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A FEASIBILITY STUDY ON INSURANCE (OR MUTUAL AID) PROGRAM OF SEA CULTURE: THE CASE OF HANGING OYSTER CULTURE

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I. Introduction

The major items of commercial sea culture in Korea include brown seaweed, laver, and oyster. Recently sea-fish culture is on the germinating stage. Among the sea culture crops with established culture technologies oyster production requires relatively larger capital investment.

Oyster culturists often face a variety of yield, resource, and price risks, which make their income unstable from year to year. In many cases oyster farmers are exposed to the risk of catastrophe. Crops may be destroyed by natural hazards such as typhoon, insects, and red tides. The types and severity of the risks vary with oceanic biological and climatological conditions. The production risk affects more seriously oyster culturists' income instability than price risk. Such risk is particularly burdensome to small-scale oyster farmers who have little resources for repropagation.

Field observations suggest that oyster culturists are strongly risk-averse and they seek to avoid risk through various managerial and institutional mechanisms. The incidence of risk and risk-averse behavior in sea culture is important for three reasons. First, fluctuations in incomes, and particularly the risk of catastrophic losses, may cause welfare problems for fishing village people for the household operating small-scale culture, these losses can be too easily translated into misery. Second, because sea culturists are typically risk-averse and seek to avoid risks through management practices, the average returns to their resources are reduced. Third, sea farmers exposed to severe risks are more likely to default on bank loans, particularly in years of natural catastrophes. The provision of subsidized credit through fishery cooperatives is a cornerstone in the fishery development strategy. However, the performance and long term viability of credit institutions can be severely impaired

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by poor loan collection, particularly if many culturists default at the same time because of a common catastrophe.

Given these concerns, should government intervene by providing formal risk sharing institutions to assist sea farmers? Risk–sharing arrangements aim to reduce the burden of risk for the individual sea culturists. One way to do this is a risk–pooling strategy across regions, which take advantage of less than perfectly covariate risks. Efficient risk–pooling can reduce the total risk burden to society and may benefit sea culturists even if they have to pay the full cost of the risk–spreading mechanism.

This paper consists of six sections. Section two describes hanging oyster culture process and associated risks. Section three develops a theoretical framework. Section four describes the data set. Section five examines the requisites for oyster–culture insurance(or mutual aid) program. In the last section summary and conclusions are given.

Ⅱ. Hanging Oyster Culture Process and Associated Risks

The hanging oyster culture process is basically determined by the choice of seed oysters. There are two types of seed oysters: one is ordinary seeds and another hardened ones. In recent, hardened seeds are much preferred to ordinary ones since the former guarantees higher survival rate during the entire growing period. There are five stages in the hanging oyster culture process: egg–laying, gathering fertilized eggs, transplantation, growing and harvest.

1. Egg–laying Stage

Oysters generally lay eggs in June when water temperature rises to 23–25℃. However, during this period drought often occurs. High salinity and water temperature changes are followed, which cause severe crop damage. Another risk of this stage is associated with red–tides which usually occur from May to October. Once it arises, a wide range of culture area is affected. In particular, when it occurs with high level of density, oysters are suffocated to death.

2. The Culture Process with Ordinary Seed Oysters

First, gathering fertilized eggs is carried out from mid June to mid July by using the gathering boards. Then transplantation to the culture area is made. During this period drought and flood often occur. To the contrary of drought, flood leads to lowering salinity and water temperture.

After transplantation, the growing stage starts and continues until next May. The worst weather conditions are concentrated to this stage: typoons, fouling organisms, radical changes in water temperature, and red–tides. Typhoon involves the large destruction of culture facilities and damage to

TABLE 1 **Hanging Oyster Culture Process and the Risks with Ordinary Seed Oysters**

Month	Culture Process		Associated Risks		
June	Gathering Fertilized eggs	Egg Laying	Drought		Red-tides
July	Transplantation		Flood		
August			Typhoon	Fouling orgainism	
Septemeber					
October					
November	Growing		changes in water temperature		
December					
January					
February					
March					
April	Harvest		Drought		
May					Red-tides

crops. Often, this is the worst natural hazard which makes oyster farmers unable to enter the reproduction process. Fouling organisms directly damage to oysters by eating up them while indirectly through lowering the level of nutrient salts.

The last stage of oyster culture is harvest which is carried out between April and May. During this period drought and red–tides often occur and result in large economic losses.

3. The Oyster Culture Process with Hardened Seed Oysters

The oyster culture using hardened seed oysters begins with gathering eggs from the mid of August. Since, however, typhoon usually comes during this season, gathering fertilized eggs involves weather–related risks.

Fertilized eggs are gathered on the hardening boards. The seeds are then trained on the boards for about ten months from August to next May. The rest of the culture process is much similar to that of the culture using ordinary seeds. But the major difference between the two culture processes lies in the length of production period(i.e., from egg gathering to harvest). The former process takes one year while the latter takes two years in production.

III. Risk and Individual Behavior

1. The Expected Utility Hypothesis

Risk and uncertainty are the major ingredient in the expected utility paradigm. Frank Knight(1921) first distinguished between risk and uncertainty on the basis of the amount of information available about the likelihood of outcomes. More specifically, risk requires empirical information to generate probabilities while uncertainty lacks this empirical bases.

When it comes to insurance scheme, an insurance company should be able to predict the statistical probabilities of outcomes with a degree of certainty. In this sense, such phenomena under consideration are classified as risk which is insurable in actuarial sense.

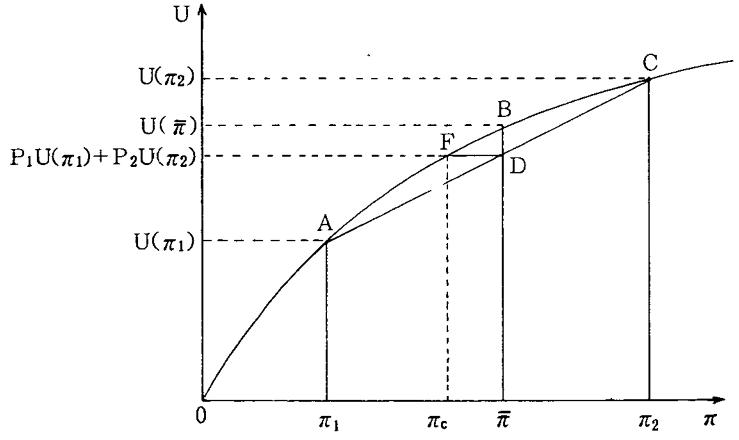
The expected utility approach has been proved useful for analyzing a decision maker's behavior under risky situation and for providing the theoretical bases for insurance policies. The expected utility hypothesis asserts that if a decision maker's behavior is consistent with a set of Newman–Morgenstern axioms. They will weigh outcomes according to a personalized function $U(\pi)$ where π is profit normalized by output price. The expected value of $U(\pi)$ provides the single–valued index which orders action choices according to preferences or attitudes of the decision maker.

If $U(\pi_i)$ is the utility which arises in state i from profit π_i and there are two possible outcomes, expected utility is $P_1U(\pi_1)+P_2U(\pi_2)$ where P_i's($i=$ 1, 2)are probabilities associated with state i and $\sum_{i=1}^{2} P_i = 1.0$. Thus, the previous general function is now assumed to be the expected utility form:

$$(1) \qquad V=(\pi_1,\ \pi_2 : P_1,\ P_2)=P_1 U(\pi_1)+P_2U(\pi_2)$$

Assume that π_2 is greater than π_1. Then the expected profit is $P_1\pi_1 + P_2\pi_2 = \bar{\pi}$. As shown in Figure 1, if an oyster farmer faces state 1, his utility is $U(\pi_1)$. Under state 2 his utiltity is $U(\pi_2)$.

FIGURE 1 **Expected Utility : A Risk–Aversion Utility Function**



To measure this, note that the height of A measures $U(\pi_1)$, and the height of C measures $U(\pi_2)$. So if we bisect the cord AC at D, the height of D measures the average of the two. However, since B bisects the curve AC, it stands directly above the expected profit $E(\pi_i)= P_1\pi_1 + P_2\pi_2 = \bar{\pi}$. Therefore, the height $U(\bar{\pi})$ is a point B on the utility function and lying on a vertical line through D. Since the Newman–Morgenstern axioms imply that the hypothesized utility function is concave from below, $U(\bar{\pi})$ lies above any chord such as ADC but D lies in AC. Therefore, B lies above D.

Now if the oyster farmer is risk-averse, he will be willing to pay to avoid risk. This is the basis of insurance (or mutual aid) program. Suppose in figure 1 that the oyster culturist has an income π_2 but will lose $(\pi_2 - \pi_1)$ when crop is damaged, and he thinks that thers is a $P_1 : P_2$ chance of this occurence. If he does not insure, his expected utility is measured by the height of D. If, instead, someone offerred him a guaranteed income of $(\bar{\pi} - DF)$, he should be equally happy. So he is willing to pay the insurance premium of up to $\pi_2 - (\bar{\pi} - DF) = (\pi_2 - \bar{\pi}) - DF$. This means that he will have transformed the risky prospect into the new prospect which has the same expected utility. On average, the company will pay him π_c, so the profit of the insurance company is DF.

2. The Cost of Risk

It is important to know how much of his expected income the oyster farmer would be willing to sacrifice to an insurer in order to achieve certainty. This requires us to find the certainty–equivalent income (i.e., the certainty income) which gives the same utility as the expected utility of the risky prospect. Thus, the cost of risk can be defined as the difference between the expected value of a risky prospect and its certainty–equivalent income.

The cost of the risk involved in prospect$(\pi_1, \pi_2; P_1, P_2)$ is clearly the distance DF. The more concave the utility function, the greater the cost of risk.

An approximate measure of the cost of risk can be defined by Layard and Walter (1978):

$$(2) \qquad U(\bar{\pi} - CR) = \sum_{i=1}^{N} P_i U(\pi_i)$$

where N is possible states of nature and CR is the cost of risk.

To get measure CR, approximations for both sides of equation (2) are needed. Provided that CR is reasonably small, the left–hand side can be approximated by a Taylor series expansion around $\bar{\pi}$, ignoring the second and higher–order terms:

$$(3) \qquad U(\bar{\pi} - CR) = U(\bar{\pi}) - U'(\bar{\pi}) \cdot CR$$

where U' represents the first derivative of utility function. However, on the right–hand side we need to allow for the possibility that π may on occassions take values that differ quite widely from $\bar{\pi}$. The Taylor series expansion can be applied to the right–hand side of equation (2) as follows:

$$(4) \quad \sum_{i=1}^{N} P_i U(\pi_i) = U(\bar{\pi}) + \frac{1}{2!} U^1(\bar{\pi}) \sum_i P_i (\pi_i - \bar{\pi})^2 + \frac{1}{3!} U^2(\bar{\pi}) \sum_i P_i (\pi_i - \bar{\pi})^3 \\ \vdots \\ + \frac{1}{k!} U^k(\bar{\pi}) \sum_i P_i (\pi_i - \bar{\pi})^k$$

where U^j $(j=1, 2, \cdots, k)$ is the j–th derivative of utility function. Since $\pi_i - \bar{\pi} = Q$ where Q is production quantity, can be written as the moments $(M_r\ ;\ r = 1, 2, \cdots, k)$ of the variable Q:

$$(4') \quad \sum_{i=1}^{N} P_i U(\pi_i) = U(\bar{\pi}) + \frac{1}{2!} U^2(\bar{\pi}) M_2 + \frac{1}{3!} U^3(\bar{\pi}) M_3 \\ \vdots \\ + \frac{1}{k!} U^k(\bar{\pi}) M_k$$

At this point, an important problem is how many moments of the probability distribution of a random variable (i.e., Q) should be chosen to describe production risk with sufficient precision. Kendall and Stuart(1958) suggest that the first three or four moments approximation of a probability distribution often turns out to be remarkably good when a random variable is finite. Several studies (Antle 1983 ; Antle and Goodger 1984; Park 1985; Crissman 1986) show that the first three moment approximation of agricultural output distribution (i.e., mean, variance, and skewness) can provide the sufficient number of risk–related statistical parameters.

Thus, in this research the first three moments of oyster production distribution are considered. The first moment (i.e., mean) is a centeral point of the distribution. The second moment (i.e., variance) is a measure of spread or dispersion. And the third moment is a measure of the asymmetry or skewness of the distribution.

From the equations (3) and (4), the cost of risk can be expressed in terms of Arrow–Pratt absolute risk–aversion coefficient $(-U^2/U^1)$, down–side risk aversion coefficient $(-U^3/U^1)$, and M_2 and M_3 are the second and third moments of the Q probability distrbution:

$$(5) \quad CR \approx -(U^2/U^1) M_2 - (U^3/U^1) M_3.$$

In general, fishermen or sea culturists tend to be much concerned with the down–side risk due to the asymmetric characteristic of crop production distribution (see Day 1965 for detailed explanation about this). The magnitudes of risk–aversion coefficients are empirical questions. In order for the coefficient estimation to be successful, a large body of cross–sectional observations over time is required (Griffiths and Anderson 1982).

3. Risk–pooling

One major mechanism by which the cost of risk is reduced is risk pooling. The gains from risk pooling can be shown without using formal utility theory. Suppose that there is a large number *(n)* of individuals, all of whom face the same risky prospect. Each culturist's income is a random variable with a given distribution (i.e., normal distribution) which is same for all individual oyster farmers. Assume that the distribution of each culturist's income is independent of the distribution of each other culturist's income. If each culturist depends entirely on his own income, there is a risk attached to this which has to be offset against the expected value of his income.

Suppose, however, that the n individual culturists get together and pool their incomes, agreeing that each shall draw the average income out of the pool. The variance in the total of their incomes is of course the same whether the incomes are pooled or not:

$$\text{(6)} \qquad \mathrm{Var}(\pi_1 + \pi_2 + \cdots + \pi_n) = n\mathrm{Var}(\pi)$$

where Var represents variance of π_i.

Since all the incomes are independent and have the same variance. But clearly the variance in individual incomes is greatly reduced. Originally the individual received π_i and his variance was $\mathrm{Var}(\pi_i)$ but now he receives $(\pi_1 + \pi_2 + \cdots + \pi_n)/n$ and the variance of this is

$$\text{(6)} \qquad \mathrm{Var}(\pi_1/n + \pi_2/n + \cdots + \pi_n/n) = n\ \mathrm{Var}(\pi/n) = \mathrm{Var}(\pi)/n$$

which tends to zero as n goes to infinity. Therefore, the cost of risk to the individual oyster farmer tends to zero regardless of the magnitudes of risk-aversion coefficients. Thus, the more culturists join in pool, the better off the individual oyster farmer is. For his expected income is the same whether in the pool or out, but the cost of risk is reduced in the pool so social welfare increases.

Ⅳ. Data Description

The crop production and damage data were collected through the government offices for ten districts–seven in Kyongnam and three in Chonnam.

As of the end of 1985, the total number of oyster culture licenses is 641 which consist of sole ownerships and partnerships. These licenses account for 92 percent of the total. In terms of the culture scale (i.e., Dae), the licenses with 51–100 Dae are 29.2 percent and those with less than 50 Dae 16.7 percent. The rest falls in the scale of more than 100 Dae.

The entire licensed culture area amounts to 5,081 ha, They are distributed over the two areas—Kyongnam(78.3%) and Chonnam(21.7%). Particularly, three main districts (Tongyong, Koje, and Kosong) in Kyongnam account for 70.5 percent. Thus, in 1985 Kyongnam produced 20,177M/T which are 88.7 percent of the crop. In addition, the average productivity of Kyongnam (0.29M/T per ha) is higher than Chonnam (0.18M/T). This productivity difference between the two areas is due mainly to ocean conditions. For example, the deeper water depth in Kyongnam enables oyster farmers to use longer strings.

During the period from 1979 to 1985 the crop damage occurred six times. Among the damage occurrences the 1979—year typhoon caused the largest. The average crop damage in this period was 3.73 percent. Kyongnam recorded 3.32 percent and Chonnam 6.66 percent. In particular, Namhae in

TABLE 2 **The Number of Licenses by Ownership and Culture Scale**

		Total (%)	Kyongnam(%)	Chonnam(%)
		641(100.0)	501(100.0)	140(100.0)
Ownership	Sole ownership	352(54.9)	303(60.5)	49(35.0)
	Partnership	238(37.1)	167(33.3)	71(50.7)
	Cooperative	24(3.7)	22(4.4)	2(1.4)
	Uchonge*	27(4.2)	9(1.8)	18(12.9)
Culture scale	Less than 50 Dae	107(16.7)	106(21.2)	1(0.7)
	51 - 100	187(29.2)	156(31.1)	31(22.1)
	101 - 150	100(15.6)	82(16.4)	18(12.9)
	151 - 200	86(13.4)	67(13.4)	19(13.6)
	201 - 250	31(4.8)	29(5.8)	2(1.4)
	251 - 300	73(11.4)	18(3.6)	55(39.3)
	More than 300	57(8.9)	43(8.6)	14(10.0)

* The mutual aid-and-cooperation organization of fishing villages.

TABLE 3 **Licensed Culture Area, Facilities and Yield**

		Licensed Culture area	Facilities	Total yield	Yield per Facility
Total		5,081.4	83,914	22,751	0.27
Kyongnam	Subtotal	3,976.2	69,354	20.177	0.29
	Chungmu	150.7	3,456	1,083	0.31
	Tongyong	1,435.9	23,474	8,374	0.36
	Kosong	980.3	18,806	4,286	0.23
	Koje	1,168.0	20,225	5,279	0.26
	Namhae	226.6	3.145	1,104	0.35
	Uichang	10.7	208	44	0.21
	Hadong	4.0	40	7	0.18
Chonnam	Sub total	1,105.2	14,560	2,574	0.18
	Ryusu	84.5	1,690	346	0.20
	Ryuchon	745.0	7,450	1,565	0.21
	Kohung	275.7	5,420	663	0.12

TABLE 4 **Crop Damage Loss**

		Total	1979	1981	1983		1985		Average Crop damage
			Typhoon	Red-tide	Change in water temperature	Flat-insect	Red-tide	Typhoon	
Total		5,263.7	1,833.3	371.9	836.9	340.6	166.0	562.0	3.32
Kyong-nam	Sub total	4,110.7	1,833.3	371.9	836.9	340.6	166.0	562.0	3.32
	Chungmu	274.2	64.8	-	-	43.4	166.0	-	4.17
	Tongyong	1,373.3	634.5	322.0	118.4	155.4	-	143.0	2.80
	Kosong	605.1	348.5	49.9	155.9	51.0	-	-	1.99
	Koje	1,394.1	785.7	-	98.6	90.8	-	419.0	4.22
	Namhae	464.0	-	-	464.0	-	-	-	8.95
	Uichang	-	-	-	-	-	-	-	0.00
	Hadong	-	-	-	-	-	-	-	0.00
Chon-nam	Sub total	1,153.0	-	-	-	1,153.0	-	-	6.66
	Ryusu	190.0	-	-	-	190.0	-	-	8.23
	Ryuchon	963.0	-	-	-	963.0	-	-	8.79
	Kohung	-	-	-	-	-	-	-	0.00

Kyongnam and Ryusu and Ryuchon in Chonnam were the most severely affected areas.

V. The Requisites for the Insurance (or Mutual Aid) Program and Their Examination

The insurance policy of hanging oyster culture is a sort of market commodity. The insurer is going to maximize profit while the insured to pay not too high price (or risk premium). Even if the insurance policy is carried out under the public institution or government, the economic logic is very similar.

In order that the insurance policy exists in the market as a commodity, the following requisites must be met: (i) existence of insurable risks, (ii) the holding of the law of large numbers, and (iii) the measurability of crop loss.

1. Existence of Insurable Risks and the Law of Large Numbers

The first requirement for insurance (or mutual aid) program is that the risks which the insured must avoid should exist. Unfortunately, all risks are not insurable. In fact, insurance relies upon the law of large numbers (i.e., risk -pooling and reasonable measure of loss probability) as a basis for its economic operation. There are many situations that can lead to the insurer's loss where the law of large numbers does not work out satisfactorily. Such insurance risk affects both the insurer and the insured. Fron the insurer's point of view, first, the crop damage must be of sufficient numbers and quality to allow a reasonably close computation of the loss probability. If only a few loss events are coverd, the insurer is subject to the same uncertainties of random experience as the insured. Since risk varies inversely with the square root of the number of loss events exposed and with changes in the probability of loss, the insurer attempts to obtain sufficient numbers of exposed units so as to reduce its risk to the minimum.

Second, the loss should not be intentional but accidental. This requirement allows the insurer to normally exclude any loss caused intentionally by the insured. If the insured knew that the insurer would pay such losses, a moral hazard would be introduced, and there would be a tendency for losses and premiums to rise. If premiums becomes exceedingly high, few would purchace insurance so the insurer would no longer get suffieiently large numbers of exposure units to be able to obtain a reliable measure of future loss. Thus, the first requirement of an insurable risk would not be met.

Third, conditions should not be such that all or most of the culturists might suffer loss at the same time and possibly from the same peril. For example, in certain areas, typhoon may flatten entire oyster culture facilities within a very short time period. In this case, the insurer can reduce this possibility by ample dispersion of insured crops.

On the other hand, from the standpoint of the insured the two main requirements of insurable risks are that the potential loss must be severe enough to cause financial hardship and that the probability of loss must not be too high. The first requisite implies the insured tend to seek protection against crop losses that can not be safely absorbed out of current incomes or savings. While the second suggests that if the loss probability is too high, the risk premium will be greater so the cost of the premiun will become prohibitive to the insurance policy.

A. The Probability Measure of Oyster Damage Loss

The hanging oyster culture business in Korea is subject to the government license system due mainly to a strong commom property nature of ocean resources. Since the early of 1970, the oyster culture development has been well supported by the rapid progress in culture technologies.

In spite of the rapid development of oyster culture technologies, the oyster farming has been often exposed to severe natural hazards. Most production risks are caused in large by red-tides, typhoons, and flat insects. The probability of crop loss contributed by such natural hazards can be measured in terms of the number of licenses with crop damage (DL) and the total number of licenses by year TL. Letting DP be the crop loss production, we can write DP as follows;

$$(7) \qquad DP = DL / TL$$

Since, however, the damage data are available only between 1979 and 1985, the estimate of the loss probability may well be biased. To reduce the bias problem, a data adjustment was made. Defining the adjusted loss probability as DP'. DP' can be written as

(7′) $$DP'=\sum_{i=1}^{7}DL_i / \sum_{i=1}^{7}TL_i \quad (i=1(1979),\cdots,7(1985))$$

Applying the damage data to the formula (7′), we found that the probability estimate of the oyster loss is equal to 0.0674 (about 6.7%). This result implies that the loss probability in terms of the license numbers with damage is somewhat high during the period from 1979 to 1985.

B. The Rate of Crop Damage

Another way to confirm the existence of insurable risks is the calulation of crop loss rate. The rate of crop loss can be computed by the ratio of crop loss quantity to normal yield. Let crop loss be *LR*. Now, *LR* can be formulated as follows:

(8) $$LR=(LY/NY \text{ (or } AY+LY))\cdot 100$$

where NY: normal yield ; AY: actual yield ; LY : crop loss. During the given period, only four years(1979, 1981, 1983, and 1985) suffered actual crop loss. From equation (8), the *LR's* were computed. The districts (cities and kuns) ranged from 0 to 8.95%. While the bays showed the range from 0 to 16.37%. These results suggest that the oyster crop insurance program should place more consideration on the bays than the districts.

C. The Number of Exposure Units Sufficient for Oyster Insurance Program

An important question to the insurance institution is how large an exposure is necessary before a given degree of accuracy can be achieved in obtaining an actual loss frequency that is sufficiently close to the expected frequency. This questions is also related to the risk-pooling mechanism. Through this mechanism the insurer can reduce the insurance costs and may set reasonable risk premiums acceptable by the insured.

A mathematical formula (Green 1977) is available, which enables us to estimate the number of exposures required for a given degree of accuracy:

(9) $$N=[S^2P(1-P)]/e^2$$

Where N is the number of exposure units sufficient for a given degree of accuracy; P is the percentage of crop loss; S is the number of standard deviations of the distribution;e is the degree of accuracy required.

The formula is based on the assumption that losses in an insured population have a normal distribution. This formula concerns only the occurrence of crop loss. The estimation results using the formula are presented in Table 5.

As shown in table 5, the 629 exposure units can give the insurer 98% confidence with two standard deviations. This would be sufficiently large number of exposures, comparing the estimated units with the total number of the hanging oyster licenses, 641, as of the end of 1985.

TABLE 5 **The Number of Exposure Units Required for a Given Accurcy**

S	e			
	0.01	0.02	0.05	0.10
1	629	157	25	6
2	2,514	629	101	25
3	5,657	1,414	226	57

2. The Measurability of the Insurable Risks

This is one of the important requirements for the oyster culture insurance. The loss must be definite in time and place. Also, most losses should be easily recognizable and are capable of being measured with reasonable accuracy. It is extremely important to insurer since all payments are made entirely based on the measured data information of crop loss.

As mentioned in the previous sections, the major risk factors in oyster culture include red–tides, flat insects, and typhoons. Thus, the confirmation technologies for crop damage is described in terms of the sampling method and the derivation of measurement formula.

A. The Causal Investigation of Red Tides

The crop losses related to red–tides can be investigated by the following ways: eyes, density of organisms causing red–tides, and ocean–nutrient levels. The eye observations are most widely used. The following presents the three measurement methods concisely:

— The measurement by eyes; observations of water colors.

— The microscopic measurement :

Scale	Density
Occurrence covering the area wider than $79km^2$	○ single type - diatom $> 10^4$ cell/ml - flogellates $> 10^3$ cell / ml (chattonella $> 10^2$ cell / ml) ○ mixed type - total organism density $> 2 * 10^5$ cell / ml with flogellates > 50%

- The ocean-nutrient level measurement:

Factor	Ocean nutrient level		
	excessive	rich	poor
○ floating phyto plankton(cell/ml)	$3 * 10^3(+)$	$3 * 10 - 3 * 10^3$	$3 * 10(-)$
○ COD(mg/*l*)	7 − 10	1 − 7	1(−)
○ total nitrogen(ug-al/*l*)	10 − 30	30 − 80	80 − 100
○ total phosphate(ug-al/*l*)	3(+)	0.15 − 0.3	0.15(−)

B. The Confirmation of Typhoons

Typhoons are the most destructive natural hazard which often gives the oyster culturists large capital loss. Weather forecastiong in Korea are made by the Korean Central Meteorological Observatory(KCMO). The criteria of storms, typhoons, and storm waves are set as follows :

Storm	Typhoon	Storm waves
○ average max. wind velocity (or instantaneous max. wind velocity) is 21 m/sec(+) (or 26m/sec (+)) ○ the duration is longer than 3 hrs	○ the nearest coastal region from the typhoon center is situated within 500 km ○ substantial damage expected	○ the submersion of coastal regions due to sea-quakes or other causes ○ the resulting damage is expected substantial

Since these criteria provide both the insurer and the insured with the objective information about radical changes in weather conditions, storm (including typhoon and storm waves) occurrence itself may not raise serious problems in the process of insurance policy implementation.

C. The Investigation of Flat Insect Damage

Flat insects have a very strong nature of population dynamics. Thus, once the insect population reaches a threshold level, the spreading–out effect covers a wide range of culture area. The southern part of oyster culture experienced large crop losses in the past. Flat insects attach themselves to oyster shells and make holes on them. Through the holes they eat up the inner material of oysters, or they enter the inside of oysters and live there until harvest.

When they occur in a large scale over the culture area, oyster farmers may harvest a plenty of empty shells and thus face severe economic losses. The damage investigation can be made in two ways:one method is the oyster shell examination by eyes;another is the microscopic estimation of the insect population in the culture area.

D. The Measuring Process of Crop Damage

The crop damage from typhoons, flat insects, and red–tides occurs in general over a wide range of culture area due mainly to the oceanic characteristics. Thus, the damage measurement requires a large amount of labor and equipment. To reduce the costs associated with the resources the stratified sampling techniques may be a useful method for measuring crop damage. In order to apply this sampling method the affected area first should be divided into three parts in the same proportion: outside, central area, and inside.

The crop damage rate of each area can be measured in terms of the number of facilities (i.e., $Dae = 100$m):

$$(10)\qquad TDF = [SDF/SF]\cdot TF$$

Where TDF is damage rate; SF is sample facilities; SDF is damaged facilities out of the samples;TF is total number of facilites. To obtain the more accurate damage rate, crop damage per facility must be calculated in terms of the number of collectors. Letting the per facility *(Dae)* damage rate be TDC, we can express TDC in terms of the number of confirmed damaged facilities *(N)*, the number of sample strings per facility *(SG)*, the total number of strings per facility *(TG)*, and the number of collectors per standard facility (20^*):

$$(11)\qquad TDC=[\sum_{i=1}^{N}(\frac{SDC_i}{SG_i\times 20^*})/N]\times TG\times 20^*$$

From the equations (10) and (11), the damage rate for each area is computed in tems of the number of damaged collectors (see Figure 2 for details about the facility components).

VI. Summary and Conclusions

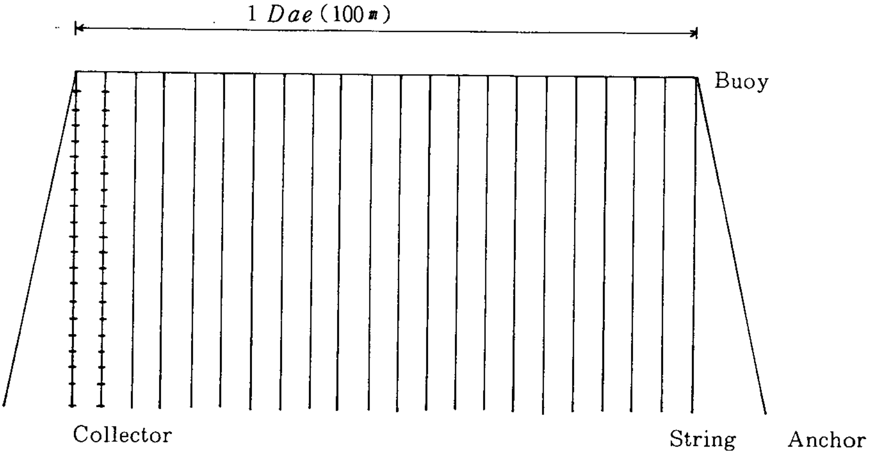
The main objective of this research is to study a feasibility of insurance (or mutual aid) program of oyster culture. The analysis is based on the investigation of the requisites for insurance program.

Six–year crop damage data were collected for ten districts-seven in Kyongnam and three in Chonnam. A theoretical model was developed to show individual behavior and risk–pooling mechanism under sea–culture production risk.

The empirical results of the insurance requisite tests show: (i) 629 exposure units to culture risks are required for the risk-pooling under the law of large numbers; (ii) the measuring technologies of crop damage are available at present. The first result implies that since the 1985–year total number of oyster culture licenses is 641, in order for the insurance policy to be successful almost culturists should buy the insurance and thus compulsory insurance scheme must be employed. The second result reflects the technical feasibilty which allows the insurer to get accurate information about crop damage, necessary for payments. In addition, the well–established measuring technologies may help the insurer avoid moral hazards from the insured.

An important limitation of this research is the use of the relatively small number of damage records. It also should be noted that the results are oyster culture–specific, so they cannot be generalized to other crops.

FIGURE 2 **The Facility Components of Hanging Oyster Culture : 1 Dae**



REFERENCES

Knight, F.H., 1921. *Risk, Uncertainty and Profit.* Houghton Mifflin Co., Boston, Mass.

Layard, P.R.G., 1978. *Microeconomic Theory.* McGraw–Hill, Inc.

Antle, J.M., 1983. "A Flexible Moment–Based Approach." *J. of Bus. and Econo. Stat.* (3). 192–201.

Antle, J.M. and W.J. Goodger, 1984. "Measuring Stochastic Technology:The Case of Tulare Milk Porcuction." *Amer. J. Agri. Econ.*(66), 342–350.

Park, S.K., 1985. "Economic Measurement of Pest Management Technology:Risk and Economics of a Worm Monitoring Program for Processing Tomato production in The Sacramento Valley." Ph.D. Dissertation, Univ. of California, Davis.

Crissman, C.C., 1986."Production Risk, Risk Attitudes and the Adoption of Modern Rice Varieties in the Philippines." Ph.D. Diss. Univ. of California, Davis.

Griffiths, W.E. and J.E. Anderson., 1982."Using Time–Series and Cross–Section Data to Estimate a Production Function with Positive and Negative Marginal Risks."*J. the Amer. Statis. Assoc.*(77). 529–536.

Day, R.H., 1921."Probability Distributions of Field Crop." *J.Farm Econ.*(47).713–741.

Greene, M.R., 1977. *Risk and Insurance* (4th ed). South–Western Pub. Co.