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-Perspectives-

Anthropocene is the epoch in which we handle our future

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Abstract

Anthropocene is a newly recognized geochronological epoch starting from the beginning of industrial revolution, in which increases in the characteristic anthropogenic impacts on global environment have been drastically accelerated thus allowing the accumulation of emitted materials or chemicals in the environments. Here, we proposed the dissection of all known parameters of Anthropocenic progress reported to date, into two types, namely, the parameters being convergent (thus, obviously approaching the limits) and the parameters seem to be divergent. It is obvious to us that slowing of the convergent parameters possibly reflecting the finiteness of resources or the presence of capacity size limit of the ecosystem, is urgently required in order to avoid the catastrophic outcomes in the ecosystem. Similarly, setting of the realistic but sustainable target levels or goals for the divergent types of Anthropocenic parameters are also important. By achieving the goals by compressing the diverging parameters into the converging ranges, the risk of environmental crisis could be minimized or buffered by the ecosystem's resilient capacity. Lastly, for further deepening the Anthropocenic studies, expansion of Anthropocenic parameters from the handling of matters (to be excavated by the future archeologists or geochronologists) to the handling of 'volatile' parameters such as energy usage and information capacity since the research target (Anthropocene) is the live epoch studied by us living on Earth today.

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Introduction: Shifting from Holocene to Anthropocene

About a half century ago, a famous forum for the discussion on the future of Earth, named The Club of Rome (TCR) was launched at *Accademia dei Lincei* in Rome, Italy, led by international and interdisciplinary scholars (King and Schneider, 1991). Through active discussions among scientists and economists, TCR has stimulated a considerable public attention upon releasing its first report "The Limits to Growth" (Meadows et al., 1972), in which TCR members sharply predicted the fate of the world facing the global population outbreak, heading for the environmental, alimental, energy, and economic crises, based on the computational simulation of exponentially growing economics and global population under a finite supply of resources, and the idea and concept brought about by TCR are still worth of re-considering (MacKenzie, 2012). Fortunately, by looking back from the present time point, some predictions made by TCR mentioning the approach of catastrophic outcomes to mankind were worn out and the most concerns discussed had not been resulted in actual crises by the date mentioned (year 2000). The author views that it was a bit early at that time, to bring about the conclusions from a series of discussion handling the fate of Earth.

Today, we are again facing the much more realistic problems possibly determining the fate of Earth in the critical time point along with the geochronological time scale as Eugene Stoermer in 1980s (Revkin, 2011) and Paul Crutzen in 2000 (Steffen et al., 2011) have pointed out that there should be a key difference between the 120 century-old Holocene and the present time that we live in now which is apparently facing the onset of anthropogenic climate changes. In fact, Holocene is the geochronological term used to be applied to define the epoch starting from approximately 11,650 years ago (according to radio-carbon dating) up to the present time (Walker et al., 2009), since most of geochronological scholars have been viewing the human history consists of a continuous piece of the progress of time within Holocene.

In 2000, Paul Crutzen has pointed out that there must be apparent discontinuity in the environmental parameters between the recent decades (1950s to the present time) and the rest of the earlier period within Holocene, thus, eventually providing a tentative name for the newest epoch following Holocene as Anthropocene meaning the human epoch.

Dissection of Anthropocenic Parameters

It is highly worth of note that Anthropocene is characterized by the impressive graphs showing the steep rises of various environmental, ecological, and economical parameters along with time. Importantly, such steep elevations took places only within the last five to seven decades. The characteristic parameters representing the onset of “Anthropocenic bursts” could be divided into two distinct groups, namely, (1) the parameters diverging and the parameters to be convergent.

The latter group of parameters are still hard to be distinguished from the first, as both groups are apparently showing the steep and drastic increases in their values in the last several decades. For examples, to initiate the discussion, Steffen and his colleagues (Steffen et al., 2014) have listed and compared the graphs of (i) global human population, (ii) total real GDP, (iii) foreign direct investment, (iv) damming of rivers, (v) water use, (vi) fertilizer consumption, (vii) urban population, (viii) paper consumption, (ix) number of McDonald’s restaurants, (x) transport (number of motor vehicles), (xi) communication (number of telephones), (xii) international tourism, (xiii) atmospheric CO_2 concentration, (xiv) atmospheric N_2O concentration, (xv) atmospheric CH_4 concentration, (xvi) ozone layer depletion, (xvii) climate changes represented by elevation of northern hemisphere average surface temperature, (xviii) frequency of great floods, (xix) ocean ecosystem (% of fisheries fully exploited), (xx) structural change in coastal zones due to shrimp farm production, (xxi) nitrogen flux from the coastal zone (a biogeochemical measure), (xxii) loss of tropical rain forest as a key measure for terrestrial ecosystems, (xxiii) increasing domesticated land uses, and (xxiv) loss of global biodiversity (measured with species extinctions).

Many of researchers and journalists reported their attempts to add more parameters of interest to the list of Anthropocenic measures such as world-wide consumption of chickens meats (50 billion birds/year) represented by massive consumption of chicken nuggets served in the fast-food restaurants (Patel and Moore, 2018).

Accordingly, clues for judging the onset of Anthropocene could be found at around 1800 and profound acceleration were observed approximately after 1950 (Steffen et al., 2004). In fact, almost all parameters may attain the limits (maximal values allowed) in this finite world on Earth, thus almost all of apparently “diverging” parameters are supposed to unveil the intrinsic convergent nature in the end, but today, many still looked as if they are divergent.

There could be simple dissection of the parameters into those measured with apparently limited and non-limited scales, which look apparently convergent and divergent, respectively (Fig. 1). As a starting point, we should think of global human population, among typical parameters of Anthropocenic shift. Theoretically, the change in human population could be divergent if its substrate to be attached (ground surface area on Earth) were not restricted, by assuming that future dispersion of mankind into the space is possible. But the reality today is that growth of human population must be restricted within the size of Earth, thus mankind is destined to attain the convergent size limit of population.

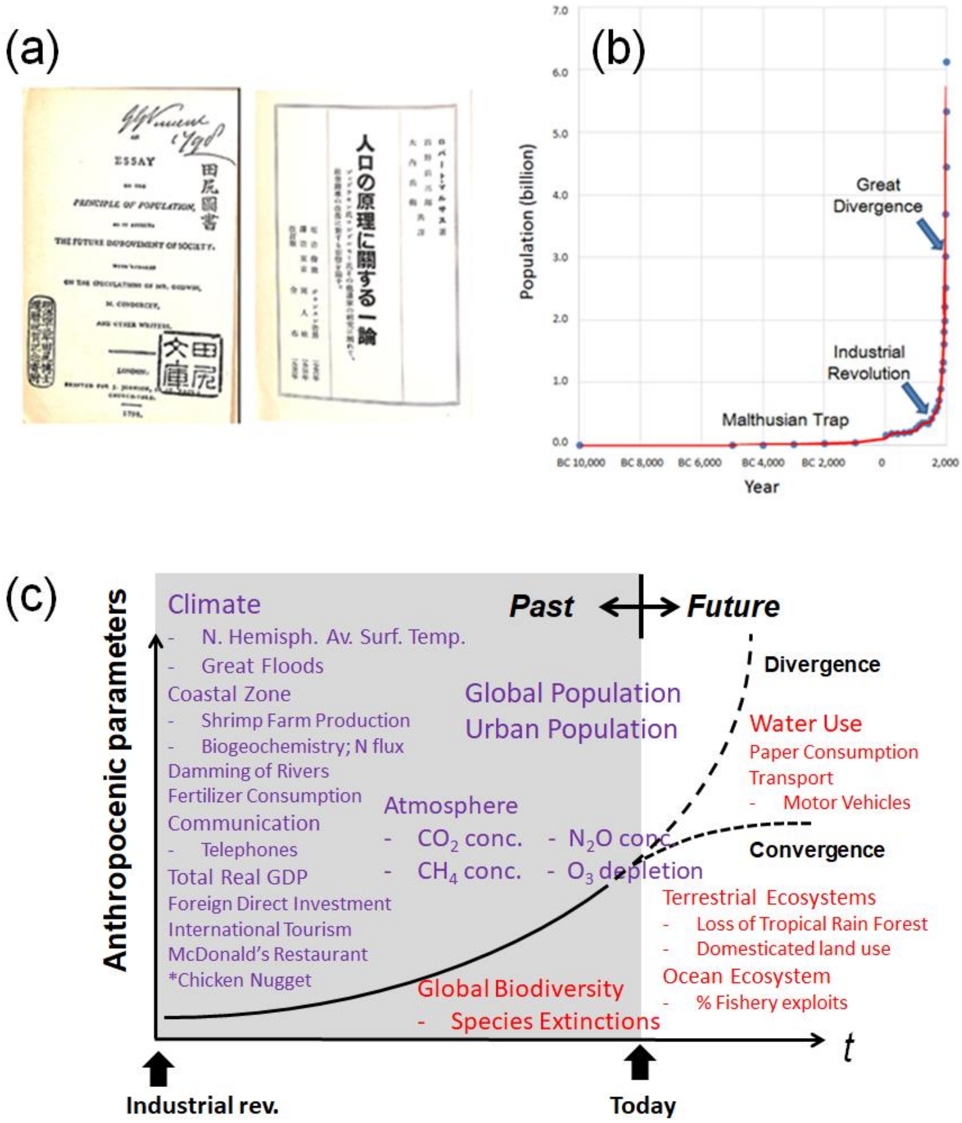


Fig. 1. Burst of anthropogenic impacts along with the increase in human population leading to the shift from Holocene to Anthropocene. (a) A translated copy of "An Essay on the Principle of Population (1798)" by Thomas Robert Malthus published in Japan in 1933 (revised eddition, Kaizosha, Tokyo, Japan). (b) Changes in human population in recent 12,000 years. (c) Hidden distinction among the curves of Anthropocenic parameters with divergent and convergent natures. The red-colored parameters with finite nature must be attaining the limit (convergent level) in the neaer future, and the violet-colored parameters are apparently of divergent nature which could be considered as the series of indirectly alerting parameters warning the approach of the limit of growth.

On the other hand, according to the Fig. 2 (top), extinction (E) of species is drastically increasing with time, therefore such continuous increase in extinction may ultimately face the mathematical endpoint where surviving species remains zero (Fig. 2, bottom) since finiteness of E is defined as below.

$$E = 1 - S$$

where E is the number of species extinct and S is number of surviving species.

Assuming that whole number of species on Earth as 1 (at the onset of Anthropocene, the beginning of the industrial revolution), the relative increase in extinction eventually attains the level closest to 1.0 but never beyond 1.0, thus this parameter are convergent, as Fig. 2 (bottom) indicates. Therefore, growth of E is apparently convergent towards 1.0 if the progress of extinction is unstoppable.

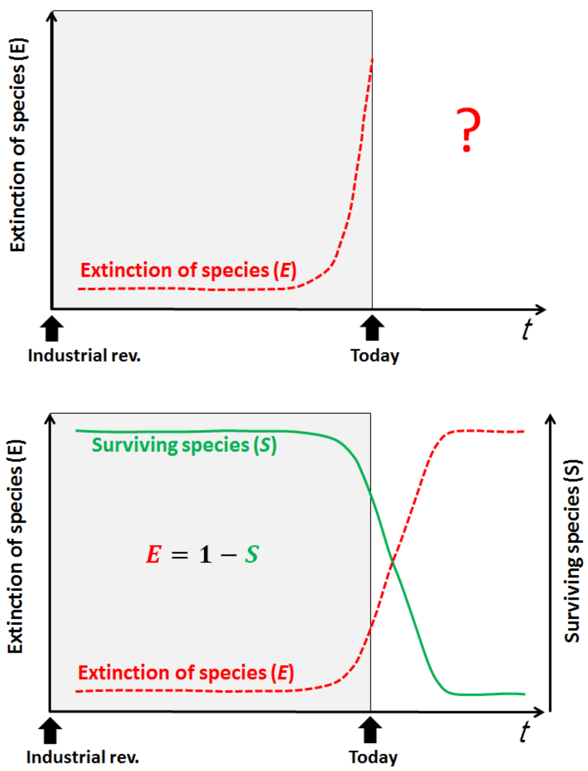


Fig. 2. Extinction of species as an example of Anthropocenic parameters with finite nature.

Why extinction is accelerated?

We have to discuss why extinction seems to be enhanced or accelerated (E increases and S decreases) in the Anthroponic epoch. As we focus on a single species facing the pressure for extinction, its population (N) likely decreases towards zero by passing the "point of no-return" in the process of population dynamics. In ecology, such situation could be mathematically handled by using the modified logistic equation. In general, the growth of population within the species of interest obey the Lotka's logistic equation as shown below.

$$\frac{dN}{dt} = r\left(1 - \frac{N}{K}\right)N$$

where N is the population, r is the rate of population increase (growth rate), and K is the carrying capacity by which upper limit of population size is defined. As K reflects the potential of ecosystem or the environmental status, the size of K might be altered when some of key environmental factors are altered. As the population (N) is low in the early phase of the ecosystem, the growth of N could be proportional to the progress of time (t), which is then followed by the phase of accelerated growth. When the size of N reaches closer to K, the apparent growth is likely slowed (Fig. 3, curve a).

On the other hand, in a case that the size of initially introduced N is far greater than K, the size of N shrinks towards the size defined by K (Fig. 3, curve b). Therefore, K predicts the equilibrium state of the size of N.

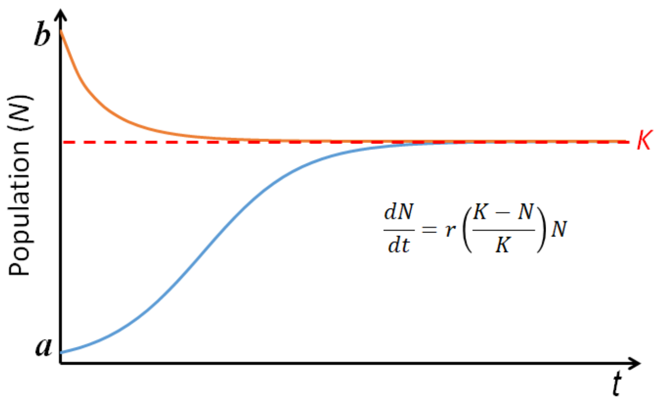


Fig. 3. Typical logistic curves for positive and negative growth.

Here, we have to discuss why the size of extinction (E) increases and the size of surviving species (S) decreases. As K in the logistic equation is lowered for the set of reasons related to human activity, N used to be maintained at the level of initial K (K_0) is now forced to approach the size allowed by newly lowered K (K_L) (or elevated K, K_H). Thus, size of N obey the K-altered logistic model (Fig. 4A). By analogy, the size of S could be expressed by defining a specific K for the species number. In general, we view that environmental preservation may act towards minimizing the decrease in K for wildlife thus the impact of K-mediated environmental pressure to lower N or S could be minimized as discussed below.

Ecological resilience

According to the K-altered logistic model, we need to understand that the size of K is the function of various parameters associated with the onset of Anthropocene such as expanded domestication of wild land and anthropogenic climate changes. Since there would be a time lag between the change in K and the induced change in population (N) of the specific species or size of diversity represented by surviving species number (S), the altered K may indicate the altered convergent point(s) for N or S, which are the newly established equilibrium state to be manifested with time (Fig. 4a).

If the shift from K_0 to K_L is smoothly achieved, N or S may smoothly decrease and approach K_L. However, in case that the shift from K_0 to K_L were rapid and drastic, the change in N or S would be overly achieved by exceeding the range of decrease defined by the difference between K_0 and K_L due to the "inertia" of the actions of the N-lowering pressure, thus N or S reaches the level below the line of K_L. Thanks to the biological and ecological systems possessing the resilient nature, N could be re-boosted to approaches K_L (Fig.4B).

As discussed above, the equilibrium of N or S could be achieved with smooth or shaky curves. Even, the change in the environmental pressure lowering N or S is overly excess and the lowering of N might runover across the level of K_L, the resultant N or S may regrow towards K_L. While the resilient recovering of N could be relatively rapid (spending ecological time scale), re-enrichment of S could be a much slower event possibly requiring the semi-revolutionary time scale. Therefore, with human historical time scale, we can hardly expect the resilient recovery of biodiversity once it is lost.

Point of no-return

As discussed above, in the case that the "runover" or the excess of decrease in N were achieved, N would recover with time only if the extent of 'runover' were within the range capable of being buffered by ecological capacity of resilience (Fig. 4b). If N were further lowered by exceeding the "point of no-return," N would be no-longer resiliently maintained and instead N would enter the course for extinction by gradually approaching the "zero" line (Fig. 4c). By this way, the species of interest would be endangered. In this case, the "zero" line rather than K_L should be considered as the effective equilibrium line for N. In ecological mathematics, such "point of no-return" can be defined as Allee threshold (A) by modifying the logistic model as below.

$$\frac{dN}{dt} = rN\left(\frac{K-N}{K}\right)\left(\frac{N-A}{A}\right)$$

where A is the critical point known as Allee threshold (Kramer et al., 2009; Allee ar ;

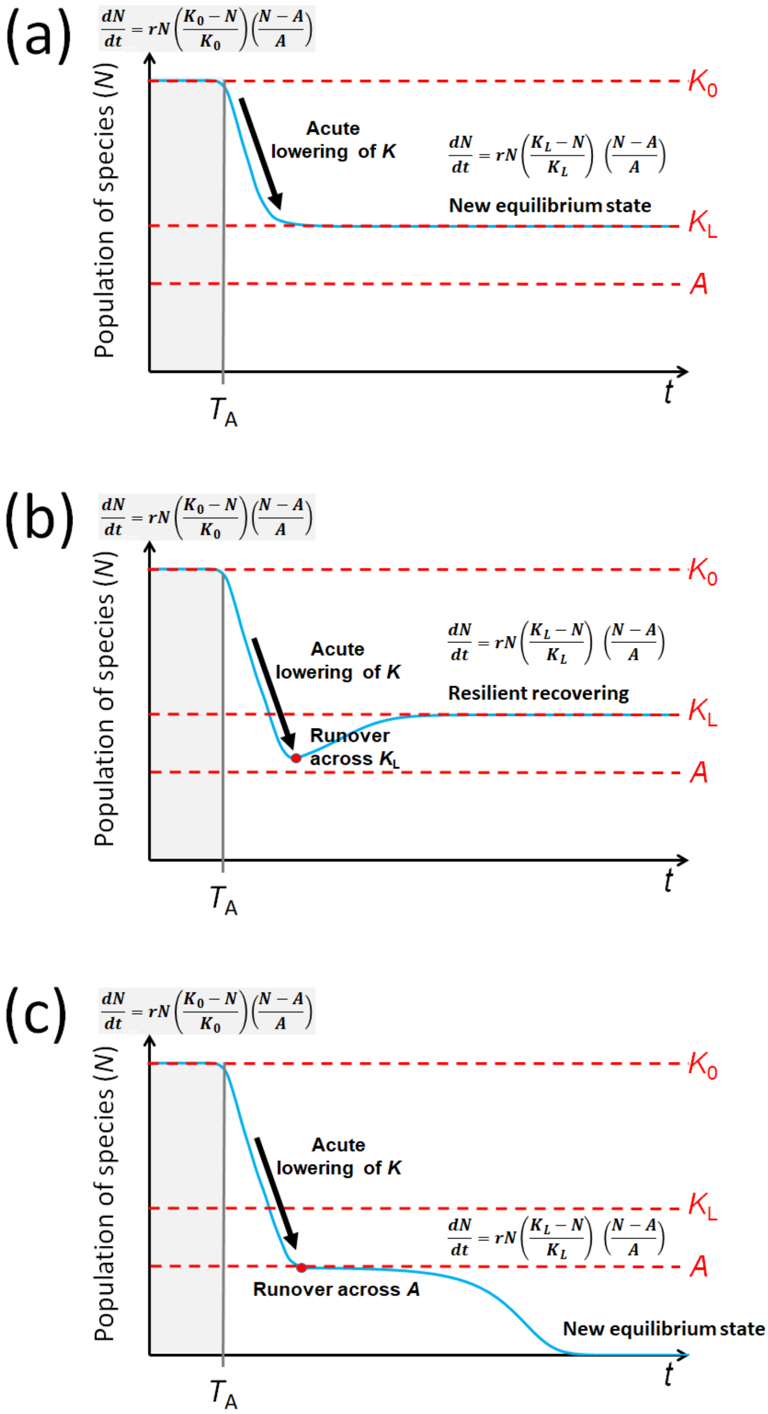


Fig. 4. *K*-altered logistic model explaining the shift of *K* at the onset of Anthropocene. Three cases of population changes following the shift of carrying capacity from K_0 to K_L are compared. (a) Case of a simple and smooth shift. (b) Transient over-decrease in *N* followed by resilient recovery. (c) Drastic decrease in *N* down to the level below Allee threshold (*A*) followed by sigmoidal decrease in *N* leading to extinction. T_A, onset of Anthropocene.

limit of population capable of further growth.

The lesson we can learn from this model is discussed below. By relying on the resilient nature of the ecological system, we should make effort to minimize the size of "runover" in order to stay within the capability of ecological resilience (above the Allee threshold, A).

Anthropogenic upward alteration of *K*

Up to here, the cases of down-ward alteration of K value were mostly discussed, but there should be some cases that K values are elevated through anthropogenic activity, thus, increase in the population of specific species of interest can be manifested. The most evident case for the elevation of K value from the pre-historical low level of K (K_0) to present high level of K (K_H) can be found in the human demography. Mankind has been altering the environments suitable for their survival for

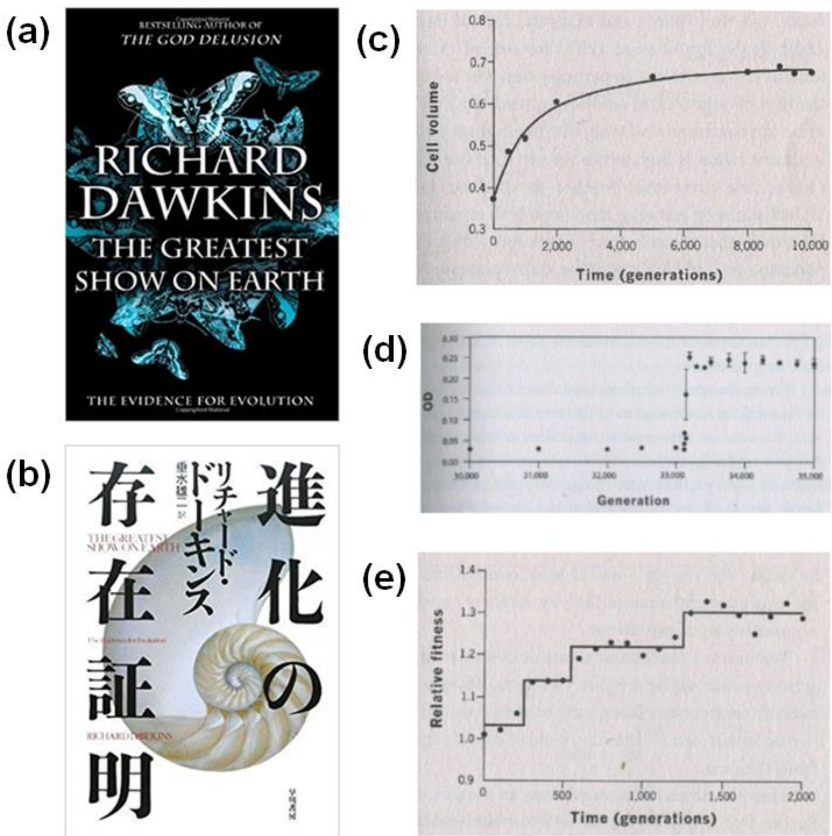


Fig. 5. Evidence for on-going bacterial evolution observed in the laboratory as cited by Dawkins (2009). (a) Paperback of Dawkins (2009). (b) Japanese version of the same book. (c-e) Data obtained by the team of Lensli which were cited by Dawkins (2009).

some tens of centuries and its rate seems being accelerated after the industrial revolution and further drastic acceleration could be found in the last several decades as we have discussed earlier in this article.

A number of additional examples of man-made K-elevation could be found in agriculture. Since the size of available land surface is one of the key factors determining the size of K for terrestrial organisms including plants and animals, expansion of agricultural land use has been globally elevating the K values for selected plant species known as major crops. Similar examples could be found in the cases of livestock populations (see discussion on the global consumption of chicken meat exceeding 50 billion-birds per year, Patel and Moore, 2018).

Bacterial evolution and upward alteration of *K*

What factor mostly altered K_0 into K_H for human being? Hints or clues to this question can be found in the study on the microbial evolution. We can learn from the record of observations that bacterial evolution could be reproduced and monitored in the laboratory. Richard Dawkins (2009) has cited, in his book (entitled *The Gratest Show on Earth*, Fig. 5a and b), the data from Lensli's group focusing on the frequency of bacterial mutation and brought a series of discussion on the nature of mutation (Fig. 5).

Accordingly, Lensli's team has noticed that the cell size (cellular volume) of one bacterial species changes along with time through lab-based-propagation for 10,000 generations (Fig. 5c), suggesting that real-time observation of evolution could be achieved if the right materials with short lifecycle such as bacteria were chosen. By making use of the original data from Lensil's group, the author tried to handle the numeric changes representing the evolution in bacteria, with a Hill-type mathematical model by viewing the change in bacterial body size as a function of generations as shown in Fig. 6a. Hill type equation were handled as previously discussed (Takaichi and Kawano, 2016).

In some cases, evolution could be successfully attributed to a single mutation as in the case that bacterial mutation allowing the utilization of citrate added as pH adjusting agent in the culture media as the additional carbon source for the bacterial growth, thus, maximal density of cells in each generation was drastically elevated (Fig. 5d). By viewing the former and newly attained size limits as K_0 and K_H, respectively, the shift from K_0 to K_H observed in the bacterial model could be expressed with a Hill-type mathematical model as in Fig. 6b.

The proposed equation for the single mutation-dependent curve employed here is:

$$D_{OD} = K_0 + \frac{(K_H - K_0)\, G^{\alpha}}{{C_G}^{\alpha} + G^{\alpha}}$$

where K_H is the elevated carrying capacity due to single mutation, G is the generation of bacteria, C_G is the constant for generation analogous to Michaelis constant in enzyme kinetic models thus

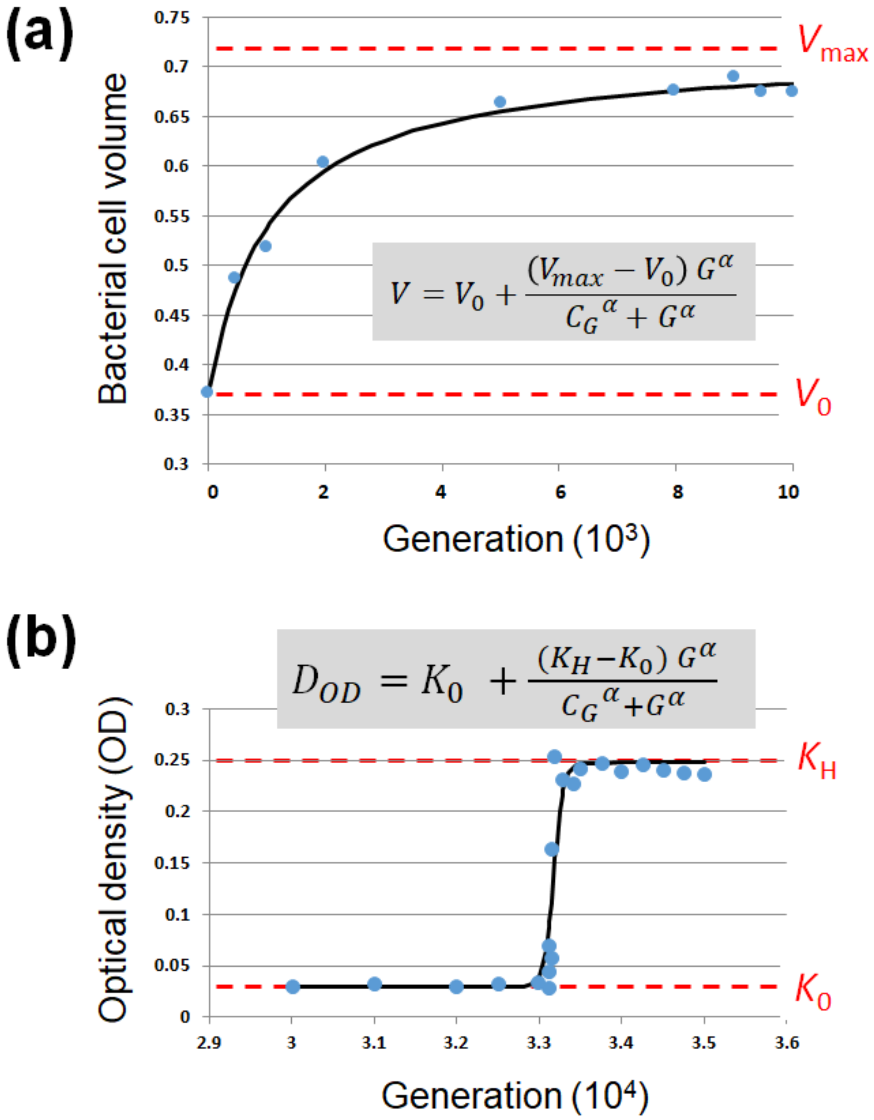


Fig. 6. Application of Hill-type equations for expressing the progress of bacterial evolutions. Evolutionary changes in bacterial body size (a) and an acute change in carrying capacity for bacterial density (b) were expressed as the function of generation.

determining the timing of the onset of mutation resulting in elevation of maximal population allowed in the constant environment.

There is an additional line of studies observing the evolution in bacteria, where step-wise evolutions through consecutive mutations have led to the additive increase in relative fitness compared to ancestral strain of bacteria (Fig. 5d). Again, these processes could be expressed with Hill-type equation but through synthesis of kinetic curves for each mutational events occurring at different

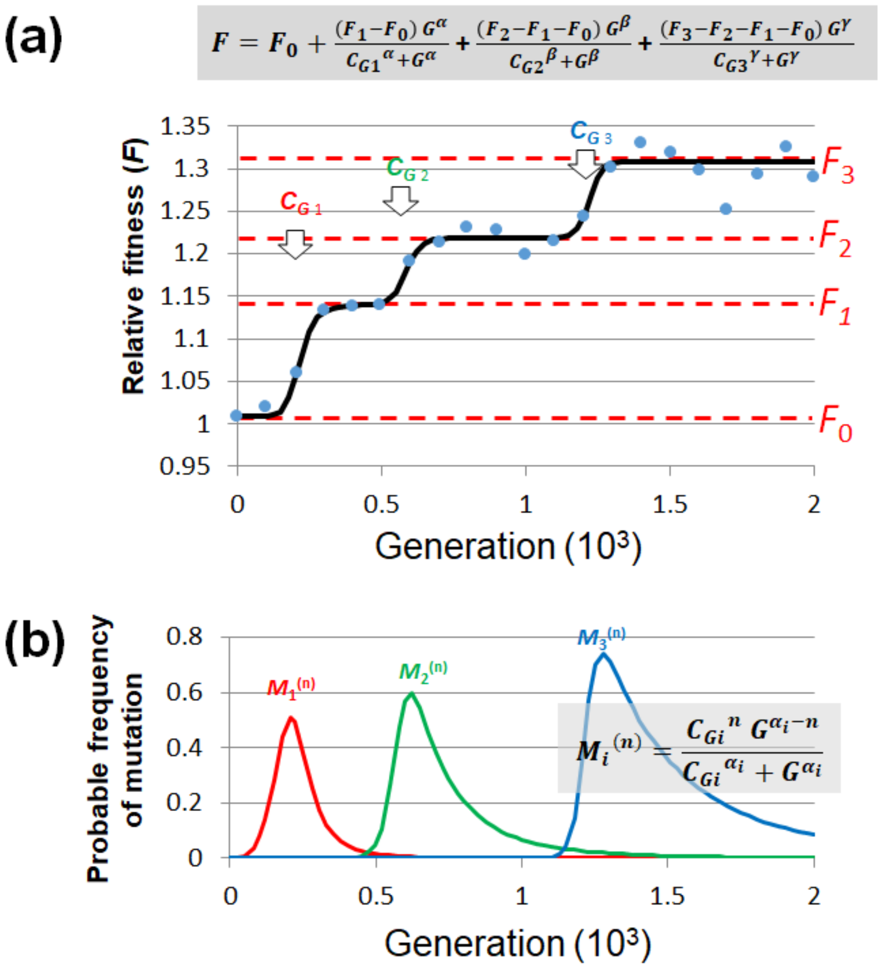
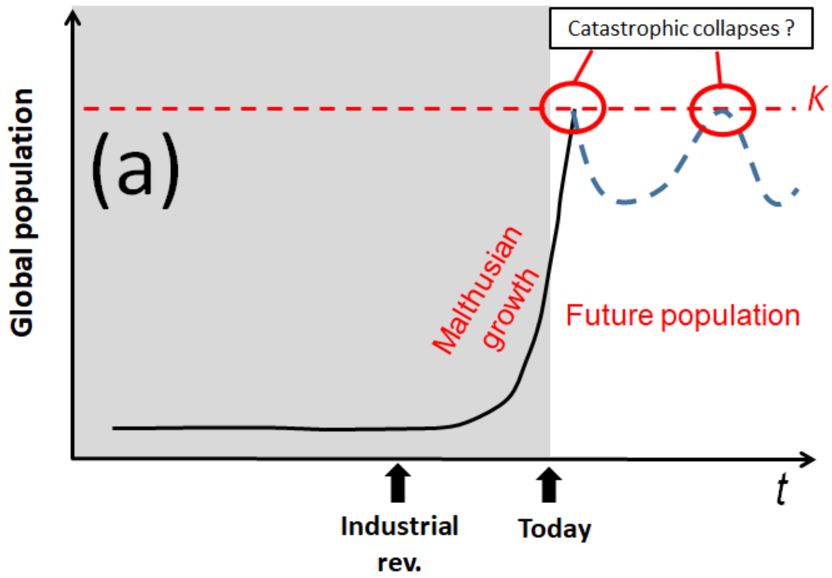


Fig. 7. Application of Hill-type equations for expressing the occurrence of step-wisely progressed evolution in bacteria. (a) Step-wisely achieved increases in relative fitness (F) were expressed as the synthesis of three distinct Hill-type equations. (b) Through some differential treatments, the probable timing of mutations could be highlighted.

timing (Fig. 7a). The advantage of the use of Hill-type equation is its convertibility into different form of curves through differential treatments, in order to highlight the probable timing of mutations along with generations (Fig. 7b).

The lesson we can learn from these model cases of bacterial evolution, especially the case that single mutation resulted in a burst of populational growth, is that the upper limit of population growth can be determined by limitation of energy available, and therefore, once novel utilization of "unused" energy or resources is manifested, the capacity for the growth of population could be boosted up.



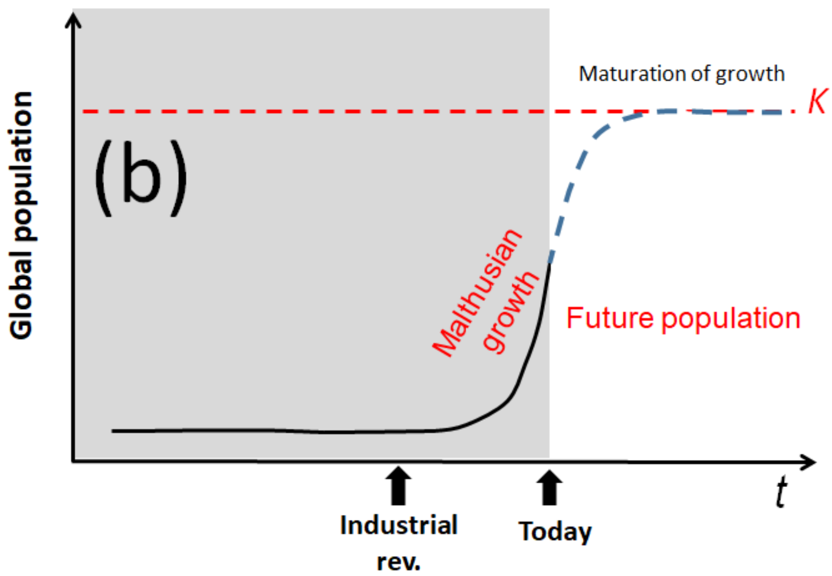


Fig. 8. Two distinct scenarios for human being (as an organism which obey the laws of population dynamics) with and without sensing the presence of approaching size limit. (a) A scenario without sensing or awareness of the upper growth limit being approached. (b) A scenario with controlled slowing of its growth based on the awareness of the limit.

Future of human population

There would be a series of questions to be answered in order for us to understand or predict our future. Is carrying capacity (*K*) of logistic model really exsists for mankind? As learned from the population dynamics in various models from bacterial to animals, there should be a specific *K* for us, human beeing too. If the answer is yes, then, how high is it? Actually, this is one of most dififcult questions to be answered. At this moment, the global human population seems to be divergent as graphed in Fig. 1b although the complex factors supporting the carrying capacity at high level is obviously finite on Earth.

In most of biological and ecological model, as the population of the organisms of interest approaches K, the apparent rate of growth gradually slows down. Lowering of growth rate is a sign that organims are aware of the upper limit of growth. However, it seems to us that the growth rate of global population is sharply increasing, so that the change in global population looks almost divergent, as if Malthusian growth model (a simple exponential growth model) could be continuously applied for predicting the future human demography. Or, is there an invisible limit of growth approaching, but we human beeing are simply unable to sense the presence of such a catastrophic threshold to be faced in the very near future?

Genetic study tells us that there would be catastorophic population collapse in the future of organisms if the resilience of the ecosystem is lost, simply due to the excess of runover of the upward growth out of controrable range (Dai et al., 2012). If an organim perform straight forward exponential growth without chances to be slowed its pace, a suddon collapse of population (Fig. 8a) rather than slowly attaining the peak level (Fig. 8b) might be caused upon hitting the upper limit of growth.

The likely Allee effect in human demography

The equation for one of Allee effect models described in an earlier section of this article employed the term (*N*-*A*)/*A*, combined with a logistic equation, where *N* and *A* are rpopulation and Allee threshold, respectively. This Allee model equation is known to represent the strong Allee effect, by assuming the presence of relatively high level of Allee threshold.

$$\frac{dN}{dt} = rN\left(\frac{K-N}{K}\right)\left(\frac{N-A}{A}\right) \qquad \text{Strong Allee effect model}$$

However, it is obvious that *A* value for fuman population should be very low if any exists as the human population continuously kept growing from the age of very low population as dated back to the begining of Holocene (Fig. 6b).

There are several mathematical model for describing the nature of Allee effects (Boukal and Berec, 2002; Ferreira et al., 2013). In the flexicible Allee effect model or in the weak Allee effect model shown below predicts the presence of Allee effect without or with very low Allee threshold (Boukal and Barec, 2002; Ferreira et al., 2013).

$$\frac{dN}{dt} = rN\left(\frac{K-N}{K}\right)\left(\frac{N-A}{K}\right) \qquad \text{Flexible Allee effect model}$$

$$\frac{dN}{dt} = \frac{r}{K}N^2\left(\frac{K-N}{K}\right) \qquad \text{Weak Allee effect model}$$

Discussion on the significance of Allee effect in the population of various organisms is likely restricted to the behavior of population below the Allee threshold in which population is destined to shrink towards extinction. In contrast, Allee effect may force the richer population getting much richer, just like so-called Matthew effect, therefore, in the presence of even a weak Allee effect, greater population hardly stops its growth without slowing down even closely approaching *K* level. We have recently proposed a working hypothesis that the demographic behavior of human population showing steep increase in growth could be partly explained by the presence of weak Allee effect without or negligibly low (if any) Allee threshold.

The author's group is handling the population dynamics of various organisms with and without Allee effect. Growth of green paramecia, a typical photosynthetic organism lacking Allee effect simply obey the standard logistic model by gradually attaining the maximal population and sustains its population for certain period of time under exposure to photosynthetic light (similarly to the model in Fig. 8b). Contrarily, suspension-cultured tobacco BY-2 cells showing weak Allee effect straightforwardly increases its cell density in the culture without slowing down and one day it hits the *K* level followed by immediate and massive decay of population by drastically leaking the ions from inside the cells as the sign of synchronized cell death (similarly to the model in Fig. 8a; unpublished results, Watanabe and Kawano, 2019). In general, lack of capability to slow down the growth rate inavoidably hit the upper limit of populational density so acutely, thus, leading to the populational collapse.

Another explanation for apparently high carrying capacity (K_H) for human population can be made from the view that K_H has been (and is now too) continuously shifted up. By analogy to the evolutonary bacterial growth model upwardly altering the carrying capacity (Fig. 6b), the factor for human outbreak on Earth observed up to today could be attributed to the historical "discovery" of abandant energy as the fom of fossil fuels and nuclear power. Therefore, histrically gained K_H could be maintained at high level or even continuously being elevated forever, if the source of enegy could be limitless. However, we now understand that the amount of fossil fuels still mined underground on Earth is obviously limited and the use of nuclear power is to be highly restricted, thus, alternative or sustaibable sources of energy is required for preventing the acute shrinks in carrying capacity for mankind in the future.

SDGs and convergent targets

In conclusion, we understand the necesity to plan slowing of the growth of anthroponenic parameters possibly accompanying the slowing of global economic activity as anounced in the pioneering scope proposed by the TCR in the past and also by the recentlly proposed projects for Sustainable Development Goals (SDGs).

Nowadays, scientists concern that the future of world population growth (and proportionally growing global economics) matters for future human well-being and our interactions with the natural environment, chiefly biodiversity and carbon sequestration (Abel et al., 2016; Marques et al., 2019), and have proposed that world population growth could be reduced by fully implementing the SDGs whose health and education targets might have direct and indirect consequences on future mortality and fertility trends (Abel et al., 2016).

Earlier in this article, possible enforcement of all the parameters representing the onset of Anthropocene with divergent nature into the convergent range was discussed (Fig. 1c). In fact, actions for enforcement of the Anthropocenic parameters (such as expansion of domestic land use due to destruction of rain forests) to be slowed down by setting the convergent (finite) goals for diverging parameters may be equivalent to the actions meeting the SDGs which is currently discussed under the framework of international interdisciplinary academic alliance among institutions in the OECD-selected Green Growth Model Cities (Kitakyushu, Paris, Chicago, and Stockholm) which periodically holding international meetings for young scholars (KEYS: Knowledge Exchange by Young Scholars).

Anthropocene Research Club (ARC) started its activities

Starting from the framework of Centre Franco-Japonais d'Histoire de Science (CFJHS) basing in Kitakyushu, Japan, and Paris, France; a novel forum tentatively named Anthropocene Research Club (ARC), was launched for the interdisciplinary studies focusing on the introduction of the idea of Anthropocene into various academic communities consisted of not only scientists and engineers but also scholars and activists engaged in social and cultural aspects. The founding members of ARC include the members of IPIRC (International Photosynthesis Industrialization Research Center, Univ.

Kitakyushu) and IEST (Institute of Environmental Science and Technology, The Uni. Kitakyushu) in Kitakyushu, Japan (Tomonori Kawano, Yoshifusa Ushifusa, Akihiro Kawaguchi, and Kensuke Nakao), the faculty members at LIED (Laboratoire Interdisciplinaire des Energies de Demain, Univ. Paris-Diderot) in Paris, France (Francois Bouteau, Patrick Laurenti, and Christophe Goupil), LINV (The International Laboratory for Plant Neurobiology, Univ. of Florence) in Florence, Italy (Stefano Mancuso, Diego Comparini), and RIKEN (Katsushi Fujii, Kayo Koike) in Wako, Japan. Initial activities of ARC will be reported as a series of perspective discussion and debates in the present and coming issues of the Bulletin de CFJHS.

Starting from this issue, Anthropocene Research Club (ARC) basing in Kitakyushu, Paris, and Florence may further propose the actions to be taken and bring about more deep and cutting-edge discussions on the future of this planet.

Expanding the scope of Anthropocenic studies: from matters to energy and information

Twentyfour examples of exponentially increasing Anthropocenic parameters examined by Steffen and his colleagues (Steffen et al., 2014), the pioneering groups of Anthropocenic studies are all matters or living organisms in scope to convincing the future scientists, chiefly, archeologists and geochronologists. However, our group gathered under the name of ARC feels like to expand the scope of study. In order to further deepening the Anthropocenic studies, but not for convincing the future scholars, drastic expansion of Anthropocenic parameters from the handling of matters to the handling of "volatile" parameters such as energy usage and information capacities, as we are inspired by the view of Claud Shannon, a father of computing, stated that "our world is made of (1) matters, (2) energy, and (3) information." This approach is also to confirm the fact that the present epoch is the target of study for us and by us living on Earth today.

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