4.0 DISCUSSION

Our use of an access point survey in conjunction with an aerial effort survey produced reliable estimates of daytime catch and harvest for key species targeted by anglers in the Delaware River during 2002. By extending the daytime sampling coverage to 9 PM we were able to also provide good coverage of fishing during the post-sunset period when night fishing activity was most prevalent. We used the access interviews to estimate the fraction of the daily fishing activity that was covered during the count period for the aerial surveys. This model-based approach enabled us to estimate total fishing effort for the period from 7 AM to 9 PM based on the aerial surveys. By combining this effort with the catch and harvest rates from the access survey, we achieved precise estimates of catch and harvest for all but a minor fraction of anglers fishing at night.

For American shad, the estimated total catch based on the original temporal stratification nearly achieved the target precision, with a relative (proportional) standard error (RSE) of 22%. The estimate of total catch based on the monthly post-strata was similar, and had the same precision (RSE=22%), suggesting that the minimal bias was introduced by the post-stratification for this species. By increasing the sampling effort for both the aerial and the access surveys considerably above plan, we nearly compensated for the higher variability in daily fishing effort for American shad that occurred in 2002, as compared to the effort variability found in the 1995 survey. We had used the 1995 survey results in establishing the statistical design of the 2002 aerial survey. During the peak fishing season for shad (April and May) the coefficient of variation (CV) of daily effort measured from the regular aerial counts were 90% in 2002, as compared to 76% for 1995. The original temporal stratification, based on the expected timing of the shad run, was somewhat less effective for estimating total catch of striped bass (RSE=22%). For this species, the monthly post-stratification improved precision, achieving the target precision (RSE=20%). The higher precision for striped bass is likely due to the wide distribution of this species, with catches recorded throughout the Delaware River, and throughout the total study period.

The estimates of total catch and harvest from the monthly post-strata generally were similar to the estimates based on the original temporal stratification. However, we caution that the post-stratification might introduce bias for some species. The reason is that enhanced intercept sampling as well as additional flights were conducted within one of the original temporal strata to cover the peak shad season (temporal stratum 2). The classification of usage levels for the access points, and their selection probabilities, remained constant within the original temporal strata, but not within all the monthly post-strata. It appears that the post-stratification causes little bias in catch and harvest estimates for most species, but for striped bass the sum of the monthly catch estimates was about 12% lower (but not statistically significant) than the total catch estimate based on the original time stratification. If monthly estimates are required for management purposes for this species, we recommend that the estimated monthly proportional catch be applied to the total catch estimated from the original temporal stratification.

Evaluation of effort distribution by fishing mode strongly indicates that boat anglers are under-represented in the access point survey in the tidal portion of the river. The likely reason is that many boat anglers that fish within the tidal stratum return to port below the Delaware Memorial Bridge, or to private harbors that were not included in our sampling frame. In the aerial surveys, many anglers in the tidal area of the river were observed fishing from large (>20 feet), recreational-type boats, especially on weekends. These anglers were included in the aerial count, but were generally not intercepted in the access survey since these larger boats do not use the launch ramps or access points included in the sampling frame. However, we believe that the aerial survey provided excellent coverage of all anglers, including those that were fishing in the survey area but fell outside the sampling frame for the access survey. The use of the aerial effort estimates for boat and shore anglers in the estimation of catch and harvest minimize the effects of under-coverage in the access survey. If the boat anglers that return to port within the survey area have similar catch and harvest rates as the anglers that return to sites outside our survey area, then the estimated total catch and harvest for boat anglers will have minimal, if any, bias. We conducted separate estimates for boat and shore anglers, and then pooled them to obtain total estimates across fishing mode. Pooling of anglers across fishing modes within primary sampling units, in contrast, would result in biased overall catch rates for the tidal stratum because boat anglers were under-represented in the access survey.

The zero catch estimated for the East Branch may not be reliable because it is based on very few angler interviews. In this portion of the river, many private access sites were outside our sampling frame, and the public access points to the river are not as well defined as for other portions of the river. Most of the land bordering the East Branch is privately owned, and fishermen must acquire permission from the landowners to gain access to this portion of the river. Such restricted access is likely to limit the angler effort. The approximate total angler effort estimated for the East Branch based on the 2002 survey (11,769 hours) is about half of the estimated effort from April 1 to September 30 in 1999 (20,273 angler hours), based on the Delaware River Tail Water Creel Census (Mcbride 2002). However, because confidence limits associated with these estimates could not be reliably estimated it is not possible to determine if they are statistically different. The number of angler trips could not be estimated separately for the East Branch because no information was available on the average trip length. The overall study design for the 2002 Delaware Creel Survey were optimized with respect to American shad and striped bass, with the sampling effort allocated uniformly throughout the Delaware drainage. The limited sampling coverage, and the low number of anglers intercepted preclude reliable estimates of catch rates specific for the East Branch. Because of diffuse angler access in the East Branch, a type of roving survey (Pollock et al. 1994) would be more appropriate than the access survey for estimating catch and harvest rates. The roving survey is also an on-site intercept design, and is typically conducted by boat to contact boat anglers and by foot to contact streamside anglers. In the East Branch, the use of canoes might be effective for contacting boat and shore anglers. The use of canoes would allow the counting and interviewing of anglers regardless of were their fishing trips began. Because of the many private access areas, some shore anglers may not be contacted if the roving survey is conducted by foot. The statistical analysis of roving surveys is more complex than for access surveys because interview data

mostly are taken from anglers who have not completed their fishing trips. Robson (1991) provides a summary of statistical issues related to roving surveys. Angler effort in the East Branch can be estimated from aerial surveys, as for this study, or by scheduling additional roving surveys for counting anglers.

The shifts that covered the time from 9 PM to midnight, although limited in number, suggested that the anglers fishing at night catch minimal, if any, shad and river herring. No catches of American shad, river herring or hickory shad were reported by anglers interviewed after 9 PM. The estimated total catch of striped bass during night, however, was substantial, representing about 12% of the estimated daytime catches. It is problematic to achieve reliable estimates of total catch and harvest at night (9 PM to midnight). All anglers that completed their trips after 9 PM intercepted in this study had started fishing before 9 PM. Thus, it was not feasible to obtain unbiased estimates of catch rates for the period from 9 PM to midnight. Catch rates for anglers that completed their trips after 9 PM are not necessarily representative for night fishing because a portion or all of the catches could be taken before 9 PM. Another potential source of bias is that night sampling was limited to access sites with medium and high usage levels to maximize the number of interviews for a given survey cost. It is likely that the fraction of anglers fishing after sunset is higher for access sites with high usage than for smaller, more remote access sites. Anglers were seldom encountered after sunset at low usage sites. One way to obtain accurate estimates of total catch and harvest at night in future surveys would be to extend all PM sampling to midnight. The distribution of fishing effort for the period from 7 AM to midnight based on interview data could then be used in conjunction with the aerial survey to estimate total effort for this period, using similar techniques employed in this study to cover the fishing from 7 AM to 9 PM.

While the design employed in this study is much more rigorous and comprehensive than the designs of the two prior surveys conducted in 1986 and 1995, the findings from those studies provide benchmarks against which we can evaluate the findings for 2002. Our estimate of total effort in the non-tidal section of the Delaware River for March 17 through May (152,498 angler hours) is approximately half the estimated effort for the months of April and May in the 1986 and 1995 surveys (299,597, and 337,571 angler hours, respectively; Miller and Lupine 1986; 1996) (Figure 4-1). However, the distribution of fishing effort by mode (based on aerial surveys) was similar in all three years. In 1986 and 1995, boat anglers accounted for 77% of the total effort in the non-tidal river in both years. In this survey, boat-angler hours accounted for 80% of the total effort in the non-tidal section. The mean length of an angler trip in 2002 was about 3.5 hours, as compared to 4.5 hours and 4.9 hours in 1986 and 1995, respectively. The 2002 estimates of mean trip length, and mean catch and harvest rates by species are based on a large number of interviews (2,357) from a representative sample of access points over time, including those with medium and low usage. The previous surveys were primarily conducted at access points in River Strata 1 and 2 with high usage level, and thus may not be representative of the mean trip length, and mean catch and harvest rates for all angler trips in the non-tidal river.

It is possible that the lower effort, shorter trips, and the higher variability in daily effort in the non-tidal portion during 2002, relative to 1986 and 1995, is related to differences in river flow patterns during spring among those years. As was already discussed, 1995 fishing effort was the highest of the three years in which surveys has been conducted (Figure 4-1). USGS Delaware River flow data from the gauge at Trenton, New Jersey (Figure 4-2) shows substantial differences in river flow for 1986, 1995 and 2002. In 1986, the mean daily river flow at the Trenton gauge exceeded the historical mean on 6 days in April and 7 days in May, while the 2002 mean daily river flow exceeded the historical mean one day during April and twenty days during May. The periodic increases in river flow during the spring of 2002 probably accounted for a portion of the decrease in fishing effort compared to the effort of the previous surveys for the same period. However, the aerial angler counts suggest that the 2002 fishing effort was substantially less than for the two previous surveys, even during the periods when river flows were suitable for fishing.

Our estimate of total catch of American shad in the non-tidal River from March 17 through June 2002 was also substantially lower than the 1986 and 1995 estimates, even though our estimate covers a longer fishing period, and includes fishing trips completed between 7 AM to 9 PM, as compared to 7 AM to 7 PM in previous surveys. This year's total catch of American shad during daytime (35,281 fish) represents 42% of the estimated catch for 1995 (83,141 fish), and 63% of the estimated catch for the 1986 (56,320 fish) (Figure 4-3). The lower catch of American shad in 2002 appears to be driven primarily by lower total effort, and not by lower catch rates. The 2002 catch rate (0.20 fish per hour) for American shad in the non-tidal section of the river was remarkably similar to the 1986 and 1995 catch rate estimates (0.19 and 0.25 fish per hour, respectively). Conversely, we saw substantial differences in the harvest rate among the three years. The harvest rate we documented for 2002 (19% overall) is about a third of the estimated 1986 harvest rate (49%), but is very close to the estimated harvest rate for 1995 (20%) (Figure 4-3).

The reported number of bluegill caught by anglers in the non-tidal portion of the Delaware River was nearly ten times higher than the reported catch of redbreast sunfish. This result is possibly biased because of species misidentification. It is likely that many interviewed anglers reported catch of sunfish species (*centrarchids*) as bluegill. A large portion of the reported bluegill catch was released before the species identification could be confirmed by the creel agents, and thus the reported catch is based upon the angler's best judgment and description. Review of the Pennsylvania Fish and Boat Commissions Fisheries assessment database (primarily based on electro-fishing surveys) revealed that in the non-tidal Delaware River redbreast sunfish outnumber bluegill by twenty to one. It is the feeling of some state biologists that due to the agents inability to observe fish caught and released that redbreast sunfish catch may have been misreported as bluegill because of their similar appearance. Bluegill is a common sunfish in lakes and ponds in the mid-Atlantic. However, we note that the catch of bluegill relative to readbreast sunfish in a hook-and-line fishery may significantly differ from the ratio of their absolute abundances because of gear selectivity.

Previous creel surveys on the Delaware River (Miller and Lupine 1986; 1996) focused on the American shad fishery in the non-tidal river, and did not cover the Estuary. Hence, we do not have any basis for comparing current total catch and harvest of the other target species with catches in previous years. However, this study clearly demonstrates that substantial catch of striped bass occurs both in the tidal and non-tidal sections of the river. The precise estimate of total catch for striped bass (RSE = 20%) based on monthly post-strata is likely to be a result of the wider distribution of this species throughout the river, and fishing throughout the study period. American shad are primarily caught in the non-tidal section during a limited season (none were caught after June). Hence, the number of interviews for estimating catch rates for American shad was substantially lower than for striped bass, contributing to the lower precision of the shad catch and harvest estimates. The variance in the estimated total catch for American shad and striped bass for the current sampling effort is highly influenced by the larger than normal (relative to the 1986 and 1996 surveys) variation in daily fishing effort in the non-tidal portion of the river, likely caused by the large fluctuations in mean daily river flow during the peak angler season.

The fishery for river herring appears very interesting. Comments from creel clerks suggest that only small number of fishermen target river herring. They often had elaborate means of keeping the river herring alive (e.g., re-circulating water tanks on the backs of pickup trucks) and used or sold the herring as live bait for striped bass. This is reflected in the relative high percentage of the catch that is kept as harvest (average 65%; Table 3-8).

As was observed in Section 3, very few hickory shad were reported caught. However, note that because the fishery on the Delaware River is so strongly catch-and-release, documentation of catch relies strongly on the reliability of the species identification by the angler. We did not have any means of independently verifying the species identification of released fish. We believe that the identification of harvested species by creel clerks generally were reliable, particularly for the four target species. A majority of the creel clerks were avid fishermen, and members of the Delaware River Shad Fisherman's Association, and thus had a good familiarity with the target species. In addition, a training manual was developed for this study, and all clerks received training in interview techniques and in the species identification of Delaware River sportfish (Anonymous 2002).

In general, the precision of harvest estimates for all species is lower than for catch estimates. The reason for this is that the only a small fraction of fish are harvested. Furthermore, the fraction harvested by trip exhibits large fluctuations.

The estimation of effort, catch and harvest rates by targeted species is an area that needs more research. The approximate estimates provided in the appendices should be interpreted with care, especially when produced for individual spatio-temporal strata. The reason is that the estimates for some spatio-temporal strata are based on a limited number of interviews in which anglers identified a target species. In some cases, the precision of estimates could not be

quantified because of sample size limitations. In addition, the allocation of effort to a single species is problematic for trips where multiple species were targeted.

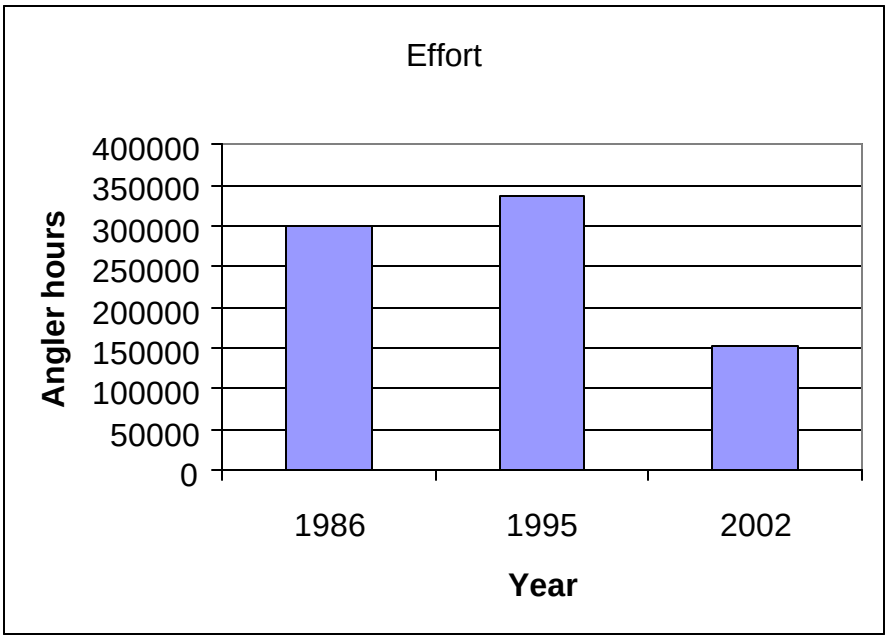

Figure 4-1. Estimated effort by boat and shore anglers in the non-tidal portion of Delaware River from March 15 to May 31.

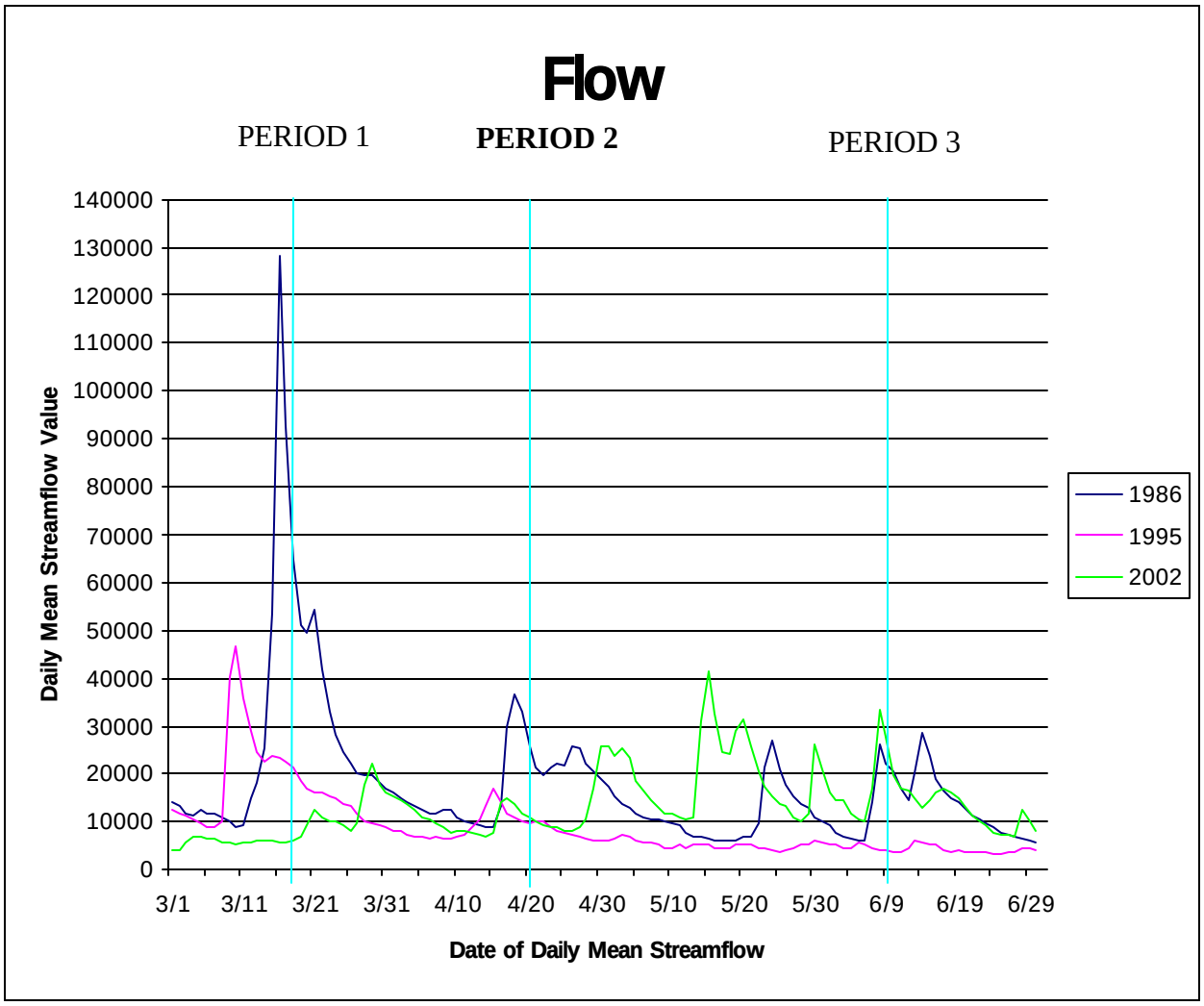

Figure 4-2. Daily mean streamflow value recorded at U.S. Geological Survey gauging station 01463500 at Trenton, NJ.

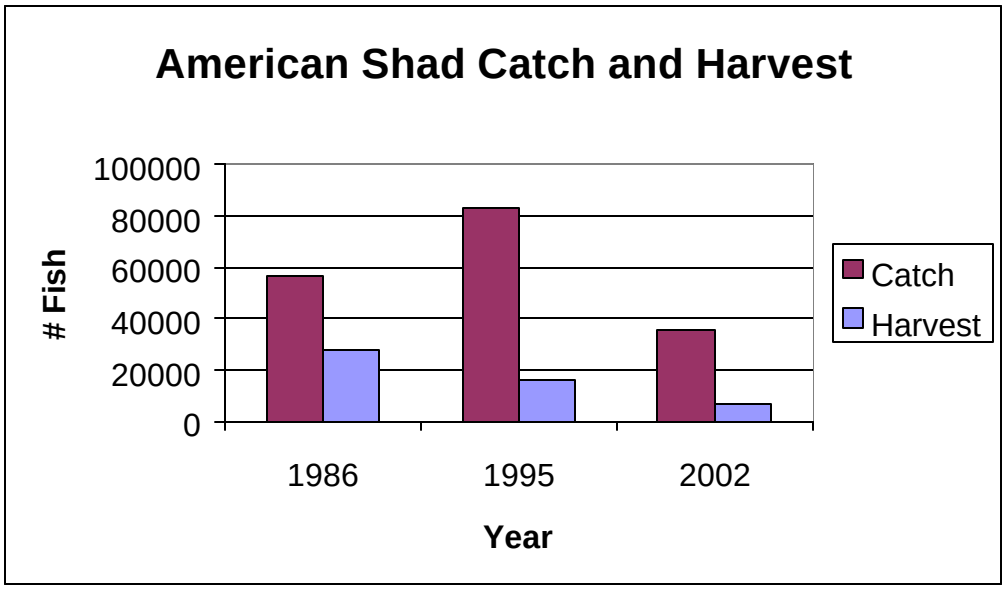

Figure 4-3. Estimated total catch and harvest of American shad in the non-tidal section of the Delaware River from March through May.

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