You are what you eat plus a few *per mill*: utilisation des isotopes stables en Ecologie Marine

Traçage des polluants chez les mammifères et autres vertébrés marins

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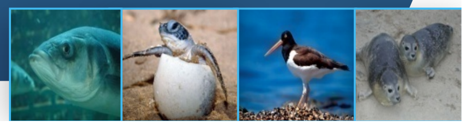
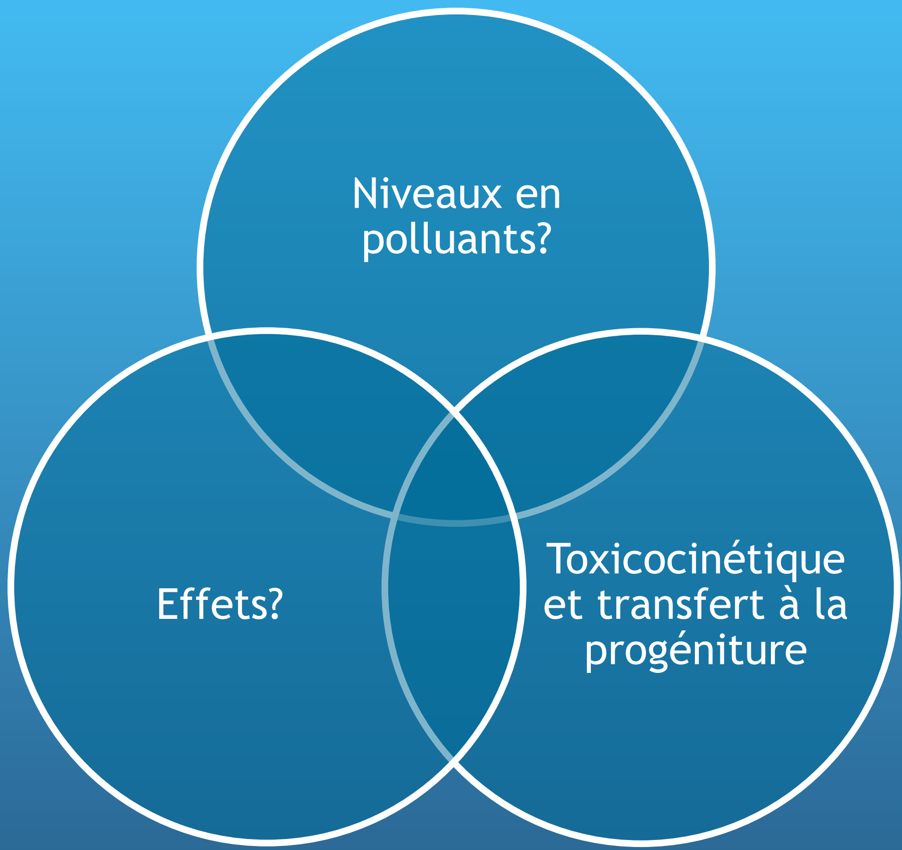


Introduction

Mes axes de recherche



Qu’est ce qu’un polluant?

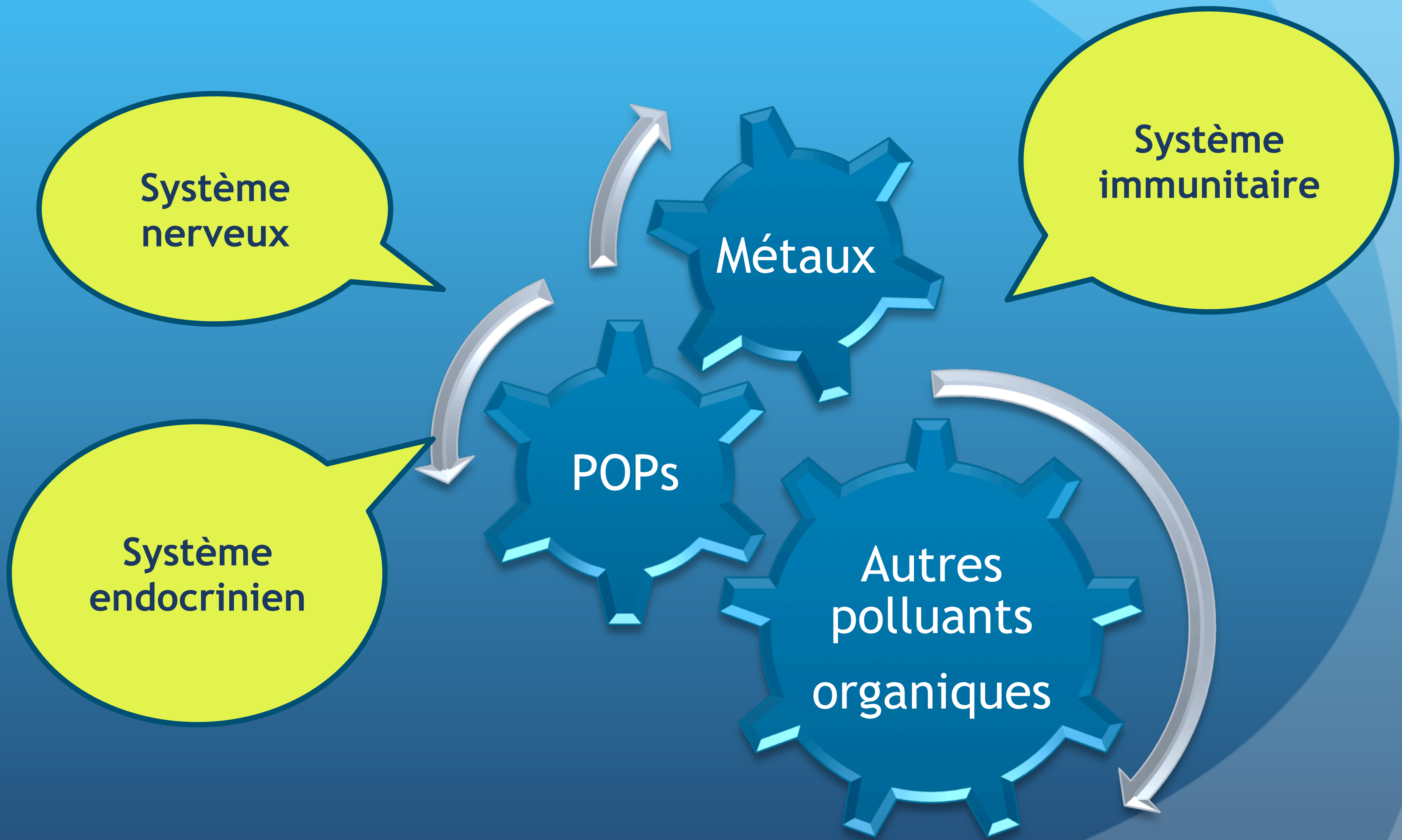
Un polluant est une substance naturelle ou d’origine anthropique

- que l’homme introduit dans un biotope donné dont elle était absente ou encore
- dont il modifie ou augmente la teneur (dans l’eau, l’air ou les sols selon le biotope) lorsqu’elle y est spontanément présente.

Peut agir comme un polluant:

- **Toute modification d'un processus physique** qui conduit à accroître les flux d'énergie ou les niveaux de radiation dans l'environnement
- **Une espèce allochtone** introduite dans un écosystème éloigné de son aire d'origine

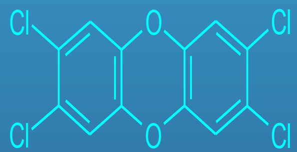
Toxicité des polluants

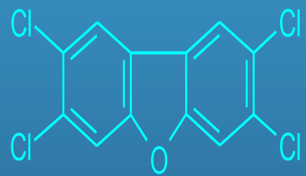


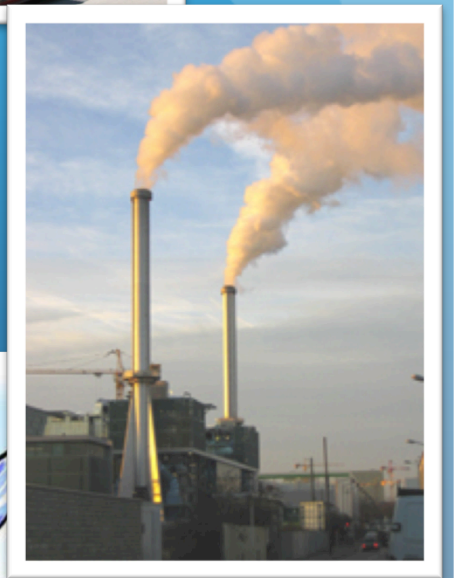
Polluants Organiques Persistants
POPs: Convention de Stockholm

PCBs

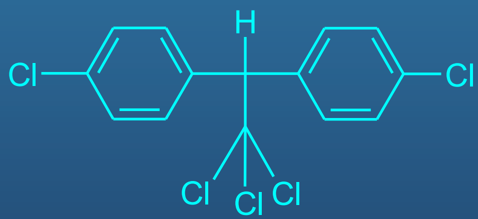
Dioxines et furannes

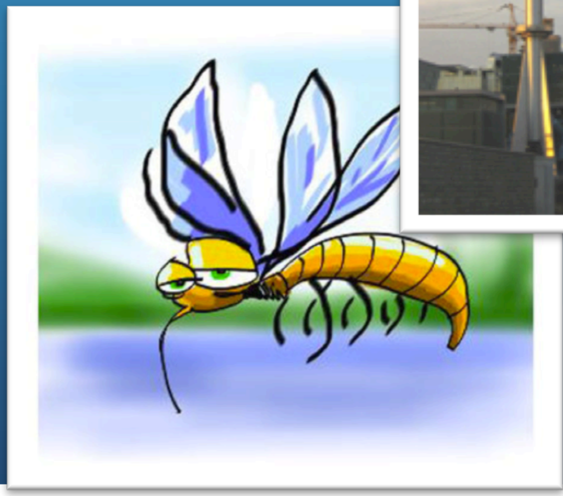




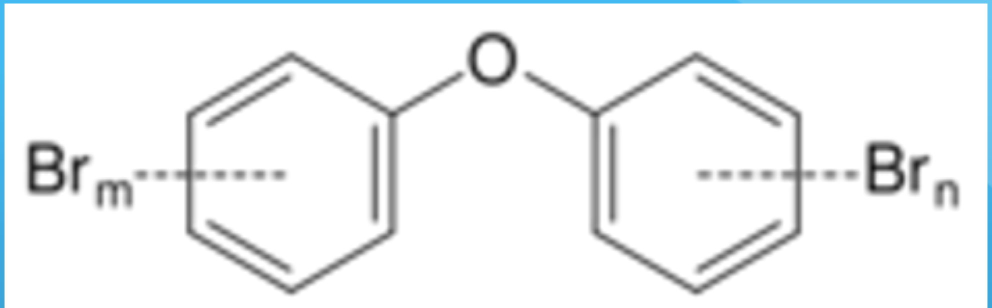


DDTs





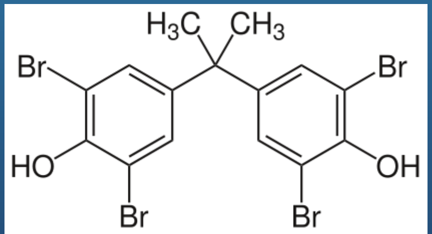
De nouvelles molécules persistantes

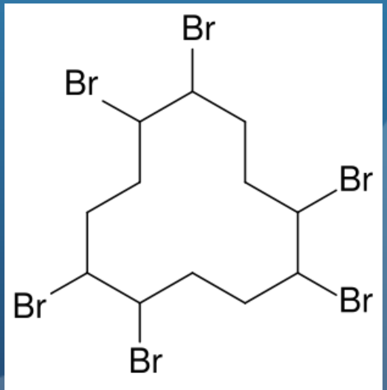


Polybromodiphenyléthers: PBDEs

Mais bien d'autres composés polybromés problématiques:

- Tetrabromobisphenol A: TBBPA
- Hexabromocyclododecane: HBCD





Illustrations: Wikipedia

Retardateurs de flamme

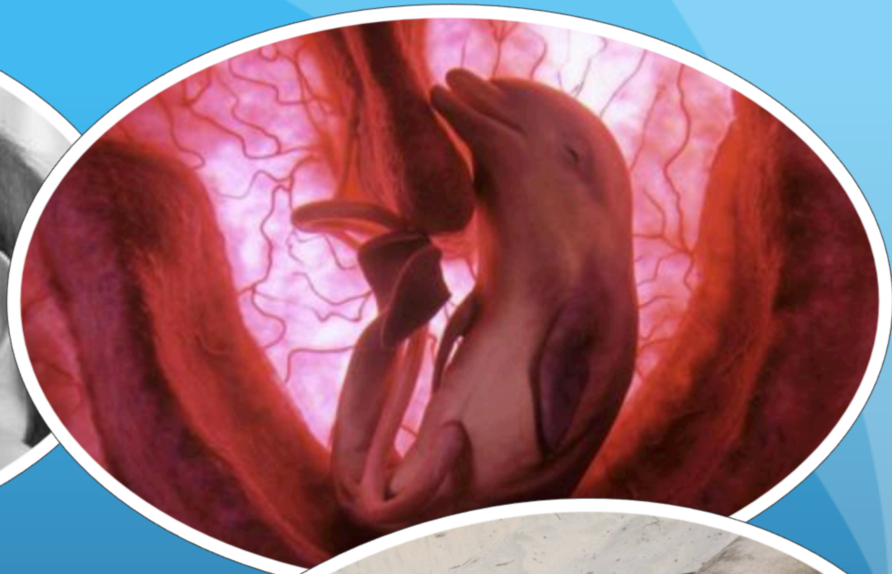
Usage domestique mais pas seulement!


NICKELODEON
LOW FIRE
DANGER
TO FIT
HEIGHT 92cm
CHEST 56cm
WAIST 54cm
SIZE 2
MADE IN CHINA
Dora
& Boots

Des points communs!

- Stables
- Lipophiles
- Transport sur de longues distances

Et transfert à la descendance…



Concentrations décuplées dans le foie des fétus entre 1998 et 2006

Introduction

Persistent Organic Pollutant Residues in Human Fetal Liver and Placenta from Greater Montreal, Quebec: A Longitudinal Study from 1998 through 2006

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[1]Health Canada, Health Products and Food Branch, Ottawa, Ontario, Canada; [2]McGill University Health Centre–Montreal Children's Hospital Research Institute, Montreal, Quebec, Canada

Background: There is general concern that persistent organic pollutants (POPs) found in the environment, wildlife, food, water, house dust, human tissues, and fluids may alter normal human physiologic activities (e.g., fetal development, immune and endocrine systems). Although the levels of some POPs [polychlorinated biphenyls (PCBs) and organochlorine pesticides (OCs)] in these matrices have decreased after their ban, others [polybrominated diphenyl ethers (PBDEs)] have increased in recent years.

Objective: To determine the longitudinal trend of specific POPs in human fetal tissues for risk assessment purposes.

Methods: We analyzed early to mid-gestation fetal liver ($n = 52$) and placental ($n = 60$) tissues, obtained after elective abortions during 1998–2006, for selected PBDEs, PCBs, and OCs using gas chromatography–mass spectroscopy.

Results: Total PBDEs in fetal liver increased over time (mean ± SE: 1998, 284.4 ± 229.8 ng/g lipid; 2006, 1,607.7 ± 605.9; $p < 0.03$), whereas placental levels were generally lower, with no clear trend. Low levels of PCBs and OCs varied yearly, with no evident trend. The major analytes in 1998 were OCs (liver, 49%; placenta, 71%), whereas the major analytes in 2006 were PBDEs (liver, 89%; placenta, 98%). The 1998–2006 tissue PBDE congener profile is similar to that of DE-71, a commercial primarily pentabrominated diphenyl ether mixture manufactured in North America.

Conclusions: Although commercial production of penta- and octa-brominated diphenyl ethers in North America was halted in 2004, their concentrations in fetal liver and placenta are now greater than the tissue burdens for the analyzed OCs and PCBs. Our findings also demonstrate that PBDEs accumulate within the fetal compartment at a very early stage in gestation.

Key words: fetus, human, liver, placenta, OCs, PBDEs, PCBs, POPs. Environ Health Perspect 117:605–610 (2009). doi:10.1289/ehp.0800205 available via http://dx.doi.org/ [Online 10 December 2008]

Persistent organic pollutants (POPs), such as organochlorine pesticides (OCs) and polychlorinated biphenyls (PCBs), contaminate many environmental matrices and can be found in human blood, adipose tissue, and breast milk (Guvenius et al. 2003; Solomon and Weiss 2002). In addition, these POPs cross the placenta and have been reported to reduce gestational length and birth weight and to a ect fetal development (Ando et al. 1985; Guvenius et al. 2003; Lanting et al. 1998; Rogan et al. 1986; Shen et al. 2007; Taylor et al. 1984). Furthermore, some of these chemicals may induce endocrine e ects, and others are classified as "reasonably anticipated to be" or "known" human carcinogens (Carpenter 2006). Multiple studies have shown that the levels of several POPs found in the environment, human fat, maternal and cord bloods, and breast milk have decreased after being banned (Bates et al. 2002; Craan and Haines 1998; Norén and Meironyte 2000; Pereg et al. 2003; Schade and Heinzow 1998; Solomon and Weiss 2002). However, this is not universal; for example, concentrations of PCBs in Great Lakes fish have continued to oscillate (Bhavsar et al. 2007).

A more recently recognized class of environmental contaminant, whose chemical structure is similar to PCBs, is the brominated flame retardants, which includes the polybrominated diphenyl ether (PBDE) congeners (Gill et al. 2004; Hites 2004). For the past two to three decades, they have been added to plastics, polyurethane foam, textiles, and electronic equipment to prevent ignition or to slow the burn rate if a fire occurs. In animal studies, PBDEs have been found to a ect neural and reproductive development as well as thyroid function (Birnbaum and Staskal 2004; Gill et al. 2004; Legler 2008; McDonald 2002; Talsness 2008). Although many of these investigations used pharmacologic doses of the PBDEs, more recent studies have demonstrated that exposure at doses relevant for humans at critical times during development can have e ects on the endocrine and neural systems (reviewed in Legler 2008; Talsness 2008). Only two clinical epidemiologic studies have been published to date on the potential e ects of *in utero* exposure and fetal outcome. Chao et al. (2007) recently reported that elevated levels of PBDEs in breast milk correlated significantly with lower newborn birth weight, birth length, chest circumference, and body mass index. In addition, Main et al. (2007) have found significantly higher PBDE levels in the breast milk of mothers whose newborn sons had cryptorchidism. One study of young adult males has reported a significant negative association between serum brominated diphenyl ether congener BDE-153 levels and testis size as well as sperm concentration (Akutsu et al. 2008).

In contrast to OCs and PCBs, many studies worldwide have reported that the amount of PBDEs found in the environment, human serum, and breast milk has been increasing steadily since the 1980s (Akutsu et al. 2003; de Wit et al. 2006; Li et al. 2006; Lorber 2008; Norén and Meironyte 2000; Pereg et al. 2003; Ryan et al. 2002; Schecter et al. 2004; Solomon and Weiss 2002). A few investigators in Europe have found that the PBDE levels in European samples peaked in 1997–1998 and subsequently have plateaued or declined, likely due to the earlier limitations on the production and use of penta- and octa-BDEs within the European Union versus North America (Darnerud et al. 2002; Law et al. 2006, 2008).

Human breast milk is only one source of environmental contaminants for a developing infant, and from a toxicology and regulatory perspective, it is the infant's total body burden that is of greatest interest. Very little is known about when *in utero* exposure begins to contribute significantly to an infant's body burden of PBDEs and other POPs. To examine this question, we analyzed the levels of multiple OCs *p,p´*-DDT (1,1,1-trichloro-2-[*o*-chlorophenyl]-2-2[*p*-chlorophenyl] ethane), *p,p´*-DDE (1,1-dichloro-2,2-bis[*p*-chlorophenyl] ethylene), *trans*-nonachlor, and hexachlorobenzene (HCB)], PCB congeners (49, 99, 118, 137, 138, 153, and 180), and BDE congeners (47, 85, 99, 100, 153, 154, and 183) in early to mid-gestation fetal liver and placental specimens obtained between

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Supplemental Material is available online at http://www.ehponline.org/members/2008/0800205/suppl.pdf

We thank T. Rawn for her insightful review of the manuscript, and the sta of the Royal Victoria Hospital Day Surgery clinic for their help with tissue collection.

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The authors declare they have no competing financial interests.

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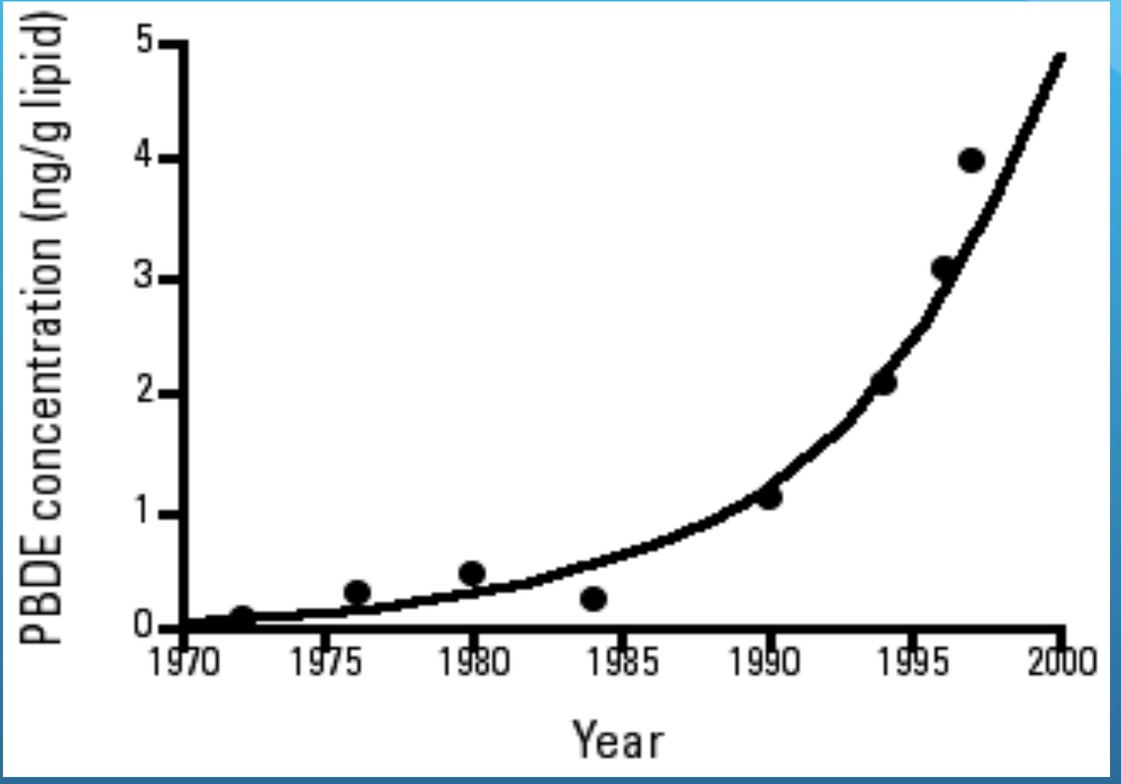
Augmentation des concentrations en PBDEs dans l'environnement

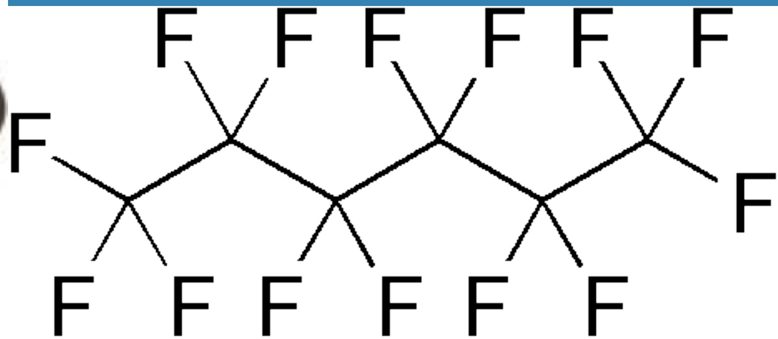


Lait maternel- Suède – (Noren and Meironyté, 1998)

concentrations doublées tous les 5 ans

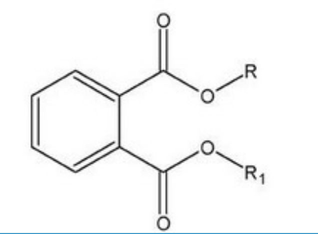
De nouvelles molécules persistantes

Composés perfluorés (PFAs)

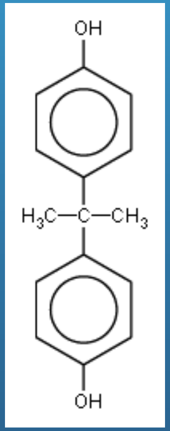


De nouvelles molécules non persistantes

- Phtalates



- Bisphenol A



Non persistantes mais une exposition chronique mène à une augmentation des teneurs chez les humains

Mer = réceptacle final de toute pollution

Introduction

Produits d’origine anthropique arrivant en mer

- Marées noires
- Armement et munitions diverses
- Déchets en provenances de bateaux
- Déchets industriels et nucléaires
- Epaves
- Stations de forage pétrolier
- Précipitations atmosphériques (métaux lourds et hydrocarbures)
- Déchets urbains et routiers
- Eaux d’égouts
- Gaz d’échappement via atmosphère
- Engrais et pesticides
- Eaux de refroidissement

…

L'impact d'un polluant dépend

De la contamination environnementale

Mais également d'évènements clés

- Migration
- Gestation
- Lactation
- Ponte
- Jeune (lié à la lactation, la mue et les migrations)

Et …du régime alimentaire

Etudier le régime alimentaire des vertébrés marins

Que mangent-ils?

Pourquoi l'étudier

- Prélèvement important par les mammifères marins
- Régulation des chaînes tophiques
- Alimentation = source de contamination

Comportement alimentaire

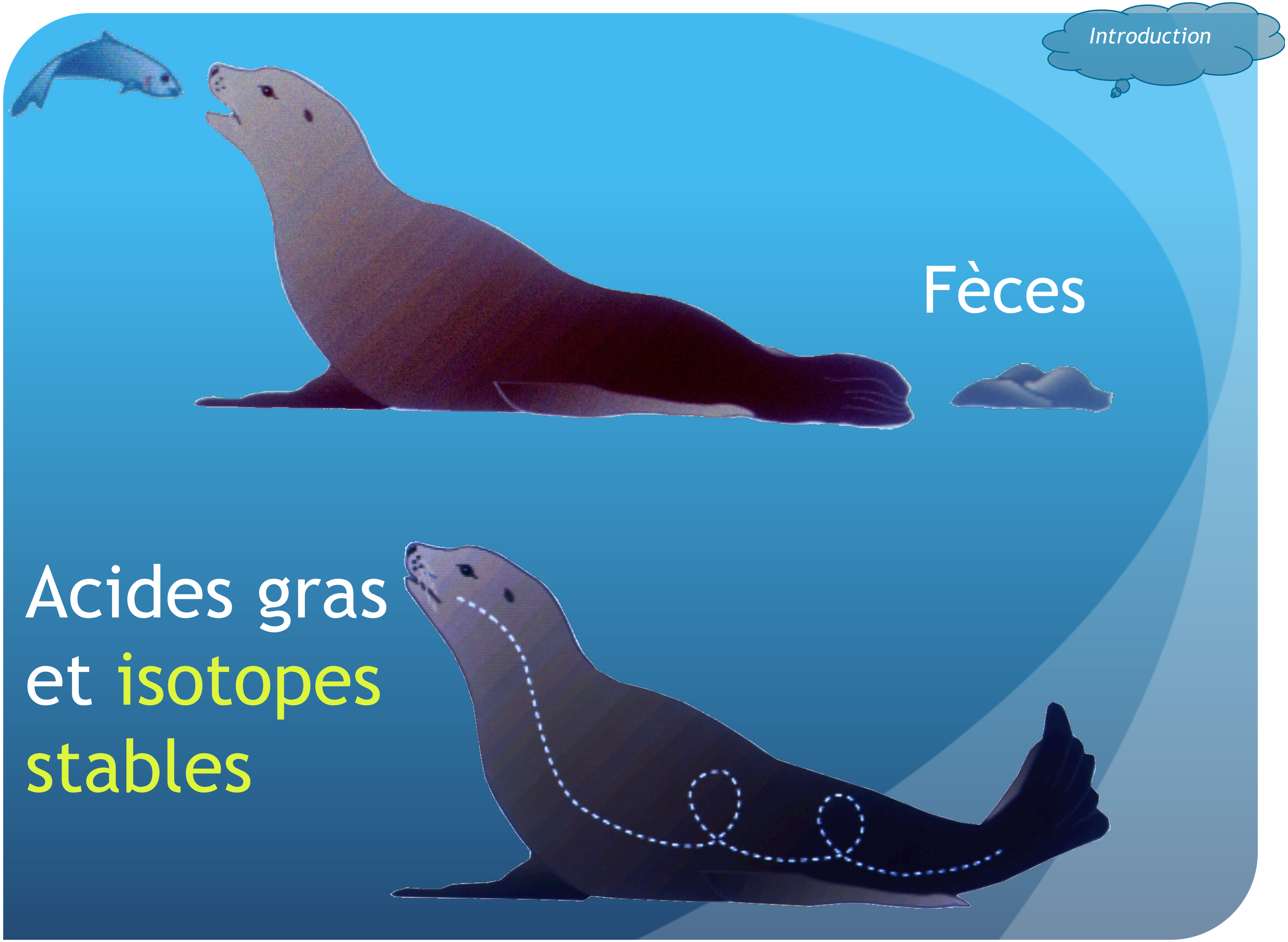
CREDIT: ARI FRIEDLAENDER
http://www.sciencemag.org/content/331/6015/274.full

- Peu applicable pour ces espèces marines
- Protocole conventionnel difficilement transposable

Contenus stomacaux

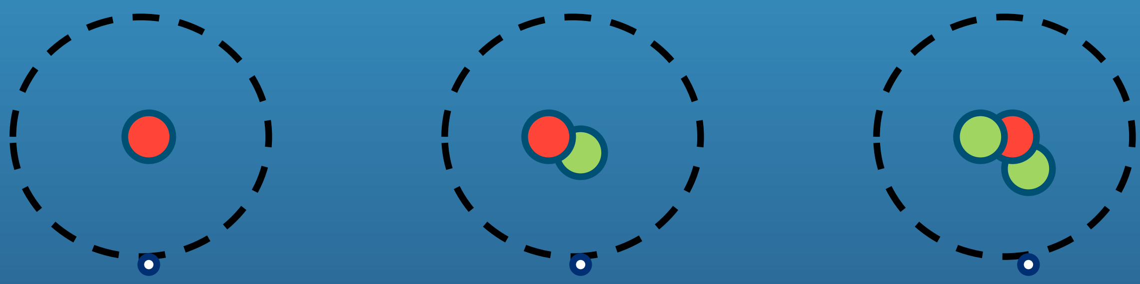
Individus échoués ou capturés dans les filets

Credit: U. Siebert et T. Jauniaux


Introduction
Fèces
Acides gras et isotopes stables

Qu’est-ce qu’un isotope stable?

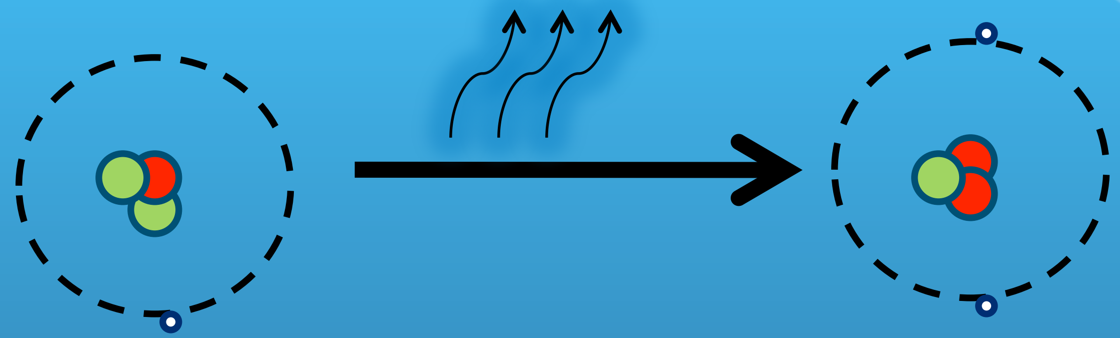
Configurations atomiques (ou atomes) qui diffèrent par leur nombre de neutrons.



Protium Deuterium Tritium

Hydrogen

Isotope radioactif *versus* isotope stable



Tritium ***non stable***: transformation en ^{3}He (Radioisotope)

Deuterium *stable*: pas de transformation (isotope stable)

Elements d'intérêt

^{1}H = isotope stable léger de l'hydrogène (~99.985%)
^{2}H (D)= isotope stable lourd de l'hydrogène(~.015%)

^{12}C = isotope stable léger du carbone (~98.9%)
^{13}C=isotope stable lourd du carbone (~1.1%)

^{14}N=isotope stable léger de l'azote (~99.63%)
^{15}N=isotope stable lourd de l'azote (0.37%)

$\delta^{13}C$ et $\delta^{15}N$

Les rapports isotopiques sont exprimés relativement à un standard international en parts pour mille

$$\delta X(\text{‰}) = \left[\frac{R_{sample} - R_{standard}}{R_{standard}}\right] \times 1000$$

X est le ^{13}C ou ^{15}N et *R* est le rapport correspondant $^{13}C/^{12}C$ or $^{15}N/^{14}N$

Hypothèses

1. Les rapports isotopiques des consommateurs sont proportionnels à ceux de leur régime alimentaire
2. Les rapports isotopiques varient selon les sources alimentaires accessibles aux consommateurs

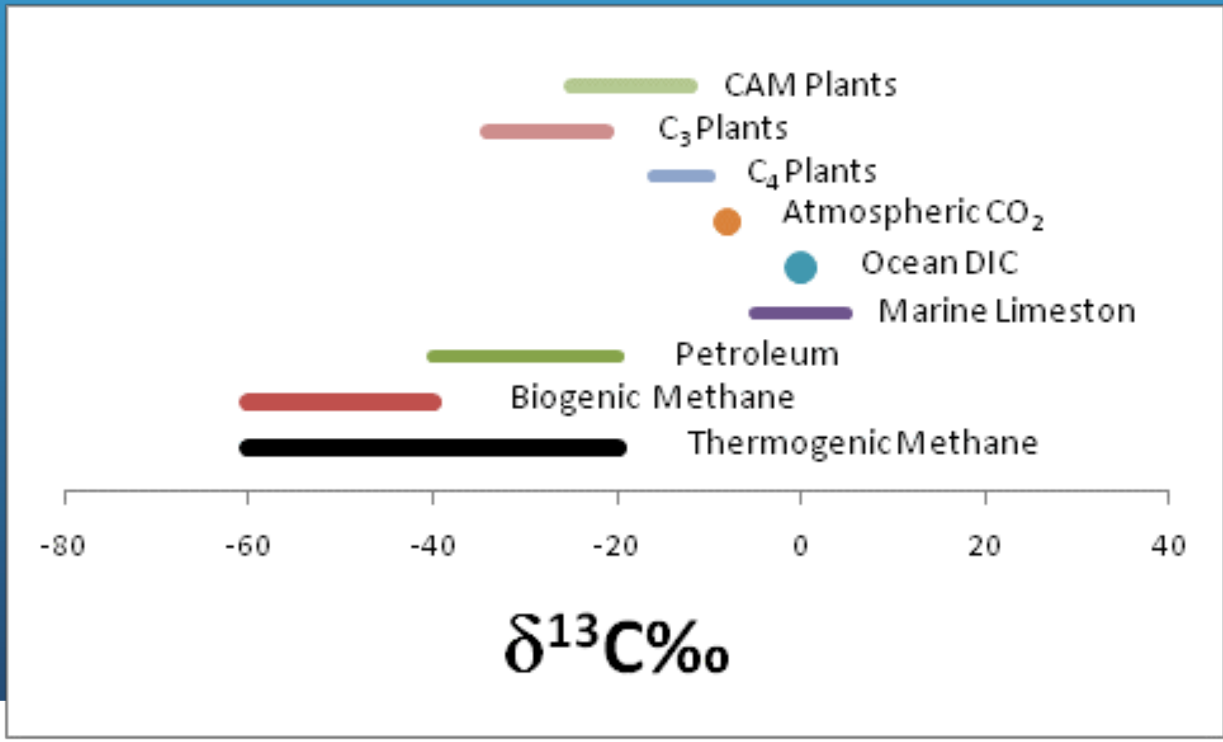
Variation des valeurs en $\delta^{13}C$

-3 -2 -1 0 +1 +2 +3

$R_{sample} < R_{standard}$

$R_{sample} = R_{standard}$

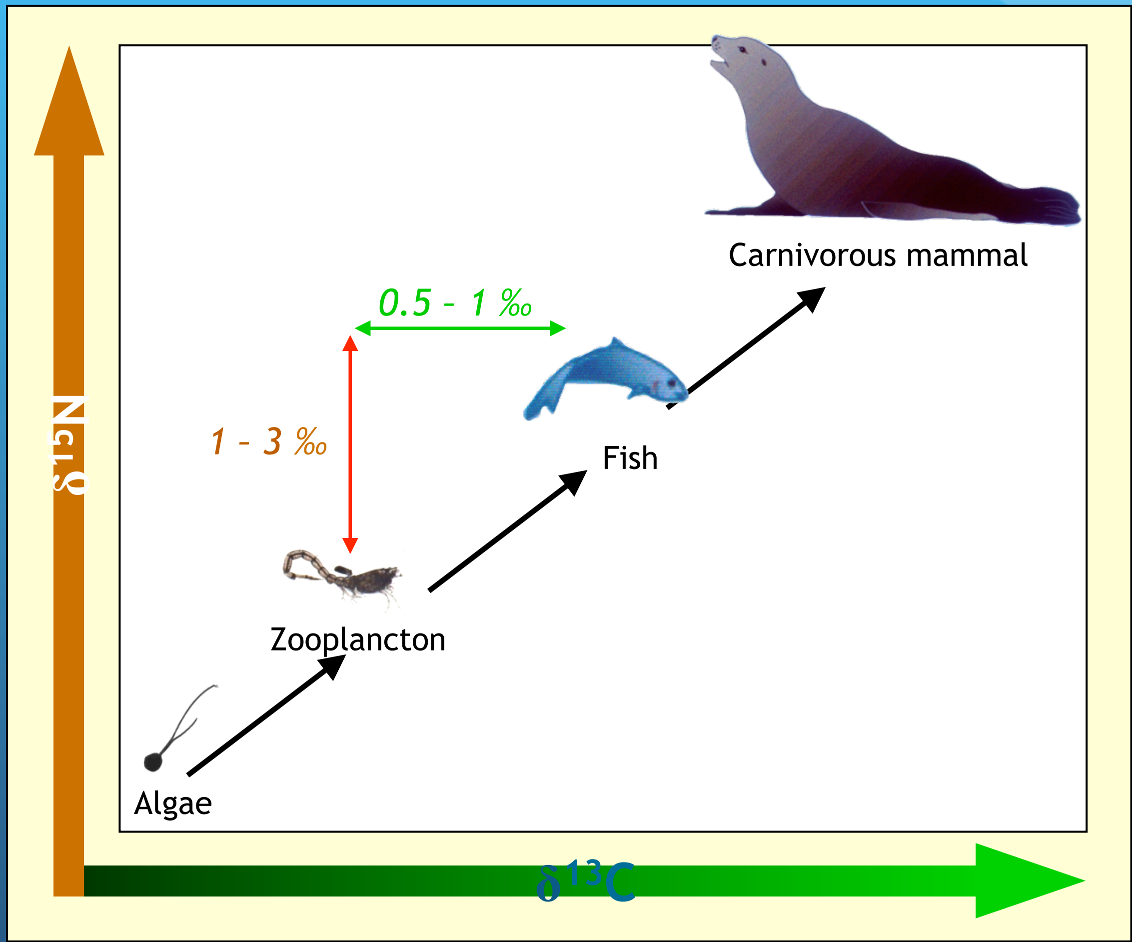
$R_{sample} > R_{standard}$



"You are what you eat ...plus a few per mille"

De Niro and Epstein. 1976. Geol. Soc. Am. Abs. Prog. 8 : 834-835

position trophique



Source de la productivité primaire

Avantages des isotopes stables

- Intégration du régime alimentaire sur une période de temps dépendant du tissus analysé

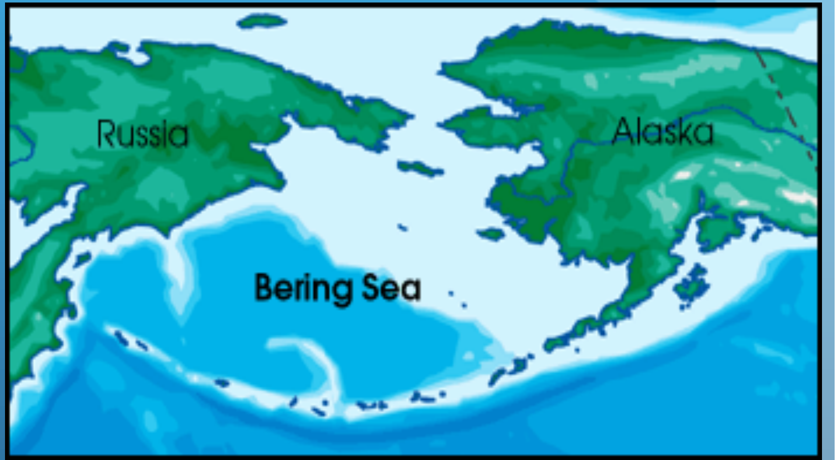
  → pas uniquement les derniers repas.

  → turn-over du tissus analysé (tissus osseux *versus* sérum)

- Mesure continue de la position trophique

1979 : une des premières études sur les isotopes stables chez les mammifères marins

McConnaughey, T. and C.P. McRoy. 1979. Food-web structure and the fractionation of carbon isotopes in the Bering Sea. Marine Biology 53: 257-262



And 30 years later, more than 250 published papers visible on ISI
488 for marine fish, 285 for seabirds and 56 for turtles

http://earthobservatory.nasa.gov/Features/Coccoliths/

Isotopes stables

Les isotopes stables chez les vertébrés marins

1. Ecologie trophique
2. Physiologie
3. Contaminants

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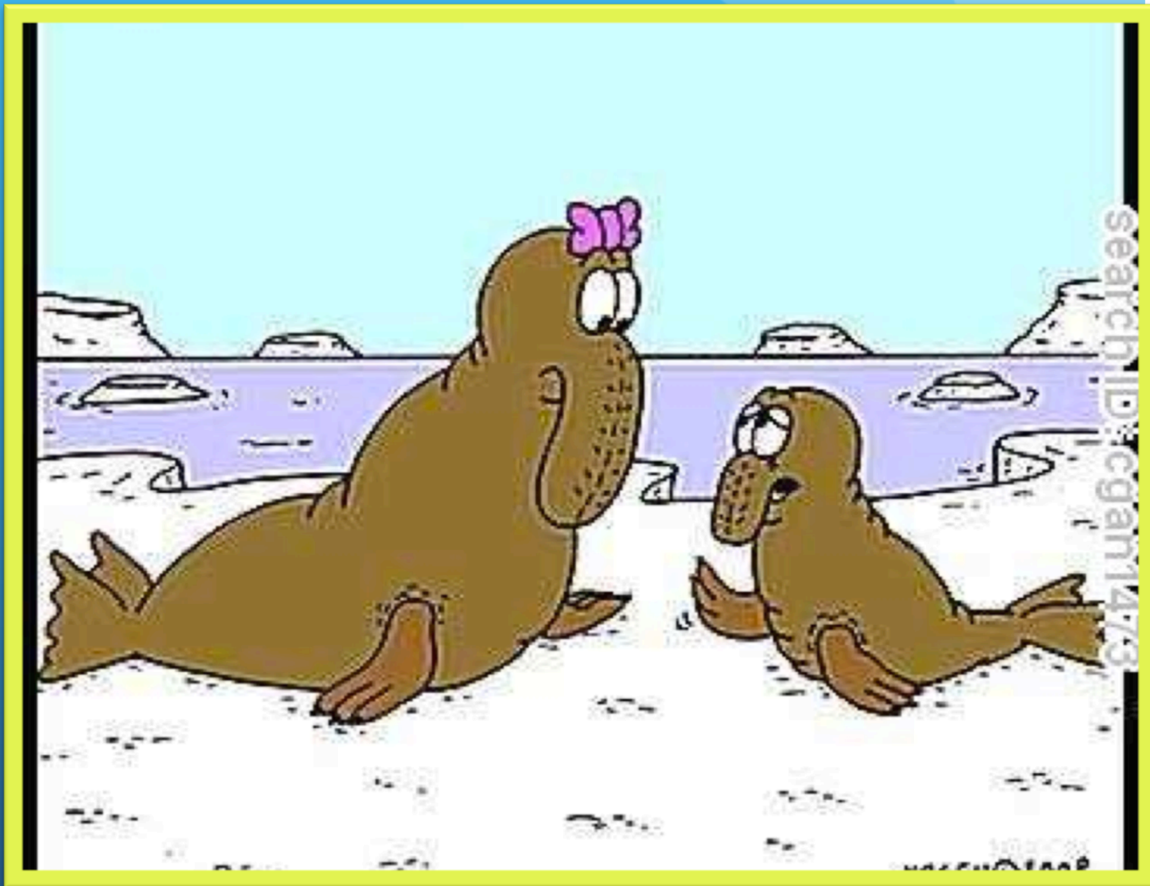

Isotopes stables

Les isotopes stables chez les vertébrés marins

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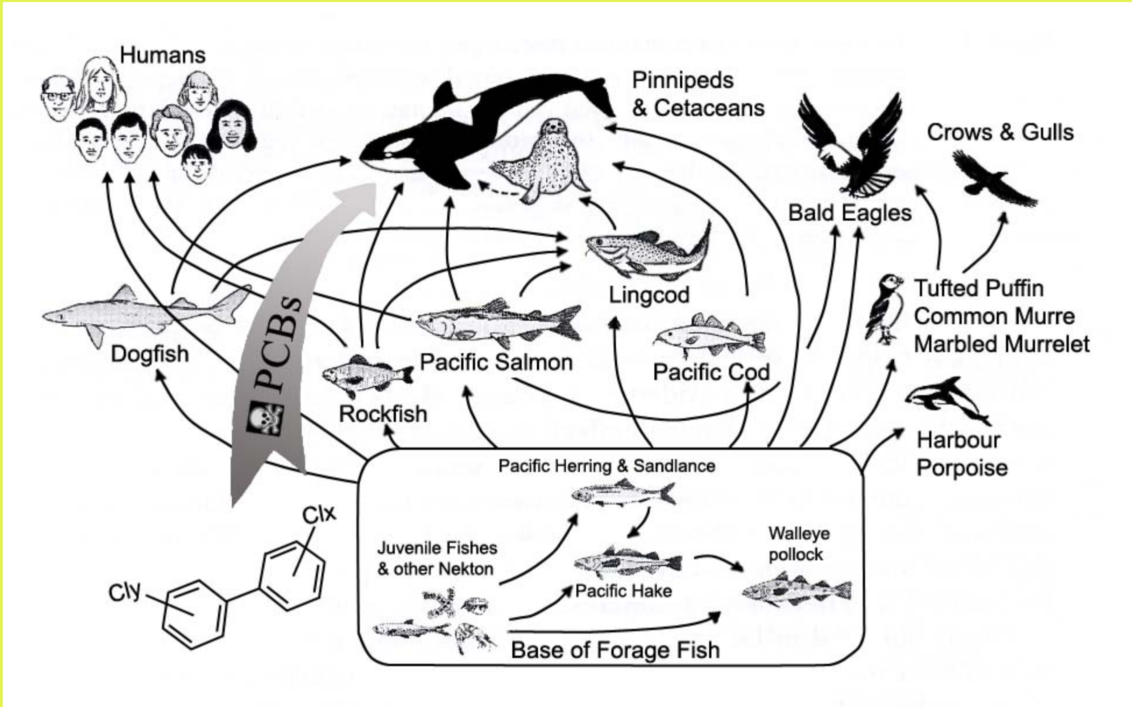

Les isotopes stables chez les vertébrés marins

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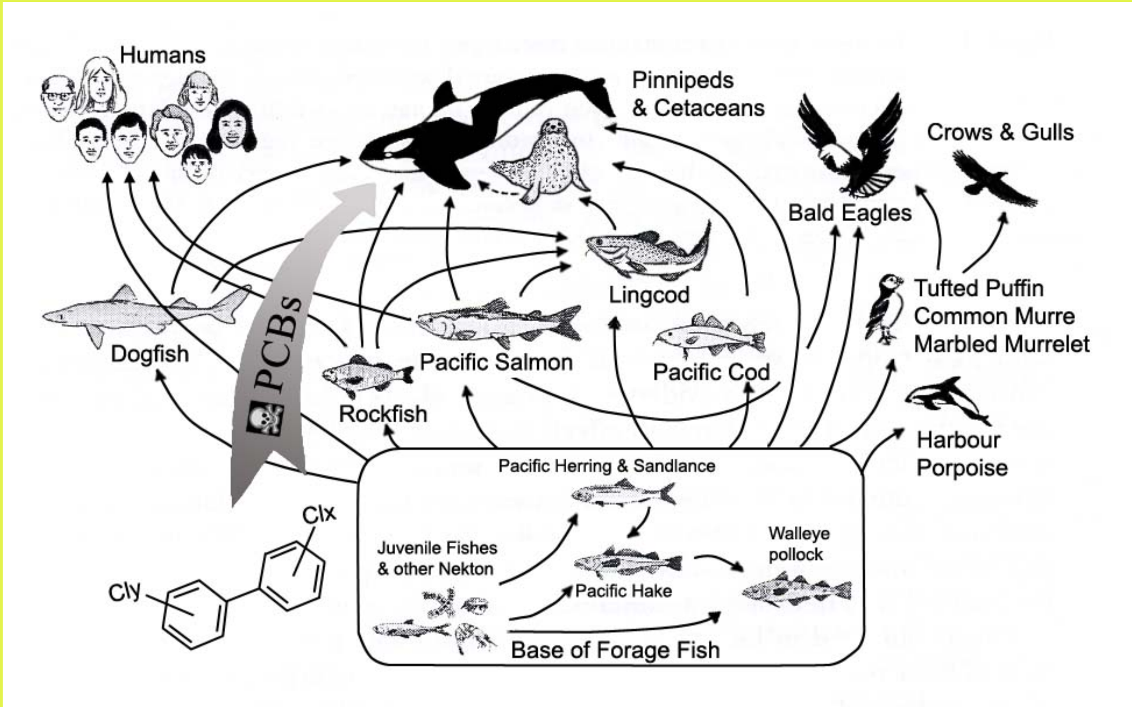


- ✓Transfert trophique
- ✓ Structure des populations
- ✓ Variation de niches écologiques

Mais comment récolter les échantillons?

- Animaux morts

Echantillons

Mais comment récolter les échantillons?

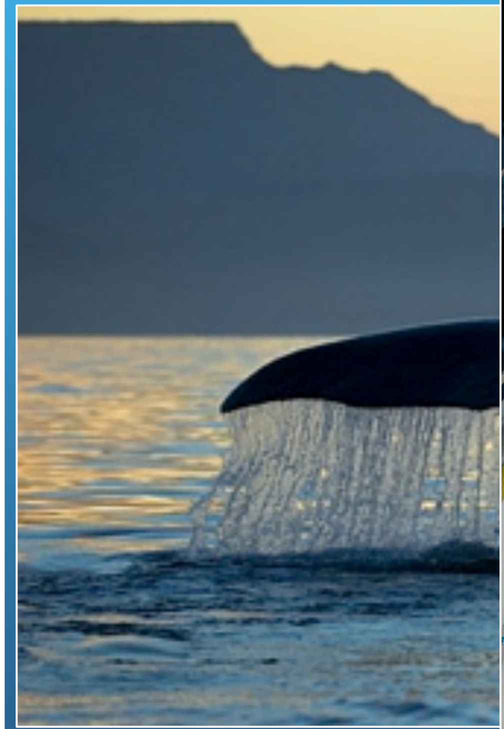
- Animaux en ponte

Crédit: E. Guirlet

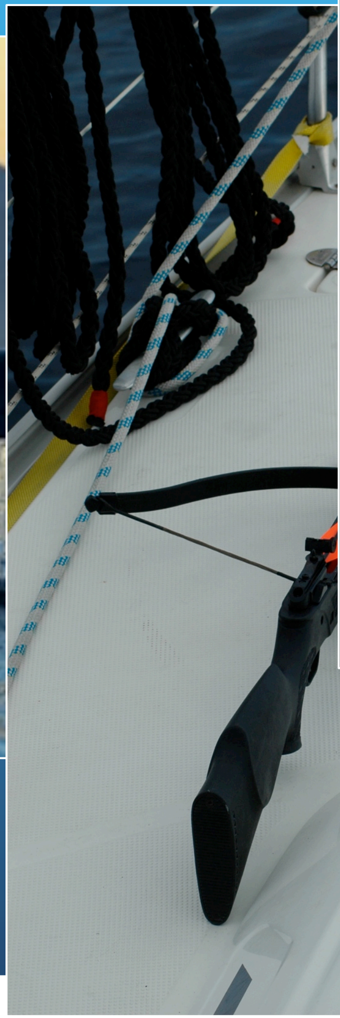
Mais comment récolter les échantillons?

- Biopsies de peau et de lard chez les cétacés

Crédit: Dr. E. Praca



http://www.oceanus.uk.com/



Les isotopes stables chez les vertébrés marins

Isotopes stables

1. **Ecologie trophique**
2. Physiologie
3. Contaminants

Ecologie trophique

Vol. 84: 9–18, 1992 | MARINE ECOLOGY PROGRESS SERIES Mar. Ecol. Prog. Ser. | Published July 23

Determination of trophic relationships within a high Arctic marine food web using $\delta^{13}C$ and $\delta^{15}N$ analysis*

Keith A. Hobson[1, 2], Harold E. Welch[2]

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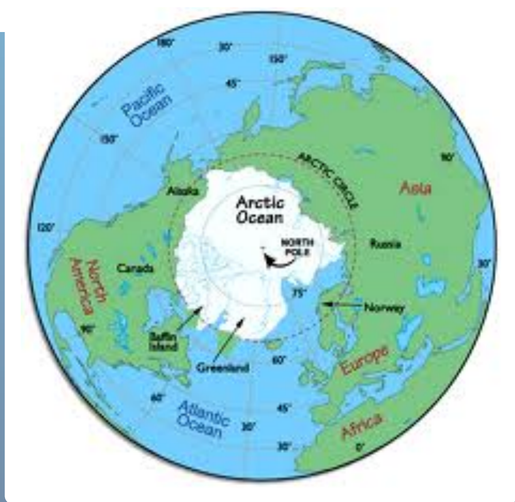
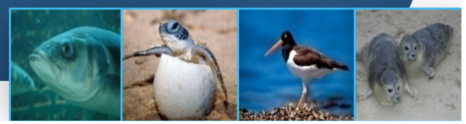
[2] Department of Fisheries and Oceans, Freshwater Institute, 501 University Crescent, Winnipeg, Manitoba, Canada R3T 2

ABSTRACT: We measured stable-carbon ($^{13}C/^{12}C$) and/or nitrogen ($^{15}N/^{14}N$) isotope ratios in 322 tissue samples (minus lipids) representing 43 species from primary producers through polar bears *Ursus maritimus* in the Barrow Strait-Lancaster Sound marine food web during July–August, 1988 to 1990. $\delta^{13}C$ ranged from −21.6 ± 0.3‰ for particulate organic matter (POM) to −15.0 ± 0.7‰ for the predatory amphipod *Stegocephalus inflatus*. $\delta^{15}N$ was least enriched for POM (5.4 ± 0.8‰), most enriched for polar bears (21.1 ± 0.6‰), and showed a step-wise enrichment with trophic level of +3.8‰. We used this enrichment value to construct a simple isotopic food-web model to establish trophic relationships within this marine ecosystem. This model confirms a food web consisting primarily of 5 trophic levels. $\delta^{13}C$ showed no discernible pattern of enrichment after the first 2 trophic levels, an effect that could not be attributed to differential lipid concentrations in food-web components. Although Arctic cod *Boreogadus saida* is an important link between primary producers and higher trophic-level vertebrates during late summer, our isotopic model generally predicts closer links between lower trophic-level invertebrates and several species of seabirds and marine mammals than previously established.



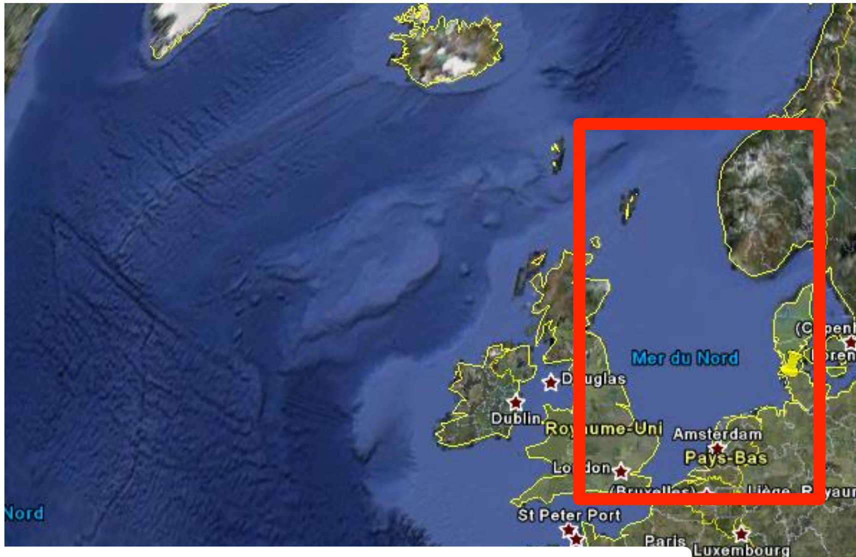
Régime alimentaire et position trophique

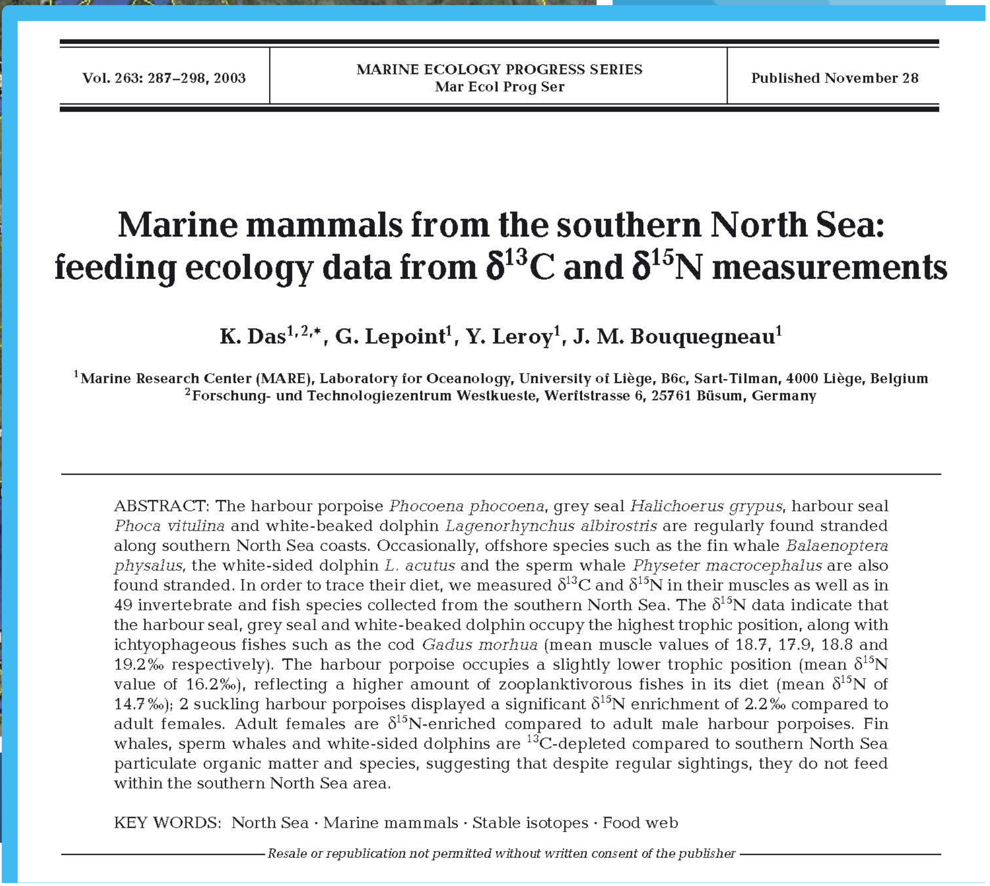
- Augmentation des valeurs en $\delta^{13}C$ and $\delta^{15}N$ avec le niveau trophique
- 5 niveaux trophiques dans l'Arctique



Ecologie trophique

Et en mer du Nord?




Vol. 263: 287–298, 2003 | MARINE ECOLOGY PROGRESS SERIES Mar Ecol Prog Ser | Published November 28

Marine mammals from the southern North Sea: feeding ecology data from $\delta^{13}C$ and $\delta^{15}N$ measurements

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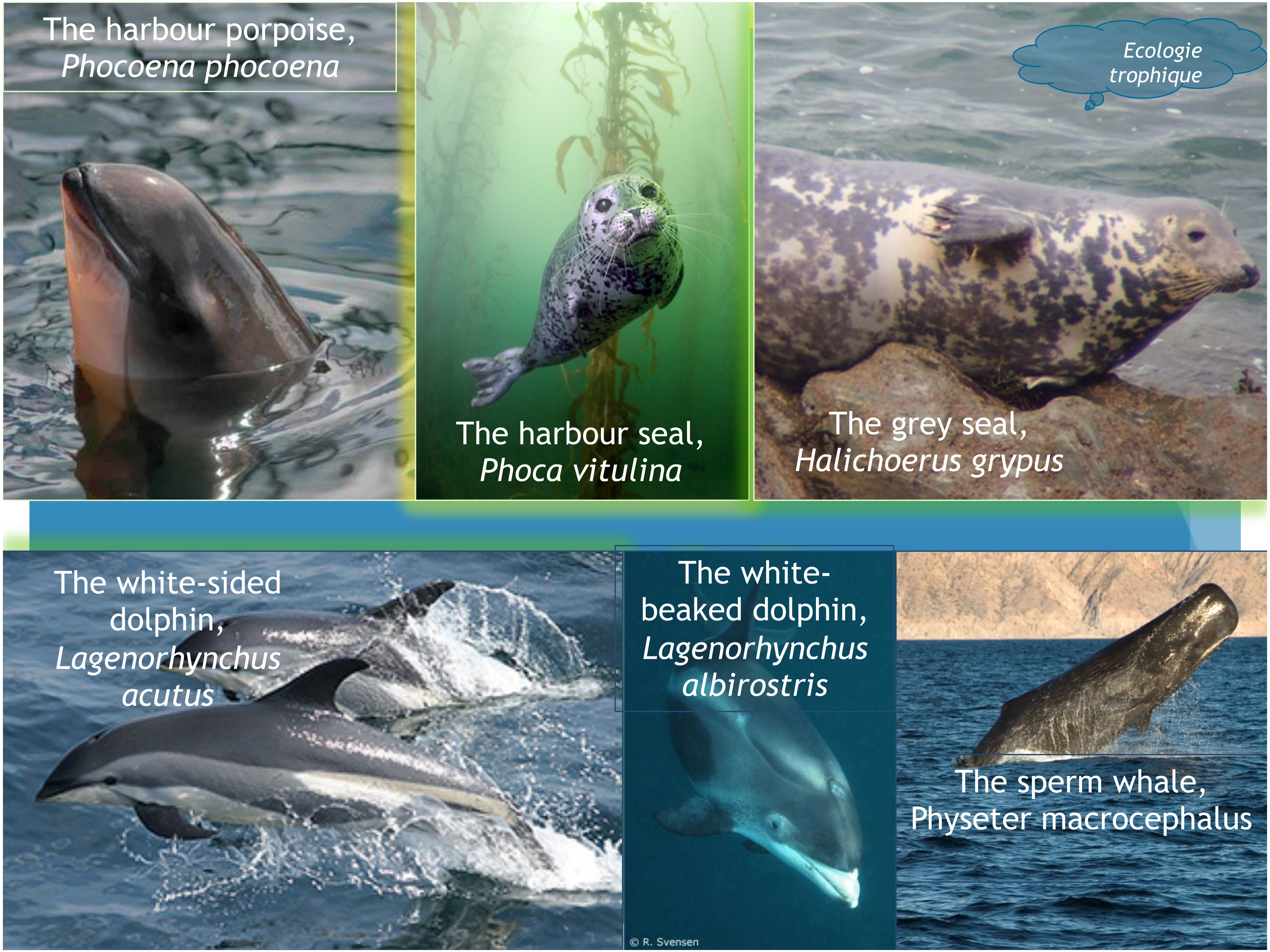
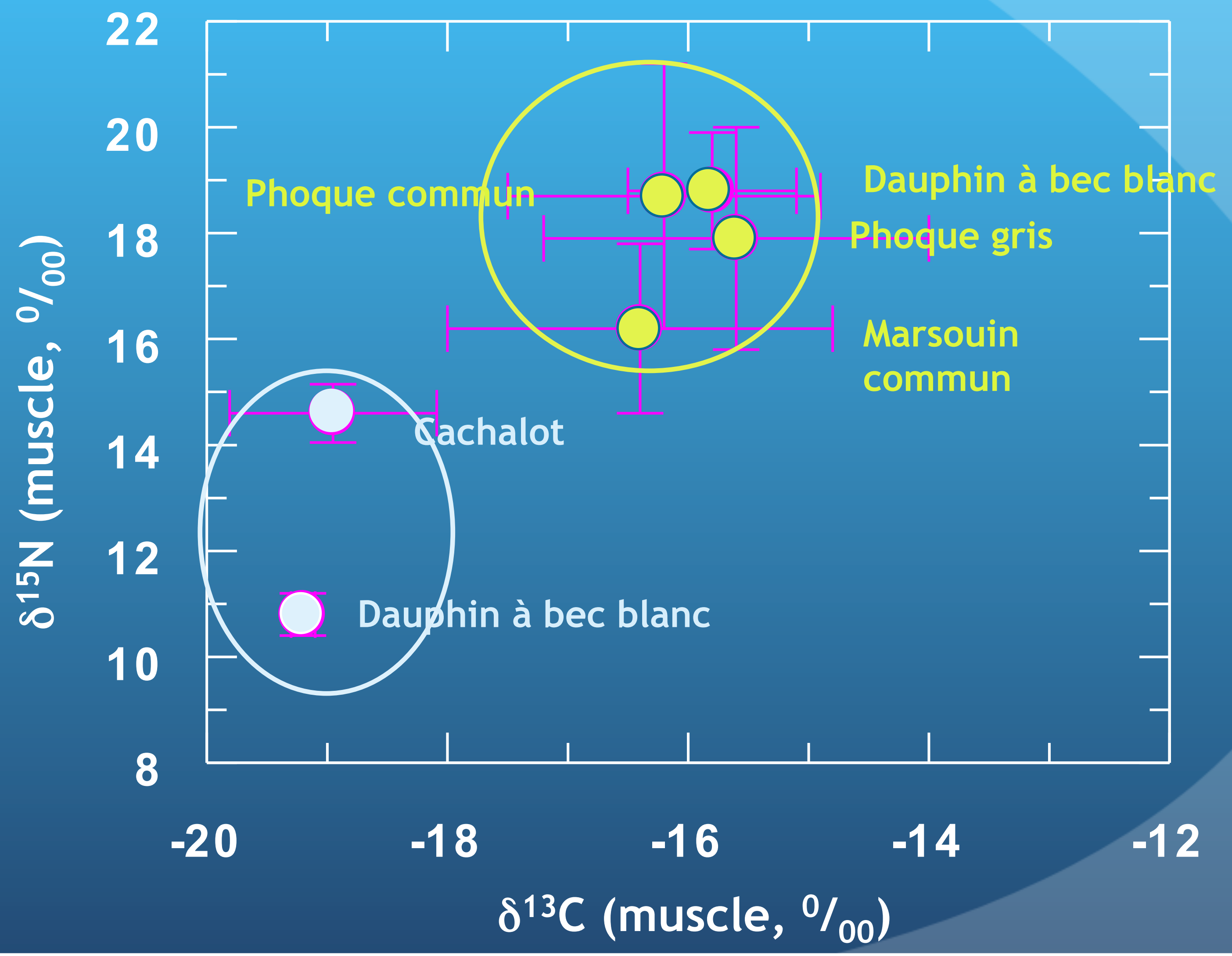
ABSTRACT: The harbour porpoise *Phocoena phocoena*, grey seal *Halichoerus grypus*, harbour seal *Phoca vitulina* and white-beaked dolphin *Lagenorhynchus albirostris* are regularly found stranded along southern North Sea coasts. Occasionally, offshore species such as the fin whale *Balaenoptera physalus*, the white-sided dolphin *L. acutus* and the sperm whale *Physeter macrocephalus* are also found stranded. In order to trace their diet, we measured $\delta^{13}C$ and $\delta^{15}N$ in their muscles as well as in 49 invertebrate and fish species collected from the southern North Sea. The $\delta^{15}N$ data indicate that the harbour seal, grey seal and white-beaked dolphin occupy the highest trophic position, along with ichtyophageous fishes such as the cod *Gadus morhua* (mean muscle values of 18.7, 17.9, 18.8 and 19.2‰ respectively). The harbour porpoise occupies a slightly lower trophic position (mean $\delta^{15}N$ value of 16.2‰), reflecting a higher amount of zooplanktivorous fishes in its diet (mean $\delta^{15}N$ of 14.7‰); 2 suckling harbour porpoises displayed a significant $\delta^{15}N$ enrichment of 2.2‰ compared to adult females. Adult females are $\delta^{15}N$-enriched compared to adult male harbour porpoises. Fin whales, sperm whales and white-sided dolphins are ^{13}C-depleted compared to southern North Sea particulate organic matter and species, suggesting that despite regular sightings, they do not feed within the southern North Sea area.

KEY WORDS: North Sea · Marine mammals · Stable isotopes · Food web

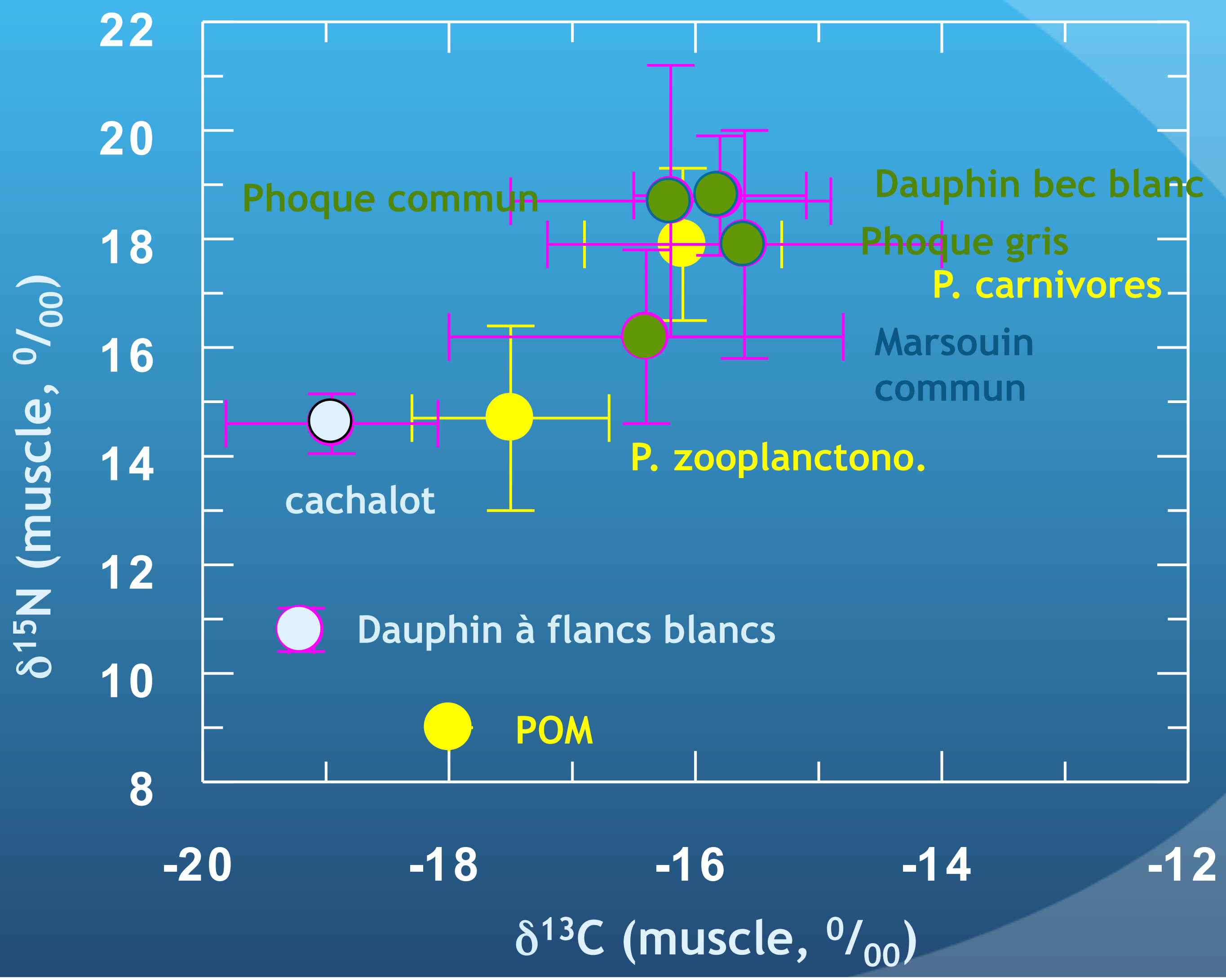

The harbour porpoise,
Phocoena phocoena
The harbour seal,
Phoca vitulina
Ecologie trophique
The grey seal,
Halichoerus grypus
The white-sided dolphin,
Lagenorhynchus acutus
The white-beaked dolphin,
Lagenorhynchus albirostris
© R. Svensen
The sperm whale,
Physeter macrocephalus

Position trophique des mammifères marins

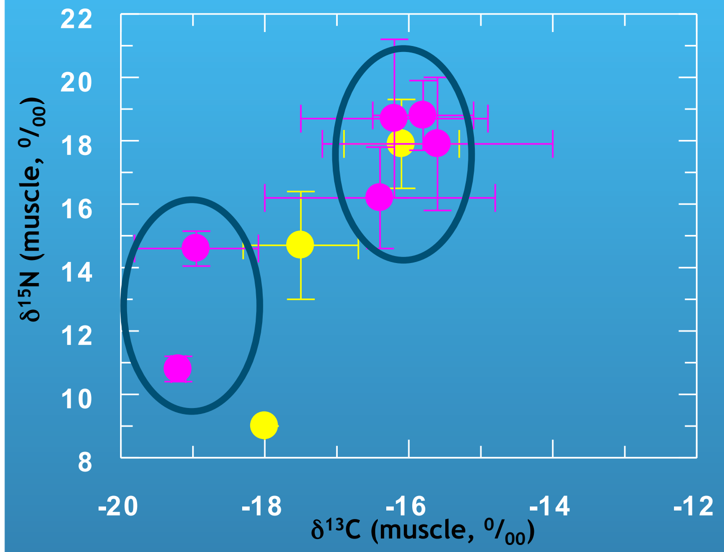
Ecologie trophique



Position trophique des mammifères marins

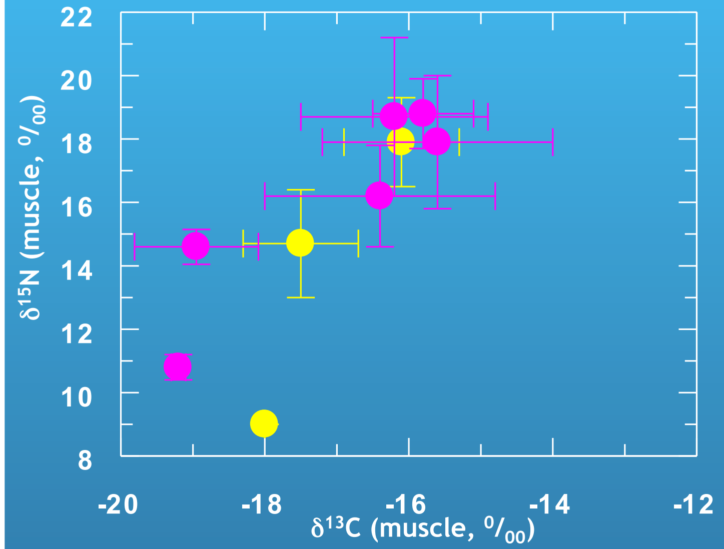


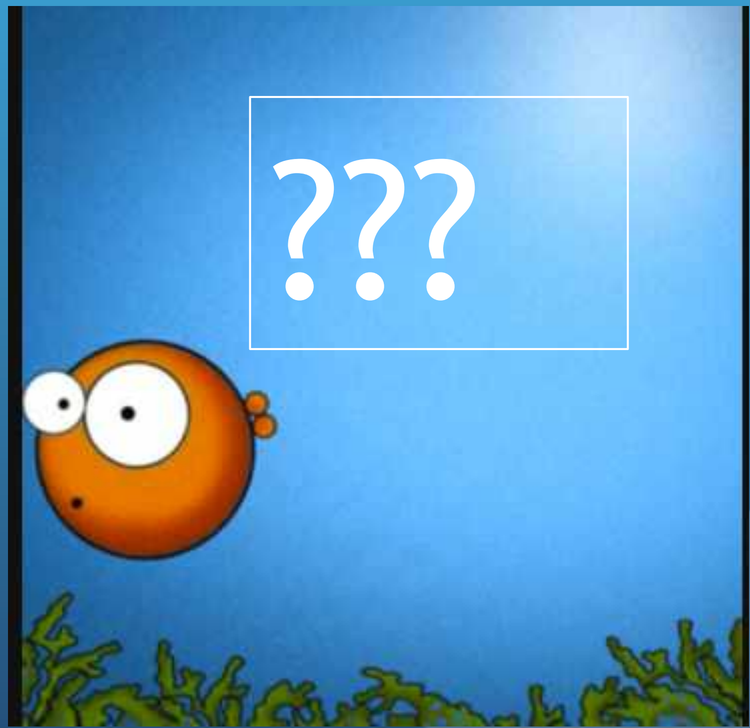
Position trophique des mammifères marins



Zone d'alimentation	SI signature
Oceanique	valeurs faibles en $\delta^{13}C$ et $\delta^{15}N$
Mer du Nord	Valeurs élevées en $\delta^{13}C$ et $\delta^{15}N$

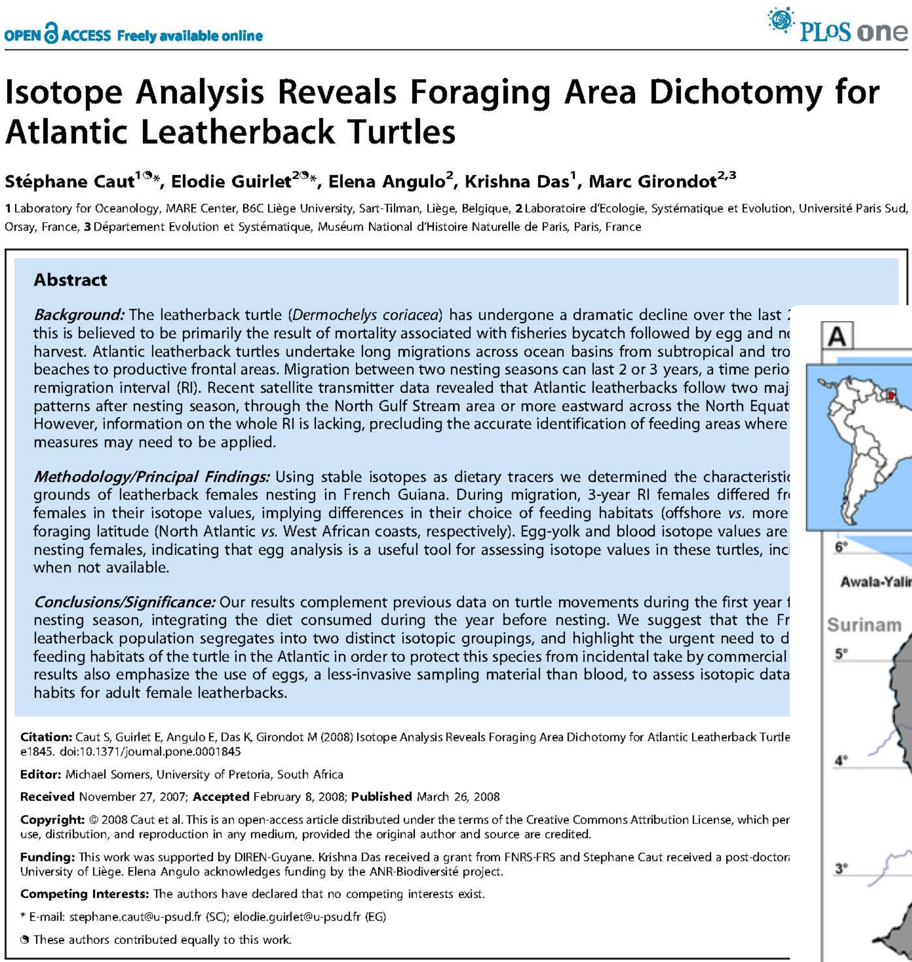
Poissons carnivores et phoques: structure des chaînes trophiques en mer du Nord





Ecologie trophique

Deux aires d'alimentation pour la tortue Luth?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PLoS one

Isotope Analysis Reveals Foraging Area Dichotomy for Atlantic Leatherback Turtles

Stéphane Caut[1]*, **Elodie Guirlet**[2]*, **Elena Angulo**[2], **Krishna Das**[1], **Marc Girondot**[2,3]

1 Laboratory for Oceanology, MARE Center, B6C Liège University, Sart-Tilman, Liège, Belgique, **2** Laboratoire d'Ecologie, Systématique et Evolution, Université Paris Sud, Orsay, France, **3** Département Evolution et Systématique, Muséum National d'Histoire Naturelle de Paris, Paris, France

Abstract

Background: The leatherback turtle (*Dermochelys coriacea*) has undergone a dramatic decline over the last
this is believed to be primarily the result of mortality associated with fisheries bycatch followed by egg and n
harvest. Atlantic leatherback turtles undertake long migrations across ocean basins from subtropical and tro
beaches to productive frontal areas. Migration between two nesting seasons can last 2 or 3 years, a time perio
remigration interval (RI). Recent satellite transmitter data revealed that Atlantic leatherbacks follow two maj
patterns after nesting season, through the North Gulf Stream area or more eastward across the North Equat
However, information on the whole RI is lacking, precluding the accurate identification of feeding areas where
measures may need to be applied.

Methodology/Principal Findings: Using stable isotopes as dietary tracers we determined the characteristi
grounds of leatherback females nesting in French Guiana. During migration, 3-year RI females differed fr
females in their isotope values, implying differences in their choice of feeding habitats (offshore *vs.* more
foraging latitude (North Atlantic *vs.* West African coasts, respectively). Egg-yolk and blood isotope values are
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when not available.

Conclusions/Significance: Our results complement previous data on turtle movements during the first year
nesting season, integrating the diet consumed during the year before nesting. We suggest that the Fr
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feeding habitats of the turtle in the Atlantic in order to protect this species from incidental take by commercial
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habits for adult female leatherbacks.

Citation: Caut S, Guirlet E, Angulo E, Das K, Girondot M (2008) Isotope Analysis Reveals Foraging Area Dichotomy for Atlantic Leatherback Turtle
e1845. doi:10.1371/journal.pone.0001845

Editor: Michael Somers, University of Pretoria, South Africa

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Funding: This work was supported by DIREN-Guyane. Krishna Das received a grant from FNRS-FRS and Stephane Caut received a post-doctor
University of Liège. Elena Angulo acknowledges funding by the ANR-Biodiversité project.

Competing Interests: The authors have declared that no competing interests exist.

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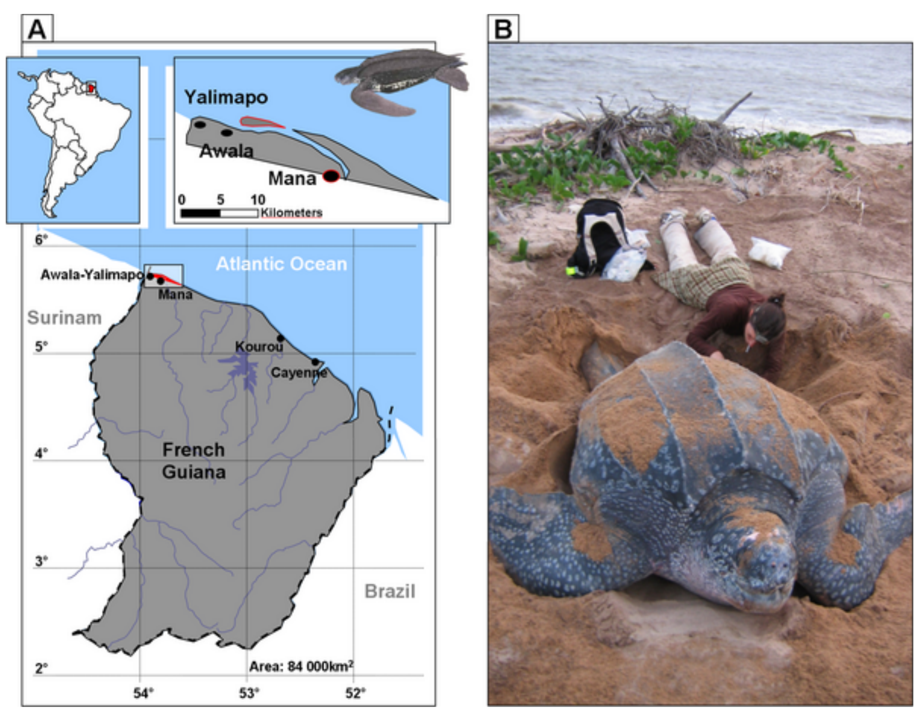
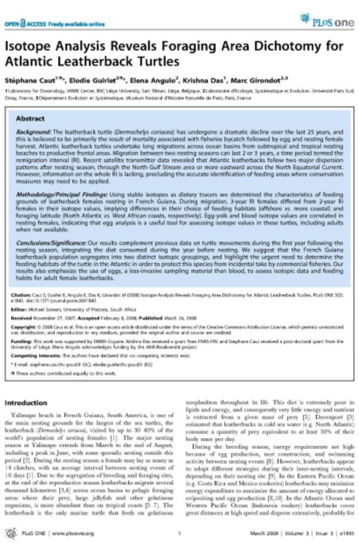
These authors contributed equally to this work.



Ecologie trophique

Deux aires d'alimentation pour la tortue Luth?



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Abstract

Background: The leatherback turtle (*Dermochelys coriacea*) has undergone a dramatic decline over the last 25 years, and this is believed to be primarily the result of mortality associated with fisheries bycatch followed by egg and nesting female harvest. Atlantic leatherback turtles undertake long migrations across ocean basins from subtropical and tropical nesting beaches to productive frontal areas. Migration between two nesting seasons can last 2 or 3 years, a time period termed the remigration interval (RI). Recent satellite transmitter data revealed that Atlantic leatherbacks follow two major dispersion patterns after nesting season, through the North Gulf Stream area or more eastward across the North Equatorial Current. However, information on the whole RI is lacking, precluding the accurate identification of feeding areas where conservation measures may need to be applied.

Methodology/Principal Findings: Using stable isotopes as dietary tracers we determined the characteristics of feeding grounds of leatherback females nesting in French Guiana. During migration, 3-year RI females differed from 2-year RI females in their isotope values, implying differences in their choice of feeding habitats (offshore vs. more coastal) and foraging latitude (North Atlantic vs. West African coasts, respectively). Egg-yolk and blood isotope values are correlated in nesting females, indicating that egg analysis is a useful tool for assessing isotope values in these turtles, including adults when not available.

Conclusions/Significance: Our results complement previous data on turtle movements during the first year following the nesting season, integrating the diet consumed during the year before nesting. We suggest that the French Guiana leatherback population segregates into two distinct isotopic groupings, and highlight the urgent need to determine the feeding habitats of the turtle in the Atlantic in order to protect this species from incidental take by commercial fisheries. Our results also emphasize the use of eggs, a less-invasive sampling material than blood, to assess isotopic data and feeding habits for adult female leatherbacks.

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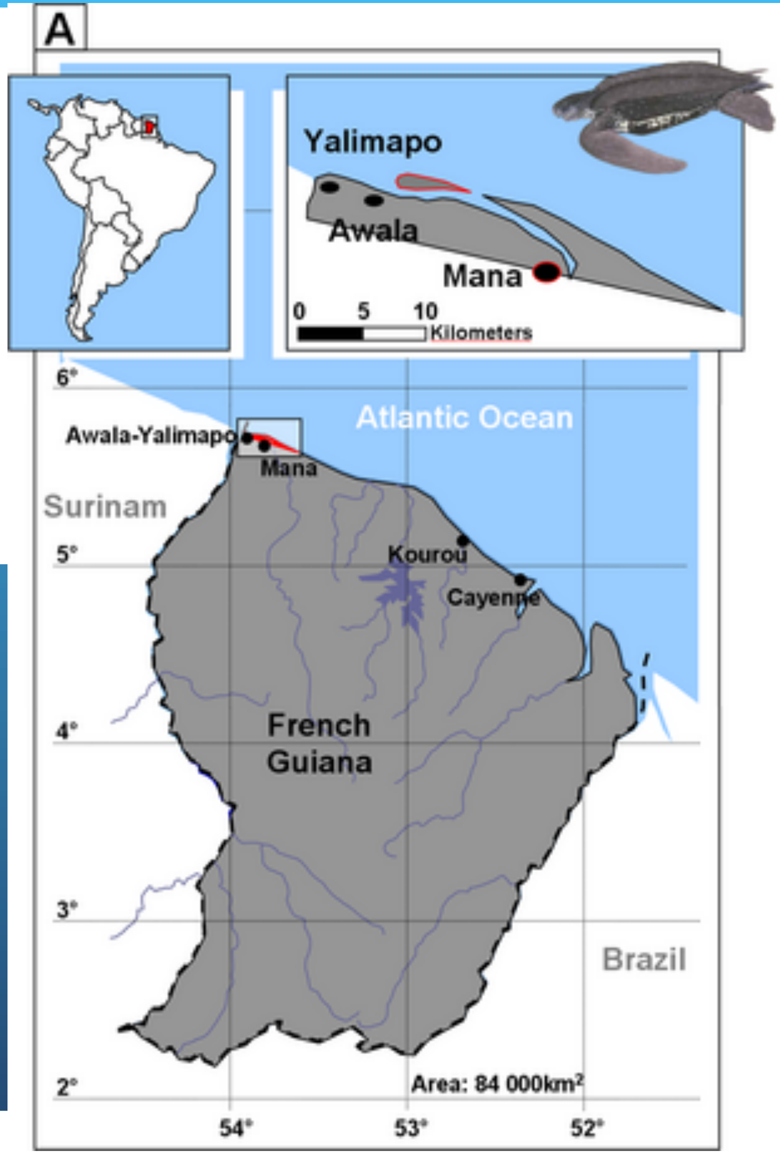
These authors contributed equally to this work.

Introduction

Yalimapo beach in French Guiana, South America, is one of the main nesting grounds for the largest of the sea turtles, the leatherback (*Dermochelys coriacea*), visited by up to 30 40% of the world's population of nesting females [1]. The major nesting season at Yalimapo extends from March to the end of August, including a peak in June, with some sporadic nesting outside this period [2]. During the nesting season a female may lay as many as 14 clutches, with an average interval between nesting events of 10 days [1]. Due to the segregation of breeding and foraging sites, at the end of the reproductive season leatherbacks migrate several thousand kilometers [3,4] across ocean basins to pelagic foraging areas where their prey, large jellyfish and other gelatinous organisms, is more abundant than on tropical coasts [5 7]. The leatherback is the only marine turtle that feeds on gelatinous zooplankton throughout its life. This diet is extremely poor in lipids and energy, and consequently very little energy and nutrient is extracted from a given mass of prey [5]. Davenport [5] estimated that leatherbacks in cold sea water (e.g. North Atlantic) consume a quantity of prey equivalent to at least 50% of their body mass per day.

During the breeding season, energy requirements are high because of egg production, nest construction, and swimming activity between nesting events [8]. However, leatherbacks appear to adopt different strategies during their inter-nesting intervals, depending on their nesting site [9]. In the Eastern Pacific Ocean (e.g. Costa Rica and Mexico rookeries) leatherbacks may minimize energy expenditure to maximize the amount of energy allocated to ovipositing and egg production [8,10]. In the Atlantic Ocean and Western Pacific Ocean (Indonesia rookery) leatherbacks cover great distances at high speed and disperse extensively, probably for

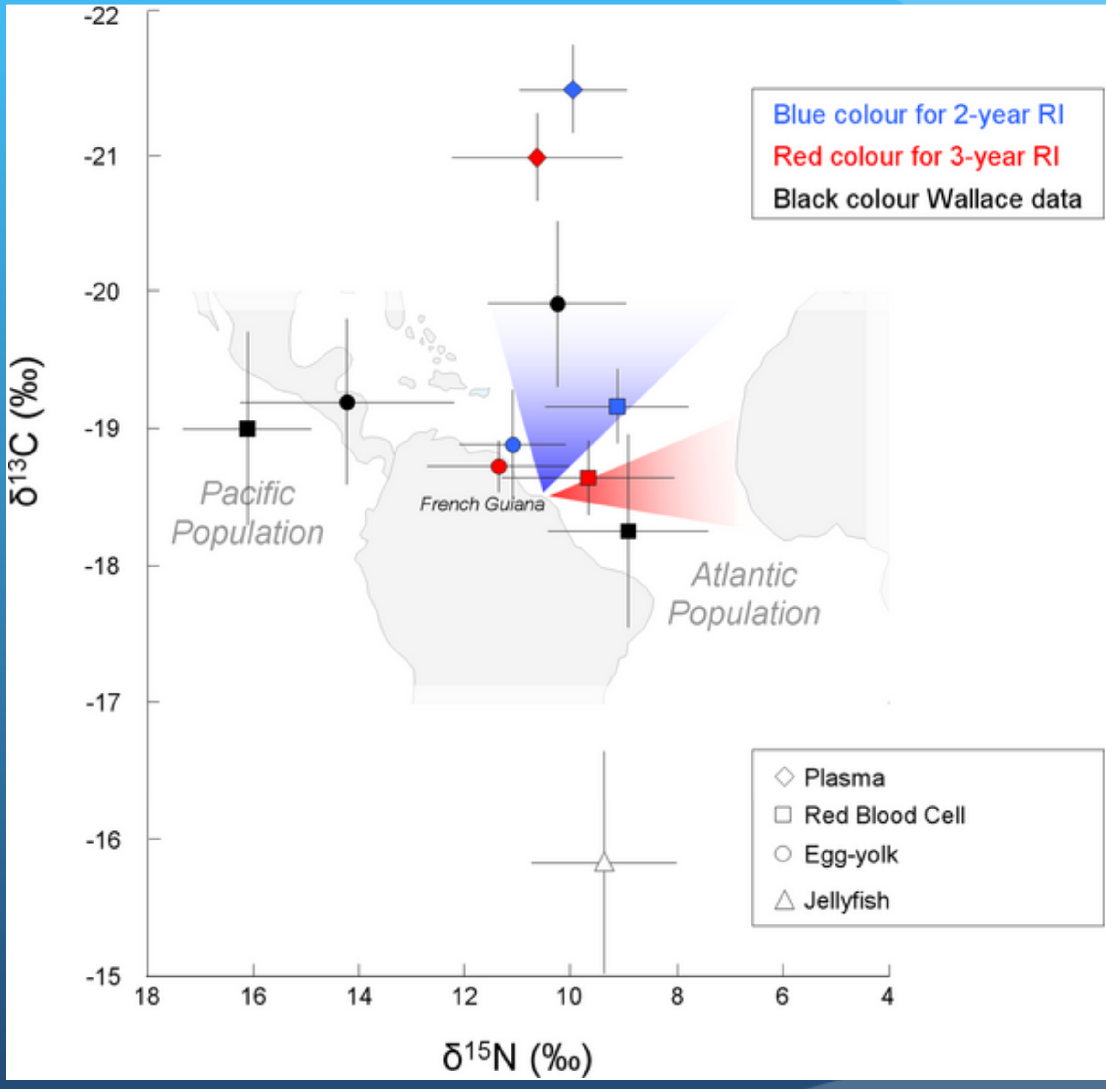


Ecologie trophique

Intervalle de Remigration:
-2 ans
-3 ans

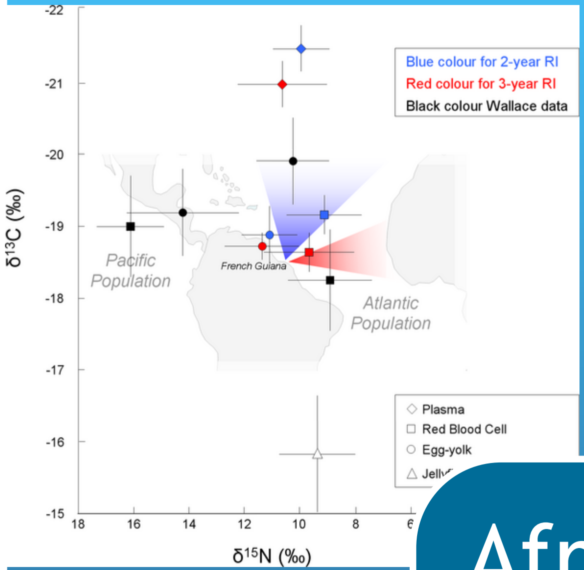
Deux aires d'alimentation pour la tortue Luth?

Ecologie trophique



Deux aires d'alimentation pour la tortue Luth?

Ecologie trophique



Afrique de l'Ouest

Atlantique Nord

- Afrique: Retard?
- Impact de la pêche côtière?

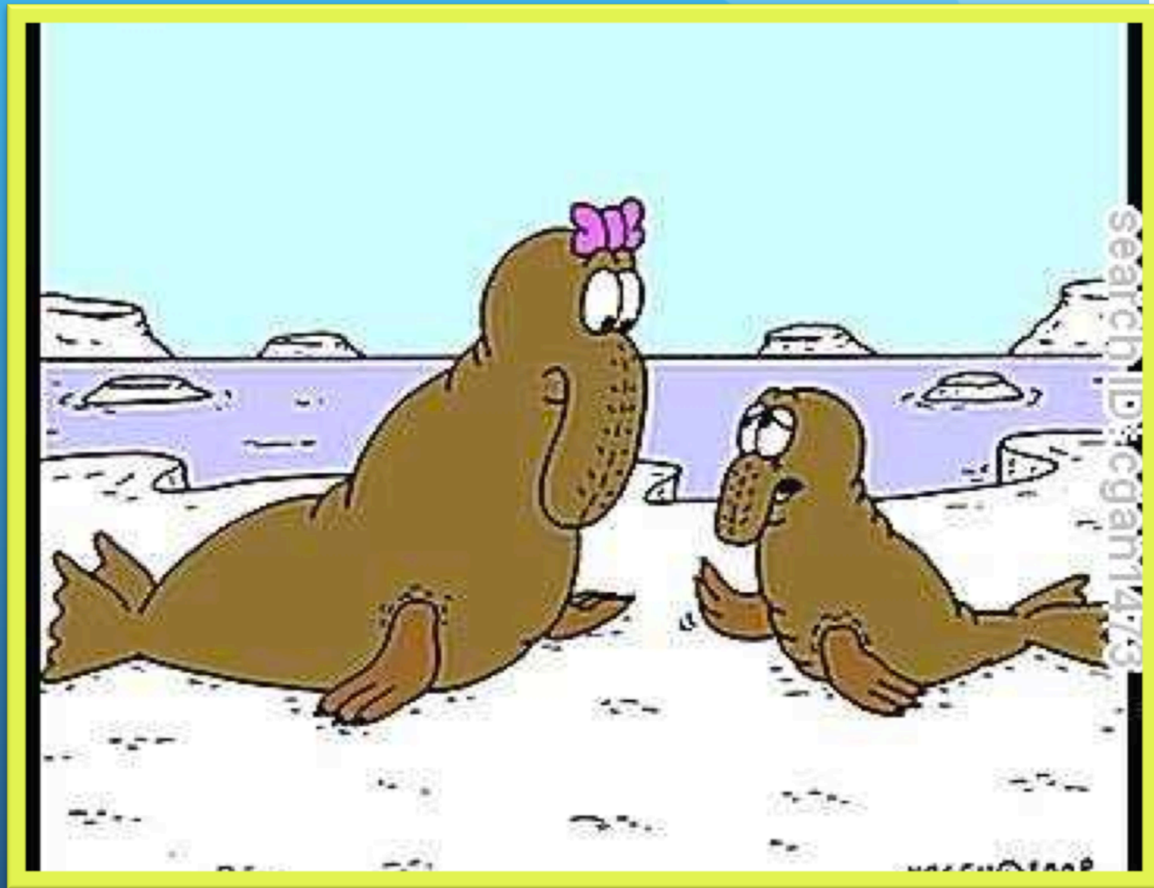
???

Traceurs oui mais...?

Credit: Oceanus

Les isotopes stables chez les vertébrés marins

1. Ecologie trophique
2. Physiologie
3. Contaminants



Physiologie et Fractionnement

1978: Michael J. DeNiro and Samuel Epstein. Influence of diet on the distribution of carbon isotopes in animals Geochimica and Cosmochemica Acta 42: 495-506

1. Les valeurs en $\delta^{13}C$ d'un consommateur sont directement proportionelles à celles de leur diète: régime controllé en laboratoire sur 8 espèces d'invertébrés et de souris.
2. Cet enrichissement en ^{13}C est minime (moins de 2‰).
3. Cette différence proie-diète dépend du type d'aliment ingéré et du tissus considéré.

Processus physiologiques

- Gestation
- Lactation
- Jeûne
- Mue

@Cathy Debier, UCL

Marine Mammal Science

MARINE MAMMAL SCIENCE, 26(4): 880–895 (October 2010)

DOI: 10.1111/j.1748-7692.2010.00372.x

Influence de la gestation, de la lactation et du jeûne sur les rapports isotopiques chez l'éléphant de mer

Assessment of gestation, lactation and fasting on stable isotope ratios in northern elephant seals (*Mirounga angustirostris*)

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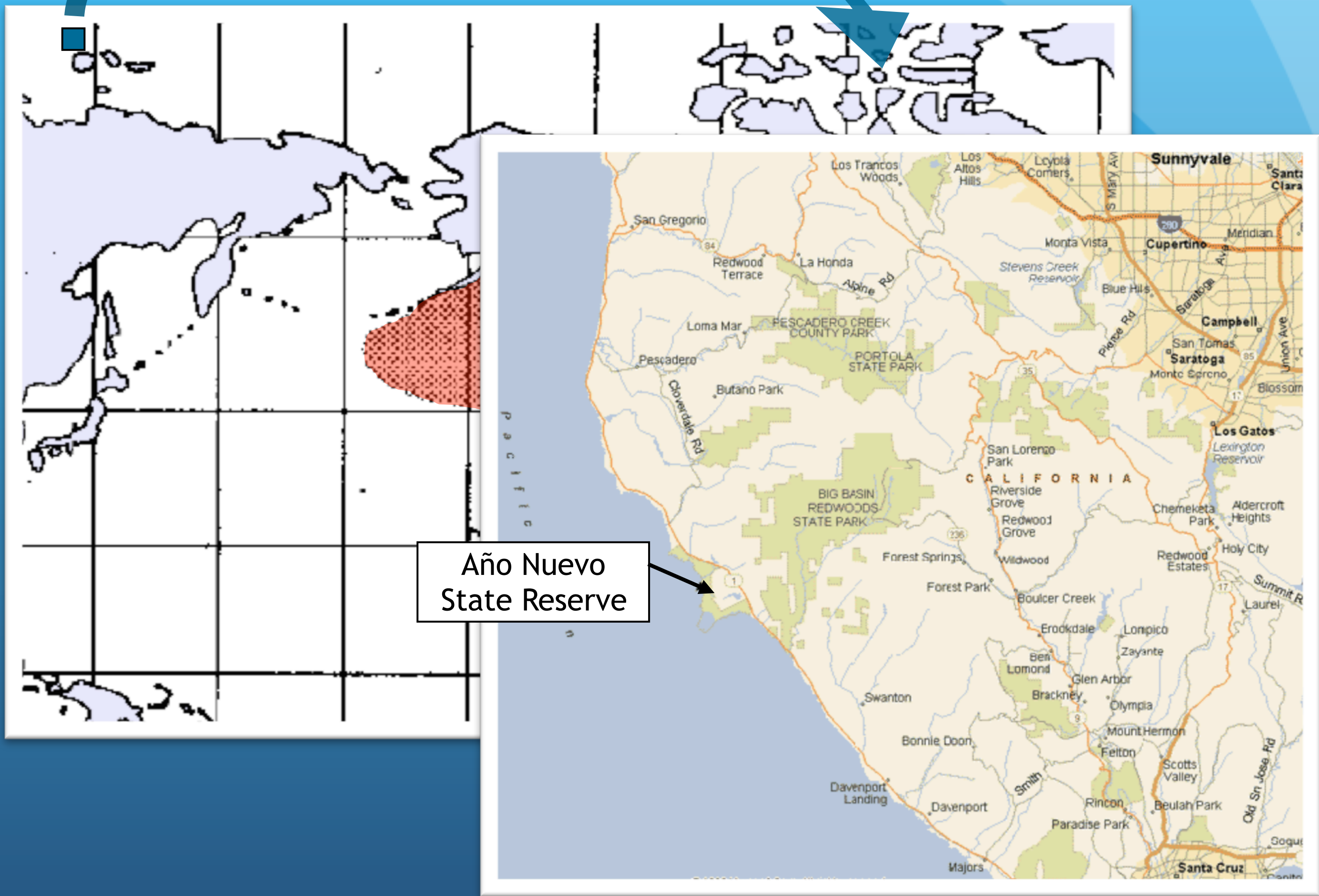
Gilles Lepoint
Jean-Marie Bouquegneau
Krishna Das
MARE Centre,
Laboratory for Oceanology B6c,
University of Liège, B-4000 Liège, Belgium

Abstract

Effects of physiological processes such as gestation, lactation and nutritional stress on stable isotope ratios remain poorly understood. To determine their impact, we investigated these processes in simultaneously fasting and lactating northern elephant seals (*Mirounga angustirostris*). Stable carbon and nitrogen isotope values were measured in blood and milk of 10 mother-pup pairs on days 5 and 22 of lactation. As long- and short-term integrators of diet, blood cells and serum may reflect foraging data or energy reserves from late gestation and lactation, respectively. Limited changes in isotopic signatures of maternal blood over the lactating period were highlighted. Nitrogen isotope fractionation associated with mother-to-offspring

Distribution de l’éléphant de mer septentrional



Physiologie

La lactation est un processus intense chez les femelles

~ 25 days

x 1/3

Début

x 4

Fin

Un peu moins chez les mâles!

Physiologie

Plages rocheuse

sang

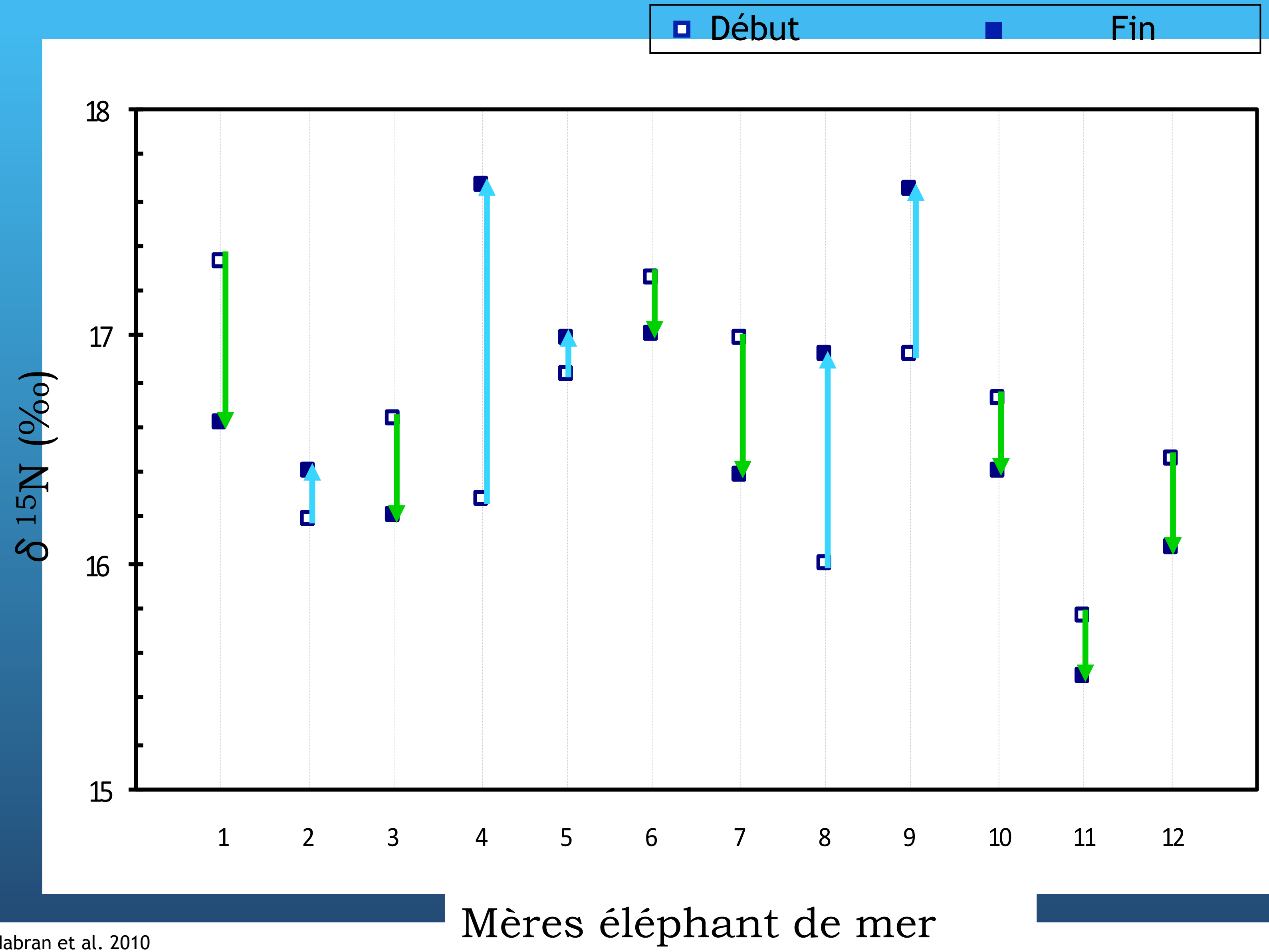
lait

lard

- ▶ Animaux sauvages
  - Representatifs de la population
  - Techniques peu invasives
- ▶ accessible

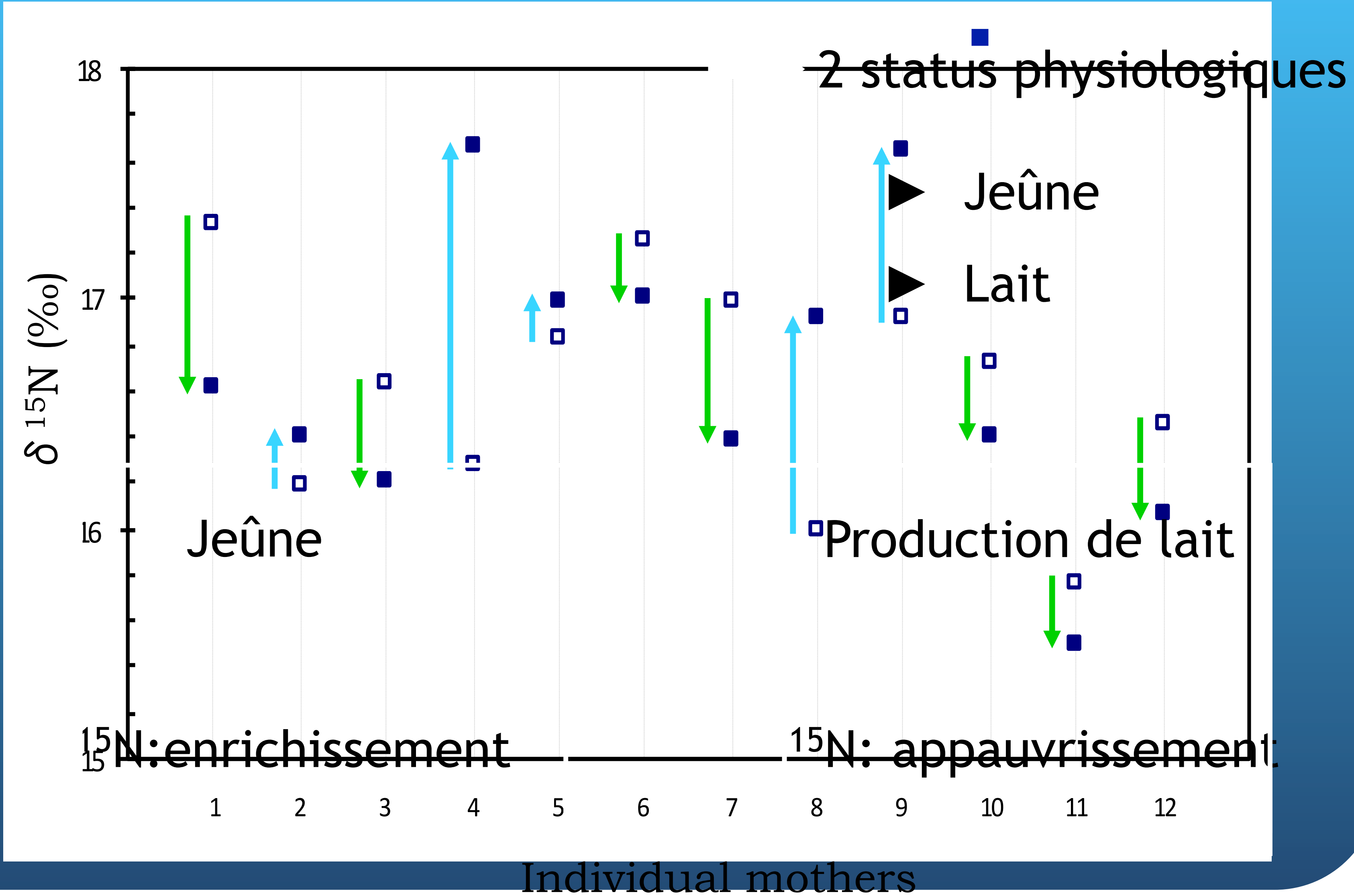
Crédit: Cathy Debier, UCL

Variabilité dans le sérum



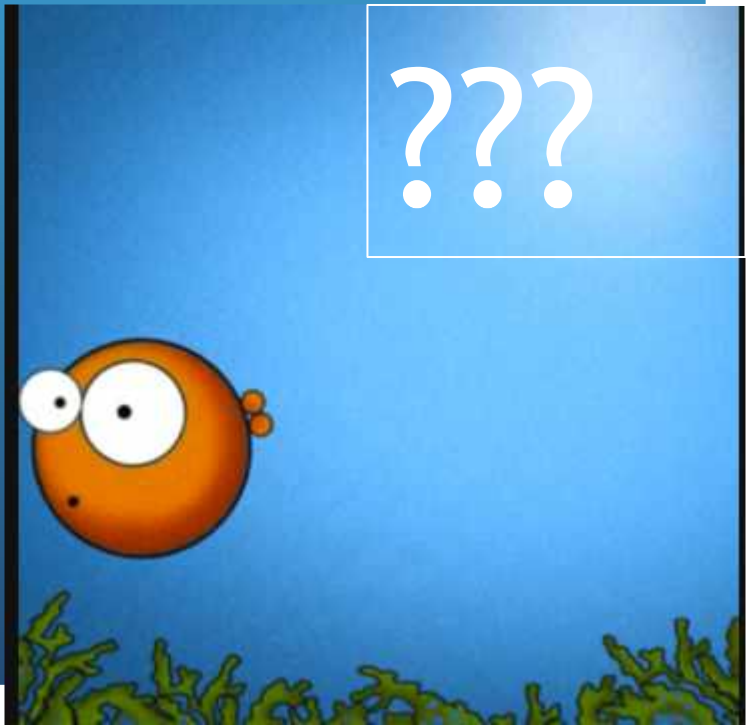
From Habran et al. 2010

Variabilité dans le sérum

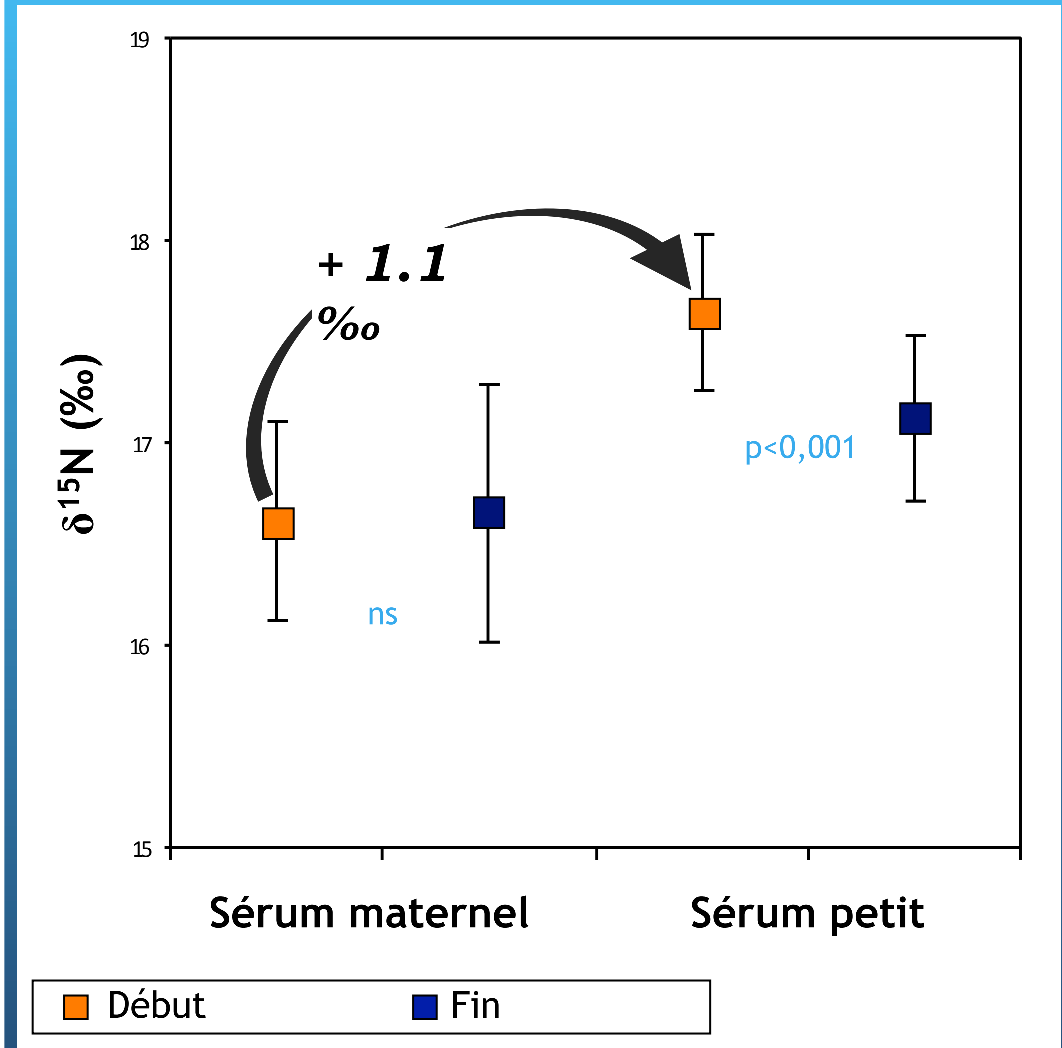


From Habran et al. 2010

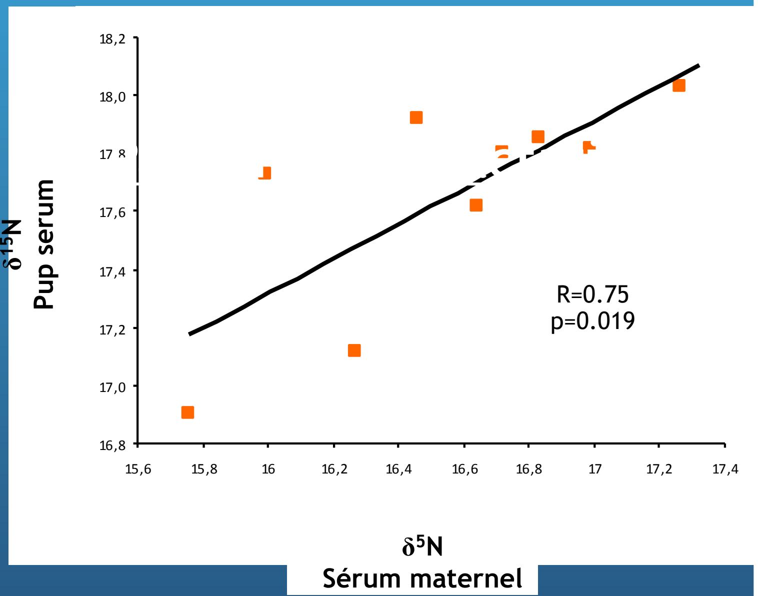
- Le sérum réagit de manière non prévisible lors des processus de jeûne et de production de lait
- Turn-over très rapide
- Temps de demi-vie des valeurs en $\delta^{13}C$ et $\delta^{15}N$ lors de ces processus?



Fractionnement mère- petit



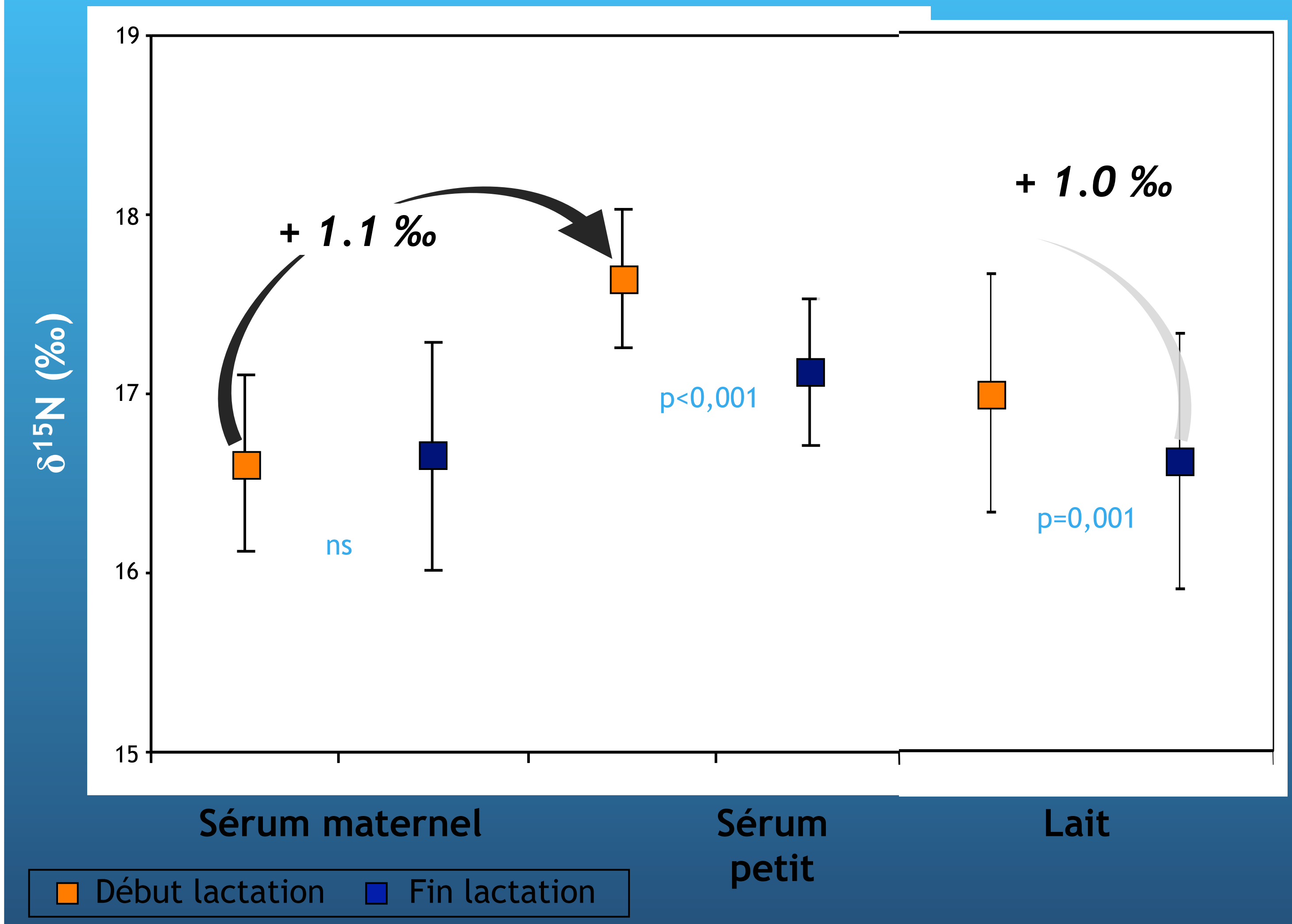
► Sérum du nouveau-né lié au sérum maternel



From Habran et al. 2010

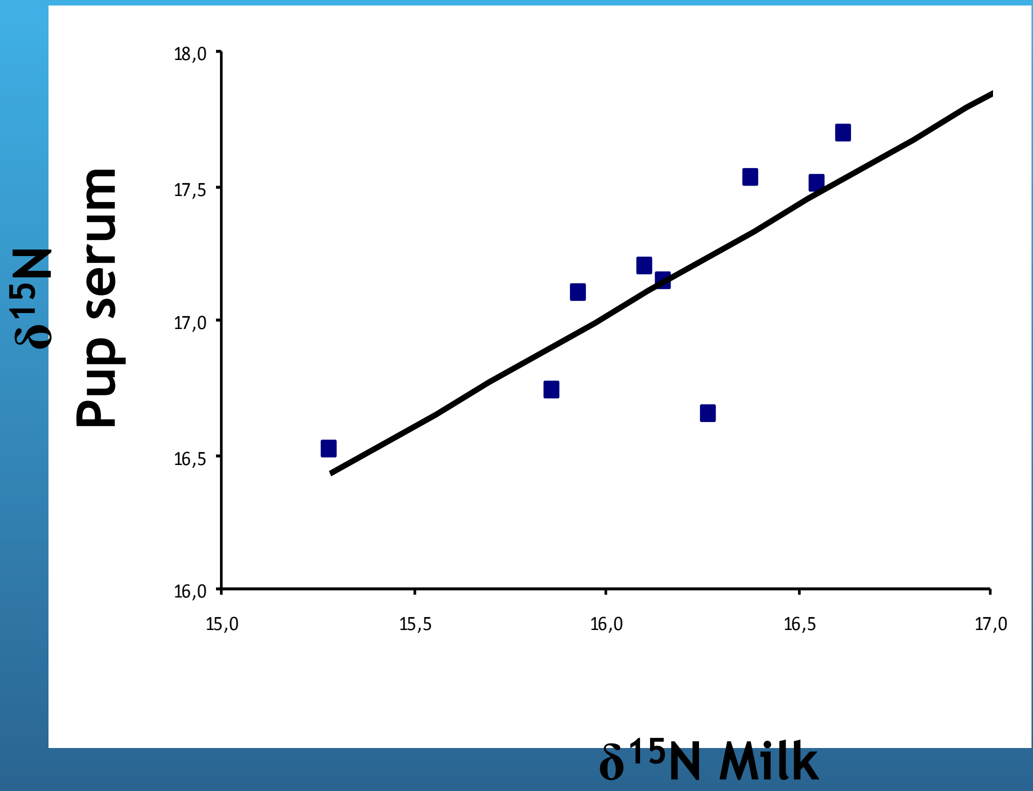
Physiologie

Fractionnement lait- petit

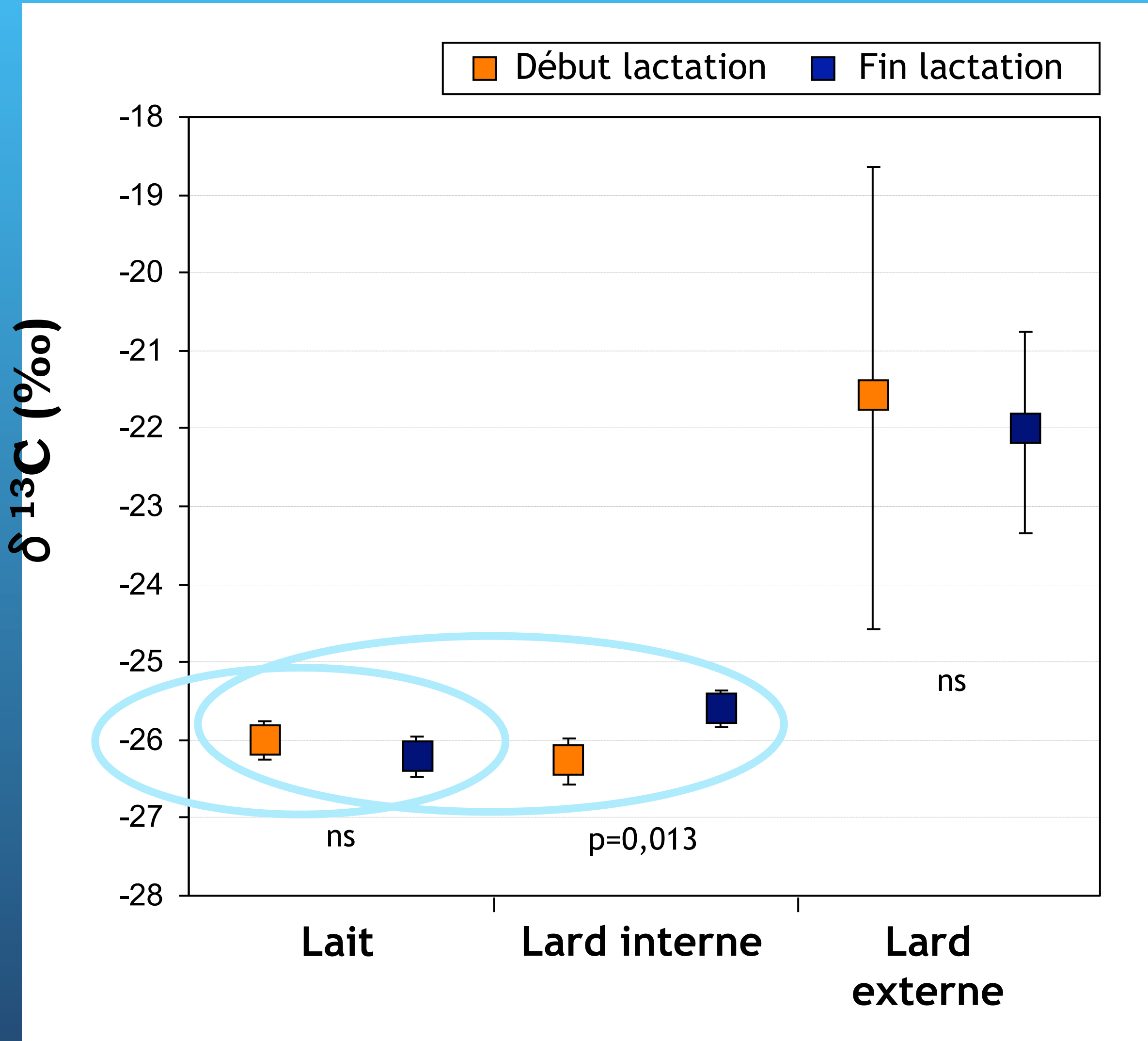


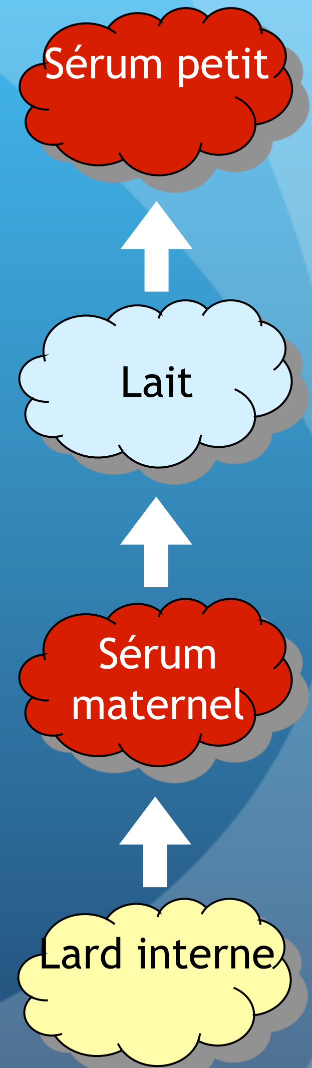
Physiologie

Sérum du petit lié au lait en fin de lactation



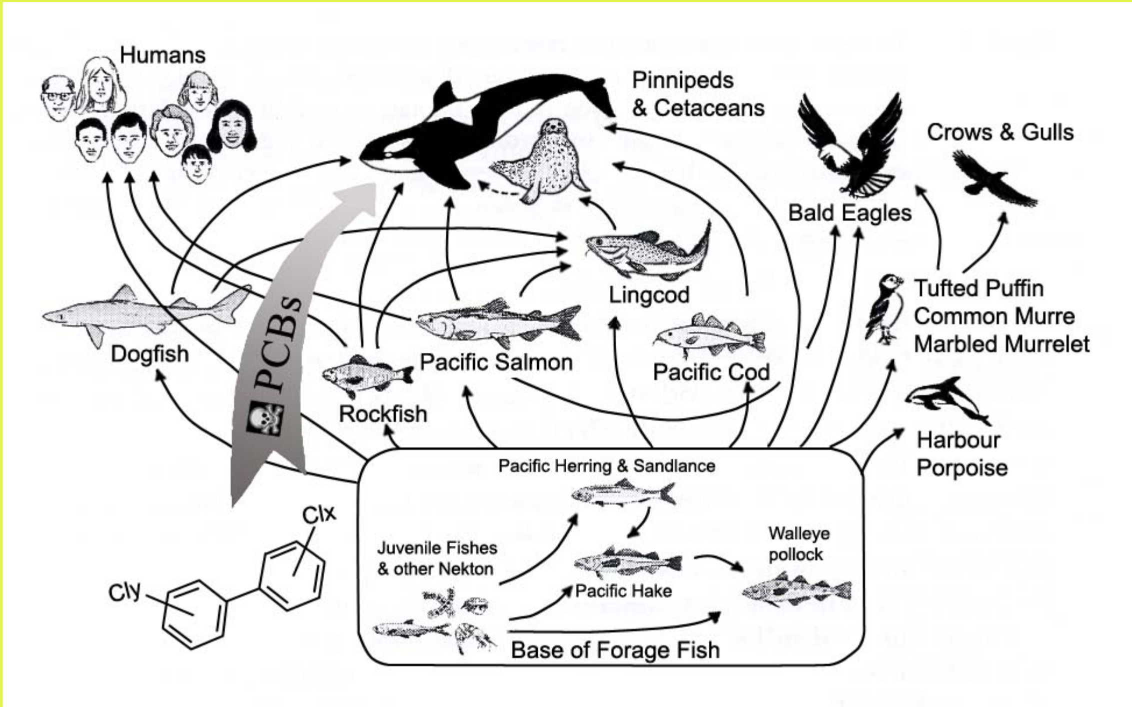
Production de lait à partir du lard interne





Les isotopes stables chez les vertébrés marins

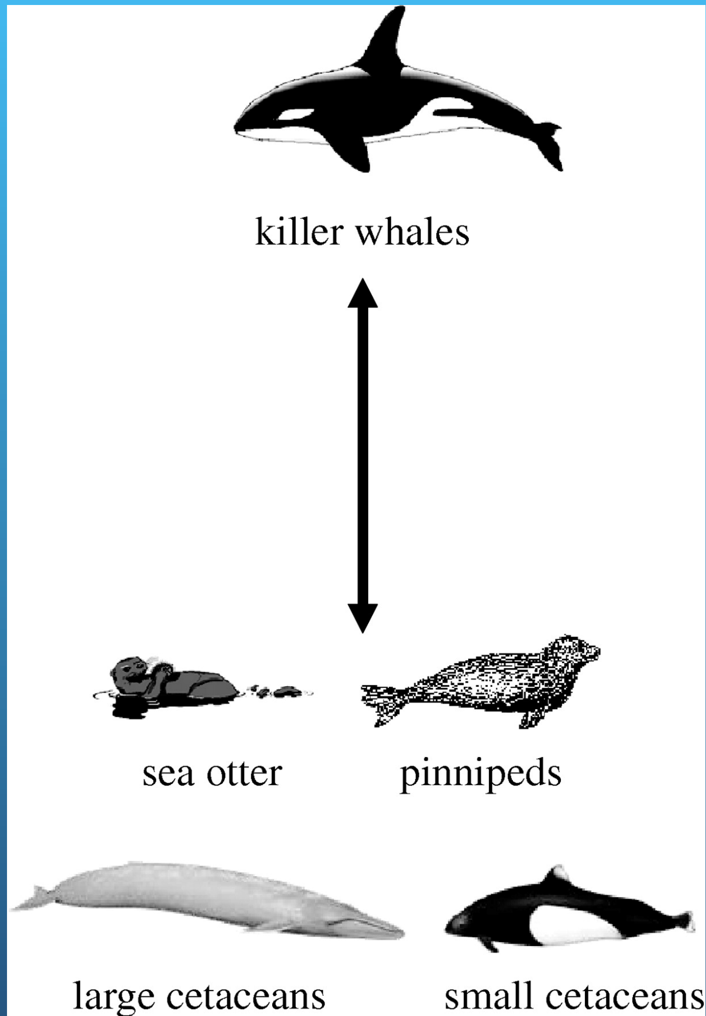
1. Ecologie trophique
2. Physiologie
3. Contaminants



✓Transfert trophique
✓ Structure des populations
✓ Variation de niches écologiques

Contaminants

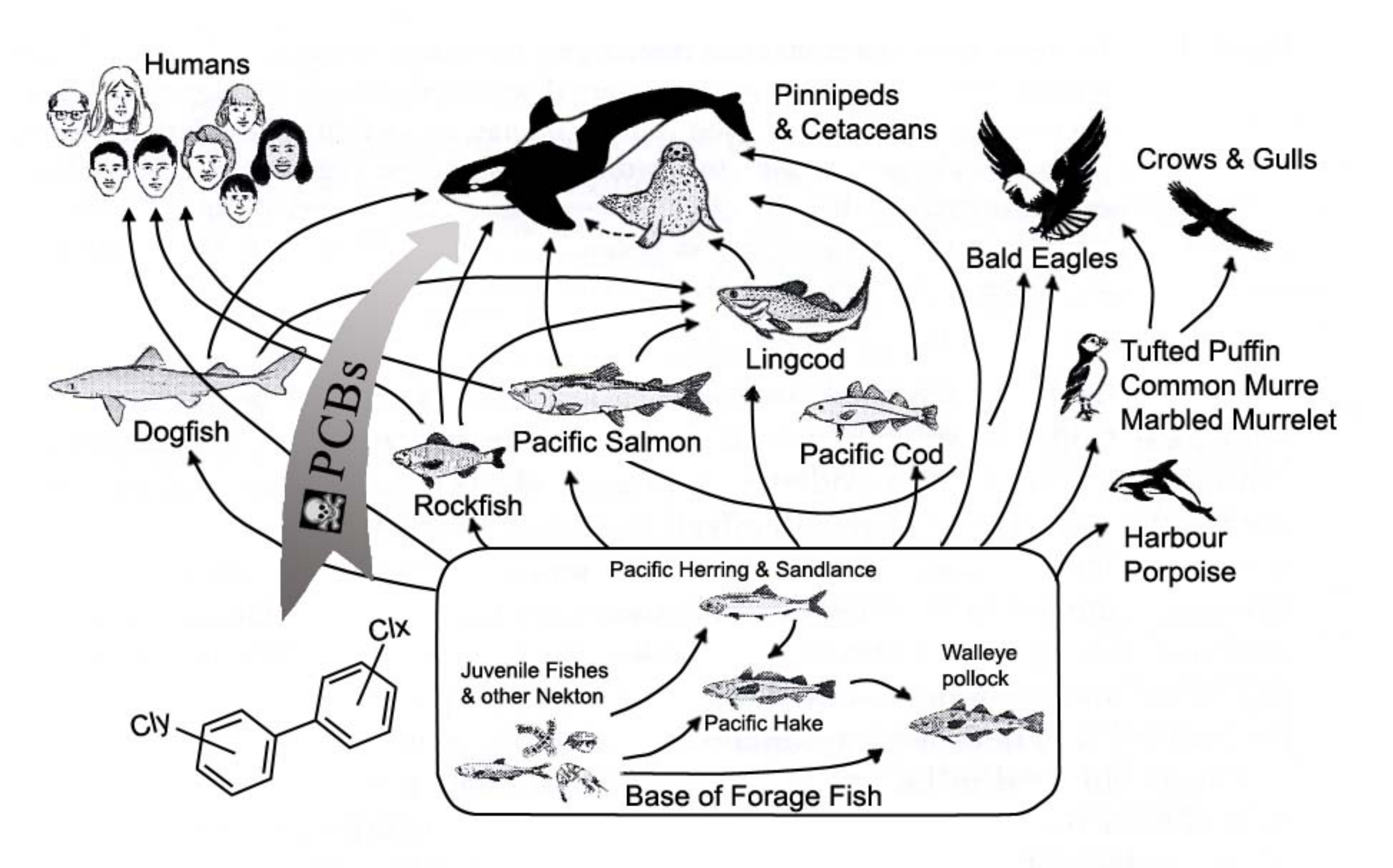
Les mammifères marins occupent le haut des chaînes trophiques



Estes J et al. Phil. Trans. R. Soc. B 2009;364:1647-1658

Contaminants

Biomagnification des polluants organiques en milieu marin!



Contaminants

L'épaulard, *Orcinus orca*, au sommet des chaînes trophiques

- > 35 ans
- Entre 5 et 7 mètres
- Mâles: 8 tonnes
- Femelles: 4 tonnes

CREDIT: ARI FRIEDLAENDER

http://www.sciencemag.org/content/331/6015/274.full

CREDIT: DAVE ELLIFRIT/NOAA ALASKA FISHERIES SCIENCE CENTER UNDER PERMIT 782-1719/NATIONAL MARINE FISHERIES

http://www.sciencemag.org/content/331/6015/274.full

Contaminants

CREDIT: LANCE BARRETT-LENNARD

http://www.sciencemag.org/content/331/6015/274.full

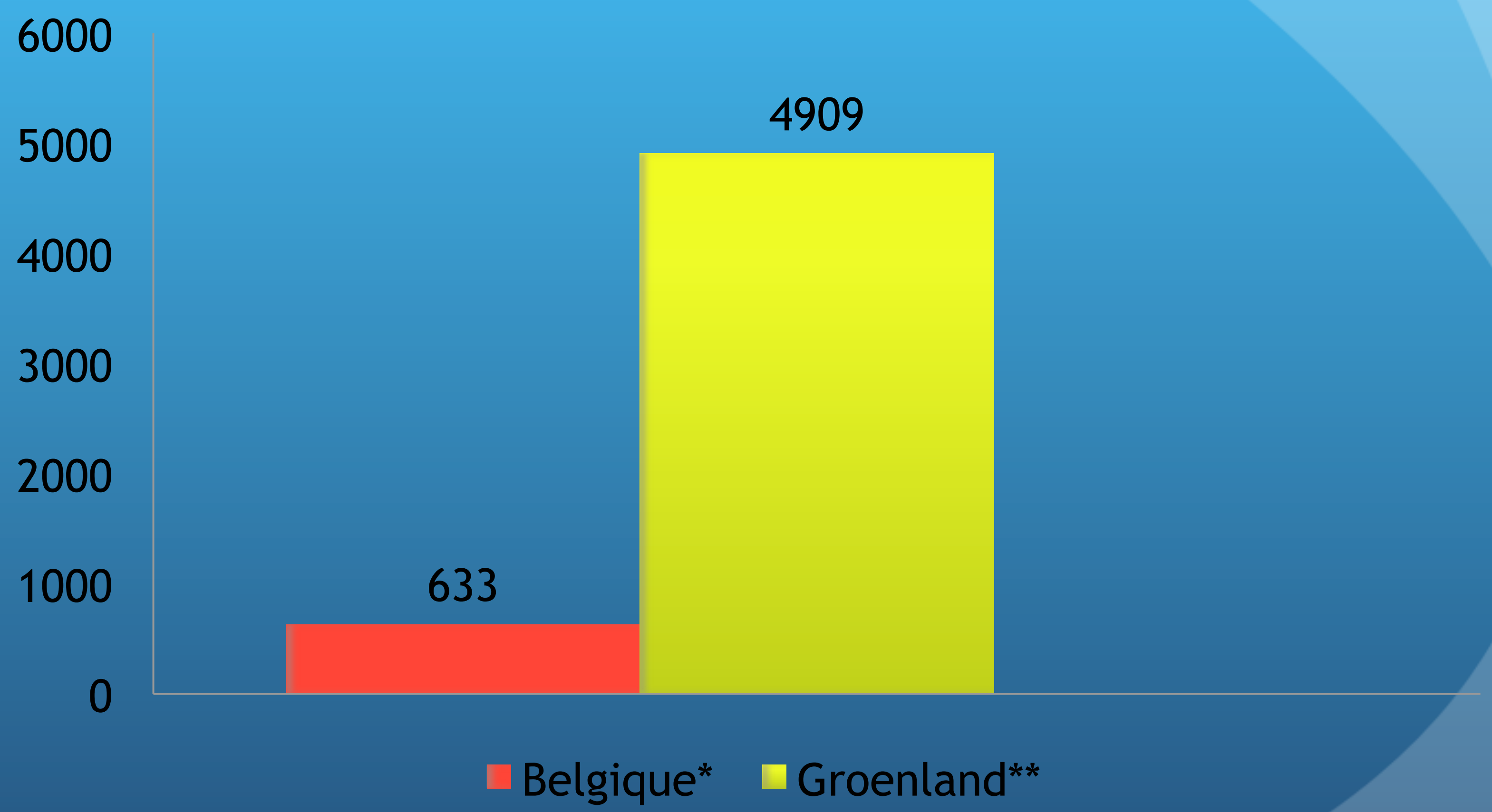
Contaminants

CREDIT: JOHN DURBAN/NORTH GULF OCEANIC SOCIETY

http://www.sciencemag.org/content/331/6015/274.full

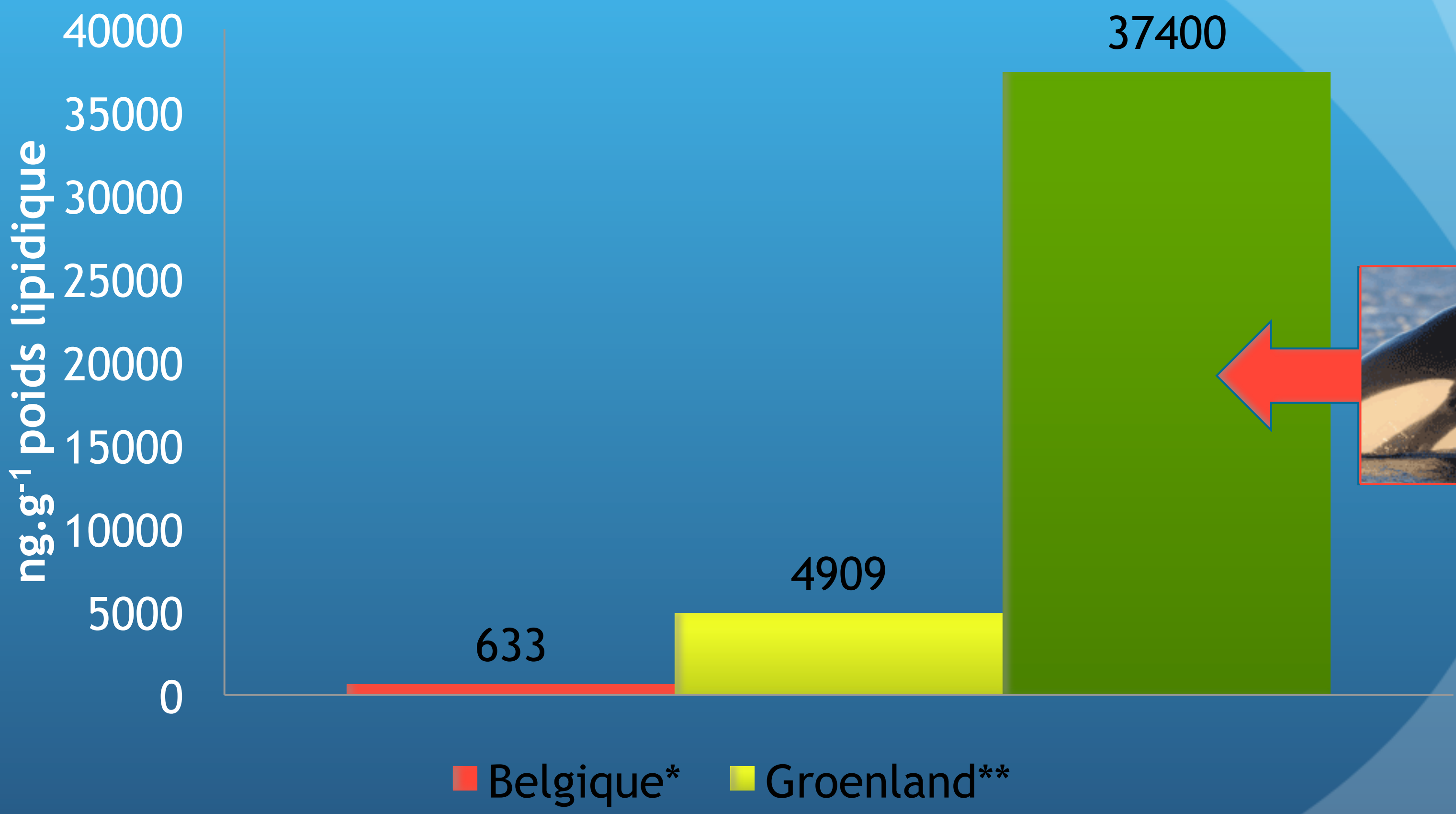
Contaminants

PCBs dans la graisse humaine
ng par g de poids lipidique

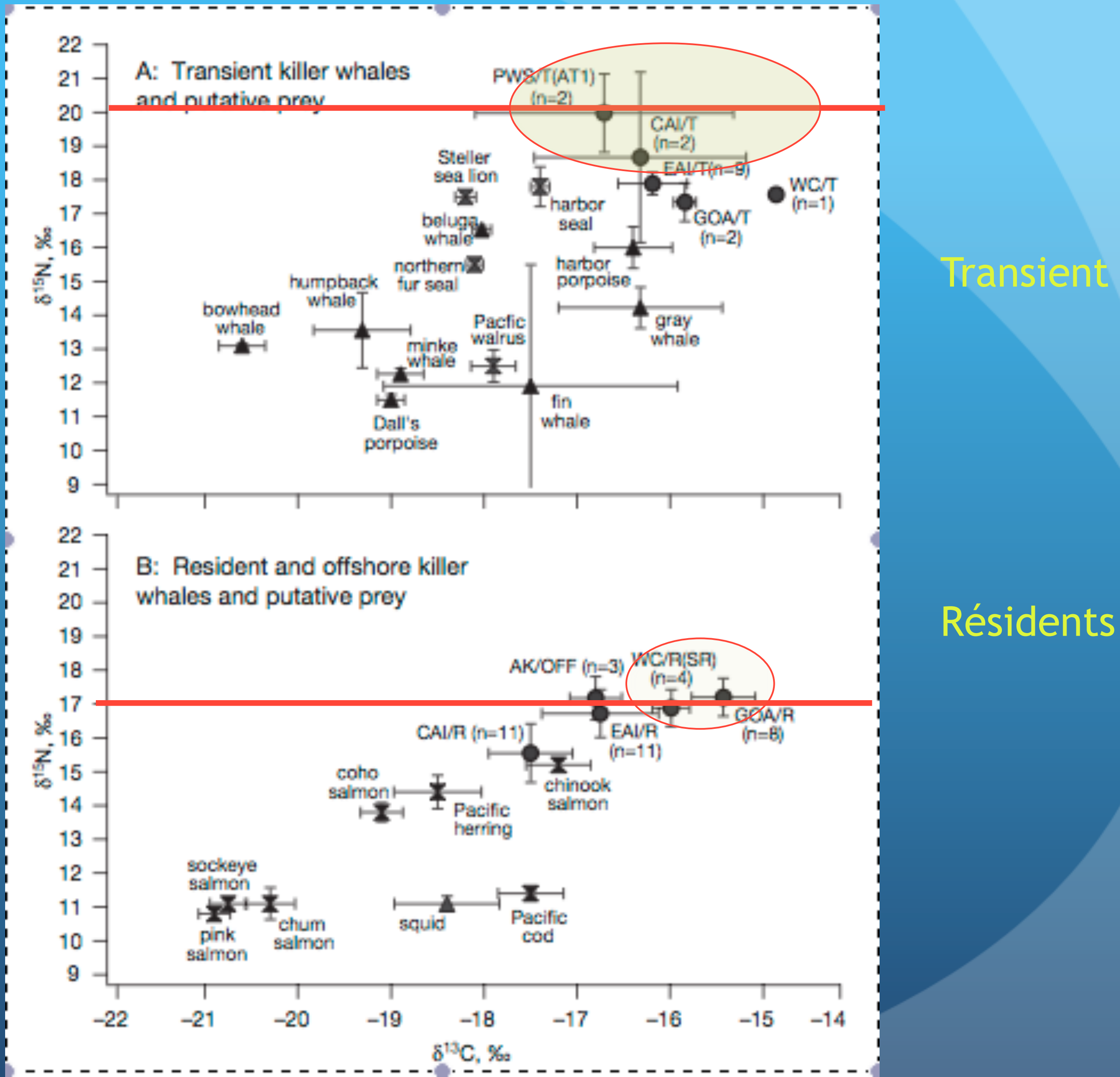


* De Saeger et al. 2005 – Moyenne pour 57 Belges mâles (Σ PCB 28, 52, 101, 118, 138, 153 et 180)
** De wailly et al., 1999 - Moyenne for 16 Groenlandais – 41-54 ans - (Σ 14 PCBs)

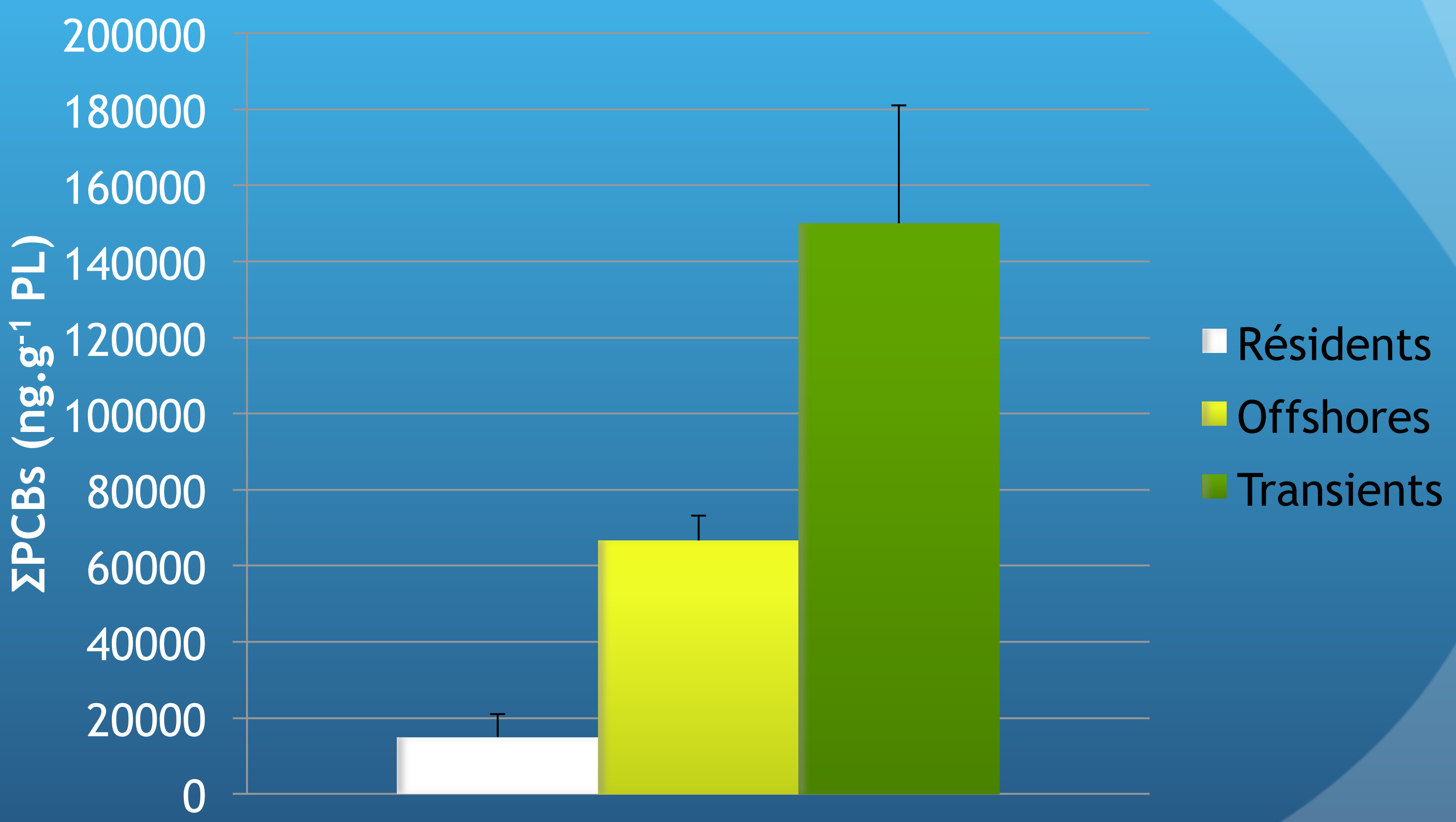
L'épaulard détient un triste record



* De Saeger et al. 2005 – Moyenne pour 57 Belges mâles (Σ PCB 28, 52, 101, 118, 138, 153 et 180)
** De wailly et al., 1999 - Moyenne for 16 Groenlandais – 41-54 ans - (Σ 14 PCBs)
*** Ross et al. 2000 in adult males (Σ 136 PCBs)


A: Transient killer whales and putative prey
PWS/T(AT1) (n=2)
CAI/T (n=2)
EAI/T(n=9)
WC/T (n=1)
GOA/T (n=2)
Steller sea lion
harbor seal
beluga whale
northern fur seal
harbor porpoise
humpback whale
bowhead whale
Pacfic walrus
minke whale
gray whale
fin whale
Dall's porpoise
B: Resident and offshore killer whales and putative prey
AK/OFF (n=3)
WC/R(SR) (n=4)
GOA/R (n=8)
CAI/R (n=11)
EAI/R (n=11)
coho salmon
chinook salmon
Pacific herring
sockeye salmon
chum salmon
pink salmon
squid
Pacific cod
δ15N, ‰
δ13C, ‰
Transient
Résidents

Concentrations en PCBs* chez les épaulards de l'Alaska



From Herman, D. P., D. G. Burrows, et al. (2005). "Feeding ecology of eastern North Pacific killer whales *Orcinus orca* from fatty acid, stable isotope, and organochlorine analyses of blubber biopsies." Marine Ecology Progress Series **302**: 275-291

* Somme de 40 congénères de PCBs

Contaminants

Et en mer du Nord?

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Ecological and pathological factors related to trace metal concentrations in harbour porpoises *Phocoena phocoena* from the North Sea and adjacent areas

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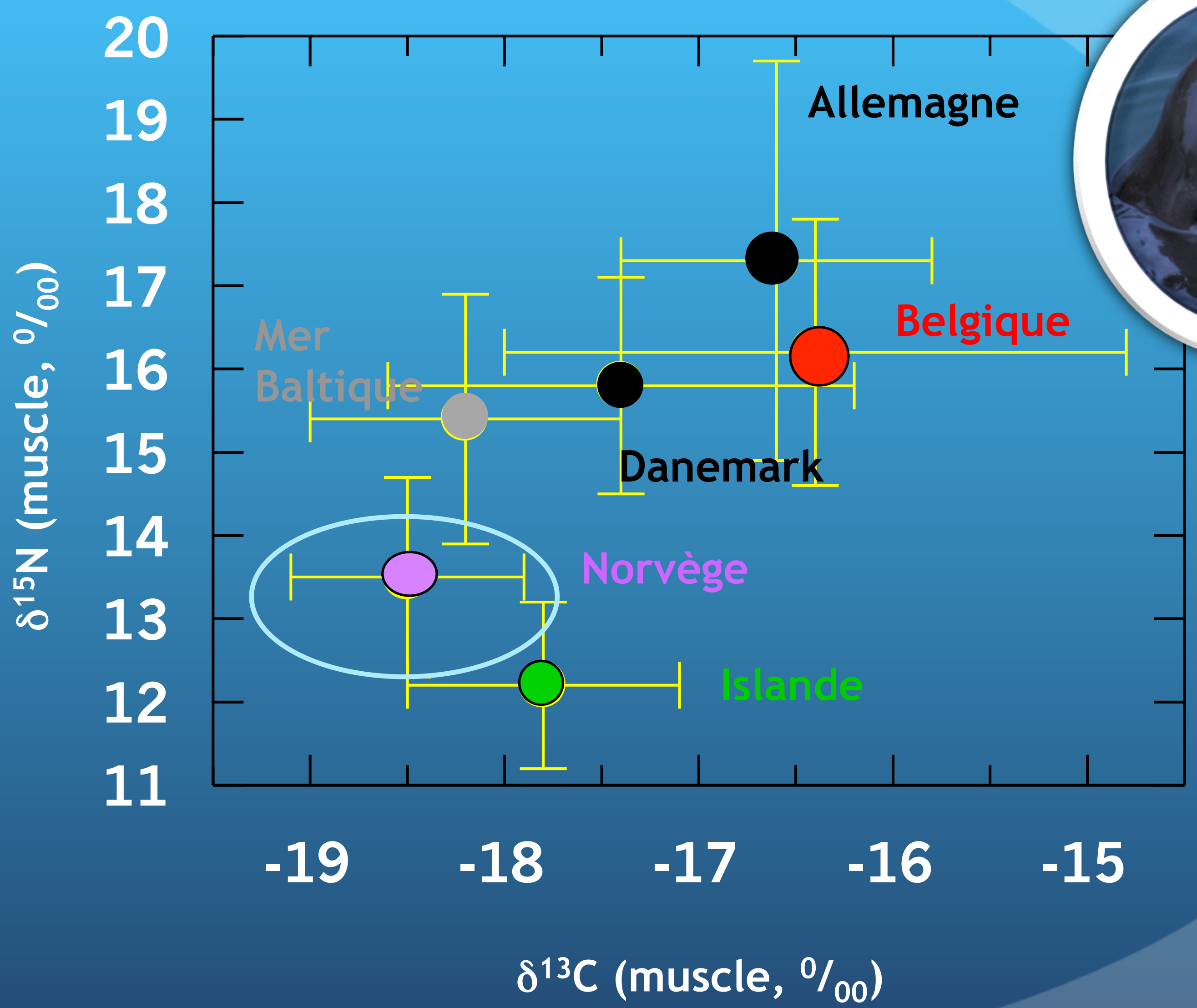
ABSTRACT: There is growing concern about the health status of the harbour porpoise *Phocoena phocoena* in the North Sea and adjacent areas. The interaction between toxicological results (Zn, Cd, Cu, Fe, Se, Hg), stable isotope data ($\delta^{13}C$ and $\delta^{15}N$) and the most common pathological findings, namely emaciation and lesions of the respiratory system, were investigated in 132 porpoises collected along the coasts of northern France, Belgium, Germany, Denmark, Iceland and Norway between 1994 and 2001. The body condition of harbour porpoises stranded on the French, Belgian and German coasts was poor compared to that of by-catch individuals from Iceland and Norway, as reflected by blubber thickness and hepatic to total body-mass ratio. High Zn and Hg concentrations were observed in some porpoises collected along the southern North Sea coast compared to by-catch individuals from Iceland, Norway and the Baltic Sea. Increasing Zn levels were observed with deteriorating health condition (emaciation and bronchopneumonia), while Hg increases were not significant. The increases were not related to shrinking liver mass which remained unchanged. These observations indicate a general redistribution of trace metals within the organs (muscles and blubber to liver), as a result of protein and lipid catabolism. Muscle $\delta^{13}C$ and $\delta^{15}N$ values remained unchanged with deteriorating body condition. Cd concentrations were associated only with age and low $\delta^{15}N$ values, indicating that high Cd concentrations in Iceland and Norway porpoises may be partly diet-related, i.e. a result of Cd contaminated prey.

KEY WORDS: North Sea · Marine mammals · Stable isotopes · Heavy metals · Harbour porpoise · Health status

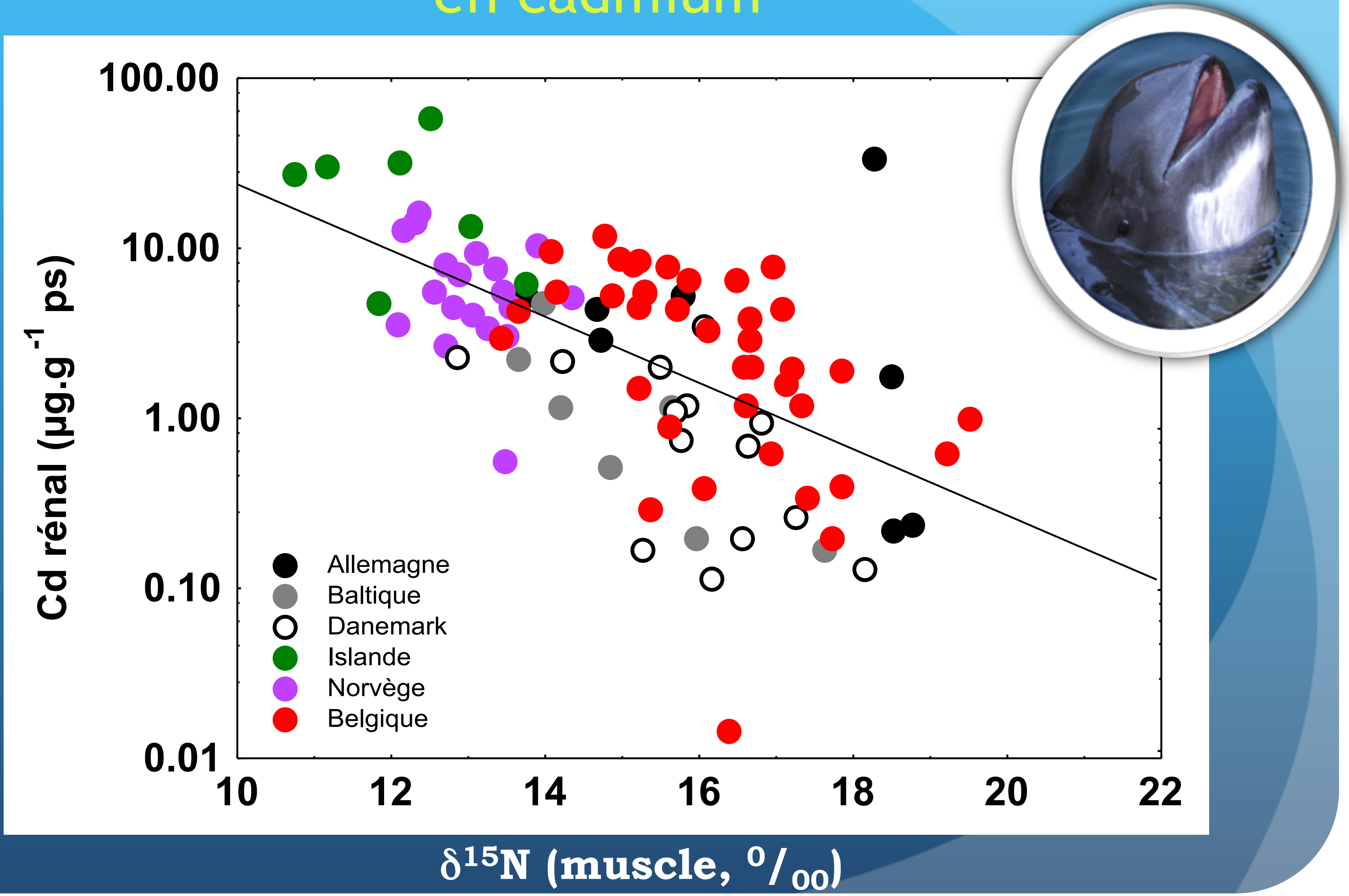
Contaminants

Le marsouin commun en Europe

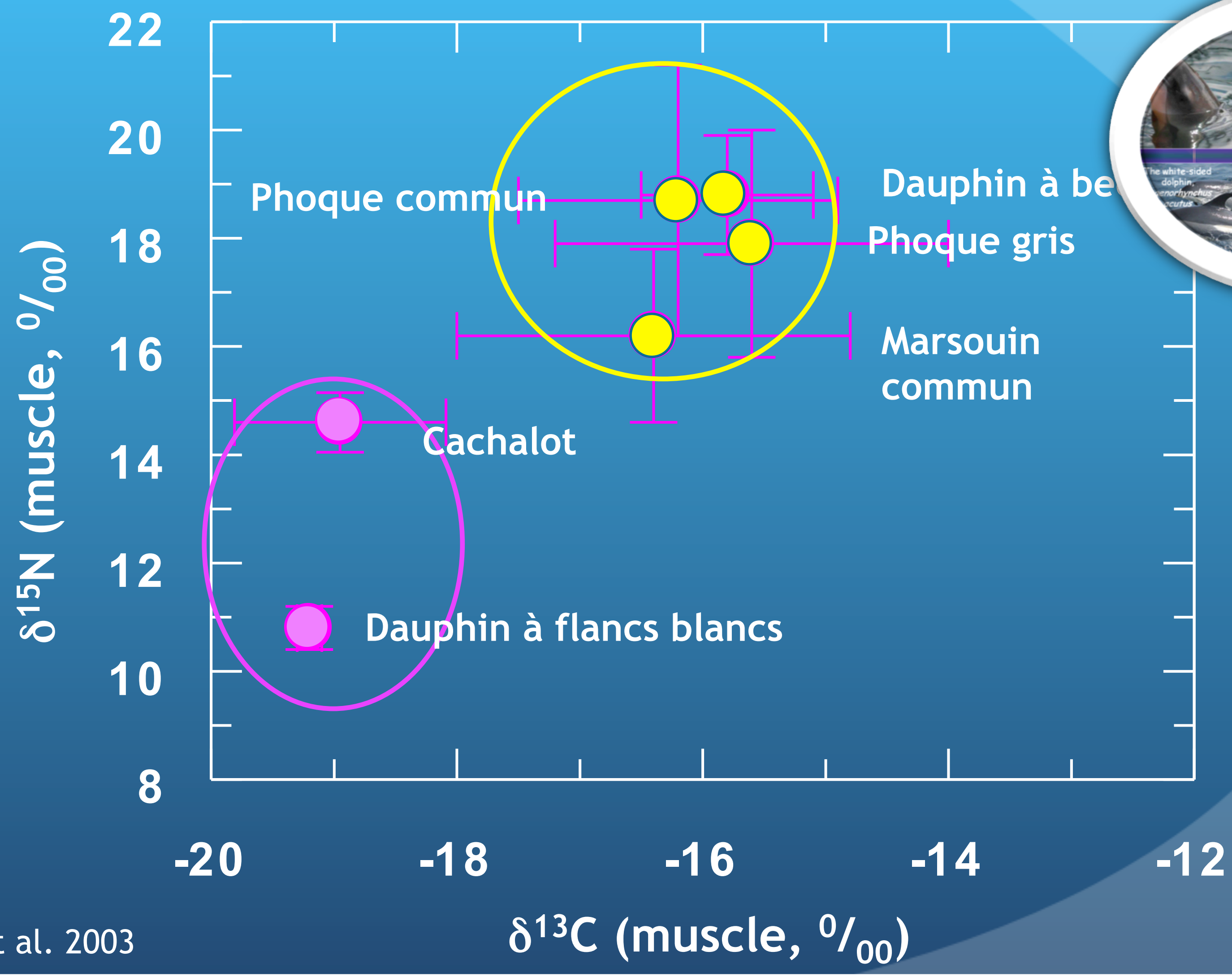


Picture from http://jeb.biologists.org/content/vol212/issue6/cover.dtl

Relation entre les valeurs en δ^{15}N et les concentrations en cadmium

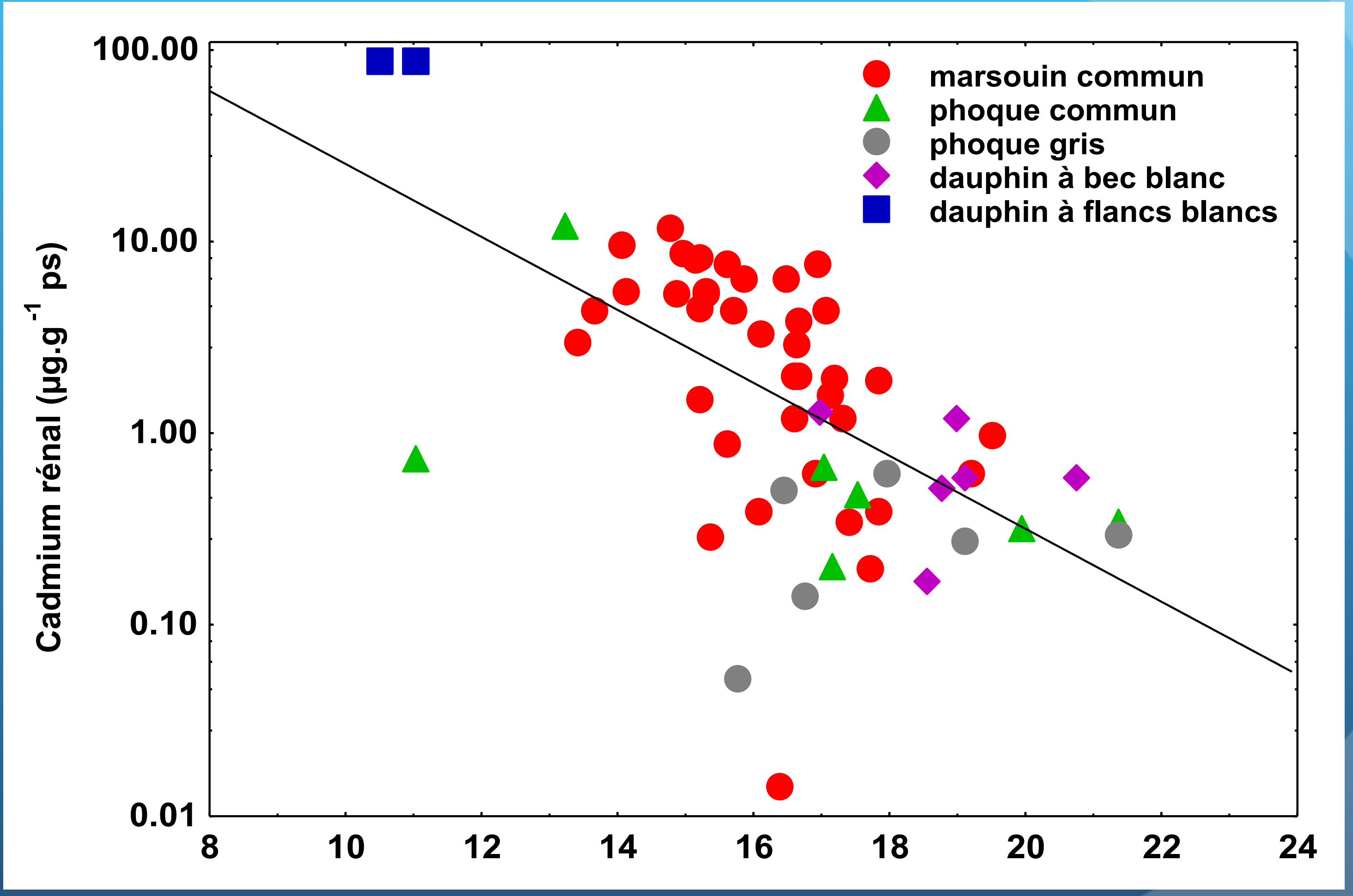


Et les autres mammifères marins?



After Das et al. 2003

Relation entre les valeurs en δ[15]N et les concentrations en cadmium



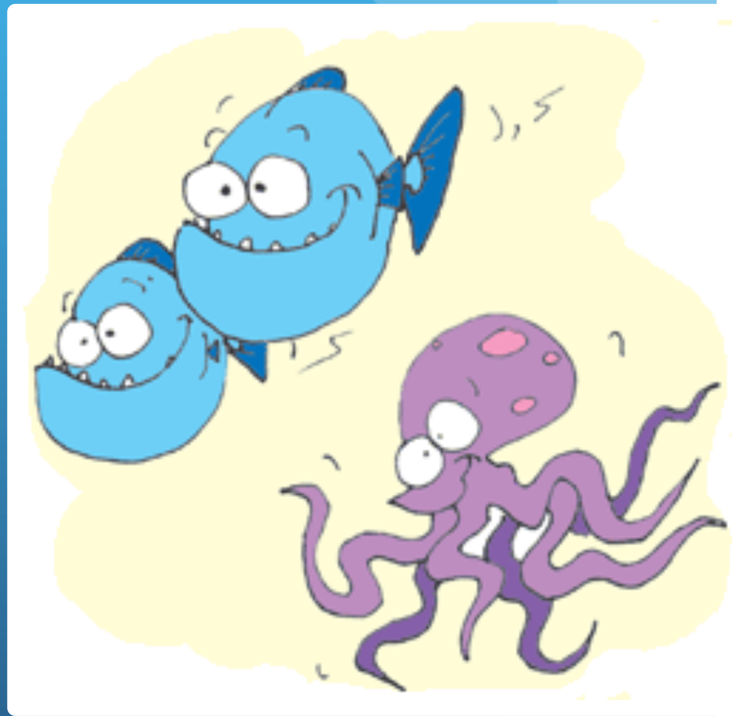
$\delta^{15}N$ (muscle, $^{0}/_{00}$)

Le cadmium, un marqueur océanique?

✓ Les céphalopodes accumulent le Cd dans leur glande digestive

✓L'Arctique contient des sédiments naturellement enrichis en Cd – Gradient Nord-Sud?

✓Pas de relation entre les concentrations en Hg et les valeurs $\delta^{15}N$



Contaminants

Quid des autres polluants?

Environ. Sci. Technol. **2003**, *37*, 5545–5550

Perfluorinated Chemicals Infiltrate Ocean Waters: Link between Exposure Levels and Stable Isotope Ratios in Marine Mammals

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Introduction

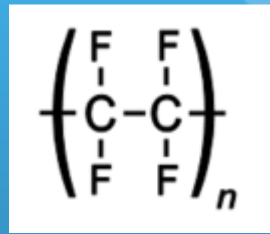
The global marine ecosystem is continuously under pressure due to expanding anthropogenic activities and the development and release of new chemicals. High contaminant burdens in animals from higher trophic levels have led to a need for more information on the occurrence, distribution, and fate of several hazardous compounds. Marine mammals occupy the highest trophic positions in the marine food web and may therefore be more affected by pollutants in comparison to other animals. High concentrations of persistent compounds in marine mammals are frequently reported in the literature (*1*–*4*). Polychlorinated biphenyls (PCBs), organochlorine pesticides (such as DDT and its derivates), and polybrominated diphenyl ethers (PBDEs) are just a few chemicals occurring in tissues of marine mammals.

To understand the fate of contaminants and their impact on the marine ecosystem, it is essential to gain knowledge on the trophic relationships within this ecosystem. In the past, trophic position was mainly assessed using food composition analysis. However, as gut content analyses give only indirect information on trophic interactions, stable nitrogen and carbon isotope measurements have recently been used in order to quantify trophic status and dietary overlap of marine organisms (*5*, *6*). Nitrogen isotope ratios

Le teflon®: un composé perfluoré

polytétrafluoroéthylène (PTFE).

C'est un polymère:



Fabriqué à partir de l'acide perfluorooctanique (C8)

Contaminants

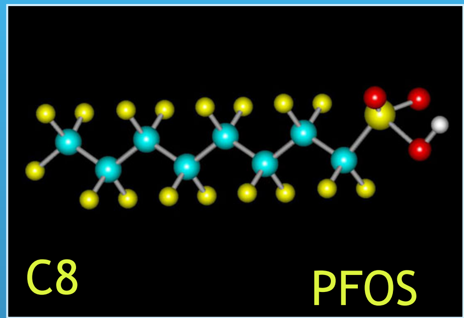
De nombreuses molécules différentes et applications très diversifiées

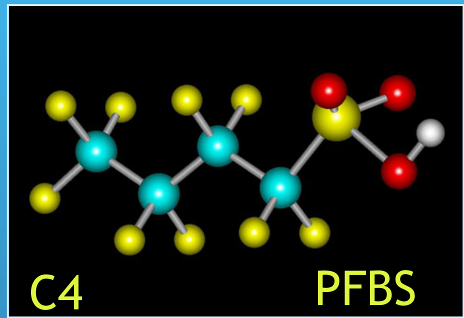
- Teflon
- Produits "Scotchgard"
- Emballage anti-graisse (pizza, popcorn…)
- Produits cosmétiques
- shampoings et soins dentaires
- Gore-Tex

Contaminants

Différentes classes de PFCs

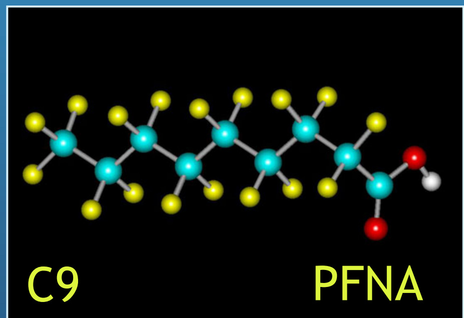
perfluorinated sulfonates

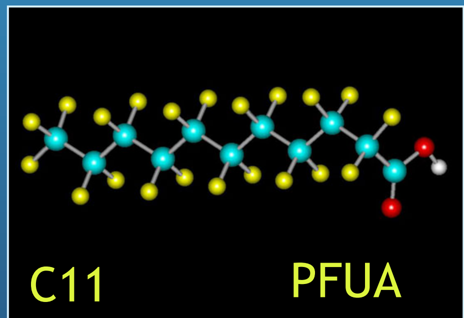




Functional group = SO^{3-}

perfluorinated carboxylic acids



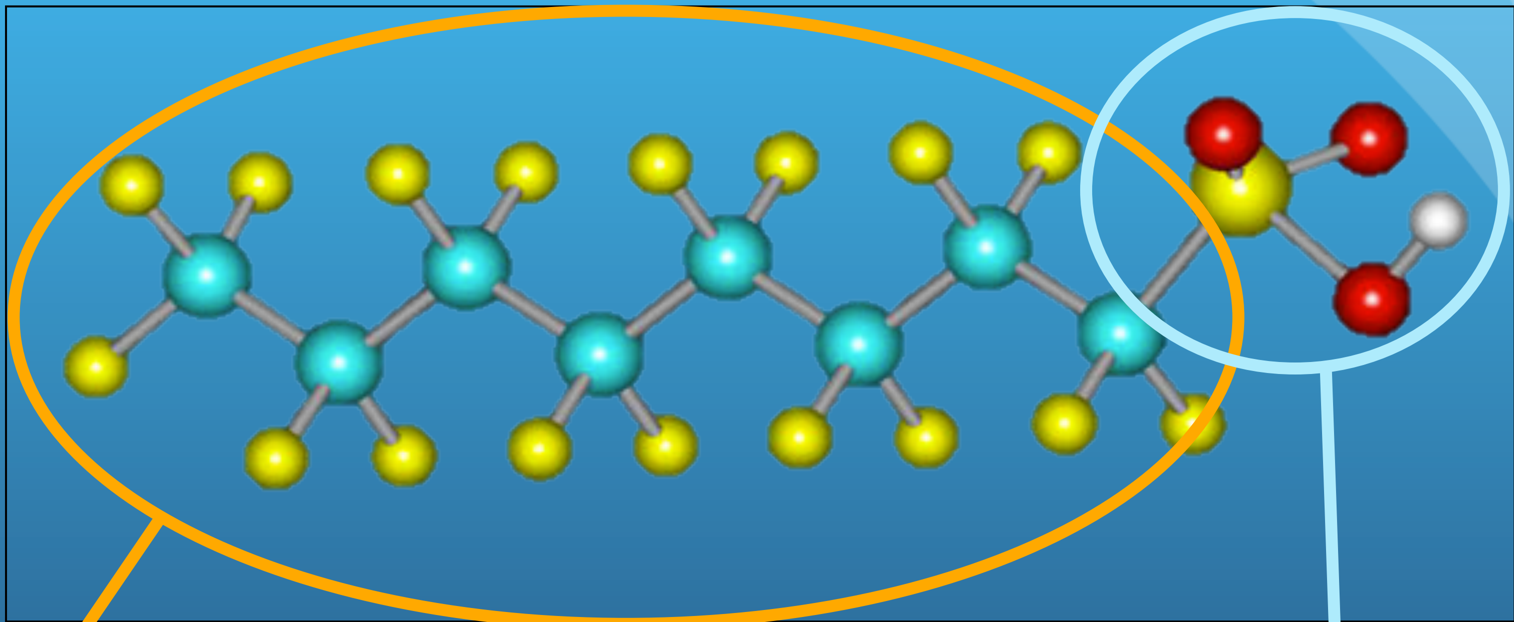


Functional group = COOH

Contaminants

Parmi les composés fluorés:

perfluorooctane sulfonate (PFOS) $C_8F_{17}SO^{3-}$



carbon-fluorine chain = hydrophobe

Group fonctionnel = hydrophile

Propriétés physico-chimiques uniques

Contaminants

D'ou viennent ces composés?

Produits depuis plus de 50 ans

Applications tant l'industrie que chez les particuliers

- revêtements de surface des tissus, cuir, tapis
- papier anti gras (burgers – pizzas)
- mousse anti-incendie
- film photographique
- Shampoing
- insecticides
- …

Contaminants

De nombreuses molécules différentes et applications très diversifiées

- Teflon
- Produits “Scotchgard”
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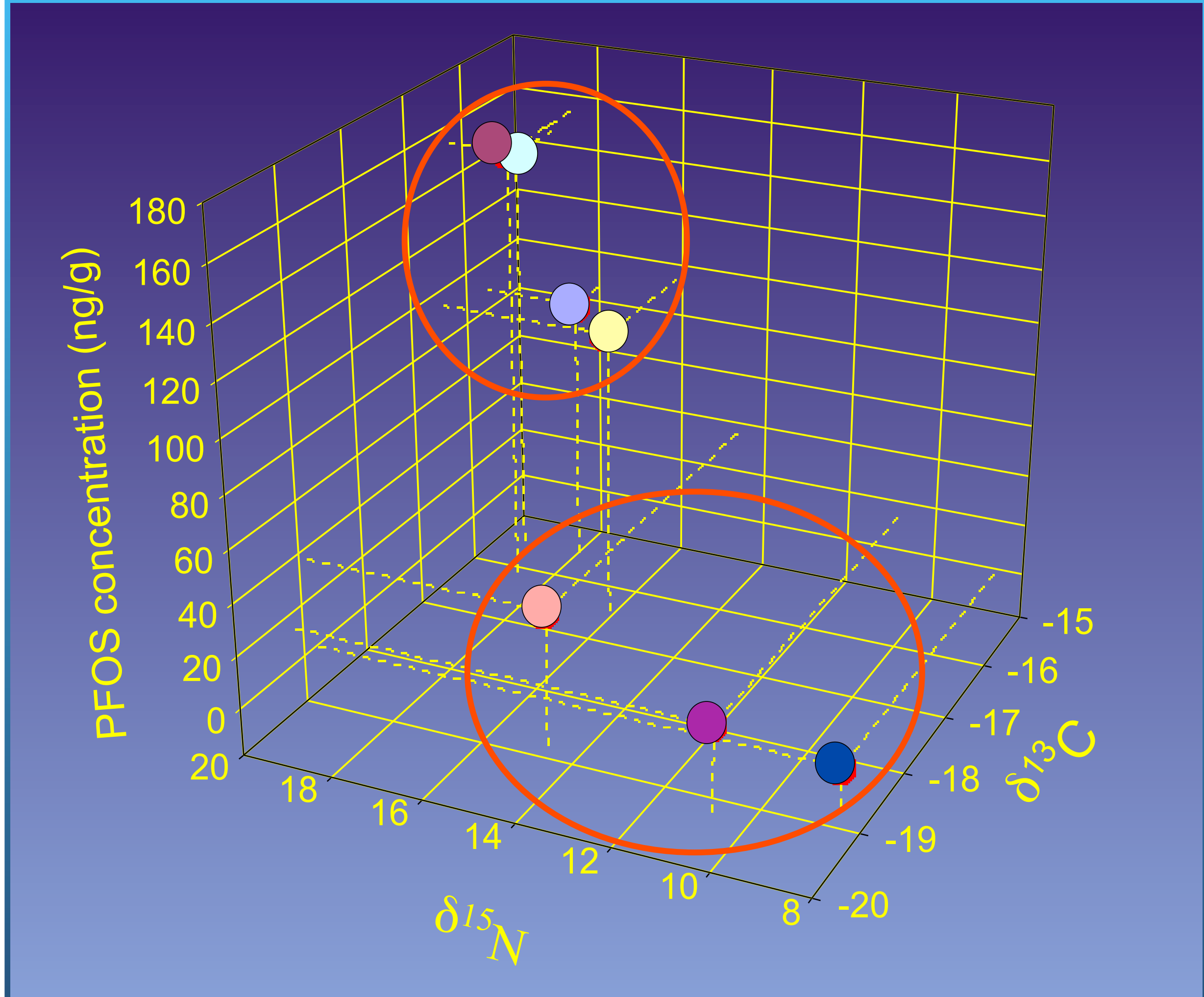
- Produits cosmétiques
- shampoings et soins dentaires
- Gore-Tex

Composés perfluorés

- Distribution à l'échelle planétaire jusque dans les zones arctiques et antarctiques
- Persistants: résistent aux dégradations biotiques et abiotiques
- Bioaccumulation: foie, sang (se lient aux protéines)

PFOS et position trophique



- Phoque commun
- Dauphin à bec blanc
- Marsouin commun
- Phoque gris

= espèces côtières

- Cachalot
- Dauphin à flancs blancs
- Rorqual commun

= Espèces océaniques

Toxiques?

Recherches tjs en cours: mais...

Niveau cellulaire:

- Effets au niveau des membranes
- Effets sur le métabolisme des lipides

Niveau de l'organisme:

- Lésions hépatiques chez les poissons
- Cancer chez les rongeurs

Niveau de la population:

- Baisse de reproduction
- ?????????

http://www.tuberose.com/Environmental_Toxicity.html

Pas de relation claire entre les isotopes stables et certains polluants plus typiques comme Hg, PCBs or PBDEs

Author's personal copy

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Biomagnification of naturally-produced methoxylated polybrominated diphenyl ethers (MeO-PBDEs) in harbour seals and harbour porpoises from the Southern North Sea

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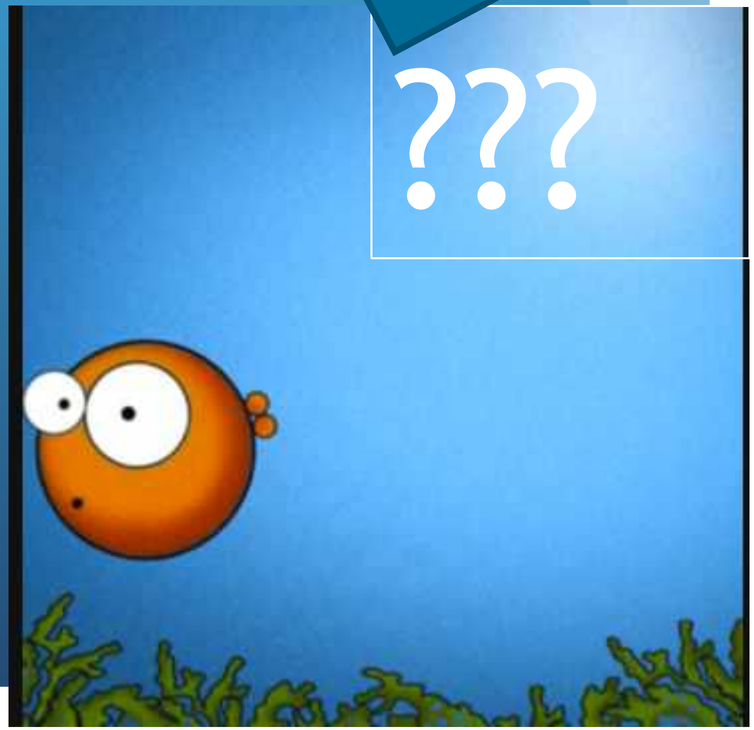
ABSTRACT

Harbour seals and harbour porpoises are top predator species from the North Sea, have long life spans and hence, are known to accumulate high levels of anthropogenic contaminants. To gain knowledge about the behaviour of naturally-produced compounds in these marine mammals, the biomagnification of naturally-produced polybrominated diphenyl ethers (MeO-PBDEs) was assessed. The biomagnification of MeO-PBDEs (2′-MeO-BDE 68 and 6-MeO-BDE 47) was lower in harbour seals (all biomagnification factors (BMFs)<1) compared to the same age–gender groups of the harbour porpoises (all BMFs>1). This may indicate a better metabolic breakdown of MeO-PBDEs in harbour seals, as was previously suggested for polybrominated diphenyl ethers (PBDEs). In both predators, 6-MeO-BDE 47 had the highest concentrations (range: 45–483 ng/g lw and 2–38 ng/g lw for harbour porpoises and seals, respectively) compared to 2′-MeO-BDE 68 (range: 2–28 ng/g lw and 1–6 ng/g lw for harbour porpoises and seals, respectively). In general, the highest concentrations were found in juveniles, suggesting an increased biotransformation capacity with age or the influence of dilution by growth for both species. Here we show that naturally-produced brominated organic compounds can biomagnify and accumulate in North Sea top predators, although to a lesser extent than anthropogenic lipophilic contaminants, such as polychlorinated biphenyls (PCBs) or PBDEs.

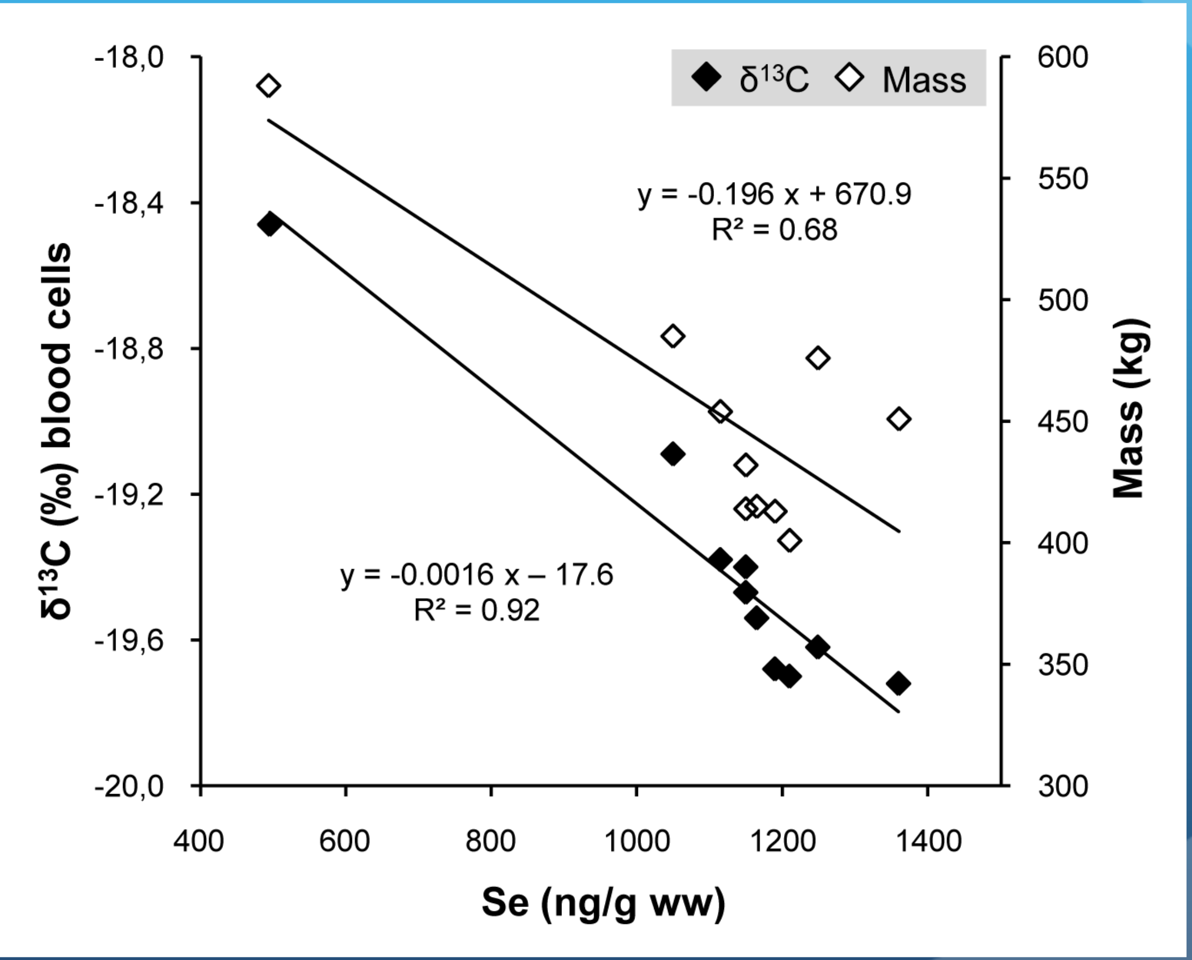


Autres facteurs :
- Teneurs en lipides
- Age
- Sexe

Et chez l'éléphant de mer septentrional?

Relations entre:

1. Se dans le sang maternel et les valeurs en $\delta^{13}C$ values dans les cellules sanguines
2. Se dans le sang maternel et la masse corporelle

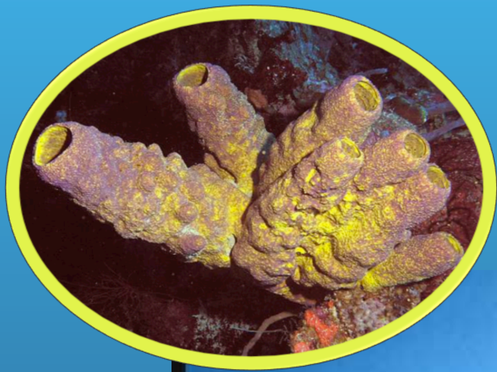


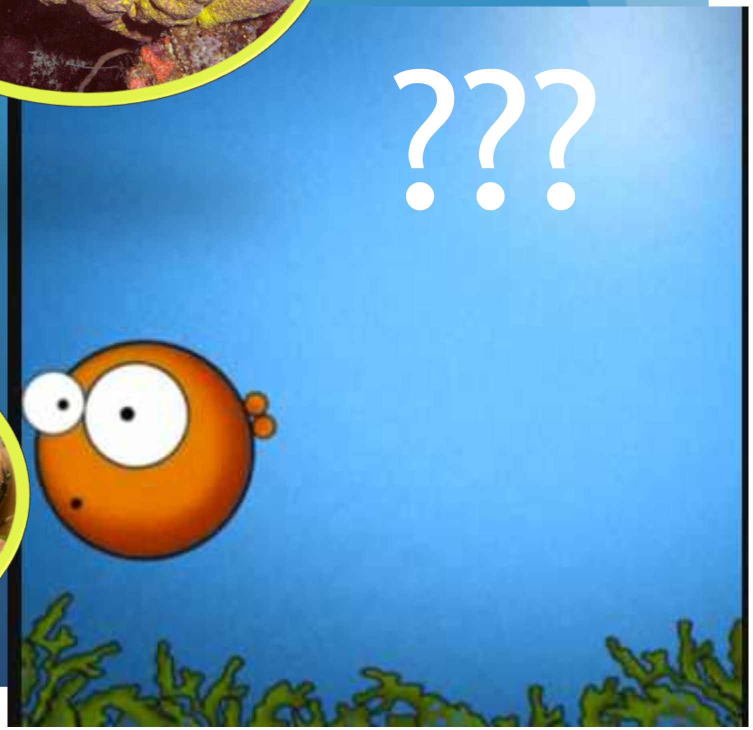
Habran et al. submitted

Transfert trophique du Sélénium chez les éléphants de mer?

Chez d'autres espèces de vertébrés marins, le Se était lié à l'ingestion de:

- Demospongiae
- Mollusques bivalves





Conclusions

Over the last decade, SIA has been used in ecotoxicology.

"Because contaminant concentrations in biota are affected by the complex interplay between several environmental processes, researchers have begun to use isotopic ratios in conjunction with physical, chemical or biological factors to understand contaminant concentrations in marine vertebrates." Jardine, 2006.

BUT…

A faire!

Etudes expérimentales

- Régime contrôlé et turn over des tissus

Standardisation des valeurs en $\delta^{15}N$

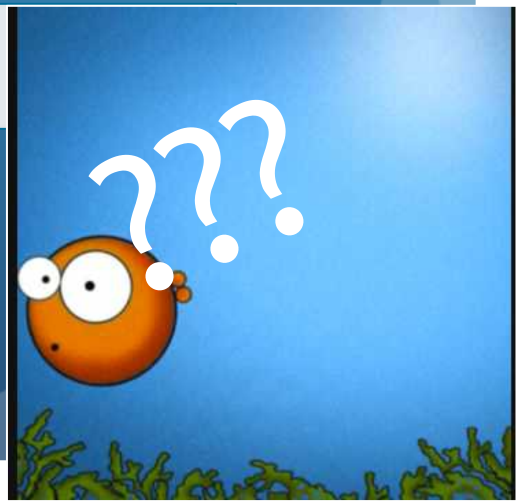
- Utilisation de mollusques pour les niveaux de base

Autres facteurs biologiques

- Physiology, animal movement pattern

CSIA: Compound-Specific Carbon Isotopic Analysis

- Sources des polluants chez les vertébrés marins



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  - University of South Florida, USA (Pr. D. Mann)

Merci de votre attention!

Et pour en savoir plus…

Plus d’info sur

http://orbi.ulg.ac.be/

et

http://www2.ulg.ac.be/oceanbio/

You are what you eat plus a few *per mill*: utilisation des isotopes stables en Ecologie Marine

Traçage des polluants chez les mammifères et autres vertébrés marins

Krishna Das et Gilles Lepoint
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