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EVALUATION OF OTTER TRAWL DATA

Otter trawls are commonly used in scientific studies and monitoring programs to obtain estimates of numbers of individuals, numbers of species, biomass, etc. of demersal fish and invertebrates. How useful are trawls taken in a standard fashion (fixed net type, trawling speed, and trawl duration) for describing an area? To evaluate the data obtained from otter trawls, I asked two questions: 1) How many trawls are required to obtain precise estimates of the number of individuals, number of species, and biomass of fish and invertebrates? and 2) What are the probabilities of detecting changes in these estimates over time?

Replicate otter trawl study in three areas on the mainland shelf near Los Angeles demonstrated that the precision of the catch parameter estimates, and the probabilities of detecting changes in those estimates, vary among the study areas and among the parameters. For example, it requires one trawl to estimate the number of species, three trawls to estimate the number of individuals, and 14 trawls to estimate the biomass of fish per trawl at a precision of 0.2 (where precision = standard error/mean) on the Palos Verdes shelf. The number of trawls required for comparable estimates in the control area of Santa Monica Bay are six, 29, and 80 respectively Similarly, there is a 99% chance of detecting a 50% change in the number of species, a 99% chance of detecting a 50% change in the number of individuals, and a 57% chance of detecting a 50% change in the biomass of fish per trawl on the Palos Verdes shelf. The probabilities of detecting a 50% change in the same parameters in the control area of Santa Monica Bay are 96%, 26%, and 8% respectively.

Variation in the precision of estimates and the probability of detecting changes among areas and among parameters is a function of the distribution of fish and invertebrates in the study areas. Increasing patchiness means higher catch parameter variance which results in estimates of lower precision and lower probabilities of detecting changes. To obtain comparable levels of precision and probabilities of detecting changes would require different sampling designs and/or different levels of effort in the study area.

MATERIALS AND METHODS

This study was conducted using methods standardized by the Project (Mearns and Allen 1978) and also used by Los Angeles and Orange County Sanitation Districts. An otter trawl with a 7.6 m headrope and 1.3 cm mesh cod-end liner was towed parallel to depth isobaths between 55 and 65 m at 1.1 m/sec for 10 minutes at a scope ratio of 3:1. The catches were processed (counted, measured and weighed) on board ship. Ten otter trawls were made in each of the

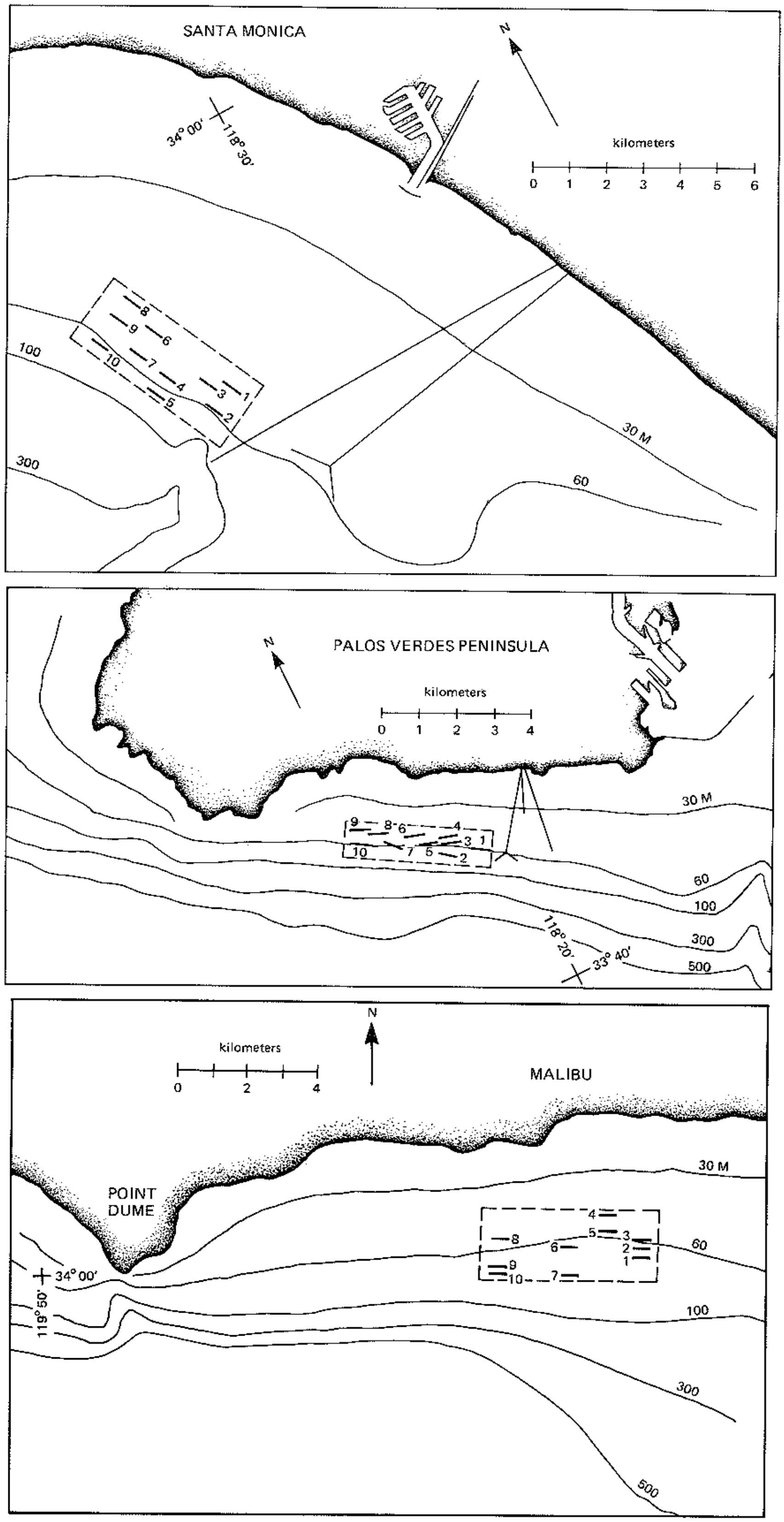

Figure 1. Location of the study areas.

three areas: northern Santa Monica Bay control area (February 4-5, 1982), Santa Monica Bay near the 7-mile outfall (May 26-27, 1982) and on the Palos Verdes shelf (March 29-30, 1982) (Figure 1). A 10 km^2 area at the Santa Monica Bay sites and a 4 km^2 area on the Palos Verdes shelf were gridded off on a chart into rectangles 0.5 km long by 0.2 km wide; ten rectangles were chosen randomly for sampling.

To answer the question of how many trawls are required to obtain precise estimates of the biological catch parameters,an index of precision (D) was used:

$$D = \frac{1}{\overline{X}} \sqrt{\frac{s^2}{n}}$$

where $\overline{X}$ = the mean, s^2 = the variance, and n = sample size (Elliott 1979). D is the ratio of the standard error to the mean and is interpreted as estimating the mean within a certain percentage (D x 100). A D of 0.2 is reasonable for most benthic samples (Elliott 1979). In the following analyses, I rearranged the equation and solved for n, the number of samples required to obtain an estimate of the catch parameters (number of individuals, number of species, and biomass of fish and invertebrates) at specified levels of precision (0.1, 0.2, and 0.3).

To answer the question of what the probabilities are of detecting changes in the biological catch parameter estimates an analysis of power (a technique of statistical hypothesis testing) was used. The objective criterion for rejecting a null hypothesis (H_o) in a statistical test is the significance level (α), generally .05. Occasionally, a true hypothesis will be rejected; this is a Type I error and happens with a frequency of α . Alternatively, if the H_o is actually false, the test may not detect it and a false hypothesis is accepted; this is a Type II error and happens with a frequency of β . The power($1-\beta$)of a statistical test is the probability of rejecting H_o when it is false and should be rejected (Sokal and Rohlf 1969). and its compliment, $1-\beta$ are areal proportions under a normal curve. They are calculated by converting the parameter in question to a normal deviate (Z) and finding the corresponding area in a table of proportions beneath a normal curve. In this study, power is the probability of detecting changes of specified magnitudes (75%, 50%, 25%, and 10%) in the catch parameters. The best estimates of the population means and variances for the catch parameters came from the 10 replicate trawls. Adjusting these means by the specified changes and assuming a constant variance, the probabilities for detecting changes were calculated.

RESULTS

A summary of the trawl catches by area is presented in Table 1. Estimates of the catch parameters and dominant species vary among the study areas.

The number of samples required for three levels of precision for the total fish catch and the total invertebrate catch are presented in Tables 2 and 3 respectively. (The total catch is all the animals collected in one 10 minute trawl). The number of samples required for a specified level of precision varies among the study areas and among the catch parameters. Comparing the fish catch parameters among areas, the fewest samples for a given level of precision are required at the Palos Verdes shelf stations and the most samples are needed in the Santa Monica Bay control area (Table 2). Comparing the fish catch parameters at a given level of precision, the fewest number of samples are required for estimating the total number of species and the most are required for estimating total biomass (Table 2). For example, it requires one trawl to estimate the number of species, three trawls to estimate the number of individuals, and 14 trawls to estimate the biomass of fish per trawl at a precision of 0.2 on the Palos Verdes shelf (Table 2).

Table 1. Summary of trawl catch statistics and dominant species for fish and invertebrates in the present study. SMB-C = Santa Monica Bay Control Area; SMB-O = Santa Monica Bay near the 7-mile outfall; PVS-O = Palos Verdes shelf near the White Point outfalls. $\bar{X}$ = mean, SD = standard deviation. 10 trawls were made in each area.

	SMB-C	SMB-O	PVS-O
Number of fish individuals ($\bar{X} \pm 1$ SD)	74.7 ± 83.2	40.0 ± 33.1	179.6 ± 66.3
Number of fish species ($\bar{X} \pm 1$ SD)	8.0 ± 3.9	8.9 ± 2.5	11.0 ± 1.9
Fish biomass (kg) ($\bar{X} \pm 1$ SD)	7.2 ± 12.9	2.7 ± 2.7	20.9 ± 15.5
Dominant fish species	*Sebastes saxicola* *Symphurus atricauda* *Icelinus quadriseriatus* *Porichthys notatus*	*Citharichthys sordidus* *Porichthys notatus* *Parophrys vetulus* *Microstomus pacificus*	*Scorpaena guttata* *Citharichthys sordidus* *Porichthys notatus* *Microstomus pacificus*
Number of invertebrate individuals ($\bar{X} \pm 1$ SD)	1017.5 ± 977.1	1565.4 ± 757.4	669.2 ± 316.3
Number of invertebrate species ($\bar{X} \pm 1$ SD)	12.6 ± 2.5	18.7 ± 7.0	12.4 ± 2.3
Invertebrate biomass (kg) ($\bar{X} \pm 1$ SD)	5.4 ± 1.3	19.5 ± 9.0	5.9 ± 2.3
Dominant invertebrate species	*Lytechinus anamesus* *Astropecten verrilli* *Sicyonia ingentis* *Ophiura lutkeni*	*Astropecten verrilli* *Lytechinus anamesus* *Parastichopus californiensis* *Sicyonia ingentis*	*Astropecten verrilli* *Sicyonia ingentis* *Crangon nigromaculata* *Pleurobranchia californica*

Table 2. Number of samples required to estimate the mean of the fish catch parameters for a standard otter trawl at a specified level of precision (D) for the three study areas. SMB-C = northern Santa Monica Bay control site; SMB-O = Santa Monica Bay site near the 7-mile outfall; PVS-O = Palos Verdes Shelf outfall site.

Precision	Total Number of Individuals			Total Number of Species			Total Biomass		
D	SMB-C	SMB-O	PVS-O	SMB-C	SMB-O	PVS-O	SMB-C	SMB-O	PVS-O
.1	118	69	14	24	8	3	321	100	55
.2	29	17	3	6	2	1	80	25	14
.3	13	8	2	3	1	1	36	11	6

The number of trawls required for comparable estimates in the control area of Santa Monica Bay are 6, 29, and 80 respectively.

The situation is not as straightforward for the trawl-caught invertebrates. Comparing the invertebrate catch parameters among areas, there is no consistent trend as to which area requires the fewest samples for estimating all parameters (Table 3). Comparing the invertebrate catch parameters at a given level of precision, the fewest number of samples are required for estimating the total number of species and the most are required for estimating the total number of individuals (Table 3). For example, it requires one trawl to estimate the number of species, four trawls to estimate the biomass, and six trawls to estimate the number of individuals of invertebrates per trawl at a precision of 0.2 on the Palos Verdes shelf (Table 3). The number of trawls required for comparable estimates in the control area of Santa Monica Bay are one, one, and 23.

The results of the power analyses are presented in Table 4 for the fish and Table 5 for the invertebrates. Comparing the fish catch parameters among areas, the highest probability of detecting change occurs on the Palos Verdes shelf while the lowest occurs in the Santa Monica Bay control area (Table 4). Comparing the fish catch parameters at a given level of change, total number of species has the highest probability for detecting change while biomass has the lowest (Table 4). For example, there is a 99% chance of detecting a 50% change in the number of species, a 99% chance of detecting a 50% change in the number of individuals, and a 57% chance of detecting a 50% change in the biomass of fish per trawl on the Palos Verdes shelf (Table 4). The probabilities of detecting a 50% change in the same parameters in the control area of Santa Monica Bay are 96%, 26%, and 8% respectively.

Comparing the invertebrate catch parameters among areas, the highest probability for detecting change occurs on the Palos Verdes shelf for total individuals and total species, and in the Santa Monica Bay control area for total biomass (Table 5). Comparing the fish catch parameters at a given magnitude of change, total number of species has the highest probability for detecting change while total biomass has the lowest (Table 5). For example, there is a 99% chance of detecting a 50% change in the number of species and the number of individuals and a 76% chance of detecting a 50% change in the biomass of invertebrates per trawl on the Palos Verdes shelf (Table 5). The probabilities of detecting a 50% change in the same parameters in the control area of Santa Monica Bay are 99%, 71%, and 91%.

DISCUSSION

The foregoing analyses demonstrate that the precision of the catch parameter estimates and the probabilities of detecting changes in the estimates vary among the parameters and among the study areas. Among the study areas, the least number of samples required for a given level of precision and the highest probability of detecting changes generally occurs on the Palos Verdes shelf; the greatest number of samples and lowest probabilities of detecting changes generally occurs in the Santa Monica Bay control area. The differences among areas are a function of the spatial distribution of the animals collected by the trawl. Variances tend to be higher in the control area (Table 1) suggesting more patchily distributed animals; variances tend to be lowest on the Palos Verdes shelf suggesting more evenly distributed animals.

Among the catch parameters, total number of fish and total number of invertebrate species require the fewest samples for a given level of precision and have the highest probability of detecting changes. Fish biomass and invertebrate numbers require the most samples and have the lowest probability of detecting changes. Differences among the catch parameters is a function of their variances. Estimates of species numbers of fish and invertebrates have the lowest

Table 3. Number of samples required to estimate the mean of the invertebrate catch parameters for a standard otter trawl at a specified level of precision (D) for the three study areas. SMB-C = northern Santa Monica Bay control site; SMB-O = Santa Monica Bay site near the 7-mile outfall; PVS-O = Palos Verdes Shelf outfall site.

Precision	Total Number of Individuals			Total Number of Species			Total Biomass		
D	SMB-C	SMB-O	PVS-O	SMB-C	SMB-O	PVS-O	SMB-C	SMB-O	PVS-O
.1	92	23	23	4	14	3	6	21	15
.2	23	6	6	1	4	1	1	5	4
.3	10	3	3	1	2	1	1	2	2

Table 4. The probability of detecting changes of a given magnitude for the total fish trawl catch at the three study sites based on 10 trawls. SMB-C = Santa Monica Bay control area; SMB-O = Santa Monica Bay near the 7-mile outfall; PVS-O = Palos Verdes Shelf outfall area. The percent change can be either positive or negative.

PERCENT CHANGE	Total Number of Individuals			Total Number of Species			Total Biomass		
	SMB-C	SMB-O	PVS-O	SMB-C	SMB-O	PVS-O	SMB-C	SMB-O	PVS-O
75	.51	.76	.99	.99	.99	.99	.13	.07	.89
50	.26	.43	.99	.96	.91	.99	.08	.05	.57
25	.10	.14	.91	.91	.38	.97	.05	.04	.18
10	.05	.05	.26	.26	.10	.34	.03	.03	.06

Table 5. The probability of detecting changes of a given magnitude for the total invertebrate trawl catch at the three study sites based on 10 trawls. SMB-C = Santa Monica Bay control; SMB-O = Santa Monica Bay near the 7-mile outfall; PVS-O = Palos Verdes shelf outfall area. The percent change can be either positive or negative.

PERCENT CHANGE	Total Number of Individuals			Total Number of Species			Total Biomass		
	SMB-C	SMB-O	PVS-O	SMB-C	SMB-O	PVS-O	SMB-C	SMB-O	PVS-O
75	.97	.99	.99	.99	.99	.99	.99	.99	.98
50	.71	.99	.99	.99	.94	.99	.91	.91	.76
25	.24	.91	.94	.94	.42	.96	.61	.38	.26
10	.07	.26	.28	.28	.10	.32	.14	.10	.08

variance of the trawl catch parameters examined (Table 1) and, if we accept a precision of 0.2 as reasonable, are probably adequately estimated by taking one trawl per station per quarter. The only other trawl catch parameter that comes close is total invertebrate biomass. The remaining catch parameters are, by the precision criterion of 0.2, inadequately estimated by one trawl per station per quarter.

CONCLUSION

Differences in the variance estimates of the catch parameters and differences in the dominant species of fish and invertebrates among the study areas (Table 1) suggest that the functional organization of the three communities is different. To obtain comparable levels of precision and comparable probabilities of detecting changes it would be necessary to use different sampling designs and/or different levels of effort in the three areas. A sampling plan designed to estimate numbers of species, numbers of individuals, and biomass in one area should not be indiscriminantly applied to different areas to answer the same question.

This study is not definitive and the results can only be regarded as a first step in evaluating data obtained by otter trawl. Seasonal changes in the distribution of demersal fish and invertebrates, which were not examined in this study, may alter the variance of the catch parameters and hence, the precision of the estimates and the probabilities of detecting changes. Nevertheless, it is evident that our confidence in the accuracy of the catch parameter estimates, i.e. how closely they approximate "truth", varies among the parameters; consequently, comparisons of catch parameters between areas should be based on rigorous statistical methods.

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