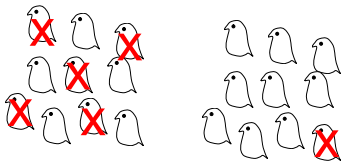
Population risk assessment of zinc concentration

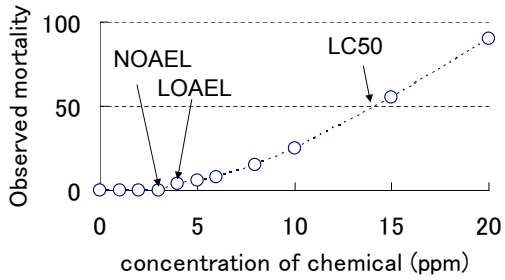
- Endpoint of human health risk = significant damage on individual (well-being)
  - NOAEL (Non-observed adverse effective level)
- Endpoint of ecological risk = s. damage on population persistence (sustainability)
  - X HC5 (Hazardous concentration for 5% of species)
  - Level of no population growth when *N*=0
  - PHC5 (Population-level HC5)

Key level of hazard for health risk

- LC50 = Median lethal concentration (unbiased estimator)
- LOAEL =Lowest observed adverse effective level
- NOAEL = Non-observed adverse effective level
- Acute toxicity
- Chronic toxicity



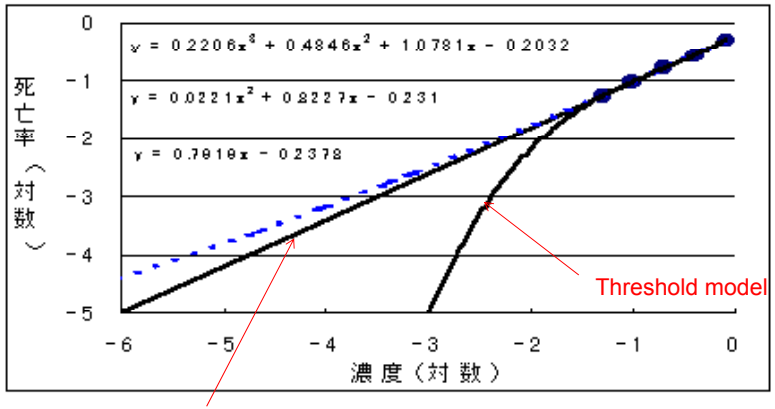
LOAEL



Why is mortality given by probability?

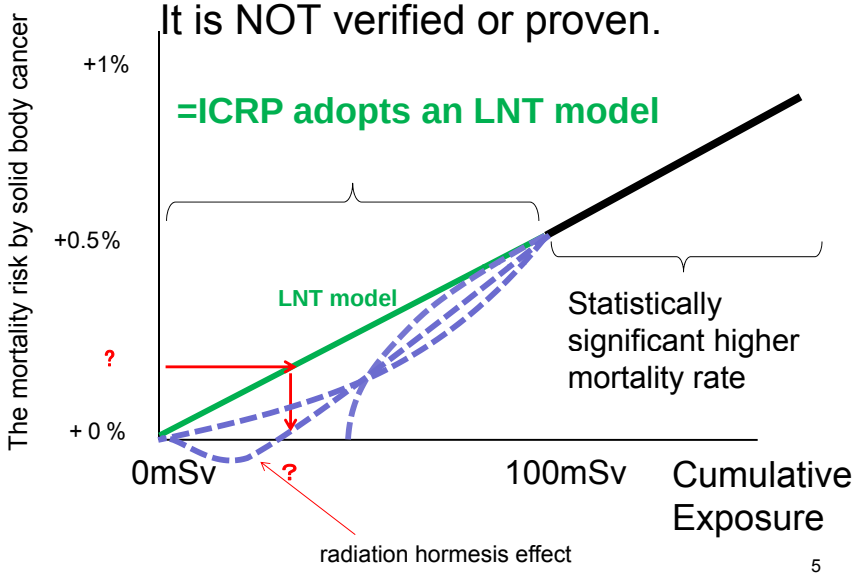
- Sensitivity = some individual is more sensitive by chemical toxicity (depending on health condition & genetic traits).
- Exposure inequality = some individual is vulnerable of chemical exposure (eating more contaminated food…)
- We cannot detect the death rate of 10^{-4} (0.01%) by bioassay (the sample size is usually <50). Therefore…

Extrapolation外挿! It's prohibited in basic science



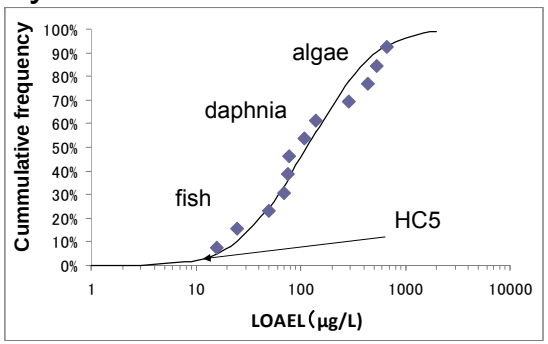
岸本充生氏より改定

LNT hypothesis is used in “regulatory science”
It is NOT verified or proven.



Key level for “ecological” risk

- Ecological risk is often evaluated by LOAEL/NOAEL of several species (not by population persistence)
- Species sensitivity distribution of NOAEL
- HC5 = Hazardous concentration for 5% of species



Zinc environmental standard is determined by ecological risks.

Japan

In order to prevent population-level effects on aquatic organisms

An environmental water quality standard for total zinc was established in 2003

Freshwater：30 μg/L

Non-observed effect concentration (NOEC) for the mayfly *Epeorus latifolium*

Based on results of laboratory single-species toxicity tests

On the other hand...

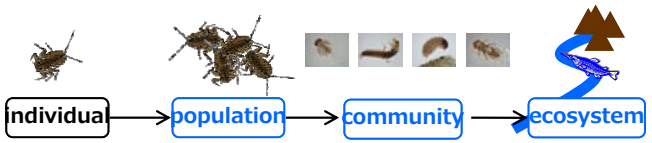
many aquatic sites at which Zn concentration exceeded the standard

- **Ministry of the Environment, Japan, made the effluent standard for zinc more stringent** (**5 to 2 mg/L**)
- Several industrial associations point out that it will cause considerable economic hardship （MoE 2006）

Why is population level assessment needed?

1. **Need to evaluate the effect of zinc (especially, around 30 μg/L) at the population and its ecosystem**
   - Single-species toxicity tests do not necessarily assess the impacts on natural populations (Levin et al. 1984)
   - The importance of evaluating the ecological risk at population and higher levels (eg., Clements & Kiffney 1994, Pastorok et al. 2001)

Benthic macroinvertebrate assemblages have been widely used to evaluate the ecological impacts of heavy metal contamination in streams (eg., Clements et al. 2000)



Population growth model

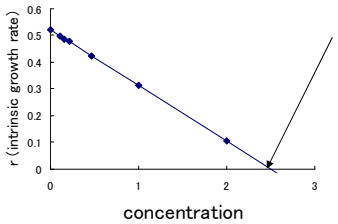
Logistic growth

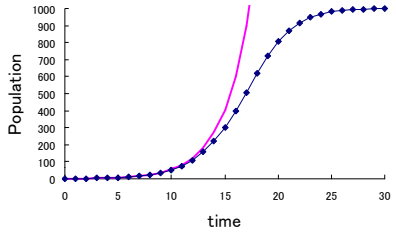
- $dN/dt = r(1\text{-}N/K)N$

r : Intrinsic growth rate of population increase

K: Carrying capacity

N : Population size



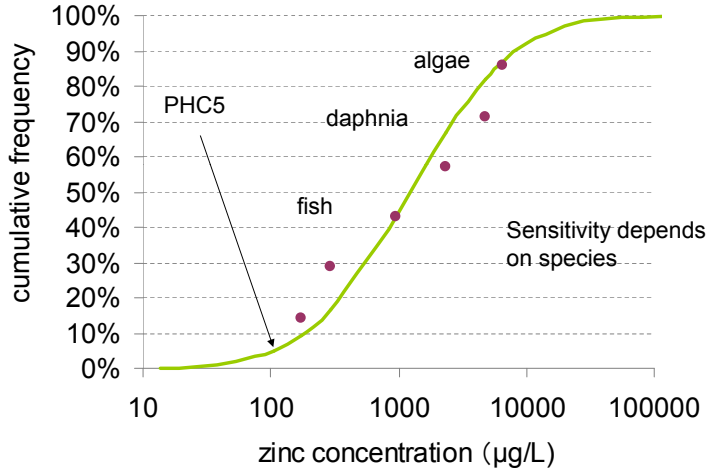


r decreases with increasing toxicity

If r =0, population goes extinct.

PHC5

Kamo & Naito (2008 Human & Ecol Risk Assessm)



Why is field verification needed?

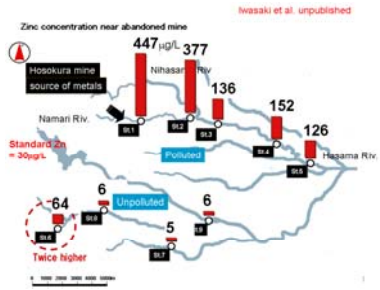
The objective of the present study is to observe the effect of zinc (2 to 3 times higher than the standard) on riverine macroinvertebrates at population and community levels

We conducted a field survey in western Japanese streams

The polluted sites in this study included the following at which total Zn concentrations were 2-3 times higher than the standard and other heavy metal concentrations were not much high

demerits of field survey

- It is difficult to separate the effect of zinc from the effects of other metals
  - In polluted sites, not only zinc concentration but also other metal concentrations were relatively high
- Biome depends on environmental condition
  - upstream/downstream, high/low-BOD water



Station	Cu	Zn	Cd	Pb	硬度 (mg/L)
1	5.2	447	2.79	11.4	831
2	4.4	377	3.97	6.2	806
3	1.9	136	1.23	2.1	262
4	1.4	152	1.12	1.9	248
5	1.3	126	0.90	2.4	232
6	3.3	64	0.49	0.6	18
7	0.3	5	N.D.	0.2	27
8	N.D.	6	0.03	0.1	23
9	0.3	6	0.01	0.2	25

Concentration of total heavy metals (μg/L)
not detecited (Cu: 0.12μg/L, Cd: 0.0026μg/L)下

BOD =biochemical oxygen demand

Iwasaki et al. 2009

Zinc concentration near abandoned mine