Development of Damage Functions Considering Toxic Impacts of Ecosystem in Japan

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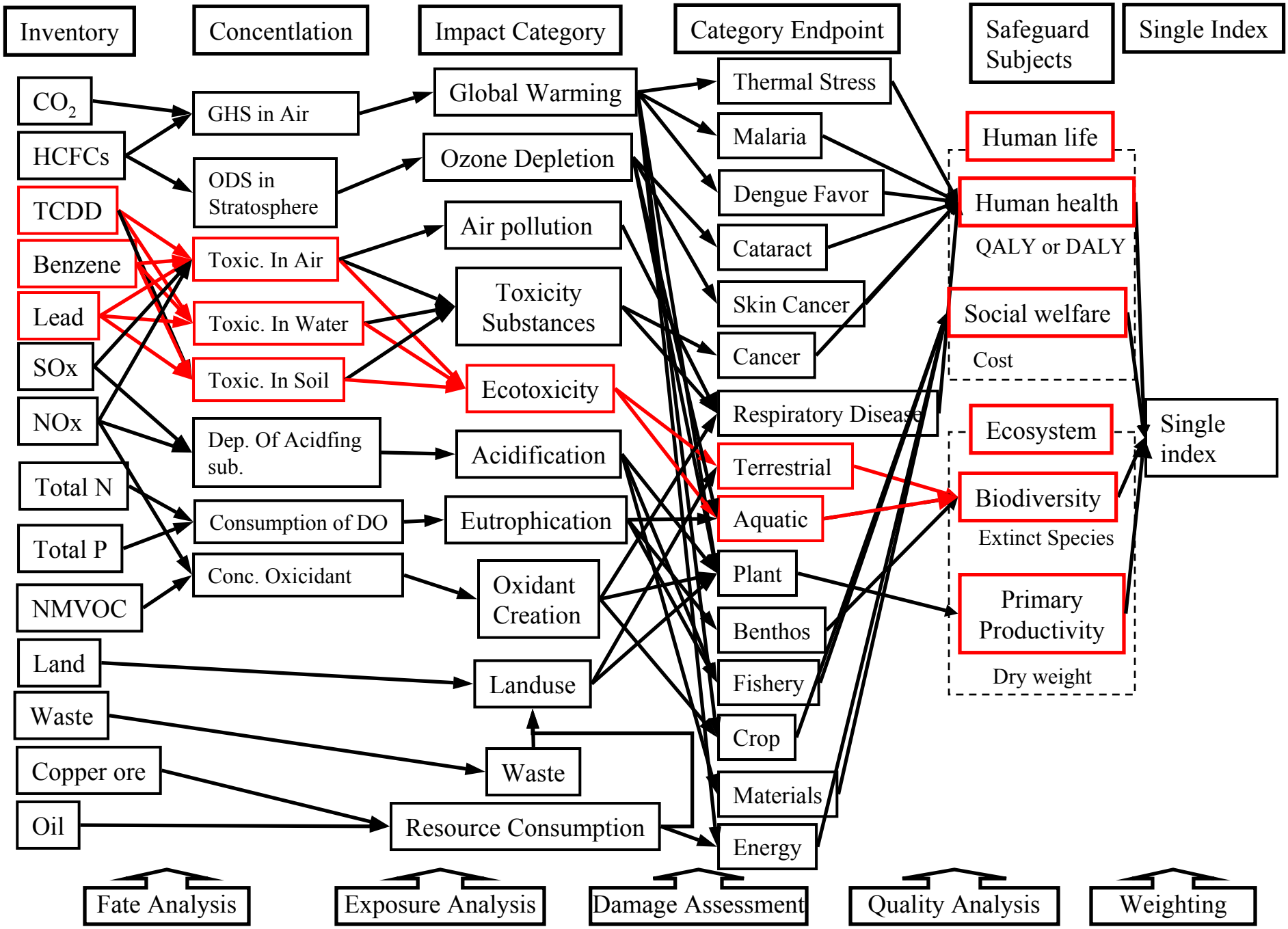
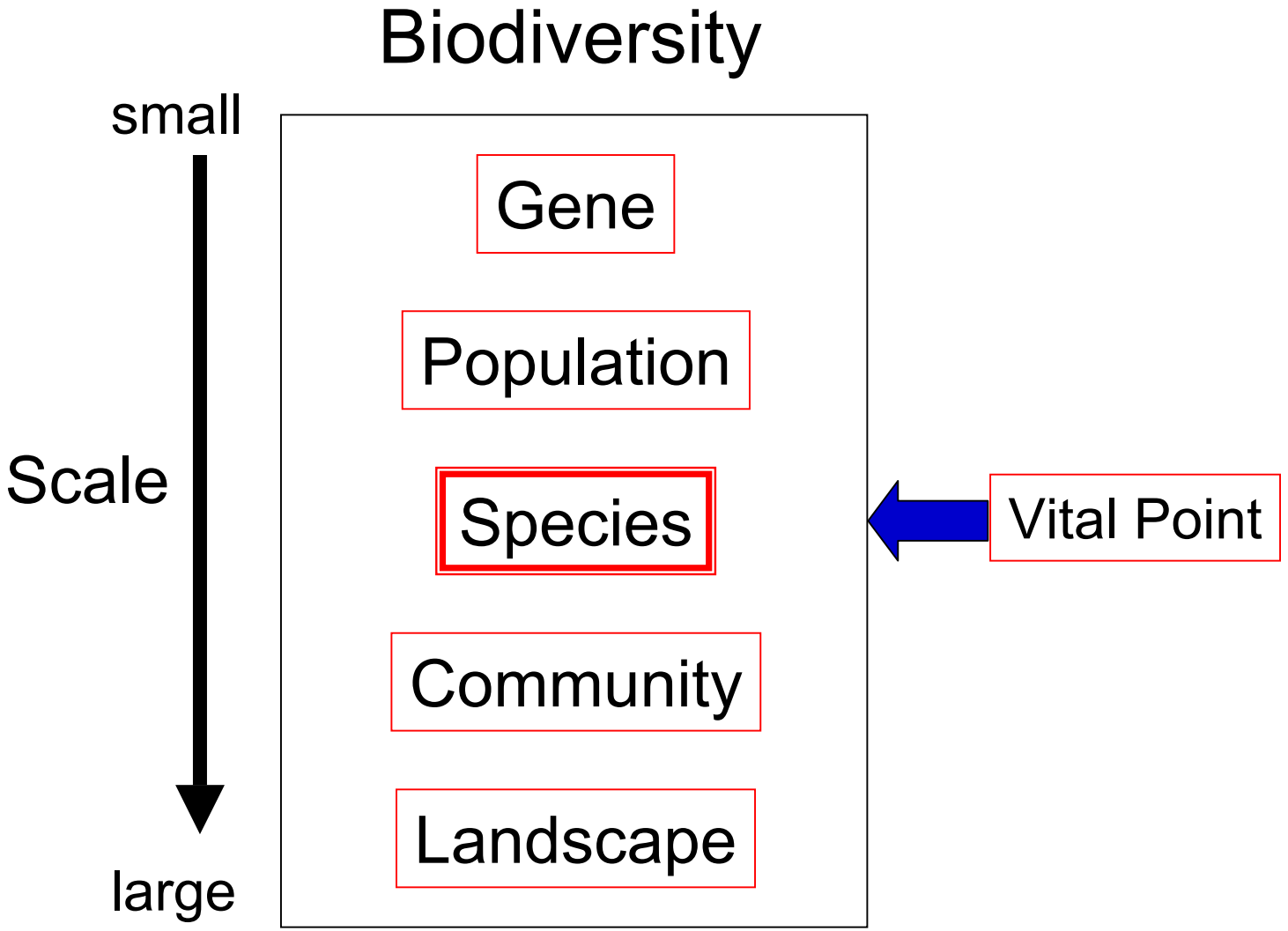
Endpoint-type LCIA Methodology for Japan



Definition (1)



Definition (2)

EINES (Expected Increased Numbers of Extinct Species)

$$EINES = \sum_{G} N_G \times \Delta R_G$$

N_G: The numbers of species for groupG

Referred from RD Book

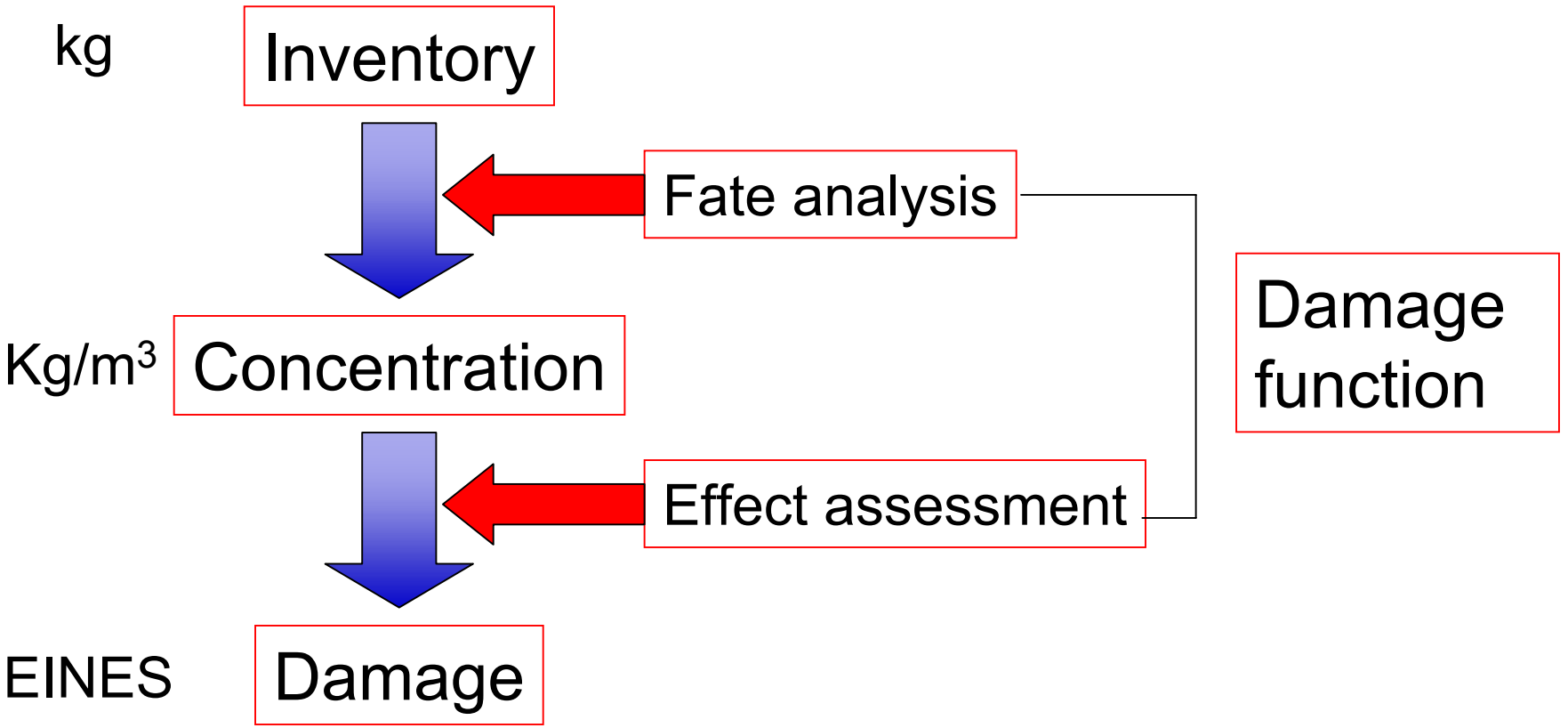
ΔR_G: The incremental risk for extinction of specie

Estimated By Models

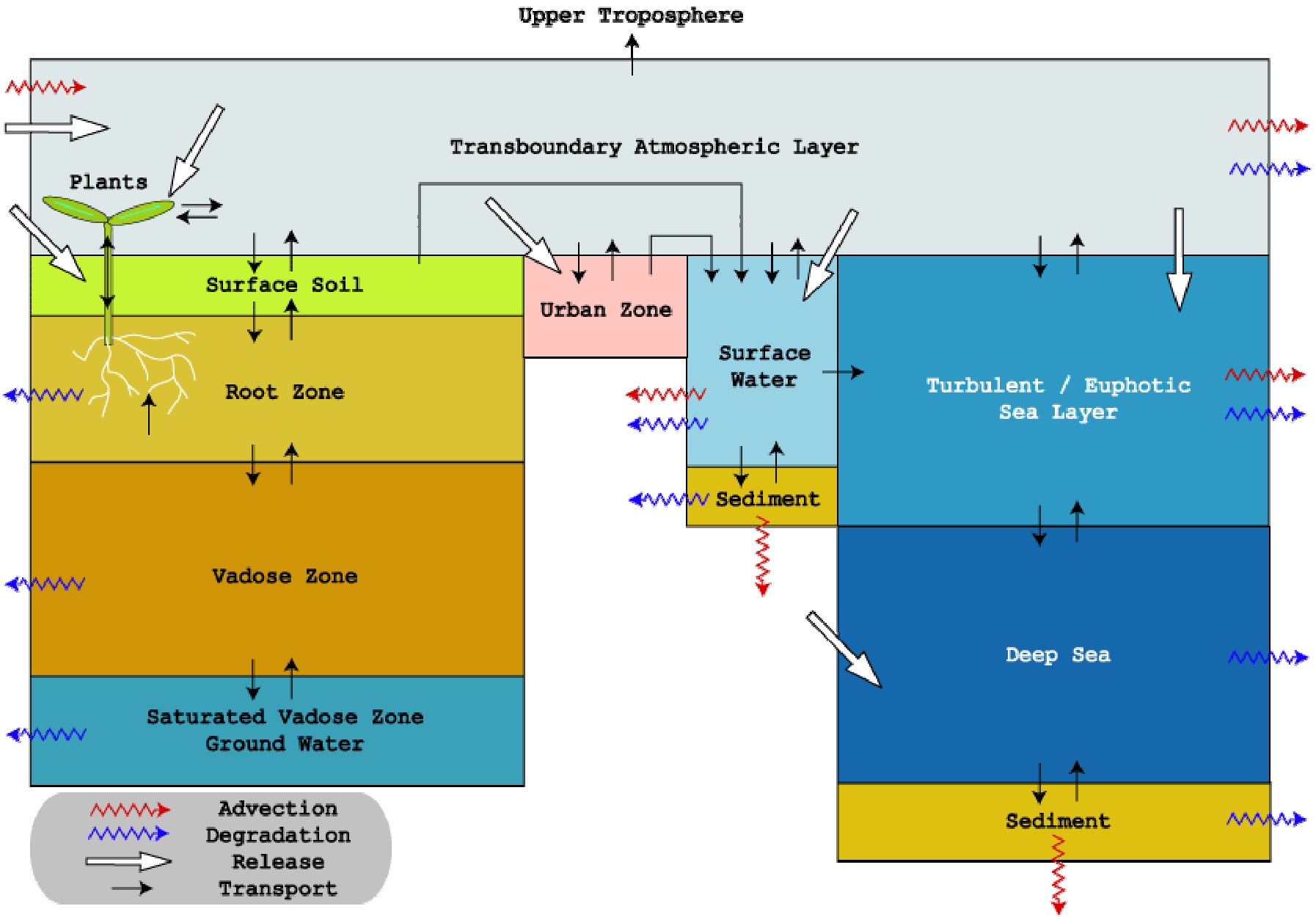
Present State of Japan

Group of Species	The numbers of existing species in Japan	State of specie	Model type
Critically Endangered (CE)	673	Decreasing	1
Endangered (EN)	634	Decreasing	1
Vulnerable (VU)	957	Stable	2
Lower Risk and Others (LR)	62,000	Stable	2

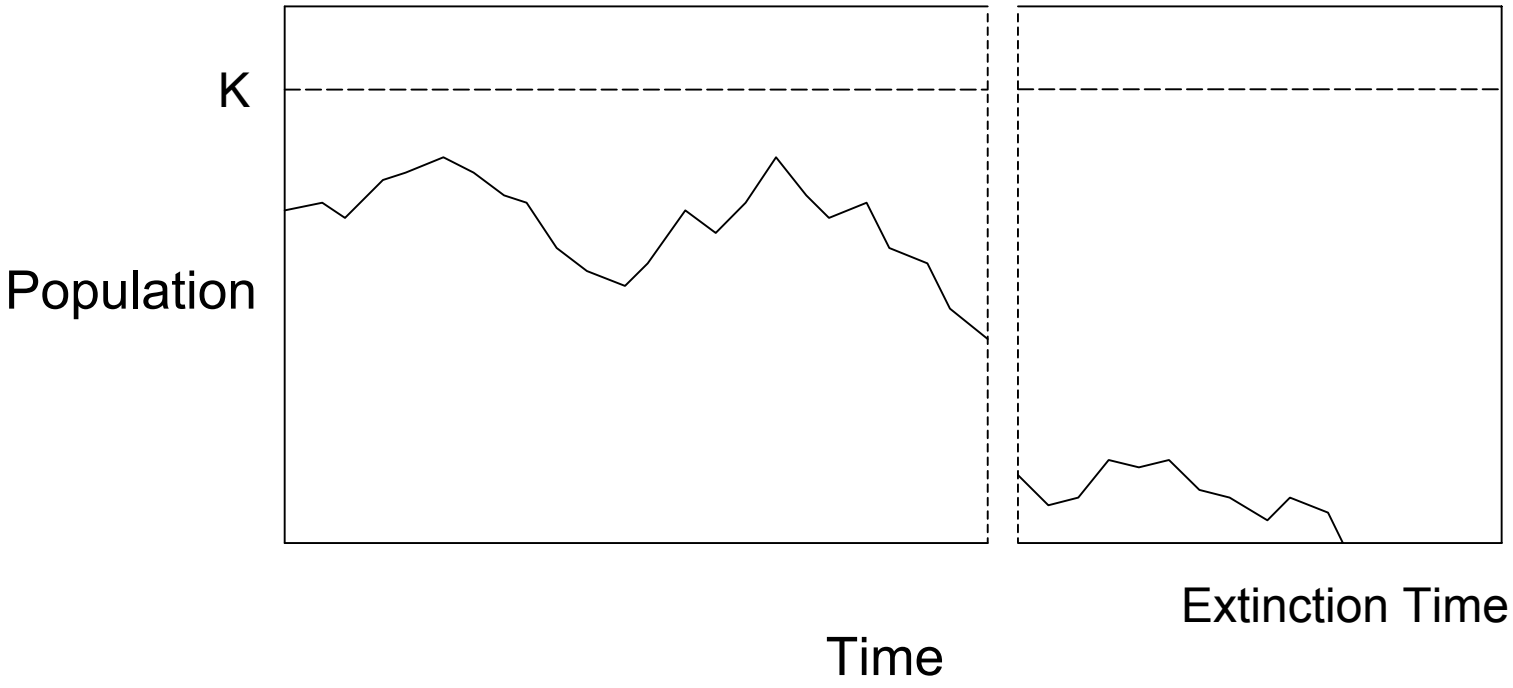
Procedure


kg
Inventory
Fate analysis
Damage function
Kg/m3
Concentration
Effect assessment
EINES
Damage

Japan Multimedia Fate Model



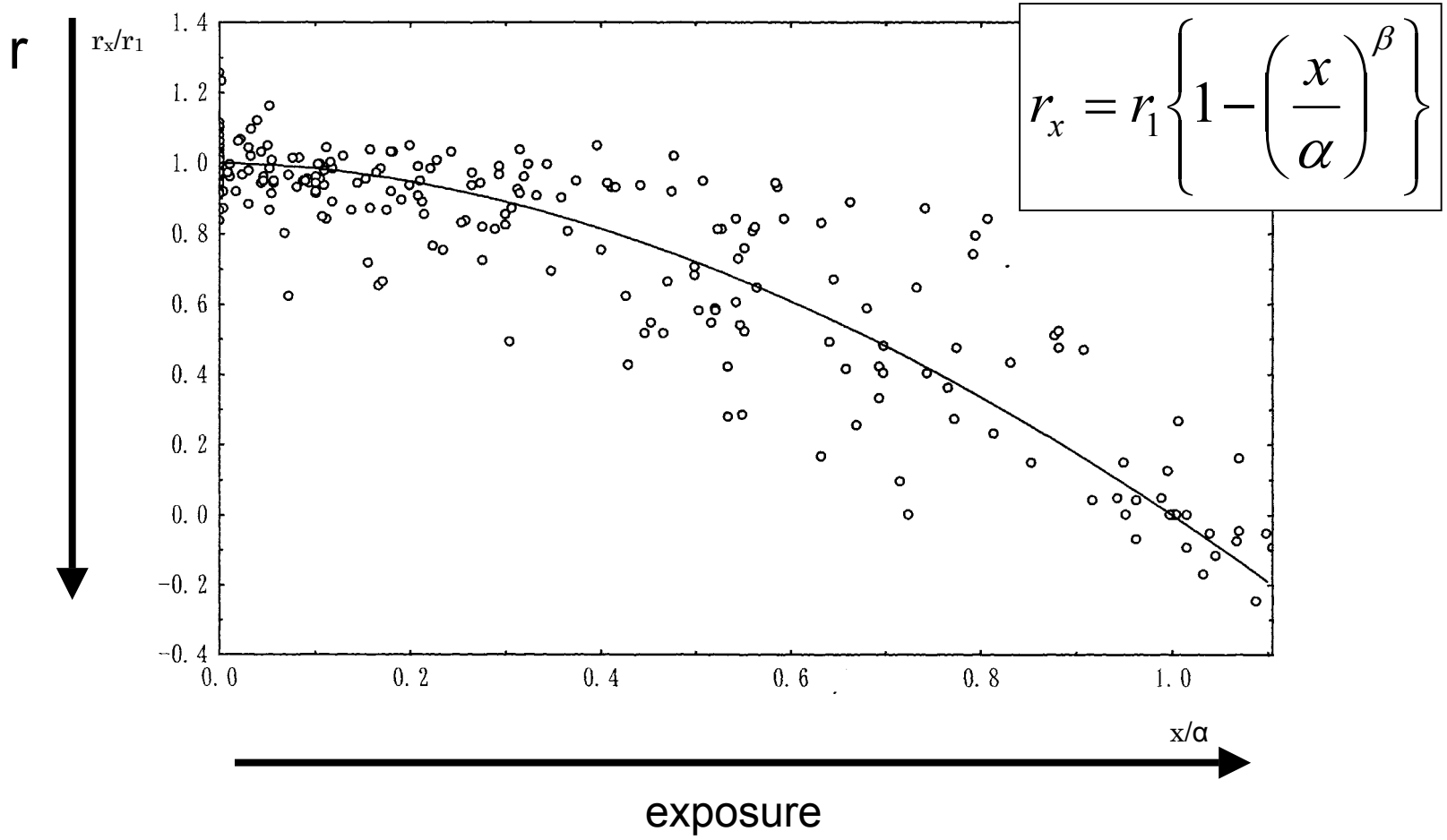
Effect Assessment



$$\text{Extinction time} = f\left(\text{K}, \text{r}, \text{v}\right)$$

K: Carrying capacity, r: Intrinsic natural growth rate, v: Environmental variance

Effect Assessment



Model (VU, LR)

Diffusion equation

$$\frac{\sigma^2(N_0)}{2}\frac{d^2T}{dN_0^2}+\mu(N_0)\frac{dT}{dN_0}=-1$$

Solution of diffusion equation

$$\mathrm{T}=\mathrm{c}\cdot\mathrm{K}^{2(\mathrm{r/v})-1} \qquad c=\frac{2\bar{r}}{V_e}-1$$

Lande; American Naturalist, Vol.142, No.6, pp.911

Estimate the increase of extinction risk

$$\Delta\mathrm{R}_\mathrm{G}=\frac{1}{\mathrm{T}_\mathrm{E}}-\frac{1}{\mathrm{T}_\mathrm{P}}$$

Model (CE, EN)

Diffusion equation

$$\frac{\partial p}{\partial t} = -\mu \frac{\partial p}{\partial x} + \left(\frac{\sigma^2}{2}\right)\frac{\partial^2 p}{\partial x^2}$$

Solution of diffusion equation

$$p(x,t|x_0) = (2\pi\pi^2 t)^{-1/2}\left[\exp\left\{-\frac{(x-x_0-\mu t)^2}{2\sigma^2 t}\right\} - \exp\left\{-\frac{2\mu\mu_0}{\sigma^2} - \frac{(x+x_0-\mu t)^2}{2\sigma^2 t}\right\}\right]$$

Estimate the possibility of extinction

$$g(t|x_0) = -\left(\frac{d}{dt}\right)\int_0^\infty p(x,t|x_0)dx$$

$$G(t|n_0) = \int_0^t g(t'|x_0)dt'$$

$$= \Phi\left[\frac{-n_0 - rt}{\sigma\sqrt{t}}\right] + \exp\left\{-\frac{2rn_0}{\sigma^2}\right\}\left(1 - \Phi\left[\frac{n_0 - rt}{\sigma\sqrt{t}}\right]\right)$$

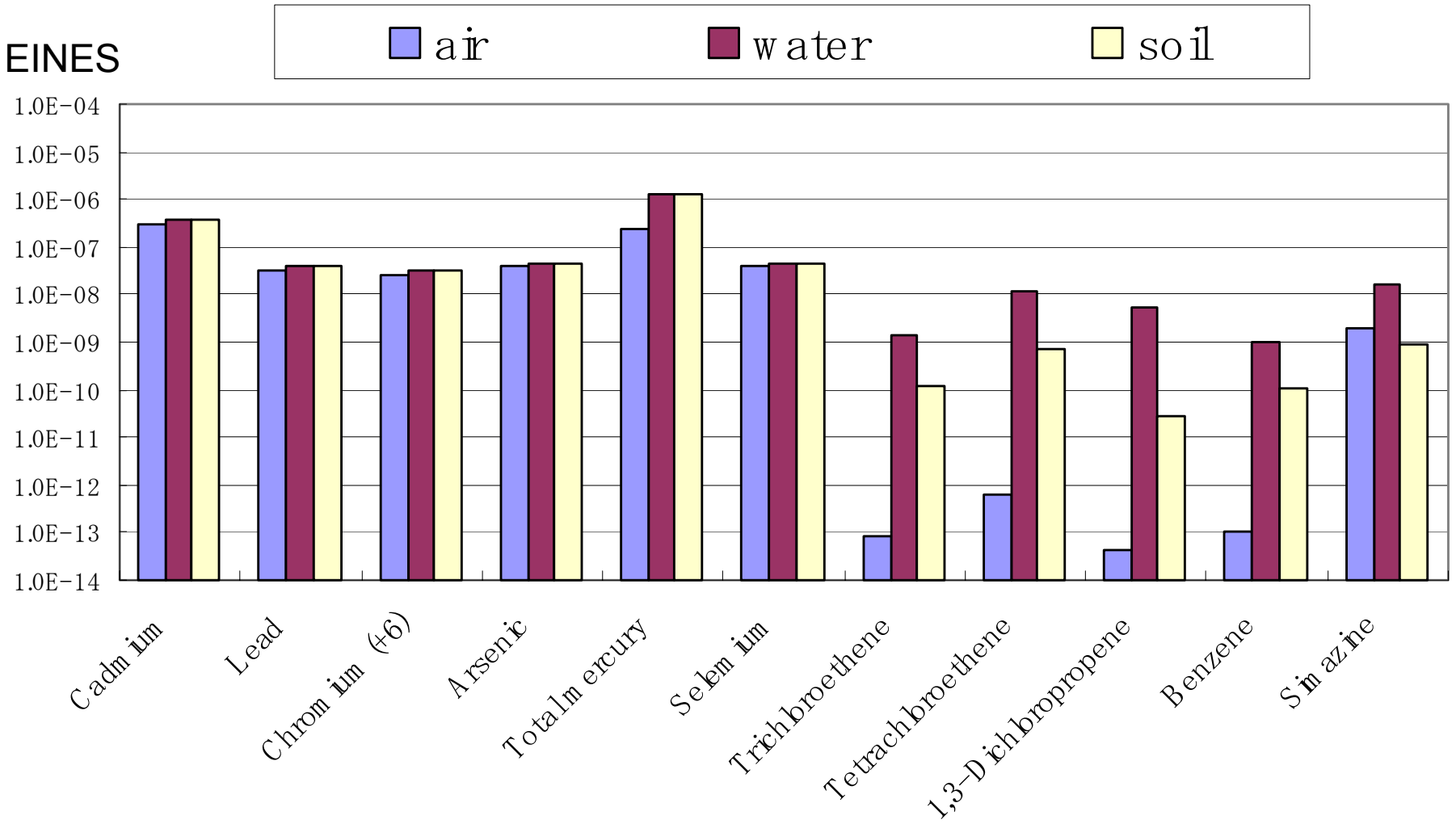
$$\Phi[y] = (2\pi)^{-1/2}\int_{-\infty}^{y}\exp\left\{-\frac{z^2}{2}\right\}dz$$

Lande & Orzack (1998)

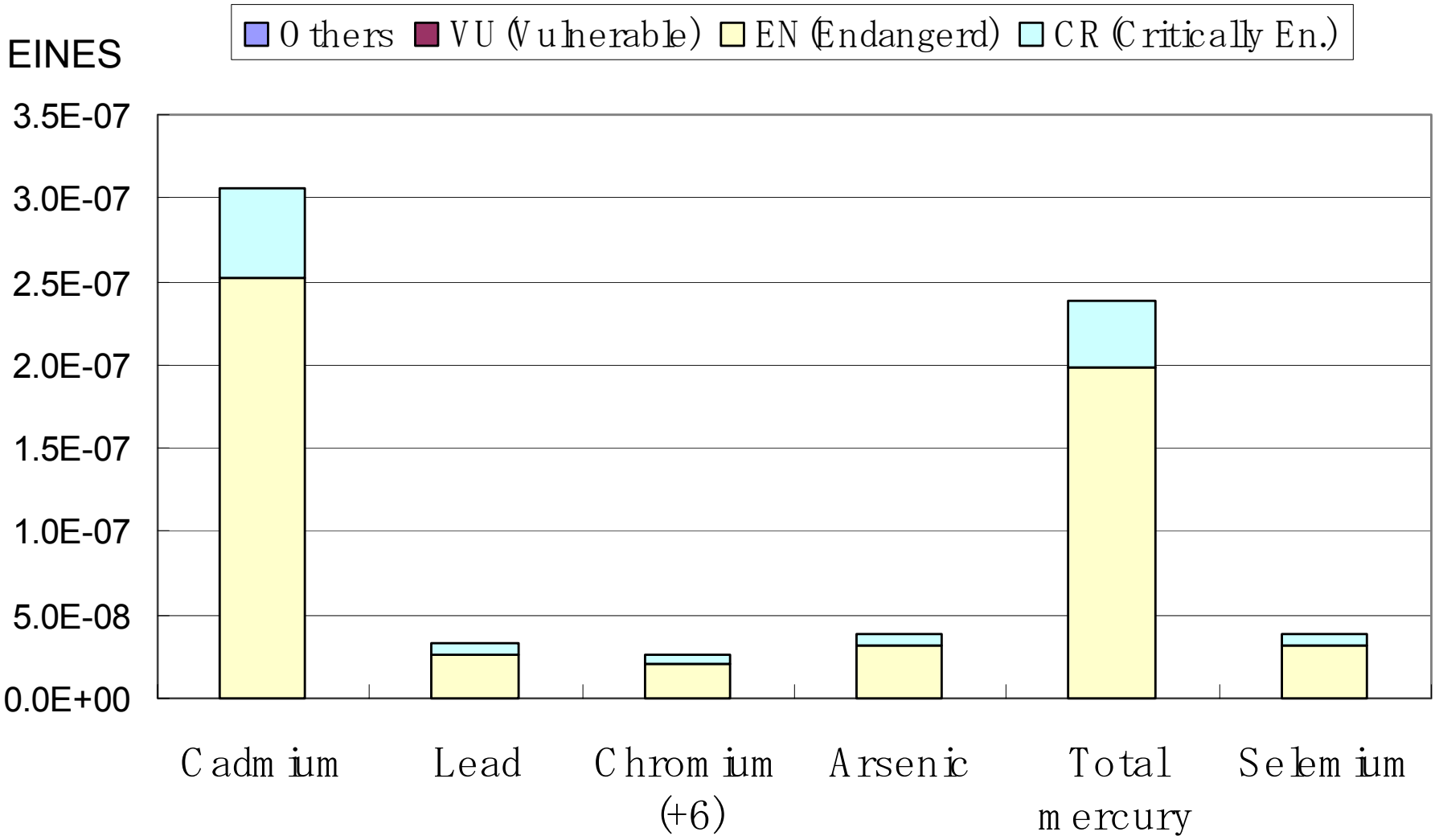
Estimate the increase of extinction risk

$$\Delta R_G = \frac{G(t|x_0)_p - G(t|x_0)_E}{t}$$

Result


EINES
air
water
soil
1.0E-04
1.0E-05
1.0E-06
1.0E-07
1.0E-08
1.0E-09
1.0E-10
1.0E-11
1.0E-12
1.0E-13
1.0E-14
Cadmium
Lead
Chromium (+6)
Arsenic
Total mercury
Selenium
Trichloroethene
Tetrachloroethene
1,3-Dichloropropene
Benzene
Simazine
Metals
Chemicals

Result


Others
VU (Vulnerable)
EN (Endangerd)
CR (Critically En.)
EINES
3.5E-07
3.0E-07
2.5E-07
2.0E-07
1.5E-07
1.0E-07
5.0E-08
0.0E+00
Cadmium
Lead
Chromium (+6)
Arsenic
Total mercury
Selemium

Conclusions and Outlook

§ 21 substances of damage function relating ecotoxicity have been developed.

§ The sensitivity of extinction for endangered species can be considered as significant.

§ EINES of metals are larger than that of selected chemicals comparatively.

§ The result of this study will be published in the end of LCA National Project (2003 March).