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ABSTRACT

Species biomass estimates for eastern Bering Sea groundfish are calculated using data collected in the Resource Assessment and Conservation Engineering Division's annual demersal trawl survey. These data are analyzed with a stratified statistical sampling model. The survey is divided into 10 strata; a common stratification scheme is used for all species. In this study, the use of species-specific stratification Schemes was examined to study how great a reduction in the variance of the biomass estimator might be achievable. New stratification schemes were developed by visually examining the distribution of catch per unit effort (CPUE) data averaged over several years. Geographically contiguous strata were drawn by grouping sampling stations with similar mean CPUEs. Reductions in the variances were achieved, but their magnitude was not large enough to yield biologically meaningful reductions in the sizes of the estimated confidence intervals of the species biomass. The use of non-geographically contiguous strata was also examined. Using this type of a stratification- scheme resulted in even smaller reductions in the variance estimates.

INTRODUCTION

The Resource Assessment and Conservation Engineering (RACE) Division of the Alaska Fisheries Science Center, National Marine Fisheries Service, annually conducts a demersal groundfish trawl survey in the eastern Bering Sea. Data collect&l in the survey are analyzed to estimate the total species-specific biomass in the survey area, the variances of the biomass estimates, and confidence intervals for the biomass estimates. A sampling model, with the same stratification scheme for all species, is used to analyze the data (Armistead and Nichol, 1993). The objective of this study was to see if a species-specific stratification, rather than a single stratification scheme, could reduce the estimate of the variance of the biomass estimate.

The annual eastern Bering Sea groundfish survey consists of bottom trawl samples collected at 329 stations located on a regular grid with 20 nautical mile (nmi) intervals, both north-south and east-west (Armistead and Nichol, 1993). The grid extends from Bristol Bay north to just north of Nunivak and St. Matthew Islands and west to the 200 m depth contour. Twenty-six additional trawl stations are located in an area around the Pribilof Islands and in a second area south of St. Matthew Island. The effect of the additional trawls is to double the sampling intensity in those areas.

Currently, the eastern Bering Sea survey area is divided into three areas containing 10 strata (Fig. 1). The three areas are based on depth: roughly the shoreline to 50 m, 50 - 100 m, and 100 - 200 m. These areas were selected based on the cluster analyses of trawl data done by Walters and McPhail (1982) and Walters (1983). Bakkala (1993) found that the eastern Bering Sea continental shelf is divided into three distinct environmental domains and that the boundaries between these domains are approximately at the 50 m and 100 m isobaths, lending further support to the appropriateness of divisions.

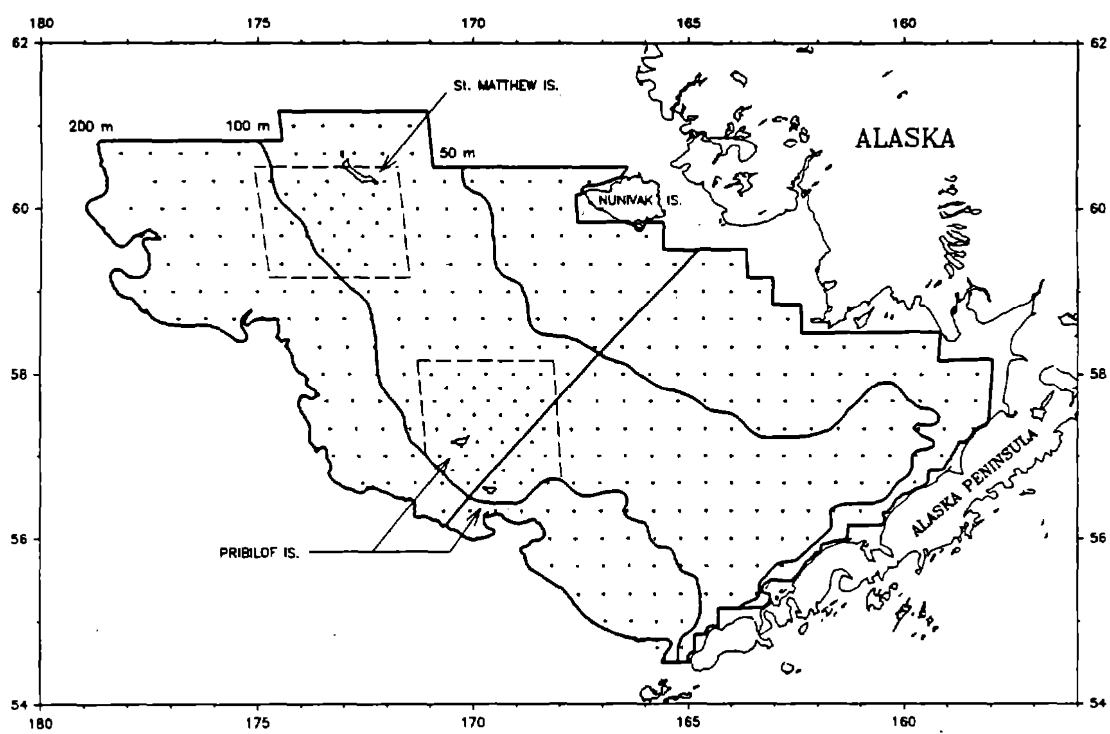

Figure 1. Map of the survey area, the target locations of the trawl stations, and the currently used stratification scheme. The heavy, solid lines show the primary strata, the dashed lines mark the high-intensity sampling areas.

The three areas are subdivided into six primary strata by a line that runs roughly southwest to northeast through the middle of the sampling area. This line was originally established to divide the areas inhabited by separate stocks of fish into different strata (Kashkina, 1965; Maida, 1972). It was believed (at present, the assumption is debatable) that there were two separate stocks of walleye pollock ***(Theragra chulcogramma)*** and two separate stocks of yellowfin sole (Pleuronectes asper) in the eastern Bering Sea. The six primary strata were first used in the 1986 eastern Bering Sea survey (Halliday and Sassano, 1988); prior years' data were reanalyzed using this stratification scheme.

Overlaying the six primary strata is the two double-intensity sampling areas, each of which is divided into two strata by the aforementioned stratum divisions. The result is six low-intensity sampling strata (approximately one trawl station per 400 nmi^2) and four high-intensity sampling strata (approximately one trawl station per 200 nmi^2).

The biomass of each species is estimated by first calculating a mean catch per unit effort (CPUE) for each stratum. The catch is measured in kilograms of biomass; the effort is measured as the area trawled. The area trawled for a specific trawl is measured as the wingtip to wingtip spread of the net times the length of the trawl. Thus, multiplying the mean CPUE by the area of the stratum produces an estimate of total species biomass for the stratum. A primary assumption of the model is that 100% of the fish in the areas trawled are caught and that no fish from outside the trawled area are caught.

Stratification is used in statistical sampling as a method to reduce the variance of the statistical estimator and hence the size of confidence intervals. Strata are defined so that observations within a stratum are similar and so that the stratum means differ. In estimating biomass in the eastern Bering Sea, the ideal strata are such that the CPUE is relatively constant across each stratum and so that the mean CPUE varies from stratum to stratum. The objective is maintain an unbiased estimate of the species biomass while reducing the variance of that estimate.

Historically, the same stratification scheme has been used to estimate the biomass of each species in the survey (Wilson and Armistead, 1991; Bakkala et al., 1992; Armistead and Nichol, 1993). The species distributions across the eastern Bering Sea, however, vary greatly from species to species. Thus, the optimal stratification scheme will usually vary from species to species. The objective of the current study was to examine the effect of species-specific stratification on the size of the estimated variance. No change in the distribution of sampling effort has been considered, only a change in the stratified model used to analyze the data.

METHODS

The data used in this analysis were taken from the eastern Bering Sea demersal trawl surveys from 1982 to 1991. Survey data from earlier years were available, but changes in the survey protocol indicated that those data should not be included. The distributions of three commercially important species were examined: ***walleye*** pollock, yellowfin sole, and rock sole ***(Pleuronectes bilineatus).***

The standard method for analyzing the eastern Bering Sea demersal trawl data uses the ***BIOMASS*** program at the Alaska Fisheries Science Center (AFSC) (see Armistead and Nichol, 1993). For this analysis, a Microsoft ***QuickBASIC*** program was written to emulate that portion of the ***BIOMASS*** program that calculates estimates of the species biomass and the population numbers plus the associated variances and confidence intervals. The program uses the standard haul file data, the standard catch file data (with catch data from only one species per program run), and a modified stratum/area file.

The variable of primary interest in this analysis was species biomass. It was estimated by first calculating a mean CPUE for each stratum with effort measured in units of area trawled. The biomass was estimated as the product of the mean

CPUE times the total area of the stratum. The stratum biomass estimates were then summed, as were the variance estimates, to yield an estimate of the eastern Bering Sea biomass of the species of interest and an estimate of the variance of the biomass estimate.

-Five different geographically contiguous stratification schemes were examined for the three species: 1) unstratified; 2) 2 strata, in which the survey area was divided into areas of high- and low-intensity sampling; 3) 6 strata, using the 6 primary strata shown in Figure 1; 4) all 10 strata shown in Figure 1; and 5) species-specific schemes (6 to 8 strata) based on an examination of patterns in the mean CPUE. Three geographically non-contiguous stratification schemes were also examined.

All 355 trawl stations of the annual eastern Bering Sea survey were included in the analysis. Of these, 329 were located on the regular 20 nmi by 20 nmi grid. The remaining 26 stations were located near the Pribilof Islands and south of St. Matthew Island in two areas of higher intensity sampling (see Fig. 1). To maintain a uniform sampling intensity across each stratum, the 26 high-intensity stations were omitted from the analyses based on the first and third stratification schemes.

The species-specific stratification in the analysis using the fifth scheme was based on historical CPUE data. The mean CPUE for each species at each trawl station was calculated and then maps were drawn (one for each species) to summarize the distribution of mean CPUEs. Mean CPUEs were calculated using only the even years (1982, 1984, 1986, 1988, and 1990). This permitted analyses of the odd-year sampling data that were independent of the data used to construct the stratification schemes.

Strata were defined subjectively, based on an inspection of each map, looking for contiguous regions with similar mean CPUE values. When appropriate, the high- and low-intensity sampling areas were retained as separate strata. Thus, data from all 355 stations could be used in the species-specific analyses. Maps of the means of the even-year CPUEs and the selected stratifications by species are shown in Figure 2.

To examine whether the species-specific stratification yields a significant reduction in the estimated variance of the biomass estimate, the estimated variance was calculated for the five stratification schemes (developed with data from the even years) for each of the five odd years (1983, 1985, 1987, 1989, and 1991). The effect of the species-specific stratification was analyzed with a two-way analysis of variance model (with stratification scheme and year as the main effects).

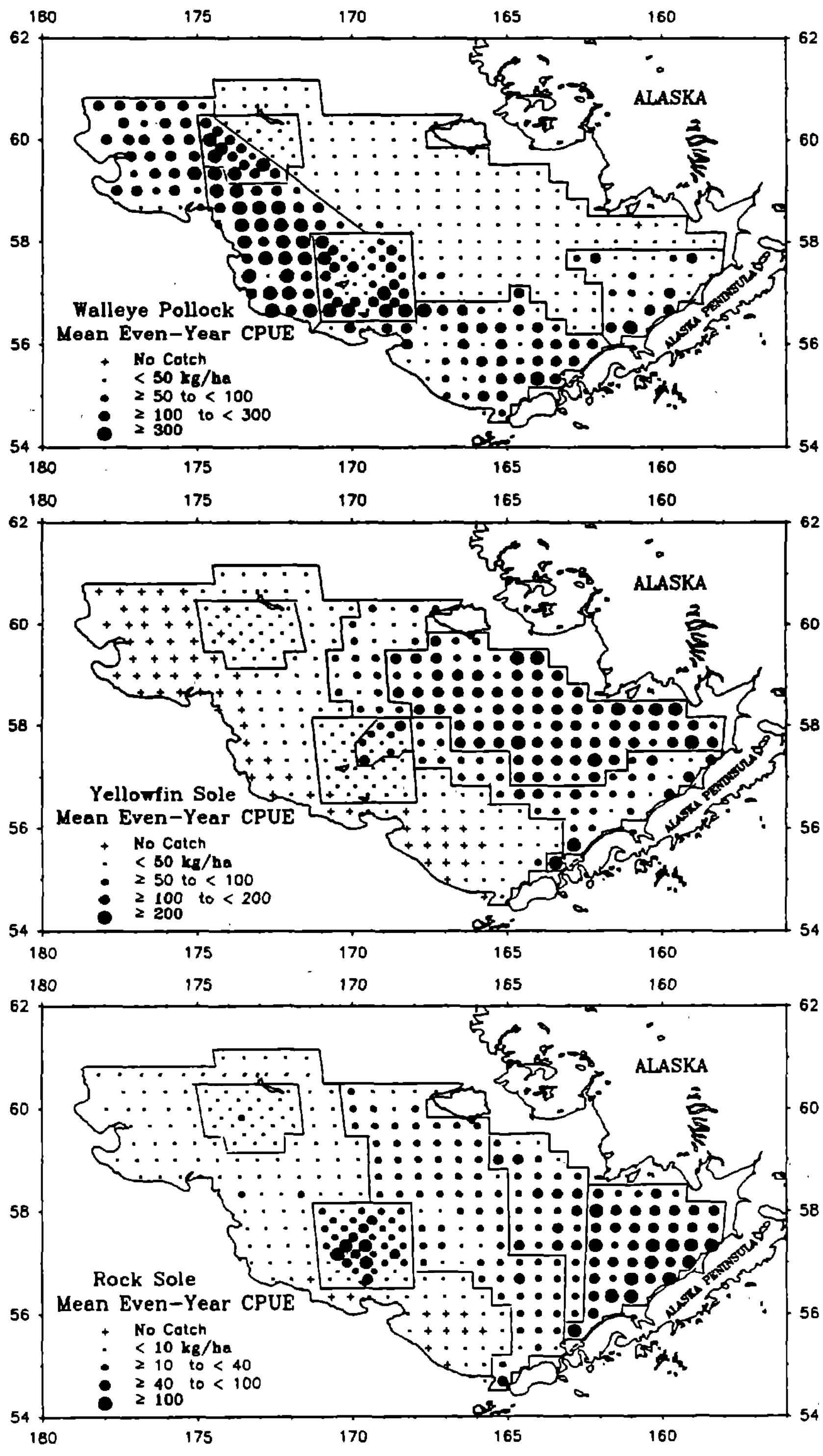

Figure 2. Species-specific stratification scheme; the numbers on the map are the means of the even-year CPUEs at the stations.

As there was no replication possible, a model without an interaction term was used. Fisher's least-significant difference test was used to specifically test for a statistically significant difference between the various species-specific schemes and the conventional lo-stratum approach.

In some ways, using post-stratification would seem to be the best way to develop an optimal stratification scheme. But in the context of estimating the biomass of a species in the eastern Bering Sea survey area, using the observed CPUE figures for a particular year to define the strata used to analyze the data for that year does not fit within the framework of the usual post-stratification model (Kish, 1965). To post-stratify in this situation is likely to introduce a negative bias in the estimate of the variance of the biomass estimate (i.e., the variance will likely be underestimated).

While using the current year's data to define strata is inappropriate, there is nothing wrong with using the previous year's data to define strata. Thus, another approach to defining non-geographically contiguous strata that was examined was to sort the trawl stations by the previous year's CPUE data and then assign the stations to strata based on the sorted order. Three-year and five-year moving averages of the station CPUE data were also used to sort the stations and then to define strata.

For example, to construct strata to analyze the 1991 data, the stations were ranked by the 1990 CPUE data. Regardless of their geographic locations, stations with the largest 1990 CPUE values were defined to be in the first stratum. Stations with somewhat smaller 1990 CPUE values were defined to be in the second stratum, etc. Stations with the smallest 1990 CPUE values were defined to be in the last stratum. No fixed rule was used to define the CPUE values used to separate one stratum from the next. The objective was not to develop an optimal stratification rule. Rather it was to simply look at the general effect on variance estimates of using such a stratification scheme. Somewhat arbitrary stratum separation values were selected in an attempt to keep the strata small when there was large within-stratum CPUE variability while allowing for larger strata when there was very little CPUE variability.

Additional analyses of the 1991 data were conducted by calculating the average CPUE for 1988 to 1990 and the average CPUE for 1986 to 1990 and then stratifying the stations by using the ranked average CPUEs. The 3-year and 5-year averages were selected in an attempt to reduce the effect of annual within-station CPUE variability on the process of defining homogeneous (with respect to CPUE) strata.

RESULTS

The geographic pattern of the means of the even-year CPUEs in the eastern Bering Sea varied by species. The number of strata into which the survey area was divided also varied from species to species. For walleye pollock, the area was divided into eight strata; for yellowfin sole, the area was divided into seven strata; and for rock sole, the area was divided into six strata.

For all three species, the estimated variance of the biomass estimate decreased as the number of strata into which the survey area was divided increased. However, the statistical significance of the differences in estimated variance among the stratification schemes varied from species to species. Of particular interest was a test of the null hypothesis ***H_0: the variance of the biomass estimate using species-specific stratification is equal to the variance obtained with the presently used I0-stratum scheme*** against the one-sided alternative hypothesis ***H_a: the variance of the biomass estimate using species-specific stratification is less than the variance obtained with the presently used I0-stratum scheme.***

For walleye pollock, the observed decrease in the variance of the biomass estimate (when going from the currently used lo-stratum stratification to the species-specific stratification) was very highly significant (P = 0.001). In contrast, for the other two species, the differences are not statistically significant (for yellowfin sole, P = 0.3 and for rock sole, P = 0.17).

For walleye pollock, the two-stratum and six-stratum models both resulted in a 4% reduction in the predicted standard deviation when compared to the standard deviation from the unstratified model. The l0-stratum model resulted in a 7% reduction in the standard deviation and the contiguous, species-specific stratification in

a 13% reduction - 7% less than the predicted l0-stratum model standard deviation (Fig. 3). Overall, the species-specific stratification resulted in a predicted variance that was significantly smaller (P = 0.05) than the variance predicted using the other stratifications. Variance estimates from the unstratified model were significantly larger than the variance estimates from any other stratified model. The differences among the variances from the 2-, 6-, and lo-stratum schemes-and the species-specific stratification were not statistically significant.

For yellowfin sole, the same reductions in the predicted standard deviations relative to those from the unstratified model were 3 %, 22%) 24 % , and 27 % - with a 4% reduction in the species-specific model standard deviation when compared to the lo-stratum results (Fig. 3). The difference between the variance of the

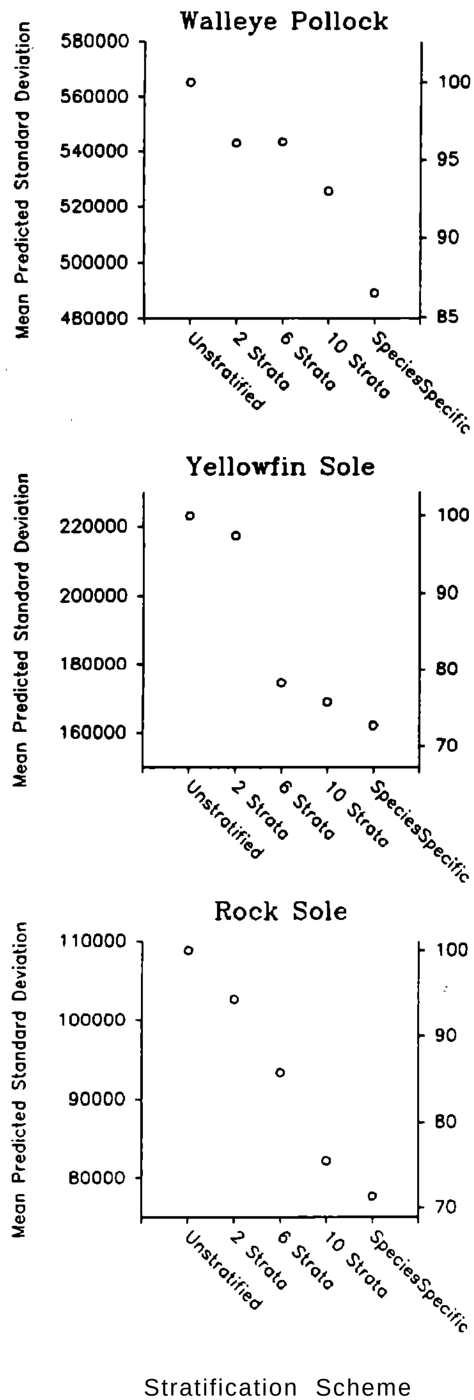

Figure 3. Mean predicted standard deviation (in metric tons) as a function of the stratification scheme.

estimated biomass from the unstratified model and the two-stratum model was not significant. Likewise, the differences among the variances from the 6-stratum, the l0-stratum, and the species-specific stratification models were not significant. But the difference in variances between the unstratified or 2-stratum model and any one of the 6-stratum, the l0-stratum, or the species-specific stratification models was, however, statistically significant.

For rock sole the 2-, 6-, and l0-stratum models and the species-specific stratification model resulted in reductions of 6%, 14%, 24%, and 29%) respectively, in the standard deviations, relative to the predicted standard deviation in the unstratified model (Fig. 3). The species-specific stratification standard deviation was 5% less than that from the l0-stratum stratification. The differences in the variances between the unstratified and the 2-stratum models, between the 2- and 6-stratum models, between the 6- and l0-stratum models, and between the N-stratum and the species-specific stratification models were not statistically significant but the differences in variances between any other pair of models were significant.

While the decreases in the estimated variances of the biomass estimates were as one would expect and some of the observed reductions were statistically significant, the magnitude of the reductions was not large enough to be biologically meaningful. For all three species, the reduction in the standard deviation when going from the in-common lo-stratum stratification (the stratification scheme presently used to analyze the eastern Bering Sea demersal trawl data for all species) to the species-specific stratification scheme was between only 4 and 7 % .

For the non-geographically contiguous stratification schemes, only the walleye pollock data were analyzed.

When just the previous year's CPUE data were used to stratify the survey area, the estimated variance of the biomass estimate was smaller than that from an unstratified analysis but larger than that from the presently used l0-stratum analysis. If the previous 3 years' CPUE data were used to stratify, the estimated variance was reduced to less than that from the l0-stratum analysis and the variance estimate was even further reduced if the previous 5 years of CPUE data were used to stratify the sampling stations.

The smallest estimated variance, however, was obtained by using the means of the even-year CPUE data to stratify the survey area into geographically contiguous strata. Statistically, the variance based on the stratification using the CPUE means for the even-year data is significantly smaller than all of the variances based on the non-contiguous stratification schemes (except for the difference between the variances from the previous 5-year means and the even-year means models where the difference is nearly, but not quite; significant at the 0.05 level). None of those latter variances was significantly different from the variance based on the presently used lo-stratum scheme and all were significantly smaller than the variance obtained from an unstratified analysis.

DISCUSSION

Eastern Bering Sea demersal trawl data from 1982, 1984, 1986, 1988, and 1990 were used to develop species-specific stratification schemes for use with sampling theory models to estimate the species biomass. The expectation was that new stratification schemes would reduce the estimates of the variances for the biomass estimates. After the strata were defined, data from 1983, 1985, 1987, 1989, and 1991 were analyzed to produce estimates of the biomass and the variance of the biomass estimate.

As anticipated, the species-specific stratification models yielded smaller estimated variances than did the more general lo-stratum sampling scheme currently in use. But the magnitude of the reductions in the estimated variance was so small - a 4 to 7% reduction in the standard deviation - that it does not seem to be worth the effort to modify the current stratification scheme to achieve the potential improvement.

In an attempt to assess the adequacy of the stratification based on the means of the even-year CPUE data, two tasks were carried out. First, maps were drawn using the means of the odd-year CPUE data. Those maps and the stratification that they suggest were not substantially different from the maps drawn using the means of the even-year CPUE data.

Second, using the stratification schemes based on the means of the even-year CPUE data, the estimated variances of the biomass estimates for the even years were calculated and analyzed. Since the stratification was based on the data being analyzed, the strata should be in some sense optimal. Qualitatively, the results were very similar to the results obtained by analyzing the odd-year data using the same stratification schemes but, surprisingly, the standard deviations calculated in the **even-year** data analyses were larger than the standard deviations achieved in the odd-year analyses. No plausible explanation for this result was apparent other than simple random variation. It may be that simply by chance there was greater CPUE homogeneity, within the strata, in the odd years.

These two analyses suggest that the stratification schemes based on the even-year data are reasonable for the distribution of CPUE data in the odd years. While there was a change in the distribution of catch from year to year, as well as a change in the total catch, there does not appear to have been a substantial change in the overall relative distribution of the three species of fish examined. The relatively small reductions in the estimated standard deviations seem to be a result of a somewhat patchy distribution of the fish. Patterns emerge when one looks at the distribution of mean CPUE, but within any contiguous area there remains substantial variation in the density of the fish stocks so that the variance in the estimates of biomass remains large.

The currently used lo-stratum scheme does relatively well, possibly because while it is largely based on changes in sea depth rather than fish distribution, the distributions of the species examined are also affected to a large extent by depth. Thus, there are some distinct similarities between the existing stratification and the species-specific stratifications.

The improved performance obtained using the geographically contiguous stratification schemes and the lack of improvement using the non-geographically contiguous schemes based on data from the catch in the previous year (or years) indicate that there is some year-to-year continuity in the areas where fish densities are high. The localized concentrations of fish are not, however, stable at any specific trawl station. This observation suggests that if further studies are undertaken to reduce the variance in the biomass estimate through the use of improved stratification, then those studies' should focus on geographically contiguous strata.

CITATIONS

Armistead, C. E. and D. G. Nichol. 1993. 1990 Bottom trawl survey of the eastern Bering Sea continental shelf. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-7, 190 p.

Bakkala,. R. G. 1993. Structure and historical changes in the groundfish complex of the eastern Bering Sea. U.S. Dep. Commer., NOAA Tech. Rpt. NMFS 114, 91 p.

Bakkala, R. G., W. A. Karp, G. F. Walters, T. Sasaki, M. T. Wilson, T. M. Sample, A. M. Shimada, D. Adams, and C. E. Armistead. 1992. Distribution, abundance, and biological characteristics of groundfish in the eastern Bering Sea based on results of U.S.-Japan bottom trawl and midwater surveys during June-September 1988. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-213, 362 p.

Halliday, **K.** L. and J. A. Sassano. 1988. Data report: 1986 Bottom trawl survey of the eastern Bering Sea continental shelf. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-147, 159 p.

Kashkina, A. A. 1965. Reproduction of yellowfin sole ***(Limanda aspera (Pallas))*** and changes in its spawning stocks in the eastern Bering Sea. Tr. Vses. Nauchno-issled. Inst. Morsk. Rybn. Khoz. Okeanogr. 58 (Izv. Tikhookean. Nauchno-issled. Inst. Rbn. Khoz. Okeanogr. 53):191-199. In Russian. (Transl. by-Isr. Program Sci. Transl., 1968, p. 182-190, in P.A. Moiseev (editor), Soviet fisheries investigations in the northeastern Pacific, Part IV, avail. U.S. Dep. Commer., Natl. Tesh. Inf. Serv., Springfield, VA, as TT67-51206.)

Kish, L. 1965. Survey Sampling. John Wiley & Sons, New York.

Maida, T. 1972. Fishing grounds of the Alaska pollock. (In Japanese, English summary.) Bull. Jap. Soc. Sci. Fish. 43:39-45.

Walters, G. E. 1983. An atlas of demersal fish and invertebrate community structure in the eastern Bering Sea: Part 2, 1971-77. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-40, 152 p.

Walters, G. E. and M. J. McPhail. 1982. An atlas of demersal fish and invertebrate community structure in the eastern Bering Sea: Part 1, 1978-81. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-35, 122 p.

Wilson, M. T. and C. E. Armistead. 1991. 1989 Bottom trawl survey of the eastern Bering Sea continental shelf. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-212, 212 p.

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17 SEASE, J. L., J. P. LEWIS, D. C. MCALLISTER, R. L. MERRICK, and S. M. MELLO. 1993. Aerial and ship-based surveys of Steller sea lions (Eumetopias jubatus) in Southeast Alaska, the Gulf of Alaska, and Aleutian Islands during June and July 1992, 57 p. NTIS number pending.

16 FISCUS, C. F. 1993. Catalogue of cephalopods at the National Marine Mammal Laboratory, 183 p. NTIS number pending.

15 KINOSHITA, R. K., A. GREIG, L. E. QUEIROLO, and J. M. TERRY. 1993. Economic status of the groundfish fisheries off Alaska, 1991, 94 p. NTIS No. PB93-197861.

14 PEREZ, M. A., and W.B. MCALISTER. 1993. Estimates of food consumption by marine mammals in the Eastern Bering Sea, 36 p. NTIS No. PB93-191195.

13 BERGER, J. D. 1993. Comparisons between observed and reported catches of retained and discarded groundfish in the Bering Sea and the Gulf of Alaska, 89 p. NTIS No. PB93-184711.

12 HARRISON, R.C. 1993. Data report: 1991 bottom trawl survey of the Aleutian Islands area,144 p. NTIS No. PB93-186237.

11 LIVINGSTON, P. A., A. WARD, G. M. LANG, and M-S. YANG. 1993. Groundfish food habits and predation on commercially important prey species in the eastern Bering Sea from 1987 to 1989, 192 p. NTIS No. PB93-184703.

10 KINOSHITA, R. K., and J. M. TERRY. 1993. Oregon, Washington, and Alaska exports of edible fishery products, 1991, 47 p. NTIS No. PB93-159101.

9 KARINEN, J. F., M. M. BABCOCK, D. W. BROWN, W. D. MACLEOD, JR., L. S. RAMOS, and J.W. SHORT. 1993. Hydrocarbons in intertidal sediments and mussels from Prince William Sound, Alaska, 1977-1980: Characterization and probable sources, 69 p. NTIS No. PB93-159093.

8 WING, B. L. 1993. Winter oceanographic conditions in the eastern Gulf of Alaska, January-February 1986, 53 p. NTIS No. PB93-158335.

7 ARMISTEAD, C. E., and D. G. NICHOL. 1993. 1990 bottom trawl survey of the eastern Bering Sea and continental shelf, 190 p. NTIS No. PB93-156677.

6 WOLOTIRA, R. J., JR., T. M. SAMPLE, S. F. NOEL, and C. R. ITEN. 1993. Geographic and bathymetric distributions for many commercially important fishes and shellfishes off the West Coast of North America, based on research survey and commercial catch data, 1912-84, 184 p. NTIS No. PB93-167682.

5 GUTTORMSEN, M., R. NARITA, J. GHARRETT, G. TROMBLE, and J. BERGER. 1992. Summary of observer sampling of domestic groundfish fisheries in the northeast Pacific Ocean and Eastern Bering Sea, 1990, 281 p. NTIS No. PB93-159085.