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ANNUAL REPORT

CHESAPEAKE BAY FISHERY INDEPENDENT MULTISPECIES FISHERIES SURVEY (CHESFIMS)

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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 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 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.). 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.).

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. From 1995 - 2000, a bay wide investigation of biological production potential and its temporal and spatial variability has been conducted. The objectives of TIES (Trophic Interactions in Estuarine Systems) research are broad and not focused solely on fish. Nevertheless, fish were sampled consistently using a midwater trawls throughout the program=s duration. Based on these data, patterns in species abundances, diversity, size and biomass distributions in the fish assemblage have been analyzed (Jung 2001). In addition, data on the dietary patterns in many of the species sampled are also available.

We proposed to develop a fishery-independent survey that addressed the critical needs identified in the Houde et al. (1998) report. Further, we recognized that although the TIES program sampled extensively throughout the Chesapeake Bay system, several important categories of habitats were not represented: specifically the extensive shoal areas < 5 m deep and the tributaries. Existing sampling programs do samples shoal and tributary areas in Virginia, but we lack a consistent, and extensive survey in the mid- and upper Chesapeake Bay. Accordingly we proposed to a survey design that extended the broadscale midwater trawling conducted for the TIES program and complemented it with a parallel shoal survey.

PROGRESS AGAINST OBJECTIVES

The CHESFIMS program identified six key research objectives. Each sought to develop or implement essential components of a bay wide fishery independent multispecies survey. Here we identify each objective and summarize the work that has been conducted to date to address the objective.

Objective 1. Conduct a baywide survey of the bentho-pelagic fish community, focusing on young (juveniles, and yearling) fishes in the mainstem of Chesapeake Bay.

We proposed to continue that portion of TIES which focuses on pelagic fishes, documenting their distribution in time and space and their trophic relationships. The TIES fish data are particularly valuable because they represent collections made over the entire bay three times annually and span a six-year time period, during which major changes in freshwater inputs and other environmental factors have occurred. Despite shortcomings, the length of the time series of collections and the breadth of data in the collections makes TIES valuable as a data source to help launch a CBSAC multispecies effort.

Methods

Three broad scale surveys were conducted in 2001, from 30 April - 5 May (CF 0101), 16 - 23 July (CF 0102) and 24 September - 1 October (CF 0103) (Table 1). All surveys were conducted from the University of Maryland Center for Environmental Science=s R/V Aquarius. Samples of the fish community were collected from between 15 - 48 stations (Table 1). At each station we profiled the water column using a Seabird SBE 25 CTD profiler. Subsequently, a midwater trawl (18-m^2 mouth opening, 6-mm cod end mesh, as in the TIES program) was deployed in a single, oblique stepped 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. The nominal tow duration was 20 minutes, however, the actual deployment time was 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 two 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.

Raw processing of net hauls was conducted on board the vessel. The total catch at each station was weighed. Fish were identified to species and total weights for individual species were recorded. Samples of length and weights of individual fish were taken for up to 30 randomly selected individuals of each species. Fish were then frozen whole, or preserved in ethanol, depending upon size for subsequently analysis in the laboratory. In the laboratory, identifications, lengths and weights were confirmed. Subsequently, stomachs and otoliths were dissected from individual fish for diet and age analysis. Stomach contents were flushed and identified to the lowest taxanomic level possible. Sizes and weights of subsamples of prey were quantified. No age analysis has yet been conducted.

Results

The first survey (CF0101) sampled 31 stations baywide and collected 1,452 fish (total weight ~ 67 kg). The second survey (CF0102) sampled 48 stations baywide, collecting 75,336 fish (total weight ~ 130 kg). The final survey sampled on 15 stations, mainly in the mid- and upper-Bay. Poor weather during the scheduled survey period prevented sampling of more stations. Despite this lower effort, 73,619 fish (total weight ~76 kg) were collected.

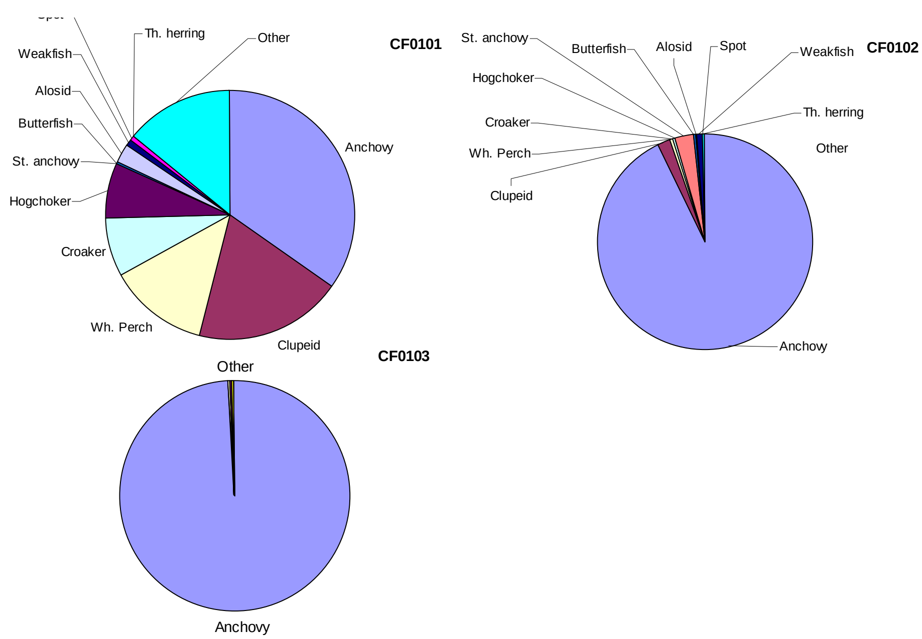
Patterns and distributions of diversity and abundance varied among the three surveys. The total number of species caught in each survey was approximately constant (Table 1).

Table 1. Summary of sampling and results (mean ± SE) from 2001 broadscale surveys

		Survey		
		CF0101	CF0102	CF0103
Dates		April 30 - May 5	July 16 -23	Sept 25 - 29
Number of Stations		31	58	13
Average CPUE (fish/haul)	Lower	63.4±22.21	1418±346.2	3280
	Mid	14±3.41	1745±586.6	9002±656
	Upper	63.66±48.45	1586±525.3	2814±1165
	Overall	49.9±14.91	1535±274.8	5639±563.4
Average CPUE (g/haul)	Lower	2179±1198	3197±1136	6361
	Mid	250.4±81.89	1054±372	8546±430.5
	Upper	6466±4884	4021±2155	3027±1294
	Overall	2044±878.7	2654±720.6	5957±568.2
Total N^{o} S		27	29	26
Average Diversity (N^{o}. Species)	Lower	5.31±3.01	6.05±1.77	10
	Mid	3.6±1.89	5.35±2.23	5±0
	Upper	4.66±3.44	5.66±2.87	5.88±2.31

The average diversity of the fish community at each station increased slightly between spring and autumn. In general, the average diversity was higher in the lower-Bay region reflecting the increased diversity of marine ecosystems (Table 1). Average catch per tow increased over the three surveys (Table 1). However, within surveys the distribution of abundance changed. In April (CF0101), the abundance in the mid-Bay region was approximately one fifth of the abundance in the other two regions (Table 1). In the summer survey, abundance was equal in all regions (Table 1). Yet, by autumn, the pattern of abundance had shifted so that fish in the mid-Bay region were almost three times more abundant than in the other regions (Table 1). Similar patterns were evident in biomass (Table 1).

Bay anchovy (*Anchoa mitchilli*) dominated the catches during all cruises (Fig. 1). Bay anchovy catches increased from 16.45 fish.tow^{-1} in April, to 1,458 fish.tow^{-1} in July and peaked at 4,871 fish.tow^{-1} in September. However, estimates for September may be inflated because we were unable to sample the lower-Bay stations at which anchovy abundances were likely lower. The seasonal pattern of catches of bay anchovy reflects the underlying biology of this species (Kimura et al. 2000). In the spring survey, the highest catches of anchovy were taken in the lower Bay. In these regions, anchovy averaged 70.28 mm TL (range 33-94 mm TL). In the summer cruise, the center of anchovy distribution had moved slightly northward (Fig. 2), and the length range had broadened (15 - 99 mm TL, average = 38.27 mm TL). The average length of anchovy was lowest in the mid-Bay region. The abundance and both minimum and maximum sizes were higher in the upper Bay region, reflecting the northward migration of newly recruited bay anchovy. We cannot infer fully the distribution of anchovy in autumn, due



to the weather-induced reduction of sampling in the lower bay. However, the available data are consistent with a general northward migration of young-of-year anchovy.

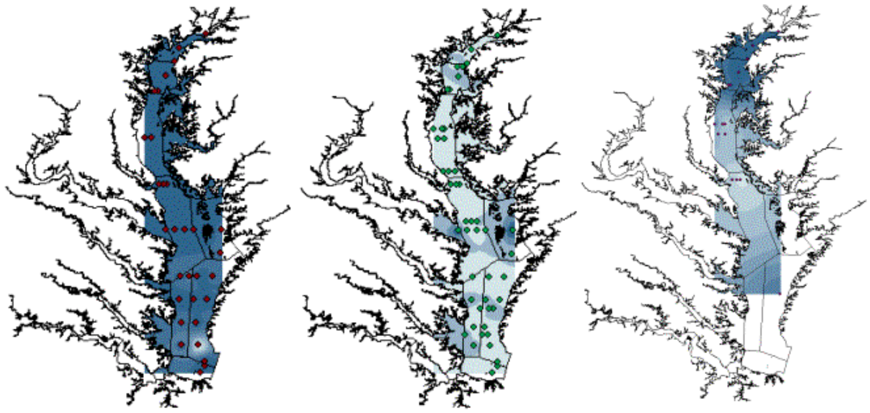


Figure 2. Distribution of bay anchovy (#.tow^{-1}). Lighter colors indicate higher concentrations

Young of year clupeids were the second most abundant fishes in both the spring and summer surveys (Fig. 1). Average catches of this species group during these surveys were 9.03 and 28.31 fish.tow^{-1} in spring and summer respectively. Young of year clupeids were only collected in the lower- and mid-Bay stations in the spring. In the summer, young of year clupeids were present in all three regions. Fish were smaller on average in the lower Bay than in either the mid- or upper-Bay. Only two fish were caught in the autumn survey; one each in the mid- and upper-Bay regions. Both fish were greater than 77 mm TL.

White perch was the 3rd, 5th and 2nd most abundant species in our collections in the spring, summer and autumn surveys (Fig. 1). In all surveys, white perch was collected only at upper-Bay stations. In the spring, the average CPUE was 11.23 fish.tow^{-1}. The average length of white perch was 192 mm TL (range 67-297 mm TL). By summer, white perch abundance had increased (95.4 fish/tow), but average size had decreased (186.7 mm TL, range 5 - 262 mm TL) due to recruitment of young of year to the survey gear.

Sciaenids were also common in catches (Fig. 1). In springtime, the sciaenid catch was dominated by croaker (*Micropogonias undulatus*), which was the 4th single-most abundant species at that time. The average CPUE for croaker was 3.516 fish.tow^{-1}, with the majority of catches being taken in the lower-Bay. In this region, the average size of croaker was 270.3 mm TL (range 270 - 283 mm TL). By summer time croaker CPUE increased to 4.79 fish.tow^{-1}, but its rank abundance was reduced to 7th. The average size of croaker was relatively unchanged from springtime, but the size range increased greatly (31 - 366 mm TL), because of recruitment of young of year croaker to the gear. Only three croaker were collected in the autumn survey, due principally to the reduced spatial coverage of that survey. Weakfish (*Cynoscion regalis*) were seasonally abundant in survey catches in summer (1.4 fish.tow^{-1}) and autumn (4.9 fish.tow^{-1}). In springtime, weakfish abundance were concentrated in lower- and mid-Bay stations, and were comprised of relatively large weakfish (184 - 286 mmTL). Young of year weakfish recruited to the survey gear in summer (size range = 21 - 303 mm TL), and were more evenly distributed among regions. This relatively broad distribution was maintained in the autumn.

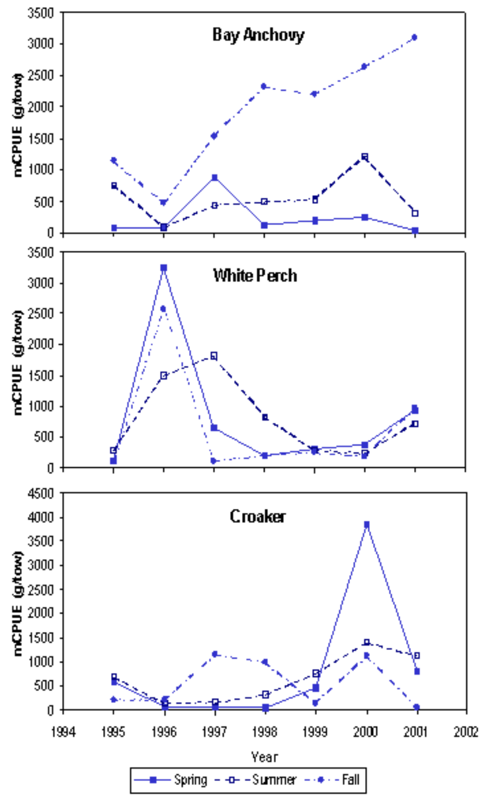


Figure 3. Time series of abundance of bay anchovy, white perch and croaker from TIES and CHESFIMS surveys

We combined CHESFIMS abundance data for the three of the most common species with the historical TIES data (Fig. 3). The composite time series for bay anchovy indicates a strong increase in autumn abundance over the period 1995 - 2001. 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 years of the time series.

Objective 2. 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.

Collections in TIES were limited to the mainstem of the bay and to water depths < 4.5 m. While the proposed sampling program outlined in **Objective 1** provides full compatibility with the TIES program, it leaves out any consideration the biologically important shallow areas (< 4.5 m). These areas are important habitats for a large variety of fish species, especially at juvenile stages. Therefore, we proposed to expand the survey into shallow waters to collect data analogous to those outlined in **Objective 1.**

Survey Design

The shoal habitat survey was conducted on three separate occasions from May through October 2001, immediately after the completion of the corresponding Chesapeake Bay mainstem survey, providing a temporal link between the two surveys. Table 2 presents a brief sampling summary from each sampling period. Sampling was confined between the MD line (approximately 37.5°N) and 38.5°N (below the mouth of the Choptank River). The selected area covers most of the shoal zone within MD waters of the bay and it includes two regions sampled by the MD DNR blue crab survey (Tangier Sound and Pocomoke Sound). We intend to utilize historical information collected by the crab survey since late 1970s and merge it with the data collected through our random survey. In addition, there are three transects of the CHESFIMS mainstem survey within the selected area. The later is important in an attempt to integrate the results of both shallow water and mainstem surveys. In addition, the proximity of the strata geographically minimizes transport time and consequently allows more data to be collected. The sampled area was divided into four geographical strata and over 100 stations were randomly allocated proportionally to the strata area. The strata were defined as follows:

a. Stratum 1: Calvert Cliffs Area. Initially Stratum 1 was defined as a stretch along the western shore between the north side of the mouth of the Potomac River and the south side of the mouth of the Patuxent River. However, our attempts to sample in stratum 1 were unsuccessful, we accounted significant problems due to a very rocky bottom. Two trawls were torn and sampling was abandoned. We redefined stratum 1 as a stretch between the mouth of the Patuxent River and $38^{0}32'$ N (Calvert Clifffs area). Ten stations were sampled in redefined stratum 1.

b. Stratum 2: Pocomoke sound area. Along the eastern shore, between 37.54°N (below Smith Island) and 38.03°N (above Smith Island) This region includes a transect from the mainstem survey and the Pocomoke Sound blue crab stations. 29 - 33 stations sampled.

c. Stratum 3: Tangier sound area. Along the eastern shore, between 38.03°N and approximately 38.22°N. This region includes a transect from the mainstem survey and the Tangier Sound blue crab stations. 55 - 59 stations sampled.

d. Stratum 4: Below Choptank River area. Along the eastern shore between 38.22°N and 38.32°N (below the mouth of the Choptank R.). 6 - 10 stations.

Additionally, a second tow of 3 minutes duration was carried out at approximately 1/3 of the stations selected at random out of the total 107 to investigate the effect of tow duration on the size and species composition of the catch. The order of the three and six minute tows at double tow stations was selected at random. The double trawls were only carried out during the September sampling period. Stations were allocated proportionally to strata area for all strata with the exception of stratum 1. The number of stations sampled in stratum 1 was fixed at n = 10 (allocation proportional to stratum 1 area would have resulted in a very small number of stations to be sampled, e.g. n=3). The stations were selected using a program maintained by the MD DNR that will randomly selected sites within confined geographic areas and between selected depths.

Methods

The shoal survey dates and level of sampling is summarized in Table 2. Stations were sampled at depth less than 5 meters (~17 ft), using 16 foot bottom trawl. A six minute tow was conducted at each station. All fish and crabs in the catch were identified by species, counted, measured and weighted. Environmental data such as air temperature, surface and bottom water temperature, salinity, dissolved oxygen, water clarity and wind conditions were recorded. The sample processing protocol was adapted from the protocol used for the mainstem stations since the boat sizes were so different.

Table 2. Summary of shoal survey sampling 2001

Month	Sampling Dates	Stratum	N° of Sites	N° of Double Trawls
		Choptank	8	0
		Tangier Sound	56	0
May	5/10/01 – 6/7/01	Pocomoke Sound	33	0
		Calvert Cliffs	6	0
		Total	**103**	**0**
		Choptank	8	0
		Tangier Sound	59	0
July	7/10/01 – 8/6/01	Pocomoke Sound	31	0
		Calvert Cliffs	10	0
		Total	**108**	**0**
		Choptank	8	1
		Tangier Sound	56	16
September	9/24/01 – 10/16/01	Pocomoke Sound	33	9
		Calvert Cliffs	10	2
		Total	**107**	**28**

Results

Catch Per Tow

Mean catch tow^{-1} indices were highly variable from month to month (Figures 4a – c). The highest catch tow^{-1} indices occurred during the July sampling period, while the lowest catches observed occurred in May. Catches were an order of magnitude higher, even greater for some species, in July than in May. September catches remained high for most species and were even greater than July catch tow^{-1} indices for some species such as the blue crab (*Callinectes sapidus*).

Within each month, catch per tow indices were also variable between strata (Figures 4a - c). The Pocomoke Sound stratum contained the highest catches among the four strata during all sampling periods. Catches were lower in the Tangier Sound but remained much higher than the Choptank and Calvert Cliffs strata. Catch estimates in the Choptank and Calvert Cliffs strata were usually low or controlled by one catch. For example, one Calvert Cliffs trawl in May caught over 1000 bay anchovy (*Anchoa mitchilli*) but a total of only 25 anchovies were caught in the remaining five trawls, resulting in a high variance of the mean catch per tow (Fig 4a).

Species composition also changed from month to month and from strata to strata. In May, catches mostly comprised of bay anchovy, blue crab, hogchoker (*Trinectes maculatus*), and northern sea robin (*Prionotus carolinus*). July was also dominated by bay anchovy, but weakfish (*Cynoscion regalis*) and spot (*Leiostomus xanthurus*) were also abundant. Anchovy abundance declined in September but still comprised a large amount of each trawl along with Atlantic croaker (*Micropogonias undulatus*) and blue crab. The Choptank and Calvert Cliffs strata were dominated by only a few species, in some cases only two different species were caught in a particular strata (Figure 4b). There was anywhere from 15 – 19 different species caught in the Tangier and Pocomoke Sounds over the course of the sampling season.

Biomass Per Tow Estimates

Biomass estimates were derived for each species and were based on the length-weight relationship derived for that particular species from the sub-sample of lengths and weights recorded over all sampling

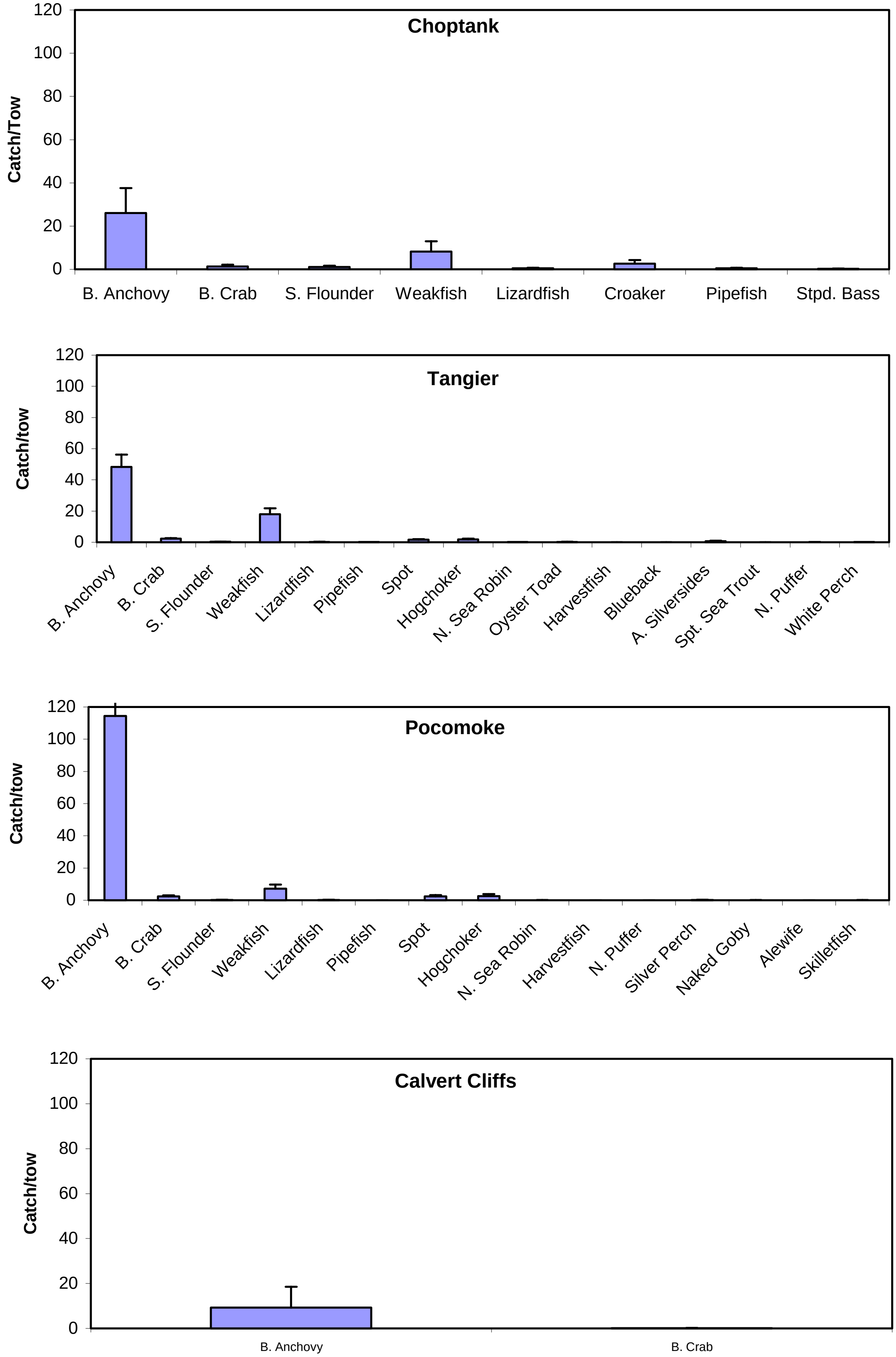
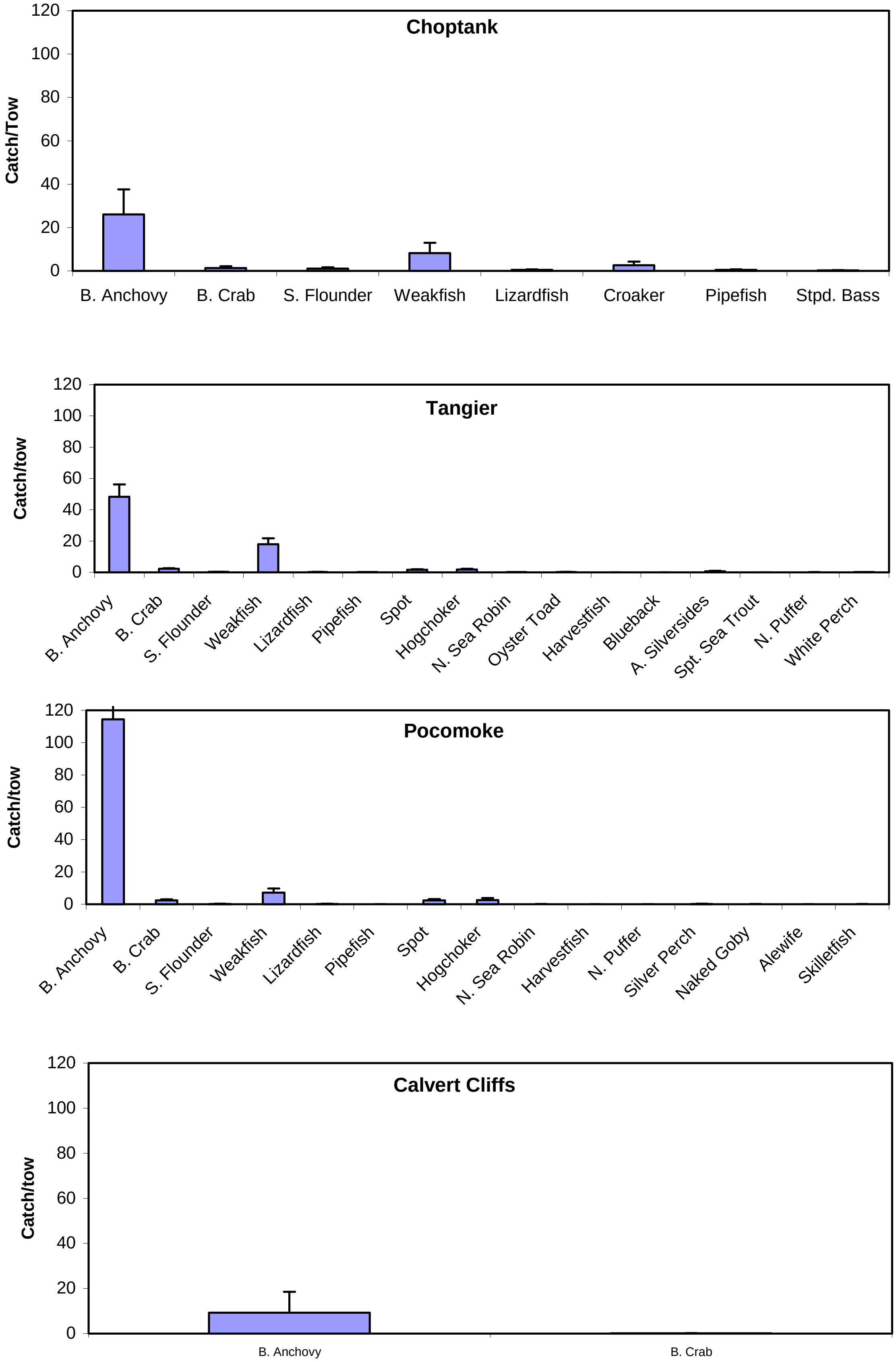


Figure 4b. Mean catch/tow for July survey. Error bars represent 1 S.E. of the mean.



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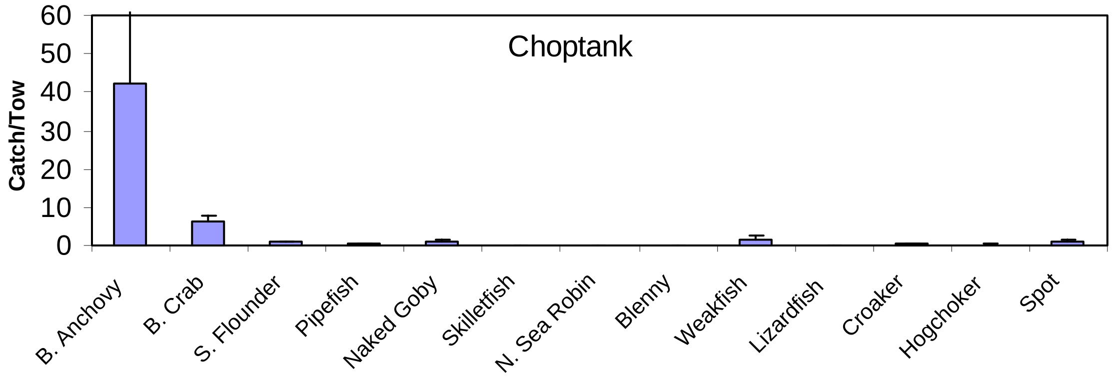
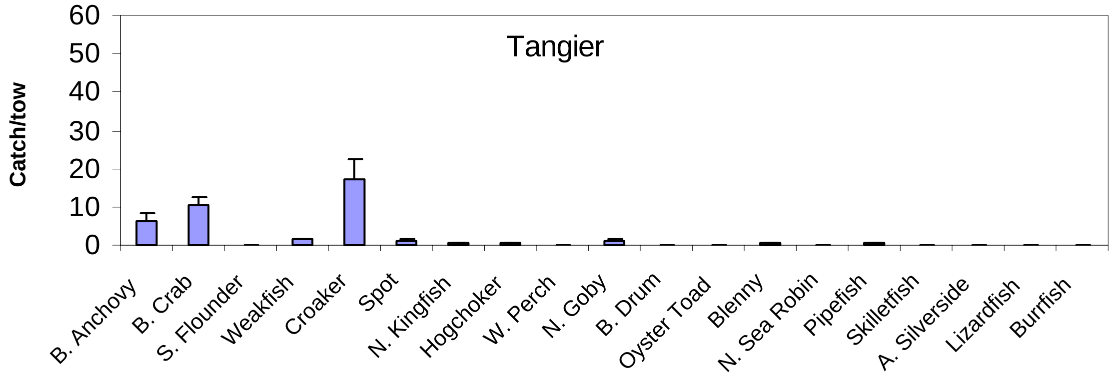

Choptank
Catch/Tow
60
50
40
30
20
10
0
B. Anchovy
B. Crab
S. Flounder
Pipefish
Naked Goby
Skilletfish
N. Sea Robin
Blenny
Weakfish
Lizardfish
Croaker
Hogchoker
Spot


Tangier
Catch/tow
60
50
40
30
20
10
0
B. Anchovy
B. Crab
S. Flounder
Weakfish
Croaker
Spot
N. Kingfish
Hogchoker
W. Perch
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Oyster Toad
Blenny
N. Sea Robin
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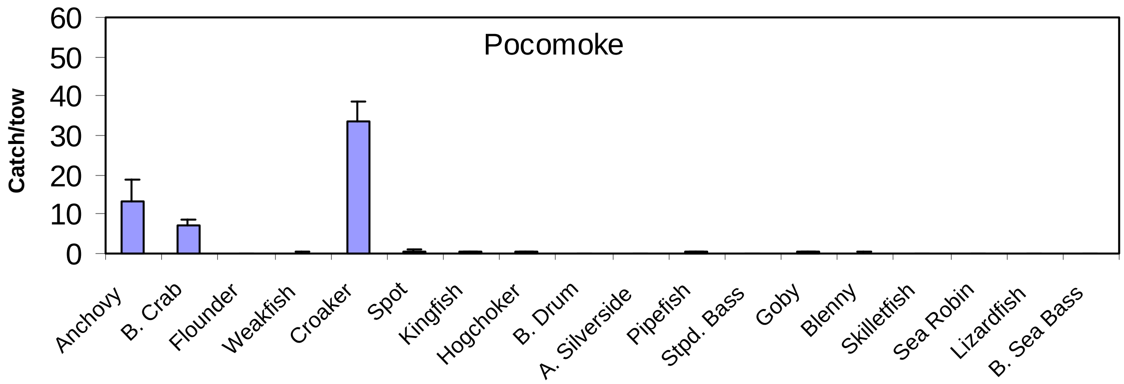
Skilletfish
A. Silverside
Lizardfish
Burrfish


Pocomoke
Catch/tow
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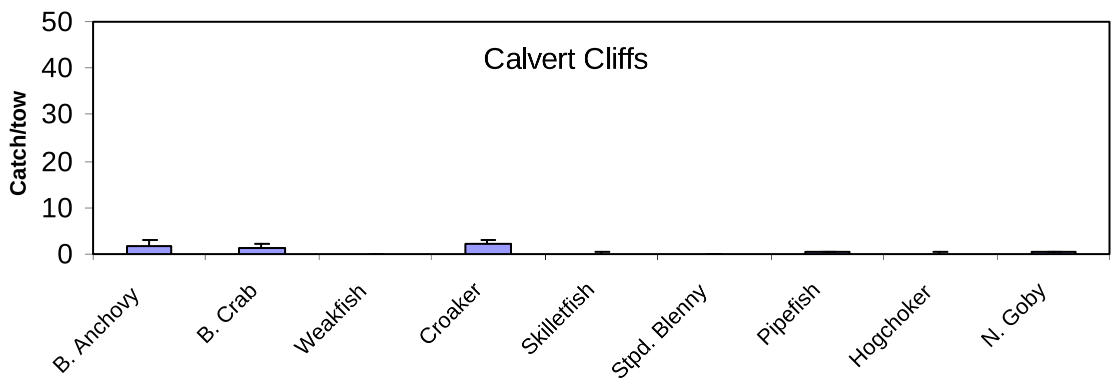
Anchovy
B. Crab
Flounder
Weakfish
Croaker
Spot
Kingfish
Hogchoker
B. Drum
A. Silverside
Pipefish
Stpd. Bass
Goby
Blenny
Skilletfish
Sea Robin
Lizardfish
B. Sea Bass


Calvert Cliffs
Catch/tow
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40
30
20
10
0
B. Anchovy
B. Crab
Weakfish
Croaker
Skilletfish
Stpd. Blenny
Pipefish
Hogchoker
N. Goby

Month	Bay Anchovy	Blue Crab	Summer Flounder	Weakfsh	Lizardfish	Pipefsh	Croaker	Striped Bass	Spot	Hogchoker	Northern Searobin
May	32.8	103.5	60.9	4.9	0.0	0.4	17.3	0.1	8.9	45.1	3.0
July	53.2	113.7	37.3	62.6	1.4	0.1	0.2	0.0	46.5	26.1	1.7
September	9.2	492.6	39.9	5.0	2.8	0.2	15.4	0.3	57.8	8.6	1.4

Month	Harvestfish	Atlantic Silverside	Puffer	Blueback Herring	Seatrout	White Perch	Silver Perch	Naked Goby	Alewife	Skilletfish	Blackcheek Tounguefish
May	0.0	0.0	0.0	0.0	0.0	36.7	0.0	0.0	0.0	0.0	0.0
July	0.2	0.6	0.0	0.0	1.3	9.1	0.4	0.0	0.0	0.0	0.0
September	0.0	0.1	0.0	0.0	0.0	5.9	0.0	0.0	0.0	0.0	0.0

Month	Menhadn	White Catfish	Atlantic Herring	American Eel	Windowpane Flounder	Winter Flounder	Blenny	Northern Kingfish	Black Drum	Burrfish	Black Sea Bass
May	0.0	8.7	0.0	0.4	0.0	0.1	0.0	0.0	0.0	0.0	0.0
July	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
September	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.7	3.9	0.0	1.4

Month	Oyster Toadfish	Spotted Hake
May	9.7	5.3
July	16.7	0.0
September	3.3	0.0

Table 3. Summary of mean biomass tow^{-1} ($g\ tow^{-1}$) estimates for every species caught within each month.

periods. Total biomass tow^{-1} estimates were then derived for each species within each stratum over all sampling periods. Individual strata estimates were then added to get a total biomass tow^{-1} estimate for each species within each sampling period (Table 3).

As with catch tow^{-1} indices, total biomass tow^{-1} estimates were variable from month to month. Biomass estimates increased from May through September. The high estimate of total biomass for September is attributed to more than a four-fold increase in the blue crab biomass tow^{-1} in September in comparison with May and July (Table 3).

Within each month, biomass tow^{-1} estimates were less variable among strata, in particular Tangier and Pocomoke Sounds. Biomass estimates tended to be higher in Tangier Sound, but the contribution from each major species was very similar in these two strata. For example, blue crab, bay anchovy, weakfish, spot, and summer flounder (*Paralichthys dentatus*) were the five highest biomass tow^{-1} estimates for both strata in July. Because catches were low or dominated by one trawl in the Choptank and Calvert Cliffs strata, biomass estimates were driven in the same manner. The mean anchovy biomass tow^{-1} in Calvert Cliffs during May was over 400g tow^{-1} due to one large catch

The most abundant species caught in any strata or month were not always the highest in terms of species biomass. Bay anchovy was the most abundant species caught, but due to its small size was not the highest in terms of biomass. Summer flounder on the other hand comprised very little in terms of catch but contributed significantly to the biomass in the catch.

Length-Frequency

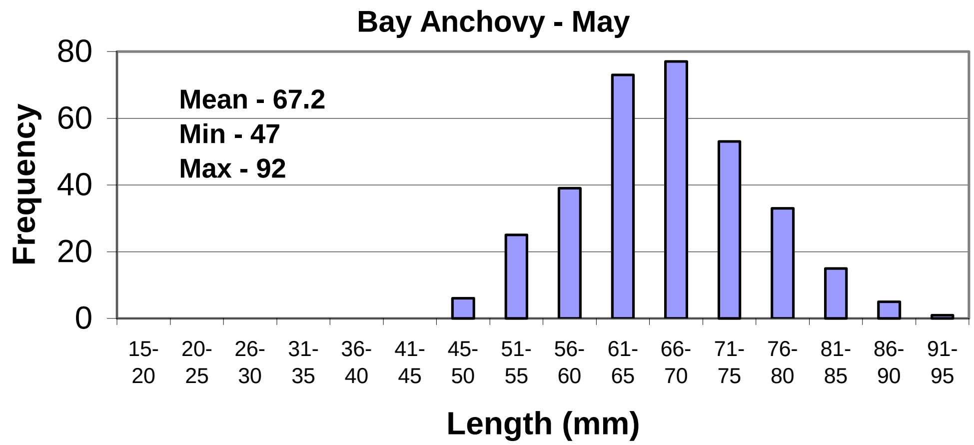
Length-frequency distributions were calculated for the six most abundant species for the entire sampling period. The six species include: 1. Bay anchovy, 2. Blue crab, 3. Hogchoker, 4. Spot, 5. Weakfish, 6. Summer flounder. Species that were abundant in only one month, Atlantic croaker for example were not included here. Length distributions were calculated for each sampling month along with the mean length and range of lengths observed for that particular month (Figures 5a – f).

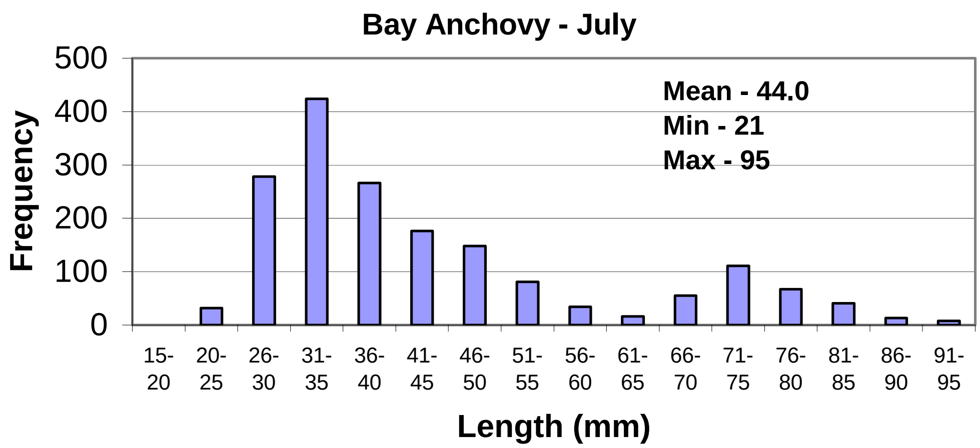
Bay Anchovy (Figure 5a) – There was a clear change in anchovy size throughout the sampling season. In May, most anchovies caught were large, older fish with a mean size of 66mm. In July, there was a shift to small anchovies with a mean size of 44mm. The older fish from the May survey were still noticeable in July survey however. The growth of these smaller fish was apparent in September with a small shift in size (mean 48mm). There was not a clear distinction of size classes in September and the catch comprised a wide range, 19mm – 94mm, of anchovies.

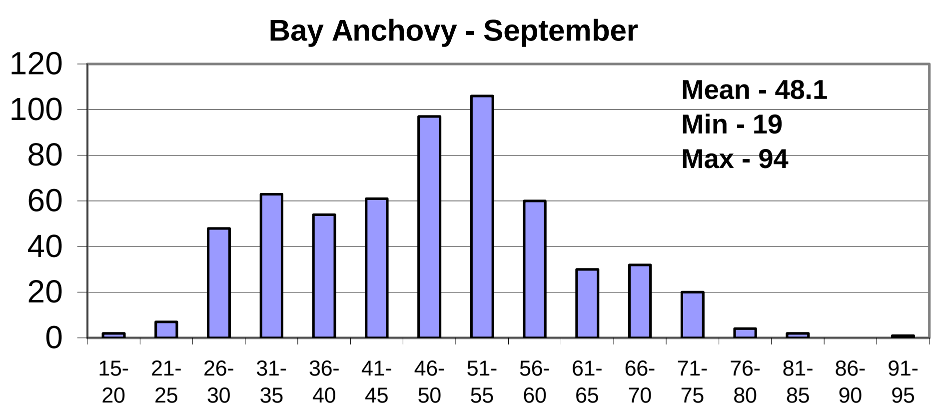
Blue Crab (Figure 5b) – There was wide range of smaller crabs (mean 66.9mm) caught in May, with most under the legal size of 127mm. The catch shifted to moderate and large crabs in July. The mean size in July was 93mm, and about a third of the catch was greater than 127mm. There was a decrease in the mean size of crabs in September to 83mm even though there was a high frequency of crabs larger than 127mm. This was due to the appearance of large numbers of young of the year crabs (CW < 60 mm), leading to a bimodal distribution of crabs (Fig.5b).

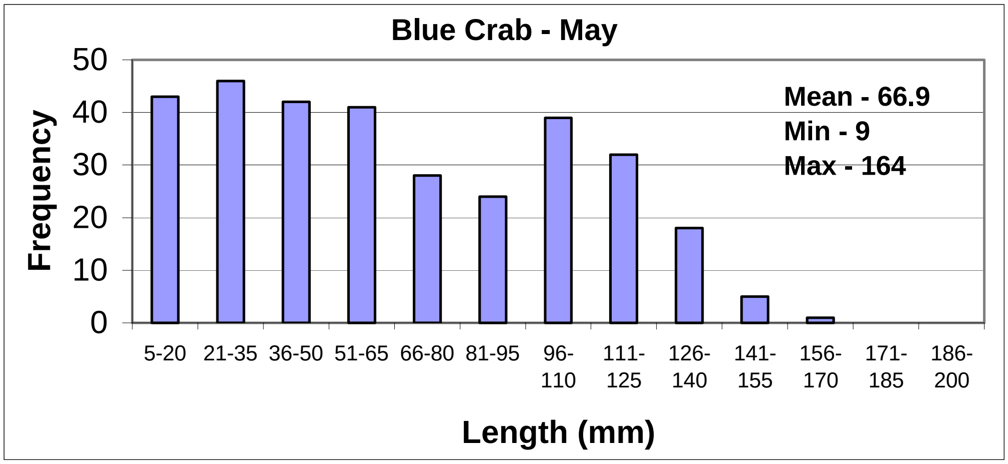
Weakfish (Figure 5c) – There were few weakfish caught in May, and those that were caught were large in size compared to the other sampling periods. The mean size of weakfish in May was 226mm. Weakfish abundance increased dramatically in July with the appearance of the young-of-the-year. The mean size in July was 78mm. There was a slight shift to larger size weakfish in September with a mean size of 81mm.

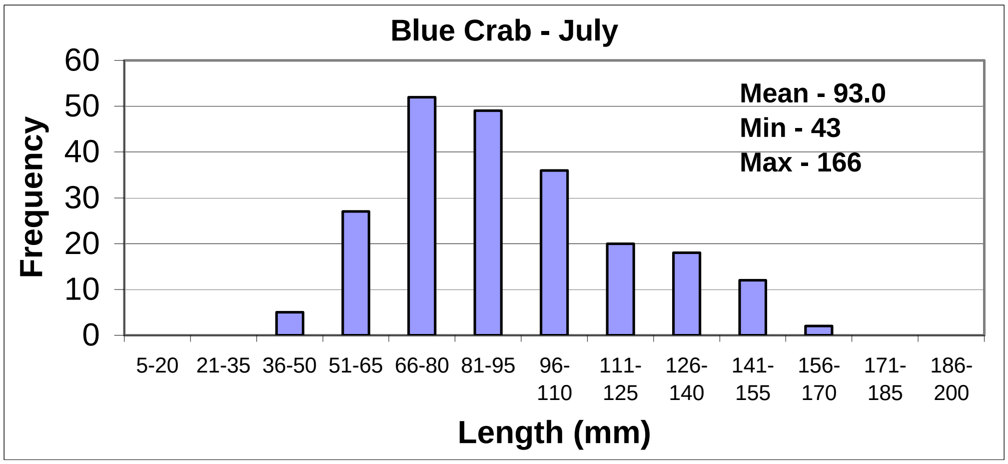
Hogchoker (Figure 5d) – Hogchoker catches displayed a typical “normal” distribution in May. There was a

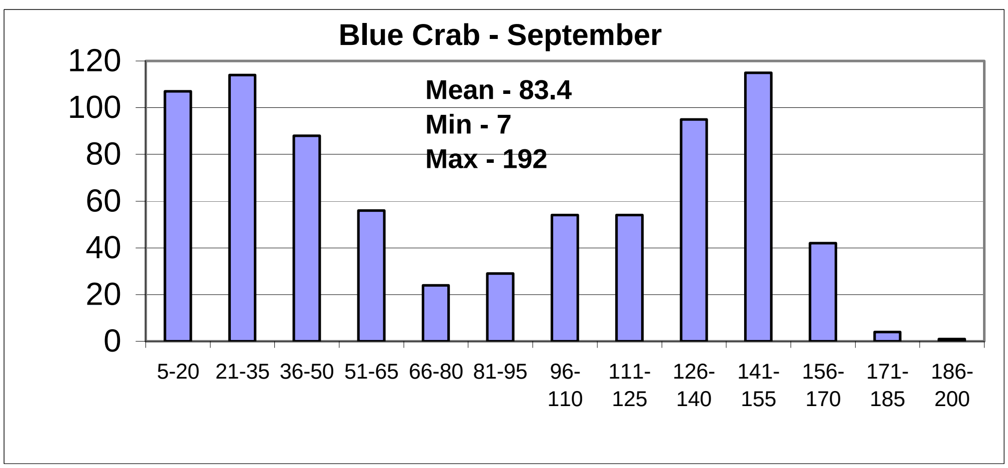

Bay Anchovy - May
Frequency
Length (mm)
Mean - 67.2
Min - 47
Max - 92
0
20
40
60
80
15-20
20-25
26-30
31-35
36-40
41-45
45-50
51-55
56-60
61-65
66-70
71-75
76-80
81-85
86-90
91-95

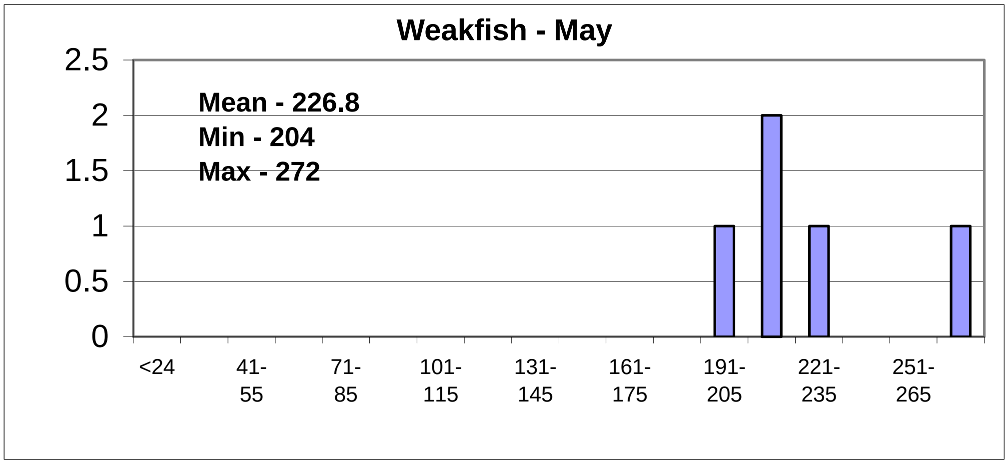

Bay Anchovy - July
Frequency
Length (mm)
Mean - 44.0
Min - 21
Max - 95
0
100
200
300
400
500
15-20
20-25
26-30
31-35
36-40
41-45
46-50
51-55
56-60
61-65
66-70
71-75
76-80
81-85
86-90
91-95

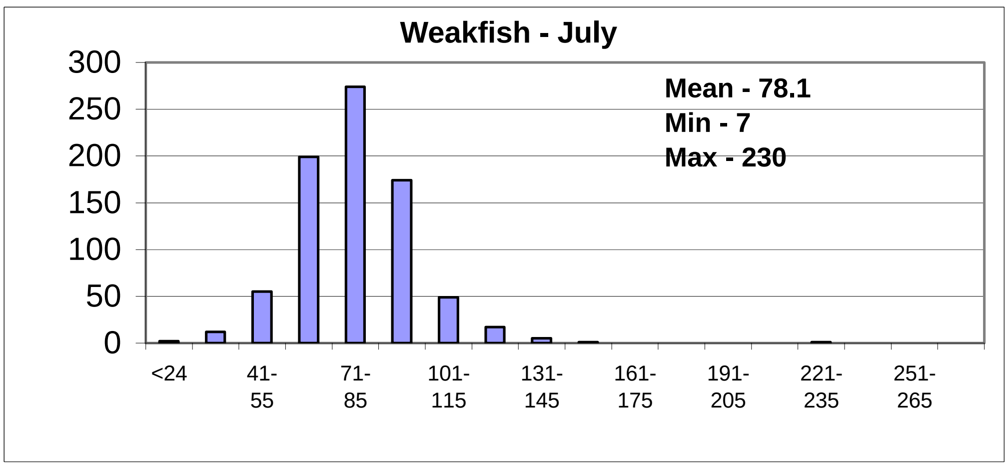

Bay Anchovy - September
Mean - 48.1
Min - 19
Max - 94
0
20
40
60
80
100
120
15-20
21-25
26-30
31-35
36-40
41-45
46-50
51-55
56-60
61-65
66-70
71-75
76-80
81-85
86-90
91-95

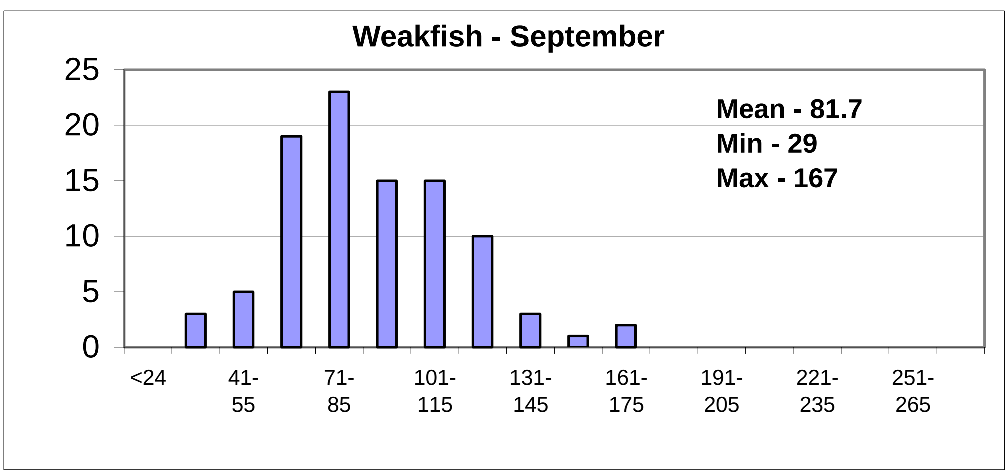

Blue Crab - May
Frequency
0
10
20
30
40
50
Mean - 66.9
Min - 9
Max - 164
5-20
21-35
36-50
51-65
66-80
81-95
96-110
111-125
126-140
141-155
156-170
171-185
186-200
Length (mm)

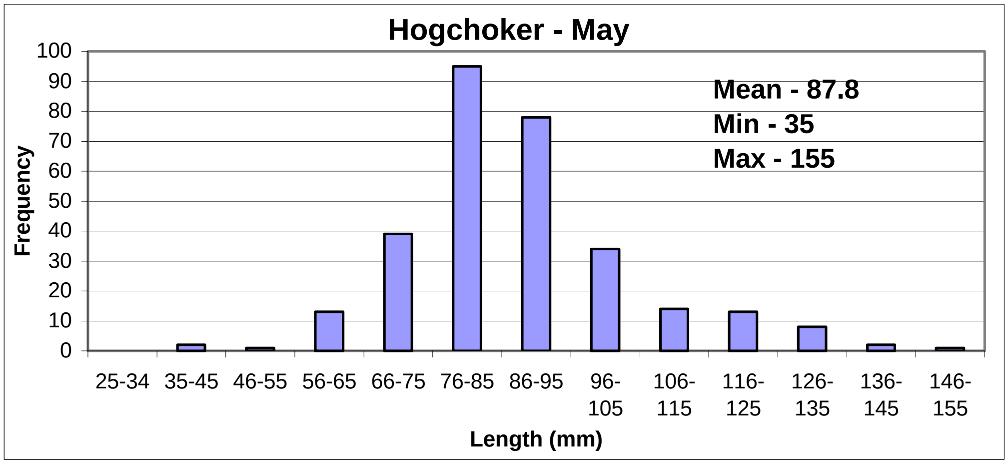

Blue Crab - July
Frequency
0
10
20
30
40
50
60
Mean - 93.0
Min - 43
Max - 166
5-20
21-35
36-50
51-65
66-80
81-95
96-110
111-125
126-140
141-155
156-170
171-185
186-200
Length (mm)

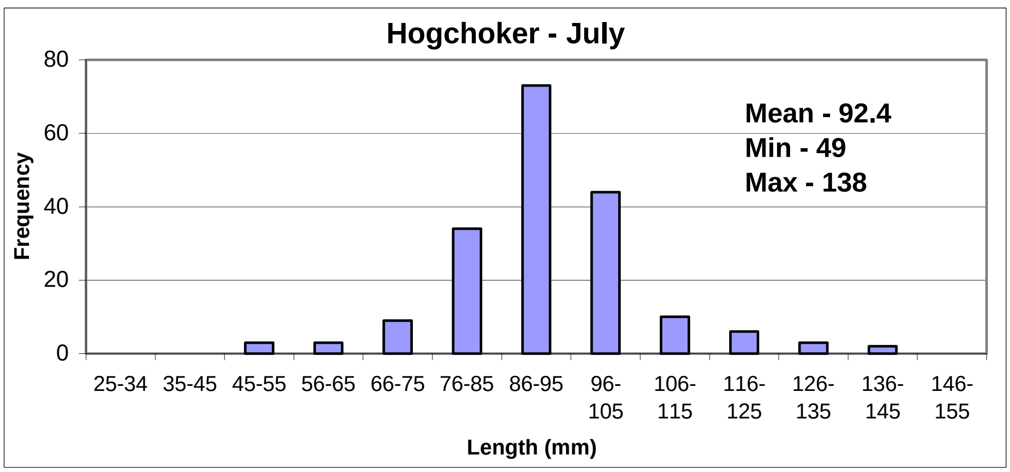

Blue Crab - September
0
20
40
60
80
100
120
Mean - 83.4
Min - 7
Max - 192
5-20
21-35
36-50
51-65
66-80
81-95
96-110
111-125
126-140
141-155
156-170
171-185
186-200

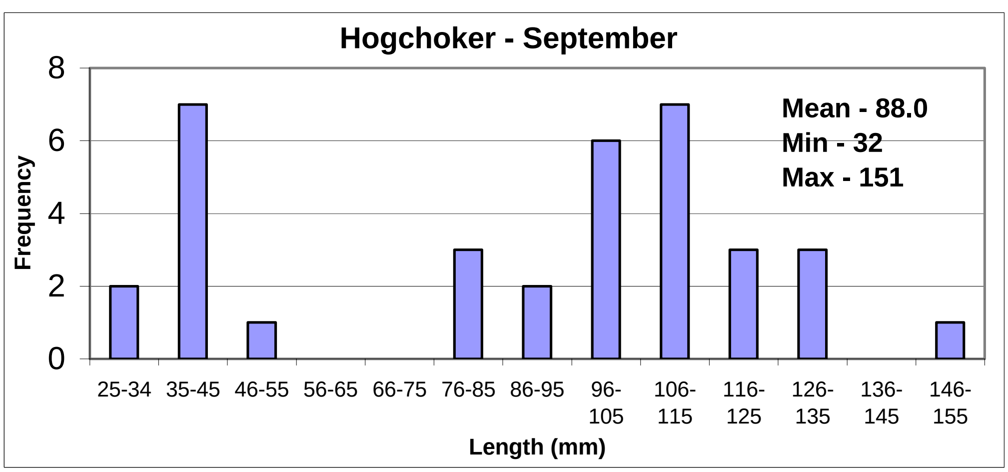

Weakfish - May
Mean - 226.8
Min - 204
Max - 272
2.5
2
1.5
1
0.5
0
<24
41-
55
71-
85
101-
115
131-
145
161-
175
191-
205
221-
235
251-
265

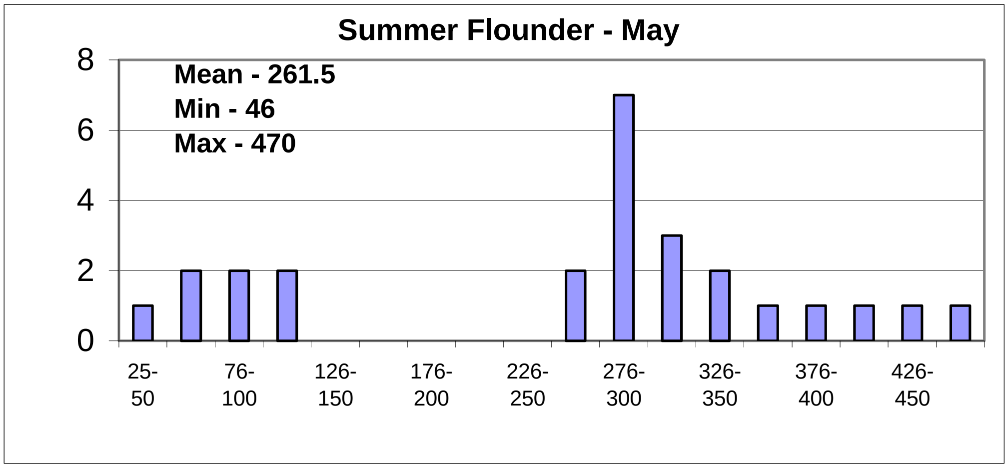

Weakfish - July
Mean - 78.1
Min - 7
Max - 230
300
250
200
150
100
50
0
<24
41-
55
71-
85
101-
115
131-
145
161-
175
191-
205
221-
235
251-
265

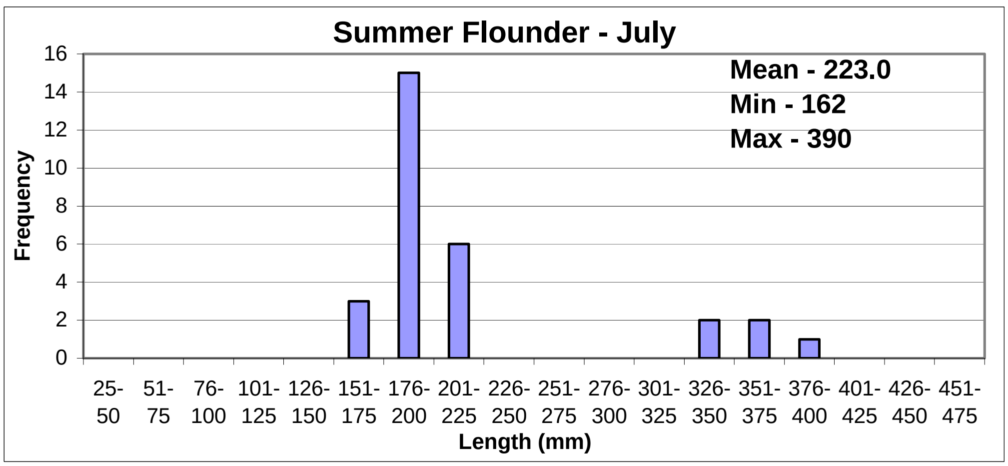

Weakfish - September
Mean - 81.7
Min - 29
Max - 167
25
20
15
10
5
0
<24
41-
55
71-
85
101-
115
131-
145
161-
175
191-
205
221-
235
251-
265

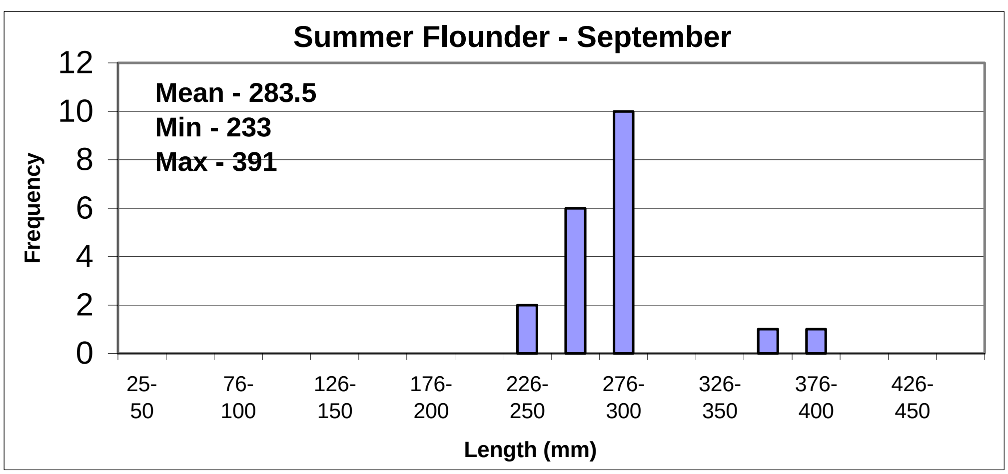

Hogchoker - May
Frequency
100
90
80
70
60
50
40
30
20
10
0
Mean - 87.8
Min - 35
Max - 155
25-34
35-45
46-55
56-65
66-75
76-85
86-95
96-105
106-115
116-125
126-135
136-145
146-155
Length (mm)

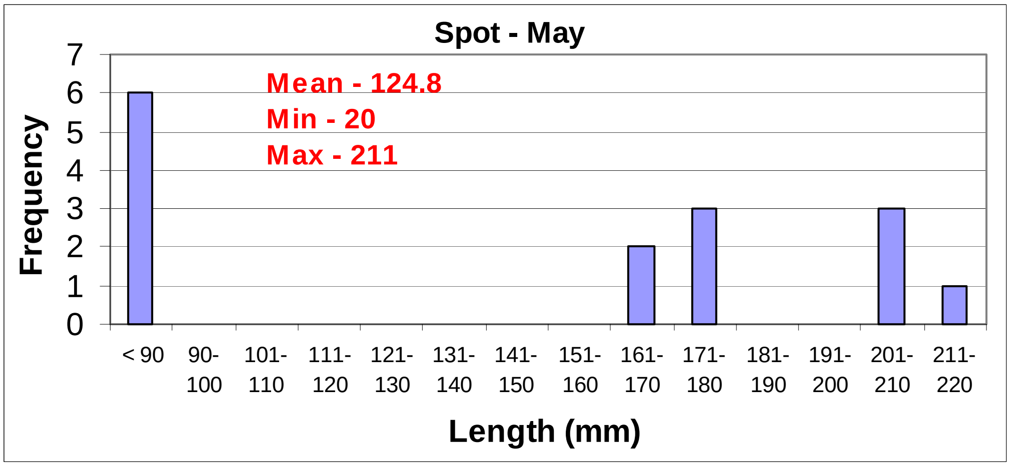

Hogchoker - July
Frequency
80
60
40
20
0
Mean - 92.4
Min - 49
Max - 138
25-34
35-45
45-55
56-65
66-75
76-85
86-95
96-105
106-115
116-125
126-135
136-145
146-155
Length (mm)

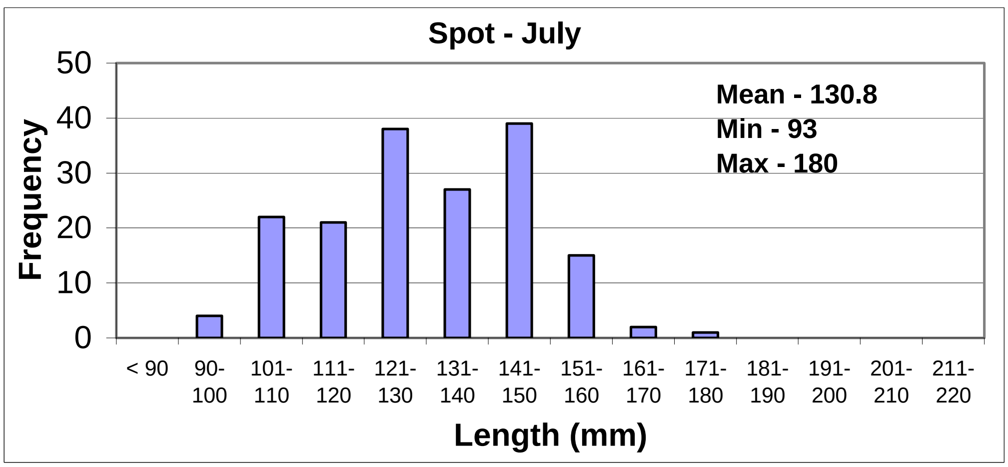

Hogchoker - September
Frequency
8
6
4
2
0
Mean - 88.0
Min - 32
Max - 151
25-34
35-45
46-55
56-65
66-75
76-85
86-95
96-105
106-115
116-125
126-135
136-145
146-155
Length (mm)

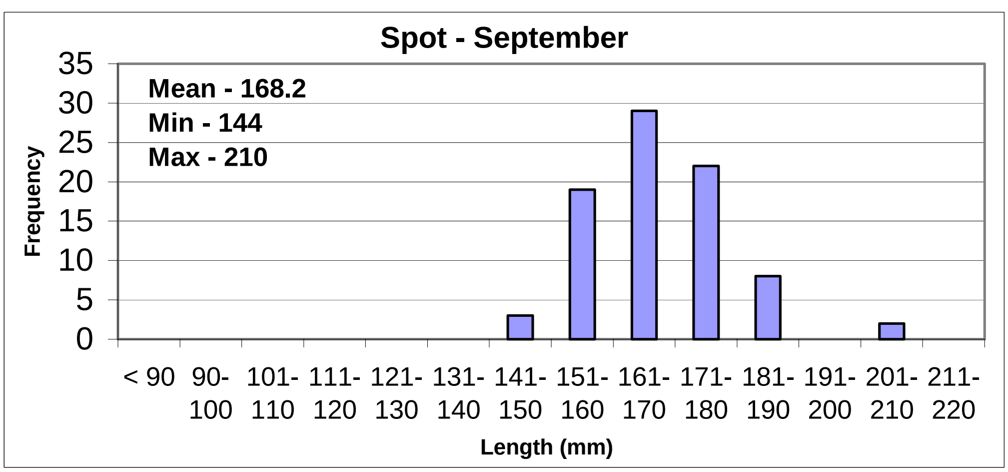

Summer Flounder - May
Mean - 261.5
Min - 46
Max - 470
8
6
4
2
0
25-
50
76-
100
126-
150
176-
200
226-
250
276-
300
326-
350
376-
400
426-
450


Summer Flounder - July
Mean - 223.0
Min - 162
Max - 390
Frequency
16
14
12
10
8
6
4
2
0
25-
50
51-
75
76-
100
101-
125
126-
150
151-
175
176-
200
201-
225
226-
250
251-
275
276-
300
301-
325
326-
350
351-
375
376-
400
401-
425
426-
450
451-
475
Length (mm)


Summer Flounder - September
Mean - 283.5
Min - 233
Max - 391
Frequency
12
10
8
6
4
2
0
25-
50
76-
100
126-
150
176-
200
226-
250
276-
300
326-
350
376-
400
426-
450
Length (mm)


Spot - May
Mean - 124.8
Min - 20
Max - 211
Frequency
Length (mm)
< 90
90-100
101-110
111-120
121-130
131-140
141-150
151-160
161-170
171-180
181-190
191-200
201-210
211-220


Spot - July
Mean - 130.8
Min - 93
Max - 180
Frequency
Length (mm)
< 90
90-100
101-110
111-120
121-130
131-140
141-150
151-160
161-170
171-180
181-190
191-200
201-210
211-220


Spot - September
Mean - 168.2
Min - 144
Max - 210
Frequency
Length (mm)
< 90
90-100
101-110
111-120
121-130
131-140
141-150
151-160
161-170
171-180
181-190
191-200
201-210
211-220

wide range, 35mm – 155mm, of hogchokers caught, with a mean size of 87mm. The same general pattern occurred in July with a slight increase in the mean size to 92mm. In September there were two distinct groups, one of smaller fish (< 55mm) and one of larger fish (> 86mm) with few fish in between. The mean size of hogchokers in September was 88mm.

Summer Flounder (Figure 5e) – There were two distinct groups caught in all three months. There was a group larger than 300mm and a group of smaller flounder that steadily increased in size throughout the sampling period. In May, this smaller group was comprised of fish smaller than 150mm. By July the group ranged in size from 150 – 250mm and increased to 225mm – 300mm by September.

Spot (Figure 5f) – In May there was no clear pattern to the size of fish caught, with a wide range of fish from 20 – 211mm. By July there was a distinct grouping of fish in a relatively small range of 93 – 180mm. The mean size of spot for July was 130.8mm. There was a shift in size to larger fish with a mean of 168 mm and an even smaller range of 144 – 210mm in September.

Summary

Understanding the dynamics of Chesapeake Bay, in particular the shallow areas that are important habitats for a variety of fish species, especially at juvenile stages, was one important goal for the overall 2001 ChesFIMS project. The data collected during the shoal trawl survey provides critical information on species interactions within these biologically important habitats. Close to 40 different species of fish, ranging in size from 15 – 500 mm, were caught from May through October, clearly indicating that a large number of species use this habitat for feeding, protection, or as nursery areas for young-of-the-year (YOY) fish. The change in relative abundance, as seen through changes in catch tow^{-1}, is an indicator of when particular species are utilizing the shoal areas at various times throughout the season. These indices also help provide information about species composition and interactions that may change both spatially, what fish are where, and temporally, what fish and when. Life history information such as growth or habitat utilization can be obtained from the length-frequency data. For example, in May there were only few, large adult weakfish caught only in the Tangier and Pocomoke Sounds, the most southern strata sampled. Larger numbers of YOY weakfish were then present in July. By September, the overall abundance of weakfish had declined from July but the mean size of these YOY fish had increased from the July survey. This data provides information about the timing and location of weakfish spawning, weakfish recruitment, and growth of juvenile weakfish. The data collected from the 2001 shoal survey will help contribute to answering the goals put forth in the 2001 ChesFIMS project summary proposal. Understanding and addressing goals such as, obtaining estimates of abundance for both commercially and ecologically important fish species and, estimates of temporal and spatial dynamics of predator-prey relationships and trophic interactions can begin with the continued collection of the information gathered from the shoal and mainstem surveys.

Objective 3. 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.

We sought to address several additional issues related to spatial coverage and the allocation of sampling effort. We proposed to conduct additional targeted cruises that provided estimates of sample variances for the main tributaries and for alternative spatial arrangements of sample effort. We did not complete any sampling toward this objective. Our decision not to conduct sampling on this objective was motivated by a desire to ensure that maximum effort could be devoted to the first two objectives. We have rolled over the ship time budgeted for this project into the next fiscal year.

Objective 4. 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.

Because biological interactions are a factor motivating the development of multispecies approaches, it is important that we understand the pattern and consequences of such interactions. We proposed to analyze the diets of species commonly caught in the core survey.

Methods
:

We preserved up to thirty fish of each species caught in every haul of the broad scale survey for subsequent diet analysis. Bay anchovy were preserved in ethanol, all other species were frozen. In the laboratory, the identificaion of individual preserved specimens was confirmed. The stomach was dissected from the specimen and weighed. We defined the stomach as that region between the pyloric caecae and the intestine. All of the stomach contents were subsequently flushed out of the stomach The remaining stomach tissue was reweighed to provide an estimate of the total weight of prey by difference. The stomach contents were then preserved in ethanol.

Subsequently we conducted a quantitative analysis of the contents of each stomach to define percent occurrence (%O – the frequency of fish of species i with prey j) and the average percentage contribution to the diet of that species of prey i by weight (%W) and number (%N). We estimated the later, by splitting a suspension of the total gut contents from a specimen in a Folsom plankton splitter to yield subsamples that could be counted. We identified all prey items to at least the genus level when possible. All fish were identified to species.

Results

We have worked diligently to complete the gut contents analysis. To date, we have completed full workup of all non bay anchovy samples from the spring cruise. We have dissected the stomachs from all fish from the summer and fall cruises and have just begun analyzing the contents of individual stomachs. Results are too preliminary to be presented.

Objective 5. Conduct statistical analyses of existing and new data to optimize the complemented pelagic survey with respect to consistency and accuracy of key parameters.

Objectives 1 - 3 continue the collection of data on the fish assemblage started under TIES and provide new data on multispecies fish assemblages for previously unstudied locations and times. To combine these data, we must develop appropriate sampling schemes which can fully utilize the extant data from TIES and the new data to be collected under this proposal. We proposed to conducted analyses of preliminary data collected under **Objective 3** along with historic TIES data to quantify the spatial and temporal distribution for the key species of interest. We also proposed to to develop improved sampling schemes for **Objectives 1 and 2** based on informed decisions from the preliminary analyses, from the expert knowledge of the investigators and from samples taken during each cruise.

Optimal Sampling Design for Design Based Estimation of Mean CPUE

We used an estimator for mean catch per unit effort (CPUE) that applies to a two-stage sampling design (Cochran 1977). For each survey, we assumed that:

1. Transects (primary sampling units) were randomly selected within each stratum; and
2. Trawl stations (secondary sampling units) were randomly selected within each transect.

Under these assumptions, an estimator for the mean CPUE by stratum (s) is:

(1.1)
$$\bar{x}_S = \frac{\sum_{i=1}^{n_S} L_i \bar{x}_i}{\sum_{i=1}^{n_S} L_i}$$

where L_i is the length of transect i and $\bar{x}_i$ is the mean CPUE for the m_i stations taken along transect i. The variance of (1.1) has two components, and is approximated by

(1.2)
$$\mathrm{var}(\bar{x}_s) = \frac{1}{\bar{L}^2 n(n-1)} \sum_{i=1}^{n} L_i^2 (\bar{x}_i - \bar{x})^2 + \frac{1}{nN\bar{L}^2} \left[\sum_{i=1}^{n} L_i^2 \frac{s_{2i}^2}{m_i} \right]$$

where s_{2i}^2 is the variance in the catches within transect i. The first components of (1.2) represents the variation in number of fish between transects, and the second component represents the mean variance in CPUE between trawl stations within transects. It can be seen that a large increase in the number of stations within each transect only reduces the second component, while an increase in the number of transects reduces both components. The stratified mean CPUE for the entire survey area is estimated by

(1.3)
$$\bar{x}_{st} = \frac{\sum A_s \bar{x}_s}{\sum A_s}$$

where A_i is the survey area for stratum s. Because the primary sampling units (transects) or of unequal size, we used SUDAAN (RTI 2001) to estimate the variance of (1.3) based on a Taylor series approximation (Wolter 1985). The efficiency of the survey design was evaluated based on the design effect (Kish 1965; Skinner et al. 1989). The design effect (DEFF) was computed as the ratio of the variance estimated according to a stratified two-stage sampling to the variance based on a simple random sample (SRS) of the same number of trawl stations. We computed the effective sample size (Kish 1965)

$$n_e = n / DEFF$$

to measure the “amount of information” in the trawl samples. Here n_e is the number of trawl stations (under simple random sampling) that would be expected to yield the same precision in the estimated mean CPUE as the n stations under the currently design.

The assessment of sampling strategies was based on the spring and summer cruises (CF0101 and CF0102). The fall cruise (CF0103) was not included in this analysis because only one transect was completed in the Lower Bay. In the spring survey 11 transects were selected across the three strata (31 trawl stations total), while 14 transects were completed in the summer survey (48 trawl stations total).

For CF0101 the design effect for mean CPUE (all species combined) was 1.64. Thus, a random sample of 19 trawl stations would be expected to achieve the same level of precision as the 31 stations under a two-stage design. For bay anchovy, the design effect was 1.55, corresponding to an effective sample size of 20 stations.

During the summer survey, the number of transects were increased, with a total of 48 trawl stations completed. The design effect for all species combined was 1.31, and the corresponding effective sample size was 36. For bay anchovy, the design effect remained at 1.55, corresponding to an effective sample size of 31 stations.

The design-based variance, as compared to the variance under simple random sampling, reflects the effect of the following study design features: stratification and clustering of stations; unequal weighting of the observations; and over (or under) sampling of the fish population in various sections of the Chesapeake Bay.

Some design changes could potentially improve the efficiency of the survey while maintaining the comparability to the TIES data:

1. If feasible, allocate additional stations (between the transects) using stratified random sampling, with number of stations in each stratum being proportional to the relative size of each stratum;
2. For fixed number of stations allocated to the transect sampling, it is recommended that the number of stations within transects be allocated proportional to transect length.

Spatial Modeling

There are two components to this section. The first is the construction of maps that provide sufficient information for developing future sampling strategies that target the areas most useful for modeling species richness, abundance and interactions in the Chesapeake Bay. The second component is related to objective 6 in which data collected under this grant is combined with data collected in previous surveys of the bay are combined in order to develop (multivariate) spatial models explaining the distribution of the important species in the Bay.

Optimal Sampling Design for Spatial Modeling

An initial study was performed in which species diversity, as measured by the Shannon-Weiner Index, for the summer cruise (CF0102) was modeled. This cruise was selected since more stations were visited than on the other cruises. A total of 48 stations were visited where the stations were mostly arranged in 14 cross-bay transects and the remainder were in N-S transects. A spatial model was run in which the data were first detrended by removing the stratum level mean and then a geostatistical model was applied to the detrended residuals. Preliminary results of the geostatistical model indicated that spatial autocorrelation does exist and that it is relatively strong at the smaller scales. On the other hand, plots of directional variograms indicated that there is insufficient data in the NE-SW direction for anisotropy to be adequately addressed if a two-dimensional model is imposed. Because of the shape of the Bay this is not unexpected and hence is not an artifact of the transect design. An important consideration for future sampling is that additional stations between transects, possibly randomly chosen, be sampled in order to ensure that enough observations exist in the N-S direction to accurately estimate the autocorrelation structure. We recommend that, given the shape and length of the mainstem of the Bay, modeling of the mainstem spatially should be done as though it was a one-dimensional object, similar to the approach that would be used for a river. The stations along a transect could be used to study small-scale covariance as would be expected when modeling a variable that tends to cluster in space (as is almost always the case with fish). Later, when the data from the mainstem are combined with the data from other surveys, including our shoal survey, this will be readdressed.

Multivariate Spatial Modeling

Currently, the only models that have been developed are based on data obtained in the mainstem during the second survey in 2001 and are based on summary measures of biodiversity. Our plans are to perform a multivariate analysis on two predator species, weakfish and striped bass, and an analysis on the three most abundant species, bay anchovy, croaker, and spot. In addition, data are being collected from other surveys and will be incorporated into the analyses if they are compatible. The other surveys include TIES, VIMS trawls, and DNR datasets.

Objective 6. Conduct statistical analyses to facilitate the integration of information from the complemented pelagic survey and existing fishery-independent surveys.

An important component of this proposal is to combine the data collected under **Objectives 1-4** with data that was collected under previous surveys such as TIES, the VIMS year-round trawls, the Maryland summer surveys and the Chesapeake Bay Stock Assessment program. We proposed to develop the methodology required to combine data from such disparate sources and collected for such disparate reasons into one coherent model of the economically important component of the bay ecosystem for pelagic fishes.

No work has yet been completed toward this objective

CONCLUSIONS

In the first 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 apparently reliable indices of abundance and distribution of ecologically and economically important finfish species in Chesapeake Bay. Of note, is that these surveys provide the reliable, baywide estimates of bay anchovy abundance, a previous unsurveyed species. Though not exploited itself, bay anchovy is an important prey item for many economically important piscivores (Hartman and Brandt 1995). Consequently, the availability of an index of abundance will be an important component of future multispecies fisheries models. Not only do our surveys provide an accurate index of anchovy abundance and recruitment, but they also provide important baywide recruitment indices for several species including Atlantic croaker, weakfish, anadromous clupeids and probably white perch.

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 ECOPATH / ECOSIM, the need for diet data, collected coincidentally with abundance estimates will become acute. A full assessment of the utility of the dietary information provided by CHESFIMS awaits completion of the laboratory analysis of preserved samples. It is important to note that preserved TIES samples are also available for analysis which offer the potential to greatly broaden the potential inferences regarding dietary patterns.

3) On going efforts with regard to statistical analysis of the data offer the opportunity to optimize current survey designs. These efforts are an important component of our work. 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.

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