperación Internacional del Japón 1982). It is unlikely, therefore, that the water of southern Chile is suitable for a spawning ground of chub mackerel.

The chub mackerel feed on zooplankton (such as planktonic polychates, euphausiids and amphipods) and small-sized fishes and squids along with phytoplankton (Miñano & Castillo 1971, Matsubara & Ochiai 1977, Ojeda & Jaksić 1979) although almost all the fish presently examined had empty stomachs.

The chub mackerel which migrated to Canal Moraleda were likely lured into Fiordo Aysén by higher water temperature (Table 2). Ensenada Baja, a narrowly-opened inlet (Fig. 1), has a shallow muddy bottom, no more than 9 m deep during high tide and there is little dissolved oxygen (0.5 to 3.5 ppm at 10° to 14°C) at the bottom layer below halocline (Agencia de Cooperación Internacional del Japón 1980). The fish which entered Ensenada Baja are presumed to have died as a result of low salinity above the halocline, the lack of dissolved oxygen below it, and the difficulty to find their way into water of suitable quality. On the other hand, it is difficult to sufficiently explain the cause of the fish decrease in Bahía Chacabuco because the bay is more broadly opened with a depth of 60 to 100 m at its center. According to the observations of dissolved oxygen near a north point of Isla Carmen (Fig. 1) between March and December 1980, the dissolved oxygen at depths of 10 to 15 m below the halocline was 3.0

ppm (at about 11°C) in December, in spite of 6.0 to 8.5 ppm (at 8° to 12°C) in other months (Agencia de Cooperación Internacional del Japón 1980). It seems that the dissolved oxygen below the halocline in Bahía Chacabuco decreased also to low levels because of a remarkable rise of water temperature, particularly in shallow areas less than 10 m, at which time the fish died.

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TABLE 1. Meteorologic and oceanographic observations at the stations A and B in a period between December 15, 1982 and January 31, 1983. Weather codes: b, blue sky, bc, blue sky with detached clouds; c, cloudy or overcast; r, rain. Transparency and depth in m, temperature (T) in °C, salinity (S) in ‰.

Station A

Date	Dec. 15		Jan. 15		Jan. 16		Jan. 17		Jan. 25		Jan. 31	
Time	12:05		19:00		17:20		11:30		16:15		15:55	
Weather	c		b		b		b		r		bc	
Air Temp.	13.5		24.5		26.0		22.0		11.0		13.5	
Transparency	2.5		2.5		2.5		3.0		2.0		2.0	
Depth	T	S	T	S	T	S	T	S	T	S	T	S
0	12.7	3.8	19.2	3.8	20.2	3.4	20.3	3.6	14.8	2.6	15.5	0.0
3	12.7	3.0	17.9	4.9	19.0	3.7	18.1	5.3	15.0	1.6	15.2	0.0
5	12.8	6.0	16.8	9.2	17.5	7.1	17.5	12.0	16.7	7.3	14.7	2.5
6.5-7.0	12.7	15.8	14.9	26.5	15.1	26.0	15.1	26.5	15.0	25.2	15.1	9.9

Station B

Date	Dec. 15		Jan. 15		Jan. 16		Jan. 17		Jan. 25		Jan. 31	
Time	11:40		19:00		16:40		11:00		15:40		15:35	
Weather	c		b		b		b		r		bc	
Air Temp.	13.5		24.5		25.0		21.0		11.0		18.5	
Transparency	2.5		-		3.5		3.0		1.5		2.0	
Depth	T	S	T	S	T	S	T	S	T	S	T	S
0	12.5	3.0	-	-	19.3	-	19.9	2.1	13.1	1.5	15.6	0.0
3	12.8	4.0	-	-	16.4	10.2	19.4	3.8	13.1	1.8	14.4	0.0
5	13.0	4.5	-	-	13.1	26.1	13.5	25.7	13.2	1.7	13.6	22.6
10	11.9	25.3	-	-	11.3	28.6	11.2	28.7	13.9	2.7	11.6	28.6
20	10.3	28.6	-	-	10.8	28.9	10.7	28.6	10.8	28.0	11.0	28.7

TABLE 2. Meteorologic and oceanographic observations at the 13 stations in fiordo Aysén and Canal Moraleda on January 13 to 15, 1983. Weather codes and oceanographic legend as in Table 1.

Station	1		2		3		4		5	
Date	Jan. 13		Jan. 13		Jan. 13		Jan. 13		Jan. 13	
Time	13:05		14:10		14:45		16:15		16:50	
Weather	c		c		c		r		c	
Air Temp.	16.0		17.5		18.0		16.5		18.5	
Transparency	3.0		7.0		5.0		8.0		7.5	
Depth	T	S	T	S	T	S	T	S	T	S
0	16.1	4.5	16.4	10.5	15.9	12.4	15.6	14.9	16.4	15.9
3	16.0	4.9	-	-	15.8	12.9	-	-	14.1	22.4
5	15.1	11.1	-	-	13.6	24.8	-	-	13.1	27.7
10	11.1	28.4	-	-	12.1	28.5	-	-	12.5	29.0
25	10.1	29.2	-	-	10.9	29.1	-	-	11.3	29.9
50	10.4	29.9	-	-	10.3	30.5	-	-	10.9	30.4

Station	6		7		12		8		11	
Date	Jan. 13		Jan. 13		Jan. 14		Jan. 14		Jan. 14	
Time	17:40		18:50		16:00		15:20		10:50	
Weather	c		c		b		b		bc	
Air Temp.	18.5		15.5		21.0		22.0		13.0	
Transparency	7.5		9.0		8.0		9.0		10.5	
Depth	T	S	T	S	T	S	T	S	T	S
0	15.8	18.7	14.1	26.4	14.1	27.9	15.1	25.9	13.1	28.6
3	14.3	23.0	-	-	-	-	-	-	13.1	28.7
5	13.8	25.7	-	-	-	-	-	-	13.1	28.8
10	12.8	27.8	-	-	-	-	-	-	13.0	28.6
25	11.9	29.6	-	-	-	-	-	-	13.0	28.8
50	11.5	29.7	-	-	-	-	-	-	12.5	30.9

TABLE 2. (Continuated from another sheet)

Station	9	10	14	1
Date	Jan. 14	Jan. 14	Jan. 14	Jan. 15
Time	09:25	08:05	13:00	16:00
Weather	c	bc	b	b
Air Temp.	13.5	13.5	17.0	27.5
Transparency	8.5	10.0	7.0	3.0

Depth	T	S	T	S	T	S	T	S
0	13.0	28.2	12.8	29.9	14.5	29.0	18.2	2.4
3	-	-	12.9	29.9	14.0	29.6	16.6	8.4
5	-	-	12.9	29.8	13.8	29.4	15.0	16.2
10	-	-	12.8	29.7	13.5	29.2	11.6	28.2
25	-	-	12.2	30.3	13.3	29.4	10.5	29.0
50	-	-	11.4	32.1	13.0	30.8	10.0	30.2