1.0 INTRODUCTION

Coastal states that are members of the Atlantic States Marine Fisheries Commission (ASMFC) and that support runs of anadromous shad and river herring are required by Amendment 1 of the interstate Fishery Management Plan for Shad and river herring to monitor recreational fishery catch, harvest and effort every 5 years (ASMFC 1999). In accordance with this requirement, the Pennsylvania Fish and Boat Commission (PFBC), on behalf of the Delaware River Basin Fish and Wildlife Management Cooperative (DRBFWMC), contracted Versar, Inc. to estimate temporal and spatial recreational catch and harvest of shad and river herring on the Delaware River and Estuary. In addition to addressing the shad and river herring fishery monitoring requirements, the 2002 Delaware River Creel Survey was also designed to provide recreational catch and harvest estimates for striped bass and other species caught by anglers fishing the Delaware River. The survey area extended from the tidal waters between the Interstate 295 Delaware Memorial Bridge and the fall line upstream to the Downsville, N.Y. on the East Branch.

Versar, Inc. used an access point survey in conjunction with an aerial effort survey to estimate angler trips and effort, and angler catch (the total number of fish caught, including the ones released), harvest (the number of fish kept), and catch and harvest per unit effort. The access point survey is an on-site intercept design in which creel clerks collect information on catch and effort from anglers who have completed their fishing trips during the clerk's assigned time shift (Pollock et al. 1994). The aerial survey provides the basis for estimating total angler fishing effort (total number of angler fishing hours), as well as separate effort estimates for shore-based and boat-based anglers. The estimates of effort derived from the aerial survey are independent of the effort estimated from the access point survey. The aerial survey was employed to provide the total effort estimate because an airplane can cover a large area quickly and numbers of anglers in these large areas can be documented using minimum personnel (Hoenig et al. 1993). Data of this type can substantially increase the precision in estimated total catch and effort for a fixed survey cost.

This report consists of two volumes. This volume presents methods and comprehensive results of the 2002 Delaware River angler survey. Chapter 2 provides a detailed description of the survey design and statistical estimation methods and a brief description of the field sampling schedule and protocol, as well as the complete flight schedule. Chapter 3 documents angler effort, catch and harvest statistics for the following primary target species: American shad, *Alosa sapidissima*; hickory shad, *Alosa mediocris;* alewife, *Alosa pseudoharengus,* and blue back herring, *Alosa aestivalis*, known collectively as "river herring;" and striped bass, *Morone saxatilis.* Chapter 3 also documents similar results for smallmouth bass and channel catfish. Chapter 4 evaluates the results, and compare angler effort and catch statistics for American shad with past survey results. Chapter 4 also explains why some angler fishing statistics only could be provided for pooled temporal or spatial strata.

Volume II contains five appendices that specify the sampling frame and schedule, and comprise extensive information on angler fishing statistics within and across spatial and temporal strata. Appendix A contains the spatio-temporal sampling frame for the access survey, including the list of all access sites included in this study. Appendix B provides a detailed sampling schedule for the access survey, and identifies changes in the schedule. Appendix C lists all species reported caught by anglers interviewed. Appendix D provides estimates of angler effort, catch and harvest statistics within and across temporal and spatial strata for all sports fish that were caught in appreciable numbers during this survey. Appendix D also provides similar statistics for targeted effort for American shad, river herring, striped bass and six other popular species. Appendix E contains the field data collection forms for the access survey and aerial survey.

2.0 MATERIAL AND METHODS

2.1 ACCESS POINT SURVEY METHODS

The access point survey (Pollock et al. 1994) is an on-site intercept design particularly suitable for the Delaware River because, based on information from prior surveys and from fisheries workers from the agencies involved, a majority of the anglers use restricted (primarily public) access sites to enter the fishery. Only a small proportion of anglers are believed to access the fishery from private docks or piers or by walking to the water from ad-hoc parking lots along roads close to the river. The access point survey provides information on the amount of time spent fishing by the anglers on each of their fishing trips (i.e., trip length), catch and harvest per unit effort (hours spent fishing) by species, and the size structure of the harvest of American shad and striped bass by gender. This is achieved by interviewing anglers that are intercepted immediately after they complete their fishing trips, at a representative sample of access points over time.

2.1.1 Development of the Sampling Frame and Stratification

The collection of data from all angler trips completed on the Delaware River from the Interstate 295 Delaware Memorial Bridge to Downsville, NY from March 17 through October would be prohibitively expensive. A more cost-effective way than a census is to collect data from a representative and sufficient number of trips to achieve reliable estimates of total catch and harvest of key species. A sampling frame was constructed to allow the representative selection of access points (clusters of anglers) from within the project area over time. We developed the sampling frame from a comprehensive list of access points (82 in total) identified from maps provided by the Delaware River Basin Commission, and with input from an expert panel identified by the Pennsylvania Fish & Boat Commission. The sampling frame was then defined by a lattice, designating days as columns and the access points as rows. In this spatio-temporal sampling frame, the primary sampling units (PSUs) are the combination of all of the times (days, part days) available for fishing during a defined period and all points of access to the fishery (Pollock et al. 1994). The primary sampling units were selected through a probabilistic design that ensured good coverage of access points geographically and over time. Data from completed angler trips were then collected from intercepts in each selected PSU.

To achieve good sampling coverage of the angler fishery across the study area, we defined four geographic strata by river mile (RM):

- The tidal portion (Estuary) – From Delaware Memorial Bridge (RM 69) to RM 133;
- Non-tidal stratum 1: From RM 133 to Delaware Watergap Bridge (Route 80), RM 212 (Zone A, B)

- Non-tidal stratum 2: From Delaware Watergap Bridge (Route 80), RM 212, to Narrowsburg RM 290 (Zone C, D);
- Non-tidal stratum 3: From Narrowsburg RM 290 to Downsville, NY, East Branch RM 348 (Zones E, F).

The zones A-E refer to the spatial strata applied in the 1986 and 1995 creel surveys on Delaware River (Miller and Lupine 1987; 1996), and were included for ease of comparison. The East Branch (Zone F) was not covered in the 1986 and 1995 surveys. The primary geographic strata for which statistics are presented in this report are the:

1. Tidal portion of the river (Estuary) and
2. Non-Tidal portions of the river (Non-tidal strata 1-3 combined), but with separate estimates provided for:
   a. Stratum 1
   b. Strata 2 and 3 pooled
   c. Stratum 2
   d. Stratum 3 (Including East Branch)
   e. East Branch

In the scheduling of weekly access point sampling and the aerial survey we at first defined seven temporal strata to ensure good temporal coverage (Table 2-1).

Table 2-1. Original Temporal Stratification.

Temporal Strata	Weeks	Dates
Original – 1	11 to 15	March 17 to April 20
Original – 2	16 to 22	April 21 to June 8
Original – 3	23 to 26	June 9 to July 6
Original – 4	27 to 30	July 7 to August 3
Original – 5	31 to 34	August 4 to August 31
Original – 6	35 to 38	September 1 to September 28
Original – 7	39 to 43	September 29 to October 31

This original temporal stratification intended to improve precision in total estimates by defining periods with relatively homogeneous effort, based on data from two previous angler surveys (Miller and Lupine 1987; 1996). Temporal stratum 2 was specifically defined to capture the peak shad fishing activity. For estimating purposes, we also post-stratified the study period into seven 4-week periods that approximately overlaps calendar months (Table 2-2).

Table 2-2. Monthly Temporal Post-stratification		
Temporal Strata	**Weeks**	**Dates (Month)**
Monthly – 1	11 to 17	March 17 to May 4 (Mar/Apr)
Monthly – 2	18 to 21	May 5 to June 1 (May)
Monthly – 3	22 to 25	June 2 to June 29 (June)
Monthly – 4	26 to 30	June 30 to August 3 (July)
Monthly – 5	31 to 34	August 4 to August 31 (Aug)
Monthly – 6	35 to 38	September 1 to September 28 (Sept)
Monthly – 7	39 to 43	September 29 to October 31 (Oct)

These seven post-strata were defined to allow for estimating monthly angler catch and harvest statistics, as required in the contract specifications. Because of data limitations, however, it was necessary to pool the data from March and April (Monthly strata 1 and 2). The angler survey started on March 17, 2002, and thus we did not have sufficient sampling coverage to provide separate estimates for this month. We used 4-week time blocks to approximate calendar months because the access interviews and aerial effort counts were scheduled on a weekly basis.

The access points in each original spatio-temporal stratum (14 strata) were further classified into three groups based on their predicted angler usage levels (High, Medium, or Low). This classification was based on historic information from two previous surveys (Miller and Lupine 1987; 1996) and on expert opinion provided by the PFBC and fisheries biologists from local state and federal agencies and our team. Following recommendations from the PFBC, we assigned four sites in non-tidal stratum 1 to an "Exceptionally high usage" stratum for the period from April 21 through June 8 (Original Temporal Stratum 2):

a) PFBC Sandts Eddy Access, along route Rt. 611 above Easton bridge (site ID 39)

b) Phillipsburg Boat Ramp at Riverside Way by "free" bridge (site ID 41)

c) Scott Park Boat Ramp Easton, along Rt. 611 at mouth of the Lehigh River (site ID 42)

d) Hugh Moore Park - Easton Fish Ladder area, south side of Lehigh River opposite Front Street Park (site ID 43)

These access points were expected to represent the highest use areas by anglers fishing on the River for American shad in late April, May and early June in non-tidal stratum 1. We periodically modified the classification of usage level throughout the survey based on the most up-to-date information from the access point and aerial surveys. This was essential to achieve good interview coverage of the angler fishery to obtain reliable estimates of catch and harvest statistics. Thus, the sampling intensity at access points with minimal angler activity was in some cases reduced, or eliminated, while the sampling at access points with medium and high usage was enhanced. The classification of usage levels for the access points remained fixed within each of the original temporal strata, but in some cases changed across weeks within the monthly strata defined for estimating purposes. The spatio-temporal sampling frame with assigned usage levels is in Appendix A.

Recreational daily angler effort on the Delaware River is typically highest on weekends, and hence we stratified the sampling days into two types: (1) weekdays; and (2) weekend days including holidays. Within each day, a daytime period was defined from 7 AM to 9 PM. On any selected sampling day, one randomly selected interview shift would either cover angler trips that were completed in the morning from 7 AM to 1 PM (Shift 1), or in the afternoon from 1 PM to 9 PM (Shift 2). Shift 2 thus included the post–sunset period with the most significant angler effort (7 PM to 9 PM). A more limited number of night shifts were allocated to high usage sites to cover trips that were completed from 9 PM to midnight. No regular sampling was conducted between midnight and sunrise; periodic verification at high usage angler sites indicated minimal fishing activity during this time. The sampling protocol for the access point survey was documented in the Training Manual (Anon. 2002).

Angler effort and fishing statistics is estimated for each of the 14 spatio-temporal strata by weekdays and weekend days, and then aggregated to produce estimates for the entire survey period in the two primary geographic strata (non-tidal and tidal). Separate estimates are produced for the original temporal stratification, and for the monthly post stratification. Estimates for individual strata within the non-tidal section of the river, and for the East Branch (which is a part of stratum 3) could generally only be produced for pooled temporal strata because of limited sample sizes.

2.1.2 Scheduling of the Access Point Sampling

The primary objective of the access point survey was to collect representative data on catch and harvest rates by species, and the average length of the angler trips. The intercept sampling was designed to provide interview data that represented the angler fishery across all access points over the study period from March 17 through October. This was achieved through spatial and temporal stratification and multiple stages of selection.

In the first stage, we used the sampling frame as a mechanism for selecting a stratified random sample of access points over time. To ensure good temporal coverage in each stratum, we used restricted random sampling (Jessen 1977), with sampling of access points scheduled on random weekdays and weekend days during each calendar week from each stratum. The inclusion probability for weekend days thus was higher than for weekdays. The access points within each original spatial-temporal stratum and usage class had equal inclusion probability. Access points in the high and medium usage were sampled at a higher frequency than the low usage sites to maximize the coverage of completed angler trips. Weekly or bi-monthly sampling on weekdays and weekend days were conducted in the medium and high usage areas in each stratum. We scheduled weekly sampling of all the "exceptionally high usage sites" from April 21 through June 8 (Time Stratum 2). The sampling effort during weekend days and holidays were relatively higher than for weekdays because the angler effort tends to be significantly higher on non-working days.

In the second stage, one AM (7 AM to 1 PM) or PM (1 PM to 9 PM) shift was selected at random within each day/site (PSU). These shifts covered the daytime fishing, as well as the time after sunset with highest fishing activity (7 PM to 9 PM). We also selected a limited number (55) of 3 hours night sampling shifts to cover the post-sunset period from 9 PM to midnight. These night shifts were conducted at a random subset of PM shifts at high usage access points.

The final sampling stage involved a census of anglers by type (shore based and boat anglers) that complete their fishing trip within the selected daily sampling period, or, if required because of large number of anglers at some sites, a random sub-sample of anglers. For these anglers, data were collected on catch and harvest in numbers by species, effort (# hours fished), size- composition of the harvest for American shad and striped bass, and other information. The total number of boat and shore-anglers was registered in both cases.

Angler interviews were collected from 396 primary sampling units (PSUs) during daytime (7 AM to 9 PM), and from 55 PSUs at night (9 PM to midnight) during the entire survey period. The times of sampling (AM or PM shifts) within daytime PSUs were randomly selected, resulting in an approximately even number of sampling shifts in the morning and afternoon (Table 2-3). In all, 401 daytime shifts were completed at the 396 PSUs (sites/days); both AM and PM shifts were completed at 5 PSUs. The schedule for sampling access points over time is in Appendix B.

Table 2-3. Number of sampling shifts that were completed in the access point survey by spatio-temporal strata. Stratum 3 includes the East Branch. *AM and PM sampling shifts were conducted at 5 of the 396 daytime PSUs.

Temporal Strata	Sampled Shift	Spatial Strata						
		Tidal	Stratum 1	Stratum 2	Stratum 3	East Branch	All Non-Tidal	All
Monthly - 1	AM	11	12	7	4	3	23	34
	PM	15	15	4	2		21	36
	Night	3	2	2	1		5	8
Original - 1	AM	8	7	2	3	3	12	20
	PM	8	7	3	1		11	19
	Night						0	0
Monthly - 2	AM	5	14	4	2		20	25
	PM	11	7	5	4	2	16	27
	Night	3	7	2	1		10	13

Table 2-3. Continued								
		Spatial Strata						
Temporal Strata	**Sampled Shift**	**Tidal**	**Stratum 1**	**Stratum 2**	**Stratum3**	**East Branch**	**All Non-Tidal**	**All**
Original - 2	AM	8	22	13	4		39	47
	PM	21	17	6	5	2	28	49
	Night	7	10	4	2		16	23
Monthly - 3	AM	7	9	7	1		17	24
	PM	7	8	8	2		18	25
	Night	1	3	1	2		6	7
Original - 3	AM	9	8	6			14	23
	PM	5	8	9	3		20	25
	Night		2	2	2		6	6
Monthly - 4	AM	10	7	7	1		15	25
	PM	10	8	6	6		20	30
	Night	2	2	2	2		6	8
Original - 4	AM	8	5	4	1		10	18
	PM	9	6	5	5		16	25
	Night	2	2	1	2		5	7
Monthly - 5	AM	8	9	10	4		23	31
	PM	7	9	8	5		22	29
	Night	2	2	2	1		5	7
Original - 5	AM	8	9	10	4		23	31
	PM	7	9	8	5		22	29
	Night	2	2	2	1		5	7
Monthly - 6	AM	7	5	10	4	1	19	26
	PM	6	10	5	6		21	27
	Night	1	2	1	1		4	5
Original - 6	AM	7	5	10	4	1	19	26
	PM	6	10	5	6		21	27
	Night	1	2	1	1		4	5
Monthly - 7	AM	10	11	7	5		23	33
	PM	6	7	9	7		23	29
	Night	3	2	1	1		4	7
Original - 7	AM	10	11	7	5		23	33
	PM	6	7	9	7		23	29
	Night	3	2	1	1		4	7
Total Period	AM	58	67	52	21	4	140	198
	PM	62	64	45	32	2	141	203
	AM+PM	120	131	97	53	6	281	*401
	Night	15	20	11	9	0	40	55

2.2 AERIAL SURVEY METHODS

2.2.1 Development of the Sampling Frame and Stratification

The sampling frame for the aerial survey was constructed as a tool for scheduling counts of anglers at representative time intervals within each spatial stratum. For logistical reasons, the study area was divided into two regions that each could be covered in a 2-hours flight (effective flying time over the river):

(1) Region 1 – The Estuary and non-tidal stratum 1; and
(2) Region 2 – Non-tidal strata 2 and 3, including the East Branch.

The temporal sampling frame consisted of all days in the study period, stratified into weekdays and weekend days. The "weekend" days also included significant holidays with expected increased fishing effort. Each primary sampling day for the aerial survey (7 AM to 7 PM) was divided into 2-hour periods (secondary sampling units). Instantaneous angler counts were recorded separately for each of the three river strata, and for the Estuary. Anglers were counted separately for the East Branch (within non-tidal stratum 3) during four flights throughout the study period (April 21, May 1, August 11, and September 8).

2.2.2 Scheduling of Angler Counts

A probability-based survey design was used to schedule the aerial effort flights. All flights were conducted on randomly selected weekdays and weekend days. On each flight, aerial observers made instantaneous counts of shore and boat anglers successively within portions of the area swept, yielding a progressive overall survey count (Pollock et al. 1994). We scheduled 32 regular flights (one flight per week) in Region 1 (Table 2-4), and 29 flights (one flight per week after April 6) in Region 2 (Table 2-5). These flights formed the core aerial survey, and represented an enhancement of sampling effort relative to the originally planned 25 flights in the non-tidal and 25 flights in the tidal portions of the river. In each region, the weekly flights were alternated systematically between weekdays and weekends, with a random start (weekday or weekend). The specific weekdays or weekend days was randomly selected for each week. The daily flight direction (upstream or downstream) also was randomized. We included contingency aerial survey days already determined using the probability sampling design (one randomly selected day every two weeks) in case bad weather forced the cancellation of a flight. The date for a flight to compensate for a lost day was generally picked from this pre-determined list. In a few cases with extended periods of bad weather, we were not able to complete the target sample size for weekdays or weekends within a 4-week period. We did not re-schedule all flights that were canceled because of the over-sampling built into the flight schedule.

We restricted the flights in the non-tidal river to stratum 1 during the first three weeks; it was determined by groundtruthing that the fishing activity occurring upstream from the

Delaware Watergap Bridge was negligible at that time. After three weeks, flights in the non-tidal river commenced in Region 2 (River Strata 2 and 3, including the East Branch). To further enhance the aerial sampling effort, we also scheduled 14 additional flights in non-tidal stratum 1 (Table 2-6) using the maximum count method (Dauk 2000; Dauk and Swartz 2001; Lockwood et al. 2001). These flights enhanced the coverage during the peak effort in angler fishing for American shad. In total, 12 maximum count flights were completed. Four of the scheduled flights were cancelled because of extended bad weather conditions or mechanical problems, and two of these were replaced.

Table 2-4. Delaware River Creel Survey 2002 - Scheduled and completed flights in the Estuary & Stratum 1. * Cancelled

Week	Sample Period		Scheduled				Cancelled Flights		
	From	To	Flight Date	Day	Time Interval	Flight Dir.	Reason for Cancellation	Replaced Flight	Date
11	3/17	3/23	3/17	WE	9 AM - 11 AM	D			
12	3/24	3/30	3/28	WD	11 AM - 1 PM	D			
13	3/31	4/6	3/31	WE	3 PM - 5 PM	U			
14	4/7	4/13	4/12*	WD	7 AM - 9 AM	D	Poor visibility	Y	4/13
15	4/14	4/20	4/14	WE	11 AM - 1 PM	D			
16	4/21	4/27	4/24	WD	3 PM - 5 PM	U			
17	4/28	5/4	5/4	WE	7 AM - 9 AM	D			
18	5/5	5/11	5/6	WD	5 PM - 7 PM	D			
19	5/12	5/18	5/18*	WE	1 PM - 3 PM	U	High Wind	N	
20	5/19	5/25	5/24	WD	3 PM - 5 PM	D			
21	5/26	6/1	6/1	WE	11 AM - 1 PM	U			
22	6/2	6/8	6/7	WD	9 AM - 11 AM	D			
23	6/9	6/15	6/9	WE	11 AM - 1 PM	D			
24	6/16	6/22	6/21	WD	1 PM - 3 PM	U			
25	6/23	6/29	6/29	WE	11 AM - 1 PM	D			
26	6/30	7/6	7/1	WD	9 AM - 11 AM	U			
27	7/7	7/13	7/7*	WE	7 AM - 9 AM	U			
28	7/14	7/20	7/15	WD	11 AM - 1 PM	U			
29	7/21	7/27	7/27	WE	1 PM - 3 PM	D			
30	7/28	8/3	7/30	WD	11 AM - 1 PM	U			
31	8/4	8/10	8/10	WE	7 AM - 9 AM	U			
32	8/11	8/17	8/14	WD	3 PM - 5 PM	U			
33	8/18	8/24	8/18	WE	7 AM - 9 AM	U			
34	8/25	8/31	8/28*	WD	1 PM - 3 PM	U	Poor flying condition	Y	8/30

Table 2-4. Continued										
Week	Sample Period		Scheduled				Cancelled Flights		
	From	To	Flight Date	Day	Time Interval	Flight Dir.	Reason for Cancellation	Replaced Flight	Date
35	9/1	9/7	9/7	WE	11 AM - 1 PM	D			
36	9/8	9/14	9/9	WD	11 AM - 1 PM	D			
37	9/15	9/21	9/15*	WE	7 AM - 9 AM	D	Rain, poor visibility	Y	9/21
38	9/22	9/28	9/26	WD	9 AM - 11 AM	D			
39	9/29	10/5	9/29	WE	11 AM - 1 PM	D			
40	10/6	10/12	10/11*	WD	7 AM - 9 AM	U	Poor flying condition	N	
41	10/13	10/19	10/19	WE	9 AM - 11 AM	D			
42	10/20	10/31	10/22	WD	1 PM - 3 PM	U			

Table 2-5. Delaware River Creel Survey 2002 - Scheduled and completed flights in Strata 2 and 3 (including East Branch). * Cancelled

Week	Sample Period		Scheduled				Flight Cancellations		
	From	To	Flight Date	Day	Time Interval	Flight Dir.	Reason for cancellation	Replaced Flight	Date
11	3/17	3/23					None were scheduled		
12	3/24	3/30							
13	3/31	4/6					None were scheduled		
14	4/7	4/13	4/13*	WE	11 AM - 1 PM	D	Fog	N	
15	4/14	4/20	4/15	WD	3 PM - 5 PM	U			
16	4/21	4/27	4/21	WE	9 AM - 11 AM	D			
17	4/28	5/4	5/1	WD	3 PM - 5 PM	D			
18	5/5	5/11	5/5	WE	11 AM - 1 PM	D			
19	5/12	5/18	5/17	WD	1 PM - 3 PM	D			
20	5/19	5/25	5/19	WE	7 AM - 9 AM	D			
21	5/26	6/1	5/31*	WD	7 AM - 9 AM	U	Technical Problem	N	
22	6/2	6/8	6/8	WE	11 AM - 1 PM	U			
23	6/9	6/15	6/13*	WD	1 PM - 3 PM	D	Poor Visibility	Y	6/18
24	6/16	6/22	6/16*	WE	3 PM - 5 PM	U	Windy	Y	6/22
25	6/23	6/29	6/24	WD	5 PM - 7 PM	U			
26	6/30	7/6	7/4	WE	11 AM - 1 PM	U			
27	7/7	7/13	7/11	WD	7 AM - 9 AM	U			
28	7/14	7/20	7/20	WE	11 AM - 1 PM	U	Poor flying conditions	N	

Table 2-5. Continued

Week	Sample Period		Scheduled				Flight Cancellations		
	From	To	Flight Date	Day	Time Interval	Flight Dir.	Reason for cancellation	Replaced Flight	Date
29	7/21	7/27	7/22	WD	5 PM - 7 PM	U			
30	7/28	8/3	8/3	WE	9 AM - 11 AM	D			
31	8/4	8/10	8/5	WD	3 PM - 5 PM	D			
32	8/11	8/17	8/11	WE	9 AM - 11 AM	U			
33	8/18	8/24	8/20	WD	9 AM - 11 AM	U			
34	8/25	8/31	8/31	WE	7 AM - 9 AM	U			
35	9/1	9/7	9/5	WD	1 PM - 3 PM	D			
36	9/8	9/14	9/8	WE	11 AM - 1 PM	D			
37	9/15	9/21	9/18	WD	11 AM - 1 PM	U	Rain, poor visibility	Y	9/28
38	9/22	9/28	9/22*	WE	7 AM - 9 AM	D	Scheduling Problem	Y	9/21
39	9/29	10/5	10/3	WD	1 PM - 3 PM	U			
40	10/6	10/12	10/12*	WE	11 AM - 1 PM	U	Poor Flying Condition	Y	10/24
41	10/13	10/19	10/17	WD	3 PM - 5 PM	U			
42	10/20	10/31	10/20	WE	9 AM - 11 AM	U			

Table. 2-6. Scheduled and completed flights for the second aerial survey in stratum 1. These flights were conducted during peak angler effort, using the Dauk and Schwarz (2001) flight scheduling method. * Cancelled flight because of poor flying conditions; replacement flights were conducted on June 2nd and 4th.

Week	Sample Period		Flight Date	Day	Time Interval	Flight Direction
	From	To				
15	4/14	4/20	4/20	WE	10 AM - 12	D
		4/16	4/16	WD	1 PM - 3 PM	U
16	4/21	4/27	4/27	WE	10 AM - 12	D
			4/23	WD	1 PM - 3 PM	U
17	4/28	5/4	5/4	WE	10 AM - 12	U
			5/3*	WD	1 PM - 3 PM	U
18	5/5	5/11	5/11	WE	10 AM - 12	U
			5/10	WD	1 PM - 3 PM	D
19	5/12	5/18	5/12*	WE	10 AM - 12	D
			5/14*	WD	1 PM - 3 PM	U
20	5/19	5/25	5/25	WE	10 AM - 12	U
			5/22	WD	1 PM - 3 PM	U
21	5/26	6/1	6/1*	WE	10 AM - 12	D
			5/30	WD	1 PM - 3 PM	U

The timing of flights within each selected day was randomized for the core survey. The selection of flight intervals (2-hour periods) was based on non-uniform inclusion probabilities determined by the expected distribution of angler effort throughout the day (Pollock et al. 1994). The nine additional flights in non-tidal stratum 1 were scheduled to cover the 2-hour interval with expected peak angling effort, following the maximum count method proposed by Dauk and Schwartz (2001). In non-tidal stratum 1 we thus had two independent surveys that overlapped in time. This additional survey effort increased the precision in estimates of effort, and provided information that can be used to identify the most effective scheduling method for future surveys.

Both methods of selecting flight intervals were based on the observed distribution of daily effort in the 1995 and 1986 creel surveys conducted in Delaware River. During these surveys, it was observed (counts from flyovers) that the distribution of angler effort throughout a typical weekday was bell shaped, with peak effort around midday, and with lowest effort at sunset and sunrise (Figure 3-1). During weekends or holidays, the typical effort distribution in the non-tidal river observed in the historic surveys was more skewed towards morning, with peak in effort around 10 AM. In method (1), the inclusion probabilities of flight intervals during a day was proportional to the expected effort, and thus more flights (on average) was scheduled in the middle of the day (weekdays), or around 10 AM (weekends and holidays). Because of lack of data, we assumed that the same effort distribution applied in the tidal portion of the river. Using the latter selection method, flights were scheduled during intervals of expected peak effort (and not based on probabilities), and therefore a model-based approach was used to estimate effort.

2.3 ESTIMATING EQUATIONS

2.3.1 Catch and Harvest Rates and Mean Trip Length

This report focuses on estimates of catch (numbers kept + numbers released), harvest (numbers kept), catch rate, harvest rate, angler effort (hours), and angler trips for four key species or group of species (Table 2-7). Monthly estimates are based on post-stratification as described in section 2.1.1, and is provided for each of the spatial strata, and then aggregated to produce monthly estimates for the two primary geographic strata (non-tidal and tidal) and for the entire river. For river strata 2 and 3, the sample sizes did not support monthly estimates, and thus we pooled some temporal strata. In the East Branch, from Hancock, NY to Downsville, NY, which is part of stratum 3, only seven anglers were interviewed throughout the study period, with no catches reported. Thus, no separate estimates could be provided for this small section of the river.

We provide estimates for the total sample period (from March 17 to October 31) based on the original seven temporal strata as well as for the monthly post-strata. The estimates based on the original temporal stratification are considered the most reliable because a bias might be introduced by the post-stratification. These total estimates best represent the level of sport fishing mortality that the Delaware River Basin Fish and Wildlife Management Cooperative is required to compile, as a component of an ASFMC compliance report. Similar statistics are provided for other species that where widely caught by anglers. Gizzard shad is another species of interest. Seining data from the Lewis Fishery indicate that the gizzard shad abundance in the Delaware River was substantial in 2002, accounting for about 38% of the numbers of shad caught by seining from April 4 to 27, and 59% of the numbers caught from April 28 to May 31 (Mark Boriek, NJ Division of Fish and Wildlife, pers. comm.). However, gizzard shad is generally not caught by anglers, and none were recorded in this survey.

Table 2-7. Focus species and their Integrated Taxonomic Information System (ITIS) taxonomic serial number ITSN), as recorded in the survey database.

Common name	**Taxonomic Serial Number (TSN)**
American shad	161702
Hickory shad	161704
River herring	161700, 161706, 161701, 161703
Striped bass	167680

The following are definitions of the variables used in the estimator formulae presented below:

n_j = number of primary units (PSU) sampled in stratum j

M_{ij} = number of angler trips (completed interviews) at PSU i in stratum j

$\bar{M}_j$ = mean number of trips (per half-day) across PSUs in stratum

y_{ijk} = catch (or harvest) for a given species reported in interview k at PSU i in stratum j

$\bar{y}_{ij}$ = mean catch (or harvest) per hour of a given species for completed trips at PSU i in stratum j for a species of interest

L_{ijk} = length of trip (hours) for angler k at PSU i in stratum j

$\bar{L}_{ij}$ = mean trip length (hours) for completed trips at PSU i in stratum j

L_{ij} = total number of angler hours at PSU i in stratum j

R_j = mean catch (or harvest) per hour in stratum j for a given species

The catch for a singe angler trip is the sum of number of fish harvested (kept) and number of fish released. Each primary sampling unit in a stratum represents an access point visited during a specific date.

Mean catch-per-unit-effort (CPUE) within each PSU by fishing mode (boat or shore) is estimated as

(1.1) $$\bar{y}_{ij} = \frac{\sum_k y_{ijk}}{L_{ij}}$$

where

$$L_{ij} = \sum_k L_{ijk}$$

is total angler hours across all interviews at the PSU.

An estimator for R_j is

(1.2) $$\hat{R}_j = \frac{\sum_{n_j} L_{ij}\bar{y}_{ij}}{\sum_{n_j} L_{ij}}$$

with variance

(1.3) $$\operatorname{var}(\hat{R}_j) = \frac{\sum_{n_j} L_{ij}^2(\bar{y}_{ij} - \hat{R}_j)^2}{n_j \bar{L}_j^2 (n_j - 1)}$$

This approach to estimate catch-rates is equivalent to the ratio of means method (Pollock et al. 1997), and is used to provide separate estimates for boat anglers and shore anglers, based on the respective interview data.

Equations 1.1 – 1.3 were also used to estimate catch rates for targeted fishing effort, using data for the subset of anglers trips that were directed towards the specific target species only. For angler trips with multiple target species, it is not possible to estimate the exact effort for each species. In this case, we assumed that the effort (angler hours) for these trips was evenly divided between the reported target species to obtain an approximate estimate of targeted effort.

2.3.2 Daytime Effort

The effort (angler hours) for daytime fishing (7AM to 9 PM) is estimated from the aerial survey, in conjunction with daily effort distributions based on the access interviews. Estimates are provided for all anglers, and for boat and shore anglers. The estimation is first done separately for weekdays and weekend days in each of the spatial strata (Estuary, non-tidal, and non-tidal 2&3) and by month or temporal strata (7) as defined in section 2.1.1. These spatio-temporal strata (21 in all) are denoted by j. The estimates for these strata are then pooled to provide a total estimate for the total sample period, as well as separate estimates for the non-tidal and tidal portions of the river.

A model-based estimator for daily effort (angler hours) in spatio-temporal stratum j ($j = 1,2,3,...,21$) is

(1.4)
$$E_{ij} = \frac{e_{ij}}{\pi_{ijk}}$$

where

- e_{ij} = the number of angler hours for flight i in stratum j, estimated by multiplying the instantaneous count of angler in a flight interval by the interval length (2 hours); and
- π_{ijk} = the proportion of daily angler effort in the 2-hour time interval that the flight i in stratum j occurred in; k defines the set of expansion factors that applies to a particular portion of the river time (non-tidal, and tidal), during a particular period (March 17 to July 6, or July 7 to October 31) and during the particular time of day.

The effort expansion factors π_{ijk} are estimated from angler interview data, and are done separately for:

1. Weekdays and weekends,
2. The two portions of the river sections: (1) Non-Tidal River, and (2) Tidal, and
3. Two periods: (1) March 17 to July 6, and (2) July 7 to October 31 (original temporal strata 1-3 and 4-7).

A similar method of defining the expansion factor (π) from daily angler activity distributions has been used in other studies (see for example Parker 1956; Fraidenburg and Bargmann 1982; McNeish and Trial 1991, Dauk 2000, Dauk and Schwarz 2001, Lockwood et al. 2001). This model-based approach assumes that the activity pattern is consistent across days in each period and geographic area.

The mean daily effort for weekdays and weekends in each spatial (3) and temporal (7) stratum is estimated as

(1.5)
$$\bar{E}_j = \frac{\sum_{n_j} E_{ij}}{n_j}$$

with variance

(1.6) $$\mathrm{var}(\bar{E}_j) = \frac{1}{n_j}\sum_{n_j}\frac{(E_{ij}-\bar{E}_j)^2}{(n_j-1)}$$

where n_j is the number of primary sampling units (PSUs) in stratum j. Each PSU represents a flight on a particular combination of time (day and flight interval) and space (stratum).

Total effort in stratum j, E_j, for weekends and weekdays is estimated by extrapolating the mean daily effort to total days in each category. For example, the total effort for weekdays in stratum j is

(1.7) $$E_{jWD} = WD \times \bar{E}_{jWD}$$

where WD is the total number of weekdays in the period covered, and $\bar{E}_{jWD}$ is mean daily effort (angler hours) for the weekdays in stratum j during the period. An estimator for the variance of the total effort, estimated by equation (1.7), is

(1.8) $$\mathrm{var}(E_{jWD}) = WD^2 \times \mathrm{var}(\bar{E}_{jWD})$$

where $\mathrm{var}(\bar{E}_{j,WD})$ is estimated from equation (1.6). The mean and total effort for weekend days and associated variances is estimated by using the same estimation approach. Because of weather conditions, only one weekend or weekday flight was completed in some months. For weekends, this happened during May in the tidal portion of the river, and during July for both the tidal portion and non-tidal stratum 1. In October, only one weekday flight was completed in non-tidal stratum 1, and in the tidal portion of the river. For these months, we used the mean variance for two neighboring months to approximate the variance of the weekend or weekday effort. Total effort for stratum j is then the sum of weekday and weekend effort,

(1.9) $$E_j = E_{j,WD} + E_{jWE}$$

with variance

(1.10) $$\mathrm{var}(E_j) = \mathrm{var}(E_{jWD}) + \mathrm{var}(E_{jWE}).$$

and relative (proportional) standard error (Jessen 1978)

(1.11) $$RSE(Y_j) = \frac{\sqrt{\text{var}(E_j)}}{E_j}.$$

Targeted effort for a species was estimated approximately by adjusting the aerial effort estimate (1.9) by the proportion of effort targeted for that species (based on the access survey),

(1.12) $$E_{j,T} = Q_{j,T} \times E_j$$

with variance

(1.13) $$\text{var}(E_{j,T}) = \text{var}(Q_{j\,T}) \times E_j^2 + Q_{j,T}^2 \times \text{var}(E_j) - \text{var}(Q_{j,T}) \times \text{var}(E_j)$$

where $Q_{j,T}$ is the fraction of angler hours in stratum *j* targeting a specific species, as determined from interview data.

For logistical reasons, one flight covered either the estuary and non-tidal stratum 1, or river strata 2 and 3. Hence, the non-tidal section of the river is covered in separate, independent, flights in stratum 1 and the pooled strata 2 and 3. We therefore used a stratified estimator to estimate total effort within the non-tidal section of the river, based on two primary strata: (1) Stratum 1, and (2) strata 2 and 3, including East Branch, pooled. Separate estimates for stratum 2, stratum 3 including the East Branch, and for the East Branch alone are included, but were not a focus of this study.

Total number of angler trips by stratum is estimated by dividing the total effort in the stratum by mean trip length,

(1.14) $$\hat{T}_j = \frac{\hat{E}_j}{\bar{L}_j}$$

where

$$\bar{L}_j = \frac{\sum_{n_j} M_{ij}\bar{L}_{ij}}{\sum_{n_j} M_{ij}}$$

The overall total effort (and its variance), as well as the total effort in a particular portion of the river during a time period is simply obtained by summing the efforts and variances across the respective spatio-temporal strata. The same approach was used to estimate the effort by fishing mode (Boat or Shore).

2.3.3 Night effort

We estimate nighttime (9 PM to midnight) fishing effort based on angler interviews from 55 nights shifts that were paired with randomly selected regular PM shifts (1 PM to 9 PM) at sites with medium or high usage levels. Because of the limited number of night samples, we estimated the night effort for the non-tidal and tidal portions of the river for temporal strata 1-3 and 4-7, and across temporal strata. For each paired PM and nigh shift i in a stratum j (geographic and temporal), we estimate the ratio

(1.15) $$\hat{Q}_{ij} = \frac{H_{night}}{H_{PM}}$$

where the effort (H) is the total angler hours for each time period estimated from the completed trip interviews. An estimator for the mean ratio of night and PM effort for stratum j is

(1.16) $$\hat{Q}_j = \frac{\sum_{n_j} Q_{ij}}{n_j}$$

where n_j is the number of paired night and PM shifts in stratum j. The variance for (1.16) is estimated by

(1.17) $$\text{var}(\hat{Q}_j) = \frac{1}{n_j} \sum_{n_j} \frac{(Q_{ij} - \hat{Q}_j)^2}{n_j - 1}.$$

The total effort (angler hours) for night by stratum (non-tidal or tidal) is estimated by

(1.18) $$\hat{E}_{j,night} = \hat{Q}_j \times \hat{E}_j \times \hat{p}_j$$

where $\hat{E}_j$ is the estimated total daytime (7 AM to 9 PM) effort in stratum j based on the aerial survey, equation (1.9), and $\hat{p}_j$ is the estimated fraction of daytime fishing effort that occurs in the PM period (1 PM to 9 PM) based on interview data. Assuming p_j is constant, an approximate variance of night effort (1.18) is based on the estimator for the variance of a product

(1.19) $$var(\hat{E}_{jnight}) = \left[\hat{E}_j^2 var(\hat{Q}_j) + \hat{Q}_j^2 var(\hat{E}_j) - \mathrm{var}(\hat{E}_j)\mathrm{var}(\hat{Q}_j) \right] \times p_j^2$$

with relative (proportional) standard error estimated by

(1.20) $$\frac{\sqrt{\mathrm{var}(\hat{E}_{jnight})}}{\hat{E}_{jnight}}.$$

The limited sample sizes preclude estimates on a finer spatial or temporal scale.

2.3.4 Total Catch and Harvest Estimates

Total catch and harvest by fishing mode is estimated by combining the respective total effort estimates and the catch and harvest rates. An estimator for the daytime total catch (or harvest) for a species of interest in stratum j, Y_j, for a given fishing mode is

(1.21) $$\hat{Y}_j = \hat{E}_j \times \hat{R}_j$$

with variance

(1.22) $$var(\hat{Y}_j) = \hat{E}_j^2 var(\hat{R}_j) + \hat{R}_j^2 var(\hat{E}_j) - \mathrm{var}(\hat{E}_j)\mathrm{var}(\hat{R}_j)$$

The relative (proportional) standard error of estimated total catch (or harvest) is

(1.23) $$RSE(Y_j) = \frac{\sqrt{\mathrm{var}(\hat{Y}_j)}}{\hat{Y}_j}$$

These equations are used for producing separate estimates for boat and shore anglers. The total catch (or harvest) for all anglers and the associated variance is obtained by pooling the catch and harvest estimates, and the variances, for boat and shore anglers. The same approach is also used to estimate total catch and harvest for night fishing, based on mean catch and harvest rates and the estimated total effort for the 9 PM to midnight.