Final Report to the VMRC and RFAB

Project Title: The value of seagrass beds to Chesapeake Bay

Report Number: 4

Principal Investigators: Robert J. Latour, Jacques van Montfrans, David Combs

Period of Performance: 1 January 2005 to 31 May 2006

Award Number: RF 05-06

Funding Total: $99,056 ($58,221 VMRC, $40,835 VIMS)

Introduction

When the Magnuson-Stevens Fisheries Management Conservation Act (MSFMCA) was reauthorized in 1996, it recognized the importance of essential-fish habitat and ecosystem-based approaches to fisheries management. Although these approaches are written in law, formal ecosystem-based fisheries management plans have yet to be put into practice. In many respects, this is due to a lack of ecological information describing community dynamics and structure on an ecosystem-level scale. Several multispecies fisheries modeling approaches can be used to assist with the development of ecosystem-based management plans; however, their application is often prohibited because the data needed for accurate model parameterization does not exist.

Seagrass beds have been identified as critical nursery habitat for many important finfish and other species. These habitats are perceived to have great intrinsic value, so much so that the National Marine Fisheries Service recently identified seagrass beds as "Essential Fish Habitat (EFH)" (Magnuson-Stevens Act, 1996). However, on a worldwide scale, there exists only peripheral evidence to support the notion that seagrass beds enhance actual production of fish populations. This lack of evidence is due in large part to a limited understanding of the population and community dynamics of the species that either permanently reside in, or systematically use, seagrass beds. It can be argued that achieving this understanding is essential if we are going to be able to truly identify seagrass as EFH and implement the ecosystem-based fisheries management plans.

With the completion of this project, we enhanced our understanding of seagrass beds as EFH by evaluating finfish community dynamics in these habitats. Specifically, we collected data on species composition, abundance/biomass, age- and size-structure, and trophic interactions of larger predatory fishes in seagrass beds in lower Chesapeake Bay. We also developed a series of predator-prey models to more formally characterize the impact of finfish predators on prey species and to investigate the effects of fluctuations in abundance and varying SAV density over time.

Collectively, our research identified and characterized the dynamics of fish trophic interactions in one very important habitat in Chesapeake Bay, SAV. Thereby, we have increased an understanding seasonal food web dynamics and fish predation impacts and foraging effects on inhabitants of SAV in Chesapeake Bay at a broad geographical and temporal scale. This information will assist in developing ecosystem-based fisheries management plans for Chesapeake Bay. The general conclusions from this research follow below.

Methods

Collection of predators
Sampling locations (n = 9) were established within three general zones in Chesapeake Bay where seagrasses occur: Western Shore, Mid-bay, and Eastern Shore (Figure 1). Potential sampling locations were established from aerial photography and onsite verification to assure the presence of SAV near to marsh edges. Western Shore sites included Goodwin Island, Mobjack Bay, and Damron Marsh. Mid-bay sampling sites incorporated locations at Tangier Island, Goose Island, and Smith Island (MD). The Eastern Shore sampling sites were located at Hungars Creek, Parkers Island, and the Big Annemessex River (MD).

Sampling for fishes occured in 6 – 12 randomly selected vegetated habitats in each of the three bay zones. At each sampling location, a 183 m long by 2 m deep trammel net that was deployed against the shoreline in the shape of an arc from a fast-moving, shallow-draft vessel. The trammel net has the following characteristics: outer walls: 17.8 cm square mesh, 8 meshes deep made from # 9 monofilament; inner wall: 3.2 cm square mesh, 60 meshes deep made from #177 monofilament; footrope – 0.95 cm diameter lead core rope weighing 38.5 kg/183 m; head rope – 127 cm diameter polyfoam line tied to 0.95 cm poly line; net hung on head and foot rope with # 9 dipped twine. A minimum of 3 and maximum of 5 net deployments were made per seagrass bed, depending on size. GPS measurements enabled quantification of the area enclosed for deriving fish density estimates after adjusting for sampling efficiency. Sampling occured surrounding daytime and nocturnal high tide. Subsets of fish from each sample (approx. 10 – 15 specimens per species or size-class within a species if necessary) were processed for length, weight, sex and maturity-at-age determination, stomach contents and aging. Stomachs were labeled, preserved in "normalin", and prey identified to the lowest possible taxon. Prey were measured, and % number and wet weight, were calculated by prey type.

Collection of prey (*primarily blue crab*)
Densities of juvenile blue crabs were determined by sampling seagrass beds (the same as sampled for fishes with the trammel net) using a suction sampler (Orth and van Montfrans, 1987). Since juvenile blue crabs are an important prey for several fishes in seagrass beds, they were targeted in this study. Hence, background densities of blue crabs were determined so that predation impact by fishes (primarily striped bass and Atlantic croaker) could be assessed.

Assessing predation

An explicit temperature sensitive gut evacuation model was used (Durbin et al 1983; Overholtz et al, 1999; Link et al, 2002) to derive daily consumption estimates for fishes (primarily striped bass (*Morone saxitilis*) and Atlantic croaker (*Micropogonias undulatus*):

$$C_{d,i} = 24 \cdot E_i \cdot \bar{S}_i^{\gamma} \tag{1}$$

where $C_{d,i}$ is total daily consumption of predator i, γ is a constant (usually assumed to be 1), $\bar{S}_i^{\gamma}$ is the mean total stomach contents (by weight) of a particular prey species in the stomach of predator i and E_i is the evacuation rate defined as:

$$E_i = \alpha e^{\beta T_p} \,, \tag{2}$$

where α and β are constants and T_p is the mean water temperature for time period p.

Percent weight will be calculated to identify the contribution of each prey type predator diets in seagrass beds in lower Chesapeake Bay (Hyslop 1980). Since trammel net collections essentially yield a cluster of each predator species at each sampling location, the aforementioned index will be calculated using a cluster sampling estimator (Buckel et al. 1999). The contribution of each prey type to the diet of predator i by weight ($\bar{S}_i$) is:

$$\bar{S}_i = \frac{\sum_{t=1}^{n_t} n_{i,t} \bar{S}_{i,t}}{n_t} \,, \tag{3}$$

where n_t is the number of trammel net samples within a particular time period (month, season, etc.) and $n_{i,t}$ is the number of predator i collected in sample t, and

$$\bar{S}_{i,t} = \frac{\sum_{k=1}^{n_{i,t}} S_{i,k}}{n_{i,t}} \,, \tag{4}$$

where k represents and individual predator.

Estimates of total annual removal of each prey species by each predator i can be calculated using the following equation:

$$C_i = \sum_{m=1}^{p} (C_{d,i} \cdot d_m \cdot N_{i,m}) \tag{5}$$

where d is the number of days in period m and the minimum abundance of predator i in period m is defined as:

$$N_{i,m} = \frac{\overline{N}_{i,m} \cdot TA}{SA}, \tag{6}$$

where TA is the total survey area and SA is the area swept per trammel net sample. Estimates of the area of seagrass beds in lower Chesapeake Bay are available from aerial surveys and estimates of SA have been calculated using GPS. Finally, the total annual consumption of each prey species by P predators in seagrass beds is represented by:

$$C = \sum_{i=1}^{P} C_i , \tag{7}$$

Seasonal striped bass consumption rates were compared to the number of crabs available in SAV during each season to evaluate overall impact by these predators. Total crab abundance during each season was evaluated as:

$$N_c = \frac{10{,}000\overline{N}_c A_{SAV}}{e} , \tag{8}$$

where N_c is the mean number of juvenile blue crabs per m^2, A_{SAV} is the area of SAV in lower Chesapeake Bay, and e is gear efficiency.

Results

Data from sampling efforts in 2004 and spring 2005, which were funded by the NOAA Chesapeake Bay Office, are presented for comparison with data from sampling efforts in fall 2005 (the objective of the current study funded by the RFAB).

Spring sampling

During spring 2004, a total of 33 trammel net samples (11 day and 22 night) were collected at 9 sampling locations. The total number of fish per set ranged from 0 to 73 with a mean of 12.53 ($\pm$ 2.87 SE), and overall, fourteen species were collected (Table 1). During spring 2005, a total of 19 trammel net samples (13 day and 6 night) were collected. The total number of fish per set ranged from 0 to 165, and overall, eleven species were collected (Table 2).

Fish feeding habits in seagrass beds were quantified for striped bass, croaker, spot, white perch, silver perch, summer flounder and weakfish from the spring samples. Diets of the 135 striped bass processed were dominated gravimetrically by blue crabs (~71%) followed by fishes (~10%), polychaetes (worms; ~5%) and shrimp (~3%) (Fig. 2a). One-hundred-sixty-six Atlantic croakers were processed, in which clams (27.5%) were the dominant prey and polychaete worms (18.1%) and blue crabs (16.5%) contributed similarly to the diet by weight (Fig. 3a). Only nine spot were processed for feeding habits during spring. Polychaetes (~36%) and amphipods/isopods (~40%) were the major prey components and contributed similarly to the diet by weight (Fig. 4a). One red drum was caught in spring; feeding habits will be described for this species during the fall season when they were more numerous in samples. White perch (n = 6) which were more common in the lower salinity mid-bay areas fed primarily on shrimps which constituted 67% of the diet (Fig. 5a). Mysids, though numerically dominant made up only 12% of the diet by weight. Similarly, mysids dominated the diet of silver perch (n = 13) numerically, but were less important gravimetrically (Fig. 6a). The most important prey for silver perch by weight were shrimps (55%) followed by fishes (23%) and then mysids (14%). Summer flounder (n = 11) were also caught by trammel net sampling. In spring, this species consumed predominantly shrimps (50%) and fishes (48%) in almost equal proportions (Fig. 7a). Other prey types were relatively unimportant gravimetrically. Finally, weakfish (n = 4) were also occasionally captured in spring and their diet by weight consisted almost entirely of fishes (Fig. 8a).

Fall sampling

During fall 2004, sampling occurred between August 25 and November 17. A total of 44 trammel net samples (18 day and 26 night) were collected at the 9 sampling locations. The total number of fish per set ranged from 0 to 88, and overall, 22 fish species were collected (Table 3). During fall 2005, a total of 17 trammel net samples (6 daytime and 11 nighttime) was collected. The total number of fishes per set ranged from 6 to 122, and overall, 22 species were collected (Table 4).

Fish feeding habits were quantified for striped bass, croaker, red drum, spot, white perch, silver perch, summer flounder and weakfish from the fall samples. Diets differed seasonally for fishes collected in spring vs fall, primarily as evidenced by the proportions of various prey categories consumed. Such differences likely reflect variations in the seasonal abundances of these prey groups. For example, in the 114 striped bass from fall that were examined, the proportional contribution to the diet by blue crabs was only 50% by weight (vs 71% in spring) and fishes were more considerably important gravimetrically (40% vs only 10% in spring; Fig. 2b). Atlantic croaker (n = 23) were not as abundant in shallow SAV habitats during fall because of declining water temperatures and those that were caught fed primarily on polychaete worms (60% of the diet vs 18% in spring), clams (13% vs 27% in spring) and shrimps (11%; Fig. 3b). Spot were abundant during fall sampling (n = 53 processed for diet data) and they consumed mostly polychaetes (23%) and shrimps (11%; Fig. 4b). This species is a well known predator on crustaceans throughout its range. White perch (n = 78) were more common during cooler fall water temperatures and in lower salinity zones of shallow water SAV beds. This species consumed primarily mysids (44%), fishes

(16%) and blue crabs (11%) by weight in fall (Fig. 5b) whereas during spring, it largely consumed shrimps (67%). Two species (silver perch and weakfish) had a relatively consistent diet seasonally for both the spring and fall. Silver perch (n = 30) consumed primarily shrimps (55% in spring vs 47% in fall) and fishes (23% vs 19%, respectively); these prey contributed similarly to the diet across seasons and other dietary components were also largely equivalent (Fig. 6a b). Summer flounder (n = 11) sampled during fall preyed primarily on fishes (92%; Fig. 7a); shrimps that were common in the diet during spring were essentially absent from the diet during fall. Weakfish were more numerous during fall, and in those examined for stomach contents (n = 11), the diet consisted entirely of fishes as during spring (Fig. 8a b). Seven red drum were caught during fall, and their diet was dominated gravimetrically (84%) by blue crab prey (Fig. 9).

These data on diets of fishes foraging in SAV beds are the first and most comprehensive for SAV beds throughout the Chesapeake Bay. Although short-term predation affects on prey populations in seagrass beds are not addressed in this study, general feeding habits of transient fishes during the spring and fall seasons demonstrate that SAV beds play an important role in supporting a variety of recreationally important fish species. Modeling such relationships will enable a better understanding of how these habitats function energetically in the lives of these species.

Predation impacts on blue crabs

Density estimates of juvenile blue crabs in lower Chesapeake Bay seagrass beds were moderate and consistent across spring seasons, ranging from 4.2 crabs in 2004 to 4.1 crabs in 2005. When fall seasons were compared, density estimates were quite high but decreased from 19.1 crabs in 2004 to 12.1 crabs in 2005 (Table 5).

Predation impacts by striped bass on juvenile blue crabs were greater than those of Atlantic croaker, however, each species consumed a very small fraction of the total abundance of blue crabs in seagrass beds. During spring, striped bass consumption estimates decreased from 24.8 million crabs (2.9% of total crab abundance) in 2004 to 21.4 million crabs (2.5% of total crab abundance) in 2005 (Table 6a). For Atlantic croaker during the same seasons, estimates of consumption of juvenile blue crabs increased from 3.8 million crabs (0.38% of total crab abundance) in 2004 to 4.9million crabs (0.58% of total crab abundance) in 2005 (Table 6b). During fall, striped bass consumption was greatest and increased from 65.3 million crabs (1.7% of total crab abundance) in 2004 to 108.7 million crabs (4.4% of total crab abundance) in 2005. Consumption of juvenile blue crabs by Atlantic croaker was lowest during fall and constituted only 0.009% and 0.11% of the total crab abundance in seagrass beds during those periods.

Acknowledgements: The PIs would like to thank Debra Parthree (Chesapeake Bay Trophic Interactions Laboratory Services; CTILS) at VIMS for providing all of the gut content data and analyses contained in this report. Kathleen McNamee, Danielle Mcullough, and Gara Luff also deserve acknowledgement for their assistance in conducting fieldwork. Funding was provided by the Recreational Fishing Advisory Board of the Virginia Marine Resources Commission and the NOAA Chesapeake Bay Office.

Literature cited

Buckel, J.A., D.O. Conover, N.D. Steinberg, and K.A. McKown. 1999. Impact of age-0 bluefish (*Pomatomus saltatrix*) predation on age-0 fishes in the Hudson River estuary: evidence for density-dependent loss of juvenile striped bass (*Morone saxatilis*). Canadian Journal of Fisheries and Aquatic Science 56:275-287.

Durbin, E. G., A. G. Durbin, R. W. Langton and R. E. Bowman. 1983. Stomach contents of silver hake, *merluccius bilinearis*, and atlantic cod, *Gadus morhua*, and estimation of their daily rations. Fishery Bulletiin 81:437-454.

Hyslop, E.J. 1980. Stomach contents analysis – a review of methods and their application. Journal of Fish Biology 17:411-429.

Link, J. S., L. P. Garrison, and F. P. Almeida. 2002. Ecological interactions between elasmobranches and groundfish species on the northeastern U.S. continental shelf. I. Evaluating predation. North American Journal of Fisheries Management 22:550-562.

Orth, R. J. and J. van Montfrans. 1987. Utilization of a seagrass meadow and tidal marsh creek by blue crabs *Callinectes sapidus*. Seasonal and annual variations in abundance with emphasis on post-settlement juveniles. Mar. Ecol Prog. Ser. 41: 278-294.

Overholtz, W. J., J. S. Link and L. E. Suslowicz. 1999. Consumption and harvest of pelagic fish and squid in the Gulf of Maine-Georges Bank ecosystem: implications for fisheries management. *In* Proceedings of the International Symposium on Ecosystem Considerations in Fisheries Management. Pp. 163-186. Ed. by B. Baxter. Alaska Sea Grant Program. University of Alaska, Fairbanks.

Table 1. Species captured in lower Chesapeake Bay seagrass beds during spring 2004.

Common Name	**Species**	**Total**	**Percent of total**
Atlantic croaker	*Micropogonias undulatus*	168	39.5
Spot	*Leiostomus xanthurus*	107	25.2
Striped bass	*Morone saxalilis*	82	19.3
Gizzard shad	*Dorosoma cepedianum*	21	4.9
Cownose ray	*Rhinoptera bonasus*	11	2.6
Hogchoker	*Trinectes maculatus*	8	1.9
Silver perch	*Bairdiella chrysoura*	7	1.6
Atlantic menhaden	*Brevoortia tyrannus*	5	1.2
White perch	*Morone americana*	5	1.2
Flounder	*Paralichthys dentatus*	4	0.9
Houndfish	*Tylosaurus crocodiles*	3	0.7
Speckled trout	*Cynoscion nebulosus*	2	0.5
Red drum	*Sciaenops ocellatus*	1	0.2
Sheepshead	*Archosargus probatocephalus*	1	0.2

Table 2. Species captured in lower Chesapeake Bay seagrass beds during spring 2005.

Common Name	Species	Total	Percent of total
Striped bass	*Morone saxatilis*	188	32.4
Atlantic croaker	*Micropogonias undulatus*	166	28.6
Spot	*Leiostomus xanthurus*	119	20.5
Cownose ray	*Rhinoptera bonasus*	32	5.5
Silver perch	*Bairdiella chrysoura*	25	4.3
White perch	*Morone americana*	12	2.1
Summer flounder	*Paralichthys dentatus*	11	1.9
Gizzard shad	*Dorosoma cepedianum*	9	1.5
Houndfish	*Tylosurus crocodilus*	6	1.0
Weakfish	*Cynoscion regalis*	4	0.7
Southern stingray	*Dasyatis americana*	3	0.5
Blueback herring	*Alosa aestivalis*	3	0.5
Hogchoker	*Trinectes maculatus*	2	0.3
Bluefish	*Pomatomus saltatrix*	1	0.2

Table 3. Species captured in lower Chesapeake Bay seagrass beds during fall 2004.

Common Name	Species	Total	Percent of total
Spot	*Leiostomus xanthurus*	219	33.1
Striped bass	*Morone saxalilis*	177	26.7
Gizzard shad	*Dorosoma cepedianum*	47	7.1
Striped mullet	*Mugil cephalus*	37	5.6
Atlantic croaker	*Micropogonias undulatus*	31	4.7
White perch	*Morone americana*	26	3.9
Weakfish	*Cynoscion regalis*	24	3.6
Silver perch	*Bairdiella chrysoura*	23	3.5
Bluefish	*Pomatomus saltatrix*	16	2.4
Cownose ray	*Rhinoptera bonasus*	12	1.8
Flounder	*Paralichthys dentatus*	11	1.7
Hogchoker	*Trinectes maculatus*	7	1.1
Atlantic menhaden	*Brevoortia tyrannus*	7	1.1
Pigfish	*Orthopristis chrysoptera*	7	1.1
Red drum	*Sciaenops ocellatus*	6	0.9
Northern puffer	*Sphoeroides maculatus*	4	0.6
Speckled trout	*Cynoscion nebulosus*	2	0.3
Pinfish	*Lagodon rhomboides*	2	0.3
Inshore lizard fish	*Synodus foetens*	1	0.2
Atlantic stingray	*Dasyatis sabina*	1	0.2
Florida pompano	*Trachinotus carolinus*	1	0.2
Spadefish	*Chaetodipterus faber*	1	0.2

Table 4. Species captured in lower Chesapeake Bay seagrass beds during fall 2005.

Common Name	**Species**	**Total**	**Percent of total**
Atlantic menhaden	*Brevoortia tyrannus*	279	24.1
Spot	*Leiostomus xanthurus*	255	22.0
Striped bass	*Morone saxatilis*	137	11.8
Gizzard shad	*Dorosoma cepedianum*	105	9.1
White perch	*Morone americana*	99	8.5
Atlantic croaker	*Micropogonias undulatus*	75	6.5
Striped mullet	*Mugil cephalus*	60	5.2
Silver perch	*Bairdiella chrysoura*	33	2.8
Pinfish	*Lagodon rhomboides*	16	1.4
Summer flounder	*Paralichthys dentatus*	15	1.3
Hogchoker	*Trinectes maculatus*	14	1.2
Weakfish	*Cynoscion regalis*	14	1.2
Bluefish	*Pomatomus saltatrix*	10	0.9
Houndfish	*Tylosurus crocodilus*	1	0.1
Black drum	*Pogonius cromis*	10	0.9
Red drum	*Sciaenops ocellatus*	9	0.8
Spotted seatrout	*Cynoscion nebulosus*	9	0.8
Pigfish	*Orthopristis chrysoptera*	9	0.8
Threadfin shad	*Dorosoma petenense*	3	0.3
Atlantic stingray	*Dasyatis sabina*	2	0.2
Southern stingray	*Dasyatis americana*	2	0.2
Black seabass	*Centropristis striata*	1	0.1

Table 5. Abundance of juvenile blue crabs in lower Chesapeake Bay seagrass beds during spring and fall, 2004 – 2005.

Season	**Mean number of crabs per m^2**	**Total abundance**
Spring 2004	4.2	865,000,000
Fall 2004	19.1	3,931,000,000
Spring 2005	4.1	844,000,000
Fall 2005	12.1	2,490,000,000

Table 6a. Predation impacts of striped bass on juvenile blue crabs in lower Chesapeake Bay seagrass beds during spring and fall, 2004 – 2005.

Season	**Mean number of fish per ha (mean, TL cm)**	**Mean number of crabs per fish**	**Days fish in seagrass**	**Total juvenile blue crabs consumed**	**Percent consumed**
Spring 2004	15.8 (45.4)	1.2	71	24,823,651	2.9
Fall 2004	24.4 (37.2)	2.4	79	65,302,737	1.7
Spring 2005	20.2 (33.1)	0.75	69	21,431,027	2.5
Fall 2005	18.5 (36.6)	3.03	101	108,798,904	4.4

Table 6b. Predation impacts of Atlantic croaker on juvenile blue crabs in lower Chesapeake Bay seagrass beds during spring and fall, 2004 – 2005.

Season	**Mean number of fish per ha (mean, TL cm)**	**Mean number of crabs per fish**	**Days fish in seagrass**	**Total juvenile blue crabs consumed**	**Percent consumed**
Spring 2004	28.2 (32.8)	0.1	71	3,810,571	0.38
Fall 2004	11.3 (35.3)	0.1	22	325,357	0.009
Spring 2005	16.9 (32.4)	0.23	62	4,962,170	0.58
Fall 2005	7.8 (29.3)	0.19	98	2,782,682	0.11

Figure 1. Trammel Net Sampling Locations

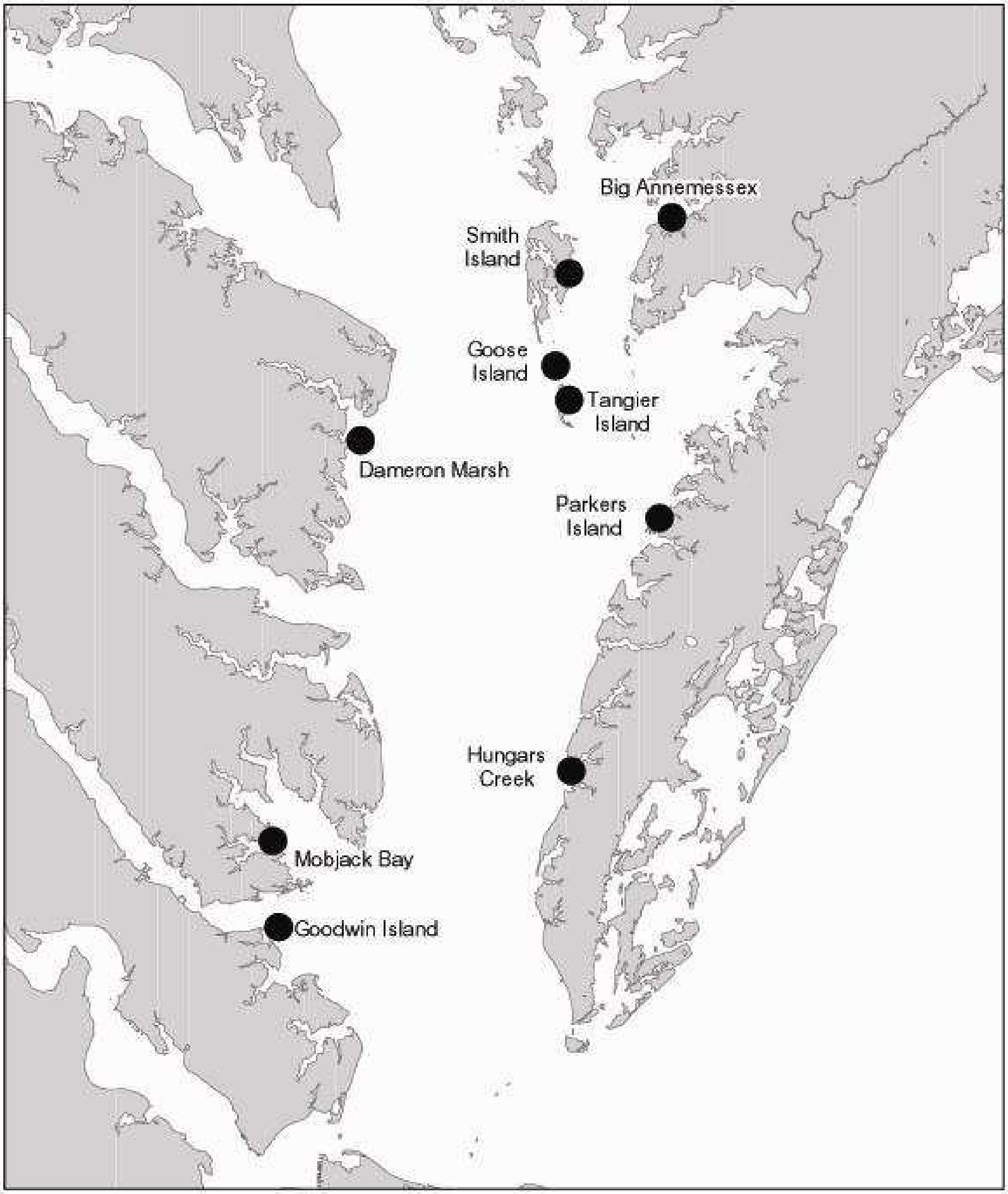
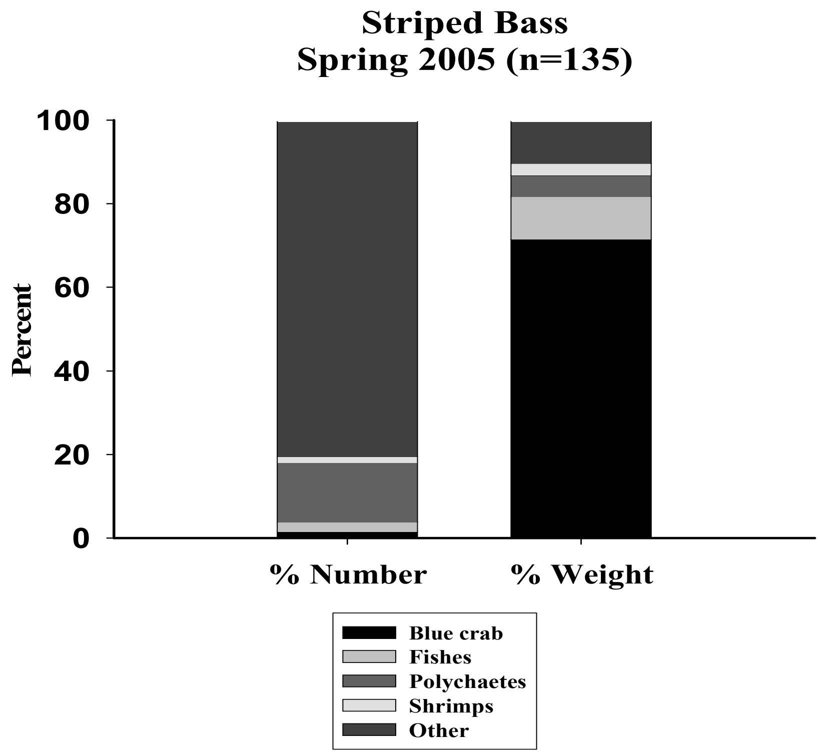


Figure 2. Diet composition (% Number and % Weight) for striped bass collected in lower Chesapeake Bay seagrass beds during 2005: (a) spring and (b) fall.

(a)



(b)

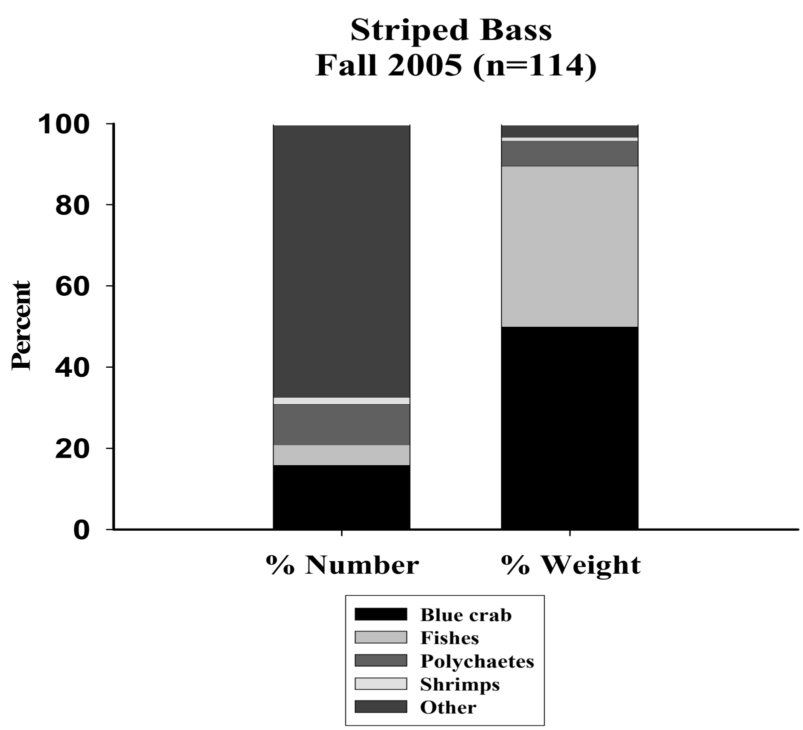
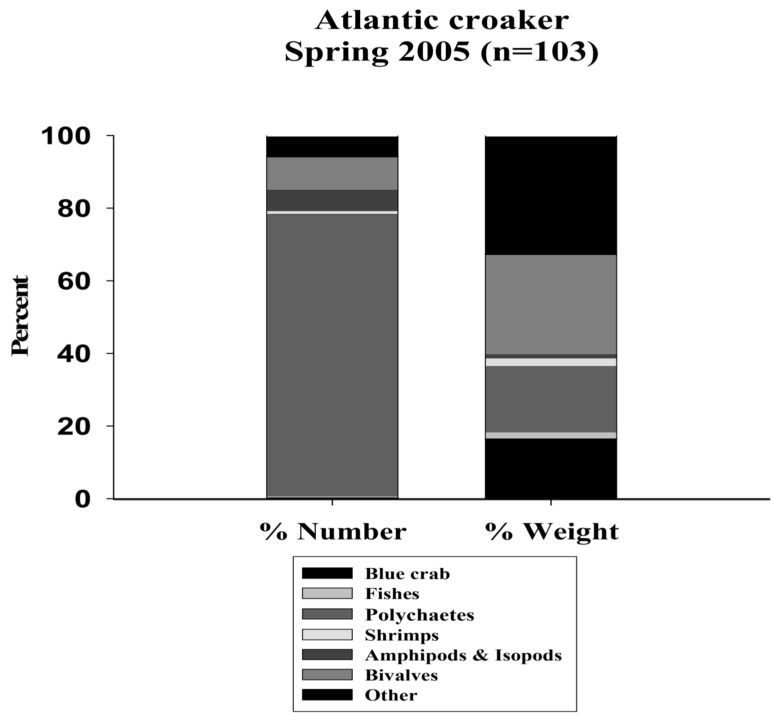


Figure 3. Diet composition (% Number and % Weight) for Atlantic croaker collected in lower Chesapeake Bay seagrass beds during 2005: (a) spring and (b) fall.

(a)



(b)

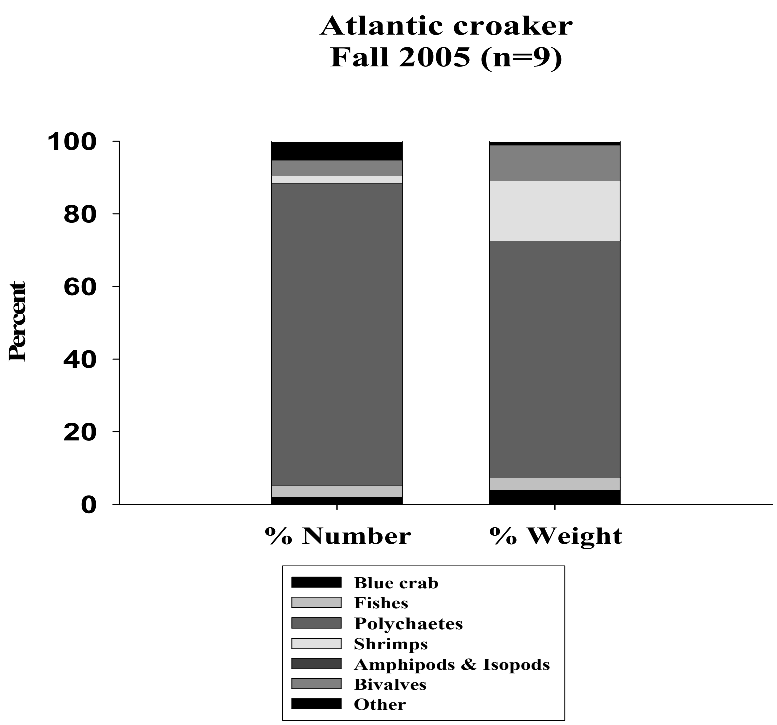
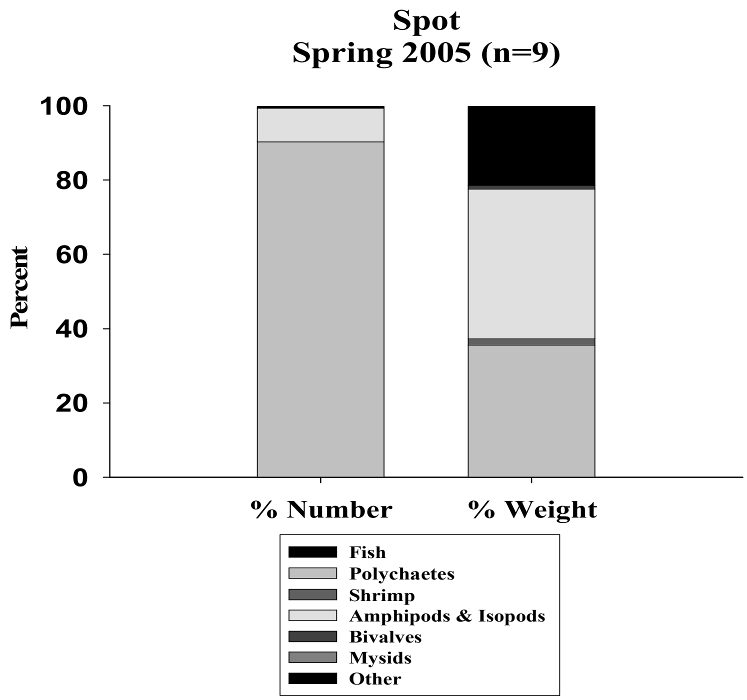


Figure 4. Diet composition (% Number and % Weight) for spot collected in lower Chesapeake Bay seagrass beds during 2005: (a) spring and (b) fall.

(a)



(b)

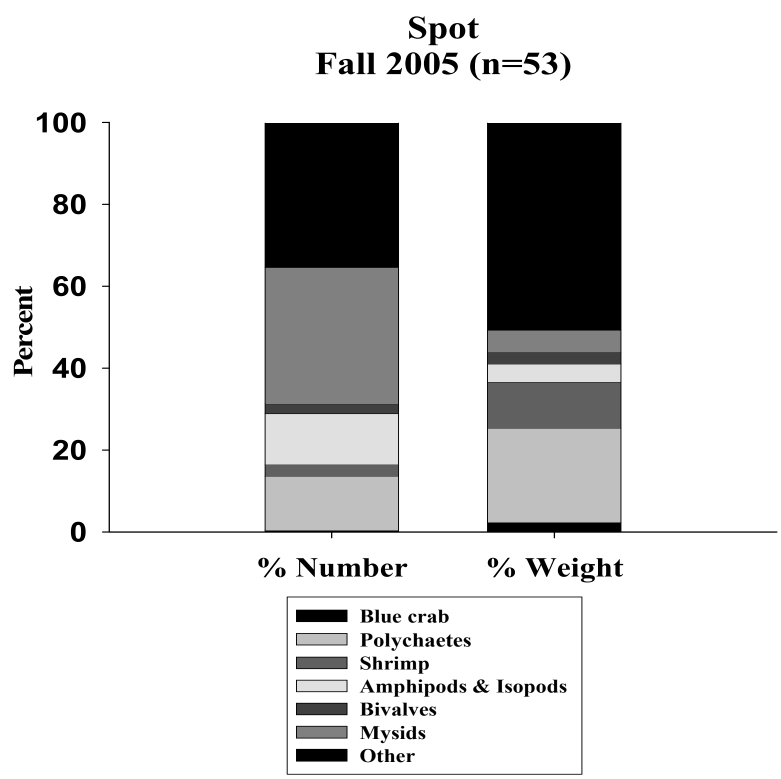
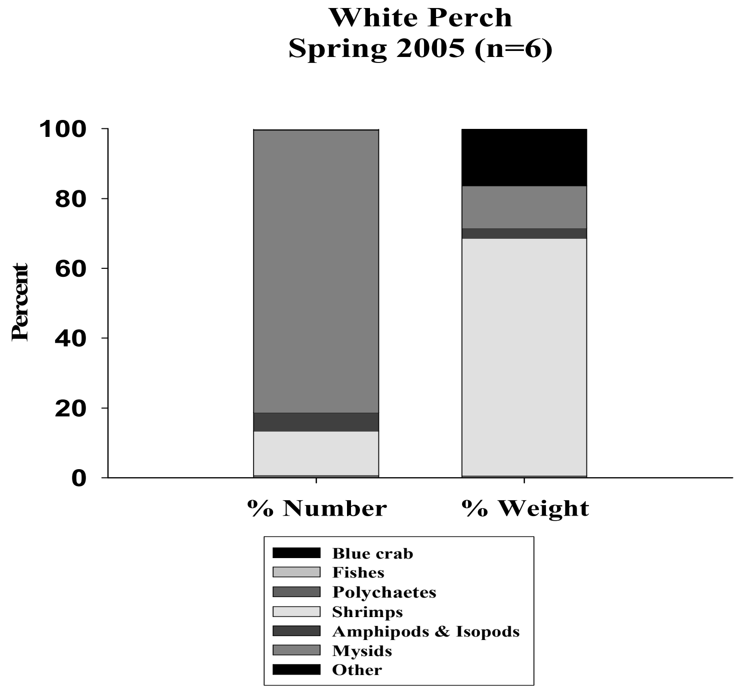


Figure 5. Diet composition (% Number and % Weight) for white perch collected in lower Chesapeake Bay seagrass beds during 2005: (a) spring and (b) fall.

(a)



(b)

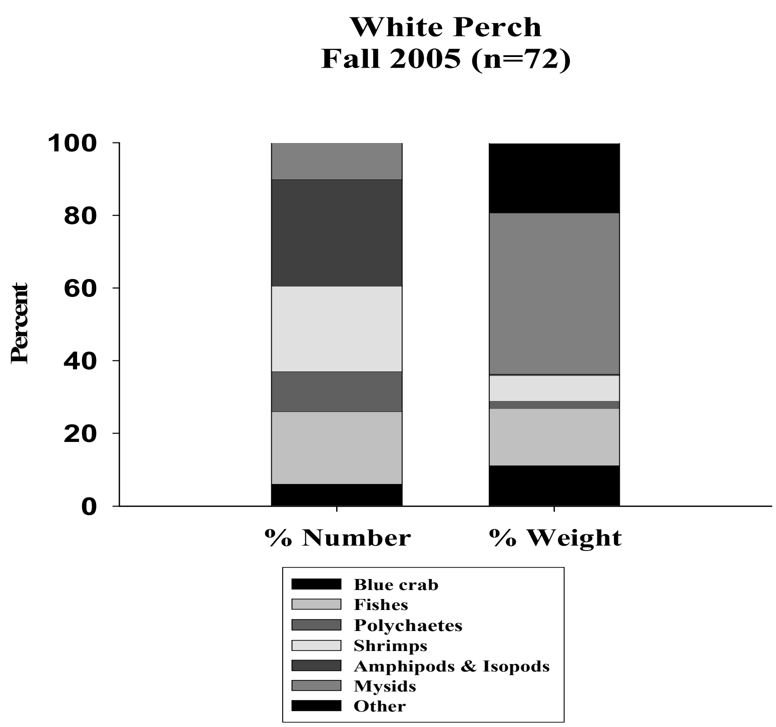
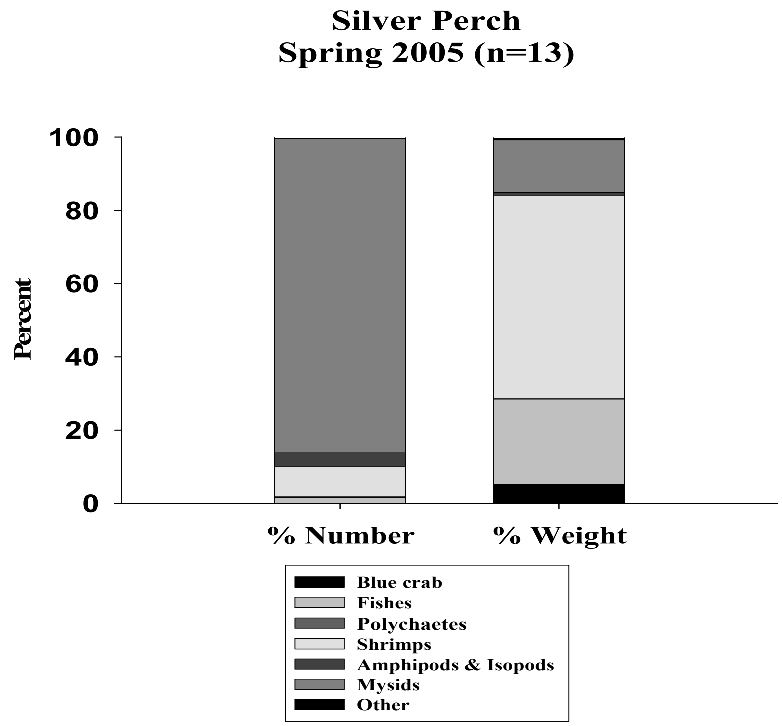


Figure 6. Diet composition (% Number and % Weight) for silver perch collected in lower Chesapeake Bay seagrass beds during 2005: (a) spring and (b) fall.

(a)



(b)

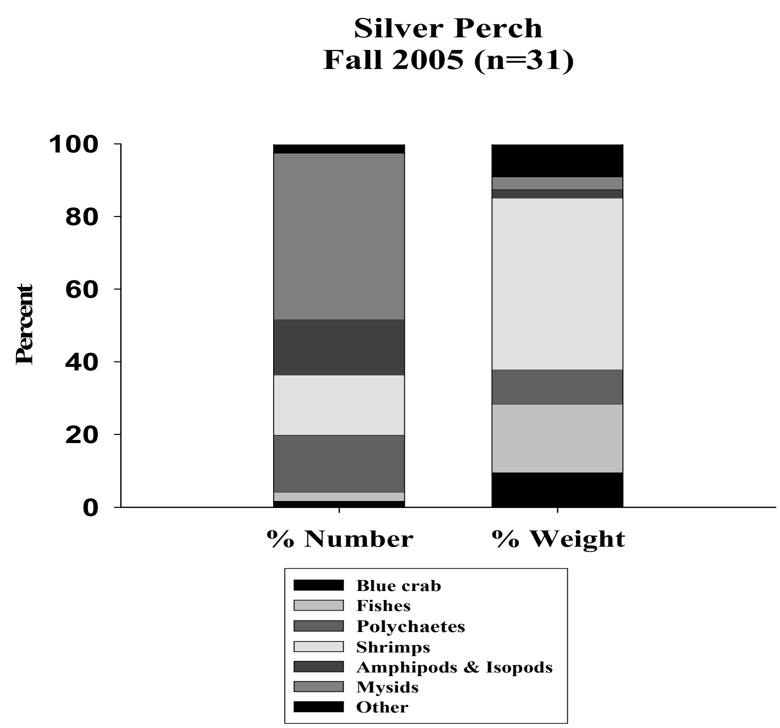
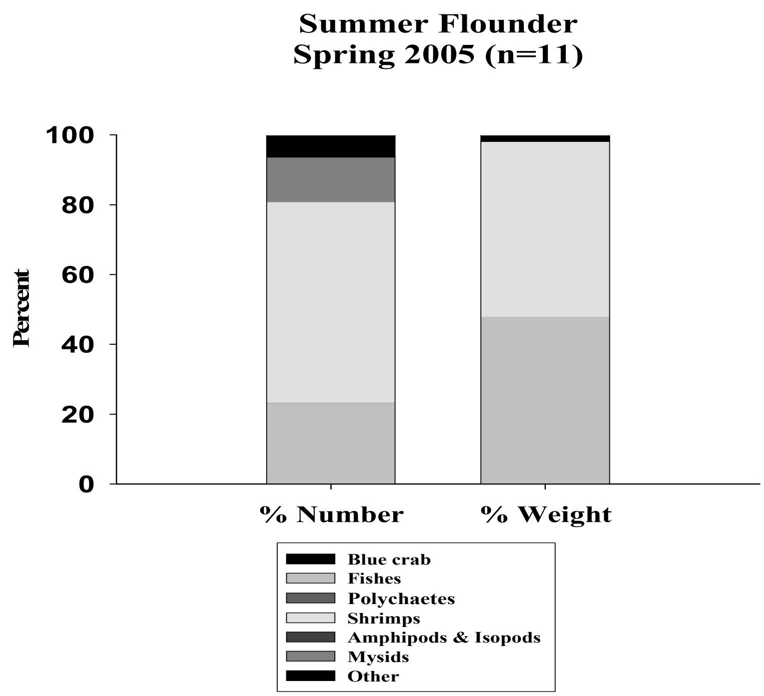


Figure 7. Diet composition (% Number and % Weight) for summer flounder collected in lower Chesapeake Bay seagrass beds during 2005: (a) spring and (b) fall.

(a)



(b)

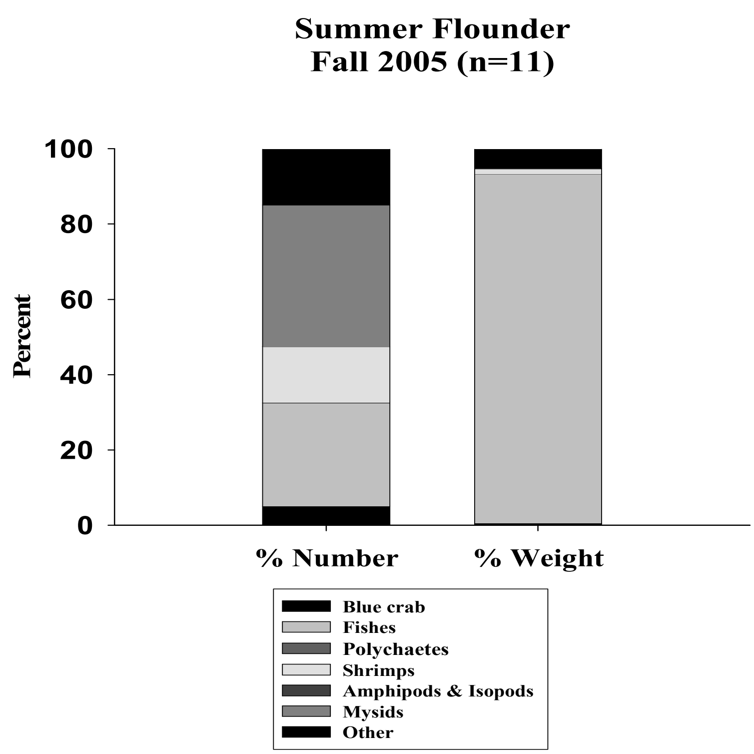
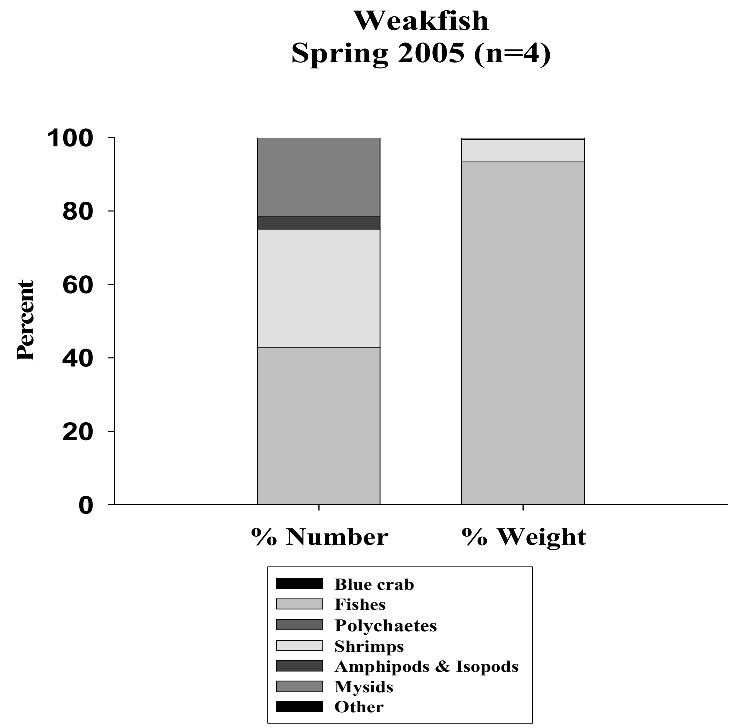


Figure 8. Diet composition (% Number and % Weight) for weakfish collected in lower Chesapeake Bay seagrass beds during 2005: (a) spring and (b) fall.

(a)



(b)

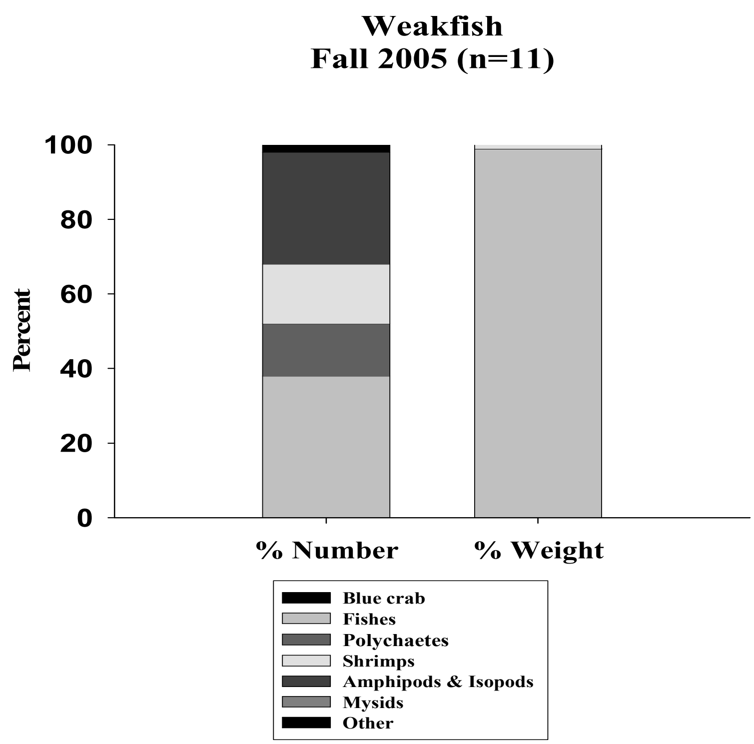


Figure 9. Diet composition (% Number and % Weight) for red drum collected in lower Chesapeake Bay seagrass beds during spring and fall 2005 combined.