Who is Controlling the Biosphere?

FIGURE 14.1 Night-time view of the world from satellite-derived measures of brightness. *Source: From http://eoimages.gsfc.nasa.gov/images/imagerecords/55000/55167/earth_lights.gif.*

The current (short-term) global carbon cycle

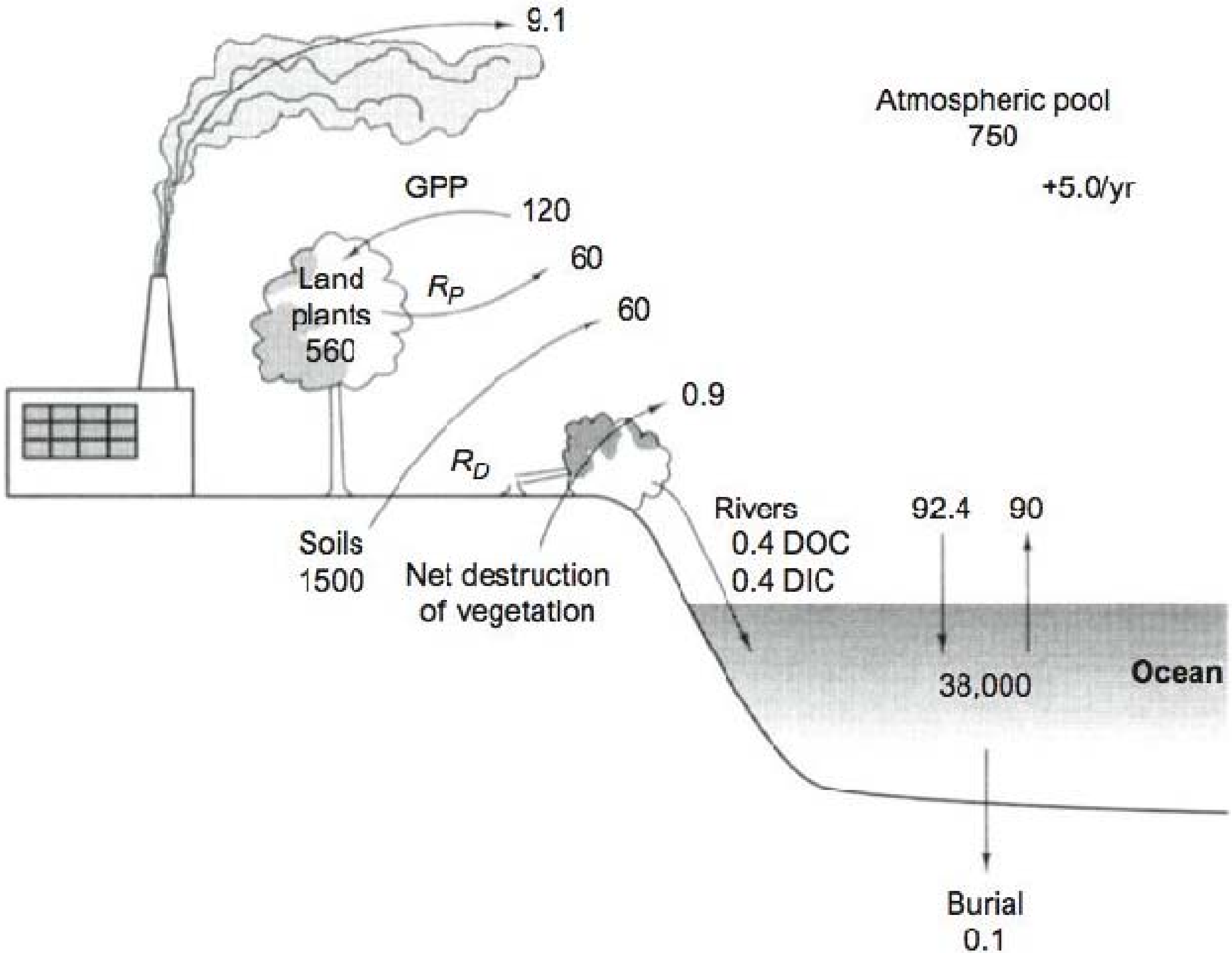


FIGURE 11.1 The global carbon cycle. All pools are expressed in units of 10^{15} g C and all annual fluxes in units of 10^{15} g C/yr, estimated for 2010. Values are taken from the text.

TABLE 11.1 Global Budget for Anthropogenic CO_2 in Earth's Atmosphere

	Fossil fuel		Biomass destruction[a]	=	Atmospheric increase		Ocean uptake		Terrestrial uptake	References
1990s	6.4	+	1.6	=	3.2	+	2.2	+	2.6	IPCC (2007)
2000–2007			1.1						2.3	Pan et al. (2011)
2010[b]	9.1		0.9		5.0		2.4		2.6	

Note: All data in 10^{15} g C/yr.

[a] *Net biomass destruction in the tropics.*

[b] *Source: www.globalcarbonproject.org/carbonbudget/index.htm.*

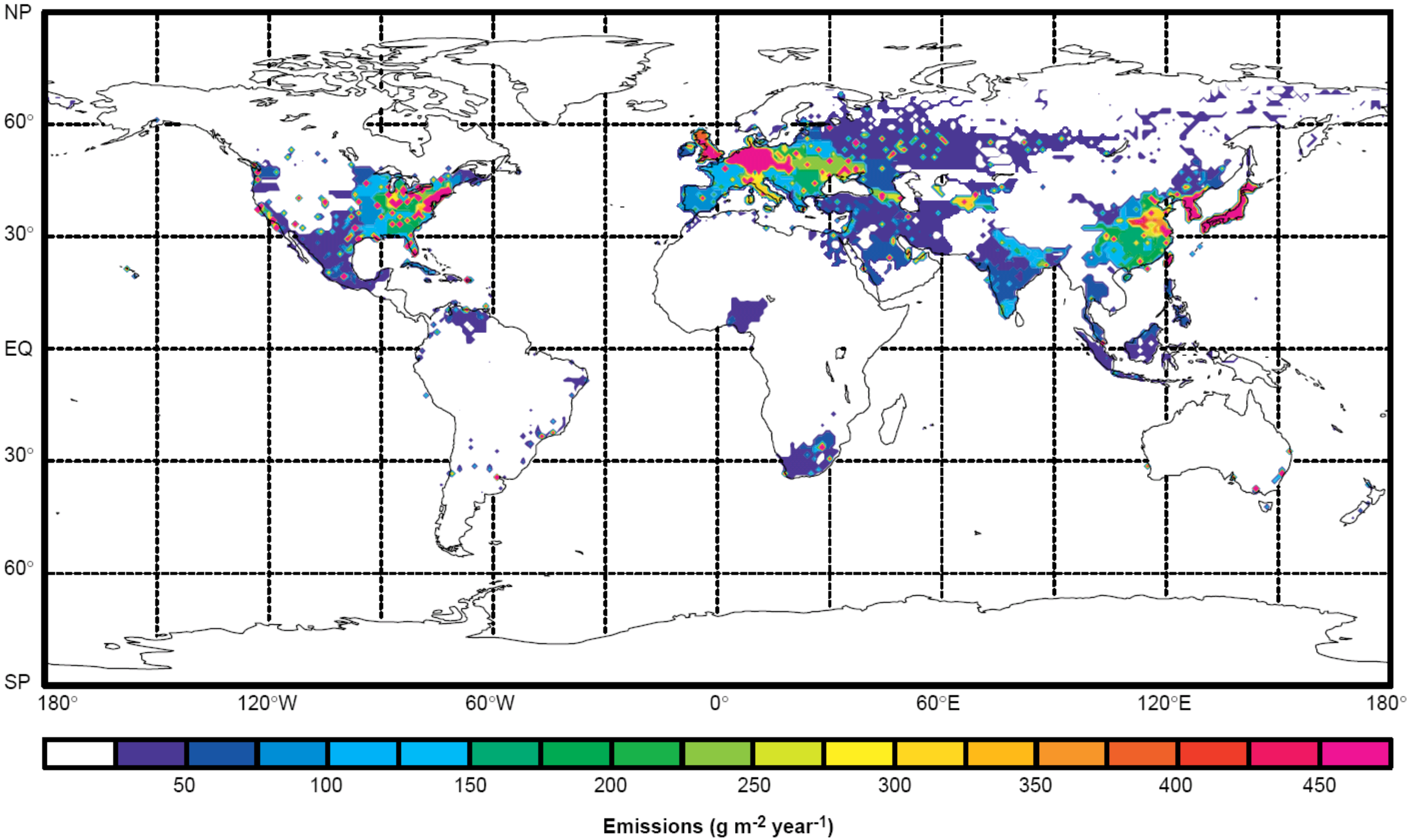


Fig. 4. Geographical distribution of fossil fuel sources of CO_2 as of 1990. The global mean is 12.2 g m^{-2} $year^{-1}$; most emissions occur in economically developed regions of the north temperate zone. EQ, equator; NP, North Pole; SP, South Pole. [Prepared by A. S. Denning, from information in (*18*)]

TABLE 12.3 Mass Balance for Nitrogen on the Earth's Land Surface

Inputs	Preindustrial	Human derived	Total
Biological N fixation	60[a]	60[b]	120
Lightning	5	0	5
Rock weathering	20[c]	0	20
Industrial N fixation	0	136[d]	136
Fossil fuel combustion	0	25	25
Total	**85**	**221**	**306**
Fates			
Biospheric increment	0	9	9
Soil accumulation	0	48	48
Riverflow	27	31	58
Groundwater	0	18	18
Denitrification	27[e]	17	44
Pyrodenitrification	25[f]	12	37
Atmospheric land–sea transport[g]	6	48	54
Total	**85**	**183**	**268**

Note: Updated from Schlesinger (2009), with permission from the Ecological Society of America. Unless otherwise indicated, preindustrial values and human-derived inputs are from Galloway et al. (2004). Fates of anthropogenic nitrogen are derived in this chapter.

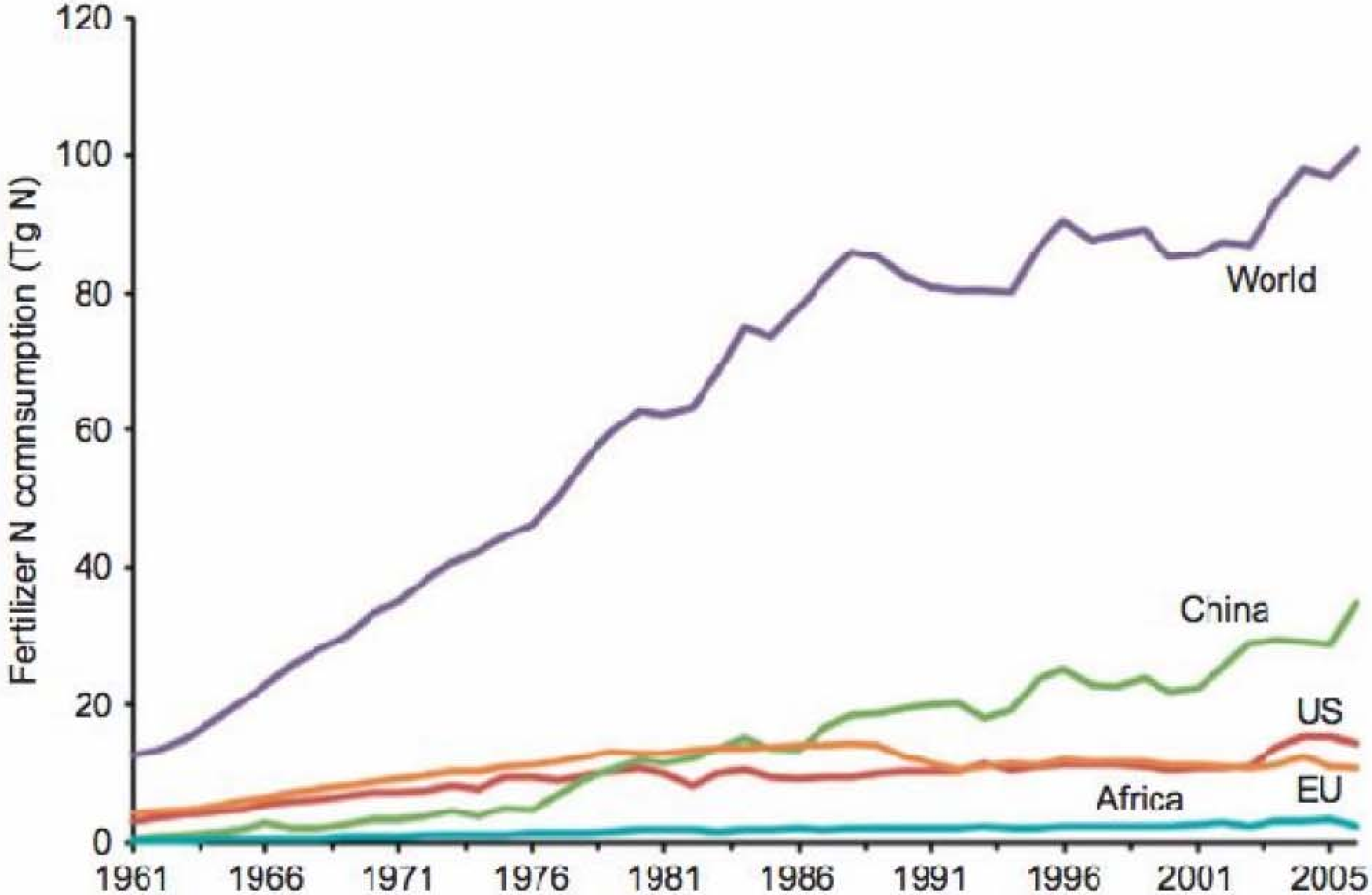
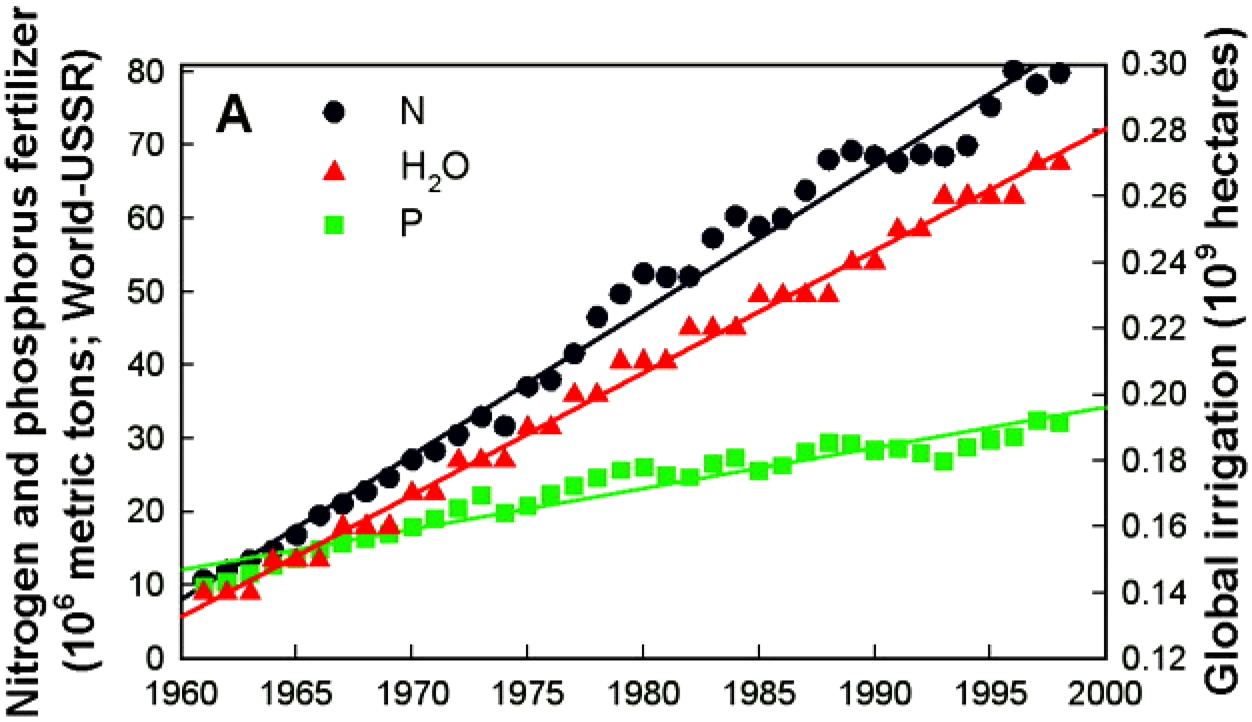
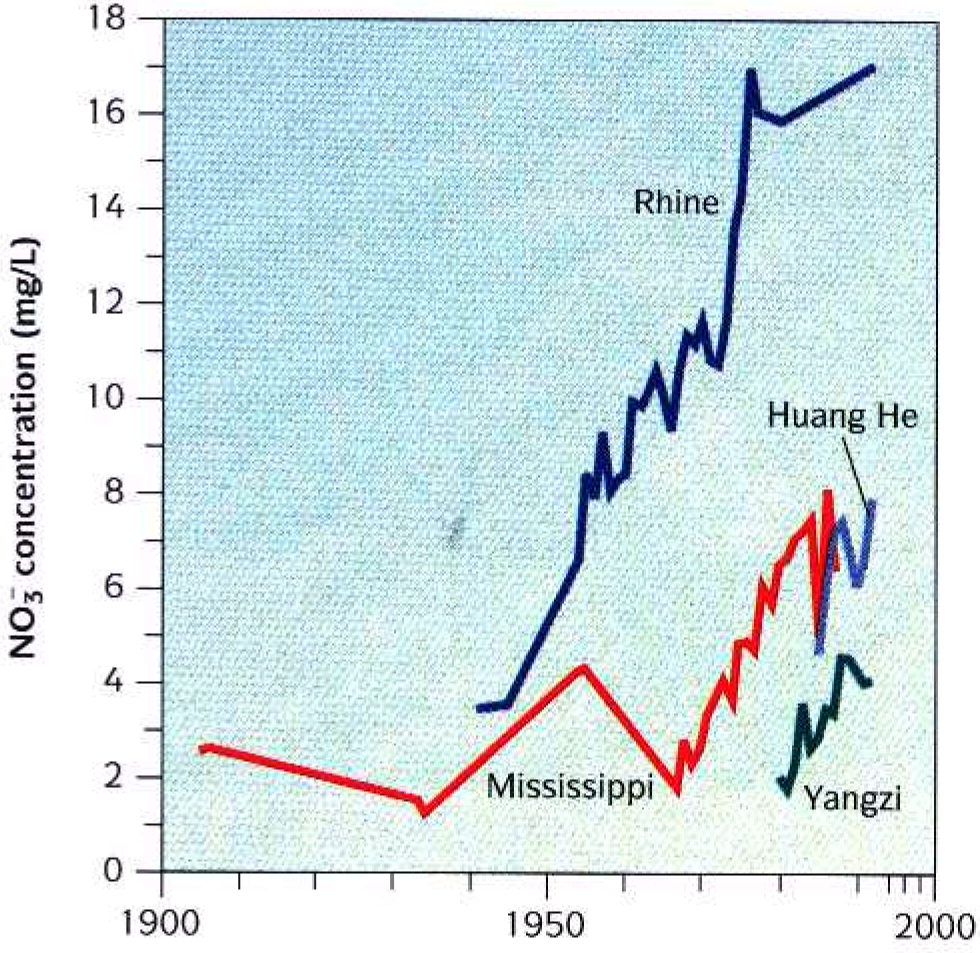


FIGURE 12.5 The production history of nitrogen fertilizer. *Source: From Robertson et al. (2009). Used with permission of the Annual Review.*

From: Tilman et al. 2001. Science 292:281-284





NO3⁻ concentration (mg/L)
18
16
14
12
10
8
6
4
2
0
1900
1950
2000
Rhine
Huang He
Mississippi
Yangzi

Atmospheric sulfur budget (10^{12} g/yr):

Input--

Natural emissions on land (volcanic Eruptions, dust, biogenic)=17
Human mining etc. = 60
Sea salt = 144
Sea biogenic = 28
Sea volcanic eruptions = 5

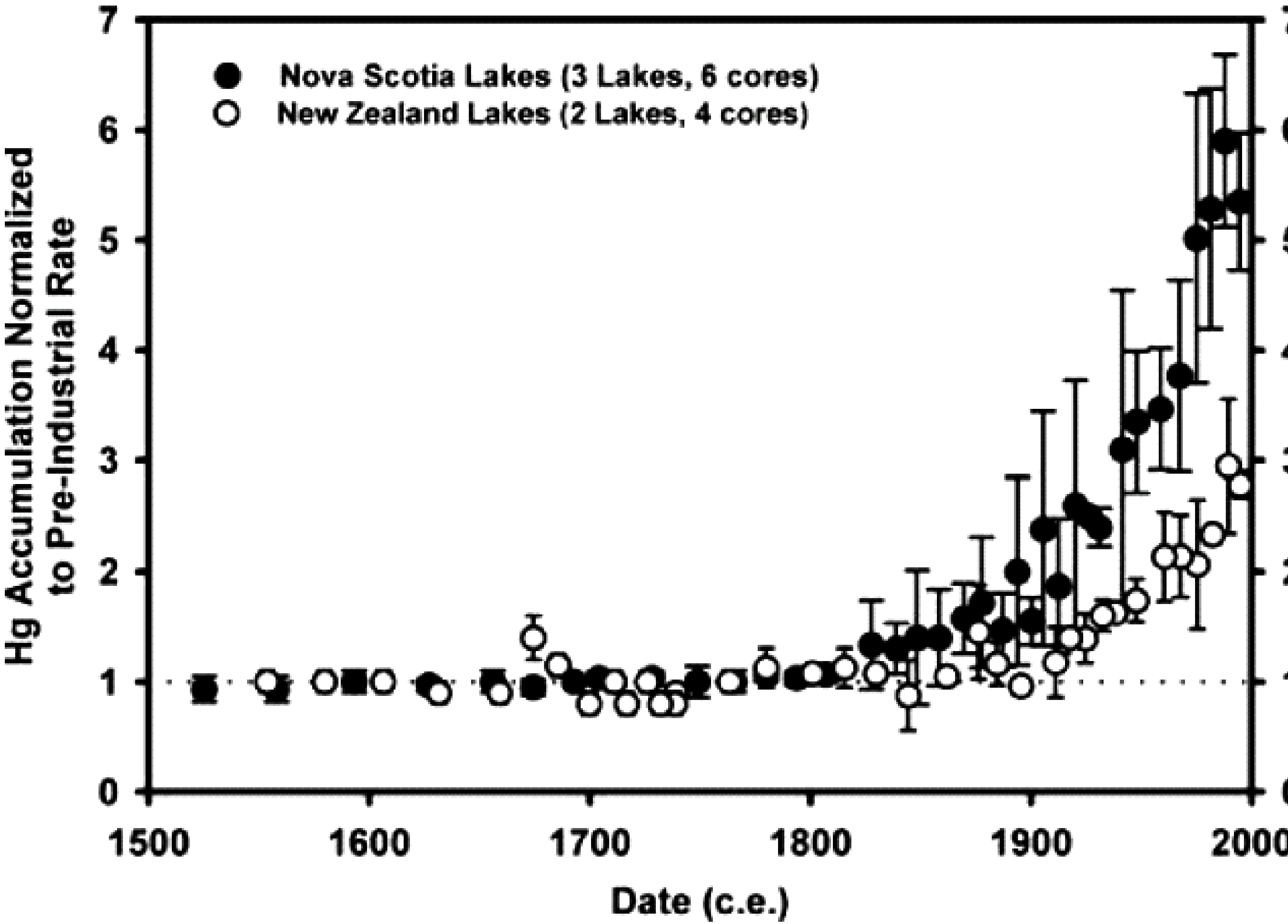
Total input = 254

Human contribution = 60/254 x 100 = 24%

Output--

Deposition on land = 60
Ocean deposition = 180

Total output = 240.



From: Lamborg et al. GLOBAL BIOGEOCHEMICAL CYCLES, VOL. 16, NO. 4, 1104-1115.

Table 15-1 Natural and anthropogenic sources of atmospheric emissions[a]

Element	Natural rate (10^2 tonnes/yr)	Anthropogenic rate (10^2 tonnes/yr)	Anthropogenic/natural ratio
Al	48 900	7 200	0.15
Ti	3 500	520	0.15
Sm	4.1	1.2	0.29
Fe	27 800	10 700	0.39
Mn	605	316	0.52
Co	7	4.4	0.63
Cr	58	94	1.6
V	65	210	3.2
Ni	28	98	3.5
Sn	5.2	43	8.2
Cu	19	263	13.6
Cd	0.3	5.5	19.0
Zn	36	840	23.5
As	2.8	78	27.9
Se	0.4	14	33.9
Sb	1	38	38.0
Mo	1.1	51	44.7
Ag	0.06	5	83.3
Hg	0.04	11	27.5
Pb	5.9	2 030	34.6

[a] Lantzy and Mackenzie (1979).

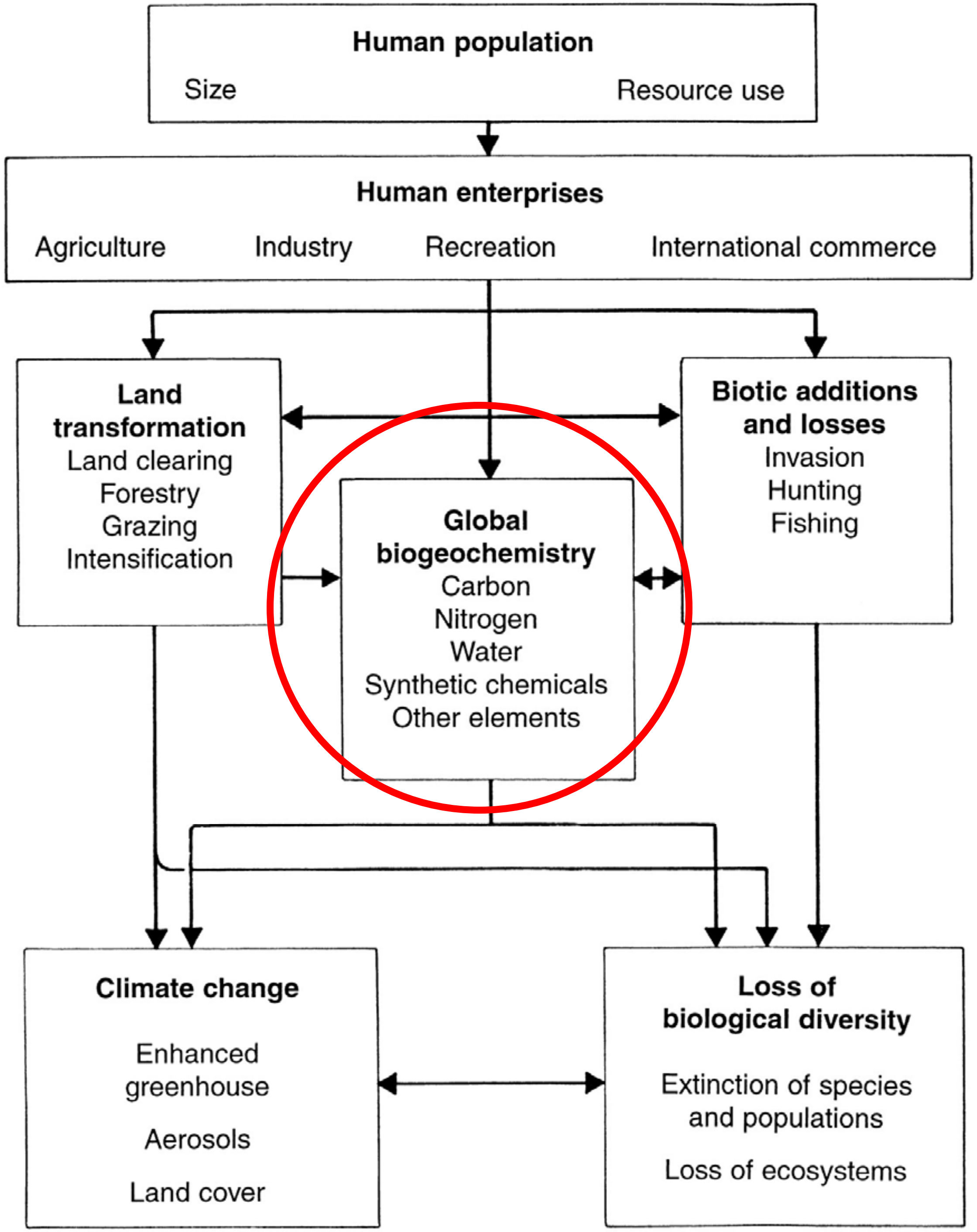
From: Jacobson, Charlson, Rodhe & Orians 2000

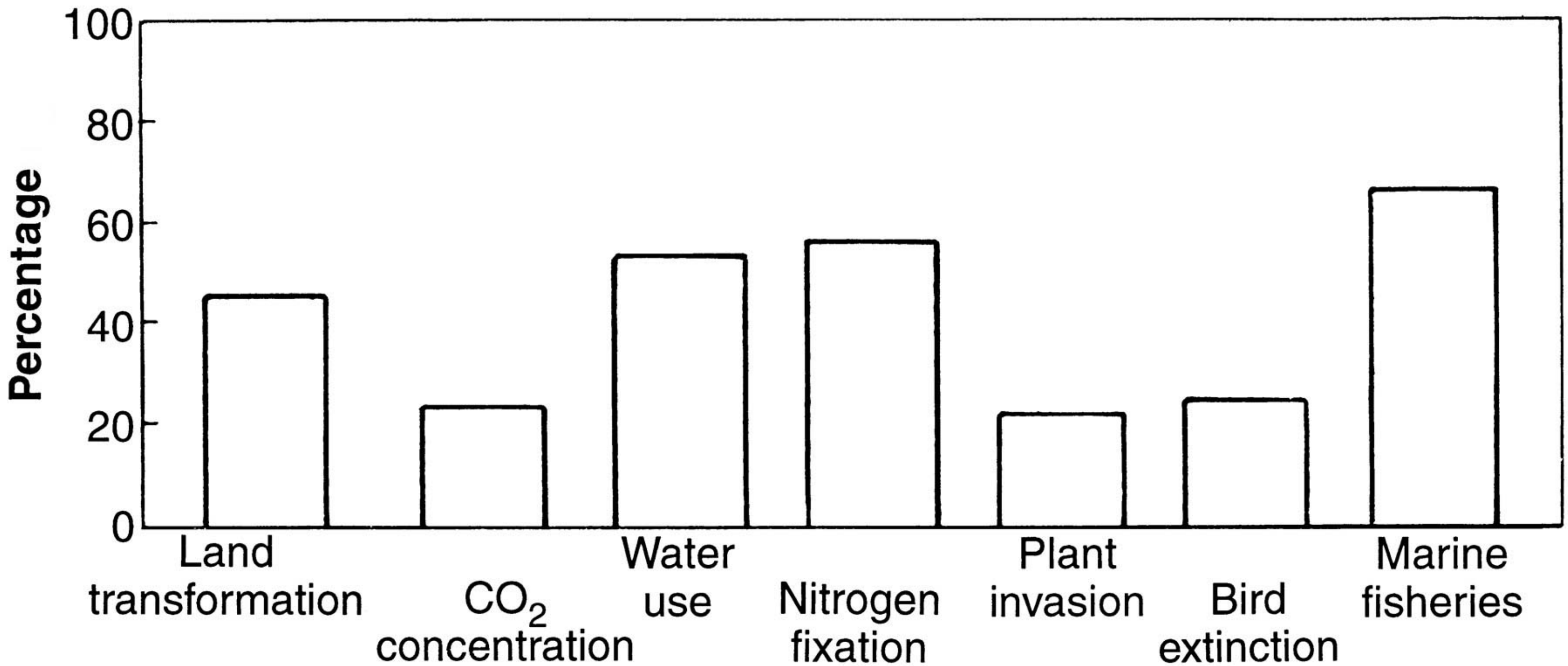
TABLE 14.1 Estimates of the Global Flux in the Biogeochemical Cycles of Certain Elements, Illustrating the Human Impact

Element	Juvenile flux[a] (1)	Chemical weathering (2)	Natural cycle[b] (3)	Biospheric recycling ratio[c] 3/(1+2)	Human mobilization[d] (4)	Human enhancement 4/(1+2)	Reference for global cycle
B	0.02	0.19	8.8	42	0.58	2.8	Park and Schlesinger (2002)
C	30	210	107,000	446	8700	36.3	Chapter 11
N	5	20[e]	9200[f]	368	221	8.8	Chapter 12
P	~0	2	1000	500	25	12.5	Chapter 12
S	10	70	450	5.6	130	1.6	Chapter 13
Cl	2	260	120	0.46	170	0.65	Figure 3.16
Ca	120	500	2300	3.7	65	0.10	Milliman et al. (1999), Caro et al. (2010)
Fe	6	1.5	40	5.3	1.1[g]	0.14	Muller et al. (2006)
Cu	0.05	0.056	2.5	23.6	1.5[g]	14.2	Rauch and Graedel (2007)
Hg	0.0005	0.0002	0.003	4.3	0.0023	3.3	Selin (2009)

Note: All data 10^{12} g/yr.

[a] *Degassing from the Earth's crust and mantle; sum of volcanic emissions to the atmosphere (subaerial) and net hydrothermal flux to the sea (Elderfield and Schultz 1996) and for N, fixation by lightning (Chapter 12).*


Human population
Size
Resource use
Human enterprises
Agriculture
Industry
Recreation
International commerce
Land transformation
Land clearing
Forestry
Grazing
Intensification
Biotic additions and losses
Invasion
Hunting
Fishing
Global biogeochemistry
Carbon
Nitrogen
Water
Synthetic chemicals
Other elements
Climate change
Enhanced greenhouse
Aerosols
Land cover
Loss of biological diversity
Extinction of species and populations
Loss of ecosystems



100
80
60
40
20
0
Percentage
Land transformation
CO_2 concentration
Water use
Nitrogen fixation
Plant invasion
Bird extinction
Marine fisheries

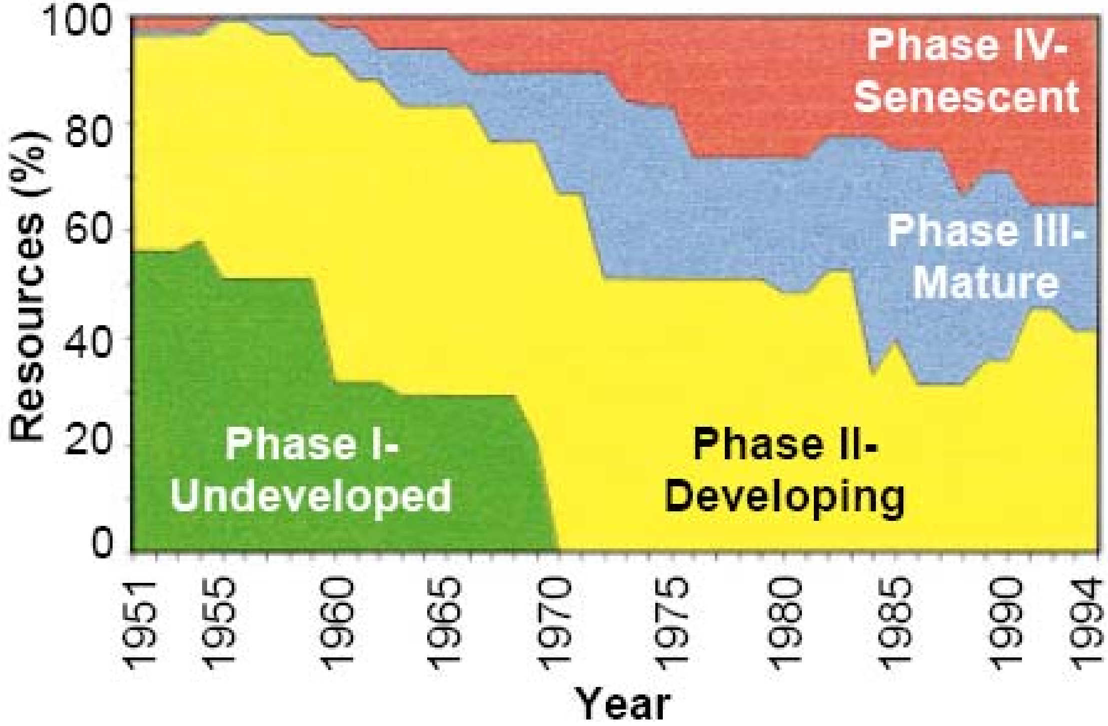
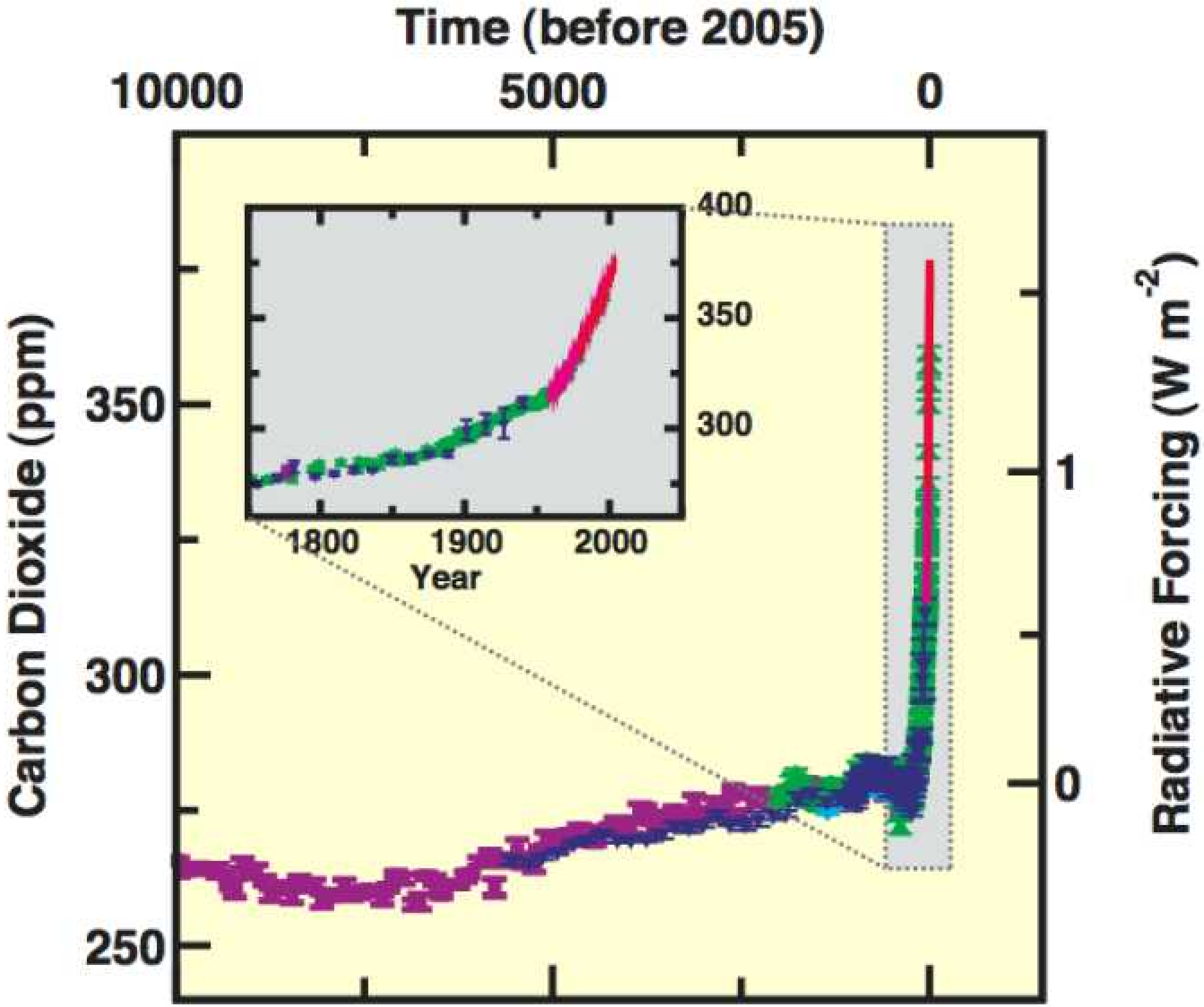
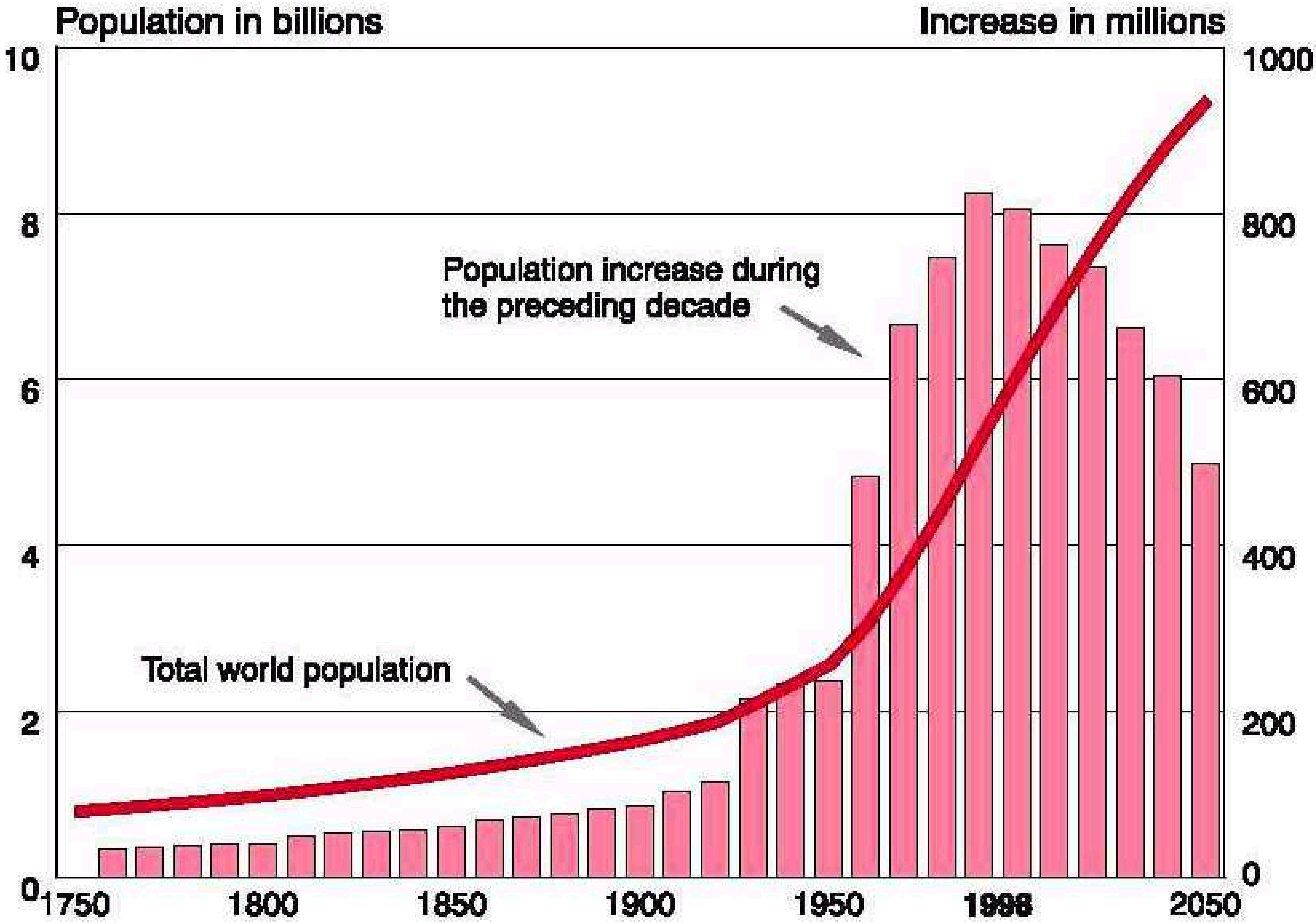


Fig. 3. Percentage of major world marine fish resources in different phases of development, 1951 to 1994 [from (*57*)]. Undeveloped = a low and relatively constant level of catches; developing = rapidly increasing catches; mature = a high and plateauing level of catches; senescent = catches declining from higher levels.

Changes in Greenhouse Gases from ice-Core and Modern Data





World human population now=7.1 billions

Is this sustainable?

Is there a carrying capacity?

Is there a carrying capacity?

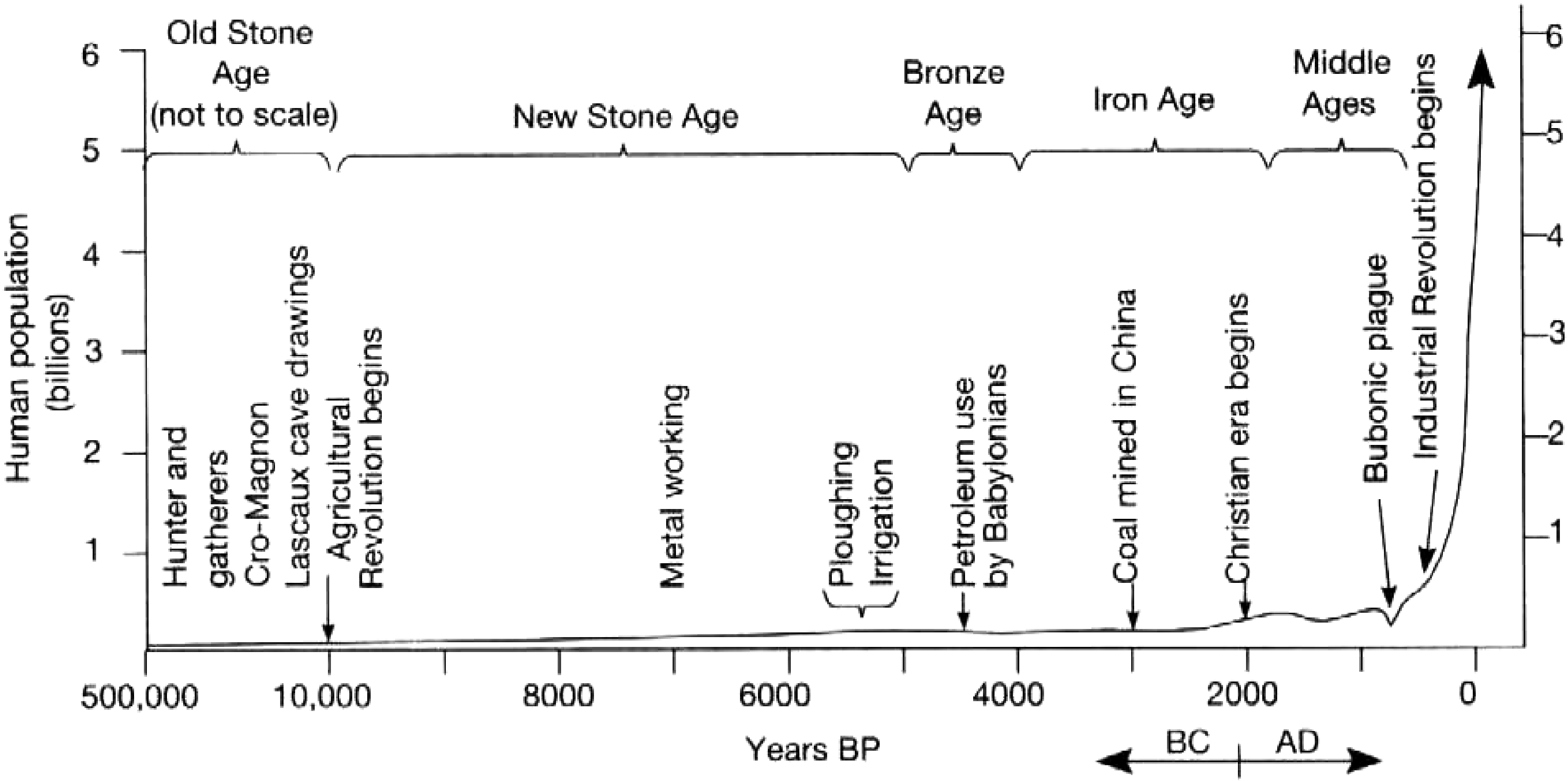
In 1798, **Thomas Malthus** published the book: ***Essay on the Principle of Population.***

In his book, he recognized that humans were not above and apart from the rest of nature but bound by ecological constraints, just like all other creatures. He argued that the linear growth of food supply could not possibly support the exponential growth of human population, thereby human population either controlled voluntarily or would crash by wars, starvation, or diseases.

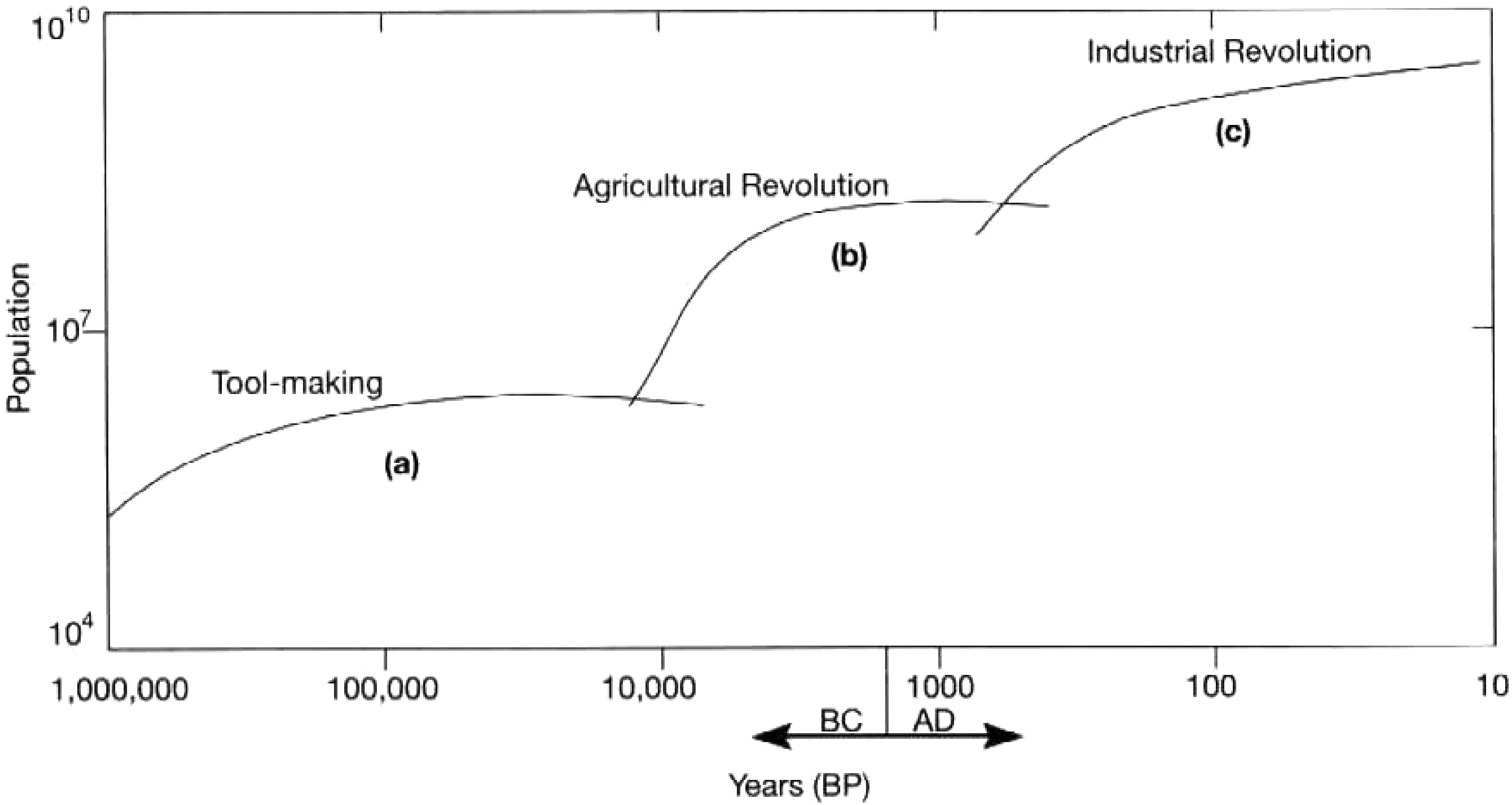
Is there a carrying capacity?

In 1968, **Paul Ehrlich** published his book: “The Population Bomb,” which stirred the first big debate in modern times about the consequences of human population growth. **Is it a timed bomb?**

We often use our history as one of the most reliable reference.

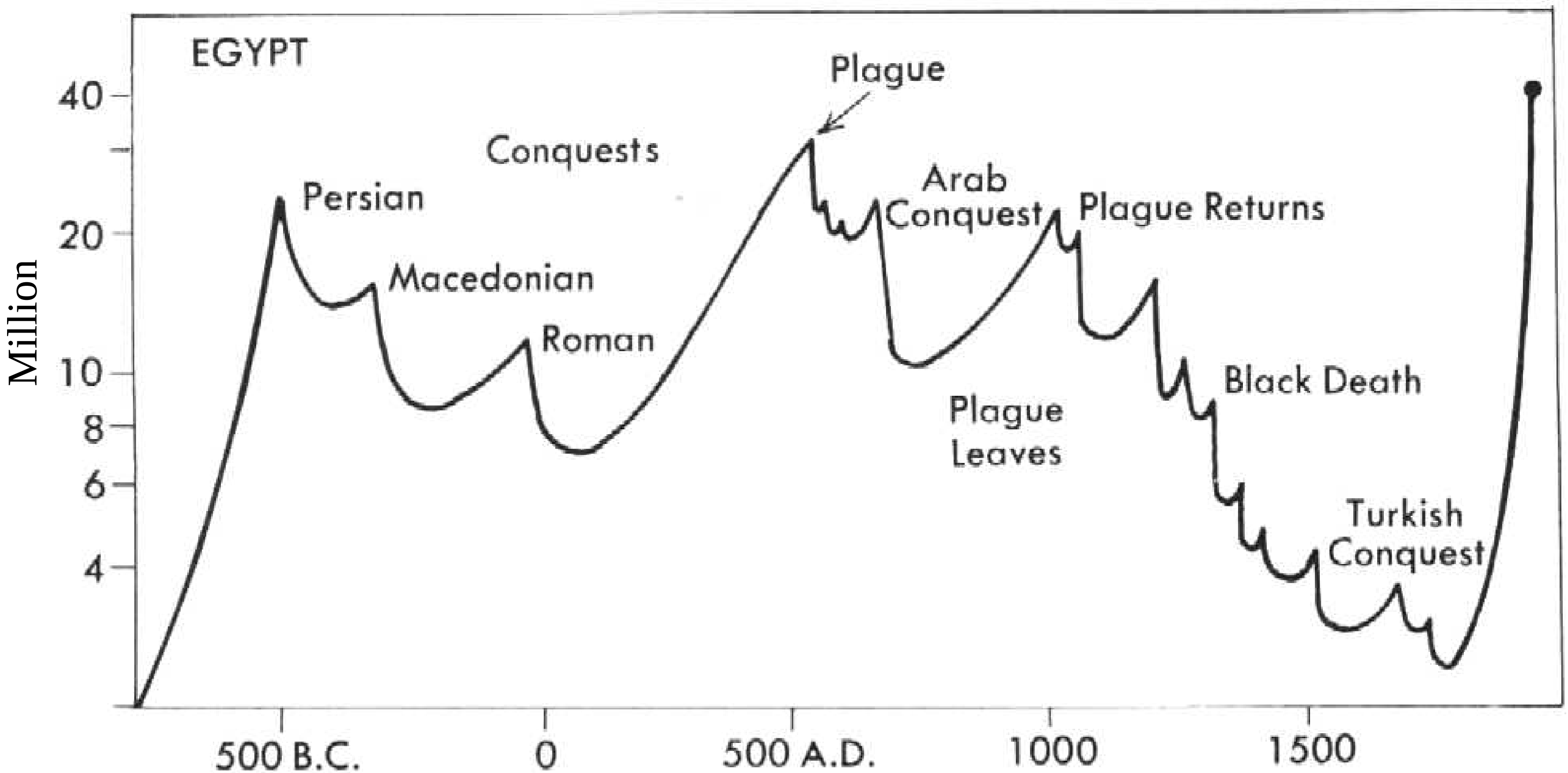


From Mackenzie “Our Changing Planet” 2002



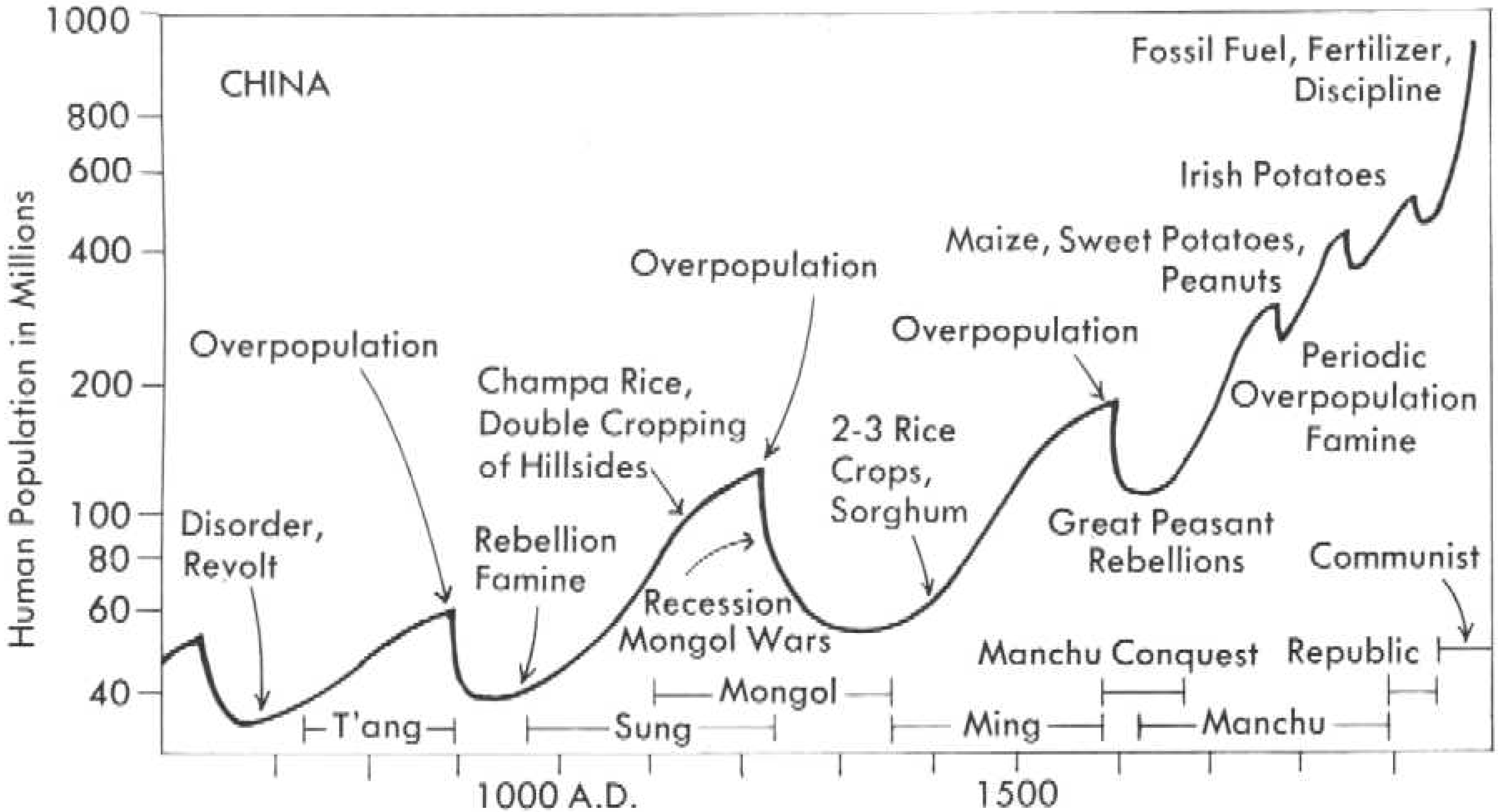
From Mackenzie “Our Changing Planet” 2002

Nile river delta provided stable food supply, but repeated conquests and some diseases resulted in population declines in Egyptian history. War or peace mattered a great deal.



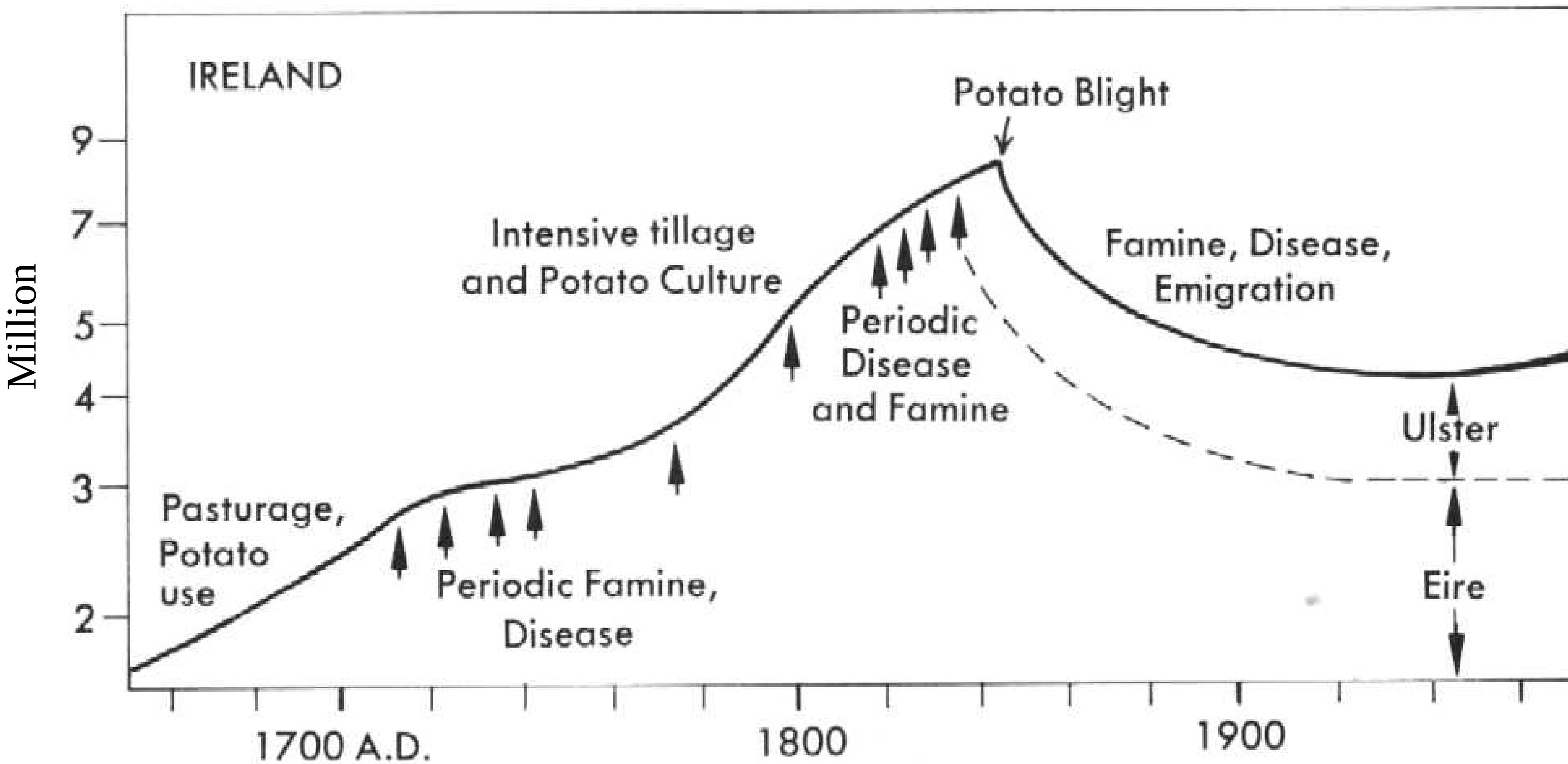
Whittaker 1975, Communities and Ecosystems, page 368)

The record of China differs in its sawtooth ascent and more clearly Malthusian implications (wars kill), and agricultural technology pushed the "carrying capacity" up through time.

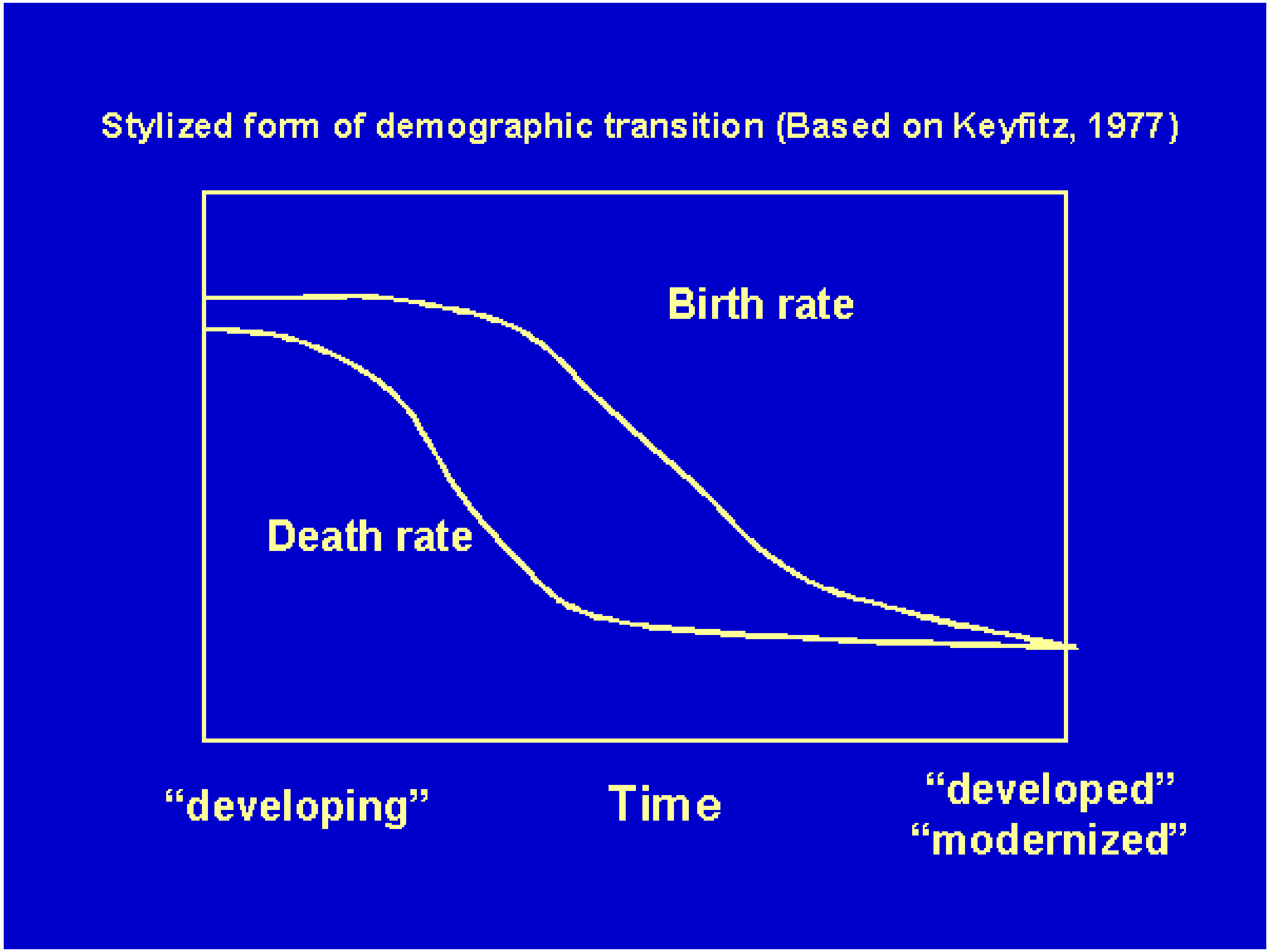


Whittaker 1975, Communities and Ecosystems, page 368

The record of Ireland features a continued increase to a point, a decline primarily due to potato blight and emigration.

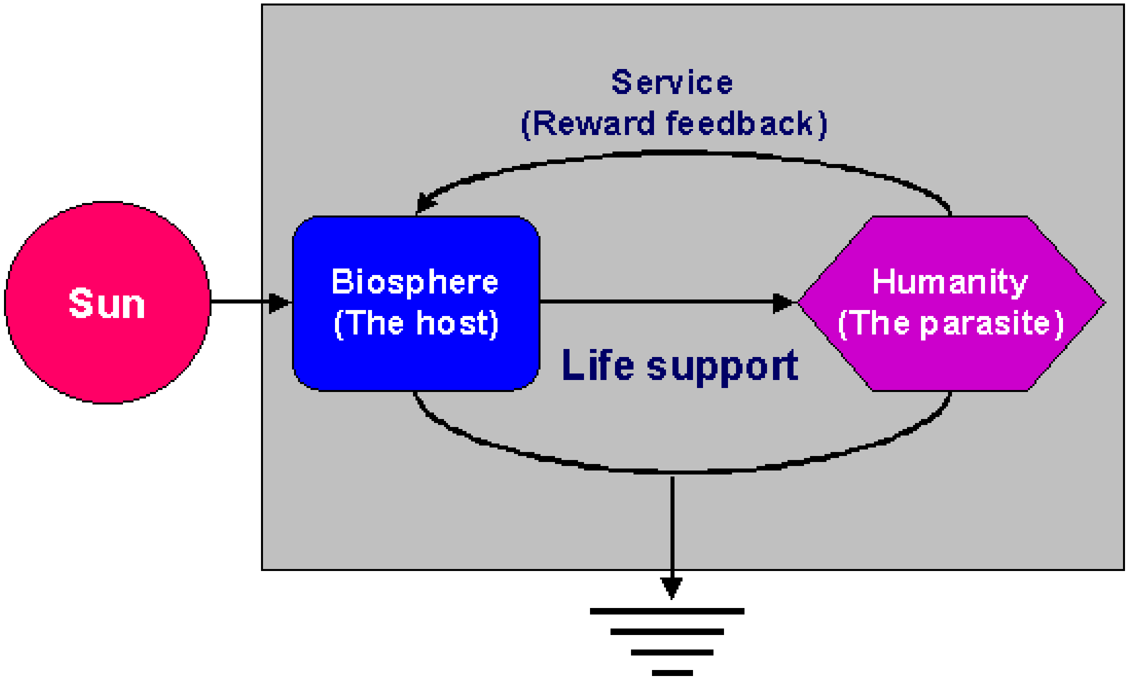


Whittaker 1975, Communities and Ecosystems, page 368



The theory is based on two observations mostly in western Europe during the 1900: (1) fertility and mortality are high in traditional societies and low in modern societies, and (2) every modern society has passed from high to low rates. There is no single explanation for this uniformity of change, even though it does not occur in the same way in every country or region.

With respect to all resources except sunlight energy, planet Earth is a "CLOSED" ecological system. Experience tells us that populations do not grow exponentially for long in a closed or limited environment. Many people believe that there is an ultimate carrying capacity of the biosphere, even though it is not known whether we are reaching the capacity now or later.



Take care of Gaia because Gaia has been taking care of us.
(Based on Odum 1993, page 284)

The above figure is shown as a host-parasite model. As a prudent parasite, humanity must service the biosphere if we expect to continue to receive high quality life-support services.

Discussion:

1. What should be our actions if a carrying capacity does exists as a hard limit to human development?

2. How could we know if such carrying capacity exists?

3. Some studies have shown that food production per capita in the world as a whole has grown at a faster rate than the rate of population growth during the past 50 years or so. Based on this, shall we say Malthus' prediction has been falsified? (see SCIENCE 1999, 285:387-389. entitled "Biotechnology and Food Security in the 21st Century")

4. If we do not believe that human ingenuity (e.g., scientific, technological, social, political, and economic advancement) will solve this "capacity" problem, what else can we hope for?

5. Is the carrying capacity issue everyone's problem, therefore, no one's problem?

6. What have we learnt from the exercise of CO_2 emissions from an average American household?

Have you read the article entitled "The Tragedy of the Commons" by Garrett Hardin published in Science in 1968?

(Science 162:1243-1248) (It is online now)

Summary

1. Can you illustrate the issue of human domination of the biosphere with facts and reasoning (land use, alteration of biogeochemical cycles, global climate change, loss of biodiversity, etc.)?

2. Are you capable of presenting a version of the debate about carrying capacity and human growth, again with facts and reasoning?

3. Have you read the “Tragedy of the Commons” article? Do you really understand what Hardin was saying?