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Comparison of Estimation Methods for Primary Net Production at Herbaceous Coastal Marsh Vegetation

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海岸 鹽濕地 植生의 純生產性 推定法의 比較

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ABSTRACT

Aboveground net productions of four stands in the coastal salt marsh of Incheon were estimated with three different methods: first method was to measure peak live standing crop; second to measure both live and dead standing crops; third to measure live and dead standing crops and dead disappearance as well. Net productions estimated by the first method were lowest with a difference of 28~50% from those by the third method. Whereas estimates by the second method approximated considerably to those by the third method with a difference of 4~15%. The third method figured out the highest values and seemed to be most appropriate in estimating net production of herbaceous community. From these results it is known that live standing crop, dead standing crop and dead disappearance respectively accounted for about 60, 30, 10% of net production estimated by the third method. Annual net productions estimated by the third method for *Suaeda japonica—Salicornia herbacea, Artemisia scoparia—Limonium tetragonum, Calamagrostis epigeios,* and *Sonchus brachyotus—Setaria viridis* stand were 650, 1,080, 1,409 and 1,126 $g \cdot m^{-2} \cdot yr^{-1}$, respectively.

INTRODUCTION

Recently net production of salt marsh plants along the west coast of Korea has been measured by several authors(Kim, 1970; Kim and Oh, 1982; Kim and Min, 1983; Min and Kim, 1983). These results were obtained from the peak live standing crop by harvest at regular intervals. Such a method had also been applied to estimation of net production in the plant communities along the Atlantic coastal marsh(Udell *et al.*, 1969; Marshall, 1970; Odum and Fanning, 1973). This technique, however, didn't account for shedding of green tissues occurring throughout growing season.

To correct for the mortality of green tissues, Smalley(1959) regarded any increase of dead standing crop as the shedding amount of green tissues. The true mortality, however, is not fully explained

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by such an increase of dead standing crop because the dead materials disappear continuously in natural vegetation.

Wiegert and Evans(1964) solved this problem by developing the technique of measuring disappearance rate of dead materials on an old field grassland. This technique has been applied to estimation of net production in salt marsh communities(Kirby and Gosselink, 1976; White *et al.*, 1978).

The purpose of this paper is to compare among aboveground net productions estimated by abovementioned three methods: (1) to measure traditionally peak live standing crop, (2) to measure live and dead standing crops after Smalley(1959), and (3) to measure dead disappearance as well as live and dead standing crops after Wiegert and Evans (1964).

STUDY AREA

The area under study is at a coastal salt marsh located at Baeksugdong, Bukgu, Incheon, Korea (37°31′N, 126°38′E). The salt marsh, about 6 ha, is a reclaimed land enclosed about 30 years ago. A little sea water soaks into through a floodgate and runs through the study area along the tributary at high tide.

The salt marsh is gently sloped with about 7°. The area around a tributary is similar to low marsh in soil condition, where vegetation consists of halophytes. As the soil become desalted, glycophytes have invaded on the high marsh. At the study area, the vegetation was divided into four stands following the gradient of soil desalinated.

The first stand consists of *Suaeda japonica* and *Salicornia herbacea* dominating at the low marsh adjoining tributary; the second does *Artemisia scoparia* and *Limonium tetragonum* in a transitional marsh being sometimes flooded by flood tide; the third does pure *Calamagrostis epigeios* population at the high marsh never flooded; the fourth does *Sonchus brachyotus, Setaria viridis* and other some glycophytes at the inland side desalinated enough.

Physical-chemical properties of the soil corresponding each vegetation were already reported by Kim and Oh(1982) and Kim and Min(1983).

METHODS

Sampling of Live and Dead Standing Crops The live biomass as well as dead materials of four stands was determined by harvesting from seven (20×20)cm quadrats chosen randomly at each sampling site from July, 1981 to August, 1982. All aboveground parts within a quadrat frame were clipped on ground level, put into polyethylene bag, brought to laboratory and then separated into live biomass and dead material. All green tissues were defined as live biomass, and both shedding parts and debris were defined as dead materials. All sampling materials were oven-dried to become a constant weight at 80°C.

Measurement of Disappearance Rate of Dead Standing Crop To determine the disappeared amount of dead standing crop for a given sampling period, sampling was made by paired-plots technique described by Wiegert and Evans(1964). The paired-plot A versus B with(20×20)cm quadrats were set randomly at a site in every sampling time. The paired-plots were laid at a similar composition and density of plant species each other. The first sampling was made only from plot A out of the paired-plots A and B. The second sampling was made only from plot B on 3 weeks later during the growing season, and on 5 months later during winter. When the plot A was sampled, all the green tissues within plot B were taken off in order to avoid adding new dead material from live standing crop. With the samples of the paired-plots, the disappearance rate was calculated by the equation of Wiegert and Evans(1964) as would be described in Eq(5).

Calculation of Net Primary Production In order to estimate the net production of four stands, three different procedures were employed.

1. Peak live standing crop: This method, as the most commonly used technique, assumes that peak standing crop represents annual net production in herbs. Thus annual net production(P_n) is expressed by maximum biomass (b_n) minus minimum one (b_1),

$$P_n = b_n - b_1 \quad \cdots\cdots (1)$$

No correction is, however, made for the shedding amount from the green tissues during the growing season.

2. Live and dead standing crops (Smalley, 1959): If the live standing crop is harvested at successive sampling intervals, the changes of the live standing crop(Δb_i) for an interval is calculated as follows,

$$\Delta b_i = b_i - b_{i-1} \quad \cdots\cdots (2)$$

where b_i and b_{i-1} are the amount of live standing crop at ith and $i-1$th sampling times The dead standing crop (d_i) would also change for an interval as follows,

$$\Delta d_i = d_i - d_{i-1} \quad \cdots\cdots (3)$$

where d_i and d_{i-1} are the amount of dead standing crop at ith and $i-1$th sampling times. Here any increase in dead standing crop is regarded as the shedding amount during the interval. Thus net production (P_n) is, provided that $(\Delta b_i + \Delta d_i) \geqq 0$, given by Smalley (1959),

$$P_n = \sum_{i=1}^{n} (\Delta b_i + \Delta d_i) \quad \cdots\cdots (4)$$

3. Live and dead standing crops and dead disappearance (Wiegert and Evans, 1964): The dead standing crop disappears by decomposition in natural vegetation. Therefore, the change of dead standing crop(Δd_i) doesn't represent true mortality of live standing crop for the interval. In order to correct the disappeared amount of the dead materials, Wiegert and Evans(1964) have calculated instantaneous disappearance rate (r_i) of the dead standing crop for an interval with data from the paired-plots technique as follows,

$$r_i = \frac{ln(d_0/d_1)}{t_1 - t_0} \quad \cdots\cdots (5)$$

where d_0 and d_1 are the dry weight of the dead standing crop in g per plot at sampling times t_0 and t_1. Also t_0 and t_1 are the times of sampling plot A and plot B respectively. And annual disappearance rate (r_a) is given by,

$$r_a = \sum_{i=1}^{n} (r_i \cdot t_i) \quad \cdots\cdots (6)$$

where t_i is the interval of sampling times in days. Then the total disappeared amount (x_i) of dead standing crop for an interval would be,

$$x_i = ((d_i + d_{i-1})/2) \cdot r_i \cdot t_i \quad \cdots\cdots (7)$$

Thus mortality (m_i), the shedding amount from the green tissues for an interval, is deduced from Eq(3) and Eq(7) as follows,

$$m_i = \Delta d_i + x_i \quad \cdots\cdots (8)$$

And net production (P_{n_i}) for an interval, as sum of the live standing crop change (Δb_i) plus mortality (m_i), is given by,

$$P_{n_i} = \Delta b_i + m_i \quad \cdots\cdots (9)$$

Finally, annual net production (P_n) is, provided that $P_{n_i} \geqq 0$,

$$P_n = \sum_{i=1}^{n} P_{n_i} \quad \cdots\cdots (10)$$

Among the three methods above-mentioned, the first and the second method used observed data in calculating production, whereas the third method used curve-fitted data from the fourth-order polynomial regression, instead of observed data. Statistically fitted regression eliminates random sampling variability from observed data, but fails to account for all of the variation. Thus Kirby and Gosselink (1976) concluded that using observed data in calculating production was more realistic than using curve-fitted data. However, they proposed that calculation by the third method necessitate uniform increase or decrease in data rather than the ups and downs of observed data caused by sampling error.

RESULT AND DISCUSSION

Live and Dead Standing Crops Seasonal changes of the live and dead standing crops of the four stands are shown in Fig. 1. Vegetation shooted up in April or May, reached the peak live standing crop in August or September and thereafter decreased rapidly to zero. The peak standing crops were 453, 782, 705 and 610 g d. wt./m² on the *Suaeda japonica—Salicornia herbacea*, *Artemisia scoparia—Limonium tetragonum*, pure *Calamagrostis epigeios*, and *Sonchus brachyotus—Setaria viridis* stand, respectively. The peak standing crop of the *Artemisia scoparia—Limonium tetragonum* stand was higher than those of any other stands.

Theoretical peak standing crops from the curve-fitted data of polynomial regression were 330, 705, 672 and 525 g/m² in the order of above stands. By comparing between experimental and theoretical data, we can find that the latters are much reduced because theoretical curve doesn't have as high a peak as does the observed data.

The dead standing crops have reduced in early summer and increased as the live standing crops die after early fall. The dead standing crops of all the stands were kept with considerably much amount over the year. It is notable that the peak dead standing crops are higher than the peak live standing crops on both the *Calamagrostis epigeios* and the *Sonchus brachyotus—Setaria viridis* stand. That amount of dead standing crop is larger than that of the live one is common to herbaceous communities, especially on old field (Wiegert and Evans, 1964) and salt marsh communities (Wiegert and McGinnis, 1975; White, *et al.*, 1978).

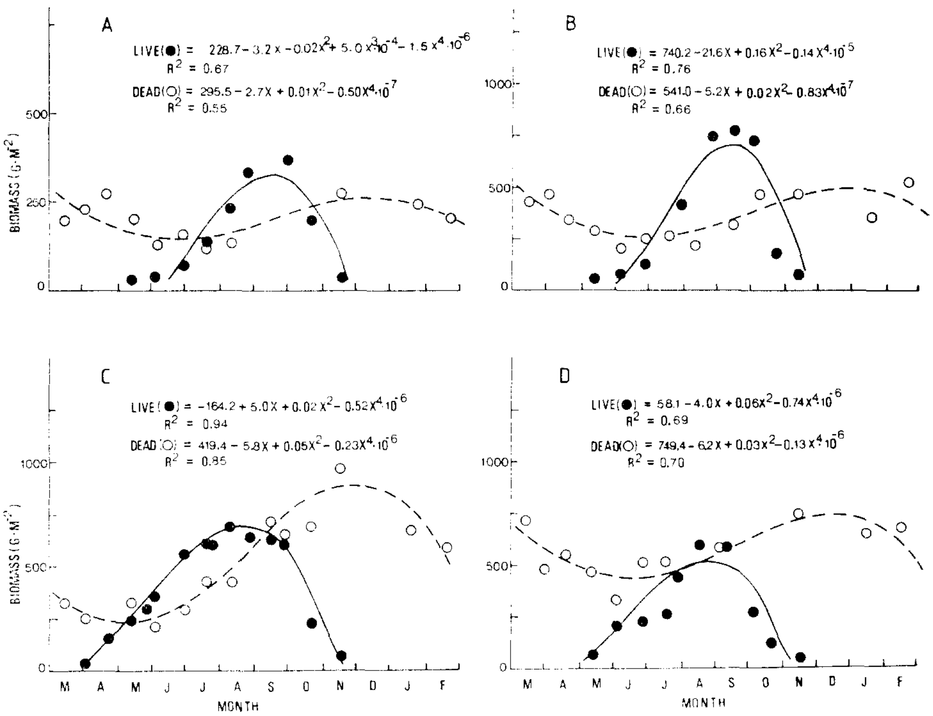

Fig. 1. Live and dead standing crops of *Suaeda japonica—Salicornia herbacea*(A), *Artemisia scoparia—Limonium tetragonum*(B), *Calamagrostis epigeios*(C). *Sonchus brachyotus—Setaria viridis* (D) stand.

Dead Disappearance, Mortality and Growth

Instantaneous disappearance rates of the dead standing crop computed after Eq(5) are summarized in Table 1. The disappearance rates, for example, in the *Suaeda japonica—Salicornia herbacea* stand were ranged from 1.15 mg/g/day for cold winter to 34.01mg/g/day for hot and wet summer.

The annual disappearance rate calculated after

Table 1. Instantaneous disappearance rates of the dead materials at the stands of *Suaeda japonica—Salicornia herbacea*(A), *Artemisia scoparia—Limonium tetragonum*(B), *Calamagrostis epigeios*(C) and *Sonchus brachyotus—Setaria viridis*(D) calculated with the paired-plots method

Interval	Period (day)	Stand			
		A	B	C	D
		Daily rate (mg·g^{-1}·day^{-1})			
Nov. 11, 1981~April 20, 1982	160	1.15	1.91	1.63	1.83
April 20, 1982~May 11, 1982	21	10.30	3.01	2.62	2.94
May 11, 1982~June 17, 1982	37	6.95	8.08	7.01	8.84
June 17, 1982~July 20, 1982	33	10.56	10.50	10.17	11.63
July 20, 1982~Aug. 29, 1982	40	34.01	16.60	8.68	10.25
Aug. 29, 1982~Nov. 11, 1982	74	1.71	3.74	4.90	4.82
		Annual rate (g·g^{-1}·yr^{-1})			
Nov. 11, 1981~Nov. 11, 1982	365	2.49	1.96	1.62	1.83

Eq(6) was highest on the *Suaeda japonica—Salicornia herbacea* stand with mainly water tissues but lowest on the *Calamagrostis epigeios* stand with rigid fibers. Our results for annual disappearance rate were favorably compared with those of Hopkinson *et al.*(1978).

Monthly amount of dead disappearance computed after Eq(7), monthly mortality after Eq(8) and monthly growth of aboveground after Eq(9) are shown in Fig. 2. Amount of disappearance was very much during the warm and wet months.

The mortality began to occur in May and con-

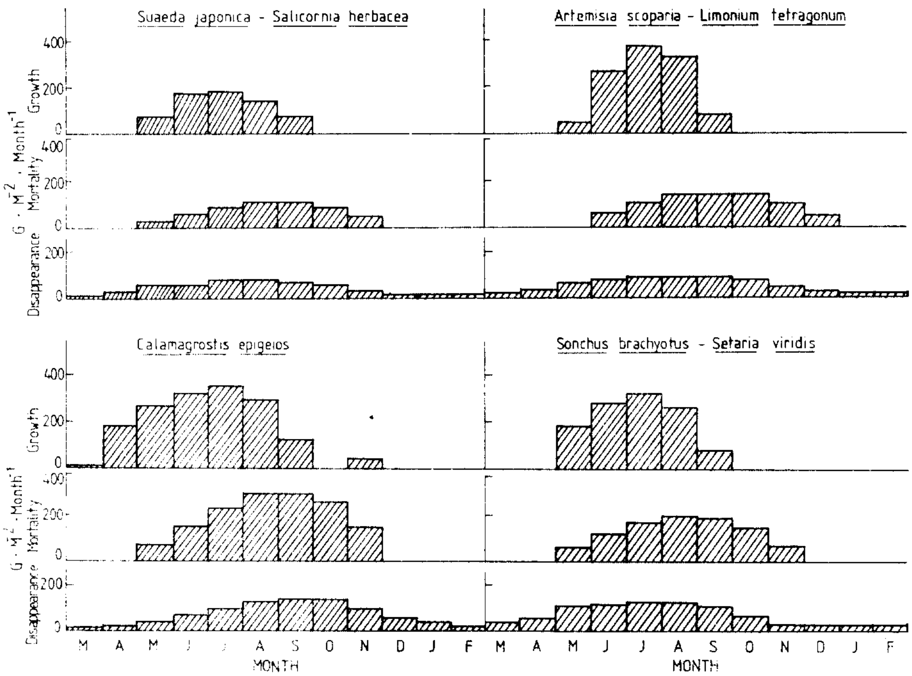

Fig. 2. Monthly growth, mortality and dead disappearance at the different stands after the third method.

tinued by the end of November or December. The highest mortality occurred during August to September on almost all the stands. As shown in Fig. 2, most of green tissues were converted into the dead materials for the year.

Growth of aboveground began in March or May, reached a peak in July and decreased to zero by September. Growth of plant was achieved mostly in from June to August.

Annual Net Production Annual net aboveground production was estimated with three different methods: first, peak live standing crop after Eq(1); second, live and dead standing crops after Eq(4) proposed by Smalley(1959); third, live and dead standing crops and dead disappearance after Eq(10) proposed by Wiegert and Evans(1964).

Table 2 shows that annual net production differs very much depending on the methods used. In order to compare among the different estimates, ratio of each estimate is calculated, supposing that the third estimates are regarded as 100. Net production calculated showed the gradually increasing value in the order of first, second and third method. The estimates from the first method were about 70% of those from the third method in *Suaeda japonica—Salicornia herbacea* and *Artemisia scoparia—Limonium tetragonum* stand. In these stands, plant species shooted up only in spring and reached their peak standing crop in the same season. Whereas, in *Calamagrostis epigeios* and *Sonchus brachyotus—Setaria viridis* stand on which new shoots emerged throughout the growing season, the estimates from the first method were only about 50% of those from the third method. Especially, in *Sonchus brachyotus—Setaria viridis* stand on which several species of plant were mixed, it was observed for the different species to show seasonal change. From these results, it is known how much the first method underestimated net production as compared with the third method. Also, the degree of such an underestimation was greater in the stand on which new shooting throughout growing season or seasonal change of plant species is shown.

Table 2. Net annual aboveground production in g d. wt. per m^2 per yr of the different stands calculated using peak live standing crop as the first method, live and dead standing crops as the second method, and live and dead standing crops and dead disappearance as the third method

Stand	Method		
	First	Second	Third
Suaeda japonica-Salicornia herbacea	453 (70)	553 (85)	650 (100)
Artemisia scoparia-Limonium tetragonum	782 (72)	943 (87)	1,080 (100)
Calamagrostis epigeios	705 (50)	1,346 (96)	1,409 (100)
Sonchus brachyotus-Setaria viridis	610 (54)	1,033 (92)	1,126 (100)

( ) : Relative ratio of production estimates calculated with regarding the third method values as 100.

Odum(1960) discussed the error in the use of the first method in estimating production. This method is simple to carry out, but error is introduced by the different species reaching their peak standing crop at the different times. And the method fails to account for the mortality of green tissues occurring throughout the growing season. Therefore, the first method may induce a wrong conclusion when net productions of various stands are compared. Net annual production of *Artemisia scoparia—Limonium tetragonum* stand, for example, was the highest value among the results from the first method. But among those from the second and the third method in which mortality was supplemented, it came down to the third high value.

Then it is notable that the estimates from the second method approximated considerably to those from the third method with a difference of 4~15%. White *et al.*(1978) pointed out that approximation of production values between the second and the third method was because there was the tendency of biasing calculation error upward in the second method. However, the second method also ignored the disappeared amount of dead standing crop.

The third method, therefore, might be most appropriate in estimating net production of herbaceous communities because it accounts for the disappeared amount of dead materials between sampling times as well as the changes of live and dead standing crops. It is, however, unknown how much close the estimates were to the true net production. Also it leaves out of count the consumption of green tissues by herbivores.

Annual net productions of aboveground by the third method for *Suaeda japonica—Salicornia herbacea, Artemisia scoparia—Limonium tetragonum, Calamagrostis epigeios, Sonchus brachyotus—Setaria viridis* stand were 650, 1,080, 1,409 and 1,126 $g \cdot m^{-2} \cdot yr^{-1}$, respectively.

In conclusion, according to the calculation methods, net production value in the same stand is very differently estimated. Therefore, if the same method doesn't be adopted, it is dangerous to compare among the production values reported already. It seems to be desirable to standardize the technique for estimating net production.

摘　要

海岸 鹽濕地에서 一次純生産性을 세가지 다른 方法으로 測定하였다. 즉 첫째 最大 現存量 測定, 둘째 生體 및 枯死體 現存量 測定, 셋째 生體, 枯死體 現存量 및 枯死體 分解量 測定法이다. 첫째 또는 둘째 方法에 의한 推定値는 각각 셋째 방법에 의한 값의 28~50% 또는 4~15%만큼 적었다. 셋째 방법이 가장 높은 生産性을 산출하였으며 草地植生의 生産性 推定法으로 합리적이었다. 셋째 방법에 의해 산출된 純生産性 중에서 生體 現存量은 약 60%를, 枯死體 現存量은 약 30%를, 그리고 枯死體 分解量은 약 10%를 각각 차지하였다. 셋째 방법에 의한 생산성 추정치는 칠면초—퉁퉁마디, 비쑥—갯질경, 산조풀 및 사데풀—강아지풀 植分에서 각각 650, 1,080, 1,409 및 1,126 $g/m^2/yr$ 이었다.

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