a world leader in new tropical agriculture

Climate Change and Potential Impact on Chemical Food Safety

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Outline

- Introduction
- Effect of climate change to food safety and contaminant and human health
- Climate change interaction with chemical contaminants, their fate and effects
- Case of heavy metal as chemical contaminant – climate change
- What’s next

Global Climate Change

- Global climate change caused by human activities is occurring now, and it is a growing threat to society.
- Accumulating data from across the globe reveal a wide array of effects.
- The pace of change and the evidence of harm have increased markedly over the last few years.

Climate Change in Malaysia

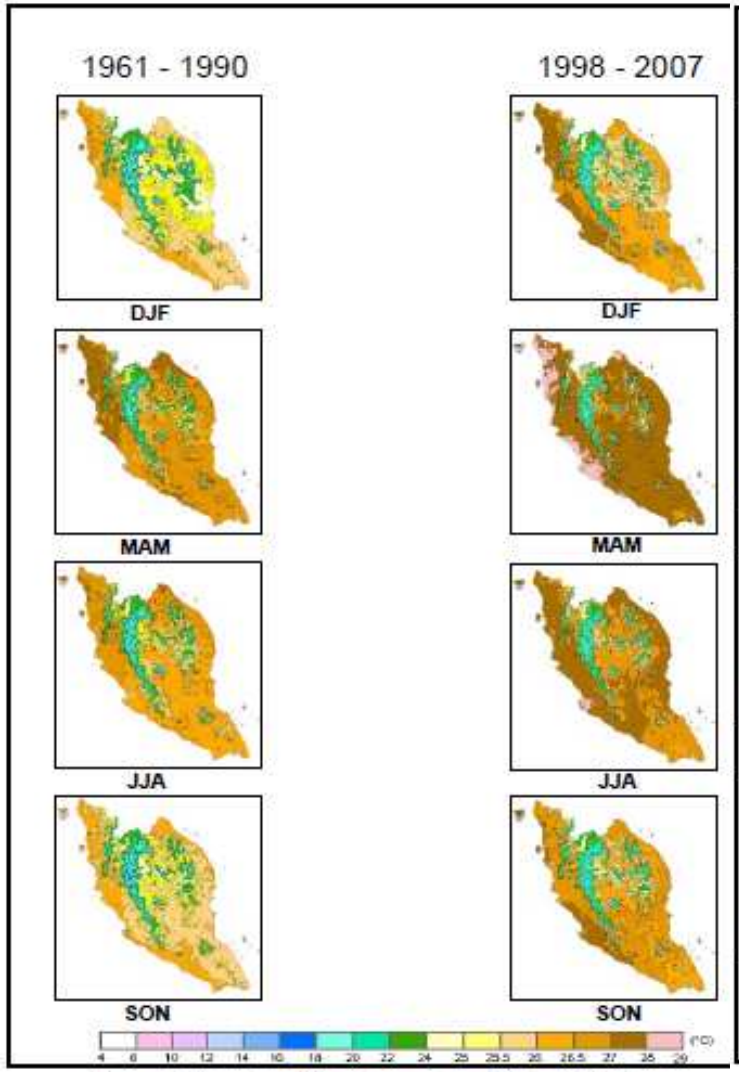


Figure 6: Long Term Mean Temperature for West Malaysia

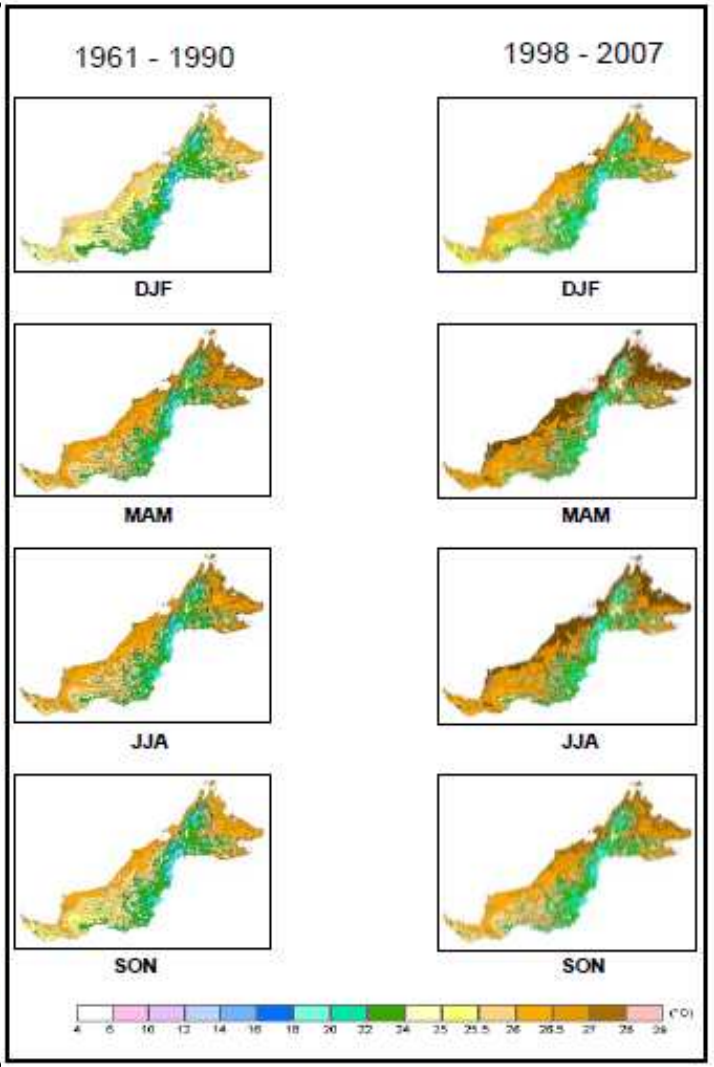
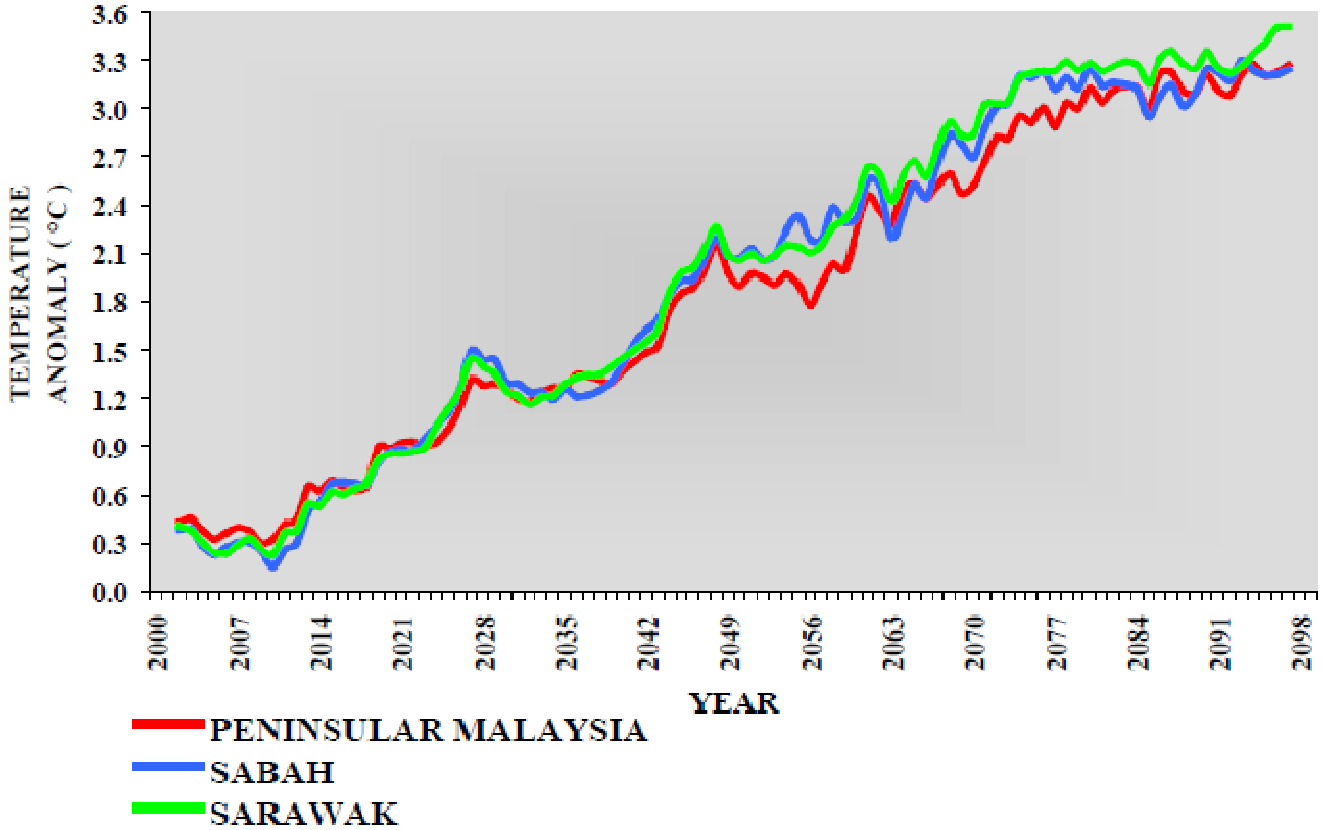


Figure 7: Long Term Mean Temperature for East Malaysia

Malaysia – Temperature



(Tangang et al., 2006)

Slope □ (^{o}C/100 years)

No	Stations	JFM	AMJ	JAS	OND
1	Sandakan	2.20	2.78*	2.14	2.06
2	Kota Kinabalu	3.98*	3.39	2.97	2.99
3	Miri	0.08	0.29*	0.20	-0.45
4	Bintulu	(1.32) *	(0.83)	(0.75)	-0.10
5	Kuching	1.46*	1.17	(100)	(0.91)
6	Mersing	2.41*	(1.34)	1.27	2.00
7	Kuantan	3.37	3.72*	3.36	2.83
8	Kota Bharu	2.15*	1.88	1.77	2.04
9	Melaka	2.87	2.88	3.07*	2.70
10	Subang	3.55	3.98	4.02*	3.49
11	Penang	2.38*	2.28	2.28	2.09

UN Intergovernmental Panel on Climate Change - end of the 21st century

- Atmospheric CO_2 will be as high as **730–1020 ppm**;
- Global mean surface temperature increase by **1.1–6.4 C**;
- Sea-level rise by **0.18–0.59 m** due to thermal warming and melting glaciers and ice sheets;
- pH of seawater will decrease by **0.14–0.35 units**;
- Atlantic Ocean Meridional Overturning Circulation may decrease by up to **50%**; and
- Water cycle will accelerate, with **increased precipitation** in tropics and high latitudes, **drier conditions** in subtropics, and increased **frequencies of extreme droughts and floods.**

(Solomon et al., 2007)

Consequences of Major Climate Change to Human Health

Driving Forces
- Population dynamics
- Unsustainable economic development

→ Green-house Gases Emissions → CLIMATE CHANGE →

Weather Changes
- Air and seawater temperature
- Ocean acidity
- Sea level
- Intensity of weather disturbances
- Weather disturbances
- Freshwater cycle
- Rainfall and wind patterns

→
- Quality and safety of food
- Biodiversity
- Availability and toxicity of chemical and biological contaminants

Natural causes → CLIMATE CHANGE

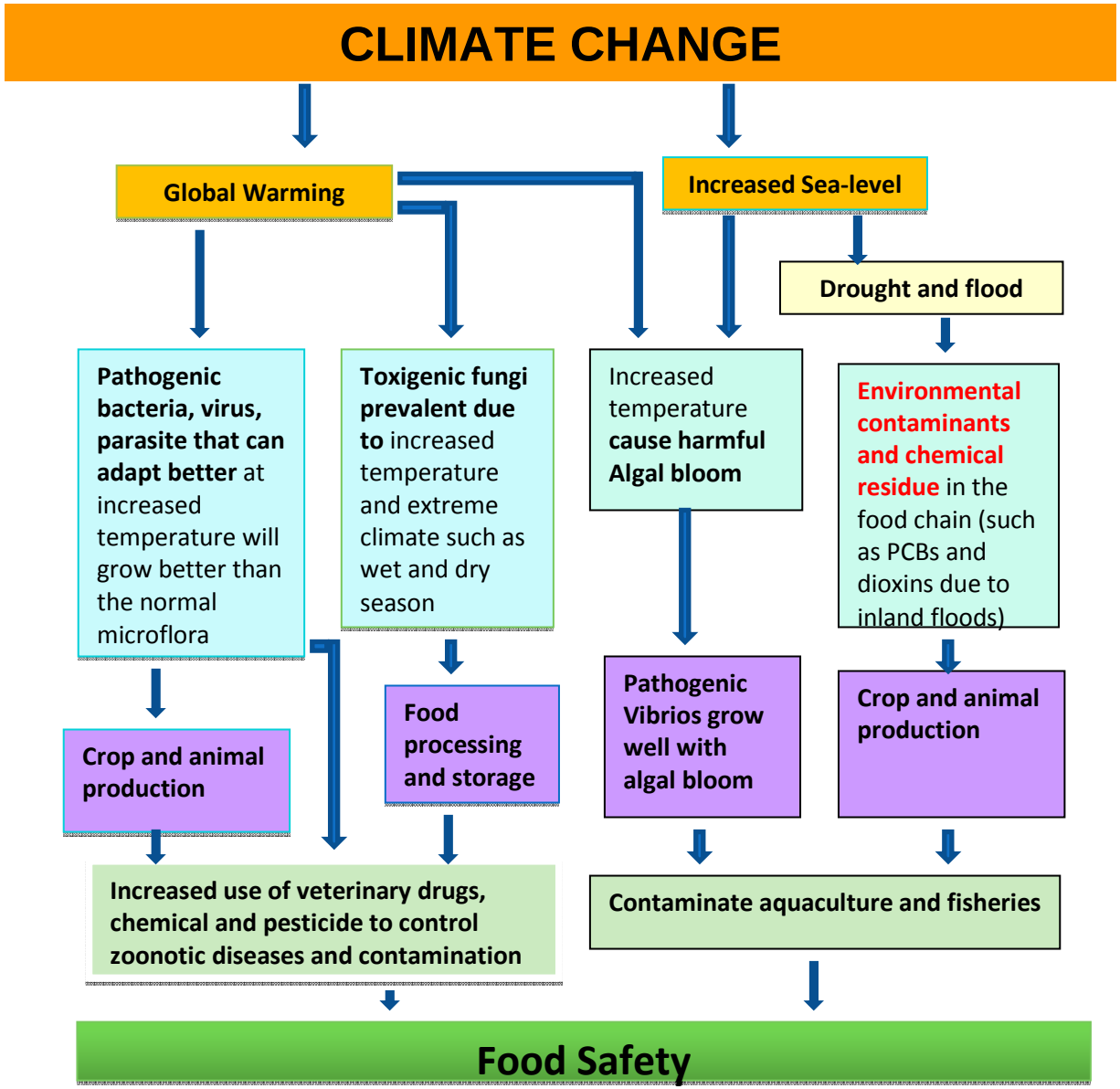
Health Effects
- Temperature-related illness and death
- Extreme weather-related health effects
- Air pollution-related health effects
- Water and food-borne diseases
- Effects of food and water shortages
- Mental, nutritional, infectious and other health effects

Marques et al (2010).

What is food safety?

Food safety is a scientific discipline describing handling, preparation and storage of food in ways that prevent health hazard to human

Looking at the whole chain from Farm to Fork


CLIMATE CHANGE
Global Warming
Increased Sea-level
Drought and flood
Pathogenic bacteria, virus, parasite that can adapt better at increased temperature will grow better than the normal microflora
Toxigenic fungi prevalent due to increased temperature and extreme climate such as wet and dry season
Increased temperature cause harmful Algal bloom
Environmental contaminants and chemical residue in the food chain (such as PCBs and dioxins due to inland floods)
Crop and animal production
Food processing and storage
Pathogenic Vibrios grow well with algal bloom
Crop and animal production
Increased use of veterinary drugs, chemical and pesticide to control zoonotic diseases and contamination
Contaminate aquaculture and fisheries
Food Safety

Climate Change Impacts on Food Safety

- **Ecosystem changes – More pests; less predators; more vectors for microbes**
- **Unseasonal rains – Humidity and fungal growth**
- **Flooding – Water contamination; soil contamination; unsafe food**
- **Higher ocean temperatures – Algal blooms; harbour *vibrios* in spore like forms; novel strains**

➔ Changes in aquatic life – Production of phytotoxins by harmful algae; formation of marine biotoxins in seafoods

Chemical Contaminants

What is Contamination?

Contamination is caused when an input from human activities causes the increase of a substance in seawater, lands, sediments, or organisms (animal and plants) above the natural background level for that area and for those organisms.

Overview of Climate Change Impacts on Ecosystem and Biota, and How they Interact with Contaminants, and their Fate and Effects

Climate change

DIRECT IMPACTS ON BIOTA (animal and plant life of region)
- Exceeding thermal acclimation limits
- Exceeding salinity tolerance limits
- Exceeding turbidity tolerance limit
- Exceeding dissolved oxygen limits
- Coral bleaching
- Exceeding contaminant exposure limits

-Habitat loss (e.g. littoral, sediment, ice)
- Change in biogeographical range
- Reduction or extinction of species
- Invasion of non-native species
- Alteration of food-web structure

IMPACTS ON ECOSYSTEM
- Sea level rise
- Change in precipitation form & pattern
- Change in freshwater run-off
- Increase in extreme events
- Land based erosion
- Change in mixing
- Change in salinity regime
- Change in currents and winds
- Decrease pH
- Reduce ice cover
- Increase UV
- Altered biogeochemical cycles
- Change in food availability

Synergistic Impacts on Biota

Humans ↕ Ecosystem

Impact on Contaminants

Contaminant exposure interacts with direct and indirect stresses on ecosystems and biota

- Bioavailability, altered contaminant toxicity (synergism), biological effects

- Transport, transfer, transformation
- Chemical portioning
- Degradation, exchange
- Deposition, resuspension
- Biomagnification
- Biovectors

- Change in land use & hence sources

Change in environmental conditions alter fate of and biological exposure to contaminants

Marques et al (2010); Schiedek et al, 2007).

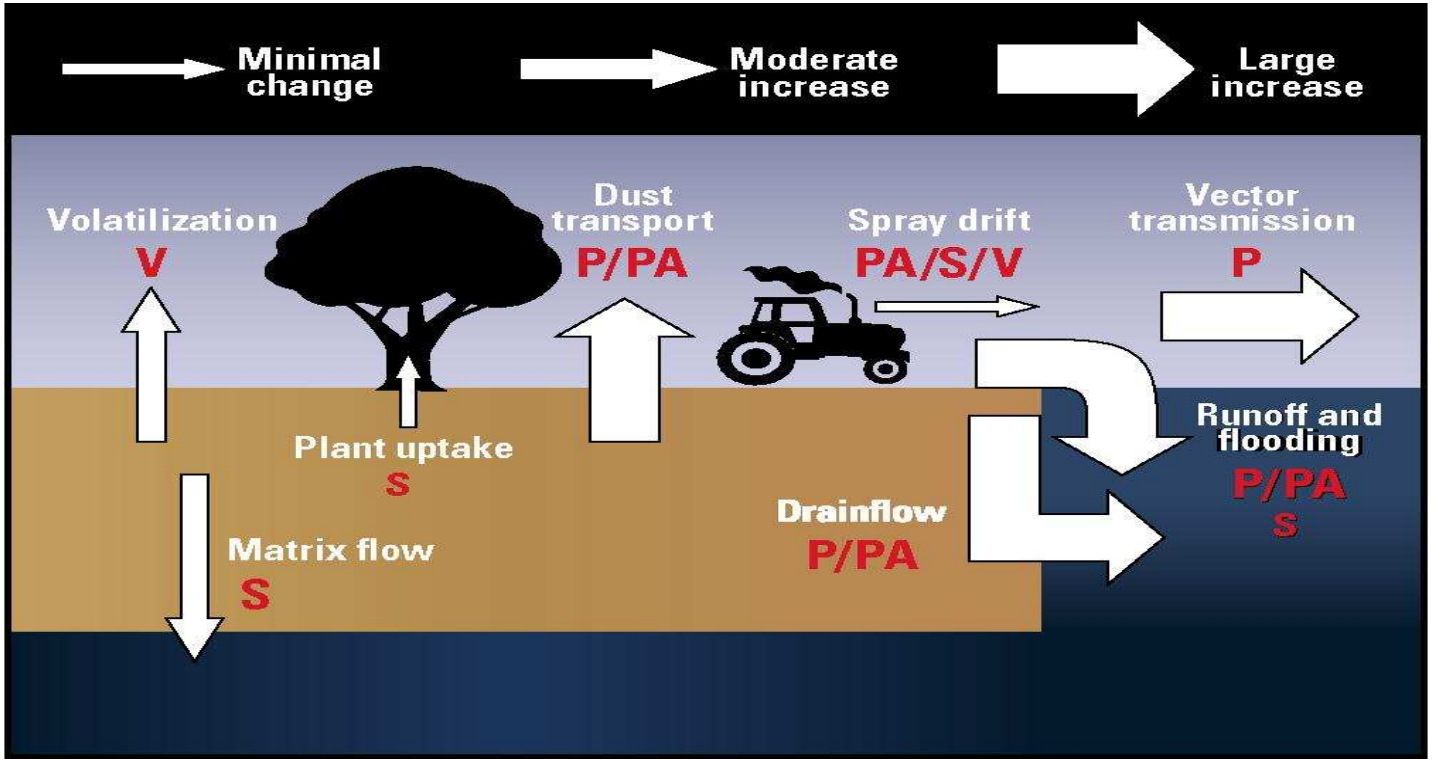
Chemical Contamination

- **Toxins**
  - **Marine toxins**
  - **Mycotoxins**
- **Heavy metals**
  - **Mercury**
  - **Lead**
  - **Arsenic**
  - **Cadmium**
- **Organic chemicals**
  - **Pesticides**
  - **Bioxins**
  - **Polycyclic aromatic hydrocarbons (PAHs)**

Driver of climate change in food safety

- Temperature
- Precipitation
- Draught
- Floods
- Salinity

Predicted Impacts of Climate Change on Major Environmental Pathways for Human Exposure to Pathogens & Chemicals from Agriculture



P = Particulate - bacteria, viruses, spores, engineered nanoparticles
PA = Particle-associated - hydrophobic organics, ammonium, heavy metals
S = Soluble contaminant - nitrates, reactive phosphorus, hydrophilic pesticides
V = Volatile contaminant - methane, nitrous oxide, ammonia, sulfides
Larger and smaller letters indicate the extent to which each contaminant type will be transported by the pathway

Boxall et al. (2009)

Impacts of climate change on the inputs of chemicals to agricultural systems

Contaminant source (type)	Effects of climate change on input	Effects
Plant protection products (herbicides, insecticides, fungicides)	Increased use due to increased abundance and activity of plant diseases	High
Fertilizers (NO_3, PO_4)	Intensification of cropping will increase use Decrease in soil organic carbon will increase use Increased leaching may increase use More efficient plant uptake will reduce use	Medium
Sewage sludge (heavy metals, Pharmaceuticals, industrial contaminants, pathogens, nutrients)	Intensification of cropping will increase use Decrease in soil organic carbon will increase the need for fertilizer use	Medium
Veterinary medicines (anti-bacterials, parasiticides)	Intensification of live stock production will increase use Increase in disease pressures will increase use	High
Irrigation water (pathogens, heavy metals, pesticides, other organic contaminants)	Irrigation of crops likely to increase during dry periods	High
Flooding (heavy metals, dioxins, polychlorinated biphenyls)	Increased flooding may mobilize legacy contaminants and transport them onto agricultural land	Medium
Aerial deposition (pesticides)	Increased aerial transport of volatile pesticides between sites, increased soil blow	Medium
Contaminants from plants and bacteria	Affect distribution, quantity, and quality of allergens, increases production of mycotoxins	High

(Boxall et al., 2009)

Potential exposure routes of chemical contaminants associated with agricultural activities

Contaminant	Potential exposure routes	Level of knowledge of exposure
Heavy metals (cadmium)	F	High
Dioxins	F	High
Mycotoxins (aflatoxins, ochratoxins)	F	Med
Nitrate	DW	High
Polychlorinated biphenyls	F	High
Pesticides	DW,F,A	High
Phycotoxins (microcystins)	DW, RW, F	Med
Pharmaceuticals	DW, F	Low
Plant toxins (glycoalkaloids, anisatin)	F	Low
Veterinary medicines	DW, F, A	Low
Ozone	A	Med

A, air; DW, drinking water; F, food; RW, recreational water contact;

(Boxall et al., 2009).

Potential health effects of chemical and biological contaminants associated with agricultural activities

Contaminant type	Health effects associated with exposure
Heavy metals (eg cadmium)	Renal and hepatic toxicity
Dioxins	Reproductive effects, carcinogenicity, immunotoxicity, endocrine disruption, neurologic effects, chloracne
Mycotoxins (aflatoxins, ochratoxins)	Stunting of growth, liver cancers, aflatoxicosis, estrogenic effects
Nitrate	Methemoglobinemia, bladder, stomach, and prostrate cancer, non-Hodgkin lymphoma
Polychlorinated biphenyls	Reproductive effects, congenital abnormalities
Pesticides	Reduced eye-hand coordination, effects on cognitive abilities, developmental toxicity, estrogenic effects, antiandrogenic effects, congenital abnormalities, reduced stamina, birth malformations, cryptorchidism in male children, pregnancy loss, Parkinson's disease
Pharmaceuticals	Estrogenic effects, carcinogenicity
Phycotoxins (microcystins)	Paralysis, gastrointestinal illness, amnesia, neurotoxicity, liver damage
Plant toxins (glycoalkaloids, anisatin)	Liver cancers, cirrhosis
Veterinary medicines	Selection of antimicrobial resistance
Ozone	Asthma

Climate Change - HAB and Heavy metal

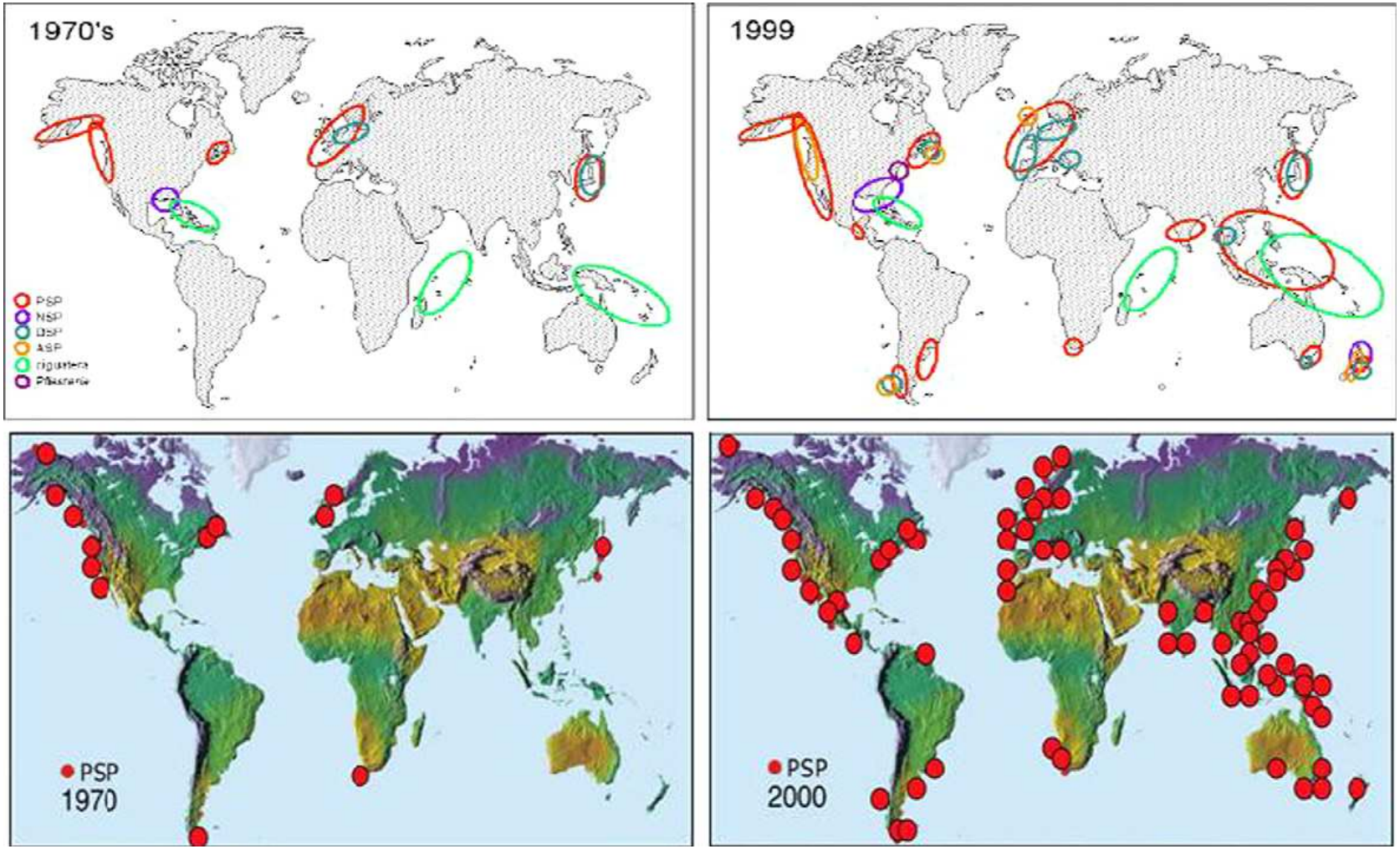
Common Illnesses Caused by Toxic Marine HABs, Symptoms, Toxins, and Associated HABs Species

Illness	Toxin(s)	Species	Symptoms
Ciguatera fish poisoning (CFP)	Ciguatoxins	*Gambierdiscus* spp.[b]	Nausea, vomiting, diarrhea, numbness of the mouth and extremities, rash, and reversal of temperature sensation. Neurological symptoms may persist for several months
Paralytic shellfish poisoning (PSP)	Saxitoxin and derivatives	*Alexandrium* spp. *Pyrodinium* spp. *Cymnodinium* spp.	Numbness and tingling of the lips, mouth, face and neck, nausea, and vomiting. Severe cases result in paralysis of the muscles of the chest and abdomen possibly leading to death
Amnesic shellfish poisoning (ASP)	Domoic acid	[a]*Pseudo-nitzschia* spp.	Nausea, vomiting, diarrhea, headache, dizziness, confusion, disorientation, short-term memory deficits, and motor weakness. Severe cases result in seizures, cardiac arrhythmias, coma, and possibly death
Azaspiracid shellfish poisoning (AZP)	Azaspiracid and its derivatives	*Protoperidinium* spp.	Nausea, vomiting, severe diarrhea, and stomach cramps
Diarrhetic shellfish poisoning (DSP)	Okadaic acid & derivatives	*Dinophysis* spp. *Prorocentrum* spp.[b]	Nausea, vomiting, severe diarrhea, and stomach cramps
Neurotoxic shellfish poisoning (NSP)	Brevetoxins	*Karenia* spp.	Nausea, temperature sensation reversals, muscle weakness, and vertigo

[a]Denotes the only diatom group in the table. [b]The remaining species are dinoflagellates, with the benthic members.

(Marques et al. 2010).

Global distribution of HAB toxins and toxicities (Dolah, 2000) and detail of increase in PSP outbreaks (Gilbert et al. 2005)



Tirado et al. 2010

In case heavy metal in fish and seafoods

Warmer Water

- Facilitates methylation Hg →MeHg
- Uptake of methyl mercury by fish increase by 3-5% for each 1ºC rise in water temp
- Cadmium and lead uptake by mussel also temp dependent
- Mercury may also be converted from a less to more bioavailable form due to temperature increases.
- Temperature-related increases in the uptake, bioaccumulation and toxicity of metals have been reported for several marine organisms

Salinity fluctuation (Climate change)

- Salinity affects the toxicity of various classes of toxic metals due to either bioavailability or physiological factors
- In particular, metals like mercury is taken up more rapidly by phytoplankton, fungi, annelids, bacteria, molluscs and crustaceans at increased salinities.
- Increase of mercury toxicity at high salinities due to:
  - reduce ability of fish to eliminate metal from the body
  - changes in the mercury chemical form and chemical interaction of the metal in seawater, thus affecting bioavailability
- Based on the evidence, both the inputs, fate and transport of mercury in marine systems will change in response to changes in climate.

Effects Temperature on Toxicity & Accumulation of Heavy Metals in Aquatic Organisms

Species	T (°C)	Toxic compound	Environment
Paragrapsus gaimardii	5,19	Cd	Marine
Corophium volutator	5, 10,15	As	Estuarine
Macoma balthica	5,10,15	As	Estuarine
Tubifex costatus	5,10,15	As	Estuarine
Mytilus edulis	2, 12	Cd	Marine
	6, 16, 26	Cd/Pb	Marine
Orconectes immunis	17, 20, 23, 24, 27	Cd/Pb	Marine
Sepia officinalis	16, 19	Cd	Marine

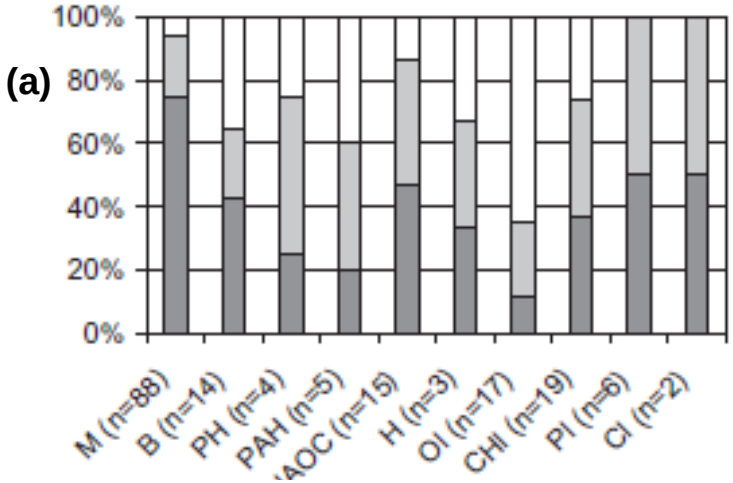



T, temperature; PCBs, polychlorinated biphenyls; ICo, inorganic Co; CCo, cobalamine Co.

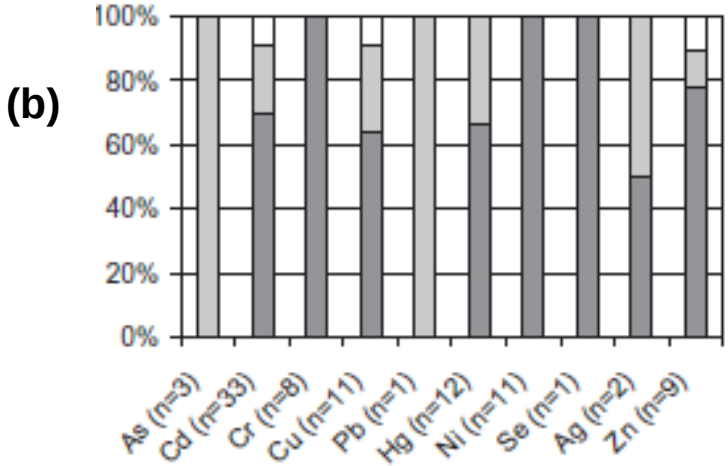
(Marques et al. 2010).

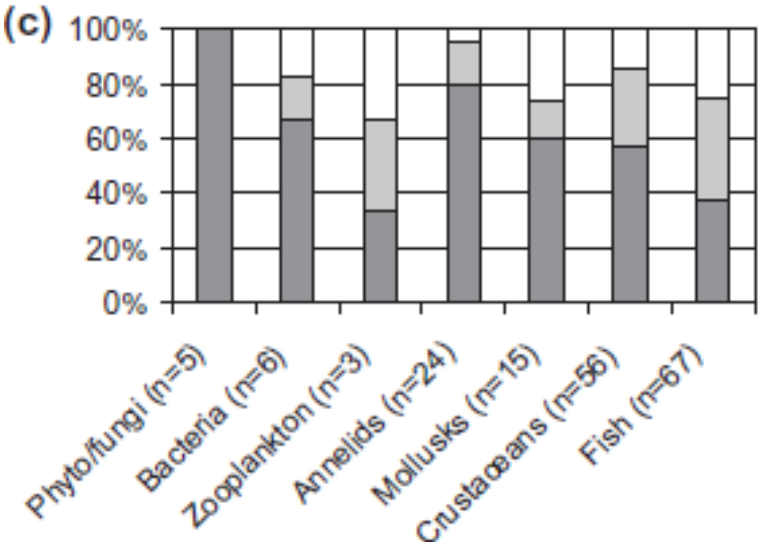
Frequency Correlation: Salinity - Toxicity

Contaminant



Metals





Various Trophic groups

Abbreviations: metals (M); biocides (B); petroleum hydrocarbons (PH); policyclic aromatic hydrocarbons (PAH); industrial and agriculture organic chemicals (IAOC); herbicides (H); organophosphate insecticides (OI); Chlorinated hydrocarbon insecticides (CHI); pyrethroid insecticides (PI); and carbamate insecticides (CI).

(Marques et al. 2010).

Mercury Toxicity

Human adults mercury toxicity symptoms include:

- Visual field constriction
- Behavioral changes, memory loss, headaches
- Tremor, loss of fine motor control, spasticity
- Hair loss

Fetus / infant mercury toxicity symptoms include:

- Seizures
- Mental retardation
- Cerebral palsy
- Blindness and deafness
- Disturbances of swallowing, sucking, and speech
- Hypertonia - muscle rigidity

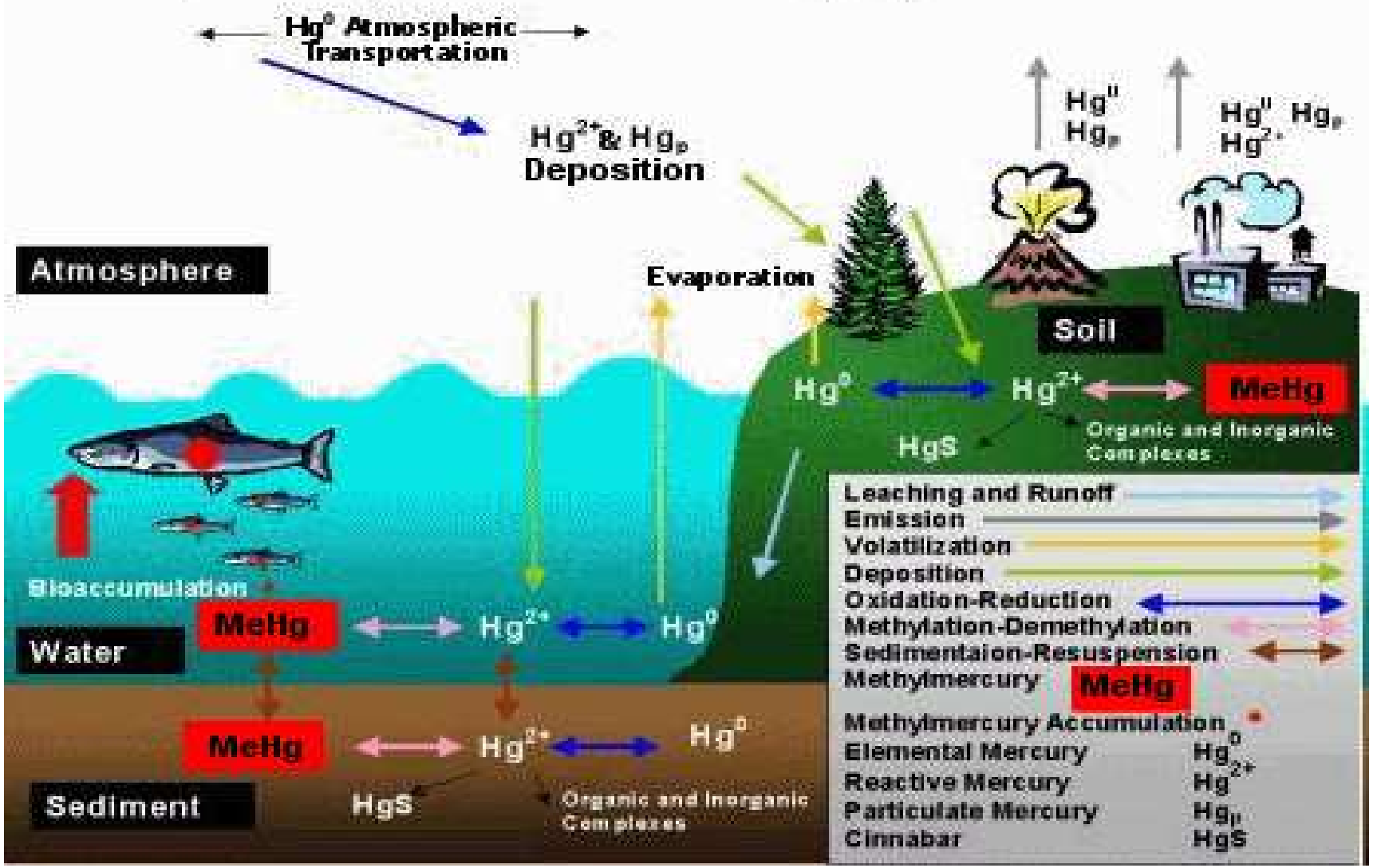
Minamata Disease

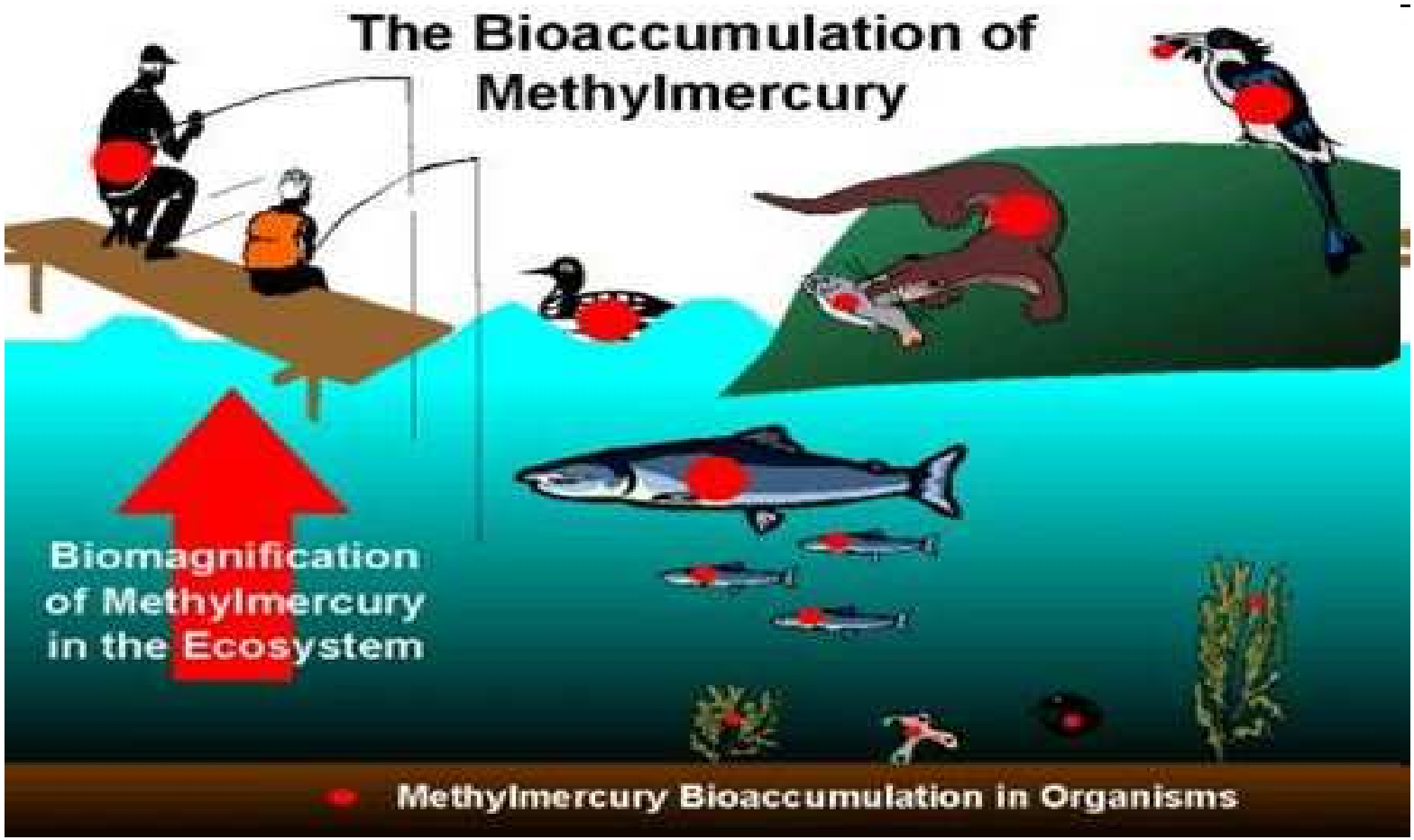
- 2000 cases; 41 deaths; 700 permanent disabilities
- Disease diagnosed in 1956 – linked to fish consumption
- 1957 - fishing banned in area
- 1959 - mercury identified as cause
- 1960 - source identified, from factory effluent
- Fish: 10-55 µg/g mercury

Minimata-Krankheit

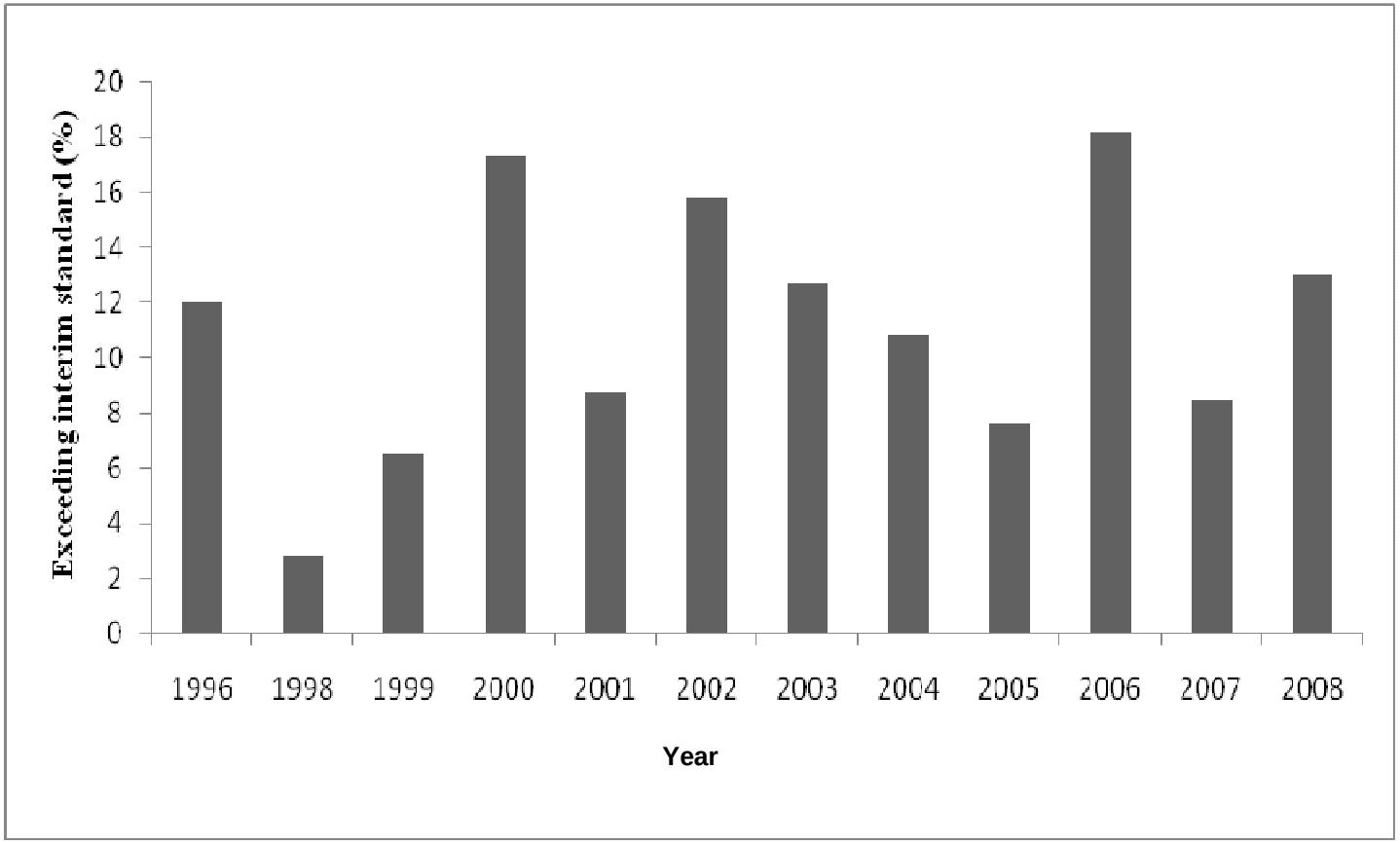
Inputs on Mercury

Conceptual Biogeochemical Mercury Cycle




The Bioaccumulation of Methylmercury
Biomagnification of Methylmercury in the Ecosystem
Methylmercury Bioaccumulation in Organisms

Mercury in Environment



Mercury status in Malaysia marine environment 1996 - 2008

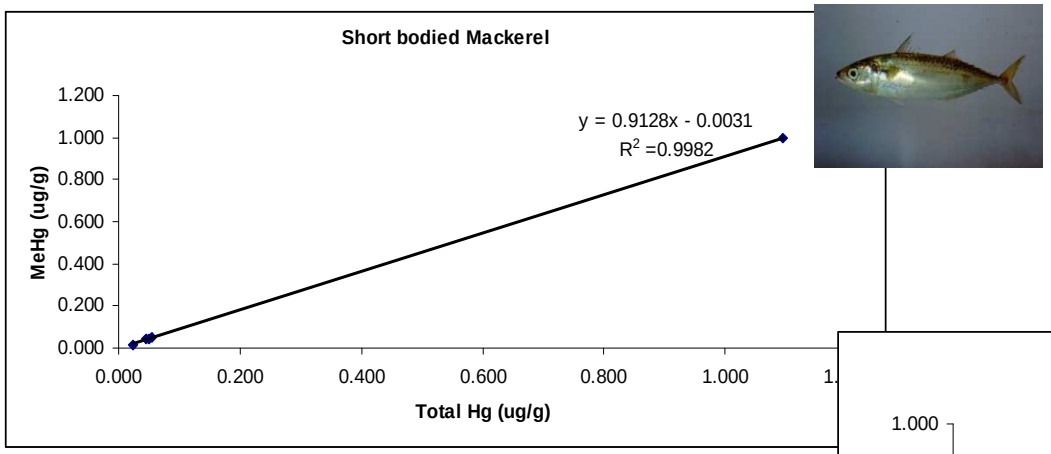
Mercury in fish

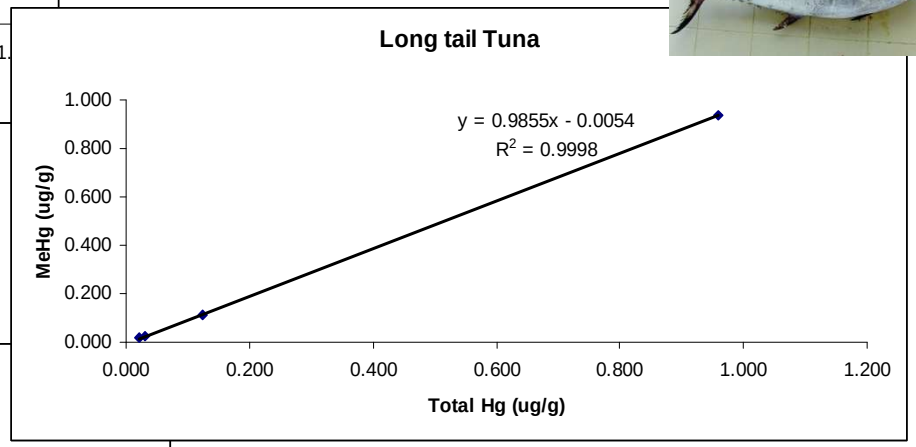
Levels of mercury have been reported in marine fish and seafood from Malaysian waters

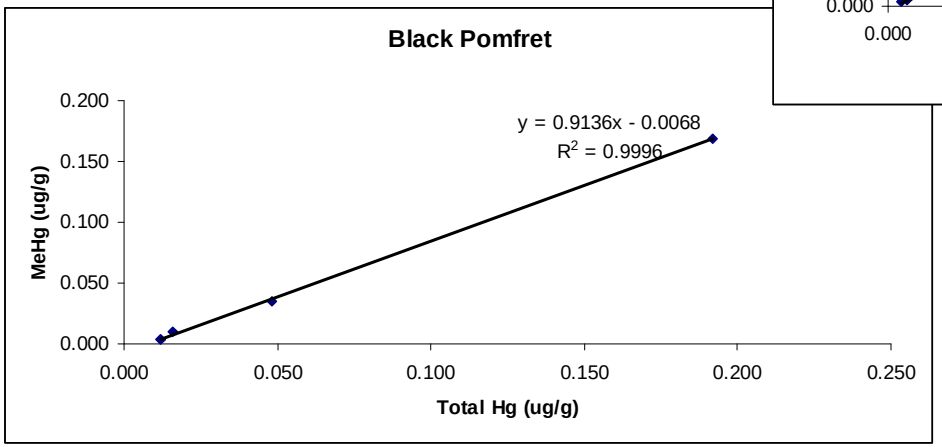
- **Tuna: up to 1.96 µg/g**
- **Mackerel: up to 1.52 µg/g**
- **Squid: up to 1.05 µg/g**
- **Shrimp: up to 0.93 µg/g**

Hajeb and Jinap, 2009

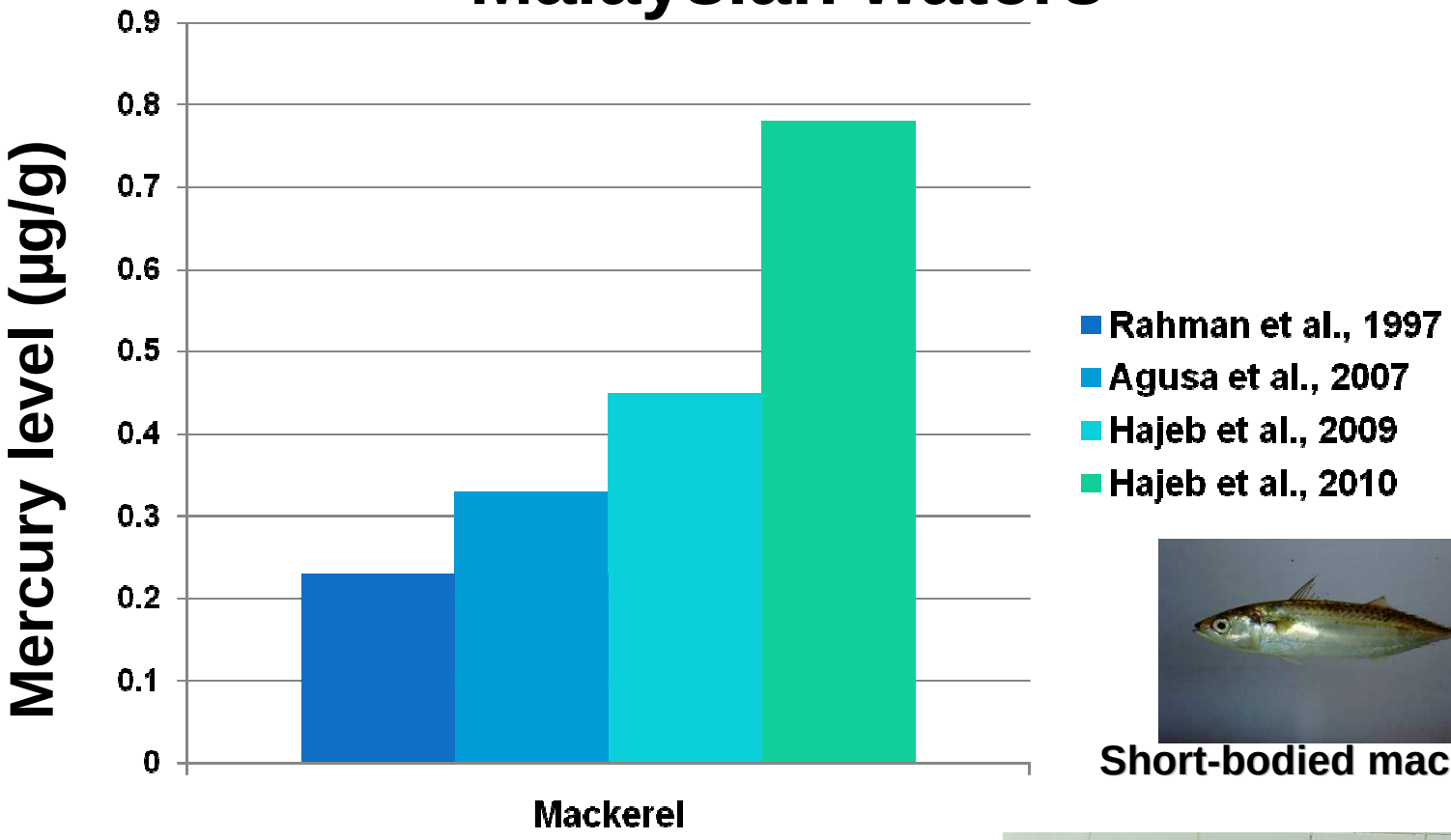
Correlation between total mercury and methylmercury







Trend of mercury content in Mackerel from Malaysian waters



Short-bodied mackerel

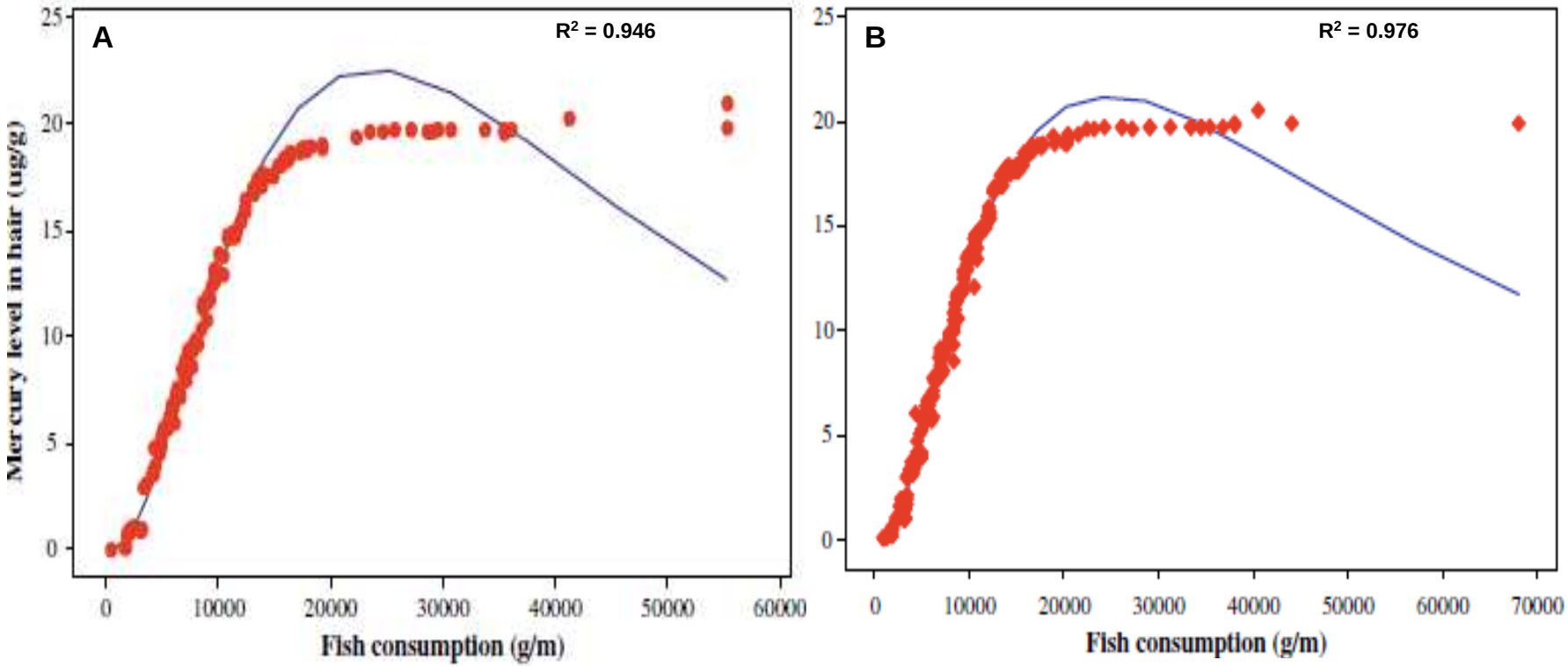
Long tail tuna

Hair mercury concentration in populations from four states in Peninsular Malaysia

Population group	Mercury concentration (μg/g dry wt)		
	Mean	SE	Range
Johor (M1)	9.94	0.78	0.60–19.76
Urban	9.84	0.88	0.60–19.76
Rural	10.31	1.66	3.80–17.40
Terengganu (M2)	10.85	0.49	0.10–19.90
Urban	9.82	0.54	0.98–19.90
Rural	12.47	0.91	0.10–19.75
M3 Kedah (M3)	13.69	0.48	0.05–21.00
Urban	11.41	0.74	0.05–20.50
Rural	15.99	0.52	3.36–21.00
Selangor (M4)	6.78	0.94	0.02–19.74
Urban	5.34	0.28	0.02–17.29
Rural	8.22	0.87	0.38–19.74

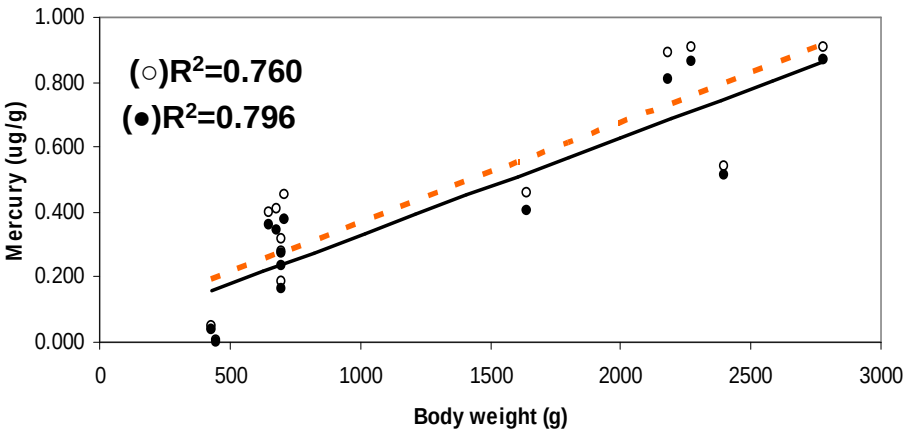
Hajeb and Jinap, 2009

Correlation: Hair Hg level (µg/g) and fish consumption (g/month) of Malaysian (A) man and (B) women.

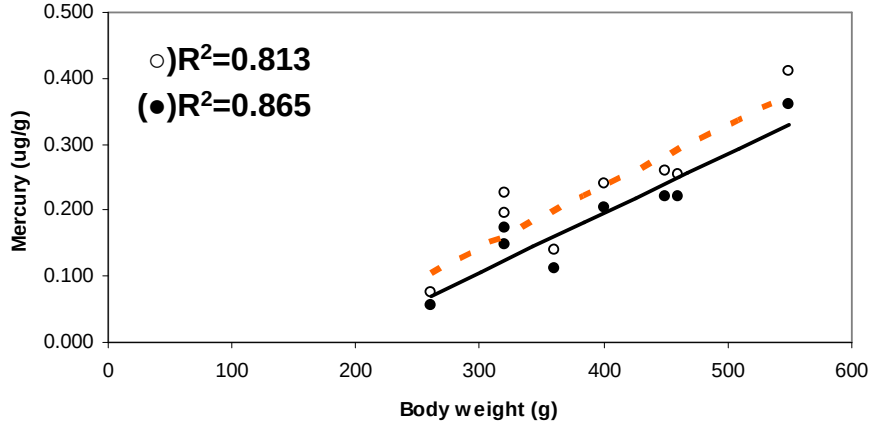


Hajeb and Jinap, 2009

Kuantan

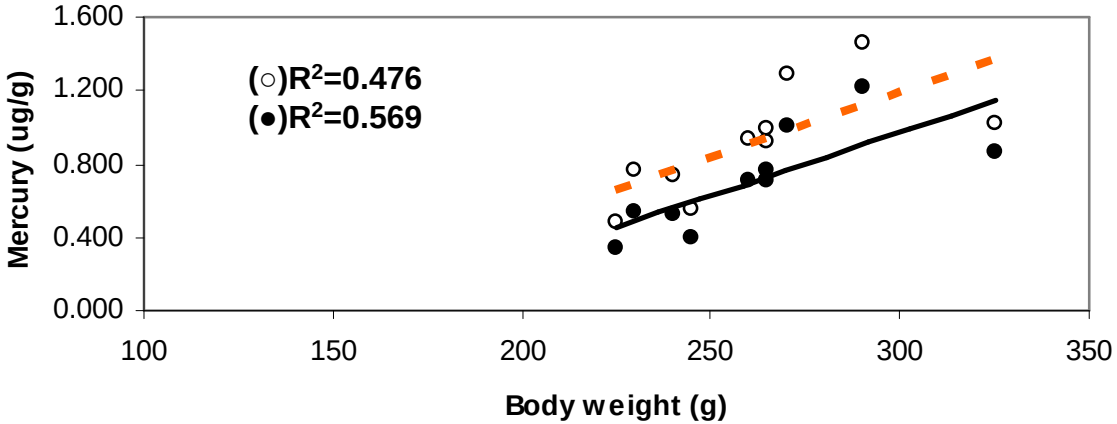


Kuala Perlis



RELATIONSHIP BETWEEN BODY WEIGHT AND MERCURY LEVEL IN THE MUSCLE OF LONG TAIL TUNA IN PENISULA MALAYSIA

Chendring



Hajeb and Jinap, 2009

Conclusion

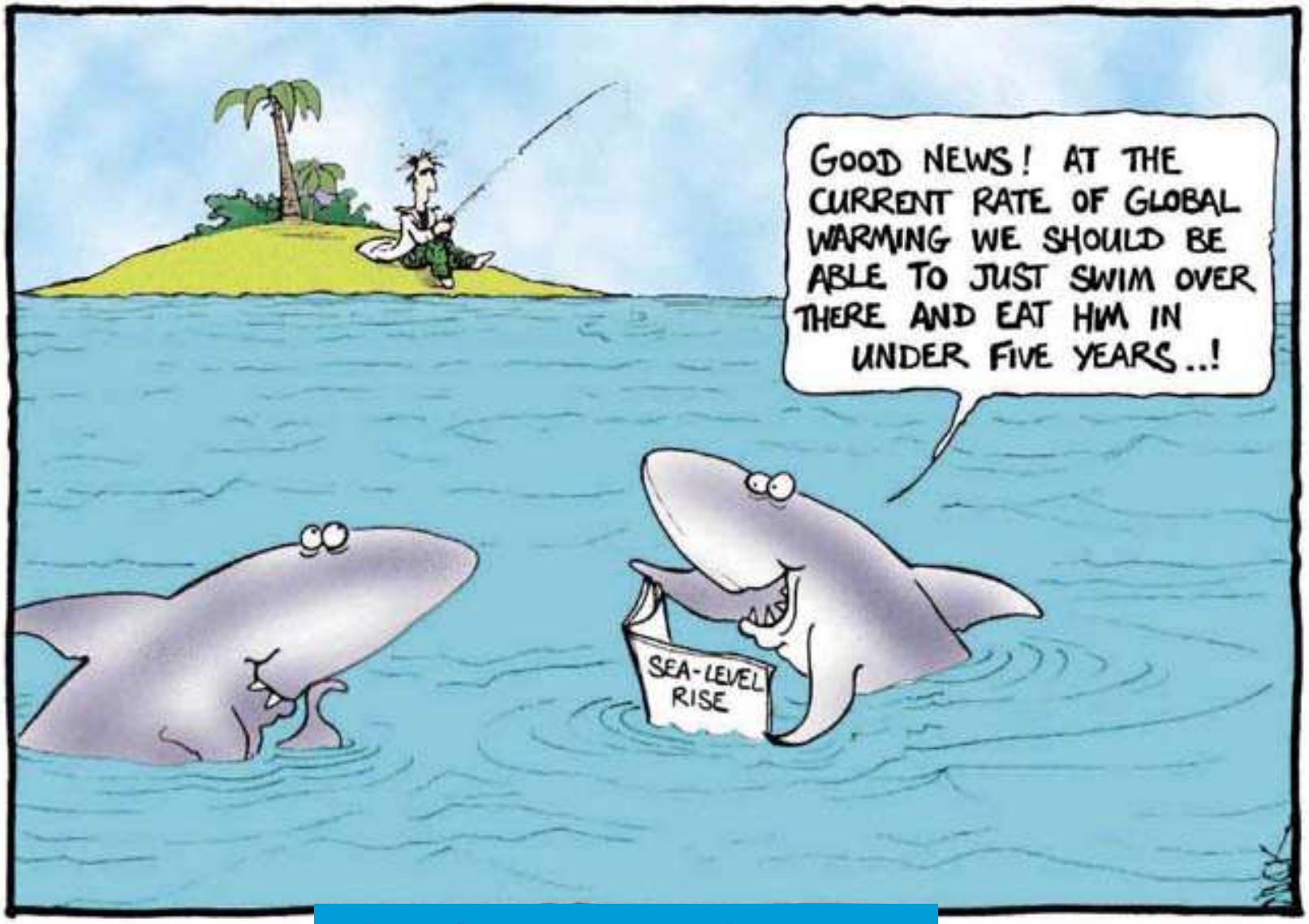
- Overall, climate change is likely to increase human exposure to chemical contaminants in foods.
- The relationship between chemical contaminants in food and the health of the population is complex. The complexity of the relationship is increased by the projected variability of climate and extreme weather events anticipated under the climate change scenarios.
- Therefore future studies into the risks of chemical contaminants due to climate change to health should be multidisciplinary and pull together expertise in epidemiology, toxicology, land use, environmental chemistry, economics, and social science.

Questions

- Research / data collection on climate change-food security is already underway; how about CC-Food Safety?
- What would be the contaminant(s) need to be used in SEA to monitor climate change changes? EU – emerging mycotoxin (corn, soy bean)
  - Heavy metals? HAB; Antibiotic used? marine toxin (water based)
  - Pesticides used?; Mycotoxin – in what crop? (land based)
- Are we in control of climate change impact on food safety contaminants
- Do we have enough database for predictive modeling, early warning strategies
- Microbial / disease related is better indicator

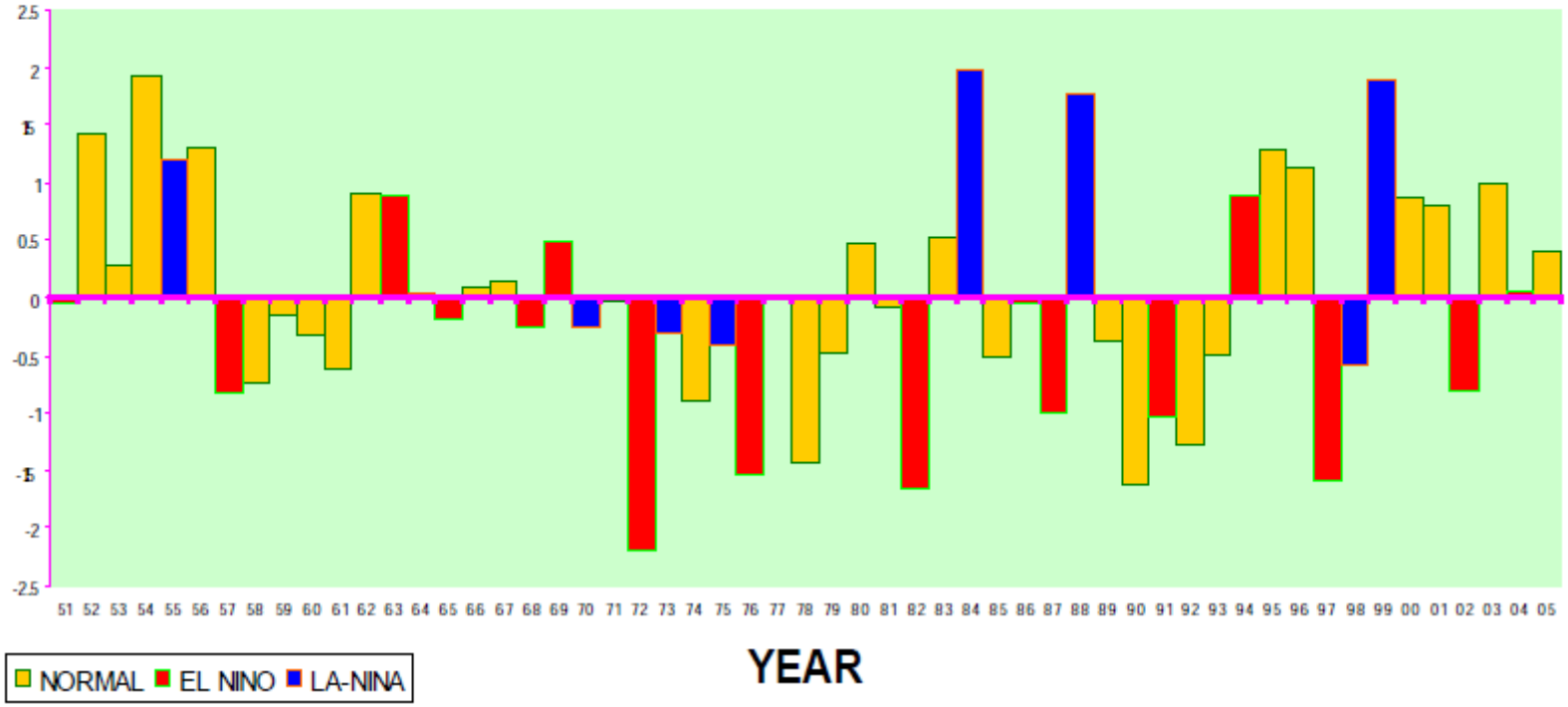
Future Studies Needed

- Research on climate change impact on food safety
- Developing/updating the food safety-climate change database
- Regional cooperation among countries in SEA/ASIAN having the same situation / impact on food safety
- Cooperation with more advanced countries / region in the subject – EU, USA
- Mitigation, adaptation - when? Are what we are doing now enough?



Thank You - Terima Kasih

Standardized Annual Rainfall Anomaly
Sabah & Sarawak



Total Hg & MeHg in muscle tissue of fish samples from market