CALIPSO

Fish and seafood consumption study and biomarker of exposure to trace elements, pollutants and omega 3.

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The CALIPSO fish and seafood study concerning dietary consumption and biomarker of exposure to trace elements, pollutants and omega 3 was performed at the initiative of the General Directorate for Foods of France's Ministry of Agriculture and Fisheries, the French Institute for Agronomy Research and the French Food Safety Agency. Unlike traditional so-called "indirect" exposure studies based on ingestions, this study enables finer characterisation of the risks and benefits associated with fish and seafood consumption by measuring the actual biological internal levels of individuals as a function of their dietary habits and local provisioning modes.

The CALIPSO study constitutes an important scientific and methodological examination of the risks-benefits question in general and that of fish and seafood consumption in particular, a subject widely debated at national and international levels.

The study shows that French coastal populations, generally high seafood consumers, are well informed and have sound knowledge of these foods. They appreciate information on this subject which is a source of concern, yet they tend regard the public controversy on this issue with some scepticism. The study shows that the contaminant levels measured in provisioned fish and seafood are globally satisfactory relative to currently applicable regulations, with the exception of a few products. For trace elements this "background" contamination level is relatively homogeneous all along the French coast, whereas for persistent organic pollutants a North-South contamination gradient is observed.

From a benefits point of view, the study shows that consuming fish alone at least twice a week (including some oily fish) provides the recommended intake of omega 3 long-chain polyunsaturated fatty acids. As regards risks, the study reveals that although some high consumers exceed the reference toxicological values, the excesses are moderate and moreover difficult to interpret owing to the uncertainties inherent in all indirect exposure studies and the existence of safety factors. Nevertheless these results demonstrate the need to pursue the efforts being made to reduce exposure (by reducing pollution), especially to dioxins and all PCBs.

Finally, concerning the global question of weighing health risks against nutritional benefits, the study results confirm the validity of the recommendations made by various national scientific bodies: that the general population should consume fish at least twice a week, including some oily fish, and that pregnant or breast-feeding women should consume predator fish not more than once a week.

Looking beyond these general recommendations, this study highlights the advantages of diversifying the consumed fish and seafood species in terms of proportions and provisioning origins in order to ensure a rational balance between benefits and risks compatible with nutritional and toxicological recommendations.

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CALIPSO

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Acknowledgements

The authors would like to thank the General Directorate for Foods of the French Ministry of Agriculture and Fisheries for its financial support, Mr. Patrice Marion and Mr. Luc Marchaison for their active collaboration in the execution of the study, Mrs. Nadine Fréry of InVS for her assistance in the preparation of the study protocol, Mrs. Nathalie Arnich, Mrs. Sophie Galotti, Mr. Fernando Aguila, Mrs. Landy Razanamahefa, Ms. Céline Dumas and Mrs. Esther Kalonji from Afssa for their observations and their attentive proofreading, and the experts of Committee on residues and chemical and physical contaminants, especially Alain Baert and Michel Boisset. The authors also express their particular gratitude to all the participants in the CALIPSO survey without whose support this study would not have been possible.

Glossary

AFSSA: *French Food Safety Agency (Agence Française de Sécurité Sanitaire des Aliments)*

ALA: *Alpha-linolenic acid*

AsB: *Arsenobetaine*

AsC: *Arsenocholine*

CIQUAL: *Informatics Centre for Food Quality (Centre Informatique sur la Qualité des Aliments)*

CREDOC: *Research Center for the Study and Observation of Living Conditions (Centre de recherche pour l'étude et l'observation des conditions de vie)*

CSHPF: *High Council for Public Health (Conseil supérieur d'hygiène publique de France)*

CSTEE: *Committee on Toxicity, Ecotoxicity and the Environment*

CVD: *Cardiovascular diseases*

DBT: *Dibutyltin*

DGAL: *General Food Directorate (Direction Générale de l'Alimentation)*

DGCCRF: *General Directorate for Competition, Consumption and Fraud Prevention (Direction Générale de la Concurrence, de la Consommation et de la Répression des Fraudes)*

DHA: *Docosahexaenoic acid*

DL-PCB: *Dioxin-like polychlorobiphenyl*

DMA: *Dimethylarsinic acid*

DOT: *Dioctyltin*

DPT: *Diphenyltin*

EPA: *Eicosapentaenoic acid*

GAA: *gamma-aminolevulinic acid*

GEMS/ Food Euro: *Global Environment Monitoring System/ Food Contamination Monitoring and Assessment Program*

IARC: *International Agency for Research on Cancer*

IFREMER: *French Research Institute for Exploitation of the Sea (Institut Français de Recherche pour l'Exploitation de la Mer)*

INCA: *Individual National Food Consumption Survey*

INRA: *French Institute for Agronomy Research*

IPCS: *International Program on Chemical Safety*

JECFA: *Joint FAO/WHO Expert Committee on Food Additives and contaminants*

JMPR: *FAO/WHO Joint Meeting Pesticide Residues*

LA: *Linoleic acid*

LOD: *Limit of detection*

LOQ: *Limit of quantification*

MBT: *Monobutyltin*

MMA: *Monomethylarsonic acid*

MOT: *Monooctyltin*

MPT: *Monophenyltin*

MRL: *Minimum Risk Level*

MUFA: *Monounsaturated fatty acid*

OCA: *Food Consumption Observatory (Observatoire des Consommations Alimentaires)*

OPCST: *Parliamentary Office for Evaluation of Scientific and Technical Options (Office Parlementaire des Choix Scientifiques et Techniques)*

PAH: *Polycyclic aromatic hydrocarbon*

PBDE: *Polybromodiphenylether*

PCB: *Polychlorobiphenyl*

PCDD: *Polychlorodibenzo-p-dioxin*

PCDF: *Polychlorodibenzofuran*

POP: *Persistent organic pollutant*

PTWI: *Provisional Tolerable Weekly Intake*

PUFA: *Polyunsaturated fatty acid*

RDA: *Recommended Daily Allowance*

REGAL: *General Foods Directory (Répertoire Général des Aliments)*

SCOOP: *Scientific CO-OPeration on questions relating to food*

SFA: *Saturated fatty acid*

TBT: *Tributyltin*

TDI: *Tolerable Daily Intake*

TDS: *Total Diet Study*

TEF: *Toxic equivalency factor*

TEI: *Total energy intake*

TEQ: *Toxic Equivalent*

TOT: *Trioctyltin*

TPT: *Triphenyltin*

TRV: *Toxicological reference value*

WHO: *World Health Organisation*

Preface

The diversity of environmental pollutants, largely related to unceasing industrial and technological development, presents a permanent problem when verifying food control quality from a health point of view and evaluating the risks for consumers of foods subject to contamination. This is a real challenge for scientists, health experts and the public services responsible for food safety. The problem is particularly important in that chemical pollutants are ubiquitous and extremely varied in their chemical forms and toxicological characteristics. Moreover, due to their properties and variable persistence, they enter the food chains that lead to man through vegetable and animal foods. Consequently environmental pollutants are a constant public health concern, which is why the General Food Directorate (DGAL: Direction Générale de l'Alimentation), depends on the scientific and methodological support of risk assessment experts to face this fast and ever changing challenge.

The present work was delegated by the DGAL to the French Institute for Agronomy Research (INRA: Institut National de la Recherche Agronomique) with the aim of assessing the exposure of high consumers of seafood. The French Food Safety Agency (AFSSA: Agence Française de Sécurité Sanitaire des Aliments) made a substantial methodological contribution to the study and analysed its results. This study has improved our knowledge of the dietary habits of high consumers of fish and seafood in France and of their provisioning practices. It has yielded inventories of the levels of nutritional and toxic substances in these products consumed in different regions, and it has provided exposure data for these populations thanks to a study of the biological impregnation to contaminants. The outcome of the study is therefore an evaluation of the risks relative to the consumption of seafood products, which are then balanced with the nutritional benefits.

The study results shed new light on the relationships between diet and health and will help to better protect and inform the consumer. In addition, they enable France to make a useful contribution to the scientific and regulatory studies whether national, European or international levels.

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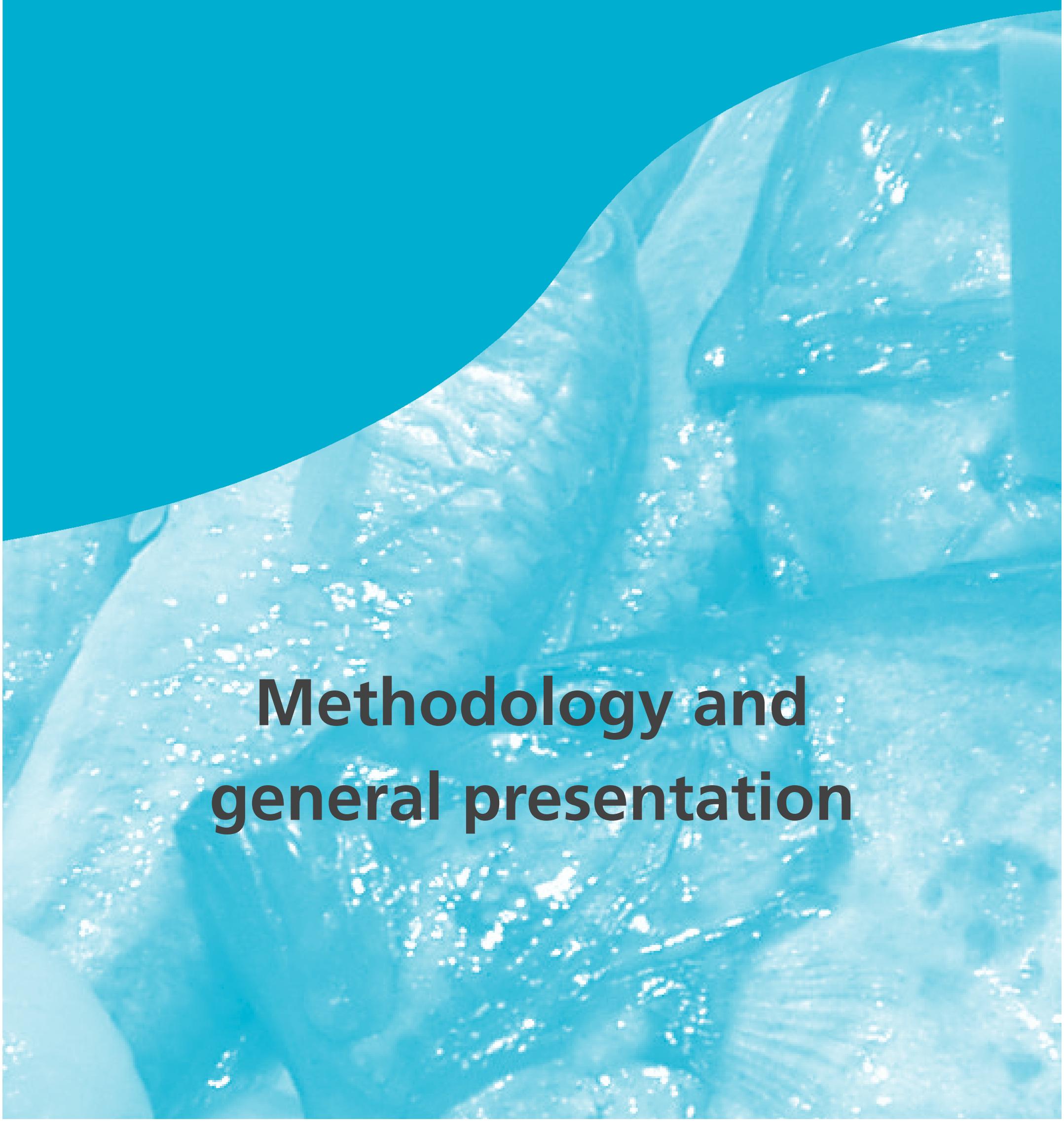
FIRST PART



Methodology and general presentation

Introduction

The scientific approach to the evaluation of the nutritional benefits of nutritive elements (minerals, fatty acids, etc.) in food and the health risks related to toxic substances (pesticides, heavy metals, natural toxins and other environmental contaminants) is to estimate the quantity of ingested substances then compare this with nutritional baselines and/or toxicological reference values. These nutritional and toxicological baselines defined by expert scientific committees form part of global public health programmes intended to confirm optimal cover of physiological needs and the absence of adverse effect on consumer health.

The evaluation of the dietary intake of a given nutriment or contaminant, also known as the "dietary exposure" is based on various approaches including the traditional one that consists in proffing consumption data with composition or contamination data[1]. In most cases this so-called "indirect" or "food exposure" approach provides a response to health questions posed by the national authorities responsible for evaluating and managing food risks.

In parallel with this first approach, a "direct" measure of the intakes by exposure biomarkers, complementary to the first, can be made if necessary in order to better characterise the benefits and/or the possible risks of a particular substance as regards consumer health. This method has the advantage of evaluating in situ, in other words in the biological tissue of individuals, the internal level of a nutriment and/or contaminant of interest; it also takes into account exposure channels other than food. However the results are not easy to interpret.

For many years seafood such as fish, molluscs and crustaceans has often been the focus of attention in nutritional and toxicological work. Nutritionists consider these products to be an important source of high-quality proteins, minerals and essential fatty acids such as omega 3, although only half the population follow the recommendation of the National Nutrition and Health Programme (PNNS) to consume fish at least twice a week[2]. Toxicologists tend to regard seafood as a major vector for toxic substances such as metal trace elements and persistent organic pollutants. The scientific reality is more complex and a reconciliation of these two viewpoints requires that we take into consideration both nutritional and toxic substances contained in food products and also consumer behaviour with regard to these products.

Concerning intakes of the omega 3 family of long-chain polyunsaturated fatty acids, today there is very little available data on the fatty acid content of fish and seafood or on biomarkers of exposure to omega 3 fatty acid in the French population, in particular in people consuming large quantities of seafood (other than through food supplements). Many studies have already demonstrated the involvement of the fatty acids eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), found mainly in fish and seafood, in the mechanisms protecting against certain pathologies, notably cardiovascular disease.

1 FAO/WHO. Guidelines for the study of dietary intakes of chemical contaminants. Geneva : WHO, Offset publication n°87. 1985.

2 Ministère de l'Emploi et de la Solidarité, Ministère délégué à la Santé. Programme National Nutrition-Santé. 2001-2005.

As regards exposure to trace elements, several recent studies have shown that for the average consumer in the general population the toxicological limits are not exceeded. Nevertheless, the absence of risk for the average consumer does not exclude a risk for heavy consumers, as underlined in many studies (French Total Diet Study (TDS) 2004[3], INCA Study 1999[4], reports of the French Upper Council for Public Health (CSHPF) in 1996[5] and the Parliamentary Office for the Assessment of Scientific and Technical Choices (OPECST) in 2001[6]). Moreover, the absence of French data on the levels of "indirect" or "direct" exposure to certain substances (omega 3 and pollutants in particular) of populations consuming large quantities of seafood does not enable a quantified assessment of the benefits or risks associated with these dietary habits, a situation that is obviously prejudicial to the global health risk evaluation and management process.

Consequently, it is necessary to push the analysis further by performing, first, a representative study of several French coastal populations that are regular consumers of seafood, and of their local provisioning and self-provisioning practices (beach fishing), and secondly a representative study of the biologicals levels of pollutants and omega 3 in these populations. The choice of coastal regions for the study is justified by their particularly high seafood consumption.

The objective of this study is therefore to make a survey of the nutritional intakes and exposure to trace elements and persistent organic pollutants of high fish and seafood consumers by examining their food consumption habits and analysing the real risks of these habits as well as their nutritional benefits, notably those associated with polyunsaturated fatty acids.

This study is described in three distinct and complementary parts (Figure 1):

- a consumption study focused on heavy fish and seafood consumers in four French coastal regions;

- a study of blood and urinary biomarkers associated with intakes of fatty acids and exposure to contaminants in a sub-sample of consumers having participated in the food consumption survey;

- a study of levels of fatty acids and contamination by trace elements and persistent organic pollutants in the seafood bought and consumed by the populations of the four coastal regions, applying a standardised international methodology of the "total diet study" (TDS) type[7] .

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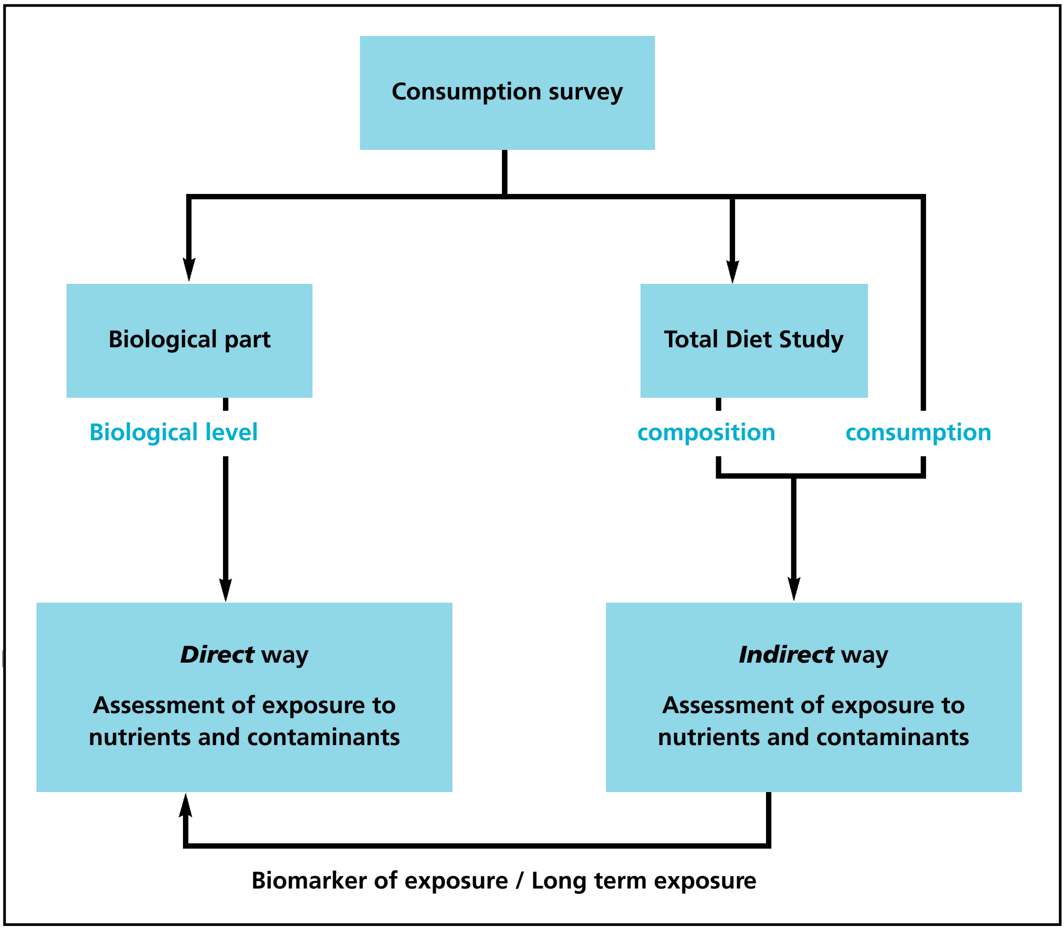
5 CSHPF, groupe de travail contaminants. Plomb, cadmium et mercure dans l'alimentation : évaluation et gestion du risque. Tec & Doc Lavoisier, Paris, 1996.

6 OPCST. Effets des métaux lourds sur l'environnement et la santé. 2001.

7 Total diet studies (TDS). Consultation US FDA/OMS, Kansas city, juillet/août 1999, consultation ANFZA/WHO/FAO, Brisbane, janvier 2002 et consultation INRA/WHO, Paris, Mai 2004.

Figure 1: General outlines of the Calipso study



1.1 Present situation

1.1.1 Fatty acids

Fish consumption and cardiovascular diseases

Many studies have demonstrated that fish consumption correlates inversely with coronarian mortality. More specifically, such mortality is observed to decrease by 15% among populations consuming fish at least once a week[8]. A 20 g increase in daily fish consumption reduces the coronary heart disease mortality risk by 7%. Moreover, these trends are accentuated in the case of oily fish.

One of the hypotheses proposed to explain this protective effect of fish consumption is their richness in fatty acids, in particular in polyunsaturated fatty acids of the omega 3 class.

8 He K., Song Y., Daviglus M.L., Liu K., Van Horn L., Dyer A.R. and Greenland P. Accumulated evidence on fish consumption and coronary heart disease mortality, a meta-analysis of cohort studies. Circulation 109 (22) : 2705-2711, 2004.

Fatty acids

Fatty acids are organic molecules composed of a carbonyl chain terminating on a carboxyl group. They are characterised by the length of their carbonyl chain, the number of double bonds and their position on the chain. We can therefore distinguish saturated fatty acids (SFA) with no double bonds, monounsaturated (MUFA) with a single double bond, and polyunsaturated (PUFA) with several double bonds. The PUFAs can be divided into four classes according to the position of the first unsaturation relative to the carbon atom at the methyl end: n-7 (omega 7), n-9 (omega 9), n-6 (omega 6) and n-3 (omega 3).

While saturated, monounsaturated and some polyunsaturated fatty acids (n-7 and n-9 classes) can be synthesised by the organism (Figure 2), the omega 3 and omega 6 precursors (alpha-linolenic and linoleic acid, respectively) must be provided by food; these are referred to as "essential fatty acids".

The physiological role of fatty acids is first and foremost energetic. But the polyunsaturated fatty acids of the essential n-6 and n-3 classes are above all important constituents of many structures (membrane phospholipids bringing fluidity and their properties to membranes) and some are precursors of oxygen mediators notably involved in the processes of inflammation and blood platelet aggregation (prostaglandins, thromboxanes, leukotrienes, etc.) [9 10].

Fatty acids and cardiovascular diseases

Many epidemiological studies have confirmed the adverse effects of an excess of SFAs in the development of cardiovascular diseases (CVD) and the associated mortality. Excessive SFA consumption correlates positively with mortality due to CVD and with factors of high risk of CVD. On the other hand, the consumption of MUFAs and above all PUFAs correlates negatively with CVD. The protective role of the n-3 PUFAs has been demonstrated in primary prevention and above all in secondary prevention of CVD. Long-chain omega 3 might help to reduce mortality, though not morbidity[10]. Long-chain omega 3 supplements might help to reduce cardiovascular risks by lowering the risk of sudden death of people with a history of cardiovascular problems. However they do not reduce the incidence of non-mortal cardiac infarct. More particularly, the protective role of alpha-linolenic acid (ALA), the precursor of the n-3 long-chain PUFAs, has been demonstrated in several clinical intervention studies, in particular those concerning prevention of sudden death in man[9]. Linoleic acid (LA), precursor of the n-6 long-chain PUFAs, tends to lower the cholesterolemy but it does not appear to reduce cardiovascular mortality. Generally speaking, the n-6 PUFAs have a lipid-lowering effect; they reduce the LDL-cholesterol, but they have no effect on the circulating triglycerides, whereas the n-3 PUFAs have a hypotriglyceridemiant effect (at least in certain population groups), although this concerns only the very long-chain compounds, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA).

Fatty acids and cancer

Today only experimental studies on animal models provide some information on the role of fatty acids in cancerous processes. The n-6 PUFAs encourage tumorous growth while the n-3 PUFAs have a protective effect[11 12]. However the mechanisms by which fatty acids act on the cellular cycle (modulation of the expression of proteins regulating the cellular cycle and the apoptosis) are not well understood.

9 Martin A. Coordonnateur. Apports nutritionnels conseillés pour la population française. 3e édition. Editions Tec & Doc, Lavoisier, Paris, 2001.

10 AFSSA. The Omega 3 fatty acids and the cardiovascular system: nutritional benefits and claims. July 2003.

11 CNERNA, CNRS. Riboli E., Decloître F. et Collet-Ribbing C., Coordonnateurs. Alimentation et cancer – Evaluation des données scientifiques. Tec & Doc, Lavoisier, Paris, 1996.

12 AFSSA. Acides gras alimentaires et cancers : état des connaissances et perspectives. 2003.

Fatty acids in food

The principal dietary sources of the precursors ALA (alpha-linolenic acid) and LA (linoleic acid) are vegetable oils and animal products. For example, rapeseed, nut and soyabean oils are rich in ALA and sunflower and maize oils are rich in LA. Animal products, in particular fish, seafood and breastmilk, provide long-chain n-3 PUFA compounds in substantial quantity. The n-6 PUFAs are found in quantity in terrestrial animal products, in particular meat and eggs and also in breastmilk.

Leaving aside dietary supplements, seafood products remain the major source of long-chain n-3 PUFAs since in humans the conversion of the precursor ALA into these long-chain derivatives is low: it has been shown that less than 1% of the ALA is converted into DHA[13 14] .

Figure 2 : Conversion capacity of fatty acids in animals and plants

n-3 Omega 3		n-6 Omega 6		n-9 Omega 9		n-7 Omega 7
				18:0	∈	16:0
				⇓ Δ 9	⇐	⇓ Δ 9
18:3		18:2				
Alpha-linolenic acid	Δ15	Linoleic acid	Δ12	18:1		16:1
(ALA)	⇐	(LA)	⇐			
⇓ Δ 6		⇓ Δ 6		⇓ Δ 6		⇓ Δ 6
18:4		18:3		18:2		16:2
⇓ ∈		⇓ ∈		⇓ ∈		⇓ ∈
20:4		20:3		20:2		18:2
⇓ Δ5		⇓ Δ 5		⇓ Δ 5		⇓ Δ 5
20:5		20:4		20:3		18:3
Eicosapentaenoic		Arachidonic				
acid		acid				
(EPA)		(AA)				⇓ ∈
⇓ ∈		⇓ ∈				
22:5	∈		∈			
Docosapentaenoic	⇒ 24:5	22:4	⇒ 24:4			20:3
acid						
(DPA)	⇓ Δ 6		⇓ Δ 6			⇓ Δ 6
22:6						
Docosahexaenoic						
acid						
(DHA)	β-ox	22:5	β-ox			
24:5	⇐ 24:6		⇐ 24:5			20:4

Plant kingdom — Plant and animal kingdom — Animal kingdom

∈ : Elongase — Δ5, Δ6 : Δ-desaturase — β-ox : β-oxydase

13 Pawlosky R.J., Hibbeln J.R., Novotny J.A. and Salem N.Jr. Physiological compartmental analysis of alpha-linolenic acid metabolism in adult humans. J. Lipid. Res., 42 : 1257-1265, 2001.

14 Goyens P.L.L., Spilker M.E., Zock P.L., Katan M.B. and Mensink R.P. Compartmental modeling to quantify alpha-linolenic acid conversion after longer term intake of multiple tracer boluses. J. Lipid. Res., 46 : 1474-1483, 2005.

Needs and intakes of the French population

Table 1 presents recommended daily allowances (RDA) determined for adults on the basis of plasmatic parameters for SFAs, MUFAs and PUFAs.

Table 1: National nutritional recommended daily intake of fatty acids in adults [9]

$kcal.d^{-1}$		SFA	MUFA	LA	ALA	LC-PUFA	DHA	Total
Adult man	$g.d^{-1}$	19.5	49	10	2	0.5	0.12	81
2200	% TEI	8	20	4.0	0.8	0.20	0.05	33
Adult woman	$g.d^{-1}$	16	40	8	1.6	0.40	0.10	66.0
1800	% TEI	8	20	4.0	0.8	0.20	0.05	33
Pregnant woman	$g.d^{-1}$	18	45.5	10	2.0	1	0.25	76.5
2050	% TEI	8	20	4.4	0.9	0.4	0.1	33.7
Breat-feeding woman	$g.d^{-1}$	20	50	11	2.2	1	0.25	84.2
2250	% TEI	8	20	4.4	0.9	0.4	0.1	33.7
Older subject	$g.d^{-1}$	15	38	7.5	1.5	0.40	0.10	62.5
1700	% TEI	8	20	4.4	0.9	0.4	0.1	33.7

TEI: Total energy intake (lipids, carbohydrates, proteins)
LC-PUFA: Long chain polyunsaturated fatty acids

Ideally, in the diet, the LA (18:2 n-6) / ALA (18:3 n-3) ratio should tend towards 5. This ratio was determined taking into account the existence of competition between the n-3 and n-6 PUFA classes in various enzymes (the desaturated $\Delta 6$ and $\Delta 5$) involved in the conversion of the precursors ALA and LA into essential long-chain PUFA derivatives (Figure 2).

To obtain the beneficial effects on the cardiovascular system and neurodevelopment some institutions recommend daily consumption of 0.2 g to 0.5 g of n-3 LC-PUFA[15]. The American Heart Association recommends daily consumption of 1 g of EPA and DHA[16].

Fatty acids and pregnant women

There have been few studies on the fatty acid needs of pregnant and breast-feeding women. Taking into account the needs of the foetus, the development needs of the placenta and state of pregnancy, the recommended daily allowances for pregnant women are estimated to be 10 g of LA and 2 g of ALA. For breast-feeding women, the daily needs are 11 g of LA and 2.2 g of ALA (Table 1).

DHA and arachidonic acid (AA) are essential in the development of the central nervous system of the foetus, in particular during the last quarter of gestation when the synthesis of brain cells is fastest. These two fatty acids are incorporated in the cellular membranes contributing to their structure and functions. However it appears that the conversion rate of the ALA into DHA is very low, which implies that the DHA content of cellular membranes depends more on dietary intake of DHA than on ALA. The RDA of DHA has been fixed at 0.25 g for pregnant and breast-feeding women.

Fatty acids and elderly people

In view of the lower energy needs after 65 years of age, the RDAs for elderly people are lower than for younger adults: 7.5 g of LA and 1.5 g of ALA. Concerning the long-chain n-3 PUFAs, there have been

15 EFSA. Opinion of the scientific panel on dietetic products, nutrition and allergies related to nutrition claims concerning omega-3 fatty acids, monounsaturated fat, polyunsaturated fat and unsaturated fat. July 2005.

16 Kris-Etherton P.M., Harris W.S., Appel L.J. Fish consumption, fish oil, (n-3) fatty acids, and cardiovascular disease. Circulation. 106 : 2747-2754. 2002.

indications of a reduction of the ability to convert EPA into DHA and/or an alteration of the oxidation of these fatty acids in elderly people[9], an alteration that has also been demonstrated on animal models[17 18].

Fatty acid intakes in the French population, in particular ALA and LA, were assessed by means of a panel of 5,008 volunteers aged between 35 and 60 in the SU.VI.MAX study (supplementation of vitamins and antioxidant minerals). The consumption data of the study were crossed with ALA and LA composition data supplied by the British Ministry of Agriculture, Fisheries and Food (MAFF), the American Department of Agriculture (USDA), and in France, the Informatics Centre for Food Quality (CIQUAL), the Meat Information Centre (CIV) and the Institute for Fats and Oils (ITERG).

Table 2: Intakes of linoleic and alpha-linolenic acids in France (data from SU.VI.MAX)[10]

		Min	P5	Mean	P95	Max
18:2 n-6 (LA)	M	1.53	2.81	4.26	6.21	10.54
(% TEI)	W	1.62	2.91	4.38	6.31	11.63
18:3 n-3 (ALA)	M	0.21	0.30	0,39	0.52	1.52
(% TEI)	W	0.19	0.32	0.41	0.55	1.11
Ratio 18:2 n-6 / 18:3 n-3	M	5.5	7.5	11.1	16.1	33.8
	W	4.5	7.3	10.8	15.7	34.6

TEI: Total energy intake, M: Men, W: Women

This work has shown that ALA intakes are lower than the RDAs (0.8% of total energy intake), regardless of age and sex (Table 2). The 18:2 n-6 / 18:3 n-3 ratio is too high, ranging from 5 to 34 with an average of about 11, compared to the RDA of 5.

On the other hand, to date there are no available data on intakes of LC-PUFA omega 3 (EPA and DHA) in the French population.

1.1.2 Trace elements

Mercury

Mercury (Hg) is a chemical compound used in many industrial activities (batteries, electric equipment, chemical industry, paints, dental amalgams). These sources are both environmental and anthropogenic, notably due to the combustion of fossil fuels, industrial releases and waste incineration.

The organic forms of mercury, in particular methylmercury (MeHg), are more toxic than the inorganic ones. The World Health Organisation (WHO) estimates that 99% of the MeHg absorbed by the population comes from food[19]. The major source of MeHg exposure for humans is fish[20 21 22]. Metallic mercury is transformed into organic mercury by marine bacterial microflora which makes it bioavailable and explains its marked ability to cumulate in shellfish and predator fish near the top of the trophic chain. Following ingestion, methylmercury is rapidly absorbed in the digestive tract and 90% is found in the blood. It then passes the hemato-encephalic barrier and concentrates essentially in the central nervous system.

17 Beier K., Volk L. and Fahimi H.D. The impact of aging on enzyme proteins of rat liver peroxisomes : quantitative analysis by immunoblotting and immunolectron microscopy. Vi rchows Archiv B Cell Pathol 63 : 139-146. 1993.

18 Perichon R. and Bourre J.M. Peroxisomal _-oxidation activity and catalase activity development and aging in mouse liver. Biochimie 77 : 288-293. 1995.

19 WHO, ICPS. Environmental Health Criteria 101, Methylmercury, Geneva : International Programme on Chemical Safety. 1990.

20 Direction Générale de la Santé (DGS). Etude sur la teneur en métaux dans l'alimentation. La diagonale des métaux Paris, 1992.

21 Decloître F. La part des différents aliments dans l'exposition au plomb, au cadmium et au mercure, en France. Cah. Nutr. Diét. 33 (3) : 167-175, 1998.

22 JECFA Evaluation of certain food additives and contaminants. 61th report of the Joint FAO/WHO Expert Committee on Food Additives and contaminants. WHO Geneva. 2004.

In humans and animals the brain is the main organ targeted by MeHg. This neurotoxicity appears in the adult brain but even more so in the developing brain. Moreover, MeHg diffuses easily through the placenta and is also found in human milk.

In both humans and animals the neurotoxic effects observed after exposure to high MeHg levels (concentrations greater than 100 mg/kg in human hair) are essentially sensorial, visual, auditory and motor deficiencies. On the other hand, in humans, the effects of exposure to low doses of MeHg are more difficult to identify.

In adults, epidemiological studies in Amazonia have revealed the presence of alterations of visual, somatosensorial and motor functions, and of memory, attention, learning ability and manual dexterity in people whose hair mercury level is 6 mg/kg or more [22, 23, 24, 25, 26]. The blood and the hair are good markers of MeHg exposure, in particular in conditions of uniform dietary regime, and these concentrations are linked to those of MeHg in the brain, which enables good estimation of the effects of mercury on health and the central nervous system [27]. Nevertheless the authors underline that the measured levels do not enable confirmation of a dose-response effect, since the concentrations measured in the biological matrices at the time of the study do not necessarily correspond to the earlier exposures that caused the observed adverse effects [22].

In children the main prospective epidemiological studies carried out in the Seychelles, New Zealand and the Faeroe Islands point to a correlation between dietary exposure to mercury during pregnancy and the appearance of neurological symptoms in children [28]. However different populations appear to have different sensitivity to mercury, which can also be affected by dietary habits and exposure to other contaminants.

Apart from its effects on the central nervous system, MeHg also appears to be able to affect the immunitary system of adults and the developing immunitary system [29, 30, 31]. Further experimental studies are necessary to confirm and clarify the mechanisms of this immunotoxicity.

In 1990 the WHO established a provisional tolerable weekly intake (PTWI) of 3.3 µg of MeHg/kg bw (kilograms of body weight) based on evaluations made by the JECFA (Joint FAO/WHO Expert Committee on Food Additives and Contaminants) from 1972 to 1989 [19]. However, in order to assure better protection for foetuses and infants, the WHO issued warnings for pregnant and breast-feeding women. In France, the CSHPF in 1998 and the AFSSA in 2002 [32] recognised the existence of sensitive groups (pregnant and breast-feeding women, very young children, fishermen operating in highly contaminated zones) and recommended the provision of specific information to encourage these particular groups to diversify the species of fish they consume. Following the publication of new results, the JECFA lowered the PTWI

23 Lebel J, Mergler D, Branches F, Lucotte M, Amorim M, Dolbec J, Miranda D, Arantes G, Rheault I, Pichet P. Evidence of early nervous system dysfunction in Amazonian populations exposed to low-levels of methylmercury. Neurotoxicology 17 : 157-168, 1996.

24 Lebel J, Mergler D, Branches F, Lucotte M, Armorin M, Larribe F, Dolbec J. Neurotoxic effects of low-level methylmercury contamination in the Amazonian Basin. Environ. Res. 79 : 20-32, 1998.

25 Dolbec J, Mergler D, Sousa Passos CJ, Sousa de Morais S, Lebel J. Methylmercury exposure affects motor performance of a riverine population of the Tapajos river, Brazilian Amazon. Int. Arch. Occup. 73 (3) : 195-203, 2000.

26 US EPA. Water quality criterion for the protection of human health : Methylmercury, Final. EPA-823-R-01-001. Washington. 2001.

27 JECFA Safety evaluation of certain food additives and contaminants. 53th report of the Joint FAO/WHO Expert Committee on Food Additives and contaminants. WHO Food Additives Series 44. WHO Geneva. 2000.

28 Murata K, Weilhe P, Araki S, Budtz-Jorgensen E, Grandjean P. Evoked potentials in Faroese children prenatally exposed to methylmercury. Neurotoxicol. Teratol. 21 : 471-472, 1999.

29 Ilback NG. Effects of methyl mercury exposure on spleen and blood natural killer (NK) cell activity in the mouse. Toxicology 25; 67 (1) : 117-124, 1991.

30 Ilback NG, Sundberg J, Oskarsson A. Methylmercury exposure via placenta and milk impairs natural killer (NK) cell function in newborn rats. Toxicol Lett. 58 (2) : 149-158, 1991.

31 Wild LG, Ortega HG, Lopez M, Salvaggio JE. Immune system alteration in the rat after indirect exposure to methyl mercury chloride or methyl mercury sulfide. Environ. Res. 74 (1): 34-42, 1997.

32 AFSSA. Avis de l'Afssa relatif à l'évaluation des risques sanitaires liés à l'exposition au mercure des femmes enceintes et allaitantes et des jeunes enfants, 21 Octobre 2002.

to 1.6 µg/kg bw in 2003[22]. This intake corresponds to a steady state concentration in the mother's blood of 56 µg of MeHg per litre assessed from a NOAEL for hair of 14 mg/kg (taking into account a hair/blood ratio of 250) that does not have any appreciable adverse effects on the foetus. The PTWI takes into account uncertainty factors: 2 for the variability between individuals of the relationship between the MeHg concentration measured in hair and that measured in the blood, and 3.2 for the inter-individual variability (pharmacokinetic component) of the relationship between the dietary intake of MeHg and the concentration measured in the blood. The AFSSA Opinion dated March 2004[33] confirmed the validity of this PTWI for the most sensitive population groups: pregnant and breast-feeding women and young children. The Food Standards Agency's advisory committees on contaminants in the United Kingdom has stated that in view of these new toxicological data there appears to be no reason to revise the PTWI established previously by the JECFA at 3.3 µg MeHg/kg bw for the general public, with the exception of sensitive populations[35].

In France, exposure studies to date tend to show that values close to or greater than the PTWI of 1.6 µg/kg bw/week can be reached by certain categories of high fish and seafood consumer, and notably very young infants and women of child-bearing age[33 36]. Better estimation of the exposure of the more sensitive groups taking into account both the species of fish consumed and their origin is necessary to correctly evaluate the risk run by these groups and, if need be, to enable the provision of better information – or even better recommendations than those made today – on dietary consumption.

Cadmium

Cadmium (Cd) is a contaminant found in the environment and in particular in the soil, due to erosion and human and agricultural activities. It thereby enters the food chain. In non-smoking individuals the main source of cadmium exposure is food. The most highly contaminated foods are molluscs, offal, leaf vegetables and cereals[20 21]. Digestive absorption of cadmium is low (about 5-10%). On the other hand, cadmium is a cumulative toxin whose biological half-life is very long (estimated to be 20-30 years in humans). The International Agency for Research on Cancer (IARC)[37] classifies cadmium as “carcinogenic for man” (category 1).

Cadmium has numerous toxic effects, but the main impact on the organism of prolonged exposure to cadmium in both man and animals is on the renal function. The nephrotoxic effects are characterised by degeneration of the proximal tubules and proteinuria[38 39 40 41]. The risk associated with this degeneration starts to increase when the urinary excretion of cadmium exceeds 2.5 µg/g creatinine. The JECFA Committee considers this to be the value for which there is an absence of prevalence of renal tubular malfunction[42]. In man, these alterations of the renal function can be accompanied by bone damage with osteomalacia

33 AFSSA. Avis de l’Afssa relatif à la réévaluation des risques sanitaires du méthylmercure liés à la consommation des produits de la pêche au regard de la nouvelle dose hebdomadaire tolérable provisoire (DHTP). 16 mars 2004.

35 FSA Advice on fish consumption : benefit and risks, Committee on toxicity and Scientific advisory committee on nutrition London TSO, 2004.

36 Crépet A., Tressou J., Verger P. and Leblanc J.C. Management options to reduce exposure to methylmercury through the consumption of fish and fishery products by the French population. Regul. Toxicol. Pharmacol. 42 : 179-189. 2005.

37 IARC. Monographs on evaluation of carcinogenic risks to humans. WHO, Lyon vol85 : 119. 1993.

38 JECFA. Safety evaluation of certain food additives and contaminants. 33th report of the Joint FAO/WHO Expert Committee on Food Additives and contaminants. WHO Technical Report Series 776. WHO Geneva. 1989.

39 Nogawa K, Honda R, Kido T, Tsuritani I, Yamada Y, Ishizaki M, Yamaya H. A dose-response analysis of cadmium in the general environment with special reference to total cadmium intake limit. Environ. Res. 48 (1) : 7-16, 1989.

40 Staessen JA, Buchet JP, Ginucchio G, Lauwerys RR, Lijnen P, Roels H, Fagard R. Public health implications of environmental exposure to cadmium and lead : an overview of epidemiological studies in Belgium. Working Groups. J. Cardiovasc. Risk 3 (1) : 26-41, 1996.

41 Jarup L, Hellstrom L, Alfven T, Carlsson MD, Grubb A, Persson B, Petersson C, Spang G, Schutz A, Elinder CG. Low level exposure to cadmium and early kidney damage: the OSCAR study. Occup. Environ. Med. 57 (10) : 668-672, 2000.

42 JECFA. Safety evaluation of certain food additives and contaminants. 55th report of the Joint FAO/WHO Expert Committee on Food Additives and contaminants. WHO. 2001.

and demineralisation[43 44]. Additionally, relationships exist in man and animals between cadmium exposure and retarded foetal growth[45]; reduced fertility in males has also been reported[46 47]. On the other hand, there is no confirmed relationship between dietary exposure to cadmium and arterial hypertension or cancer.

In France, the average daily intake of cadmium was estimated to be 19.6 µg for adults in 1998[21], 17 µg in 2000[48] and 3.6 µg in 2003[49]. Following the first French total diet study (TDS)[3], the latest estimations in 2005 indicate an average daily intake of 2.7 µg in people over 15 years old[50], which represents about 4% of the PTWI of 7 µg/kg bw/week established by the JECFA using a theoretical prediction model estimating the relationships between the dietary intake of cadmium, urinary excretion and associated prevalence of renal tubular malfunction[42].

The most contaminated foods are offal and seafood, notably molluscs. Seafood represents 8% to 25% of dietary intake of cadmium[51]. Vegetables, potatoes and similar products, due to their importance in human diets, are also major vectors of dietary exposure (23.7% and 21.2% respectively) in the general population[50].

Lead

Lead (Pb) is an environmental pollutant found in soil and the atmosphere, in particular in the neighbourhood of industrial sites and heavy automobile traffic.

The dietary intake of lead comes mainly from drinks[50], fresh fruit, vegetables and cereals. The contribution from drinks, which was non-negligible just a few years ago, is tending to decline rapidly as production methods are improved.

One of the major effects of lead on the organism is its hematological toxicity of which anaemia is the most common symptom. The presence of lead in the blood is the principal biomarker of lead exposure. Lead acts on the biosynthesis of the heme, inhibiting two key enzymes, gamma-aminolevulinic acid dehydratase (ALA-D) and ferrochelatase. In adults, urinary ALA-D excretion and free porphyrins of the erythrocytes, whose level is linked to the ferrochelatase, are exploited as biological markers for lead exposure[52]. In 1991 it was shown that lead exposure reduces the erythrocyte's defences against oxidation and shortens its life[53].

43 ATSDR. Toxicological profile for cadmium. Draft for public comment. US. Department of Health and Human Services. Public Health Service. Agency for Toxic Substances and Disease Registry, 1997.

44 Noël L., Guérin T. and Kolf-Clauw M. Subchronic dietary exposure of rats to cadmium alters the metabolism of metals essential to bone health. Food Chem. Toxicol. 42 (8) : 1203-1210. 2004.

45 Frery N, Nessmann C, Girard F, Lafond J, Moreau T, Blot, Lellouch J, Huel G. Environmental exposure to cadmium and human birthweight. Toxicology, 79 (2) : 109-118, 1993.

46 Xu B, Chia SE, Tsakok M, Ong CN. Trace elements in blood and seminal plasma and the relationship to sperm quality. Reprod. Toxicol. 7(6) :: 613-618, 1993.

47 Telisman S, Cvitkovic P, Jurasovic J, Pizent A, Gavella M, Robic B. Semen quality and reproductive endocrine function in relation to biomarkers of lead, cadmium, zinc, and copper in men. Environ. Health Perspect. 108 (1) : 45-53, 2000.

48 Leblanc J.-C., Malmauret L., Guérin T., Bordet F., Boursier B. and Verger P. Estimation of the dietary intake of pesticide residues, lead, cadmium, arsenic and radionuclides in France. Food Addit. Contam. 17 (11) : 925-932. 2000

49 Noël L., Leblanc J.-C. and Guérin T. Determination of several elements in duplicate meals from catering establishment using closed vessel microwave digestion with inductively coupled plasma mass spectrometry detection: estimation of daily dietary intake. Food Addit. Contam. 20 (1) : 44-56. 2003.

50 Leblanc J.-C., Guérin T., Noël L., Calamassi-Tran G. Volatier J.-L. and Verger P. Dietary exposure estimates of 18 elements from the 1st French Total Diet Study. Food Addit. Contam. 22 (7) : 624-641. 2005.

51 Tressou J., Crépet A., Bertail P., Feinberg M.H. and Leblanc J.-C. Probabilistic exposure assessment to food chemicals based on extreme value theory. Application to heavy metals from fish and sea products. Food Chem. Toxicol. 42 : 1349-1358. 2004.

52 Landrigan PJ. Current issues in the epidemiology and toxicology of occupational exposure to lead. Eniron. Hlth. Perspect. 89 : 61-66, 1990.

53 Sugawara E, Nakamura K, Miyake T, Fukumura A, Seki Y. Lipid peroxidation and concentration of glutathione in erythrocytes from workers exposed to lead. Br. J. Ind. Med. 48: 239-242, 1991.

Many studies have long demonstrated a correlation between hypertension and professional exposure to lead [54 55].

However, the most worrying impact of lead remains the neurotoxic effects (saturnism) it can cause. Lead perturbs the liberation of neuromediators by nerve cells and can pass the hemato-encephalic barrier. Epidemiological studies have shown that exposure of the foetus to small doses of lead can cause congenital abnormalities [56]. Exposure to doses of lead that do not result in the appearance of saturnism symptoms during infancy can nevertheless cause durable neuro-behavioural handicaps (reading difficulties, lower intellectual performance, absenteeism, etc.)[57].

The annual dietary intake of lead by the French population was estimated between 1978 and 1980 to be 60 mg, equivalent to 30% to 50% of the PTWI of 50 µg/kg bw/week fixed by the WHO in 1972. In 1987, the JECFA revised this dose to 25 µg/kg bw/week for children, then extended it to adults. The particular sensitivity of pre- and post-natal infants to the neurotoxic effect of lead implies that the dietary intake should be reduced for pregnant women, but no modification of the PTWI has been proposed. Dietary intake of lead has fallen substantially in industrialised countries with the disappearance of lead-based solders, the introduction of lead-free gasoline and improvements in food production and transformation practices, notably in vinification and wine making processes and food can soldering. The average daily dietary intake of the adult population was estimated to be 68 µg in 1998[21], 52 µg in 2000[48] and 34 µg in 2003[49], and it has been more recently estimated to be 18 µg[50], equivalent to 7% of the PTWI.

Seafood consumption (fresh fish, crustaceans and molluscs) accounts for 3% to 11% of lead intake via food. As for mercury and cadmium, we can suppose that values close to or even exceeding the PTWI are reached by the highest consumers. An estimation of the exposure of these people is therefore necessary.

Arsenic

Arsenic (As) is a soil contaminant naturally present in the environment but whose main anthropogenic origins are the use of phytosanitary products, atmospheric releases from incineration installations and industrial activity. The organic forms of arsenic – arsenobetaine (AsB), arsenocholine (AsC), monomethylarsonic acid (MMA), dimethylarsinic acid (DMA), etc. – are the predominant forms in food matrices. Whilst public health organisations still consider inorganic arsenic (As(III) and As(V)) to be the most dangerous forms and the methylated forms to be less harmful, in recent years scientists have revised this position as analytical speciation techniques continue to improve and in the light of the latest toxicological studies on the different forms of contaminants [58 59 60]. These studies reveal that DMA is probably carcinogenic or promotes carcinogenesis and that the MMA(III) and the DMA(III) are genotoxic[58]. In man, pentavalent arsenic As(V) is reduced to trivalent arsenic As(III), itself methylated into methylarsonic and dimethylarsinic acids, most of which are then excreted.

54 Cooper WC, Gaffey WR. Mortality of lead workers. J. Occup. Med. 17 : 100-107, 1975.

55 De Kort WLAM, Verschoor MA, Wibowo AAE, Van Hemmen JJ. Occupational exposure to lead and blood pressure: a study in 105 workers. Brit. J. Ind. Med. 11 : 145-156, 1987.

56 Baghurst PA, Robertson EF, Mc Michael AJ, Vimpani GV, Wigg NR, Roberts RR. The Port Prire cohort study: lead effects on pregnancy outcome and early childhood development. Neurotoxicology. 8: 395-401, 1987.

57 Needleman HL, Schell A, Bellinger D, Leviton A, Allred RN. The long-term effect of exposure to low doses of lead in childhood. N. Engl. J. Med. 322: 83-88, 1990.

58 Velez D. and Montoro R. Inorganic arsenic in foods : Current overview and future challenges. Recent Res. Devel. Agricultural & Food Chem. 5 : 55-71. 2001.

59 Vahter M. Mechanisms of arsenic biotransformation. Toxicology. 181-182 : 211-217. 2002.

60 Hirano S., Kobayashi Y., Cui X., Kanno S., Hayakawa T. and Shraim A. The accumulation and toxicity of méthylated arsenicals in endothelial cells : important roles of thiol compounds. Toxicol. Appl. Pharmacol. 198 (3) : 458-467. 2004.

The IARC classifies arsenic as "carcinogenic for man" (category 1). Severe exposure to arsenic results in vomiting, abdominal pain and diarrhoea; prolonged exposure to low doses of arsenic in drinking water can cause cancer of the skin, lung, bladder or kidney, and cutaneous disorders such as hyperkeratosis and pigmentation modifications[61 62].

In 1989 the WHO[38] fixed a PTWI of 15 µg/kg bw/week for inorganic arsenic.

The exposure to total arsenic can be of atmospheric origin and it is also increased by cigarette smoking, but dietary exposure remains the prime source. Much of the arsenic comes from fish and seafood. The scientific literature reports that 0.4% to 5.3% of the arsenic present in fish and seafood are in the form of inorganic arsenic[63]. The average daily intake of total arsenic in Europe was estimated in 2003 to be 125 µg in adults, and the contribution of seafood to this exposure exceeded 50%[64]. However little contamination data on all seafood is available today. More particularly in France, the average daily intake for the adult population was estimated in 2000 to be 109 µg[48] and in 2003 to be 147µg[49] of which 135 µg (95%) comes from fish. However this report underlines the difficulty in evaluating precisely the exposure to arsenic due to the diversity of its origins (sea fish, river fish, fish farms, etc.). European data provide average contamination levels for fish and seafood (including molluscs, crustaceans and echinoderms) ranging from less than 0.1 µg/g to 18 µg/g[64]. A more recent estimation indicates an average daily intake of 62 µg for adults (6.2 µg/kg bw/week for a person weighing 70 kg), of which 62% comes from seafood[50].

Organotin compounds

Organostannic compounds (OTC) present in the environment are mainly of anthropogenic origin. They are used as stabilizers and catalysts, vermifuges in the composition of plastics, biocides in paints, and in washing products and pesticides. Sludges from sewage treatments plants and industrial and agricultural activities are the main sources of environmental contamination.

Water pollution leads to contamination of living marine organisms almost permanently exposed to organic tin. These active substances are very certainly responsible for the toxic effects observable in marines species at very low doses, such as growth and reproduction disorders in oysters and sex changes in certain gasteropods.

In humans, food – and seafood in particular[65] – is the principal origin of organic tin absorption. Trisubstituted organic tin – tributyltin (TBT) and triphenyltin (TPT) – appear to be the most toxic. TBT causes endocrine perturbations and TPT affects the reproductive system and development[65]. Generally speaking, the organostannic compounds such as dibutyltin (DBT), tributyltin (TBT) and triphenyltin (TPT) are immunotoxic, causing a drop in the lymphocytes in the thymus and peripheral lymphoid organs[66 67].

61 Wu M.M., Kuo T.L., Hwang Y.H. and Chan C.J. Dose-response relation between arsenic concentration in well water and mortality from cancers and vascular diseases. Am. J. Epidemiol. 130 (6) : 1123-1132, 1989.

62 Chen C.J., Chen C.W., Wu M.M. and Kuo T.L. Cancer potential in liver, lung, bladder and kidney due to ingested inorganic arsenic in drinking water. Br. J. Cancer. 66 (5) : 888-892, 1992.

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64 SCOOP reports on tasks 3.2.11. Assessment of dietary exposure to arsenic, cadmium, lead and mercury of the population of EU Members States. 2003.

65 SCOOP reports on tasks 3.2.13. Assessment of dietary exposure to organotin compounds of the population of EU Members States. 2003.

66 Gennari A., Potters M., Seinen W. and Pieters R.. Organotin-induced apoptosis as observed in vitro is not relevant for induction of thymus atrophy at antiproliferative doses. Toxicol. Appl. Pharmacol. 147 : 259-266. 1997.

67 Gennari A., Bol M., Seinen W., Penninks A. and Pieters R. Organotin-induced apoptosis occurs in small CD4(+)CD8(+) thymocytes and is accompanied by an increase in RNA synthesis. Toxicology. 175 : 191-200. 2002.

In 2004 the European Food Safety Authority (EFSA)[68] established a group tolerable daily intake (TDI) of 0.25 µg/kg bw/day for tributyltin (TBT), dibutyltin (DBT), triphenyltin (TPT) and dioctyltin (DOT) based on TBTO molecular mass; this group TDI is 0.1 µg/kg bw when expressed as Sn content, in line with the CSTEE proposals (Committee on Toxicity, Ecotoxicity and the Environment) in 2003[69] and the WHO recommendations in 1999.

The rarity of the contamination data, in particular in France where they are almost inexistent, makes it difficult to evaluate population exposure. The data published in the SCOOP task 3.2.13[65] or in the European OT-SAFE report[70] are difficult to exploit for purposes of risk evaluation due to their qualitative and quantitative disparity. However these two studies do show that shellfish accumulate more organic tin than fish and crustaceans.

1.1.3 Persistent organic pollutants

Persistent organic pollutants are environmental contaminants mainly of anthropogenic origin (industrial and agricultural utilisations over the last 30 years) which, mainly due to their lipophilic nature, accumulate in food chains. Their have multiple effects on human health including genotoxicity, embryotoxicity and endocrine perturbations.

Dioxins and "dioxin-like" polychlorobiphenyls

Polychlorodibenzo-p-dioxins (PCDD) and polychlorodibenzofurans (PCDF) are compounds of similar molecular structure and physicochemical properties. There are 210 dioxin congeners, 75 PCDDs and 135 PCDFs. However only the toxicity of the 2.3.7.8-tetrachloro-dibenzo-p-dioxin (2.3.7.8-TCDD), the "Seveso dioxin", has been widely verified. This therefore serves as a reference in the calculation of toxicities as so-called Toxic Equivalents (TEQ) by applying Toxic Equivalent Factors (TEF) to the 16 other dioxin congeners and furans similar to 2.3.7.8-TCDD.

The polychlorobiphenyls (PCB) include 209 congeners that differ only in the number and position of the chlorine atoms on the biphenyl molecule. Twelve PCBs have toxicological properties similar to those of dioxins and are therefore referred to as "dioxin-like PCBs" (DL-PCB). TEF weightings are also applied to the DL-PCBs and they form part of the toxicity calculation along with the PCDDs and PCDFs.

In 2001, the JECFA fixed a provisional tolerable monthly intake for PCDDs, PCDFs and DL-PCBs at 70 pg TEQ_{WHO}/kg bw[71].

68 EFSA. Opinion of the Scientific Panel on Contaminants in the food chain on a request from the Commission to assess the health risks to consumers associated with exposure to organotins in foodstuffs. Question N°EFSA-Q-2003-110. September 2004.

69 Opinion of the Scientific Committee on Toxicity, Ecotoxicity and the Environment (CSTEE) on Revised assessment of the risks to health and the environment associated with the use of organostannic compounds (excluding use in antifouling paints). 43rd plenary meeting. 28 May 2004.

70 OT SAFE. Sources, consumer exposure and risks of organotin contamination in seafood. Final report of the European Commission Research Project OT-SAFE N° QLK1-2001-01437, 149p. Décembre 2004.

71 JECFA. Summary of the 57th meeting of the Joint FAO/WHO Expert committee on food additives. Rome, 5-14 June 2001.

"Indicator" polychlorobiphenyls

The seven congeners called "indicator PCBs" (i-PCB) 28, 52, 101, 118, 138, 153 and 180 have properties different from DL-PCBs. They have antithyroidian and neurotoxic effects. It is estimated that the exposure to i-PCB account for half the exposure to total PCB congeners due to their tendency to cumulate in food matrices and their toxicological impact on man [72]. Recent European studies indicate for adults an average daily intake of 0.01 to 0.045 µg i-PCB/kg bw [73].

Concerning all the PCBs, in 2002 the WHO proposed a TDI of 0.02 µg/kg bw, in Aroclor Equivalent [74]. The i-PCB analysis results must be multiplied by two to be expressed in Aroclor Equivalent. The calculated exposure is then compared with the TDI.

Polybromodiphenylethers

Polybromodiphenylethers (PBDEs) are flame retardants used in plastics and textiles. Since the 1970s they have accumulated in food chains, in aquatic biotopes in particular. These compounds are hepatotoxic, embryotoxic and also have antithyroidian effects, which is particularly worrying in view of the PBDE concentrations found in human milk [75].

To date no PTWI has been fixed for PBDEs at national, European or international level.

Fish and seafood are major contributors to dietary exposure to persistent organic pollutants: 25% to 30% for the 17 congeners of dioxin and furan type [78 79], 75% for PCBs (from the i-PCBs) [78], and 30% for the 7 PBDE congeners (28, 47, 99, 100, 153, 154, 183) [80]. In France, data from the INCA survey point to an estimated daily dietary intake of PCDDs and PCDFs in adults of 1.45 pg TEQWHO/kg bw in 2000 [78], and 0.5 pg/kg bw in 2005 [79]. The daily intake of DL-PCBs was estimated to be 1.2 pg/kg bw in 2006 [79].

72 AFSSA. Avis sur l'existence éventuelle d'une corrélation significative entre les teneurs dans différents congénères de PCB. Saisine n°2002-SA-0149. 2003.

73 EFSA. Opinion of the CONTAM panel related to the presence of non dioxin-like polychlorinated biphenyls (PCB) in feed and food. 2005. www.efsa.europa.eu <http://www.efsa.europa.eu>

74 WHO/IPCS. Polychlorinated biphenyls : Human health aspects. Geneva. 2003.

75 Norén K and Meironyté D. Contaminants in Swedish human milk. Decreasing levels of organochlorine and increasing levels of organobromine compounds. Organohalogen Comp 38 : 1-4. 1998.

78 SCOOP reports on tasks 3.2.5. Assessment of dietary intakes of dioxins and related PCBs by the population of EU Members States. 2000.

79 AFSSA, Rapport Dioxines, furanes et PCB de type dioxines : Evaluation de l'exposition de la population française. Avril 2006.

80 The third International Workshop on Brominated flame retardants, Toronto, June 2004.

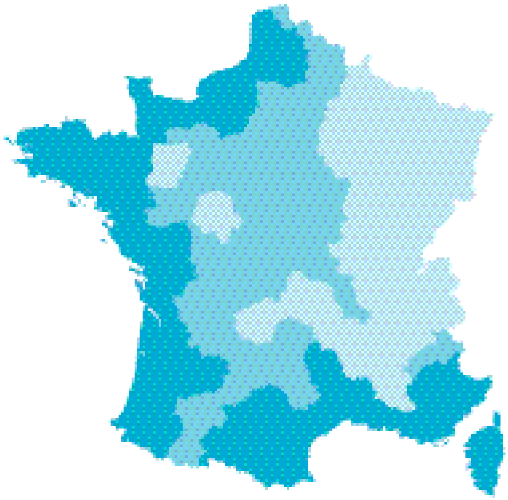
1.2 Study methodology

1.2.1 Selection of study zones and populations

The four coastal zones selected for the seafood consumption survey are Mediterranée/Var, Normandie/Baie de Seine, Bretagne sud, and Gironde/Charente Maritime sud.

The populations in these regions are the highest consumers of fish and seafood, as confirmed by a Food Consumption Observatory study in 1996 (OCA-CREDOC[81]). For example, as regards fish the highest consumptions are in Nord-Pas-de-Calais, Picardie, the Parisian Region, Haute-Normandie, Basse-Normandie, Pays de la Loire, Poitou-Charentes, Aquitaine, Languedoc-Roussillon, Provence-Alpes-Côte d'Azur and Corsica where annual consumption per household is 18.5 to 32.7 kg. It appears that fish consumption declines as we move away from the coast, which may be partly explained by widespread self-procurement of seafood by coastal populations. This hypothesis is supported by a CREDOC[82] survey of 400 representative households in the north of the Cotentin peninsular which reveals that 20% of the seafood consumed (fish, crustaceans and shellfish) is self-provisioned. Moreover we also note that the coastal regions have the highest number of retail seafood outlets[83][84] (Figure 3).

Figure 3: Retail trade for fish in 2002



Retail trade for fish in (2002)
Number of outlets for 100,000 inhabitants

- Light bleue : 0 à 2.5
- Middle bleue : 2.5 à 5
- Dark bleue : 5 à 30

There are many more fisheries near the coasts. The proximity of the sea explains why consumers are more tempted to buy fish, and when they do, to buy it in a traditional fishery rather than a supermarket.

Source : DGCCRF, 2002.

For each of the four zones one nearby fishing port enabling direct provisioning was selected where beach fishing is possible. Individuals were recruited within a radius of 20 to 25 km around this point. Between 20 and 27 towns were visited in each zone and the number of individuals questioned per town was calculated on the basis of the number of inhabitants published in the 1999 INSEE survey. The four large regions finally selected are Le Havre in Normandie/Baie de Seine, Lorient in Bretagne sud, La Rochelle in Gironde/Charente Maritime sud, and Toulon in Mediterranee/Var. The existence in each of these zones of an environmental source of a contaminant of interest was also a selection criterion, notably PCBs in the Baie de Seine and cadmium in the Gironde estuary.

81 OCA-CREDOC. Les disparités régionales de la consommation alimentaire des ménages français. Rapport n° CP004. Février 1996.
82 Dufour A. et Volatier J.-L. Enquête sur la consommation alimentaire dans le Nord Cotentin pour la Cogema. Juin 1998.
83 OFIMER (Office national interprofessionnel des produits de la mer et de l'aquaculture). La Lettre de l'OFIMER. Novembre 2001.
84 Cochez N. DGCCRF – Bureau A2. Les entreprises du petit commerce en France entre 1993 et 2003.

A representative consumer population sample was ensured by random recruitment (apart from the quotas applied) by door-to-door canvassing every five doors, using the so-called "random route" method.

About one thousand individuals were recruited, or 250 per zone. The people satisfying the inclusion criteria listed below were questioned.

Inclusion criteria

- Adult (18 years or older),

- Consumes seafood at least twice a week, a criterion defined in the 1999 INCA study and the recommendations of the PNNS. The median consumption frequency calculated from the individual seafood consumption data in the population of the INCA study was twice a week (CREDOC-AFSSA-DGAL, 2000[85]),

- Permanent resident in the zone for several years.

Exclusion criteria

- Refusal to participate: during the pilot survey about 42% of the people contacted refused to participate in the survey[86].

Over and above these inclusion criteria, the female population aged 18 to 44 years corresponding to women of child-bearing age was over-represented in order to obtain a sample representative of this population and a larger volume of consumption and biological data in view of the health risks associated with methylmercury. Based on an evaluation of the health risks of methylmercury consumed in seafood, in 2004 the AFSSA recommended that pregnant and breast-feeding women should consume no more than 150g of predator fish per week, in addition to their usual consumption of non-predator fish[32].

The dietary study covered all foods consumed by adults (18 years or older): seafood and other foods. This study is based on a questionnaire concerning consumption frequency validated during the pilot survey by means of 7-day consumption diaries. The portion sizes usually consumed were estimated by means of a book of sample photographs[87]. The survey involved a single interview during which the following points were covered:

- Presentation of the study to obtain the consent of the adult person to participate;

- Questionnaire concerning the frequency of food consumption in general and seafood in particular. Information was also collected on purchasing methods (fresh, frozen, canned, etc.) and on the usual origin of the seafood consumed (commercial and self-provisioning), the socio-demographic profile of the respondent and about ten closed questions on the perception of the food risks associated with seafood;

- Presentation of the biological part to obtain the informed consent of the respondent to participate if eligible (see below the exclusion criteria for the biological part).

85 CREDOC-AFSSA-DGAL, 2000. Enquête Nationale sur les Consommations Alimentaires. Editions Tec & Doc.

86 Afssa. Etude de faisabilité d'une enquête sur les "modes d'approvisionnement locaux en produits de la mer chez des forts consommateurs": évaluation de l'exposition aux métaux lourds et quantification du risque sanitaire associé. Note technique OCA/NB/JLV/2003-574. 2003.

87 Portions alimentaires : manuel photos pour l'estimation des quantities. SUVIMAX. 1994.

Exclusion criteria for the biological part

- Refusal to participate;

- People suffering from pathologies that could have repercussions on the biological level of omega 3, lead, mercury, arsenic or cadmium (renal disease, arterial hypertension, urinary incontinence).

1.2.2 Consumption survey

In order to have data on habitual consumptions, we gave priority to the food frequency questionnaire (FFQ). However, and in view of the fact that FFQs are less precise than questionnaires concerning short periods, such as consumption diaries or 24 h recall, we first performed a FFQ validation study[86].

This pilot survey was intended to prepare for the full-scale survey and was performed in two coastal zones (La Rochelle on Atlantic and Toulon on Mediterranean). The field survey involved 61 people aged 15 or over. The consumptions were recorded using a consumption diary and a food frequency questionnaire. Owing to the heavy work implied by a consumption diary and its poor representativeness of dietary habits over the year, this solution was excluded for the full-scale survey. It was therefore necessary to validate the lighter and less restrictive food frequency questionnaire for the main surveys. The results of this survey reveal poor correlation (correlation coefficient ranging from -0.1 to 0.15) between the consumption of some seafood products and the two collection methods. Several reasons could explain this disagreement. First, the seasonality of the consumption of certain seafood products. Indeed, since the diary does not reflect the dietary habits over the year, a large number of fish in the list on the FFQ had not been consumed when filling in the diary. Moreover some confusion was observed for several categories of products:

- Seafood products consumed fresh but also canned and/or smoked: these were therefore well separated and well identified in the FFQ used in the full-scale survey to avoid risk of confusion.

- Products for which several denominations are sometimes used (cod, grenadier/hoki, etc) or which have local names: for these we tried to be as exhaustive as possible by indicating all the known names or by grouping the names designating the same product.

These two points led us to review the classification of products subject to confusion in the statistical analysis of the pilot survey data.

On the other hand, satisfactory correlations were observed for well identified seafood products (salmon, skate, perch and trout for which the correlation coefficient ranged from 0.35 to 0.5) and for the other food categories.

The FFQ was therefore validated and improvements were made prior to the full-scale survey.

The survey was carried out in all the selected zones between October and December 2004. In all, 6,379 people were contacted by door-to-door recruitment and 43% agreed to participate. Of these 2,768 people, 1,757 (almost 66%) failed to meet the inclusion criteria previously defined and were therefore ineligible:

- 24% said they do not eat any fish or seafood,
- 34% did not consume seafood at least twice a week,
- 2% did not reside permanently in the town concerned,
- 3% were under 18 years old.

In the four zones a total of 1,011 interviews were carried out.
Tables 3 and 4 present the detailed results concerning the acceptability of the food survey part for each of the four zones.

Table 3 and 4: Participation in the study and distribution by zone

	Refusal	Agreement	Total
Le Havre	1,028	777	1,805
Lorient	950	742	1,692
La Rochelle	804	564	1,368
Toulon	829	685	1,513
Total	**3,611**	**2,768**	**6,379**

	Eligible	Non eligible					Total
	Interview	City	Age	Consumption	Consumption frequency	Other	
Le Havre	251	7	13	256	250	-	777
Lorient	249	14	31	229	219	-	742
La Rochelle	253	10	19	21	261	-	564
Toulon	258	33	26	153	214	1	685
Total	**1,011**	**64**	**89**	**659**	**944**	**1**	**2,768**

In order to assure consistency between the exploitation of the data and the national and/or international recommendations concerning omega 3 intake and exposure to contaminants, the population was divided into three categories and one sub-category (Table 5):

- Male adults: men aged 18 to 64 years,
- Female adults: women aged 18 to 64 years,
    - In order to acquire information on the risks or benefits of fish consumption by women of child-bearing age, a sub-category was also defined: women from 18 to 44 years old.
- Elderly people: the population aged 65 or over without distinction of sex.

The data on consumption, nutritional intakes and exposure to contaminants were analysed for each of these population categories in each of the zones.

Table 5: Distribution of the respondents by survey region

Category	Le Havre	Lorient	La Rochelle	Toulon	Total
Adult men (aged 18-64)	45	53	88	60	246
Adult women (aged 18-64)	180	159	125	177	641
Women of childbearing age (aged 18-44)	98	77	79	96	350
Older subjects (aged 65 and more)	26	37	40	21	124
Total	**251**	**249**	**253**	**258**	**1,011**

The female population is effectively over-represented (about 2.5 times more than men) and in particular women aged 18 to 44, which enabled us to better exploit the data for this particular target population. The data for pregnant women were not exploited owing to the very small sample size (n=14).

Tables 6 and 7 present the professional situations and the professional categories of the respondents who were still working at the time of the study. More than the half the respondents had a profession, the other half being inactive (unemployed, homemaker, invalid, etc.), retired or military. All social categories are represented.

Table 6: Professional situation of the respondents

Present professional situation	Le Havre	Lorient	La Rochelle	Toulon	Total	
Exercises a profession	133	111	148	131	523	51.7%
Student	27	7	4	14	52	5.1%
Job seeker	1	3	2	5	11	1.1%
Annuitant	1	6	4	3	14	1.4%
Retiree	43	66	55	29	193	19.1%
Long-duration illness or invalid	3	6	6	10	25	2.5%
Housewife, Homemaker	31	38	12	47	128	12.7%
Unemployed worker	12	12	21	18	63	6.2%
Military	0	0	1	1	2	0.2%
Total	**251**	**249**	**253**	**258**	**1011**	**100%**

Table 7: Distribution of professional situation among active individuals

Professionnal situation	Le Havre	Lorient	La Rochelle	Toulon	Total	
Farmer	0	1	0	0	1	0.2%
Artisan, trader or contractor	8	13	13	8	42	8.0%
Manager or high intellectual profession	8	13	15	13	49	9.4%
Intermediate profession	26	20	41	35	122	23.3%
Employee	68	42	54	53	217	41.5%
Worker	16	21	20	19	76	14.5%
No reply	7	1	5	3	16	3.1%
Total	**133**	**111**	**148**	**131**	**523**	**100%**

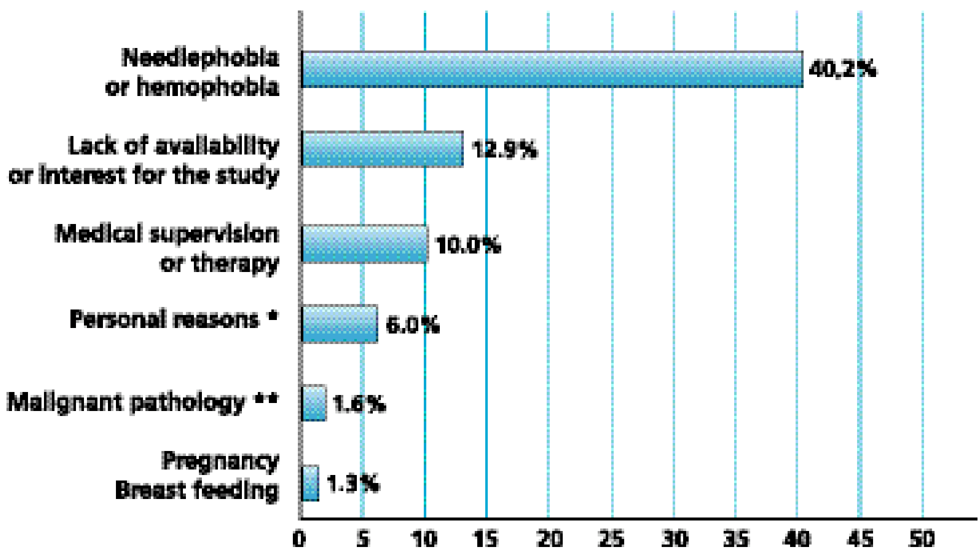
1.2.3 Biological part

This is a study of biomarkers of exposure to fatty acids and environmental contaminants, exploiting biological samples taken from consumers participating in the food consumption survey. Despite the general interest shown in the subject of this study, 52.8% of the people questioned did not participate in the biological part: 39.1% did not wish to, for the reasons shown below, 13.2% were not eligible for health reasons (see the exclusion criteria for the biological part) and 0.5% (5 people) did not reply (Table 8). The 55% acceptance rate among the eligible people is high for this type of public health study. Figure 4 shows the distribution of the reasons for refusal (several replies were possible; the results correspond to the aggregated replies).

Table 8: Participation in the biological part

	Agreement	Refusal	Non eligible	No reply	Total
Le Havre	103	109	38	1	251
Lorient	126	80	41	2	249
La Rochelle	119	106	28	-	253
Toulon	129	100	27	2	258
Total	**477**	**395**	**134**	**5**	**1,011**

Figure 4: Reasons for refusal to participate in the biological part



* refusal to take a sample for religious or philosophical convictions, or considering it as an attack on privacy or fear to be infect during sampling
** cancer or haemophilia

Of the eligible respondents 477 people agreed to participate in this biological part; 83 desisted and 394 were sampled (Table 9).

Table 9: Summary of sampling

	Agreement	Desistance	Sampling	among		Age
				Females	Males	
Le Havre	103	15	84	66	18	44 ± 15 y
Lorient	126	13	115	91	24	46 ± 14 y
La Rochelle	119	25	100	57	43	47 ± 14 y
Toulon	129	30	95	75	20	44 ± 13 y
Total	**477**	**83**	**394**	**289**	**105**	

From October to December 2004, the samples were taken by selected medical laboratories in each of the four zones. They also performed the lipids profile for each individual. The samples were stored at -20°C in suitable containers until their analysis. This storage temperature was maintained throughout the transportation of the samples to the analytical laboratories.

The biological samples were analysed for a profile of fatty acids in the erythrocyte membrane, and also for lead, mercury, arsenic and cadmium and the toxic forms of arsenic and mercury (inorganic arsenic and methylmercury).

The exposure of the subjects to fatty acids was evaluated by performing a fatty acids profile of the phospholipids in erythrocyte membranes, since with a 120 days half-life these phospholipids provide a good marker of the long-term dietary regime[88], unlike adipose tissue or plasma which could only reflect the last meal. Plasma being constituted essentially by triglycerides, it does not provide a good marker for long-chain n-3 PUFAs intake. Similarly a profile based on adipose tissue takes into account only the latest variations of the fatty acid levels in the diet. The level of the erythrocyte membrane phospholipids integrates all these fluctuations over the preceding three months.

Concerning trace elements, total blood and urine constitute the most appropriate biomarkers for evaluating the levels of individuals chronic exposure[89 90 91 92 93].

Analysis of the biological samples

Lipids profiles were performed using 4 ml blood samples:

- Lipids profile (total cholesterol, HDL cholesterol, LDL cholesterol and triglycerides) based on serum using the classic analysis methods of medical laboratories.

- Fatty acids profile on the pellet fraction of the erythrocyte membrane phospholipids, notably long-chain PUFAs: EPA (eicosapentaenoic acid) and DHA (docosahexaenoic acid).

88 Weill P., Schmitt B., Chesneau G., Daniel N., Safraou F. and Legrand P. Effects of introducing linseed in livestock diet on blood fatty acid composition of consumers of animal products. Ann. Nutr. Metab. 46 : 182-191. 2002.

89 WHO/IPCS. Biomarkers and risk assessment : Concepts and Principles. Environmental Health Criteria 155. Geneva. 1993.

90 WHO/IPCS. Environmental Health Criteria 224. Arsenic and arsenic compounds. Geneva. 2001.

91 WHO/IPCS. Biomarkers and risk assessment : Validity and validation. Environmental Health Criteria 222. Geneva. 2001.

92 Kido T., Sunaga K., Nishijo M., Nakagawa H., Kobayashi E. and Nogawa K. The relation of individual cadmium concentration in urine with total cadmium intake in Kakehashi River basin, Japan. Toxicol. Letters. 152 : 57-61. 2004.

93 Sanzo J.M., Dorronsoro M., Amiano P., Amurrio A., Aguinagalde F.X., Azpiri M.A. and the EPIC group of Spain. Estimation and validation of mercury intake associated with fish consumption in an EPIC cohort of Spain. Public Health Nutr. 4(5) : 981-988. 2001.

Fatty acids

The fatty acid profile of erythrocytes was performed on the blood collected in heparin tubes and immediately centrifuged (3,500 g, 10 min., 4°C) after elimination of the plasma. The erythrocytes were frozen at -80°C.

The erythrocyte lipids were first extracted[94]. After evaporation of the solvents, the total lipids were saponified then esterified. The methylic esters were extracted then separated and quantified by gas phase chromatography coupled to a flame ionisation detector. The identification of the methylic esters of fatty acids is based on the retention times obtained for standard methylic esters.

Trace elements

The trace elements analyses were based on total blood and urine.

The total lead, mercury, cadmium and arsenic were determined by Inductively Coupled Plasma-Mass Spectrometry (ICP-MS), a sensitive, multi-element detection system. To ensure optimal reliability of the blood analysis results, the lead, cadmium and mercury were measured by two different laboratories on all the samples taken. The lead, cadmium and total arsenic were measured in the urine samples. The laboratories' detection limits for these trace elements are presented in Table 10.

The speciation of arsenic was performed on a hundred samples presenting the highest total arsenic concentration (>75 µg/g creatinine). The inorganic arsenic, the most toxic forms, was measured after elimination of the AsB and AsC by extraction in liquid-liquid phase. The remaining arsenic, inorganic As, As(III) and As(V) and their intermediate mono- and dimethylated derivatives, MMA and DMA of degree V was determined by graphite furnace atomic absorption spectroscopy using Zeeman effect background correction.

Table 10: Standards and analytical limits for trace elements [95] :

Trace element	Biological matrice	Limit of detection	Limit of quantification	Standard*
Lead (Pb)	Total blood	0.2-0.3 µg/L	0.7-10 µg/L	<90 µg/L total blood (man) <70 µg/L (woman)
	Urine	0.15 µg/L	0.5 µg/L	<25 µg/g créatinine
Cadmium (Cd)	total blood	0.03-0.3 µg/L	0.1-1 µg/L	<2 µg/L (smoker) <1 µg/L (no smoker)
	Urine	0.1 µg/L	0.5 µg/L	<2 µg/g créatinine
Mercury (Hg)	Total blood	0.3 µg/L	1.0 µg/L	<10 µg/L
Methylmercury (MeHg)	Total blood	0.3 µg/L	1.0 µg/L	
Total Arsenic (As)	Urine	1.3 µg/L	5 µg/L	
Arsenic forms**	Urine		10 µg/L	<10 µg/g créatinine

* correspond to the P95 for the general French population which is not professionally exposed
** As(III), As(V), MMA (V) and DMA (V), considered as more toxic

94 Rioux V., Lemarchal P. and Legrand P. Myristic acid unlike palmitic acid, is rapidly metabolized in cultured rat hepatocytes. J. Nutr. Biochem., 11 : 198-207, 2001.

95 INRS. Biotox. www.inrs.fr. Mise à jour en mai 2005

1.2.4 "Total Diet Study" part

This part of the study is intended to estimate the intakes of nutriments and environmental contaminants of the adult population studied by means of a local total diet study (TDS) covering consumed fish and seafood. This study is based on the methodology developed in the total diet study of the French population [3]. It consists in sampling the fish and seafood mainly consumed by the population studied, taking into account the form of purchase (fresh, frozen, canned, etc.) and provisioning (bought or self-procured) and seasonal effects (consumption and contamination). However in this study seasonal effects were not taken into account in view of the fact that all the sampling was performed between January and April 2005. In a traditional total diet study foods are analysed "as-consumed" (with the exception of conserves), in other words pre-cooked, cooked, raw, etc. In the present case, the foods were not cooked and the analyses were made on raw samples conserved from one to four weeks at -20°C, which does not modify the fatty acids composition [96] or the content of trace elements or persistent organic pollutants.

Preparation of the list of food samples

The list of sampled food is based on an analysis of the individual dietary consumptions of the respondents. It is composed of the seafoods (fish, molluscs, crustaceans, etc.) mainly consumed by the respondents. The list is designed to cover:

- Sea fish whose daily consumption per person is at least 1 g;
- All predator fish, whatever their level of consumption: tuna, ray, ling, seabass, seabream, grenadier, halibut, eel, anglerfish, catshark, swordfish, emperor;
- Crustaceans and molluscs whose average daily consumption per person is at least 1 g;
- All other canned or smoked seafood or seafood-based products, whatever their level of consumption.

The final list included 138 fresh and frozen products (32 for Le Havre, 38 for Lorient, 35 for La Rochelle, 33 for Toulon), plus 21 canned products, smoked products or prepared seafood-based dishes mentioned in the food frequency questionnaire, making 159 products in all (Appendix 1).

As shown in Table 11, these cover 88% to 100% of the total consumption of fish and seafood.

Table 11: Coverage by sampling of the total fish and seafood consumption in each region

Site	Fish	Mollusc, crustacean	Other seafood *
Le Havre	89.2%	89.7%	100%
Lorient	96.1%	89.2%	100%
La Rochelle	89.0%	90.9%	100%
Toulon	93.0%	88.1%	100%

*canned food, smoked fish and seafood-based dish

96 AFSSA. Avis relatif à l'évaluation des différences qui existent entre le poisson d'appellation "frais" et le poisson d'appellation "congelé", de deux points de vue : celui de la nutrition et celui de l'information au consommateur au moment de l'achat. Saisine n°2003-SA-0367. 2004.

Sampling

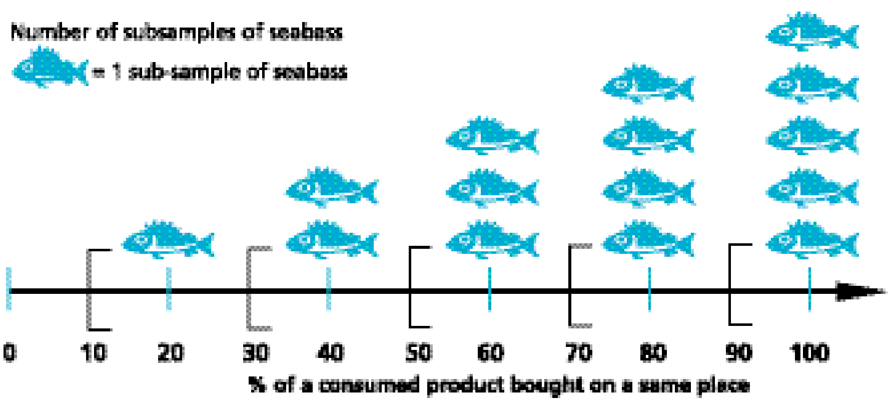
The following parameters were taken into account:

- quantities consumed,
- consumption frequencies,
- purchase methods (fresh, semi-fresh, frozen, canned, etc.),
- provisioning place (beach fishing, purchase on the fish dock, at the market, from a fish merchant, in another type of shop, or consumption outside the home),
- product origins (preferentially local, regional, etc.).

The sampling has not taken into account the proportion of wild fish and farmed fish insofar as this information did not appear in the food frequency questionnaire.

A sample of about 1,000 g was taken for each fresh product, allowing five 200 g sub-samples. The origin and distribution of these sub-samples were determined according to the place of purchase, based on the purchase frequency data of the consumption survey, which were weighted by the consumption frequency and quantity consumed. Figure 5 presents the manner in which the samples were constituted. For example, if 10% to 29% of a fish consumed is bought in a supermarket, a sub-sample of the composite sample comes from a supermarket. If 30% to 49% of the same fish is bought from a fishmonger, two sub-samples of the composite sample come from fishmongers, and so on. The purchase form (percentage of purchases of fresh and/or frozen products) was taken into account in the number of samples corresponding to purchases made in supermarkets.

Figure 5: Composition of a food composite sample according to the place of purchase (Example of seabass)



The samples of canned and smoked products and prepared seafood dishes were composed taking into account the market shares of the different brands, based on the purchasing data of households in the Secodip panel (2001). These are not composed of five sub-samples, as for the fresh products, but of x samples of different brands covering the market shares as widely as possible, as presented in Table 12 for a product shared between 5 different brands.

Table 12: Illustration of the representative sampling for a product

Brand	Found on the market	Market share	% in sample
A	Yes	40%	50.0%
B	Yes	30%	37.5%
C	No	10%	-
D	Yes	10%	12.5%
E	No	10%	-
Total		**100%**	**100%**

Taking into account the effective presence of products on the market, the market coverage was 37% to 80.4% for canned products, 42.9% to 91.5% for smoked products and 50.3% to 72.3% for other products (prepared seafood-based dishes).

For each product in the list, the 5 sub-samples were mixed, ground and remixed to obtain a single homogeneous composite sample of the product. The sub-samples were composed only of the comestible parts of the products. More precisely, fish were filleted and skinned (notably the smoked fish). The canned foods were drained, particularly when they contained oil; for shellfish only the soft content was ground (plus the coral in the case of scallops); crustaceans were peeled in order to sample only the flesh (notably legs and claws of crabs and lobsters); mollusc and crustacean samples were composed of raw and/or cooked sub-samples.

The use of intermediate recipients was not allowed during the preparation of the samples. The mixing equipment used was made of stainless steel (K55 Dito Cutter/Mixer). In compliance with good laboratory practices, the hardware used to prepare the composite samples was thoroughly washed (RBS.25 detergent) between each preparation in order to avoid cross-contamination between samples.

After preparation, the samples were stored at -20°C in suitable containers until the time of analysis. This storage temperature was maintained throughout the transportation of the samples to the analytical laboratories.

Analysis of the food samples

The analyses involved both nutritional and toxic elements in the products sampled. Concerning the toxic elements, the measurements concerned total lead, cadmium, arsenic and mercury, the various forms of speciation of arsenic (As(III), As(V), MMA, DMA, AsB), of mercury (methylmercury) and of organostannic compounds (monobutyltin (MBT), dibutyltin (DBT), tributyltin (TBT), monophenyltin (MPT), diphenyltin (DPT), triphenyltin (TPT), monooctyltin (MOT), dioctyltin (DOT) and trioctyltin (TOT)), and persistent organic pollutants (POPs): 17 dioxins and furans, 12 dioxin-like PCBs, 7 indicator PCBs and 7 PBDEs, most of them found (28, 47, 99, 100, 153, 154, 183).

The same samples were also analysed for saturated, monounsaturated and polyunsaturated fatty acids (48 fatty acids in all).

Table 13 shows the detection limits (LOD) and quantification limits (LOQ) of the various analyses.

Fatty acids

The principle consists in extracting, purifying and esterifying the free fat in the samples according to the AFNOR NF V04-403 standard. After drying the sample, the fat is extracted, filtered through a column, then weighed and esterified. The esters are analysed using a gas phase chromatograph equipped with a flame ionisation detector. The identification of the esters in fatty acids is based on the retention times obtained for standard esters. The concentrations, calculated relative to a standard, are based on the areas of the corresponding peaks.

Trace elements

The trace elements in the food matrices were measured by ICP-MS. Sixteen replicas were analysed. The speciation of mercury (methylmercury) was performed by coupling gas phase chromatography and ICP-MS, and that of arsenic (AsB, MMA, DMA, As(III) and As(V)) by coupling liquid phase chromatography and ICP-MS. The compounds MMA and DMA detected in the tissue of fish and seafood are of redox potential V. The organostannic compounds were analysed by gas phase chromatography coupled with a microwave-induced plasma and an atomic emission detector.

Persistent organic pollutants

The samples are first lyophilised then ground. For the analysis of the dioxin congeners, furans, DL-PCBs, i-PCBs and PBDEs, markers preimplanted with ^{13}C are added before extraction. The fat is then extracted by accelerated solvent extraction (ASE) using a toluene/acetone mixture under high pressure and temperature (P=100 bar, T=120°C)[97]. The solvents are evaporated in order to determine the quantity of fat extracted. The extract is finally purified in three successive open chromatographic columns.

After these fat extraction and purification steps, a quantification standard is added in order to evaluate the recovery yields.

The four fractions obtained corresponding to each of the pollutant classes are analysed by gas phase chromatography coupled to a high-resolution mass spectrometer (GC-HRMS).

97 Marchand P., Matayron G., Gadé C., Le Bizec B. et André F. PCDD/F, dioxin-like and markers PCBs in trouts from French aquaculture. Organohalogen Compounds, vol 66.

Table 13: Analytical limits for fatty acids, trace elements and persistent organic pollutants in food samples

	Limit of detection	Limit of quantification
Fatty acids (mg/g lipid)	-	1
Trace elements (µg/g fresh weight)		
Lead (Pb)	0.0004	0.001
Cadmium (Cd)	0.0004	0.001
Mercury (Hg)	0.0008	0.003
MeHg	0.0007	0.002
Arsenic (As)	0.002	0.005
AsB	0.005	0.002
As(III)	0.002	0.008
DMA	0.002	0.008
MMA	0.007	0.02
As(V)	0.01	0.03
Organotin		
MBT	0.0002	0.0005
DBT	0.0001	0.0004
TBT	0.00008	0.0003
MPT	0.0002	0.0008
DPT	0.0002	0.0005
TPT	0.0002	0.0005
MOT	0.0002	0.0005
DOT	0.0002	0.0008
TOT	0.0002	0.0008
Persistent organic pollutants ($pgTEQ_{WHO}$/g fresh weight - ng/g fw)		
PCDD	-	-
PCDF	-	-
PCB-DL	-	-
iPCB	0.001	0.001
PBDE	0.001	0.001

1.3 Presentation and interpretation of the results

The results are described in five parts. The first treats the results of the fish and seafood consumption survey, the second the composition in nutriments and contamination in contaminants of these same products, the third the nutritional intakes and exposure to contaminants. Two methodological approaches of evaluation of nutriment intakes and exposure to contaminants are presented, first a so-called "direct" or "biomarkers of exposure" approach, then an "indirect" or "food exposure" approach. The fourth part presents the perception of risks by participating consumers, and the fifth part presents some general remarks for discussion.

In the sections entitled "Seafood composition and contamination" and "Nutritional intakes and exposure to contaminants" the following substances are treated successively: fatty acids, trace elements and persistent organic pollutants.

1.3.1 Estimation of consumptions and concentrations

Concerning fish and seafood consumption, the results are presented in the form of three national tables, the first one for fish, the second for molluscs and crustaceans, and the last one for other seafood (canned, smoked, prepared dishes). Each table describes the average quantities consumed, the 95th percentile of consumption and the consumption rate (the % of consumers consuming a given product), for each product and each group of individuals (male adults, female adults, women of child-bearing age and people over 65 years old).

Concerning the composition of the products, and as in the "consumption" part of the study the results are presented in the form of three national tables: one for each category of foods. Each table describes the average quantities of each element analysed in the food samples listed in alphabetic order. The total lipids (total and unsaponifiable fatty acids) expressed in g/100 g corresponds to an average of two analyses on the same samples, but made two different laboratories using two methods (NF V04-403 standard and accelerated extraction by solvents). The unsaponifiable parts not having been analysed, the levels were deduced from the literature when possible (USDA database for the common species). For fish not covered by the literature, the unsaponifiable levels were estimated as recommended by the FAO and applied by the CIQUAL[98]. For molluscs, crustaceans and other products the average unsaponifiable levels were estimated from values found in the literature.

The consumption data are expressed in g/week, the fatty acid levels in mg/100 g of food, the trace elements in µg/g of food, and the persistent organic pollutants in pg TEQ_{WHO}/g of food for dioxins, furans and DL-PCBs and in ng/g of food for i-PCBs and PBDEs.

1.3.2 Estimation of missing or censured data

Missing composition data for the products not sampled in the study zones were completed on a case-by-case basis. In some cases, a data item missing in one zone was replaced by the average of the data available for the other zones. In others cases a product was not sampled at all (not found on the markets at the time of sampling or very little consumed) so no measurement could be made (7 fish and 12 molluscs or crustaceans). The fatty acid level was then estimated either by exploiting information available in the national and/or international literature or by applying the calculated average for products of the same family, class or order.

The trace elements that were undetectable (<LOD) or unquantified (<LOQ) were taken to be equal to half these limits, in line with international recommendations[99]. For the persistent organic pollutants, since it is generally accepted that at high resolution (GC-HRMS) the LOD is equal to the LOQ, half the LOD was taken for undetectable concentrations. For the censured fatty acid measurements, the levels were not taken into consideration.

1.3.3 Estimation of fatty acids and contaminants intakes

Food exposure (Indirect approach)

The average intakes of fatty acids and contaminants were calculated by crossing the individual consumption data from the food consumption survey with the individual composition and/or contamination data obtained by analysis of the representative food samples in the consumption/provisioning sets selected in each study zone. The estimation of these intakes takes into account a coverage exceeding 90% of the individual consumptions of fish and seafood declared by the populations studied in each of the four zones (Table 11).

The fatty acid intakes via fish and seafood are expressed in mg/day; the trace element intakes are expressed in µg/kg bw/week; the persistent organic pollutants intakes are expressed in pg TEQ_{WHO}/kg bw/week for dioxins, furans and DL-PCBs or in ng/kg bw/day for i-PCBs and PBDEs.

98 Greenfield H. and Southgate D.A.T. Food composition data. Production, managements and use. Second edition. FAO. Rome 2003. To express fatty acid levels in g/100 g of fatty acids from fatty acid levels in g/100 g of lipid, we use a corrective factor: 0.70 for lean fish (<1% of total lipid), 0.80 for semioily fish (1 to 5% of total lipid), 0.90 for oily fish (>5% of total lipid).

99 International Programme on Chemical Safety/Gems/Food Euro Workshop on reliable evaluation of low level contamination of food, Kulmbach, Federal Republic of Germany. May 1995.

These results are presented in the form of a table for each region showing the average quantities and high quantiles (P95) of fatty acids and contaminants contained in food for the four groups of individuals (mean ± standard deviation, or SD). The exposure value for the high quantiles does not correspond to the sum of the high quantiles of exposure of each group of foods taken into account since the high consumers associated with each group are not the same. We should remember that the exposure is calculated for each individual on the basis of his/her declared real body weight. Eighteen individuals out of the 1,011 respondents did not state their body weight, so this was taken to be the average weight of individuals of the same sex and age group.

Moreover, when necessary the text indicates the main vector(s) contributing to the total exposure and/or toxicological reference value (TRV), expressed here as a poucentage, following the methodology of fixing food standards as recommended by the Codex Alimentarius Committee on Food Additives and Contaminants[100].

biomarker of exposure (direct approach)

One table for each region describes for each group of individuals the average and high-quantile (P95) results of the levels of biological exposure of the 394 subjects of the study, for fatty acids measured in the erythrocytes, and for trace elements in urine and blood.

Fatty acid and trace element levels that were undetectable (<LOD) or unquantified (<LOQ) were taken to be equal to the half these limits. The composition of the fatty acid profile of the erythrocytes is expressed as a percentage of the total lipids. The trace element concentration is expressed in µg/L for blood or in µg/L or µg/g creatinine for urine.

Characterisation of risks/benefits

This final stage of the risk evaluation aims to describe the breakdowns of intakes or biomarker and to compare the average level, the P95 and even the P97.5 of the exposed population with reference nutritional or toxicological values established by national, European or international expert scientific committees (AFSSA, EFSA, JECFA). The results obtained are expressed as equivalents or as contribution to the reference values.

Unlike the food exposure approach which in this study concerned only the contribution of fish and seafood products but not other foods, the biomarker approach enables us to characterise the real levels of omega 3 and contaminant biological exposure of populations. In theory it therefore offers a suitable risk/benefit approach for fish and seafood consumption. However a prerequisite is the availability of a common physiological target for which beneficial and adverse effects have been described and linked to an effect or state of health of a population studied. The comparison of these two information sources is indispensable for an objective analysis in this type of approach. In reality, from a methodological point of view the scientific approach is complex and necessitates further in-depth work later.

At this stage, only a descriptive analysis of the benefits of daily consumption of omega 3 as regards cardiovascular diseases and an analysis of the risks of daily intake of methylmercury was performed, based on existing recommendations and published epidemiological data, but without correlating the impact on the health of our population. To do this, we start from the assumption that beneficial nutritional

100 Joint FAO/WHO Food standards programme, Codex Alimentarius Commission (CCFAC), CCFAC policy for exposure assessment of contaminants and toxins in foods or food groups adopted, procedural manual, 15éme edition, Rome 2005

effects may appear in individuals whose omega 3 intakes conform to the recommendations and that, inversely, toxicological effects may appear in individuals whose exposures exceed the reference toxicological values. A quantification of these risk/benefit effects in relation to fish and seafood consumption is thereby obtained empirically simply by estimating the number of individuals that match the nutritional recommendations and those that exceed the reference toxicological values.

Moreover, to better explain or explore any differences in dietary habits, in the composition of the provisionings, in the estimated intakes of nutriments and contaminants and in biological levels, a statistical analysis was performed between the regions. Additionally, correlations were calculated between the different variables, fatty acid intakes, exposure to contaminants evaluated by the indirect approach and the direct approach and also using socio-demographic variables using SAS.7 in order to validate the selected exposure markers from a methodological point of view.

Interpretation of the results

It is necessary here to make some important remarks regarding the interpretation of the results:

- *The use of the average concentration of composition or contamination in the indirect approach represents a realistic and appropriate estimation of the long-term omega 3 intakes and exposure to contaminants from fish and seafood products in that these data are based on representative sets of consumptions and provisionings of the populations studied in the four zones, and also in that these data are compared with reference lifelong nutritional and toxicological levels established by European or international scientific committees[101].*

- *Toxicologists generally agree that as regards chronic toxic effects, occasional exposure exceeding the reference toxicological values for short periods of the life of an individual does not necessarily induce a significant human health risk due to the fact that the toxicological reference values (TRV) contain a safety margin[102].*

- *Nutritionists generally agree that omega 3 fatty acids have a beneficial effect on prevention of CVDs and development of the cerebral nervous system. Nevertheless at present the respective involvement of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) LC-PUFAs is debatable. In France the ratio of the precursors of omega 6 and omega 3, linoleic acid (LA) / alpha-linolenic acid (ALA), is recommended to tend to 5 in adults. The recommended daily intakes vary depending on scientific authority. In France the recommended daily intakes are 2 g ALA and 500 mg n-3 and n-6 LC-PUFAs including 120 mg DHA[15 a]. At international level, the International Society for the Study of Fatty Acids and Lipids (ISSFAL) recommends a minimal daily intake of 500 mg n-3 LC-PUFAs (EPA and DHA) concerning the prevention of CVDs[103].*

- *Epidemiologists generally agree that validated exposure biomarkers constitute good indicators of the total long-term dietary (or other) exposure of individuals and are consequently valid indicators for interpreting the level of toxicological risk or nutritional benefit to which consumers are exposed.*

101 FAO/WHO. Food consumption and exposure assessment of chemicals Geneva: WHO, Offset publication n° 97. 1997.

102 ILSI Europe, Significance of Excursions of intake above the Acceptable Daily Intake (ADI), Report of a workshop held in April 1998.

[a] ANC, 2001. Recommended daily intake in adult male for a total energy intake of 2200 kcal/day, i.e. 0.8% of the total energy intake (TEI) for ALA, 0.2% of the TEI for omega 3 and 6, and 0.05% of the TEI for DHA. A discussion has been opened in France on an update of this values.

103 International Society for the study of Fatty Acids and Lipids. Report of the Sub-Committee on commendations for intake of PUFA in healthy adults. Issfal Newsletter. June 2004.

Moreover, it is important to bear in mind that this study is representative of the methodology applied and that there is some "background noise" in exposures of dietary origin of high fish and seafood consumers in the four coastal areas. Consequently, a priori it does not take into account special situations of overexposure, for example due to possible local environmental sources of contaminated food (e.g. consumers who do not respect interdiction of beach fishing) or to atypical consumer behaviour (e.g. intake of food supplements).

Finally, in view of our adoption of a composite food sampling approach (Total Diet Study method), one should bear in mind that the comparative statistics calculated on the composition or contamination of food and for which trends are observed, not significant differences, necessitate complementary investigations in view of the relative smallness of our sampling compared to statistical sampling of monitoring plan type.

SECOND PART

Fish and seafood consumption

Seafood consumption by high consumers

On examination of the results relating to weekly seafood consumption, and despite our verifications of the completed questionnaires, some data appeared absurd. It therefore appeared reasonable to eliminate individuals consuming more than 5 kg of seafood per week (corresponding to a consumption of 714 g per day or 357 g per meal) and individuals consuming less than 200 g of seafood per week (29 g per day), since these are not representative of high seafood consumption. In all 15 individuals were excluded for this reason.

Consequently, the results concerning the seafood consumption are presented for 996 individuals.

For the questions relating to provisioning habits or perception of food risks, the calculations include the entire sample of 1,011 individuals.

2.1.1 Fresh and frozen fish

National level (4 zones)

We were able to verify that the selected consumers were indeed high seafood consumers. The average consumption of fresh and frozen fish (excluding conserved or smoked products) was found to be 633 g/week, or 90 g/day in men aged 18 to 64 years with a 95th percentile of 1,491 g (Table 14). For women in the same age group the average is 637 g/week, or 91 g/day, with a 95th percentile of 1,522 g/week. Finally, the average consumption of subjects over 65 years old is 788 g/week, or 112 g/day, with a 95th percentile of 1,783 g/week.

In all the zones and all the population groups (male adults, female adults and elderly people) cod is the fish most consumed, not only in terms of quantity but also in percentage of consumers: the average quantity consumed is about 93 g/week, and the consumer rate is between 81% and 88%. Women of child-bearing age conform to the same trend as female adults, but with an even higher consumer rate.

Salmon, saithe and sole are also among the most consumed fish. Women consume more salmon and saithe (67 and 59 g/week) than men (56 and 54 g/week) and elderly people (57 and 50 g/week). On the other hand, for the latter group sole is the second most consumed fish (63 g/week) while it is only fourth in the other groups (50 g/week for men and 35 g/week for women).

Apart from these four fish, the distribution of the consumed species differs between groups. For example, elderly people consume much more herring than the other groups (32 g/week versus 8 g and 9 g/week for male and female adults, respectively). Elderly people also consume more ray (42 g/week versus 25 and 26 g/week for under-65 men and women, respectively), with a consumers rate of around 56%.

Regional level

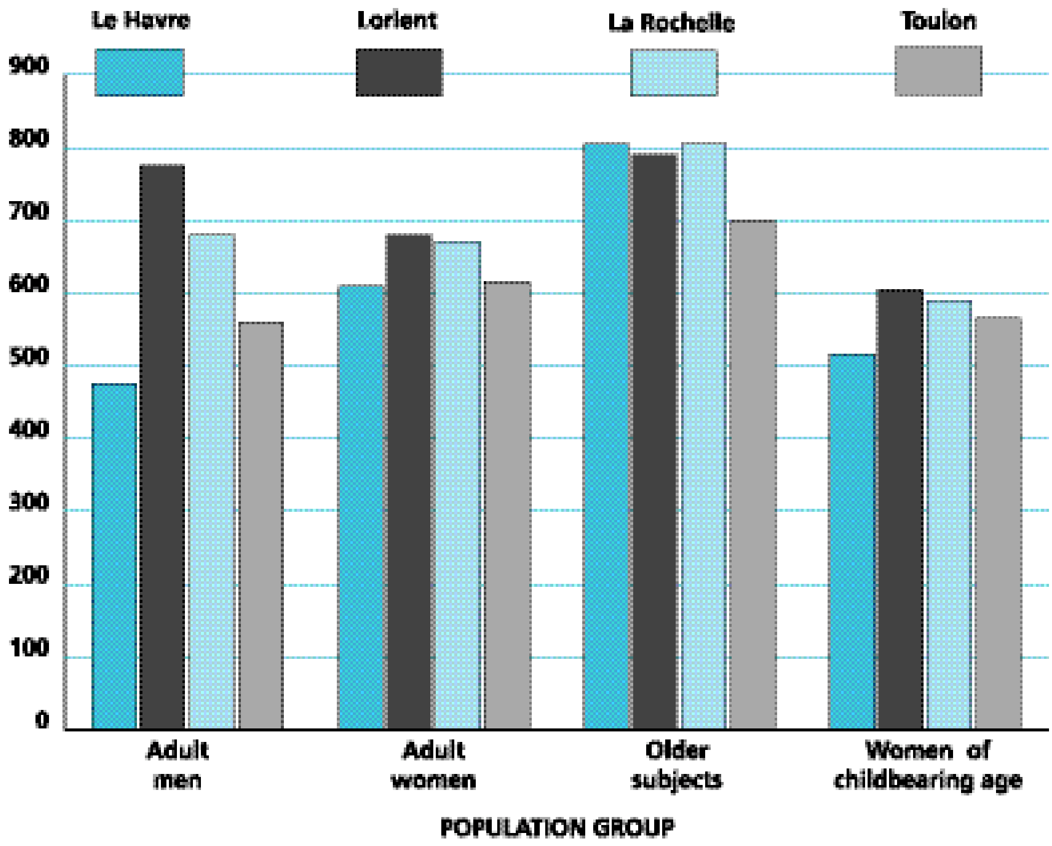
The regional differences are presented in Figure 6. Generally, male adults in Le Havre consume significantly less fish than those in Lorient ($p<0.01$) and La Rochelle ($p<0.05$). The average fish consumption in Lorient is also higher than that in Toulon for this same age group ($p<0.05$). In the other groups, no difference in fish consumption was observed between the different zones.

Table 14: Consumptions of fresh and frozen fish by high consumers (g/week)

Fish	Adult men (18-64 y) n = 243			Adult women (18-64 y) n = 630			Older subjects (65 y and more) n = 123			Women of childbearing age 18-44 y) n = 344		
	Mean	P95	%***	Mean	P95	%***	Mean	P95	%***	Mean	P95	%***
Anchovy	7.70	37.5	10.7	6.50	22.5	7.60	3.90	45.0	9.80	9.50	18.8	7.60
Angler fish*	14.1	55.0	39.1	16.9	62.5	42.9	21.3	93.8	40.7	13.0	50.0	35.8
Catshark*	7.80	50.0	16.9	10.2	62.5	20.8	9.00	50.0	20.3	10.3	62.5	19.5
Cod	92.6	325	81.5	93.3	245	87.5	93.6	231	81.3	86.4	219	88.7
Dab	9.40	50.0	18.5	14.5	93.8	22.1	23.5	100	28.5	12.7	93.8	17.4
Eel*	6.70	25.0	15.2	4.70	17.5	8.30	3.00	25.0	10.6	2.40	17.5	8.10
Emperor*	3.70	18.8	8.20	3.80	25.0	9.40	4.10	25.0	13.0	1.20	0.00	4.40
Goatfish	9.20	50.0	23.0	9.60	45.0	26.8	20.3	113	34.1	6.60	37.5	21.5
Grenadier*	8.80	50.0	18.1	14.8	93.8	27.1	20.0	93.8	30.1	13.3	93.8	23.5
Grouper	0.60	0.00	2.50	1.80	0.00	4.10	0.60	0.00	2.40	1.20	0.00	3.50
Gurnard	4.10	22.5	8.20	4.70	18.1	6.80	10.6	47.5	15.4	3.50	0.00	4.40
Haddock	7.50	25.0	11.1	4.90	37.5	9.70	15.7	100	20.3	3.50	18.8	6.40
Hake	25.7	125	33.3	24.5	138	31.9	31.7	138	45.5	21.4	119	31.1
Halibut*	7.30	37.5	18.5	12.6	62.5	23.0	12.7	50.0	20.3	10.2	50.0	20.1
Herring	7.70	56.3	18.5	8.90	45.0	18.4	32.2	100	17.9	7.50	37.5	16.0
John dory	3.60	18.8	10.3	4.40	25.0	14.4	8.00	50.0	17.9	2.30	18.8	8.10
Ling*	20.0	100	30.9	18.2	100	33.2	28.6	125	44.7	13.2	62.5	29.7
Mackerel	26.7	109	41.2	24.9	113	39.7	28.4	150	45.5	24.4	113	33.7
Mullet	2.80	18.8	6.60	4.70	18.8	5.70	1.00	0.00	3.30	3.70	0.00	4.90
Plaice*	8.20	50.0	12.3	11.5	75.0	16.5	22.1	100	20.3	8.10	37.5	11.3
Pollack	12.0	55.0	20.2	14.1	93.8	21.7	18.9	119	33.3	10.6	50.0	18.6
Pout	2.20	13.0	6.20	2.20	6.50	5.60	2.30	25.0	6.50	1.60	0.00	4.40
Ray*	25.2	125	43.6	25.6	119	46.3	42.3	125	56.1	22.6	100	40.7
Redfish. rockfish	0.50	0.00	0.80	0.90	0.00	1.40	1.90	0.00	3.30	0.50	0.00	1.20
Saithe / coalfish	53.8	200	62.6	58.5	200	67.9	49.6	200	52.0	64.1	200	76.7
Salmon	55.6	191	60.5	67.3	220	71.1	56.5	220	60.2	70.6	220	74.7
Sardine	24.7	109	54.7	19.6	93.8	44.1	26.7	109	56.9	14.3	93.8	34.9
Scorpionfish	3.30	25.0	8.60	3.20	22.5	11.0	5.70	25.0	12.2	2.30	18.8	9.30
Seabass*	29.7	109	53.9	23.3	100	44.6	26.2	125	45.5	16.6	65.6	41.9
Sea bream*	26.5	119	37.9	23.4	113	37.3	30.3	150	39.8	16.3	70.0	30.2
Smelt	2.80	18.8	7.00	2.10	17.5	7.00	1.60	6.30	6.50	2.30	18.8	7.60
Sole	49.5	250	58.0	35.1	172	48.7	62.8	275	60.2	35.9	172	47.1
Sprat	0.40	0.00	0.80	0.30	0.00	1.40	0.70	0.00	3.30	0.20	0.00	1.20
Swordfish*	7.90	48.8	16.0	5.70	27.5	11.6	8.30	27.5	17.9	4.90	27.5	9.90
Tuna*	32.6	191	45.3	28.0	138	43.2	29.3	138	48.8	24.0	113	38.1
Turbot	3.90	23.8	6.20	2.30	18.8	8.30	4.20	25.0	10.6	2.00	18.8	7.00
Whiting	25.2	125	37.0	26.1	125	43.3	27.5	125	43.1	23.8	100	41.3
Other**	3.10	9.40	5.30	3.20	22.5	7.10	2.60	0.00	3.30	2.50	18.8	6.40
TOTAL	**633**	**1,491**	**99.6**	**637**	**1,522**	**100**	**788**	**1,783**	**100**	**569**	**1,287**	**100**

* Predatory fish as described in the Commission Regulation (EC) No 78/2005 of 19 January 2005 ** Other: Perch, blenny, trout, scabbard-fish, wrasse, conger, Atlantic needlefish, sard, goby, maigre, shark, mahimahi, barbet *** Consumers rate

Figure 6: Mean consumptions of fish per zone, age group and sex (g/week)



2.1.2 Molluscs and crustaceans

National level (4 zones)

The average consumption of molluscs and crustaceans is 270 g per week for men aged 18 to 64, with a 95th percentile of 703 g; 260 g for women in the same age group, with a 95th percentile of 665 g; 279 g for people over 65, with a 95th percentile of 649 g (Table 15).

In male adults, the highest average consumption is of oysters, shrimps and great scallops, with respectively 41 g, 36 g and 34 g per week. Shrimps have the highest consumers rate of the three (92% versus 70% for great scallops and 67% for oysters). Mussels are also very widely consumed: 88% of all men aged 18 to 44 years say they consume on average 23 g per week.

Among women in the same age group, shrimps, great scallops, oysters and mussels are the most consumed seafood, with respectively 42 g, 40 g, 28 g and 22 g per week. Shrimps and mussels have the highest consumers rates (92% and 86% respectively).

Women consumers aged 18 to 44 years (i.e. women of child-bearing age) display the same trends both in terms of average consumption (235 g per week, with a 95th percentile of 607 g) and similar of molluscs and crustaceans consumption profiles.

Among elderly people, oysters and great scallops (51 g and 43 g per week) stand out from other crustaceans and molluscs. Shrimps and mussels, consumed less than oysters (37 g and 24 g respectively) are consumed by more individuals (85% and 88% respectively).

Table 15: Consumptions of molluscs and crustaceans by high consumers (g/week)

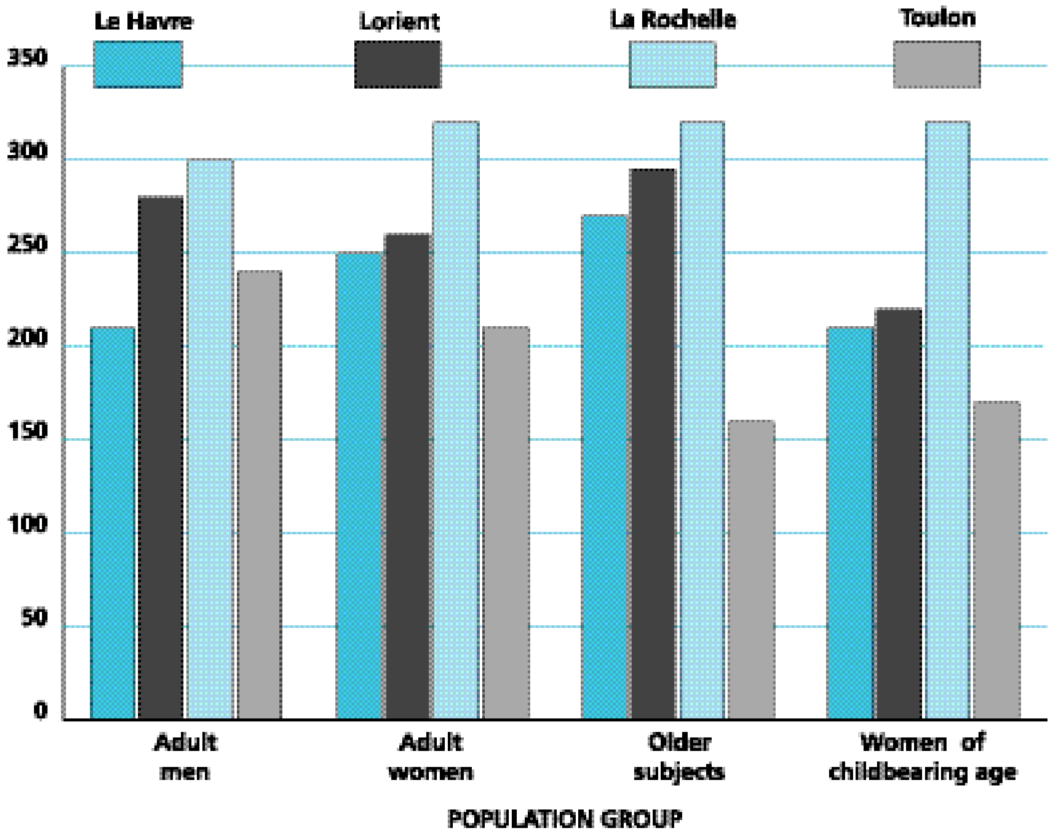
Molluscs, crustaceans	Adult men (18-64 y) n = 243			Adult women (18-64 y) n = 630			Older subjects (65 y and more) n = 123			Women of childbearing age (18-44 y) n = 344		
	Mean	P95	%**	Mean	P95	%**	Mean	P95	%**	Mean	P95	%**
Abalone	0.60	0.00	1.20	0.30	0.00	1.10	1.70	0.00	1.60	0.40	0.00	1.20
Calico scallop	14.6	46.9	21.4	11.5	45.0	26.5	22.5	113	33.3	13.8	45.0	24.7
Carpet shell	3.50	20.0	26.3	2.20	10.0	21.4	2.90	12.0	33.3	1.90	10.0	18.3
Clam	0.30	0.00	4.50	0.20	0.00	4.00	0.20	0.00	1.60	0.10	0.00	4.10
Cockle	2.40	12.5	23.5	3.20	17.5	26.2	3.00	17.5	22.0	2.50	12.5	23.3
Common periwinkle	3.80	15.0	47.7	4.20	25.0	47.6	5.10	25.0	44.7	3.60	12.5	43.0
Crab	8.80	40.0	61.7	8.30	40.0	58.7	8.00	25.0	51.2	7.50	25.0	57.8
Crayfish	1.80	12.5	12.8	1.60	12.5	13.7	0.40	0.00	4.10	1.80	12.5	16.0
Donax clam	0.10	0.00	0.80	0.40	0.00	1.90	0.20	0.00	1.60	0.20	0.00	0.90
Great scallop	34.0	125	69.5	39.8	156	73.2	42.6	156	67.5	34.0	125	70.1
Grooved sea squirt	1.30	0.00	2.50	0.90	0.00	3.20	0.70	0.00	1.60	0.70	0.00	2.60
Hard clam	1.40	9.40	16.9	1.10	6.30	14.4	2.60	12.5	20.3	0.70	6.30	9.90
Limpet	0.10	0.00	0.40	0.30	0.00	1.40	0.40	0.00	0.80	0.30	0.00	1.20
Lobster	4.10	22.5	13.6	5.50	45.0	18.4	3.20	22.5	12.2	6.20	45.0	19.5
Mussel	23.1	70.0	88.1	21.6	70.0	85.6	24.1	70.0	87.8	21.2	70.0	84.0
Octopus	7.10	32.5	18.5	4.10	26.3	13.7	1.60	16.3	7.30	3.60	26.3	13.4
Oyster	40.9	144	67.1	27.9	90.0	61.4	51.3	144	71.5	23.8	90.0	55.5
Queen scallop	1.10	0.00	2.50	0.00	0.00	0.20	0.20	0.00	1.60	0.00	0.00	0.30
Razor clam	0.80	0.00	3.30	0.30	0.00	1.10	0.00	0.00	0.00	0.60	0.00	1.70
Scampi	19.4	90.0	54.3	17.4	75.0	52.7	25.9	113	58.5	14.4	60.0	49.4
Sea urchin	8.20	52.5	11.9	13.0	52.5	10.8	8.30	43.8	10.6	7.60	52.5	10.2
Seiche	9.90	50.0	27.2	6.70	32.5	19.8	5.90	32.5	17.9	6.40	32.5	20.1
Shrimp	36.0	100	91.8	41.5	125	91.7	37.1	100	84.6	43.0	140	92.7
Slipper lobster	0.00	0.00	2.10	0.00	0.00	0.60	0.00	0.00	0.80	0.00	0.00	0.60
Spider crab	4.50	20.0	29.2	4.30	20.0	29.0	4.00	25.0	31.7	2.70	10.0	24.4
Spiny lobster	1.30	12.5	13.6	1.60	6.30	17.0	1.50	6.30	17.9	1.90	12.5	17.4
Squid	20.9	103	52.7	16.1	80.0	51.6	10.9	50.0	35.8	15.1	81.3	47.4
Swimcrab	7.80	50.0	15.6	8.30	50.0	16.0	8.20	50.0	15.4	4.20	25.0	10.8
Whelk	12.6	62.5	35.4	17.3	93.8	33.3	6.70	37.5	19.5	17.0	93.8	33.4
TOTAL	**270**	**703**	**98.4**	**260**	**665**	**99.7**	**279**	**649**	**100**	**235**	**607**	**99.4**

** Consumers rate

Regional level

Concerning the geographic differences, the people in La Rochelle consume more molluscs and crustaceans (Figure 7). The average consumption of adult women in this town is significantly different from that in Le Havre ($p<0.05$) and Toulon ($p<0.01$). People in Lorient consume more crustaceans and molluscs than those in Toulon ($p<0.05$). For men in the same age group, those in La Rochelle consume significantly more molluscs and crustaceans than those in Le Havre ($p<0.05$). Among the elderly, people in Toulon consume significantly less molluscs and crustaceans than those in La Rochelle and Lorient ($p<0.05$),

Figure 7: Mean consumptions of molluscs and crustaceans per zone, age group and sex (g/week)



2.1.3 Other seafood

National level (4 zones)

This category of products includes canned and smoked fish and the other seafood-based products. The consumptions of these foods must be interpreted with care since the recipes of products such as fish soup and paella are very variable between individuals and commercial brands; their fish or crustacean content can differ. Table 16 includes the consumption of a few complete dishes without taking into account the recipe or the proportion of seafood they contain. Consequently these data do not reliably indicate the actual consumption of seafood and overestimate it

The weekly consumption of canned seafood is 125 g for men aged 18 to 64, 102 g for women of the same age and 72 g for elderly people. Tuna is the most widely consumed canned product in all the groups, except for elderly people whose average consumption of anchovy is almost the same as that of tuna (20 g/week for anchovy, 22 g/week for tuna). While the average consumptions of sardine and mackerel are lower, these are consumed by large numbers of people.

The weekly consumptions of smoked products by men, women and the elderly are 22 g, 19 g and 13 g respectively. Salmon is the most-consumed smoked product with an average quantity of about 10 g/week for adult male and female and 7 g/week for the elderly.

Paella and fish soup are widely consumed in all the population groups, though with a marked preference for soup among elderly people.

Table 16: Mean consumptions of canned food, smoked fish and seafood-based dish by high consumers (g/week)

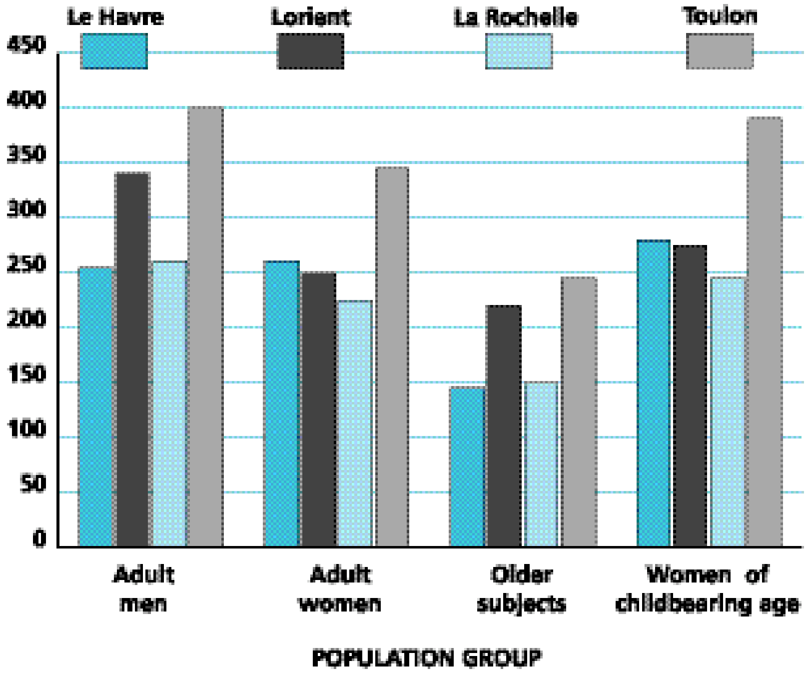
Other seafood	Adult men (18-64 y) n = 243			Adult women (18-64 y) n = 630			Older subjects (65 y and more) n = 123			Women of childbearing age (18-44 y) n = 344		
	Mean	P95	%**	Mean	P95	%**	Mean	P95	%**	Mean	P95	%**
Canned food												
Anchovy	31.7	180.0	39.1	22.8	120.0	36.2	19.5	93.8	35.8	16.9	75.0	28.8
Crab	4.7	22.5	25.5	6.4	22.5	33.2	2.5	15.0	27.6	8.6	37.5	32.0
Mackerel	17.6	65.6	59.3	14.1	60.0	54.9	10.0	37.5	54.5	16.3	60.0	55.8
Pilchard	2.8	15.0	10.3	1.4	7.5	10.2	1.0	7.5	7.3	1.3	7.5	7.8
Sardine	15.7	60.0	68.7	12.0	40.0	65.2	17.5	60.0	81.3	11.4	40.0	59.9
Tuna*	52.3	180.0	91.8	45.0	120.0	91.6	21.8	90.0	78.9	55.3	180.0	93.6
Total canned food	**124.8**	**381.3**	**98.8**	**101.8**	**302.5**	**97.9**	**72.3**	**182.5**	**93.5**	**109.8**	**360.0**	**98.8**
Smoked fish												
Haddock	1.0	7.5	10.3	1.8	7.5	12.5	0.5	3.8	5.7	1.3	7.5	11.0
Herring	7.9	46.9	37.9	4.6	22.5	30.0	4.5	22.5	32.5	4.4	22.5	27.9
Mackerel	3.1	15.0	16.0	2.1	11.3	12.9	0.9	5.0	8.1	2.8	15.0	15.7
Salmon	10.1	37.5	78.6	10.3	37.5	81.3	7.1	25.0	63.4	10.3	40.0	81.1
Total smoked fish	**22.1**	**75.0**	**86.8**	**18.8**	**70.0**	**85.7**	**13.0**	**40.0**	**79.7**	**18.8**	**66.3**	**85.8**
Seafood-based dish												
Fish soup	65.2	250.0	57.6	56.9	250.0	51.1	61.1	250.0	66.7	62.2	250.0	48.3
Paella	68.9	175.0	70.4	52.3	200.0	62.1	27.0	125.0	35.8	60.5	200.0	66.6
Surimi	26.3	70.0	70.8	35.7	140.0	77.0	11.6	43.8	46.3	40.9	140.0	81.4
Tarama	5.0	31.3	35.8	6.8	31.3	40.5	2.6	12.5	17.1	8.7	31.3	41.3
Total seafood-based dish	**165.4**	**450.0**	**92.2**	**151.7**	**472.5**	**95.1**	**102.3**	**256.3**	**85.4**	**172.2**	**522.5**	**95.3**
Total	**312.3**	**798.8**	**99.6**	**272.2**	**742.5**	**99.5**	**187.7**	**472.5**	**99.2**	**300.8**	**795.0**	**99.1**

* Predatory fish as described in the Commission Regulation (EC) No 78/2005 of 19 January 2005 ** Consumers rate

Regional level

Significant differences between the average consumptions are observed between the study zones for all the groups studied. In particular the consumptions in Toulon are higher than in the other regions (Figure 8).

Figure 8: Mean consumptions of canned food, smoked fish and other seafood per zone, age group and sex (g/week)



2.2. Comparison of consumption data from the CALIPSO study and the Individual National Food Consumption Survey (INCA 99)

We compared the consumption data of fish, molluscs and crustaceans, smoked, canned or other products, taken from the INCA 99 survey and collected by means of a 7-day consumption diary with the results obtained in the present survey.

As often observed in this type of comparison, the values obtained by means of a food frequency questionnaire are greater than those obtained using a consumption diary, although we should remember that the CALIPSO survey concerned only high consumers, in other words those consuming seafood products twice a week or more, which tends to amplify the observed differences. We therefore decided to compare the results with the consumption data for seafood consumers alone.

The consumptions in the CALIPSO survey are about 2.5 times higher for consumption of fish, molluscs and crustaceans, and about 1.5 times higher for the other products. For the total consumption of these products, a factor of about 3.5 is observed between the two studies, which demonstrates that the CALIPSO study's objective of targeting high fish and seafood consumers was effectively reached (Appendix 3a).

2.3 Seafood provisioning

One question relative to the provisioning of fresh seafood was included in the survey for each product consumed. Several replies were possible, the results presented in the figures are expressed as a percentage of the replies.

In addition to the question on the provisioning method, when several methods were used the respondents were asked to decompose them (beach fishing, port, market, fishmonger, large and mid-size shops, consumption outside the home) in order to have a more detailed distribution of the provisioning methods for each seafood product consumed.

Only purchases of fish (fresh and frozen), molluscs and crustaceans are detailed below, since the other products (canned, smoked and seafood-based products) are procured only in retail shops.

The declared provisioning frequency at each place of purchase was weighted by the quantities consumed in order to calculate a distribution of the provisioning for each seafood product and for all consumers. For each seafood product i and each individual j, the provisioning share of a given method k (called AP) weighted by the consumption was calculated as follows:

$$\mathbf{AP_{ijk} = Pct_{ijk} x C_{ij}}$$

where Pct is the purchase share of product i declared by the consumer j for the provisioning method k, and C is the consumed quantity of the product i consumed by the consumer j, all provisioning methods included.

For the whole population, the distribution of the provisioning method k (called RP) was calculated as follows:

$$\mathbf{RP_{ik} = \frac{\sum_j AP_{ijk}}{\sum_j C_{ij}} x\ 100}$$

where C is the total quantity of the seafood product i consumed by the entire population, all provisioning methods included.

Two important points should be made here:

- Since the towns of Lorient and La Rochelle both have large covered fish markets, the replies “I buy at the market” and “I buy from a fishmonger” could possibly refer to the same supplier.

- Direct sales to the public are forbidden on the port in Le Havre and Toulon, so nearby markets have appeared where fishermen sell their products. Consequently, the replies “I buy at the market” and “I buy at the port” could refer to the same place of purchase in these two towns.

These two facts may explain the observed differences relative to the other zones.

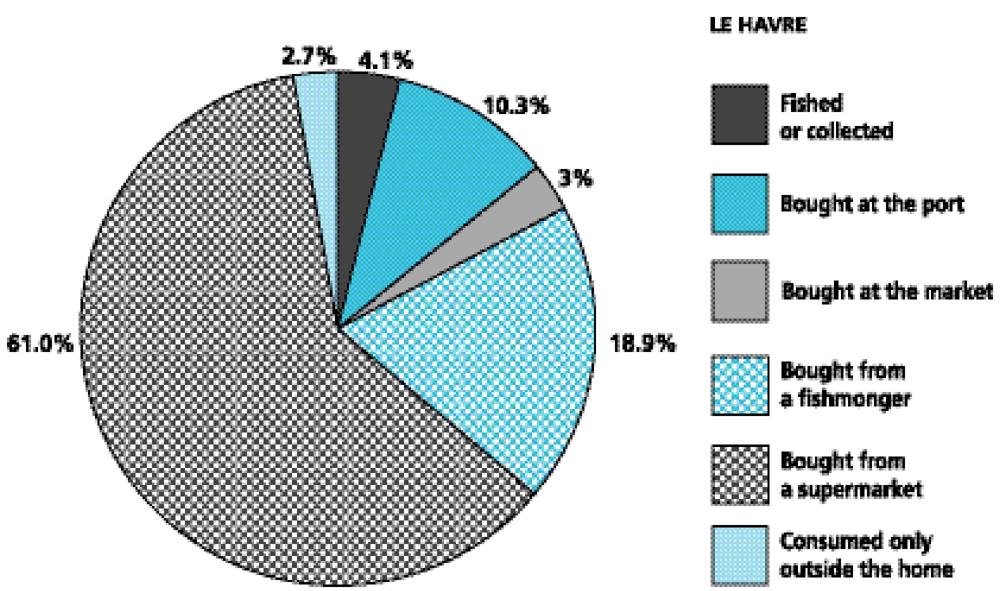
2.3.1 Fresh and frozen fish

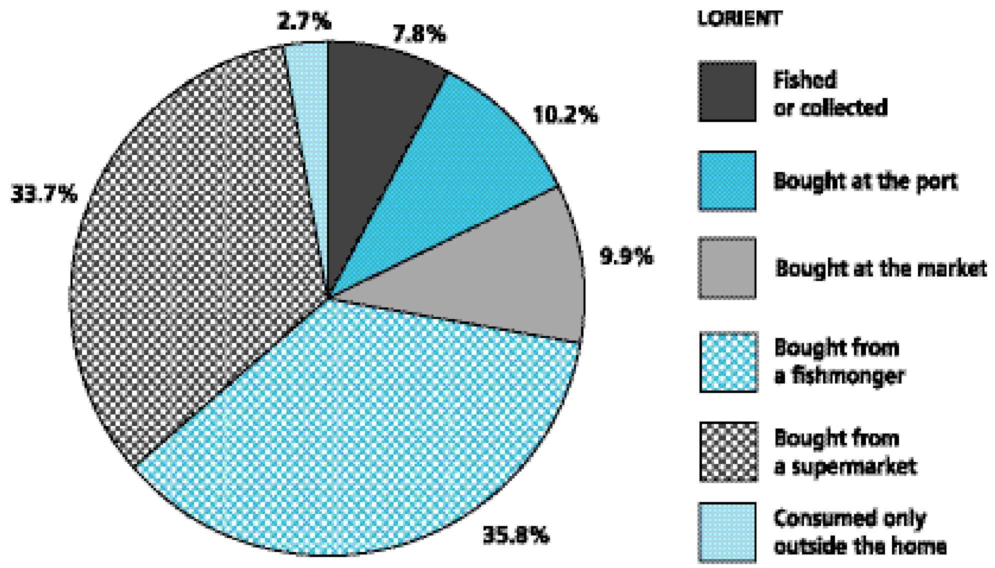
Figure 9 shows that, all species included, fresh and frozen fish is generally purchased in large stores (supermarket or hypermarket), in all the study zones, in particular in Le Havre and Hyères-Toulon where this provisioning method accounts for more than half of all purchases (61% and 54%, respectively).

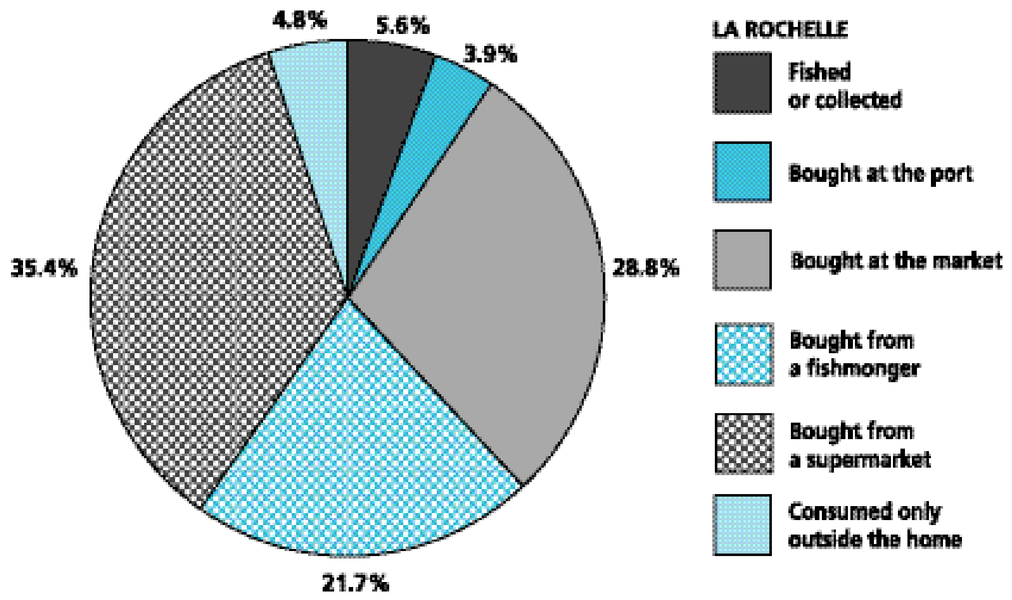
In Lorient and La Rochelle, purchases from fishmongers and the market account for almost half of all purchases, and large stores for one third.

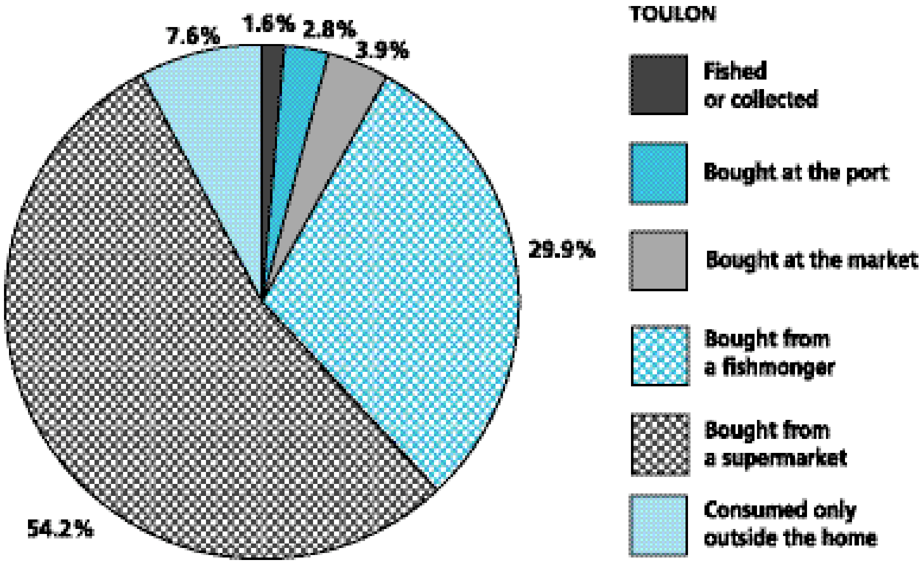
Purchases on the port are mentioned by 10% of respondents in Le Havre and Lorient, 4% in La Rochelle and 3% in Hyères-Toulon. Very few people consume fish they have caught themselves; these are most numerous in the region of Lorient and La Rochelle (8% and 6% respectively).

Figure 9: Provisioning shares of fresh and frozen fish at different places of purchase in the 4 zones (% of purchases)




LORIENT
2.7%
7.8%
10.2%
9.9%
35.8%
33.7%
Fished or collected
Bought at the port
Bought at the market
Bought from a fishmonger
Bought from a supermarket
Consumed only outside the home


LA ROCHELLE
4.8%
5.6%
3.9%
28.8%
21.7%
35.4%
Fished or collected
Bought at the port
Bought at the market
Bought from a fishmonger
Bought from a supermarket
Consumed only outside the home



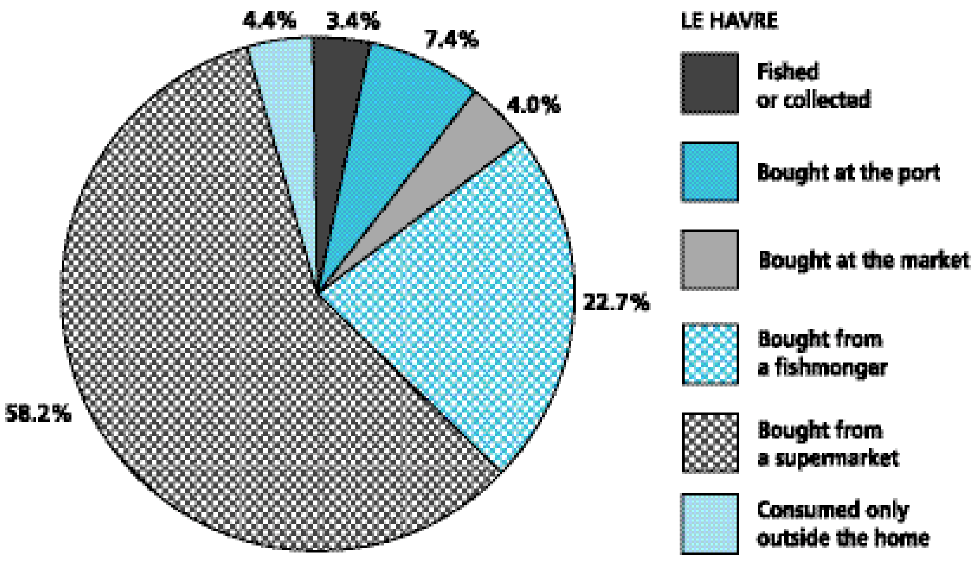
2.3.2 Molluscs and crustaceans

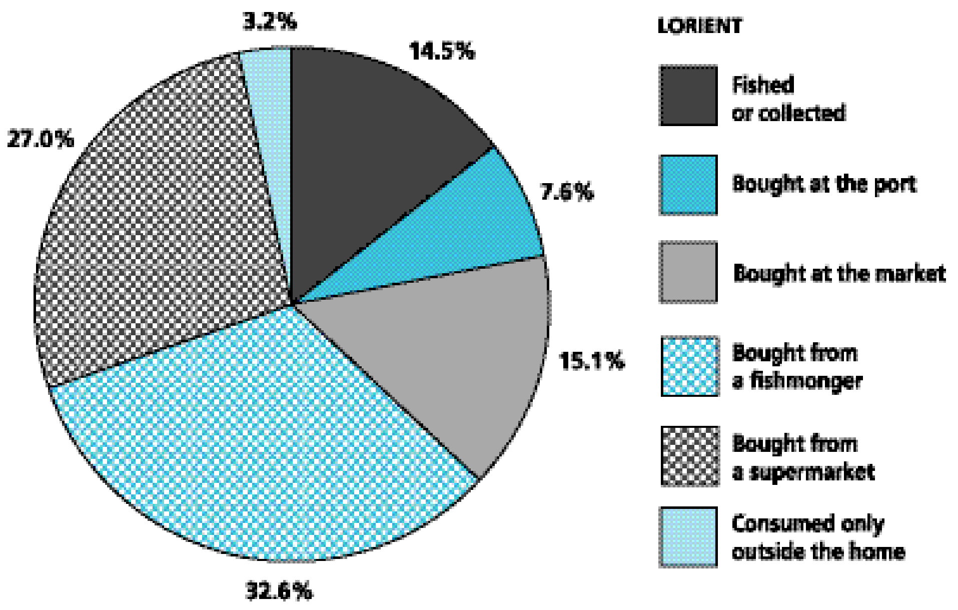
Molluscs and crustaceans are bought more often in large stores (supermarket, hypermarket) in Le Havre and Hyères-Toulon (Figure 10): half or more of all provisioning is by this method. In these regions about a quarter of all purchases are made at fishmongers. In the Mediterranean region, 14% of the respondents consume molluscs and crustaceans only outside their home.

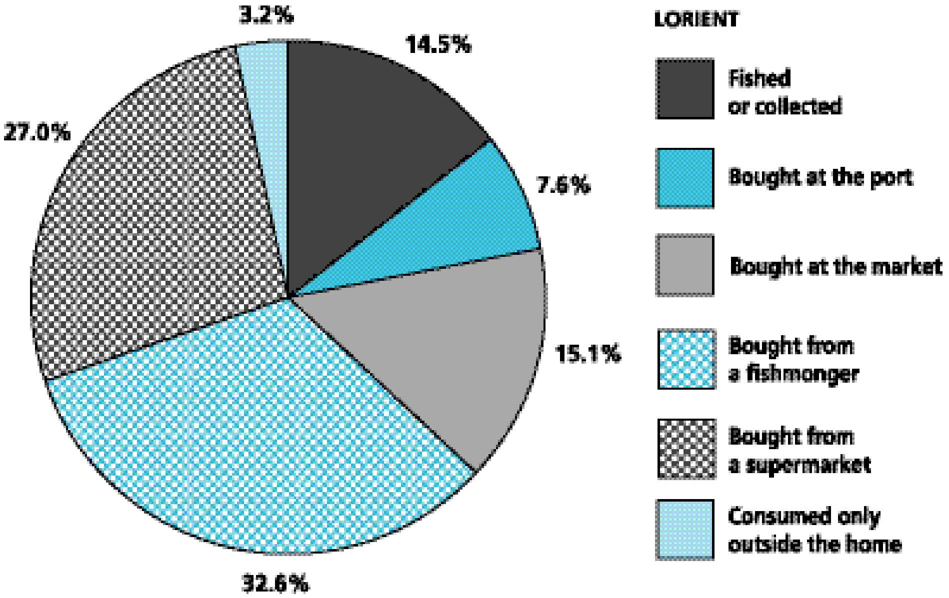
In Lorient and La Rochelle almost 75% of total provisioning is via the market, fishmongers and large stores, although the distribution varies between the regions.

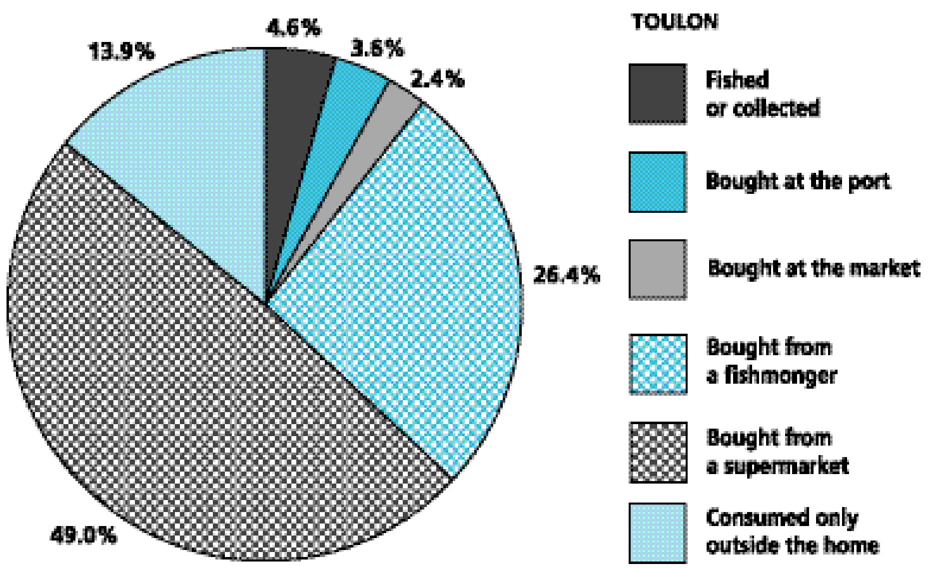
Provisioning by beach fishing is much more prominent in Lorient and La Rochelle (15% to 10% compared to 3% to 5% in the other regions). However this remains a minority method.

Figure 10: Distribution of mollusc and crustacean provisioning in the 4 zones (% of purchases)






3.2%
14.5%
27.0%
7.6%
15.1%
32.6%
LORIENT
Fished
or collected
Bought at the port
Bought at the market
Bought from
a fishmonger
Bought from
a supermarket
Consumed only
outside the home


4.6%
3.6%
13.9%
2.4%
26.4%
49.0%
TOULON
Fished
or collected
Bought at the port
Bought at the market
Bought from
a fishmonger
Bought from
a supermarket
Consumed only
outside the home

THIRD PART

Seafood composition and contamination

3.1 Fatty acid composition

As described in the first part, 159 fish and seafood products sampled in the four study zones were analysed for their fatty acids composition: 95 fish, 43 molluscs and crustaceans and 21 other products (canned, smoked and seafood-based products). Tables 17 to 19 present the results of the analysis of total lipids (in g/100 g) and fatty acids in these foods (in mg/100 g), averaged for the four regions, representing 30 species of fish, 17 species of molluscs and crustaceans and 14 other products.

3.1.1 Fresh and frozen fish

Total Lipids : The fish containing most lipids are eel, salmon, swordfish and halibut, in all the regions, with respective average levels of 20.4, 13.5, 12.4 and 11.7 g of lipids for 100 g of fish (Table 17). However the lipids profile of eel must be interpreted with care since the composite sample came from a single batch imported from the Netherlands. Mackerel and sardine are also rich in lipids (7.1 and 5.7 g/100 g) but unlike the fish mentioned previously the levels are not homogeneous between the different zones. The composite sample of sardine in Toulon is particularly low in fat (0.8 g/100 g), as is the composite sample of mackerel in La Rochelle (2.3 g/100 g) (results not presented). These differences may be explained by the difference of size observed during the sampling, a seasonal effect, different provisioning origins or a reproduction period dependent on the region. A regional effect may also explain the difference observed for the sardine sample in Toulon given that this comprised 80% of Mediterranean sardines (diet, etc.).

Angler fish, pout and cod display the lowest fat levels: 0.2 to 0.3 g of lipids/100 g.

These results are consistent with the data of the national CIQUAL database [104].

LC-PUFAs : The fish richest in n-3 LC-PUFAs (EPA, DPA, DHA) are mainly the oiliest fish and also fresh anchovy (3,241 mg/100 g including 1,365 mg DHA/100 g). Logically, the fish the least rich in n-3 LC-PUFA are the least oily: gurnard, angler fish and pout (46, 66 and 77 mg/100 g respectively), although some low-oil fish are also found to be rich in n-3 LC-PUFAs, for example cod, whiting and pollack for which respectively 55%, 52% and 51% of fatty acids are n-3 LC-PUFAs, which are relatively high levels (results not presented).

Data in the literature are absent or incomplete for two thirds of all fish[104 105 106]. For the majority of products, our data (lipid level and lipids profile) are consistent with the literature. The differences when they exist may be explained by the large variability of the oil level in the fish flesh, this being dependent on the period of the year, age, size, sex, reproduction period, fishing zone or breeding method, the specific species, food and even particularly large individual variability. Our results for fresh tuna for example indicate a total lipids level of 0.73 g/100 g versus 6.2 g/100g in the CIQUAL database, 15.5 g/100 g in the German database and 4.90 g/100g in the American database. This may be explained by the provisioning period of the samples analysed (end of January to April) and by the provisioning methods: tuna sold in France at this time of year are "fattened" tuna weighing 10 to 35 kg, not necessarily the same as those analysed to constitute the French[104], German[105] and American[106] databases.

104 Data from the French database REGAL of the Informatics Centre for Food Quality of the French Food Safety Agency. Retrieved September 2005.

105 Souci S.W., Fachmann W. and Kraut H. Food composition and nutrition tables. 6th edition revised and completed. Medpharm Scientific Publishers, CRC Press, Boca Raton. 2000.

106 USDA-Agricultural research service. USDA National nutrient database for standard reference. http://www.ars.usda.gov

3.1.2 Molluscs and crustaceans

Total lipids : In general molluscs (Table 18) contain much less fat than fish (0.4 to 6.7g of lipids/100 g). Crustaceans have a higher lipids level than molluscs with 6.7 g/100 g for the common crab, 4.4 g/100 g for the spider crab and 3.8 g/100 g for the swimcrab.

LC-PUFAs : Crustaceans are also richer than molluscs in n-3 LC-PUFAs and more particularly in DHA: 714 mg/100 g for the common crab, for example. The molluscs with the least lipids are the cephalopods, in particular octopus (0.4 g/100 g) and cuttlefish (0.9 g/100 g).

There is little available composition data on this type of product in the French and international literature (9 products compared), but our results are consistent with the data in the CIQUAL[104] and German[105] databases.

3.1.3 Other seafood

Total lipids : Concerning canned and smoked products and prepared seafood-based dishes, the lipid and fatty acid levels obtained are very variable (Table 19) despite our standardised preparation protocol of the comestible part, notably as regards draining. Mackerel (conserved in oil or smoked) has, as we might expect, the highest fat level (13.2 and 17.0 g of lipids/100 g).

LC-PUFAs : Once again the products the least rich in total lipids are not necessarily those the least rich in omega 3: of the total fatty acids, we find 20% of DHA in fish soup, canned pilchard and smoked salmon compared to 1.3% in tarama (which is very rich in total lipids - the results are not presented).

The results for these products must be interpreted with care. The total lipids level corresponds to the average of two analyses made on the same sample and the difference between the two levels could be as much as 21.4 g/100 g for tarama or 14.7 g/100 g for canned tuna. These differences, much smaller for fish, molluscs and crustaceans, can perhaps be explained by the difficulty of homogenising these products.

Tuna, sardine and mackerel contain two to eight times more fat when they are canned (including conservation in oil) compared to fresh or frozen forms. For sardine and tuna, this difference may be partially explained by the presence of oil in cans, despite draining during preparation of the samples or by different fishing periods for canned and fresh product. We always used preparation methods as close as possible to real consumption habits. Oleic (C18:1 n-9) and linolenic (C18:2 n-6) fatty acids, the most common in many oils, appear in higher concentrations in canned products than in fresh ones. Moreover, in the case of tuna the samples of fresh tuna were constituted only of red tuna whereas the samples of canned tuna (including the sub-samples of conserved in oil) are constituted of different species (yellowfin, albacore and skipjack). For mackerel, the differences in total lipids appear to be due to a concentration of arachidonic acid (C20:4 n-6) ten times higher in the composite sample of canned mackerel (including the sub-samples conserved in oil) than in fresh fish, and a concentration of parinaric acid (C18:4 n-3) four times higher in canned and smoked mackerel than in fresh mackerel. We are unable to explain these differences.

Smoked mackerel contains more fat (total lipids) than fresh mackerel. In this case the difference may be due to cooking prior to smoking which could concentrate the lipids. Smoked mackerel is much richer in n-3 PUFAs, whether as a precursor (ALA) or as long-chain derivatives. Smoked mackerel is also richer in saturated fatty acids (C18:0 and C20:0). These differences are perhaps due to the different fishing zones according to the final use of the product, direct consumption or transformation.

On the other hand, the compositions of fresh and smoked salmon are relatively close, a homogeneity that is perhaps explained by the fact that cultivated salmon accounts for 90% of salmon consumption in France, most of it coming from Norway [107]. In addition, the salmon is smoked cold (25°C) without cooking, so there is no water loss and the fatty acids are not concentrated by the smoking.

3.1.4 Regional variations

There is no significant difference in the average compositions of fish in the different study zones in terms of the total lipidic composition or the level of LC-PUFAs omega 3. Similarly, there is no significant difference between the compositions of molluscs and crustaceans sampled in these zones.

107 OFIMER. Note thématique sur les marchés – Le marché du saumon. Février 2004. http://www.ofimer.fr

Table 17: Mean fatty acid composition of fresh and frozen fish (mg/100 g)

Fish	Nb samples[a]	Lipids (g/100g)	C12:0	C14:0	C14:1 n-5	C15:0	C16:0	C16:1 n-7	C18:0	C18:1 trans	C18:1 cis n-9	C18:1 cis n-7	C18:2 n-6 (LA)	C18:3 n-6	C18:3 n-3 (ALA)	C18:4 n-3	C20:0	C20:2 n-6	C20:4 n-6 (AA)	C20:5 n-3 (EPA)	C22:5 n-3 (DPA)	C22:6 n-3 (DHA)	SFA[b]	MUFA[b]	PUFA[b]	LC-PUFA n-3[b]	LC-PUFA n-6[b]
Anchovy	1	7.51	-	134	-	-	964	97	422	-	840	-	172	-	211	-	-	-	510	701	964	1,365	1,520	937	3,923	3,241	682
Angler fish*	4	0.21	-	8	-	-	32	6	12	1	18	2	1	-	-	1	-	-	6	26	2	37	52	33	71	66	7
Catshark*	4	0.55	-	-	-	-	71	5	20	-	42	1	2	-	-	1	-	-	22	113	15	66	93	70	219	195	23
Cod	4	0.30	-	1	-	-	45	2	10	2	19	2	1	-	-	5	-	-	7	28	4	75	57	24	121	112	8
Common dab	4	0.72	-	14	-	1	119	25	27	1	83	-	3	-	1	13	5	-	28	84	22	131	174	120	281	250	30
Eel*	1	20.4	56	675	112	31	3,525	1,759	847	-	7,379	-	618	-	151	296	-	-	666	432	286	716	5,583	9,591	3,205	1,880	1,285
Emperor*	3	5.78	78	26	-	-	541	412	77	30	1,616	106	132	3	6	667	8	-	65	471	53	742	847	2,212	2,141	1,940	201
Plaice*	2	0.37	-	10	-	-	60	20	12	-	22	9	1	-	1	2	4	-	14	46	6	41	97	53	111	97	15
Goatfish	3	3.75	-	54	3	5	673	173	151	-	592	-	19	2	4	50	10	-	127	348	77	669	908	801	1,295	1,147	148
Grenadier / hoki*	4	0.44	-	4	-	-	50	6	16	1	45	2	3	-	2	30	-	-	4	41	8	78	74	66	168	160	8
Gurnard	1	0.73	-	26	-	-	194	-	68	53	66	-	10	-	-	-	49	-	-	43	-	3	336	120	54	46	10
Haddock	2	0.25	-	-	-	-	44	1	11	4	12	-	2	-	2	-	-	-	8	18	5	60	60	18	94	84	10
Hake	4	0.59	-	7	-	-	89	13	21	-	73	-	3	1	1	9	11	-	10	28	19	123	130	87	193	180	14
Halibut*	4	11.7	-	366	-	-	1,832	808	295	109	1,544	329	75	-	9	1,296	143	-	116	969	285	1,400	3,041	3,069	4,186	3,960	191
John dory	2	0.59	-	5	-	-	93	5	27	-	57	-	2	-	2	5	2	-	10	32	8	156	129	63	217	203	13
Ling*	4	0.33	-	-	-	-	47	4	16	1	22	3	2	-	-	2	1	-	3	45	1	65	65	45	117	112	4
Mackerel	4	7.07	-	179	-	10	1,198	145	327	15	1,258	-	145	-	58	343	120	-	114	662	118	1,404	1,867	1,436	2,845	2,585	259
Pollack	3	0.27	-	-	-	-	45	2	11	1	18	3	1	-	-	1	-	-	4	15	4	76	64	24	103	97	5
Pout	1	0.29	-	4	-	1	43	6	20	1	6	-	1	-	1	4	1	-	13	36	6	30	89	20	91	77	14
Ray*	4	0.61	-	-	-	-	105	2	20	1	71	-	-	-	-	7	-	-	23	17	15	156	129	77	216	195	23
Saithe / coalfish	4	1.04	17	10	-	-	144	5	32	1	162	5	120	-	2	9	2	-	7	71	7	173	206	174	391	262	126
Salmon	4	13.5	-	640	7	8	2,472	576	360	248	2,204	74	577	13	174	672	105	-	81	1,112	349	2,164	4,006	3,237	5,146	4,472	671
Sardine	4	5.72	-	179	-	11	1,200	197	276	-	808	3	37	4	40	146	42	-	89	638	178	1,269	1,779	1,081	2,407	2,270	130
Scorpionfish	1	2.27	-	52	-	-	342	72	51	25	265	-	13	-	-	205	16	-	45	121	57	507	464	399	949	890	57
Seabass*	4	2.99	2	44	1	3	502	124	154	3	380	27	47	4	12	40	7	2	72	357	65	617	732	561	1,221	1,090	125
Sea bream*	4	4.89	-	93	-	-	887	249	234	287	605	37	195	6	27	70	28	-	149	497	140	773	1,308	1,233	1,859	1,507	350
Sole	4	0.40	-	6	-	-	62	12	21	-	30	7	3	-	1	-	4	-	16	14	22	72	101	52	128	109	19
Swordfish*	4	12.4	-	241	-	30	2,035	488	651	37	2,108	469	70	24	39	367	191	-	447	1,265	343	1,750	3,398	3,328	4,331	3,764	541
Tuna*	4	0.73	-	6	-	1	109	10	53	-	94	1	12	1	3	4	3	-	18	35	7	131	187	113	211	179	31
Whiting	4	0.25	-	1	-	-	37	2	9	-	22	-	1	-	1	6	1	-	3	15	3	69	53	29	98	93	5

- : < LOQ (1 mg/g lipid) ; a : Nb composite samples. Each sample is composed by 5 subsamples of the same species, representative of the provisioning methods in each zone (port, market, supermarket…). b : The total for SFA, MUFA, PUFA and LC-PUFA include all the analysed fatty acids, some of which are minority and are not presented in the table. * Predatory fish as described in the Commission Regulation (EC) No 78/2005 of 19 January 2005

Table 18: Mean fatty acid composition of molluscs and crustaceans (mg/100 g)

Mollusc, crustacean	Nb samples[a]	Lipids (g/100g)	C12:0	C14:0	C14:1 n-5	C15:0	C16:0	C16:1 n-7	C18:0	C18:1 trans	C18:1 cis n-9	C18:1 cis n-7	C18:2 n-6 (LA)	C18:3 n-6	C18:3 n-3 (ALA)	C18:4 n-3	C20:0	C20:2 n-6	C20:4 n-6 (AA)	C20:5 n-3 (EPA)	C22:5 n-3 (DPA)	C22:6 n-3 (DHA)	SFA[b]	MUFA[b]	PUFA[b]	LC-PUFA n-3[b]	LC-PUFA n-6[b]
Calico scallop	1	1.06	-	21	7	4	130	43	45	19	39	1	8	3	8	35	8	2	32	110	6	119	232	123	326	278	45
Common periwinkle	3	1.84	-	36	26	1	201	24	65	3	89	-	36	-	34	138	10	-	114	210	42	77	375	155	650	500	149
Cockle	2	0.40	-	4	-	1	51	8	27	-	15	-	1	-	1	19	6	-	15	49	6	33	102	28	123	108	16
Crab	3	6.66	-	46	5	18	525	619	54	-	915	-	15	19	7	113	18	-	327	1,160	41	714	706	1,552	2,404	2,035	360
Cuttle fish	2	0.85	-	11	-	-	134	2	35	-	18	2	-	-	-	27	-	-	22	69	9	156	193	33	282	261	22
Great scallop	4	0.80	-	15	-	4	128	12	33	4	21	-	4	3	4	19	10	-	13	105	9	105	201	48	263	242	20
Lobster	1	1.53	-	19	-	6	166	31	62	-	320	21	9	-	2	64	2	-	19	28	30	178	289	389	334	303	27
Mussel	4	1.09	-	15	1	4	158	49	29	3	25	11	9	1	10	33	12	-	32	162	12	151	240	102	410	368	42
Octopus	1	0.36	-	3	-	-	59	-	19	-	3	6	-	-	-	6	-	-	16	37	3	56	84	12	122	103	16
Oyster	4	0.55	-	12	-	-	99	12	16	10	38	5	6	-	8	22	15	-	17	82	4	64	153	67	208	180	24
Scampi	3	0.63	-	6	-	3	79	19	20	-	77	9	4	1	5	11	5	-	16	76	8	72	121	116	197	172	21
Sea urchin	1	0.81	-	62	2	5	104	17	20	9	14	-	3	4	6	42	2	-	68	98	6	6	219	63	234	158	75
Shrimp	4	0.76	-	3	-	4	69	48	61	-	81	7	62	1	3	4	1	-	21	71	6	66	162	149	235	150	84
Spider crab	1	4.39	-	80	13	39	376	209	160	-	566	-	18	31	14	338	28	-	154	536	39	294	779	807	1,445	1,221	202
Squid	4	1.33	-	14	1	3	186	8	46	-	77	-	136	1	1	23	-	1	12	68	31	167	255	103	440	290	150
Swimcrab	2	3.78	-	69	-	-	340	314	48	-	483	-	5	-	9	76	-	-	109	633	93	290	478	844	1,285	1,100	113
Whelk	3	0.88	-	10	-	2	95	12	54	-	51	18	8	1	3	29	12	-	25	88	37	71	201	102	262	228	34

- : < LOQ (1 mg/g lipid) ; a : Nb composite samples. Each sample is composed by 5 subsamples of the same species, representative of the provisioning methods in each zone (port, market, supermarket…). b : The total for SFA, MUFA, PUFA and LC-PUFA include all the analysed fatty acids, some of which are minority and are not presented in the table.

Table 19: Mean fatty acid composition of other seafood (mg/100 g)

Other seafood	Nb samples[a]	Lipids (g/100g)	C12:0	C14:0	C14:1 n-5	C15:0	C16:0	C16:1 n-7	C18:0	C18:1 trans	C18:1 cis n-9	C18:1 cis n-7	C18:2 n-6 (LA)	C18:3 n-6	C18:3 n-3 (ALA)	C18:4 n-3	C20:0	C20:2 n-6	C20:4 n-6 (AA)	C20:5 n-3 (EPA)	C22:5 n-3 (DPA)	C22:6 n-3 (DHA)	SFA[b]	MUFA[b]	PUFA[b]	LC-PUFA n-3[b]	LC-PUFA n-6[b]
Canned food																											
Anchovy	2	7.36	-	101	-	-	1,294	156	860	-	1,145	-	814	-	127	54	3	-	106	466	238	886	2,259	1,301	2,694	1,771	919
Crab	1	0.57	-	3	-	3	59	16	42	-	43	13	7	-	3	1	1	-	33	73	4	77	122	80	199	159	40
Mackerel	1	13.22	-	546	-	-	2,224	-	569	37	1,313	278	346	22	162	1,263	-	129	1,090	791	152	1,985	3,730	1,794	5,976	4,353	1,587
Pilchard	1	9.80	-	365	10	32	1,551	283	182	-	751	245	149	-	68	634	-	-	797	773	83	1,591	2,219	1,427	4,095	3,149	946
Sardine	1	11.85	-	340	-	30	2,322	365	522	-	2,579	-	590	16	53	338	-	-	206	1,108	156	1,999	3,328	3,093	4,484	3,653	813
Tuna*	5	6.03	-	56	1	4	404	44	717	8	1,683	21	106	-	88	4	1	-	63	177	52	408	1,197	1,760	901	729	168
Smoked fish																											
Haddock	1	0.24	-	1	-	-	39	1	19	-	23	-	3	-	15	-	-	-	5	23	5	24	59	25	75	67	8
Herring	1	10.04	-	52	-	-	908	192	641	-	768	66	138	7	540	513	30	-	906	1,508	691	1,640	1,643	1,152	5,943	4,892	1,051
Mackerel	1	16.95	-	318	-	-	1,525	298	1,376	-	1,160	111	230	-	1,299	1,149	-	-	1,565	2,329	948	2,283	3,219	1,658	9,871	8,008	1,795
Salmon	1	9.79	-	165	-	-	1,612	255	1,615	-	636	49	227	-	471	317	-	-	462	902	471	1,829	3,391	940	4,678	3,990	689
Seafood-based dish																											
Fish soup	2	0.98	-	12	-	-	131	22	118	-	76	2	16	-	37	15	-	-	32	55	40	139	260	101	332	285	48
Paella	1	4.06	-	62	-	-	938	114	283	-	1,303	106	726	-	76	30	-	-	101	110	18	145	1,300	1,552	1,205	378	827
Surimi	1	2.29	-	28	-	-	327	28	64	-	662	64	219	-	88	60	-	-	-	152	-	307	415	754	821	606	219
Tarama	1	38.66	-	109	-	-	2,173	129	115	69	23,119	-	6,435	135	624	279	-	-	411	755	255	525	2,539	23,513	12,609	2,437	6,981

- : < LOQ (1 mg/g lipid) ; a : Nb composite samples. Each sample is composed by 5 subsamples of the same species, representative of the provisioning methods in each zone (port, market, supermarket…). b : The total for SFA, MUFA, PUFA and LC-PUFA include all the analysed fatty acids, some of which are minority and are not presented in the table. * Predatory fish as described in the Commission Regulation (EC) No 78/2005 of 19 January 2005

3.2 Contamination by trace elements

Table 20 indicates the proportion of censured data, in other words less than the detection limit (LOD).

For all the products sampled – fish, molluscs, crustaceans and other products – arsenic is present mainly in the form arsenobetaine (organic arsenic) considered as non-toxic. The forms of speciation of inorganic toxic arsenics, As(III) and As(V), are in a minority, but the As(III) is detected in 91.2% of the samples whereas the As(V) never is. The total inorganic arsenic is therefore constituted mainly by the species As(III) considered to be the most toxic.

The samples contain mainly butyltins along with some phenyltins. Apart from monooctyltin (MOT), detectable in 10% of the samples, the presence of octyltins is sporadic.

In all the foods, mercury is mainly found in its toxic methyl form, methylmercury.

Finally, more than 54% of the samples contain lead and cadmium in detectable quantities.

Table 20: Proportion of censured data (< LOD) in analysing the trace elements in food samples.

Trace element	% censured data (<LOD)
As total	**0.00**
AsB	0.00
MMA	85.5
DMA	16.3
As(III)	8.80
As(V)	100
Hg total	**0.00**
MeHg	0.00
Cd total	**45.3**
Pb total	**30.2**
Organotincompounds	
MBT	15.1
DBT	10.7
TBT	12.6
MPT	49.1
DPT	46.5
TPT	52.2
MOT	90.0
DOT	99.4
TOT	100

Tables 21 to 24 present the results of the trace elements (in µg/g fresh weight) in the sampled foods, averaged for the four regions.

3.2.1 Fresh and frozen fish

Arsenic : The species of fish containing the highest concentrations of total arsenic are bottom fish (plaice, pout, sole, goatfish, ray, common dab and catshark). Their levels are between 12 and 34 µg/g fresh weight. Fish containing the highest levels of toxic inorganic arsenic (As(III) and As(V)) are pout, ray and goatfish with respectively 0.077, 0.073 and 0.072 µg/g. The least contaminated by inorganic arsenic are eel with 0.009 µg/g, ling, grenadier and emperor with 0.012 µg/g. Inorganic arsenic in fresh and frozen fish represents 0.1% to 3.5% of total arsenic, which is consistent with the literature[63]. Our results are particularly consistent with the British FSA study in October 2005[108].

108 FSA. Arsenic in fish and shellfish. 2005. http://www.food.gov.uk/

Mercury : As regards total mercury, the data shown in Table 21 are particularly consistent with the results of MAP monitoring plan[109], for all species. Predator fish are found to contain the highest levels of methylmercury (MeHg): swordfish (0.94 µg/g), emperor (0.57 µg/g), tuna (0.33 µg/g) and eel (0.32 µg/g). These species also have the highest levels of total mercury, although they do not exceed the maximum authorised limit of 1 mg/kg[110], which is reassuring when we consider that our results are obtained from composite samples. None of the non-predator species exceeds the maximum level of 0.5 mg/kg[110]. The fish the least contaminated by MeHg are anchovy (0.020 µg/g), salmon (0.038 µg/g) and saithe (0.041 µg/g). MeHg represents 67% to 100% of the total mercury in fish, within the limits of measuring uncertainty of the two analysis techniques employed.

Cadmium : Some species have cadmium levels exceeding 0.30 µg/g, 0.10 µg/g or 0.05 µg/g, the maximum authorised species to species[110] : saithe (0.07 µg/g), swordfish (0.07 µg/g), and catshark with the highest observed cadmium level (0.42 µg/g). These high average values are due to the exceptional contamination of the composite sample from Le Havre (1.65 µg/g), the concentrations of the composite samples of the three other zones do not exceed the maximal authorised level.

Lead : Halibut is the fish the most contaminated by lead (0.1 µg/g). However no species exceeds the maximum authorised limits (0.2 to 0.4 µg/g)[110]. Our data are generally consistent with the MAP monitoring plans[109], both for lead and cadmium, considering that many levels in these plans are less than the analytical limits of our study.

Organic tin : Concerning the organostannic compounds (OTC), many of our data are censured: 11% to 15% for the butyltin, 47% to 52% for the phenyltin and more than 90% for the octyltin. The fish presenting the highest levels are halibut (0.023 µg/g) and swordfish (0.019 µg/g), all forms of organic tin included. These results are consistent with the data of the SCOOP task 3.2.13.[65].

3.2.2 Molluscs and crustaceans

Arsenic : Octopus is the species with the highest level of total arsenic (42.3 µg/g), as shown in Table 22. However it should be underlined once again that we had only one composite sample (5 sub-samples) coming from the Toulon region. Otherwise crustaceans are found to be the most contaminated by arsenic, with 37.2 µg/g for the spider crab and 16.8 µg/g for crabs including the common crab; these also have very high levels of toxic inorganic arsenic (0.188 and 0.257 µg/g respectively). We also note a high inorganic arsenic level in Mediterranean sea urchins (0.222 µg/g). Unlike fish, the total arsenic and inorganic arsenic levels in our mollusc and crustacean samples exceed those found in the FSA study in 2005, which is perhaps explained by different provisioning (local fishing, etc.).

Mercury : Octopus and crab are also the species the most contaminated by mercury, in particular by MeHg (0.219 and 0.175 µg/g respectively). However none exceed the limit fixed at 0.5 µg Hg/g for fish products (excluding predator fish)[110]. The sea urchin is the least contaminated species, with less than 0.003 µg MeHg/g.

Cadmium : The maximum authorised limits[110] are exceeded by several species, in particular crab (4.1 versus 0.5 µg/g), shrimp (1.1 versus 0.5 µg/g) and calico scallops (1.1 versus 1.0 µg/g). The other bivalve molluscs display lower cadmium levels not exceeding 0.04 µg/g. These average contaminations are greater than the mean levels measured in the French monitoring plans: 0.46 µg/g for crab or 0.05 µg/g for shrimp.

109 Ministère de l'Agriculture et de la Pêche. DGAL. Résultats des plans de surveillance sur les produits de la mer de 1999 à 2004.

110 Commission Regulation (EC) No 78/2005 of 19 January 2005 amending Regulation (EC) No 466/2001 setting maximum levels for certain contaminants in foodstuffs as regards heavy metals.

These differences are due to high contamination of our composite crab sample in Lorient (12 µg/g versus less than 1 µg/g in the other sampling zones) and of our composite shrimp sample in Le Havre (4 µg/g versus less than 0.05 µg/g on the other zones).

Lead : None of the species sampled exceeds the maximum authorised limits[110]. For the common samples, in the case of both lead and cadmium our levels are generally lower than those found in the FSA study[108].

Organic tin : The organic tin levels are relatively low with a lower maximum value than for fish (0.01 µg/g for squid and swimcrab). As for fish, these results are consistent with the data found in the SCOOP task 3.2.13.[65]

3.2.3 Other seafood

Among other seafood, the canned products are the most contaminated by trace elements (Table 23). We find total arsenic levels of 3.54 µg/g in canned sardine and 2.23 µg/g in canned crab; more particularly, for inorganic arsenic the average level is 0.07 µg/g for canned crab and pilchard. The same is true for mercury, the maximum level being found in canned tuna (0.2 µg/g), but without exceeding the authorised limits[110].

On the other hand, canned or bottled anchovy and canned sardines reveal cadmium concentrations higher than the authorised limits (0.35 and 0.22 µg/g versus 0.1 µg/g). However these results must be interpreted with care in view of the homogenisation problems encountered during the sampling of canned products.

The other products, smoked fish or prepared seafood-based dishes, contain very low levels of trace elements.

Finally, the organic tin levels are equivalent to those measured in the composite samples of molluscs and crustaceans (0.01 µg/g).

3.2.4 Regional variations

Despite the deliberate choice of zones contrasted by the existence of old local environmental pollution, no significant differences are found between the trace element contaminations measured in the different study zones, for all the trace elements except inorganic arsenic (Table 24). For the species common to two zones, fish sampled in Lorient contain significantly more inorganic arsenic than fish in Toulon ($p<0.05$, significant differences not presented). They also appear to be more contaminated than fish sampled in Le Havre and La Rochelle, although the difference is not significant.

As regards molluscs and crustaceans, it appears that the samples from Le Havre are more contaminated by organic tin than those in the other zones. However, this result must be interpreted with care in view of the small number of samples (10 to 12 species or 40 to 48 sub-samples depending on the zone), the large number of censured data and the fact that the sampled species are different from one zone to another (molluscs, crustaceans, etc.).

This absence of regional differences can be largely explained by the low representation of explicitly local origins in the provisioning of seafood products mentioned earlier and by the general respect of local fishing interdictions when these exist.

Table 21: Mean contamination by trace elements of fresh and frozen fish (µg/g fresh weight)

Fish	n [a]	As_T [b]	AsB	MMA	DMA	As(III)	As(V)	Hg_T	MeHg	Cd	Pb	OTC [c]	MBT	DBT	TBT	MPT	DPT	TPT	MOT	DOT	TOT
Anchovy	1	0.94	0.72	0.025	0.003	0.014	0.005	0.012	0.020	0.0295	0.0075	0.0039	0.0013	0.0006	0.0015	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Angler fish*	4	6.00	6.64	0.004	0.004	0.012	0.005	0.147	0.131	0.0002	0.0031	0.0031	0.0006	0.0006	0.0008	0.0002	0.0003	0.0002	0.0001	0.0001	0.0001
Catshark*	4	34.3	31.2	0.004	0.014	0.041	0.005	0.251	0.232	0.4183	0.0106	0.0063	0.0017	0.0014	0.0014	0.0003	0.0007	0.0005	0.0002	0.0001	0.0001
Cod	4	5.25	5.31	0.004	0.010	0.016	0.005	0.063	0.059	0.0004	0.0019	0.0034	0.0007	0.0007	0.0007	0.0004	0.0004	0.0002	0.0001	0.0001	0.0001
Common dab	4	21.8	19.9	0.004	0.006	0.029	0.005	0.106	0.098	0.0002	0.0018	0.0018	0.0006	0.0003	0.0002	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001
Eel*	1	0.71	0.58	0.004	0.004	0.004	0.005	0.324	0.315	0.0033	0.0205	0.0047	0.0001	0.0011	0.0016	0.0006	0.0004	0.0006	0.0001	0.0001	0.0001
Emperor*	3	1.19	0.83	0.004	0.002	0.007	0.005	0.609	0.574	0.0048	0.0176	0.0052	0.0005	0.0008	0.0016	0.0003	0.0008	0.0007	0.0003	0.0001	0.0001
Goatfish	3	16.1	15.6	0.038	0.041	0.067	0.005	0.120	0.130	0.0005	0.0036	0.0013	0.0001	0.0002	0.0003	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Grenadier / hoki*	4	3.90	4.16	0.004	0.002	0.007	0.005	0.109	0.112	0.0036	0.0041	0.0046	0.0014	0.0008	0.0011	0.0003	0.0005	0.0002	0.0001	0.0001	0.0001
Gurnard	1	6.28	6.91	0.004	0.014	0.017	0.005	0.179	0.143	0.0002	0.0002	0.0011	0.0001	0.0003	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Haddock	2	6.52	6.57	0.004	0.009	0.012	0.005	0.086	0.102	0.0036	0.0035	0.0028	0.0010	0.0005	0.0000	0.0004	0.0004	0.0002	0.0001	0.0001	0.0001
Hake	4	4.28	4.21	0.004	0.035	0.017	0.005	0.148	0.157	0.0002	0.0085	0.0045	0.0011	0.0008	0.0012	0.0003	0.0005	0.0003	0.0001	0.0001	0.0001
Halibut*	4	5.69	4.98	0.004	0.053	0.012	0.005	0.078	0.082	0.0335	0.1001	0.0232	0.0022	0.0059	0.0105	0.0006	0.0005	0.0023	0.0004	0.0005	0.0001
John dory	2	1.12	0.81	0.297	0.037	0.014	0.005	0.075	0.092	0.0444	0.0137	0.0088	0.0011	0.0018	0.0028	0.0009	0.0013	0.0007	0.0001	0.0001	0.0001
Ling*	4	4.70	4.36	0.004	0.004	0.007	0.005	0.310	0.305	0.0043	0.0003	0.0030	0.0010	0.0004	0.0007	0.0001	0.0004	0.0001	0.0001	0.0001	0.0001
Mackerel	4	2.41	1.70	0.078	0.138	0.028	0.005	0.047	0.072	0.0002	0.0022	0.0088	0.0021	0.0016	0.0024	0.0006	0.0008	0.0008	0.0003	0.0001	0.0001
Plaice*	2	12.4	13.0	0.004	0.022	0.014	0.005	0.069	0.059	0.0002	0.0036	0.0046	0.0015	0.0005	0.0004	0.0002	0.0007	0.0010	0.0001	0.0001	0.0001
Pollack	3	3.65	3.36	0.004	0.006	0.039	0.005	0.081	0.083	0.0006	0.0003	0.0035	0.0004	0.0005	0.0005	0.0003	0.0008	0.0006	0.0001	0.0001	0.0001
Pout	1	13.8	16.8	0.004	0.070	0.072	0.005	0.149	0.158	0.0002	0.0024	0.0028	0.0006	0.0002	0.0001	0.0001	0.0001	0.0001	0.0015	0.0001	0.0001
Ray*	4	21.8	17.6	0.004	0.065	0.068	0.005	0.096	0.097	0.0388	0.0269	0.0026	0.0003	0.0007	0.0008	0.0003	0.0002	0.0001	0.0001	0.0001	0.0001
Saithe / coalfish	4	1.40	1.41	0.014	0.010	0.016	0.005	0.029	0.041	0.0719	0.0394	0.0063	0.0012	0.0009	0.0022	0.0004	0.0004	0.0006	0.0004	0.0001	0.0001
Salmon	4	1.66	1.32	0.015	0.003	0.023	0.005	0.040	0.038	0.0002	0.0010	0.0059	0.0018	0.0009	0.0007	0.0004	0.0006	0.0005	0.0007	0.0001	0.0001
Sardine	4	6.02	5.81	0.025	0.100	0.047	0.005	0.070	0.099	0.0019	0.0194	0.0064	0.0012	0.0017	0.0015	0.0004	0.0004	0.0005	0.0005	0.0001	0.0001
Scorpionfish	1	1.92	1.85	0.004	0.014	0.010	0.005	0.172	0.196	0.0002	0.0002	0.0018	0.0001	0.0006	0.0006	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Seabass*	4	1.90	1.70	0.004	0.007	0.021	0.005	0.144	0.149	0.0005	0.0118	0.0110	0.0011	0.0014	0.0043	0.0011	0.0015	0.0012	0.0003	0.0001	0.0001
Sea bream*	4	3.30	2.68	0.054	0.075	0.050	0.005	0.109	0.098	0.0002	0.0008	0.0051	0.0011	0.0010	0.0010	0.0005	0.0005	0.0004	0.0003	0.0001	0.0001
Sole	4	14.3	14.5	0.004	0.044	0.010	0.005	0.112	0.126	0.0014	0.0041	0.0024	0.0004	0.0004	0.0003	0.0002	0.0004	0.0002	0.0001	0.0001	0.0001
Swordfish*	4	1.00	0.70	0.013	0.026	0.030	0.005	0.844	0.944	0.0671	0.0002	0.0192	0.0066	0.0029	0.0077	0.0006	0.0006	0.0004	0.0001	0.0001	0.0001
Tuna*	4	2.45	1.79	0.029	0.016	0.008	0.005	0.331	0.330	0.0132	0.0004	0.0073	0.0018	0.0018	0.0019	0.0004	0.0007	0.0004	0.0001	0.0001	0.0001
Whiting	4	3.85	3.75	0.011	0.006	0.027	0.005	0.252	0.170	0.0011	0.0013	0.0037	0.0009	0.0007	0.0005	0.0003	0.0004	0.0004	0.0003	0.0001	0.0001

a: Nb composite samples. Each sample is composed by 5 subsamples of the same species, representative of the provisioning methods in each zone (port, market, supermarket…).
b: The total for the forms of speciation of arsenic is not equal to the total arsenic (As_T) for all species since the concentrations supplied correspond to individual analyses of elements
c: The column of OTC results corresponds to the sum of the 9 organostannic compounds
* Predatory fish as described in the Commission Regulation (EC) No 78/2005 of 19 January 2005.

Table 22: Mean contamination by trace elements of molluscs and crustaceans (µg/g fresh weight)

Mollusc, crustacean	n [a]	As_T [b]	AsB	MMA	DMA	As(III)	As(V)	Hg_T	MeHg	Cd	Pb	OTC [c]	MBT	DBT	TBT	MPT	DPT	TPT	MOT	DOT	TOT
Calico scallop	1	2.42	1.90	0.004	0.190	0.003	0.005	0.011	0.007	1.1391	0.0931	0.0040	0.0005	0.0004	0.0025	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Cockle	2	1.78	1.50	0.004	0.024	0.105	0.005	0.018	0.016	0.0358	0.0437	0.0074	0.0006	0.0013	0.0046	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001
Common periwinkle	3	6.39	4.08	0.020	0.055	0.185	0.005	0.011	0.009	0.1890	0.0901	0.0033	0.0009	0.0007	0.0006	0.0004	0.0002	0.0003	0.0001	0.0001	0.0001
Crab	3	16.8	13.1	0.004	0.051	0.252	0.005	0.176	0.175	4.0954	0.0189	0.0087	0.0011	0.0014	0.0028	0.0003	0.0004	0.0011	0.0014	0.0001	0.0001
Cuttle fish	2	5.59	5.30	0.014	0.035	0.030	0.005	0.040	0.048	0.0559	0.0921	0.0035	0.0014	0.0009	0.0007	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Great scallop	4	2.96	2.41	0.004	0.049	0.096	0.005	0.025	0.034	0.2695	0.0665	0.0098	0.0009	0.0010	0.0067	0.0004	0.0002	0.0002	0.0001	0.0001	0.0001
Lobster	1	7.08	5.35	0.004	0.094	0.041	0.005	0.073	0.092	0.4326	0.0039	0.0012	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Mussel	4	6.61	5.55	0.023	0.174	0.089	0.005	0.041	0.038	0.0329	0.1073	0.0033	0.0008	0.0005	0.0011	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001
Octopus	1	42.3	32.0	0.004	0.015	0.226	0.005	0.340	0.219	0.0324	0.0598	0.0053	0.0013	0.0005	0.0029	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Oyster	4	2.20	1.61	0.005	0.080	0.109	0.005	0.007	0.007	0.0343	0.0298	0.0075	0.0012	0.0012	0.0042	0.0002	0.0001	0.0002	0.0001	0.0001	0.0001
Scampi	3	8.75	7.08	0.004	0.006	0.089	0.005	0.084	0.087	0.1077	0.0314	0.0063	0.0010	0.0013	0.0006	0.0004	0.0009	0.0019	0.0001	0.0001	0.0001
Sea urchin	1	3.25	2.90	0.004	0.030	0.217	0.005	0.006	0.003	0.0643	0.1488	0.0053	0.0008	0.0006	0.0033	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Shrimp	4	1.31	1.12	0.004	0.020	0.009	0.005	0.033	0.031	1.0915	0.0072	0.0021	0.0003	0.0003	0.0007	0.0003	0.0001	0.0002	0.0001	0.0001	0.0001
Spider crab	1	37.2	27.4	0.159	0.067	0.183	0.005	0.034	0.036	0.4606	0.0583	0.0016	0.0003	0.0002	0.0000	0.0004	0.0001	0.0002	0.0001	0.0001	0.0001
Squid	4	5.92	5.06	0.004	0.008	0.006	0.005	0.049	0.055	0.0511	0.0071	0.0133	0.0009	0.0014	0.0100	0.0003	0.0002	0.0001	0.0001	0.0001	0.0001
Swimcrab	2	10.1	8.37	0.004	0.157	0.053	0.005	0.073	0.069	0.1274	0.1254	0.0140	0.0052	0.0036	0.0027	0.0005	0.0002	0.0015	0.0001	0.0001	0.0001
Whelk	3	15.8	14.5	0.004	0.018	0.077	0.005	0.051	0.034	0.7807	0.0603	0.0054	0.0010	0.0011	0.0020	0.0002	0.0003	0.0005	0.0001	0.0001	0.0001

a: Nb composite samples. Each sample is composed by 5 subsamples of the same species, representative of the provisioning methods in each zone (port, market, supermarket…).
b: The total for the forms of speciation of arsenic is not equal to the total arsenic (As_T) for all species since the concentrations supplied correspond to individual analyses of elements
c: The column of OTC results corresponds to the sum of the 9 organostannic compounds

Table 23: Mean contamination by trace elements of other seafood (µg/g fresh weight)

Other seafood	n [a]	As_T [b]	AsB	MMA	DMA	As(III)	As(V)	Hg_T	MeHg	Cd	Pb	OTC [c]	MBT	DBT	TBT	MPT	DPT	TPT	MOT	DOT	TOT
Canned food																					
Anchovy	2	0.80	0.57	0.019	0.036	0.018	0.005	0.022	0.016	0.3506	0.0571	0.0093	0.0033	0.0013	0.0041	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Crab	1	2.23	2.05	0.004	0.003	0.067	0.005	0.053	0.136	0.1713	0.0109	0.0050	0.0021	0.0013	0.0010	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Mackerel	1	0.70	0.18	0.082	0.186	0.006	0.005	0.031	0.027	0.0446	0.0058	0.0130	0.0075	0.0021	0.0028	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Pilchard	1	1.91	1.59	0.004	0.139	0.064	0.005	0.020	0.021	0.0126	0.0059	0.0041	0.0008	0.0004	0.0022	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Sardine	1	3.54	2.14	0.004	0.018	0.030	0.005	0.043	0.023	0.2159	0.2882	0.0100	0.0058	0.0017	0.0019	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Tuna*	5	0.81	0.94	0.004	0.011	0.003	0.005	0.190	0.210	0.0178	0.0023	0.0139	0.0050	0.0058	0.0022	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001
Smoked fish																					
Haddock	1	1.06	1.16	0.004	0.001	0.016	0.005	0.007	0.010	0.0002	0.0097	0.0009	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Herring	1	1.25	1.62	0.004	0.015	0.008	0.005	0.022	0.037	0.0002	0.0053	0.0033	0.0008	0.0007	0.0012	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Mackerel	1	2.06	1.58	0.004	0.307	0.030	0.005	0.025	0.042	0.0027	0.0045	0.0063	0.0020	0.0009	0.0028	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Salmon	1	2.00	1.48	0.004	0.049	0.001	0.005	0.027	0.037	0.0002	0.0053	0.0056	0.0009	0.0008	0.0032	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Seafood-based dish																					
Fish soup	2	0.68	0.89	0.004	0.003	0.019	0.005	0.009	0.007	0.0151	0.0070	0.0012	0.0001	0.0001	0.0005	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Paella	1	0.11	0.27	0.004	0.007	0.001	0.005	0.000	0.000	0.0128	0.0119	0.0013	0.0001	0.0002	0.0004	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Surimi	1	0.39	0.33	0.004	0.001	0.006	0.005	0.021	0.018	0.0083	0.0033	0.0083	0.0020	0.0046	0.0011	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Tarama. terrine ou mousse	1	0.18	1.18	0.004	0.118	0.001	0.005	0.001	0.001	0.0002	0.0002	0.0008	0.0001	0.0001	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

a: Nb composite samples. Each sample is composed by 5 subsamples of the same species, representative of the provisioning methods in each zone (port, market, supermarket…).
b: The total for the forms of speciation of arsenic is not equal to the total arsenic (As_T) for all species since the concentrations supplied correspond to individual analyses of elements
c: The column of OTC results corresponds to the sum of the 9 organostannic compounds
* Predatory fish as described in the Commission Regulation (EC) No 78/2005 of 19 January 2005

Table 24: Mean contamination by trace elements of fish (excluding eel), molluscs and crustaceans per site (µg/g fresh weight)

Site		n[a]		As_T[b]	AsB	MMA	DMA	As(III)	As(V)	Hg_T	MeHg	Cd	Pb	OTC[c]	MBT	DBT	TBT	MPT	DPT	TPT	MOT	DOT	TOT
Le Havre	Fish	22	Mean	7.67	7.40	0.020	0.028	0.021	0.005	0.137	0.141	0.0816	0.0055	0.0078	0.0017	0.0015	0.0024	0.0005	0.0005	0.0010	0.0001	0.0001	0.0001
			SD	8.36	7.79	0.056	0.040	0.018	0.000	0.155	0.174	0.3606	0.0097	0.0069	0.0016	0.0011	0.0039	0.0004	0.0004	0.0018	0.0001	0.0000	0.0000
	Mollusc.	10	Moy	7.19	5.43	0.011	0.053	0.120	0.005	0.079	0.078	0.6311	0.0694	0.0164	0.0026	0.0026	0.0080	0.0005	0.0006	0.0014	0.0005	0.0001	0.0001
	Crustacean		SD	5.50	4.10	0.025	0.052	0.101	0.000	0.140	0.136	1.3307	0.0650	0.0126	0.0028	0.0021	0.0103	0.0002	0.0006	0.0018	0.0012	0.0000	0.0000
Lorient	Fish	27	Mean	7.78	7.51	0.037	0.039	0.043	0.005	0.175	0.168	0.0179	0.0092	0.0039	0.0010	0.0005	0.0007	0.0003	0.0005	0.0003	0.0003	0.0002	0.0001
			SD	7.34	7.26	0.116	0.076	0.045	0.000	0.232	0.217	0.0569	0.0298	0.0042	0.0014	0.0007	0.0020	0.0003	0.0004	0.0002	0.0004	0.0003	0.0000
	Mollusc.	11	Mean	10.90	8.68	0.023	0.058	0.102	0.005	0.043	0.047	1.1964	0.0428	0.0033	0.0004	0.0005	0.0014	0.0004	0.0002	0.0002	0.0001	0.0001	0.0001
	Crustacean		SD	11.18	8.43	0.048	0.082	0.130	0.000	0.025	0.031	3.6751	0.0363	0.0025	0.0002	0.0006	0.0018	0.0002	0.0001	0.0001	0.0000	0.0000	0.0000
La Rochelle	Fish	23	Mean	6.40	5.57	0.012	0.023	0.016	0.005	0.177	0.180	0.0109	0.0103	0.0055	0.0013	0.0010	0.0015	0.0004	0.0006	0.0004	0.0002	0.0001	0.0001
			SD	8.11	5.76	0.023	0.033	0.016	0.000	0.175	0.165	0.0329	0.0238	0.0063	0.0024	0.0014	0.0024	0.0003	0.0007	0.0005	0.0003	0.0000	0.0000
	Mollusc.	12	Mean	5.90	4.96	0.004	0.075	0.070	0.005	0.038	0.034	0.2779	0.0597	0.0038	0.0008	0.0006	0.0017	0.0002	0.0001	0.0002	0.0001	0.0001	0.0001
	Crustacean		SD	5.57	5.15	0.000	0.143	0.089	0.000	0.041	0.037	0.5127	0.0527	0.0020	0.0007	0.0004	0.0015	0.0002	0.0001	0.0002	0.0000	0.0000	0.0000
Toulon	Fish	23	Mean	8.29	7.57	0.008	0.030	0.020	0.005	0.211	0.220	0.0129	0.0200	0.0080	0.0013	0.0019	0.0031	0.0004	0.0005	0.0003	0.0003	0.0001	0.0001
			SD	13.29	12.55	0.021	0.049	0.029	0.000	0.274	0.300	0.0339	0.0828	0.0108	0.0018	0.0039	0.0055	0.0003	0.0004	0.0003	0.0006	0.0000	0.0000
	Mollusc.	10	Mean	8.36	6.98	0.006	0.048	0.093	0.005	0.059	0.050	0.1196	0.0479	0.0036	0.0007	0.0005	0.0018	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	Crustacean		SD	12.63	9.77	0.006	0.047	0.093	0.000	0.101	0.065	0.1654	0.0667	0.0025	0.0005	0.0003	0.0018	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

a: Nb composite samples. Each sample is composed by 5 subsamples of the same species, representative of the provisioning methods in each zone (port, market, supermarket…).

b: The total for the forms of speciation of arsenic is not equal to the total arsenic (As_T) for all species since the concentrations supplied correspond to individual analyses of elements

c: The column of OTC results corresponds to the sum of the 9 organostannic compounds

Figure 11 clearly shows that the species with the highest MeHg levels are predator fish (swordfish, emperor, tuna, eel, ling and catshark). However, with the exception of swordfish, these are not necessarily the fish containing the most omega 3 fatty acids. Some fish with much lower concentrations of MeHg (<0.1 µg/g) have much higher levels of omega 3; examples include halibut, mackerel, salmon, anchovy and sardine. In other words, we find large disparities in the MeHg/Omega 3 ratio between species.

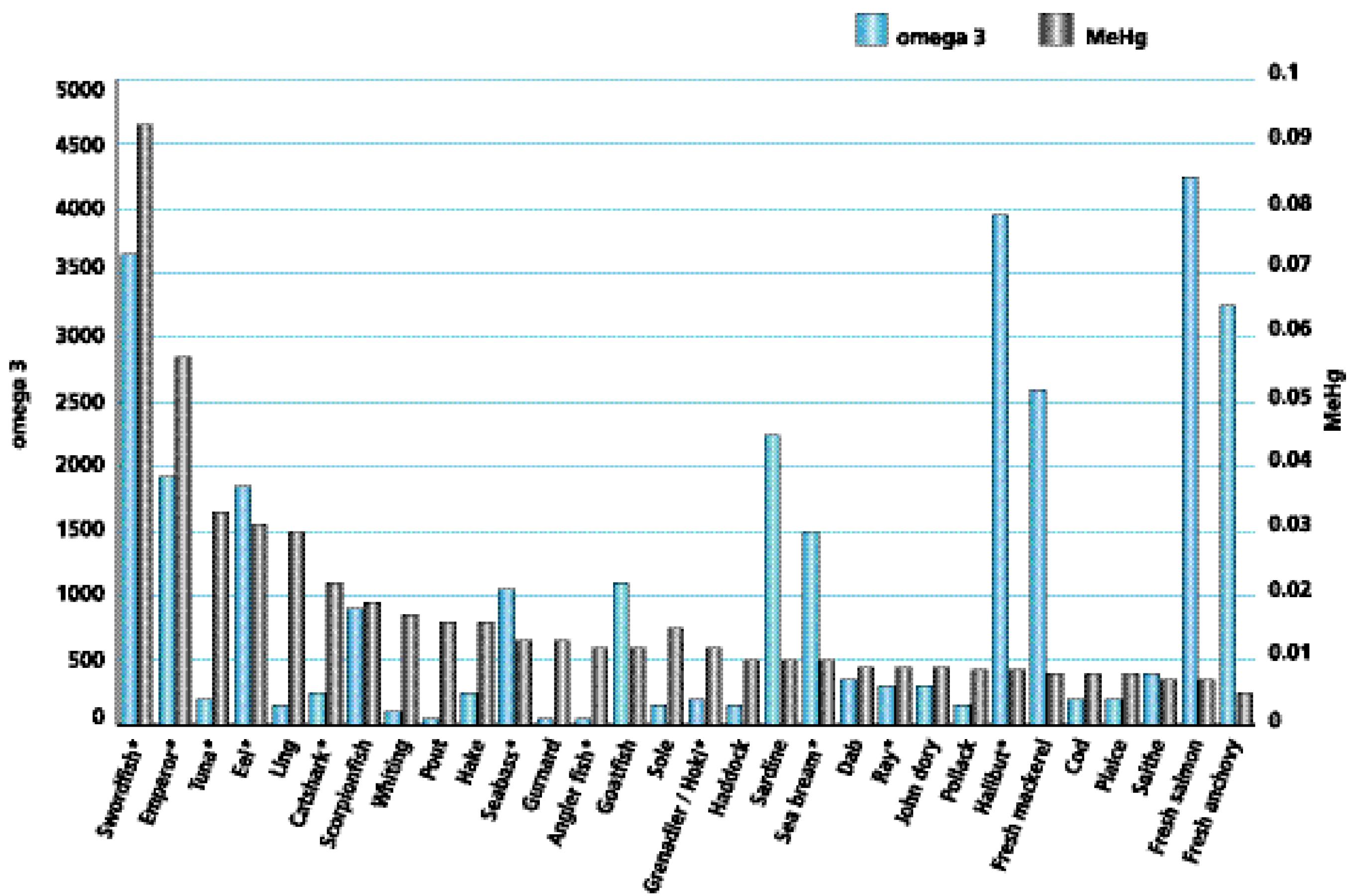
Those differences are less obvious for molluscs and crustaceans (Figure 12).

Nevertheless we note that for all the products (excepting canned and smoked products and prepared dishes) the lipid level correlates positively with the methylmercury level (Pearson correlation coefficient r=0.27, p=0.01). Similarly the level of n-3 LC-PUFAs (EPA, DPA and DHA) correlates positively with the methylmercury level (r=0.23, p=0.03). This may be explained by the fact that the fish with the highest MeHg levels are at the end of the food chain: the MeHg accumulates along the chain. In parallel, some fatty acids including the precursors and long-chain n-3 and n-6 derivatives also accumulate. Kainz and his team propose a regulation of the assimilation of these fatty acids by marine organisms in order to optimise their physiological performance[111].

We also note that while the MeHg/Omega 3 profile is homogeneous for fish (tuna, sardine, mackerel, anchovy, salmon), whatever its form (fresh, smoked, canned), this is not true for crab. The omega 3 concentration of canned crab is much lower than that of fresh and frozen crab despite a comparable MeHg level (not shown in Figures 11 and 12).

111 Kainz M., Telmer K. and Mazumder A. Bioaccumulation patterns of methyl mercury and essential fatty acids in lacustrine planktonic food webs and fish. Sci. Total Environ. 2005.

Figure 11: Mean Omega 3 and MeHg concentrations of fish (mg/100 g fresh weight)



* Predatory fish as described in the Commission Regulation (EC) No 78/2005 of 19 January 2005

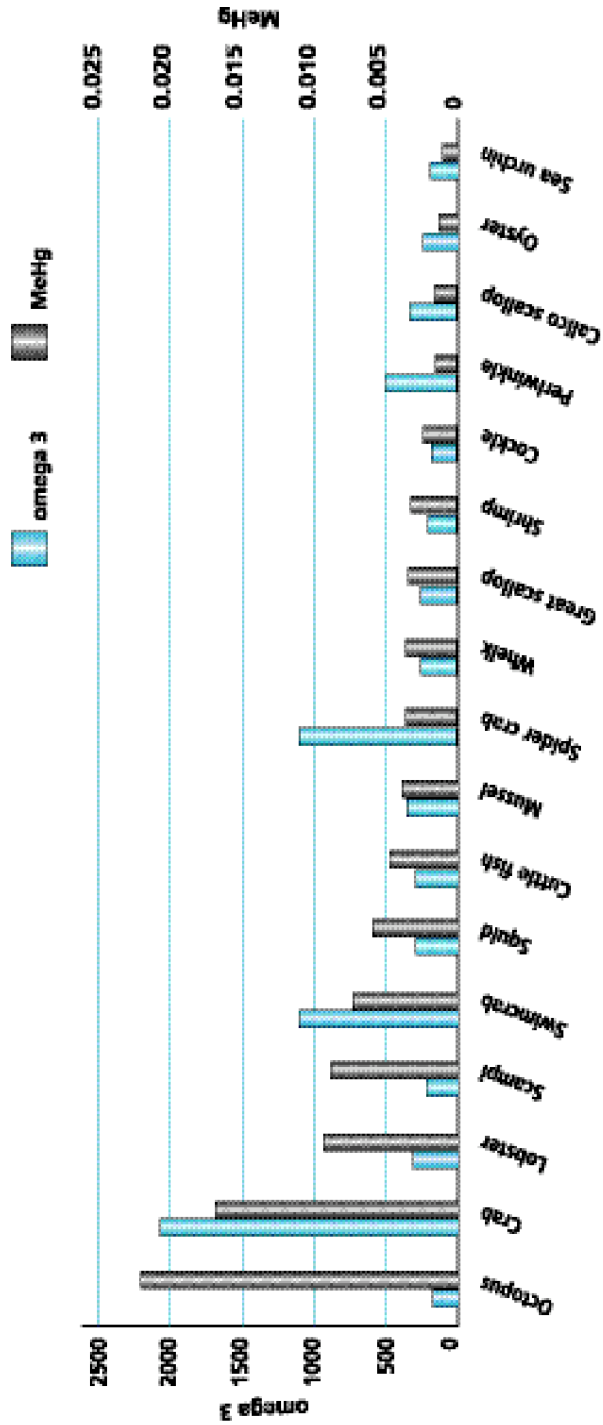


Figure 12: Mean Omega 3 and MeHg concentrations of molluscs and crustaceans (mg/100 g fresh weight)

3.3 Contamination by persistent organic pollutants

Tables 25 to 28 present the results of the analyses of persistent organic pollutants in sampled food, averaged for the four regions.

3.3.1 Fresh and frozen fish

PCDD/F et PCB-DL : Table 25 shows that the fish the most contaminated by dioxins (PCDD/Fs) and dioxin-like polychlorobiphenyls (DL-PCBs) are eel (88.3 pg TEQ_{WHO}/g fresh weight) and sardine (10.6 pg TEQ_{WHO}/g fresh weight). These are followed by the predators emperor fish and seabass with levels of 7.0 to 3.9 pg TEQ_{WHO}/g fresh weight. The least contaminated fish are catshark, anglerfish, saithe and cod with less than 0.15 pg TEQ_{WHO}/g fresh weight.

These results are consistent with the DGAL[109] monitoring plans and with the English data[112].

The results for eel are subject to reservation in view of the composition and origin of the sample, as explained earlier concerning the fatty acid composition. We note that this sample of eel exceeds the regulatory limit fixed for PCDD/Fs and DL-PCBs (12 pg TEQ_{WHO}/g fresh weight), as does the composite sample of sardine (limit fixed at 8 pg TEQ_{WHO}/g fresh weight). The other samples all have levels less than the limits (4 pg TEQ_{WHO}/g fresh weight for PCDD/Fs and 8 pg TEQ_{WHO}/g fresh weight for the total of the PCDD/Fs and DL-PCBs)[113].

i-PCB : Eel and sardine are also the fish most heavy contaminated by "indicator polychlorobiphenyls" (i-PCB), with respectively 2,26 and 117 ng/g fresh weight. The i-PCBs being representative of the PCBs contamination, we find emperor, seabass and seabream in which the i-PCBs levels exceed 30 ng/g fresh weight. The least contaminated fish are saithe and cod with values of 1.1 and 1.2 ng/g fresh weight respectively. With the exception of the eel, these results are consistent with the DGAL[109] monitoring plans. We recall that at present there is no regulation concerning the i-PCBs levels in fish and seafood products.

PBDE : The fish the most contaminated by polybromodiphenylethers (PBDE 28, 47, 99, 100, 153, 154, 183) is again eel with an average of 26.6 ng/g fresh weight. This level is exceptional in that the other fish have contamination levels of less than 3 ng/g. The PBDEs level increases with the fat content: mackerel, anchovy, seabass, sardine and salmon all have moderately heavy high contaminations between 2 and 3 ng/g fresh weight. The least contaminated fish is catshark with 0.3 ng/g fresh weight and less than 1% of lipids. The PBDEs contamination does not depend on whether the species is a predator or not. These results are consistent with the JECFA data in 2005 on fish and seafood products[114]. As in the case of i-PCBs, to date there is no regulation concerning PBDEs levels in fish and seafood.

112 FSA. Dioxins and dioxin-like PCBs in farmed and wild fish and shellfish. February 2006.

113 Commission Regulation (EC) No 199/2006 of 3 February 2006 amending Regulation (EC) No 466/2001 setting maximum levels for certain contaminants in foodstuffs as regards dioxins and dioxin-like PCBs.

114 JECFA. Safety evaluation of certain food additives and contaminants. 64th report of the Joint FAO/WHO Expert Committee on Food Additives and contaminants. WHO Geneva. 2005.

3.3.2 Molluscs and crustaceans

When the contamination is expressed relative to grams of fat, molluscs and crustaceans generally have lower levels of persistent organic pollutants than fish (results not presented), but when the contamination is expressed relative to grams of fresh weight this difference (apart from eel) is less marked (Table 26).

PCDD/F and DL-PCB : The species most contaminated by PCDD/Fs and DL-PCBs are swimcrab with 18.6 pg TEQ_{WHO}/g fresh weight and crab with 6.5 pg TEQ_{WHO}/g fresh weight. This can be partly explained by the very heavy contamination of the crab and swimcrab samples from Le Havre. Moreover, the composite swimcrab sample exceeds the regulatory limits for PCDD/Fs (4 pg TEQ_{WHO}/g fresh weight) and for PCDD/Fs and DL-PCBs (8 pg TEQ_{WHO}/g fresh weight)[113]. These species are followed by the spider crab with 5.6 pg TEQ_{WHO}/g fresh weight. The least contaminated species are shrimp and periwinkle with 0.1 pg TEQ_{WHO}/g fresh weight.

i-PCB : Swimcrab, crab and spider crab also display the highest levels of i-PCB, with respectively 187, 58 and 20 ng/g gross fresh weight. Shrimp and cockle are the least contaminated with 0.4 and 0.7 ng/g fresh weight respectively.

PBDE : Spider crab displays the highest level of PBDEs (28, 47, 99, 100, 153, 154, 183) with 3.0 ng/g fresh weight. Octopus and calico scallop are the species the least contaminated with PBDEs, with an average level below 0.2 ng/g fresh weight.

3.3.3 Other seafood

PCDD/F and DL-PCB : The products with the highest concentrations of PCDD/Fs and DL-PCBs are canned sardine with 3.9 pg TEQ_{WHO}/g fresh weight (Table 27). These data are quite consistent with the English data in 2006[112]. No product exceeds the regulatory values.

i-PCB : Canned sardine also has the highest level of i-PCBs (35.5 ng/g fresh weight) along with smoked mackerel and smoked salmon (13.9 and 12.8 ng/g fresh weight respectively).

PBDE : Canned pilchard, smoked mackerel and smoked salmon have the highest levels of PBDEs (28, 47, 99, 100, 153, 154, 183) with 3.2, 2.8 and 2.7 ng/g fresh weight respectively. These same products are relatively rich in total lipids (>10%).

The products the least contaminated by POPs, all pollutants included, are paella and smoked haddock.

Table 25: Mean contamination by persistent organic pollutants of fresh and frozen fish

Fish	Nb samples[a]	Lipids (g/100 g)	PCDD/F (pg TEQ_{OMS}/g FW)	PCB-DL (pg TEQ_{OMS}/g FW)	Total PCDD/F and PCB-DL (pg TEQ_{OMS}/g FW)	iPCB (ng/g FW)	PBDE (ng/g FW)
Anchovy	1	10.8	0.10	0.67	0.77	8.90	2.24
Angler fish*	4	0.33	0.03	0.08	0.11	1.67	0.46
Atshark*	4	0.88	0.03	0.08	0.10	2.38	0.27
Cod	4	0.52	0.03	0.11	0.14	1.19	0.54
Common dab	4	1.02	0.21	0.34	0.55	2.61	0.59
Eel*	1	22.1	1.50	86.8	88.3	2257	26.6
Emperor*	3	6.42	1.44	5.58	7.02	56.4	1.21
Goatfish	3	4.25	0.54	2.07	2.61	18.8	0.74
Grenadier / hoki*	4	0.59	0.08	0.09	0.17	2.83	0.52
Gurnard	1	1.15	0.49	1.11	1.60	13.3	0.51
Haddock	2	0.37	0.07	0.21	0.28	2.74	0.64
Hake	4	0.96	0.04	0.26	0.30	3.36	0.49
Halibut*	4	12.5	0.89	1.37	2.27	15.0	1.59
John dory	2	0.91	0.08	0.41	0.50	5.99	0.51
Ling*	4	0.44	0.04	0.11	0.15	1.75	0.49
Mackerel	4	7.93	0.60	2.20	2.80	34.5	2.71
Plaice*	2	0.52	0.24	0.53	0.77	6.47	0.63
Pollack	3	0.30	0.02	0.23	0.25	3.26	0.41
Pout	1	0.43	0.05	0.18	0.23	1.95	0.42
Ray*	4	1.17	0.09	0.13	0.22	1.52	0.43
Saithe / coalfish	4	1.43	0.02	0.10	0.12	1.08	0.75
Salmon	4	13.5	0.50	1.32	1.82	14.5	2.55
Sardine	4	5.64	1.80	8.77	10.6	117	2.10
Scorpionfish	1	3.39	0.47	1.74	2.20	16.0	0.60
Seabass*	4	3.70	0.64	3.22	3.86	37.8	2.39
Sea bream*	4	5.49	0.38	2.20	2.58	26.9	1.10
Sole	4	0.50	0.05	0.15	0.21	4.91	0.39
Swordfish*	4	13.8	0.09	0.43	0.52	4.23	0.85
Tuna*	4	1.02	0.04	0.35	0.39	3.88	0.56
Whiting	4	0.42	0.05	0.24	0.29	4.26	0.54

FW: fresh weight. a: Nb composite samples. Each sample is composed by 5 subsamples of the same species, representative of the provisioning methods in each zone (port, market, supermarket…).

* Predatory fish as described in the Commission Regulation (EC) No 78/2005 of 19 January 2005

Table 26: Mean contamination by persistent organic pollutants of molluscs and crustaceans

Mollusc, crustacean	Nb samples[a]	Lipids (g/100 g)	PCDD/F (pg TEQ_{OMS}/g FW)	PCB-DL (pg TEQ_{OMS}/g FW)	Total PCDD/F and PCB-DL (pg TEQ_{OMS}/g FW)	iPCB (ng/g FW)	PBDE (ng/g FW)
Calico scallop	1	1.37	0.20	0.15	0.34	3.15	0.20
Cockle	2	0.57	0.07	0.11	0.18	0.73	0.20
Common periwinkle	3	2.46	0.06	0.09	0.15	1.04	0.60
Crab	3	7.76	2.62	3.90	6.52	58.1	0.77
Cuttle fish	2	1.63	0.07	0.10	0.16	2.15	0.23
Great scallop	4	1.31	0.20	0.19	0.39	4.98	0.30
Lobster	1	2.03	0.72	0.81	1.52	4.38	0.42
Mussel	4	1.48	0.23	0.33	0.56	3.95	0.45
Octopus	1	0.66	0.06	0.20	0.25	1.97	0.20
Oyster	4	0.93	0.27	0.32	0.60	2.70	0.25
Scampi	3	0.86	0.27	0.20	0.47	1.82	0.28
Sea urchin	1	1.09	0.04	0.24	0.28	1.34	0.25
Shrimp	4	1.22	0.05	0.06	0.11	0.44	0.32
Spider crab	1	4.94	2.36	3.22	5.58	19.5	3.01
Squid	4	1.87	0.33	0.59	0.91	6.59	0.69
Swimcrab	2	4.66	4.79	13.8	18.6	187	1.03
Whelk	3	1.45	0.49	0.20	0.68	1.74	0.38

FW: fresh weight. a: Nb composite samples. Each sample is composed by 5 subsamples of the same species, representative of the provisioning methods in each zone (port, market, supermarket…).

Table 27: Mean contamination by persistents organic pollutants of other seafood

Other seafood	Nb samples[a]	Lipids (g/100 g)	PCDD/F (pg TEQ_{OMS}/g FW)	PCB-DL (pg TEQ_{OMS}/g FW)	Total PCDD/F and PCB-DL (pg TEQ_{OMS}/g FW)	iPCB (ng/g FW)	PBDE (ng/g FW)
Canned food							
Anchovy	2	8.19	0.03	0.14	0.17	1.21	1.02
Crab	1	13.9	0.05	0.05	0.10	0.22	0.74
Mackerel	1	10.4	0.21	0.65	0.86	6.06	1.46
Pilchard	1	13.0	0.85	0.93	1.78	9.32	3.24
Sardine	1	7.84	0.77	3.12	3.87	35.5	1.36
Tuna*	5	0.88	0.02	0.07	0.09	1.47	0.59
Smoked fish							
Haddock	1	0.35	0.032	0.038	0.070	0.315	0.275
Herring	1	10.3	0.346	0.434	0.779	4.963	0.958
Mackerel	1	17.1	0.331	1.014	1.345	13.89	2.828
Salmon	1	10.3	0.303	1.057	1.360	12.84	2.733
Seafood-based dish							
Fish soup	2	0.98	0.036	0.095	0.131	0.920	0.240
Paella	1	28.0	0.027	0.019	0.046	0.173	0.199
Surimi	1	4.08	0.013	0.023	0.036	1.260	0.628
Tarama, terrine ou mousse	1	4.43	0.026	0.062	0.089	1.159	1.060

FW: fresh weight. a: Nb composite samples. Each sample is composed by 5 subsamples of the same species, representative of the provisioning methods in each zone (port, market, supermarket…).
* Predatory fish as described in the Commission Regulation (EC) No 78/2005 of 19 January 2005

3.3.4 Regional variations

Generally speaking, the contamination by persistent organic pollutants of our fish and seafood samples displays a north-south gradient. The Le Havre samples are the most contaminated, for all the pollutants considered, and the Toulon samples are the least contaminated (Table 28), although these differences are not statistically significant (on all the products and on the 19 common fish sampled in the four zones).

In Le Havre, the average PCDD/Fs and DL-PCBs contamination is 1.9 pg TEQ_{WHO}/g fresh weight for fish and 5.1 pg TEQ_{WHO}/g fresh weight for molluscs and crustaceans. The average i-PCB contamination reaches 20.5 ng/g fresh weight for fish and 55.0 ng/g for molluscs and crustaceans. The average PBDEs (28, 47, 99, 100, 153, 154, 183) contamination is 1.3 ng/g of fresh weight for fish and 0.6 ng/g of fresh weight for molluscs and crustaceans, the highest average being found in the Lorient samples (just slightly higher at 0.7 ng/g fresh weight). However, we note that these averages are not calculated for the same species in the four regions, but for species that in each region cover about 90% of the fish and seafood consumption of heavy consumers see 1.3.

The samples in Toulon are generally the least contaminated with POPs with average PCDD/Fs and DL-PCBs levels of 1.1 pg TEQ_{WHO}/g in fish and 0.39 pg TEQ_{WHO}/g in molluscs and crustaceans. The average i-PCBs contamination is 12.2 ng/g for fish and 2.1 ng/g for molluscs and crustaceans. Finally, the average PBDEs contaminations of the Toulon samples are again the lowest: 0.8 ng/g fresh weight for fish and 0.3 ng/g fresh weight for molluscs and crustaceans.

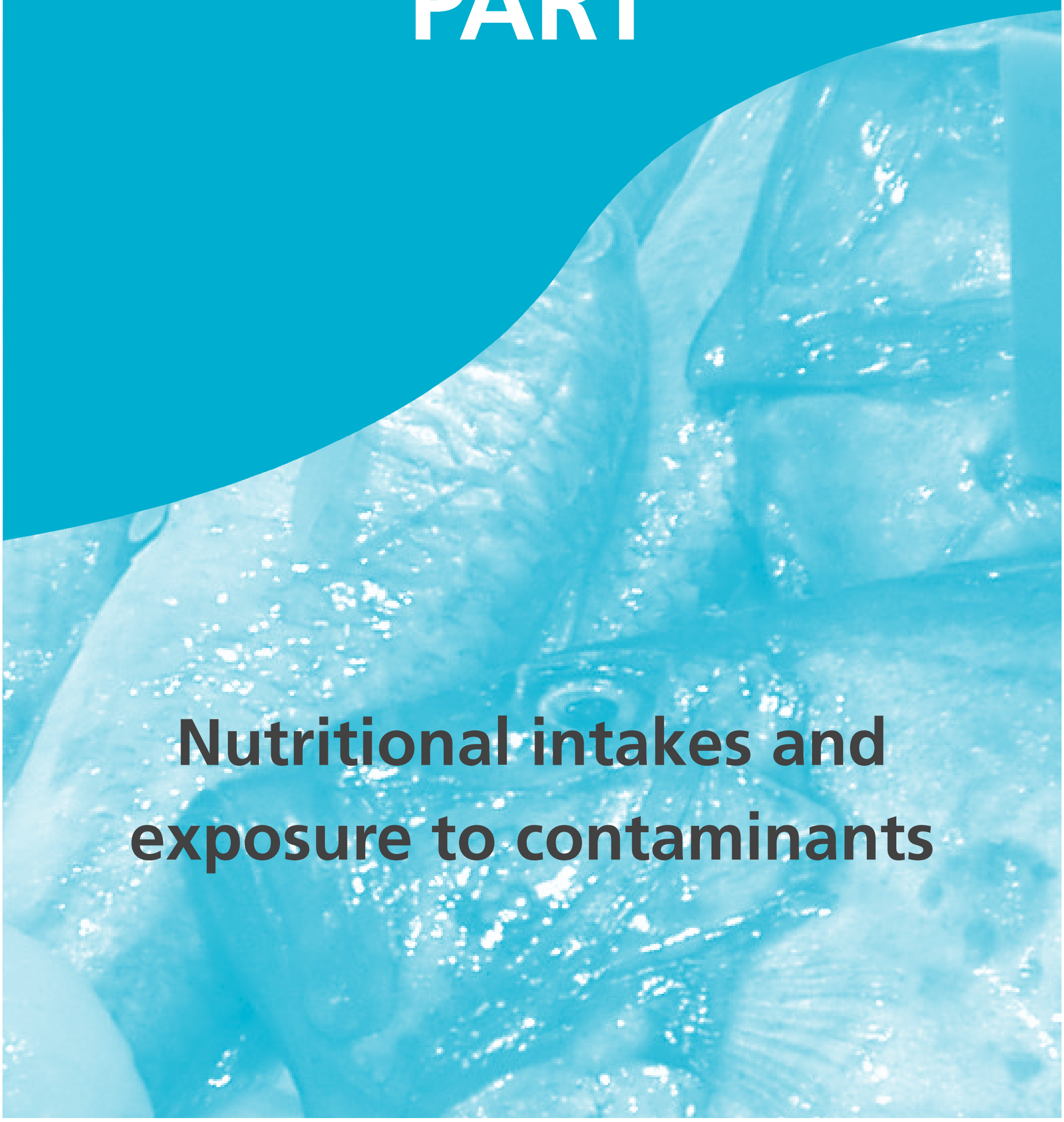
When the contamination is expressed per gram of fat rather than fresh weight, the contamination gradient still exists for PBDEs contamination of fish and PCDD/Fs and DL-PCBs contamination of molluscs and crustaceans (results not presented). We also note that the PBDEs contamination of molluscs and crustaceans, when expressed per gram of fat, is relatively homogeneous across the study zones. The same is true for i-PCBs contamination of fish, molluscs and crustaceans (with the exception of samples from Le Havre). The high PCDD/Fs, DL-PCBs and i-PCBs levels found in molluscs and crustaceans from Le Havre are due to the heavy contamination of the crab and swimcrab samples.

Table 28: Mean contamination by persistent organic pollutants of fish (excluding eel), molluscs and crustaceans per site

		Nb samples[a]		Lipids (g/100 g)	PCDD/F (pg TEQ_{OMS}/g FW)	PCB-DL (pg TEQ_{OMS}/g FW)	Total PCDD/F and PCB-DL (pg TEQ_{OMS}/g FW)	iPCB (ng/g FW)	PBDE (ng/g FW)
Le Havre	Fish	22	Mean	3.74	0.363	1.565	1.929	20.49	1.311
			SD	4.78	0.625	3.580	4.176	48.94	1.455
	Mollusc, Crustacean	10	Mean	2.70	1.440	3.707	5.147	55.01	0.616
			SD	2.13	2.457	7.852	0.28	114.9	0.507
Lorient	Fish	27	Mean	3.24	0.341	1.277	1.618	14.60	0.852
			SD	4.85	0.649	2.365	2.979	26.76	0.750
	Mollusc, Crustacean	11	Mean	2.56	0.731	0.882	1.614	5.965	0.695
			SD	2.62	1.012	1.226	2.222	7.795	0.832
La Rochelle	Fish	23	Mean	3.19	0.336	1.196	1.532	13.78	0.881
			SD	4.21	0.473	1.835	2.283	20.58	0.676
	Mollusc, Crustacean	12	Mean	1.78	0.314	0.225	0.539	3.008	0.343
			SD	1.54	0.399	0.221	0.571	3.259	0.144
Toulon	Fish	23	Mean	3.91	0.246	0.884	1.130	12.22	0.809
			SD	4.73	0.291	0.992	1.243	14.57	0.626
	Mollusc, Crustacean	10	Mean	1.22	0.161	0.226	0.387	2.061	0.319
			SD	0.69	0.209	0.228	0.432	1.648	0.102

FW: fresh weight. a: Nb composite samples. Each sample is composed by 5 subsamples of the same species, representative of the provisioning methods in each zone (port, market, supermarket…).

FOURTH PART



Nutritional intakes and exposure to contaminants

4.1 Fatty acid intakes

4.1.1 Food exposure

Fatty acid intakes through fish and seafood consumption for the four study zones are presented in Tables 29 to 33.

Note that these results correspond to fatty acid intakes only through fish and seafood, not intakes through the total diet. However, as mentioned in the introductory section of this report, leaving aside consumption of dietary supplements, marine products are the main source of long-chain polyunsaturated omega 3 fatty acids given that the conversion of the precursor ALA is very low (less than 1%, see "Methodology and General Presentation").

For the four study zones, the intakes of long-chain polyunsaturated omega 3 are lower but of the same order of magnitude as the estimated intakes of the Inuit and Japanese populations, both high seafood consumers[115 116]. Average EPA intakes are 419 to 517 mg/day for adult males and 403 to 509 mg/day for adult females; DHA intakes are 739 to 960 mg/day for men and 713 to 885 mg/day for women. The variability between individuals is also consistent with the results found in the literature.

Compared to intakes of the general French population through seafood[117], the PUFA intakes of the subjects of this study are 4.1 times higher in adult males and 4.2 times higher in women. More than half of these PUFAs are LC-PUFAs of the omega 3 family, EPA, DPA and DHA.

The RDAs of long-chain PUFAs, in particular DHA, are well covered (786 ± 612 mg DHA/day on average for an RDA of 100 to 120 mg/day), regardless of the age and sex and notably in adult females and women of child-bearing age.

As regards women of child-bearing age (18 to 44 years), in the four study zones fish and seafood consumption alone provides average intakes largely exceeding the RDA of LC-PUFAs and DHA for adult females and pregnant women.

Generally speaking, in all the zones, and whatever the age group and sex considered, the average EPA+DHA intakes exceed the 1 g/day recommended by the American Heart Association, yet they generally remain below the maximum limit of EPA+DHA intake of 2 g/day according to the AFSSA in 2003[10]; 14% of our subjects exceed this recommendation – through fish and seafood consumption alone. However, given the rarity of available data, this limit is not considered to be an intake beyond which health risk can appear, but rather an intake beyond which there is no proven nutritional benefit.

The statistical analyses reveal that the subjects in Le Havre, regardless of age and sex, have an estimated EPA intake through their fish and seafood consumption higher than subjects in Lorient and La Rochelle, and a DHA intake higher than subjects in La Rochelle and Toulon (Table 33).

Moreover, within a given zone there are no clear disparities in terms of n-3 LC-PUFA intakes between the different age groups and sexes (results not presented), apart from Lorient where men aged 18 to 64 have EPA, DHA, PUFA and omega 3 intakes significantly higher than women in the same age group ($p<0.05$).

115 Yamada T., Strong J.P., Ishii T., Ueno T., Koyama M., Wagayama H., Shimizu A., Sakai T., Malcom G.T. and Guzman M.A. Atherosclerosis and omega-3 fatty acids in the populations of a fishing village and a farming village in Japan. Atherosclerosis 153 : 469-481. 2000.

116 Dewailly E., Blanchet C., Lemieux S., Sauvé L., Gringas S., Ayotte P. and Holub B.J. n-3 fatty acids and cardiovascular disease risk factors among the Inuit of Nunavik. Am. J. Clin. Nutr. 74 : 464-473. 2001.

117 Razanamahefa L., Lafay L., Oseredczuk M., Thiebaut A., Laloux L., Gerber M., Astorg P. et Berta J.-L. Consommation lipidique de la population française et qualité des données de composition des principaux groupes d'aliments vecteurs. Bull. Cancer 92 (7-8) : 647-657. 2005.

Elderly subjects (≥ 65 years) in Le Havre have relatively higher intakes than those in other zones, with average EPA and DHA levels of 693 and 1,164 mg/day respectively compared to a maximum of 416 mg EPA and 770 mg DHA per day in the other zones. However these regional differences are not statistically significant. This particularity of elderly people in Le Havre can no doubt be explained by their very high consumption of herring (excluding smoked herring) of 129.3 g/week. According to the literature this fish is one of the most oily (8.5 to 12.3 g of lipids for 100 g[104]; 17.8 g of lipids for 100 g including 2.8 g of n-3 LC-PUFA[105]).

According to the zone and the group of individuals considered, consumption of fish and seafood products provides 3.3% to 5.8% of the RDA of the omega 3 precursor (ALA), 6.4% to 10% of the RDA of saturated fatty acids and 2.6% to 4.2% of the RDA of monounsaturated fatty acids.

The Appendix 5 shows that the main contributors to omega 3 exposure are salmon (27%), mackerel (12%), sardine (10%), anchovy and herring (about 5%). The consumption of salmon contribute on average to 33% of the recommended daily intake of EPA and DHA, mackerel to 28% and sardine to 24% (Appendix 6).

Indeed mackerel, sardine and salmon are major contributors in all four study zones, providing respectively 7% to 16%, 6% to 17% and 24% to 31% of the intake. Herring, an other oily fish, account for at least 5% of the intake only in Le Havre and La Rochelle, while anchovy contributes to omega 3 intake in Lorient and Toulon.

Table 29: Dietary intakes of fatty acids from fish and other seafood – Le Havre (mg/d)

	Adult men (18-64 y)			Adult women (18-64 y)			Older subjects (65 y and more)			Women of childbearing age (18-44 y)		
	n=44			n=179			n=26			n=98		
	Mean	SD	P95	Mean	SD	P95	Mean	SD	P95	Mean	SD	P95
Lipids (g/d)	**5.30**	**3.17**	**10.33**	**6.18**	**6.04**	**15.45**	**7.02**	**7.28**	**15.75**	**5.80**	**4.97**	**15.46**
Fatty acid												
C12:0	0	1	2	1	8	4	0	1	2	0	1	3
C14:0	113	85	229	141	174	379	159	165	419	126	113	365
C14:1 n-5	1	1	2	2	17	2	1	1	2	1	2	2
C15:0	4	3	11	5	7	14	5	5	14	5	7	14
C16:0	768	467	1,506	924	968	2,391	1,138	1,340	2,833	849	758	2,479
C16:1 n-7	145	96	304	206	350	513	236	253	617	164	152	436
C18:0	288	167	681	299	265	723	322	341	910	293	248	773
C18:1 trans	89	145	279	109	131	298	105	127	278	95	90	261
C18:1 cis n-9	872	509	1,850	1,053	1,441	2,574	1,009	1,104	2,538	1,026	1,014	2,850
C18:1 cis n-7	67	54	141	85	87	225	74	70	192	78	71	178
C18:2 n-6 (LA)	235	156	505	266	252	624	222	205	686	268	253	636
C18:3 n-6	5	5	11	5	5	14	5	5	17	5	6	15
C18:3 n-3 (ALA)	87	60	162	93	79	233	95	88	208	94	78	258
C18:4 n-3	132	92	261	178	215	625	166	144	408	161	174	591
C20:0	13	13	29	20	28	63	24	28	70	18	28	58
C20:2 n-6	3	4	11	4	8	11	2	3	6	4	9	15
C20:4 n-6 (AA)	130	86	281	145	164	419	163	178	423	144	153	568
C20:5 n-3 (EPA)	442	275	958	509	413	1,335	693	812	1,642	472	415	1,337
C22:5 n-3 (DPA)	126	105	376	137	134	375	190	226	527	128	120	334
C22:6 n-3 (DHA)	782	537	1,728	885	751	2,408	1,164	1,317	2,809	837	762	2,393
SFA	**1,254**	**755**	**2,418**	**1,471**	**1,523**	**3,960**	**1,745**	**1,960**	**4,407**	**1,364**	**1,197**	**3,806**
MUFA	**1,254**	**767**	**2,303**	**1,563**	**2,050**	**3,756**	**1,542**	**1,518**	**3,728**	**1,455**	**1,307**	**3,924**
PUFA	**1,960**	**1,261**	**4,233**	**2,248**	**1,912**	**5,859**	**2,729**	**2,841**	**6,263**	**2,145**	**1,880**	**5,946**
omega 3	**1,569**	**1,045**	**3,478**	**1,802**	**1,528**	**4,874**	**2,307**	**2,535**	**5,335**	**1,692**	**1,498**	**4,836**
omega 6	**373**	**223**	**750**	**420**	**404**	**1,050**	**392**	**337**	**1,140**	**421**	**392**	**1,074**

Table 30: Dietary intakes of fatty acids from fish and other seafood – Lorient (mg/d)

	Adult 917 060-64 y2			5772 women (18-64 y)			Older subjects (65 y and more)			Women of childbearing age (18-44 y)		
	n=52			n=158			n=37			n=76		
	Mean	SD	P95	Mean	SD	P95	Mean	SD	P95	Me87	12	725
Lip225 742d)	**6.7C**	2.=2	**14.51**	1.23	**1.62**	12.10	C.09	**2.[illegible]6**	(.A)	**5.28**	7.52	**12.95**
F283 08id												
C1612	3	**1**	5	0	0	0	0	0	0	0	0	0
C14:0	158	96	369	123	104	271	131	92	286	127	120	342
C14:1 n-5	2	0	5	1	1	2	1	1	2	1	1	1
C15:0	7	3	16	5	3	12	5	3	11	**1**	0	46
016:0	2,237	255	2,495	870	594	1,992	877	514	1,630	857	661	2,020
C16:1 n-7	197	99	417	157	115	340	160	99	288	146	123	332
C18:0	393	66	914	290	198	618	265	136	48/	408	724	679
1/ 671 SFAns	**71**	9	745	**3/**	133	**1/3**	**52**	**90**	**19/**	**05**	**71/**	**34**
C1612 /47 4-9	1,276	1,172	2,626	1,031	849	2,753	919	688	1,899	1,081	943	3,015
C18:1 cis n-7	41	2	100	26	23	74	24	19	61	27	22	78
C18:2 n-6 (LA)	315	298	715	261	232	649	19m	en(	183	280	)Ad	u[illegible]t
C18:3 n-6	6	5	14	5	5	13	4	3	9	4	5	12
C18:3 n-3 (ALA)	87	34	223	64	61	155	50	32	99	73	76	178
C18:4 n-3	263	66	722	187	131	469	177	116	345	180	130	489
/0010	30	1a	nS	DP	95	72	3i	ds	(g	/7	28	78
43 l3 n-6	5	0	5	**3**	**0**	30	2	3	9	**1**		89
5 0:4 n-3 9 14	183	34	**11**	121	123	att	yac	55	202	:00	039	278
C20:5 n-3 (EPA)	517	247	1,155	403	303	889	406	226	743	389	347	862
C22:5 n-3 (DPA)	148	53	512	114	173	274	431	1C	189	11/	138	561
C22:6 n-3 (DHA)	960	421	2,235	733	559	1,779	770	458	1,285	214	537	C,8:1
tra	**1,411**	**112**	4,933	1,341	626	3,311	4,839	78=	1isn	**,332**	**1,003**	**3,042**
MUFA	**1,602**	**1,299**	**2,932**	**1,289**	**967**	**3,462**	**1,176**	**799**	**2,202**	**1,310**	**1,078**	**3,759**
PUFA	**2,514**	**1,260**	**5,853**	**1,927**	**1,440**	**4,269**	**1,840**	**1,073**	**3,290**	**1,939**	**1,701**	**4,506**
omega 3	**1,975**	**822**	**4,587**	**1,502**	**1,164**	**3,439**	**1,506**	**872**	**2,732**	**1,488**	**1,372**	**3,411**
omega 6	**508**	**339**	**1,002**	**389**	**319**	**983**	**313**	**214**	**739**	**410**	**368**	1,20:

Table 31: Dietary intakes of fatty acids from fish and other seafood – La Rochelle (mg/d)

	Adult men (18-64 y) n=87			Adult women (18-64 y) n=122			Older subjects (65 y and more) n=39			Women of childbearing age (18-44 y) n=78		
	Mean	SD	P95	Mean	SD	P95	Mean	SD	P95	Mean	SD	P95
Lipids (g/d)	**5.46**	**3.83**	**12.21**	**5.32**	**3.13**	**11.09**	**4.68**	**3.45**	**11.68**	**5.56**	**3.29**	**10.89**
Fatty acid												
C12:0	9	14	23	7	9	24	7	9	22	7	8	21
C14:0	141	129	398	146	111	323	126	112	315	155	122	329
C14:1 n-5	3	9	10	2	3	7	2	3	6	2	3	6
C15:0	5	4	11	4	3	11	4	3	11	4	3	11
C16:0	892	674	2,141	861	546	1,791	777	562	1,947	893	578	1,735
C16:1 n-7	177	189	609	164	120	404	158	162	366	163	119	372
C18:0	275	177	604	247	155	525	218	132	429	253	158	528
C18:1 trans	8	11	26	7	7	22	8	13	34	7	7	24
C18:1 cis n-9	1,062	863	2,840	1,017	619	1,979	781	598	1,633	1,095	679	2,457
C18:1 cis n-7	30	32	80	22	23	68	16	15	37	21	18	56
C18:2 n-6 (LA)	251	198	603	238	162	539	154	115	374	269	173	565
C18:3 n-6	3	3	9	3	3	8	2	2	5	3	3	9
C18:3 n-3 (ALA)	65	44	162	60	49	133	43	27	91	67	54	136
C18:4 n-3	178	156	500	183	127	414	175	223	427	187	128	423
C20:0	26	29	83	30	28	71	28	28	94	32	31	70
C20:2 n-6	3	5	11	3	4	11	2	3	7	3	4	10
C20:4 n-6 (AA)	145	103	308	126	108	284	117	71	253	129	119	281
C20:5 n-3 (EPA)	419	317	956	438	289	1,027	416	395	1,092	452	303	989
C22:5 n-3 (DPA)	109	91	243	117	155	250	95	70	224	128	186	263
C22:6 n-3 (DHA)	739	563	1,700	757	505	1,654	709	491	1,623	783	544	1,622
SFA	**1,394**	**1,023**	**3,304**	**1,335**	**833**	**2,777**	**1,201**	**856**	**3,037**	**1,381**	**874**	**2,780**
MUFA	**1,315**	**1,085**	**3,638**	**1,240**	**734**	**2,561**	**994**	**792**	**2,127**	**1,315**	**782**	**2,702**
PUFA	**1,933**	**1,355**	**4,108**	**1,952**	**1,245**	**4,027**	**1,721**	**1,315**	**4,168**	**2,053**	**1,336**	**4,091**
omega 3	**1,510**	**1,138**	**3,424**	**1,556**	**1,053**	**3,367**	**1,439**	**1,155**	**3,473**	**1,616**	**1,134**	**3,396**
omega 6	**403**	**275**	**864**	**370**	**237**	**787**	**275**	**175**	**624**	**404**	**255**	**804**

Table 32: Dietary intakes of fatty acids from fish and other seafood – Toulon (mg/d)

	Adult men (18-64 y)			Adult women (18-64 y)			Older subjects (65 y and more)			Women of childbearing age (18-44y)		
	n=52			n=158			n=37			n=76		
	Mean	SD	P95	Mean	SD	P95	Mean	SD	P95	Mean	SD	P95
Lipids (g/d)	**6.49**	**4.32**	**14.69**	**6.28**	**4.57**	**15.43**	**5.04**	**2.49**	**9.24**	**6.40**	**5.00**	**15.61**
Fatty acid												
C12:0	0	1	0	0	1	1	0	0	0	0	1	2
C14:0	146	117	403	152	137	427	127	85	311	150	129	427
C14:1 n-5	3	3	9	4	4	10	3	3	9	4	4	10
C15:0	7	7	22	7	6	20	5	4	12	7	6	17
C16:0	972	644	2,208	927	664	2,316	814	394	1,505	918	682	2,316
C16:1 n-7	189	137	490	191	160	498	174	106	374	181	157	473
C18:0	375	248	810	319	230	742	254	129	456	331	267	818
C18:1 trans	12	12	35	15	14	45	10	9	29	14	13	43
C18:1 cis n-9	1,349	934	3,162	1,376	1,386	3,686	939	657	1,980	1,511	1,707	4,376
C18:1 cis n-7	51	54	152	42	43	114	26	23	75	46	47	132
C18:2 n-6 (LA)	391	266	851	368	384	959	244	188	515	402	470	1,228
C18:3 n-6	6	7	22	7	9	23	4	4	14	8	10	25
C18:3 n-3 (ALA)	90	67	212	83	63	202	55	30	98	88	72	208
C18:4 n-3	207	175	565	223	205	634	185	138	400	218	200	604
C20:0	25	36	78	22	31	78	20	16	45	20	32	73
C20:2 n-6	2	4	12	2	5	10	1	1	3	3	7	11
C20:4 n-6 (AA)	144	123	398	127	101	313	102	48	172	126	113	332
C20:5 n-3 (EPA)	467	354	1,374	433	326	1,237	388	194	650	407	327	1,133
C22:5 n-3 (DPA)	145	104	375	136	102	313	135	86	240	127	104	319
C22:6 n-3 (DHA)	750	514	1,564	713	517	1,648	686	336	1,074	678	541	1,648
SFA	**1,674**	**1,129**	**4,076**	**1,604**	**1,197**	**4,046**	**1,353**	**674**	**2,345**	**1,599**	**1,225**	**4,043**
MUFA	**1,645**	**1,123**	**3,684**	**1,669**	**1,524**	**4,477**	**1,192**	**773**	**2,470**	**1,796**	**1,831**	**4,747**
PUFA	**2,249**	**1,565**	**4,778**	**2,149**	**1,569**	**5,118**	**1,819**	**882**	**3,147**	**2,127**	**1,685**	**5,396**
omega 3	**1,659**	**1,184**	**3,549**	**1,588**	**1,166**	**3,827**	**1,449**	**689**	**2,544**	**1,517**	**1,196**	**3,820**
omega 6	**544**	**378**	**1,193**	**504**	**454**	**1,216**	**351**	**224**	**734**	**538**	**549**	**1,576**

Table 33: Dietary intakes of fatty acids from fish and other seafood per site (mg/d, Mean ± SD)

	Le Havre n=249	Lorient n=247	La Rochelle n=248	Toulon n=252	All subjects n=996
EPA	516 ± 454 [a]	428 ± 304 [b]	428 ± 316 [b]	437 ± 324 [a, b]	452 ± 356
DPA	141 ± 142 [a]	120 ± 153 [a]	111 ± 124 [a]	138 ± 101 [a]	127 ± 132
DHA	896 ± 800 [a]	786 ± 568 [a, b]	743 ± 522 [b]	720 ± 502 [b]	786 ± 612
Omega 3*	1,814 ± 1.596 [a]	1,602 ± 1,177 [a]	1,521 ± 1,096 [a]	1,594 ± 1,136 [a]	1,633 ± 1,270
PUFA	2,248 ± 1.937 [a]	2,037 ± 1,452 [a]	1,909 ± 1,293 [a]	2,145 ± 1,522 [a]	2,085 ± 1,572

* The intake of Omega 3 correspond to the intakes of ALA, C18:4 n-3, EPA, DPA and DHA
Values in the same raw with different superscript letters are significantly different, $p<0.05$ (Tukey's test)

4.1.2 Biomarker of exposure

The results of the erythrocyte fatty acid profile of the 391 subjects in the study are presented in Tables 34 to 38.

Unlike the food exposure results obtained by crossing food composition and individual consumption data, the results of the direct approach yield the fatty acid biological level resulting from the total diet.

The results obtained suggest that adult males have the most triglycerides in the blood, but with high variability (0.9 g/L ± 0.6 to 1.6 g/L ± 2.3 depending on the zone) compared to women and to males in other age groups, the norm being 0.5 to 2 g/L[118]. On the other hand, elderly subjects (≥ 65 years) have the highest total cholesterol (2.15 to 2.48 g/L), HDL-cholesterol (0.62 to 0.69 g/L) and LDL-cholesterol (1.35 to 1.66 g/L). 39% of the subjects exceeds the norm of the total cholesterol level, fixed at 2.0 to 2.6 g/L depending on age. Generally, only women of child-bearing age (18 to 44 years) have average total cholesterol levels corresponding to the norm for their age.

The lipidic fraction of the erythrocyte membrane is constituted by 50% of SFA on average in adult males and 47% in women and elderly people. MUFAs represent about 18% of total lipids, and PUFAs 27% for omega 6 and 7% for omega 3. The EPA, DPA and DHA account for almost all the omega 3 in the erythrocyte membrane, the precursor ALA representing only 0.2% of total lipids on average. The omega 6 precursor (LA) constitutes only about 11% of the membrane lipidic fraction.

118 Godeau P., Herson S. and Piette J.C. Traité de médecine, 4e édition. Médecine-Sciences Flammarion. 2004.

Table 34: Fatty acid composition of red blood cells – Le Havre (% total FA)

	Adult men (18-64 y) n=18			Adult women (18-64 y) n=60			Older subjects (65 y and more) n=7			Women of childbearing age (18-44 y) n=29		
	Mean	SD	P95	Mean	SD	P95	Mean	SD	P95	Mean	SD	P95
Triglycerides (g/L)	0.90	0.63	1.86	0.86	0.43	1.85	0.81	0.20	0.99	0.78	0.32	1.39
Total cholesterol (g/L)	1.99	0.37	2.55	2.00	0.39	2.62	2.15	0.44	2.61	1.82	0.33	2.44
HDL (g/L)	0.57	0.10	0.73	0.66	0.20	0.91	0.64	0.13	0.81	0.61	0.24	0.83
Cholesterol/HDL	3.61	0.95	5.01	3.25	0.86	4.71	3.46	0.86	4.79	3.29	0.91	4.76
LDL (g/L)	1.24	0.32	1.67	1.18	0.33	1.71	1.35	0.39	1.75	1.09	0.30	1.66
Fatty acids (% total lipids)												
C12:0	0.28	0.13	0.49	0.32	0.19	0.59	0.30	0.18	0.59	0.28	0.13	0.50
C14:0	0.84	0.24	1.27	0.77	0.25	1.27	0.90	0.35	1.37	0.78	0.24	1.25
C14:1 n-5	0.12	0.05	0.21	0.12	0.05	0.19	0.17	0.12	0.36	0.12	0.05	0.22
C15:0	0.25	0.11	0.44	0.26	0.06	0.37	0.32	0.10	0.46	0.27	0.06	0.38
C16:0	20.58	1.36	22.67	20.29	1.04	21.99	20.86	0.97	21.91	20.55	1.14	22.27
C16:1 n-9	0.36	0.14	0.61	0.33	0.18	0.77	0.38	0.25	0.77	0.36	0.18	0.77
C16:1 n-7	1.25	0.53	2.04	1.15	0.46	1.87	1.48	0.54	2.14	1.19	0.44	1.85
C18:0	23.69	6.85	36.29	24.02	4.72	30.20	23.09	4.96	29.41	23.59	4.75	31.05
C18:1 n-9t	0.40	0.20	0.72	0.30	0.18	0.62	0.37	0.16	0.56	0.30	0.17	0.62
C18:1 n-9	15.09	3.13	19.19	14.56	2.18	18.49	15.83	2.09	18.17	14.74	2.27	18.34
C18:1 n-7	1.17	0.21	1.43	1.20	0.16	1.55	1.29	0.17	1.50	1.22	0.15	1.52
C18:2 n-6 (LA)	14.22	5.50	21.22	12.90	4.53	20.62	12.99	3.84	17.65	13.42	4.84	20.54
C18:3 n-6	0.25	0.12	0.39	0.19	0.10	0.34	0.26	0.09	0.34	0.20	0.10	0.35
C18:3 n-3 (ALA)	0.25	0.11	0.41	0.25	0.11	0.45	0.26	0.10	0.41	0.23	0.08	0.35
C20:0	0.19	0.07	0.33	0.18	0.08	0.31	0.23	0.07	0.31	0.19	0.08	0.32
C20:2 n-6	0.31	0.06	0.41	0.34	0.05	0.40	0.34	0.05	0.40	0.34	0.06	0.42
C20:3 n-6	1.28	0.25	1.60	1.42	0.32	2.02	1.39	0.21	1.60	1.51	0.33	2.08
C20:4 n-6 (AA)	11.00	1.61	13.91	12.13	1.98	14.69	10.58	2.47	13.92	12.04	2.17	15.91
C20:5 n-3 (EPA)	0.87	0.53	1.49	0.79	0.41	1.71	1.12	0.53	1.95	0.58	0.21	1.05
C22:4 n-6	1.87	0.63	2.78	2.02	0.69	3.06	1.58	0.56	2.25	2.12	0.69	3.35
C22:5 n-6	0.39	0.09	0.50	0.43	0.16	0.75	0.37	0.10	0.51	0.49	0.16	0.75
C22:5 n-3 (DPA)	1.70	0.40	2.37	1.74	0.38	2.33	1.61	0.55	2.26	1.57	0.31	2.06
C22:6 n-3 (DHA)	3.64	1.05	5.25	4.29	1.17	6.66	4.27	1.24	5.60	3.90	1.02	5.30
SFA	**45.83**	**7.56**	**59.54**	**45.85**	**4.48**	**53.07**	**45.71**	**5.53**	**52.61**	**45.67**	**4.49**	**53.14**
MUFA	**17.99**	**3.74**	**23.36**	**17.36**	**2.73**	**22.38**	**19.14**	**2.67**	**21.78**	**17.63**	**2.77**	**22.34**
omega 6	**29.32**	**4.79**	**35.50**	**29.43**	**3.51**	**34.52**	**27.51**	**3.21**	**31.94**	**30.13**	**3.40**	**34.46**
omega 3	**6.46**	**1.53**	**8.83**	**7.06**	**1.67**	**10.07**	**7.27**	**1.97**	**9.30**	**6.27**	**1.23**	**7.82**
omega 6/omega 3	**4.82**	**1.59**	**7.90**	**4.44**	**1.30**	**6.74**	**4.00**	**1.03**	**5.32**	**5.04**	**1.36**	**7.05**
LA/ALA	**70.20**	**59.14**	**214.40**	**58.19**	**23.71**	**99.77**	**52.89**	**12.38**	**70.52**	**63.33**	**28.05**	**119.21**

Table 35: Fatty acid composition of red blood cells – Lorient (% total FA)

	Adult men (18-64 y) n=21			Adult women (18-64 y) n=84			Older subjects (65 y and more) n=10			Women of childbearing age (18-44 y) n=39		
	Mean	SD	P95	Mean	SD	P95	Mean	SD	P95	Mean	SD	P95
Triglycerides (g/L)	1.28	0.67	2.62	0.90	0.49	1.77	1.01	0.47	1.75	0.85	0.42	1.70
Total cholesterol (g/L)	2.10	0.46	2.81	2.21	0.41	2.75	2.48	0.44	3.17	2.11	0.42	2.76
HDL (g/L)	0.50	0.10	0.64	0.61	0.13	0.84	0.66	0.20	0.89	0.59	0.13	0.79
Cholesterol/HDL	4.37	1.19	6.20	3.73	0.92	5.32	4.07	1.21	5.91	3.69	0.98	5.13
LDL (g/L)	1.39	0.41	1.95	1.44	0.35	2.00	1.66	0.39	2.21	1.37	0.36	1.88
Fatty acids (% total lipids)												
C12:0	0.87	0.49	1.24	0.59	0.34	1.11	0.82	0.46	1.58	0.60	0.38	1.13
C14:0	1.16	0.50	1.80	0.97	0.40	1.67	1.04	0.43	1.46	0.96	0.44	1.72
C14:1 n-5	0.39	0.16	0.65	0.34	0.18	0.64	0.32	0.15	0.54	0.33	0.18	0.62
C15:0	0.80	0.33	1.38	0.67	0.30	1.18	0.66	0.26	0.98	0.65	0.32	1.26
C16:0	21.79	2.65	25.72	20.40	2.26	24.76	20.39	1.70	23.23	20.58	2.33	24.07
C16:1 n-9	0.39	0.16	0.67	0.38	0.19	0.82	0.45	0.26	0.81	0.41	0.20	0.82
C16:1 n-7	1.33	0.46	2.04	1.34	0.60	2.37	1.37	0.51	2.12	1.31	0.57	2.23
C18:0	25.44	5.33	32.03	22.81	5.81	32.55	21.76	4.72	27.49	23.26	5.88	32.76
C18:1 n-9t	0.40	0.41	0.97	0.42	0.42	0.70	0.32	0.19	0.60	0.37	0.19	0.68
C18:1 n-9	14.62	1.57	16.60	15.61	3.03	22.71	16.22	2.77	20.75	15.69	2.71	20.06
C18:1 n-7	1.48	0.24	1.84	1.46	0.23	1.84	1.48	0.25	1.87	1.43	0.22	1.79
C18:2 n-6 (LA)	10.82	2.20	13.63	13.36	4.17	21.11	12.83	4.17	20.00	13.27	3.84	20.14
C18:3 n-6	0.21	0.10	0.39	0.21	0.09	0.36	0.20	0.09	0.35	0.21	0.09	0.37
C18:3 n-3 (ALA)	0.27	0.15	0.53	0.25	0.14	0.53	0.25	0.12	0.40	0.23	0.14	0.50
C20:0	0.20	0.10	0.38	0.26	0.12	0.45	0.25	0.12	0.40	0.26	0.14	0.45
C20:2 n-6	0.61	0.29	1.01	0.48	0.23	0.95	0.41	0.23	0.72	0.50	0.22	0.94
C20:3 n-6	1.26	0.49	2.00	1.28	0.45	2.18	1.34	0.34	1.82	1.34	0.49	2.18
C20:4 n-6 (AA)	10.20	3.37	14.56	10.73	2.78	14.52	11.00	3.02	14.58	10.68	3.01	14.27
C20:5 n-3 (EPA)	0.64	0.33	1.12	0.75	0.34	1.27	0.82	0.41	1.41	0.59	0.29	1.09
C22:4 n-6	1.87	0.76	3.16	1.76	0.65	2.87	1.67	0.63	2.45	1.86	0.70	3.02
C22:5 n-6	0.66	0.28	1.07	0.54	0.24	0.90	0.43	0.26	0.83	0.56	0.22	0.91
C22:5 n-3 (DPA)	1.58	0.76	2.60	1.60	0.56	2.45	2.03	0.97	3.36	1.49	0.60	2.45
C22:6 n-3 (DHA)	3.01	1.79	6.59	3.78	1.43	6.08	3.93	1.40	5.74	3.41	1.30	5.26
SFA	**50.26**	**7.69**	**62.66**	**45.70**	**7.01**	**55.93**	**44.92**	**5.87**	**53.59**	**46.31**	**7.43**	**57.11**
MUFA	**18.21**	**1.65**	**20.89**	**19.13**	**3.51**	**27.47**	**19.85**	**3.51**	**25.56**	**19.16**	**3.08**	**22.89**
omega 6	**25.63**	**5.27**	**31.52**	**28.36**	**4.81**	**36.24**	**27.88**	**3.92**	**32.92**	**28.43**	**5.20**	**36.30**
omega 3	**5.49**	**2.55**	**10.10**	**6.38**	**2.01**	**9.31**	**7.03**	**1.97**	**9.22**	**5.73**	**1.87**	**8.34**
omega 6/omega 3	**5.47**	**2.01**	**8.70**	**4.91**	**1.78**	**8.78**	**4.40**	**1.79**	**7.24**	**5.49**	**1.90**	**8.93**
LA/ALA	**52.99**	**29.23**	**103.25**	**68.64**	**48.30**	**130.85**	**63.72**	**34.29**	**121.65**	**76.54**	**61.03**	**132.87**

Table 36: Fatty acid composition of red blood cells – La Rochelle (% total FA)

	Adult men (18-64 y) n=37			Adult women (18-64 y) n=46			Older subjects (65 y and more) n=14			Women of childbearing age (18-44 y) n=28		
	Mean	SD	P95	Mean	SD	P95	Mean	SD	P95	Mean	SD	P95
Triglycerides (g/L)	1.62	2.30	3.21	0.90	0.37	1.60	1.18	0.55	2.18	0.86	0.36	1.26
Total cholesterol (g/L)	2.14	0.32	2.79	2.09	0.38	2.71	2.29	0.35	2.80	1.99	0.35	2.57
HDL (g/L)	0.54	0.13	0.73	0.68	0.16	0.96	0.69	0.19	1.03	0.67	0.17	1.02
Cholesterol/HDL	4.20	1.28	6.71	3.28	1.02	4.75	3.48	0.81	4.43	3.15	0.88	4.56
LDL (g/L)	1.34	0.29	1.95	1.25	0.39	1.81	1.36	0.27	1.67	1.17	0.39	1.71
Fatty acids (% total lipids)												
C12:0	0.57	0.39	1.20	0.55	0.36	1.17	0.57	0.37	1.01	0.57	0.36	1.20
C14:0	0.84	0.25	1.23	0.84	0.30	1.30	0.85	0.40	1.49	0.85	0.30	1.29
C14:1 n-5	0.15	0.11	0.41	0.18	0.12	0.42	0.19	0.19	0.58	0.20	0.14	0.43
C15:0	0.26	0.17	0.78	0.22	0.09	0.30	0.23	0.10	0.41	0.23	0.10	0.30
C16:0	20.20	1.40	22.52	20.59	2.13	24.37	20.39	1.65	22.76	20.60	2.05	24.25
C16:1 n-9	0.23	0.13	0.35	0.24	0.10	0.38	0.25	0.15	0.52	0.23	0.11	0.39
C16:1 n-7	0.64	0.27	1.17	0.71	0.25	1.14	0.89	0.49	1.91	0.67	0.26	0.98
C18:0	28.16	8.07	42.53	28.29	7.86	39.35	25.54	7.17	34.18	28.55	8.26	39.31
C18:1 n-9t	0.36	0.14	0.67	0.34	0.10	0.48	0.34	0.12	0.47	0.35	0.11	0.48
C18:1 n-9	12.93	2.33	16.36	12.89	2.70	16.36	15.13	4.43	24.35	12.54	2.77	16.33
C18:1 n-7	1.07	0.19	1.40	1.12	0.19	1.41	1.24	0.24	1.71	1.11	0.20	1.39
C18:2 n-6 (LA)	8.65	2.27	12.21	8.62	1.97	11.15	9.82	2.96	14.93	8.64	1.96	11.14
C18:3 n-6	0.16	0.07	0.26	0.18	0.10	0.36	0.14	0.09	0.28	0.18	0.11	0.36
C18:3 n-3 (ALA)	0.14	0.05	0.21	0.18	0.07	0.26	0.19	0.13	0.42	0.17	0.06	0.26
C20:0	0.19	0.09	0.36	0.19	0.08	0.33	0.22	0.09	0.38	0.18	0.08	0.30
C20:2 n-6	0.38	0.16	0.65	0.36	0.18	0.63	0.33	0.14	0.47	0.35	0.19	0.63
C20:3 n-6	1.61	0.48	2.32	1.37	0.40	1.92	1.33	0.43	2.07	1.39	0.43	1.90
C20:4 n-6 (AA)	12.98	2.86	17.56	12.77	3.39	17.39	12.15	3.77	16.27	12.84	3.44	17.39
C20:5 n-3 (EPA)	0.80	0.36	1.43	0.83	0.31	1.37	0.80	0.37	1.35	0.77	0.23	1.14
C22:4 n-6	2.17	0.62	3.46	2.08	0.75	3.46	1.86	0.70	2.53	2.25	0.76	3.57
C22:5 n-6	0.49	0.16	0.78	0.44	0.15	0.69	0.36	0.13	0.48	0.49	0.14	0.73
C22:5 n-3 (DPA)	2.14	0.60	2.98	1.89	0.59	2.92	1.97	0.65	2.82	1.83	0.50	2.67
C22:6 n-3 (DHA)	4.88	1.44	7.35	5.12	1.53	7.46	5.23	1.91	7.43	5.02	1.49	7.17
SFA	**50.22**	**9.17**	**66.60**	**50.69**	**8.87**	**63.59**	**47.80**	**7.45**	**56.11**	**50.97**	**9.32**	**64.17**
MUFA	**15.02**	**2.62**	**18.71**	**15.14**	**2.97**	**18.99**	**17.69**	**5.31**	**28.92**	**14.75**	**3.00**	**18.95**
omega 6	**26.43**	**5.45**	**33.68**	**25.81**	**5.77**	**33.74**	**25.98**	**4.85**	**32.34**	**26.14**	**6.05**	**34.26**
omega 3	**7.96**	**2.26**	**11.67**	**8.02**	**2.23**	**11.54**	**8.18**	**2.60**	**11.00**	**7.79**	**2.12**	**10.99**
omega 6/omega 3	**3.47**	**0.78**	**4.62**	**3.35**	**0.74**	**4.02**	**3.46**	**1.14**	**5.89**	**3.45**	**0.63**	**4.00**
LA/ALA	**68.50**	**34.57**	**131.20**	**53.17**	**22.55**	**95.93**	**64.21**	**30.39**	**119.10**	**59.08**	**26.43**	**103.42**

Table 37: Fatty acid composition of red blood cells – Toulon (% total FA)

	Adult men (18-64 y) n=17			Adult women (18-64 y) n=69			Older subjects (65 y and more) n=9			Women of childbearing age (18-44 y) n=41		
	Mean	SD	P95	Mean	SD	P95	Mean	SD	P95	Mean	SD	P95
Triglycerides (g/L)	1.26	0.59	2.06	0.88	0.60	1.88	1.00	0.35	1.56	0.90	0.66	2.04
Total cholesterol (g/L)	2.12	0.35	2.73	2.03	0.38	2.62	2.37	0.54	3.22	1.90	0.35	2.44
HDL (g/L)	0.42	0.10	0.56	0.54	0.16	0.85	0.62	0.17	0.84	0.48	0.13	0.77
Cholesterol/HDL	5.40	1.79	9.14	4.01	1.13	6.15	3.91	0.72	4.88	4.15	1.21	6.20
LDL (g/L)	1.45	0.32	1.97	1.32	0.32	1.84	1.55	0.37	2.09	1.24	0.30	1.75
Fatty acids (% total lipids)												
C12:0	0.77	0.40	1.37	0.69	0.34	1.26	0.70	0.28	1.06	0.68	0.37	1.28
C14:0	1.38	0.54	1.96	1.21	0.49	1.92	1.42	0.43	1.88	1.19	0.54	1.94
C14:1 n-5	0.34	0.15	0.58	0.34	0.17	0.59	0.34	0.08	0.43	0.33	0.16	0.58
C15:0	1.00	0.34	1.52	0.80	0.35	1.47	0.77	0.39	1.37	0.77	0.37	1.52
C16:0	22.94	3.55	27.87	21.32	3.49	27.06	22.11	2.60	26.18	21.24	3.45	26.73
C16:1 n-9	0.68	0.21	0.88	0.56	0.23	0.87	0.43	0.22	0.77	0.51	0.24	0.87
C16:1 n-7	1.19	0.60	1.96	1.26	0.64	2.22	1.24	0.73	2.49	1.29	0.69	2.25
C18:0	26.37	4.38	32.23	23.76	5.44	33.98	25.84	8.00	39.03	23.26	5.53	33.10
C18:1 n-9t	0.27	0.13	0.49	0.24	0.13	0.43	0.22	0.14	0.44	0.23	0.12	0.42
C18:1 n-9	14.41	2.45	17.92	15.05	2.76	19.56	15.09	3.36	19.87	15.25	2.85	18.86
C18:1 n-7	1.44	0.24	1.81	1.42	0.31	1.93	1.43	0.27	1.81	1.42	0.30	1.91
C18:2 n-6 (LA)	10.30	2.06	13.80	11.74	3.33	17.70	11.69	2.83	15.82	12.07	2.98	17.83
C18:3 n-6	0.17	0.09	0.32	0.14	0.09	0.31	0.17	0.09	0.30	0.14	0.09	0.30
C18:3 n-3 (ALA)	0.20	0.13	0.47	0.26	0.13	0.47	0.30	0.09	0.40	0.24	0.10	0.43
C20:0	0.28	0.11	0.43	0.27	0.11	0.43	0.28	0.10	0.43	0.25	0.11	0.42
C20:2 n-6	0.42	0.14	0.66	0.38	0.20	0.74	0.39	0.15	0.58	0.38	0.19	0.74
C20:3 n-6	1.15	0.44	1.89	1.21	0.34	1.75	1.15	0.42	1.75	1.25	0.34	1.78
C20:4 n-6 (AA)	9.80	3.99	15.79	11.13	4.14	16.04	9.66	4.17	15.25	11.36	4.10	15.79
C20:5 n-3 (EPA)	0.52	0.26	0.83	0.62	0.31	1.05	0.54	0.29	0.97	0.52	0.22	0.85
C22:4 n-6	1.83	0.89	3.05	2.17	1.06	3.70	1.86	1.28	3.72	2.39	1.16	4.12
C22:5 n-6	0.37	0.20	0.68	0.41	0.26	0.89	0.27	0.17	0.54	0.44	0.29	0.95
C22:5 n-3 (DPA)	1.38	0.74	2.66	1.55	0.66	2.64	1.38	0.47	1.91	1.55	0.65	2.58
C22:6 n-3 (DHA)	2.79	2.00	5.86	3.49	1.80	6.79	2.72	1.13	4.19	3.25	1.85	6.87
SFA	**52.73**	**8.16**	**63.30**	**48.03**	**8.62**	**64.49**	**51.13**	**8.86**	**65.98**	**47.39**	**8.36**	**63.23**
MUFA	**18.06**	**2.40**	**21.98**	**18.62**	**2.89**	**23.27**	**18.53**	**4.07**	**24.65**	**18.81**	**3.12**	**23.12**
omega 6	**24.04**	**6.02**	**30.64**	**27.19**	**6.53**	**36.23**	**25.20**	**6.03**	**31.59**	**28.03**	**6.43**	**36.75**
omega 3	**4.90**	**2.82**	**9.45**	**5.92**	**2.48**	**10.51**	**4.93**	**1.67**	**7.10**	**5.55**	**2.49**	**10.39**
omega 6/omega 3	**6.07**	**2.59**	**10.16**	**5.17**	**1.79**	**8.35**	**5.37**	**1.27**	**7.12**	**5.75**	**1.91**	**8.47**
LA/ALA	**67.65**	**35.22**	**117.67**	**56.48**	**30.23**	**99.20**	**42.50**	**16.93**	**70.39**	**61.29**	**29.98**	**99.42**

Table 38: Composition in EPA, DPA, DHA and omega 3 of the red blood cells of the subjects of all areas regardless of the age and sex (% total lipids, Mean ± SD)

	Le Havre n=84	Lorient n=115	La Rochelle n=97	Toulon n=95	All subjects n=391
EPA	0.83 ± 0.45 [a]	0.74 ± 0.35 [a]	0.81 ± 0.34 [a]	0.59 ± 0.30 [b]	0.74 ± 0.37
DPA	1.72 ± 0.40 [a]	1.63 ± 0.65 [a]	2.00 ± 0.61 [b]	1.51 ± 0.66 [a]	1.71 ± 0.62
DHA	4.16 ± 1.17 [a]	3.65 ± 1.52 [a, c]	5.04 ± 1.55 [b]	3.29 ± 1.80 [c]	4.02 ± 1.66
Omega 3*	6.96 ± 1.67 [a]	6.28 ± 2.14 [a, c]	8.02 ± 2.27 [b]	5.65 ± 2.50 [c]	6.70 ± 2.34

* The composition in Omega 3 corresponds to ALA, EPA, DPA and DHA
Values in the same raw with different superscript letters are significantly different, $p<0.05$ (Tukey's test)

Table 38 shows that heavy consumers in Toulon have significantly less EPA in their erythrocyte membrane than subjects in the other zones ($p<0.05$). The people in La Rochelle have erythrocyte DPA, DHA and omega 3 levels significantly higher than those in the other zones, although the differences are relatively small.

4.2 Exposure to trace elements

4.2.1 Food exposure

As for fatty acids, it is important to note that the results presented in this section correspond to the exposure to the trace elements only through consumption of fish and seafood, not through the total diet. Nevertheless, as stated in the first part, food (and fish and seafood in particular) remain the main contributor of exposure to arsenic, organic tin and mercury, particularly methylmercury, its most toxic form. The intake results are presented in Tables 39 to 43. The contributions of food to the exposure to the different contaminants and to the TRV are presented in the Appendix 5 and 6.

Some of the contamination data being censured (levels below the limit of detection), these have been taken to be equal to $^1/_2$ LOD, particularly As(V) and octyltins for which almost all the data were censured.

Arsenic : The average exposure to total arsenic (AsT) of 84.0 ± 64.2 µg/kg bw/week is very much higher than the average intake of French people estimated in 2004 to be 6.2 µg/kg bw/week (see Introduction). The proportion of inorganic arsenic in the total arsenic of 0.8% is consistent with the figures of 0.4% to 5% usually found in the literature[63]. The average exposure to inorganic arsenic is between 0.40 and 0.72 µg/kg bw/week for men aged 18 to 64 years and between 0.52 and 0.85 µg/kg bw/week in women of the same age group and the P95 reaches 1.82 µg/kg bw/week in these same women who are more exposed than the other groups, although these values remain well below the PTWI of 15 µg/kg bw/week[38] (<15% of the PTWI)[119] established by the JECFA, an intake that none of our subjects exceeds. However, inorganic arsenic may be absorbed from sources other than seafood, in particular from drinking water. The Appendix 5 show that the products contributing most to the exposure of our population to toxic inorganic arsenic are great scallop (8.6%), oyster (7.0%), cod (6.3%) and ray (5.1%). Some differences are noticed between the different regions. While ray and cod appear to be major contributors to As and As_{inorg} exposure in all four zones, the great scallop is a majority contributor to As_{inorg} exposure only in Le Havre (15%) and in Toulon (14%), and the sea urchin is a majority contributor only in Toulon (12%). Nevertheless the fish and seafood consumption only provide 4.2% of the TRV (Appendix 6).

Mercury : The data reveal that mercury is almost exclusively absorbed in the form of methylmercury with an average exposure ranging from 0.88 to 1.50 µg MeHg/kg bw/week for adult males and from 1.17 to 1.69 µg MeHg/kg bw/week for adult females. The exposure is of the same order of magnitude for elderly subjects (1.26 to 1.79 µg MeHg/kg bw/week) and women of child-bearing age (1.07 to 1.60 µg MeHg/kg bw/week). We should underline that these average exposures are close to or even above the JECFA's PTWI of 1.6 µg MeHg/kg bw/week. More than a third of the subjects (35%) have an intake exceeding the PTWI. Among these 29% are in Lorient, 28% in La Rochelle, 28% in Toulon and 14% in Le Havre. A third (32%) are women of child-bearing age, considered to be the most sensitive population in view of the effects of high exposure on the foetus. The 95th percentile exposure of women of child-bearing age is 3.09 µg MeHg/kg bw/week in La Rochelle and 4.26 µg MeHg/kg bw/week in Toulon, or 1.9 and 2.7 times the PTWI respectively, and 2 to 3 times the P95 level of such women in the INCA survey[32].

The products contributing most to MeHg exposure, in all the subjects combined, are tuna (19%), cod (7%), ling and sole (6% each), with little difference from one zone to another. Fish generally accounts for 86% of the MeHg exposure, molluscs and crustaceans for 13% and other seafood for less than 2% (Appendix 5). This consumption contribute to 92% of the TRV with the same major contributors (Appendix 6).

Lead : The average exposures of high seafood consumers, even the highest percentiles, are well below the PTWI (25 µg/kg bw/week). The average exposure ranges from 0.27 to 0.49 µg/kg bw/week according to the group of individuals and the zone considered, or 1% to 2% of the PTWI. The highest P95 level is found in women of child-bearing age in La Rochelle (1.14 µg/kg bw/week). The main contributor to lead exposure is sardine (17%), but we also note large contributions from hake in Lorient (28%), great scallop in Le Havre (22%), mussels in La Rochelle (16%) and sea urchin in Toulon (14%). We should remember that there exist contributors to lead exposure other than fish and seafood.

Cadmium : The highest average exposure, in Le Havre subjects (3.50 to 5.00 µg/kg bw/week), is less than the JECFA's PTWI of 7 µg/kg bw/week. However, in the French population fish and seafood represent only 8% to 25% of the cadmium intake via food. The exposure of our heavy consumers should be interpreted with caution since it takes into account only their fish and seafood consumptions; their average total diet exposure could be higher. The PTWI is exceeded by 8.5% of our subjects through their fish and seafood consumption alone. The main contributors to this exposure are shrimp (16%), crab (15%), anchovy (10%), periwinkle (7%), great scallop (9%) and sardine (5%). However these contributions are not the same in all zones: the main contributors in Le Havre are shrimp (60%), great scallop (14%) and catshark (10%); in Lorient they are crab (53%) and saithe (15%); in La Rochelle they are molluscs: periwinkle (21%), calico scallop (19%) and oyster (11%); in Toulon they are anchovy (23%) and great scallop (20%). For the most exposed individuals in each zone (P90) we find the same main contributors (results not presented). These consumptions represent 35% of the TRV. Shrimps and crab are the major contributors (Appendix 6).

119 The InVS prefers using the USEPA's TRV (0.3 µg/kg bw/d or 2.1 µg/kg bw/wk) to the JECFA's PTWI. Using this value would mean an exposure of 87% of this TRV for adult males in Lorient and that without the other food intakes.

Organic tin : The average exposure to all the organostannic compounds does not exceed 0.14 µg Sn/kg bw/week, or 0.34 µg Sn/kg bw/week at P95, regardless of the zone, age group and sex, which represent respectively 19% and 47% of the PTWI fixed at 0.72 µg Sn/kg bw/week[68] for TBT, DBT, TPT and DOT alone.

Generally speaking, regardless of the zone considered and whatever the trace element, women and elderly subjects (≥ 65 years) are more exposed than men aged 18 to 64 years. More particularly, adult males are significantly less exposed to inorganic arsenic than women of the same age group ($p<0.05$), all zones included.

Table 39: Food exposure of the high fish and seafood consumers to trace elements – Le Havre (µg/kg bw/week)

	Adult men (18-64 y) n=44			Adult women (18-64 y) n=179			Older subjects (65 y and more) n=26			Women of childbearing age (18-44 y) n=98		
	Mean	SD	P95	Mean	SD	P95	Mean	SD	P95	Mean	SD	P95
As_T	**59.49**	**43.31**	**144.65**	**89.79**	**70.56**	**242.83**	**87.97**	**56.03**	**200.18**	**78.93**	**63.13**	**212.64**
AsB	57.02	42.09	135.96	85.20	66.08	230.09	83.58	53.01	185.94	75.45	59.37	192.00
MMA	0.22	0.19	0.55	0.29	0.36	0.77	0.29	0.29	0.94	0.31	0.45	1.04
DMA	0.34	0.26	0.81	0.44	0.36	1.14	0.44	0.31	0.94	0.44	0.39	1.29
As(III)	0.44	0.37	1.13	0.58	0.50	1.50	0.65	0.40	1.39	0.52	0.39	1.46
As(V)	0.06	0.03	0.13	0.08	0.05	0.19	0.07	0.04	0.16	0.08	0.05	0.20
As_{org}	57.59	42.39	137.49	85.93	66.48	231.65	84.32	53.33	187.16	76.21	59.84	194.22
As_{inorg}	0.49	0.39	1.24	0.67	0.54	1.69	0.72	0.44	1.56	0.60	0.44	1.62
Hg_T	**0.87**	**0.55**	**1.94**	**1.17**	**1.15**	**2.69**	**1.25**	**1.22**	**3.45**	**1.04**	**0.96**	**2.28**
MeHg	0.88	0.57	1.93	1.17	1.17	2.69	1.26	1.31	3.45	1.07	1.02	2.27
Cd	**3.50**	**2.32**	**7.23**	**5.00**	**5.04**	**12.70**	**4.15**	**4.33**	**9.69**	**4.64**	**4.17**	**11.82**
Pb	**0.27**	**0.21**	**0.65**	**0.35**	**0.31**	**0.79**	**0.37**	**0.26**	**0.66**	**0.31**	**0.26**	**0.78**
OTC_T	**0.11**	**0.07**	**0.21**	**0.14**	**0.10**	**0.34**	**0.13**	**0.09**	**0.34**	**0.13**	**0.09**	**0.34**
Butyl	0.09	0.06	0.18	0.11	0.08	0.29	0.10	0.08	0.28	0.10	0.08	0.27
Phényl	0.02	0.01	0.03	0.02	0.02	0.06	0.02	0.02	0.05	0.02	0.02	0.04
Octyl	0.00	0.00	0.01	0.01	0.00	0.01	0.00	0.00	0.01	0.01	0.00	0.01

As_T: total arsenic, As_{org}: organic arsenic, As_{inorg}: inorganic arsenic, Hg_T: total mercury, OTC_T: All organostannic compounds, in µg Sn/kg bw/wk, Butyl: butyltin, Phenyl: phenyltin, Octyl: octyltin.

Table 40: Food exposure of the high fish and seafood consumers to trace elements – Lorient (µg/kg bw/week)

	Adult men (18-64 y) n=52			Adult women (18-64 y) n=158			Older subjects (65 y and more) n=37			Women of childbearing age (18-44 y) n=76		
	Mean	SD	P95	Mean	SD	P95	Mean	SD	P95	Mean	SD	P95
As_T	**91.58**	**53.54**	**199.79**	**104.47**	**74.64**	**232.80**	**116.84**	**67.28**	**244.47**	**97.53**	**81.43**	**230.26**
AsB	82.96	37.49	181.01	95.64	69.73	219.04	108.93	64.04	228.01	89.66	76.51	220.44
MMA	0.31	1.14	0.68	0.32	0.38	0.74	0.32	0.31	0.84	0.27	0.42	0.53
DMA	0.81	0.37	2.07	0.76	0.72	2.01	0.61	0.42	1.40	0.68	0.76	1.92
As(III)	0.64	0.27	1.38	0.75	0.57	1.63	0.72	0.40	1.49	0.68	0.62	1.54
As(V)	0.09	0.01	0.17	0.09	0.05	0.18	0.09	0.04	0.17	0.09	0.06	0.18
As_{org}	84.08	39.00	183.50	96.72	70.55	220.57	109.85	64.53	229.72	90.61	77.47	222.68
As_{inorg}	0.72	0.29	1.54	0.85	0.62	1.82	0.81	0.43	1.67	0.77	0.67	1.71
Hg_T	**1.40**	**0.21**	**3.11**	**1.63**	**1.13**	**3.75**	**1.74**	**0.89**	**3.32**	**1.50**	**1.15**	**2.79**
MeHg	1.44	0.34	3.10	1.67	1.15	3.67	1.75	0.89	3.30	1.54	1.16	2.80
Cd	**3.10**	**1.36**	**8.79**	**2.92**	**3.14**	**10.04**	**2.24**	**2.49**	**6.44**	**2.62**	**2.70**	**6.63**
Pb	**0.43**	**0.29**	**0.96**	**0.44**	**0.31**	**0.94**	**0.43**	**0.23**	**0.81**	**0.40**	**0.30**	**0.93**
OTC_T	**0.07**	**0.03**	**0.12**	**0.07**	**0.04**	**0.16**	**0.07**	**0.03**	**0.12**	**0.07**	**0.05**	**0.15**
Butyl	0.05	0.02	0.09	0.05	0.03	0.11	0.04	0.02	0.07	0.05	0.03	0.10
Phényl	0.01	0.01	0.03	0.02	0.01	0.04	0.02	0.01	0.03	0.02	0.01	0.04
Octyl	0.01	0.00	0.01	0.01	0.00	0.01	0.01	0.00	0.01	0.01	0.00	0.01

As_T: total arsenic, As_{org}: organic arsenic, As_{inorg}: inorganic arsenic, Hg_T: total mercury, OTC_T: All organostannic compounds, in µg Sn/kg bw/wk, Butyl: butyltin, Phenyl: phenyltin, Octyl: octyltin.

Table 41: Food exposure of the high fish and seafood consumers to trace elements – La Rochelle (µg/kg bw/week)

	Adult men (18-64 y) n=87			Adult women (18-64 y) n=122			Older subjects (65 y and more) n=39			Women of childbearing age (18-44 y) n=78		
	Mean	SD	P95	Mean	SD	P95	Mean	SD	P95	Mean	SD	P95
As_T	**64.78**	**53.50**	**153.88**	**77.38**	**50.82**	**175.58**	**86.64**	**55.77**	**189.20**	**69.27**	**43.57**	**156.61**
AsB	59.06	48.36	139.18	70.96	45.42	155.38	77.42	48.64	169.13	63.49	39.34	142.36
MMA	0.13	0.11	0.36	0.15	0.12	0.37	0.16	0.11	0.34	0.15	0.12	0.37
DMA	0.58	0.48	1.22	0.75	0.54	1.74	0.83	0.51	1.58	0.73	0.59	2.02
As(III)	0.32	0.22	0.69	0.42	0.28	0.93	0.39	0.28	0.93	0.41	0.30	0.91
As(V)	0.08	0.05	0.15	0.09	0.05	0.21	0.09	0.04	0.17	0.09	0.05	0.20
As_{org}	59.77	48.73	140.48	71.86	45.75	157.58	78.41	48.91	170.04	64.38	39.68	143.68
As_{inorg}	0.40	0.26	0.79	0.52	0.33	1.09	0.48	0.32	1.07	0.50	0.34	1.09
Hg_T	**1.39**	**1.29**	**3.01**	**1.59**	**1.15**	**3.52**	**1.75**	**1.06**	**3.58**	**1.39**	**0.92**	**3.03**
MeHg	1.42	1.27	3.08	1.65	1.19	3.62	1.79	1.09	3.81	1.43	0.96	3.09
Cd	**1.22**	**2.16**	**3.26**	**1.72**	**2.46**	**6.06**	**1.55**	**1.78**	**5.19**	**1.92**	**2.92**	**7.85**
Pb	**0.38**	**0.30**	**0.76**	**0.48**	**0.31**	**1.13**	**0.49**	**0.32**	**1.06**	**0.47**	**0.34**	**1.14**
OTC_T	**0.07**	**0.05**	**0.14**	**0.09**	**0.05**	**0.20**	**0.08**	**0.04**	**0.16**	**0.08**	**0.05**	**0.18**
Butyl	0.05	0.04	0.11	0.07	0.04	0.14	0.06	0.03	0.11	0.06	0.04	0.14
Phényl	0.01	0.01	0.03	0.02	0.01	0.04	0.02	0.01	0.03	0.01	0.01	0.03
Octyl	0.01	0.00	0.01	0.01	0.00	0.02	0.01	0.00	0.01	0.01	0.00	0.01

As_T: total arsenic, As_{org}: organic arsenic, As_{inorg}: inorganic arsenic, Hg_T: total mercury, OTC_T: All organostannic compounds, in µg Sn/kg bw/wk, Butyl: butyltin, Phenyl: phenyltin, Octyl: octyltin.

Table 42: Food exposure of the high fish and seafood consumers to trace elements – Toulon (µg/kg bw/week)

	Adult men (18-64 y) n=60			Adult women (18-64 y) n=171			Older subjects (65 y and more) n=21			Women of childbearing age (18-44 y) n=92		
	Mean	SD	P95	Mean	SD	P95	Mean	SD	P95	Mean	SD	P95
As_T	**64.53**	**57.33**	**143.34**	**76.32**	**65.02**	**222.04**	**80.42**	**58.94**	**146.55**	**72.00**	**63.00**	**232.77**
AsB	54.63	47.54	120.97	66.63	57.28	193.31	69.78	52.42	131.78	63.06	55.86	209.70
MMA	0.10	0.09	0.25	0.12	0.10	0.26	0.10	0.06	0.20	0.12	0.11	0.30
DMA	0.49	0.40	1.24	0.52	0.37	1.18	0.60	0.38	1.04	0.52	0.39	1.21
As(III)	0.50	0.49	1.58	0.58	0.87	1.61	0.49	0.45	1.53	0.46	0.41	1.45
As(V)	0.08	0.05	0.15	0.09	0.06	0.20	0.08	0.03	0.11	0.09	0.05	0.18
As_{org}	55.23	47.96	122.08	67.27	57.61	194.36	70.48	52.69	132.74	63.70	56.16	211.56
As_{inorg}	0.58	0.54	1.81	0.67	0.91	1.78	0.56	0.47	1.63	0.55	0.45	1.67
Hg_T	**1.54**	**1.31**	**4.73**	**1.71**	**1.44**	**4.11**	**1.54**	**1.13**	**3.05**	**1.61**	**1.27**	**3.87**
MeHg	1.50	1.29	4.09	1.69	1.42	4.43	1.50	0.80	2.87	1.60	1.29	4.26
Cd	**0.83**	**0.75**	**2.16**	**0.76**	**0.76**	**1.92**	**0.67**	**0.66**	**2.28**	**0.71**	**0.79**	**1.73**
Pb	**0.38**	**0.30**	**0.96**	**0.42**	**0.59**	**1.19**	**0.39**	**0.27**	**0.77**	**0.36**	**0.40**	**1.03**
OTC_T	**0.10**	**0.05**	**0.18**	**0.11**	**0.08**	**0.27**	**0.09**	**0.04**	**0.14**	**0.11**	**0.08**	**0.27**
Butyl	0.08	0.04	0.16	0.09	0.06	0.21	0.07	0.03	0.11	0.09	0.07	0.22
Phényl	0.01	0.01	0.03	0.02	0.01	0.04	0.01	0.01	0.02	0.02	0.01	0.03
Octyl	0.01	0.01	0.02	0.01	0.01	0.02	0.01	0.00	0.01	0.01	0.01	0.02

As_T: total arsenic, As_{org}: organic arsenic, As_{inorg}: inorganic arsenic, Hg_T: total mercury, OTC_T: All organostannic compounds, in µg Sn/kg bw/wk, Butyl: butyltin, Phenyl: phenyltin, Octyl: octyltin.

Table 43: Food exposure of the high fish and seafood consumers to trace elements of all areas regardless of the age and sex (µg/kg bw/week, Mean ± SD)

	Le Havre n=249	Lorient n=247	La Rochelle n=248	Toulon n=252	All subjects n=996
As_T	84.2 ± 65.9 ^{a}	104 ± 69.7 ^{b}	74.4 ± 52.9 ^{a}	73.9 ± 62.8 ^{a}	84.0 ± 64.2
As_{inorg}	0.64 ± 0.51 ^{a}	0.81 ± 0.56 ^{b}	0.47 ± 0.31 ^{c}	0.64 ± 0.81 ^{a}	0.64 ± 0.59
Pb	0.34 ± 0.29 ^{a}	0.44 ± 0.29 ^{b}	0.45 ± 0.31 ^{b}	0.40 ± 0.51 $^{a,\,b}$	0.41 ± 0.37
Cd	4.64 ± 4.63 ^{a}	2.86 ± 3.01 ^{b}	1.52 ± 2.27 ^{c}	0.77 ± 0.74 ^{d}	2.44 ± 3.34
Hg_T	1.12 ± 1.08 ^{a}	1.60 ± 1.04 ^{b}	1.55 ± 1.19 ^{b}	1.66 ± 1.38 ^{b}	1.48 ± 1.20
MeHg	1.13 ± 1.11 ^{a}	1.63 ± 1.05 ^{b}	1.59 ± 1.21 ^{b}	1.63 ± 1.35 ^{b}	1.49 ± 1.20
OTC_T	0.13 ± 0.09 ^{a}	0.07 ± 0.04 ^{b}	0.08 ± 0.05 ^{b}	0.11 ± 0.07 ^{c}	0.10 ± 0.07

As_T: total arsenic, As_{inorg}: inorganic arsenic, Hg_T: total mercury, OTC_T: All organostannic compounds, in µg Sn/kg bw/wk
Values in the same raw with different superscript letters are significantly different, p<0.05 (Tukey's test)

Table 43 indicates that the total arsenic exposure in Lorient is significantly higher than in the other zones ($p<0.05$). For inorganic arsenic, the most toxic form (As_{inorg}), the subjects in Lorient are also significantly more exposed and the subjects in La Rochelle are significantly less exposed than those in the other zones.

Regarding cadmium, we observe a significant north-south exposure gradient ($p<0.05$) with a maximum in Le Havre and a minimum in Toulon. On the other hand, for mercury (HgT) and more particularly methylmercury the exposure of subjects is significantly less in Le Havre than in the other zones.

Finally, for organostannic compounds (OTC_T) we observe that subjects in Le Havre and Toulon are significantly more exposed than people in the other zones ($p<0.05$).

4.2.2 Biomarkers of exposure

Table 44 presents the trace element concentrations found in the blood of our tested subjects.

Lead : Twenty-two subjects (6% of the subjects for which a blood sample was taken) display a blood level exceeding the so-called "standard" (90 µg/L for men, 70 µg/L for women)[120], but none exceed the concentration of 200 µg/L above which medical monitoring is required. The average lead levels in the blood range from 27.1 to 52.3 µg/L in individuals aged 18 to 64 years; they are slightly higher in elderly subjects at 40.7 to 77.2 µg/L.

Mercury : For total mercury, 13 subjects (3%) exceed the "standard" of 10 µg/L of blood[120]. In all the zones women of child-bearing age (under 45 years old) are the group with the lowest Hg and MeHg levels in the blood (1.91 to 4.13 µg/L and 2.29 to 3.39 µg/L respectively, depending on the zone). Elderly subjects constitute the group with the highest levels, except in Toulon (3.12 to 5.91 µg Hg/L and 3.85 to 5.34 µg MeHg/L). The P95 level is 9.07 µg MeHg/L in Toulon and 9.69 µg MeHg/L in Le Havre.

Cadmium : The urinary cadmium level is the biomarker usually used (see Introduction). Nevertheless depending on the zone, the average cadmium levels in the blood range from 0.42 to 0.94 µg/L for men or from 0.54 to 0.64 µg/L for women aged 18 to 64 years. A concentration exceeding the "standard" (1 µg/L for non-smokers and 2 µg/L for smokers)[120] was found in 18 individuals (4.6%). No individuals exceeded the concentration associated with toxicity (20 µg/L).

120 The "standard value", or reference value, corresponds to the P95 level for the general French population which is not professionally exposed. This value is absolutely not an upper limit which must not be exceeded (see Table 10, p28).

Table 44: Blood concentrations in trace elements (µg/L)

			Cd	Pb	Hg_T	MeHg
Le Havre	Adult men (18-64 y) n=18	Mean	0.42	36.4	2.6	2.95
		SD	0.34	19.6	2.54	2.40
	Adult women (18-64 y) n=59	Mean	0.54	28.9	2.75	3.44
		SD	0.44	14.9	2.05	2.53
	Older subjects (65 y and more) n=6	Mean	0.49	40.7	3.12	3.85
		SD	0.19	14.9	2.31	2.87
	Women of childbearing age (18-44 y) n=28	Mean	0.62	20.6	1.91	2.29
		SD	0.54	7.02	1.41	1.27
	All subjects n=83	Mean	0.51	31.4	2.76	3.37
		SD	0.41	16.3	2.16	2.51
		P95	1.43	57.6	7.49	9.69
Lorient	Adult men (18-64 y) n=21	Mean	0.94	40.6	3.27	3.32
		SD	1.00	20.1	1.64	1.82
	Adult women (18-64 y) n=84	Mean	0.57	27.1	3.61	3.57
		SD	0.44	13.1	2.35	2.27
	Older subjects (65 y and more) n=10	Mean	0.55	54.1	4.83	5.34
		SD	0.26	39.5	3.15	3.51
	Women of childbearing age (18-44 y) n=39	Mean	0.65	21.1	2.54	2.55
		SD	0.53	11.7	1.65	1.49
	All subjects n=115	Mean	0.63	31.9	3.65	3.68
		SD	0.59	19.8	2.33	2.36
		P95	1.72	69.6	8.40	8.34
La Rochelle	Adult men (18-64 y) n=38	Mean	0.76	52.3	4.07	3.55
		SD	0.90	22.7	2.55	2.18
	Adult women (18-64 y) n=46	Mean	0.64	39.3	4.61	3.74
		SD	0.48	22.3	3.38	3.02
	Older subjects (65 y and more) n=14	Mean	0.67	77.2	5.91	4.82
		SD	0.33	40.6	4.23	3.35
	Women of childbearing age (18-44 y) n=28	Mean	0.67	32.0	4.13	3.39
		SD	0.60	18.6	3.11	2.94
	All subjects n=98	Mean	0.69	49.7	4.59	3.82
		SD	0.66	28.5	3.24	2.78
		P95	1.94	103.3	11.9	8.79
Toulon	Adult men (18-64 y) n=17	Mean	0.73	48.0	2.96	3.57
		SD	0.50	28.4	2.29	2.80
	Adult women (18-64 y) n=69	Mean	0.58	33.3	3.14	4.02
		SD	0.44	21.4	5.34	7.07
	Older subjects (65 y and more) n=9	Mean	1.05	57.3	3.37	4.72
		SD	1.49	21.4	2.03	2.92
	Women of childbearing age (18-44 y) n=41	Mean	0.66	26.7	2.35	2.84
		SD	0.52	18.8	2.26	2.23
	All subjects n=95	Mean	0.65	38.2	3.13	4.01
		SD	0.63	24.0	4.68	6.19
		P95	1.53	84.0	7.01	9.07
	All subjects n=391	Mean	0.62	37.8	3.57	3.73
		SD	0.58	23.8	3.30	3.76
		P95	1.70	84.3	8.90	8.84

Hg_T : total mercury

Tables 45 and 46 present the trace element concentrations found in the urine of our tested subjects.

12 subjects (3%) have a total arsenic level less than the limit of quantification (5 µg/L); 242 subjects (63%) have urinary cadmium levels less than the LOQ (0.5 µg/L); 335 subjects (87%) have lead levels less than the LOQ (5 µg/L). However, in order not to underestimate the biological level, the averages presented in Table 45 include all the subjects, with levels below the LOQ taken to be equal to $^1/_2$ LOQ for each of the trace elements.

Cadmium : The measurements indicate that the cadmium levels in urine are in the "standard" range, less than 2 µg/g creatinine, even for the high percentiles (P95). Only 12 people (3%) exceed this norm, yet these are not the people having the highest cadmium concentrations in the blood.

Lead : The lead levels are also low for all age groups and both sexes, on average 5.7 ± 4.4 µg/g creatinine. Levels of 25 µg/g creatinine (the "standard"[120]) or more were observed in four individuals (1%), who were also among the people having the highest lead concentrations in the blood.

Arsenic : Table 46 presents the results of the arsenic speciation performed on the 101 subjects displaying the highest level of total arsenic in the urine (>75 µg/g creatinine). 87 subjects (86%) have levels of inorganic arsenic (As(III), As(V) and its derivatives MMA(V)and DMA(V)) exceeding the "standard" of 10 µg/g creatinine[120]. These forms of arsenic account for 16.1% of total arsenic in urine.

Table 45: Urinary concentrations in trace elements

			As_T (µg/g creatinine)	Cd (µg/g creatinine)	Pb (µg/g creatinine)
Le Havre	Adult men (18-64 y) n=18	Mean ± SD	39.0 ± 50.4	0.5 ± 0.4	4.2 ± 3.6
	Adult women (18-64 y) n=60	Mean ± SD	58.4 ± 87.4	0.6 ± 0.3	4.8 ± 2.5
	Older subjects (65 y and more) n=6	Mean ± SD	50.8 ± 48.3	1.0 ± 0.7	5.7 ± 1.5
	Women of childbearing age (18-44 y) n=29	Mean ± SD	41.7 ± 58.1	0.5 ± 0.2	4.2 ± 2.3
	All subjects n=84	Mean ± SD	53.7 ± 78.4	0.6 ± 0.4	4.8 ± 2.7
		P95	175	1.2	9.8
Lorient	Adult men (18-64 y) n=21	Mean ± SD	55.9 ± 101	0.4 ± 0.2	3.7 ± 1.9
	Adult women (18-64 y) n=84	Mean ± SD	84.7 ± 152	0.7 ± 0.4	6.5 ± 4.3
	Older subjects (65 y and more) n=10	Mean ± SD	57.4 ± 39.0	1.0 ± 0.5	7.3 ± 2.6
	Women of childbearing age (18-44 y) n=39	Mean ± SD	36.7 ± 36.4	0.5 ± 0.5	6.0 ± 5.4
	All subjects n=115	Mean ± SD	77.1 ± 137	0.7 ± 0.4	6.0 ± 4.0
		P95	269	1.4	12.5
La Rochelle	Adult men (18-64 y) n=38	Mean ± SD	69.9 ± 92.0	0.5 ± 0.3	3.7 ± 1.7
	Adult women (18-64 y) n=46	Mean ± SD	160 ± 449	0.7 ± 0.6	6.5 ± 6.2
	Older subjects (65 y and more) n=13	Mean ± SD	94.9 ± 119	0.6 ± 0.3	7.2 ± 3.7
	Women of childbearing age (18-44 y) n=28	Mean ± SD	70.9 ± 79.2	0.6 ± 0.6	5.6 ± 6.1
	All subjects n=97	Mean ± SD	116 ± 319	0.6 ± 0.5	5.5 ± 4.8
		P95	333	1.5	15.0
Toulon	Adult men (18-64 y) n=16	Mean ± SD	52.2 ± 68.7	0.6 ± 0.4	4.0 ± 2.4
	Adult women (18-64 y) n=66	Mean ± SD	100 ± 292	0.7 ± 0.5	6.0 ± 4.8
	Older subjects (65 y and more) n=9	Mean ± SD	79.9 ± 75.4	1.3 ± 0.4	12.0 ± 8.9
	Women of childbearing age (18-44 y) n=39	Mean ± SD	114 ± 70.6	0.5 ± 0.3	4.7 ± 2.8
	All subjects n=91	Mean ± SD	89.7 ± 251	0.7 ± 0.5	6.2 ± 5.4
		P95	258	1.7	16.4
	All subjects n=387	Mean ± SD	84.8 ± 218	0.7 ± 0.5	5.7 ± 4.4
		P95	288	1.5	12.7

As_T : total arsenic

Table 46: Arsenic speciation in the urine of the 101 subjects with the highest urinary total arsenic level (Mean ± SD)

	Le Havre n=15	Lorient n=33	La Rochelle n=32	Toulon n=21	All subjects n=101
As_T (µg/L urine)	193 ± 127	180 ± 167	315 ± 377	344 ± 496	259 ± 331
Creatinine (g/L urine)	1.20 ± 0.60	1.00 ± 0.40	1.40 ±0.70	1.20 ± 0.60	1.20 ± 0.60
As_T / Creat (µg/g Creat)	180 ± 118	201 ± 210	283 ± 520	304 ± 469	245 ± 383
As_{inorg} (µg/L urine)	24.6 ± 21.5	19.9 ± 11.2	31.8 ± 26.7	38.2 ± 41.6	28.2 ± 26.8
As_{inorg} / Creat (µg/g)	25.7 ± 24.8	22.8 ± 12.3	26.0 ± 24.1	33.7 ± 28.9	26.5 ± 22.3
% As_{inorg}	16.5 ± 12.4	16.3 ± 10.4	14.4 ± 10.8	18.3 ± 11.9	16.1 ± 11.1

As_T : total arsenic. As_{inorg}: inorganic arsenic (As(III), As(V) and their metabolits MMA(V) and DMA(V)), Creat: creatinine

Whatever the trace element, age group and sex considered, the subjects in Le Havre have the lowest blood levels, although there are no statistically significant differences between zones (table 47). These trends are consistent with the exposures calculated by the indirect approach, with the exception of cadmium. We calculated an average exposure in Le Havre of 4.64 µg Cd/kg bw/week, which is 2 to 6 times more than in the other zones, whereas the biological results suggest an equivalent exposure in the four study zones (differences not statistically significant). The north-south gradient that appeared significantly with the indirect approach for cadmium is therefore not reflected in the biological level results. For lead, mercury and methylmercury we find similar trends between the level of dietary intake and the biological exposure, with a minimum in Le Havre and a maximum in La Rochelle. For lead in particular it would appear that the subjects in La Rochelle are often the most exposed (indirect approach and direct approach). This is confirmed by the statistical analysis ($p<0.05$).

In the cases of arsenic, cadmium and lead, there are no significant differences in concentrations in urine samples between the study zones, despite the fact that dietary exposure to inorganic arsenic is significantly higher in Lorient and significantly lower in La Rochelle.

Table 47: Blood and urinary concentrations in trace elements of the subjects of all areas regardless of the age and sex (Mean ± SD)

	Le Havre	Lorient	La Rochelle	Toulon	All subjects
Blood concentrations	**n=83**	**n=115**	**n=98**	**n=95**	**n=391**
Cd (µg/L Blood)	0.51 ± 0.41 ^{a}	0.63 ± 0.59 ^{a}	0.69 ± 0.66 ^{a}	0.65 ± 0.63 ^{a}	0.62 ± 0.58
Pb (µg/L Blood)	31.7 ± 16.3 ^{a}	31.9 ± 19.8 ^{a}	49.8 ± 28.5 ^{b}	38.2 ± 24.0 ^{a}	37.8 ± 23.8
Hg_T (µg/L Blood)	2.76 ± 2.16 ^{a}	3.65 ± 2.33 ^{a,b}	4.59 ± 3.24 ^{b}	3.13 ± 4.68 ^{a}	3.57 ± 3.30
MeHg (µg/L Blood)	3.37 ± 2.51 ^{a}	3.68 ± 2.36 ^{a}	3.82 ± 2.78 ^{a}	4.01 ± 6.19 ^{a}	3.73 ± 3.76
Urinary concentrations	**n=84**	**n=115**	**n=97**	**n=91**	**n=387**
As_T/Creat (µg/g Creat)	53.7 ± 78.4 ^{a}	77.1 ± 137.4 ^{a}	116.1 ± 318.5 ^{a}	89.7 ± 251.0 ^{a}	84.8 ± 217.5
Cd/Creat (µg/g Creat)	0.6 ± 0.4 ^{a}	0.7 ± 0.4 ^{a}	0.6 ± 0.5 ^{a}	0.7 ± 0.5 ^{a}	0.7 ± 0.5
Pb (µg/g Creat)	4.8 ± 2.7 ^{a}	6.0 ± 4.0 ^{a}	5.5 ± 4.8 ^{a}	6.2 ± 5.4 ^{a}	5.7 ± 4.4
Speciation in urines	**n=15**	**n=33**	**n=32**	**n=21**	**n=101**
As_{inorg} (µg/L urine)	24.6 ± 21.5 ^{a}	19.9 ± 11.2 ^{a}	31.8 ± 26.7 ^{a}	38.2 ± 41.6 ^{a}	28.2 ± 26.8
As_{inorg} / Creat (µg/g Creat)	25.7 ± 24.8 ^{a}	22.8 ± 12.3 ^{a}	26.0 ± 24.1 ^{a}	33.7 ± 28.9 ^{a}	26.5 ± 22.3

As_T : total arsenic. As_{inorg}: inorganic arsenic (As(III), As(V) and their metabolits MMA(V) and DMA(V)), HgT: total mercury, Creat: creatinine. Values in the same raw with different superscript letters are significantly different, $p<0.05$ (Tukey's test)

4.3 Exposure to persistent organic pollutants

4.3.1 Food exposure

These results correspond to the exposure to persistent organic pollutants through fish and seafood consumption only, not through total diet; they also exclude environmental exposure via the respiratory tract. However food is the principal vector accounting for more than 90% of total exposure of the population to PCDD/Fs and DL-PCBs [121], and fish and seafood are found to be the most contaminated products (see Introduction).

Tables 48 and 49 present the exposure to dioxins and furans, DL-PCBs, i-PCBs and PBDEs of the different population groups in each study zone. The Appendix 5 and 6 presents for all the consumers in all the zones the main contributions (as percentages) to the total exposure for each class of pollutants and to TRV when they do exist.

PCDD/F and DL-PCB : Only the subjects in Toulon and women of child-bearing age in Lorient have an average exposure to dioxins, furans and DL-PCBs less than the WHO's PTMI of 70 pg TEQ_{WHO}/kg bw/month. However 62% of the subjects have an exposure through their fish and seafood consumptions less than the PTMI. Clearly the average is strongly influenced by certain high values; the statistical distribution is not symmetric. This average exposure ranges from 9.70 to 20.0 pg TEQ_{WHO}/kg bw/week in adult males and from 11.9 to 27.1 pg TEQ_{WHO}/kg bw/week in women. Elderly subjects have the highest exposure, in particular those in Le Havre (average 32.0 pg TEQ_{WHO}/kg bw/week, or 109 pg TEQ_{WHO}/kg bw/week at P95).

However we should underline that the real exposure to dioxins is almost certainly overestimated since the cooking of fish and seafood reduces the PCDDs level, as pointed out by Hori and his team[122]. The DL-PCBs account for 76% of the total exposure and the PCDD/F account for 24% which is consistent with the conclusions of the report of the Afssa (2006)[121].

The main contributors to PCDD/Fs and DL-PCBs exposure are sardine (19%), salmon (14%), seabass (7%), mackerel (7%), and seabream (5%). The swimcrab accounts for almost 5% of the exposure on average in the 4 zones; but it is an important contributor to PCDD/Fs and DL-PCBs exposure only in Le Havre (16%). Similarly, eel is a major contributor to DL-PCB exposure only in La Rochelle (18%).

i-PCB : Only 278 people (28%) have a i-PCBs exposure through their fish and seafood consumption less than the TDI of 0.02 µg/kg bw/day. The highest average exposure is that of elderly people in Le Havre with more than 0.67 µg/kg bw/week; the P95 level of these same subjects is 2.36 µg/kg bw/week. The main contributors to this exposure are sardine (20%), salmon (13%), seabass (8%) and mackerel (7%). The eel is a major contributor in La Rochelle (26%) and the swimcrab in Le Havre (16%), but not in the other zones.

In subjects exceeding the TRV of PCDD/Fs and DL-PCBs or i-PCBs, we find the same major contributors to the exposure, the most important being the sardine (23% for PCDD/Fs, DL-PCBs and i-PCBs) and the eel (16% for PCDD/Fs and DL-PCBs, 12% for i-PCBs).

PBDE : The average exposure to PBDEs (28, 47, 99, 100, 153, 154, 183) ranges from 1.61 to 2.39 ng/kg bw/day for men aged 18 to 64 years and from 1.98 to 2.58 ng/kg bw/day for women in the same age group. The most exposed adult females in Le Havre (P95) have an exposure of 5.95 ng/kg bw/day. The main contributors to this exposure are salmon (19%), mackerel (9%), cod (6%), sardine (7%) and tuna (5%). Once again, in La Rochelle we find eel is a major contributor (12%) to PBDEs exposure.

121 Afssa. Avis de l'Agence française de sécurité sanitaire des aliments relatifs à l'évaluation de l'exposition de la population française aux dioxines, furanes et PCB de type dioxine. 9 janvier 2006.

122 Hori T. Nakagawa R., Tobiishi K., Iida T., Tsutsumi T., Sasaki K. and Toyoda M. Effects of cooking on concerns of polychlorinated dibenzo-p-dioxins and related compounds in fish and meat. J.Agric. Food Chem. 53 (22) : 8820-8828. 2005.

Table 48: Food exposure of high fish and seafood consumers to persistent organic pollutants

			PCDD/F (pg TEQ_{OMS}/ kg bw/week)	PCB-DL (pg/TEQ_{OMS} /kg bw/week)	Total diox (pg/TEQ_{OMS}/ kg bw/week)	iPCB (µg/kg bw/week)	PBDE (ng/kg bw/day)
Le Havre	Adult men (18-64 y) n=45	Mean	4.15	13.64	17.79	0.38	1.74
		SD	3.91	13.41	17.18	0.38	1.06
		P95	8.88	43.47	51.79	1.21	3.93
	Adult women (18-64 y) n=180	Mean	5.78	21.31	27.09	0.51	2.34
		SD	6.47	52.48	56.98	0.59	1.84
		P95	16.58	56.43	71.57	1.60	5.95
	Older subjects (65 y and more) n=26	Mean	7.67	24.31	31.98	0.67	2.23
		SD	7.97	25.19	33.15	0.72	1.52
		P95	26.51	82.05	108.55	2.36	5.25
	Women of childbearing age (18-44 y) n=98	Mean	4.92	15.93	20.85	0.47	2.32
		SD	5.16	17.63	22.53	0.56	2.04
		P95	15.94	56.68	70.69	1.59	7.04
Lorient	Adult men (18-64 y) n=53	Mean	4.78	15.27	20.05	0.40	2.17
		SD	0.69	4.49	5.18	0.11	0.11
		P95	12.20	40.61	53.59	1.15	5.06
	Adult women (18-64 y) n=159	Mean	4.89	14.60	19.49	0.34	2.16
		SD	4.04	13.95	17.71	0.35	1.60
		P95	11.89	42.80	56.74	0.97	4.31
	Older subjects (65 y and more) n=37	Mean	4.68	14.04	18.73	0.33	1.98
		SD	3.00	9.72	12.66	0.26	1.04
		P95	11.26	35.97	48.05	0.86	3.59
	Women of childbearing age (18-44 y) n=77	Mean	3.95	11.63	15.58	0.27	2.10
		SD	3.21	13.21	16.17	0.35	1.75
		P95	9.10	24.90	33.79	0.64	4.04
La Rochelle	Adult men (18-64 y) n=88	Mean	3.94	15.98	19.92	0.54	2.39
		SD	3.63	24.70	27.54	1.12	3.07
		P95	8.62	33.43	42.52	1.09	5.06
	Adult women (18-64 y) n=125	Mean	5.20	16.23	21.43	0.46	2.58
		SD	3.72	14.58	17.60	0.52	1.88
		P95	12.41	48.70	56.76	1.42	6.08
	Older subjects (65 y and more) n=40	Mean	4.47	16.00	20.47	0.47	2.21
		SD	3.13	11.49	14.07	0.41	1.40
		P95	9.77	38.73	43.95	1.53	4.59
	Women of childbearing age (18-44 y) n=79	Mean	4.90	13.80	18.70	0.39	2.53
		SD	3.96	13.94	17.19	0.49	2.04
		P95	12.81	38.83	51.83	1.36	6.17
Toulon	Adult men (18-64 y) n=60	Mean	2.04	7.65	9.69	0.22	1.61
		SD	1.35	5.86	7.12	0.21	1.09
		P95	4.38	17.10	21.22	0.56	3.51
	Adult women (18-64 y) n=177	Mean	2.47	9.39	11.86	0.27	1.98
		SD	1.89	9.61	11.26	0.38	1.60
		P95	6.67	25.48	31.89	0.85	4.77
	Older subjects (65 y and more) n=21	Mean	2.44	9.23	11.67	0.25	1.58
		SD	1.16	5.82	6.88	0.18	0.73
		P95	4.04	15.15	19.20	0.35	2.55
	Women of childbearing age (18-44 y) n=96	Mean	2.25	8.53	10.78	0.25	1.97
		SD	1.80	10.54	12.02	0.45	1.76
		P95	5.49	19.79	24.44	0.72	3.74

Table 49: Food exposure to persistent organic pollutants of high fish and seafood consumers of all areas regardless of the age and sex (Mean ± SD)

	Le Havre n=249	Lorient n=247	La Rochelle n=248	Toulon n=252	All subjects n=996
PCDD/F (pg TEQ_{OMS}/kg bw/week)	5.58 ± 6.01 [a]	4.84 ± 3.79 [a]	4.65 ± 3.63 [a]	2.37 ± 1.73 [b]	4.34 ± 4.25
PCB-DL (pg TEQ_{OMS}/kg bw/week)	17.7 ± 19.3 [a]	14.7 ± 13.0 [a]	16.1 ± 18.4 [a]	8.96 ± 8.59 [b]	14.3 ± 15.7
Total PCDD/F et PCB-DL (pg TEQ_{OMS}/kg bw/week)	23.3 ± 25.2 [a]	19.5 ± 16.6 [a]	20.8 ± 21.1 [a]	11.3 ± 10.1 [b]	18.7± 19.6
iPCB (µg/kg bw/week)	0.53 ± 0.58 [a]	0.35 ± 0.35 [b]	0.49 ± 0.77 [a]	0.26 ± 0.33 [b]	0.40 ± 0.55
PBDE (ng/kg bw/day)	2.23 ± 1.70 [a, b]	2.14 ± 1.50 [a, b]	2.45 ± 2.31 [a]	1.86 ± 1.44 [b]	2.17 ± 1.78

Values in the same raw with different superscript letters are significantly different, $p<0.05$ (Tukey's test)

For all the classes of pollutant we observe a similar trend: the subjects in Toulon are less exposed than those in the other zones.

This trend is significant for dioxins, furans and DL-PCBs: the subjects in Toulon are significantly less exposed than the subjects in the other zones, without distinction of age or sex ($p<0.05$). For the i-PCBs, subjects in both Toulon and Lorient have a significantly lower exposure than those in the two other zones. Moreover, for the dioxins, furans and i-PCBs, the subjects in Le Havre are more exposed than those in Lorient and La Rochelle, although this difference is not statistically significant.

Finally, the average exposure to PBDEs (28, 47, 99, 100, 153, 154, 183) is significantly less in Toulon than in La Rochelle ($p<0.05$), but it is equivalent to that in the two other zones.

Generally for food exposure we find a north-south gradient like the one observed for seafood contamination by POPs.

FIFTH PART

Perception of risks

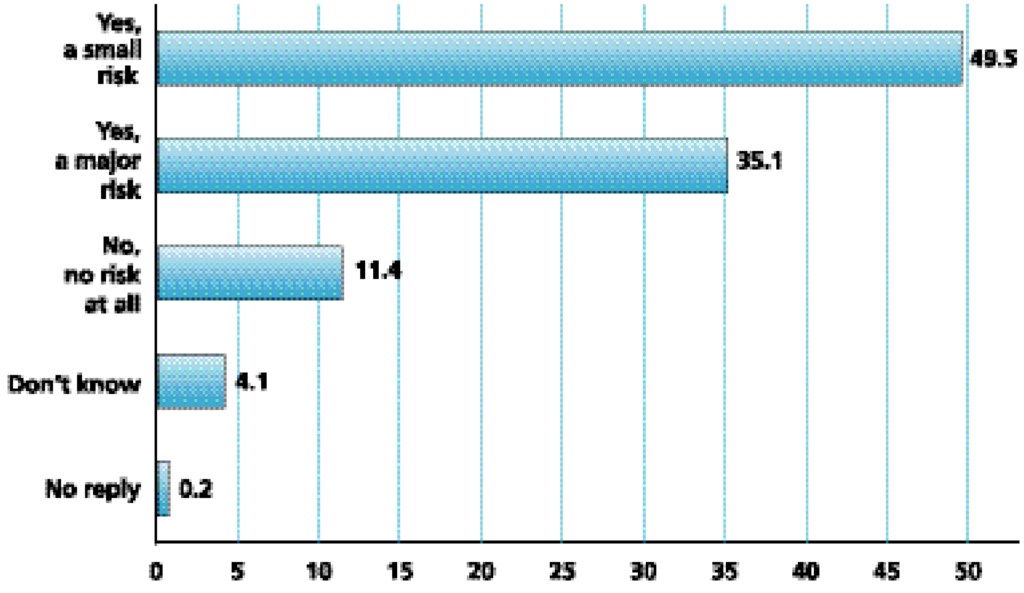
In addition to the food frequency questionnaire, questions on the perception of food risks in general and on the risks associated with seafood in particular were asked to the respondents in order to better appreciate their knowledge, their attitudes and their selection criteria, in particular those of coastal dwellers and high seafood consumers. The subjects were questioned during a period when no serious food crisis was in the news.

5.1 General dietary risks

A first general question on the perception of dietary risks formulated identically during the INCA 99 national study reveals the awareness of the existence of risks linked to food, although this is somewhat moderate.

"In your opinion, do today's food products present a health risk?"

Figure 13 : High seafood consumers' perception of the health risk of food products (% of replies)

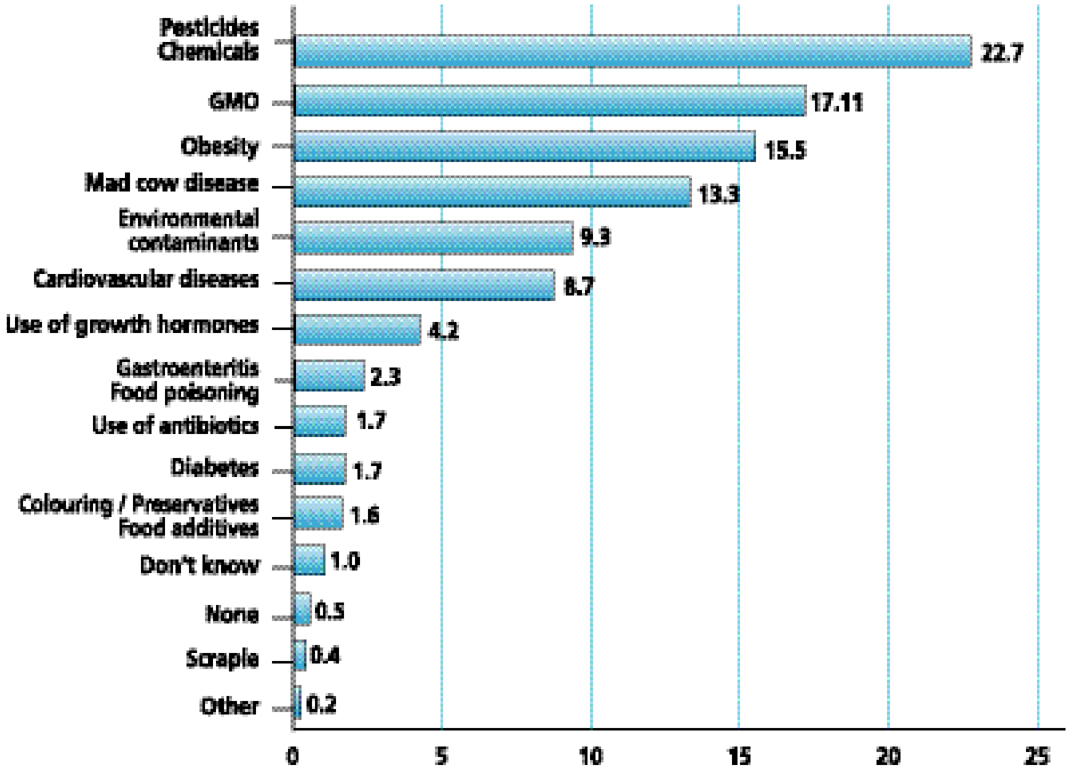


Almost half the participants believe there is a small risk, 35% think there is a major risk, and about 11% think there is no risk at all.

"Among the risks associated with food, in your opinion which, among the following proposals, is the one that today represents the most worrying health risk?"

En premier ?

Figure 14 : The most worrying health risks associated with food - first choice (% of replies)

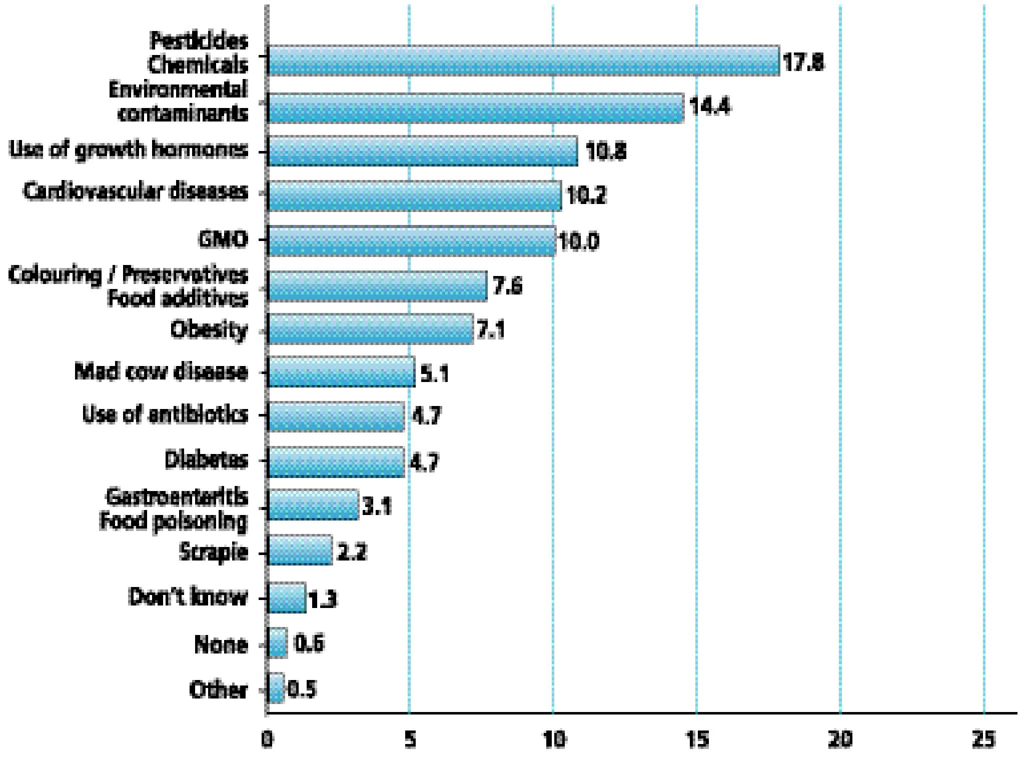


Almost 23% of the respondents think that contamination of food by pesticides and chemical products represents the greatest health risk today (figure 14). This is followed by GMOs (17%) then obesity (16%) having received wide media coverage recently; mad cow disease is in 4th position (13%). We note that during the pilot survey, mad cow disease topped this list of the most serious risks and was mentioned as by 30% of respondents. This illustrates the evolution of food concerns and the preoccupations of the population as regards health and food safety.

The other risks were all mentioned by less than 10% of the participants.

Second choice?

Figure 15 : The most worrying health risks associated with food - second choice (% of replies)



Chemical products appear to be a matter of concern for a majority of respondents (18%) since these are found once again at the top of the list of the most serious health risks (figure 15). Environmental contaminants, the use of growth hormones in farms, cardiovascular diseases and GMOs are also mentioned by more than 10% of the participants.

The "Other risks" mentioned include cancer, avian influenza, food allergies and infantile obesity. The fact that avian influenza was little mentioned is explained by the fact that the survey was made prior to recent intense media coverage of this problem.

These results are consistent with those of the IRSN barometer of risk perception performed during the same year. In this study, the most frequently mentioned hazards or risks potentially linked to food are obesity and pesticides and, to a lesser degree, GMOs[123].

123 IRSN Baromètre IRSN sur la perception des risques et de la sécurité, résultats du sondage (2004).

5.2 Risks associated with marine pollution

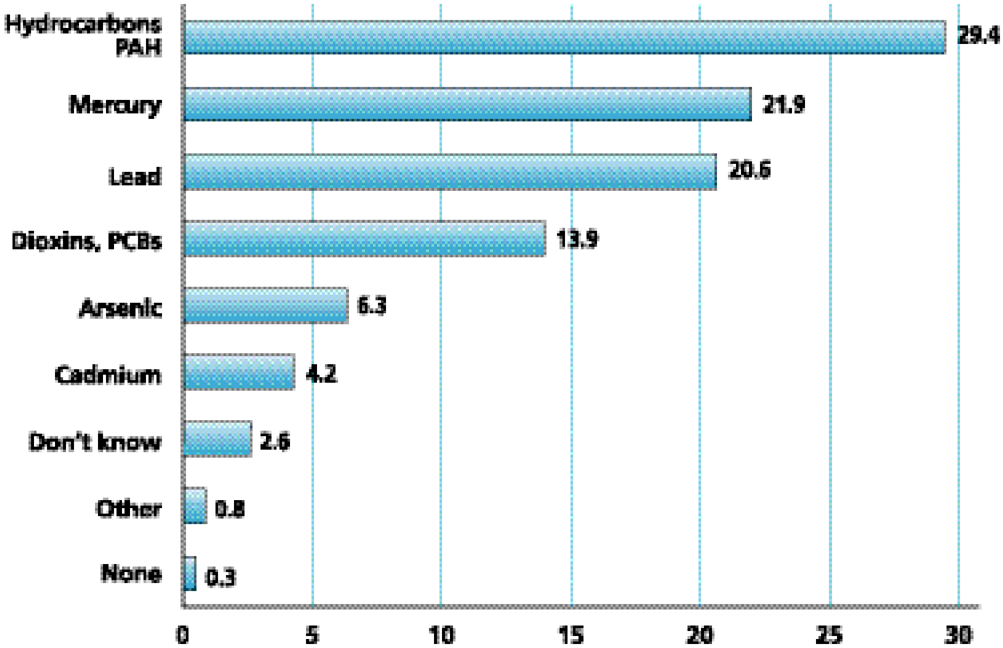
"In your opinion, does marine pollution present a major health risk through seafood consumption?"

Of the people questioned, 81.1% believe marine pollution can present health risks through food consumption. This general awareness of the potential health risks relating to maritime pollution and possible contamination of marine products is no doubt due to the fact that the respondents reside in coastal areas. Only 13.6% of the respondents think that marine pollution presents no major health risk. This high level of risk awareness in relation to fish and seafood consumption, without prejudice to their seriousness, contrasts with the results of other studies that often reveal a phenomenon of habituation to risks, or even denial of these risks by the people exposed. This has been observed in risk perception studies around listed installations, notably nuclear power plants[124], and in studies on the perception of risks associated with "mad cow disease" which revealed the absence of changes in consumption habits among the highest meat consumers during the crisis, whereas occasional consumers reduced their consumption[125].

This general perception of the risk is accompanied by very good knowledge of the environmental contaminants contained in fish and seafood.

"In your opinion, which pollutants can be present in seafood?"(several replies possible).
The results correspond to the aggregated replies.

Figure 16 : Pollutants present in the sea, according to the respondents (% of replies)



124 Milochevitch A Effet de la distance sur la perception des mesures de protection en cas d'accident nucléaire Actes de la 21ème réunion de l'Observatoire des opinions sur les risques et la sécurité IRSN 2002

125 Adda J. "Les consommateurs français et la vache folle" INRA Sciences Sociales n°4 Décembre 1999

Hydrocarbons are the best-known pollutants, in particular among people living near the coast who are very sensitive to marine pollution issues, no doubt due to their experience of oil spillages, notably that of the oil tanker "Erika" recently. Heavy metals (mercury and lead) are mentioned in second place. The frequent mention of lead is rather surprising in view of the moderate contribution of marine products to tolerable intake to lead (< 2% PTWI, see Appendix 6). This can be explained by the bad reputation of lead as an environmental contaminant. Dioxins, which had been the subject of much media coverage a few months earlier, are also often mentioned as marine pollutants.

The "Other" pollutants mentioned include toxic algae, radioactivity, pesticides, general waste (plastics, metals) and bacteria.

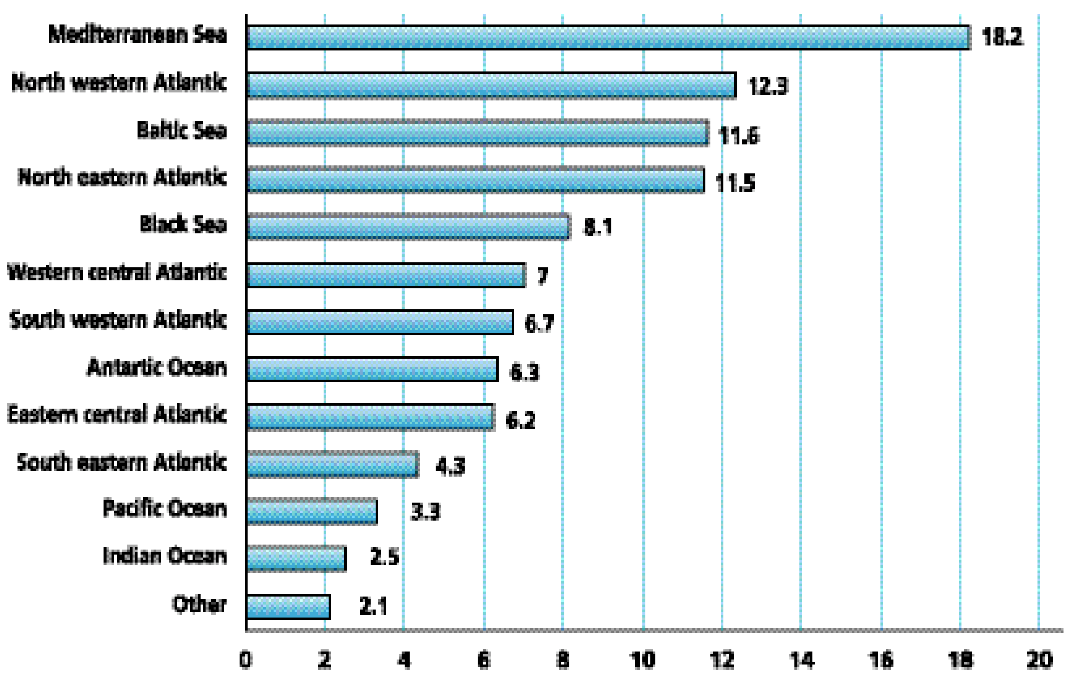
5.3 Behaviour of seafood consumers

> *"Do you pay particular attention to the origin of the seafood you buy, in the sense that you know some coastal zones can be more polluted than others?"*

More than the half the respondents (53%, or 539) say they attach importance to the origin of the seafood they buy. Among them, 4% said the origin was the first criterion when selecting seafood and 22% said it was the second criterion. This sensitivity to the origin of the fishing is confirmed by OFIMER studies that reveal the importance of consumer information, notably for well-informed consumers who constitute a large part of our study population. However, we shall see later that the geographic origin is of little importance compared to the main criteria: appearance, freshness, price and season.

> *"Which seafood origins do you avoid?"* (several replies possible). The results correspond to the aggregated replies.

Figure 17 : Seafood origins avoided by high consumers (% of replies)

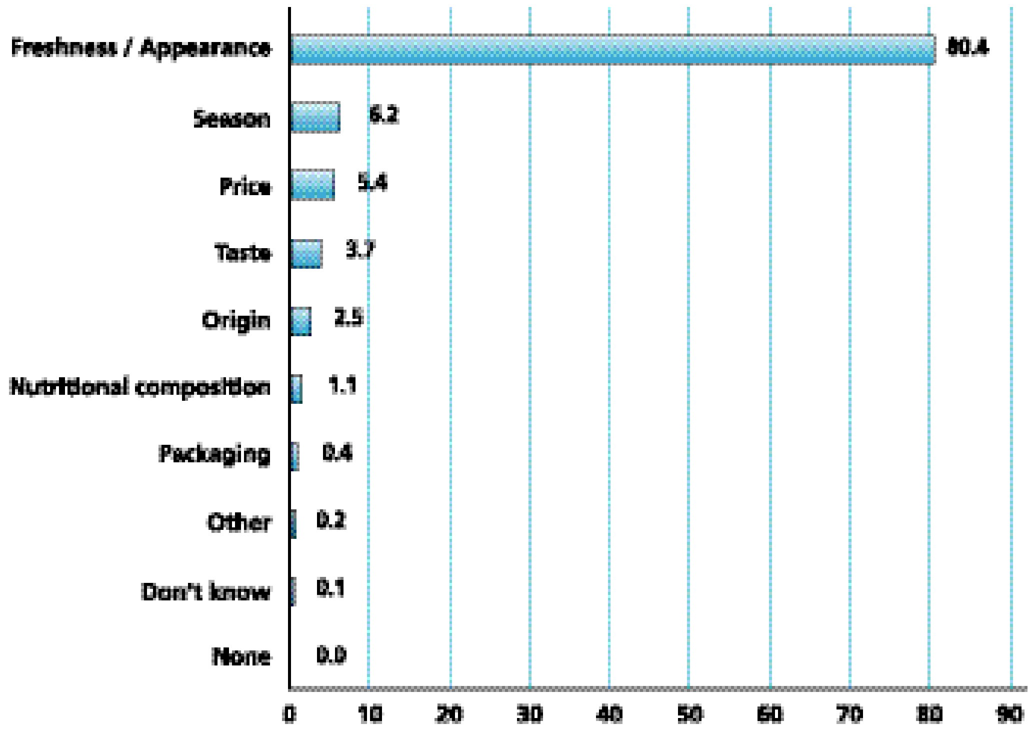


The Mediterranean Sea is the most avoided when purchasing seafood (18% of respondents), followed by the northern oceans: Northwest and Northeast Atlantic and the Baltic mentioned in about 12% of replies.

"Among the following criteria, to which do you attach the greatest importance when buying seafood?"

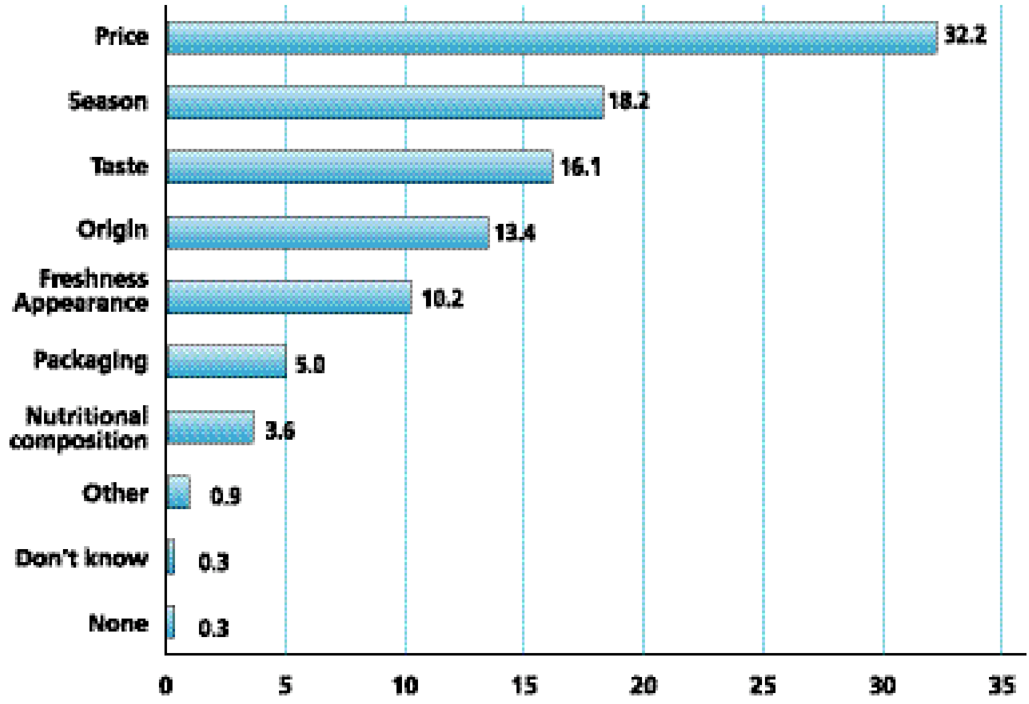
First choice?

Figure 18 : Consumers' first selection criterion when purchasing seafood (% of replies)



Second choice?

Figure 19 : Consumers' second selection criterion when purchasing seafood (% of replies)



Freshness and appearance are undeniably the prime purchasing criteria for 80% of respondents. Price is the second criterion for 32% of respondents and to a lesser degree the season (18%), the taste (16%) and the origin (13%). These are therefore consumers who trust their own judgement when making their choices.

Very few people appear to be concerned by the nutritional value of the products bought. We have seen that the fatty acid composition of fish is nevertheless highly variable and could interest the consumer. It appears that for the moment this type of very important information for nutritionists, dieticians and public health professionals in general is not well integrated in consumers' criteria when selecting products, despite the increasing reputation of omega 3 fatty acids.

The "Other" criteria mentioned include product availability, impulsive desire, presence/absence of bones, use-by date and odour. Ease of preparation is not often mentioned, although has been shown elsewhere that this is an important selection criterion for consumers in general. Perhaps the fact that our study population are high fish and seafood consumers means they are not put off by the preparation of whole fish, a supposition well supported by OFIMER studies [126].

126 OFIMER Etude sur les poissonniers en France La lettre de l'OFIMER Novembre 2001

5.4 Consumer information

"To ensure effective information of consumers, since 1st January 2002 community regulations require that seafood labelling includes the commercial denomination of the species, the production method and the zone of capture. Are you aware of this?"

Almost the two thirds of the people questioned (62.8%) are aware of the new regulation now applicable to seafood labelling. This result is not surprising in view of the high frequency of purchases of fish and seafood by the respondents in the study.

"Do you think this measure will affect your buying habits?"

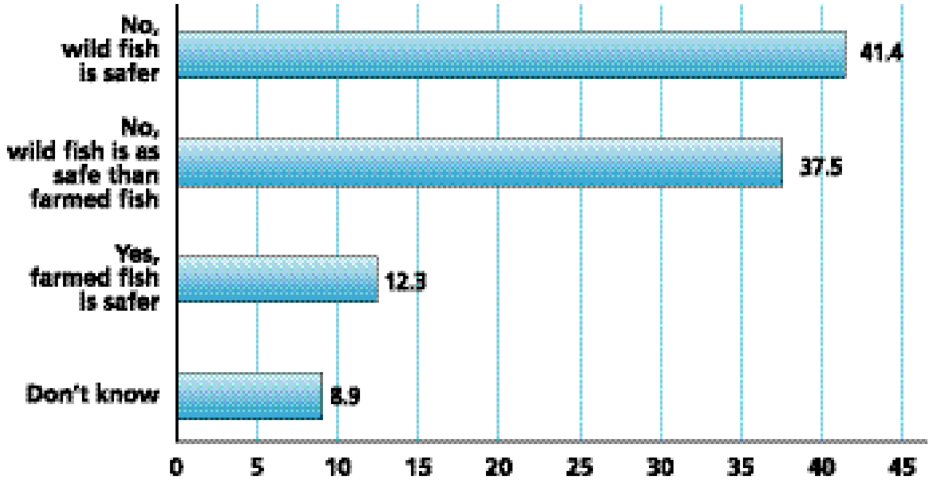
Of the people questioned, 47% or 473 think that the new regulation (of which 71% were aware) will influence their buying habits, while 46% or 460 (of which 60% were aware of the regulation) do not think so.

"Do you think that the controls carried out at seafood points of sale are sufficient or insufficient?"

The controls made on seafood appear to reassure only one third of the respondents. More than half of them (50.7%) believe these controls to be insufficient, and 16% have no opinion on the subject. This result no doubt reflects the visible preoccupation of this population of high fish and seafood consumers as regards possible environmental contamination of the fish, crustaceans or molluscs they consume.

"Do you think that consumption of cultivated fish is safer than consumption of wild fish?"

Figure 20 : High consumers' opinions as regards the risks of consuming cultivated fish (% of replies)

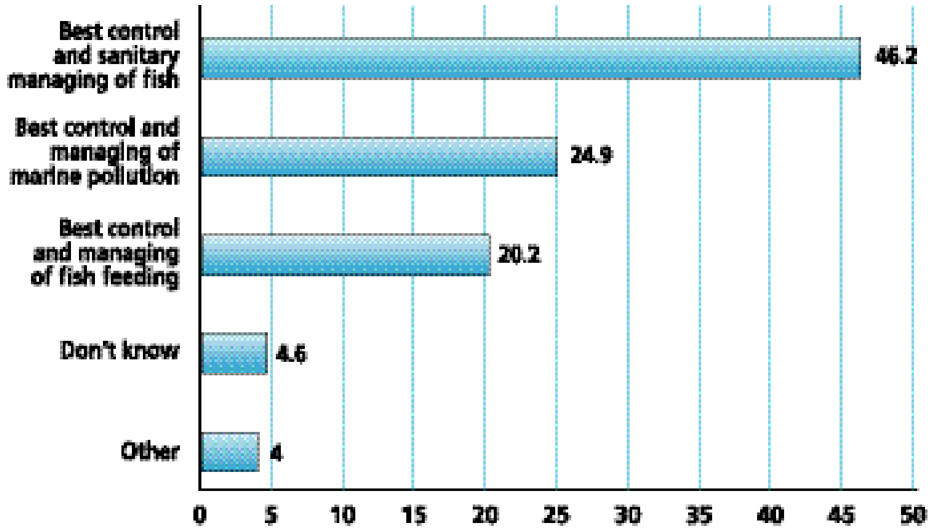


A majority of respondents believe consumption of wild fish is safer (41%), or at least no less safe than consuming cultivated fish (38%) (figure 20).

Various media alerts, notably that stirred up by the publication in January 2004 of an article in "Science" about the contamination of farmed salmon in Europe, explains this undercurrent of suspicion as regards fish farming. In this media context, however, we note that 4 out of 10 of our subjects consider that farmed fish and wild fish are equivalent.

"If so, why?" (several replies possible) The results correspond to the aggregated replies.

Figure 21 : Reasons given for believing that consumption of farmed fish is safer then consumption of wild fish (% of replies)



Almost half the respondents believe that consumption of farmed fish is safer thanks to better control and regular surveillance of the fish (figure 21). A quarter of them are reassured by the fact that the marine milieu in which these fish live is not only controlled and regularly analysed but also by the fact that this environment is less exposed to external pollution (boats, toxic waste, etc.). More than 20% of them believe eating farmed fish is better for health: more natural, more healthy, better monitoring, etc.

About 5% of respondents support the idea that consumption of farmed fish is safer, but without knowing precisely why. Finally, 4% give philosophical reasons, prejudices or information read or heard in the media.

In conclusion, this part of the study on perceptions and attitudes of high fish and seafood consumers as regards the possible risks of their consumption shows that this population has extensive knowledge of fish and seafood. They are consumers seeking information, preoccupied, but they remain somewhat detached from public controversy on this subject.

SIXTH PART

Discussion

6.1 Fatty acids

The lipids of the erythrocyte membranes of the subjects contain 0.74% of EPA, 1.71% of DPA and 4.02% of DHA, or 6.47% of n-3 LC-PUFAs. Few data are available on this subject in the scientific literature, and when they do exist they are not comparable with ours since they generally come from intervention studies involving omega 3 supplementation of subjects, or they do not concern the general population, or they do not use the same biomarker of exposure.

In controls of an intervention study, Weill et al. in 2002 found DHA accounted for 4.8 ± 0.89% of total lipids in the red blood cell membrane, and EPA for 0.5 ± 0.12%[88]. In 2004, Payet et al. measured 4.8 ± 1.2 % of DHA and 1.1 ± 0.81% of EPA in elderly people before supplementation[127]. In 2003, Dewailly and his team reported n-3 LC-PUFAs levels of 1.8%, 3.9% and 8.0% in circulating phospholipids in plasma in three Canadian population groups consuming respectively 13g, 60g and 131g of fish per day[128].

The trends observed in the results of the measurements in the erythrocytes for the different zones (Tables 34 to 38) are not completely in agreement with the intakes calculated by crossing consumption and composition data (Tables 29 to 33).

The relationship between n-3 LC-PUFAs intake and the erythrocyte composition is not proportional, which implies that many other factors are acting. Knowing that n-3 fatty acids are subject to beta-oxidation, the quantity of total lipids in the diet influences the oxidation of the n-3 LC-PUFAs. We note a Pearson correlation coefficient of 0.26 ($p<0.0001$) between the n-3 LC-PUFAs levels in the erythrocytes and the proportion of n-3 LC-PUFAs in the dietary lipids.

Moreover, since age influences peroxidation of lipids, in particular the n-3 LC-PUFAs, the correlation between age and the erythrocyte n-3 LC-PUFAs levels is 0.23 ($p<0.0001$). For smokers the number of cigarettes smoked per day correlates negatively with the blood DHA ($r=-0.22$, $p=0.02$).

It is particularly difficult to find a simple mathematical model linking the erythrocyte composition to n-3 LC-PUFAs consumption, which may be explained in several ways:

- The first hypothesis is that the fatty acids composition of the blood tissue (erythrocyte) is not a good marker for all n-3 fatty acids. It is accepted that the DHA of the erythrocytes reflects very poorly the ingested quantity, unlike other n-3 PUFAs[129]. In man and general population, we must nevertheless settle for this accessible tissue.

- The second hypothesis is the variability between individuals related to beta-oxidation of fatty acids and its multiple regulation factors. In the case of fatty acids, although they are essential, their availability is highly dependant on their energy usage by beta-oxidation, which is not the case for many other essential nutrients, including vitamins and minerals. This beta-oxidation, which does not spare the n-3 PUFAs, can represent up to 90% of the n-3 metabolism; it is influenced by the physiological and physiopathological status of the energy expenditure and the fatty acids composition (quantity of saturated acids) and other energy-providing nutrients in the diet.

- The third hypothesis is that the presence of the precursor alpha-linolenic acid (ALA) in the diet can also bring non-negligible additional quantities of n-3 LC-PUFAs (EPA and DHA)[88]. This could explain why the French population, even heavy fish consumers, has an n-3 LC-PUFAs status lower than other

127 Payet M., Esmail M.H., Polichetti E., Le Brun G., Adjemout L., Donnoarel G., Portugal H. and Pieroni G. Docosahexaenoic acid-enriched egg consumption induces accretion of arachidonic acid in erythrocytes of erderly patients. Br. J. Nutr. 91 : 789-796. 2004.

128 Dewailly E., Blanchet C., Gingras S., Lemieux S., and Holub B.J. Fish consumption and blood lipids in three ethnic groups of Québec (Canada). Lipids. 38 (4) : 359-365. 2003.

129 Patch C., Murphy K., Mansour., TapsellL., Meyer B., Mori T., Noakes M., Clifton P., Puddey I. and Howe P. Erythrocyte biomarker-based validation of a diet history method used in a dietary intervention trial. NSA Poster Presentations. Asia Pac. J. Clin. Nutr. 13 : 60. 2004.

populations, in view of the small quantities of ALA consumed[4] and the richness of the diet in n-6 fatty acids that inhibit the ALA conversion. By way of comparison, we could assume that a population consuming the precursor ALA (Canada, Japan) and little LA would increase its very long-chain n-3 status by ALA conversion, in this case non-negligible. The study of Weill et al. suggests this idea since the n-3 LC-PUFA status is high with a diet rich in ALA (flax-eating animals products) but in which fish is absent[88]. In our population, those most consumed oils are sunflower and olive which provide 1.0 ± 1.0 g ALA/week (high estimation) and 23.2 ± 22.6 g LA/week compared to 11.2 ± 8.9 g ALA/week and 23.5 ± 18.6 g LA/week if the subjects consumed only rapeseed oil.

• A fourth explanation is that the variability over a long period of the biological exposure in the general population is less than that found in the intervention studies over short periods. The literature on intervention studies relates that the variations in the erythrocyte membrane composition can be large. Harris reports a 4.3% increase of EPA + DHA resulting from supplementation of one gram of EPA + DHA over 6 months. For a higher n-3 LC-PUFAs intake (0.14 g/day) Weill noted a 0.69% increase in the n-3 LC-PUFAs in the erythrocyte membrane. Our subjects are high fish and seafood consumers, but the large panel of products and the differences in the nutritional composition of the products could lead to considerable variation in intakes depending on the products consumed (see the chapter on “Seafood composition and contamination”). Furthermore the biological samples were taken between October and December 2004, which means they reflect summer consumptions, whereas the samples were taken between January and April 2005, a period during which most of the fish tend to display higher total lipid and fatty acid levels than those measured in summer. In addition to this seasonal variation of lipids levels in fish there may also be some seasonality in the consumption of oily fish. These factors could well imply that the erythrocyte membrane is not an ideal marker of long-term n-3 LC-PUFAs consumption, but in fact only a short-term marker as suggested by certain studies[130]. Intervention studies presenting significant results are often made over a few days or even a few weeks, but rarely over a duration corresponding to the hematopoietic cycle.

• A last hypothesis is that the relationship between the DHA consumed and the proportion of DHA in the erythrocyte membrane is not linear. It could be logarithmic, polynomial…

6.2 Trace elements

Arsenic : Concerning the levels found in food samples, we noted that the total of the contents of the different arsenic forms was not always equal to the As_T level. When the sum is less than the As_T level, the difference may be explained by the non-detection of certain arsenic species which induces a slight underestimation of the total of the arsenic species relative to the total level. In the opposite case, this is mainly due to the fact that the As_T and the forms of speciation were quantified using two distinct analytical techniques, although the observed differences generally remain within the estimated limits of measuring uncertainty of the methods.

The total arsenic concentrations measured in urine are relatively high. This is not surprising in view of the diet rich in seafood of the subjects tested. In effect, organic arsenic is of dietary origin (AsB in particular), which accounts for a large part of total arsenic in the urine, reflects the intake at the last meal. It is therefore important to take the arsenic speciation into account here.

Regarding indirect exposure, note that the inorganic arsenic corresponds to the forms As(III) and As(V). In toxicology and occupational medicine (direct exposure or biomarkers) inorganic arsenic is understood to mean the As(III) and As(V) forms and their mono- and dimethyl metabolic derivatives, MMA and DMA of redox potential V. Nevertheless, these methylated forms are in a minority.

130 Poppitt S.D., Kilmartin P., Butler P. and Keogh G.F. Assessment of erythrocyte phospholipids fatty acid composition as a biomarker for dietary MUFA, PUFA or saturated fatty acid intake in a controlled cross-over intervention trial. Lipids Health Dis. 4 : 30. 2005.

There is no significant correlation between arsenic (total and inorganic) consumed and arsenic found in the urine, but the quantity of predator fish consumed correlates significantly with the inorganic arsenic measured in the urine, weighted by the creatinine ($r=0.25$, $p=0.01$).

These results are highly consistent in view of the very low inorganic arsenic intakes from fish and seafood compared to other sources (water, etc.).

Mercury : The analyses of mercury in seafood products, either to determine the total level or the methylmercury, were self-checked on each series of tests by internal quality controls (IQC) performed using suitable certified reference material (CRM). In 83% of cases, the average measured concentration of total Hg tallies with that of the MeHg concentrations, allowing for the respective enlarged uncertainties of the two analytical methods used. The dispersion of these values is identical in both cases and is Gaussian. Nevertheless in 17% of cases there subsists significant differences between the total and methylmercury concentrations. To explain these differences and notably the fact that the MeHg levels can appear higher than the total mercury, we must take into consideration the possible existence of a analytical bias in the isotopic dilution method, although this approach is recognised as one of the best. In current research work it is now envisaged that native mercury may behave differently from mercury added during the isotopic dilution method. The analytical biases usually corrected by this method are therefore no longer corrected perfectly.

Generally speaking, the calculated exposures are higher than the estimations found in the international literature which often indicate that very few consumers exceed the PTWI. However the calculations are often made for populations that are not high fish consumers, and the studies often concern only a small number of products (less than 30, versus 84 in our study). In 1995 Buzina *et al.* reported, for Adriatic populations consuming fish and seafood 2 to 6 times per week, exposures ranging from 132 to 294 µg Hg/week on average[131], or 1.9 to 4.2 µg Hg/kg bw/week for individuals of 70 kg aged 15 to 59 years, which is of the same order of magnitude as the results of our study. This comparison therefore illustrates well that our study concerns mainly high seafood consumers. However, the consumption study method based on a food frequency questionnaire, it is probable that the consumptions and therefore the exposures are overestimated.

We note that the calculated mercury exposure (Hg_T) of the subjects and more particularly the methylmercury exposure appears significantly lower in Le Havre than in the other zones (Table 43). This could be explained by lower consumption of the main contributors to this exposure which are predator fish, notably fresh tuna (mean consumption and consumer rate, see Appendix 2).

As regards the MeHg biomarker of exposure data, these confirm the consequences of high consumption of seafood products and predator fish in particular. In view of the quality procedure applied in the Hg_T analysis of the blood samples, the values of total Hg level obtained are considered to be reliable. Two series of independent measurements were performed by two specialized analytical laboratories. The measurements were made using a reference analytical technique recognised to be reliable and sensitive, and the results tally satisfactorily for at least 80% of the results around the tolerated confidence interval (CI) (between 70% and 130% of the determined Hg_T level). The rest of the data outside this interval are essentially low biomarker values, but not high values, which increases the confidence in the interpretation of the data.

131 Buzina R., Stegnar P., Buzina-Suboticanec K., Horvat M., Petric I. and Farley T.M.M. Dietary mercury intake and human exposure in an Adriatic population. Sci. Total Environ. 170 : 199-208. 1995.

On the other hand, the mercury speciation results in the blood samples are more difficult to interpret in that the technique was developed during this study.

The average ratio between the MeHg and HgT concentrations is 115%, i.e. a 15% difference. About 30% of the samples analysed have quantified MeHg levels that lie outside the tolerated confidence interval CI, CI being determined from the estimated uncertainties of the two methods used in order to establish a pertinent internal quality control (IQC). Of these 30%, 10% of the observed differences are less than the lower limit of 0.7 of the CI, probably due to the small concentrations close to the estimated quantification limit, and 20% are higher than the upper limit of this CI. This overestimation of the results appear to be linked to the global composition of the blood matrix resulting in different behaviour between added mercury, present in the dissolved phase, and native mercury which is chelated by proteins that can precipitate in an acid milieu (isotopic dilution method). Actually, the quantification by isotopic dilution used during this study offers the possibility of developing a primary reference method enabling greater precision and reliability [132 133 134], however subject to verifying that the enriched isotope added is not extracted differently from the analyte present in the matrix[135]. This is probably what we observe in 20% of cases on the blood matrix. Further detailed investigations are necessary in order to confirm this and to attempt to correct it.

The MeHg measured in the blood correlates significantly with the quantity of MeHg absorbed from fish and seafood ($r = 0.36$, $p<0.0001$). This conclusion is borne out by the fact that the quantity of predator fish consumed correlates positively with the MeHg measured in the blood ($r = 0.26$, $p<0.0001$). Furthermore we also note a significant correlation between the MeHg level in the blood and the ages of the subjects ($r = 0.25$, $p<0.0001$). We should bear in mind that our population is relatively homogeneous (only high consumers) and that it is difficult to obtain a very good correlation contrary to a heterogeneous population representing a wide range of consumption and exposure levels.

Moreover the blood analysis results are consistent with the results of the study of Bjornberg *et al.* (2005) concerning Swedish women of child-bearing age and who are high fish consumers [136]. Such women in our study have an average MeHg level in the blood of 2.3 to 3.4 µg/l depending on the zone, with a median for all the zones combined of 2.4 µg/L. The Swedish study indicates a median value of 1.7 µg/L for these high seafood consumers. For comparison, the NHANES study indicates for the general American population (not high fish consumers) a geometric average of 1.02 µg/L for women aged 16 to 49 years[137].

The blood analyses results for MeHg in the subjects of our study are reassuring. We recall that a PTWI of 1.6 µg/kg bw/week was established by the JECFA[22]. This corresponds to a concentration of 14 mg of Hg/kg in the mother's hair, or 56 µg of MeHg/L in the mother's blood (mean ration hair/blood of 250), having no adverse effects on the foetus. The PTWI includes an uncertainty factor of 2 corresponding to the inter-individual variability of the relation between MeHg concentration measured in hair and that measured in blood. In fact, even among the very high consumers of fish and seafood, consuming up to 4.5 kg of product per week and with exposures calculated from these high consumptions of as much as

132 Rivier C., Stumpf C., Labarraque G., Hervouët G., Désenfant M., Priel M., Rouyer J.-M. et Seiller M.-P. Matériaux de référence et essais d'aptitude : deux outils au service de la qualité des analyses. Spectra Analyse. 256 : 33-35. 2005.

133 Monperrus M., Tessier E., Veschambre S., Amouroux D. and Donard O.F.X. Simultaneous speciation of mercury and butyltin compounds in natural waters and snow by propylation and species-specific isotope dilution mass spectrometry analysis. Anal. Bioanal. Chem. 381 (4) : 854-862. 2005.

134 Centineo G., Rodriguez-Gonzalez P., Gonzalez E.B., Garcia Alonso J.I. and Sanz-Medel A. Simultaneous determination of mono-, di- and tributyltin in enviromnental samples using isotope dilution gas chromatography mass spectrometry. J. Mass. Spectrom. 39 (5) : 485-494. 2004.

135 Monperrus M., Krupp E., Amouroux D., Donard O.F.X. and Rodriguez Martin-Doimeadios R.C. Potential and limits of speciated isotope-dilution analysis for methodology and assessing environmental reactivity. Trend. Analyt. Chem. 23 (3) : 261-272. 2004.

136 Bjornberg K.A., Vahter M., Grawe K.P. and Berglund M. Methyl mercury exposure in Swedish women with high fish consumption. Sci Total Environ. 341 (1-3) : 45-52. 2005.

137 Schober S.E., Sinks T.H., Jones R.L., Bolger P.M., McDowell M., Osterloh J., Garrett E.S., Canady R.A., Dillon C.F., Sun Y., Joseph C.B. and Mahaffey K.R. Blood mercury levels in US children and women of childbearing age, 1999-2000. JAMA. 289 (13) : 1667-1674. 2003.

9.6 µg/kg bw/week, we find MeHg blood levels well below the value of 56 µg/L, the maximum being 18 µg/L. In fact only one person displayed a concentration exceeding this value, and this can be partly explained by this person's use of a medication affecting the renal and hepathic functions.

Given that the biological results do not indicate that the total Hg and MeHg values associated with toxicity are exceeded, whereas the exposure calculation indicates that a third of the subjects exceed the recommended PTWI for MeHg, to characterise the risk associated with exposure to MeHg we exploit the biomarker results of our study. The measurements in the biological matrices (blood or hair) enable us to calculate, using a pharmacokinetic model, a “steady state dietary intake” which relates the daily intake of MeHg to the concentration in blood or hair, as described by international scientific bodies such as JECFA, EPA, FDA, NRC and WHO[19 138]. The use of biomarker data to estimate exposures requires that the methylmercury concentrations in the blood of our population be effectively in a steady state, which we believe to be the case in view of our recruitment criteria and the homogeneous dietary habits stable over time. Taking only the individuals for which blood analyses were made (n=385), by crossing the consumption and contamination data we calculate an average exposure of 1.61 ± 1.28 µg MeHg/kg bw/week for the general population excluding women of child-bearing age, and for such women an average exposure of 1.34 ± 0.92 µg/kg bw/week. The use of blood concentrations and the single-compartment pharmacokinetic model indicate for the general population, excluding women of child-bearing age, an average exposure of 0.65 ± 0.64 µg/kg bw/week, and for women of child-bearing age, the subjects most “at risk”, an average exposure of 0.39 ± 0.29 µg/kg bw/week. These average exposures can be compared with the PTWI which takes into account a safety factor of 3.2 corresponding to the inter-individual variability of the pharmacokinetic model. Applying the pharmacokinetic model at individual level this variability is clearly not integrated, but we can consider that, in view of the size of our population, this variability can be ignored for the average of the population. The average intakes of MeHg of 0.39 ± 0.29 µg/kg bw/week estimated for women of child-bearing age, and of 0.65 ± 0.64 µg/kg bw/week estimated for the general population are only half the estimated intakes via indirect exposure.

138 NAS/NRC. Toxicological effect of MeHg. National Academy Press. Washington DC. 2000.

Table 50 : Modelling of methylmercury exposure at the steady state of subjects participating in the biological part, and quantification of the probability of exceeding the PTWI of 1.6 µg/kg bw/week

	Intake (µg/kg bw/week)			Blood concentrations (µg/L)		Exposure calculated with the pharmacokinetic model "Steady State Ingestion" (µg/kg bw/week)	
	Mean ± SD	P95	%>PTWI	Mean ± SD	P95	Mean ± SD	P95
General population excluding women of childbearing age. n=252	1.61 ± 1.28	3.87	37%	4.27± 4.34	9.91	0.65 ± 0.64	1.49
Women of childbearing age (18-44 y), n=132	1.34 ± 0.92	2.87	32%	2.70± 2.00	5.61	0.39 ± 0.29	0.85

The mean of the individual ratios of calculated exposure to steady-state dietary intake is 4.3, with a minimum of 0.2 and a P95 of 14 for all the people who were sampled. This ratio is lower, close to 1-2, when the calculated exposure and the blood MeHg level are high. Two explanations are possible: first, it is possible that the consumptions declared on the food frequency questionnaire by the highest consumers in our study (the people most exposed) are closer to the reality and overestimate the real consumptions less than the declared consumptions of low consumers. Another hypothesis is possible when the consumption overestimation on the questionnaire is the same for all consumers. The absorption of MeHg, its distribution in the blood and its excretion are perhaps dependant on the quantity ingested. This point is interesting to underlined as the linearity of absorption as never been demonstrated. In this case the model describing the steady state would be more suitable for high consumptions (high exposures) than low consumptions.

This comparison between food exposure calculated by consumptions and exposure estimated by application of the pharmacokinetic model shows that the factor of 3.2 applied by the JECFA to take account of the inter-individual pharmacokinetic variability is somewhat protective with regard to high biomarker levels for which the ratio of calculated exposure to steady state dietary intake is around 1 or 2. This is reassuring from a public health point of view.

The fact that the factor between the calculated dietary intakes based on consumptions and the results of the pharmacokinetic model is higher in the JECFA study tends to support the assumption that food frequency questionnaire overestimates consumptions, a point that should be underlined since many exposure studies use this type of questionnaire.

The Codex at its meeting on April 2005 underlined the need to better define the target populations to which the PTWI is applicable, in particular to know whether its PTWI of 1.6 µg/kg bw/week established in 2003 should be used as a reference toxicological value for the general adult population or if a different PTWI should be defined [139]. This toxicological issue has been submitted for clarification at the next meeting of the JECFA's expert committee scheduled for June 2006 [140]. The FSA report on the benefits and risks of fish consumption [35] states that there has been no new published information suggesting that the previous PTWI of 3.3 µg/kg bw/week established in 2000 was not sufficiently protective for the general population. In this case, on the basis of the calculated exposures in our study for the general population, excluding women of child-bearing age, only 7.9% of our blood-sampled consumers would exceed the PTWI, instead of 37%.

139 Codex Alimentarius Commission. 28e session. Rome. 4-9 juily 2005.

140 JECFA. Safety evaluation of certain food additives and contaminants. 67th Joint FAO/WHO Expert Committee on Food Additives and contaminants. WHO Rome. June 2006.

Lead : As regards lead, we noted that 22 subjects (6%) have blood levels higher than the standard (70 to 90 µg/L) and that 4 others have urine levels higher than the standard (25 µg/g creatinine). For most of these people, this high concentration can be at least partly explained by professional or leisure activities exposing them to lead (welding, paints, manipulation of metals, hunting, etc.) and/or by the fact that their homes were built before 1948 (after which lead paint was forbidden), although no direct statistical link can be established.

There is a significant correlation between the quantity of lead consumed in seafood and the lead measured in the blood ($r=0.18$, $p=0.0005$). However this correlation is less marked than for mercury. This is explained by the fact that other sources of lead intake (water, other foods) have not been taken into account here. Age also correlates positively with the presence of lead in the blood ($r=0.46$, $p<0.0001$)

Cadmium : The urine analyses reveal that 12 people (3%) have a cadmium concentration exceeding 2 µg/g of creatinine, among which 7 are smokers or former smokers with an average age of 52.

As for MeHg we observe that the cadmium results in the biological matrices do not lead to the same interpretations as those for the calculated food exposures. According to our calculations, 8.5% of the subjects exceed the PTWI, whereas the results of the biological analyses indicate that the cadmium levels remain below the standards.

Some factors have major impact on the cadmium levels measured in the biological matrices. For example the number of cigarettes smoked per day correlates strongly with cadmium level in the blood ($r=0.62$, $p<0.0001$). For non-smokers, age also correlates with these cadmium levels ($r=0.38$, $p<0.0001$), which is normal for an element that accumulates in the body over time.

Age correlates with cadmium level expressed in µg Cd/g creatinine, with a correlation of 0.34 ($p<0.0001$), which means that the individuals with the highest levels (>2 µg/g creatinine) are over 50 years old.

We note a correlation between the urinary cadmium level and the dietary exposure to cadmium from seafood ($r=0.32$, $p<0.0001$). On the other hand, the blood cadmium level does not correlate with the exposure to cadmium ($p=0.65$). This phenomenon may be explained by the fact that seafood are not the only foods contributing to cadmium exposure. The total diet study shows that the main food sources of cadmium are vegetables and potatoes, a long way ahead of crustaceans and molluscs, bread, poultry and offal[3]. Substitutions between consumptions of terrestrial meat products and fish and seafood consumption may explain the absence of a relationship between seafood consumption and blood cadmium level.

Another parameter to be taken into account when comparing the differences between the biological results and the calculated dietary exposures is the difficulty in quantifying the real contamination variability of the seafood products consumed. The contribution of beach fishing to the provisioning, in particular in Lorient and La Rochelle for molluscs and crustaceans, can induce non-negligible variability in the contamination of the consumed foods. Indeed the IFREMER monitoring plans indicate contaminations levels that can correspond to large differences in concentrations from one point of control to another, which is not the case in Toulon for example. It is therefore possible that the subjects in Toulon are more likely to consume products with trace elements levels close to the average, whereas in La Rochelle and Lorient the food contamination can be much more variable, depending on the provisioning. This may be due to the fact that the ports of Lorient and La Rochelle (and more generally Brittany and the Atlantic coast) commercialise products of more varied origins (fishing zones, foreign boats, etc.) than Mediterranean ports such as Toulon. Consequently applying an average contamination to products in Toulon is without doubt more in line with the reality than doing so in other zones.

6.3 Persistent organic polluants

In view of the blood volumes already taken for the analysis of trace elements and the large quantities of blood necessary we preferred not to perform blood analyses. However the calculations of exposure already enable us to raise some points for discussion relative to the existing literature.

PCDD/Fs, DL-PCBs and iPCBs: We find that 39% of the individuals exceed the PTMI of 70 pg TEQ_{WHO}/kg bw/month fixed for PCDD/Fs and DL-PCBs, and that 72% of them exceed the TDI of 0.02 µg/kg bw/day fixed for i-PCBs. We must remember that other foods also contribute to the intake of PCDD/Fs, DL-PCBs and i-PCBs and that consequently the total exposures are higher. The PCDD/F, DL-PCB and i-PCB contaminations of seafood products are comparable to those measured by the monitoring plans of Administrations. And the PCDD/F and DL-PCB contaminations are within the interval reported by the European Authority in 2005: between 0.3 and 5.8 pg TEQ/g fresh weight[141], except in the case of the very heavily contaminated eel sample from the Netherlands and some crustaceans rarely consumed, such as swimcrab. The study confirms that even when consuming fish and seafood that comply with the European maximum contamination limits, a high consumer can exceed the JECFA's PTMI, a fact that has already been revealed by other studies[142]. This demonstrates the need to make an effort to reach target values lower than the regulatory limits as rapidly as possible, which is what the new European regulation proposes.

The biggest contributors are oily fish (appendix 5 and 6). The lower exposure of the subjects in Toulon is concomitant with the lower POP contaminations measured in the Toulon samples. Moreover, although the consumption of fish with the highest contaminations is generally equivalent in the four study zones, it is found that in Toulon the consumption of the most contaminated crustaceans (swimcrab, crab, spider crab) is less.

However in no zone in particular do we find a dietary exposure significantly higher than in the other zones.

PBDEs : The average exposure to PBDEs (28, 47, 99, 100, 153, 154, 183) is 2.17 ± 1.78 ng/kg bw/day, all zones and all subjects included, which is consistent with exposures recently estimated in other countries.

Total Diet Studies (TDS) published in several countries (Canada, USA, Finland, Netherlands, Spain, Sweden, United Kingdom and Japan) report average exposures of 13 to 228 ng PBDE/day[114]. The levels found in our population of high fish consumers range from 139 to 161 ng PBDE/day with an average of 150 ng/day. Our results are therefore very consistent with those other studies using similar methodologies. Our study population consumes on average four times more fish and seafood than the only consumers of the French adult population in the INCA survey (Appendix 3a). We have applied an average deterministic exposure model exploiting the INCA consumption data and our contamination data for fish and seafood

141 EFSA. Opinion of the Scientific Panel on contaminants in the Food chain on a request from the European Parliament related to the safety assessment of wild and farmed fish. The EFSA Journal. 236 : 1-118. 2005.

142 Baars A.J., Bakker M.I., Baumann R.A., Boon P.E., Freijer J.I., Hoogenboom L.A., Hoogerbrugge R., van Klaveren J.D., Liem A.K., Traag W.A. and de Vries J. Dioxins, dioxin-like PCBs and non-dioxin-like PCBs in foodstuffs: occurrence end dietary in The Netherlands. Toxicol Lett. 151 (1): 51-61. 2004.

and those of other product groups contributing to PBDE exposure taken from European studies. This calculation yields an estimated PBDE exposure of about 63 to 142 ng PBDE/day for the French population compared to 172 to 250 ng/day for our study population [143].

In its evaluation in 2005, the JECFA concluded that the observed exposure of the general population is estimated to be about 4 ng/kg bw/day, which corresponds to 240 ng/day for a person weighing 60 kg, or slightly more than our calculated exposure. This result is very consistent since the JECFA estimation was not based on fish consumption alone. The JECFA considered that in view of the consequent margin of exposure for a non-genotoxic compound, the current intakes do not appear to be a cause for concern as regards public health[114].

Today it remains very difficult to measure the PBDEs in biological matrices. Gas phase chromatography coupled with mass spectrometry (GC-NCI-MS or GC-EI-HRMS) is for the moment the most suitable method for detecting PBDEs in matrices of dietary or human origin. But precise evaluation of PBDEs levels in these matrices is hampered by two serious problems: possible contamination of the samples and the technical difficulty of measuring the heaviest compounds.

Nevertheless, there have been some studies of PBDEs levels in maternal milk. The data indicate values ranging from less than 0.1 ng/g lipids in the earliest studies (in the 1970s) to 1.7 to 3.8 ng/g lipids more recently (1997 to 2003)[143]. Other studies have measured the PBDEs in blood and adipose tissue. The average levels range from 0.4 to 5.6 ng/g in blood or plasma, and from 0.5 to 11.6 ng/g of lipids in adipose tissue [143]. Sjodin and his team have moreover showed that a correlation exists between a fish-rich diet and elevation of the measured plasma levels for certain PBDEs[144]. We note that whatever the matrix considered the tissual concentrations in American studies are always much higher than in other studies.

Globally, the data presently available on the concentration in biological tissue are insufficiently documented to enable to establish a relation with the dietary exposure we have observed.

6.4 Characterisation of benefits and risks

Table 51 summarises the EPA and DHA intakes and the exposures to various contaminants of the population studied, and the probability of exceeding the recommended intakes for n-3 LC-PUFAs or the TRV.

143 AFSSA. Avis relatif à une évaluation du risqué lié à la présence de retardateurs de flamme bromes dans les aliments (PBDE). Août 2006.

144 Sjodin A, Hagmar L, Klasson-Wehler E, Bjork J, Bergman A. Influence of the consumption of fatty Baltic Sea fish on plasma levels of halogenated environmental contaminants in Latvian and Swedish men. Environ. Health Perspect. 108 (11) : 1035-1041. 2000.

Table 51 : Distribution of exposure to omega 3 and toxic elements and probability for high consumers to exceed the recommendations and TRV

Element	TRV or recommendation	Exposure P2.5	Exposure P50	Exposure P97.5	%>TRV or reco
EPA + DHA (mg/d) :	500 (ISSFAL. 2004)	255	1006	1500	84
Trace element (µg/kg bw/week) :					
As_T	350	15.18	66.57	254.42	0.7
As_{inorg}	15 (JECFA. 1989)	0.14	0.51	1.92	0.0
Hg_T	5	0.28	1.21	4.68	2.1
MeHg	1.6 (JECFA. 2003)	0.29	1.19	4.46	34
Pb	25 (JECFA. 1987)	0.05	0.32	1.19	0.0
Cd	7 (JECFA. 2001)	0.06	1.28	11.38	8.5
Organotin (µg Sn/kg bw/wk) :					
TBT. DBT. TPT and DOT*	0.72 (AESA. 2004)	0.01	0.05	0.20	0.0
Persistent organic pollutants :					
PCDD/F and PCB-DL (pg TEQ_{OMS}/kg bw/month)	70 (JECFA. 2001)	8.36	54.4	381	39
iPCB (µg/kg bw/day)	0.02 (WHO. 2003)	0.006	0.034	0.42	72

As_T: total arsenic, As_{inorg}: inorganic arsenic, Hg_T: total mercury, reco: recommendation
* Tributyltin, Dibutyltin, Triphenyltin and Dioctyltin

The vast majority (84%) of the individuals in our study have EPA and DHA intakes exceeding the recommendations (Table 51), with a daily average of 1,238 ± 961 mg. The people with an EPA and DHA intake less than 500 mg/day consume fish and seafood at least twice a week, which therefore qualifies them as high consumers. Their low intake of n-3 LC-PUFAs is explained by the fact that they consume products containing little of these fatty acids, on average 596 g of fish and seafood products per week including 52 g of fatty fish, versus 1,277 g of fish and seafood including 277 g of fatty fish for the people whose intake exceeds the recommendations

We also note cases in which the PTWI of trace elements is slightly exceeded (except for MeHg (34%) discussed previously) and in which the TRV of POPs is exceeded.

After characterising the individuals for which the calculated exposure exceeds the TRV for a given contaminant (Table 51), the consumption levels of the main foods contributing to these high exposures were analysed. Table 52 presents the results for the adult population exceeding the TRVs of PCDD/Fs, DL-PCBs and i-PCBs, and for women of child-bearing age exceeding the PTWI of MeHg. In parallel, the consumptions of the main foods contributing to the omega 3 intake of individuals whose EPA and DHA intake reaches the recommendations are presented.

Table 52 : Consumptions (g/week) of the major contributors (>5% exposure) to the exposure to persistent organic pollutants, MeHg and Omega 3 by subjects who have an exposure above the TRV or recommendations

Major Contributors	Subjects who have an exposure to PCDD/F and PCB-DL > TRV**			Subjects who have an exposure to iPCB > TRV**			Women of childbearing age who have an exposure MeHg > TRV**			Subjects who have an intake of EPA and DHA > Recommendation**		
	% contrib	Mean±SD	P95	% contrib	Mean±SD	P95	% contrib	Mean±SD	P95	% contrib	Mean±SD	P95
Eel*	16	9 ± 30	37	12	4 ± 19	19	-	-	-	-	-	-
Seabass*	7	40 ± 80	175	9	25 ± 56	102	-	-	-	-	-	-
Sea bream*	5	38 ± 84	197	5	25 ± 61	114	-	-	-	-	-	-
Swimcrab	9	19 ± 48	100	6	8 ± 32	50	-	-	-	-	-	-
Mackerel	7	18 ± 105	256	7	42 ± 75	173	-	-	-	12	47 ± 79	181
Sardine	23	60 ± 57	164	23	35 ± 45	138	-	-	-	9	39 ± 47	147
Salmon	9	102 ± 126	288	11	73 ± 95	225	-	-	-	23	82 ± 98	230
Cod	-	-	-	-	-	-	5	93 ± 103	212	-	-	-
Swordfish*	-	-	-	-	-	-	7	13 ± 38	50	-	-	-
Ling	-	-	-	-	-	-	5	19 ± 37	98	-	-	-
Whiting	-	-	-	-	-	-	5	36 ± 62	137	-	-	-
Hake	-	-	-	-	-	-	5	38 ± 73	190	-	-	-
Sole	-	-	-	-	-	-	6	65 ± 98	250	-	-	-
Tuna*	-	-	-	-	-	-	26	139 ± 123	335	-	-	-
Anchovy	-	-	-	-	-	-	-	-	-	5	40 ± 89	180

* Predatory fish as described in the Commission Regulation (EC) No 78/2005 of 19 January 2005
** PTMI for PCDD/F and PCB-DL = 70 pg TEQ_{OMS}/kg bw/month (JECFA, 2001). TDI for iPCB = 0.02 µg/kg bw/day (WHO, 2003). PTWI for MeHg = 1.6 µg/kg bw/week (JECFA, 2003). Recommended intake for EPA + DHA = 500 mg/d (ISSFAL, 2004)

Table 52 and the tables in Appendix 5 listing the contributions to the exposures do not reveal any particular contaminated fish species contributing significantly to the exposure to contaminants covered by this study. Although it is difficult to weigh the nutritional benefits of omega 3 in fish and seafood against the risks associated with their contamination, some points can nevertheless be underlined.

It is useful to recall the correlation between the MeHg content of fish and seafood products (excepting canned and smoked products and prepared dishes) and the n-3 LC-PUFAs content (EPA, DPA, DHA): r=0.23 (p=0.03). Nevertheless, the major contributors to MeHg exposure in women of child-bearing age (tuna, cod, ling, sole, whiting and hake) are not the main contributors to n-3 LC-PUFAs intake (salmon, mackerel, sardine, anchovy and herring). More particularly, the contribution to n-3 LC-PUFAs intake of the main vectors of MeHg is negligible, representing less than 5%.

Figures 11 and 12 (Chapter 3: Seafood composition and contamination) show clearly the nutritional benefits of salmon, mackerel, sardine, anchovy and halibut, accompanied by low MeHg content.

Nevertheless, we should remember that these species, in particular salmon, sardine and mackerel which are oily fish and therefore rich in omega 3, also contain high levels of POPs and are, regardless of the congeners considered, the main vectors of these pollutants. These same species also contribute to lead, cadmium and organotin exposure, although this is not necessarily due to heavy contamination, but often to their high level of consumption which is visible in the regional data.

From one zone to another we tend to find the same major contributors to contaminant and omega 3 fatty acid intakes. However some geographic differences are seen (Appendix 5).

These disparities are largest as regards the trace elements (other than MeHg) and it clearly appears that the average contributions in all the zones are not representative of each region. The differences are due to particularly high contaminations in a given zone and/or regional food consumptions differences.

- *Contamination* : crab accounts for 53% of the Cd exposure in Lorient, but less than 5% in the other zones, which is due to heavy contamination of the composite sample in Lorient (12 µg/g versus less than 1 µg/g in the other sampling zones). Similarly, shrimp accounts for 60% of Cd exposure in Le Havre, but less than 2% in the other zones, due to heavy contamination of the composite sample in Le Havre (4 µg/g versus less than 0.05 µg/g in the other zones). The same observation can be made concerning whelks in La Rochelle (21% of the exposure and a Cd level of 2 µg/g versus less than 1 µg/g elsewhere). Ray, a fish relatively contaminated by As_T and As_{inorg}, appears in some zones as a majority contributor; similarly for the great scallop in Toulon (14%). The swimcrab, which appears to be a majority contributor to PCDD/F, DL-PCB and i-PCB exposure in general in the four zones, is in fact a major contributor only in Le Havre, due to the heavy contamination of the composite sample in Le Havre.

- *Consumption* : the great scallop appears to contribute heavily to Pb exposure in Le Havre (22%) due to high consumption, as do mussels in La Rochelle (16%) and sea urchin in Toulon (14%). The great scallop is also a majority contributor to As_{inorg} exposure in Le Havre (15%), again due to high consumption, along with cod, less contaminated than ray but widely consumed. The sea urchin in Toulon is also a majority contributor to As_{inorg} exposure (12%) since it is highly consumed compared to the other zones. The eel appears to be the only heavy contributor to PBDE, DL-PCB and i-PCB exposure, but only in La Rochelle due to high consumption and a high consumer rate in all the population groups there, compared to the other zones. Finally, as regards the organotins, in view of the low levels of each compound in the samples, the contributions are explained by the different consumptions from one region to another.

- *Contamination and consumption* : other large regional contributions to Cd exposure – faithe in Lorient and Toulon, whelks in La Rochelle, anchovy in Lorient and Toulon, great scallop in Le Havre and Toulon – are due not only to slightly higher contamination in these zones, but also to higher consumption of these products. Similarly, faithe, a fish widely consumed, appears to be a main contributor (28%) to Pb exposure in Lorient in particular since the composite sample is more contaminated in this zone (0.2 µg/g versus less than 0.002 µg/g elsewhere).

On the basis of our analysis is appears that consumption recommendations should take account of all the data presented here and, if they are based on synthetic results, they should also take into account the fact that consumption levels vary for given species and above that the contamination levels for certain species and certain contaminants can vary greatly from one region to another, even from one sampling point to another within the same region. It is therefore important to incorporate in the analysis the provisioning methods, local ones in particular, of certain products, and encourage consumers to diversify their provisioning origins for local species (and species bought locally but not of local origin) subject to the highest contaminations.

Lastly the analysis of the consumption and exposure data shows that for many subjects exceeding the TRV by the indirect approach, particularly for MeHg, this exceeding is not due to the consumption of highly contaminated products but to their high consumption, in quantities and variety. Low contaminated products consumed in high quantities can lead to exceeding of TRV. For example we can consider an "average fish" including all the 81 different products consumed by subjects exceeding the PTWI for MeHg, weighting the contaminations of those products by the mean consumption of those subjects. The contamination of this "average fish" is 0.096 µg MeHg/g fresh weight. A consumption of this fish higher than 1,167 g per week would lead to an exceeding of the TRV for a subject of 70 kg bw. In other words a high consumer who would consume a important variety of products with about 8 portions of fish and seafood per week or more might present a risk of exceeding the PTWI for MeHg by the indirect approach calculation.

In view of the possible overestimation of consumptions by the data collection method - the food frequency questionnaire - used in this survey, we calculated a correction factor applicable to the consumption data of this survey, using the data collected from the feasibility study[86].

Having calculated contaminants and Omega 3 contributions of each seafood product, the products for which at least one intake was greater than or equal to 5% of the total intake were selected. These products and their contribution to the total intake are shown in the Appendix 5.

During the feasibility study, two methods of collecting dietary consumption data had been employed: the food frequency questionnaire and a 7-day diary record. Among the seafood products consumed in the feasibility survey and common to the two methods, we selected the products also common with the list of contributors of the full-scale survey identified previously.

Three categories of products were constituted:

- 1: Fish consumed only fresh or frozen
- 2: Molluscs and crustaceans consumed only fresh or frozen
- 3: Fish and crustaceans consumed fresh, frozen, smoked or canned

For each individual in the database of the pilot survey, the ratios between the quantity of product noted in the 7-day diary record and the quantity declared on the food frequency questionnaire were calculated. Table 53 presents the results of these calculations.

Table 53 : Consumption correction coefficient between the FFQ and the 7 day diary record in the feasibility study for the three categories defined

CI 95%			
Categorie	**Mean**	**Inf. limit**	**Sup. limit**
1	0.47	0.20	0.73
2	0.58	0.31	0.85
3	0.65	0.43	0.86

CI : Confidence interval

The results show clearly here that the food frequency questionnaire tends to overestimate consumptions, compared to the 7-day diary record, by a factor 1.5 to 2 depending on the category.

Applying these correction coefficients, the consumptions of all the products concerned for the 996 individuals of the CALIPSO survey were calculated and compared with the consumption data of fish and seafood collected among consumers only in the INCA 99 survey (Appendix 3b).

The difference factor between the consumption values from the two surveys is less than in the first comparison (Part 2.2.) for fish and molluscs and crustaceans where it falls from about 2.5 to 2. On the other hand, it is reduced much less, from 1.5 to about 1.3, for other seafood products (canned, smoked and others). For the total consumption, the difference factor between the two surveys falls from about 2.5 to 3.

After correction of the consumptions, it appears that the probability of exceeding the TRVs for all contaminants is less. In particular, before correction the i-PCBs exposure of 72% of the subjects exceeded the TDI; after correction this figure falls to 58%. Similarly, before correction 39% of the subjects exceeded the PTMI for PCDD/Fs and DL-PCBs, but only 26% after correction. Concerning cadmium exposure, the percentage of people exceeding the PTWI drops from 8.5% to 2.2%, and for arsenic from 0.7% to 0.03%.

Finally, while 34% of the subjects in our study have an MeHg exposure exceeding the PTWI of 1.6 µg/kg bw/week, after correction this figure falls to 20%. If we consider the two PTWIs (1.6 µg/kg bw/week for women of child-bearing age, 3.3 µg/kg bw/week for other adult people), the cases exceeding the PTWI fall from 16% to 7%. Moreover, if we apply to these new exposures the average correction factor of 4.3 (exposure / steady state) we obtain a new average steady state of 0.27 ± 0.24 µg/kg bw/week (versus 0.35 ± 0.88 µg/kg bw/week before correction) and 0.67 µg/kg bw/week at P95 (0.82 before correction).

The correlations between dietary exposure and blood levels are not improved after correction of the consumptions, either for fatty acids or contaminants.

SEVENTH PART

Conclusion

Unlike traditional so-called "indirect" exposure studies based on ingestions, the CALIPSO study enables finer characterisation of the risks and benefits associated with fish and seafood consumption by measuring actual biological levels. The study reveals that French coastal populations, generally high seafood consumers, are well informed and have sound knowledge of these foods. They appreciate information on this subject which is a source of concern, yet they tend to be ambivalent as regards the public controversy on this issue.

The study shows that the contaminant levels measured in provisioned fish and seafood are globally satisfactory relative to currently applicable regulations, with the exception of a few products. For trace elements this "background" contamination level is relatively homogeneous all along the French coast, whereas for persistent organic pollutants a North-South contamination gradient is observed.

From a "benefits" point of view, the study shows that consuming fish alone at least twice a week (including some oily fish) ensures the recommended intake of omega 3 long-chain polyunsaturated fatty acids. Consequently, in view of the measured data and current scientific knowledge of the benefits of consuming omega 3, notably prevention of cardio-vascular diseases, it is legitimate to conclude that such effects are observed in our study population, even if the study reveals that physiological, nutritional and behavioural factors also affect the homeostasic regulation of omega 3.

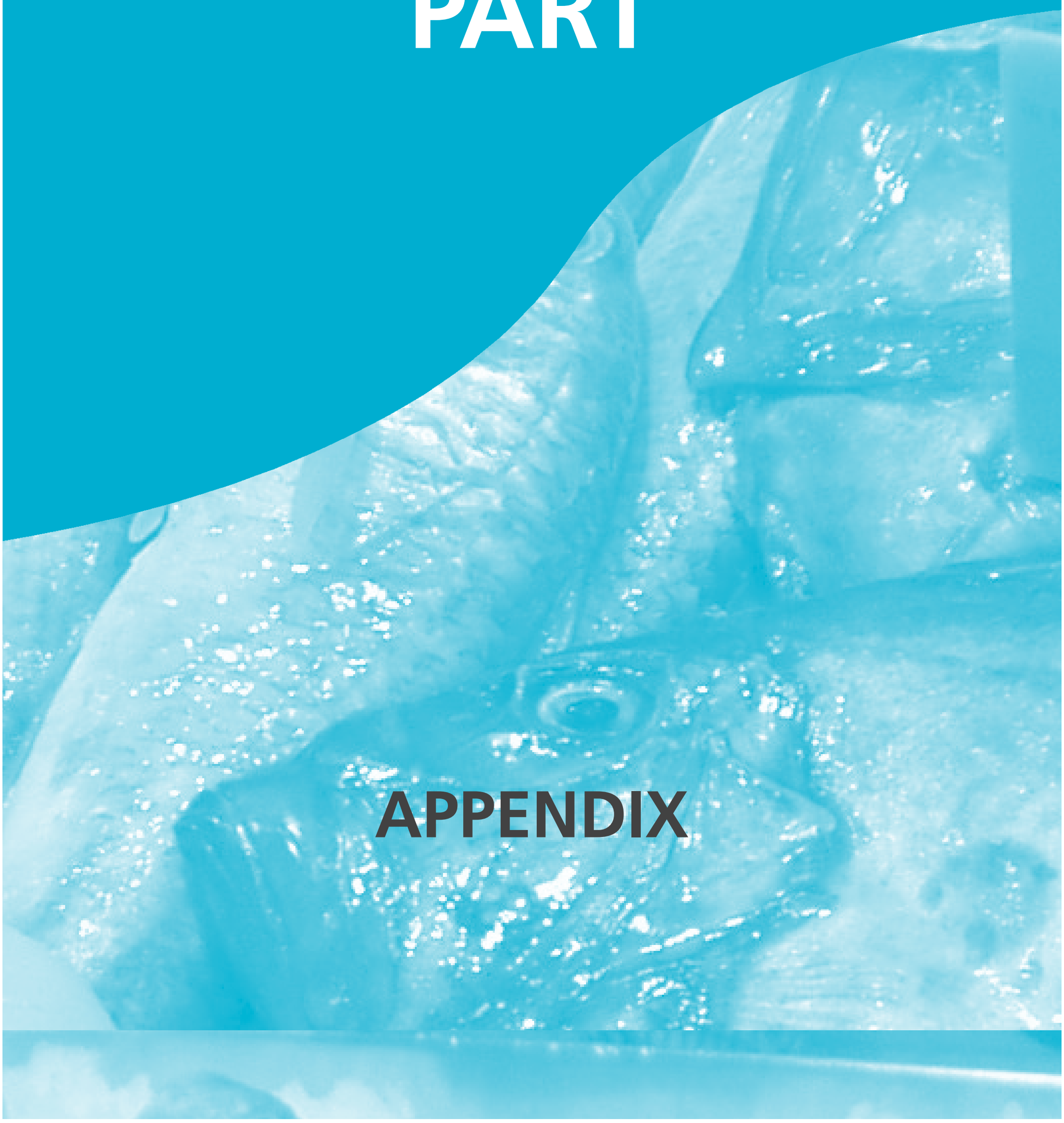
As regards risks, only the highest consumers of our study population present a non-negligible probability of exceeding the reference toxicological values, notably for methylmercury, cadmium, dioxins and PCBs ("dioxin-like" or not). For these persistent organic pollutants (POP), other foods not taken into account in this study are also vectors. However, the study of biomarkers and the rectification of the consumptions revealed by the food consumption survey shows that these calculated excess levels are difficult to interpret owing to the uncertainties inherent in all indirect exposure studies and the existence of safety factors. Even when the reference toxicological values are exceeded, the levels remain relatively close to these values, in particular for methylmercury and cadmium. Nevertheless these results demonstrate the need to pursue the efforts being made to reduce exposure (by reducing pollution), especially to dioxins and all PCBs.

With the exception of a few fish, the foods contributing most to omega 3 intake and to exposure to persistent organic pollutants are often the same specifies, in particular salmon, mackerel and sardine, owing mainly to their high fat content and their high consumers rate. For trace elements, the contributing foods are different: for example tuna and swordfish for methylmercury, and shrimp, crab, anchovy, great scallop and periwinkle for cadmium, mainly due to a higher level of contamination and/or consumption in certain regions.

Finally, concerning the global question of weighing health risks against nutritional benefits, the study results confirm the validity of the recommendations formulated by various national scientific bodies: that the general population should consume fish at least twice a week, including some oily fish, and that pregnant or breast-feeding women should consume predator fish not more than once a week.

Looking beyond these general recommendations, this study highlights the advantages of diversifying the consumed fish and seafood species in terms of proportions and provisioning origins in order to ensure a rational balance between benefits and risks compatible with nutritional and toxicological recommendations.

EIGHTH PART



APPENDIX

Appendix 1 : Fish and seafood sampled in the 4 study zones

	Fish		Mollusc, crustacean
Le Havre	Angler fish*	Pollack	Crab
	Catshark*	Ray*	Great scallop
	Cod	Saithe / Coalfish	Mussel
	Dab	Salmon	Oyster
	Eel*	Sardine	Periwinkle
	Grenadier / hoki*	Seabass*	Scampi
	Hake	Sea bream*	Shrimp
	Halibut*	Sole	Squid
	Ling	Swordfish*	Swimcrab
	Mackerel	Tuna*	Whelk
	Plaice	Whiting	
Lorient	Angler fish*	Mackerel	Cockle
	Catshark*	Plaice	Crab
	Cod	Pollack	Great scallop
	Dab	Ray*	Mussel
	Emperor*	Saithe / Coalfish	Oyster
	Goatfish	Salmon	Periwinkle
	Grenadier / hoki*	Sardine	Scampi
	Gurnard	Seabass*	Shrimp
	Haddock	Sea bream*	Spider crab
	Hake	Sole	Squid
	Halibut*	Swordfish*	Swimcrab
	John dory	Pout Tuna*	
	Ling	Whiting	
La Rochelle	Angler fish *	Pollack	Calico scallop
	Catshark*	Ray*	Cockle
	Cod	Saithe / Coalfish	Crab
	Dab	Salmon	Cuttle fish
	Emperor*	Sardine	Great scallop
	Goatfish	Seabass*	Mussel
	Grenadier / hoki*	Sea bream *	Oyster
	Haddock	Sole	Periwinkle
	Hake	Swordfish*	Scampi
	Halibut*	Tuna*	Shrimp
	Ling	Whiting	Squid
	Mackerel		Whelk
Toulon	Angler fish*	Ray*	Cuttle fish
	Catshark*	Saithe / Coalfish	Great scallop
	Cod	Scorpion fish	Lobster
	Dab	Seabass*	Mussel
	Emperor*	Sea bream *	Octopus
	Goatfish	Salmon	Oyster
	Grenadier / hoki*	Sardine	Sea urchin
	Hake	Sole	Shrimp
	Halibut*	Swordfish*	Squid
	John dory	Tuna*	Whelk
	Ling	Whiting	
	Mackerel		

* Predatory fish as described in the Commission Regulation (EC) No 78/2005 of 19 January 2005

Samples common to the four zones

Fresh anchovy	Smoked haddock
Canned anchovy	Smoked herring
Preserved anchovy	Smoked mackerel
Canned mackerel	Smoked salmon
Canned pilchard	
Canned sardines	Tarama
Canned Yellow fin tuna*	Surimi
Canned Albacore tuna*	Dehydrated fish soup
Canned Skipjack tuna*	Liquid fish soup
Canned flaked Yellow fin tuna*	Paella
Canned flaked tuna (without further details)*	
Canned crab	

* Predatory fish as described in the Commission Regulation (EC) No 78/2005 of 19 January 2005

Appendix 2 : Consumptions of fish and seafood by high consumers per zone (g/week)

Consumptions of fresh and frozen fish by high consumers – Le Havre (g/week)

Fish	Adult men (18-64 y) n= 44			Adult women (18-64 y) n= 179			Older subjects (65 y and more) n= 26			Women of childbearing age (18-44 y) n= 98		
	Mean	P95	%***	Mean	P95	%***	Mean	P95	%***	Mean	P95	%***
Anchovy	8.4	37.5	13.6%	0.8	0.0	2.2%	1.9	18.8	7.7%	0.5	0.0	2.0%
Angler fish*	10.1	37.5	22.7%	11.7	50.0	36.3%	18.9	56.3	38.5%	7.8	37.5	28.6%
Catshark*	17.2	125.0	27.3%	20.6	125.0	38.0%	14.6	50.0	34.6%	20.7	125.0	36.7%
Cod	73.3	220.0	81.8%	101.4	300.0	95.5%	111.5	231.3	92.3%	77.8	200.0	95.9%
Dab	2.3	18.8	9.1%	13.5	100.0	20.7%	8.4	37.5	23.1%	9.9	100.0	15.3%
Eel*	0.5	0.0	2.3%	9.7	10.0	5.6%	0.0	0.0	0.0%	1.7	10.0	6.1%
Emperor*	2.1	18.8	6.8%	3.0	25.0	10.1%	1.9	25.0	7.7%	2.0	25.0	7.1%
Goatfish	1.6	12.5	11.4%	4.3	22.5	15.1%	10.8	45.0	26.9%	2.2	12.5	8.2%
Grenadier / hoki*	3.7	25.0	11.4%	14.2	100.0	25.1%	5.0	25.0	26.9%	11.4	100.0	20.4%
Grouper	0.0	0.0	0.0%	0.2	0.0	1.1%	0.0	0.0	0.0%	0.3	0.0	1.0%
Gurnard	0.3	0.0	2.3%	5.2	0.0	4.5%	0.9	0.0	3.8%	8.0	0.0	2.0%
Haddock	4.7	36.3	13.6%	5.5	25.0	8.4%	18.6	100.0	30.8%	2.5	0.0	2.0%
Hake	0.5	0.0	2.3%	12.0	93.8	15.6%	6.8	62.5	15.4%	9.9	93.8	16.3%
Halibut*	2.7	18.8	9.1%	19.5	100.0	24.6%	14.6	62.5	30.8%	11.8	50.0	18.4%
Herring	15.2	62.5	38.6%	22.5	120.0	41.3%	129.3	760.0	53.8%	15.1	100.0	29.6%
John Dory	0.0	0.0	0.0%	2.6	22.5	12.8%	4.6	25.0	7.7%	0.7	0.0	4.1%
Ling	13.6	125.0	20.5%	18.9	100.0	39.1%	37.5	137.5	73.1%	9.4	47.5	31.6%
Mackerel	25.7	109.4	61.4%	33.7	150.0	49.7%	41.7	237.5	73.1%	41.0	237.5	46.9%
Mullet	1.3	0.0	2.3%	1.3	0.0	3.4%	0.0	0.0	0.0%	1.7	0.0	3.1%
Plaice	19.4	100.0	27.3%	30.3	125.0	34.6%	39.0	250.0	50.0%	22.2	100.0	23.5%
Pollack	16.6	22.5	9.1%	11.1	50.0	21.2%	18.9	100.0	46.2%	6.6	45.0	16.3%
Pout	0.4	0.0	2.3%	0.8	0.0	4.5%	0.0	0.0	0.0%	0.7	0.0	4.1%
Ray*	23.9	125.0	45.5%	29.7	125.0	53.1%	46.8	125.0	57.7%	24.0	100.0	45.9%
Redfish	0.0	0.0	0.0%	0.2	0.0	0.6%	0.0	0.0	0.0%	0.4	0.0	1.0%
Saithe / coalfish	48.4	200.0	65.9%	49.8	200.0	67.6%	55.5	200.0	65.4%	54.2	200.0	82.7%
Salmon	63.8	220.0	70.5%	75.1	220.0	79.9%	72.3	220.0	88.5%	66.4	190.0	79.6%
Sardine	11.9	62.5	25.0%	8.2	62.5	26.8%	11.2	62.5	34.6%	9.1	62.5	24.5%
Scorpion fish	0.0	0.0	0.0%	0.8	0.0	2.8%	1.7	0.0	3.8%	1.2	0.0	4.1%
Seabass*	19.5	120.0	38.6%	12.0	62.5	30.2%	16.6	118.8	42.3%	9.1	50.0	28.6%
Sea bream*	16.2	47.5	22.7%	8.8	47.5	20.1%	10.5	47.5	23.1%	9.4	47.5	22.4%
Smelt	0.4	0.0	2.3%	2.3	12.5	7.3%	1.0	6.3	11.5%	2.2	12.5	6.1%
Sole	38.7	118.8	43.2%	32.6	171.9	48.0%	33.8	150.0	42.3%	38.6	200.0	50.0%
Sprat	0.0	0.0	0.0%	0.5	0.0	2.8%	0.2	0.0	3.8%	0.5	0.0	2.0%
Swordfish*	1.7	0.0	4.5%	3.7	0.0	3.9%	21.8	55.0	15.4%	4.2	18.8	5.1%
Tuna*	12.5	97.5	18.2%	13.3	87.5	22.9%	11.3	48.8	23.1%	14.4	87.5	26.5%
Turbot	3.4	50.0	6.8%	2.5	18.8	9.5%	4.6	25.0	7.7%	1.8	12.5	7.1%
Whiting	14.6	125.0	22.7%	24.5	118.8	44.1%	25.9	125.0	50.0%	20.9	100.0	40.8%
Other**	8.2	62.5	13.6%	5.2	45.0	9.5%	9.6	112.5	7.7%	5.5	62.5	9.2%
TOTAL	**483.0**	**928.8**	**100.0%**	**612.1**	**1,629**	**100.0%**	**807.7**	**1,701**	**100.0%**	**525.9**	**1,303**	**100.0%**

* Predatory fish as described in the Commission Regulation (EC) No 78/2005 of 19 January 2005 ** Other: Perch, bogue, trout, scabbard-fish, sea wrasse, conger eel, needlefish, sard, rainbow wrasse, gobie, croaker, shark, sea-bream coriphene, ling, bassbu *** Consumers rate

Consumptions of molluscs and crustaceans by high consumers – Le Havre (g/week)

Mollusc, crustacean	Adult men (18-64 y) n= 44			Adult women (18-64 y) n= 179			Older subjects (65 y and more) n= 26			Women of childbearing age (18-44 y) n= 98		
	Mean	P95	%*	Mean	P95	%*	Mean	P95	%*	Mean	P95	%*
Abalone	0.0	0.0	0.0%	0.3	0.0	1.1%	1.3	0.0	3.8%	0.4	0.0	1.0%
Calico scallop	6.2	56.3	13.6%	7.3	45.0	21.8%	11.9	56.3	26.9%	8.0	56.3	20.4%
Carpet shell	0.0	0.0	2.3%	0.3	2.0	5.6%	0.6	6.0	7.7%	0.4	2.5	5.1%
Clam	0.3	0.0	2.3%	0.1	0.0	1.1%	0.0	0.0	0.0%	0.0	0.0	0.0%
Cockle	1.0	6.3	13.6%	1.6	8.8	19.6%	0.9	6.3	11.5%	1.6	12.5	20.4%
Crab	6.6	20.0	59.1%	9.3	50.0	59.8%	8.0	40.0	61.5%	7.9	40.0	55.1%
Crayfish	1.6	8.8	13.6%	2.5	12.5	20.1%	1.3	10.0	11.5%	2.0	12.5	20.4%
Cuttle fish	1.9	16.3	6.8%	2.4	32.5	8.4%	5.8	16.3	11.5%	2.4	32.5	8.2%
Donax clam	0.0	0.0	0.0%	0.2	0.0	0.6%	0.5	0.0	3.8%	0.0	0.0	0.0%
Great scallop	47.6	156.3	72.7%	57.9	250.0	83.8%	58.2	187.5	88.5%	51.8	300.0	77.6%
Grooved sea squirt	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%
Hard clam	1.0	6.3	13.6%	1.2	7.5	19.0%	3.1	15.0	23.1%	0.9	7.5	14.3%
Limpet	0.0	0.0	0.0%	0.0	0.0	0.6%	0.0	0.0	0.0%	0.0	0.0	0.0%
Lobster	4.1	22.5	18.2%	5.9	22.5	17.9%	5.2	45.0	15.4%	7.9	45.0	20.4%
Mussel	18.4	50.0	86.4%	16.9	50.0	83.8%	18.8	43.8	88.5%	15.4	50.0	80.6%
Octopus	0.4	0.0	4.5%	1.9	16.3	7.3%	0.6	0.0	3.8%	1.9	10.0	7.1%
Oyster	19.1	90.0	40.9%	17.9	90.0	51.4%	33.0	90.0	69.2%	11.1	72.0	48.0%
Periwinkle	4.3	12.5	50.0%	3.7	15.0	49.7%	4.0	25.0	50.0%	2.9	12.5	45.9%
Queen scallop	0.3	0.0	2.3%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%
Razor clam	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%
Scampi	7.1	45.0	38.6%	6.2	30.0	38.5%	6.3	30.0	38.5%	4.3	30.0	30.6%
Sea urchin	0.0	0.0	0.0%	0.2	0.0	0.6%	0.5	0.0	3.8%	0.4	0.0	1.0%
Shrimp	41.5	93.8	90.9%	49.6	150.0	95.5%	43.8	150.0	88.5%	44.7	150.0	95.9%
Slipper lobster	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%
Spider crab	2.3	10.0	15.9%	2.2	10.0	18.4%	2.4	10.0	26.9%	1.1	10.0	14.3%
Spiny lobster	1.8	12.5	15.9%	2.1	12.5	16.2%	0.7	6.3	11.5%	3.0	12.5	17.3%
Squid	19.9	81.3	52.3%	14.3	50.0	51.4%	15.5	81.3	38.5%	12.6	50.0	50.0%
Swimcrab	11.2	62.5	25.0%	14.0	62.5	32.4%	33.2	187.5	53.8%	8.3	62.5	23.5%
Whelk	24.2	62.5	52.3%	36.3	150.0	58.1%	17.6	75.0	50.0%	27.5	130.0	51.0%
TOTAL	**220.9**	**526.5**	**100.0%**	**254.3**	**631.3**	**100.0%**	**273.1**	**529.1**	**100.0%**	**216.5**	**588.3**	**100.0%**

* Consumers rate

Consumptions of canned food, smoked fish and seafood-based dishes by high consumers – Le Havre (g/week)

Other seafood	Adult men (18-64 y) n= 44			Adult women (18-64 y) n= 179			Older subjects (65 y and more) n= 26			Women of childbearing age (18-44 y) n= 98		
	Mean	P95	%**	Mean	P95	%**	Mean	P95	%**	Mean	P95	%**
Canned food												
Anchovy	8.5	45.0	27.3%	9.3	37.5	22.3%	22.1	45.0	38.5%	3.1	30.0	14.3%
Crab	17.3	56.3	68.2%	19.2	60.0	63.1%	10.6	37.5	57.7%	22.9	180.0	65.3%
Mackerel	2.6	13.1	11.4%	1.6	7.5	17.3%	2.5	18.8	15.4%	1.3	7.5	12.2%
Pilchard	15.1	43.8	77.3%	11.7	40.0	62.0%	13.7	40.0	84.6%	11.8	40.0	62.2%
Sardine	75.6	180.0	97.7%	50.4	180.0	95.5%	17.0	56.3	88.5%	59.6	315.0	95.9%
Tuna*	2.7	22.5	20.5%	8.1	30.0	40.2%	4.6	22.5	42.3%	10.6	37.5	37.8%
Total canned food	**121.9**	**302.5**	**100.0%**	**100.3**	**371.3**	**98.3%**	**70.5**	**171.3**	**96.2%**	**109.4**	**405.0**	**100.0%**
Smoked fish												
Haddock	1.3	11.3	15.9%	2.3	11.3	16.2%	0.7	3.8	7.7%	1.8	7.5	15.3%
Herring	7.8	56.3	36.4%	4.3	22.5	28.5%	3.8	15.0	30.8%	4.9	22.5	28.6%
Mackerel	1.3	11.3	11.4%	2.7	11.3	15.1%	1.6	5.0	7.7%	4.4	15.0	19.4%
Salmon	12.7	40.0	88.6%	13.1	40.0	87.2%	12.2	37.5	80.8%	13.4	40.0	86.7%
Total smoked fish	**23.2**	**61.3**	**88.6%**	**22.4**	**72.5**	**89.4%**	**18.3**	**46.3**	**92.3%**	**24.4**	**80.0**	**88.8%**
Seafood-based dish												
Fish soup	20.2	100.0	29.5%	27.0	100.0	31.3%	25.7	75.0	46.2%	27.6	187.5	28.6%
Paella	2.6	12.5	25.0%	3.9	20.0	32.4%	3.6	31.3	23.1%	5.4	25.0	37.8%
Surimi	35.3	70.0	72.7%	49.8	210.0	87.7%	9.0	37.5	57.7%	50.1	245.0	87.8%
Tarama	53.5	175.0	68.2%	56.0	200.0	66.5%	18.8	125.0	26.9%	63.4	200.0	69.4%
Total seafood-based dish	**111.6**	**245.0**	**86.4%**	**136.7**	**395.0**	**96.6%**	**57.2**	**162.5**	**84.6%**	**146.6**	**442.5**	**98.0%**
Total	**256.6**	**572.5**	**100.0%**	**259.4**	**765.0**	**100.0%**	**145.9**	**361.3**	**100.0%**	**280.4**	**792.5**	**100.0%**

* Predatory fish as described in the Commission Regulation (EC) No 78/2005 of 19 January 2005 ** Consumers rate

Consumptions of fresh and frozen fish by high consumers – Lorient (g/week)

Fish	Adult men (18-64 y) n= 52			Adult women (18-64 y) n= 158			Older subjects (65 y and more) n= 37			Women of childbearing age (18-44 y) n= 76		
	Mean	P95	%***	Mean	P95	%***	Mean	P95	%***	Mean	P95	%***
Anchovy	16.6	187.5	9.6%	11.7	30.0	8.9%	6.4	56.3	10.8%	20.4	45.0	10.5%
Angler fish*	19.9	56.3	61.5%	23.9	125.0	57.0%	24.4	112.5	59.5%	21.5	93.8	55.3%
Catshark*	2.1	23.8	7.7%	2.2	17.5	5.7%	1.6	25.0	5.4%	1.8	0.0	3.9%
Cod	93.6	337.5	80.8%	65.2	200.0	81.0%	79.0	237.5	73.0%	66.2	200.0	81.6%
Dab	9.9	93.8	17.3%	16.0	100.0	20.9%	37.6	150.0	40.5%	15.6	100.0	14.5%
Eel*	4.6	31.3	13.5%	0.7	0.0	4.4%	1.0	0.0	2.7%	0.2	0.0	1.3%
Emperor*	1.2	12.5	5.8%	5.4	25.0	13.3%	3.8	25.0	16.2%	0.6	0.0	2.6%
Goatfish	9.5	35.0	26.9%	11.8	45.0	22.2%	23.8	125.0	32.4%	4.8	45.0	14.5%
Grenadier / hoki*	16.1	112.5	32.7%	24.1	100.0	36.7%	18.6	118.8	37.8%	22.9	100.0	31.6%
Grouper	0.0	0.0	0.0%	0.4	0.0	0.6%	0.0	0.0	0.0%	0.0	0.0	0.0%
Gurnard	4.0	27.5	9.6%	6.0	22.5	7.0%	20.7	112.5	21.6%	0.6	0.0	3.9%
Haddock	3.7	12.5	9.6%	4.9	37.5	10.8%	23.8	125.0	21.6%	4.3	50.0	7.9%
Hake	45.8	200.0	59.6%	41.5	180.0	48.1%	48.5	200.0	64.9%	38.1	150.0	47.4%
Halibut*	3.5	25.0	11.5%	4.7	27.5	14.6%	5.5	25.0	21.6%	4.0	18.8	10.5%
Herring	14.1	93.8	23.1%	2.8	12.5	6.3%	0.0	0.0	0.0%	1.5	0.0	3.9%
John Dory	5.9	25.0	9.6%	3.9	27.5	11.4%	13.0	100.0	21.6%	2.9	25.0	6.6%
Ling	28.4	125.0	46.2%	26.0	125.0	39.2%	34.0	125.0	51.4%	22.1	125.0	35.5%
Mackerel	65.9	280.0	61.5%	40.6	200.0	58.2%	25.9	150.0	48.6%	35.8	180.0	48.7%
Mullet	4.6	47.5	5.8%	1.2	0.0	1.9%	0.0	0.0	0.0%	0.5	0.0	1.3%
Plaice	2.9	50.0	5.8%	4.3	22.5	8.2%	28.4	400.0	10.8%	0.2	0.0	1.3%
Pollack	17.9	62.5	42.3%	29.0	125.0	39.9%	33.1	137.5	45.9%	22.6	112.5	34.2%
Pout	4.4	23.4	11.5%	6.5	47.5	13.3%	3.0	45.0	8.1%	4.5	28.6	10.5%
Ray*	36.2	243.8	50.0%	31.1	125.0	51.3%	43.5	125.0	67.6%	33.7	190.0	42.1%
Redfish	0.0	0.0	0.0%	0.0	0.0	0.0%	4.4	55.0	8.1%	0.0	0.0	0.0%
Saithe / coalfish	70.4	200.0	75.0%	59.2	200.0	68.4%	51.5	250.0	51.4%	57.7	200.0	71.1%
Salmon	46.5	190.0	51.9%	51.2	220.0	58.2%	57.4	190.6	54.1%	62.4	243.8	67.1%
Sardine	35.7	109.4	76.9%	22.9	93.8	59.5%	31.3	150.0	78.4%	17.0	93.8	48.7%
Scorpion fish	0.9	0.0	1.9%	0.8	0.0	1.9%	0.6	0.0	2.7%	0.7	0.0	1.3%
Seabass*	24.0	95.0	55.8%	21.2	95.0	43.0%	25.8	180.0	40.5%	17.4	95.0	40.8%
Sea bream*	22.3	70.0	40.4%	24.9	93.8	34.2%	15.2	47.5	35.1%	16.8	47.5	17.1%
Smelt	1.4	18.8	7.7%	0.2	0.0	1.3%	2.0	25.0	5.4%	0.2	0.0	1.3%
Sole	46.4	250.0	53.8%	32.9	171.9	39.9%	48.6	250.0	59.5%	36.2	250.0	36.8%
Sprat	0.0	0.0	0.0%	0.1	0.0	0.6%	0.5	0.0	2.7%	0.0	0.0	0.0%
Swordfish*	7.7	48.8	17.3%	4.6	27.5	11.4%	6.5	27.5	21.6%	2.5	27.5	5.3%
Tuna*	62.4	243.8	69.2%	43.4	190.6	58.9%	35.2	137.5	62.2%	34.6	190.6	50.0%
Turbot	1.1	0.0	3.8%	2.0	23.8	6.3%	4.0	27.5	13.5%	2.3	25.0	6.6%
Whiting	33.7	171.9	42.3%	33.1	150.0	48.7%	34.7	125.0	59.5%	36.2	200.0	48.7%
Other**	3.3	0.0	3.8%	2.9	0.0	4.4%	0.0	0.0	0.0%	0.0	0.0	0.0%
TOTAL	**766.5**	**1,794**	**100.0%**	**663.3**	**1,409**	**100.0%**	**793.3**	**2,341**	**100.0%**	**608.9**	**1,053**	**100.0%**

* Predatory fish as described in the Commission Regulation (EC) No 78/2005 of 19 January 2005 **Other: Perch, bogue, trout, scabbard-fish, sea wrasse, conger eel, needlefish, sard, rainbow wrasse, gobie, croaker, shark, sea-bream coriphene, ling, bassbu.
*** Consumers rate

Consumptions of molluscs and crustaceans by high consumers – Lorient (g/week)

Mollusc, crustacean	Adult men (18-64 y) n= 52			Adult women (18-64 y) n= 158			Older subjects (65 y and more) n= 37			Women of childbearing age (18-44 y) n= 76		
	Mean	P95	%*	Mean	P95	%*	Mean	P95	%*	Mean	P95	%*
Abalone	0.5	0.0	1.9%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%
Calico scallop	7.6	45.0	21.2%	7.2	37.5	27.2%	12.7	112.5	24.3%	5.9	28.1	23.7%
Carpet shell	10.3	37.5	59.6%	5.4	30.0	43.7%	5.5	30.0	56.8%	4.4	30.0	32.9%
Clam	0.1	0.0	1.9%	0.2	0.0	3.8%	0.0	0.0	0.0%	0.1	0.0	3.9%
Cockle	6.7	37.5	48.1%	7.9	50.0	49.4%	6.1	31.3	40.5%	4.9	17.5	38.2%
Crab	15.3	50.0	76.9%	10.7	50.0	70.9%	9.2	50.0	59.5%	9.4	40.0	73.7%
Crayfish	0.8	0.0	3.8%	0.3	0.0	2.5%	0.0	0.0	0.0%	0.4	0.0	2.6%
Cuttle fish	3.3	30.0	11.5%	1.8	0.0	3.8%	1.8	16.3	5.4%	1.7	0.0	1.3%
Donax clam	0.0	0.0	0.0%	0.6	0.0	1.9%	0.0	0.0	0.0%	0.0	0.0	0.0%
Great scallop	22.1	62.5	78.8%	40.6	156.3	84.8%	52.0	125.0	78.4%	33.6	125.0	84.2%
Grooved sea squirt	0.0	0.0	0.0%	0.3	0.0	0.6%	0.0	0.0	0.0%	0.0	0.0	0.0%
Hard clam	1.8	12.5	23.1%	2.1	9.4	17.7%	3.9	37.5	24.3%	1.4	9.4	13.2%
Limpet	0.0	0.0	0.0%	1.0	0.0	3.2%	0.0	0.0	0.0%	0.7	0.0	1.3%
Lobster	4.5	45.0	11.5%	3.9	45.0	13.9%	2.1	22.5	10.8%	3.3	22.5	11.8%
Mussel	23.1	50.0	96.2%	22.8	70.0	83.5%	21.7	70.0	81.1%	21.0	70.0	76.3%
Octopus	1.9	25.0	7.7%	1.4	0.0	1.9%	1.4	0.0	2.7%	1.1	0.0	1.3%
Oyster	43.9	180.0	75.0%	33.3	144.0	63.9%	57.8	180.0	83.8%	31.3	144.0	52.6%
Periwinkle	9.6	40.0	75.0%	8.1	40.0	68.4%	12.0	40.0	83.8%	5.9	25.0	56.6%
Queen scallop	0.0	0.0	0.0%	0.0	0.0	0.6%	0.0	0.0	0.0%	0.0	0.0	1.3%
Razor clam	0.6	0.0	3.8%	0.1	0.0	0.6%	0.0	0.0	0.0%	0.2	0.0	1.3%
Sea urchin	0.8	0.0	1.9%	1.2	0.0	3.8%	0.2	0.0	2.7%	0.1	0.0	1.3%
Scampi	43.0	120.0	84.6%	37.9	144.0	80.4%	43.0	135.0	81.1%	27.9	75.0	76.3%
Shrimp	38.4	100.0	94.2%	39.8	125.0	88.0%	41.1	125.0	83.8%	45.2	150.0	88.2%
Slipper lobster	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%
Spider crab	11.7	50.0	75.0%	12.4	50.0	71.5%	10.3	40.0	64.9%	7.8	40.0	63.2%
Spiny lobster	0.0	0.0	0.0%	0.5	6.3	8.2%	0.1	0.0	2.7%	0.7	6.3	10.5%
Squid	25.9	125.0	55.8%	16.4	81.3	50.0%	10.4	81.3	29.7%	17.7	125.0	46.1%
Swimcrab	11.9	62.5	23.1%	11.0	75.0	19.0%	3.0	37.5	8.1%	3.6	25.0	9.2%
Whelk	4.8	37.5	15.4%	2.6	12.5	10.1%	2.0	0.0	2.7%	1.8	12.5	6.6%
TOTAL	**288.6**	**700.9**	**100%**	**269.6**	**667.3**	**100.0%**	**296.4**	**623.8**	**100.0%**	**229.9**	**641.0**	**100.0%**

*Consumers rate

Consumptions of canned food, smoked fish and seafood-based dishes by high consumers – Lorient (g/week)

Other seafood	Adult men (18-64 y) n= 52			Adult women (18-64 y) n= 158			Older subjects (65 y and more) n= 37			Women of childbearing age (18-44 y) n= 76		
	Mean	P95	%**	Mean	P95	%**	Mean	P95	%**	Mean	P95	%**
Canned food												
Anchovy	26.4	150.0	34.6%	26.2	150.0	42.4%	11.9	75.0	27.0%	17.1	90.0	34.2%
Crab	24.3	90.0	67.3%	11.6	56.3	55.1%	10.2	56.3	56.8%	11.9	56.3	52.6%
Mackerel	4.5	56.3	13.5%	1.6	7.5	8.9%	0.5	0.0	2.7%	1.7	7.5	5.3%
Pilchard	22.6	60.0	76.9%	13.4	50.0	64.6%	22.1	60.0	86.5%	11.5	50.0	52.6%
Sardine	51.9	90.0	90.4%	37.2	120.0	88.6%	34.3	105.0	81.1%	44.1	180.0	90.8%
Tuna*	0.9	7.5	7.7%	2.4	15.0	15.8%	2.2	18.8	21.6%	3.0	18.8	18.4%
Total canned food	**130.6**	**420.0**	**98.1%**	**92.4**	**268.8**	**96.8%**	**81.1**	**201.3**	**94.6%**	**89.2**	**268.8**	**97.4%**
Smoked fish												
Haddock	1.2	7.5	7.7%	0.7	5.6	7.0%	0.9	11.3	8.1%	0.3	0.0	2.6%
Herring	11.4	56.3	42.3%	5.2	22.5	31.0%	3.4	22.5	24.3%	4.5	22.5	25.0%
Mackerel	6.1	56.3	21.2%	2.6	22.5	11.4%	0.7	7.5	13.5%	3.9	37.5	14.5%
Salmon	9.2	31.3	76.9%	8.4	37.5	77.8%	5.4	25.0	54.1%	9.3	37.5	85.5%
Total smoked fish	**27.7**	**93.8**	**88.5%**	**16.9**	**71.3**	**84.8%**	**10.4**	**40.0**	**73.0%**	**18.1**	**70.0**	**89.5%**
Seafood-based dish												
Fish soup	61.2	350.0	53.8%	60.3	300.0	46.8%	70.3	400.0	62.2%	67.7	350.0	44.7%
Paella	5.4	31.3	44.2%	6.9	31.3	42.4%	3.5	35.0	16.2%	8.1	31.3	44.7%
Surimi	17.1	70.0	57.7%	20.3	70.0	69.0%	13.3	120.0	56.8%	23.2	70.0	72.4%
Tarama	89.1	200.0	90.4%	54.5	200.0	59.5%	40.6	125.0	43.2%	67.7	312.5	71.1%
Total seafood-based dish	**172.8**	**518.8**	**98.1%**	**142.0**	**460.0**	**92.4%**	**127.7**	**545.0**	**83.8%**	**166.7**	**537.5**	**93.4%**
Total	**331.2**	**798.8**	**100.0%**	**251.3**	**648.8**	**99.4%**	**219.2**	**622.5**	**100.0%**	**273.9**	**726.3**	**98.7%**

* Predatory fish as described in the Commission Regulation (EC) No 78/2005 of 19 January 2005 ** Consumers rate

Consumptions of fresh and frozen fish by high consumers – La Rochelle (g/week)

Fish	Adult men (18-64 y) n= 87			Adult women (18-64 y) n= 122			Older subjects (65 y and more) n= 39			Women of childbearing age (18-44 y) n= 78		
	Mean	P95	%***	Mean	P95	%***	Mean	P95	%***	Mean	P95	%***
Anchovy	4.2	18.8	9.2%	13.0	22.5	9.0%	3.6	45.0	10.3%	19.7	45.0	11.5%
Angler fish*	13.2	50.0	34.5%	19.0	93.8	32.8%	12.1	125.0	23.1%	15.6	68.8	29.5%
Catshark*	10.4	62.5	23.0%	7.3	36.3	13.9%	14.7	100.0	25.6%	5.5	35.0	10.3%
Cod	103	325.0	83.9%	94.7	245.0	86.1%	108.4	380.0	87.2%	82.7	220.0	88.5%
Dab	9.1	50.0	18.4%	9.5	37.5	19.7%	17.6	93.8	25.6%	9.9	45.0	21.8%
Eel*	14.9	50.0	32.2%	6.3	35.0	21.3%	8.0	50.0	28.2%	5.1	35.0	19.2%
Emperor*	6.7	18.8	10.3%	3.4	18.8	5.7%	5.0	37.5	17.9%	0.5	0.0	2.6%
Goatfish	11.0	62.5	23.0%	9.7	45.0	24.6%	22.3	180.0	30.8%	8.6	45.0	24.4%
Grenadier / hoki*	12.4	93.8	21.8%	16.4	93.8	37.7%	41.9	380.0	41.0%	15.0	87.5	35.9%
Grouper	0.8	0.0	2.3%	1.6	0.0	3.3%	1.0	0.0	2.6%	0.7	0.0	2.6%
Gurnard	8.0	25.0	11.5%	3.9	25.0	7.4%	12.6	112.5	23.1%	3.8	37.5	9.0%
Haddock	10.2	25.0	11.5%	7.3	45.0	13.9%	14.4	180.0	20.5%	6.1	45.0	11.5%
Hake	41.6	171.9	52.9%	38.2	150.0	51.6%	49.3	180.0	71.8%	28.4	180.0	44.9%
Halibut*	9.5	37.5	24.1%	14.1	62.5	31.1%	18.4	300.0	7.7%	13.1	93.8	29.5%
Herring	4.2	25.0	13.8%	6.8	25.0	16.4%	11.6	93.8	17.9%	8.9	50.0	17.9%
John Dory	3.5	18.8	10.3%	4.6	18.8	10.7%	3.5	37.5	12.8%	2.7	18.8	7.7%
Ling	27.4	125.0	32.2%	17.3	68.8	34.4%	21.1	150.0	30.8%	14.8	62.5	34.6%
Mackerel	13.9	70.0	33.3%	14.6	95.0	28.7%	33.8	190.0	41.0%	11.9	95.0	24.4%
Mullet	3.7	22.5	10.3%	7.6	37.5	9.8%	3.0	37.5	10.3%	7.1	50.0	10.3%
Plaice	9.3	25.0	10.3%	4.4	35.0	11.5%	9.0	93.8	15.4%	4.3	37.5	11.5%
Pollack	13.2	62.5	23.0%	7.3	37.5	12.3%	15.2	100.0	28.2%	6.9	50.0	12.8%
Pout	2.7	19.5	6.9%	1.6	0.0	3.3%	4.4	37.5	12.8%	1.5	0.0	2.6%
Ray*	30.2	150.0	55.2%	27.4	125.0	56.6%	56.2	200.0	64.1%	23.9	125.0	53.8%
Redfish	1.5	0.0	2.3%	1.1	0.0	1.6%	1.9	0.0	2.6%	1.6	0.0	2.6%
Saithe / coalfish	50.4	150.0	57.5%	54.1	200.0	62.3%	48.9	190.0	48.7%	61.9	220.0	71.8%
Salmon	60.5	190.6	60.9%	78.8	220.0	77.9%	51.1	220.0	53.8%	91.0	220.0	83.3%
Sardine	25.1	125.0	57.5%	30.0	150.0	50.0%	38.2	150.0	61.5%	21.7	150.0	41.0%
Scorpion fish	3.0	18.8	5.7%	4.0	18.8	9.0%	3.2	25.0	12.8%	2.5	18.8	6.4%
Seabass*	31.9	100.0	55.2%	30.6	112.5	44.3%	21.9	125.0	41.0%	19.3	95.0	46.2%
Sea bream*	24.2	125.0	33.3%	16.3	90.6	32.0%	30.3	275.0	43.6%	7.2	37.5	24.4%
Smelt	5.7	50.0	11.5%	3.8	21.9	12.3%	2.4	37.5	7.7%	5.3	25.0	17.9%
Sole	55.6	200.0	65.5%	47.7	171.9	62.3%	65.6	275.0	71.8%	33.6	150.0	55.1%
Sprat	1.1	0.0	1.1%	0.2	0.0	0.8%	1.6	25.0	5.1%	0.2	0.0	1.3%
Swordfish*	6.5	27.5	13.8%	5.2	37.5	11.5%	3.1	27.5	12.8%	4.0	38.1	11.5%
Tuna*	24.7	137.5	40.2%	27.5	112.5	45.9%	39.2	137.5	56.4%	26.7	137.5	43.6%
Turbot	6.2	37.5	8.0%	1.9	18.8	6.6%	5.8	50.0	12.8%	1.6	18.1	5.1%
Whiting	23.0	125.0	33.3%	14.4	62.5	26.2%	17.9	112.5	28.2%	11.9	62.5	25.6%
Other**	1.3	0.0	2.3%	2.9	18.8	8.2%	1.7	27.5	5.1%	2.9	27.5	10.3%
TOTAL	684.1	1,580	98.9%	654.4	1,410	100.0%	819.6	2,009	100.0%	588.2	1,303	100.0%

* Predatory fish as described in the Commission Regulation (EC) No 78/2005 of 19 January 2005 ** Other : Perch, bogue, trout, scabbard-fish, sea wrasse, conger eel, needlefish, sard, rainbow wrasse, gobie, croaker, shark, sea-bream coriphene, ling, bassbu
*** Consumers rate

Consumptions of molluscs and crustaceans by high consumers – La Rochelle (g/week)

Mollusc, crustacean	Adult men (18-64 y) n= 87			Adult women (18-64 y) n= 122			Older subjects (65 y and more) n= 39			Women of childbearing age (18-44 y) n= 78		
	Mean	P95	%*	Mean	P95	%*	Mean	P95	%*	Mean	P95	%*
Abalone	0.4	0.0	1.1%	0.1	0.0	0.8%	4.5	0.0	2.6%	0.2	0.0	1.3%
Calico scallop	30.4	75.0	32.2%	32.7	150.0	39.3%	50.4	300.0	61.5%	40.5	281.3	37.2%
Carpet shell	3.4	25.0	32.2%	2.8	15.0	24.6%	3.1	12.0	41.0%	3.0	15.0	26.9%
Clam	0.1	0.0	4.6%	0.2	0.0	4.1%	0.4	0.0	2.6%	0.3	2.0	6.4%
Cockle	1.9	8.8	24.1%	3.4	17.5	26.2%	2.7	30.0	15.4%	3.9	18.8	30.8%
Crab	9.1	25.0	67.8%	9.2	25.0	63.9%	10.1	50.0	53.8%	8.9	25.0	65.4%
Crayfish	1.6	10.0	13.8%	2.0	15.0	12.3%	0.2	0.0	2.6%	2.9	31.3	16.7%
Cuttle fish	16.8	81.3	49.4%	19.0	81.3	46.7%	11.3	81.3	35.9%	18.0	81.3	50.0%
Donax clam	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%
Great scallop	33.5	100.0	66.7%	31.2	100.0	63.9%	27.7	156.3	56.4%	29.6	125.0	62.8%
Grooved sea squirt	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%
Hard clam	1.2	9.4	12.6%	0.5	0.0	4.9%	1.3	12.5	15.4%	0.2	0.0	3.8%
Limpet	0.0	0.0	0.0%	0.3	0.0	1.6%	1.3	0.0	2.6%	0.4	0.0	2.6%
Lobster	2.8	22.5	12.6%	5.1	22.5	19.7%	3.8	22.5	12.8%	4.6	22.5	17.9%
Mussel	26.5	70.0	80.5%	32.3	70.0	87.7%	36.6	70.0	100.0%	32.8	70.0	91.0%
Octopus	1.6	16.3	8.0%	0.6	0.0	2.5%	1.0	20.0	5.1%	1.0	0.0	3.8%
Oyster	66.8	216.0	81.6%	57.8	180.0	77.9%	80.5	288.0	79.5%	49.0	180.0	73.1%
Queen scallop	2.6	0.0	3.4%	0.0	0.0	0.0%	0.7	9.4	5.1%	0.0	0.0	0.0%
Periwinkle	2.2	10.0	46.0%	4.2	15.0	48.4%	1.9	12.5	25.6%	5.6	31.3	51.3%
Razor clam	0.5	0.0	3.4%	1.6	0.0	4.9%	0.0	0.0	0.0%	2.4	25.0	6.4%
Sea urchin	0.6	0.0	3.4%	0.0	0.0	0.0%	1.5	13.1	5.1%	0.0	0.0	0.0%
Scampi	22.0	90.0	69.0%	26.5	112.5	73.8%	34.4	180.0	69.2%	26.6	135.0	71.8%
Shrimp	34.0	75.0	93.1%	43.3	125.0	91.8%	34.8	100.0	76.9%	47.1	150.0	91.0%
Spiny lobster	1.2	6.3	13.8%	0.3	0.0	4.9%	2.4	12.5	23.1%	0.4	6.3	6.4%
Slipper lobster	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	2.6%	0.0	0.0	0.0%
Spider crab	4.0	20.0	25.3%	2.0	10.0	18.0%	1.3	10.0	20.5%	1.8	10.0	17.9%
Squid	17.7	81.3	50.6%	14.0	50.0	41.8%	11.4	50.0	41.0%	13.0	50.0	37.2%
Swimcrab	7.4	50.0	14.9%	7.9	12.5	8.2%	0.8	12.5	5.1%	4.3	18.8	7.7%
Whelk	17.3	100.0	50.6%	22.8	125.0	46.7%	6.7	37.5	23.1%	27.3	150.0	50.0%
TOTAL	**305.7**	**730.3**	**99.1%**	**319.9**	**974.3**	**99.2%**	**330.6**	**721.3**	**100.0%**	**323.9**	**1,163**	**98.7%**

* Consumers rate

Consumptions of canned food, smoked fish and seafood-based dishes by high consumers – La Rochelle (g/week)

Other seafood	Adult men (18-64 y) n= 87			Adult women (18-64 y) n= 122			Older subjects (65 y and more) n= 39			Women of childbearing age (18-44 y) n= 78		
	Mean	P95	%**	Mean	P95	%**	Mean	P95	%**	Mean	P95	%**
Canned food												
Anchovy	19.8	112.5	33.3%	12.8	60.0	27.0%	12.6	150.0	28.2%	9.3	60.0	26.9%
Crab	17.5	60.0	62.1%	13.7	56.3	54.9%	11.8	60.0	53.8%	14.0	56.3	59.0%
Mackerel	2.6	22.5	10.3%	1.6	15.0	9.0%	0.6	7.5	7.7%	1.1	7.5	7.7%
Pilchard	11.5	40.0	60.9%	12.3	40.0	69.7%	13.8	60.0	71.8%	10.9	40.0	61.5%
Sardine	30.8	90.0	87.4%	29.5	90.0	88.5%	14.3	56.3	74.4%	31.9	90.0	91.0%
Tuna*	4.8	22.5	24.1%	2.8	15.0	22.1%	1.1	9.4	17.9%	3.2	15.0	19.2%
Total canned food	**87.0**	**240.6**	**97.7%**	**72.7**	**168.8**	**98.4%**	**54.1**	**182.5**	**89.7%**	**70.4**	**172.5**	**97.4%**
Smoked fish												
Haddock	1.0	7.5	10.3%	2.5	11.3	14.8%	0.2	0.0	2.6%	2.3	11.3	17.9%
Herring	6.7	28.1	41.4%	3.9	18.8	27.9%	7.1	45.0	46.2%	4.4	22.5	33.3%
Mackerel	2.5	15.0	19.5%	1.7	12.5	13.1%	0.9	7.5	5.1%	1.7	11.3	15.4%
Salmon	9.0	31.3	65.5%	7.9	30.0	69.7%	4.5	20.0	59.0%	8.2	37.5	66.7%
Total smoked fish	**19.2**	**58.1**	**79.3%**	**16.1**	**52.5**	**76.2%**	**12.7**	**56.3**	**74.4%**	**16.6**	**52.5**	**76.9%**
Seafood-based dish												
Fish soup	77.4	250.0	66.7%	73.6	250.0	61.5%	64.6	312.5	71.8%	86.1	400.0	60.3%
Paella	3.6	18.8	31.0%	5.0	21.9	33.6%	0.9	8.8	17.9%	6.6	40.0	37.2%
Surimi	25.9	80.0	71.3%	23.3	70.0	68.9%	7.9	40.0	33.3%	27.3	70.0	76.9%
Tarama	54.9	175.0	50.6%	33.6	125.0	41.0%	14.6	80.0	25.6%	38.7	175.0	44.9%
Total seafood-based dish	**161.8**	**475.0**	**87.4%**	**135.4**	**368.8**	**91.0%**	**88.0**	**312.5**	**82.1%**	**158.7**	**462.5**	**89.7%**
Total	**268.1**	**736.3**	**98.9%**	**224.1**	**574.4**	**98.4%**	**154.8**	**476.3**	**97.4%**	**245.6**	**607.5**	**97.4%**

* Predatory fish as described in the Commission Regulation (EC) No 78/2005 of 19 January 2005 ** Consumers rate

Consumptions of fresh and frozen fish by high consumers – Toulon (g/week)

Fish	Adult men (18-64 y) n= 60			Adult women (18-64 y) n= 171			Older subjects (65 y and more) n= 21			Women of childbearing age (18-44 y) n= 92		
	Mean	P95	%***	Mean	P95	%***	Mean	P95	%***	Mean	P95	%***
Anchovy	4.4	37.5	11.7%	3.2	22.5	11.1%	2.9	15.0	9.5%	1.6	15.0	7.6%
Angler fish*	13.3	68.8	38.3%	14.5	50.0	43.9%	35.7	93.8	42.9%	9.2	47.5	32.6%
Catshark*	2.1	17.5	8.3%	8.6	37.5	21.6%	4.5	25.0	19.0%	10.2	50.0	21.7%
Cod	90.9	325.0	78.3%	109.9	300.0	86.0%	69.6	190.0	71.4%	115.2	275.0	87.0%
Dab	14.5	92.2	26.7%	17.6	100.0	26.3%	28.0	145.0	19.0%	15.5	100.0	18.5%
Eel*	0.9	0.0	1.7%	1.9	12.5	5.3%	1.2	0.0	4.8%	2.7	25.0	6.5%
Emperor*	2.7	25.0	8.3%	3.5	18.1	7.6%	6.0	0.0	4.8%	1.3	0.0	4.3%
Goatfish	11.7	62.8	28.3%	13.2	62.5	45.0%	22.3	90.0	52.4%	11.0	62.5	39.1%
Grenadier / hoki*	1	6.3	5.0%	5.8	37.5	12.9%	0.0	0.0	0.0%	6.0	50.0	9.8%
Grouper	1.5	18.4	6.7%	4.7	35.0	11.1%	1.7	12.5	9.5%	3.6	31.3	9.8%
Gurnard	1.4	18.1	6.7%	3.5	18.8	8.8%	1.1	0.0	4.8%	0.9	0.0	3.3%
Haddock	8.8	37.5	10.0%	2.8	12.5	7.0%	0.6	0.0	4.8%	1.6	6.3	5.4%
Hake	3.7	12.5	5.0%	12.3	93.8	19.9%	0.0	0.0	0.0%	13.7	100.0	21.7%
Halibut*	10.7	50.0	23.3%	11.5	50.0	23.4%	12.2	50.0	28.6%	11.2	50.0	21.7%
Herring	1.8	9.4	6.7%	2.0	12.5	7.0%	7.1	0.0	4.8%	3.2	25.0	9.8%
John Dory	4.3	24.4	18.3%	6.4	37.5	21.6%	12.0	68.8	33.3%	3.2	25.0	14.1%
Ling	6.8	25.0	23.3%	11.2	93.8	20.5%	22.3	125.0	23.8%	8.6	50.0	18.5%
Mackerel	11.8	47.5	20.0%	8.7	62.5	19.9%	6.3	25.0	14.3%	7.8	45.0	15.2%
Mullet	1.3	3.1	5.0%	9.4	45.0	8.8%	0.0	0.0	0.0%	5.6	18.8	5.4%
Plaice	2.9	25.0	10.0%	3.6	25.0	8.8%	14.3	100.0	9.5%	2.9	18.8	6.5%
Pollack	1.7	12.5	5.0%	8.3	45.0	12.3%	0.6	0.0	4.8%	8.1	37.5	13.0%
Pout	1.0	0.0	3.3%	0.2	0.0	1.2%	0.0	0.0	0.0%	0.1	0.0	1.1%
Ray*	9.4	50.0	20.0%	14.9	50.0	27.5%	8.8	47.5	19.0%	10.7	50.0	22.8%
Redfish	0.0	0.0	0.0%	2.2	0.0	3.5%	0.0	0.0	0.0%	0.1	0.0	1.1%
Saithe / coalfish	48.2	162.5	56.7%	70.0	200.0	71.9%	40.5	145.0	42.9%	81.8	200.0	79.3%
Salmon	50.5	210.0	60.0%	65.9	220.0	69.0%	45.8	220.0	47.6%	64.4	220.0	68.5%
Sardine	24.0	101.6	53.3%	21.2	100.0	43.9%	16.7	37.5	38.1%	11.4	78.1	29.3%
Scorpion fish	8.0	52.5	25.0%	7.3	45.0	29.2%	24.2	125.0	38.1%	4.6	25.0	23.9%
Seabass*	38.9	125.0	61.7%	31.8	112.5	61.4%	46.5	95.0	66.7%	21.7	95.0	53.3%
Sea bream*	41.1	160.0	53.3%	42.4	180.0	62.0%	81.5	400.0	61.9%	30.8	150.0	54.3%
Smelt	1.3	0.0	3.3%	2.5	22.5	8.2%	0.0	0.0	0.0%	1.5	12.5	5.4%
Sole	51.2	250.0	61.7%	30.7	171.9	48.0%	118.6	400.0	61.9%	34.7	171.9	45.7%
Sprat	0.2	0.0	1.7%	0.2	0.0	1.2%	0.0	0.0	0.0%	0.1	0.0	1.1%
Swordfish*	14.7	49.4	26.7%	9.3	48.8	19.9%	4.7	22.5	23.8%	8.6	48.8	17.4%
Tuna*	32.9	144.1	51.7%	29.7	137.5	48.0%	23.0	55.0	42.9%	23.2	137.5	35.9%
Turbot	3.3	12.5	5.0%	2.4	22.5	9.9%	1.1	0.0	4.8%	2.1	22.5	8.7%
Whiting	28.8	125.0	48.3%	29.8	125.0	49.7%	34.9	125.0	33.3%	26.9	125.0	48.9%
Other**	1.9	13.8	5.0%	1.6	12.5	6.4%	0.0	0.0	0.0%	1.2	9.4	5.4%
TOTAL	553.4	1,420	100.0%	624.4	1,581	100.0%	694.7	1,295	100.0%	567.2	1,330	100.0%

* Predatory fish as described in the Commission Regulation (EC) No 78/2005 of 19 January 2005 ** Other : Perch, bogue, trout, scabbard-fish, sea wrasse, conger eel, needlefish, sard, rainbow wrasse, gobie, croaker, shark, sea-bream coriphene, ling, bassbu *** Consumers rate

Consumptions of molluscs and crustaceans by high consumers – Toulon (g/week)

Mollusc, crustacean	Adult men (18-64 y) n= 60			Adult women (18-64 y) n= 171			Older subjects (65 y and more) n= 21			Women of childbearing age (18-44 y) n= 92		
	Mean	P95	%*	Mean	P95	%*	Mean	P95	%*	Mean	P95	%*
Abalone	1.5	0.0	1.7%	0.7	0.0	2.3%	0.0	0.0	0.0%	1.0	0.0	2.2%
Calico scallop	3.7	33.8	11.7%	4.9	28.1	21.6%	1.1	0.0	4.8%	4.0	22.5	19.6%
Carpet shell	0.5	5.0	6.7%	0.6	5.0	15.2%	0.7	5.0	9.5%	0.6	5.0	13.0%
Clam	0.5	3.0	8.3%	0.3	2.5	7.0%	0.2	0.0	4.8%	0.3	2.0	6.5%
Cockle	0.5	5.0	8.3%	0.5	3.8	11.7%	0.7	3.8	14.3%	0.3	1.9	7.6%
Crab	4.3	20.0	41.7%	4.5	20.0	42.7%	2.4	20.0	19.0%	4.1	20.0	41.3%
Crayfish	3.0	15.0	18.3%	1.7	12.5	18.1%	0.6	0.0	4.8%	1.8	12.5	21.7%
Cuttle fish	11.4	50.0	23.3%	6.8	32.5	27.5%	3.5	25.0	14.3%	4.7	32.5	22.8%
Donax clam	0.2	0.0	3.3%	0.8	0.0	4.7%	0.3	0.0	4.8%	0.7	0.0	3.3%
Great scallop	34.8	156.3	63.3%	26.3	100.0	57.9%	34.5	156.3	42.9%	19.0	75.0	56.5%
Grooved sea squirt	5.2	45.0	10.0%	3.0	15.0	11.1%	4.0	25.0	9.5%	2.5	15.0	9.8%
Hard clam	1.8	13.8	20.0%	0.6	5.0	13.5%	2.0	12.5	19.0%	0.4	3.8	7.6%
Limpet	0.2	0.0	1.7%	0.0	0.0	0.6%	0.0	0.0	0.0%	0.1	0.0	1.1%
Lobster	5.6	45.0	13.3%	6.9	45.0	22.2%	1.6	11.3	9.5%	8.3	45.0	26.1%
Mussel	21.7	50.0	93.3%	17.6	50.0	87.7%	11.7	43.8	76.2%	17.6	50.0	88.0%
Octopus	24.6	103.1	53.3%	11.4	50.0	39.2%	4.6	20.6	23.8%	9.8	41.3	38.0%
Oyster	16.8	72.0	58.3%	12.1	45.0	57.9%	8.6	36.0	38.1%	9.8	36.0	51.1%
Periwinkle	0.9	5.0	25.0%	1.0	5.0	25.7%	0.1	0.0	4.8%	0.8	5.0	21.7%
Queen scallop	0.7	0.0	3.3%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%
Razor clam	1.8	10.0	5.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%
Scampi	4.0	27.0	18.3%	3.9	18.0	26.9%	4.4	24.0	23.8%	3.7	15.0	28.3%
Sea urchin	31.9	105.0	41.7%	46.7	131.3	35.7%	45.0	175.0	42.9%	27.8	109.4	35.9%
Shrimp	32.5	112.5	88.3%	33.3	100.0	91.2%	25.8	62.5	95.2%	35.8	100.0	94.6%
Slipper lobster	0.0	0.1	8.3%	0.0	0.0	2.3%	0.0	0.0	0.0%	0.0	0.0	2.2%
Spider crab	0.7	5.0	5.0%	0.8	10.0	8.8%	0.0	0.0	0.0%	0.9	10.0	8.7%
Spiny lobster	2.1	12.5	23.3%	3.0	12.5	34.5%	3.4	12.5	42.9%	2.9	12.5	32.6%
Squid	22.1	103.1	53.3%	19.2	81.3	60.2%	5.0	16.3	33.3%	17.4	81.3	54.3%
Swimcrab	2.4	0.0	3.3%	0.2	0.0	1.8%	0.0	0.0	0.0%	0.3	0.0	1.1%
Whelk	4.1	28.1	18.3%	7.1	30.0	19.3%	1.2	0.0	4.8%	9.5	37.5	22.8%
TOTAL	**239.5**	**811.5**	**99.2%**	**213.9**	**561.5**	**99.4%**	**161.4**	**461.8**	**100.0%**	**183.8**	**521.9**	**98.9%**

* Consumers rate

Consumptions of canned food, smoked fish and seafood-based dishes by high consumers – Toulon (g/week)

Other seafood	Adult men (18-64 y) n= 60			Adult women (18-64 y) n= 171			Older subjects (65 y and more) n= 21			Women of childbearing age (18-44 y) n= 92		
	Mean	P95	%**	Mean	P95	%**	Mean	P95	%**	Mean	P95	%**
Canned food												
Anchovy	70.4	262.5	60.0%	41.0	187.5	51.5%	42.9	93.8	61.9%	37.9	187.5	41.3%
Crab	12.1	77.8	41.7%	11.3	56.3	46.2%	5.7	18.8	47.6%	14.8	60.0	45.7%
Mackerel	1.6	7.5	6.7%	0.7	0.0	4.7%	0.9	0.0	4.8%	1.2	7.5	5.4%
Pilchard	16.3	65.0	66.7%	10.8	40.0	66.1%	21.2	60.0	85.7%	11.2	40.0	62.0%
Sardine	66.9	315.0	95.0%	57.8	210.0	92.4%	19.4	60.0	71.4%	80.0	315.0	95.7%
Tuna*	9.3	56.3	46.7%	11.1	56.3	49.7%	3.0	9.4	38.1%	15.7	90.0	47.8%
Total canned food	**176.6**	**532.5**	**100.0%**	**132.7**	**360.0**	**98.2%**	**93.1**	**167.5**	**95.2%**	**160.8**	**667.5**	**100.0%**
Smoked fish												
Haddock	0.5	5.6	8.3%	1.6	7.5	12.3%	0.4	0.0	4.8%	0.8	7.5	7.6%
Herring	6.8	51.6	30.0%	5.1	22.5	32.2%	2.1	15.0	23.8%	3.7	22.5	25.0%
Mackerel	2.6	22.5	10.0%	1.2	7.5	11.7%	0.4	0.0	4.8%	1.3	7.5	13.0%
Salmon	10.8	37.5	91.7%	10.8	40.0	86.5%	8.6	25.0	66.7%	9.5	40.0	83.7%
Total smoked fish	**20.7**	**85.0**	**95.0%**	**18.7**	**70.0**	**89.5%**	**11.5**	**28.8**	**85.7%**	**15.3**	**56.3**	**87.0%**
Seafood-based dish												
Fish soup	84.2	250.0	68.3%	73.2	250.0	68.4%	82.1	250.0	90.5%	74.3	400.0	62.0%
Paella	8.5	50.0	43.3%	11.2	50.0	52.0%	3.1	2.5	9.5%	14.3	100.0	45.7%
Surimi	28.1	70.0	80.0%	44.0	140.0	78.9%	18.9	43.8	38.1%	57.0	210.0	85.9%
Tarama	83.0	312.5	83.3%	59.6	200.0	74.9%	36.2	125.0	52.4%	69.9	312.5	78.3%
Total seafood-based dish	**203.7**	**407.5**	**98.3%**	**188.0**	**540.0**	**98.8%**	**140.3**	**275.0**	**95.2%**	**215.5**	**606.3**	**98.9%**
Total	**401.0**	**987.2**	**100.0%**	**339.4**	**843.8**	**100.0%**	**244.9**	**472.5**	**100.0%**	**391.6**	**937.5**	**100.0%**

* Predatory fish as described in the Commission Regulation (EC) No 78/2005 of 19 January 2005 ** Consumers rate

Appendix 3a :
Comparison between consumption data from Calipso and INCA before correction

Seafood group	Calipso (n=243) Adult men (18-64 y)		INCA (n=509) Consumers only (83,5%)	
	Mean	P95	Mean	P95
Fish	633.0	1,491	267.2	705.0
Mollusc, crustacean	270.3	703.4	115.1	285.0
Seafood-based dishes	312.3	798.8	223.2	730.0
Total	**1,216**	**2,486**	**365.9**	**1,075**
	Calipso (n=630) Adult women (18-64 y)		INCA (n=610) Consumers only (84.3%)	
Fish	636.5	1,522	229.0	580.0
Mollusc, crustacean	259.9	665.3	109.8	258.0
Seafood-based dishes	272.2	742.5	168.1	640.0
Total	**1,169**	**2,588**	**304.5**	**800.0**
	Calipso (n=123) Older subjects (65 y and more)		INCA (n=243) Consumers only (86.1%)	
Fish	787.8	1,783	290.2	695.0
Mollusc, crustacean	279.3	648.8	115.3	330.0
Seafood-based dishes	187.7	472.5	127.0	410.0
Total	**1,255**	**2,764**	**332.5**	**850.5**
	Calipso (n=344) Women of childbearing age (18-44 y)		INCA (n=404) Consumers only (82.7%)	
Fish	569.4	1286.9	224.3	580.0
Mollusc, crustacean	235.1	607.4	109.3	250.0
Seafood-based dishes	300.8	795.0	174.4	650.0
Total	**1,105**	**2,401**	**300.3**	**785.0**

Appendix 3b :
Comparison between consumption data from Calipso and INCA after correction

Seafood group	Calipso (n=243) Adult men (18-64 y)		INCA (n=509) Consumers only (83,5%)	
	Mean	P95	Mean	P95
Fish	441.8	1,076	267.2	705.0
Mollusc, crustacean	205.7	511.9	115.1	285.0
Seafood-based dishes	268.4	695.0	223.2	730.0
Total	**915.8**	**1,967**	**365.9**	**1,075**
	Calipso (n=630) Adult women (18-64 y)		INCA (n=610) Consumers only (84.3%)	
Fish	451.8	1,155	229.0	580.0
Mollusc, crustacean	194.7	544.7	109.8	258.0
Seafood-based dishes	236.1	641.0	168.1	640.0
Total	**882.6**	**1,943**	**304.5**	**800.0**
	Calipso (n=123) Older subjects (65 y and more)		INCA (n=243) Consumers only (86.1%)	
Fish	575.6	1,413	290.2	695.0
Mollusc, crustacean	208.5	535.6	115.3	330.0
Seafood-based dishes	161.9	396.9	127.0	410.0
Total	**946.0**	**2,148**	**332.5**	**850.5**
	Calipso (n=344) Women of childbearing age (18-44 y)		INCA (n=404) Consumers only (82.7%)	
Fish	391.9	870.5	224.3	580.0
Mollusc, crustacean	174.1	487.9	109.3	250.0
Seafood-based dishes	262.4	691.9	174.4	650.0
Total	**828.4**	**1,806**	**300.3**	**785.0**

Appendix 4: Distribution of provisioning per site (% of consumed product)

Fish

Le Havre	Fished or collected	Bought at the port	Bought at the market	Bought from a fishmonger	Bought from a supermarket	Consumed only outside the home
Anchovy (excluding canned)	-	-	4.0	57.3	38.7	-
Angler fish*	0.4	7.6	2.1	20.0	68.1	1.9
Catshark*	0.5	19.0	2.0	12.1	65.6	0.8
Cod	0.1	4.3	2.6	14.1	76.7	2.2
Dab	4.1	12.8	16.4	18.1	44.9	3.7
Eel*	3.9	16.0	5.7	65.5	7.9	1.0
Emperor*	-	0.5	12.7	26.5	60.3	-
Goatfish	2.0	15.8	2.6	21.2	42.1	16.3
Grenadier / Hoki*	-	0.9	0.9	13.5	84.5	-
Grouper	57.1	-	-	-	42.9	-
Gurnard	-	4.6	-	25.7	69.7	-
Haddock	-	0.2	6.0	15.4	78.5	-
Hake	1.0	0.3	14.4	6.6	77.7	-
Halibut*	-	0.6	0.3	4.5	93.2	1.4
Herring (excluding smoked)	1.7	10.7	5.8	30.7	50.7	0.4
John dory	3.3	9.6	-	34.3	52.9	-
Ling	0.5	3.2	2.8	16.7	75.1	1.8
Mackerel	10.5	37.4	1.7	11.0	37.3	2.2
Mullet	69.2	-	-	-	22.6	8.1
Plaice	2.4	38.1	5.1	12.9	41.4	-
Pollack	2.2	4.4	8.4	13.9	55.9	15.2
Pout	15.5	43.8	-	7.8	32.9	-
Ray*	4.1	6.4	3.3	16.4	65.0	4.9
Redfish	-	-	-	-	100.0	-
Saithe / Coalfish		3.9	2.1	10.9	82.4	0.8
Salmon (excluding smoked)	0.0	0.9	1.7	17.1	75.8	4.5
Sardine (excluding canned)	0.3	5.0	4.3	23.2	65.1	2.2
Scorpion fish	-	-	-	36.0	64.0	-
Seabass*	27.2	18.2	1.3	13.1	27.9	12.2
Sea bream*	2.3	24.2	5.0	16.8	48.9	2.7
Smelt	2.1	24.2	-	36.6	37.1	-
Sole	5.9	30.6	0.6	17.7	34.0	11.2
Sprat	37.5	-	12.5	12.5	37.5	-
Swordfish*	-	1.4	-	5.1	93.4	-
Tuna (excluding canned)*	-	1.3	1.5	7.3	87.2	2.7
Turbot	4.8	21.6	-	39.2	29.2	5.2
Whiting	1.4	9.8	3.1	21.0	64.0	0.7
Other**	19.6	-	-	-	80.4	-

* Predatory fish as described in the Commission Regulation (EC) No 78/2005 of 19 January 2005
** Other: Perch, trout, scabbard-fish, sea wrasse, conger eel, croaker, shark, bassbu

Fish

Lorient	Fished or collected	Bought at the port	Bought at the market	Bought from a fishmonger	Bought from a supermarket	Consumed only outside the home
Anchovy (excluding canned)	1.5	2.1	12.5	68.3	14.6	1.0
Angler fish*	5.6	9.9	13.3	34.7	33.9	2.6
Catshark*	1.3	-	3.6	57.8	37.3	-
Cod	2.7	13.4	7.1	30.6	44.8	1.4
Dab	2.6	14.0	7.3	49.0	24.0	3.1
Eel*	52.8	1.6	7.6	17.3	20.7	-
Emperor*	1.8	4.0	10.1	26.4	55.2	2.4
Goatfish	8.5	21.6	14.5	42.0	12.6	0.7
Grenadier / Hoki*	3.6	2.4	2.9	38.2	45.4	7.5
Grouper	-	-	-	100.0	-	-
Gurnard	3.9	20.1	4.3	41.6	30.0	-
Haddock	3.9	0.8	2.5	35.1	57.7	-
Hake	3.4	26.4	11.7	29.8	25.9	2.7
Halibut*	3.2	1.8	22.4	29.6	37.6	5.3
Herring (excluding smoked)	30.4	15.4	12.8	26.2	13.9	1.3
John Dory	5.9	-	27.9	31.4	8.3	26.5
Ling	1.4	3.8	5.0	45.3	43.5	0.9
Mackerel	19.0	30.6	8.6	26.6	15.3	-
Mullet	55.9	44.1	-	-	-	-
Plaice	7.6	3.7	10.6	34.2	43.9	-
Pollack	13.2	12.7	5.4	40.6	27.4	0.5
Pout	15.8	38.1	26.9	12.0	5.5	1.7
Ray*	2.5	2.3	8.8	44.8	38.5	3.0
Redfish	-	-	33.5	66.5	-	-
Saithe / Coalfish	1.8	8.4	6.8	34.5	46.1	2.3
Salmon (excluding smoked)	0.8	1.1	6.7	35.5	53.2	2.8
Sardine (excluding canned)	3.4	9.9	15.3	40.8	28.6	1.8
Scorpion fish	26.5	-	-	28.5	19.9	25.2
Seabass*	31.7	21.7	7.8	21.6	14.2	3.0
Sea bream*	5.2	10.7	20.8	37.4	20.3	5.5
Smelt	16.3	13.2	-	53.6	16.9	-
Sole	16.3	20.4	3.9	46.4	10.2	2.6
Sprat	-	-	50.0	-	50.0	-
Swordfish*	2.6	8.8	27.1	31.4	23.9	6.3
Tuna (excluding canned)*	4.1	29.0	7.5	28.2	29.2	2.0
Turbot	12.8	0.7	17.9	22.8	13.2	32.7
Whiting	4.2	24.4	10.5	32.4	28.1	0.5
Other**	10.8	-	-	7.5	81.7	-

* Predatory fish as described in the Commission Regulation (EC) No 78/2005 of 19 January 2005
** Other: Perch, trout, scabbard-fish, sea wrasse, conger eel, croaker, shark, bassbu

Fish

La Rochelle	Fished or collected	Bought at the port	Bought at the market	Bought from a fishmonger	Bought from a supermarket	Consumed only outside the home
Anchovy (excluding canned)	1.2	0.5	79.7	3.7	14.5	0.4
Angler fish*	1.1	2.1	33.9	20.7	33.5	8.7
Catshark*	5.9	18.2	21.9	15.0	29.2	9.7
Cod	0.4	4.8	29.3	17.3	47.3	0.8
Dab	5.2	23.2	19.2	17.7	31.6	3.2
Eel	24.1	1.9	30.6	11.0	27.8	4.6
Emperor*	-	8.5	36.1	20.9	29.1	5.5
Goatfish	3.3	6.1	49.4	16.7	22.7	1.8
Grenadier / Hoki*	0.4	16.7	21	19.9	34.4	7.6
Grouper	-	-	32.9	43.5	18.4	5.2
Gurnard	-	8.9	26.8	15.4	46.6	2.3
Haddock	-	24.8	19.7	14.0	37.3	4.1
Hake	2.5	10.2	29.5	24.1	33.4	0.3
Halibut*	0.0	2.1	34.2	25.1	37.6	1.0
Herring (excluding smoked)	1.0	13.5	25.0	17.1	43.4	-
John Dory	1.0	31.4	42.0	9.8	7.2	8.6
Ling	0.3	13.0	15.4	18.6	39.0	13.8
Mackerel	16.4	14.0	24.0	11.2	34.0	0.4
Mullet	38.7	30.4	18.5	4.1	8.3	-
Plaice	4.2	42	23.2	9.2	20.6	0.8
Pollack	5.5	19.0	27.3	16.7	31.0	0.5
Pout	33.1	15.1	21.4	10.1	16.6	3.7
Ray*	3.0	6.9	35.6	24.1	27.2	3.3
Redfish	-	50.3	-	-	34.8	14.8
Saithe / Coalfish	0.1	8.0	20.6	12.9	56.8	1.6
Salmon (excluding smoked)	0.2	2.4	24.8	18.8	45.8	7.9
Sardine (excluding canned)	1.2	6.2	33.5	21.4	36.4	1.3
Scorpion fish	-	14.3	39.5	27.4	12.4	6.4
Seabass*	34.8	2.1	36.0	13.9	8.6	4.6
Sea bream*	18.2	12.7	31.1	9.6	26.1	2.0
Smelt	17.6	1.2	19.2	22.6	32.8	6.7
Sole	12.4	5.3	35.8	14.5	28.2	3.9
Sprat	-	12.7	11.4	19.0	47.5	9.5
Swordfish*	-	5.6	60.2	19.4	11.3	4.1
Tuna (excluding canned)*	3.9	3.5	33.8	21.2	34.8	2.8
Turbot	2.2	8.7	19.8	8.8	35.4	25.0
Whiting	4.2	9.2	27.6	18.8	35.3	5.0
Other**	27.5	5.2	37.2	9.2	17.3	3.6

* Predatory fish as described in the Commission Regulation (EC) No 78/2005 of 19 January 2005
** Other: Perch, trout, scabbard-fish, sea wrasse, conger eel, croaker, shark, bassbu

Fish

Toulon	Fished or collected	Bought at the port	Bought at the market	Bought from a fishmonger	Bought from a supermarket	Consumed only outside the home
Anchovy (excluding canned)	-	1.2	4.9	40.5	39.6	13.7
Angler fish*	-	0.9	2.2	30.5	58.6	7.8
Catshark*	-	2.2	-	38.7	55.0	3.7
Cod	-	0.6	2.3	16.9	77.7	2.6
Dab	1.0	0.9	4.9	38.4	50.6	4.2
Eel*	6.3	8.1	0.6	17.5	61.3	6.3
Emperor*	-	7.1	-	40.2	50.1	2.6
Goatfish	1.2	6.7	1.3	36.6	47.1	7.1
Grenadier / Hoki*	-	4.8	-	16.3	76.8	2.1
Grouper	-	3.2	4.3	31.1	29.1	32.3
Gurnard	2.7	8.9	3.7	13.2	58.2	13.3
Haddock	-	1.2	-	13.2	83.1	2.4
Hake	-	-	-	10.3	86.8	2.9
Halibut*	-	1.7	0.5	26.2	68.8	2.8
Herring (excluding smoked)	-	-	-	31.4	68.6	-
John Dory	-	7.2	3.1	26.0	29.9	33.7
Ling	-	1.3	6.6	23.0	67.0	2.1
Mackerel	3.5	2.3	0.9	34.2	57.2	1.9
Mullet	21.2	34.6	1.3	10.9	28.3	3.8
Plaice	4.6	2.9	-	18.1	71	3.4
Pollack	-	0.8	1.6	35.0	62.5	-
Pout	-	-	-	34.1	65.9	-
Ray*	-	0.3	0.2	21.5	68.7	9.4
Redfish	14.8	3.4	-	-	72.1	9.7
Saithe / Coalfish	-	0.8	1.9	13.4	83.9	-
Salmon (excluding smoked)	-	0.2	0.4	15.5	80.6	3.2
Sardine (excluding canned)	0.2	6.3	5.2	34.1	51.9	2.2
Scorpion fish	4.4	3.4	8.9	30.3	36.2	16.7
Seabass*	2.0	2.5	5.7	30.8	45.7	13.2
Sea bream*	6.9	6.3	5.6	32.2	40.6	8.4
Smelt	-	-	0.5	22.2	60.9	16.4
Sole	-	2.9	3.4	34.3	54.7	4.7
Sprat	-	-	-	63.2	13.8	23.0
Swordfish*	-	2.1	7.6	15.0	57.8	17.5
Tuna (excluding canned)*	0.4	3.6	5.0	30.7	57.4	2.9
Turbot	-	7.3	5.0	32.8	37.8	17.2
Whiting	-	3.8	4.5	27.5	63.2	1.0
Other**	22.0	8.6	-	27.6	41.8	-

* Predatory fish as described in the Commission Regulation (EC) No 78/2005 of 19 January 2005
** Other : Bogue, roquier, trout, conger eel, sard, shark, coriphaire, rainbow wrasse, gobie

Mollusc, crustacean

Le Havre	Fished or collected	Bought at the port	Bought at the market	Bought from a fishmonger	Bought from a supermarket	Consumed only outside the home
Abalone	27.3	-	10.9	-	25.5	36.4
Calico scallop	2.0	9.7	1.9	6.6	77.8	2.0
Carpet shell	19.9	3.3	-	37.7	36.4	2.6
Clam	62.5	-	-	-	37.5	-
Cockle	16.5	1.4	14.7	22.0	43.2	2.1
Crab	2.6	17.1	3.1	18.3	57.3	1.6
Crayfish	12.6	-	0.5	26.0	59.3	1.6
Cuttle fish	-	28.5	2.1	23.5	43.4	2.4
Donax clam	71.4	-	-	-	28.6	-
Great scallop	2.8	13.8	2.8	19.1	56.2	5.3
Grooved sea squirt	-	-	-	-	-	-
Hard clam	0.3	0.3	3.8	33.5	59.9	2.2
Limpet	100.0	-	-	-	-	-
Lobster	3.6	3.1	1.0	10.2	69.8	12.3
Mussel	0.4	0.3	8.4	25.4	61.4	4.0
Octopus	-	2.2	10.7	17.7	65.1	4.4
Oyster	2.0	4.6	24.4	27.6	39.9	1.5
Periwinkle	4.8	1.8	6.7	23.8	61.4	1.4
Queen scallop	-	-	-	-	-	100.0
Razor clam	-	-	-	-	-	-
Scampi	1.9	1.2	4.0	24.7	62.7	5.4
Sea urchin	-	-	-	-	100.0	-
Shrimp	1.7	2.3	5.0	18.7	71.1	1.2
Slipper lobster	-	-	-	-	-	-
Spider crab	21.5	17.8	3.8	24.5	31.5	0.9
Spiny lobster	-	5.2	0.4	11.2	76.1	7.1
Squid	-	7.1	1.1	11.8	77.3	2.7
Swimcrab	12.2	25.9	5.6	22.0	34.0	0.3
Whelk	0.2	3.5	9.4	22.3	64.2	0.4

Mollusc, crustacean

Lorient	Fished or collected	Bought at the port	Bought at the market	Bought from a fishmonger	Bought from a supermarket	Consumed only outside the home
Abalone	-	100.0	-	-	-	-
Calico scallop	9.7	7.8	12.3	19.7	48.6	1.9
Carpet shell	49.1	11.4	12.2	21.9	3.3	2.0
Clam	41.9	-	21.3	27.1	4.8	4.8
Cockle	65.0	0.9	12.1	12.8	9.2	-
Crab	7.8	15.7	13.9	41.5	20.2	0.8
Crayfish	6.1	-	13.3	13.9	48.6	18.1
Cuttle fish	7.3	4.9	1.2	29.5	57.2	-
Donax clam	68.8	-	-	31.3	-	-
Great scallop	0.5	4.2	6.8	23.1	62.3	2.8
Grooved sea squirt	100.0	-	-	-	-	-
Hard clam	33.6	13.6	11.7	23.1	15.5	2.6
Limpet	100.0	-	-	-	-	-
Lobster	17.5	4.8	6.0	42.8	20.5	8.4
Mussel	5.0	2.2	17.1	36.9	33.9	4.9
Octopus	-	-	14.7	49.2	36.1	-
Oyster	7.5	9.5	34.3	39.5	8.4	1.0
Periwinkle	24.6	2.9	22.6	35.3	14.3	0.4
Queen scallop	-	-	-	-	-	100.0
Razor clam	88.2	-	-	11.8	-	-
Scampi	3.2	14.2	15.2	46.5	20.2	0.7
Sea urchin	23.6	21.8	5.5	21.8	-	27.3
Shrimp	12.3	2.4	10.6	34.9	38.9	1.5
Slipper lobster	-	-	-	-	-	-
Spider crab	14.3	15.3	13.1	37.5	18.3	1.5
Spiny lobster	7.4	3.7	7.4	56.3	17.8	7.4
Squid	10.2	7.6	5.7	30.4	43.4	2.8
Swimcrab	46.9	6.6	13.7	21.0	11.8	-
Whelk	1.7	3.6	9.6	48.9	32.7	3.4

Mollusc, crustacean

La Rochelle	Fished or collected	Bought at the port	Bought at the market	Bought from a fishmonger	Bought from a supermarket	Consumed only outside the home
Abalone	-	-	7.7	-	84.6	7.7
Calico scallop	21.9	8.8	20.2	19.9	27.9	1.3
Carpet shell	32.3	20.8	21.1	9.7	11.8	4.2
Clam	-	33.8	12.8	15.5	30.4	7.4
Cockle	18.3	17.2	28.9	21.2	12.2	2.2
Crab	4.3	9.7	22.1	25.8	33.7	4.5
Crayfish	33.2	7.5	25.8	15.4	5.5	12.6
Cuttle fish	7.2	11.3	20.5	28.1	32.3	0.6
Donax clam	-	-	-	-	-	-
Great scallop	3.0	13.7	21.2	22.7	35.9	3.6
Grooved sea squirt	-	-	-	-	-	-
Hard clam	6.5	26.0	28.8	17.7	19.9	1.1
Limpet	10.2	15.5	37.2	-	37.2	-
Lobster	3.0	10.0	21.4	29.4	21.2	15.0
Mussel	3.6	7.0	33.9	28.2	22.8	4.6
Octopus	6.4	-	53.6	15.5	20.6	3.9
Oyster	10.2	13.2	39.5	17.8	18.3	1.0
Periwinkle	24.0	0.8	36.0	15.3	19.1	4.8
Queen scallop	-	42.4	24.6	10.6	22.5	-
Razor clam	72.6	4.3	-	5.1	5.1	12.8
Scampi	1.7	4.5	28.6	36.8	23.5	4.9
Sea urchin	39.1	-	26.1	6.5	21.7	6.5
Shrimp	5.8	3.7	27.4	28.1	33.6	1.3
Slipper lobster	-	-	100.0	-	-	-
Spider crab	17.0	16.4	29.3	13.5	23.8	-
Spiny lobster	2.4	27.4	14.3	11.9	28.6	15.5
Squid	3.4	11.9	24.8	18.5	37.7	4.1
Swimcrab	26.3	0.3	28.2	35.8	8.5	0.9
Whelk	1.6	11.1	34.6	15.6	25.9	11.1

Mollusc, crustacean

Toulon	Fished or collected	Bought at the port	Bought at the market	Bought from a fishmonger	Bought from a supermarket	Consumed only outside the home
Abalone	25.0	-	-	4.2	12.5	58.3
Calico scallop	-	2.0	0.7	24.3	59.6	13.5
Carpet shell	4.2	3.3	2.8	26.5	35.4	27.8
Clam	1.3	5.0	2.5	31.7	19.6	40.0
Cockle	7.5	-	-	35.2	45.2	12.1
Crab	6.2	0.9	0.9	35.9	37.1	18.9
Crayfish	5.3	-	0.8	12.0	48.1	33.8
Cuttle fish	5.5	2.5	1.3	18.3	67.7	4.7
Donax clam	10.0	-	-	37.6	36.4	16.0
Great scallop	0.3	0.8	-	12.5	79.2	7.2
Grooved sea squirt	3.6	14.9	9.2	34.4	19.0	19.0
Hard clam	2.1	5.1	1.7	33.9	21.4	35.8
Limpet	-	-	-	33.3	-	66.7
Lobster	1.9	2.1	2.7	17.8	48.8	26.7
Mussel	0.2	1.3	3.3	26.5	51.4	17.2
Octopus	16.0	3.2	1.8	17.1	52.0	9.9
Oyster	1.1	2.1	7.1	29.8	43.2	16.7
Periwinkle	9.0	1.0	-	26.9	39.4	24.2
Queen scallop	-	-	-	-	-	100.0
Razor clam	-	-	-	-	54.5	45.5
Sea urchin	59.6	16.9	1.5	9.8	9.2	3.0
Scampi	-	1.0	0.7	25.6	59.3	13.4
Shrimp	0.2	1.0	1.4	17.7	75.5	4.2
Slipper lobster	7.9	15.8	-	31.6	28.9	15.8
Spider crab	17.6	5.9	1.5	36.8	35.3	2.9
Spiny lobster	-	2.6	0.9	16.1	57.4	23.9
Squid	4.8	2.7	0.9	12.9	74.4	4.4
Swimcrab	0.3	1.0	1.0	14.8	55.2	27.6
Whelk	-	25.4	3.4	24.2	33.6	13.5

Appendix 5:
Contributors to the total exposure to omega 3 and contaminants (%) - All subjects, all areas

	OMEGA 3	TRACE ELEMENTS						PERSISTENT ORGANIC POLLUTANTS				
Species	n-3**	MeHg	Cd	Pb	OTC	As_T	As_{inorg}	PBDE	PCDD/F	PCB-DL	Tot diox	iPCB
Anchovy	4.85	0.59	9.93	5.20	3.66	0.57	1.74	3.59	0.62	0.97	0.88	0.81
Angler fish*	0.11	2.23	0.01	0.26	0.96	1.96	0.67	0.85	0.27	0.22	0.23	0.40
Calico scallop	0.43	0.07	4.76	1.61	0.53	0.41	0.23	0.19	0.54	0.18	0.28	0.29
Catshark*	0.27	1.70	2.68	1.00	1.13	4.55	1.40	0.33	0.18	0.18	0.18	0.38
Cockle	0.04	0.06	0.12	0.25	0.47	0.08	0.65	0.07	0.07	0.05	0.05	0.03
Cod	1.38	6.89	0.10	1.59	5.89	10.93	6.04	6.26	1.79	2.17	2.02	1.78
Crab	1.90	2.47	14.61	0.91	1.17	2.49	4.89	1.05	5.78	2.88	3.60	2.81
Cuttle fish	0.24	0.38	0.46	1.20	0.41	0.89	0.57	0.15	0.17	0.07	0.09	0.15
Dab	0.38	1.29	0.01	0.13	0.40	3.75	1.19	0.82	1.13	0.64	0.75	0.40
Eel*	0.66	1.01	0.12	0.42	0.33	0.06	0.10	4.39	1.56	7.00	6.44	8.28
Emperor*	0.69	1.24	0.02	0.18	0.27	0.06	0.09	0.37	1.36	1.50	1.44	1.29
Fish soup	1.90	0.57	2.05	2.12	1.39	0.99	4.13	1.79	1.19	1.05	1.07	0.82
Goatfish	1.08	1.07	0.01	0.12	0.21	2.48	1.41	0.70	2.13	2.23	2.18	1.69
Great scallop	1.10	1.41	9.04	10.67	6.10	2.40	8.55	1.31	3.25	1.29	1.80	2.36
Grenadier/Hoki*	0.23	1.57	0.07	0.25	0.96	1.08	0.51	0.74	0.43	0.20	0.26	0.49
Gurnard	0.02	0.18	0.0004	0.001	0.04	0.11	0.05	0.08	0.19	0.15	0.16	0.15
Haddock	0.07	0.39	0.06	0.11	0.28	0.47	0.28	0.28	0.12	0.10	0.10	0.11
Hake	0.38	4.56	0.01	1.19	2.31	2.57	1.60	1.47	0.53	1.23	1.03	1.33
Halibut*	3.37	0.96	0.95	2.81	2.89	1.31	0.61	1.77	3.35	2.00	2.33	1.76
Herring	4.66	0.25	0.002	0.13	0.32	0.14	0.18	0.58	0.82	0.35	0.46	0.32
John dory	0.09	0.27	0.10	0.13	0.44	0.06	0.15	0.16	0.09	0.16	0.15	0.19
Ling	0.24	5.73	0.17	0.03	1.19	1.89	0.73	1.14	0.39	0.38	0.37	0.48
Lobster	0.16	0.15	1.13	0.03	0.03	0.23	0.18	0.08	0.65	0.25	0.34	0.11
Mackerel	11.52	2.29	1.17	0.59	6.22	1.42	2.80	8.55	6.27	6.84	6.62	6.84
Mussel	0.98	1.15	1.86	10.47	1.34	2.89	4.61	1.34	2.32	1.17	1.45	1.08
Octopus	0.05	0.74	0.26	0.87	0.28	2.71	1.69	0.09	0.15	0.15	0.15	0.12
Oyster	0.68	0.33	3.22	5.08	2.54	1.28	7.04	0.91	3.29	1.51	1.91	1.06
Paella	2.55	0.04	1.72	3.85	1.38	0.17	1.09	1.48	0.96	0.23	0.42	0.17
Periwinkle	0.23	0.04	0.73	1.31	0.26	0.50	1.56	0.28	0.09	0.05	0.06	0.05
Pilchard	0.44	0.04	0.03	0.03	0.10	0.06	0.29	0.51	0.52	0.20	0.28	0.16
Plaice	0.11	0.79	0.00	0.17	0.58	1.63	0.18	0.61	0.70	0.55	0.58	0.50
Pollack	0.15	0.98	0.02	0.02	0.71	0.79	1.55	0.59	0.09	0.51	0.40	0.60
Pout	0.02	0.21	0.001	0.02	0.10	0.28	0.20	0.06	0.02	0.03	0.03	0.03
Ray*	0.52	2.89	2.36	2.95	1.08	9.94	5.15	1.27	1.04	0.49	0.62	0.44
Sea bream*	3.45	2.23	0.02	0.07	1.82	1.77	2.55	2.88	4.10	5.40	5.04	4.88
Saithe / Coalfish	1.76	3.03	4.04	7.17	6.12	1.95	3.48	4.73	0.77	1.18	1.06	1.02
Salmon	26.59	3.72	0.04	0.82	6.45	3.10	4.78	18.76	14.33	14.18	13.99	12.86
Sardine	9.53	2.75	5.24	17.23	4.24	3.86	4.17	6.52	15.84	20.10	18.91	20.39
Scorpion fish	0.30	0.48	0.001	0.002	0.06	0.10	0.10	0.18	0.60	0.63	0.62	0.47
Seabass*	2.72	3.26	0.02	1.37	4.39	0.96	1.57	4.82	5.25	8.09	7.35	8.01
Sea urchin	0.15	0.03	1.24	3.42	0.68	0.61	3.01	0.29	0.25	0.43	0.39	0.21
Scampi	0.33	1.93	1.23	2.19	1.04	2.55	4.40	0.60	1.46	0.49	0.74	0.39
Shrimp	0.69	1.51	15.53	1.83	1.67	1.22	1.56	1.57	0.93	0.39	0.52	0.25
Sole	0.59	5.71	0.18	1.10	1.85	9.69	1.71	1.92	1.11	1.05	1.04	2.46
Spider crab	0.59	0.10	1.03	0.65	0.10	1.49	0.97	0.95	2.08	1.11	1.36	0.64
Squid	0.50	1.16	1.47	0.62	2.57	1.84	0.48	1.19	1.79	1.18	1.32	1.03
Surimi	2.29	0.88	0.74	0.77	4.39	0.39	1.22	2.57	0.31	0.19	0.22	0.76
Swimcrab	0.78	0.53	0.38	2.61	1.01	0.89	0.79	0.54	4.84	4.61	4.65	4.47
Swordfish*	1.83	3.78	0.80	0.01	1.43	0.11	0.42	0.53	0.21	0.36	0.32	0.30
Tarama	1.40	0.01	0.004	0.01	0.09	0.03	0.12	0.77	0.10	0.08	0.09	0.12
Tuna*	4.35	19.21	3.26	0.85	13.34	2.38	2.10	5.07	1.01	1.87	1.62	2.20
Whelk	0.37	0.64	6.95	3.35	1.24	3.81	2.24	0.57	2.15	0.39	0.91	0.28
Whiting	0.28	4.50	0.05	0.22	1.53	2.09	2.21	1.66	0.79	1.27	1.15	1.77

* Predatory fish as described in the Commission Regulation (EC) No 78/2005 of 19 January 2005
For certain species the different packaging are taken into account: Herring: fresh and canned, Mackerel: fresh, canned and smoked, Sardine: fresh and canned, Salmon: fresh and smoked, Tuna :fresh and canned, Anchovy: fresh and canned, Crab: fresh and canned, Haddock: fresh and smoked
** omega 3 (ALA, C18:4 n-3, EPA, DPA and DHA)

Contributors to the total exposure to omega 3 and contaminants (%) – All subjects – Le Havre

	OMEGA 3	TRACE ELEMENTS						PERSISTENT ORGANIC POLLUTANTS				
Species	n-3**	MeHg	Cd	Pb	OTC	As_T	As_{inorg}	PBDE	PCDD/F	PCB-DL	Tot diox	iPCB
Anchovy	1.94	0.29	1.68	2.43	1.10	0.21	0.64	1.41	0.21	0.37	0.33	0.31
Angler fish*	0.12	1.66	0.00	0.25	0.32	1.05	0.91	0.62	0.15	0.11	0.12	0.08
Catshark*	0.83	1.38	10.28	3.71	2.98	6.76	2.70	0.80	0.58	0.51	0.52	0.86
Cod	1.72	8.04	0.03	1.70	4.90	20.45	13.26	9.36	1.08	2.13	1.83	1.70
Crab	2.15	6.98	0.47	1.35	2.74	2.69	5.96	1.56	9.92	7.45	8.01	9.00
Dab	0.41	1.13	0.00	0.13	0.40	3.79	0.99	0.93	1.59	1.10	1.23	0.59
Eel*	0.38	0.78	0.34	0.46	0.17	0.04	0.06	2.09	0.85	2.97	2.76	3.44
Fish soup	0.71	0.34	0.21	0.86	0.41	0.42	1.50	0.71	0.34	0.31	0.32	0.22
Great scallop	2.12	0.59	13.84	22.21	13.30	2.53	15.33	1.18	5.65	2.71	3.52	4.71
Grenadier/Hoki*	0.13	1.22	0.00	0.89	0.30	0.63	0.27	0.93	0.36	0.15	0.21	0.29
Hake	0.24	0.93	0.00	0.02	0.39	0.22	0.49	0.41	0.10	0.24	0.20	0.26
Halibut*	3.71	1.99	0.00	0.02	3.64	1.82	0.46	2.73	3.27	3.09	3.12	2.58
Herring	7.23	0.28	0.00	0.14	0.19	0.13	0.15	0.41	0.57	0.25	0.33	0.21
Ling	0.35	7.62	0.00	0.02	0.46	1.66	0.55	1.09	0.20	0.21	0.20	0.23
Mackerel	16.10	3.58	0.54	0.60	8.00	1.44	2.16	16.35	13.38	13.42	13.32	13.31
Mussel	0.97	0.31	0.02	14.29	1.29	0.69	10.18	0.80	2.62	1.52	1.80	1.41
Oyster	0.45	0.37	0.01	0.02	3.31	0.98	9.13	0.32	2.64	1.18	1.55	0.58
Paella	2.43	0.05	0.49	4.04	1.01	0.16	0.99	1.38	0.86	0.22	0.39	0.14
Periwinkle	0.30	0.06	0.37	1.65	0.04	0.30	1.18	0.35	0.07	0.04	0.05	0.04
Pilchard	0.53	0.07	0.01	0.05	0.09	0.07	0.31	0.69	0.51	0.21	0.29	0.16
Plaice	0.30	2.97	0.00	0.62	1.93	5.86	0.43	2.20	2.61	2.05	2.18	1.83
Pollack	0.20	1.91	0.00	0.01	0.58	0.94	0.67	0.73	0.11	0.49	0.40	0.58
Ray*	0.51	2.91	0.03	0.31	1.20	9.69	5.24	1.30	0.80	0.47	0.55	0.44
Saithe / Coalfish	1.10	3.95	0.01	0.72	4.07	1.65	4.42	4.07	0.59	0.95	0.84	0.86
Salmon	31.46	5.57	0.02	0.48	7.33	3.21	3.03	18.29	9.60	12.13	11.36	11.01
Sardine	6.22	1.25	1.92	16.93	3.19	2.30	2.12	4.30	9.25	14.02	12.89	13.28
Scampi	0.15	0.50	0.67	1.10	1.07	1.49	0.90	0.18	1.03	0.22	0.45	0.14
Seabass*	1.60	4.97	0.00	1.81	2.03	0.64	0.47	5.31	4.90	6.57	6.14	5.37
Sea bream*	1.76	0.95	0.00	0.06	0.81	0.49	0.26	1.24	0.72	1.12	1.01	0.92
Shrimp	0.91	1.26	59.89	4.91	0.73	1.47	1.97	2.11	0.51	0.30	0.35	0.31
Sole	0.48	3.90	0.00	0.04	0.35	8.69	2.37	1.55	0.76	1.30	1.14	2.64
Squid	0.69	2.59	0.07	0.42	6.56	2.92	0.66	2.80	4.99	3.07	3.55	2.44
Surimi	3.44	1.51	0.41	1.23	5.04	0.58	1.70	3.73	0.47	0.31	0.35	1.07
Swimcrab	1.54	1.59	0.88	8.36	3.84	2.41	2.88	1.04	15.48	16.26	15.97	16.39
Swordfish*	0.72	1.72	0.07	0.00	0.52	0.04	0.07	0.23	0.09	0.09	0.09	0.10
Tarama	0.76	0.01	0.00	0.00	0.03	0.01	0.05	0.37	0.03	0.03	0.03	0.04
Tuna*	4.47	19.82	1.29	1.12	10.29	2.14	2.01	4.24	0.94	1.35	1.24	1.63
Whelk	0.76	1.69	6.41	6.93	3.87	7.50	1.61	1.35	1.95	0.86	1.16	0.64
Whiting	0.10	3.24	0.01	0.03	1.51	1.89	1.81	0.80	0.22	0.22	0.21	0.19

* Predatory fish as described in the Commission Regulation (EC) No 78/2005 of 19 January 2005
For certain species the different packaging are taken into account: Herring: fresh and canned, Mackerel: fresh, canned and smoked, Sardine: fresh and canned, Salmon: fresh and smoked, Tuna :fresh and canned, Anchovy: fresh and canned, Crab: fresh and canned, Haddock: fresh and smoked
** omega 3 (ALA, C18:4 n-3, EPA, DPA and DHA)

Contributors to the total exposure to omega 3 and contaminants (%) – All subjects – Lorient

	OMEGA 3	TRACE ELEMENTS						PERSISTENT ORGANIC POLLUTANTS				
Species	n-3**	MeHg	Cd	Pb	OTC	As_T	As_{inorg}	PBDE	PCDD/F	PCB-DL	Tot diox	iPCB
Anchovy	5.43	0.58	7.30	4.76	4.80	0.47	1.50	3.83	0.58	1.07	0.93	1.06
Angler fish*	0.11	2.97	0.01	0.25	1.72	2.43	0.64	1.13	0.17	0.15	0.15	0.15
Catshark*	0.03	0.37	0.00	0.05	0.20	0.93	0.10	0.08	0.01	0.01	0.01	0.03
Cockle	0.10	0.21	0.36	0.29	1.61	0.22	2.07	0.22	0.25	0.17	0.19	0.09
Cod	0.87	6.94	0.15	0.37	4.43	6.35	1.99	4.52	0.91	1.58	1.39	1.48
Crab	2.24	1.02	53.11	1.32	0.79	3.50	9.30	0.97	8.64	3.05	4.55	1.67
Dab	0.12	2.88	0.00	0.01	0.70	3.89	1.23	0.54	0.17	0.13	0.14	0.18
Eel*	0.22	0.49	0.01	0.17	0.16	0.02	0.02	2.16	0.60	3.78	3.42	4.70
Emperor*	0.74	2.48	0.04	0.00	0.44	0.09	0.12	0.66	2.25	3.15	2.90	2.63
Fish soup	2.00	0.52	1.04	1.91	1.80	0.81	3.12	1.81	1.01	0.94	0.95	0.80
Goatfish	1.35	1.06	0.00	0.24	0.22	2.01	2.17	0.79	1.53	1.88	1.78	1.72
Great scallop	0.80	4.10	0.01	1.31	4.79	0.93	2.56	1.54	1.06	0.37	0.55	0.44
Grenadier/Hoki*	0.19	0.81	0.01	0.08	1.35	1.63	0.57	1.09	0.50	0.31	0.35	0.91
Gurnard	0.03	0.71	0.00	0.00	0.15	0.44	0.20	0.31	0.78	0.59	0.63	0.61
Haddock	0.06	0.56	0.00	0.20	0.54	1.27	0.42	0.36	0.14	0.10	0.11	0.14
Hake	0.42	11.26	0.01	0.97	6.10	6.71	3.95	2.87	0.67	1.59	1.35	2.01
Halibut*	1.31	0.38	0.00	0.00	0.91	0.44	0.23	0.74	1.84	0.92	1.16	0.68
Herring	3.60	0.23	0.00	0.14	0.43	0.12	0.15	0.64	0.75	0.34	0.44	0.35
John dory	0.16	0.24	0.39	0.53	0.42	0.08	0.07	0.34	0.20	0.28	0.25	0.41
Ling	0.21	9.17	0.67	0.03	2.33	2.01	0.96	1.33	0.21	0.34	0.30	0.53
Mackerel	12.92	2.42	0.86	0.49	7.22	1.82	5.00	8.60	5.15	6.67	6.23	6.42
Mussel	0.98	1.27	2.02	11.31	1.10	7.30	4.46	0.82	2.64	1.33	1.66	0.79
Oyster	0.61	0.31	0.01	9.16	2.19	1.13	0.56	1.20	2.79	0.98	1.44	0.79
Paella	2.99	0.04	1.36	3.65	2.00	0.14	0.90	1.64	0.86	0.22	0.38	0.18
Periwinkle	0.47	0.08	1.75	2.35	0.58	1.02	2.14	0.59	0.20	0.12	0.14	0.13
Pilchard	0.45	0.03	0.02	0.03	0.13	0.06	0.26	0.52	0.57	0.21	0.30	0.18
Plaice	0.05	0.20	0.00	0.05	0.38	0.66	0.30	0.22	0.20	0.14	0.15	0.16
Pollack	0.25	1.19	0.06	0.07	1.42	1.48	5.21	1.27	0.19	1.38	1.07	1.67
Pout	0.05	0.83	0.00	0.07	0.40	1.15	0.80	0.26	0.09	0.11	0.10	0.10
Ray*	0.54	3.19	0.01	0.03	0.74	11.84	9.15	1.70	0.90	0.39	0.52	0.41
Saithe / Coalfish	0.98	4.50	15.32	28.00	5.90	2.03	3.82	3.55	0.82	1.56	1.36	1.64
Salmon	25.18	3.51	0.03	0.31	2.28	2.66	7.23	17.04	11.06	11.56	11.29	11.42
Sardine	17.45	0.73	4.36	17.51	4.24	3.45	1.83	8.99	25.52	29.25	28.05	30.20
Seabass*	2.10	2.92	0.03	0.81	1.48	0.74	2.39	5.86	4.18	6.91	6.16	7.09
Scampi	0.67	3.49	2.64	5.72	1.32	6.76	6.77	1.33	2.84	1.00	1.47	0.79
Sea bream*	2.28	1.07	0.00	0.12	1.96	0.82	4.92	2.02	1.98	6.35	5.35	7.58
Shrimp	0.74	1.98	0.58	0.04	3.82	0.84	1.54	1.46	2.04	0.79	1.13	0.35
Sole	0.43	4.41	0.01	0.72	3.41	7.52	0.89	1.84	0.74	0.66	0.67	1.37
Spider crab	1.67	0.42	4.15	2.61	0.41	6.02	3.90	3.84	8.38	4.49	5.48	2.58
Squid	0.17	0.48	0.01	1.14	1.45	1.86	0.39	0.55	0.77	0.56	0.60	0.65
Surimi	1.42	0.45	0.23	0.33	3.98	0.17	0.53	1.59	0.14	0.09	0.11	0.47
Swimcrab	0.94	0.52	0.64	2.09	0.18	1.16	0.29	1.12	3.90	2.19	2.65	1.51
Swordfish*	1.52	3.68	0.59	0.00	2.35	0.16	1.23	0.60	0.17	0.37	0.32	0.24
Tarama	1.40	0.01	0.00	0.01	0.12	0.03	0.10	0.77	0.09	0.07	0.07	0.11
Tuna*	3.57	12.30	2.20	0.71	15.60	2.21	1.58	5.03	0.56	0.75	0.69	1.16
Whiting	0.19	2.98	0.01	0.03	1.46	2.62	2.42	1.68	0.92	1.11	1.05	1.41

* Predatory fish as described in the Commission Regulation (EC) No 78/2005 of 19 January 2005
For certain species the different packaging are taken into account: Herring: fresh and canned, Mackerel: fresh, canned and smoked, Sardine: fresh and canned, Salmon: fresh and smoked, Tuna :fresh and canned, Anchovy: fresh and canned, Crab: fresh and canned, Haddock: fresh and smoked
** omega 3 (ALA, C18:4 n-3, EPA, DPA and DHA)

Contributors to the total exposure to omega 3 and contaminants (%) – All subjects – La Rochelle

	OMEGA 3	TRACE ELEMENTS						PERSISTENT ORGANIC POLLUTANTS				
Species	n-3**	MeHg	Cd	Pb	OTC	As_T	As_{inorg}	PBDE	PCDD/F	PCB-DL	Tot diox	iPCB
Anchovy	3.78	0.40	7.69	3.25	2.65	0.41	1.54	2.43	0.35	0.59	0.52	0.51
Angler fish*	0.11	1.88	0.01	0.01	0.57	2.02	0.59	0.83	0.15	0.08	0.09	0.05
Calico scallop	1.16	0.27	19.12	6.45	2.12	1.65	0.91	0.75	2.17	0.71	1.12	1.15
Catshark*	0.16	2.53	0.03	0.21	0.83	4.88	1.57	0.30	0.05	0.13	0.10	0.49
Cockle	0.03	0.02	0.13	0.70	0.27	0.09	0.56	0.04	0.05	0.01	0.02	0.01
Cod	1.50	6.92	0.06	0.10	8.80	8.58	4.16	3.78	1.20	2.11	1.78	2.04
Crab	2.21	0.58	1.21	0.28	0.44	3.34	2.59	0.81	4.25	0.92	1.70	0.55
Cuttle fish	0.77	1.47	0.53	0.01	1.41	3.38	1.73	0.44	0.17	0.06	0.08	0.29
Dab	0.25	0.37	0.00	0.15	0.20	1.29	0.21	0.69	0.94	0.51	0.58	0.31
Eel*	1.93	2.46	0.13	0.87	0.89	0.15	0.28	11.55	3.90	18.23	16.73	21.55
Emperor*	0.69	1.34	0.03	0.69	0.30	0.10	0.18	0.40	1.63	1.34	1.36	1.16
Fish soup	2.47	0.66	2.38	2.22	1.80	1.31	6.09	2.03	1.20	1.20	1.16	0.95
Goatfish	1.15	1.37	0.02	0.22	0.46	2.99	2.29	0.78	1.67	1.72	1.65	1.05
Great scallop	1.02	0.48	2.28	11.03	4.37	2.08	2.04	1.46	5.30	1.89	2.73	4.04
Grenadier/Hoki*	0.52	3.75	0.06	0.01	1.63	1.46	0.98	0.64	0.55	0.20	0.29	0.38
Haddock	0.13	0.98	0.24	0.10	0.53	0.55	0.54	0.69	0.31	0.30	0.28	0.30
Hake	0.51	5.25	0.02	3.16	2.08	3.08	1.65	2.08	0.86	2.83	2.26	2.87
Halibut*	4.67	1.30	0.01	0.01	0.49	0.74	0.48	1.35	2.47	1.39	1.62	1.89
Herring	4.85	0.25	0.00	0.10	0.40	0.16	0.23	0.65	0.71	0.32	0.40	0.30
Ling	0.21	1.10	0.01	0.02	1.28	1.68	0.88	1.26	0.22	0.39	0.33	0.44
Mackerel	10.39	1.90	1.69	0.82	6.39	1.65	3.12	5.02	3.31	3.43	3.24	3.14
Mussel	1.64	1.91	5.41	16.41	2.34	1.90	2.76	2.44	1.62	0.47	0.76	0.36
Oyster	1.51	0.63	11.29	11.13	2.57	1.89	14.42	1.41	5.62	3.14	3.61	2.32
Paella	1.71	0.03	1.08	1.84	1.01	0.12	0.84	0.89	0.46	0.12	0.21	0.10
Periwinkle	0.11	0.03	0.84	1.26	0.42	0.68	2.95	0.16	0.08	0.05	0.06	0.04
Pilchard	0.58	0.04	0.04	0.04	0.14	0.07	0.42	0.52	0.58	0.24	0.32	0.20
Pollack	0.11	0.86	0.00	0.01	0.87	0.74	0.36	0.38	0.06	0.16	0.13	0.14
Ray*	0.67	4.42	9.41	11.48	1.63	15.38	5.89	1.23	1.53	0.46	0.72	0.33
Saithe / Coalfish	3.87	2.26	0.58	0.06	8.62	1.73	1.26	8.43	0.75	1.08	0.95	0.65
Salmon	27.14	3.61	0.04	0.27	4.65	2.81	5.28	20.90	21.52	17.12	17.69	14.78
Sardine	8.66	6.11	5.92	15.79	6.27	4.29	3.63	7.54	16.57	20.58	19.16	18.71
Seabass*	1.14	2.97	0.01	0.20	3.93	1.28	1.56	1.85	4.05	6.17	5.48	5.98
Sea bream*	1.70	2.69	0.01	0.02	1.55	1.30	1.49	1.27	3.38	3.96	3.67	3.49
Scampi	0.46	3.79	1.64	2.00	1.80	2.02	10.01	0.89	1.99	0.73	1.05	0.62
Shrimp	0.82	1.37	0.02	0.03	1.35	0.59	2.01	1.52	0.24	0.36	0.31	0.26
Sole	0.70	7.52	0.57	1.68	1.02	11.83	2.36	2.66	1.09	0.86	0.87	2.43
Squid	0.40	0.62	3.10	0.25	1.56	2.28	0.29	0.63	1.21	0.97	0.99	0.95
Surimi	1.56	0.51	0.63	0.42	3.50	0.23	0.93	1.55	0.14	0.10	0.11	0.44
Swordfish*	2.30	2.16	0.58	0.01	2.21	0.10	0.24	0.60	0.24	0.30	0.27	0.11
Tarama	1.22	0.01	0.00	0.00	0.07	0.02	0.10	0.56	0.05	0.06	0.05	0.08
Tuna*	4.43	20.67	2.33	0.38	15.37	1.67	2.56	5.28	1.39	4.06	3.29	4.06
Whelk	0.59	0.65	20.69	6.18	0.90	6.07	6.15	0.65	5.82	0.47	2.11	0.35
Whiting	0.18	1.86	0.16	0.14	0.27	1.40	1.83	0.64	0.17	0.14	0.14	0.12

* Predatory fish as described in the Commission Regulation (EC) No 78/2005 of 19 January 2005
For certain species the different packaging are taken into account: Herring: fresh and canned, Mackerel: fresh, canned and smoked, Sardine: fresh and canned, Salmon: fresh and smoked, Tuna :fresh and canned, Anchovy: fresh and canned, Crab: fresh and canned, Haddock: fresh and smoked
** omega 3 (ALA, C18:4 n-3, EPA, DPA and DHA)

Contributors to the total exposure to omega 3 and contaminants (%) – All subjects – Toulon

	OMEGA 3	TRACE ELEMENTS						PERSISTENT ORGANIC POLLUTANTS				
Species	n-3**	MeHg	Cd	Pb	OTC	As_T	As_{inorg}	PBDE	PCDD/F	PCB-DL	Tot diox	iPCB
Anchovy	8.41	1.08	22.86	10.29	6.06	1.17	3.27	6.65	1.33	1.83	1.70	1.37
Angler fish*	0.09	2.43	0.01	0.51	1.23	2.34	0.53	0.83	0.59	0.54	0.55	1.30
Catshark*	0.07	2.52	0.41	0.01	0.51	5.59	1.24	0.12	0.08	0.07	0.07	0.13
Cod	1.50	5.66	0.17	4.15	5.43	8.33	4.73	7.36	3.93	2.84	3.06	1.91
Crab	1.09	1.30	4.04	0.71	0.71	0.49	1.76	0.88	0.41	0.12	0.19	0.04
Cuttle fish	0.09	0.07	1.30	4.74	0.25	0.18	0.55	0.17	0.49	0.23	0.29	0.30
Dab	0.75	0.79	0.02	0.23	0.32	6.00	2.31	1.13	1.80	0.82	1.05	0.53
Eel*	0.19	0.32	0.02	0.19	0.08	0.02	0.03	1.80	0.89	3.10	2.92	3.52
Emperor*	0.80	1.16	0.03	0.04	0.35	0.07	0.06	0.41	1.57	1.51	1.51	1.36
Fish soup	2.51	0.75	4.54	3.45	1.56	1.42	5.78	2.59	2.17	1.75	1.83	1.31
Goatfish	1.44	1.84	0.01	0.02	0.16	4.90	1.19	1.24	5.28	5.27	5.24	3.97
Great scallop	0.51	0.47	19.81	8.10	1.97	4.02	14.13	1.08	0.99	0.23	0.40	0.25
Grenadier/Hoki*	0.11	0.52	0.19	0.01	0.55	0.59	0.23	0.32	0.30	0.16	0.19	0.36
Haddock	0.04	0.01	0.00	0.06	0.02	0.02	0.06	0.04	0.03	0.01	0.01	0.01
Hake	0.38	0.91	0.02	0.62	0.72	0.34	0.34	0.56	0.50	0.28	0.33	0.21
Halibut*	3.97	0.17	3.76	11.07	6.47	2.22	1.25	2.23	5.78	2.60	3.41	1.86
Herring	3.21	0.25	0.00	0.15	0.26	0.16	0.19	0.63	1.25	0.48	0.65	0.42
John dory	0.09	0.84	0.00	0.01	1.34	0.14	0.52	0.31	0.16	0.38	0.33	0.37
Lobster	0.17	0.58	4.46	0.11	0.11	0.90	0.70	0.32	2.58	0.97	1.36	0.42
Ling	0.18	5.04	0.01	0.07	0.71	2.21	0.56	0.90	0.92	0.58	0.65	0.72
Mackerel	7.23	1.27	1.58	0.44	3.32	0.80	0.97	4.25	3.26	3.87	3.70	4.50
Mussel	0.39	1.10	0.02	0.03	0.63	1.73	1.06	1.29	2.41	1.36	1.58	1.74
Octopus	0.15	2.91	1.03	3.43	1.10	10.69	6.69	0.36	0.58	0.58	0.58	0.46
Oyster	0.20	0.03	1.60	0.14	2.09	1.13	4.07	0.72	2.15	0.77	1.07	0.56
Paella	3.18	0.05	3.92	5.85	1.51	0.27	1.62	2.01	1.66	0.37	0.68	0.27
Pilchard	0.23	0.02	0.03	0.02	0.06	0.04	0.17	0.32	0.43	0.15	0.21	0.11
Ray*	0.37	1.09	0.01	0.02	0.73	2.97	0.44	0.86	0.95	0.63	0.69	0.58
Saithe / Coalfish	1.25	1.44	0.36	0.13	5.91	2.38	4.40	2.91	0.90	1.14	1.07	0.93
Salmon	23.87	2.22	0.07	2.20	11.45	3.70	3.60	18.81	15.13	15.88	15.61	14.23
Sardine	6.14	2.90	8.70	18.69	3.30	5.38	9.02	5.29	12.14	16.67	15.64	19.48
Scorpion fish	0.82	1.90	0.01	0.01	0.25	0.40	0.41	0.70	2.38	2.49	2.45	1.86
Seabass*	6.10	2.19	0.03	2.62	10.05	1.17	1.85	6.25	7.84	12.65	11.56	13.50
Sea bream*	8.17	4.19	0.06	0.08	2.92	4.44	3.53	6.95	10.23	10.09	10.05	7.51
Sea urchin	0.58	0.12	4.90	13.53	2.70	2.42	11.90	1.14	0.99	1.72	1.55	0.83
Shrimp	0.34	1.43	1.62	2.34	0.80	1.97	0.74	1.21	0.91	0.13	0.30	0.08
Sole	0.76	6.99	0.12	1.95	2.64	10.70	1.23	1.63	1.83	1.37	1.47	3.39
Squid	0.77	0.93	2.67	0.69	0.73	0.31	0.58	0.80	0.21	0.14	0.16	0.10
Surimi	2.83	1.03	1.66	1.09	5.04	0.57	1.72	3.37	0.50	0.27	0.32	1.08
Swordfish*	2.86	7.50	1.95	0.01	0.65	0.16	0.13	0.68	0.35	0.69	0.61	0.76
Tarama	2.29	0.02	0.01	0.01	0.14	0.06	0.21	1.37	0.24	0.17	0.19	0.26
Tuna*	5.11	23.93	7.16	1.21	12.14	3.48	2.24	5.73	1.16	1.33	1.28	1.96
Whelk	0.10	0.23	0.79	0.32	0.19	1.66	1.22	0.29	0.84	0.23	0.36	0.14
Whiting	0.64	9.83	0.04	0.69	2.86	2.44	2.75	3.52	1.86	3.57	3.17	5.32

* Predatory fish as described in the Commission Regulation (EC) No 78/2005 of 19 January 2005
For certain species the different packaging are taken into account: Herring: fresh and canned, Mackerel: fresh, canned and smoked, Sardine: fresh and canned, Salmon: fresh and smoked, Tuna :fresh and canned, Anchovy: fresh and canned, Crab: fresh and canned, Haddock: fresh and smoked
** omega 3 (ALA, C18:4 n-3, EPA, DPA and DHA)

Appendix 6: Contributors to the recommendation for EPA and DHA and to the tolerable intake of contaminants (%) - All subjects, all areas

	OMEGA 3	TRACE ELEMENTS						PERSISTENT ORGANIC POLLUTANTS	
	EPA+DHA	MeHg	Cd	Pb	OTC	As_T	As_{inorg}	Tot diox	iPCB
Anchovy	**13.3**	0.49	1.90	0.09	0.33	0.11	0.07	0.86	1.92
Angler fish*	0.27	2.15	0.00	0.00	0.05	0.45	0.03	0.17	0.60
Calico scallop	0.89	0.06	2.04	0.05	0.05	0.09	0.01	0.26	0.56
Catshark*	0.66	1.58	1.77	0.01	0.10	1.24	0.05	0.12	0.63
Cockle	0.08	0.05	0.02	0.00	0.05	0.02	0.03	0.05	0.05
Cod	2.76	**5.08**	0.01	0.01	0.38	2.13	0.20	1.19	2.41
Crab	4.65	1.79	**7.76**	0.01	0.10	0.59	0.24	4.20	**8.18**
Cuttle fish	0.54	0.37	0.06	0.02	0.03	0.19	0.02	0.07	0.26
Dab	0.83	1.42	0.00	0.00	0.03	1.39	0.05	0.62	0.70
Eel*	1.16	1.01	0.00	0.00	0.03	0.01	0.00	**9.79**	**55.6**
Emperor*	1.31	1.79	0.00	0.00	0.03	0.02	0.00	2.18	4.11
Fish soup	3.29	0.41	0.20	0.03	0.10	0.18	0.15	0.74	1.21
Goatfish	3.15	1.20	0.00	0.00	0.03	0.69	0.07	2.40	4.04
Great scallop	2.47	1.22	2.60	0.16	0.80	0.46	0.40	1.44	4.36
Grenadier / hoki*	0.46	1.57	0.01	0.00	0.05	0.24	0.02	0.21	0.79
Gurnard	0.07	0.24	0.00	0.00	0.00	0.05	0.00	0.26	0.51
Haddock	0.17	0.45	0.00	0.00	0.00	0.12	0.01	0.13	0.28
Hake	0.78	4.99	0.00	0.02	0.13	0.68	0.07	0.95	2.60
Halibut*	**8.06**	0.95	0.09	0.07	0.55	0.29	0.02	2.36	3.97
Herring	**14.0**	0.19	0.00	0.00	0.03	0.03	0.01	0.38	0.57
John dory	0.24	0.27	0.02	0.00	0.05	0.01	0.01	0.13	0.37
Ling	0.60	**5.54**	0.02	0.00	0.05	0.38	0.03	0.25	0.68
Lobster	0.29	0.14	0.15	0.00	0.00	0.05	0.01	0.23	0.15
Mackerel	**28.0**	1.88	0.14	0.01	0.40	0.31	0.12	**8.45**	**20.8**
Mussel	2.00	0.86	0.20	0.15	0.10	0.64	0.18	1.05	1.64
Octopus	0.12	0.75	0.03	0.01	0.03	0.67	0.08	0.08	0.16
Oyster	1.33	0.24	0.40	0.09	0.25	0.26	0.29	1.72	1.92
Paella	3.88	0.03	0.15	0.04	0.10	0.03	0.03	0.23	0.20
Periwinkle	0.40	0.03	0.16	0.02	0.03	0.11	0.07	0.05	0.09
Pilchard	1.13	0.03	0.00	0.00	0.00	0.01	0.01	0.27	0.33
Plaice	0.32	0.60	0.00	0.00	0.05	0.52	0.01	0.83	1.62
Pollack	0.34	0.86	0.00	0.00	0.05	0.19	0.08	0.33	1.03
Pout	0.04	0.20	0.00	0.00	0.00	0.08	0.01	0.03	0.06
Ray*	1.22	2.58	0.28	0.05	0.10	2.79	0.23	0.49	0.76
Saithe	3.78	2.21	0.94	0.15	0.45	0.35	0.12	0.64	1.34
Salmon	**66.2**	1.33	0.00	0.00	0.23	0.27	0.09	**6.15**	**11.6**
Sardine	**23.8**	2.63	0.65	0.27	0.25	0.77	0.16	**24.0**	**57.4**
Scampi	0.73	1.63	0.24	0.03	0.08	0.64	0.18	0.67	0.67
Scorpion fish	0.63	0.41	0.00	0.00	0.00	0.02	0.00	0.45	0.77
Sea bream*	8.96	2.29	0.00	0.00	0.13	0.39	0.14	**5.93**	**13.9**
Sea urchin	0.34	0.03	0.17	0.11	0.10	0.17	0.27	0.30	0.35
Seabass*	**7.12**	2.96	0.00	0.02	0.45	0.20	0.07	**7.94**	**19.0**
Shrimp	1.59	1.14	**10.97**	0.02	0.10	0.22	0.06	0.40	0.40
Sole	1.02	**5.16**	0.02	0.01	0.10	2.55	0.06	0.77	4.34
Spider crab	1.03	0.10	0.30	0.01	0.00	0.48	0.06	1.55	1.27
Squid	1.10	0.85	0.18	0.01	0.40	0.41	0.02	1.30	2.19
Surimi	3.99	0.53	0.06	0.01	0.40	0.05	0.03	0.10	0.84
Swimcrab	2.22	0.41	0.18	0.05	0.13	0.26	0.04	**12.1**	**29.0**
Swordfish*	**5.89**	**6.48**	0.11	0.00	0.13	0.03	0.02	0.32	0.68
Tarama	2.15	0.01	0.00	0.00	0.00	0.00	0.00	0.05	0.16
Tuna*	**8.62**	**17.5**	0.27	0.01	1.05	0.45	0.07	1.35	3.73
Whelk	0.72	0.44	2.80	0.06	0.15	0.97	0.10	0.86	0.53
Whiting	0.63	4.52	0.00	0.00	0.10	0.45	0.09	0.81	2.86
TOTAL	**239**	**91.7**	**34.9**	**1.62**	**8.23**	**23.7**	**4.19**	**108**	**274**

In bold: mean contributors (>5%)
* Predatory fish as described in the Commission Regulation (EC) No 78/2005 of 19 January 2005
For certain species the different packaging are taken into account: Herring: fresh and canned, Mackerel: fresh, canned and smoked, Sardine: fresh and canned, Salmon: fresh and smoked, Tuna :fresh and canned, Anchovy: fresh and canned, Crab: fresh and canned, Haddock: fresh and smoked
COT=TBT+DBT+TPT+DOT; Tot diox=PCDD/F+DL-PCB

Contributors to the recommendation for EPA and DHA and to the tolerable intake of contaminants (%) – All subjects, Le Havre

	OMEGA 3	TRACE ELEMENTS						PERSISTENT ORGANIC POLLUTANTS	
	EPA+DHA	MeHg	Cd	Pb	OTC	As_T	As_{inorg}	Tot diox	iPCB
Anchovy	**5.38**	0.19	0.76	0.04	0.13	0.04	0.03	0.30	0.66
Angler fish*	0.41	1.10	0.00	0.00	0.03	0.24	0.04	0.11	0.18
Catshark*	2.01	0.75	**7.05**	0.04	0.28	1.56	0.10	0.36	1.46
Cod	3.53	4.42	0.00	0.01	0.55	4.26	0.50	1.02	2.30
Crab	**6.25**	4.46	0.27	0.02	0.30	0.59	0.26	**10.2**	**28.4**
Dab	1.04	0.91	0.00	0.00	0.03	1.59	0.04	1.15	1.16
Eel*	0.46	0.41	0.00	0.00	0.00	0.00	0.00	3.94	**22.4**
Fish soup	1.42	0.17	0.08	0.01	0.05	0.08	0.06	0.31	0.51
Great scallop	4.75	0.32	**7.39**	0.33	2.28	0.49	0.75	2.59	**8.63**
Grenadier / hoki*	0.31	0.87	0.00	0.01	0.05	0.15	0.01	0.19	0.61
Haddock	0.18	0.02	0.00	0.00	0.00	0.01	0.00	0.01	0.01
Hake	0.49	0.76	0.00	0.00	0.05	0.05	0.02	0.11	0.34
Halibut*	10.7	1.79	0.00	0.00	0.98	0.50	0.02	3.73	**6.52**
Herring	**29.6**	0.16	0.00	0.00	0.03	0.02	0.01	0.33	0.49
Ling	1.14	**6.50**	0.00	0.00	0.08	0.42	0.02	0.19	0.49
Mackerel	**49.2**	2.26	0.17	0.01	0.73	0.30	0.08	**20.1**	**49.4**
Mussel	2.23	0.17	0.01	0.17	0.10	0.13	0.42	1.47	2.74
Oyster	1.23	0.22	0.00	0.00	0.53	0.21	0.51	1.71	1.50
Paella	3.77	0.02	0.14	0.04	0.08	0.03	0.03	0.22	0.19
Periwinkle	0.44	0.03	0.17	0.02	0.00	0.06	0.05	0.04	0.09
Pilchard	1.27	0.04	0.00	0.00	0.00	0.01	0.01	0.30	0.36
Plaice	0.85	2.15	0.00	0.01	0.18	1.78	0.02	3.13	**6.08**
Pollack	0.49	1.34	0.00	0.00	0.08	0.20	0.03	0.32	1.13
Ray*	1.34	1.88	0.01	0.00	0.15	2.62	0.24	0.47	0.90
Saithe	2.28	2.26	0.00	0.01	0.35	0.30	0.16	0.41	1.07
Salmon	**80.4**	1.55	0.00	0.00	0.40	0.28	0.06	4.72	**10.8**
Sardine	**17.1**	0.72	0.56	0.22	0.28	0.44	0.07	**19.6**	**51.9**
Scampi	0.35	0.28	0.32	0.01	0.13	0.32	0.04	0.38	0.28
Sea bream*	**5.54**	0.78	0.00	0.00	0.08	0.11	0.01	1.19	2.56
Seabass*	4.44	3.63	0.00	0.02	0.18	0.11	0.02	**8.30**	**16.7**
Shrimp	2.36	0.71	**43.73**	0.05	0.05	0.30	0.08	0.27	0.57
Sole	0.97	2.68	0.00	0.00	0.03	2.45	0.10	1.00	**5.92**
Squid	1.80	1.69	0.03	0.00	1.25	0.62	0.02	3.65	**5.67**
Surimi	**5.64**	0.74	0.08	0.01	0.55	0.07	0.05	0.14	1.18
Swimcrab	4.79	1.07	0.49	0.16	0.50	0.57	0.14	**43.6**	**112**
Swordfish*	4.01	4.00	0.06	0.00	0.13	0.01	0.01	0.17	0.44
Tarama	1.32	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.09
Tuna*	**9.02**	**13.1**	0.21	0.01	1.05	0.37	0.07	0.66	2.00
Whelk	1.55	1.00	**4.79**	0.11	0.55	2.06	0.07	1.04	1.23
Whiting	0.32	2.34	0.00	0.00	0.10	0.40	0.07	0.20	0.41
TOTAL	**270**	**67.5**	**66.3**	**1.33**	**12.3**	**23.8**	**4.21**	**138**	**349**

In bold: mean contributors (>5%)
* Predatory fish as described in the Commission Regulation (EC) No 78/2005 of 19 January 2005
For certain species the different packaging are taken into account: Herring: fresh and canned, Mackerel: fresh, canned and smoked, Sardine: fresh and canned, Salmon: fresh and smoked, Tuna :fresh and canned, Anchovy: fresh and canned, Crab: fresh and canned, Haddock: fresh and smoked
COT=TBT+DBT+TPT+DOT; Tot diox=PCDD/F+DL-PCB

Contributors to the recommendation for EPA and DHA and to the tolerable intake of contaminants (%) – All subjects, Lorient

	OMEGA 3	TRACE ELEMENTS						PERSISTENT ORGANIC POLLUTANTS	
	EPA+DHA	MeHg	Cd	Pb	OTC	As_T	As_{inorg}	Tot diox	iPCB
Anchovy	**16.3**	0.59	1.94	0.09	0.35	0.13	0.08	1.22	2.90
Angler fish*	0.23	2.98	0.00	0.00	0.05	0.66	0.03	0.14	0.27
Catshark*	0.07	0.40	0.00	0.00	0.00	0.24	0.00	0.01	0.03
Cockle	0.20	0.19	0.07	0.00	0.13	0.06	0.11	0.19	0.17
Cod	1.86	**6.21**	0.02	0.00	0.10	1.52	0.08	1.06	2.17
Crab	4.80	0.97	**30.51**	0.02	0.05	1.07	0.54	4.87	3.17
Dab	0.27	3.80	0.00	0.00	0.03	1.71	0.08	0.17	0.44
Eel*	0.53	0.43	0.00	0.00	0.00	0.00	0.00	4.16	**23.63**
Emperor*	1.51	3.03	0.01	0.00	0.03	0.02	0.01	3.76	**6.15**
Fish soup	3.43	0.44	0.21	0.03	0.10	0.19	0.16	0.79	1.29
Goatfish	4.36	1.28	0.00	0.00	0.00	0.75	0.15	2.60	**5.12**
Great scallop	1.77	3.81	0.00	0.02	0.38	0.22	0.12	0.45	0.69
Grenadier / hoki*	0.43	0.70	0.00	0.00	0.05	0.38	0.02	0.28	1.45
Gurnard	0.10	0.97	0.00	0.00	0.00	0.19	0.02	1.06	2.04
Haddock	0.14	0.47	0.00	0.00	0.03	0.33	0.02	0.07	0.17
Hake	0.99	**13.7**	0.00	0.01	0.28	2.06	0.22	1.27	3.80
Halibut*	2.26	0.34	0.00	0.00	0.05	0.10	0.01	1.15	1.18
Herring	**9.51**	0.21	0.00	0.00	0.03	0.03	0.01	0.44	0.65
John dory	0.41	0.27	0.10	0.01	0.03	0.03	0.00	0.31	0.91
Ling	0.47	**9.89**	0.10	0.00	0.08	0.48	0.04	0.22	0.73
Mackerel	**25.3**	2.30	0.14	0.01	0.28	0.52	0.29	**7.13**	**14.8**
Mussel	2.10	1.08	0.27	0.17	0.05	1.90	0.21	1.42	1.26
Oyster	1.32	0.29	0.00	0.16	0.15	0.32	0.03	1.56	1.60
Paella	4.35	0.03	0.17	0.04	0.10	0.03	0.04	0.26	0.23
Periwinkle	1.06	0.07	0.33	0.03	0.03	0.26	0.11	0.12	0.22
Pilchard	1.38	0.04	0.01	0.00	0.00	0.02	0.01	0.32	0.39
Plaice	0.16	0.23	0.00	0.00	0.03	0.30	0.02	0.20	0.41
Pollack	0.49	1.12	0.01	0.00	0.05	0.39	0.29	0.89	2.72
Pout	0.10	0.81	0.00	0.00	0.00	0.32	0.04	0.11	0.23
Ray*	1.18	2.81	0.00	0.00	0.03	3.69	0.51	0.39	0.57
Saithe	2.35	3.82	3.76	0.58	0.15	0.46	0.18	1.01	2.41
Salmon	**66.0**	1.37	0.00	0.00	0.05	0.27	0.16	4.73	**9.24**
Sardine	**46.0**	0.66	0.78	0.32	0.15	0.96	0.09	**38.1**	**83.1**
Scampi	1.53	3.22	0.47	0.09	0.05	1.93	0.37	1.52	1.54
Sea bream*	**6.26**	1.35	0.00	0.00	0.13	0.30	0.39	**9.19**	**28.8**
Seabass*	**5.72**	3.39	0.01	0.01	0.05	0.23	0.14	**8.40**	**19.4**
Shrimp	1.64	1.75	0.08	0.00	0.25	0.22	0.07	0.95	0.55
Sole	0.90	4.53	0.00	0.01	0.10	2.75	0.05	0.73	2.89
Spider crab	2.84	0.41	1.20	0.04	0.03	1.94	0.23	**6.25**	**5.11**
Squid	0.41	0.42	0.00	0.01	0.08	0.52	0.02	0.50	1.03
Surimi	2.43	0.32	0.03	0.00	0.25	0.03	0.02	0.06	0.52
Swimcrab	2.17	0.59	0.22	0.04	0.00	0.49	0.02	4.73	4.57
Swordfish*	2.80	**5.00**	0.08	0.00	0.18	0.04	0.06	0.34	0.51
Tarama	2.23	0.01	0.00	0.00	0.00	0.00	0.00	0.05	0.15
Tuna*	**7.35**	**11.4**	0.29	0.01	0.90	0.54	0.07	0.52	1.60
Whiting	0.37	2.89	0.00	0.00	0.08	0.71	0.13	0.97	2.60
TOTAL	**238**	**101**	**40.8**	**1.74**	**4.88**	**29.3**	**5.27**	**115**	**243**

In bold: mean contributors (>5%)
* Predatory fish as described in the Commission Regulation (EC) No 78/2005 of 19 January 2005
For certain species the different packaging are taken into account: Herring: fresh and canned, Mackerel: fresh, canned and smoked, Sardine: fresh and canned, Salmon: fresh and smoked, Tuna :fresh and canned, Anchovy: fresh and canned, Crab: fresh and canned, Haddock: fresh and smoked
COT=TBT+DBT+TPT+DOT; Tot diox=PCDD/F+DL-PCB

Contributors to the recommendation for EPA and DHA and to the tolerable intake of contaminants (%) – All subjects, La Rochelle

	OMEGA 3	TRACE ELEMENTS						PERSISTENT ORGANIC POLLUTANTS	
	EPA+DHA	MeHg	Cd	Pb	OTC	As_T	As_{inorg}	Tot diox	iPCB
Anchovy	**10.9**	0.40	1.20	0.06	0.23	0.09	0.05	0.90	2.18
Angler fish*	0.27	1.99	0.00	0.00	0.03	0.45	0.02	0.10	0.12
Calico scallop	2.27	0.23	**8.20**	0.19	0.23	0.35	0.03	1.06	2.27
Catshark*	0.36	2.48	0.00	0.00	0.05	1.32	0.05	0.08	0.83
Cockle	0.05	0.01	0.02	0.01	0.03	0.02	0.02	0.02	0.02
Cod	2.89	**5.73**	0.00	0.00	0.43	1.55	0.11	1.37	3.19
Crab	4.86	0.52	0.14	0.00	0.03	0.61	0.08	1.66	1.11
Cuttle fish	1.59	1.41	0.06	0.00	0.08	0.74	0.06	0.08	0.56
Dab	0.58	0.35	0.00	0.00	0.03	0.30	0.01	0.67	0.74
Eel*	3.15	2.70	0.01	0.01	0.08	0.03	0.01	**26.3**	**149**
Emperor*	1.39	2.42	0.00	0.02	0.03	0.03	0.01	3.38	**7.31**
Fish soup	4.07	0.49	0.24	0.03	0.13	0.21	0.18	0.89	1.45
Goatfish	3.21	1.80	0.00	0.00	0.05	0.83	0.08	2.81	4.00
Great scallop	2.16	0.38	0.25	0.20	0.35	0.36	0.06	2.51	**7.82**
Grenadier / hoki*	0.95	4.38	0.01	0.00	0.10	0.34	0.03	0.27	0.73
Haddock	0.27	1.31	0.01	0.00	0.03	0.14	0.02	0.44	0.95
Hake	0.97	4.77	0.00	0.05	0.13	0.57	0.05	2.27	**6.08**
Halibut*	**12.0**	1.56	0.00	0.00	0.03	0.18	0.02	2.23	**5.55**
Herring	**10.3**	0.19	0.00	0.00	0.03	0.03	0.01	0.38	0.57
Ling	0.46	0.87	0.00	0.00	0.05	0.32	0.03	0.27	0.73
Mackerel	**18.3**	1.49	0.15	0.01	0.33	0.26	0.09	3.59	**8.08**
Mussel	2.89	1.38	0.51	0.27	0.18	0.29	0.07	0.52	0.48
Oyster	2.35	0.44	1.51	0.19	0.15	0.31	0.47	3.08	3.93
Paella	2.78	0.02	0.10	0.03	0.08	0.02	0.02	0.16	0.14
Periwinkle	0.04	0.02	0.13	0.02	0.03	0.13	0.11	0.05	0.06
Pilchard	1.23	0.03	0.00	0.00	0.00	0.01	0.01	0.29	0.35
Pollack	0.24	0.98	0.00	0.00	0.05	0.19	0.01	0.13	0.28
Ray*	1.31	4.25	1.10	0.21	0.08	3.99	0.18	0.58	0.57
Saithe	**8.11**	1.79	0.04	0.00	0.75	0.29	0.03	0.67	0.95
Salmon	**68.8**	1.51	0.00	0.00	0.18	0.26	0.08	**10.1**	**15.9**
Sardine	**19.1**	**6.65**	0.60	0.27	0.33	0.79	0.10	**28.2**	**59.1**
Scampi	0.89	3.08	0.16	0.03	0.08	0.33	0.33	0.78	0.85
Sea bream*	4.57	3.24	0.00	0.00	0.10	0.32	0.05	**6.02**	**12.3**
Seabass*	2.42	3.18	0.00	0.00	0.18	0.28	0.05	**6.98**	**17.2**
Shrimp	1.70	1.07	0.00	0.00	0.10	0.10	0.06	0.24	0.38
Sole	1.28	**7.14**	0.06	0.03	0.05	2.57	0.06	0.75	4.89
Squid	0.84	0.53	0.46	0.00	0.15	0.43	0.01	0.97	1.97
Surimi	2.86	0.37	0.04	0.00	0.28	0.04	0.02	0.07	0.59
Swordfish*	**6.03**	2.87	0.06	0.00	0.20	0.02	0.01	0.24	0.18
Tarama	1.41	0.01	0.00	0.00	0.00	0.00	0.00	0.03	0.09
Tuna*	**8.43**	**21.6**	0.19	0.00	1.18	0.27	0.07	3.67	**9.46**
Whelk	0.97	0.51	**6.38**	0.13	0.05	1.38	0.25	2.12	0.61
Whiting	0.43	1.72	0.01	0.00	0.00	0.24	0.05	0.13	0.22
TOTAL	**219**	**97.9**	**21.7**	**1.78**	**6.55**	**21.0**	**3.05**	**117**	**334**

In bold: mean contributors (>5%)
* Predatory fish as described in the Commission Regulation (EC) No 78/2005 of 19 January 2005
For certain species the different packaging are taken into account: Herring: fresh and canned, Mackerel: fresh, canned and smoked, Sardine: fresh and canned, Salmon: fresh and smoked, Tuna :fresh and canned, Anchovy: fresh and canned, Crab: fresh and canned, Haddock: fresh and smoked
COT=TBT+DBT+TPT+DOT; Tot diox=PCDD/F+DL-PCB

Contributors to the recommendation for EPA and DHA and to the tolerable intake of contaminants (%) – All subjects, Toulon

	OMEGA 3	TRACE ELEMENTS						PERSISTENT ORGANIC POLLUTANTS	
	EPA+DHA	MeHg	Cd	Pb	OTC	As_T	As_{inorg}	Tot diox	iPCB
Anchovy	**20.6**	0.79	3.69	0.17	0.60	0.18	0.12	1.02	1.96
Angler fish*	0.17	2.53	0.00	0.01	0.13	0.47	0.02	0.31	1.80
Catshark*	0.19	2.68	0.03	0.00	0.05	1.82	0.05	0.05	0.21
Cod	2.77	3.99	0.00	0.03	0.38	1.19	0.12	1.31	1.97
Crab	2.71	1.23	0.35	0.01	0.05	0.09	0.07	0.09	0.05
Cuttle fish	0.27	0.07	0.16	0.09	0.03	0.04	0.03	0.20	0.47
Dab	1.44	0.66	0.00	0.00	0.00	1.95	0.08	0.49	0.46
Eel*	0.52	0.50	0.00	0.00	0.00	0.01	0.00	4.84	**27.5**
Emperor*	1.38	1.75	0.00	0.00	0.05	0.02	0.00	1.60	3.02
Fish soup	4.24	0.53	0.26	0.03	0.13	0.23	0.20	0.96	1.57
Goatfish	3.74	1.72	0.00	0.00	0.00	1.16	0.04	4.15	**7.01**
Great scallop	1.20	0.39	2.72	0.10	0.23	0.74	0.65	0.22	0.32
Grenadier / hoki*	0.17	0.37	0.01	0.00	0.03	0.08	0.01	0.08	0.38
Haddock	0.11	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.01
Hake	0.69	0.85	0.00	0.01	0.05	0.08	0.01	0.16	0.22
Halibut*	**7.26**	0.10	0.34	0.29	1.13	0.38	0.03	2.31	2.62
Herring	**6.75**	0.19	0.00	0.00	0.03	0.03	0.01	0.39	0.57
John dory	0.22	0.82	0.00	0.00	0.15	0.03	0.02	0.22	0.57
Ling	0.33	4.93	0.00	0.00	0.05	0.32	0.01	0.31	0.77
Lobster	0.36	0.56	0.60	0.00	0.00	0.20	0.03	0.90	0.61
Mackerel	**19.3**	1.49	0.12	0.01	0.30	0.17	0.04	3.07	**10.8**
Mussel	0.79	0.81	0.00	0.00	0.05	0.27	0.03	0.80	2.05
Octopus	0.37	2.98	0.10	0.05	0.10	2.63	0.34	0.33	0.61
Oyster	0.44	0.02	0.08	0.00	0.20	0.18	0.14	0.56	0.68
Paella	4.61	0.03	0.18	0.05	0.10	0.03	0.04	0.28	0.24
Pilchard	0.64	0.02	0.00	0.00	0.00	0.01	0.01	0.17	0.21
Ray*	1.03	1.38	0.00	0.00	0.10	0.87	0.02	0.53	1.00
Saithe	2.41	0.98	0.01	0.00	0.58	0.34	0.12	0.48	0.96
Salmon	**50.0**	0.88	0.00	0.01	0.20	0.28	0.05	**5.12**	**10.6**
Sardine	**13.3**	2.50	0.65	0.26	0.20	0.88	0.37	**10.5**	**35.9**
Scorpion fish	1.59	1.63	0.00	0.00	0.03	0.07	0.01	1.79	3.04
Sea bream*	**19.3**	3.76	0.00	0.00	0.20	0.83	0.11	**7.35**	**12.2**
Sea urchin	1.28	0.13	0.66	0.42	0.43	0.66	1.06	1.20	1.36
Seabass*	**15.8**	1.65	0.00	0.02	1.38	0.20	0.05	**8.07**	**22.5**
Shrimp	0.68	1.05	0.07	0.02	0.05	0.29	0.02	0.15	0.09
Sole	0.93	**6.28**	0.00	0.01	0.18	2.43	0.03	0.59	3.65
Squid	1.33	0.75	0.22	0.01	0.08	0.05	0.02	0.08	0.13
Surimi	4.99	0.67	0.07	0.01	0.50	0.07	0.04	0.13	1.07
Swordfish*	**10.6**	**13.9**	0.23	0.00	0.05	0.04	0.01	0.54	1.59
Tarama	3.62	0.01	0.00	0.00	0.00	0.01	0.01	0.09	0.28
Tuna*	**9.65**	**23.8**	0.36	0.01	1.05	0.61	0.06	0.55	1.89
Whelk	0.21	0.25	0.08	0.00	0.03	0.44	0.06	0.29	0.27
Whiting	1.40	**11.0**	0.00	0.01	0.23	0.43	0.09	1.92	**8.15**
TOTAL	**220**	**101**	**11.0**	**1.61**	**9.13**	**20.8**	**4.22**	**64.2**	**171**

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COT=TBT+DBT+TPT+DOT; Tot diox=PCDD/F+DL-PCB

CALIPSO

Fish and seafood consumption study
and biomarker of exposure to
trace elements, pollutants and omega 3.

Issue date :
August 2006

Design-production :
Pascal Devriendt - 02 communication
Rue Charles Humbert 9 - 1205 Genève
02com@bluewin.ch

Printing :
Mâcon Imprimerie

Photo Crédit :
Veronique Sirot - AFSSA