Reflections on quantitative analysis of sustainable ecotourism development based on Butler model

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Received 1 October 2014, www.cmnt.lv

Abstract

This paper uses the Butler Model to give a quantitative description of the sustainable ecotourism development. It is supposed that the ecological system is stable under the best condition. The increase in the number of tourist has presented the following features: limited, rapid and constant. The number of tourist will not exceed the environmental capacity K. The rising velocity r, the number of tourist N and the rising number of tourist per unit time dN/dt present a symmetric relation. There is a linear relationship between r, N, dN/dt and t. According to the theory of Butler, we can obtain the formula for the prediction and the assessment of the sustainable ecotourism development. This paper takes the Bird Island of Qinghai Lake as an example to account for the Butler Model and conduct the quantitative analysis.

Keywords: Ecotourism; sustainable development; Butler Model; quantitative analysis

1 Introduction

Ecotourism is an emerging recreational activity. As people bear so much of the noise in the metropolitans, a return to Nature will release one's pressure and enable one to have a good repose. Ecotourism holds that people should enjoy and co-exist with the Nature during the trip without damaging the eco-system. Unlike traditional tourism that has wrecked the environment, the sustainable ecotourism development presses on reaching a good balance between the economic gains and the environmental protection. It is the undeniable development trend of tourism. So far, researches on sustainable ecotourism development are from the qualitative perspective but lack quantitative analysis. However, it is significant to analyse factors that contribute to the variation of the environment of a diversified ecotourism scenic spot.

2 Current development of Ecotourism

As Ecotourism develops steadily, more and more people go outdoors and embrace the beauty of Nature, which not only paves the way for the rising importance of Ecotourism in the tourism industry but also brings in huge profits. China's Ecotourism has a good foundation owing to rich natural resources. The annual number of tourist has exceeded 25 million with overall revenue of 520 million Yuan.

However, some problems have loomed large. People lack a proper understanding of Ecotourism and equal tourism with going away from the industry. As people travel afar more and more often, the Ecotourism in China is still in its infancy. Prominent problems include:

(1) Environment degradation. According to data available, the air, water and soil in the Ecotourism scenic spots have been polluted to different extent. PM and DB are below the standard. 135 rivers have suffered from pollution, among which 52 were greatly polluted. These rivers can't serve for irrigation or drinking water for people and animals. These problems are derived from a lack of proper management in China's tourism industry. A large population and a weak mind in environmental protection make things worse. So many scenic spots are under pollution. Thus, we need to consider the consequence of environment degradation while developing the tourism industry rather than only pursue the economic gains.

(2) The random development

In many places, government neglects the importance of full investigation of the Ecotourism scenic spots. Without assessment and planning, and out of economic reasons, random development is common to see, which results in the loss of precious natural resources. Meanwhile, the construction of hotels for more accommodations also weakens the "natural" atmosphere of local spots. What's more, wild animals are in the danger of slaughter. Illegal businessmen seek the loopholes and entertain tourists with wild animals, making the latter endangered.

There is hardly any planning for cave development.

(3) The overall destruction of Ecotourism scenic spots

In some scenic spots, due to over development, many mountains have been split and many trees have been cut down, ending up with water and soil erosion. Floods rush to the scenic spots, dash down the environment and drown tourists. Some places suffer from severe drought and a lack of water. Even in Xishuangbanna, an evergreen tourist area, deforestation has taken its toll. The forest area is decreasing sharply, weakening the already fragile ecological environment.

In some Ecotourism scenic spots, profit-oriented people build a large quantity of hotels and restaurants and add the tourist area with more recreational facilities, such as the cableway. In other countries, the construction of the cableway is carefully planned and managed. The US and

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Japan even ban the construction. Roads are built at two third of Fujiyama and tourists should climb to the top by themselves. But in China, no laws or institutions rule out cableway construction, which damage local spots.

With the expansion of the city, tourist areas near cities have been influenced by urbanization. Some factories settle down near scenic spots and release the smoke to the air and the wasted water to the river. As a result, both the air and the water turn out to be poor in quality. Modern equipment and flooring tiles cannot hide the artificial trace of man, which is a departure from natural beauty.

3 Sustainable ecotourism developments

Current situation calls for immediate strategy of sustainable development. The planning is as follows:

3.1 POPULARIZE KNOWLEDGE ABOUT THE ENVIRONMENTAL PROTECTION

In China, there lacks a systematic planning of Ecotourism. The purpose of the tourism industry still lies in gaining profits. The propaganda of Ecotourism is also weak. Tour guides and management staff are not well-educated in professional knowledge and overlook ecological education. Bulletin boards are almost empty. Therefore, it is necessary to not only popularize the concept of Ecotourism, but also the idea of ecological protection, so as to make people aware of it.

3.2 PLANNING REASONABLY AND DEVELOPING SCIENTIFICALLY

Ecotourism planning is very complicated. It is inter-related with economic gains, environmental protection and social problems. A reasonable planning will serve to environmental protection and avoid random development. In planning the Ecotourism area, it is necessary to conduct a full investment on flora and fauna resources, soil and water, etc. And be aware of possible consequences of tourism development. In the meantime, take proper measures and supervision to lower the damage to the minimum. The management staff in scenic spots should also monitor the development in an order way. Noticeably, the less artificial factors added to the scenic spot, the better, for the purpose of preserving the original elegance of Nature. And we should say "no" to any project that requires high investment and high consumption but ends up with high pollution.

3.3 EMPLOYING HIGH TECHNOLOGY

The development of Ecotourism in China is far from successful compared to other countries. The daunting task is to probe into the theory and practices of Ecotourism in order to lay a solid foundation for the sustainable ecotourism development. In this high-developed and informative world, the development of Ecotourism should integrate with advanced technologies, such as GPS. GPS can help to monitor scenic spots of Ecotourism and bring convenience to the management so as to minimize the destruction of local environment.

4 The application of the Butler Model in Ecotourism

4.1 THE ESTABLISHMENT OF THE BUTLER MODEL

4.1.1. The hypothesis of the model

(1) Suppose there were no severe natural disasters like earthquake and flood. Otherwise they would destroy the Nature and the latter cannot recover.
(2) Natural landscape in the Ecotourism area is well-preserved. The eco-system is stable and hasn't been destroyed;
(3) The number of tourist N will rise after conducting propaganda or receiving package tour. Suppose the total number of tourist N has a positive relationship with the rising velocity of tourist per unit time dN/dt;
(4) The system can have self-adjustment to some extent;
(5) No factories release the wasted water or gas to scenic spots;
(6) Under the condition that the environment in the Ecotourism area has not been destroyed, the number of tourist will stop rising when it reaches a certain level.

4.1.2. Symbols

Environmental remediation spending——M;
Environmental capacity (the maximum number of people that a scenic spot can accommodate)——k;
Cost of every tourist——q;
Daily rising velocity of the tourist——r;
The initial number of tourist——N0;
The number of tourist at t in the Ecotourism area (the total number of the local staff and the tourist in the tourist area).

4.1.3. The establishment of the model

The total number of tourist N has a positive relationship with the rising velocity of tourist per unit time $\frac{dN}{dt}$. If the number of tourist adds 1 more, the $\frac{dN}{dt}$ should decrease $\frac{1}{k}$, that is, every tourist takes up $\frac{1}{k}$ of total space. At t, there are N tourists al-together. The overall space available is $\frac{N}{k}$. 1—$\frac{N}{k}$ is left for more tourists. So, $\frac{dN}{dt}$ has a positive relation with 1—$\frac{N}{k}$.

With Logistic law, we can deduce the equation between the total number of tourist N and the time t [1-2]:

$$Nr(1-\frac{N}{k}) = \frac{dN}{dt} \tag{4-1}$$

In the expression, r is the proportion coefficient.

$$N_0 = N(t)|_{t=0}$$

According to expression (1), there is

$$\frac{\frac{dN}{dt}}{N(1-\frac{N}{k})} = r$$

.

Regard r as the growth rate of the total number of tourist at a certain time. Substitute r into expression (1) and there is:

$$N(t)=\frac{k}{e^{-rt}(\frac{k}{N_0}-1)+1} \tag{4-2}$$

4.2 THE ANALYSIS OF THE MODEL

(1) Under the presumption of the paper, Ecotourism area is a stable eco-system capable of

Self-adjustment. In expression (1), there is $-\frac{N}{k}$, if $k<N$, then $\frac{dN}{dt}<0$. So the total number of tourist will reduce. In other word, it is a negative growth. Self-adjustment of an eco-system plays a role at this moment and the system can recover to the original state. That is to say, the fluctuation of the number of tourist can boost the self-adjustment of the environment.

(2) The growth of tourist is rapid, limited and constant [3]

At t, there is $\frac{dN}{dt}$. According to the feature of derivative, $N(t)$ is an increasing function. So the growth of tourist is constant. When N is infinitely close to 0, 1—$\frac{N}{k}$ will be infinitely close 1. K is not fully reached. There is $\frac{dN}{dt}$ ≈rN. The number of tourist takes on an exponential growth, indicating the maximum ability of growth of tourist.

When the total number N is close to k, the space k is almost used up. And there is no potential space for more people. So, it becomes crowded at this moment.

In expression (2), N(t) has an exponential item, so the growth rate of N is very fast. At any time t, there is $k>N(t)$. Thus, we conclude that the growth of the number of tourist is limited and fast.

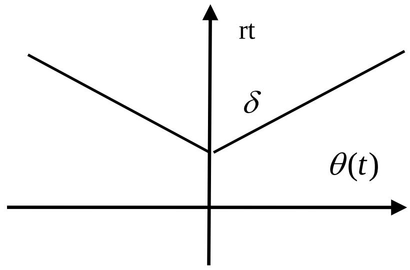
(3) The linear relation between N(t), t, r and $\frac{dN}{dt}$

Transform expression (2), there is

$$In\frac{N_r}{k-N_t}+In\frac{k-N_0}{N_0}=tr$$

Let $\theta\ (t)=In\frac{N_t}{k-N_t},\delta=In\frac{k-N_0}{N_0}$

Substitute the abovementioned expression and obtain $\delta+\theta(t)=tr$, as Fig.1 shows



$$\delta+\theta(t)=tr$$

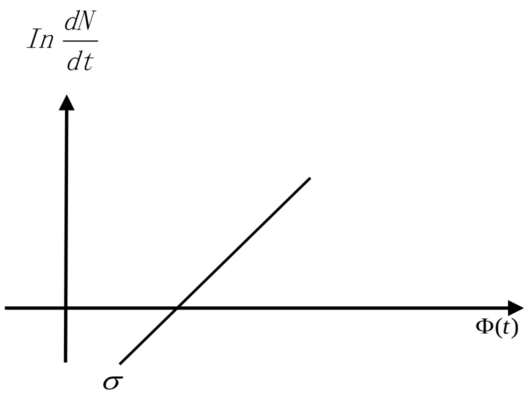
FIGURE 1

Get the average growth rate of the total number of tourist r_0. Substitute it to (4-1) for transformation, and there is

$$Inr_0N_t(k-N_t)-Ink=In\frac{dN}{dt}$$

Let $\sigma=Ink,\Phi(t)=Inr_0N_t(k-N_t)$.

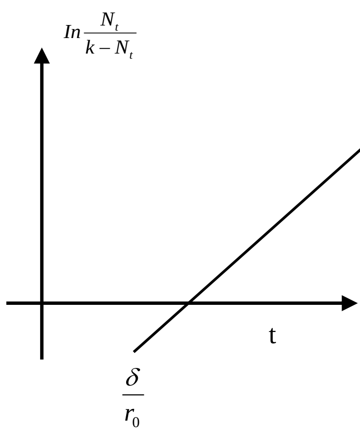
So there is $In\frac{dN}{dt}=\Phi(t)-\sigma$, as is described in Fig.2.



$$In\frac{dN}{dt}=\Phi(t)-\sigma$$

FIGURE 2

Expression (4-2) can transformed to $In\frac{N_t}{k-N_t}=r_0t-\delta$, as Fig.3 shows:



$$In\frac{N_t}{k-N_t}=r_0t-\delta$$

FIGURE 3

4.3 THE EXPANSION OF THE MODEL

The Butler model is a dynamics model about the growth of the species populations. This model is popular for researchers to study the development of the tourism industry in a certain place. Butler holds that the curve that the number of tourist changes with time is under the influence of the environmental capacity. The number of tourist will increase and then decrease, making the curve an "S" shape, as is described in the following Fig. [4]:

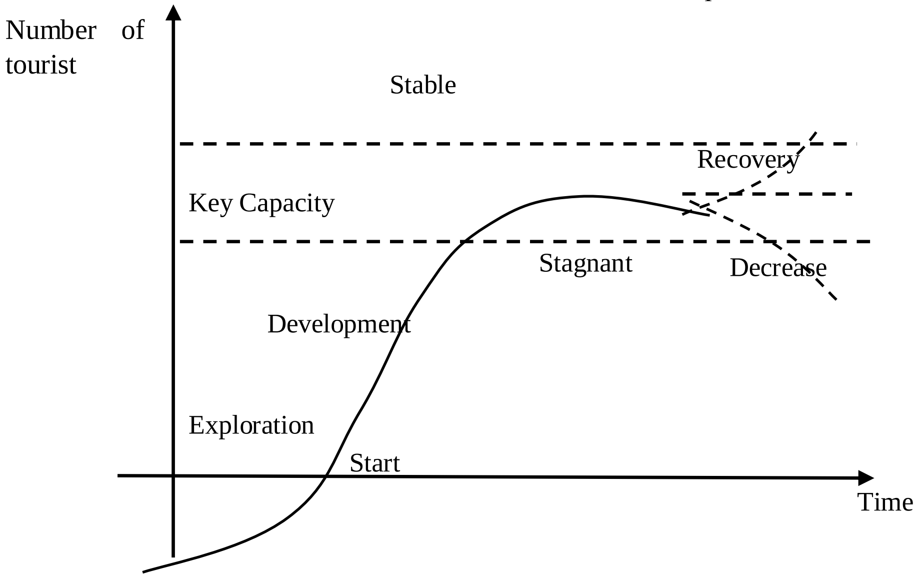


FIGURE 4 Butler life cycle

The steps of the Butler Model:

(1) According to the past and current situation of the Ecotourism area, compute the environment capacity K;

(2) According to relevant data and the variation of the number of tourist in the Ecotourism area, compute the growth rate of the number of tourist r;

(3) Based on (1)(2) and according to differential equation of dynamics $N(t)=\frac{k}{e^{-rt}(\frac{k}{N_0}-1)+1}$, draw the variation curve of the number of tourist changing with time;

(4) Use the curve to estimate the development in the Ecotourism area. Make proper assessment and plan for future development.

4.4 THE APPLICATION OF THE MODEL

4.4.1. Compute the environmental capacity k of Bird Island

There are many fauna and flora on the Bird Island and pavements as well. Compute the environmental capacity with the combination of the area capacity and the road capacity.

(1) Compute the road capacity [5]:

Use t to express the business hours of the Bird Island (hour/day); t_0 refers to the annual time of every tourist spending on the Bird Island (hour); L_0 refers to the annual length of road of every tourist; L refers to the total length of road and D refers to the number of open days (d).

So:

Moment capacity: $\frac{L}{L_0}=C_0$

$$\text{Daily capacity: } C_0\times\frac{t}{t_0}=C_d \tag{4-3}$$

Annual capacity: $C_d\times D=C_y$

(2) Compute the maximum area capacity of the scenic spot

Use S_0 to express the land area that every tourist occupies (m^2/ person); S refers to the total land area on the Bird Island (m^2)

Moment capacity: $\frac{s}{s_0}=T_0$

$$\text{Daily capacity: } T_0\times\frac{t}{t_0}=T_d \tag{4-4}$$

Annual capacity: $T_d\times D=T_y$

(3) Compute the water capacity

Use P to express the number of tourist that a yacht accommodates

Moment capacity: $p=H_0$

$$\text{Daily capacity: } p\times\frac{t}{t_0}=H_d \tag{4-5}$$

Annual capacity: $H_d\times D=H_y$

After consulting relevant data, it is computed that the average length of road per person occupies L_0 is set up as 100m. The average land area that every tourist occupies S_0 is taken as 200m^2/person, according to the standard from Beijing Municipal Bureau of Parks.

4.4.2. Data collection

(1). the number of tourist to the Bird Island per month (Year 2007 is set up as the standard)

Month	1	3	4	5	6	7	8	9	10
Number		Starting the business from Mar. 20th	2363	21250	14562	13071	12447	14604	707(Closing the business at Oct. 10th)
The total number of seasons			38175			40122			707

(2). the growth of the number of tourist (10 thousand people)

Year	2000	2001	2002	2003	2004	2005	2006	2007
Number		6.78	6.41	5.43(SARS)	11.42	3.34 (Bird Flu)	9.08	7.88

(3).Annual revenue of the scenic spot (10 thousand Yuan) the Bird Island has not been developed before 2000

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Total revenue				281.7	264.2	222.8	470.4	135.9	359.9	480.1

4.4.3. Compute the environmental capacity:

Water area: 4456 square kilometers

Land area: Punta Cormorant 0.96 hectare; Dan Island 0.11hectare

Daily open hours O: 9h

Tourism hours per person O_0:2h

Land area of Bird Island S: 0.8 square kilometers

Land area per person S_0: total area / average daily number of tourist

Number of days for tourism each year D: 200d (Mar. 20th—Oct. 10th)

4.4.4. Facilities in the scenic spots:

(1) Total length of tourism roads:16 kilometers

(2) Number of scenic spots: Punta Cormorant and Dan Island

(3) Number of hotel and restaurant:5～6

(4) Entrance fee: 118yuan

4.5 THE CALCULATION OF THE MODEL AND RESULT ANALYSIS

4.5.1. Compute the environmental capacity K

According to expression (4-3), the scenic spots in the Bird Island are divided into linear and face. Thus, the calculation is done separately.

For the linear scenic spot, there are

$$\frac{L}{L_0} = A_0, \quad A_0 \times \frac{T}{T_0} = A_d, \quad A_d \times D = A_a$$

L equals to 5.76 kilometers, L_0 is 100m^2, Daily open hours T is 9h/d; the total hours for sightseeing T_0 is 2h; and the number of days for tourism each year D is 200d/a. Substitute them into (4-3) and get the maximum capacity of the linear scenic spot in the Bird Island Aa=5.18(10 thousand people)

For the face scenic spot, there are

$$\frac{S}{S_0} = P_0, \quad P_0 \times \frac{T}{T_0} = P_d, \quad P_d \times D = P_a,$$

in which S_0 refers to the area that every tourist occupies, 200m^2/ person; and the calculation of T, T_0, D is the same with those for the linear scenic spot. Substitute them into the expression and get the maximum capacity of the face scenic spot in the Bird Island Pa=0.494+4.321=4.815(10 thousand people)

So the ecological capacity k is:

$k=P_a+A_a$=9.999(10 thousand people)

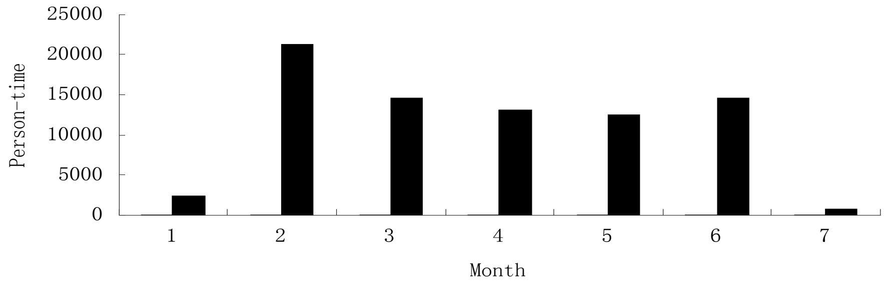
4.5.2. Result analysis

Since the Bird Island of the Qinghai Lake became the Ecotourism scenic spot, the number of tourist in 2004 reached 114.2 thousand people, exceeding the ecological capacity. It indicates that the Ecotourism area has lost its self-adjustment ability. If the number of tourist is not controlled, the Ecotourism will not be sustainable. In 2005, the number of tourist reduced to 33.4 thousand people due to bird flu, easing the situation to some extent and boosting the sustainable development of the Bird Island. In other years, the number of tourist is below the capacity, which means it is bearable.

4.6 STATISTICS ANALYSIS

4.6.1. The variation of tourist

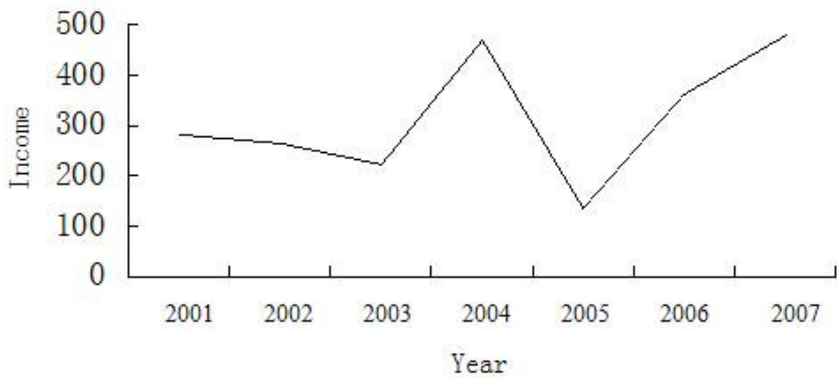
Month	1	3	4	5	6	7	8	9	10
Number		Starting the business from Mar. 20th	2363	21250	14562	13071	12447	14604	707 (Closing the business at Oct. 10th)
The total number of seasons			38175			40122			707



From the table above, it is clear that the hot seasons are from May to September. These four months are the main business periods. Most of the birds lay egg in May and June. And birds migrate to the south because of the climate.

4.6.2. Statistics of revenue growth in the Bird Island

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Total revenue				281.7	264.2	222.8	470.4	135.9	359.9	480.1



From the table we can see, after 2007, the number of tourist has reduced but the revenue is on the rise. After investigation, it is revealed that in 2007, the entrance fee has increased. It limited the number of tourist but received more revenue.

5 Conclusion

1. The emerging Ecotourism enables more and more people to go outdoors and embrace the Nature. However, since many people lack the consciousness of environmental protection and due to improper management of scenic spots, the environment in the Ecotourism area has been destroyed. Thus, it is significant to advocate sustainnable Ecotourism development;
2. According to the Butler model, we can assess the sustainable development of Ecotourism. This paper holds that Ecotourism can have self-adjustment. The rising velocity r, the number of tourist N and the rising number of tourist per unit time dN/dt present a symmetric relation. Under such situation, it is thought that Ecotourism has sustainable development.
3. With quantitative analysis on the Bird Island, we can see that the number of tourist is within the environmental capacity. But if the scenic spot raises its fame and attracts more tourists, and the ecological environment becomes close to the capacity k, the scenic spot will ends up being crowded and face the risk of being polluted.

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