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Comments on natural mortality rate of adult female fur seals of Robben Island origin*

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Introduction

The natural mortality rate is an important factor to evaluate the population level of wild life animals. In the northern fur seals (*Callorhinus ursinus*), the natural mortality rate of females has been estimated on the basis of the age composition obtained from the pelagic research as well as the land research in the past. Citing the apparent annnual rate of decrease in females which NAGASAKI (1961) calculated from the age compositions of female kill on Pribilof Islands in 1956 and 1957, North Pacific Fur Seal Commission Report on Investigations from 1958 to 1961 concludes that the rate of decrease indicates the extreme variability for females from both rookeries and hauling grounds. This suggests that the natural mortality rate can not be estimated from the samples on land because of natural segregation in females during the breeding season.

CHAPMAN (1964) estimates 0.11 for the annual mortality rate of the whole female over age 3. This rate was calculated from the age composition collected in the eastern Pacific by the pelagic research from 1958 through 1961. The recovery of tag indicates that most of female seals inhabiting the eastern Pacific is from the Pribilof Islands origin.

On the other hand, the natural mortality rate of female seals from Robben Island was estimated as 0.10 by ICHIHARA (1972) who applied Heincke's method to the age composition of females over age 8. These samples were collected by the pelagic research in the Sea of Japan from 1960 through 1968. Seals wintering in the Sea of Japan are from Robben Island.

The increment of pup population in the past on Robben Island is closely related to the pregnancy rate, the survival rate of young females and to the natural mortality rate of adult females. From the mutual relations among these four factors, the upper limit of the natural mortality rate of adult females is estimated for the Robben seal herd in this paper. The bias of age composition in female seals which distribute off the northern Japan in the western Pacific is interpreted in relation to these estimates.

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Pup population on Robben Island in the past years

On Robben Island, the number of pups born has been counted since the early years of this century. Before the second world war, Japan continued to carry out per head count for pups born from 1908 through 1938. The statistics for pup population for the pre-war days is recorded and listed in Table 1 (Sakhalin Agency, 1936). The increasing trend for this period can be represented by a straight line as indicated in Fig. 1. Although there is the fluctuation in the pup population, the annual rate of increment is about 9%. After the war, The reports on fur seal investigation of the USSR (VNIRO, 1958–71) have recorded the number of pups born on Robben Island since 1958. The pup count made by USSR shows that the pup population increased annually at a constant rate of about 8% from 1958 throught 1964. After 1964, the pup population began to fluctuate greatly on Robben Island.

Table 1. Number of pups born at Robben Island, 1908–38 and 1958–71.

Count by Japan

Year	Pup production	year	Pup production
1908	1,600	1924	9,613
9	1,650	25	8,797
10	1,800	26	9,654
11	2,700	27	11,086
12	2,388	28	12,630
13	3,187	29	13,000
14	1,899	30	11,855
15	2,316	31	12,460
16	2,927	32	13,000
17	3,988	33	13,500
18	4,497	34	13,700
19	4,544	35	14,000
20	5,045	36	14,300
21	6,134	37	14,500
22	7,019	38	14,800
23	7,917		

Count by USSR

Year	Pup production	Year	Pup production
1958	32,200	1965	48,400
59	35,000	66	44,900
60	38,000	67	56,500
61	41,200	68	45,800
62	44,700	69	43,500
63	49,000	70	31,500
64	51,400	71	41,100

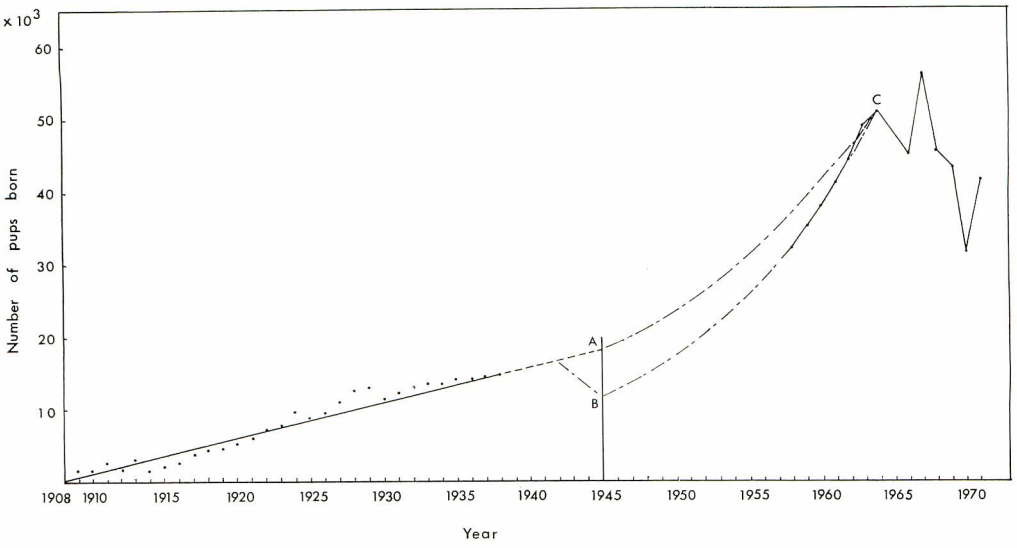

Fig. 1. Increasing trend of number of pups born in the Robben seal herd from 1908 through 1971.
•——• Actual count for pups born
A——- - ——- C 6% increase
B——- - ——- C 8% increase

Considering that the pup population attained the higher level of 51,400 pups (Point C) in 1964, two increasing trends are assumed for the period from 1939 to 1957, when no record to be examined is available. The first assumption is as follows. If a backward extrapolation is applied to the exponential increase of pup population from 1958 through 1964 which grows up a constant rate of 0.08, the number of pups born is estimated to be 11,920 (Point B). Point B is less than the pup population of 18,000 (Point A) which is expected in 1945 from the linear increase of the earlier years. The divergence between A and B may be explained by the intended female kill on Robben Island in autumn in 1944. At that time, an amount of females was killed for the commercial purpose but the number of kill was not recorded unfortunately. Several informations from the persons of management suggest the evidence that the commercial kill on Robben Island was restricted to bachelors and excess bulls untill 1943. Consequently, it is reasonable to interpret that the number of pups born in 1945 was reduced by the female kill carried on in the previous year.

It is possible to draw on the second assumption on the increment of pups from the past available informations. If the exponential increase continues from Point A to Point C, the annual rate of growth is calculated to be 0.057. An exponential curve A–C is drawn in Fig. 1 in accordance with the increase rate of 6%. Even if the pup productions in 1958 and 1959 were underestimated through the oversight in the course of the pup count, it is hard to accept the population size of pups born

exceeded the curve A–C. This curve gives an upper limit to the size of pup population produced on Robben Island from 1945 to 1964. The actual pup population probably ranges between the exponential curve A–C and B–C.

Relationship between the survival rate of young females and the natural mortality rate of adult females

The increasing trends from 1945 through 1964 of pup population on Robben Island are expressed as folows.

$$P_n = P_0 (1+\alpha)^n \quad \cdots\cdots (1)$$

$$P_{n+1} = P_n (1+\alpha) \quad \cdots\cdots (2)$$

Where

P_0; Number of pups born in 1945

P_n; Number of pups born in n year later

P_{n+1}; Number of pups born in $(n+1)$ year later

α; Constant rate of increase

P_0 is 18,000 pups when α is 0.06 and 11,900 pups when α is 0.08.

The number of pups born is calculated from

$$P_n = N_n \cdot P \quad \cdots\cdots (3)$$

Where

N_n; Number of adult females in n year later

P; Constant mean pregnancy rate

The pelagic research in the Sea of Japan from 1960 through 1968 indicates that the females of Robben origin attain the sexual maturity of 50% at age 3. Since the half of pup population comprises females and adult females are mostly recruited at age 4,

$$N_{n+1} = N_n (1-a) + R \quad \cdots\cdots (4)$$

$$R = \frac{S}{2} \cdot P_{n-4} \quad \cdots\cdots (5)$$

Where

R; Recruitment of adult females

S; Survival rate of females from birth to age 4

a; Natural mortality rate of adult females

The expression (4) is rewritten from (1), (2), (3) and (5) in the next formula,

$$\frac{P_n}{P}(1-a) + \frac{S}{2} P_{n-4} = \frac{P_{n+1}}{P}$$

Therefore

$$2P_n(1-a) + S \cdot P \cdot P_{n-4} = 2P_{n+1}$$

Survival rate of females from birth to age 4 is

$$S = \frac{2P_n(a+\alpha)}{P \cdot P_{n-4}}$$

This indicates the relationship among the survival rate of females from birth to age 4, the natural mortality rate of adult females and the mean pregnancy rate,

when the pup population increases exponentially. The relation of S to a is linear when the pregnancy rate is constant. The value of S decreases with the increment of pregnancy rate.

For both cases that α is 0.06 or 0.08, the value of S is calculated and shown in

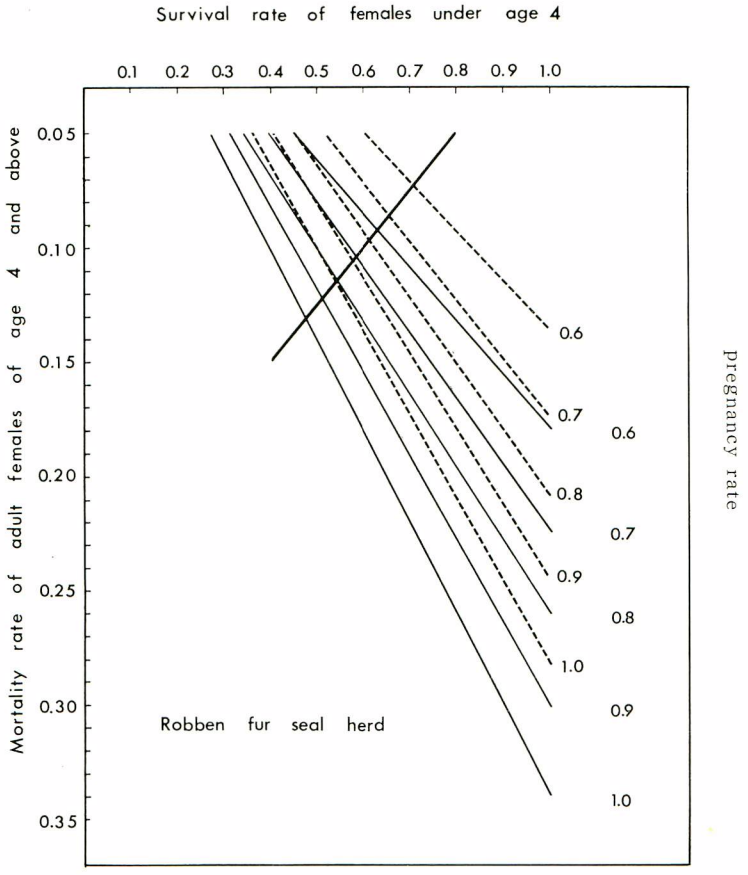

Fig. 2. Relationship between the survival rate of young females and the natural mortality rate of adult females, in the case that the pregnancy rate varies from 0.60 to 1.00
····· 8% annual increment in pup population
——— 6% annual increment in pup population
━━━ Upper limit of the natural mortality rate of adult females

Fig. 2 in which the mean pregnancy rate of female seals from the Robben origin varies from 0.60 to 1.00 and the natural mortality rate of adult females changes from 0.05 to 0.34.

On the other hand, there is another relationship between the survival rate of young females and the natural mortality rate of adult females. In fur seals as well as in other wild life animals, the natural mortality rate of the adult animal will be less than that of the young. This means that a does not exceed 0.05 when S is 0.80 and that a does not exceed 0.20 when S is 0.20. Such a border line also is drawn

in Fig. 2 and hence the relationship of a to S is valid in the left side of border line. The points at which the border line intersects the lines S–a is the upper limits of a for the given pregnancy rate. The upper limits of a are indicated in Table 2 when the pregnancy rate varies from 0.60 to 1.00. Table 2 also shows that the natural mortality rate should be low to expect the rapid growth of pup population when the pregnancy rate is constant, and that the natural mortality rate should be low to maintain the same level of the increase rate in pup population when the pregnancy rate is low.

Table 2. Upper limit of the natural mortality rate of adult female seals from the Robben origin, when the pregnancy rate and the rate of increase in pup population vary

Pregnancy rate	Annual rate of increase in pup population	
	0.08	0.06
1.00	0.116	0.131
0.90	0.106	0.122
0.80	0.097	0.114
0.70	0.086	0.105
0.60	0.072	0.093

Underlines indicate possible cases in pregnancy rate

The pregnancy rate of 100% is not expected from the population of fur seals. Since the possible pregnancy rate ranges from 60% to 80% on the basis of the pelagic samples collected in the Sea of Japan, Table 2 indicates that the natural mortality rate of adult females can not exceed 0.114. From the above procedure, the upper limit of natural mortality rate is 0.12 for adult females from the Robben origin. Unless the harmful change in the marine ecosystem happens in relation to the food abundance of fur seals, it is hard to conceive the natural mortality rate of adult female seals fluctuates greatly dependent on the density of population. On the breeding islands, most of mature females can enter into harem area without hostile acts from others. Such a gregarious habit of adult females on land is a reason for the stable low mortality rate. The value of 0.10 estimated by ICHIHARA (1972) is less than this upper limit but the implications of the slightly lower mortality rate may be considered.

Total rate of decrease in the pelagic samples

Western Pacific

Since 1958, the pelagic research has been carried out off the northern Japan in the western Pacific. From 1958 through 1966, a total of 6,548 female seals was taken for the research purpose in April and May. The size of samples was maximal in these months during the research season. As the size of samples differs among

years, the percent age composition of female seals in each year is calculated for the convenience of comparison and rearranged by each year class as shown in Table 3. The logarithms of these percent age composition are plotted against the age of fe-

Table 3. Percent age composition of femals seals collected by the Japanese pelagic researches off the northern Japan in the western Pacific in April and May, by year class

Year class

Age	1940	41	42	43	44	45	46	47	48	49	50	51
1												
2												
3												
4												
5												
6												
7												33
8											23	29
9										19	18	24
10									11	13	11	15
11									10	12	12	12
12								8	10	4	9	7
13							4	10	7	4	7	4
14						1	6	10	4	7	9	6
15						1	7	8		15	3	3
16				3	1	5	1	2	4	3	3	
17			5	2	7	4	2	2	6	3		
18		3		3	3	3	2					
19	3	1	3			5		3				
20	1		1	2	4							

Year class

Age	1952	53	54	55	56	57	58	59	60	61	62	63	64
1						15	32	11	7	21	22	40	19
2					138	165	158	152	164	121	100	61	71
3				323	248	185	215	205	158	177	127	136	
4			164	208	183	191	185	190	155	141	167		
5		137	120	168	141	109	171	153	139	169			
6	72	81	106	143	87	99	104	125	102				
7	43	70	45	82	50	47	133	82					
8	40	22	49	81	46	58	85						
9	11	34	42	66	64	62							
10	19	18	31	58	25								
11	15	20	30	23									
12	16	11	31										
13	17	28											
14	6												

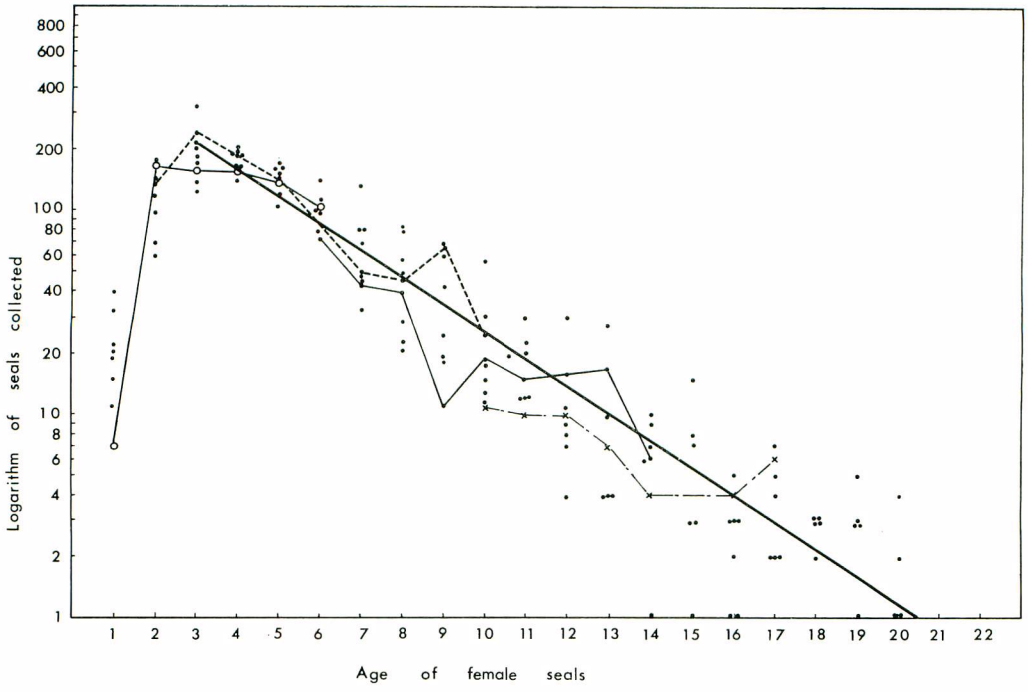

Fig. 3. Age composition of female seals collected by the Japanese pelagic research vessels off the coast of Sanriku and Hokkaido from April fo May, 1940-1964 year class
×——– ——× 1948 year class •——• 1952 year class ····· 1956 year class
○——○ 1960 year class —— 1940-1964 year class

males in Fig. 3. When the least square method is applied to the each value of age 3 and above, the decreasing trend of age composition is expressed by a straight line which is indicated by a thick solid line in the figure. The coefficient of decrease is 0.31 and hence the apparent rate of decrease is 0.27. It exceeds the upper limit of the natural mortality rate for adult females from the Robben origin.

The waters off the northern Japan in the western Pacific are the wintering habitat of mixed seal populations. Three major breeding populations from the Pribilof Islands, Commander Islands and Robben Island intermingle in this feeding area. Even if intermingling is taken into consideration, the apparent rate of decrease estimated is higher than the natural mortality rate of adult females. It suggests that there is a segregative pattern in the distribution of seals in this area. In other words, the sharp decline of the female age composition indicates that the younger seals of age 3 and below are abundant, while the older seals are scarce in April and May. The decline of age composition increases gradually from January to June in this waters and the older females leave this waters with advance of month, however, the general pattern of segregation by age is kept.

It should be noticed that the declining trend is similar in each year class. As examples, the slopes of decline by age are shown for four year classes; 1948, 1952,

Fig. 4. Age composition of female seals collected by the Japanese research vessel in the adjacent waters to Robben Island in Okhotsk Sea.
A total of 298 seals was collected in july and August of 1972.

1956 and 1960 year class in Fig. 3.

Okhotsk Sea

Systematic collection of seals in Okhotsk Sea was made by the Japanese research vessel, in July and August of 1972. The age composition of 298 female seals collected in the feeding area around Robben Island is indicated on the semilogarithmic scale in Fig. 4. When the decreasing trend in the age component of age 8 and above is expressed by a straight line which is given by the least square method, the coefficient of decrease is 0.11 and hence the apparent rate of decrease is 0.10. This is the same rate that is estimated by application of Heincke's method to the pelagic samples of age 8 and above collected in the Sea of Japan. Although the size of sample in Okhotsk Sea is too small to attain the final estimate, it is considered that the apparent rate of decrease is very close to the natural mortality rate of older females. Since females after parturition go down periodically to sea to take food, the pelagic samples around Robben Island is possibly randomized if the dispersion of animals is uniform. In the topography, the waters around Robben Island has the advantage of those around Pribilof Islands, because the expansion of shallow waters in the west side of Robben Island is restricted by the land of Sakhalin.

The amount of young females increases in the component of catch with advance of month. Such a characteristics in the behavior of seals suggests a possibility which the natural mortality rate of adult females under age 8 can be estimated from the pelagic samples from late August to November. From the male composition of the pelagic samples, the ratio of escapement from the commercial kill will be estimated in the waters around Robben Island.

Conclusion

There is strong evidence that the fur seal population from the Robben Island the origin is almost independent of the other major breeding populations derived from the Pribilof and Commander Islands in the North Pacific, and that the population of Robben Island has attained recently the level to produce the maximum sustainable yield and then leveled off. Among parameters necessary to evaluate more accurately, the natural mortality rate is an important one. Reviewing the previous estimate for the natural mortality rate of females and reexamining the records of pup count made on Robben Island in the past, this paper gives the upper limit to the natural mortality rate of adult female seals. The apparent rates of decrease in the pelagic samples collected from January through June off the northern Japan in the western Pacific and collected from July and August in Okhotsk Sea are discussed in relation to the natural mortality rate of female seals. The conclusive statements are summarized as follows.

1. Pup population increased annually at a constant rate of about 9% from 1908 through 1938 on Robbe Island and thereafter no information on the pup count was available for 19 years from 1939 through 1957.
2. Pup count from 1958 throug 1964 is estimated that the rate of increase in the pup population is annually about 8%.
3. From the above two data sources and from the status of commercial kill from 1939 through 1944, the upper limit of increase in the pup population can be estimated for the population of Robben Island origin.
4. From the mutual relationships among the survival rate from birth to age 4, the natural mortality rate of females of age 4 and above, and the pregnancy rate, the upper limit of the natural mortality rate in adult females is estimated to be 0.12 for the population of Robben Island origin.
5. Younger females are predominant in the wintering area off the northern Japan in the western Pacific, while the older females are scarce. It is derived from the segregative distribution by age of female seals.
6. The waters around Robben Island will be the best area to evaluate the natural mortality rate of females from the Robben origin, if the time of pelagic research is selected.

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ロベン島起源の成熟雌オットセイの自然死亡率についての意見

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要　　約

自然死亡率は資源を評価する際の重要なパラメータのひとつである。オットセイの雌成獣に対する自然死亡率は過去において海上調査および陸上調査から入手される年令組成をよりどころに推定されてきた。北太平洋に生息するオットセイに対する大規模な標識が継続された結果，ロベン島起源のオットセイは他の繁殖系群との混合割合が少く独立性を保つ系群とされており，資源保護の結果最近に至って最大持続生産水準を超える状態になってきた。

この論文では，ロベン系オットセイ群に焦点を絞り，戦前わが国が領有していた頃（海豹島）からソ連が領有した戦後までの出生仔獣数増加傾向に着目して，資源増加時における雌成獣の自然死亡率の上限を推定した。このためには，生まれてから4才までの生残率と4才以上の雌成獣死亡率および妊娠率との間に関係式を導入してある。推定された自然死亡率の上限は年間 0.12 であり，海上捕獲による8才以上の雌年令組成から求めた自然死亡率 0.10 をわずかに上回る結果がえられた。本研究で得た死亡率の推定値と比較すると，冬季から春季にかけて日本太平洋岸に来遊する成熟雌オットセイの見かけの全減少率は 0.27 であり，明らかに年令組成別の分布に偏りがみられる。また年級別全減少率を1948年級から1960年級まで追跡してみるとほとんど一致していて，上述の年令による分布の偏りが安定したものであることを示唆している。