C.I.P.S.

MATHEMATICAL MODEL OF THE POLLUTION IN THE NORTH SEA

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MERCURY CONTENT OF FISH AND SHRIMPS CAUGHT OFF THE BELGIAN COAST

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Introduction.

In recent years, the concentration of heavy metals, pesticides and other pollutants in fish has become a cause for concern and has received increased interest. Mercury especially is regarded as a problem since the outbreak of mercury poisonings in Japan was found to originate from the consumption of heavily contaminated fish. Comprehensive reviews on the problems related to mercury in fish were published by Meyer (1972) and Holden (1973).

As in several other countries, a large-scale survey of the levels of contaminants in fish was started in Belgium. This report is the result of a study of mercury concentration in representative fish species, viz. plaice (Pleuronectes platessa L.), whiting (Merlangus merlangus L.), cod (Gadus morhua L.), sprat (Clupea sprattus L.) and shrimps (Crangon crangon L.) caught off the Belgian coast.

This area was surveyed specifically because of the increased risks of pollution in coastal waters. In this connection, the vicinity of the Scheldt estuary should be stressed. Furthermore, Belgian coastal waters are known to be a nursery ground for several important fish species and shrimps. For that reason, special attention was also paid to the pre-recruitment stock (O, I and for some fish species the II-age groups). Emphasis was laid on the possible relationship between mercury levels and different biological parameters (age, sex, length, weight) of fish. For shrimps, which are sedentary organisms, the fishing ground and the season were taken into account.

Methods and materials.

- Sampling.

Experimental fisheries were carried out during a one year's period (October 1971 - October 1972) by the R.V. "Hinders" in an area up to 10 miles off the Belgian coast. Fishing took place during day time with the otter trawl (mesh size 18 mm). Hauling time was 15 min.

Two areas were sampled on a monthly basis viz. five Western stations in the "Westdiep"-ground off Nieuport and five Eastern stations in the "Vlakte van de Raan"-ground off Zeebruges. Furthermore, an overall survey of 30 stations scattered over the whole area was undertaken in October 1971, May and October 1972. In total, 800 samples were taken.

The whole catch of plaice, whiting and cod was examined and classified in age-groups. The average composition per hour fishing of the catches was :

- plaice : O-I : 55 % ; II : 16 % ; III + : 29 %
- whiting : O-I : 93 % ; II + : 7 %
- cod : O-I : 67 % ; II + : 33 %

The samples of these three fish species were analysed individually and the following parameters were determined :

- length (in cm),
- weight (in g),
- age (otolith readings),
- sex (gonads and testes).

The samples of sprat consisted of 1 to 10 specimens, depending upon their availability.

For shrimps a sample of 250 g was taken. For practical reasons, the shells were not removed.

- Mercury analysis.

Digestion method with H_2SO_4/H_2O_2 ; reduction of Hg with $NaBH_4$. Determination with A.A. (M.A.S. 50).

- Statistical analyses :

Regression analyses and analyses of variance were carried out as outlined by Snedecor and Cochran (1971).

Results and discussion.

The results of the mercury analyses are reported in table 1.

The age-groups of plaice, whiting and cod were considered separately. An estimate of the average mercury content on an individual animal basis of the three populations was also made by taking into account the average composition of the experimental catches in the period under survey.

The population standard deviation was estimated by pooling the age-group variances.

An analysis of variance was carried out to test the differences between males and females per age group but showed no significant differences at the 95 % probability level.

The mercury concentrations tended to increase with the age of the fish.

The increase in mercury levels with age was also reported by several other workers (Johnels et al. 1967, Bligh and Armstrong 1971, Thibaud 1971, Forrester et al. 1972.

Table 1 - Mercury analyses of fish and shrimp caught off the Belgian coast.

Species	Age-groups	Number of samples	p.p.m. Hg		
			Average	s	v(%)
Plaice	0-I	66	0,172	0,093	54
	II	91	0,171	0,068	40
	III	73	0,153	0,067	44
	IV	26	0,174	0,070	40
	V-IX	11	0,216	0,094	44
	total (*)	-	0,168	0,077	46
Whiting	0-I	97	0,151	0,059	39
	II	112	0,173	0,087	50
	III	26	0,202	0,090	45
	IV+V	4	0,245	0,072	29
	total (*)	-	0,153	0,079	52
Cod	0-I	37	0,106	0,051	48
	II	37	0,137	0,046	34
	III	5	0,180	0,085	47
	total (*)	-	0,116	0,055	47
Sprat	total	66	0,144	0,064	44
Shrimp	total	148	0,101	0,039	39

(*) On an individual animal basis, taking into account the average composition of the catch.

The nature of this relationship was studied further by calculating the regression between mercury content and length of the fish (table 2). For the sake of completeness, the equations expressing the relation mercury content - weight, are also reported. As the relation between weight and length is curvilinear, these equations were of the type $y : ax^b$ where y : mercury content (ppm) and x = body weight (g). For plaice, no significant regressions were found. The regressions for whiting and cod are shown graphically in fig. 1 to 4.

Table 2 - Regression between mercury content (ppm) and length (cm) or weight (g).

Species	Sex	Length		Weight
		Equation	r(a)	Equation
Whiting	M	$y = 8,8 \cdot 10^{-3}x - 23 \cdot 10^{-3}$	0,566	$y = 31,4\ x^{0,4} \cdot 10^{-3}$
	F	$y = 7,3 \cdot 10^{-3}x + 26 \cdot 10^{-3}$	0,383	$y = 33,2\ x^{0,3} \cdot 10^{-3}$
	M + F	$y = 7,0 \cdot 10^{-3}x + 19 \cdot 10^{-3}$	0,410	$y = 49,6\ x^{0,3} \cdot 10^{-3}$
Cod	M	$y = 4,1 \cdot 10^{-3}x - 24 \cdot 10^{-3}$	0,616	$y = 18,8\ x^{0,3} \cdot 10^{-3}$
	F	-	0,098	-
	M + F	$y = 2,4 \cdot 10^{-3}x + 33 \cdot 10^{-3}$	0,378	$y = 34,4\ x^{0,2} \cdot 10^{-3}$

(a) Correlation coefficient ; significance 99,9 %.

Male and female whiting and male cod showed rather low but very significant (99,9 % probability) regressions. The relationship mercury content - length (or weight) however appeared to be not significant in female cod, indicating different behaviour towards mercury accumulation.

In order to have a better knowledge of the variations in mercury levels, frequency distributions were also calculated. Figures 5, 6 and 7 show the histograms per age-group. The highest age-group of the three species was not taken into consideration owing to the low number of specimens available. The overall frequency distribution of the whole population was also determined by taking the composition of the catches into account.

The histograms show the Hg-concentrations to be fairly well distributed. It should be noted in this respect that the standard deviations of the different groups were very similar (table 1).

The greater portion of values were situated below 0,250 ppm, and were probably within the natural range for the species considered (Holden 1973). The highest frequencies occurred between 0,100 and 0,250 ppm.

These data are in general agreement with results obtained in other countries for coastal areas (less than 25 miles from the coast). For plaice, Portmann (1972) reported an average of 0,25 ppm (n = 51) in British coastal waters, Koeman et al. (1971) 0,21 ppm (n = 8) in the Dutch Wadden Sea and Antonacopoulos (1973) 0,25 ppm in the Elbe estuary. Greve and Wit (1971) on the other hand mentioned five analyses of plaice caught off the Southern Dutch coast with a markedly lower range of 0,05 to 0,14 ppm.

For cod, Portmann (1972) found an average value of 0,26 ppm (n = 37) in British coastal waters, Greve and Wit (1971) 0,18 ppm (n = 5) off the Southern Dutch coast and Bligh and Armstrong (1971) 0,02 to 0,23 with an average of 0,12 ppm (n = 163) off the Canadian Atlantic coast.

For shrimps, an average value of 0,12 ppm (n = 50) was reported in the Wadden Sea (Koeman et al. 1971) whilst a range of 0,15 to 0,21 ppm was found in British coastal waters (Ministry of Agriculture, Fisheries and Food 1971).

It should be noted that all analyses on shrimps in this work were for practical reasons carried out on whole crustaceans. However, a specific investigation was conducted on the mercury distribution in the body of the shrimps. The results showed a distribution of 56 % in the flesh, 32 % in the cephalothorax, 12 % in the shell and 0 % in the telson. Hence, taking into account an average percentage of 30 % shrimp flesh, a mean content of 0,186 ppm (standard deviation 0,072) was present in the shrimp muscle.

Shrimps being sedentary animals, migrating over distances not exceeding 10 to 15 miles (Tiews 1963), the possible influence of the area (West and East coast)(table 3), and the season was evaluated statistically.

Neither the t-test carried out on the mercury contents of the West and East coast nor the regression analysis between mercury and time of catching appeared to be significant, stressing again the fairly uniform distribution of mercury levels over the whole area.

Table 3 - Mercury content of shrimps from the East and West coast (ppm).

Area	n	Mean	s	v(%)
Eastern	65	0,099	0,040	40
Western	83	0,103	0,039	38

The mercury concentration in sea-water off the Belgian coast averages 0,15 ppb (C.I.P.S. 1972) which seems to be normal for surface waters (Sillen 1963, Beasley 1971). Sediments on the other hand contained about twice as much mercury as in more distant waters (0,27 vs 0,15 ppm) (C.I.P.S. 1972). Hence, it is not surprising that mercury concentrations in Belgian inshore fish appeared to be higher than in fish caught in distant waters where reported levels are almost exclusively below 0,100 ppm, Westöö 1967, Bligh and Armstrong 1971, Thibaud 1971, Antonacopoulos 1973, Portmann 1972, Icelandic Fisheries Laboratories 1973).

On the other hand, the reported values contrast with the high concentrations recorded in heavily contaminated fishing grounds. Ackefors (1968) reported values up to 3,1 ppm for plaice and 2,7 ppm in cod caught in the Oresund. Also in cod, Boëtius (1971) found an average of 0,667 ppm (n = 15) with maximum concentrations of 1,29 ppm in the Sund (Denmark). In a survey covering 13 Norwegian fjords, Berge and Palmork (1971) recorded maximum levels of 4,70 (n = 215) and 1,88 ppm (n = 18) in cod and whiting respectively.

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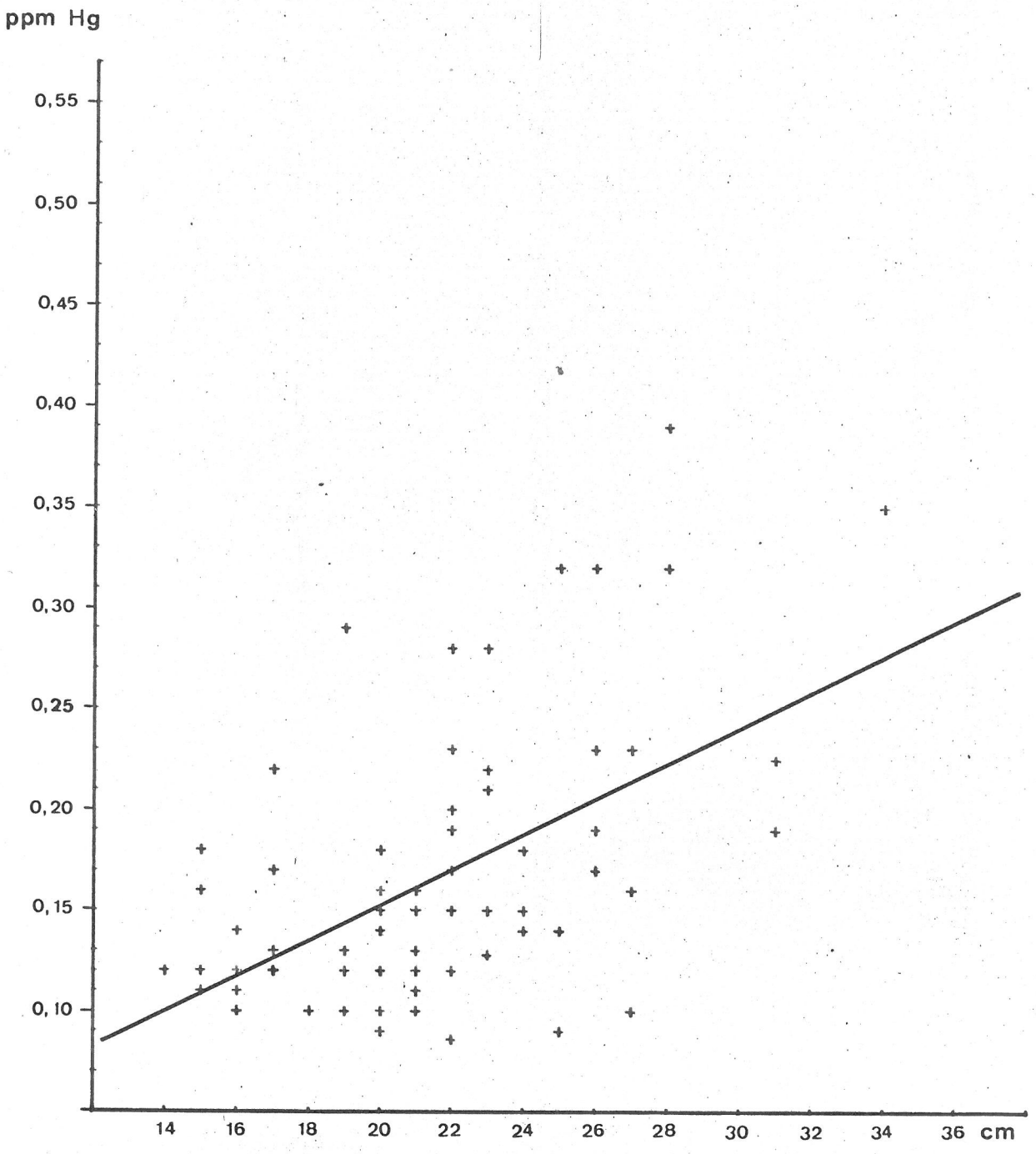

Fig. 1 - Regression between mercury content and length of male whiting

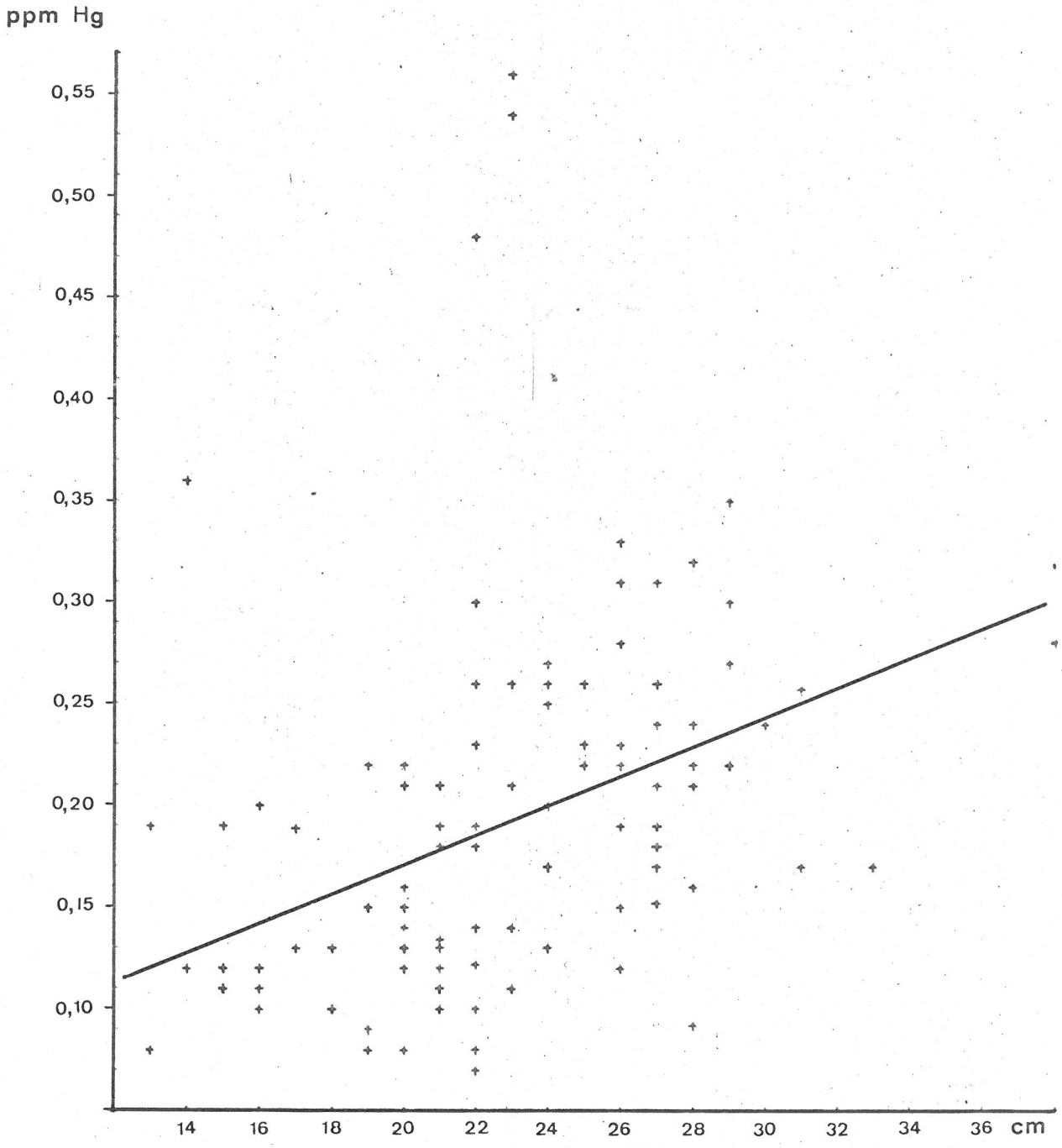

Fig. 2 - Regression between mercury content and length of female whiting.

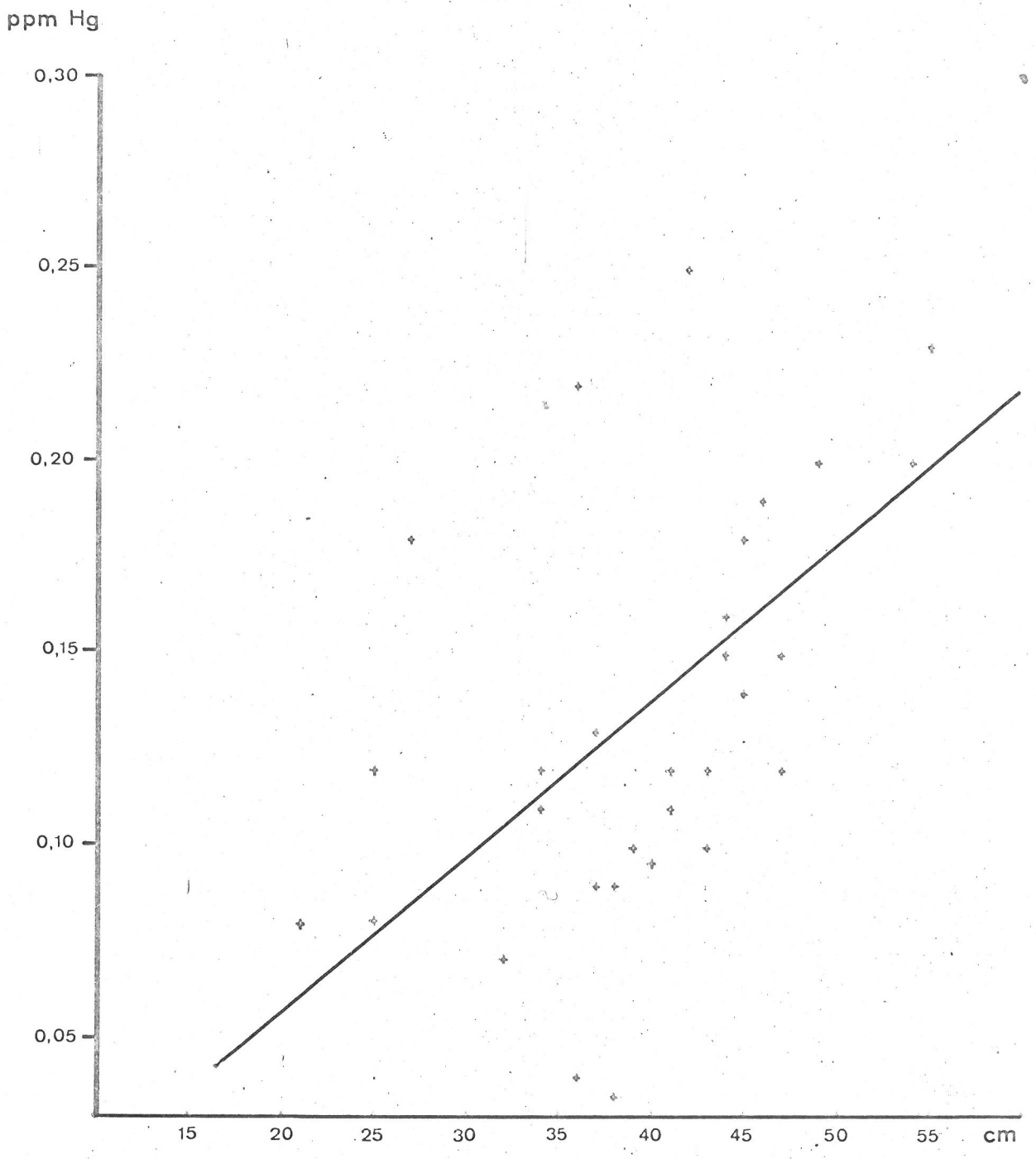

Fig. 3 - Regression between mercury content and length of male cod

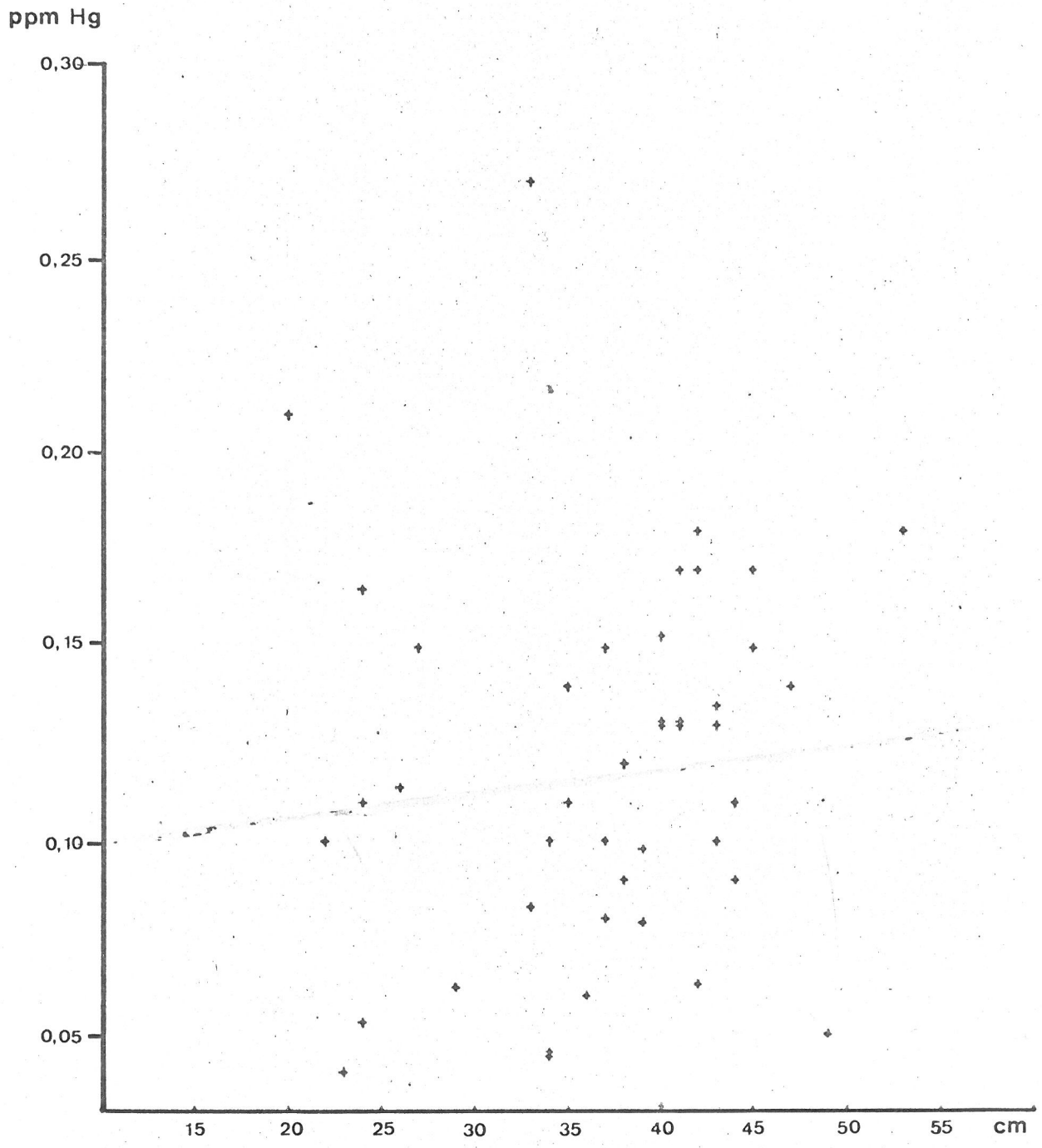

Fig. 4 - Relationship between mercury content and length of female cod

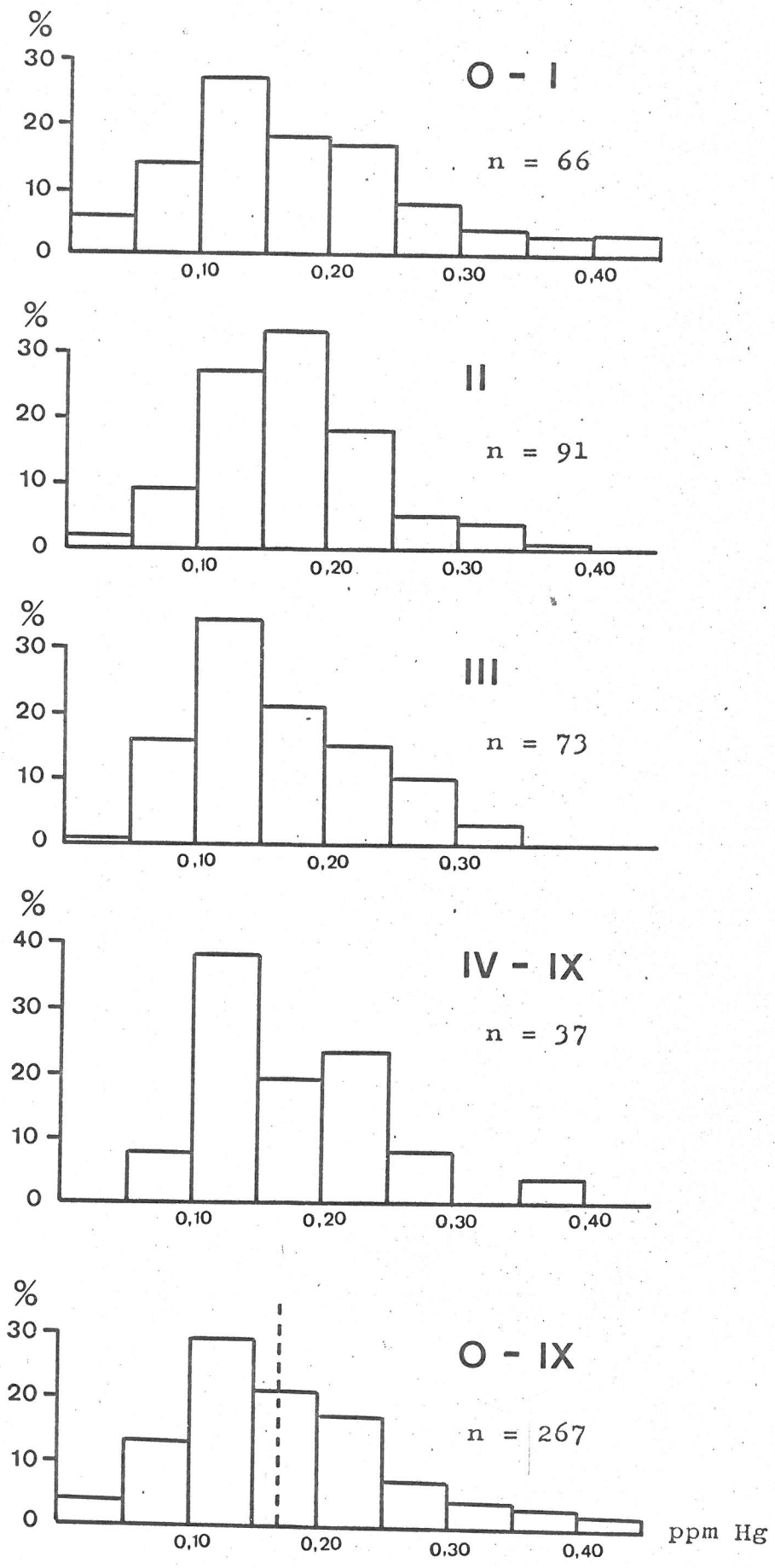

Figure 5 - Histogram per age-group of plaice.

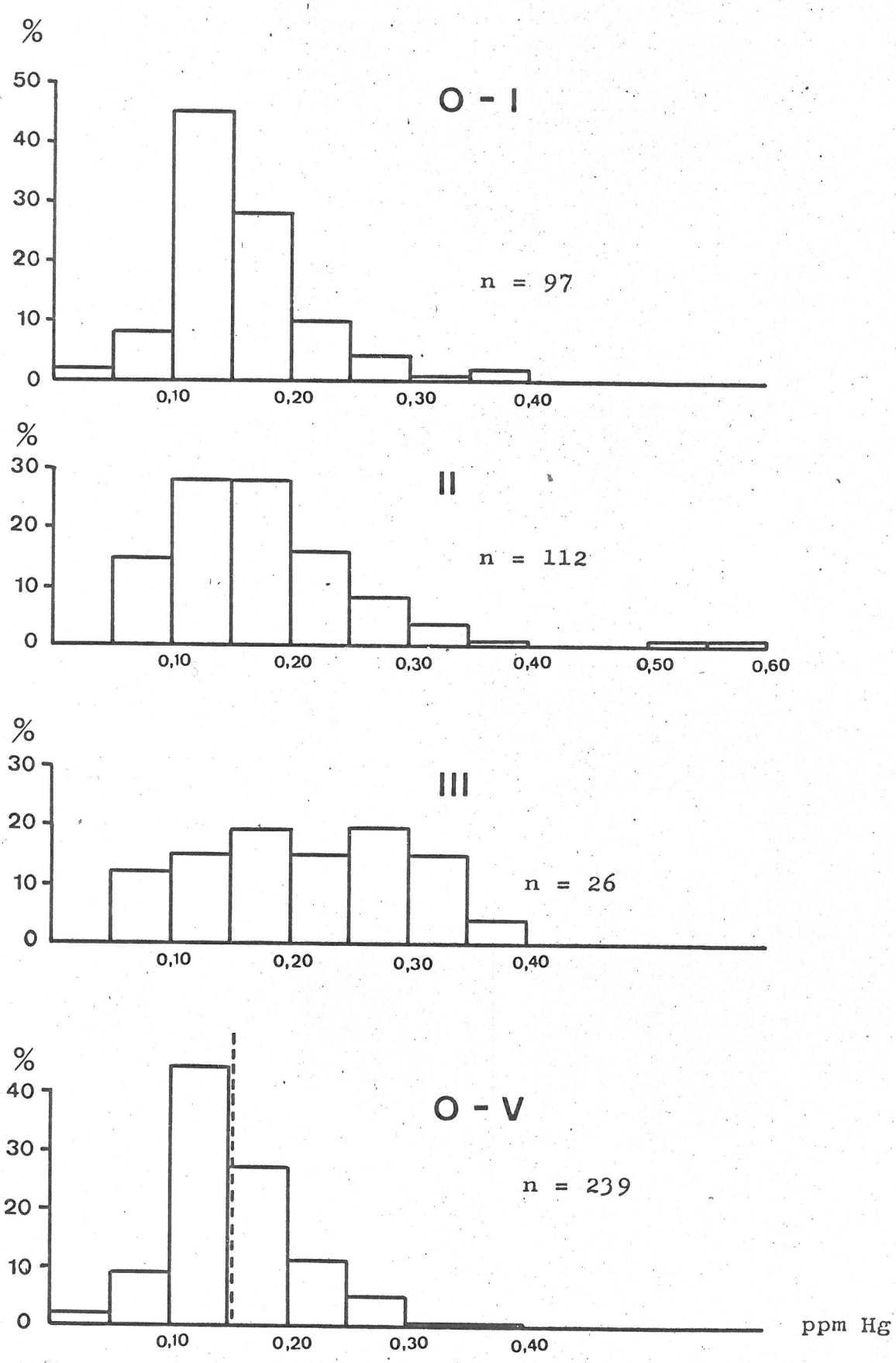

Figure 6 - Histogram per age-group of whiting

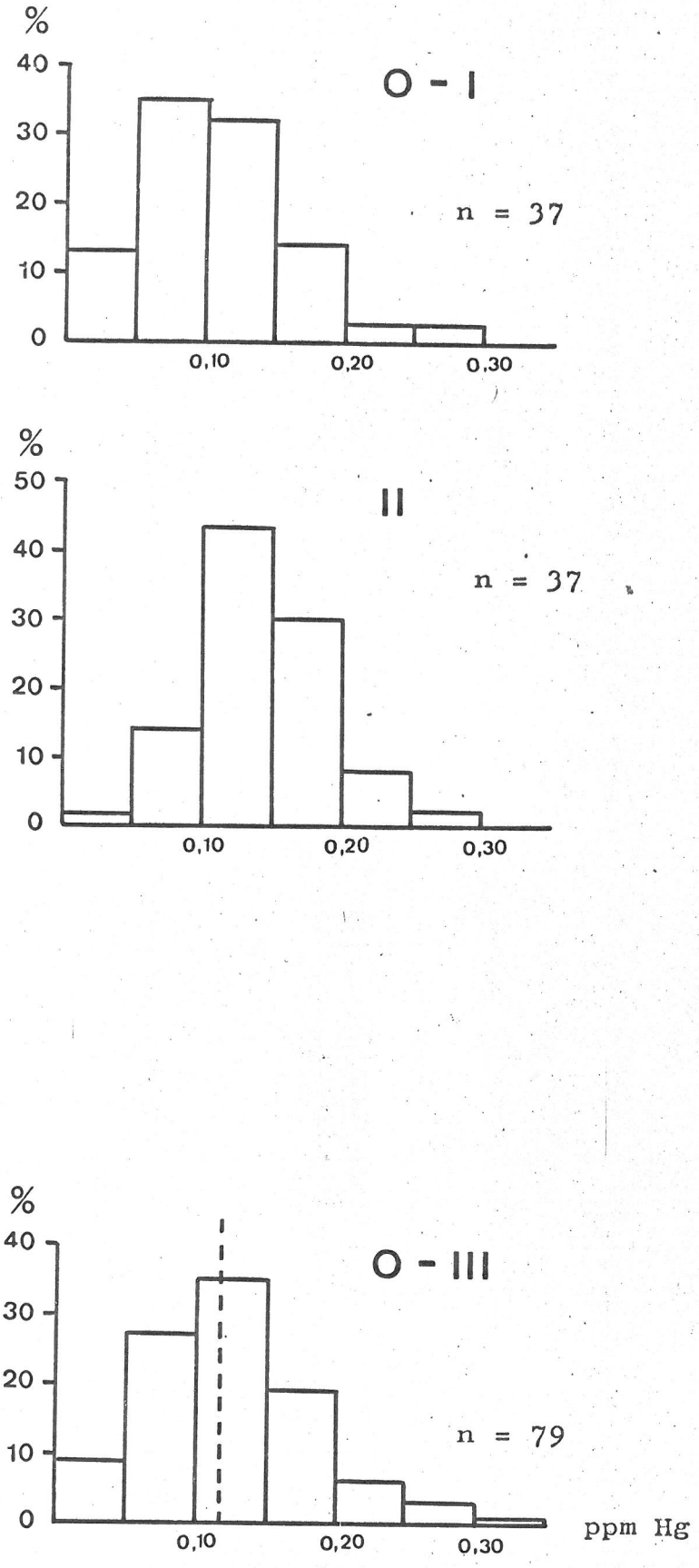

Figure 7 - Histogram per age-group of cod.