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Northeast Region
Boston, MA



Inventory of Freshwater Turtles at Cape Cod National Seashore with Recommendations for Long-Term Monitoring

Technical Report NPS/NER/NRTR--2007/091



ON THE COVER

Painted Turtle

NPS Photograph by: Brennan Murray

Inventory of Freshwater Turtles at Cape Cod National Seashore with Recommendations for Long-Term Monitoring

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Cape Cod National Seashore
Wellfleet, MA 02661

July 2007

U.S. Department of the Interior
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Table of Contents

Tables.....	v
Figures.....	vi
Acknowledgements.....	vii
Introduction.....	1
Materials and Methods.....	3
Site Selection	3
Trapping Effort	3
Sexing and Aging	15
Estimating Abundance, Density, and Biomass.....	16
Community Structure	17
Comparing Measures of Abundance	17
Results.....	18
Distribution.....	18
Sex Ratio, Size and Age Structure.....	24
Community Structure	28
Comparing Measures of Abundance	28
Discussion.....	38
CACO Turtle Community Structure.....	38
Painted Turtle	40
Snapping Turtle	45
Spotted Turtle	49
Musk Turtle	58
Comparing Measures of Abundance	61

Recommendations Regarding Monitoring and Research	62
Literature Cited	67

Tables

Table 1. Summary by year of turtle trapping effort. # trap nights is the number of traps deployed multiplied by the number of nights deployed.....	4
Table 2. Turtle trapping effort by habitat type. For each habitat type, number of sites sampled, % of total sample sites, % occurrence of habitat type at CACO, number of trap nights (TN), and a measure of sampling intensity (TN/ha) are presented.	4
Table 3. Details of trapping effort at each site during each sampling session. Asterisk (*) indicates area < 3 m depth was used to estimate trap density.	8
Table 5. Summary of turtle occurrence and captures, by habitat and species. For each habitat, number of sites sampled (sites), number of trap nights sampled (#TN), sites each species was present (pres), number of individuals captured (# inds), and individuals per trap night (inds/TN) are presented.	19
Table 6. Turtle captures, population estimates, and density at each site. Number of unique individuals captured, individuals/trap night (TN), Lincoln-Petersen population estimate N_{LP} , and density (N_{LP}/ha) are presented.	20
Table 7. Weighted mean density (inds/ha) and biomass (kg/ha) by turtle species and habitat type.	23
Table 8. Biomass (BM)(kg/ha) and total biomass (Total BM)(kg) estimates for each species at each site sampled.	25
Table 9. Morphometric data (carapace length CL, plastron length PL, and body mass), t-test results, and sexual dimorphism index (SDI) for all turtle species by sex.	33
Table 10. Values of Rho resulting from analysis of similarity (ANOSIM), pairwise comparisons between habitat types. Values significant at $p < 0.05$ in bold type.	36
Table 11. Comparison of painted turtle population estimates for site where #inds ≥ 20	37
Table 12. Latitude and mean size and mass of male and female snapping turtles.	47
Table 13. Spotted turtle capture rates at sites where present.	53
Table 14. Plastron growth in CACO spotted turtles. Based on animals captured in two or more field seasons. PL, Total Growth, and Annual Growth are in millimeters. Growth rate is annualized over indicated number of years.	57
Table 15. Recommendations for monitoring freshwater turtles at Cape Cod National Seashore. To the extent allowed by water levels, use equal numbers of hoop and D traps at sites where both types are specified.	66

Figures

Figure 1. Turtle trapping sample sites in Eastham and Wellfleet.	5
Figure 2. Turtle trapping sample sites in Truro and Wellfleet.	6
Figure 3. Turtle trapping sample sites in Provincetown.	7
Figure 4. Maximum and minimum carapace length (CL) of turtles captured, and number of species captured, by each of the four trap types used.	12
Figure 5. Dorsal view of a turtle shell carapace, illustrating the notch code system used to mark turtles (Cagle 1939).	14
Figure 6. Frequency distribution of CACO painted turtles based on plastron length.	29
Figure 7. Frequency distribution of CACO snapping turtles based on carapace length.	30
Figure 8. Frequency distribution of CACO musk turtle carapace length.	31
Figure 9. Frequency distribution of CACO spotted turtle plastron length.	32
Figure 10. Capture probability of adult male, adult female, and juvenile painted turtles at six sites sampled, calculated under the constant probability of capture model. Shown are the estimated probability of capture for each group, and the upper and lower 95% confidence limits.	34
Figure 11. Multi-dimensional scaling (MDS) of turtle community by habitat.	35

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Introduction

Turtles comprise a familiar group of vertebrates that occupy a broad range of habitats and ecological functions. Some species are important in energy flow, and may dominate vertebrate biomass, particularly in aquatic habitats (Congdon et al. 1986). By virtue of their trophic position, biomass, and vulnerability to anthropogenic perturbations, reptiles can be important indicators of environmental quality (Gibbons and Stangel 1999). Due to their longevity and habits, turtles accumulate environmental contaminants and are ideal for monitoring their presence in aquatic environments (Golet and Haines 2001, Rie et al. 1999). Turtle populations appear to be declining throughout the United States, as well as globally, due to the combined impacts of habitat loss, degradation, and fragmentation, road kill, invasive species, pollution, disease, unsustainable harvest, and global climate change (Gibbons et al. 2000, Klemens 2000).

Cape Cod National Seashore (CACO) supports populations of six species of non-marine turtles, occupying terrestrial, freshwater, and estuarine habitats. These include presently common and/or widespread species such as painted turtle (*Chrysemys picta*) and snapping turtle (*Chelydra serpentina*), the less common musk turtle (*Sternotherus odoratus*) and spotted turtle (*Clemmys guttata*), as well as the Massachusetts “threatened” northern diamondback terrapin (*Malaclemmys t. terrapin*), an estuarine species, and the terrestrial eastern box turtle (*Terrapene c. carolina*), a Massachusetts “special concern” species.

Turtle communities composed of viable populations of native species are indicative of intact native habitats and landscape processes at CACO, but there are several agents of change operating that have the potential to affect the turtle community and its component species. These include land use and development adjacent to the park, fire suppression, water pollution, increased traffic, recreational use, and exploitation. Some of the mechanisms by which these agents can negatively affect turtle abundance, population structure, and distribution include: 1. Alteration of aquatic habitats through nutrient loading or changes in water level (groundwater withdrawal), salinity (tidal alterations), and plant communities (invasive plants and groundwater withdrawal); 2. Declines in food abundance due to pesticide use or changes in aquatic habitats; 3. Increased road kill as increasing local human population and visitation increases habitat fragmentation and traffic volume; 4. Increased predation of turtle nests by over abundant populations of native predators, i.e. “subsidized predators” such as raccoons (*Procyon lotor*); 5. Loss of open nesting sites for turtles as fire suppression alters patch dynamics and forest succession advances; and 6. Direct loss of animals to collection by visitors and poachers.

Prior to this work, there was only general knowledge of the occurrence of aquatic turtles on outer Cape Cod (Lazell 1976, Jones 1992). Details of site-specific occurrence and abundance, as well as species’ distribution and habitat use were not well documented. Given recent concerns over trends in turtle populations, there was a need to better document these aspects of the aquatic turtles here, particularly the spotted turtle (a “special concern” species in Massachusetts until de-listed in 2006), and to assess the need for and feasibility of monitoring. Considering the many site and landscape parameters that can influence turtle abundance and community structure, and the many sites at CACO where turtles occur, a better general understanding of aquatic turtles at CACO, the issues

affecting them, and the sites where these issues are most critical or can be most effectively monitored was called for.

Materials and Methods

Site Selection

We conducted field sampling of 76 non-estuarine aquatic habitats for turtles from 1999 through 2003, with most sampling in 2000, 2001, and 2002 (Table 1; Figures 1, 2, 3). The majority of sites were sampled in only one year, except for five sites (E15, Portnoy's Bog, T30, T32 and Horseleech Pond) sampled in two or more years. We sampled sites over multi-years to better determine occurrence and status of spotted turtles, except at Horseleech Pond, where it was done to increase sampling effort. While most of the 76 sites represent discrete, isolated wetlands, some are pools of open water, ditches, or sections of river within larger riparian systems.

We stratified sample sites by wetland type and town to assess the different non-estuarine wetland types present at CACO, as well as potential geographic variation in species distribution due to the park's linear nature. Most sites were chosen at random, but sites where spotted turtles were known to or potentially occurred, or where management action was being considered were also included. Although the number of each wetland type sampled was not strictly proportional to each wetland types' occurrence at CACO, the numbers of each type sampled did not differ significantly from overall occurrence at CACO (Wilcoxon matched pairs test $T=18.0$, $Z=0.96$, $p=0.33$). However, since vernal ponds and dune slacks comprise ca. 60% of identified wetlands at CACO (Cook and Boland, unpublished data) and do not always contain water, we sampled relatively fewer of these short hydro-period wetlands and correspondingly more long hydro-period wetlands (Table 2).

Trapping Effort

Trapping effort varied considerably among habitat types (Table 2) and individual sites (Table 3). For a given habitat type, mean trapping intensity ranged from 6 trap nights/hectare (TN/ha) in impoundments to 421 TN/ha in vernal ponds (Table 2). Larger sites usually received greater numbers of traps, though sampling effort at some very large kettle ponds in 1999 and 2000 was insufficient to cover the entire site. Sites known or thought to potentially support spotted turtles also received greater sampling effort, generally, longer duration trapping sessions. As a result, many vernal ponds, dune slacks, bogs, red maple swamps, and riparian marsh sites received relatively high sampling effort. For individual sites, sampling effort ranged from 4.14 TN/ha at Gull pond to 4167 TN/ha at E27, a small vernal pond (Table 3). While there may be concern that numbers of turtles captured at a given site or habitat reflect intensity of trapping there, this does not appear to be the case. Based on all individual ponds, there was a significant but weak negative correlation between trapping intensity and numbers of individuals captured (Spearman $R=-0.25$, $p=0.02$). Within each habitat type, there was no significant correlation between trapping intensity at a site and numbers captured. In addition, there was an insignificant negative correlation between mean trapping intensity and number of individuals captured in each of the 10 habitat types (Spearman $R=-.55$, $p=0.10$). The negative correlation results when continued trapping captures few or no new individuals. These results suggest that, in spite of differences in trapping intensity, differences between sites and habitats in numbers of turtles captured are not a function of trapping intensity.

Table 1. Summary by year of turtle trapping effort. # trap nights is the number of traps deployed multiplied by the number of nights deployed.

Year	# sites	#trap nights
1999	8	136
2000	35	3039
2001	20	2460
2002	15	2883
2003	6	476
Totals	76*	8994

*unique sites, some were sampled in two or more years

Table 2. Turtle trapping effort by habitat type. For each habitat type, number of sites sampled, % of total sample sites, % occurrence of habitat type at CACO, number of trap nights (TN), and a measure of sampling intensity (TN/ha) are presented.

Habitat Type	# of Sites	% Sites Sampled	% CACO Wetlands	Total # TN	TN ha ⁻¹
bog	5	6.6	3.8	736	97
dune slack	10	13.2	23.8	1129	221
impoundment	2	2.6	1.0	805	6
inter-dune pond	20	26.3	13.3	1494	35
kettle-deep	7	9.2	6.2	265	13
kettle-shallow	8	10.5	6.2	435	27
riparian marsh	5	6.6	3.8	1323	262
stream	4	5.3	1.9	616	49
swamp-red maple	2	2.6	1.9	1232	55
vernal pool	13	17.0	38.1	959	421
Total	76	100%	100%	8994	33.4

Turtle sample sites in Eastham/Wellfleet

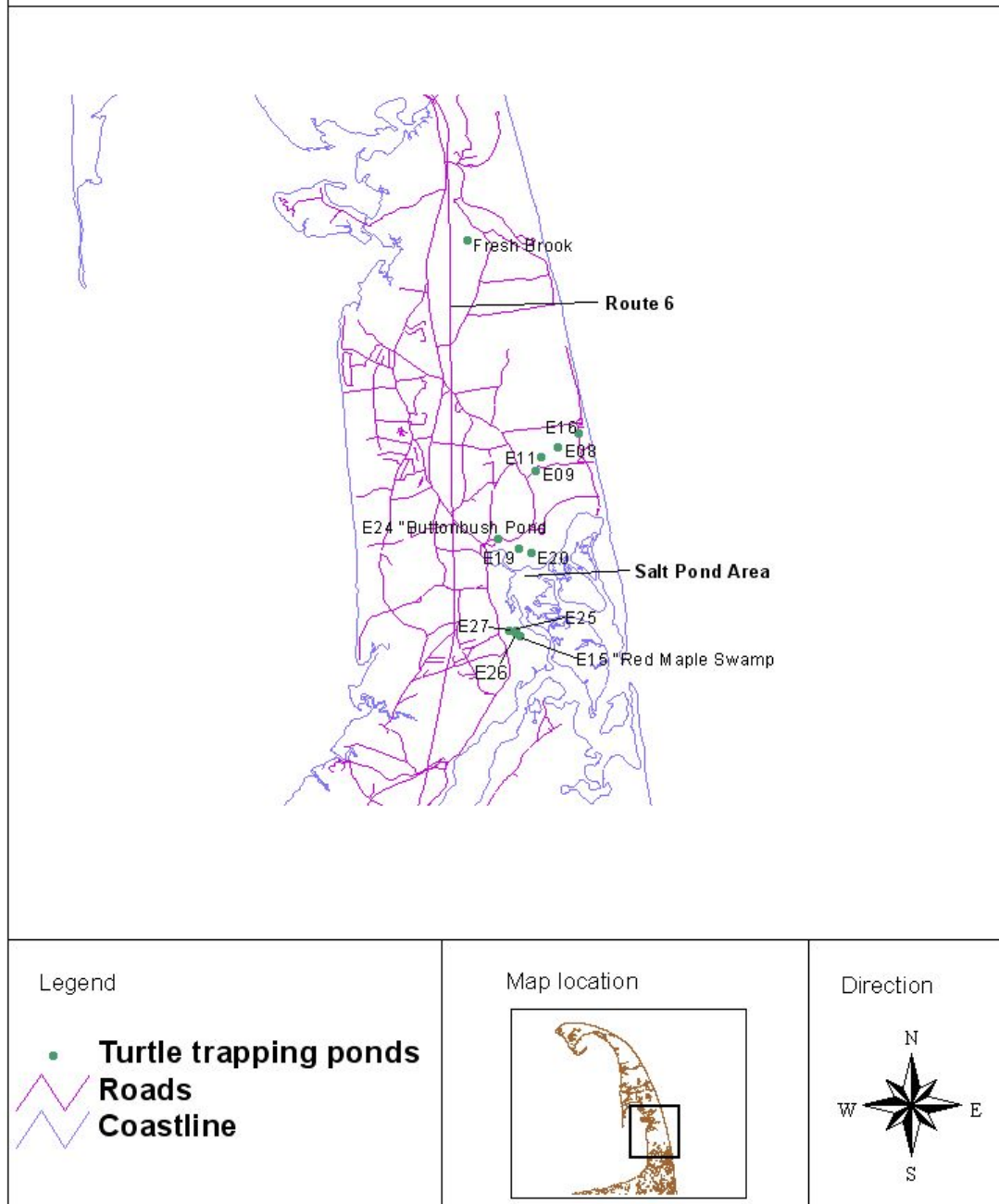


Figure 1. Turtle trapping sample sites in Eastham and Wellfleet.

Turtle sample sites for Truro/Wellfleet

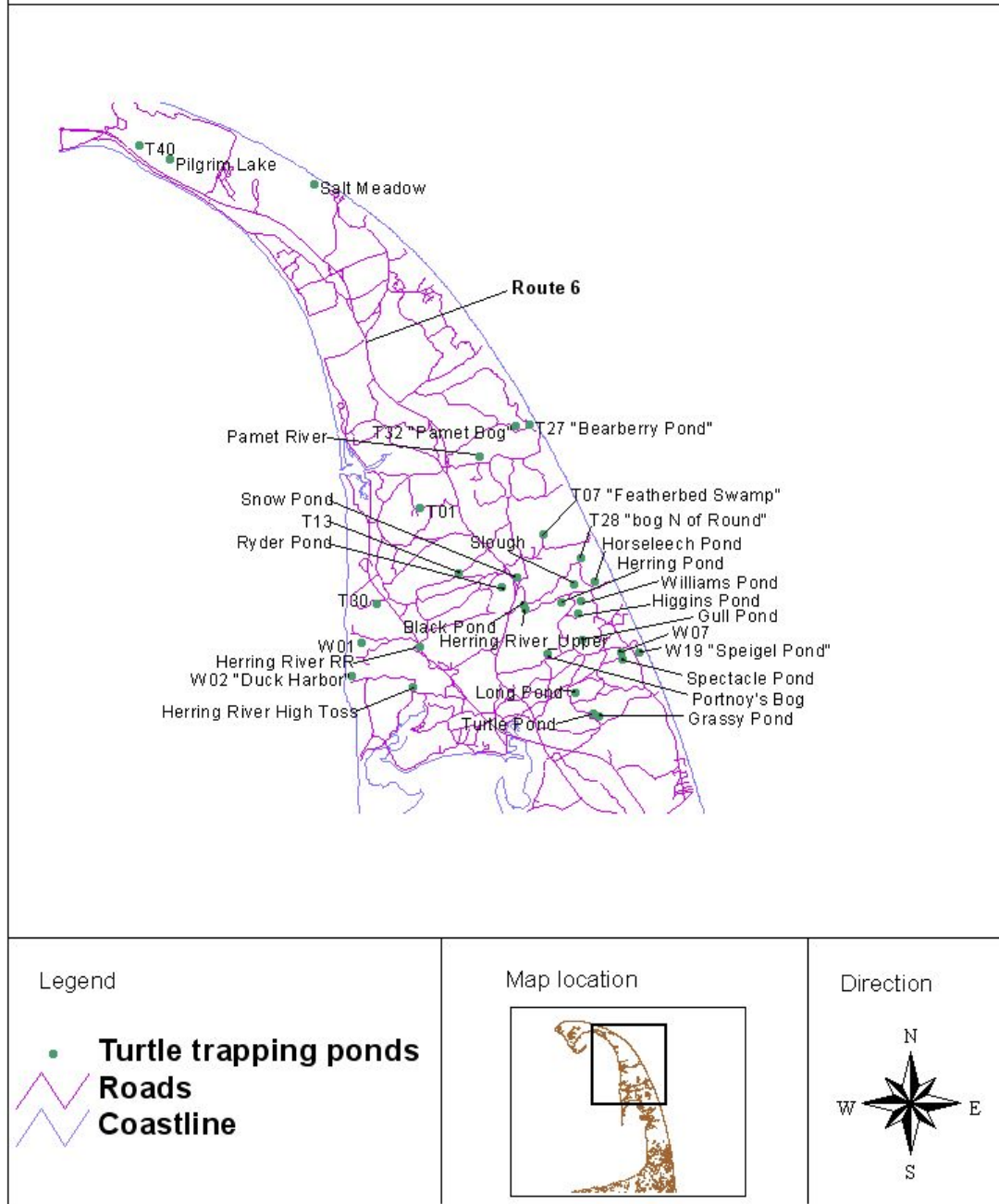


Figure 2. Turtle trapping sample sites in Truro and Wellfleet.

Turtle sample sites in Provincetown

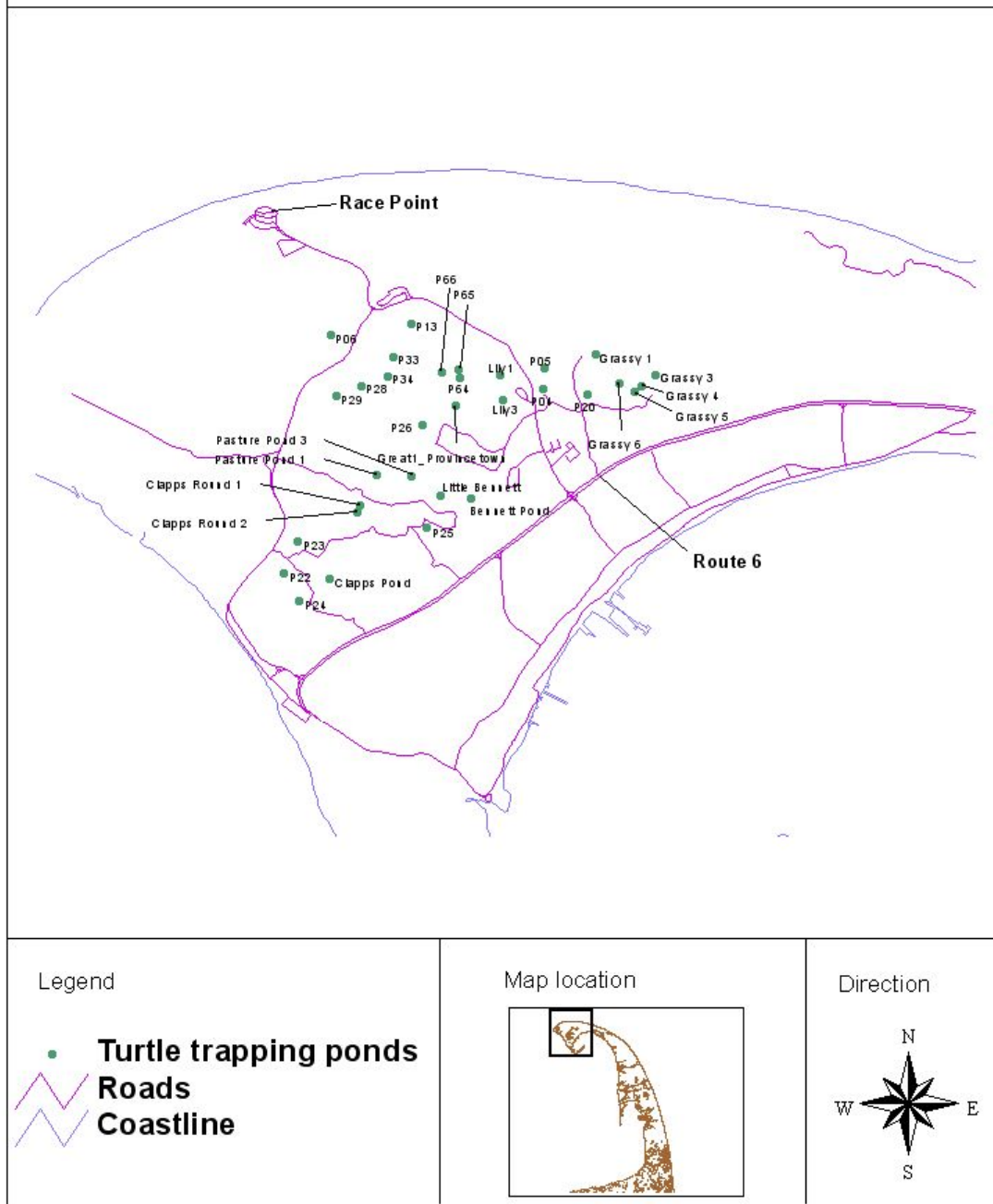


Figure 3. Turtle trapping sample sites in Provincetown.

Table 3. Details of trapping effort at each site during each sampling session. Asterisk (*) indicates area < 3 m depth was used to estimate trap density.

Location	Habitat	Area (ha)	start	end	nights	traps	#TN	TN/ha	#Box	# 'D'	Hoop Large	Hoop Small
Bennett Pond	inter-dune pond	2.078	08/21/02	09/11/02	21	7	147	70.7		2	3	2
Black Pond	riparian marsh	0.300	06/22/00	07/13/00	21	3	63	210.1		1	2	
Clapps Pond	inter-dune pond	17.804	09/16/02	09/27/02	11	20	220	12.4		4	10	6
Clapps Round 1	inter-dune pond	0.451	09/17/01	09/28/01	11	3	33	73.1			3	
Clapps Round 2	inter-dune pond	0.229	09/17/01	09/28/01	11	3	33	144.1	2	1		
E08	vernal pool	0.425	05/22/00	06/05/00	15	3	45	106.0	1	2		
E09	vernal pool	0.217	05/15/00	06/19/00	35	5	175	807.6	3	2		
E11	vernal pool	0.084	05/15/00	05/22/00	7	2	14	166.7	1	1		
E15 "Red Maple Swamp"	swamp-red maple	5.610	05/15/00	06/05/00	21	15	315	18.5	8	7		
E15 "Red Maple Swamp"	swamp-red maple	5.610	04/24/01	05/25/01	31	15	465	26.4	7	8		
E15 "Red Maple Swamp"	swamp-red maple	5.610	09/30/02	10/09/02	9	10 to 12	104	56.1	7	4		1
E15 "Red Maple Swamp"	swamp-red maple	5.610	08/18/03	08/29/03	8	17 to 20	148	82.9	10	10		
E16	vernal pool	0.267	05/30/00	06/19/00	20	4	80	300.1	2	2		
E19	vernal pool	0.072	05/30/00	06/19/00	20	5	100	1398.6	1	4		
E20	vernal pool	0.295	05/30/00	06/19/00	20	5	100	338.8	1	4		
E24 "Buttonbush Pond"	vernal pool	0.323	05/15/00	05/22/00	7	5	35	108.4	2	3		
E25	kettle-shallow	0.181	04/29/02	05/24/02	25	7	175	964.7		5	2	
E26	swamp-red maple	0.114	04/29/02	05/24/02	25	8	200	1754.4	5	3		
E27	vernal pool	0.036	04/29/02	05/24/02	25	6	150	4166.7	4	2		
Fresh Brook	impoundment	2.100	09/11/00	09/22/00	11	20	220	104.8	5	5	10	
Grassy 1	inter-dune pond	2.337	09/04/01	09/14/01	10	4	40	17.1	1	3		
Grassy 3	bog	1.202	09/04/01	09/14/01	10	4	40	33.3	2	2		
Grassy 4	inter-dune pond	0.919	09/04/01	09/14/01	10	4	40	43.5	2	2		
Grassy 5	inter-dune pond	0.071	09/04/01	09/14/01	10	2	20	281.3	1	1		
Grassy 6	inter-dune pond	0.678	09/04/01	09/14/01	10	4	40	59.0	2	2		
Grassy Pond	kettle-shallow	0.361	05/24/99	05/28/99	4	5	20	55.5			5	
Great1_Provincetown	inter-dune pond	4.930	08/21/02	09/11/02	21	10	210	42.6		2	7	1
Gull Pond*	kettle-deep	9.660	07/31/00	08/11/00	8	5	40	4.1		5		
Herring Pond*	kettle-shallow	3.629	07/31/00	08/11/00	8	5	40	11.0		2	3	
Herring River HighToss	stream	na	06/27/00	07/13/00	16	4	64	na			4	
Herring River RR	stream	na	06/25/00	07/13/00	23	3	69	na		1	2	
Herring River_Upper	stream	na	06/22/00	07/13/00	21	7 to 8	153	na	3	4	1	

Table 3. Details of trapping effort at each site during each sampling session (continued)

Location	Habitat	Area (ha)	start	end	nights	traps	#TN	TN/ha	#Box	# 'D'	Hoop Large	Hoop Small
Higgins Pond*	kettle-deep	2.653	06/07/99	06/11/99	4	5	20	7.5			5	
Horseleeche Pond*	kettle-shallow	3.135	05/18/99	05/21/99	3	5	15	4.8			5	
Horseleeche Pond*	kettle-shallow	3.135	09/25/00	10/06/00	11	5	55	17.5	2	1	2	
Lily Pond 1	inter-dune pond	2.246	06/05/00	06/19/00	14	10	140	62.3	2	8		
Lily Pond 3 (south)	inter-dune pond	1.856	06/12/00	06/19/00	6	5	30	16.2	3	2		
Little Bennett	inter-dune pond	1.016	09/17/01	09/28/01	11	5	55	54.1		5		
Long Pond*	kettle-deep	0.617	09/25/00	10/06/00	11	5	55	89.1	1	1	3	
P04	vernal pool	0.024	06/06/00	06/19/00	13	2	26	1076.6	1	1		
P05	dune slack	0.898	06/06/00	06/19/00	13	5	65	72.4	2	3		
P06	dune slack	1.191	06/12/00	06/19/00	7	5	35	29.4	2	3		
P13	dune slack	1.120	05/29/02	06/28/02	30	10	300	267.9	6	4		
P20	inter-dune pond	0.454	09/04/01	09/14/01	10	2	20	44.0	1	1		
P22	inter-dune pond	0.773	08/20/01	08/31/01	11	5	55	71.2	2	3		
P23	inter-dune pond	0.628	08/20/01	08/31/01	11	5	55	87.6	2	3		
P24	inter-dune pond	0.403	08/20/01	08/31/01	11	5	55	136.5	2	3		
P25	inter-dune pond	0.560	08/20/01	08/31/01	11	5	55	98.3	2	3		
P26	inter-dune pond	0.648	09/17/01	09/28/01	11	4	44	68.0	2	2		
P28	dune slack	0.307	05/29/02	06/28/02	30	5	150	488.0	2	3		
P29	dune slack	0.716	05/29/02	06/28/02	30	5	150	209.6	4	1		
P33	dune slack	0.075	05/29/02	06/28/02	30	3	90	1200.0	1	2		
P34	dune slack	0.266	05/29/02	06/28/02	30	5	150	564.3	3	2		
P64	dune slack	0.128	08/04/03	08/15/03	8	5	40	313.5	5			
P65	dune slack	0.099	08/04/03	08/15/03	8	3	24	241.4	3			
P66	dune slack	0.298	07/29/03	08/15/03	11	9 to 14	125	419.7	5	5		
Pamet River	stream	6.762	07/17/00	07/28/00	11	30	330	48.8		10	20	
Pasture Pond 1	inter-dune pond	2.920	08/21/02	09/11/02	21	7	147	50.3		4		3
Pasture Pond 3	inter-dune pond	1.350	09/17/01	09/28/01	11	5	55	40.7	2	3		
Pilgrim Lake	impoundment	138.528	07/08/02	08/16/02	39	15	585	4.2		4	7	4
Portnoy's Bog	bog	1.730	06/07/99	06/11/99	4	4	16	9.2				4
Portnoy's Bog	bog	1.730	06/22/00	07/13/00	20	5	100	57.8	5			
Ryder Pond*	kettle-deep	1.685	07/31/00	08/11/00	8	5	40	23.7			5	

Table 3. Details of trapping effort at each site during each sampling session (continued)

Location	Habitat	Area (ha)	start	end	nights	traps	#TN	TN/ha	#Box	# 'D'	Hoop Large	Hoop Small
Salt Meadow	riparian marsh	2.923	07/23/01	08/17/01	25	20	500	171.1	2	3	15	
Slough Pond*	kettle-deep	4.732	09/25/00	10/06/00	11	5	55	11.6	2	3		
Snow Pond*	kettle-deep	0.924	07/31/00	08/11/00	8	5	40	43.3			5	
Spectacle Pond*	kettle-deep	0.327	05/12/99	05/15/99	3	5	15	45.8			5	
T01	vernal pool	0.132	05/22/00	06/12/00	21	5	105	797.3	2	3		
T07 "Featherbed Swamp"	bog	0.014	08/28/00	09/08/00	7	5	35	2592.6	2	3		
T13	vernal pool	0.116	05/22/00	06/12/00	21	5	105	906.0	3	2		
T27 "Bearberry Pond"	kettle-shallow	0.243	08/14/00	08/18/00	4	5	20	82.3			5	
T28 "bog N of Round"	bog	0.042	05/18/99	05/21/99	3	5	15	353.8			5	
T30 "Bound Brook North"	riparian marsh	0.328	06/23/00	07/13/00	20	8	160	488.3	2	3	3	
T30 "Bound Brook North"	riparian marsh	0.328	06/25/01	07/20/01	25	15	375	1144.3	10	5		
T32 "Pamet Bog"	bog	0.956	08/14/00	08/18/00	4	10	40	41.8		5	5	
T32 "Pamet Bog"	bog	0.956	05/29/01	06/22/01	24	15	360	135.9	7	8		
T32 "Pamet Bog"	bog	0.956	07/21/03	08/01/03	7	10 to 20	130	376.5	9	11		
T40	riparian marsh	0.120	07/08/02	07/29/02	21	5	105	878.7			5	
Turtle Pond_Wellfleet	kettle-shallow	1.526	05/24/99	05/28/99	4	5	20	13.1			5	
W01	vernal pool	0.117	07/28/03	08/01/03	3	3	9	77.1	3			
W02 "Duck Harbor"	riparian marsh	1.060	06/26/01	07/20/01	24	5	120	113.2		4	1	
W07	vernal pool	0.174	05/12/99	05/15/99	3	5	15	86.3			5	
W19 "Speigel Pond"	kettle-shallow	0.376	08/28/00	09/08/00	7	5	35	93.2			5	
Williams Pond	kettle-shallow	3.625	09/25/00	10/06/00	11	5	55	15.2			5	

We employed four different trap types, with water depth being the primary determinant of trap type (Table 4). “Box” traps were set in the shallowest waters, followed by “D” traps, small hoop traps, and large hoop traps in the deepest water. We placed at least two types of traps, and sometimes three, to sample a spectrum of water depths at each site (Table 3). Since traps must be set with an air space to prevent drowning, we set traps along the margins of large, deep sites while at shallower sites they were set more centrally. For the shallowest sites, water depth often determined trap placement. Where water depth did not dictate trap placement, traps were set to maximize captures and, to the extent practical, to sample the site as uniformly as possible. At small and medium size sites, we spread traps out a minimum of 10 m apart and distributed them uniformly across the wetland. At larger sites, traps were set in groups of five traps (each a minimum 10 m apart) and the groups were uniformly distributed, as much as practical, throughout the site. However, issues of logistics, ease of access, or private ownership at several sites (e.g. Pilgrim Lake and large kettle ponds such as Gull Pond and Horseleech Pond) prevented an even distribution of traps at these sites. When setting traps, we used features such as downed logs, ditches, and channels of open water to maximize likelihood of capture.

Because trap types varied in dimensions (Table 4), there is potential for size-based sampling bias. Although minimum carapace length of turtles captured in each of the four trap types did not vary much, there is a substantial difference in the largest individuals captured by “box” traps and small hoop traps versus large hoop and “D” traps (Figure 4). Therefore trap types did not influence the smallest individuals captured, but large individuals were probably excluded from box traps and possibly from small hoop traps. In the case of small hoop traps, however, they were only deployed for 373 trap nights (compared to 2898 trap nights of box traps, 3578 trap nights of “D” traps, and 2145 trap nights of large hoop traps) and their failure to capture large individuals may also be partly due to fewer opportunities.

In spite of possible bias, the trap types with the largest and smallest values for maximum carapace length, “D” traps and box traps respectively, each caught individuals of all four species recorded in this survey (Figure 4). Thus, trap type does not appear to influence minimum sizes or species detected, but does appear to affect the size distribution of captures. In particular, “box” traps only caught small snapping turtles and small to medium-sized painted turtles, and thus give biased size data for these species. However, partially mitigating this bias in most cases is the fact that box traps were usually deployed in a given site with equal numbers of “D” traps (Table 3). Thus, we sampled nearly all sites with traps capable of capturing individuals across the full range of sizes. The sites we sampled only with box traps were a few very shallow sites where we were targeting spotted turtles.

Table 4. Dimensions of the four different traps used in turtle trapping.

	D-frame	Small Hoop	Large Hoop	Box
Frame length (cm)	129	140	175	60
Frame width (cm)	54	49	75	31
Frame height (cm)	45	49	75	31
Stretched entrance width (cm)	49.5	24	52	8
Non-stretched entrance width (cm)	21.5	17	20	8
Entrance height (cm)	x	x	x	8
Mesh length (cm)	2.5	2.5	2.5	1
Mesh width (cm)	2.5	2.5	2.5	2
Minimum trap depth placement (cm)	22	25	34	17
Maximum trap depth placement (cm)	36	41	67	27
# entrances	1	2	1	1

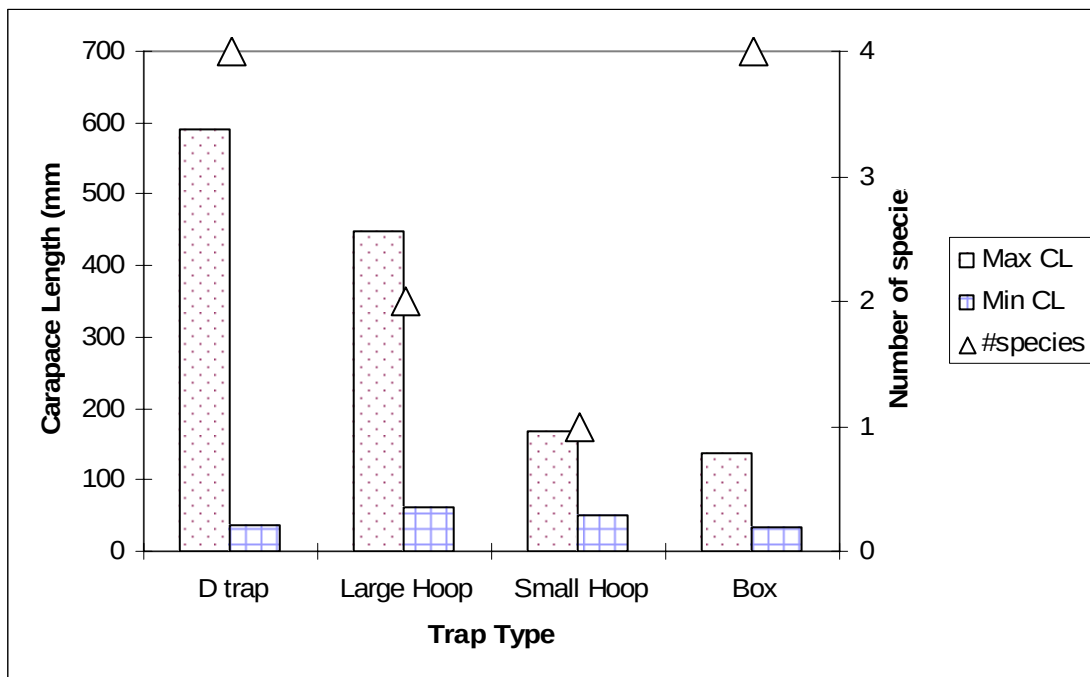


Figure 4. Maximum and minimum carapace length (CL) of turtles captured, and number of species captured, by each of the four trap types used.

We set and baited traps in the morning. In 1999 and 2000 we checked traps daily and re-baited every other day. In 2001 and 2002 we checked and re-baited traps every other day, except at spotted turtle sites, which we checked daily. We baited traps with 1.75 ounces of canned sardines in vegetable oil. At each trap check, all turtles captured were identified, marked, measured, and sex and age determined. Marking was based on a system similar to that of Cagle (1939) where each marginal scute had a numeric value (Figure 5). By marking different combinations of scutes, each turtle was given a unique identification number. Marking consisted of using a flat file or “Dremel” tool to create a square notch in the center of one or more marginal scutes of each turtle. For all species, we measured straight-line carapace length (CL), maximum carapace width (CW), and straight line plastron length (PL) to the nearest mm with “Haglof” tree calipers or, for small individuals, vernier calipers. For snapping turtles, length of posterior plastron lobe (PPL) and pre-anal tail (PAT) length were also recorded. Because of the wide range in weight between the smallest and largest specimens captured, a variety of “Pesola” spring scales, with different weight capacities, and “Ohaus” Portable Standard Balance models CS200 and CS2000 were used to determine body mass (mass). Individuals were weighed on the smallest capacity device possible.

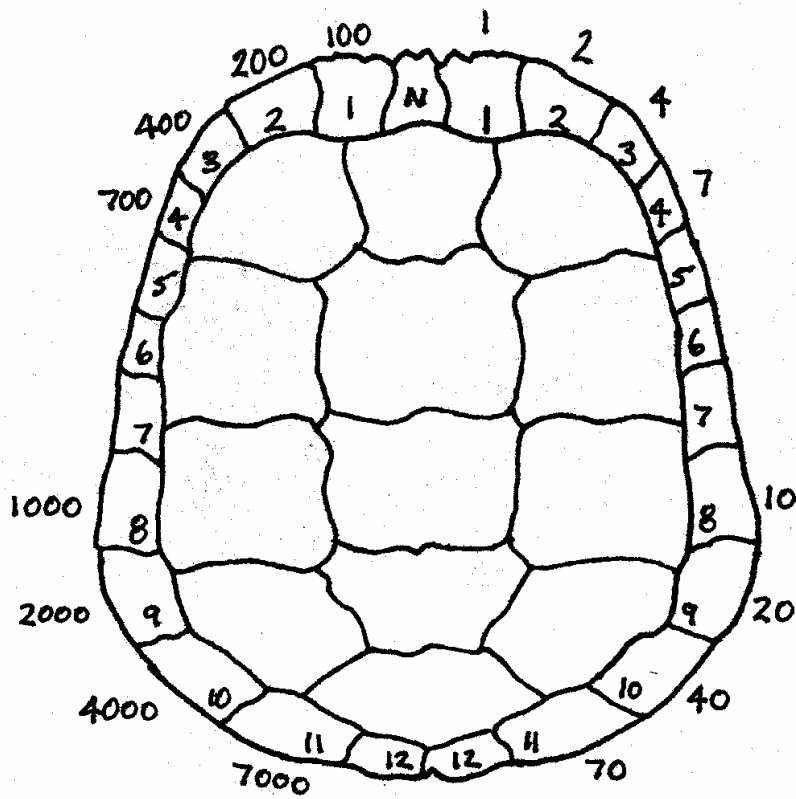


Figure 5. Dorsal view of a turtle shell carapace, illustrating the notch code system used to mark turtles (Cagle 1939).

Sexing and Aging

We determined sex and age of turtles using the approach of Cagle (1942). We classified individuals exhibiting male secondary sex characteristics as adult males. Of the remaining individuals, those exceeding the minimum size at which females mature were considered adult females, and the remainder were classified as immature. Attainment of sexual maturity in turtles is generally a function of size rather than age. Size at sexual maturity varies among individuals within a population and also often varies latitudinally between populations (i.e. size at attainment of sexual maturity increases with latitude) (Tinkle 1961, Iverson 1992). Field determination, based on species-specific criteria, and data on minimum size at sexual maturity from the most geographically appropriate literature available was used to categorize individuals into age classes “juvenile”, “adult male”, or “adult female”.

Snapping turtles were sexed on the basis of the relative location of the vent on the tail. In males the vent is posterior to the carapace margin. In addition the PAT/PPL ratio is commonly > 1.2 in males whereas in females it is generally < 1.1 (Ernst et al. 1994). Based on data from Michigan and Quebec (Congdon et al. 1987, 1992, Ernst et al. 1994), males with CL > 210 mm and females with CL > 200 mm were generally considered adult.

Musk turtles were sexed based on males having a longer, thicker tail, with a more distal vent and a blunt terminal nail, as well as more exposed skin around the medial plastron seams (Ernst et al. 1994). Based on data for “northern” populations, males with CL > 63 mm and females with CL > 80 mm were considered adults (Tinkle 1961).

In painted turtles, we sexed males based on the presence of elongated foreclaws and a long thick tail, with the anal opening posterior to the carapace margin (Ernst et al. 1994). Zweifel (1989) found that elongation of toenails occurred in Long Island, NY, males as small as 76 mm PL and in most, if not all males, by 90 mm PL. Thus, we classified any painted turtle > 90 mm PL and lacking male secondary sexual characteristics as a female (Zweifel 1989). Based on Long Island, NY, data (Zweifel 1989), males with PL > 80 mm and females with PL > 110 mm were considered adults. Spotted turtles were also sexed based on males having a thicker longer tail with a more distal anal opening relative to females, and a concave plastron (Ernst et al. 1994). In his work with Massachusetts spotted turtles, Graham (1995) classified individuals with PL < 80 mm as juveniles.

We evaluated sexual dimorphism in each species by comparing mean values of CL, PL, and mass for adults of each sex. We also calculated a Sexual Dimorphism Index (SDI), based on the CL or mass of the larger sex divided by the smaller sex, with a positive value if females are largest and a negative if males are larger (Gibbons and Lovich 1990).

Because turtle samples can be sex or age biased (Ream and Ream 1966, Gibbons 1990), capture probabilities for adult male, adult female, and juvenile painted turtles were calculated for the six sites where relatively large numbers of painted turtles were captured. These were Fresh Brook (117 inds), Clapps Pond (112 inds), Bennett Pond (112 inds), Pamet River (99 inds), Williams Pond (88 inds), and Great Pond 1 Provincetown (83 inds). The closed captures routine of program MARK (White and Burnham 1999) was used to calculate an overall capture probability for each group at each pond under the constant capture probability model. The parameter estimated was the

probability of capture of an individual of a given group, on a given sampling occasion (i.e. occasion when traps were checked).

Estimating Abundance, Density, and Biomass

We used Chapman's modified Lincoln-Petersen method (Thomson et al 1998) to provide an unbiased estimate of population size (N_{LP}). Because the Lincoln-Petersen method is a single mark and recapture method, multiple trapping occasions at a site were consolidated into two periods of equal or nearly equal sampling effort to provide the two sampling periods used in the Lincoln-Petersen method (Menkens and Andersen 1988).

We calculated density based on estimated population size (N_{LP}) and size of sampling site. We estimated wetland size by onscreen digitizing using ArcGIS (ESRI Corp., 2002) and Cape Cod National Seashore vegetation map shape files superimposed over orthophotos (MassGIS 2001, 0.5m resolution). For smaller sites not discernible on orthophotos, e.g. vernal ponds, we used field measures of length and width to estimate wetland size, based on the formula for area of an oval (Calhoun et al. 2003). Although total area was considered to be usable habitat for turtles at most sites, we made adjustments in riparian marsh and kettle ponds to account for portions of those sites not likely to be used. In marsh habitat with areas of dense, emergent vegetation, turtle use is primarily in the open water pools with submergent and floating-leaved vegetation. (Congdon and Gibbons 1989). Thus, in riparian marsh, we followed Congdon and Gibbons (1989) and estimated usable habitat as the area of the open water pools where we sampled. In addition, the species of turtles found at CACO are shallow water species (Ernst et al. 1994) and generally do not utilize the deeper portions of large, deep water bodies. Because they are generally restricted to portions of large water bodies where water is < 2-3 meters deep (Cagle 1942, 1944, Dodd 1989, Galbraith et al. 1988), we estimated usable habitat in kettle ponds as the portion of the pond where water depth was ≤ 3 m, based on bathymetric data from Portnoy et al. (2001) and Eichner et al. (2003).

We calculated biomass (BM) for each species at a site as kg/ha by multiplying estimated density (inds/ha) by mean mass of individuals captured at that site. While Congdon and Gibbons (1989) partitioned a species' population at a site into adult males, females, and juveniles, and estimated site biomass by summing the estimated biomass of each, our data were not sufficient for such an approach. Instead, we followed Iverson (1982), and pooled all individuals of a species captured at a site together to estimate population size, mean mass, and biomass.

Because individual sites within a habitat type were different sizes, we estimated mean density and mean biomass for each habitat type using a weighted mean. For mean density, the area and estimated populations of all sites within a given habitat type were summed and mean density for the habitat type calculated as the sum of population estimates divided by the sum of areas. Similarly, we estimated mean biomass of a species in a given habitat type by calculating total biomass of that species at each site (e.g. kg/ha x number of ha), and then dividing the sum of total estimated biomass by the sum of areas. Because both raw and log transformed density and biomass data were not normally distributed, we analyzed the relationship between habitat type, density, and biomass of each species using a non-parametric Kruskal-Wallis test (Zar 1996). The relationship between a species density (weighted mean) and how widespread it was in a given habitat type (sites present/sites sampled) was analyzed by ranked correlation.

Community Structure

We examined turtle community structure (i.e. species composition) in two ways. Multi-dimensional scaling (MDS) was used to ordinate the relationship of species composition at the ten habitat types in two dimensional space. Mean density of each species in each habitat type was subjected to a fourth root transformation, to balance contributions of abundant versus rare species (Clarke and Warwick 2001), and used to generate the Bray-Curtis similarity matrix in program PRIMER used for MDS. In addition, we used Analysis of Similarity (ANOSIM) to analyze variation in community structure due to habitat type. Data used in ANOSIM were fourth root transformed density estimates for each species at each sampling site.

Comparing Measures of Abundance

Because animal abundance can be quantified as indices or population estimates (Conroy 1996) and it is important to determine which is optimal for use in a monitoring program, a number of different methods were compared (Lindeman 1990, Koper and Brooks 1998). For each species detected at a site during a given sampling session, we calculated total numbers of unique individuals and an index of abundance (number of unique individuals per trap night). However, indices are not estimates of the actual population size (N). Because capture probabilities may vary among individuals, as well as species, site, and trap type, indices may not be unbiased (Nichols 1986, Conroy 1996). Unbiased estimates of actual population size (N) were made using the modified Lincoln-Petersen method (N_{LP}), and for painted turtles, population estimates were also generated using program CAPTURE (White et al. 1982). CAPTURE selected the most appropriate model and estimated population size (N_{CAP}) with that model. Since CAPTURE requires that numbers of individuals captured are “several times larger than 10 or 20” to produce satisfactory results (White et al. 1982), only sites with 20 or more individuals captured were used.

We used correlation analysis to compare the results of the different measures of abundance and population estimation methods. For all instances where the number of unique individuals captured was 10 or more, the correlation between number of unique individuals (#INDS), number of unique individuals/trap night (INDS/TN), and modified Lincoln-Petersen population estimate (N_{LP}) was analyzed. Because the Shapiro-Wilks test determined that these data were not normally distributed, we used the non-parametric Spearman's Ranked Correlation test. Similarly, for sites where 20 or more painted turtles were captured, correlation analysis between the above three measures of abundance, plus the population size estimated by program CAPTURE (N_{CAP}) was conducted.

Results

Distribution

We captured a total of 1447 individuals, representing four species (Table 5). Painted turtles comprised 81.1% of all individuals captured, snapping turtles 14.7%, spotted turtles 2.7%, and musk turtles 1.5%. Painted turtles occurred at more sites than other species, 65% (49 of 76) of sites sampled, followed by snapping turtles (38%), musk turtles (9%), and spotted turtles (8%). Painted turtles and snapping turtles were detected in all wetland habitats sampled except for red maple swamps. Musk turtles were detected only in shallow and deep kettle ponds, and spotted turtles were detected in five wetland types, bog, dune slack, riparian marsh, red maple swamp, and vernal pond (Table 5). In terms of geographic distribution, painted turtles, snapping turtles, and spotted turtles were detected at sites in Eastham, Wellfleet, Truro, and Provincetown, whereas musk turtles were only detected at sites in Wellfleet and Truro.

Abundance, Density, Biomass, and Habitat

Individual sites were quite variable in the numbers of individuals captured, estimated population size, and density of a given species (Table 6). For sites at which they were detected, the estimated density of painted turtles ranged from 0.1 inds/ha at Gull Pond to 201.4 inds/ha at W07. For snapping turtles the range was 0.1 inds/ha at Gull Pond to 48.8 inds/ha at Bound Brook North, for musk turtles it was 0.28 inds/ha at Williams Pond to 3.39 inds/ha at Higgins Pond, and for spotted turtles it was 0.94 inds/ha at W02 to 16.7 inds/ha at Pamet Bog. Density also varied by species and habitat type (Table 7). Parkwide, painted turtles had the highest mean density (7.22 inds/ha), followed by snapping turtles (1.38 inds/ha), spotted turtles (0.19 inds/ha), and musk turtles (0.14 inds/ha). When calculated based only on the habitats in which a species was detected, this relationship generally remained, though density estimates were higher (Table 7).

There were significant among-habitat differences in the density of the total turtle community (Kruskal-Wallis $H = 19.41$, $df=9$, $p=0.022$), with the weighted mean density for all species combined greatest in riparian marsh habitats (47.36 inds/ha) and lowest in impoundment (1.70 inds/ha; Table 7). Painted turtle density also varied significantly among habitats (Kruskal-Wallis $H = 19.31$, $df=9$, $p=0.02$) and was greatest in shallow kettle ponds, vernal pool, riparian marsh, and stream habitats and lowest in impoundment and bogs (Table 7). Snapping turtle density was highest in riparian marsh and lowest in vernal pools and deep kettle ponds (Table 7). These differences were significant (Kruskal-Wallis $H = 33.19$, $df=9$, $p=0.0001$). Musk turtle density was roughly equal in the two habitats that it was detected in, deep and shallow kettle ponds, 1.12 and 0.92 inds/ha, respectively. While there were significant among-habitat differences in musk turtle density when all habitats were considered (Kruskal-Wallis $H = 37.67$, $df=9$, $p=0.0000$), differences between their density in shallow versus deep kettle ponds were not (Kruskal-Wallis $H = 0.016$, $df=1$, $p=0.90$). Spotted turtle density was greatest in bog and red maple swamp habitat and, among the other habitats where it was detected, lowest in vernal pools (Table 7). Spotted turtle density varied significantly among all habitats considered (Kruskal-Wallis $H = 28.74$, $df=9$, $p=0.0007$) and but not among those habitats in which it was detected (Kruskal-Wallis $H = 3.73$, $df=4$, $p=0.4432$).

Table 5. Summary of turtle occurrence and captures, by habitat and species. For each habitat, number of sites sampled (sites), number of trap nights sampled (#TN), sites each species was present (pres), number of individuals captured (# inds), and individuals per trap night (inds/TN) are presented.

Habitat	sites	#TN	painted turtle			snapping turtle			musk turtle			spotted turtle			all species		
			pres	# inds	inds /TN	pres	# inds	inds /TN	pres	# inds	inds /TN	pres	# inds	inds /TN	pres	# inds	inds /TN
bog	5	736	1	20	0.027	1	13	0.018				1	17	0.023	1	50	0.068
dune slack	10	1129	3	49	0.043	2	6	0.005				1	4	0.004	5	59	0.052
impoundment	2	805	2	161	0.200	2	31	0.039							2	192	0.239
inter-dune pond	20	1494	14	419	0.280	6	27	0.018							15	446	0.299
kettle-deep	7	265	7	81	0.306	4	6	0.023	3	14	0.053				7	101	0.381
kettle-shallow	8	435	8	204	0.469	4	12	0.028	4	8	0.018				8	224	0.515
riparian marsh	5	1323	4	84	0.063	5	84	0.063				2	4	0.02	5	172	0.130
stream	4	616	4	129	0.209	4	33	0.054							4	162	0.263
swamp-red maple	2	1232										1	13	0.011	1	13	0.011
vernal pool	13	959	6	26	0.027	1	1	0.001				1	1	0.001	6	28	0.029
Total	76	8994	49	1173	0.130	29	213	0.024	7	22	0.002	6	39	0.004	54	1447	0.161

Table 6. Turtle captures, population estimates, and density at each site. Number of unique individuals captured, individuals/trap night (TN), Lincoln-Petersen population estimate N_{LP} , and density (N_{LP}/ha) are presented.

Location	Year	painted turtle				snapping turtle				musk turtle				spotted turtle			
		# inds	inds /TN	N_{LP}	density	# inds	inds /TN	N_{LP}	density	# inds	inds /TN	N_{LP}	density	# inds	inds /TN	N_{LP}	density
Bennett Pond	2002	112	0.762	133±15	64.0	7	0.048	13±13	6.3								
Black Pond	2000	13	0.206	19±12	63.4	1	0.016	1±0	3.3								
Clapps Pond	2002	112	0.509	138±17	7.8	6	0.027	15±17	0.8								
Clapps Round 1	2001	6	0.182	11±11	24.4												
Clapps Round 2	2001	2	0.061	2±0	8.7												
E08	2000																
E09	2000	1	0.006	3±3	13.8									1	0.006	1±0	4.6
E11	2000																
E15 "Red Maple Swamp"	2000													6	0.019	9±6	1.6
E15 "Red Maple Swamp"	2001													8	0.017	23±26	4.1
E15 "Red Maple Swamp"	2002													1	0.010	1±0	0.2
E15 "Red Maple Swamp"	2003													1	0.007	1±0	0.2
E16	2000																
E19	2000	2	0.020	2±0	28.0												
E20	2000	1	0.010	1±0	3.4	1	0.010	1±0	3.4								
E24 "Buttonbush Pond"	2000																
E25	2002	12	0.069	17±10	93.7												
E26	2002																
E27	2002	3	0.020	4±2	111.1												
Fresh Brook	2000	117	0.532	133±12	63.3	3	0.014	5±5	2.0								
Grassy 1	2001	11	0.275	21±21	9.0												
Grassy 3	2001																
Grassy 4	2001																
Grassy 5	2001																
Grassy 6	2001																
Grassy Pond	1999	37	1.850	56±20	155.3					1**							
Great1_Provincetown	2002	83	0.395	270±167	54.8	5	0.024	11±12	2.2								
Gull Pond*	2000	1	0.025	1±0	0.10	1	0.025	1±0	0.1	1	0.025	3±3	0.31				
Herring Pond*	2000	29	0.725	60±35	19.0	3	0.075	5±5	1.4	4	0.100	7±7	1.93				
Herring River High Toss	2000	9	0.141	12±7	na	11	0.172	22±17	na				na				na
Herring River RR	2000	11	0.159	23±19	na	3	0.043	3±0	na				na				na

Table 6. Turtle captures, population estimates, and density at each site. Number of unique individuals captured, individuals/trap night (TN), Lincoln-Petersen population estimate N_{LP} , and density (N_{LP}/ha) are presented.

Location	Year	painted turtle				snapping turtle				musk turtle				spotted turtle			
		# inds	inds /TN	N_{LP}	density	# inds	inds /TN	N_{LP}	density	# inds	inds /TN	N_{LP}	density	# inds	inds /TN	N_{LP}	density
Herring River_Upper	2000	10	0.065	34±40	na	5	0.033	7±4	na				na				na
Higgins Pond*	1999	7	0.350	19±21	7.2	1	0.050	1±0	0.4	6	0.300	9±9	3.4				
Horseleech Pond*	1999	1	0.067	1±0	0.3												
Horseleech Pond*	2000					1		1±0	0.3	2	0.036	3±3	1.0				
Lily Pond 1	2000	2	0.014	2±0	0.9	5	0.036	11±12	4.9								
Lily Pond 3 (south)	2000	1	0.033	1±0	0.5	3	0.100	5±5	2.7								
Little Bennett	2001	35	0.636	107±86	105.3												
Long Pond*	2000	18	0.327	39±29	63.2												
P04	2000																
P05	2000																
P06	2000					1	0.029	1±0	0.8								
P13	2002	15	0.041	19±7	17.0	3	0.008	5±5	4.7								
P20	2001					1	0.050	1±0	2.2								
P22	2001	3	0.055	3±0	3.9												
P23	2001																
P24	2001	10	0.182	10±0	24.8												
P25	2001	3	0.055	3±0	5.4												
P26	2001	4	0.091	4±0	6.2												
P28	2002	14	0.076	21±11	68.3												
P29	2002																
P33	2002																
P34	2002	5	0.027	11±12	41.4												
P64	2003	7	0.175	10±0	78.4												
P65	2003																
P66	2003	8	0.064	12±0	40.3	2	0.016	3±0	10.1					4	0.032	4±1	13.4
Pamet River	2000	99	0.300	137±24	20.3	14	0.042	54±65	8.0								
Pasture Pond 1	2002	35	0.238	63±30	21.6												
Pasture Pond 3	2001																
Pilgrim Lake	2002	44	0.075	48±6	0.3	28	0.048	53±32	0.4								
Portnoy's Bog	1999																

Table 6. Turtle captures, population estimates, and density at each site. Number of unique individuals captured, individuals/trap night (TN), Lincoln-Petersen population estimate N_{LP} , and density (N_{LP}/ha) are presented.

Location	Year	painted turtle				snapping turtle				musk turtle				spotted turtle			
		# inds	inds /TN	N_{LP}	density	# inds	inds /TN	N_{LP}	density	# inds	inds /TN	N_{LP}	density	# inds	inds /TN	N_{LP}	density
Portnoy's Bog	2000																
Ryder Pond*	2000	20	0.500	23±5	13.7	1	0.025	1±0	0.6								20
Salt Meadow	2001	47	0.094	52±4	17.8	57	0.114	103±41	35.2								47
Slough Pond*	2000	7	0.127	10±6	2.1					7	0.127	11±5	2.3				7
Snow Pond*	2000	24	0.600	24±2	26.0	3	0.075	5±5	5.4								24
Spectacle Pond*	1999	4	0.267	7±7	21.4												4
T01	2000	5	0.048	7±4	53.2												5
T07 "Featherbed Swamp"	2000																
T13	2000																
T27 "Bearberry Pond"	2000	15	0.750	39±35	160.4												15
T28 "bog N of Round"	1999																
T30 "Bound Brook North"	2000	16	0.100	21±8	64.1	14	0.088	16±4	48.8					2	0.013	2±0	16
T30 "Bound Brook North"	2001	4	0.011	4±0	12.2	8	0.021	8±0	24.4					1	0.003	1±0	4
T32 "Pamet Bog"	2000	9	0.225	9±0	9.4	2	0.050	2±0	2.1					2	0.050	2±0	9
T32 "Pamet Bog"	2001	5	0.014	9±9	9.4	5	0.014	7±5	7.3					15	0.042	16±2	5
T32 "Pamet Bog"	2003	6	0.046	9±0	9.4	6	0.046	8±0	8.3					9	0.069	9±0	6
T40	2002	4	0.038	4±1	33.5	2	0.019	2±0	16.7								4
Turtle Pond_Wellfleet	1999	20	1.000	31±16	20.3	1	0.050	1±0	0.7	1	0.050	1±0	0.7				20
W01	2003																
W02 "Duck Harbor"	2001					2	0.017	3±3	2.8					1	0.008	1±0	
W07	1999	14	0.933	35±31	201.4												14
W19 "Speigel Pond"	2000	2	0.057	2±0	5.3												2
Williams Pond	2000	88	1.600	117±21	32.3	7	0.127	12±8	3.3	1	0.018	1±0	0.3				88

* density based on area < 3m depth

** incidental record outside of survey period

Table 7. Weighted mean density (inds/ha) and biomass (kg/ha) by turtle species and habitat type.

Habitat	painted turtle		snapping turtle		musk turtle		spotted turtle		all species	
	density	biomass	density	biomass	density	biomass	density	biomass	density	biomass
bog	2.28	0.73	1.78	5.37			4.06	0.63	8.12	6.73
dune slack	14.32	4.12	1.77	2.84			0.79	0.18	16.87	7.15
impoundment	1.29	0.40	0.41	6.55					1.70	6.95
inter-dune pond	18.14	4.92	1.32	16.17					19.46	21.10
kettle-deep	5.97	1.82	0.39	3.07	1.12	0.21			7.48	5.10
kettle-shallow	25.39	7.22	1.45	19.66	0.92	0.22			27.76	27.10
riparian marsh	20.30	6.75	26.43	213.03			0.63	0.12	47.36	219.91
stream	20.26	5.72	7.99	81.43					28.25	87.14
swamp-red maple							4.02	0.82	4.02	0.82
vernal pool	22.81	7.06	0.44	0.03			0.44	0.08	23.69	7.18
All habitats combined	7.22	2.15	1.38	12.04	0.14	0.03	0.19	0.03	8.94	14.24
In habitats present	7.40	2.20	1.41	12.32	1.04	0.21	2.16	0.39		

There was no significant relationship between a species' density in a habitat type and its frequency of occurrence in that habitat. For painted turtles, $R = 0.11$, $p = 0.77$, $n = 9$; snapping turtles, $R = 0.17$, $p = 0.68$, $n = 9$; spotted turtles $R = 0.50$, $p = 0.39$, $n = 5$; all species combined, $R = 0.24$, $p = 0.52$, $n = 10$.

Individual sites were also quite variable in biomass and total biomass (Table 8). Estimated biomass of the entire turtle community at individual sites ranged from 0.1 to 321.7 kg/ha, with total biomass at sites ranging from 0.1 to 940.3 kg. For sites at which they were detected, painted turtle biomass ranged from 0.1 to 66.1 kg/ha. For snapping turtle the range was 0.1 to 315.2 kg/ha for musk turtle it was 0.06 to 0.58 kg/ha and for spotted turtle it was 0.15 to 3.04 kg/ha (Table 8).

Biomass also varied by species and habitat type (Table 7). Snapping turtle had the highest mean parkwide estimated biomass (12.04 kg/ha), followed by painted turtle (2.15 kg/ha), spotted turtle (0.035 kg/ha), and musk turtle (0.025 kg/ha). When calculated based only on the habitats in which a species was detected, this relationship remained, though biomass estimates were higher (Table 7).

There were significant among-habitat differences in total turtle community biomass (Kruskal-Wallis $H = 22.87$, $df = 9$, $p = 0.007$), with turtle community biomass greatest in riparian marsh habitats (219.91 kg/ha) and lowest in red maple swamp (0.82 kg/ha; Table 7). Painted turtle biomass ranged from 0.40 kg/ha in impoundment habitat to 7.22 kg/ha in shallow kettle pond habitat (Table 7), but these differences were not significant (Kruskal-Wallis $H = 15.53$, $df = 9$, $p = 0.08$). Snapping turtle biomass varied significantly among habitats (Kruskal-Wallis $H = 25.27$, $df = 9$, $p = 0.003$) and was highest in riparian marshes (213.0 kg/ha) and lowest in vernal pools (0.03 kg/ha; Table 7). Musk turtle biomass was equal in the two habitats that it was recorded in, deep and shallow kettle ponds, 0.21 and 0.22 kg/ha respectively. While among-habitat differences in musk turtle biomass were significant when all habitats were considered (Kruskal-Wallis $H = 35.21$, $df = 9$, $p = 0.0001$), we detected no difference in their biomass between shallow and deep kettle ponds (Kruskal-Wallis $H = 0.059$, $df = 1$, $p = 0.81$). Spotted turtle biomass was greatest in bog and red maple swamp habitat and, among habitats in which it was detected, lowest in vernal pools (Table 7). However, differences in spotted turtle biomass due to habitat were not significant (Kruskal-Wallis $H = 15.02$, $df = 9$, $p = 0.09$).

Sex Ratio, Size and Age Structure

The park-wide sex ratio for painted turtle was 1.51:1 (M/F), which deviates significantly from a 1:1 ratio ($\chi^2 = 43.215$, $p < 0.001$, $df = 1$, $n = 1040$). For snapping turtle, the sex ratio 0.98:1 did not deviate from 1:1 ($\chi^2 = 0.022$, $p > 0.75$, $df = 1$, $n = 174$). Musk turtle sex ratio (5.5:1) was significantly male biased ($\chi^2 = 12.46$, $p < 0.001$, $df = 1$, $n = 26$) and the spotted turtle sex ratio, though female biased (0.68:1), did not deviate significantly from 1:1 ($\chi^2 = 1.32$, $p = 0.25$, $df = 1$, $n = 37$).

Table 8. Biomass (BM)(kg/ha) and total biomass (Total BM)(kg) estimates for each species at each site sampled.

Location	Habitat	Area (ha)	painted turtle		snapping turtle		musk turtle		spotted turtle		all turtles	
			BM	Total	BM	Total	BM	Total	BM	Total	BM	Total
				BM		BM		BM		BM		BM
Bennett Pond	inter-dune pond	2.08	20.5	42.7	77.9	161.8					98.4	204.4
Black Pond	riparian marsh	0.30	18.8	5.6	0.2	0.1					19.0	5.7
Clapps Pond	inter-dune pond	17.80	2.3	41.3	15.3	273.2					17.7	314.5
Clapps Round 1	inter-dune pond	0.45	8.1	3.7							8.1	3.7
Clapps Round 2	inter-dune pond	0.23	1.7	0.4							1.7	0.4
E08	vernal pool	0.42										
E09	vernal pool	0.22	2.3	0.5					0.83	0.18	3.2	0.7
E11	vernal pool	0.08										
E15 "Red Maple Swamp"	swamp-red maple	5.61							0.83	4.67	0.8	4.7
E16	vernal pool	0.27										
E19	vernal pool	0.07	13.3	1.0							13.3	1.0
E20	vernal pool	0.30	1.4	0.4	0.3	0.1					1.6	0.5
E24 "Buttonbush Pond"	vernal pool	0.32										
E25	kettle-shallow	0.18	34.0	6.2							34.0	6.2
E26	swamp-red maple	0.11										
E27	vernal pool	0.04	37.1	1.3							37.1	1.3
Fresh Brook	impoundment	2.10	18.6	39.0	19.3	40.5					37.8	79.4
Grassy 1	inter-dune pond	2.34	2.6	6.1							2.6	6.1
Grassy 3	bog	1.20										
Grassy 4	inter-dune pond	0.92										
Grassy 5	inter-dune pond	0.07										
Grassy 6	inter-dune pond	0.68										
Grassy Pond	kettle-shallow	0.36	42.1	15.2			0.41	0.15			42.5	15.3
Great1_Provincetown	inter-dune pond	4.93	13.1	64.5	22.1	108.9					35.2	173.4
Gull Pond*	kettle-deep	9.66	0.1	0.5			0.07	0.71			0.1	1.2
Herring Pond*	kettle-shallow	3.63	4.7	17.0	15.5	56.3	0.41	1.49			20.6	74.8
Higgins Pond*	kettle-deep	2.65	1.6	4.2	6.8	18.0	0.58	1.53			8.9	23.7
Horseleech Pond*	kettle-shallow	3.14	0.1	0.3	2.8	8.7	0.26	0.81			3.1	9.8

Table 8. Biomass (BM)(kg/ha) and total biomass (Total BM)(kg) estimates for each species at each site sampled (continued).

Location	Habitat	Area (ha)	painted turtle		snapping turtle		musk turtle		spotted turtle		all turtles	
			BM	Total BM	BM	Total BM	BM	Total BM	BM	Total BM	BM	Total BM
Lily Pond 1	inter-dune pond	2.25	0.2	0.5	46.0	103.4					46.3	103.9
Lily Pond 3 (south)	inter-dune pond	1.86	0.2	0.4	15.5	28.8					15.8	29.2
Little Bennett	inter-dune pond	1.02	25.4	25.8							25.4	25.8
Long Pond*	kettle-deep	0.62	20.3	12.5							20.3	12.5
P04	vernal pool	0.02										
P05	dune slack	0.90										
P06	dune slack	1.19			0.1	0.1					0.113	0.1
P13	dune slack	1.12	3.9	4.4	12.1	13.6					16.0	18.0
P20	inter-dune pond	0.45			19.6	8.9					19.6	8.9
P22	inter-dune pond	0.77	0.5	0.4							0.5	0.4
P23	inter-dune pond	0.63										
P24	inter-dune pond	0.40	8.0	3.2							8.0	3.2
P25	inter-dune pond	0.56	1.1	0.6							1.1	0.6
P26	inter-dune pond	0.65	1.2	0.8							1.2	0.8
P28	dune slack	0.31	32.3	9.9							32.3	9.9
P29	dune slack	0.72										
P33	dune slack	0.08										
P34	dune slack	0.27	19.2	5.1							19.2	5.1
P64	dune slack	0.13	5.6	0.7							5.6	0.7
P65	dune slack	0.10										
P66	dune slack	0.30	2.9	0.9	2.7	0.8			3.04	0.91	8.6	2.6
Pamet River	stream	6.76	5.7	38.6	81.4	550.6					87.1	589.2
Pasture Pond 1	inter-dune pond	2.92	6.2	18.2							6.2	18.2
Pasture Pond 3	inter-dune pond	1.35										
Pilgrim Lake	impoundment	138.53	0.1	17.4	6.4	880.1					6.5	897.5
Portnoy's Bog	bog	1.73										
Ryder Pond*	kettle-deep	1.68	5.2	8.7	0.6	1.0					5.8	9.7
Salt Meadow	riparian marsh	2.92	6.5	18.9	315.2	921.4					321.7	940.3

Table 8. Biomass (BM)(kg/ha) and total biomass (Total BM)(kg) estimates for each species at each site sampled (continued).

Location	Habitat	Area (ha)	painted turtle		snapping turtle		musk turtle		spotted turtle		all turtles	
			BM	Total BM	BM	Total BM	BM	Total BM	BM	Total BM	BM	Total BM
Slough Pond*	kettle-deep	4.73	0.6	2.8			0.42	1.98			1.0	4.8
Snow Pond*	kettle-deep	0.92	7.4	6.8	47.9	44.3					55.3	51.1
Spectacle Pond*	kettle-deep	0.33	6.1	2.0							6.1	2.0
T01	vernal pool	0.13	10.7	1.4							10.7	1.4
T07 "Featherbed Swamp"	bog	0.01										
T13	vernal pool	0.12										
T27 "Bearberry Pond"	kettle-shallow	0.24	58.2	14.1							58.2	14.1
T28 "bog N of Round"	bog	0.04										
T30 "Bound Brook North"	riparian marsh	0.33	19.0	6.2	170.9	56.0			1.23	0.40	191.2	62.7
T32 "Pamet Bog"	bog	0.96	3.0	2.9	22.1	21.2			2.60	2.48	27.8	26.5
T40	riparian marsh	0.12	9.7	1.2	191.6	22.9					201.3	24.1
Turtle Pond_Wellfleet	kettle-shallow	1.53	5.8	8.8	3.1	4.8					8.9	13.6
W01	vernal pool	0.12										
W02 "Duck Harbor"	riparian marsh	1.06			6.8	7.2			0.15	0.16	6.9	7.4
W07	vernal pool	0.17	66.1	11.5							66.1	11.5
W19 "Speigel Pond"	kettle-shallow	0.38	1.9	0.7							1.9	0.7
Williams Pond	kettle-shallow	3.63	8.8	32.0	51.7	187.4	0.06	0.23			60.6	219.6

*based on area <3m depth, not total area

Painted turtle females tended to be larger than males (Figure 6), with significant differences in mean carapace length (CL), plastron length (PL) and body mass (Table 9). Snapping turtle males tended to be larger than females (Figure 7), with significantly greater mean CL, PL, and body mass (Table 9). Musk turtle males tended to be larger than females in CL (Figure 8) and body mass, but differences in PL were not significant (Table 9). Though the largest spotted turtles tended to be females (Figure 9), there was no significant between sex difference in mean CL and PL. However, mean body mass of females was significantly greater than in males (Table 9). Based on pooled, parkwide samples, the percent of adults in the population was 89% of painted turtle, 83% of snapping turtle, 90.2% of spotted turtles, and 100% of musk turtles.

Painted turtle capture probabilities tended to be higher for adult males than adult females or juveniles, with exceptions, but very few differences were statistically significant (Figure 10). Male capture probability was greater than female in five of six cases, with female capture probability greater in the remaining case. However, in only one of these six cases (Bennett Pond) was the difference significant. For juveniles, capture probability was greater than in adult females in two of five cases, less than adult females in three of five cases, but none of these differed significantly. Juveniles had higher capture probability than adult males in two of five cases, and had lower capture probability in three of five cases. Only in the case of Fresh Brook, where capture probability of juveniles and adult males were 0.146 and 0.441 respectively, was the difference significant.

Community Structure

Multi-dimensional scaling showed that red maple swamps differed from all other habitat types (Figure 11). ANOSIM found significant differences in community structure among habitat types ($R=0.148$, $p=0.001$). Of 45 pairwise between-habitat comparisons of turtle community composition, 13 were significantly different (Table 10). While all four species were not detected in any one habitat type, three out of the four species were detected in six of ten habitat types. Red maple swamp had the lowest species richness (Table 5). Painted turtles, snapping turtles, and musk turtles were sympatric at five sites (Gull, Herring, Higgins, Horseleeche, and Turtle ponds), and painted turtles, snapping turtles, and spotted turtles were sympatric at three sites (T30, T32, and P66). Musk turtle and spotted turtle were allopatric.

Comparing Measures of Abundance

For all instances where #INDS was 10 or more ($n=33$) there was significant correlation between N_{LP} and #INDS ($R=0.83$, $p<0.00001$), between N_{LP} and INDS/TN ($R=0.47$, $p=0.005$), and between #INDS and INDS/TN ($R=0.42$, $p=0.014$). For measures of painted turtle abundance at sites with larger sample sizes (#INDS>20, $n=13$; Table 11), there was significant correlation between N_{LP} and N_{CAP} ($R=0.89$, $p=0.00004$), N_{LP} and #INDS ($R=0.84$, $p=0.0004$) and N_{CAP} and #INDS ($R=0.81$, $p=0.0008$). All other correlations were non-significant.

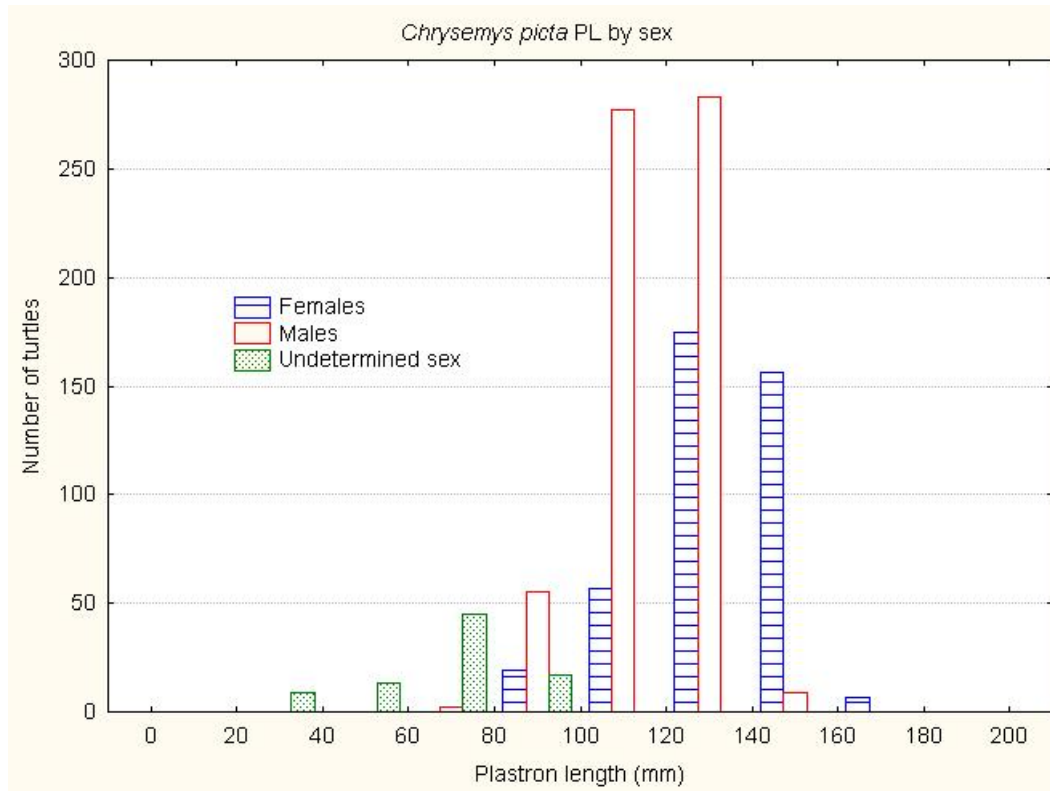


Figure 6. Frequency distribution of CACO painted turtles based on plastron length.

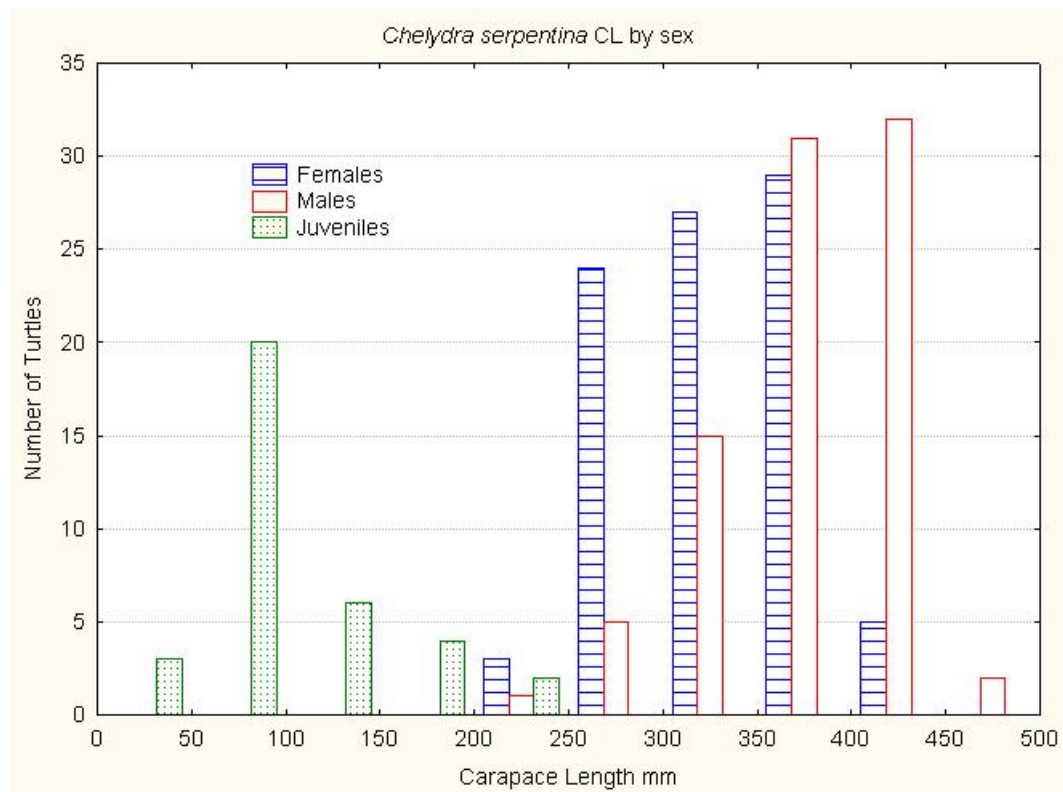


Figure 7. Frequency distribution of CACO snapping turtles based on carapace length.

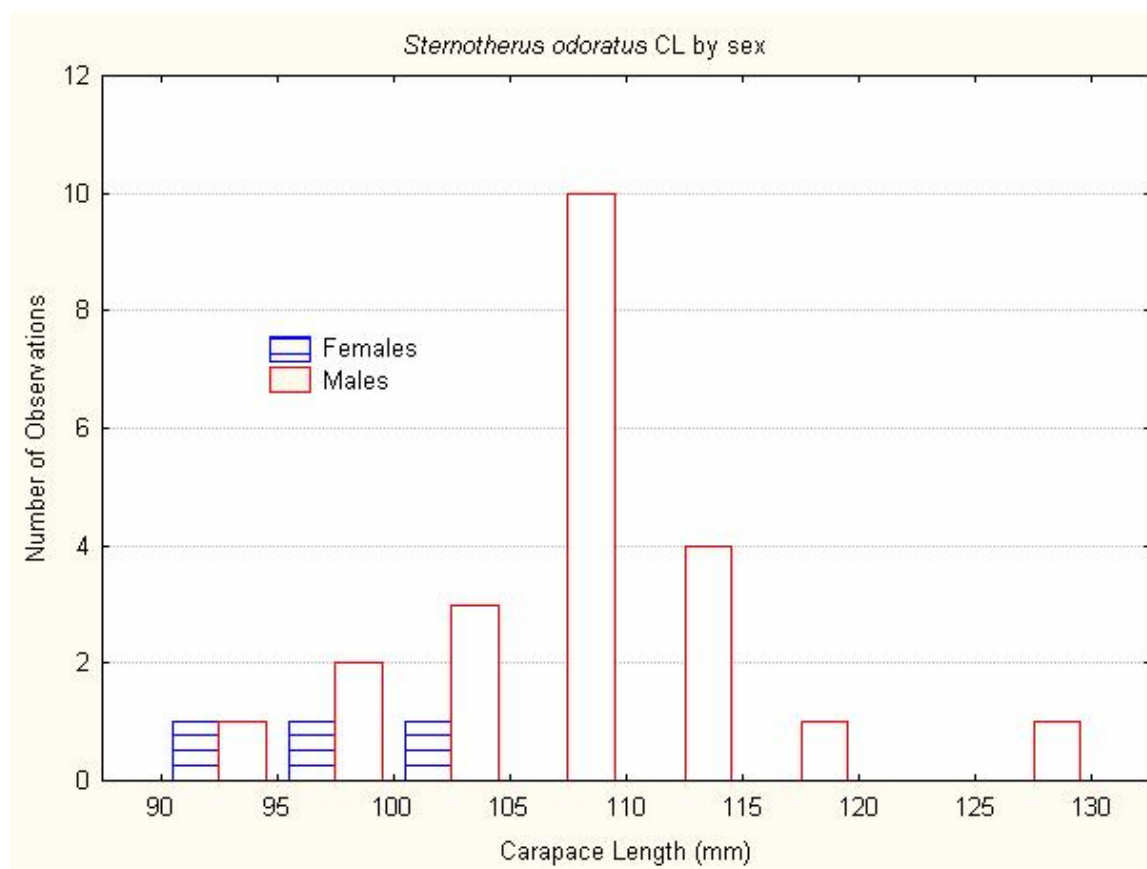


Figure 8. Frequency distribution of CACO musk turtle carapace length.

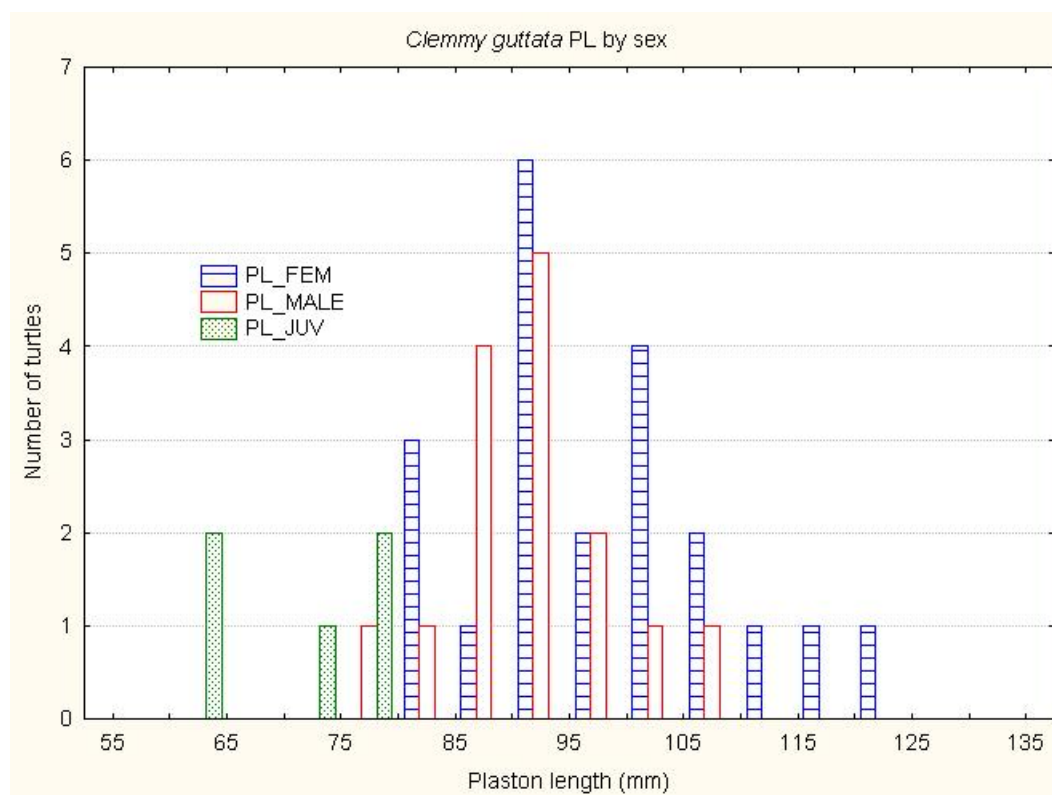


Figure 9. Frequency distribution of CACO spotted turtle plastron length.

Table 9. Morphometric data (carapace length CL, plastron length PL, and body mass), t-test results, and sexual dimorphism index (SDI) for all turtle species by sex.

Species	Parameter	Females					Males					T-test results			SDI
		n	Mean	Low	High	SE	n	Mean	Low	High	SE	t	df	p	
painted	CL (mm)	397	141	92	173	0.86	612	126	76	166	0.53	-15.37	1007	0.000	1.12
	PL (mm)	414	134	90	168	0.78	626	118	74	156	0.48	-18.23	1038	0.000	1.13
	mass (g)	414	396	115	850	5.72	625	262	87	578	2.63	23.79	1037	0.000	1.52
snapping	CL (mm)	88	332	241	431	4.91	86	381	249	490	5.21	-6.79	172	0.000	-1.15
	PL (mm)	88	244	159	323	3.54	86	265	176	330	3.53	-4.24	172	0.000	-1.09
	mass (g)	87	8590	2450	17750	392.66	84	12235	2850	24040	497.16	-5.77	169	0.000	-1.42
spotted	CL (mm)	21	106	87	129	2.52	15	107	91	120	1.98	-0.18	34	0.860	-1.01
	PL (mm)	21	99	81	124	2.46	15	92	78	106	1.82	1.96	34	0.059	1.07
	mass (g)	21	207	114	317	10.95	15	174	114	221	9.14	2.13	34	0.040	1.18
musk	CL (mm)	4	99	94	103	1.94	22	108	95	126	1.42	2.79	24	0.010	-1.10
	PL (mm)	4	72	69	76	1.47	22	71	63	83	1.08	-0.55	24	0.588	1.02
	mass (g)	4	156	130	180	10.87	22	199	142	296	8.54	2.10	24	0.047	-1.28

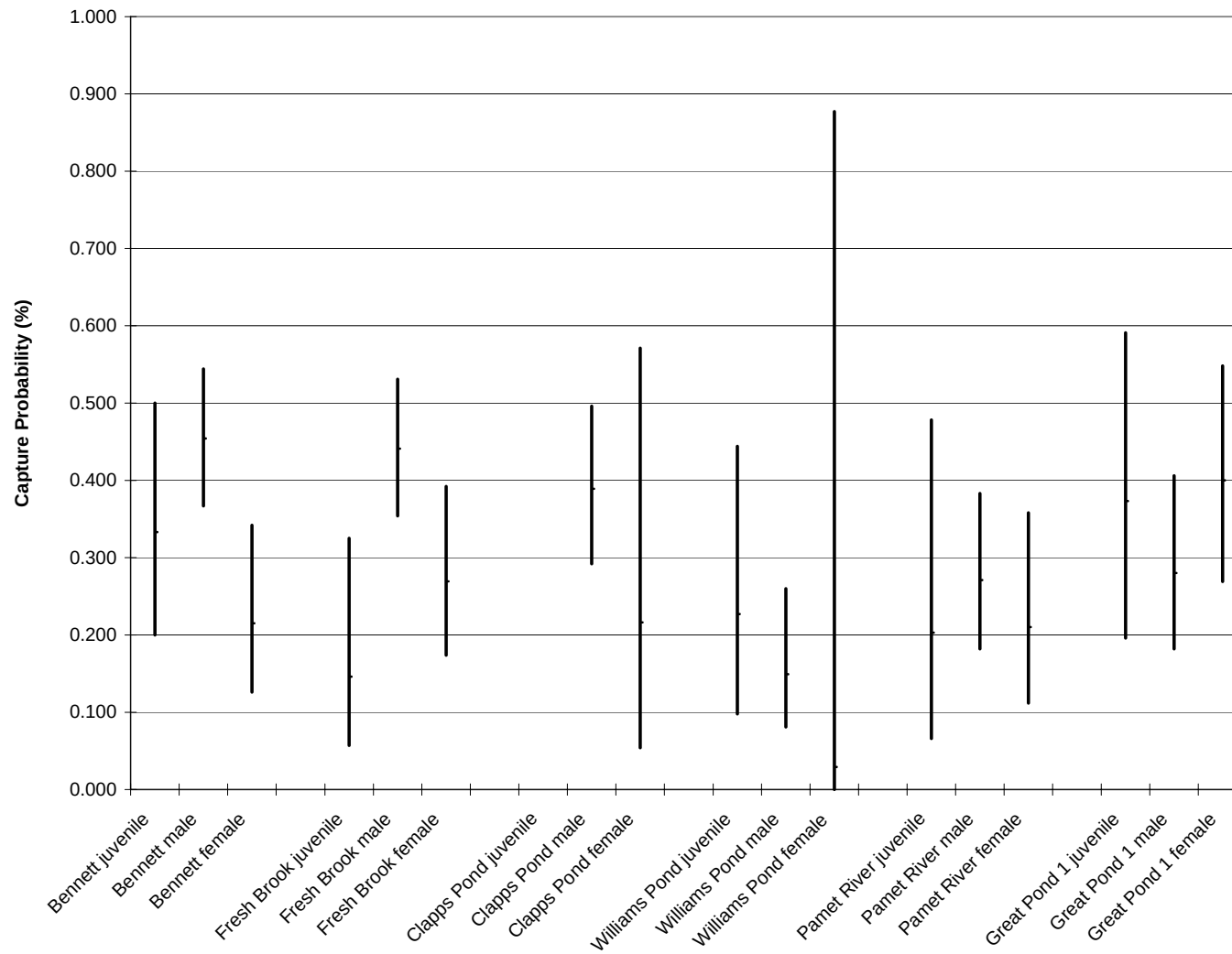


Figure 10. Capture probability of adult male, adult female, and juvenile painted turtles at six sites sampled, calculated under the constant probability of capture model. Shown are the estimated probability of capture for each group, and the upper and lower 95% confidence limits.

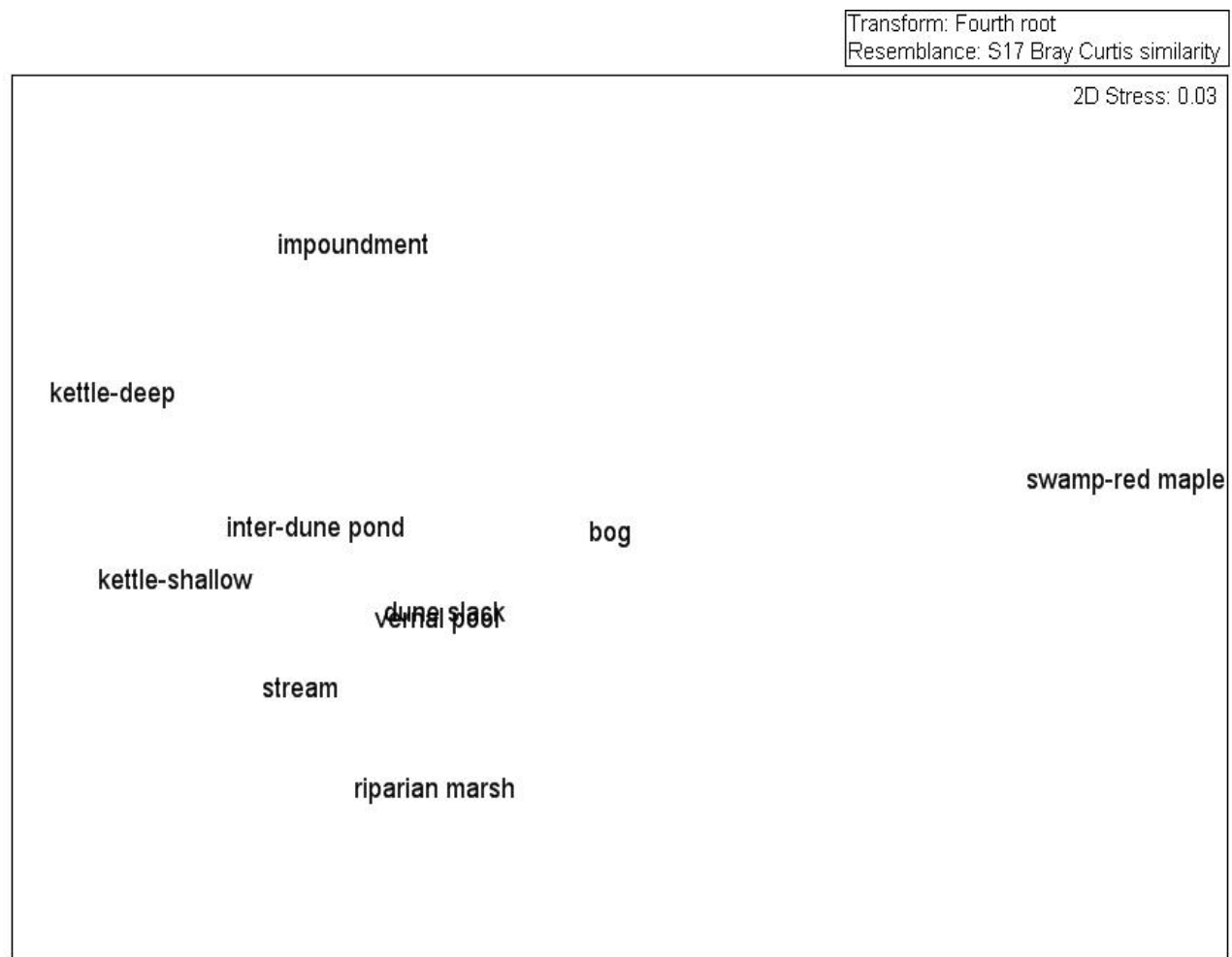


Figure 11. Multi-dimensional scaling (MDS) of turtle community by habitat.

Table 10. Values of Rho resulting from analysis of similarity (ANOSIM), pairwise comparisons between habitat types. Values significant at $p < 0.05$ in bold type.

	bog	dune slack	impoundment	inter-dune pond	kettle-deep	kettle-shallow	riparian marsh	stream	swamp-red maple
bog									
dune slack	-0.056								
impoundment	0.200	-0.098							
inter-dune pond	0.167	0.059	-0.014						
kettle-deep	0.535	-0.002	-0.052	0.042					
kettle-shallow	0.583	0.091	-0.043	0.150	-0.074				
riparian marsh	0.540	0.271	-0.018	0.503	0.412	0.386			
stream	0.200	-0.093	-1.000	0.217	0.156	0.116	-0.480		
swamp-red maple	-0.018	-0.039	0.250	0.251	0.773	0.741	0.673	1.000	
vernal pool	-0.038	-0.022	0.038	0.030	0.088	0.187	0.413	0.288	-0.059

Table 11. Comparison of painted turtle population estimates for site where #inds ≥ 20 .

Location	Year	#TN	#inds	inds/TN	N _{LP}		N _{LP} Upper	N _{cap}	N _{cap}		Model _{cap}	Range		P _{cap}
					N _{LP}	lower			lower	upper		N _{LP}	N _{cap}	
Bennett Pond	2002	147	112	0.762	133	118	158	133	119	175	bh	40	56	0.194
Clapps Pond	2002	220	112	0.509	138	121	155	125	118	147	bh	34	29	0.250
Fresh Brook	2000	220	117	0.532	133	121	145	122	119	132	bh	24	13	0.200
Grassy Pond	1999	20	37	1.85	56	36	76	62	47	104	t (Chao)	40	57	0.176
Great1_Provincetown	2002	210	83	0.395	270	103	437	216	96	1443	tb	334	1347	0.050
Herring Pond	2000	40	29	0.725	60	25	95	54	39	93	o	70	54	0.090
Little Bennett	2001	55	35	0.636	107	21	193	43	36	156	tb	172	120	0.042
Pamet River	2000	330	99	0.3	137	113	161	193	151	271	th	48	120	0.130
Pasture Pond 1	2002	147	35	0.238	63	33	93	83	52	173	th	60	121	0.069
Ryder Pond	2000	40	20	0.5	23	18	28	23	21	32	o	10	11	0.212
Snow Pond	2000	40	24	0.6	24	22	26	24	24	27	h (Chao)	4	3	0.270
Turtle Pond_Wellfleet	1999	20	20	1	31	15	47	20	20	20	b	32	0	0.098
Williams Pond	2000	55	88	1.6	117	96	138	132	114	164	t	42	50	0.110

Discussion

CACO Turtle Community Structure

Aquatic turtle communities are variable in their species composition, density, and biomass. This variability reflects broad geographic distributions (i.e. the suite of species that occur in a given area available for inclusion), the extent to which an available species is a generalist or specialist, a species' colonization abilities, and the type of habitat found at a given site. While some researchers have suggested that species occurrence and abundance is influenced by inter-specific interactions (Bury 1979, Fuselier and Edds 1994), the structure of freshwater turtle communities (i.e. species composition, relative abundance, density) primarily reflects the response of each turtle species to the habitat present at a given site (Cagle 1942, Congdon et al. 1986), and a partitioning of available food resources based on interspecific differences in food habits (Teran et al. 1995). Consistent with this, changes in aquatic turtle communities over time or space are due primarily to habitat changes (DonnerWright et al. 1999, Stone et al. 1993).

At CACO, the number of species in the aquatic turtle community is limited by the depauperate nature of the lower Cape's herpetofauna (Lazell 1976), which is due to its the coastal location, peninsularity, and lack of certain aquatic habitats such as major stream and river systems and associated large lakes. While there are 12 species of freshwater turtles in the Northeastern U.S. (Ernst et al. 1994), only eight occur in Massachusetts (Lazell 1972) and only four of these occur at CACO. These four species are relatively common and widespread and more generalized in their habitat selection than the four Massachusetts species that do not occur here.

In spite of the limited species pool, the freshwater turtle communities of CACO wetlands are generally similar to those found elsewhere in the Northeast U.S. in comparable habitat, and demonstrate similar patterns of relative abundance, density, and biomass. Painted turtles and, to a lesser extent, snapping turtles occur in nearly all aquatic habitats and are typically the number one and two most abundant turtles in marshes and small ponds of the northern U.S. (Congdon et al. 1986). For example, in a Missouri marsh, the six species turtle community was dominated numerically by painted turtles (276/ha), followed by Blanding's turtle (*Emydoidea blandingii*) (77/ha) and snapping turtles (69/ha; Kofron and Schreiber 1985). In a Pennsylvania marsh, the six species aquatic turtle community was also dominated by painted turtles (76.3% of individuals captured), followed in abundance by spotted turtles (10.2%), musk turtles (4.5%) and snapping turtles (3.5%)(Ernst 1976). Similarly, at a site in Hyde Park, Dutchess County NY, painted turtles comprised 82.7% of all captures, followed by musk turtles (5.0%), snapping turtles (4.4%), and spotted turtles (4.2%) (Klemens et al. 1992). Thus, the overwhelming numerical dominance of painted turtles at CACO is consistent with this well established pattern (Ernst et al. 1994). Only in bog and red maple swamps did they not dominate numerically (Table 7).

Musk turtles frequently co-occur with painted and snapping turtles in pond, marsh, and riparian/reservoir habitats (Congdon et al. 1986, Holinka et al. 2003) and can be as abundant as painted turtles in some reservoirs (Mitchell 1988). However, unlike the high density populations reported from shallow sites in the southeastern United States (Congdon et al. 1986, Holinka et al.

2003, Mitchell 1988) musk turtles at CACO are a minor component of the turtle community, mostly limited to kettle ponds. Spotted turtles, with their affinity for shallow-water habitats sometimes co-occur with painted and snapping turtles, and occasionally also with musk turtles (Ernst 1976, Mitchell 1988). Here at CACO, snapping and/or painted turtles were generally present in the habitats where spotted turtles occurred, with the exception of red maple swamp. In the two shallow water habitats where spotted turtles were most dense, bog and red maple swamp, they were the numerically dominant species.

Significant among-habitat dissimilarity in turtle communities at CACO appears to be driven by very high densities of either painted or snapping turtles, and the presence/absence of the two uncommon species, musk or spotted turtles, in a particular habitat type. Riparian marsh, which differed significantly from other habitat types in seven of nine pairwise comparisons (Table 10) had the highest snapping turtle density (far exceeding all other habitats), third highest painted turtle density, as well as spotted turtles present (Table 7). Shallow kettle pond habitat, which differed significantly from other habitat types in five of nine pairwise comparisons, had the highest painted turtle density as well as musk turtles present. In the case of the shallow kettle pond turtle community, four of the five habitats it differed significantly from were other shallow-water habitats where spotted turtles were detected. Thus it appears that differences in turtle community structure at CACO reflect the response of individual species to habitat differences (Cagle 1942, DonnerWright et al. 1999).

Freshwater turtle community biomass is quite variable, due in part to the fact that biomass of individual species varies across their range (Iverson 1982). Differences in habitat quality, food availability, and plasticity of food habits of species present all affect biomass. The biomass of three different communities in Michigan ranged from 23.3 kg/ha in a farm pond to 58.4 kg/ha in a marsh, and in South Carolina, community biomass ranged from 63.8 to 877.3 kg/ha (Congdon et al. 1986). This latter case involved a population of the generally omnivorous slider (*Pseudemys scripta*) becoming carnivorous in response to an abundance of fish (Congdon et al. 1986). Generally, biomass is correlated with habitat productivity, with marshes and ponds more productive than lakes and bogs (Galbraith et al. 1988). Marshes, with greater amounts of emergent vegetation, have greater turtle biomass than ponds (Congdon et al. 1986).

Turtle community biomass at CACO sites ranged from 0.1 to 321.7 kg/ha (Table 8), and mean biomass for habitat types ranged from 0.82 kg/ha in red maple swamps to 219.91 in riparian marshes (Table 7). The greater range in biomass values at CACO compared to the three Michigan sites reflects the broader ecological range of the 10 habitat types sampled at CACO. Variation in turtle community biomass at CACO is consistent with patterns shown elsewhere (Congdon et al. 1986, Galbraith et al. 1988). Biomass at CACO is greatest in habitats that are a mixture of shallow open water, and emergent and floating leaved vegetation, such as riparian marsh and stream, which at CACO are low gradient and heavily vegetated. In contrast, habitats that are very deep, very shallow, or lacking in aquatic vegetation have low biomass. This pattern of biomass variation reflects habitat preferences of the two numerically dominant species here. Painted turtles and snapping turtles are generally more abundant in marshes and eutrophic water bodies than in mesotrophic or oligotrophic ones (Galbraith et al. 1988, Cagle 1942, Bayless 1975), and at CACO their densities are significantly correlated (Spearman $R=0.31$, $p=0.006$).

Although painted turtles are generally the numerically dominant species in northern wetlands, and are at CACO, snapping turtles, due to their much greater size, generally dominate biomass. In Michigan they comprised from 58% to 68% of biomass (Congdon et al. 1986). Snapping turtles dominated biomass at CACO, accounting for 85% of estimated biomass, mostly because of their high density and biomass in riparian marshes and streams (Table 7). Riparian marshes at CACO are muddy and/or mucky. Snapping turtles prefer habitats with such substrates (Kofron and Schreiber 1987) and may attain high densities in marshes and highly eutrophic water bodies (Galbraith et al. 1988). However, the high density and biomass estimates of turtles reported from riparian marshes and streams may also be partially a sampling artifact. Obbard (1983, cited in Galbraith et al. 1988) suggested that smaller sites are sampled more thoroughly than large sites, leading to positively biased estimates of density and biomass. Riparian marshes at CACO, especially Salt Meadow, as well as streams, tended to be narrow and linear, conditions conducive to high capture rates. Thus there could be some positive bias in these estimates. The mean biomass of snapping turtles in riparian marshes (213 kg/ha) was far greater than in any other habitat at CACO, and ranged as high as 315 kg/ha in Salt Meadow. Galbraith et al. (1988) also found snapping turtle biomass to range from 14-18 kg/ha, except at a shallow, nutrient rich site in Canada that had an estimated biomass of 341 kg/ha (Galbraith et al. 1988). Thus, while biomass estimates in riparian marshes and streams may be positively biased, they are consistent with high density populations elsewhere, and reflect an abundance of turtles in these habitats.

Painted Turtle

Distribution and Habitat Use

The painted turtle is the only North American turtle that ranges across the continent, from southern Canada down through the Pacific northwest, midwest, and the northeast coast to Louisiana, Georgia, and the Carolinas (Ernst et al. 1994). There are four subspecies, with standard English names that describe each subspecies' distribution. These are western painted turtle (*Chrysemys picta belli*), southern painted turtle (*C. p. dorsalis*), midland painted turtle (*C. p. marginata*), and eastern painted turtle (*C. p. picta*) (Crother et al. 2000). In the northeast and New England *C. p. picta* and *C. p. marginata* intergrade, forming a hybrid swarm (Cagle 1954, Pough and Pough 1968). Intergrade populations contain individuals that vary in the extent to which their characters (e.g. alignment of carapacial scutes, plastral markings) tend towards one or the other subspecies (Klemens 1993, Lazell 1976). While no data were collected in this regard, painted turtles at CACO were quite variable in exhibiting *picta*-like and *marginata*-like plastral markings and carapacial scute alignment.

The painted turtle is New England's most familiar and conspicuous turtle (Babcock 1919, Klemens 1993). Its distribution at CACO agrees with that depicted by Lazell (1976), with this species occurring throughout. Painted turtles are well documented as occurring in most aquatic habitats except for swift-flowing streams (Klemens 1993, Ernst et al. 1994), and were detected in all habitat types sampled here except red maple swamp. However, their frequency of occurrence in habitats that typically have a temporary hydroperiod (dune slacks, red maple swamp, vernal ponds), 35% (9/25 sites), is less than their occurrence in habitats with permanent hydroperiod, 78% (40/51), though this difference is not quite statistically significant ($\chi^2=3.18$, $p=0.07$, $df=1$). Thus while

painted turtles occur throughout CACO, and in nearly all aquatic habitats, they occur somewhat more frequently in habitats with permanent hydroperiods.

Abundance, Density, and Biomass

Though widespread, painted turtles are quite variable in their abundance, reflecting differences in habitat quality (Mitchell 1988). Painted turtles prefer shallow, slow moving waters with soft bottoms, basking sites, and aquatic vegetation (Carr 1952, Ernst et al. 1994). Painted turtle abundance is positively correlated with muck and basking sites (DonnerWright et al. 1999) and high densities occur in habitats with large amounts of emergent or floating aquatic vegetation as opposed to open water (Bayless 1975, Congdon et al. 1986, Klemens 1993). At CACO, density variation in painted turtles follows this pattern, with high densities in shallow kettle ponds, vernal ponds, streams, and riparian marshes, all generally characterized by shallow water, muck, and abundant vegetation. Conversely, the three habitats with low mean densities, bogs, impoundments, and deep kettle ponds generally lack these features. However, much of the reason why the mean density estimate for impoundment habitat at CACO is low is due to Pilgrim Lake. This very large (138.5 ha) and open water body lacks aquatic vegetation and has a very low density (0.3 inds/ha) (Table 6). In contrast, the other two impoundment sites, Fresh Brook (2.50 ha) and Pamet River (6.8 ha), are narrow and linear, with an even mix of open water and vegetation and moderately high estimated densities of 63.3 and 20.3 inds/ha, respectively.

Density estimates for painted turtles range from 11.1 inds/ha in a Saskatchewan river (MacCulloch and Secoy 1983) up to 828 inds/ha in a Michigan marsh (Frazer et al. 1991). Of 19 density estimates collectively reviewed by Ernst et al. (1994), MacCulloch and Secoy (1983), and Zweifel (1989), the mean value is 216 inds/ha, with a median of 129 inds/ha. Nine of the density estimates are less than 100 inds/ha, four were between 100 and 200 inds/ha, two were between 200 and 300 inds/ha, with the remaining five ranging up to 828 inds/ha. In addition to between-site variation in density reflecting genuine differences in habitat quality, some of the variation in density estimates is methodological, due to issues associated with population estimation techniques or in defining the area involved (Mitchell 1988, Zweifel 1989). In addition, density also varies as the size of a site varies over time in response to water level changes (Sexton 1959) and due to actual changes in a site's population size (Frazer et al. 1991).

Painted turtle density estimates at CACO, ranging from 0.1 to 201.4 inds/ha for individual sites and from means of 1.29 to 25.39 inds/ha for habitat types (Tables 6 and 7), are comparable with these other estimates, and conform to the observed pattern of low density being associated with large open water sites and high density being associated with small, shallow sites with a high ratio of marshy vegetation to open water (Bayless 1975, Cagle 1942, Congdon et al. 1986). For example, sites with very low density estimates tended to be large, open water sites with little aquatic vegetation (e.g. Gull Pond, 0.1 inds/ha; Horseleeche Pond, 0.3 inds/ha; and Pilgrim Lake, 0.3 inds/ha; Table 6). Conversely, sites with the highest densities (W07, 201.4 inds/ha; T27-Bearberry Pond, 160.4 inds/ha; and Grassy Pond in Wellfleet, 155.3 inds/ha) are all small, shallow sites with abundant emergent and aquatic vegetation interspersed with open water.

While these six CACO sites conform to the relationship between habitat and painted turtle density documented elsewhere, estimates of painted turtle density may also reflect a sampling bias

suggested by Obbard (1983) regarding snapping turtles, i.e. that density estimates of large water bodies are negatively biased due to relatively low sampling intensity. This suggestion has some basis, at least regarding intensity of sampling. Of these six sites, the smaller, high density sites were more intensely sampled than the larger, low density sites (71 TN/ha v. 4 TN/ha). Among all sites sampled, there was a significant inverse relationship between site size (number of ha) and sampling intensity (TN/ha) (Spearman's $R=-.81$, $p<0.001$). In addition, painted turtle density was positively correlated with sampling intensity (Spearman's $R=0.48$, $p=0.0006$) and negatively correlated with water body size (Spearman's $R=-.52$, $p=0.0002$). Yet, while these correlations suggest that density estimates may be an artifact of sampling intensity, sampling intensity had a non-significant negative correlation with the numbers of unique individuals (Spearman's $R=-.27$, $p=0.066$) and capture events (Spearman's $R=-.20$, $p=0.170$). Thus, greater sampling effort did not result in more individuals being captured or capture events. Moreover, capture rates standardized by unit effort are 1.56 captures/TN for high density sites and 0.21 for low. Similarly, the numbers of unique individuals captured were 1.2 Individuals/TN for high density sites and 0.07 for low. The higher rates of capture events and unique individuals at the high density sites strongly suggest that density estimates are not biased and the negative relationship between water body size and painted turtle density at CACO is actual. Considering that small wetlands and ponds tend to be shallower (Portnoy et al. 2001, Brooks and Hayashi 2002), and painted turtles are most abundant in shallow wetlands, the general inverse relationship between density and wetland size makes sense. The correlation between sampling intensity and population density is likely the result of both being correlated to water body size.

Biomass (kg/ha) is the product of population density and body size (i.e. mean population body mass). Since density is potentially more variable than mean body size, most of the variation in biomass is likely due to density variation. This appears to be the case for CACO painted turtles, with density and biomass highly correlated (Spearman's $R=0.95$, $p=0.000$). Consequently, variation in biomass estimates would be expected to be similar to those of density in terms of magnitude and patterns. Estimates of painted turtle biomass range from 4.6 kg/ha to 154 kg/ha, with a mean of 42 kg/ha and a median of 24.2 kg/ha (Congdon et al. 1986, Frazer et al. 1991, Iverson 1982, Mitchell 1988, Zweifel 1989). As with density, biomass estimates vary among sites due to variation in density as well as mean body size, both of which reflect habitat quality (Congdon et al. 1986). In addition, biomass can vary over time at a single site by a factor of ca. two to five (Congdon et al. 1986, Frazer 1991, Zweifel 1989). The variation in biomass estimates for painted turtles at CACO, from 0.1 to 66.1 kg/ha for individual sites (Table 8), and from 0.40 to 7.22 kg/ha for habitat means (Table 7) is generally consistent with these other estimates.

Given the strong correlation between biomass and density, patterns of variation in biomass are essentially the same as those discussed above regarding density. However, for both density and biomass, values at the low end of the range at CACO are below other reported values. This is likely an artifact of sampling. At CACO, a large number of sites representing a broad range of habitat types and conditions were sampled to determine turtle occurrence and abundance. In contrast, most sites reported in the literature were chosen for long term study of known turtle populations, and therefore are not likely to be marginal turtle habitat. Considering this, painted turtles at CACO are fairly consistent with other sites in terms of their estimated density and biomass, and the relationship of these population parameters to habitat types.

Population Structure

Most long term studies of painted turtle populations show a sex ratio that does not differ statistically from 1:1, though many show a degree of male dominance, sometimes significant (Ernst et al. 1994). Among those that did not differ significantly from 1:1, sex ratio in Saskatchewan was 1.05:1 (MacCulloch and Secoy 1983), 1.16:1 in Virginia (Mitchell 1988), 1.33:1 in Michigan (Sexton 1959), 1.45:1 in NY (Bayless 1975), 0.85:1 in Illinois (Cagle 1942), and 1.0:1.0 in Pennsylvania (Ernst 1971). Gibbons (1968) also reported that sex ratio in a Michigan population did not differ from 1:1. But, while the sex ratio based on estimated numbers of each sex (1.13:1) did not differ significantly from 1:1, the sex ratio based on numbers actually caught (1.23:1) shows significant male dominance. Other instances of significant male dominance include populations in the Pacific northwest with sex ratios of 2.63:1 and 2.08:1 (Lindeman 1996), and as well as 2.4:1 in the St. Croix River of Missouri and Wisconsin (DonnerWright et al. 1999). Conversely, Koper and Brooks (1998) report an Ontario population significantly dominated by females, with a sex ratio was 0.33:1. In addition, sex ratios can vary over time. Over an 18 year period, the adult sex ratio of a population of painted turtles on Long Island, NY ranged from 0.36:1 to 1.91:1, with a mean of 0.98:1 (Zweifel 1989). While the significantly male-dominated sex ratio of painted turtles caught here at CACO (1.51:1) diverges from the generalization of Ernst et al. (1994) regarding even sex ratios in painted turtles, the skewing is not extreme and well within the reported range.

In aquatic turtles, juveniles appear to be a variable but generally small percentage of most populations (Bury 1979). Thus, painted turtle populations tend to be dominated by adults (Ernst et al. 1994), with adults comprising 40% in Michigan (Gibbons 1968), 59% in Illinois (Cagle 1942), 66% in Virginia (Mitchell 1988), 78% in Ontario (Lefevre and Brooks 1995), 80% in Pennsylvania (Ernst 1971), 82% in Saskatchewan (MacCulloch and Secoy 1983), and 84% in New York (Bayless 1975). In four Nebraska populations, adults comprised from 94 to 99% of the population (Rowe 1997). Zweifel (1989) found that the percentage of adults varied over the years, ranging from 31% to 86%, with an overall 18 year mean of 68%. However, because this was a small population (long term mean size < 39 inds), age structure was highly variable, reflecting variation in annual recruitment (Zweifel 1989). The adult dominated painted turtle population here at CACO (89% adult), is within, but at the upper range, of these reported values.

In addition to temporal variation in the sex and age structure of turtle populations (Zweifel 1989), much has been written regarding the potential for sampling bias. Ernst et al. (1994) suggest that juvenile painted turtles are more difficult to find and catch, and probably comprise a greater portion of the population than data indicate. Similarly, Gibbons (1970a) felt that reports of unequal sex ratios in turtle populations were sampling artifacts, though more recently he concluded that sex ratios may differ from 1:1 due to sex-specific differences in age at maturity (Gibbons 1990). Ream and Ream (1966) reported that different methods yield different sex ratios and age structure. They found that hoop traps caught more males than females and relatively few juveniles. Hand captures yielded mostly juveniles and an unbiased adult sex ratio. Multiple methods were recommended to minimize sampling bias (Ream and Ream 1966). Yet, data from a population of known sex ratio show no significant difference in sex ratios obtained by basking compared to hand capture and pooling data from both methods, nor did these ratios differ significantly from the true ratio (Kofer and Brooks 1998). In addition, there was no significant difference in catchability in net traps due to sex, though capture rates were low. Moreover, in this population sampled by multiple methods, the

sex ratio (0.33:1) was significantly female biased (Kofer and Brooks 1998) and 78% adult (Lefevre and Brooks 1995). Lindeman (1996) also used multiple methods and found high male dominance (2.63:1 and 2.08:1) in two populations and no significant between sex differences in catchability. Similarly, in four populations where adults comprised from 94 to 99% of the population, multiple sample methods were used (Rowe 1997). Thus, while sampling bias is an important issue in interpreting sex and age ratio data, it is clear that biased sex ratios and adult dominance do occur in some populations.

While Ream and Ream (1966) recommended the use of multiple methods to minimize sex and age bias, Mitchell (1988), relying primarily on funnel traps, had high capture frequencies of all sex and age groups, though probability of capture in the course of a field season was higher in juveniles, adult males, and immature females (ca. 90%) than in females (77%). At CACO, the lack of significant differences in capture probabilities due to sex and age in most comparisons (Figure 10) suggest that, while there may be some bias towards males and against the very young, the sex and age structure reported here is not the result of highly biased sampling.

Size and Sexual Dimorphism

Size in painted turtle populations is positively correlated with latitude and elevation, with mean adult size increasing from south to north, and at higher elevations (Iverson and Smith 1993, MacCulloch and Secoy 1983). In addition, there may also be considerable, though generally less, variation in mean size among populations locally (Rowe 1997). Populations with greater access to high protein food tend to attain greater size and mass than those without (Gibbons 1967, Gibbons and Tinkle 1969, Lindeman 1996, Mitchell 1988). Based on adult female plastron length (PL), mean size ranges from 114 mm in Louisiana *C. p. dorsalis* to 202 mm in Saskatchewan, Canada. *C.p. belli* (Iverson and Smith 1993). However, there are also sub-specific differences in size as well, e.g. *C. p. belli* is the largest of the subspecies (MacCulloch and Secoy 1983), and interpreting these trends is best done with this in mind. Among populations of *C. picta* in the mid-Atlantic and northeastern states (reported as *C. p. picta*, *C. p. marginata*, or *C. p. picta x marginata*), the range in size is less, but the pattern of latitudinal variation still holds (Rhodin and Mittelhauser 1994). Mean PL (mm) of adult females was 120.5 and 124.1 in two Virginia populations (Mitchell 1988), 121 in a Pennsylvania population (Ernst 1971), 120.3, 130.5, 136.1 in three nearby Michigan populations (Gibbons and Tinkle 1969), and 143 in Quebec (Christens and Bider 1986). Painted turtle size at CACO falls into this broad pattern, while at the same time also demonstrating more localized variation. Painted turtles at CACO (mean female PL of 134 mm) are similar to those in central Massachusetts (mean female PL of 132.2), but considerably smaller than an insular population ca. 200 miles to the north, on Mount Desert Island, Maine, with mean female PL of 151.6 (Rhodin and Mittelhauser (1994). Similar patterns occur with carapace length (CL) and mass, and apply to males as well.

Sexual dimorphism in painted turtles is well known, with females larger than males (Ernst et al. 1994, Zweifel 1989). At CACO, female painted turtles were significantly larger than males in all metrics (Table 9). The mean CL of female and male CACO painted turtles (141 and 126 mm, respectively) provides a Sexual Dimorphism Index (SDI) of 1.12. Across its range, SDI of painted turtles, based primarily on PL, ranges from 1.17 to 1.58 (Gibbons and Lovich 1990), with a mean of 1.28 (calculated by Rowe (1997)). Based on CL, which is a more appropriate metric than PL

(Gibbons and Lovich 1990), SDI of four *C. p. marginata* populations from Nebraska ranged from 1.11 to 1.27, with a mean of 1.22 (Rowe 1997). For *C. p. belli* in the Saint Croix River of Minnesota and Wisconsin, SDI was 1.08 (DonnerWright et al. 1999). Mean CL of painted turtles from throughout Connecticut, was 137.6 mm for females and 119.9 for males (Klemens 1993), providing an SDI of 1.15. SDI from populations in central Massachusetts and Mount Desert Island Maine (based on data from Rhodin and Mittelhauser (1994)) are 1.16 and 1.18 respectively. Thus, painted turtles at CACO conform to this range-wide pattern of sexual dimorphism in which females are larger than males, and while the SDI of CACO painted turtles is near the low end of the species-wide range, it is similar to other New England populations.

Conclusions Regarding Painted Turtles at CACO

Based on a total of 1173 individuals captured and marked from 1999 through 2003, painted turtles are widespread throughout CACO. They were recorded in all habitat types except red maple swamp, though they occurred more frequently at permanent water sites. Painted turtles were the most abundant freshwater species at CACO, representing 81% of all individuals captured, and accounted for 81% of the total estimated turtle density as well. In terms of biomass, painted turtles were second to snapping turtles, accounting for 15% of the turtle community's biomass. Density and biomass were highest in shallow kettle ponds, riparian marshes, vernal pools, and streams, conforming to a range-wide pattern in which density and biomass are greatest in small, shallow sites, such as marshes and ponds with a high ratio of marshy vegetation to open water. Estimated density and biomass in these more favorable habitats was comparable to those from other populations in similar habitats.

Painted turtle population structure at CACO was similar to other populations, with adults most abundant. However, unlike most painted turtle populations, the sex ratio was significantly male biased, though well within the range of reported values. Painted turtles at CACO conformed to the species-wide pattern of sexual dimorphism, with females larger than males, and also conform to established patterns of latitudinal size variation. Mean size of CACO painted turtles was greater than more southern populations, less than more northern ones, and similar to others from nearby sites in New England. Although small numbers of painted turtles are killed by vehicles on park roads each year, at present painted turtles appear to be abundant and secure at CACO.

Snapping Turtle

Distribution and Habitat Use

Snapping turtles occur from southern Canada, south through the mid-west and east coast, down to Florida and the Gulf of Mexico (Ernst et al. 1994). It is ubiquitous in New England (Klemens 1993). Lazell (1976) found snapping turtles throughout Cape Cod and considered it to occur virtually everywhere. We found snapping turtle distribution at CACO to be generally consistent with this, occurring throughout the park and in all habitats except red maple swamp. Its overall frequency of occurrence, 38% (29/76 sites) suggests it is moderately widespread. However, its frequency of occurrence, 12% (3/25 sites), in temporary hydroperiod habitats (dune slacks, red maple swamp, vernal ponds) is significantly less than its occurrence in permanent hydroperiod habitats, 51% (25/51) ($\chi^2=5.45$, $p=0.02$, $df=1$). Thus while it occurs throughout CACO, and in nearly all aquatic

habitats, its occurrence is significantly linked to permanent hydroperiod sites, a preference for which has been noted by a number of authors (Klemens 1993, Pope 1939).

Abundance, Density, and Biomass

Abundance, density, and biomass of snapping turtles are quite variable. Densities range from 1 to 74.3 inds/ha, with density >50 inds/ha not uncommon (Galbraith et al. 1988). Similarly, biomass ranges from less than 10 kg/ha to 341 kg/ha, though sites with biomass estimates >100 kg/ha are uncommon (Ernst et al. 1994, Galbraith et al. 1988, Iverson et al. 2000). Density and biomass of snapping turtles are primarily a function of a site's primary productivity and trophic status, with high densities of snapping turtles associated with marshes and highly eutrophic water bodies and low density populations in lakes, and other mesotrophic and oligotrophic systems (Congdon et al. 1986, Galbraith et al. 1988). Patterns of variation in density and biomass of snapping turtles at CACO (Tables 6, 7, 8) conform closely to this range-wide pattern, with density and biomass highest in riparian marshes, streams, shallow kettle ponds and inter-dune ponds. The high biomass of snapping turtles at Salt Meadow (315 kg/ha) is higher than most estimates for this species, e.g. 181 kg/ha in a Tennessee pond and 242 kg/ha in a South Dakota pond (Iverson et al. 2000), but not as high as the 341 kg/ha reported from an Ontario marsh (Galbraith et al. 1988).

Population Structure

Sex ratio in snapping turtles is generally even (Ernst et al. 1994), though several accounts suggest a tendency towards a male bias. Snapping turtles in the St. Croix River of Minnesota and Wisconsin were significantly male biased (2.39:1; DonnerWright 1999), as were populations from South Carolina (2.6:1; Congdon et al. 1986). Of three Ontario populations, one was significantly male biased (1.96:1), one was insignificantly male (1.25:1), and the third was insignificantly female biased (0.65:1) (Galbraith et al. 1988). Populations with insignificant male bias are reported from Illinois (1.2:1; Cagle 1942), Michigan (1.2:1; Congdon et al. 1986), and South Carolina (1.6:1; Tuberville et al. 1996). Ernst et al. 1994 suggest that male dominated sex ratios result from males dominating the larger size classes and collection bias. While males did dominate the very largest size classes of snapping turtles at CACO (Figure 7), the even sex ratio of adult snapping turtles here (0.98:1) indicates that overall, males do not predominate.

Snapping turtle populations are generally dominated by adults, though fall samples may be dominated by newly emerged hatchlings (Ernst et al. 1994). Percent adult ranges from 26% in South Carolina (Congdon et al. 1986), to 55% in Illinois (Cagle 1942), 58% in Michigan (Congdon et al. 1986), 65% in Missouri (Kofron and Schreiber (1987), and from 85% to 95% in three Ontario populations (Galbraith et al. 1988). Adults comprised 83% of the snapping turtles caught at CACO, similar to the Ontario populations.

Size and Sexual Dimorphism

Size at sexual maturity in snapping turtles increases with latitude (Galbraith et al. 1989; Glesenkamp et al. 2003), suggesting that the general trend of mean adult size increasing with latitude (Tinkle 1961, Iverson 1992) also applies to snapping turtles. Data obtained from the literature (Table 12) show that female mean CL increases positively and almost significantly with

Table 12. Latitude and mean size and mass of male and female snapping turtles.

Location	Latitude	CL Male	CL Female	Mass Male	Mass Female	Source
SC	33	255.9	258.5	4.87	4.83	Congdon et al. 1986
SC	33	219	209			Gibbons and Lovich 1990
TN	33.83	251	219			Froese and Burghardt 1975
IA	41	259	255			Christiansen and Burken 1979
Ohio	41.47			9.1	5.8	Meeks and Ultsch 1990
MI	42	253.4	238.3	4.159	3.16	Congdon et al. 1986
CACO	42	380.9	332.3	12.234	8.59	this study
MI	42.47		257.8			Congdon et al. 1987
South Dakota	43.15	335	319			Hammer 1969
Ont_ West Lake	43.17			5.52	5.03	Galbraith et al. 1988
Ontario_Cootes	43.28			8.2	5.5	Pettit et al. 1995
Ontario_Cootes	43.28		268			Brown et al. 1994
Quebec	45	253	235			Mosimann and Bider 1960
MN, WI	45.2	304	276			DonnerWright et al. 1999
Ont_Lake Sas	45.58			10.5	5.24	Galbraith et al. 1988
Ont_Broadwing	45.58			9.34	4.78	Galbraith et al. 1988
Ont_Lake Sas	45.58		283			Brown et al. 1994

latitude ($R=0.58$, $p=0.06$) and male mean CL increases positively but non-significantly ($R=0.60$, $p=0.12$). Mean weight of males also increases positively but non-significantly ($R=0.60$, $p=0.15$), and there is no relationship between mean female weight and latitude ($R=0.09$, $p=0.85$).

While these data suggest a positive relationship between latitude and size in snapping turtles, size of CACO snapping turtles exceeds even populations at higher latitudes (Table 12). Factors such as site productivity and type and quantity of foods also affect growth and size in turtles (Dunham and Gibbons 1990, Parmenter and Avery 1990). Among snapping turtle populations, there can be considerable size variation among populations at similar latitudes (Galbraith et al. 1988) and different growth rates in response to productivity differences (Brown et al. 1994). Among three nearby populations of *C. picta* with herbivorous, omnivorous, and carnivorous diets, growth rate and size were greatest in the population with a carnivorous diet and lowest for the herbivorous (Gibbons 1967). In the usually omnivorous *P. scripta*, a population with access to high densities of fish was carnivorous, and individuals attained unusually large sizes (Congdon et al. 1986, Gibbons et al. 1979). The same was true of a population of *C. picta* at the northern limits of its range in Canada (MacCulloch and Secoy 1983). While no data regarding diet or fish densities were recorded in this survey, fish were often caught in our traps, particularly at sites such as Clapp's Pond (mean adult mass = 18.215 kg), Pilgrim Lake (mean adult mass = 11.70 kg), and Salt Meadow (mean adult mass = 9.28 kg). While speculative, the abundance of fish in many of the sites where snapping turtles are abundant may contribute to their large mean size. Thus, while size of CACO snapping turtles is somewhat consistent with the pattern of increasing size and mass in northern populations, mean size of CACO snapping turtles is greater than in other populations studied to date and may reflect a high protein diet. Snapping turtles exhibit sexual dimorphism, with males larger than females (Galbraith et al. 1988, Gibbons and Lovich 1990). The significantly greater CL, PL, and mass of males at CACO (Table 9) are consistent with this relationship. The Sexual Dimorphism Index (SDI) of CACO snapping turtles (-1.15 based on CL) is comparable to the highest values reported by Gibbons and Lovich (1990). However, when based on mean body mass, the SDI of CACO snapping turtles (-1.42) is not nearly as extreme as in some Ontario populations, where SDI values based on mean body mass (Galbraith et al. 1988) are -1.95 and -2.00.

Berry and Shine (1980) attributed greater male size in turtles to sexual selection pressures which arise in species with male combat (predominantly in terrestrial species) and/or forced insemination (predominantly in semi-aquatic and "bottom-walking" species). Galbraith et al. (1988) found an inverse relationship between the degree of male dominance in sex ratio and size dimorphism, and rejected sexual selection as an explanation for the variation in size dimorphism. However, Berry and Shine (1980) attributed sexual size dimorphism in snapping turtles to forcible insemination of females by larger males rather than to male combat. Thus, sex ratio may not play much of a role in the development of sexual dimorphism in snapping turtles, and the data of Galbraith et al. (1988) may not be inconsistent with this aspect of the model of sexual size dimorphism and sexual selection (Berry and Shine 1980). While resolving this issue is beyond the scope of this report, the greater male size and even sex ratio in CACO snapping turtles is consistent with most other populations of this species (Ernst et al, 1994), including two of the three Ontario populations reported on by Galbraith et al. (1988).

Conclusions Regarding Snapping Turtle at CACO

Based on a total of 213 individuals captured and marked from 1999 through 2003, snapping turtles are widespread at CACO. They were recorded in all habitat types except red maple swamps, but tend to occur more often at permanent water sites. Snapping turtles were second to painted turtles in abundance at CACO, but dominated biomass, accounting for 85% of the turtle community's biomass. Density and biomass were highest in riparian marshes, streams, shallow kettle ponds, and inter-dune ponds, conforming to a range-wide pattern of higher density and biomass in shallow, permanent marshes and eutrophic water bodies. The high biomass of snapping turtles at Salt Meadow, 315 kg/ha, is among the highest biomass estimates recorded and is attributable to a moderately high density (35.2 inds/ha) in combination with high body mass (mean mass of 8.945 kg). Structure of the snapping turtle population at CACO is similar to most others in being dominated by adults, having an even sex ratio, and exhibiting sexual dimorphism in the form of greater male size and mass. Although the degree of sexual dimorphism in CACO snapping turtles was not extreme, the mean size and body mass of both sexes at CACO was greater than estimated for other populations. The relatively large size of CACO snapping turtles may be due to an abundance of fish providing a high protein food resource. Snapping turtles at present appear to be fairly abundant and secure here.

Spotted Turtle

Distribution

The spotted turtle occurs primarily along the Atlantic coastal plain, from Maine to Florida, including lower elevation areas of southern New England (Klemens 1993), and westward into Ohio, Indiana, Illinois, Michigan, and southeastern Canada (Ernst et al. 1994). Although Lazell (1976) reported the spotted turtle only as far out on Cape Cod as Eastham, Rich (unpublished data) collected one at Fresh Brook in Wellfleet in 1960. Subsequent incidental reports (e.g. Brian Butler, pers. comm. 1998) and our study extends their range to Provincetown. Spotted turtles typically occupy various shallow, muddy bottomed wetlands, including marshes, bogs, red maple swamps, ditches, vernal pools, and small streams (Klemens 1993, Graham 1995). Their occurrence at CACO, in bogs, red maple swamps, vernal pond, dune slacks, and riparian marsh is consistent with this pattern. However, although spotted turtles were detected in several habitat types, they were only captured at six of 76 sites sampled (7.9%). Even when only based on the five habitat types they were detected in, their frequency of occurrence is low, six of 35 sites (17.1%; Tables 5, 6). While incidental records expand the range of habitats and sites they have been recorded from to include three inter-dune ponds, spotted turtles are not abundant nor widespread at CACO.

Seasonal Activity and Habitat Use

Assessing the status, distribution, and abundance of spotted turtles at CACO is complicated by their complex and varied pattern of seasonal activity and habitat use. Spotted turtles are most active in the spring, or at least most captures occur this time of year (Ernst 1982, Ernst and Zug 1994). In Maryland, 97% of captures occurred from March to June (Ward et al. 1976) and in central Massachusetts, 92% of captures occurred in this time period (Milam and Melvin 2001). Lovich (1988) concluded that spotted turtle activity is highest in the spring throughout its range, and that

southern populations reach their activity peak earlier in the season and it is more narrowly compressed. Thus, populations in Maryland and Pennsylvania became semi-dormant by late May and June respectively (Ward et al 1976, Ernst 1982) whereas Ontario spotted turtles were active from April until late October, with only limited periods of inactivity (Haxton and Berrill 1999, 2001). However, some of the apparent difference between northern and southern populations may be methodological (Haxton and Berrill 2001). Studies of northern populations were recent, based on radio-telemetry, while those of southern populations were older and based heavily on hand captures. Since spotted turtles are more observable in spring when vegetation is sparse and turtles bask, studies based on hand captures may be biased (Haxton and Berrill 2001).

Seasonal habitat use may vary latitudinally. In southern populations, hibernation and spring activity (mating and feeding) occur in shallow aquatic habitats (Ernst 1976, Ward et al. 1976). By late May and June, as aquatic habitats dry up and water temperatures rise, turtles in Maryland move into marshy woods and burrow (Ward et al. 1976). In Pennsylvania, spotted turtles became dormant in summer when water temperatures reached 30°C, burrowing into muskrat burrows, lodges, or stream bottoms (Ernst 1982). In autumn, Maryland spotted turtles returned to shallow aquatic habitats to hibernate, whereas most of the Pennsylvania population hibernated at the sites used for aestivation. In New England, the general pattern appears to be more complex and variable. Hibernation takes place in red maple swamps (Graham 1995) or a number of different shallow wetland types, i.e. emergent wetlands, wooded and shrub swamps, and seasonal pools (Milam and Melvin 2001). Following hibernation, most turtles moved to vernal ponds and seasonal pools, where insects and eggs masses of wood frogs and spotted salamanders provide an abundant food resource in the spring (Graham 1995, Perillo 1997). In one Massachusetts population, vernal ponds were used from late March until August, followed by a few weeks of terrestrial aestivation and then a return to red maple swamp by September, where turtles remained active into October (Graham 1995). In another Massachusetts population, seasonal pond use generally lasted until June, followed by nesting in uplands and aestivation in upland forest, shrub swamps, emergent wetlands or activity in seasonal pools with longer hydroperiods. By late September, turtles returned to the vicinity of their hibernacula (Milam and Melvin 2001). A similar pattern was found in Connecticut (Perillo 1997), Maine (Joyal et al. 2001), and Ontario (Haxton and Berrill 1999, Litzgus and Brooks 2000). However, since many Ontario animals remained active in shallow ponds during the “aestivation season” and long inactive periods were not detected, some northern populations may not really aestivate (Litzgus and Brooks 2000).

Past research has shown great variability in the seasonal activity and habitat use of spotted turtles, both within and among populations. Duration of wetland use and aestivation varies between wet and dry years, with turtles spending more time in ponds and less time aestivating in uplands in wet years (Milam and Melvin 2001, Perillo 1997). In addition, nearby populations may differ in the use of seasonal pools and emergent wetlands based on the availability of these habitats (Milam and Melvin 2001). The study sites of Ward et al. (1976) and Ernst (1976) were small, insular, and simple in comparison to those studied by Graham (1995), Milam and Melvin (2001), Perillo (1997), Joyal et al (2001), Litzgus and Brooks (2000), and Haxton and Berrill (1999), which contained a great variety of upland and wetland habitat types interspersed in a non-insular landscape. This variability in activity patterns and habitat use suggests that spotted turtles are plastic in their use of habitat, and that variation between sites, while partly due to latitude, largely reflects variation in habitat availability.

The occurrence of spotted turtles in six different shallow water habitat types at CACO is consistent with the idea that they utilize whatever shallow water habitats are available in the local landscape. However, the extent of inter-wetland movement, and whether there is a seasonal pattern is unclear. Trapping at E15, CACO's largest red maple swamp, was most productive in April and May of 2000 and 2001, as opposed to late September 2002 or August 2003 (Tables 3 and 6). Since red maple swamps were the primary hibernation habitat in a central Massachusetts population of spotted turtles (Graham 1995), the individuals caught at E15 in April and May could have been in-between emerging from hibernation and moving to vernal ponds. But, movement to vernal ponds and seasonal pools generally occurs immediately or soon after emergence in early spring (Joyal et al. 2001, Milam and Melvin 2001). In central Massachusetts this occurred in late March (Graham 1995). Thus, spotted turtles would have been expected to have moved from E15 to vernal ponds by May. It is possible that the individuals captured at E15 in May were those that did not move from the site, and that other individuals had already moved to nearby wetlands. But, trapping at E25 (shallow kettle pond), E26 (red-maple swamp), and E27 (vernal pond), all located within 100 m of E15, in the spring of 2002 did not capture any spotted turtles. Also, there is minimal evidence that spotted turtles at CACO use vernal ponds. Only one spotted turtle was captured in one of 13 vernal ponds trapped. This individual had been captured crossing a road 358 m away from vernal pond E09, 10 days prior to being trapped, indicating she was dispersing. While this seems consistent with a pattern of spring migration to vernal ponds, during vernal pond egg mass monitoring activities from 2002-2004, in a total of 238 observer hours spent in repeated, systematic searches of 16 to 40 vernal ponds in late March through early May, no spotted turtles were observed. The persistence of spotted turtles at E15 into late May, coupled with observations of basking individuals in late April (R. Cook, pers. obs.) suggest that use of red maple swamp habitat at E15 is more extended than in other Massachusetts populations (Graham 1995, Milam and Melvin 2001) and that vernal ponds are not extensively used by spotted turtles at CACO.

Elsewhere at CACO, use of bog habitat at T32 in summer contrasts with Ontario spotted turtles which hibernated in bogs and then moved to marsh habitat (Haxton and Berrill 1999). Trapping in the marshes of the nearby Pamet River in July 2000 did not detect any spotted turtles there. While our data indicate that some spotted turtles were active at T32 during summer, we do not know if other individuals are aestivating in the uplands. One individual, a young male, captured at T32 in June 2001 and July 2003, was found crossing a road in North Truro in August 2004, ca. 4.27 km from T32, indicating that some individuals leave this wetland and may travel considerable distances. In Provincetown, we only detected spotted turtles at P66, a dune slack wetland, which was one of 10 dune slack wetlands trapped. However, late April-early May incidental records from Lily pond 1 and Lily pond 3, as well as carapace remains from Clapps pond, suggest that spotted turtles in the Province Lands may hibernate at these permanent, shallow, inter-dune ponds and move to the temporary dune slacks in spring. When spotted turtles were trapped in P66 in August 2003, water levels in Province Lands ponds were exceptionally high that year, and use of this temporary wetland likely extended later into the summer, as has been documented elsewhere (Perillo 1997).

There is considerable within-site heterogeneity at most spotted turtle sites at CACO (i.e. E15, T30, T32, W02). Each of these sites includes ditches which retain water in most years, as well as open, shallow pools and a mix of both herbaceous and woody-dominated patches. Water temperatures at these sites did not approach 30°C, the temperature which Ernst (1982) believed triggered spotted

turtles in Pennsylvania to leave the wetland. At CACO, it may be that within-site heterogeneity has reduced the need for and extent of inter-site movements and use of vernal ponds. However, radio-telemetry and a more thorough landscape analysis is needed to determine the extent to which spotted turtles at CACO exhibit seasonal movements between wetland and utilize terrestrial habitats.

Abundance and Density

Spotted turtles were considered nearly as common as painted turtles in late 19th - early 20th century New England (Allen 1868, Babcock 1919) and while they may remain locally abundant in some areas, they are declining in many areas due to habitat loss and collection for the pet trade (Ernst and Zug 1994, Ernst et al. 1994). Spotted turtles were removed from the list of special concern species in Massachusetts in 2006, but remain a “listed” species in most Northeastern states. They appear to be uncommon, widely scattered, and hard to find on the contemporary New England landscape. Lazell (1976) speaks of finding up to two spotted turtles in vernal ponds in the spring, and Joyal et al. (2001) note that individuals of their population were dispersed among several wetlands such that the numbers in any one wetland were low. Capture rates in traps are quite low: 0.007 captures/TN in Worcester County, MA (Graham 1995); 0.06/TN in Franklin County, MA; and 0.12 captures/TN in Hampshire County (Milam and Melvin 2001). Capture rates of spotted turtles at CACO are comparable. For all sites at which spotted turtles were detected, the capture rate was 0.038 captures/TN (96 captures/2517 TN). Capture rates at individual sites ranged from a low of 0.006 at E9 to a high of 0.115 captures/TN at T32 “Pamet Bog”, where setting traps in ditches in summer facilitated capture (Table 13).

Table 13. Spotted turtle capture rates at sites where present.

Site	Year	Trap Nights	Captures	Captures/TN
E09	2000	175	1	0.006
E15	2000	315	7	0.022
E15	2001	465	9	0.019
E15	2002	104	0	0.000
E15	2003	148	2	0.014
Site total	all years	1032	18	0.017
P66	2003	125	11	0.088
T30	2000	160	2	0.013
T30	2001	375	1	0.003
Site total	all years	535	3	0.006
T32	2000	40	2	0.050
T32	2001	360	44	0.122
T32	2003	130	15	0.115
Site total	all years	530	61	0.115
W02	2001	120	2	0.017
Total of above sites		2517	96	0.038

Estimates of spotted turtle density are quite varied, reflecting both actual differences in density as well as in methodology. Since spotted turtles frequently occupy multiple wetlands over the course of an activity season (Lovich 1990, Joyal et al. 2001, Haxton and Berrill 1999), and may also spend significant time in terrestrial habitats, defining the area for which density is being estimated is difficult. While early works such as Ernst (1976) were based on hand captures within a wetland, more recent works (e.g. Milam and Melvin 2001, Haxton and Berrill 1999) use radio telemetry to define the total area used. Comparing estimates based on different approaches is questionable (Milam and Melvin 2001) and must be made with care.

Ernst (1976) estimated spotted turtle density within a Pennsylvania wetland to range from 39.2 to 79.6 inds/ha over four different years, and Graham (1995) estimated density within the central Massachusetts wetland complex he trapped at 6.7 inds/ha. Other density estimates presented by Graham (1995), also for wetlands, include 9.35 inds/ha in Dutchess County, NY, 10.60 inds/ha in Cayuga County, New York, 5.80 inds/ha in Maryland, and 0.94 inds/ha in Illinois. This latter, based on Capler and Moll (1998) is believed to be an underestimate. At two other central Massachusetts sites, Milam and Melvin (2001) estimated densities in wetlands as 2.4 inds/ha and 8.0 inds/ha. However, when based on total area used (wetlands plus uplands), density estimates were 0.2 inds/ha and 1.4 inds/ha, respectively. Similarly, based on total area used as defined by radio-telemetry, Haxton and Berrill (1999) estimated spotted turtle density at 0.52 inds/ha. For an area of wetland and upland on Nantucket Island, Massachusetts where he felt it was “unusually abundant”, Lazell (1976) estimated minimum density at 0.4 inds/ha.

Spotted turtle density estimates for sites at CACO, based on wetland area, range from a high of 16.7 inds/ha at T32 “Pamet Bog” in 2001 to lows of 0.18 at E15 “Red Maple Swamp” in 2002 and 2003 (Table 6). However, this latter estimate occurred in late summer when low water levels made trapping difficult and may be an underestimate. For most of the sites at which spotted turtles were detected, the numbers of individuals captured are so few that estimates of population size and density are questionable. Confidence intervals are generally very large or not calculable (Table 6). However, E15 and T32 are sites that support more substantial populations of spotted turtles, with a total of 13 and 17 individuals, respectively, recorded during this survey. Compared to other populations, spotted turtle density at T32 (16.7 inds/ha) is higher than other sites in Massachusetts (Graham 1995, Milam and Melvin 2001), but much less than densities reported by Ernst (1976). E15, with an estimated density of 4.1 inds/ha in 2001, is somewhat low compared to other wetland sites, but this may be because E15 is a highly interspersed mix of swamp pools, ditches, and hydric woodlands, with standing water comprising only a portion of its total area.

Although methodological differences and a lack of data on landscape use by spotted turtles at CACO strain the utility of some of these comparisons, they do suggest that spotted turtle densities at some CACO sites are comparable to other sites in Massachusetts. However, due to the relatively small size of sites at CACO, total populations are likely less. The population at E15 (5.61 ha) is estimated at ca. 23 individuals and T32 (0.96 ha) at 16. In contrast, in Worcester County, MA, Graham (1995) captured 38 individuals, estimated a population of 98 individuals in the 14.7 ha area trapped, and extrapolated the total population for the 180.8 ha area occupied by spotted turtles to be 1204 individuals. Similarly, Milam and Melvin (2001) captured 18 individuals and estimated a population of 18 occupying a 7.7 ha wetland in Franklin County, MA. At a site in Hampshire County, with 5.3 ha of wetland, they captured 41 individuals and estimated the population at 43.

Elsewhere, populations studied by Ernst (1976) in Pennsylvania involved 96-180 individuals captured in a given year, with population estimates ranging from 127-258, Ward (1976) captured 1205 individuals during a four year period on a 346 ha island in Maryland, and Litzgus and Brook (1998) captured 118 individuals over the course of six years on 300 ha island in Ontario. In contrast, spotted turtle populations at CACO appear small and localized, with records concentrated in four areas: E15 “Red Maple Swamp” in Eastham; the marshes of the Herring River system above High Toss road in Wellfleet; T32 “Pamet Bog” in Truro; and the dune slacks and inter-dune ponds of Provincetown.

Population Structure

Sex ratio in spotted turtles tend to show slight female bias, with the following male/female ratios; 0.53:1 (Haxton 1998), 0.57:1 (Graham 1995), 0.68:1 (Ernst 1976), 0.84:1 (Litzgus and Brooks 1998), 0.90:1 (Klemens 1993), and 1.3:1 (Klemens et al. 1992). Since most of these were based on small sample sizes, differences did not deviate significantly from 1:1. Only Ernst (1976), with a sample size of 207 individuals, deviated significantly from even. At CACO, the spotted turtle sex ratio of 0.714:1 falls within the range of these other accounts. The percentage of sub-adults reported from populations is also variable; 4.2% (Klemens et al. 1992), 9.3% (Litzgus and Brooks 1998), 14.5% (Milam and Melvin 2001), 18% (Graham 1995), 26% (Haxton 1998), and 32.3 % (Ernst 1976). In this latter case, the high proportion of juveniles involved a population that had doubled over a seven year period (Ernst 1976). At CACO, juveniles comprised 9.8 % (4 of 41), which is within but at the lower end of this range of reported values.

Size and Sexual Dimorphism

Consistent with a general trend in turtles, mean size of spotted turtles tends to increase with latitude (Litzgus and Brooks 1998, Haxton 1998). For example, mean female PL was 89.8 mm in Pennsylvania (40° N, Ernst 1976) and 80.7 mm in Ohio (40.1° N, Lovich 1985) whereas, at the northern limit of the species’ range, in northern Ontario (45° N), mean female PL in three populations was 92.4 mm (Chippindale 1984), 101.1 mm (Litzgus and Brooks 1998) and 108 mm (Haxton 1998). The largest wild specimens of spotted turtle come from the population studied by Haxton (1998). Size of spotted turtles at CACO is consistent with this pattern. Mean female PL of 98.9 mm (Table 8) is intermediate, and close to the 101.5 mm mean female PL of a Worcester County, MA population (Graham 1995).

Although female spotted turtles reportedly average larger than males (Ernst 1970, 1975, Gibbons and Lovich 1990), Litzgus and Brooks (1998) concluded that sexual dimorphism is slight or non-existent. This apparent contradiction stems from the finding that while there are no significant sexual differences in CL, female PL is longer than male (Pope 1939, Litzgus and Brooks 1998). A relatively shorter male plastron in turtles is thought to help facilitate copulation (Moll and Legler 1971). Spotted turtles at CACO conform to this pattern of slight dimorphism, with mean CL nearly identical for the two sexes and male PL less than female, almost significantly so (Table 8). Spotted turtles in Ohio also lack sexual size dimorphism (Lewis and Faulhaber 1999).

Growth

Although few investigators have studied growth in spotted turtles, this species follows the general pattern of chelonian growth in which growth rates decline with increasing size and age (Graham 1970, Ernst 1975). Multi-year sampling of CACO spotted turtles provides limited growth data demonstrating this pattern (Table 15). Mean annual growth rates in a Pennsylvania population, by plastron length classes were: 70-79 mm PL - 5.70%; 80-89 mm PL - 4.12%; 90-99 mm PL - 2.72% (Ernst 1975). For CACO spotted turtles, corresponding mean annual growth rates were: 70-79 mm PL - 7.4%; 80-89 mm PL - 4.43%; 90-99mm PL - 2.05%; 100-109 mm - 1.45%. Thus rates of growth in CACO spotted turtles appear similar to other populations.

Conclusions Regarding Spotted Turtles at CACO

Based on a total of 39 individuals captured and marked through trapping or hand capture from 1999 through 2004, plus other reliable records, spotted turtles occur in all four towns sampled and occupy several different shallow water habitats. Spotted turtle populations at CACO appear to be small and localized, and concentrated in four areas; E15 "Red Maple Swamp" in Eastham, the marshes of the Herring River system above High Toss road in Wellfleet, T32 "Pamet Bog" in Truro, and the dune slacks and inter-dune ponds of Provincetown. Density estimates, sex and age structure, and patterns of sexual size dimorphism and growth are similar to other populations. Mean size is intermediate between northern and southern populations which is consistent with documented patterns of latitudinal variation. Although inter-pond movement and extensive use of terrestrial habitats and vernal ponds has been documented elsewhere, there was little evidence of this behavior here. More detailed radio-telemetry studies are needed to determine patterns of activity, movement, and habitat use.

Table 14. Plastron growth in CACO spotted turtles. Based on animals captured in two or more field seasons. PL, Total Growth, and Annual Growth are in millimeters. Growth rate is annualized over indicated number of years.

ID	Sex	PL start	PL end	Total Growth	#years	Annual Growth	Annual Rate
3	m	78	90	12	2	6	7.40%
803	f	81	92	11	2	5.5	6.57%
702	f	83	92	9	2	4.5	5.28%
902	m	87	89.5	2.5	2	1.25	1.43%
903	m	90	93	3	2	1.5	1.65%
203	f	93	97.5	4.5	2	2.25	2.40%
2	m	95	98	3	1	3	3.16%
601	m	97	98	1	1	1	1.03%
601	m	98	99	1	1	1	1.02%
901	f	99	102	3	1	3	3.03%
901	f	102	105	3	2	1.5	1.45%

Musk Turtle

Distribution

Musk turtles occur throughout most of the eastern United States, including southern New England, excluding higher elevations (Ernst et al. 1994, Klemens 1993). On Cape Cod, Lazell (1976) reported musk turtle throughout most of the upper Cape, but believed it did not extend beyond Orleans onto the lower Cape. However, Rich (unpublished data) collected musk turtle from the Herring River above Route 6 and from Higgins Pond in 1960, indicating this species' presence in the Herring River and associated kettle ponds. While we did not detect it in the Herring River, its presence in several kettle ponds in Wellfleet and Truro (Table 6), and in Eastham, at sites outside of CACO (R. Cook, personal observation) confirm it still occurs on lower Cape Cod into Truro. However, it is not widespread, having been detected at only 7 of 76 (9 %) sites sampled and at 7 of 15 (47%) of the shallow and deep kettle ponds sampled (Table 5).

Habitat Use

Musk turtles typically occur in standing or slow moving, soft bottomed freshwater habitats (Ernst et al. 1994). In southeastern New England, they are usually restricted to riparian systems, where they favor slow-moving muddy streams and rivers, and flourish in shallow, weedy reservoirs (Klemens 1993, Mitchell 1988). They are usually absent from temporary ponds (Carr 1952) and ponds and lakes isolated from riparian systems (Klemens 1993). Musk turtles at CACO conform in part to this pattern, with six of the seven kettle ponds they were detected in (Table 6) connected to the Herring River or in close proximity to a pond that is. However, their absence from some stream and riparian marsh habitats is puzzling, considering their presence in the Herring river in 1960 (Rich, unpublished data), and the abundance of painted and snapping turtles, two species that frequently co-occur with musk turtles (Holinka et al. 2003, Mitchell 1988) in these habitats. On the other hand, their absence from the Pamet River likely reflects that river's history. The Pamet was naturally open to tidal flow and, since musk turtles are intolerant of brackish conditions (Ernst et al. 1994), they would have been excluded. Although the Pamet was diked in 1869 and became a freshwater system, overwash of the barrier separating the Pamet from the Atlantic Ocean occasionally occurs, temporarily creating brackish conditions (Portnoy 2001). The Pamet River supports an abundance of painted and snapping turtles, but these species are far more tolerant of brackish water (Ernst et al. 1994) and have greater dispersal abilities than the musk turtle, which is a poor colonizer (Stone et al. 1993)

Abundance and Density

Musk turtles are generally abundant wherever they occur (Babcock 1919, Klemens 1993). However, density estimates are highly variable, ranging from 7.5 to 700 inds/ha (Holinka et al. 2003), although some researchers question the extremely high estimates (Mitchell 1988). Density estimates of CACO musk turtles fall well below these estimates, ranging from 0.3 to 3.4 inds/ha. Because sampling effort in kettle ponds was not nearly as intense as in most other habitats (Table 2) and population estimates at several sites are based on relatively few captures (Table 6), we considered that these may be underestimates. Mitchell (1988) found that musk turtle capture probabilities were slightly higher than painted turtles (88% v. 85%, respectively) and captured

nearly as many musk turtles as painted turtles (636 v. 818 respectively) in a shallow Virginia reservoir. At the seven CACO sites where musk turtles were detected, 152 painted turtles and 22 musk turtles were captured. Assuming capture probabilities of these two species are roughly similar (Mitchell 1988), this would indicate that musk turtles are not as abundant as painted turtles at CACO and that our estimates reflect the fact that they are not abundant.

Most reports of musk turtle populations with high densities are from the southern United States, (Iverson 1982, Dodd 1989, Ernst et al. 1994), where they are often a significant component of the turtle community (Congdon et al. 1986, Mitchell 1988). Moreover, their abundance is positively correlated with the abundance of aquatic vegetation (Pope 1939). While it is likely that the predominantly open water kettle ponds of CACO are not optimal habitat for musk turtles, it may also be that in northern populations they are a less significant component of the aquatic turtle community. At a site in Dutchess County, NY, that consisted of a shallow, muddy, weedy impoundment, seemingly ideal habitat for musk turtle, they comprised only 5% of the aquatic turtle captures (Klemens et al. 1992). Similarly, musk turtle density in a Pennsylvania marsh and shallow pond system was only 4.1% that of painted turtles (Ernst 1986).

Population Structure

Sex ratio in musk turtles appears quite variable. Many populations are reportedly female biased. Risley (1933) found a statistically significant female bias (0.43:1) in a Michigan population, and several other studies found varying degrees of female bias that were not statistically significant (Cagle 1942, Tinkle 1961, Dodd 1989, Mitchell 1988, Gibbons 1970b). In contrast, a Virginia population was significantly male biased (1.73:1; Holinka et al. 2003), as was one in Ontario (3.37:1; Edmonds and Brooks 1996). Holinka et al. (2003) suggested that sexual differences in habitat use, as well as differential catchability may have contributed to male dominance of the captures he documented. Over a 21 year period, an Indiana population was consistently male biased, with an average sex ratio of 1.85:1 (Smith and Iverson 2002). Other populations where males tended to predominate included South Carolina (1.22:1; Tuberville et al. 1996), South Carolina (1.28:1; Congdon et al. 1986), Pennsylvania (1.34:1; Ernst 1986), and Dutchess County, New York (1.75:1; Klemens et al 1992), although none of these sex ratios differed significantly from 1:1. The sex ratio of 5.5:1 at CACO suggests overwhelming dominance by males, though it is based on a small sample size ($n=26$). It is outside the range of reported values, though not far above the 4.0:1 ratio reported for one year by Smith and Iverson (2002). More extensive sampling is needed to better determine sex ratio of musk turtles at CACO.

Samples of musk turtle populations obtained by trapping or hand/dip net capture are dominated by adults (Ernst et al. 1994). For example, adults accounted for 71.6% of turtles captured in Pennsylvania (Ernst 1986), 83.9% in Alabama (Dodd 1989), 84.7% in Virginia (Mitchell 1988), 94% in South Carolina (Congdon et al. 1986), and 94.6% in Ontario (Edmonds and Brooks 1996). The comparatively small sample of musk turtles obtained at CACO during this survey (Figure 8), was consistent with this, and contained only adults.

Size and Sexual Dimorphism

Similar to other turtle species, mean size of musk turtles increases with latitude (Tinkle 1961). Mean male CL ranges from 72 mm in the southernmost populations of Florida to 103.6 mm in Ontario, Canada (Edmonds and Brooks 1996). Mean CL of male musk turtles at CACO (108.2 mm, Table 8) is consistent with this trend, though it exceeds both the Ontario population studied by Edmonds and Brooks (1986) and a sample collected from throughout Connecticut with mean male CL of 101.5 mm (Klemens 1993). Although the general trend is one in which turtle size increases with latitude, there is considerable variation between populations at similar latitudes (Edmonds and Brooks 1996), likely due to differences in habitat quality (Mitchell 1988).

Several investigators have hypothesized about the adaptive advantages of sexual size dimorphism in musk turtles. Both Tinkle (1961) and Berry and Shine (1980) concluded there is little evidence of sexual size dimorphism throughout most of the musk turtle's range. However, there was some evidence in the extreme south, where females averaged larger than males (Gibbons 1970). In contrast, at the northernmost extreme of the musk turtle's range, in Ontario, mean male CL (103.6 mm) was significantly greater than female (98.7 mm) (Edmonds and Brooks 1996). Edmonds and Brooks (1996) hypothesized that the male-biased sex ratio of their Ontario population led to more intense competition for mates, and selection for larger size in males. Male musk turtles at CACO were also significantly larger than females, with mean CL of 108.2 mm and 98.5 mm respectively, although based on a small sample size of females ($n=4$) (Table 8). Similarly, mean CL of 50 male Connecticut musk turtles was greater than mean CL of 40 females, 101.5 mm and 95.4 mm respectively (Klemens 1993), suggesting that male musk turtles in northern populations are larger than females. The small sample size of CACO musk turtles makes conclusions tentative but the size data for males and females are consistent with data from these other northern populations, and seem to support the hypothesis of increased male size in populations with strongly male-biased sex ratios. As with sex ratio, more extensive sampling is needed to better address this question.

Conclusions Regarding Musk Turtle at CACO

Based on a total of 22 individuals captured and marked through trapping or hand capture from 1999 through 2004, musk turtles occur in the kettle ponds of north Wellfleet and south Truro, particularly those connected or close to the Herring River. Although historically documented in the Herring River above Route 6, we did not detect it there during this survey. The musk turtle is uncommon and infrequently observed. Although part of this is behavioral (it is highly aquatic and not prone to bask, making it inconspicuous), the small numbers caught at sites where it is present, particularly relative to numbers of painted turtles also captured, show that it is not very abundant. As a species whose optimum habitat is shallow, muddy, vegetation-choked wetlands, the deep, predominantly open-water kettle ponds of CACO are probably marginal habitats. While based on a small sample size, the population at CACO appears to be highly male biased, exhibiting a sexual size dimorphism in which males are larger than females. More intensive sampling is needed to better understand musk turtle ecology and population structure at CACO.

Comparing Measures of Abundance

Estimating the abundance of turtle populations is problematic due to a variety of potential sampling biases (Obbard 1983, Ream and Ream 1966) and violation of the assumptions of most population estimation models (Koper and Brooks 1998). While models such as CAPTURE (White et al. 1982) are able to account for many of the problems of unequal probability of capture, CAPTURE requires large sample sizes, “several times larger than 10 to 20” (White et al. 1982). Menkens and Andersen (1988) noted that CAPTURE often produces poor estimates of population size when sample size is small and McKelvey and Pearson (2001) reported that 98% of published small mammal studies they reviewed had samples too small (<100) for effective model selection by CAPTURE. Consequently, Menkens and Andersen (1988) recommend using Chapman’s version of the Lincoln-Petersen estimator, and found it performed better as a result of pooling multiple trapping dates into single mark and recapture periods.

CAPTURE worked well in terms of model selection and population estimation for 13 sites with relatively large sample sizes ($n > 19$) of painted turtles, but these represented only 27% of the sites where painted turtles occurred. Only three sites had sample sizes greater than the minimum of 100 recommended by McKelvey and Pearson (2001). Although sample size could be increased at some sites with more sampling effort this option would not work at sites where populations are small. Thus, CAPTURE’s utility is limited to sites with larger populations. In contrast, Chapman’s modified Lincoln-Petersen performs well with smaller sample sizes (Menkens and Andersen 1988), and was highly correlated with estimates obtained by CAPTURE ($R=0.89$). The modified Lincoln-Petersen also tended to produce more precise estimates (Table 11).

McKelvey and Pearson (2001) suggest that the widespread use of indices (e.g. number of unique individuals captured) rather than population estimators is due to the constraints of small sample size. Moreover, both Slade and Blair (2000) and McKelvey and Pearson (2001) found high correlation between indices and numeric estimators, indicating that indices closely track numeric estimations of abundance and lead to the same conclusions regarding trends and population comparisons. The results here at CACO, with highly significant correlations between #INDS and numeric estimators (N_{LP} , $R=0.84$; N_{CAP} , $R=0.81$) are consistent with these findings.

Although the small sample sizes obtained here, and the high correlation between indices and numeric estimators suggest that abundance could be monitored using indices, this approach has drawbacks. Indices are not direct estimates of population size, and the relationship between an index and the actual population is generally not known (Conroy 1996, Thomson et al. 1998). Because indices do not estimate capture probabilities, it is not possible to know if differences in index values across time, space, or between species reflect differences in abundance or capture probabilities (Nichols 1986, Williams et al. 2001). For this reason, even though indices are correlated with numerical estimators and generally lead to the same conclusions, both Slade and Blair (2000) and McKelvey and Pearson (2001) concur with Nichols (1986) in recommending estimators over indices, particularly when making inter-specific comparisons. Given these arguments for numerical estimators and against indices, and the constraints presented by small sample sizes, for the purpose of producing population estimates to compare many sites across a wide range of population sizes, Chapman’s modified Lincoln-Petersen estimator is the best solution. However, for a site or sites with larger sample sizes, population estimation with Programs

CAPTURE and MARK have the benefit of providing estimates based on selection of the model that best fits the capture-recapture data. Regardless of which estimation method is used, comparison among sites or over time at the same site should be based on the same method.

Although Chapman's modified Lincoln-Petersen method seems to provide the most reasonable approach to population estimation based on CACO painted turtle data, work by Koper and Brooks (1998) casts doubt on the accuracy and precision of attempts to estimate the size of turtle populations. Working with a painted turtle population known to contain 110 individuals in a 1.7 ha pond, they found that the Lincoln-Petersen estimator was the most variable and least accurate of four different population estimation models. Moreover, they also found that hoop nets produced far fewer "captures" than basking surveys or hand capture with dipnet from a canoe. They concluded that data collected by pooling all methods and entered into the Schumacher-Eschmeyer model or CAPTURE provided the most accurate and consistent estimates, but still did not meet acceptable levels of accuracy (within 10% of the true population).

Although the conclusions of Koper and Brooks (1998) suggest that hoop traps are inadequate for sampling turtles, the density of traps they deployed was 4.1 traps/ha (7 traps/1.7 ha) and sampling was limited to six non-consecutive nights, for a total of 42 trap nights and a sampling intensity of 25 TN/ha. In contrast, ca. 80% of sampling efforts in this survey were more intense (Table 3). Koper and Brooks report capture probabilities of 0.0624 using hoop nets, whereas capture probabilities at CACO are generally higher. For 13 ponds at CACO where the number of individuals was >20, the capture probability for a single sampling occasion, estimated under the null or constant probability model of CAPTURE, ranged from 0.042 to 0.27 (Table 11). Also, Koper and Brooks (1998) based each of their Lincoln-Petersen estimates on only two sampling occasions, each representing a single overnight trap set. Thus each of their population estimates is based on only 14 trap nights of effort. In contrast, sampling effort underlying population estimates in this survey averaged 107 trap nights (range 9-585, median 55). We pooled data from multiple trapping dates into single mark and recapture periods to increase sample size. This approach makes the Lincoln-Petersen method more robust and accurate (Menkens and Andersen 1988). The poor performance of hoop traps and the Lincoln-Petersen method reported by Koper and Brooks (1988) appears to be the result of low capture rates, low sampling intensity, and not pooling the data from multiple trapping dates. With more intense sampling, both in terms of trap density and trapping occasions, and pooling of data, hoop trapping should provide data capable of accurately estimating population size using the Lincoln-Petersen method.

Recommendations Regarding Monitoring and Research

Although population estimation is a challenge to turtle monitoring, many activities and issues occurring in and around CACO have the potential to affect turtles. Local towns are approaching build-out and home construction has advanced up to the park boundary, altering upland habitats and potentially altering aquatic systems through groundwater withdrawal and nutrient inputs. Increasing numbers of year-round residents and tourists cause increasing traffic volume in and adjacent to the park. Thus the likelihood of road mortality has increased, particularly as forest succession has reduced the open habitats used by turtles for nesting, and forces them to travel greater distances to nest, placing them at greater risk of road kill (Baldwin et al. 2004, Gibbs and Steen 2005). More people will also provide more food resources for subsidized predators such as raccoon and skunk,

which could lead to higher rates of nest predation. On-going or planned restoration of tidal flow to a number of wetland systems will also change these systems, including their turtle communities. These are widespread issues (Gibbons et al. 2000, Klemens 2000,), but CACO-specific monitoring is needed to determine their impacts here.

While a broad program of turtle community monitoring across a wide spectrum of sites and habitats is not necessary or practical, monitoring that is more narrowly focused in terms of sites and species would be useful and feasible. Such monitoring would measure status and trends in the turtle community at selected sites, monitor the well-being of special concern species, assess the effects of management actions such as tidal restoration, and provide continuing baseline data on sites being considered for future management action.

Aquatic turtles are characterized by high adult survival, longevity, and relatively low recruitment (Gibbons 1987, Congdon and Gibbons 1990, Congdon et al. 1994, Gibbs and Amato 2000, Iverson 1990). Population size is relatively stable over the short term (a span of a few years) but may be more variable over longer time spans (Bayless 1975, Brooks et al. 1991, Ernst 1976, Frazer et al. 1991, Zweifel 1989). Because aquatic turtle populations do not generally change rapidly, sampling at longer time intervals, (e.g. every 5-10 years) should be adequate for monitoring long term trends in abundance at CACO or other similar sites. However, where poaching or disease are concerns, population declines could be more rapid, necessitating more frequent monitoring. For monitoring to provide useful data, care must be taken to ensure adequacy of sampling effort throughout the site being monitored and sample sizes must be large enough to produce population estimates with relatively narrow confidence limits. Without data capable of providing such estimates, it will be difficult to estimate population trends.

Based on the results and experience of the inventory work reported here, we offer the following general recommendations regarding size of sample sites, trapping density and duration, and other considerations for design of future inventories or monitoring

1. In terms of logistics and adequacy of sampling, populations at small sites (<5 ha) will be easier to monitor than at larger water bodies. Larger water bodies can be monitored, but will require larger numbers of traps and/or longer trapping periods. Selection of large versus small sample sites should be based on the questions to be answered, not the sampling effort required. In addition, species associated with larger bodies of water at CACO, snapping turtle and painted turtle, tend to be less affected by anthropogenic factors, thus there may be less need to monitor large permanent wetlands
2. In this inventory, sites where relatively large numbers of captures and recaptures of painted turtles resulted in population estimates with relatively narrow confidence intervals were Bennett Pond, Clapps Pond, Fresh Brook, Pamet River, Salt Meadow, and Williams Pond (Table 6). Trap density at these sites ranged from 1.12 to 9.5 traps/ha and trapping intensity ranged from 12.4 to 171.1 TN/ha, with the lowest values at Clapp's Pond, the largest site. While the number of individuals trapped depends on population size and capture probabilities, a trap density of 5 to 10/ha distributed as uniformly as possible to ensure that animals present have a relatively equal chance of capture is recommended for all species.

3. The use of closed population models such as Lincoln-Petersen or those of CAPTURE or MARK require that sampling be conducted over a relatively short time period. Sampling periods longer than several weeks likely violate the closure assumption (Lindeman 1990). Depending on size of a site and capture rates, sampling should be from two to four weeks to minimize closure violations. With a trap density of 10/ha, this equals a trapping intensity from 140 to 280 TN/ha.

4. While details of trapping and marking, aging, and sexing are beyond the scope of these recommendations, field procedures described in Methods section are relevant, particularly in the Northeastern U.S. However, determination of sex and age for a species should be based on the most applicable available data for a given locale. Size and age at sexual maturity varies with latitude and nutritional conditions.

5. Do not use “box traps” used in this inventory. The small throat dimensions limit captures to small specimens. “D” shaped or square frame hoop traps should be used in shallow habitats and large hoop traps in deeper habitats. Recognize that mesh size, hoop diameter, and throat size will influence size of turtles captured. For large, more open bodies of water, adding wings to the traps will increase capture probabilities.

To better understand the status of sensitive species at CACO and provide information relevant to management actions, the following monitoring and research activities are recommended (Table 15):

1. Spotted Turtles. Red Maple Swamp (E15) and Pamet Bog (T32) support the two most important (largest) populations of spotted turtles at CACO and should be monitored. The marshes adjacent to Bound Brook Island and Griffin Island (Duck Harbor and Bound Brook) are also important areas for spotted turtles and could be altered by tidal restoration, though spotted turtles tolerate brackish conditions (Ernst et al. 1994). The complex of dune slacks and inter-dune ponds in Provincetown also appear important for spotted turtles, although large size and number of ponds has made it difficult to identify areas of concentration. While these areas are recommended for monitoring spotted turtles, because so little is known about seasonal patterns of movement and habitat use of this species at CACO, radio-telemetry studies would be very useful to better understand their use of the CACO landscape and identify the more heavily utilized areas within the Bound Brook Marshes or Province Lands.

2. Effects of tidal restoration on turtles in Pilgrim Lake–Salt Meadow system. Moderate to large populations of painted and snapping turtles occur in this system. Ongoing restoration of tidal flow has increased salinity, resulting in changes to vegetation, fish, and invertebrates. While these changes have not yet affected Salt Meadow, they are likely to alter the turtle community in Pilgrim Lake. Snapping turtles are tolerant of moderate salinity (Ernst et al. 1994) but painted turtles appear to be excluded from brackish habitats in New England (Klemens 1993). Thus, increased salinity would likely cause a shift in these species into Salt Meadow, with painted turtles more affected than snapping turtles. In addition, with conversion back to tidal marsh, colonization by the Massachusetts Threatened Northern Diamondback Terrapin is possible. Monitoring is needed to determine the extent of changes in abundance, composition, and spatial distribution of this turtle community in response to tidal restoration.

3. Monitoring of turtle community at Fresh Brook, Herring River, and Pamet River. Similar to Pilgrim Lake-Salt Meadow, these three sites support moderate to large populations of painted turtles and snapping turtles. There is also an historic record of spotted turtle in Fresh Brook, and both spotted and musk turtles have been recorded in the Herring River system. These three sites have had tidal flow restricted. Tidal restoration is in the planning stages at Herring River and may be pursued at Pamet River and Fresh Brook in the future. As with Pilgrim Lake-Salt Meadow, restoring tidal flow will likely cause changes in the turtle community. Periodic monitoring at these sites will provide data needed to predict changes in the turtle community as a result of tidal flow restoration, and provide a baseline for measuring change if and when tidal restoration does occur.

4. Monitoring of representative sites. A number of sites not associated with current or proposed management actions currently support moderate to large turtle populations. However, the turtle communities at these sites may be affected by agents of change such as changes in water quality and quantity, changes in wetland and adjacent vegetation, as well as visitor impacts, road impacts, and habitat fragmentation. For example, female painted turtles may travel up to 273 m to nest, depending on the availability and proximity to a pond of open habitat for nesting (Baldwin et al. 2004). Such movement, in combination with more roads and increasing volumes of traffic puts them at greater risk of road kill, and has lead to increasingly male dominated sex ratios in aquatic turtles in urbanized states (Gibbs and Steen 2005). Given their demography, turtle populations are not able to sustain increased, anthropogenic-induced mortality, particularly of females (Brooks et al. 1991, Congdon et al. 1994, Gibbs and Amato 2000). Monitoring of population size and structure would allow comparison of trends in population parameters at sites with different levels of development-related stressors. Recommended sites are;

-E25 in Eastham. In close proximity to residential development and Hemenway Road, this site may be impacted by cumulative effects of development, habitat fragmentation, increased traffic and numbers of subsidized predators in residential areas.

-Herring Pond in Wellfleet. This site is fairly well removed from roads, not heavily visited, with low housing density nearby. With few identifiable agents of change, it would serve as a “control” site.

-Snow Pond in Truro. This site is adjacent to heavily traveled Route 6 and among the most heavily visited kettle ponds in summer.

-Bennett Pond in Provincetown. This pond is surrounded on three sides by fairly intact, woodland habitat and is sufficiently removed from roads. But, it is adjacent to the former Provincetown landfill and current transfer station.

-Pasture Pond 1 in Provincetown. This pond is in intact woodland habitat and removed from roads and other sources of anthropogenic impacts. It would serve as a “control”.

Table 15. Recommendations for monitoring freshwater turtles at Cape Cod National Seashore. To the extent allowed by water levels, use equal numbers of hoop and D traps at sites where both types are specified.

Site	Target Species	# traps x types	Duration	When	Frequency
E15	CLGU	20 "D"	4 weeks	May-June	5 years
T32	CLGU	15 "D"	4 weeks	May-June	5 years
Bound Brook-Duck Harbor	CLGU	30 "D"	4 weeks	May-June	5 years
Pilgrim Lake	all	30 hoop, D	2 weeks	July-Sept	10 years
Salt Meadow	all	30 hoop, D	2 weeks	July-Sept	10 years
Fresh Brook	all	20 hoop, D	2 weeks	July-Sept	10 years
Herring River	all	30 hoop, D	2 weeks	July-Sept	10 years
Pamet River	all	30 hoop, D	2 weeks	July-Sept	10 years
E25	all	10 hoop, D	2 weeks	July-Sept	10 years
Herring Pond	all	10 hoop, D	2 weeks	July-Sept	10 years
Snow Pond	all	10 hoop, D	2 weeks	July-Sept	10 years
Pasture 1	all	10 hoop, D	2 weeks	July-Sept	10 years
Bennett Pond	all	10 hoop, D	2 weeks	July-Sept	10 years

Literature Cited

- Allen, J.A. 1868. Catalogue of the reptiles and batrachians found in the vicinity of Springfield, Mass., with notices of all the other species known to inhabit the state. Proc. Boston Soc. Nat. Hist., vol 12, p.171-204, 248-250.
- Babcock, H.L. 1919. Turtles of New England. Mem. Boston Soc. Nat. Hist. 8: 325-431.
- Baldwin, E.A., M.N. Marchand, and J.A. Litvitis. 2004. Terrestrial habitat use by nesting painted turtles in landscapes with different levels of fragmentation. Northeastern Naturalist 11: 41-48.
- Bayless, L.E. 1975. Population parameters for *Chrysemys picta* in a New York pond. Amer. Midl. Nat. 93: 168-176.
- Berry, J. F., and R. Shine. 1980. Sexual size dimorphism and sexual selection in turtles (Order Chelonia). Oecologia 44: 185-191.
- Brooks, R.J., G.P. Brown, and D.A. Galbraith. 1991. Effects of a sudden increase in natural mortality of adults on a population of the common snapping turtle (*Chelydra serpentina*). Can. J. Zool. 69: 1314-1320.
- Brooks, R.T. and M. Hayashi. 2002. Depth-area-volume and hydroperiod relationships of ephemeral (vernal) forest pools in southern New England. Wetlands 22: 247-255.
- Brown, G.P., C.A. Bishop and R.J. Brooks. 1994. Growth rate, reproductive output, and temperature selection of snapping turtles in habitats of different productivities. J. Herpet. 28: 405-410.
- Bury, R. B. 1979. Population ecology of freshwater turtles. pp 571-602 in Harless, M. and Morlock, H. (eds). Turtles: Perspective and Research. John Wiley and Sons, NY, 695 pp.
- Cagle, F.R. 1939. A system of marking turtles for future identification. Copeia 1939: 170-173.
- Cagle, F.R., 1942. Turtle populations in Southern Illinois. Copeia 1942: 155-162.
- Cagle, F.R. 1944. Home range, homing behavior, and migration in turtles. Miscellaneous Publications Museum of Zoology, University of Michigan, No.61.
- Cagle, F.R. 1954. Observations of the life cycles of painted turtles (Genus *Chrysemys*). Amer. Midl. Nat. 52: 225-236.
- Calhoun, A.J.K., T.E. Walls, S.S. Stockwell, and M. McCollough. 2003. Evaluating vernal pools as a basis for conservation strategies: A Maine case study. Wetlands 23:7-81.

- Capler, J.M., and E.O. Moll 1988. Survey of a spotted turtle population (*Clemmys guttata*) at Lockport Prairie Nature Preserve, Will Co., Illinois. Unpublished report to the Will County Forest Preserve District, 34 pp.
- Carr, A.F. 1952. Handbook of turtles. The turtles of the United States, Canada, and Baja California. Comstock Publishing Associates, Cornell University Press, Ithaca, NY.
- Chippindale, P. 1984. A study of the spotted turtle (*Clemmys guttata*) in the Mer Bleue Bog. Conservation Studies Publication No. 25, National Capital Commission, Ottawa, Ontario.
- Christens, E., and J.P. Bider. 1986. Reproductive ecology of the painted turtle (*Chrysemys picta marginata*) in southwestern Quebec. Can. J. Zool. 64:914-920.
- Christiansen, J. L. and R.R. Burken. 1979. Growth and maturity of the snapping turtle (*Chelydra serpentina*) in Iowa. Herpetologica 35: 261-266.
- Clarke, K.R., and R.M. Warwick 2001. Change in marine communities; an approach to statistical analysis and interpretation. 2nd ed. PRIMER-E Ltd. Plymouth Marine Laboratory, UK.
- Congdon, J. D., and J.W. Gibbons. 1989. Biomass productivity of turtles in freshwater wetlands: A geographic comparison. In: Freshwater Wetlands and Wildlife, p. 583-592. Sharitz, R.R., and J.W. Gibbons, Eds. DOE Symposium Series No. 61. USDOE Office of Science and Technical Information, Oak Ridge, Tennessee.
- Congdon, J. D., and J.W. Gibbons. 1990. The evolution of turtle life histories. pp 45-54. In *Life History and Ecology of the Slider Turtle*. J. Whitfield Gibbons (ed.). Smithsonian Institution Press. Washington, D.C.
- Congdon, J.D., G. L. Breitenbach, R. C. van Loben Sels, and D. W. Tinkle. 1987. Reproduction and nesting ecology of snapping turtles (*Chelydra serpentina*) in southeastern Michigan. Herpetologica 43: 39-54.
- Congdon, J.D., A.E. Dunham, and R.C. van Loben Sels. 1994. Demographics of common snapping turtles (*Chelydra serpentina*): Implications for conservation and management of long-lived organisms. Amer. Zool. 34: 397-408.
- Congdon, J.D., S.W. Gotte, and R.W. McDiarmid. 1992. Ontogenetic changes in habitat use by juvenile turtles, *Chelydra serpentina* and *Chrysemys picta*. Can. Field-Naturalist 106: 241-248.
- Congdon, J. D., J.L. Greene, and J.W. Gibbons. 1986. Biomass of freshwater turtles; A geographic comparison. Amer. Midl. Nat. 115: 165-173.

- Conroy, M. 1996. Abundance Indices p179-192 in Wilson, D.E., F.R. Cole, J.D. Nichols, R. Rudran, and M.S. Foster. Measuring and Monitoring Biological Diversity: Standard Methods for Mammals. Washington D.C.: Smithsonian Institution Press.
- Crother, B.I. (ed.). 2000. Scientific and standard English names of amphibians and reptiles of North America north of Mexico, with comments regarding confidence in our understanding. SSAR Herpetological Circular 29.
- Dodd, C. K., Jr. 1989. Population structure and biomass of *Sternotherus odoratus* (Testudines: Kinosternidae) in a northern Alabama lake. *Brimleyana* 15: 47-56.
- DonnerWright, D.M., M.A. Bozek, J.R. Probst, and E.M. Anderson. 1999. Responses of turtle assemblage to environmental gradients in the St. Croix River in Minnesota and Wisconsin, USA. *Can. J. Zool.* 77: 989-1000.
- Dunham, A.E., and J.W. Gibbons. 1990. *Growth of the slider turtle*, pp. 135-145. In *Life History and Ecology of the Slider Turtle*. J. Whitfield Gibbons (ed.). Smithsonian Institution Press. Washington, D.C.
- Dunham, A.E., and J. W. Gibbons. 1990. pp 135-145. In *Life History and Ecology of the Slider Turtle*. J. Whitfield Gibbons (ed.). Smithsonian Institution Press. Washington, D.C.
- Edmonds, J. H. and R. J. Brooks, 1996. Demography, sex ratio, and sexual size dimorphism in a northern population of common musk turtles (*Sternotherus odoratus*). *Can. J. Zool.* 74: 918-925.
- Eichner, E.M., T.C. Cambareri, G.Belfit, D. McCaffery, S.Michaud, B. Smith, and M. Fenn. 2003. Cape Cod Pond and Lake Atlas. Barnstable, MA. Cape Cod Commission Water Resources Office.
- Ernst, C.H. 1970. Reproduction in *Clemmys guttata*. *Herpetologica* 26: 228-232.
- Ernst, C.H. 1971. Population dynamics and activity cycles in *Chrysemys picta* in southeastern Pennsylvania. *J. Herpetol.* 5:151-160.
- Ernst, C.H. 1975. Growth of the spotted turtle, *Clemmys guttata*. *J. Herpetol.*9: 313-318.
- Ernst, C.H. 1976. Ecology of the spotted turtle, *Clemmys guttata* (Reptilia, Testudines, Testudinidae), in southeastern Pennsylvania. *J. Herpetol.*10: 25-33.
- Ernst, C.H. 1982. Environmental temperatures and activities in wild spotted turtles, *Clemmys guttata*. *J. Herpetol.*16: 112-120.
- Ernst, C.H. 1986. Ecology of the turtle, *Sternotherus odoratus*, in southeastern Pennsylvania. *J. Herpetol.*20: 341-352.

- Ernst, C.H. and G.R. Zug. 1994. Observations on the reproductive biology of the spotted turtle, *Clemmys guttata*, in southeastern Pennsylvania. J. Herpetol. 28: 99-102.
- Ernst, C.H., J.E. Lovich, and R.W. Barbour. 1994. Turtles of the United States and Canada. Smithsonian Institution Press. Washington and London.
- ESRI Corp., 2002. ArcGIS. Environmental Systems Research Institute, Redlands CA.
- Fuselier, L. and D. Edds. 1994. Habitat partitioning among three sympatric species of map turtles, genus *Graptemys*. J. Herpetol. 28: 154-158.
- Frazer, N.B., J.W. Gibbons, and J.L. Greene. 1991. Growth, survivorship and longevity of painted turtles *Chrysemys picta* in a southwestern Michigan marsh. Am. Midl. Nat. 125: 245-258.
- Froese, A.D. and G.M. Burghardt. 1975. An unusually dense natural population of snapping turtle (*Chelydra s. serpentina*). Herpetologica 31: 204-208.
- Galbraith, D.A., C.A. Bishop, R.J. Brooks, W.L. Simser, and K.P. Lampman. 1988. Factors affecting the density of populations of common snapping turtles (*Chelydra serpentina*). Can. J. Zool. 66: 1233 – 1240.
- Galbraith, D.A., R.J. Brooks, and M.E. Obbard. 1989. The influence of growth rate on age and body size at maturity in female snapping turtles (*Chelydra serpentina*). Copeia 1989 (4):896-904.
- Gibbons, J.W. 1967. Variation in growth rates in three populations of the painted turtle, *Chrysemys picta*. Herpetologica 23: 296-303.
- Gibbons, J.W. 1968. Population structure and survivorship in the painted turtle, *Chrysemys picta*. Copeia 1968: 260-268.
- Gibbons, J.W. 1970a. Sex ratios in turtles. Res. Popul. Ecol. XII: 252-254.
- Gibbons, J.W. 1970b. Reproductive characteristics of a Florida population of musk turtles (*Sternotherus odoratus*). Herpetologica 26: 268-270.
- Gibbons, J.W. 1987. Why do turtles live so long? BioScience 37: 262-269.
- Gibbons, J. W. 1990. Sex ratios and their significance among turtle populations. pp 171-182. In *Life History and Ecology of the Slider Turtle*. J. Whitfield Gibbons (ed.). Smithsonian Institution Press. Washington, D.C.
- Gibbons, J.W. and J.E. Lovich. 1990. Sexual dimorphism in turtles with emphasis on the slider turtle (*Trachemys scripta*). Herpetological Monographs 4: 1-29

- Gibbons, J.W. and P.W. Stangel (coordinators). 1999. Conserving amphibians and reptiles in the new millennium. Proceedings of the partners in amphibian and reptile conservation (PARC) conference. Savannah River Ecology Laboratory Herp Outreach Publication #2. Aiken SC.
- Gibbons, J.W. and D.W. Tinkle. 1969. Reproductive variation between turtle populations in a single geographic area. *Ecology* 50: 340-341.
- Gibbons, J.W., G.H. Keaton, J.P. Schubauer, J.L. Greene, D.H. Bennett, J.R. McAuliffe, and R.S. Sharitz. 1979. Unusual population size structure in freshwater turtles on barrier islands. *Georgia J. Sci.* 37:155-159.
- Gibbons, J.W., D.E. Scott, T.J. Ryan, K.A. Buhlmann, T.D. Tuberville, B.S. Metts, J.L. Greene, T. Mills, Y. Leiden, S. Poooop, and C.T. Winne. 2000. The global decline of reptiles, déjà vu amphibians. *BioScience* 50(8):653-666.
- Gibbs, J. P. and G.D. Amato. 2000. Genetics and demography in turtle conservation. In: *Turtle Conservation*, p. 207-217. Klemens, M.W. Ed. Smithsonian Institution Press. Washington and London.
- Gibbs, J.P. and D.A. Steen. 2005. Trends in sex ratios of turtles in the United States: Implications of Road Mortality. *Conservation Biology* 19: 552-556.
- Glesenkamp, L.L., G.R. Zug, and J.C. Mitchell. 2003. Reproductive cycle of male snapping turtles (*Chelydra serpentina*) in Southeastern Virginia. *Chelonian Conservation and Biology* 4: 697-700.
- Golet, W.J. and T.A. Haines. 2001. Snapping turtles (*Chelydra serpentina*) as monitors for mercury contamination of aquatic environments. *Environmental Monitoring and Assessment* 71:211-220.
- Graham, T.E. 1970. Growth rate of the spotted turtle, *Clemmys guttata*, in southern Rhode Island. *J. Herpetol.* 4: 87-88.
- Graham, T.E. 1995. Habitat use and population parameters of the spotted turtle, *Clemmys guttata*, a species of special concern in Massachusetts. *Chelonian Conservation and Biology*. 1: 207-214.
- Hammer, D.A. 1969. Parameters of a marsh snapping turtle population Lacreek Refuge, South Dakota. *J. Wildlife Management*. 33: 995-1005.
- Haxton, T.J. 1998. Large spotted turtles, *Clemmys guttata*, sampled in central Ontario. *Can. Field Nat.* 112: 717-718.
- Haxton, T. and M. Berrill. 1999. Habitat selectivity of *Clemmys guttata* in central Ontario. *Can. J. Zool.* 77: 593-599.

- Haxton, T. and M. Berrill. 2001. Seasonal activity of Spotted Turtles (*Clemmys guttata*) at the northern limit of their range. *J. Herpetol.* 35: 606-614.
- Holinka, A.M., R. Dave, and R.M. Chambers. 2003. Population ecology of musk turtles (*Sternotherus odoratus*) in a lake in Virginia. *Chelonian Conservation and Biology* 4 : 721-725.
- Iverson, J.B. 1982. Biomass in turtle populations: a neglected subject. *Oecologia* 55: 69-76.
- Iverson, J.B. 1990. Patterns of survivorship in turtles (order Testudines). *Can. J. Zool.* 69:385-391.
- Iverson, J.B. 1992. Correlates of reproductive output in turtles (Order Testudines). *Herpetological Monographs*, 6: 25-42.
- Iverson, J.B. and G.R. Smith. 1993. Reproductive ecology of the painted turtle (*Chrysemys picta*) in the Nebraska sandhills and across its range. *Copeia* 1993: 1-21.
- Iverson, J.B., D. Hearne, J. Watters, D. Croshaw, and J. Larson. 2000. *Chelydra serpentina* (Common Snapping Turtle). Density and Biomass. *Herp. Review* 31: 238.
- Jones, L.K. 1992. Cape Cod National Seashore Reptile and Amphibian Survey. CACO Natural Resources Report 92-04, Cape Cod National Seashore, Wellfleet, MA.
- Joyal, L.A., M. McCollough, and M.L. Hunter Jr. 2001. Landscape ecology approaches to wetland species conservation: a case study of two turtle species in southern Maine. *Conservation Biology* 15(6):1755-1762.
- Klemens, M.W. 1993. Amphibians and reptiles of Connecticut and adjacent regions. *Conn. State Geol. Nat. Hist. Surv. Bull.* 112: 318pp.
- Klemens, M.W. 2000. *Turtle Conservation*. Smithsonian Institution Press. Washington and London.
- Klemens, M.W., R.P. Cook, and D.J. Hayes. 1992. Herpetofauna of Roosevelt-Vanderbilt National Historic Sites Hyde Park, New York, with emphasis on Blanding's Turtle (*Emydoidea blandingii*). Technical Report NPS/NAROSS/NRTR-92/08. Dept. of Interior NPS North Atlantic Region. 34pp.
- Kofron, C.P. and A.A. Schreiber. 1985. Ecology of two endangered aquatic turtles in Missouri, *Kinosternon flavescens* and *Emydoidea blandingii*. *J. Herpetol.* 19: 27-40.
- Kofron, C.P. and A.A. Schreiber. 1987. Observations of aquatic turtles in a northeastern Missouri marsh. *Southwestern Naturalist*, 32: 517-521.

- Koper, N. and R.J. Brooks. 1998. Population-size estimators and unequal catchability in painted turtles. *Can. J. Zool.* 76: 458-465.
- Lazell, J.D. 1972. Reptiles and amphibians in Massachusetts. Massachusetts Audubon Society, Lincoln.
- Lazell, J.D. 1976. *This Broken Archipelago*. New York: Demeter Press (Quadrangle, The New York Times Book Co).
- Lefevre, K. and R.J. Brooks. 1995. Effects of sex and body size on basking behavior in a northern population of the painted turtle, *Chrysemys picta*. *Herpetologica* 51: 217-224.
- Lewis, T.L. and C.A. Faulhaber. 1999. Home ranges of spotted turtles (*Clemmys guttata*) in southwestern Ohio. *Chelonian Conservation and Biology* 3(3):430-434.
- Lindeman, P.V. 1990. Closed and open model estimates of abundance and tests of model assumptions for two populations of the turtle, *Chrysemys picta*. *J. Herpetol.* 24(1):15-28.
- Lindeman, P.V. 1996. Comparative life-history of painted turtles (*Chrysemys picta*) in two habitats in the inland Pacific northwest. *Copeia* 1996: 114-130.
- Litzgus J.D. and R.J. Brooks. 1998. Growth in a cold environment: body size and sexual maturity in a northern population of spotted turtles, *Clemmys guttata*. *Can. J. Zool.* 76: 773-782.
- Litzgus J.D. and R.J. Brooks. 2000. Habitat and temperature selection of *Clemmys guttata* in a northern population. *J. Herpetol.* 34: 178-185
- Lovich, J.E. 1985. The spotted turtles of Cedar Bog: a population in decline. Division of Natural Areas and Preserves, Ohio Department of Natural Resources, Columbus.
- Lovich, J. E. 1988. Geographic variation in the seasonal activity cycle of spotted turtles, *Clemmys guttata*. *J. Herpetol.* 22: 482-485.
- Lovich, J. 1990. Spring movement patterns of two radio-tagged male spotted turtles. *Brimleyana* 16:67-71.
- MacCulloch, R.D. and D.M. Secoy. 1983. Demography, growth, and food of western painted turtles, *Chrysemys picta belli* (Gray) from southern Saskatchewan. *Can. J. Zool.* 61: 1499-1509.
- MassGIS, 2001. Massachusetts Geographic Information System. Commonwealth of Massachusetts, Executive Office of Environmental Affairs, Boston.
- McKelvey, K.S. and D.E. Pearson. 2001. Population estimation with sparse data: the role of estimators versus indices revisited. *Can. J. Zool.* 79: 1754-1765.

- Meeks, R.L. and G.R. Ultsch. 1990. Overwintering behavior of snapping turtles. *Copeia* 1990 (3): 880-884.
- Menkens, G.E. Jr., and S.H. Anderson. 1988. Estimation of small-mammal population size. *Ecology* 69: 1952-1959.
- Milam, J.C. and S.M. Melvin. 2001. Density, habitat use, movements, and conservation of spotted turtles (*Clemmys guttata*) in Massachusetts. *J. Herpetol.* 35: 418-427.
- Mitchell, J.C. 1988. Population ecology and life histories of the freshwater turtles *Chrysemys picta* and *Sternotherus odoratus* in an urban lake. *Herpetological Monographs* 2: 40-61.
- Moll, E.O. and J.M. Legler. 1971. The life history of a neotropical slider turtle, *Pseudemys scripta* (Schoepff), in Panama. *Bulletin of the Los Angeles county Museum of Natural History Science* 11:102pp.
- Mosimann, J.E. and J.R. Bider. 1960. Variation, sexual dimorphism, and maturity in a Quebec population of the common snapping turtle, *Chelydra serpentina*. *Can. J. Zool.* 38: 19-38.
- Nichols, J.D. 1986. On the use of enumerations estimators for interspecific comparisons, with comments on a 'trapability' estimator. *J. Mamm.*, 67(3): 590-593.
- Obbard, M.E. 1983. Population ecology of the common snapping turtle, *Chelydra serpentina*, in north-central Ontario. Ph.D. dissertation, University of Guelph, Guelph, Ontario.
- Parmenter, R.R., and H.W. Avery. 1990. The feeding ecology of the slider turtle. pp 257-265. In *Life History and Ecology of the Slider Turtle*. J. Whitfield Gibbons (ed.). Smithsonian Institution Press. Washington, D.C.
- Perillo, K.M. 1997. Seasonal movements and habitat preferences of spotted turtles (*Clemmys guttata*) in north central Connecticut. *Chelonian Conservation Biology* 2: 445-447.
- Pettit, K.E., C. E. Bishop, and R.J. Brooks. 1995. Home range and movements of the common snapping turtle, *Chelydra serpentina*, in a coastal wetland of Hamilton Harbour, Lake Ontario. *Can. Field Nat.* 109: 192-2000.
- Pope, C.H. 1939. *Turtles of the United States and Canada*. New York, Alfred A. Knopf.
- Portnoy, J.W. 2001. Truro's Upper Pamet River: Environmental history and future prospects. *Environment Cape Cod* 4:1-9.
- Portnoy, J.W., M.G. Winkler, P.R. Sanford and C. N. Farris. 2001. Kettle Pond Data Atlas: Paleoecology and modern water quality. Cape Cod National Seashore, National Park Service, U.S. Department of Interior. 119p.

- Pough, F.H., and M.B. Pough 1968. The systematic status of painted turtles (*Chrysemys*) in the northeastern United States. *Copeia* 1968:612-618.
- Ream, C. and R. Ream. 1966. The influence of sampling methods on the estimation of population structure in painted turtles. *Amer. Midl. Nat.* 75:325-338.
- Rhodin, A.G.J. and G.H. Mittelhauser. 1994. Maximum size and clutch records for eastern painted turtles, *Chrysemys picta picta*, from mid-coastal Maine. *Chelonian Conservation and Biology* 1: 148-150.
- Rich, P. (unpublished). Notes on specimens collected on Cape Cod and deposited in the Royal Ontario Museum.
- Rie, M.T., K.A. Lendas, I.P. Callard. 1999. Reproductive changes in the turtle, *Chrysemys picta*, on Cape Cod, MA: Indices of Endocrine Disruption? *Biology of Reproduction* 60:194.
- Risley, P.L. 1933. Observations on the natural history of the common musk turtle, *Sternotherus odoratus* (Latrielle) . *Pap. Mich. Acad. Arts, Sci., and Letters* 17: 685-711.
- Rowe, J.W. 1997. Growth rate, body size, sexual dimorphism and morphometric variation in four populations of painted turtles (*Chrysemys picta belli*) from Nebraska. *Amer. Midl. Nat.* 138: 174-188.
- Sexton, O.J. 1959. Spatial and temporal movements of a population of the painted turtle, *Chrysemys picta marginata* (Agassiz). *Ecol. Monogr.* 29:113-140.
- Slade, N.A. and S.M. Blair. 2000. An empirical test of using counts of individuals captured as indices of population size. *J. Mamm.* 8: 1035-1045.
- Smith, G.R. and J. B. Iverson. 2002. Sex ratio of common musk turtles (*Sternotherus odoratus*) in a North-Central Indiana lake: a long-term study. *Am. Midl. Nat.* 148: 185-189.
- Stone, P.A., J.B. Hauge, A.F. Scott, C.Guyer, J.L. Dobie. 1993. Temporal changes in two turtle assemblages. *J. Herpetol.* 27: 13-23.
- Teran, A.F., R. C. Vogt, M.D.F. Soares Gomes. 1995. Food habits of an assemblage of five species of turtles in the Rio Guapore, Rondonia, Brazil. *J. Herpetol.* 29: 536-547.
- Tinkle, D.W. 1961. Geographic variation in reproduction, size, sex ratio and maturity of *Sternotherus odoratus* (Testudinata:Chelydridae). *Ecology* 42: 68-76.
- Thomson, W.L., G.C. White, and C. Gowan. 1998. *Monitoring Vertebrate Populations*. San Diego, Academic Press.
- Tuberville, T.D., J. Whitfield, J.L. Greene. 1996. Invasion of new aquatic habitats by male freshwater turtles. *Copeia* 3: 713-715.

- Ward, F.P., C.J. Hohmann, J.F. Ulrich, and S.E. Hill. 1976. Seasonal microhabitat selections of spotted turtles (*Clemmys guttata*) in Maryland elucidated by radioisotope tracking. *Herpetologica* 32: 60-64.
- White, G. C., D. R. Anderson, K. P. Burnham, and D. L. Otis. 1982. Capture-recapture and removal methods for sampling closed populations. Los Alamos Nat. Lab. Report LA-8787-NERP, Los Alamos, NM. 235pp.
- White, G. C., and K. P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. *Bird Study* 46 Supplement: 120-138.
- Williams, B.K., J.D. Nichols, and M.J. Conroy. 2001. Analysis and Management of Animal Populations. San Diego, CA: Academic Press
- Zar, J.H. 1996. Biostatistical Analysis. (3rd. Ed.) Upper Saddle River, NJ: Prentice Hall.
- Zweifel, R.G. 1989. Long-term ecological studies on a population of painted turtles, *Chrysemys picta*, on Long Island, New York. *American Museum Novitates*. 2952: 1-55.

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