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Estimation of Dredge Sampling Efficiency for Blue Crabs in Chesapeake Bay

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Using a successive removal approach the mechanism of sampling capture efficiency of blue crabs by dredges was studied in Chesapeake Bay during winter 1992. For the twenty-six field experiments no significant statistical differences were detected in dredge efficiency using general linear model analysis by factors including bottom sediments, water depths, and sampling vessels. Dredge efficiency (i.e., catchability) was estimated by two methods, Leslie (Leslie and Davis, 1939) and a simple revised method. Mean catchability was estimated at 0.26 (SE=0.03), indicating that only 26%(95% C. I.=20~32%) of crabs present in the path of the dredge of a given sampling area are caught with a single dredge tow. Dredge efficiency declined exponentially as crab density increased.

Introduction

Blue crabs *Callinectes sapidus* (Rathbun) comprise important commercial and recreational fisheries in Chesapeake Bay. Landings for both Maryland and Virginia combined have been fairly stable during the past decade, averaging abount 90 million pounds (Anon, 1990). To maintain the blue crab stock at a high level and to achieve sustained resource use, reliable scientific knowledge concerning both stock abundance and population dynamics of blue crabs is required for management.

Blue crabs are a portunid or swimming crab. During the warm-water months (April-November) blue crabs are distributed throughout the water column over a wide spatial distribution of Chesapeake Bay, while during the winter months (December-March) blue crabs quasi-hibernate in the bottom sediments of Chesapeake Bay. The quasi-hibernation behavior was used to facilitate sampling the population to estimate abundance, and thus a winter baywide fishery-independent sampling program was established in 1989 (Rothschild *et al.*, 1991).

In the winter survey commercial crab dredges were employed as the sampling gear. This choice was predicated on observations by Orth and van Montfrans (1987) that bottom trawls were less than one percent efficient for capturing blue crabs during winter. Presumably, bottom trawls are ineffectual because crabs are buried in the substrate at this time. However, the dredge is known to be a good sampling gear for bottom dwelling shellfish species, such as oysters, clams and scallops (Caddy, 1989), and is the principal commercial gear used in the Virginia winter blue crab fishery.

In fact, preliminary observations suggested that the dredge might be inefficient in removing all crabs from a given area, and that the catchability might be less than 50 percent (Rothschild *et al.*, 1991).

In this paper we describe a comprehensive study of the dredge capture efficiency, and analyze the efficiency by physical factors which may affect blue crab capture.

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Materials and Method

Experimental design

Four steps are involved in development of an appropriate sampling design for estimating blue crab population abundance using data from the winter dredge survey: 1) measure crab numbers per unit-tow area; 2) estimate sampling gear efficiency; 3) estimate overwintering habitat area; and finally, 4) calculate absolute population abundance and its variance. Therefore, reliable population abundance estimates require absolute knowledge of dredge capture efficiency, because if the gear is less than 100 percent efficient then the abundance estimates must be corrected by the appropriate factor.

In winter 1992 an experiment to determine dredge capture efficiency was conducted by scientists from the University of Maryland's Chesapeake Biological Laboratory (CBL) and the Maryland Department of Natural Resources (MDNR) using two chartered commercial dredge vessels. A standard Virginia crab dredge, which has 1.83*m* in width and lined with hexagonal chicken wire mesh (12.7*mm*) was used. The gear is persumed to exhibit 'knife-edged' selectivity for crabs>15*mm* carapace width (Sulkin and Miller, 1975).

We used a successive removal method for estimating both gear efficiency and area-specific abundance. The procedure involves continuous dredging (i.e., removal) of crabs in a designated area until all crabs present are captured.

Bottom sediment type, depth, and crab density may correlate with one another. It was recognized that bottom sediment tended to be comprised of a higher proportion of fine particles (i.e., mud) as water depth increases, and crabs preferred muddy bottoms to sandy bottoms (Rothschild *et al.*, 1991). We used general linear model analysis of our 1989~1991 winter dredge survey data to examine the relationships between crab abundance and physical variates. The analysis suggested that sediment types could be divided into two classes, that is, 0~80% and 80~100% gravel-sand (GS) compositions, and that crab abundance was higher in the 0~80% GS areas.

For our efficiency experiments, we isolated our samples to the high abundance areas (0~80% GS) and broke this into two smaller categories: 1) 0~20% GS, and 2) 20~80% GS. Depth was divided into two categories, that is, 5~23 feet and >23 feet. The depth 23 feet was selected since it was the median depth of Chesapeake Bay, based on the survey results from the 1991 winter dredge survey data. Therefore, we allocated dredge efficiency experiments by two factors, i.e., bottom sediment compositions and depths.

To determine the most efficient sampling design for the track numbers and stopping rule criteria, we developed a Monte Carlo computer simulation program (Endo, 1992). Based on the results of the simulations, we determined the three-track experiment with a maximum of eighteen tows (six runs) to be the best design to employ.

Field sampling method

Based on the experimental design by sediment composition and depth factors, we selected enough extra candidate sites where we obtained a good catch (more than seven crabs per tow in most cases) using previous survey data. We have experienced through previous surveys that the experiment was considerably affected by the weather condition, and also that moderately high crab densities were required for the successful experiment.

Before each experiment, we performed several test tows to determine whether the density of crabs were adequate for the experiment. If we could not find enough crabs, we moved to another possible site. The test tow was also performed for determining the best location within a given site.

After an adequate experiment site was found, a sampling area of 100*m* in length and 5.49*m* in width was marked off (Figure 1). Anchored buoys were placed on the corners of the sampling area allowing 2*m* margin (one-half of the sampling vessel's beam) on either side.

We dredged each track redundantly in random order. Each successive tow was made in an opposite direction. Each dredging experiment was stopped either when three consecutive tows yielded zero crabs, or when six runs (18 tows) were completed.

Data collected in each experiment were the number of crabs captured per tow, length, sex, and maturity of each crab, minimum and maximum depth of the area dredged, air and water temperature, and salinity. A sediment sample was taken from each experimental location to complement existing sediment composition data which were collected both in the previous surveys and obtained by the Environment Protection Agency of the United States.

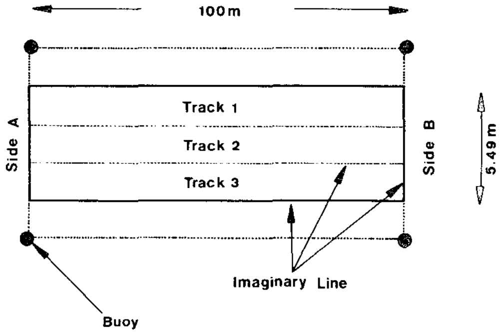

Fig. 1. Schematic diagram of the sampling area for crab dredge capture efficiency experiments in the Chesapeake Bay, winter 1992.

Models employed

We modified the standard "Leslie model" (Leslie and Davis, 1939) slightly to estimate dredge catchability. The Leslie model is based on the basic assumption that catch per unit effort (CPUE) at a given time t (C_t/F_t) is linearly pro-portional to the population present at time t (N_t):

$$\frac{C_t}{f_t} = qN_t \qquad (1)$$

where q is the constant of proportionality, or catchability coefficient. This equation means that CPUE decreases as a population becomes depleted, and the amount of decrease reflects the extent of the depletion. N_t is equal to the initial population (N_o) less cumulative catch to the start of the interval (K_t):

$$N_t = N_o - K_t \qquad (2)$$

Then, from equations (1) and (2) the Leslie model becomes,

$$\frac{C_t}{f_t} = qN_o - qK_t;\ K_t = \sum_{i=1}^{t-1} C_i \qquad (3)$$

In our modified model we defined a sample run to be three-track dredging as a sample unit for our experiment rather than one-track dredging. If one run (one coverage of the sampling area) is one unit of effort, the model can be expressed as

$$\sum_{j=1}^{m} C_{ij} = q\sum_{j=1}^{m} N_{0j} - q\sum_{k=1}^{i-1}\sum_{j=1}^{m} C_{kj} \qquad (4)$$

where C_{ij} is the catch from j-th track in i-th run, m is total number of tracks in the sampling area (in our case $m=3$), N_{0j} is the initial population size present in the j-th track of sampling area at the start of the experiment, C_{kj} is the catch from j-th track in k-th run, and q is the catchability coefficient, which is the average fraction of the population removed by one tow. $\sum_{j=1}^{m} N_{0j}$ and q are estimated by a simple linear regression from equation (4). Assumptions required for the above method are as follows: first, no natural mortality, no recruitment, no immigration and emigration; second, all individuals have the same probability of being caught; third, units of effort are constant; fourth, CPUE is linearly proportional to abundance with constant catchability.

The first assumption is equivalent to saying that the population is closed and the experiments are conducted during a short period. Since blue crabs overwinter in a quasi-hibernating state in the bottom sediments during the winter months, we can consider the winter population of blue crab as a closed population. Also, our efficiency experiment is performed within a short time period, like a few hours.

The second assumption indicates no size selectivity. Howerver, we used a dredge lined with 12.7 *mm* wire mesh, which is known to be roughly knife-edged selective for crabs>15*mm* carapace width.

In our experiments, a prescribed area was sampled until almost all the crabs were removed. Each complete coverage of the prescribed sampling area can be considered as one unit of effort (one experimental run). We considered three aspects of our experimental method to fit the assumption of constant unit of effort: (i) randomizing the order of tow tracks; (ii) performing each successive tow in the opposite direction; and (iii) considering each coverage of the sampling area (three-track dredging) as one unit of effort. Both (i) and (ii) reduce the dependence between consecutive dredge tows. Aspect (iii) accounts for the fact that, in contrast to fish swimming in the water, quasi-hibernating crabs in the sediments will not redistribute and remain constantly within the sampling area after each dredge tow.

However, for the fourth assumption we were not sure whether CPUE is still linearly proportional to abundance with constant catchability when the abundance is very high. If this assumption is not satisfied, the output of the linear regression model is not statistically significant, possibly resulting in negative catchability coefficients. In this case we revised the above Leslie equation, which is based on the number of crabs caught from the first run ($\sum_{j=1}^{m} C_{1j}$) and the initial population number ($\sum_{j=1}^{m} N_{0j}$)

$$q=\frac{\sum_{j=1}^{m} C_{1j}}{\sum_{j=1}^{m} N_{0j}} \tag{5}$$

To obtain $\sum_{j=1}^{m} N_{0j}$ we calculated the average proportion of the initial population number to the total catch ($\overline{w}$) as

$$\overline{w}=\frac{1}{n}\sum_{1=1}^{m}\frac{\sum_{k=1}^{i-1}\sum_{j=1}^{m} C_{kj_1}}{\sum_{j=1}^{m} N_{0j_1}} \tag{6}$$

where $\sum_{j=1}^{m} N_{0j_1}$ are estimates of the initial population number for the 1-th experiment which were obtained from statistically significant Leslie model, assuming that the fourth assumption is valid applying Leslie model for these cases, $\sum_{k=1}^{i-1}\sum_{j=1}^{m} C_{kj_1}$ are total number of crabs caught by the 1-th experiment, and then we calculated $\sum_{j=1}^{m} N_{0j}$ dividing the total catch by $\overline{w}$.

We needed to determine whether estimated catchabilities could be combined by sediment types, by depths, or by any combination of the two factors for estimating blue crab population abundance.

However, the fishing power of vessels was also important since there was difference in horse power (HP) between the two vessels used for our experiments, that is 450 HP and 320 HP. Therefore, we desired to determine if there was any difference in catchability between vessels. We set up a general linear model for testing differences in catchability by the three factors and their interactions as:

$$Y_{ijk}=u+a_i+b_j+c_k+ab_{ij}+bc_{jk}+ac_{ik}+e_{ijk} \tag{7}$$

where, Y_{ijk} = catchability for

a_i = ith sediment type,

b_j = jth depth,

c_k = kth vessel.

And u is overall mean catchability, and e_{ijk} is random error. We tested the null hypothesis (Ho) using GLM procedure of SAS/STAT software (SAS Institute Inc.) as

$$Ho:\ a_i=b_j=c_k=ab_{ij}=bc_{jk}=ac_{ik}=0 \tag{8}$$

at the 5% critical level. We performed stepwise backward tests by dropping the least significant factor.

We also examined changes in catchability with respect to crab density. Assuming that catchability decreases exponentially as the crab density increases, that is,

$$\frac{dq}{dN}=-bp \tag{9}$$

By separating variables and integrating both sides, and putting the initial condition as, $N=0$, $q=q_o$, we get the following equation.

$$q(N)=q_o e^{-bN} \tag{10}$$

where, b is instantaneous coefficient of decrease in the catchability with respect to crab densities. Using the estimated catchabilities (q) and the initial numbers of crabs (N_0), we estimated the coefficient b by linearizing equation (10), and tested for the null hypothesis (Ho) that the coefficient is zero (Ho: $b=0$), suggesting no density-dependent catchability.

Results

From January through March, 1992, we conducted a total of twenty six dredge capture experiments by considering two factors (Table 1). In the sediment factor we made similar experiments for each group, however, in the depth factor we made more experiments in shallow areas (nineteen) than in deep areas (seven).

Figure 2 shows typical plots of the number of crabs caught per run versus cumulative number of catch, which were arbituarily selected from the twenty six experiments. Data points in the right panels were highly variable, however, those in the left panels showed apparently decreasing trends in the number of crabs per run with the cumulative crab catch, indicating favorable fits to the modified Leslie model.

Table 1. Blue crab winter dredge capture efficiency experiments by bottom sediments and depths conducted during winter 1992.

Sediment (%gravel-sand)	Depth (ft) Shallow (≤23)	Depth (ft) Deep (>23)	Depths Combined
0~20	9	3	12
20~80	10	4	14
Sediments Combined	19	7	26

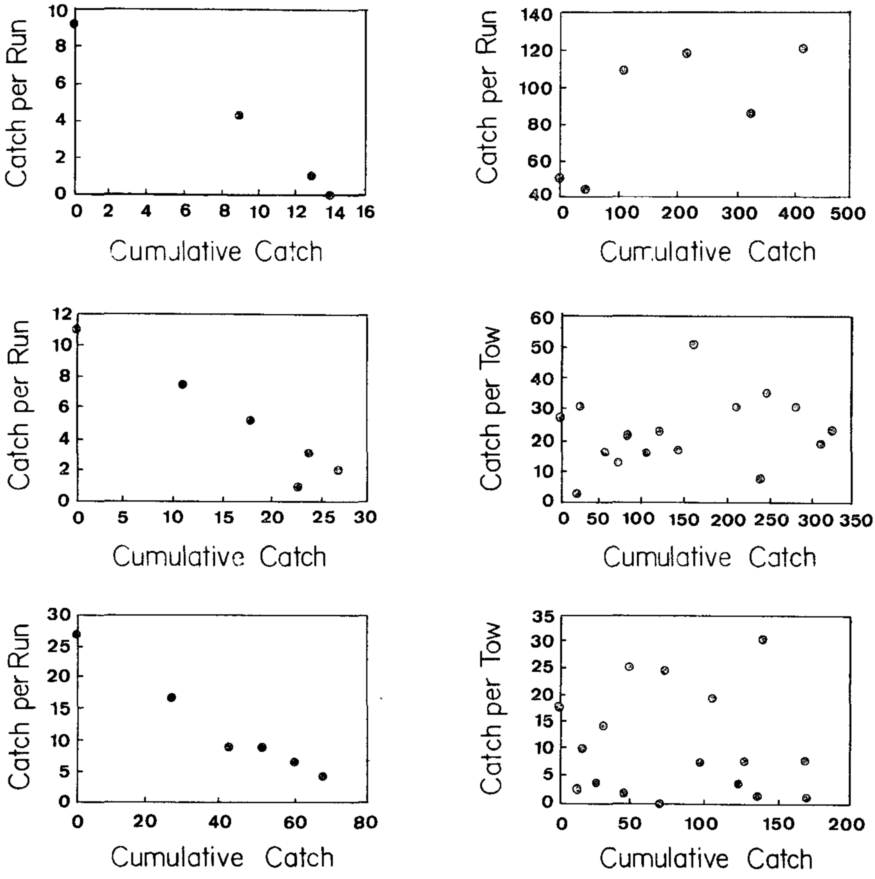

Fig. 2. Typical plots of number of crab catch per run versus cumulative crab catch from dredge capture efficiency experiments in the Chesapeake Bay in winter 1992. Left panels show good fits for the Leslie model, while right panels show poor fits.

The number of runs for each experiment ranged from four to six, in which the maximum run has been fixed at six (Table 2). Experiments were stopped for eight cases before six runs, that is, three cases with four runs and five cases with five runs, since no crabs were caught with three consecutive tows.

The total catches from three tracks of each experiment varied, and it was less than 100 crabs for more than half of the experiments, ranging from 14 to 518 crabs. As we expected, 11 out of 26 experiments (42%) were not significant for the modified Leslie regression at the 5% level, which resulted in unrealistic estimates of catchabilities and the initial number of crabs. Catchability estimates from the modified Leslie method ranged from 0.11 to 0.66 for the fifteen experiments which were statistically significant for the method, while those from the revised method ranged from 0.10 to 0.42 for all twenty six experiments (Table 2). Figure 3 shows relationships of catchability estimates (upper panel) and initial number estimates (lower panel)

Table 2. Information on 1992 blue crab dredge capture efficiency experiments and catchability estimates from the modified Leslie and its revised method.

					q estimates		N_0 estimates	
Vessel	Depth	Sediment	No. Run	Catch	Leslie	Revised	Leslie	Revised**
A	Shallow	0-20 GS	6	170	0.108	0.141	310	199
〃	〃	〃	6	76	0.451	0.382	75	89
〃	〃	〃	5	76	0.658	0.573	76	89
B	〃	〃	4	14	0.631	0.563	15	16
〃	〃	〃	6	37	0.283	0.302	43	42
〃	〃	〃	6	131	0.169	0.196	197	153
〃	〃	〃	6	36	0.261	0.214	43	42
〃	〃	〃	6	45	*	0.089	*	53
〃	〃	〃	4	19	*	0.421	*	22
A	〃	20-80 GS	6	79	0.150	0.183	127	93
〃	〃	〃	5	106	*	0.226	*	124
B	〃	〃	5	59	0.420	0.348	64	69
〃	〃	〃	6	48	0.358	0.357	50	56
〃	〃	〃	5	36	0.377	0.310	41	42
〃	〃	〃	6	129	0.282	0.252	148	151
〃	〃	〃	6	119	*	0.227	*	139
〃	〃	〃	6	128	*	0.125	*	150
〃	〃	〃	4	25	*	0.160	*	29
〃	〃	〃	6	159	*	0.226	*	186
A	Deep	0-20 GS	6	29	0.356	0.324	31	34
〃	〃	〃	5	235	0.219	0.258	333	275
〃	〃	〃	6	54	*	0.185	*	63
〃	〃	20-80 GS	6	518	*	0.099	*	607
B	〃	〃	6	137	0.312	0.281	148	160
〃	〃	〃	6	352	*	0.173	*	412
〃	〃	〃	6	179	*	0.112	*	210

* represents nonsignificant experiments for the modified Leslie regression ($\alpha=0.05$).

** denotes estimates from the revised method, using $\overline{w}=0.854$.

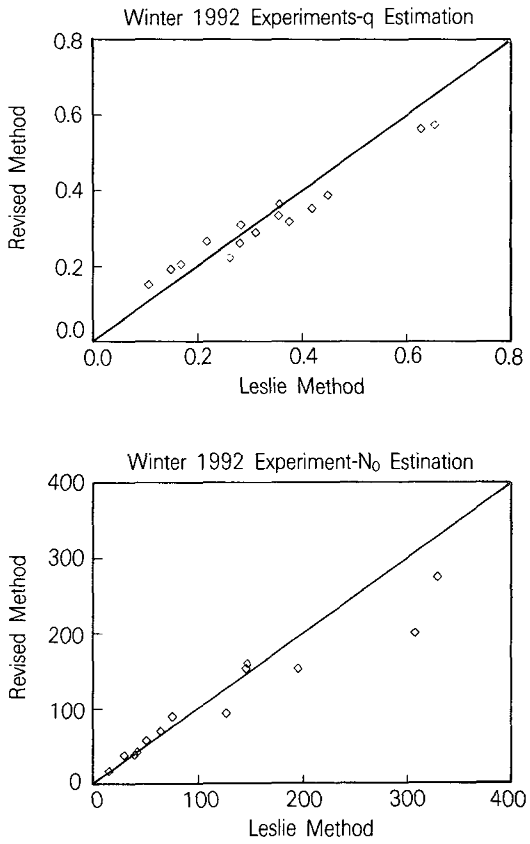

Fig. 3. Comparisons of catchabilities and initial numbers estimated from the Leslie and the revised methods.

between the Leslie and revised method, for the experiments which were statistically significant with Leslie method. The two methods generally yielded similar catchability estimates, though more data points were below the 45 degree line, suggesting the revised method produced lower estimates than Leslie method. A different pattern was identified in initial number estimates by the two methods, since catchabilities are inversely related to the initial numbers, that is, more data points above the 45 degree line. Also, the agreement in the initial number estimates by the two methods was fairly good. Therefore, we used the catchability estimates from the revised method as complements for those cases which were statisticaly non-significant with Leslie method. The overall mean of the twenty six estimates of catchability by the two methods was 0.26 with a standard error of 0.03.

According to tests of difference in catchability by three factors and their interactions, no statistically significant difference was detected for the null hypothesis of equation (8) from the full model (equation (7)). The statistics of the test showed that the sediment-vessel interaction factor was the least significant, and the vessel factor was the next significant (Table 3). The difference in mean catchabilities between two vessels were almost negligible at 0.261 and 0.259. The sediment factor was

Table 3. Results of general linear model tests for differences in dredge catchability by sediment, depth, vessel, and their interactions.

Source	DF	SS (Type I)	Mean Square	F Value	Pr > F
Sediment	1	0.0532	0.0532	2.16	0.1578
Depth	1	0.0354	0.0354	1.44	0.2450
Vessel	1	0.0001	0.0001	0.00	0.9582
Sed*Depth	1	0.0000	0.0000	0.00	0.9883
Sed*Vessel	1	0.0396	0.0396	1.61	0.2197
Depth*Vessel	1	0.0001	0.0001	0.00	0.9498

Level	Category	Sample Size	Mean	SE
Sediment	0-20 GS	12	0.3086	0.1860
	20-80 GS	14	0.2179	0.1116
Depth	Deep	7	0.1960	0.1049
	Shallow	19	0.2832	0.1651
Vessel	A	9	0.2611	0.1824
	B	17	0.2590	0.1435

the most significant, even though it was not statistically rejectable at the 5% significance level. The mean catchabilities were more or less different between two sediment types with 0.309 for the 0~20 % gravel-sand type and 0.218 for the 20~80% gravel-sand type, as well as between two different depth categories with 0.283 for shallow water areas and 0.196 for deep water areas. When we proceeded with stepwise backward tests, dropping the least significant factor one by one, we could not obtain any significant difference. The test for the difference in catchability between sediments which was the most significant factor from the full model test, was also not significant at the 5% critical level with a higher probability ($p=0.138$).

To examine changes in catchability with respect to crab density we plotted estimated catchabilities (q) versus estimated initial number of crabs (N_0) (Figure 4). There was apparently a negative relationship between them. The result of the test for $b=0$ null hypothesis was highly significantly rejected ($p<0.005$), suggesting density-dependent mechanism of catchability by crab dredge.

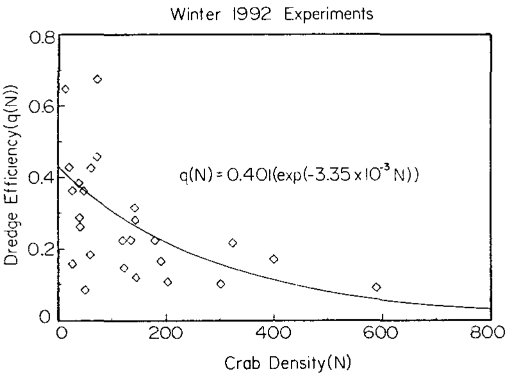

Fig. 4. Relationship between dredge catchability and crab density in the Chesapeake Bay during winter 1992.

Discussion

Knowledge of crab dredge catchability is essential to properly estimate crab population abundance. Even though we have accurate and precise estimates of crab density from a well-designed dredge survey, without this catchability information we can not get an absolute estimate of crab population abundance which is necessary basic information for crab population management.

Overall dredge catchability (q) may be defined as the products of gear selectivity (s), capture efficiency (e), and vertical vulnerability (v) by dredging, where gear selectivity (s) is the proportion of number of crabs caught to number of crabs entering the dredge, capture efficiency (e) is the proportion of number of crabs entering the dredge to number of crabs in the dredging layer (dredging depth) with respect to the dredge bottom contact, and vertical vulnerability (v) by the dredge is the proportion of number of crabs in the dredging layer to number of crabs in the dredge path which are not reached by a single dredging. Therefore, for understanding the overall dredge catchability, intensive investigation should be essential including knowledge on crab distribution and behavior as well as physical mechanisms of dredge operation.

In our study we used the quasi-hibernating behavior of crabs in winter to enable us to make sure of the immobility of crabs to estimate capture efficiency (e) clearly. We also have information on gear selectivity (s) for crabs by dredge, and thus we did not worry about this factor. However, we were not sure whether most crabs distribute in the depth layer for a single dredging, which can affect vertical vulnerability (v). Therefore, the two factors, i.e., efficiency and vulnerability, were only considered for our catchability estimation.

For evaluating methods we adopted for catchability estimation, we have to examine estimated results carefully. If we remove all the crabs in an experimental area, the total catch of the experiment should be the same as the initial number of crabs in the area. Then, the difference between the total catch and estimate of N_0 can be a measure of accuracy of q in some extent. As shown in Table 2, the difference was not so significant. This fact also facilitated us to use this ratio for estimating the initial number of crabs from the total catch, which were used for the revised method.

However, if we examine the applicability of our methods for estimating blue crab dredge catchability, the basic assumption of linear proportionality of catch to population abundance of the modified Leslie method was not always reasonable since there were quite a few cases which have increasing numbers of crab catch with sampling runs and which sometimes resulted in negative q's (Figure 2; Table 2). This phenomenon occurred mainly in deeper water and/or high crab density area. This problem might be attributed to two reasons, that is, ill-performance of physical towing and/or the crabs' patchy distribution. In deeper water, dredging operations can not be controlled as well and the towing position may be less accurate than in shallow water areas, because longer chains are used to dredge in the deeper water. This phenomenon can cause tow error and result in nonlinearity of the plot of catch per run versus cumulative catch and the possible underestimation or even negative values of the catchability. Lower average q's in deep water comparing to shallow water (see Tables 2 and 3) may be explained by this mechanism in some extent. For this situation the revised method can correct this phenmenon and give more reasonable q estimates. However, at the same time, if crabs are abundant and their distribution is patchy both horizontally and vertically in sediments, this distribution pattern can result in increases in catch with towing runs, since the first towing run can not remove significant portion of crabs in the sediment and a number of crabs are still caught with continuous towing runs. In this case the Leslie model does not give any idea of catchability, just showing scattered data points. Our revised method, however, can still give catchability estimates in this case, but possibly causes underestimation of the initial numbers of crab and thus overestimation of q, if the experiments were stopped without catching all crabs in the sediment of the path in abundant areas. Since the initial numbers of crab are calculated from the total crab catch with a maximum of six runs, using the proportion (w) of the total crab catch to the initial number of crabs, which is obtained from the modified Leslie method, our revised method estimates catchability mostly based on the catch of crabs from the first run and total catch, while the Leslie method is based on catch from each run and their cumulative catches before the run. Thus, the revised method can be sensitive to the catch from the first run if there occurs any sampling error in the first run. However, in actual situations of our abundance estimation we only used one tow from each station as the relative density. In this sense the Leslie method estimates an average catchability for a sampling station. At any rate, the two methods yielded similar catchability estimates, and therefore the revised method can be used as the complement to the Leslie method when Leslie model is not satisfied. As another possible problem with Leslie method, since x values (cumulative catch) of the equation (4) were calculated from y values (catch), y values are not independently distributed for any given value of x's, potentially causing autocorrelation.

Even though there were no statistically significant differences in dredge catchability due to sediment type and depth, we should be careful to conclude that there was no variability in catchability, because (i) sample size was not enough, (ii) there might be additional sources of variability, for example, weather or other physical factors, and/or crab size and sex, (iii) the range of depth and sediment types were not sufficiently covered, even no experiments were conducted for 80~100% gravel-sand category, and (iv) the variance of each estimate was not considered.

Nevertheless, the depth-sediment classification of dredge capture efficiency seems to be more or less promising when we see the difference in average q's between shallow and deep or muddy and sandy bottoms. However, the division of depth and sediment type is quite arbitrary, so we may need to reexamine these categorizations precisely using more comprehensive data and information.

Because we could not distinguish the difference in q's among categories, we may be able to conclude that the overall average of q of 0.26 with the SE of 0.03 is the best estimate of crab dredge catchability. No such studies of crab dredge efficiencies have been conducted at present to compare with our estimate. But, some results of studies on scallop dredge efficiencies were available, even though scallops have different behavior and dredging mechanisms for scallops are different from crabs. Their estimated catchabilities were more or less similar with ours, ranging from 0.12 (McLoughlin *et al.*, 1991) to 0.35 (Dupony, 1982). Because crab dredge catchabilities were negatively correlated with crab densities (Figure 4), we need to investigate more accurately and precisely to compensate for this density-dependent factor for estimating population abundance.

Recognizing the phenomena of relatively low dredge catchability and density-dependent catchability, as well as some cases of increasing trends of the number of crabs in the consecutive sampling runs in high abundance areas (Figure 2), we may speculate that blue crabs may distribute more deeply than the layer dredged by a single tow when crabs are very abundant, so that they are not vertically vulnerable to the single tow by a dredge.

To get more accurate estimates of gear efficiency, it will be necessary to have more experiments complemented with direct observation of dredging performance and crab distribution and behavior by divers or using underwater television (Conan and Maynard, 1987), even though this will not be easy to conduct especially in winter on muddy bottoms.

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췌세픽만 꽃게의 예망에 의한 채집효율성 추정

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1992년 동계에 췌세픽만의 꽃게자원에 대하여 예망을 사용한 연속채집법에 의한 어획효율성을 조사하였다. 일반선형모델 분석에 따르면 26회에 걸친 야외시험 결과 어획효율성은 저질이나 수심, 사용된 조사선박에 따라 통계학적으로 유의한 차이가 나타나지 않았다. 예망효율(즉, 어획율)은 Leslies방법과 단순히 개조된 방법 등의 두 방법을 사용하여 추정하였다.

평균 어획율은 0.26 (표준오차 : 0.03)으로 추정되었는데 이는 한번의 예망을 사용하여 채집장소에 존재하고 있는 꽃게 가운데 단지 26%(95% 신뢰한계 : 20~32%)를 잡을 수 있다는 의미이다. 예망효율은 꽃게의 밀도가 증가함에 따라 지수적으로 감소하였다.