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Abundance, Distribution and Diversity of Chesapeake Bay Fishes: Results from CHESFIMS
(Chesapeake Bay Fishery Independent Multispecies Fisheries Survey)

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BACKGROUND

The Chesapeake 2000 (C2K) Agreement commits regional jurisdictions to implement multispecies approaches to fisheries management. The potential for biological interactions and technical interactions within traditional single species management has motivated the development of multispecies approaches. Houde et al. (1998) reported the recommendations of a workshop to explore the utility and advisability of adopting multispecies approaches in Chesapeake Bay. An important conclusion of the workshop was the development of coordinated, baywide surveys to estimate key species abundances and to provide biological data on both economically and ecologically important species that are currently lacking (Houde et al. op. cit.). Several fishery-independent surveys for the assessments of important fish and shellfish stocks in the Chesapeake Bay are currently ongoing but their study design and spatio-temporal coverage limits their applicability for exploring the multispecies question directly. The workshop recommended that these surveys should permit the estimation of the temporal and spatial dynamics of key predator-prey relationships and trophic interactions (Houde et al. op. cit.).

Since 2001, we have conducted research that seeks to provide information that will be needed to design a suitable baywide multispecies survey in support of C2K commitments. This research has several objectives that directly address issues relating to the design of future fishery-independent surveys. Our research focuses on providing estimates of the mean and variability in the distribution and abundance of fishes, estimates of trophic interactions as well as the utility of alternative survey designs and analytical frameworks. Here we report the results for the second year of research, provide comparisons with data from earlier periods and compare the utility and efficiency of alternative surveys designs and analytical approaches examined to date.

OBJECTIVES

Our **Ches**apeake Bay **F**ishery-**I**ndependent **M**ultispecies **S**urvey (CHESFIMS) builds on and expands earlier research, the NSF-funded Trophic Interactions in Estuarine Systems (TIES) program, into biological production potential and its temporal and spatial variability in the Chesapeake Bay ecosystem that had been conducted from 1995 – 2000. By using TIES as a foundation, CHESFIMS can be viewed as an ongoing 8-year survey of the abundances and key trophic interactions in the Chesapeake Bay fish community. In 2002 we had five specific objectives:

- **Conduct a baywide survey of the bentho-pelagic fish community, focusing on young (juveniles, and yearling) fishes in the mainstem of Chesapeake Bay.**
- **Design and implement a complementary survey of the bentho-pelagic fish community in the extensive shoal habitats (< 5 m depth) in the mainstem of Chesapeake Bay.**
- **Conduct pilot surveys of the pelagic fish community in key tributaries and in the mainstem to generate sampling statistics that will of use in subsequent design improvements.**
- **Determine trophic interactions among key components of the pelagic fish community, and examine the implication of the relationships uncovered in empirical studies using bioenergetic modeling.**
- **Conduct statistical analyses of existing and new data to optimize the complemented pelagic survey with respect to consistency and accuracy of key parameters.**

We completed successfully work and report progress on all five objectives.

PROGRESS AGAINST OBJECTIVES

Objective 1: Broad Scale Survey

Three broad scale surveys were conducted in 2002; from April 30 - May 7 (CF0201), July 8 – 15 (CF0202) and September 9- 17 (CF0203) (Table 1). Samples of the fish community were collected from between 43 - 51 stations (Table 1). All surveys were conducted from the University of Maryland Center for Environmental Science=s R/V Aquarius. Sampling procedures were identical to previous surveys (Miller et al. 2002). Briefly, sampling involved deploying a CTD and a single, oblique stepped midwater trawl (18-m^2 mouth opening, 6-mm cod end mesh, as in the TIES program) tow. The net was fished for two minutes in each of ten depth zones distributed throughout the water column from the surface to the bottom. Deployment times and locations were recorded. The section of the tow conducted in the deepest zone sampled epibenthic fishes close to or on the bottom. The remaining portion of the tow sampled pelagic and neustonic fishes. All survey deployments were conducted between 19:00 and 07:00 to reduce problems with gear avoidance and to take advantage of the diurnal distribution patterns of pelagic fish species.

Table 1. Summary of sampling and results (mean ± SE) from 2002 broadscale surveys assuming a simple random sample

		Survey		
		CF0201	CF0202	CF0203
Dates		April 30 - May 7	July 8 -15	Sept 9 - 17
Number of Stations		43	50	51
Average CPUE (fish/haul)	Lower	138.88±24.79	586.9±108.6	686.9±151.6
	Mid	141.4±54.83	722.2±238.6	2133±496.0
	Upper	89.64±33.73	625.6±155.9	2245±544.7
	Overall	134.82±20.83	628.5±97.83	1207±174.1
Average CPUE (g/haul)	Lower	1950±434.1	1378±259.3	3654±544.9
	Mid	1463±557.8	1136±311.9	8546±430.5
	Upper	4285±1916	2051±675.4	3479±442.4
	Overall	2077±375.7	1361±194.8	3659±392.1
Total N^{o} S		33	47	57
Average Diversity (N^{o}. Species)	Lower	4.82±3.00	6.69±2.53	8.12±2.68
	Mid	4.51±1.95	4.46±1.95	6.82±2.12
	Upper	5.92±2.88	5.25±2.41	7.11±2.42

The first survey (CF0201) sampled 43 stations baywide and collected 5,921 fish (>108 kg) from 34 taxonomic categories. The second survey (CF0202) sampled 50 stations baywide, collecting 31,994 fish (>70 kg) from 47 different taxonomic categories**.** The final survey sampled on 51 stations baywide and collected 73,646 fish (>189 kg) from 57 different taxonomic categories. Overall, abundances in 2002 appeared slightly reduced compared to 2001, but diversity was higher, particularly in the suumer and spring surveys. As in past years, the patterns and distributions of abundance varied among the three surveys (Table 1). The average catch per tow increased over the three surveys (Table 1, Fig. 1). The center of abundance was in the lower Bay spring (CF0201), the mid Bay in summer (CF0202) and the upper Bay in autumn (CF0203 --Table 1). The abundance pattern represents the recruitment of bay anchovy. The distribution of biomass was markedly different, with the center of mass shifting from the upper Bay in spring (CF0201) to the mid Bay in summer and autumn (Table 1).

Bay anchovy (*Anchoa mitchilli*) continued to dominate catches as in previous years

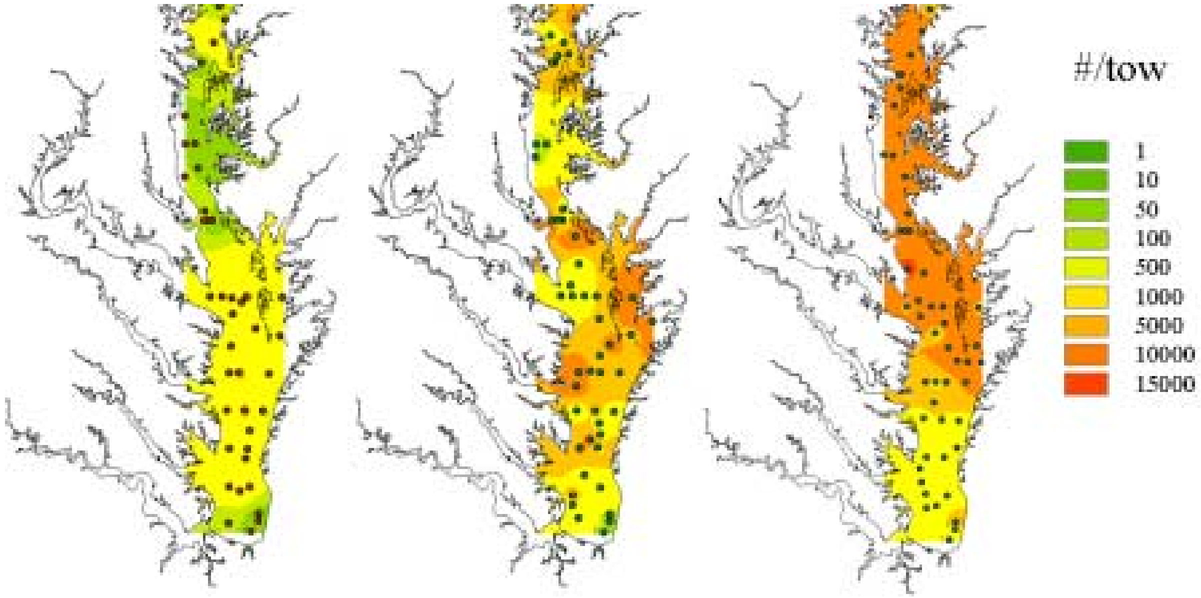

Figure 1. *Distribution of fish abundance in 2002. Survey stations are shown*

(Miller et al. 2002). However, anchovy catches were lower in 2002 than in the previous year, particularly in the autumn (Fig. 2). The abundance and size distributions of bay anchovy in the three surveys was consistent with known aspects the life history of this species (Kimura et al. 2000). The distribution and abundance of the conspecific striped anchovy, *Anchoa hepsetus*, was most notable in 2002. In previous CHESFIMS and TIES surveys, striped anchovy was restricted to lower Bay and Bay mouth stations and was always a minor component of the catch. In 2002, striped anchovy was widely distributed, occurring in large numbers as far north as the Bay bridge. In the summer survey (CF0202), striped anchovy accounted for 17% of all fish collected, up from 2% in 2001. We ascribe this marked difference to the unusually high salinities experienced in mid and upper Bay stations during the summer and autumn cruises.

We analyzed the biomass of fish per tow in our surveys also. These data indicate the importance of white perch (*Morone Americana*) and Atlantic croaker (*Micropogonias undulates*) in the Chesapeake Bay fish assemblage. The contribution of white perch to the biomass in survey catches increased from 20% in the spring to 42% by autumn. Croaker catches represented an average of 14.3% of biomass of fish caught during surveys. The increase in white perch and croaker biomasses reflects the recruitment of young of year fish (< 70 mm TL) in spring to the population. Seasonally striped bass (*Morone saxatilis*) contributes substantially to catches (~24% of spring biomass), and declines in importance thereafter. A range of clupeid species (e.g., gizzard shad, menhaden, alewife and shads) are important components of the catch in Spring.

We combined CHESFIMS abundance data for the three important species (bay anchovy, white perch and croaker) with the historical TIES data (Fig. 2). The composite time series for bay anchovy indicates a strong increase in autumn abundance over the period 1995 – 2001. However, autumn abundances of bay anchovy were greatly reduced in 2002. The Atlantic croaker and white perch time series exhibit complementary patterns. White perch was most abundant early in the time series; Atlantic croaker is most abundant in the latter time series.

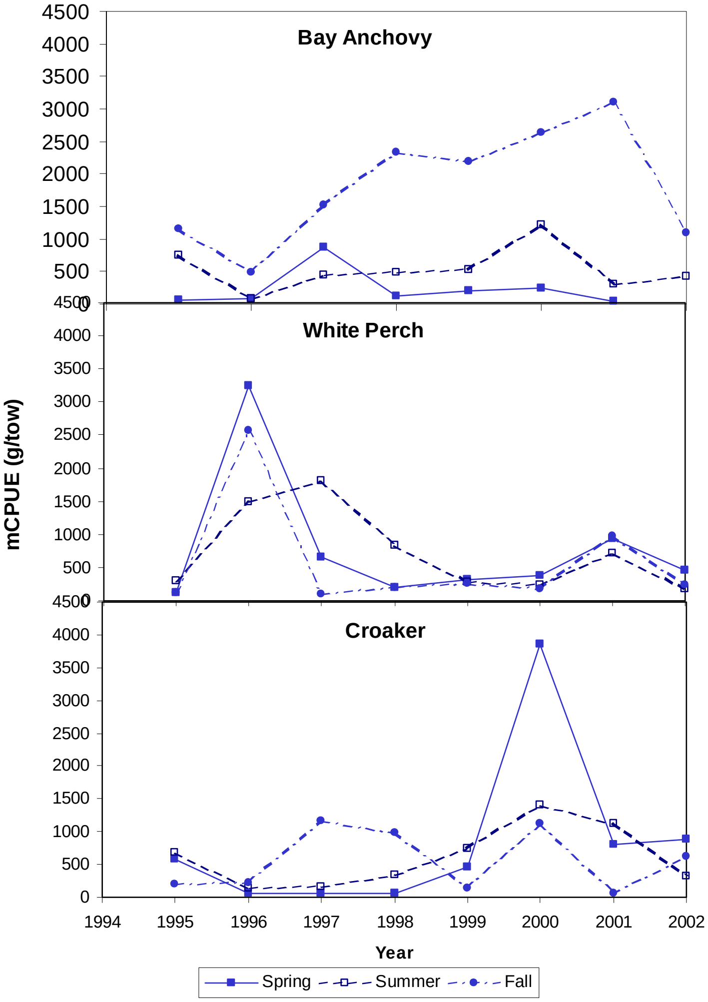

Figure 2. Time series of biomass per unit effort for three important Chesapeake Bay fish.

Objective 2: Shoal Survey

Three shoal surveys were conducted in 2002, from 5 – 26 May, 8 – 26 July, and 17 September – 4 October (Table 2). As in 2001, the shoal survey was conducted in a stratified random design, but based on results in 2001, station allocation and the designated strata changed in 2002 to increase the spatial coverage, provide increased connectivity to the broad scale and other surveys, and capture other important fish species (i.e. white perch, striped bass) previously under-represented in 2001. A total of 9 strata were surveyed in 2002.

Stratum 1 – **Calvert Cliffs**, from Patuxent R. mouth to 38.32’00”N. Total stratum area 23.0 km^2; 10 stations.
Stratum 2 – **Pocomoke**, from the VA/MD line to 38.03’00”N. Total stratum area 346.2km^2; 20 stations.
Stratum 3 – **Tangier**, from the Pocomoke line to 38.22’00”N. Total stratum area 617 km^2; 33 stations.
Stratum 4 – **Little Choptank**, from Tangier line to 38.32’00”N. Total stratum area 64.4 km^2; 9 stations.
Stratum 5 – **Choptank**, the entire Choptank R. mouth to 38.44’00”N. Total stratum area 105.6 km^2; 12 stations.
Stratum 6 – **Eastern Bay**, all of Eastern Bay east to the mouth of the Miles R. Total stratum area 84.0 km^2; 9 stations.
Stratum 7 – **Chester**, the entire Chester R. mouth to 39.09’00”N. Total stratum area 53.3 km^2; 8 stations.
Stratum 8 – **Patapsco**, from the north side of Patapsco R. to 39.15’00”N. Total stratum area 62.7 km^2; 8 stations.
Stratum 9 – **Severn/South**, from Herring Bay (38.46’00”N) to the Severn R. (38.57’00”N). Total stratum area 44.4 km^2; 8 stations.

Procedures in the field were identical to previous CHESFIMS shoal survey (Miller et al. 2001), and were compatible with the MDDNR blue crab trawl survey. During the first survey (May), 118 stations were sampled from all 9 strata and 1,837 fish (total weight ~ 29.2 kg) were collected (Table 2). The second survey (July), 113 stations were sampled from all 9 strata and 2,477 fish (total weight ~ 66.5 kg) were collected. The final survey (September) sampled 120 stations from all 9 strata and collected 3,061 fish (total weight ~ 117.7 kg). Considering all three surveys together, the overall catch of 7,365 fish in 2002 was less than half the total catch, 17,742 fish, in 2001.

Species diversity and abundance were highly variable between strata and between seasons. The total number of species caught within a given season was relatively constant, while the number of species tow^{-1} increased from May through September (Table 2). The average

Table 2. *Summary of sampling and results (mean ± SE) from 2002 shoal surveys*

	Spring	Summer	Autumn	Total
Sampling Dates	5/6/02 - 5/29/02	7/8/02 - 7/26/02	9/17/02 - 10/4/02	****
# of Trawls	118	113	120	351
# of Fish	1837	2477	3061	7375
Average CPUE (fish haul^{-1})	15.6 ± 3.3	21.9 ± 2.6	25.5 ± 3.5	****
Total Weight (kg)	29.15	66.48	117.68	213.31
Average CPUE (g haul^{-1})	247.0 ± 54.4	588.3 ± 84.8	980.6 ± 169.8	****
# of Species	23	27	25	34
Average Diversity (species haul^{-1})	2.6 ± 0.18	3.6 ± 0.25	4.0 ± 0.26	****

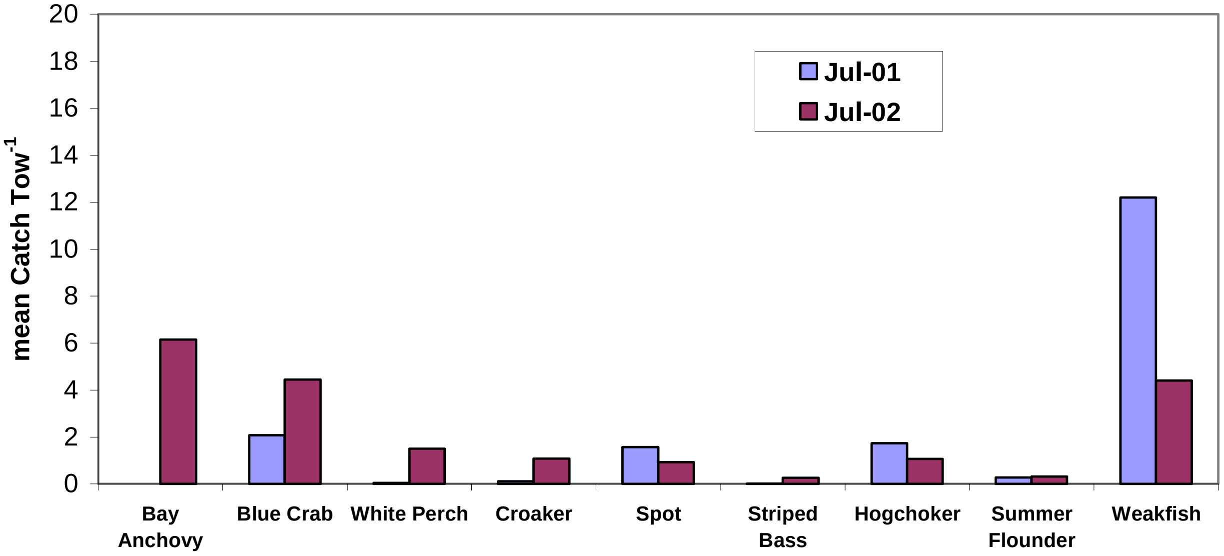

Figure 3. Mean catch per tow (all stations) for July 2001 and 2002

diversity was higher in the lower or southernmost strata except for high numbers in the Patapsco stratum. Species richness (number of different species within a stratum) was consistently higher, in some cases 2 – 3 times higher, in the lower strata where uncommon species were more likely to be caught. Overall, species diversity tended to be higher in 2002 compared to 2001, particularly during the July survey. The average catch tow^{-1} also increased from May through September (Table 3) in all 9 strata. In May the average abundance in the Patapsco and Severn/South strata was 3 times higher than Pocomoke and Tangier and 7 – 8 times higher than the other five strata. By July, abundances were similar in Patapsco, Severn/South, Pocomoke and Tangier and were twice as abundant as the other five strata. By September, the pattern of abundance again shifted and high abundances were observed in the Little Choptank, Tangier and Patapsco strata and were 3 – 10 times greater the than other strata.

Bay anchovy was the most abundant species caught during the three surveys (Figure 3) and comprised anywhere from 28 – 40% of the overall catch within a particular survey. Blue crab was usually the second most common species caught as abundance increased throughout the survey and comprised anywhere from 16 – 22% of the total catch (Figure 3). Blue crab biomass, however, was the most significant contributor, ranging from 36 – 58%, to the total weight of the catch (second only to white perch during the May survey). Due to the re-allocation of stations and increased effort in the upper bay, white perch abundance and biomass estimates were much higher in 2002 than in 2001 (Figure 3). White perch catches comprised approximately 10% of the total catch in all sample periods and more than 70% of the catch in the most northern strata. Croaker and weakfish (*Cynoscion regalis*) were also important seasonal components to the overall catch.

Objective 3: Tributary and gear comparison surveys.

We conducted work in the Patuxent River in August 2002 which formed the basis for both a gear comparison between the broadscale and shoal survey gear and also quantified the fish assemblage in a tributary . The survey was conducted as a completed randomized block design involving samples taken during daylight and night time hours, sampling deep (~ 8 m) and shallow (~4m) depths at two sites.

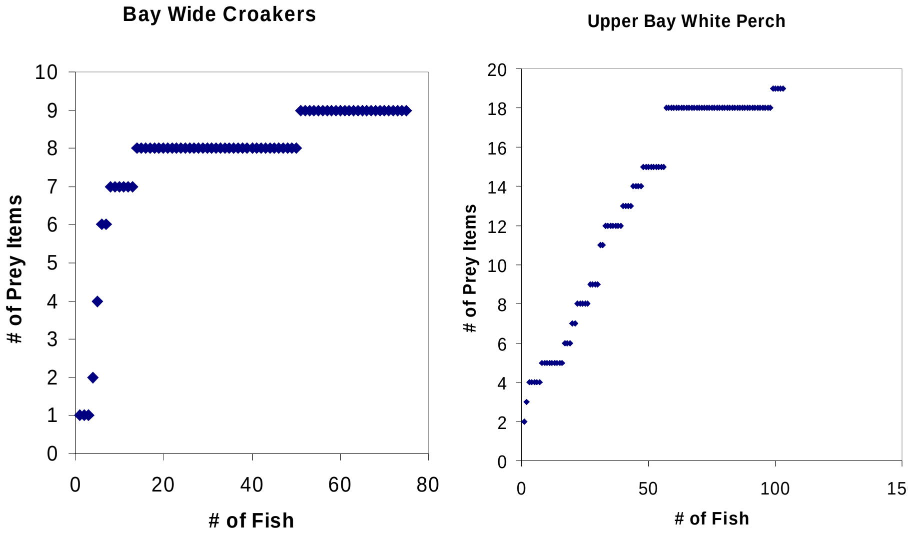

Figure 4 *Rarefication curves for croaker and white perch used to estimate sampling effort*

Analyses of these data are currently ongoing. Preliminary analyses indicate that there were no significant differences in the diversity between the nets, sites, depths or times. However, these same analyses indicate a significant difference between the catch rates of the two gears. We will complete these analyses by exploring difference in the biological characteristics of the fish sampled in the two gears. However, it is clear from these preliminary analyses that additional efforts in the area of gear calibration are required.

Objective 4; Defining Trophic Relationships

Dietary data is a critical need if multispecies management is to be implemented effectively in the Chesapeake Bay ecosystem (Houde et al,. 1998). Dietary data is required to apply the majority of multispecies assessment approaches, including EwE, MS-VPA, and multispecies production models. More directly, dietary data provides insights into which species may covary in abundance, either positively or negatively, when the system is harvested or when it responds to environmental change. Clearly, if two species are related as predator and prey, removal of prey will mean fewer predators can be supported, and conversely removal of predators mean more prey can be supported.

Subsamples of species collected during the broadscale and shoal surveys in 2002 and the broadscale surveys in 2001 were preserved for dietary analyses. We have made substantial progress in analyzing the stomach contents of preserved fish. A statistically representative sample of all principal species has been analyzed for all 2001 collections, and we have largely completed analysis of CF0201 samples. To determine how many individual stomachs of each species needed to be analyzed to produce statistically representative samples we developed rarefication curves for the principal species (Fig. 4). These curves show the relationship between

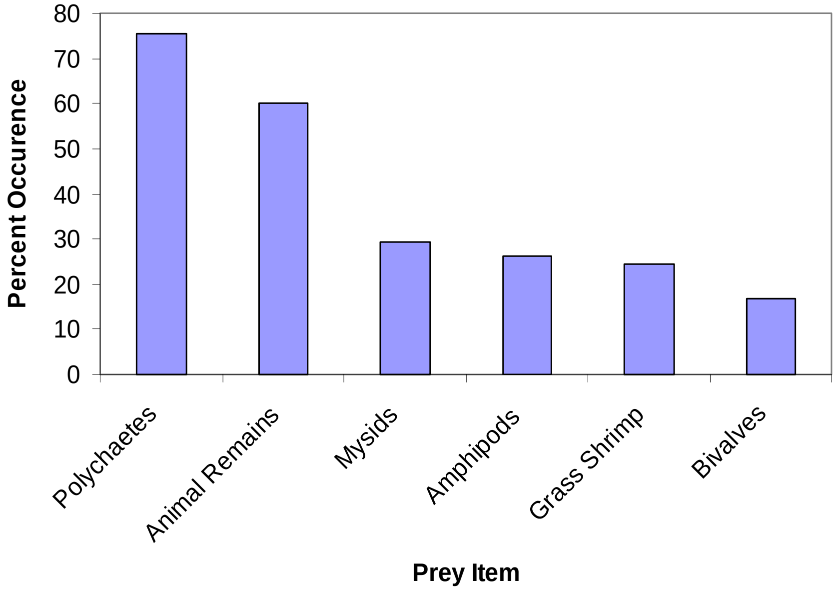

Figure 5. *Percent occurrence of croaker stomachs with specified prey in spring 2002*

the estimated diversity of prey in the diet and the number of stomachs quantified. For croaker, spot, and weakfish it was determined that 20 individual stomachs per Bay region (Lower, Mid, Upper) needed to be analyzed. However, 20 stomachs were insufficient to adequately quantify the diets of white perch. For this species, we have determined the need to examine 60 stomachs per region to adequately define diet diversity.

We have initiated the statistical analysis of the dietary data. Preliminary analyses involve estimating the proportion of all fish that are found to have at least one of the specified prey in their diet (% Occurrence – Fig. 5), the contribution of that prey to the total number of prey in the diet (% N – an indication of the predatory impact of the fish on its prey) and the contribution of that prey to the total biomass of the diet (%W – an indication of the importance of that prey to the fish bioenergetically). We will estimate %O, %N and %W for the principal species collected during CHESFIMS cruises for all regions of the Bay.

Objective 5: Evaluation of survey design and analysis options

Research into the performance of alternative survey designs, and a comparison of the utility of standard survey design approaches and spatial modeling have been the focus of work conducted to meet this objective.

Survey Design Performance

Survey cruises during 2002 involved a complex design of both transect sampling and stratified random surveys on each cruise. We evaluated the effectiveness of the two survey designs by comparing their respective design effects (Kish 1965; 1995) with respect to estimates of mean catch per unit effort (CPUE). Design effects are useful for planning purposes, and for evaluating the effects attributable to stratification with proportional allocation of sample sizes among strata, and deviations from simple random sampling within strata due to clustering of stations in the transect surveys. The *design effect* is defined by the ratio,

$$deff = V_c(\hat{\theta}_v) / V_{SRS}(\hat{\theta}_{SRS}) \tag{1.1}$$

where

θ is the mean CPUE; $\hat{\theta}_c$ is an approximately unbiased estimator of θ computed from a sample of size n for a specific survey design, $V_c(\hat{\theta}_v)$ is the variance of $\hat{\theta}_c$ estimated with respect to the complex design; $\hat{\theta}_{SRS}$ is a standard approximately unbiased estimator of θ based on simple random sampling (SRS) of size n with replacement selected from the same sampling frame, and $V_{SRS}(\hat{\theta}_{SRS})$ is the variance of $\hat{\theta}_{SRS}$ estimated under the same simple random sampling design. For a given parameter θ, the estimator $\hat{\theta}_c$ based on data from a complex survey with a sample size of n has the same variance as the estimator $\hat{\theta}_{SRS}$ for a simple random sampling design with a sample of size $n / deff$. The "effective sample size" for estimation of θ using data from the complex survey design C is defined as

$$n_{eff} = n / deff \tag{1.2}$$

If, for example, the design effect equals two for a particular complex survey design, then a simple random sample of half the size as for the complex design would achieve the same precision. We used SUDAAN (RTI 2002) to estimate the design effects for the two overlapping surveys.

In the stratified random survey, the number of stations was allocated proportional to the volume of each stratum. In the transect survey, the stations were clustered because 2-3 stations were assigned to each transect and, hence, the selection probabilities for stations in the transect survey were heterogeneous within strata. In the estimation of mean CPUE and associated design effects, we treated the transect survey (Trans) as a two-stage design (Cochran 1977; Wolter 1985) with primary sampling units (transects) being of unequal size. We assumed that transects and stations within transects were randomly selected, and applied standard estimators for a two-stage survey to estimate means and variances (Wolter 1985). For the stratified random survey with replacement (STRWR), we applied the usual stratified random estimators (Wolter 1985).

We used a composite estimator (e.g., Korn and Graubard 1999) to combine the CPUE estimates for the two overlapping surveys:

$$CPUE_{comb} = (w_1 CPUE_{STRWR} + w_2 CPUE_{Trans}) / (w_1 + w_2) \tag{1.3}$$

with the weights being the effective sample sizes for each survey. Thus, the CPUE from the most effective survey receives higher weight in the estimation of a combined CPUE. An estimator for the variance of the combined CPUE was similarly obtained as

$$V(CPUE) = \frac{w_1^2 \times V(CPUE_{STRWR}) + w_2^2 \times V(CPUE_{Trans})}{(w_1 + w_2)^2} \tag{1.4}$$

As an example, we produced estimates of mean CPUE (number of fish per standard tow) and associated standard errors, as well as design effects, and effective sample sizes for selected species, and for all species combined for the transect survey (Table 3).

Estimates of mean catch per unit effort (CPUE), and associated measures of precision and survey efficiency suggest that the stratified random survey is more effective than the sampling along transects for bay anchovy, croaker, and white perch. The design effect for these species were ~1 for the stratified random survey, but considerably > 1 for the transect survey. For these species the effective number of stations visited was substantially less than the actual number of transect stations occupied (Table 3) . For one species (weakfish), the transect surveys had a design effect of unity, or less, and thus appear to be more effective than the stratified random survey.

Table 3. *Mean catch-per-unit-effort and measures of precision and design effects for the 2002 transect surveys. The relative standard error is in the last column.*

Survey	Species	deff	n	n_eff	mean	Se	rse
Spring	Bay Anchovy	1.3	29	22	98.0	27.1	0.28
Summer	Bay Anchovy	2.2	31	14	482.6	157.4	0.33
Fall	Bay Anchovy	3.0	31	10	1452	422.8	0.29
Spring	Croaker	1.5	29	19	3.3	1.1	0.33
Summer	Croaker	3.9	31	8	2.6	1.6	0.62
Fall	Croaker	0.7	31	44	7.8	2.2	0.28
Spring	White Perch	3.5	29	8	14.1	9.6	0.68
Summer	White Perch	4.2	31	7	4.8	4.1	0.85
Fall	White Perch	3.7	31	8	7.9	7.0	
Spring	Weakfish	0.6	29	48	1.6	0.7	0.44
Summer	Weakfish	1.0	31	31	1.1	0.5	0.45
Fall	Weakfish	0.4	31	78	13.4	1.3	0.10
Spring	All Species	1.3	29	22	145.2	25.5	0.18
Summer	All Species	2.2	31	14	565.0	177.6	0.31
Fall	All Species	3.1	31	10	1557.8	419.6	0.27

We also calculated CPUE's for each species in the full complex survey design. The combined survey resulted in a relative precision (RSE) of 20% or less for mean CPUE across all species.

Spatial Modeling

Statistical spatial modeling of the multispecies data collected in 2001 has been performed and will soon be performed for the 2002 datasets. One of our intentions was to use kriging in order to map the spatial distribution of the Shannon-Weiner Index (SWI) of biodiversity, the total number of fish per tow, and the total number of species per tow for each of the three cruises in each year. So far, for 2001, the data collected during the July cruise (CF0102) have been amenable to spatial statistical modeling. The data from the first cruise (CF 0101) do not show any spatial autocorrelation and the third cruise (CF 0103) had insufficient stations for spatial modeling. Initial reviews of the 2002 data from July and September (CF0202 and CF0203) indicate that they are likely suitable for spatial modeling. Analyses should be completed before March 2003.

Table 4. *Mean number of fish per tow from CF0102 in each stratum and bay-wide based on two methods of calculation.*

Stratum	Sample Means	Kriging-Based Means
Lower	1685	1973
Mid	1747	1641
Upper	1663	1727
Bay-Wide	1701	1823

Work performed to date includes development of S+ code to perform the statistical analyses and development of the equations for estimating variances and prediction errors for various quantities derived from the modeling. Our intent is to compare the prediction errors for several estimators of the mean for the variables of interest. The methods which we expect to compare include: the “design-based” sampling approach; an approach based on ordinary kriging; an approach using kriging of a spatial average; and a method based on regression-type estimation. These will be applied to at least two of the datasets, probably the July cruises from 2001 (CF0102) and 2002 (CF0202). We intend to compare the results for different subsets of the Bay as well.

We have started the comparison of the performance of standard design based and spatial model approaches to estimate the average CPUE. We present a sample of these results of the summer survey in 2001 in Table 4. There is broad congruence between the two approaches. We are currently developing variance estimators for the spatial modeling approach so that we can compare variables statistically.

We have also begun to conduct multivariate spatial analyses to quantify the correlation structure in the abundances of the species sampled. These analyses will help in identify the degree of overlap of species guilds, and the potential for trophic interactions.

CONCLUSIONS

In the second year of CHESFIMS we completed three broadscale and three shoal surveys and met and exceeded the project goals. The results from the different surveys provide a solid foundation from which to address important questions relevant to multispecies management.

1) Our surveys provide reliable indices of abundance and distribution of ecologically and economically important finfish species in Chesapeake Bay. Our current estimate is that the precision of the abundance estimate is ~ 20%. The survey document changes in abundance and in the distribution of important Chesapeake Bay fishes during 2002. In combination with previous CHESFIMS surveys and with the data from the TIES program, we are now capable of developing eight-year times series of estimated abundances of these same species. Importantly, these data provide estimates of not only commercially important species, but also of ecologically important species, such as bay anchovy, on which many of the commercial species rely. The abundance estimates we develop will be important to the development of a range of multispecies assessment models including EwE, multispecies production models, and MSVPA.

2) Our sampling will provide important information on the trophodynamics of key components of the Chesapeake Bay fish community. As regional agencies begin to explore multispecies management models, such as EwE, the need for diet data, collected coincidentally with abundance estimates will become acute. We are developing spatially and temporally explicit diet

matrices for key species. A full assessment of the utility of the dietary information provided by CHESFIMS awaits completion of the laboratory analysis of preserved samples.

3) On going efforts with regard to statistical analysis of the data offer the opportunity to optimize current survey designs. We have estimated the utility of transect-based and stratified random designs that can provide information on the trend and characteristics of species surveyed. In addition we have developed spatial models of surveyed species that will permit the spatial and temporal associations among species to be quantified. Knowledge of the relative efficiency of alternative stratification schemes, spatial distribution and sampling intensity will be important if multispecies surveys are to become a routine feature of the assessment of the Chesapeake Bay fish community.

LITERATURE CITED.

Houde, E. D., M. J. Fogarty and T. J. Miller. 1998. Prospects for multispecies management in Chesapeake Bay: A workshop. STAC Publication 98-002. Chesapeake Research Consortium, Edgewater, MD.

Kimura R., D. H. Secor, E. D. Houde and P. M. Picoli. 2000. Up-estuary dispersal of young of year bay anchovy in the Chesapeake Bay: inferences from microprobe analysis of strontium> Mare. Ecol. Progr. Ser. 208:217-227

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

Kish, L. (1995). Methods for Design Effects. Journal of Official Statistics **11**, 55-77.

Korn, E.L., and B.I. Graubard. 1999. *Analysis of Health Surveys.* John Wiley & Sons.

New York.

Miller T. J.[1], C. J. Heyer[1], A. F. Sharov[2], B. Muffley[2] M. C. Christman[3], N. Herman[3] J. H. Volstad[4], E.D. Houde[1], and K. Curti[1] . 2002. Abundance, Distribution and Diversity of Chesapeake Bay Fishes: Results from CHESFIMS. Annual Report to NOAA

Pennington, M. and J.H. Vølstad. 1994. The effect of intra-haul correlation and variable density on estimates of population characteristics from trawl surveys. Biometrics 50, 725-732.

Research Triangle Institute (2001). SUDAAN User's Manual, Release 8.0. Research Triangle Park, NC: Research Triangle Institute.

Williams, R.L. 2000. A Note on Robust Variance Estimation for Cluster-Correlated Data. Biometrics **56,** 645-646.

Wolter, K.M. (1985). *Introduction to Variance Estimation.* Springer-Verlag. New York.