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# Diet Analysis of Kemp's Ridley Sea Turtles (*Lepidochelys kempii*) in Virginia

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**Abstract. – Examination of sea turtles that stranded in Virginia during the late 1970s and early 1980s indicated that Kemp's ridleys (*Lepidochelys kempii*) fed primarily on blue crab (*Callinectes sapidus*). We examined digestive tract samples and diet data collected in Virginia from 59 ridleys during 1983 to 2002. Blue crabs and spider crabs (*Libinia* spp.) were important components of Virginia Kemp's ridley diet throughout the dataset.**

**Key Words. – Reptilia; Testudines; Cheloniidae; *Lepidochelys kempii*; sea turtle; diet; crabs; Chesapeake Bay; Virginia; USA**

The Kemp's ridley, *Lepidochelys kempii*, is the second most abundant species of sea turtle in Virginia, USA (Keinath et al., 1987). Kemp's ridleys are listed as Endangered under the United States Endangered Species Act of 1973 and as Critically Endangered by the World Conservation Union (IUCN, 2003). They forage in large numbers in US waters of the Atlantic Ocean and in the Gulf of Mexico, but the only major nesting site is found in Tamaulipas, Mexico (Musick and Limpus, 1997; Turtle Expert Working Group (TEWG), 2000). A significant portion of the juvenile population summers in estuaries along the US Atlantic coast (Musick and Limpus, 1997), and some juveniles tagged in the northwestern Atlantic (including one from Virginia) have been encountered nesting in Mexico (TEWG, 2000).

The Chesapeake Bay, Virginia, serves as an important seasonal foraging ground for an estimated 3900 to 8100 sea turtles annually (Keinath et al., 1987; Mansfield, 2003). Most of these turtles are benthic-stage juvenile loggerheads (*Caretta caretta*), but annual Kemp's ridley numbers are estimated to be in the low- to mid-hundreds (Keinath et al., 1994). Sea turtles enter Virginia's coastal waters and the Chesapeake Bay when water temperatures reach approximately 18–20°C, generally in mid- to late-May, and they begin to migrate south in the fall once temperatures decrease (Lutcavage and Musick, 1985; Byles, 1988; Musick and Limpus, 1997; Coles, 1999). Virginia's strandings typically number between 200 and 400 per year, of which Kemp's ridleys comprised approximately 3–12% of the annual totals during 1983–2002 (mean = 7.8%, standard deviation (SD) = 3.5%) (Coles, 1999; Mansfield, 2003; VIMS, unpubl. data). A large stranding peak is usually seen in the late spring or early summer as the turtles complete migrations to Chesapeake Bay, and a smaller peak in Kemp's ridley strandings is often seen in the fall (Lutcavage and Musick, 1985; Coles, 1999).

During 1979–86, Kemp's ridleys examined by the Virginia Institute of Marine Science (VIMS) consumed primarily blue crabs (*Callinectes sapidus*) (Lutcavage and Musick, 1985; Keinath et al., 1987). The level of fishing for the blue crab in Chesapeake Bay has been considered "intensive" since the early 1900s (Van Engel, 1958). Recent findings indicate that the Lower Chesapeake Bay blue crab spawning stock, larval abundance, and postlarval recruitment were significantly lower during 1992–99 than during 1985–91 (Lipcius and Stockhausen, 2002). Poor recruitment in 1991 in concert with high fishing and natural mortality are the proposed cause of the diminished spawning stock in 1992. The blue crab stock, larval abundance, and recruitment are not likely to rebound without significant reductions in fishing and natural mortality, along with conditions conducive to successful recruitment (Lipcius and Stockhausen, 2002). This decline in the blue crab population may have implications for the diet of Kemp's ridley sea turtles in Virginia.

## METHODS

*Sample Collection.* — Kemp's ridley gut samples ($n$ = 15) were collected in Virginia during August 1987 through October 1994. These samples were archived and stored in either 10% formalin or 70% ethanol. Those in 10% formalin were transferred to 70% ethanol prior to data collection. Additional samples ($n$ = 18) were collected from July 2000 to September 2002. The collection and preservation methods used for the 2000 through 2002 samples were similar to the earlier samples (D.E. Barnard, *pers. comm.*; J.A. Keinath, *pers. comm.*; R.A. Pemberton, *pers. comm.*), so that the samples would be comparable.

To obtain whole gut content samples, the entire digestive tract was dissected from dead stranded or incidentally caught Kemp's ridleys. After its removal, each digestive tract was frozen, placed in 10% formalin, or immediately sieved. Each digestive tract was cut open and the contents emptied into a 500 µm sieve and rinsed thoroughly with water. The gut contents were stored in 10% freshwater formalin for at least 24 hrs, soaked in water for several hours, and transferred to 70% ethanol. Preservation procedures for stomach samples, other par-

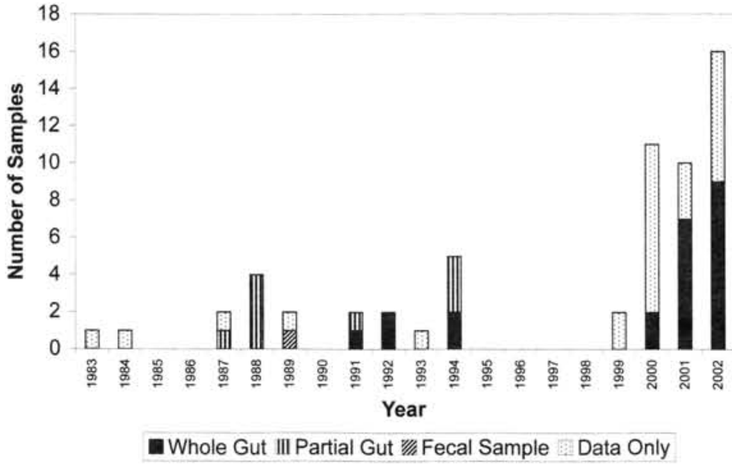


**Figure 1.** Annual distribution of data and samples from 1983–2002 ($n$ = 59).

tial gut samples, and one fecal sample matched those used for whole samples.

*Data Collection.* — Each gut sample was sorted into general prey groups, and prey items were identified to the lowest possible taxonomic level. All samples were retained after sorting to provide a reference collection of prey items. Whole fish, scales, and skeletal preparations were also used for reference. Numbers of prey items were determined when possible, and the samples were dried at approximately 60°C in a drying oven for 24–48 hrs (Shaver, 1991; Burke et al., 1994; Forbes, 1999). Dry weights were measured to the nearest 0.1 g after cooling. Numerical counts and weights were recorded because they can provide information about feeding behavior and nutritional values, respectively (Macdonald and Green, 1983); however, the large amounts of indigestible crab, fish, and mollusc parts present in whole sea turtle digestive tracts and fecal samples may result in some bias (Burke et al., 1993).

All gut content data were linked to the original stranding data in a Microsoft Access® database. Additional diet information on turtles that were necropsied without being systematically sampled was compiled from the VIMS stranding database. All data entry was verified prior to analysis.

*Data Analysis.* — Cumulative prey curves were used to evaluate whether a sufficient number of whole samples had been examined to adequately describe the diet of Kemp's ridleys during various temporal periods (Ferry and Calliet, 1996; Cortés, 1997). These curves were constructed by randomizing the order in which samples were analyzed ten times and then plotting the mean cumulative number of prey types versus the number of samples examined. The minimum number of gut samples that are needed to obtain "precise" and "more reliable" results occurs once the curve has reached its asymptote (Cortés, 1997).

Percent occurrences (frequency, %F) of general prey groups (horseshoe crab, crustaceans, molluscs, and fish) were determined for all diet data, and percent occurrences of specific prey items were determined for all samples and whole samples. Percent dry weight (%W) and percent number (%N) were also calculated for prey items in the whole samples, since multiple measures are often necessary when prey items differ in size (Ferry and Calliet, 1996).

Carapace length measurements of turtles examined were notch-to-notch SCL, and the conversions determined by Coles (1999) were used for turtles for which this measurement was not available. Linear regression was performed

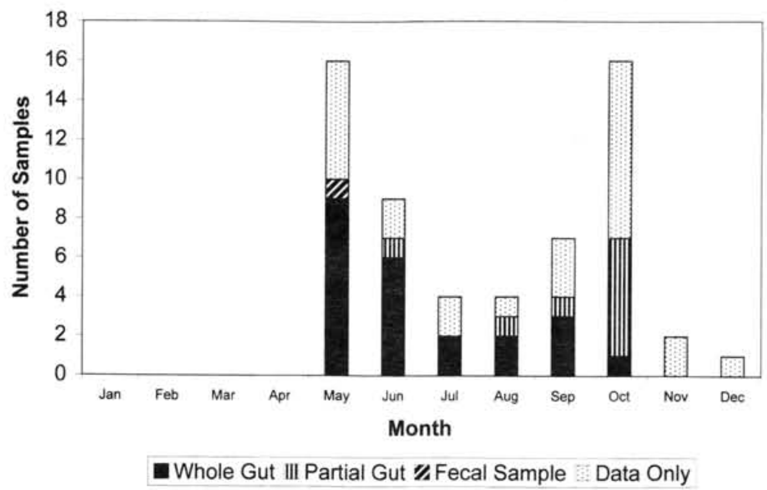


**Figure 2.** Monthly distribution of data and samples from 1983–2002 ($n$ = 59).

using Minitab® Version 14.12.0 to determine if there was any linear relationship between turtle size (SCL) and dry weights or numbers of prey items in whole samples.

Due to the limited amount of Kemp's ridley data, the year divisions of 1983–94 and 1999–2002 were used to compare general diet information. Samples were only collected during 1987–94 and 2000–02, so these divisions were used in the more specific sample analyses. Seasonal (May–July versus August–October) and spatial (bay versus ocean) differences were also examined. Analysis of variance (ANOVA) was performed in Minitab® Version 14.12.0 to examine differences between the year, month, and spatial divisions. Values of %F were transformed according to Krebs (1989) to better achieve normality:

$$\%F\text{–transformed} = \arcsin\sqrt{(\%F/100)}.$$

Only main effects could be examined because of the use of %F values. A significance level of $p < 0.05$ was used in all tests. Use of individual ANOVA tests was preferable to multiple analysis of variance (MANOVA) because of the relatively small number of turtles examined.

Based on the suggestions of Wallace (1981), diet overlap between Kemp's ridley and loggerhead (Seney, 2003) sea turtles in Virginia was estimated using the Schoener (1970) index:

$$\alpha = 1 - 0.5(\sum |p_{xi} - p_{yi}|)$$

where $p_{xi}$ is the proportion of food category $i$ in the diet of species $x$, and $p_{yi}$ is the proportion of food category $i$ in the diet of species. This index ranges from zero to one (no diet overlap to complete overlap) and can be multiplied by 100 to yield percent overlap. Average dry weight values for samples from 2001 and 2002 were used in the calculations.

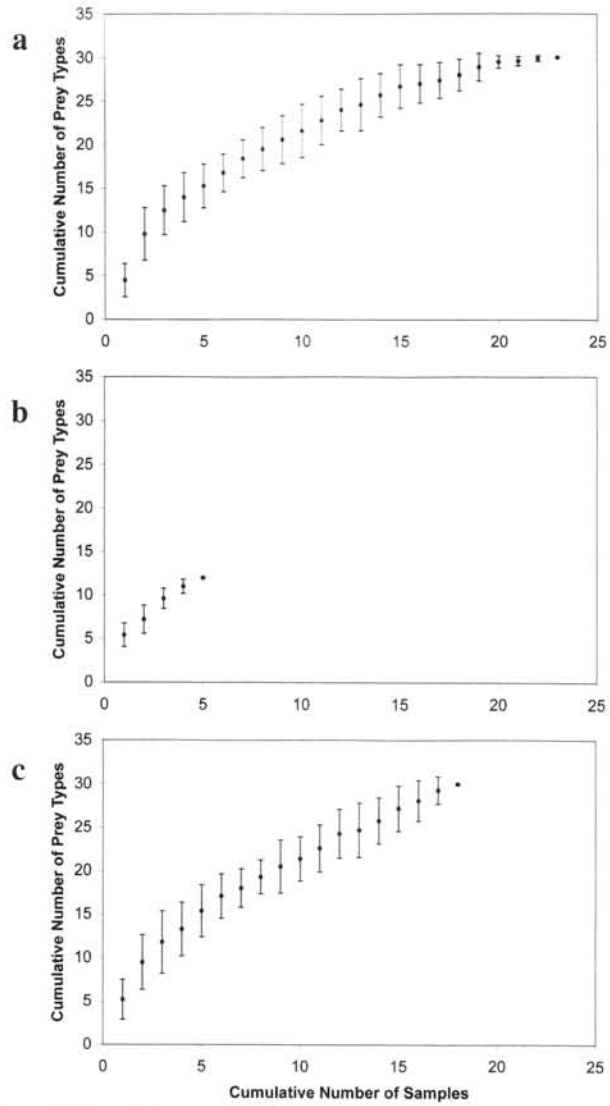


**Figure 3.** Cumulative prey curves for whole digestive tract samples from **(a)** 1991–2002 ($n = 23$), **(b)** 1991–94 ($n = 5$), and **(c)** 2000–02 ($n = 18$). Error bars represent ± one standard deviation.

## RESULTS

Nine partial digestive tract samples and one fecal sample were collected from Kemp's ridleys in Virginia and archived at VIMS during 1987–94. Five whole ridley gut samples were archived from 1991–94, and 18 were collected from 2000–02. Additional diet data were available on 26 Kemp's ridleys examined during 1983–2002. Of these 59 turtles, 45 (23 samples) were encountered along Chesapeake Bay waters and 14 (10 samples) were from the oceanside of Virginia Beach.

Eighteen of the 33 samples and the majority of the general diet data were collected during 2000–02 (Fig. 1). The monthly distribution of samples and data (Fig. 2) is consistent with Virginia spring and fall stranding peaks, and the vast majority of samples and data were collected in May, June, and October.

The turtles with whole samples taken ($n = 23$) ranged in size from 23.1–49.9 cm SCL (mean = 36.7 cm, SD = 7.3 cm), and all of those with samples ($n = 33$) ranged in size from 23.1–53.4 cm SCL (mean = 37.9 cm, SD = 8.5 cm). Kemp's ridleys with data ($n = 59$) ranged from 23.0–53.4 cm SCL (mean = 36.0 cm, SD = 8.6 cm). The data set was comprised entirely of turtles in the "benthic immature" size class (TEWG, 2000), and the range included all but the largest ridleys encountered in Virginia (Musick and Limpus, 1997).

Of those Kemp's ridleys with samples ($n = 33$), 78.8% (26) had no obvious trauma or abnormalities, and 15.2% (5) had propeller-like or crushing injuries. One ridley sampled had ingested hook and line fishing gear, and one was an incidental dredge take. This distribution was similar for all turtles with diet information ($n = 59$): 79.7% (47) had no visible trauma, 11.9% (7) had propeller-like wounds, and 5.1% (3) showed evidence of fisheries interactions. Diet comparisons were not made among these categories because of the high proportion of turtles without obvious trauma, which can often be attributed to the decomposition state of stranded carcasses (EES, pers. obs.).

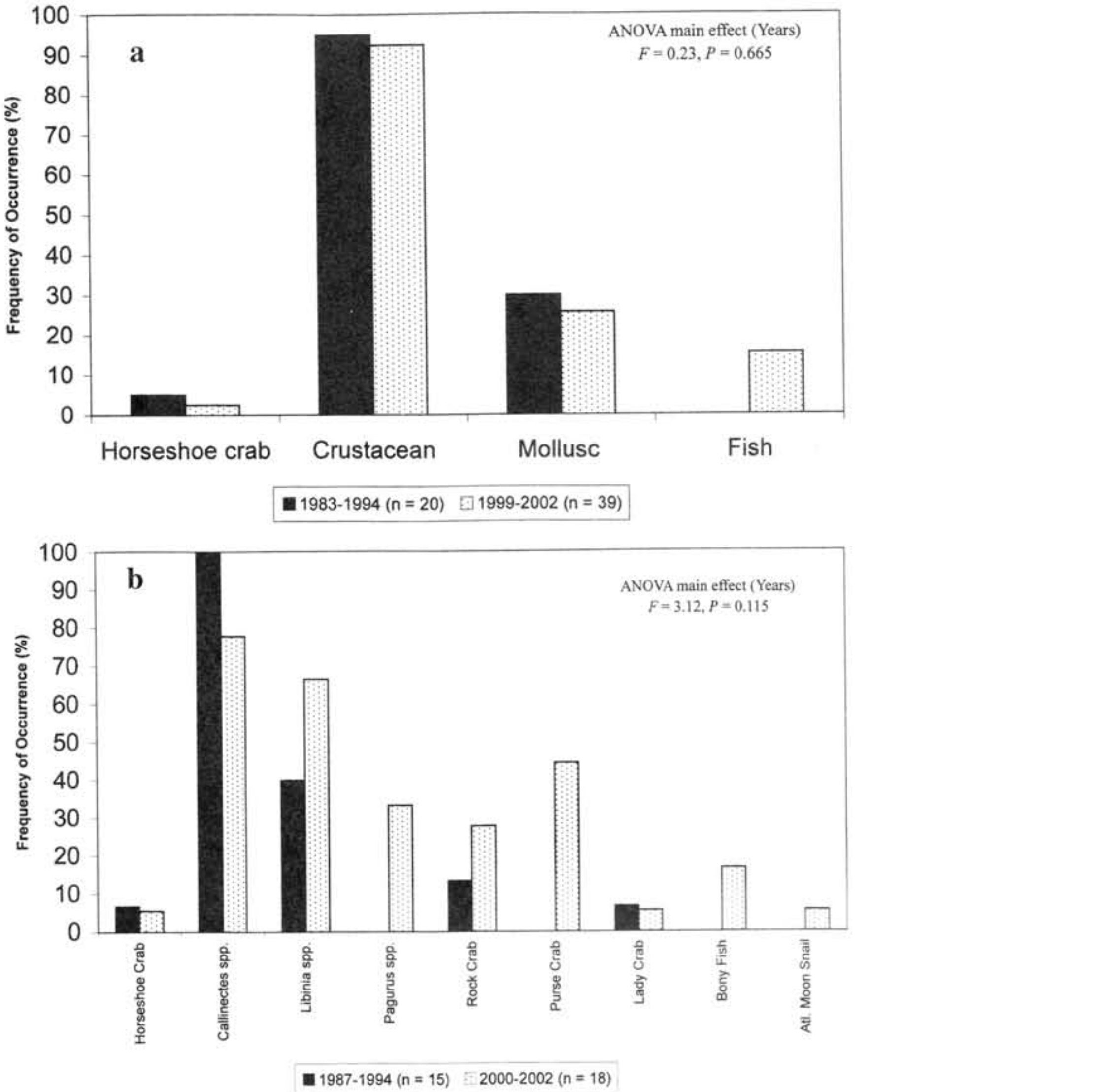


**Figure 4.** Frequency of occurrence of **(a)** major prey groups in all diet data ($n = 59$) and **(b)** target prey species in all samples ($n = 33$), grouped by years.

The cumulative prey curve for the Kemp's ridley whole samples collected in Virginia from 1991–2002 appeared to reach an asymptote, suggesting that most major prey items were encountered (Fig. 3a). The whole samples ($n = 23$) had a mean dry weight of 51.1 g (SD = 51.4 g, median = 33.2 g), and there were an average of 12.3 prey items per whole sample (SD = 16.9, median = 7.0) and 6.3 large prey items (horseshoe crab, crabs, fish, Atlantic moon snail, *Neveritia duplicata*) per whole sample (SD = 4.1, median = 6.0). Simple linear regression indicated a positive relationship between Kemp's ridley SCL and total dry weights ($F_{1,21} = 14.52$, $p = 0.001$) and large prey dry weights ($F_{1,21} = 12.51$, $p = 0.002$), but there was no significant linear relationship between SCL and total prey numbers ($F_{1,21} = 0.34$, $p = 0.564$) or large prey numbers ($F_{1,21} = 0.98$, $p = 0.333$). Small sample size, however, must be considered when interpreting these regressions and all of the following results.

The cumulative prey curve for whole Kemp's ridley samples collected in Virginia during 2000–02 ($n = 18$) appeared to be approaching an asymptote, but the 1991–94 curve ($n = 5$) did not (Figs. 3b,c). Due to these sampling limitations, only general diet data ($n = 59$, 1983–2002) and %F data for all samples ($n = 33$, 1987–2002) were examined statistically.

General prey data were compiled from the 59 Kemp's ridleys examined and divided into two different year groups (1983–94 and 1999–2002) (Fig. 4a). Crustaceans were dominant throughout the ridley data set. The rare occurrence of horseshoe crabs and fish may be an artifact of small sample size, but neither has been reported previously in the literature as part of the diet in Virginia (Lutcavage and Musick 1985; Keinath et al. 1987). ANOVA indicated that the differences between these two year groups were not significant (main effect (Years): $F = 0.23$, $p = 0.665$).

More specific data were acquired for those Kemp's ridleys that were sampled (Tables 1–2). Horseshoe crabs, decapod crustaceans, fish, and Atlantic moon snails were considered target prey items (Fig. 4b). As with horseshoe

**Table 1.** Frequency of occurrence of all prey items found in Kemp's ridley samples (whole and partial) from Virginia during 1987–2002 ($n$ = 33).

| | | 1987-94 ($n$=15) | 2000-02 ($n$=18) | Overall ($n$=33) |
|---|---|---|---|---|
| **Chelicerates** | | **6.7** | **5.6** | **6.1** |
| Horseshoe crab | *Limulus polyphemus* | 6.7 | 5.6 | 6.1 |
| **Crustaceans** | | **100.0** | **100.0** | **100.0** |
| **Decapods** | | | | |
| Blue crab | *Callinectes sapidus* | 93.3 | 72.2 | 81.8 |
| Unident. portunid | *Callinectes* sp. | 6.7 | 5.6 | 6.1 |
| Rock crab | *Cancer irroratus* | 13.3 | 27.8 | 21.2 |
| Spider crab spp. | *Libinia* spp. | 40.0 | 66.7 | 54.5 |
| Lady crab | *Ovalipes ocellatus* | 6.7 | 5.6 | 6.1 |
| Hermit crab spp. | *Pagurus* spp. | 0.0 | 33.3 | 18.2 |
| Purse crab | *Persephona mediterranea* | 0.0 | 44.4 | 24.2 |
| Mantis shrimp | *Squilla empusa* | 0.0 | 5.6 | 3.0 |
| **Other Crustaceans** | | | | |
| Crab barnacle | *Chelonibia patula* | 6.7 | 0.0 | 3.0 |
| Unident. crustaceans | — | 26.7 | 61.1 | 45.5 |
| **Fish** | | **0.0** | **16.7** | **9.1** |
| Bony fish | — | 0.0 | 16.7 | 9.1 |
| **Molluscs** | | **40.0** | **50.0** | **45.5** |
| **Bivalves** | | | | |
| Eastern Amer. oyster | *Crassostrea virginica* | 0.0 | 5.6 | 3.0 |
| Blue mussel | *Mytilus edilus* | 20.0 | 22.2 | 21.2 |
| Unident. bivalve | — | 13.3 | 11.1 | 12.1 |
| **Gastropods** | | | | |
| Cerith sp. | *Bittium* sp. | 0.0 | 11.1 | 6.1 |
| Wentletrap | *Epitonium* sp. | 0.0 | 5.6 | 3.0 |
| Eastern mud snail | *Ilyanassa obsoleta* | 0.0 | 5.6 | 3.0 |
| Three-line mud snail | *Ilyanassa trivittatus* | 6.7 | 22.2 | 15.2 |
| Unident. mud snail | *Ilyanassa* or *Nassarius* sp. | 0.0 | 11.1 | 6.1 |
| Mottled dog whelk | *Nassarius vibex* | 6.7 | 5.6 | 6.1 |
| Atlantic moon snail | *Neverita duplicata* | 0.0 | 5.6 | 3.0 |
| Unident. gastropod | — | 0.0 | 5.6 | 3.0 |
| **Plants** | | **53.3** | **55.6** | **54.5** |
| Widgeon grass | *Ruppia maritima* | 6.7 | 16.7 | 12.1 |
| Gulfweed sp. | *Sargassum* sp. | 6.7 | 5.6 | 6.1 |
| Eelgrass | *Zostera marina* | 26.7 | 38.9 | 33.3 |
| Unident. marine plant | — | 26.7 | 22.2 | 24.2 |
| Unident. terrestr. plant | — | 0.0 | 5.6 | 3.0 |
| **Miscellaneous** | | **26.7** | **16.7** | **21.2** |
| Rocks | — | 13.3 | 5.6 | 9.1 |
| Unident. tissue | — | 20.0 | 16.7 | 18.2 |
| **Anthropogenic Items** | | **0.0** | **5.6** | **3.0** |
| Hook and line gear | — | 0.0 | 5.6 | 3.0 |

**Table 2.** Percent occurrence (%F), percent dry weight (%W), and percent number (%N) of all prey items found in whole Kemp's ridley gut samples from Virginia during 2000–02 ($n$ = 18).

| | | %F | %W | %N |
|---|---|---|---|---|
| **Chelicerates** | | **5.6** | **0.3** | **0.4** |
| Horseshoe crab | *Limulus polyphemus* | 5.6 | 0.3 | 0.4 |
| **Crustaceans** | | **100.0** | **94.0** | **51.2** |
| **Decapods** | | | | |
| Blue crab | *Callinectes sapidus* | 72.2 | 21.7 | 16.1 |
| Unident. portunid | *Callinectes* sp. | 5.6 | 0.1 | 4.4 |
| Rock crab | *Cancer irroratus* | 27.8 | 0.8 | 3.2 |
| Spider crab spp. | *Libinia* spp. | 66.7 | 40.1 | 12.9 |
| Lady crab | *Ovalipes ocellatus* | 5.6 | 0.1 | 0.8 |
| Hermit crab spp. | *Pagurus* spp. | 33.3 | 0.2 | 3.6 |
| Purse crab | *Persephona mediterranea* | 44.4 | 7.1 | 9.7 |
| Mantis shrimp | *Squilla empusa* | 5.6 | 0.0 | 0.4 |
| **Other Crustaceans** | | | | |
| Unident. crustaceans | — | 61.1 | 23.7 | — |
| **Fish** | | **16.7** | **3.0** | **2.0** |
| Bony fish | — | 16.7 | 3.0 | 2.0 |
| **Molluscs** | | **50.0** | **0.7** | **46.4** |
| **Bivalves** | | | | |
| Eastern Amer. oyster | *Crassostrea virginica* | 5.6 | 0.0 | 0.4 |
| Blue mussel | *Mytilus edulis* | 22.2 | 0.0 | 6.9 |
| Unident. bivalve | — | 11.1 | 0.0 | 0.8 |
| **Gastropods** | | | | |
| Cerith sp. | *Bittium* sp. | 11.1 | 0.0 | 5.6 |
| Wentletrap | *Epitonium* sp. | 5.6 | 0.0 | 0.4 |
| Eastern mud snail | *Ilyanassa obsoleta* | 5.6 | 0.1 | 0.8 |
| Three-line mud snail | *Ilyanassa trivittatus* | 22.2 | 0.1 | 6.5 |
| Unident. mud snail | *Ilyanassa* or *Nassarius* sp. | 11.1 | 0.2 | 2.4 |
| Mottled dog whelk | *Nassarius vibex* | 5.6 | 0.2 | 20.6 |
| Atlantic moon snail | *Neverita duplicata* | 5.6 | 0.0 | 0.8 |
| Unident. gastropod | — | 5.6 | 0.0 | 1.2 |
| **Plants** | | **61.1** | **0.1** | **—** |
| Widgeon grass | *Ruppia maritima* | 11.1 | 0.0 | — |
| Gulfweed sp. | *Sargassum* sp. | 11.1 | 0.0 | — |
| Eelgrass | *Zostera marina* | 33.3 | 0.0 | — |
| Unident. marine plant | — | 27.8 | 0.0 | — |
| Unident. terrestr. plant | — | 5.6 | 0.0 | — |
| **Miscellaneous** | | **16.7** | **2.0** | **—** |
| Rocks | — | 5.6 | 0.0 | — |
| Unident. tissue | — | 16.7 | 2.0 | — |
| **Anthropogenic Items** | | **5.6** | **—** | **—** |
| Hook and line gear | — | 5.6 | missing | — |

crabs and fish, the appearance of hermit crabs, purse crabs, and Atlantic moon snails in the 2000–02 diet data may be due to the increased sampling effort, and these differences were not significant (main effect (Years): $F = 3.12, p = 0.115$). At best, it can be concluded that *Callinectes* spp. (predominantly *C. sapidus*) and *Libinia* spp. (*L. dubia and L. emarginata*) were important components of ridley diet in Virginia during 1987–2002.

The diet data were also grouped seasonally (Fig. 5) and spatially (Fig. 6). Although crustaceans, molluscs, and fish occurred with higher frequency in the May–July data than in the August–October data, the difference was not significant (main effect (Months): $F = 7.15$, $p = 0.075$). Within the samples, ridleys consumed a greater variety of target prey species in May–July, but the difference in %F values was also not significant (main effect (Months): $F = 4.46$, $p = 0.068$). Frequency of occurrence of general prey groups (main effect (Location): $F = 1.75$, $p = 0.278$) and specific target prey (main effect (Location): $F = 1.78, p = 0.219$) were similar between bay and ocean turtles.

The Schoener (1970) index was used to estimate diet overlap between loggerhead (Seney, 2003) and Kemp's ridleys in Virginia during 2001 and 2002. Earlier years were not examined due to small numbers of ridley samples, and only whole samples were used in this calculation. Average dry weight values for horseshoe crabs, *Callinectes* spp., spider, hermit, rock, and purse crabs, bony fish, *Busycon* whelks (consumed only by loggerheads), and Atlantic moon snails were used. The overlap calculated for the two years combined (45 loggerheads, 16 ridleys) was 46.1%.

## DISCUSSION

All of the Kemp's ridleys examined were in the benthic immature size class (TEWG, 2000), and the majority of samples were collected during 2000–02; however, it is clear that blue crabs and spider crabs were key components of Virginia ridley diet during 1987–2002. In comparison, the smaller Kemp's ridleys found in New York appear to concentrate their foraging efforts on slower-moving types of crabs, including spider crabs and rock crabs (*Cancer irroratus*) (Burke et al., 1993, 1994). Ridleys from Georgia (Frick and Mason, 1998) and Texas (Shaver, 1991) appear to consume a large amount of blue crabs and other portunid

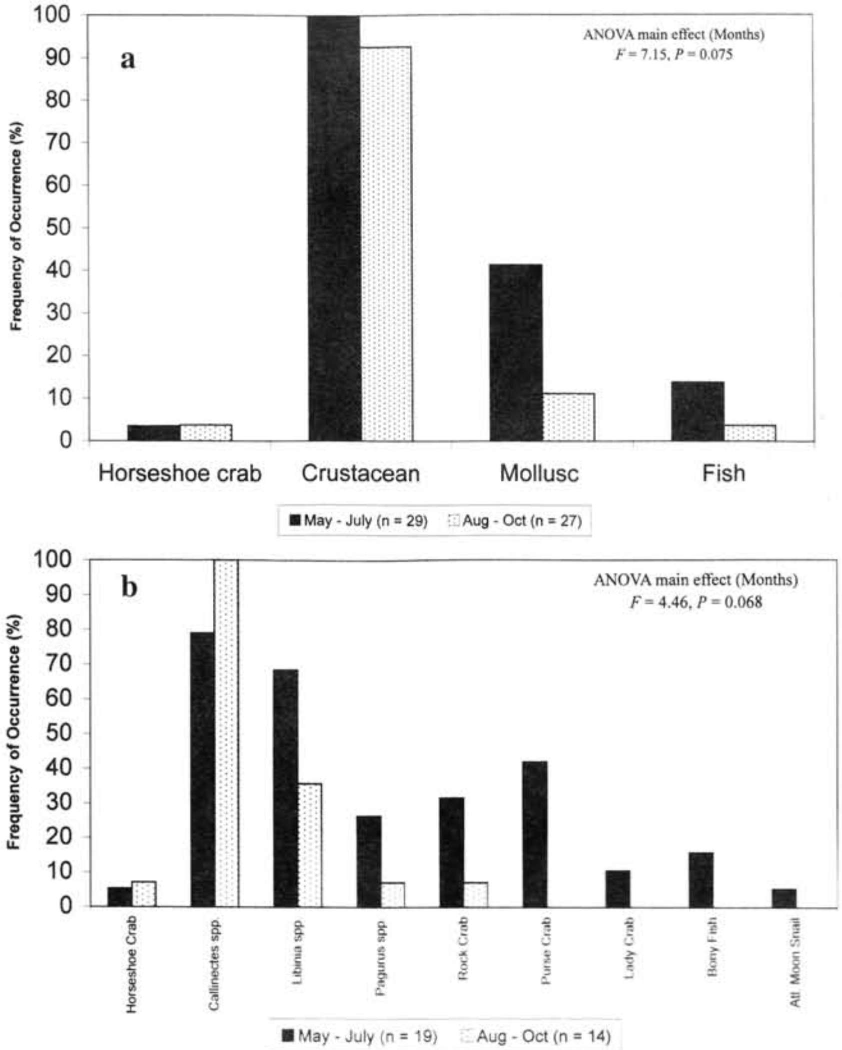


**Figure 5.** Frequency of occurrence of (**a**) major prey groups in all diet data ($n$ = 56, excludes 3 from November–December) and (**b**) target prey species in all samples ($n$ = 33), grouped by months.

crabs, in addition to the slower, walking crabs. Both turtle size range and prey composition of the Virginia samples appear to be more comparable to the ridleys examined in Georgia and Texas than to those from New York, suggesting similar foraging habits among similar-sized ridleys.

The appearance of new prey items in the 2000–02 samples could be due to increased sampling efforts, or it may suggest that Chesapeake Bay blue crab declines (Lipcius and Stockhausen, 2002) are beginning to affect ridley diet. Although statistically not significant, a more diverse diet was apparent in May–July as compared to August–October, suggesting that either ridley foraging areas or prey distributions and abundances may change during the months these turtle occupy Virginia waters. Diet was similar between turtles examined from bay and ocean areas, but these results may be confounded by post-mortem movements of carcasses prior to stranding.

The estimated diet overlap for 2001 and 2002 combined (46.1%) may be a reasonable estimation of the overlap between loggerhead and ridley diet in Virginia; however, the actual foraging range overlap may be minimal, as telemetry data suggest that loggerheads forage in deeper waters than ridleys (Keinath et al., 1987; Byles, 1988). Further investigations of loggerhead and ridley diet, foraging sites, and movements are necessary to determine the implications of diet overlap between these two protected species.

Kemp's ridleys appear to concentrate their foraging efforts in Virginia on both portunid and walking crabs, particularly blue crabs and spider crabs. In order to better understand and monitor potential effects of Virginia's blue crab declines on ridley diet, gut contents should continue to be examined. Additionally, larger sample sizes and further monitoring are necessary to better examine potential seasonal diet shifts. Such information may be useful in the management of the blue crab fishery, as well as in conservation schemes for the Kemp's ridley and other sea turtle species.

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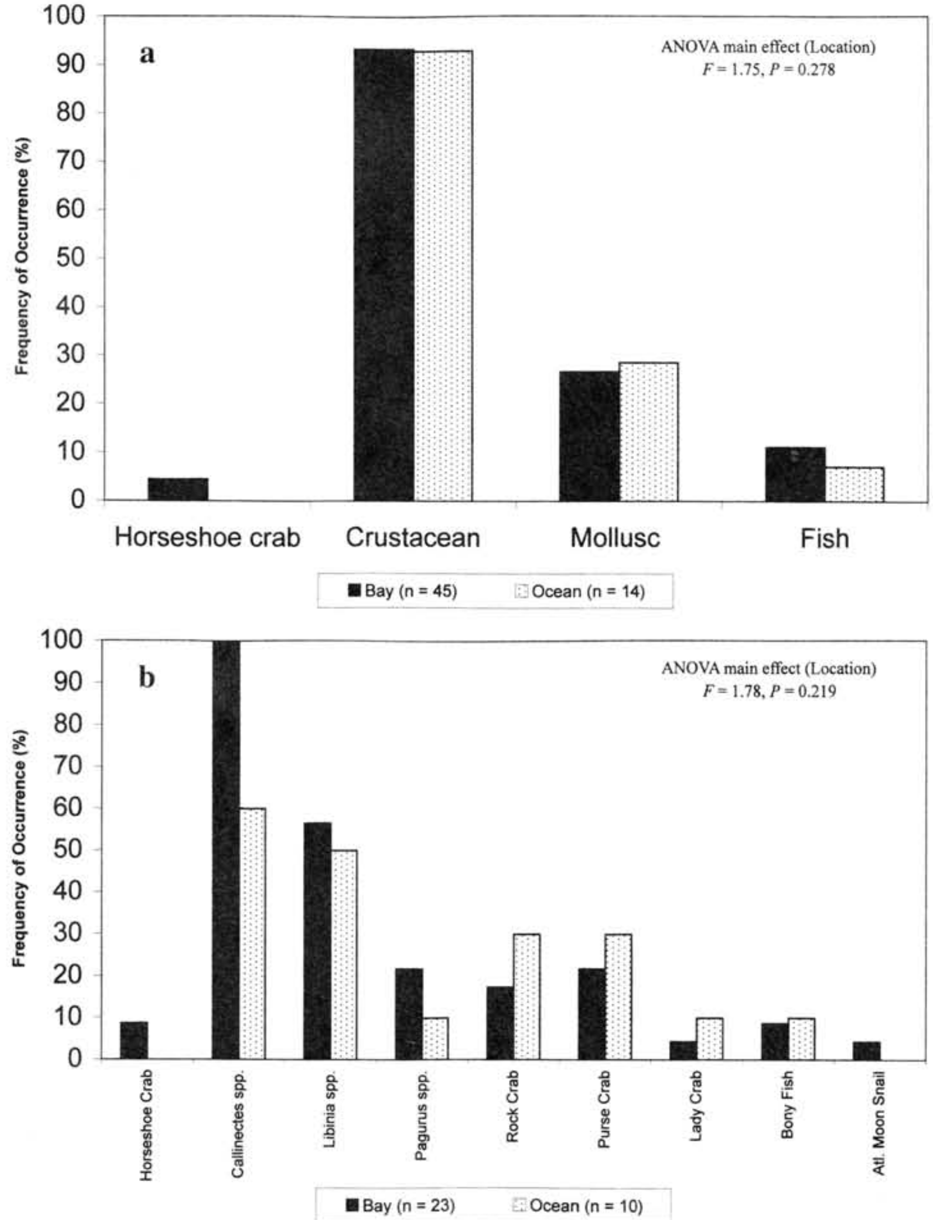


**Figure 6.** Frequency of occurrence of **(a)** major prey groups in all diet data ($n = 59$) and **(b)** target prey species in all samples ($n = 33$), grouped by location.

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