

**2007
STATEWIDE COMMERCIAL MUSSEL
REPORT**



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INTRODUCTION

This report contains mussel population and commercial harvest data collected during 2007, and compares harvest trends during the period 2003-2007. Activities described in this report were partially funded by the fee on commercial mussels and license sales associated with the commercial mussel program. Any person, firm or corporation who purchases or otherwise obtains freshwater mussels taken from Tennessee waters is required to pay the Tennessee Wildlife Resources Agency (TWRA) the amount equal to \$0.0145 per pound of mussel shells or \$0.0124 per pound of mussel (shell with meat) purchased or obtained. During 2007, TWRA received the following revenues associated with the sale of commercial musseling licenses and collection of the shell fee:

<u>TYPE LICENSE</u>	<u>NUMBER</u>	<u>REVENUE</u>
Resident Commercial Musseling	307	\$ 61,400
Non-Resident Commercial Musseling	27	\$ 27,000
Wholesale Mussel Dealer	15	\$ 7,500
Cultured Pearl	<u>1</u>	<u>\$ 1,000</u>
Total License	351	\$ 96,900
Shell Tax (accrued Jan. 1 to Dec. 31, 2007)		<u>\$ 33,924</u>
TOTAL REVENUE		<u>\$130,824</u>

Adequate funding has been a problem for the commercial mussel program for more than a decade due to the decline in license sales. TWRA has experienced a drastic decline in the number of harvester licenses sold since the fee was levied (down from average of 1,440/year during 1990-95 to 262/year for last 5 years). Costs of annual harvester's licenses have increased from \$125 to \$200 for residents and from \$250 to \$1,000 for non-residents, yet license revenue remains inadequate to fund the program. The current shell fee paid to TWRA by the shell companies has not increased since it was levied in July 1991. While it was originally intended to provide a mechanism for tracking annual shell harvests, increasing the fee has now become the logical method to fund the program. In order to balance the commercial mussel program's funding deficit, TWRA's Commercial Mussel strategic plans have recommended an increase in the shell fee for more than 10 years.

The majority of freshwater mussel shells harvested in Tennessee were shipped to Japan, China and other countries where they were cut and polished into beads. These beads were inserted into marine oysters and freshwater mussels to form cultured pearls. According to Olson (2006), Tennessee continues to lead the United States in pearl and mother of pearl shell production. Tennessee's commercial mussel shell industry accounted for 71% of the total shell harvest value and 21% of the total value of all natural gemstones produced in the United States during 2006 (latest figures available from USGS).

Through the early 1990's, commercial musseling employed as many as 3,000 people in Tennessee. However, biological problems affecting the survival and production of Japan's pearl producing oysters combined with other factors affecting the cultured pearl industry, Japanese and U.S. economies, reduced the market for Tennessee's mussel shells beginning in 1997. Some shell exporters chose to ship only their highest quality shells during this period creating a

narrower market with a lower demand for the standard quality shells that contributed to lower domestic wholesale shell prices. The decreased demand and lower prices paid for mussel shells caused a substantial decline in the number of mussel harvesters working in Tennessee. Since 2003, Tennessee's shellfishery has stabilized at a lower level where on average, less than 300 harvesters take less than 1,500 tons per year.

During the last century, the harvest of mussel shell has fluctuated according to market demands. Mussels were first harvested for the natural pearls they can produce, then as a source of raw material for buttons and mother of pearl inlay, and finally for the production of cultured pearl nuclei. As of 2004, the estimated value of pearl production by market share was: White South Sea cultured pearls (Australia, Indonesia, the Philippines, Myanmar) 35% US\$ 220 million, Freshwater cultured pearls (China) 24% US\$ 150 million, Akoya cultured pearls (Japan, China) 22% US\$ 135 million, Tahitian cultured pearls (French Polynesia) 19% US\$ 120 million, total estimated pearl production US\$ 625 million (PEARL OYSTER 2006). Each rise and fall in cultured pearl demand has affected the quantity and quality of the mussel shell resource available for harvest. In 2004, 2005 and 2006, China increased its use of shell bead pearl nuclei resulting in modest wholesale shell price increases and corresponding higher shell harvests.

Tennessee's quality commercial mussel stocks were primarily limited to Kentucky Reservoir (Hubbs 2007a). Kentucky Reservoir stretched 184.3 miles from Pickwick Dam at Tennessee River mile (TRM) 206.7 in Hardin County, TN to Kentucky Dam at TRM 22.4 near Gilbertsville, Kentucky. The Tennessee portion contained 1,971 shoreline miles and approximately 110,990 surface acres, ending at TRM 49.2 in Stewart County, TN. The main channel and over-bank widths varied from 0.25 to 2 miles. Information gathered from wholesale mussel dealers showed that most of the annual harvest was reported from Kentucky Reservoir. No other Tennessee waters appeared to contain mussel populations of sufficient quality, size and diversity to sustain a continuous commercial harvest.

Some wholesale mussel dealers did complain about the lower quality of shells being produced in the northern half of Kentucky Reservoir and the increase in "snoot nosed mapleleaves" (*Quadrula apiculata*). They described the shells as having a "river grade" appearance, indicating that the periostracum in the umbonal area of the shell was damaged or missing, and the shells had a generally rougher exterior. The increased abundance of lower quality shells from this region could be attributed to the accumulation of Asian clam (*Corbicula fluminea*) shell shards, which now compose the top substrate layer on many of the clay bars where mussels are harvested (personal observation). The periostracum of mussels growing in these shell shards is worn away as the mussel moves through the substrate exposing the shell to degradation through dissolution, erosion, and staining.

During the first week of July, 2007 a mussel die-off was reported from the upper portion of Kentucky Reservoir, below Pickwick Dam between river miles ~201 to 190 by TWRA wildlife officers and a commercial shell dealer, Mrs. Janice Doyle of Adamsville, TN. Commercial divers had reported to her that mussel bodies were floating on the surface and related that it was affecting mostly ebony's including sub-legal sized individuals. By July, Tennessee was experiencing a severe drought, with much of the state 50% below normal rainfall levels, and the Tennessee Valley Authority produced less hydroelectricity than usual due to reduced river flow from low water levels and minimal rainfall. These drought conditions also

increased the growth of aquatic vegetation growing in the reservoir, coontail and southern naiad dominated vegetation identified in Kentucky Reservoir, while hydrilla sp. was identified in the middle portion of the reservoir (Broadbent 2007).

Old Hickory Reservoir was also sampled during 2007 to ascertain the status of its mussel resources in relation to altered flows and water temperatures resulting from maintenance operations at Wolf Creek Dam. The reservoir is located on the Cumberland River between Carthage and Nashville, running 97.3 river miles between Cordell Hull Dam (CRM 313.5), Smith County, TN and Old Hickory Dam (CRM 216.2), Davidson County, TN. Substrate ranged from silt to sand, gravel, cobble, and bedrock. Recently, this reservoir has not produced significant quantities of commercial mussel shells due to inconsistency of shell quality and reduced recruitment due to prolonged exposure to cold hypolimnetic releases from upstream reservoirs. Survey efforts were limited due funding constraints and availability of sufficient personnel to complete field studies.

During 2007, commercial musselers were restricted to harvesting only those individuals of the 10 freshwater mussel species listed below. Only individuals that will not pass through a ring with an inside diameter specified for that species as legal in Tennessee may be harvested. All other mussels were required to be returned immediately and unharmed to the bed from which they were taken.

<u>Mussel Species Listed for Harvest</u>	<u>Inside Ring Diameter in inches</u>
Pink heelsplitter (<i>Potamilus alatus</i>)	4.0
Washboard (<i>Megalonaias nervosa</i>)	4.0
River pigtoe (<i>Pleurobema cordatum</i>)	2 5/8
Lake pigtoe (<i>Fusconaia flava</i>)	2 5/8
Mapleleaf (<i>Quadrula quadrula</i>)	2 5/8
Snoot nose Mapleleaf (<i>Quadrula apiculata</i>)	2 5/8
Three ridge (<i>Amblema plicata</i>)	2 5/8
Elephant Ear (<i>Elliptio crassidens</i>)	2 5/8
Monkeyface (<i>Quadrula metanevra</i>)	2 3/8
Ebony (<i>Fusconaia ebena</i>)	2 3/8

METHODS and MATERIALS

The wholesale value of the mussel harvest was calculated by surveying active commercial mussel dealers' monthly records, and reviewing TWRA mussel receipts to collect price data for each shell category. Wholesale mussel receipt reports provided by TWRA's Data Management Division were used to calculate the total commercial harvest volume, species distribution and percent size composition (Clouse 2008). In 2007, the commercial mussel shell category known as "lake mix" was composed of the following species: threeridge (*Amblema plicata*), snootnose mapleleaf (*Q. apiculata*), mapleleaf (*Q. quadrula*), and lake pigtoe (*Fusconaia flava*). Multiplying the average annual price per pound by the estimated number of pounds harvested and then summing the categories derived the annual harvest value.

Commercial mussel population assessments were conducted on Kentucky Reservoir because it contains the most important commercial mussel beds. On Kentucky Reservoir, several techniques were employed to collect mussels from a variety of habitat types. Major collection efforts were directed toward sampling areas frequented by commercial harvesters. Because mussels exist as clumped, contiguous aggregations, stratified sampling techniques were employed. The reservoir was divided into three sections based on major hydrological characteristics. Specific sample locations were selected based on presence of significant mussel resources (density, diversity, and harvest activity).

Old Hickory Reservoir on the Cumberland River was also sampled during 2007 to ascertain the status of its mussel resources at five sites within the sanctuary located between CRM 264 to 265.5 and two sites in the Rome Ferry Landing sanctuary. Each collection site was characterized according to location, substrate composition, water depth and any other relevant characteristics. The specific location of each site was recorded by river mile, proximity (left, right descending side or center), and latitude and longitude (determined by a global position system). To aid data interpretation, population metrics were calculated with individual samples pooled for all collection methods and presented for each section.

SCUBA and surface supplied air compressor (Hookah system) were used to conduct surveys and collect samples in deep water environments (reservoirs and mainstream rivers). Before sampling a given area, side-scanning sonar (Hummingbird model 987c) was used to analyze bottom characteristics and detect underwater obstructions that might impair collection efforts. In shallow water where samples could be collected by snorkeling or hand picking the aerial extent of the mussel bed (shoal) was visually determined. A representative sample was collected from the bed. Species composition was determined with timed collections. Effort was directed toward the collection of commercial mussel species consistent with methods employed by commercial mussel harvesters utilizing surface-supplied air diving equipment. Shallow water (<20 ft depth) site assessments consisted of ten tethered dives with five minutes of active collecting per sample replicate. Because a larger sample size could be attained during timed collections, this was the preferred method. However, sites where depths were greater than 20 ft or swift current rendered this method impractical; timed dives of varied duration were employed to generate catch per unit effort data (CPUE).

All mussels collected were placed in mesh bags, brought to the surface for examination, and either retained for additional analyses or returned to the bed after enumeration. Mussels collected during population surveys were identified to species, enumerated, and recorded. Commercial species were measured (using rings of 2 3/8, 2 5/8 and 4.0 inches inside diameter according to current size limits for each species) to determine size distribution. Data were entered into a computer spreadsheet to tabulate species composition, size distribution, and relative abundance parameters. The legal-sized portion of the population was determined for all commercial species.

The mussel die-off downstream of Pickwick Dam was sampled at four sites during August 1 to 2, by taking 10 random quadrat (0.25m²) samples per site. All live and fresh-dead Unionid mussels and zebra mussels were removed from each quadrat to a depth of four to six inches, depending on substrate embeddedness, placed in mesh bags and brought to the surface for examination. Fresh dead mussels were identified as those with at least some tissue still

attached to the shell.

RESULTS and DISCUSSION

Commercial Shell Market Assessment

The shell industry in Tennessee has harvested 27,473 tons (54,945,404 lb) of mussels with an estimated wholesale value of \$61,643,507 since 1992 (Table 1). The export value of this harvest is estimated to range \$184,930,520 to \$308,217,540 (three to five times the wholesale value). During the same period, TWRA received \$2,111,185 in revenue (\$1,404,340 from license sales and \$706,845 from the fee on mussel shells) only 3.42 % of the wholesale value of the resource. These figures indicate sufficient value exists in the commercial shell industry to provide improved funding for its management.

While the shellfishery volume has declined since the 1990's, more recently shell prices have begun to increase (average up \$0.42/lb since 2003), and recent annual harvests are averaging 2.8 million pounds per year. Increasing the shell fee is the most practical way to fund the management of this unique resource. Given current harvest and license trends, the shell fee should be set at \$0.10 /lb (yield ~\$280,000/year) to balance the current program cost of ~\$275,000/year and recoup past funding deficits.

During the late 1980's through 1995, intense harvest pressure on Kentucky Reservoir's mussel stocks resulted in mussels being taken almost immediately after attaining legal size. TWRA's concern for declining percentages in the adult portion of mussel populations led to recommendations to increase the legal size limit on washboards from 3 ¾" to 4", and increasing the size limit on lake mix shells from 2 5/8" to 2 ¾". In April 1999, the Tennessee Wildlife Resources Commission voted to increase the size limit on washboards from 3 ¾" to 4", staggering the increase in 1/16" increments over a four-year period beginning in 2000 and ending in 2003 when the size limit reached 4". The size limit on lake mix shells remains at 2 5/8", however reduced demand and lower harvest pressure has allowed some expansion of the 2 ¾" size class.

Tennessee's freshwater mussel shell market volume decreased slightly during 2007 (Figure 1), however higher prices paid for 2 5/8" and larger shells increased the total market value (Figure 2). Monthly price data obtained from wholesale mussel dealers and TWRA mussel receipts were tabulated to compute average price paid for the major categories of shell. After harvest, shells are normally sized and grouped into the categories listed in Table 2. Shell values were only reported for green (live mussels), because the wholesale market for open (dead) mussel shell was very limited.

Information from TWRA's wholesale mussel receipt system, wholesale mussel dealer summaries, in addition to the wholesale price survey were used to compute the volume and value of the reported mussel harvest (Table 3). Tennessee wholesale mussel dealers reported purchasing 2,505,205 pounds (1,253 tons) of mussels from Tennessee waters during 2007. The harvest value was estimated at \$2,378,398 compared to \$2,336,027 paid for 2,800,901 pounds (1,400 tons) in 2006. Higher average prices were paid for the larger sized categories of mussels, and buyers were actively trading during the summer, thus the harvest level was similar to 2006. Increased prices attracted additional harvesters, the number of licensed harvesters increased from

250 in 2006 to 334 in 2007 (Table 4). The average income per harvester decreased from \$9,344 to \$7,121 due to the increased number of licenses sold (Figure 1).

Decreased demand for smaller sized shells in 2007 drove the average price of 2 3/8" ebony shells down \$0.13 from \$0.61 to \$0.48/lb, while the 2 5/8" increased \$0.14 from \$0.74 to \$0.88, and the 2 3/4" increased \$0.11 from \$0.89/lb to \$1.00/lb. Greater demand for lake mix shells drove the 2 5/8" price up \$0.28 from \$0.97 to \$1.25/lb, while 2 3/4" lake mix shells increased \$0.14 to \$1.25/lb (Figure 2). Minimum sized 4.0" lake washboard (*Megaloniaias nervosa*) prices increased \$0.22 to \$1.28/lb.

The lower priced 2 3/8" and 2 1/2" (ebony and monkey-face *Q. metanevra*) categories combined, comprised 33% of the harvest weight but only 17% of the total value. Ebony shell in the 2 5/8" to 2 3/4" size comprised 15% by weight and 15% by value of the 2007 harvest. All size categories combined, the ebony shell produced 48% by weight and 32% by value of the harvest. Increased landings of lake mix categories (2 5/8" and 2 3/4") produced 47% of the harvest weight and 62% of the total value (Table 2). Lake grade washboards 4.0" and larger produced only 5.02% by weight and 6.77% by value of the harvest. River grade washboard production decreased from 12,509 in 2006 to 360 pounds in 2007. The market for colored shells (pinks) was very limited, producing only 0.02% by weight and 0.03% by value. These shifts in species and sizes of commercial shell landings were attributed to a general increase in market demand for lake mix shells. Weighted average wholesale price paid to harvesters (\$0.95/ lb in 2007), has maintained a steady increase during the last five years (Table 4).

According to wholesale dealer receipts, 98.75% of the 2007 Tennessee mussel harvest came from Kentucky Reservoir (Appendix I). An analysis of Kentucky Reservoir's harvest data and size distribution by species group showed 68% by weight of the ebony shells were between 2 3/8" and 2 1/2", compared to 32% at 2 5/8" and larger. Increased harvest pressure on the lake mix group reduced the weight of 2 3/4" shells (from 58% in 2006) to 37%, with the 2 5/8" increasing (from 42% in 2006) to 63%. Lake grade washboards were almost entirely made up of 4.0" grade shells with only five pounds reported as ≥ 5.0 ". Mussel shells imported from other states equaled 37,030 down from 219,072 pounds in 2006, and comprised 1.5% by weight of the total Tennessee market.

Because of their longevity and relatively slow growth, commercial mussel populations subjected to intense harvest pressure are susceptible to being "cropped off" (very low percentage of legal-sized and larger individuals present in a population). When this occurs, the shell industry has to fill orders with higher percentages of the more abundant, smaller categories of mussel shell. Conversely, when harvest pressure is reduced, viable commercial mussel populations recoup allowing increased recruitment into the larger size classes. Variation in the size distribution of the shells harvested can also be attributed to shifts in demand for different shell products. This is evident when comparing the distribution of the percent weight by size category data during 2003 to 2007. During this period, the combined percent weight of the 2 3/8" and 2 1/2" categories fluctuated from 33% to 41%. The shell industry has experienced difficulty meeting the market demand for the 2 3/4" lake mix (down to 21% in 2007) and legal sized washboard shells (≥ 4 ") which remained $\leq 7\%$ of the total harvest weight (Table 5).

Mussel Population Assessments

The Tennessee portion of Kentucky Reservoir was sampled at nine commercial mussel sites (eight open water sites and one site on the closed to harvest mussel management area) during 2007. Eighty discrete five-minute timed samples were taken from open harvest waters and 10 from closed harvest waters: for a total of 450 minutes of collection effort netting 3,209 mussels. Thirty-three freshwater mussel (Unionid) taxa were recorded, during all 2007 survey activities on Kentucky Reservoir along with two exotic bivalve species (Asian clam, *Corbicula fluminea* and zebra mussel, *Dreissena polymorpha*) (Appendix II).

Section I – Tennessee River Mile 49.2 to 82.5. Paris Landing/White Oak Creek. This section is dominated by reservoir over-bank habitat with silt, sand, Asian clam shells, and clay substrates, with gravel along the shorelines. During years of high commercial shell demand, mussel harvest pressure has reached ten harvesters per river mile. Harvest pressure is spread across the shallow (<10 - 15 ft) bars, shoreline habitats, old creek channels and river channel wall (depth >20 - 50 ft). Commercially valuable mussel species are found amongst the clay and gravel bars, scattered in the bays, along shorelines, and more concentrated near and along sloping channel walls. Densities rarely exceed ten mussels per square meter away from the main channel. Mussel recruitment is primarily limited to areas with well-established mussel populations. Mussels in this section of the lake exhibit the fastest shell growth rate, but overall densities are low. Few recent records of endangered mussel species are known from this section.

Three productive sites were sampled during 2007, producing 1,110 individuals representing nine of the ten commercial mussel species (Table 6). The five most abundant species are all commercially important; the ebony shell (*F. ebena*) 48%, washboard (*M. nervosa*) 19%, threeridge (*A. plicata*) 16%, and mapleleaf 13% (*Q. quadrula* and *Q. apiculata* combined). Approximately 31% of the commercial species collected were legal-size or larger, up from 20% in 2006. Timed sampling resulted in an average collection rate of 7.40 mussels per minute down from 8.02 in 2006. The zebra mussel collection rate increased dramatically from 0.04 per minute (four individuals) in 2006 to 1.6 per minute (240 individuals) in 2007 (Figure 4). The Asian clam was abundant at all sites, with their dead shells comprising a majority of the top layer of substrate.

Section II - TRM 82.5 to 111.1. Harmons Creek/New Johnsonville/Duck River. This section is a transitional area with both lotic and lentic habitats. Mussel harvest pressure has reached ten harvesters per river mile. Harvest pressure is dispersed over the bays, submerged creek channels, over-bank bars, channel walls and old riverbed at depths from one to > 50 ft. Mussel populations are dispersed throughout the varied habitats, and reach maximum densities (> 100 mussels per square meter) in the river channel. Population recruitment is high in and near the main river and creek channels resulting in colonies expanding from these habitats. Substrate composition varies from silt, sand, clay, to gravel, Asian clam shells, cobble, and bedrock. Several recent endangered mussel species records (pink mucket, *Lampsilis abrupta*) exist for this section (Parmalee and Bogan 1998).

Four sites were sampled during 2007; three in waters open to commercial harvest and one from closed waters. Eight of the ten commercial mussel species were collected from the open water sites totaling 961 individuals during 100 minutes of sampling effort. The collection rate

was 6.41 mussels per minute up from 6.06 in 2006. The closed harvest site yielded eight of ten commercial species during 50 minutes of sampling effort totaling 451 individuals with a CPUE of 9.02 up from 8.24 in 2006 (Table 6). Two commercially important species composed 76% of the open water population (threeridge 21%, and ebony 55%), followed by washboard 21%, and mapleleaves (4%). Heavy harvest pressure on the ebony shell and increased sample size (three open water sites instead of one) contributed to a decrease in the legal-sized portion from 82% in 2006 to 10% in 2007. Washboards collected were 4% legal-sized and comprised 14% of the sample from open waters compared to 29% legal-sized but only 2% abundance from closed waters. Approximately 15% of all commercial species collected from open waters were legal-sized or larger compared to 34% in 2006, and 36% from the closed water site. It is understood that localized mussel poaching along with high juvenile mussel recruitment on the closed water site depressed the washboard and other commercial species legal sized portion of the population (F. Couch, personal communication). The zebra mussel collection rate increased dramatically from zero per minute (zero individuals) in 2006 to 0.6 per minute (92 individuals) in 2007 (Figure 4). The Asian clam was abundant at all sites, with their dead shells comprising a portion of the top layer of substrate.

Section III - TRM 111.1 to 206.7. Located south of the mouth of the Duck River to Pickwick Dam. Lotic habitats dominate this section. Harvest pressure averages less than one harvester per river mile. However, harvest pressure can be intense around the shallow (10 - 25 ft deep) sand/gravel bars and around mainstream islands. Some harvest also occurs in the larger bays of this reach. Mussel populations are primarily found outside the navigation channel when depths are less than 40 feet, in and near the old river channel, and along the shorelines. Maximum densities (> 100 mussels per square meter) and recruitment levels are found outside the navigation channel in the shallow gravel deposits on the inside river bends and at the head and tail areas of mainstream islands. Many recent endangered mussel records for several different species exist for this section (Hubbs 2008).

Two commercial mussel population assessments were performed in this section during 2007, one along the head of Swallow Bluff Island (~TRM 170.3) and one in the back shoot of Eagle Nest Island (~TRM 164.0). Seven of the ten commercial mussel species were collected, totaling 689 individuals. The collection rate was 6.89 up from 4.43 mussels per minute in 2006, but only 13% were legal size or larger compared to 21% previously. Ebony shell comprised 78% of the sample population followed by monkeyface (12%). Fresh dead mussel shells from an earlier mussel die-off were evident at both sample sites. One five-minute collection of only fresh dead individuals at the Eagle Nest Island site resulted in a CPUE of 14.8 fresh dead mussels per minute of which 82% were Ebony. The Asian clam was abundant at all sites, with their dead shells comprising a portion of the top layer of substrate. Seven zebra mussels were encountered during 100 minutes of sampling (0.07 per minute) compared to 23 (0.23 per minute) during 2006. These results conflict with those collected two weeks earlier approximately 30 miles upstream during assessment of a mussel die-off. Quantitative sampling at four sites below Pickwick Dam between river miles 203 to 195 resulted in zebra mussel density estimates of two to 28 per square meter increasing in a downstream direction (Figure 5).

A mussel die-off occurred in this section during July and August. Mussel soft parts comprised mainly of gravid female ebony were observed floating on the surface and lining the

shore between river miles 190 and 203. Four sites were quantitatively sampled below Pickwick Dam between river miles 203 to 195 (Table 7). Fresh dead shells were readily visible on the substrate surface and were dominated by mature aged ebony; however, some sub-adult mussels were also affected. The highest percentage (17%) of fresh dead mussels occurred at TRM 203 the upstream most location, which had the lowest mussel density (Figures 6 and 7).

After being notified of the ongoing mussel die-off below Pickwick Dam, TVA began pulsing flows through the dam once every four hours on July 20th to help improve water quality downstream, previously the dam had released zero flow between the hours of 7pm and 11 am. During mussel kill assessment sampling conducted August 1 and 2, 2007, 13 commercial dive boats were harvesting mussels between river miles 195 to 200. Two commercial harvesters interviewed reported 50 to 75% of the shells they were taking were dead.

Section I, II, & III combined - Reservoir wide sampling of open waters resulted in the collection of 2,758 mussels representing the ten commercial taxa at an average collection rate of 6.9 mussels per minute, 21% of which were legal sized or larger down from 23% in 2006. It was noted that only one percent of the washboards sampled were of legal size (5 of 344), down from two percent in 2006. The low percentage of legal sized washboards was attributed to the impact of harvest pressure and previous years (2001 to 2004) illegal harvest and sale of sub-legal sized washboards documented by TWRA and USFWS law enforcement investigations (F. Couch, personal communication). Commercial harvest of Tennessee's mussel shells did not exceed 2,000 tons during 2003 to 2007. Market fluctuation and lower demand has allowed mussel populations to recover somewhat from more than a decade of intense harvest activity. However, the last five consecutive years of harvest pressure above 1,200 tons per year has caused a localized decrease in the percentage of legal-sized mussels in the Kentucky Reservoir population (Figure 3).

The ebony shell is the foundation species of Tennessee's commercial shell market. On average, the ebony shell comprised 53% by weight and 42% by value of the harvest during the last five years. Under the continuous harvest pressure, the legal-sized population has decreased from 61% in 2005 to 23% in 2007. The legal-sized washboard population has remained very low during the last five years. It averaged less than 3% legal-sized shells during 2003-07, while averaging 5% by weight and 7% by value of the harvest. The 1/16" per year (2000 to 2003) incremental size limit increase, and illegal harvest of smaller than 4.0" washboards during 2001 to 2004, are considered contributing factors to its decline in the harvest.

The lake mix group (threeridge, mapleleaf, and pigtoe) with legal sizes averaging 21.5% for the period 2003-07, has not been as sensitive to harvest pressure as the washboard. During the last five years, the lake mix group averaged 37% by weight and 47% by value of Tennessee's commercial shell market. However, it has fluctuated between 15% to 26% legal-sized during 2003 to 2007. The inverse relationship between the tons of shell harvested and the percent legal-sized remaining, suggests the washboard population remains overharvested while the ebony and lake mix groups are also affected by sustained moderate harvest pressure (Table 7). Because abundance of the adult portion of the population is negatively correlated with harvest pressure, some populations (washboard and lake mix) remain below the markets demand and the reservoir's carrying capacity. Current size limits appear adequate to protect reproduction; however, previous year's harvests may affect recruitment into the fishery.

Zebra mussels were encountered with greater frequency in 2007 compared to previous years. A total of 339 individuals were collected during 400 minutes of commercial mussel population sampling for a collection rate of 0.8 per minute compared to 27 individuals collected during 2006 (collection rate = 0.08 per minute). Quantitative sampling at four sites below Pickwick Dam between river miles 203 to 195 resulted in zebra mussel density estimates of two to 28 per square meter, increasing in a downstream direction.

Old Hickory Reservoir – On September 5, the Hunter’s Point mussel sanctuary located between CRM 264 to 265.5 was sampled at five sites with depths ranging from 30 to 50 feet for a total of 80 minutes of effort. Water temperature was measured at 70.1°F and dissolved oxygen level of 5.0 mg/l near the bottom. Flow through the reservoir was barely perceptible due to repair work underway on Wolf Creek Dam upstream in Russell County, Kentucky. Divers spent 15 to 20 minutes per site attempting to locate mussels with little success. The sites examined had been covered with three to six inches of silt over what years earlier had been sand and gravel substrate. Only 22 live mussels were located from the five sites during 80 minutes of effort resulting in a CPUE of 0.5 mussels per minute. The river pigtoe (*P. cordatum*) was the most abundant species collected, comprising 63.6% of the sample (Table 8). Five fresh dead individuals were collected, one fragile papershell (*Leptodea fragilis*) and four river pigtoes, along with a relic of the federally endangered catspaw (*Epioblasma obliquata*).

On December 14, the Rome Ferry Landing mussel sanctuary located between CRM 292.5 and Cordell Hull Dam, CRM 313.5, was sampled at two sites where depths ranged from 13 to 20 feet. Surface water temperature was 49 °F; flow was moderately swift (~7,900 cubic feet per second according to TVA river information website, <http://lakeinfo.tva.gov/>) and water clarity was stained with visibility less than three feet due to recent rain. Divers using underwater lights spent 55 minutes of effort to collect 59 individuals representing 8 species including one federally endangered pink mucket (*L. abrupta*) (Table 9). The CPUE was 1.1 mussels per minute; the washboard was the most abundant commercial species collected, comprising 56% of the sample, followed by the non-commercial pimpleback (*Q. pustulosa*). Relic shells of the washboard were abundant in depositional areas of the riverbed. Mussel recruitment in this reach of the Cumberland River has long been suppressed by cold water resulting from the hypolimnetic releases from upstream reservoirs (Wolf Creek, Dale Hollow, and Center Hill). Recruitment was noted for a two species (*Q. pustulosa*, *L. fragilis*), while the rest were represented by older specimens which continue to decline in abundance.

SUMMARY

Work performed under TWRA Commercial Musseling project number 7363 addressed Strategic Plan Problem I. Strategies 1, 2 and 3. License sales and mussel fee revenue associated with the commercial mussel program garnered \$130,824 during 2007. Tennessee’s mussel shell market volume decreased while the value experienced a slight increase during 2007, due to higher prices paid for larger sized shells. Tennessee wholesale mussel dealers reported purchasing 2,505,205 pounds (1,253 tons) of mussels from Tennessee waters during 2007. The harvest value was estimated at \$2,378,398 compared to \$2,336,027 paid for 2,800,901 pounds (1,400 tons) in 2006. Increased prices attracted additional harvesters, the number of licensed

harvesters increased from 250 in 2006 to 334 in 2007.

Decreased demand for smaller sized shells drove the average price of 2 3/8" ebony shells down \$0.13 from \$0.61 to \$0.48/lb, while the 2 5/8" increased \$0.14 from \$0.74 to \$0.88, and the 2 3/4" increased \$0.11 from \$0.89/lb to \$1.00/lb. Greater demand for lake mix shells drove the 2 5/8" price up \$0.28 from \$0.97 to \$1.25/lb, while 2 3/4" lake mix shells increased \$0.14 to \$1.25/lb. Minimum sized 4.0" lake washboard prices increased \$0.22 to \$1.28/lb. The market for colored shells (pinks) was very limited, producing only 0.02% by weight and 0.03% by value. These shifts in species and sizes of commercial shell landings were attributed to a general increase in market demand for lake mix shells. Weighted average wholesale price paid to harvesters (\$0.95/ lb in 2007), has maintained a steady increase during the last five years.

According to wholesale dealer receipts, 98.75% of the 2007 Tennessee mussel harvest came from Kentucky Reservoir. An analysis of Kentucky Reservoir's harvest data and size distribution by species group showed 68% by weight of the ebony shells were between 2 3/8" and 2 1/2", compared to 32% at 2 5/8" and larger. Increased harvest pressure on the lake mix group reduced the weight of 2 3/4" shells (from 58% in 2006) to 37%, with the 2 5/8" increasing (from 42% in 2006) to 63%. Lake grade washboards were almost entirely made up of 4.0" grade shells with only five pounds reported as => 5.0". Mussel shells imported from other states equaled 37,030 down from 219,072 pounds in 2006, and comprised 1.5% by weight of the total Tennessee market.

The Strategic Plan objective of increasing/maintaining commercial mussel populations to a level where $\geq 15\%$ are above legal-size limits was met for the ebony and lake mix categories. Although, sustained harvest pressure caused a decline in the ebony shell population (33% in 2006 to 23% in 2007), while the lake mix population increased (15% in 2006 to 26% in 2007). Kentucky Lake washboards failed to reach the objective, measuring only 1.0% above legal-size, due to heavy harvest pressure during 1999-2000, the new (in 2003) 4" minimum size limit and the illegal harvest of washboards $\leq 4"$ during 2001 to 2004. Strategic Plan Problem VII. Strategy 2 dealing with the introduced aquatic nuisance species *Dreissena polymorpha* (zebra mussel) was partially accomplished in Appendix III, via cooperation with the U.S. Army Corps of Engineers and Tennessee Valley Authority (R. Tippit 2006). Lack of funding restricted monitoring efforts to only those that coincided with scheduled freshwater mussel investigations.

Even during periods of decreased harvest activity, law enforcement continues to play a critical role in the management and protection of Tennessee's valuable mussel resources. History of the commercial shell industry's buying practices indicates that market demand for a particular category of shell can trump any regulation against the harvesting of said shell. The viability of the commercial mussel populations can be assured only through adherence to adequate minimum size regulations and maintaining the integrity of closed waters for population comparisons and species protection. Minimum shell size regulations are based on conservative age and growth estimates, which allow brooding female mussels several years to spawn before reaching the species-specific legally harvestable size limit.

RECOMMENDATIONS

The commercial mussel program continues to be inadequately funded. In order to monitor and protect this valuable renewable resource, many man-hours of biological and law enforcement effort are required to guard against illegal take, overexploitation, and habitat degradation. Therefore, in order for this program to meet its fiduciary and resource management responsibilities, the following recommendations are offered:

1. Seek increased revenue to fund fully the existing commercial mussel program (Appendix IV). The current shell fee paid to TWRA by wholesale dealers has not increased since it was levied in July 1991 at \$0.0124/lb for live mussels (shell with meat) and \$0.0145/lb for open shells (shells without meat). In order to balance the commercial mussel program's deficit, TWRA's Commercial Mussel strategic plans have recommended an increase in the shell fee for more than 10 years. TWRA has experienced a drastic decline in the number of harvester licenses sold since the fee was levied (down from average of 1,440/year during 1990-95 to 244/year for last 5 years). The fee on commercial mussels and shells should be increased to a level sufficient to fund the commercial mussel program (approximately \$0.10 per pound at 2007 harvest level).
2. Extend the Cedar Creek Sanctuary to include Kelly's Island and Tennessee River Mile 145.0. Combined brail and dive samples indicate that the majority of the mussel stocks in this reach lie within a bed that extends from TRM 145 - 141.0. This extension would protect a population of the rare spectaclecase mussel (*Cumberlandia monodonta*) (Garner, 1991) and better protect the existing mussel bed. By making these two additions to the sanctuary system, not only would rare and endangered species be protected, but several commercial species would also be afforded a greater opportunity to reproduce without being disturbed. This additional protection would enhance mussel recruitment that could help replenish populations adjacent to the protected zones through dispersion of juvenile mussels by their fish hosts.
3. Consider closing the Cumberland River to commercial mussel harvesting due to the low recruitment rate of the upper reservoirs (Old Hickory and Cordell Hull) and lack of viability of the fishery in the lower reservoirs (Barkley and Cheatham). The Cumberland River reservoirs have not produced significant shell harvests during the last five years (combined average of 0.75% of annual harvest weight). Water quality and flow alterations resulting from emergency repair operations to Wolf Creek Dam are scheduled to continue for the next six years. The warmer temperatures predicted for this period may negatively affect Barkley Reservoir mussel populations, but could allow for increased recruitment in the upper reservoirs that could enhance the future commercial shellfishery. Closing the commercial mussel harvest on the Cumberland River would afford the population the opportunity for expansion and create the possibility of a rejuvenated fishery in the future.
4. Continue to monitor the mussel resource through commercial industry, population surveys, and laboratory analysis. These surveys provide critical trend data on the species composition, condition, volume of the mussel harvest, and population status.

LITERATURE CITED

- Broadbent, T. 2007. Personal communication. Tennessee Wildlife Resources Agency, Region I Fisheries. Jackson, Tennessee.
- Couch, F. 2004. Personal communication. Tennessee Wildlife Resources Agency, Law Enforcement Division. Nashville, Tennessee.
- Clouse, G. 2008. 2007 Mussel harvest summary by lake. Tennessee Wildlife Resources Agency, Data Management Division. Nashville, Tennessee.
- Garner, J. 1991. Personal communication. Aquatic Resources Center. P.O. Box 680818, Franklin, Tennessee 37068-0818.
- Hubbs, D. 2007a. 2006 Statewide commercial mussel report. Tennessee Wildlife Resources Agency, Fish Management, Nashville, Tennessee. Report Number 07-09. 36pp.
- _____ 2008. Brood stock collection of *Plethobasus cooperianus* (orangefoot pimpleback mussel) and *Lampsilis abrupta* (pink mucket) from the Tennessee River downstream of Pickwick Landing Dam. Tennessee Wildlife Resources Agency, Endangered Species, Nashville, Tennessee.
- Olson, D.W. 2007. 2006 Annual Review Mineral Industry Surveys, Gemstones. United States Geological Survey, 983 National Center, Reston, VA 20192.
- Parmalee, P.W. and A. E. Bogan. 1998. The Freshwater Mussels of Tennessee. The University of Tennessee Press/Knoxville. 328p.
- PEARL OYSTER information bulletin. November 2006. Issue 17 - Secretariat of the Pacific Community <http://www.spc.int/Coastfish/News/POIB/POIB.htm>

FIGURES

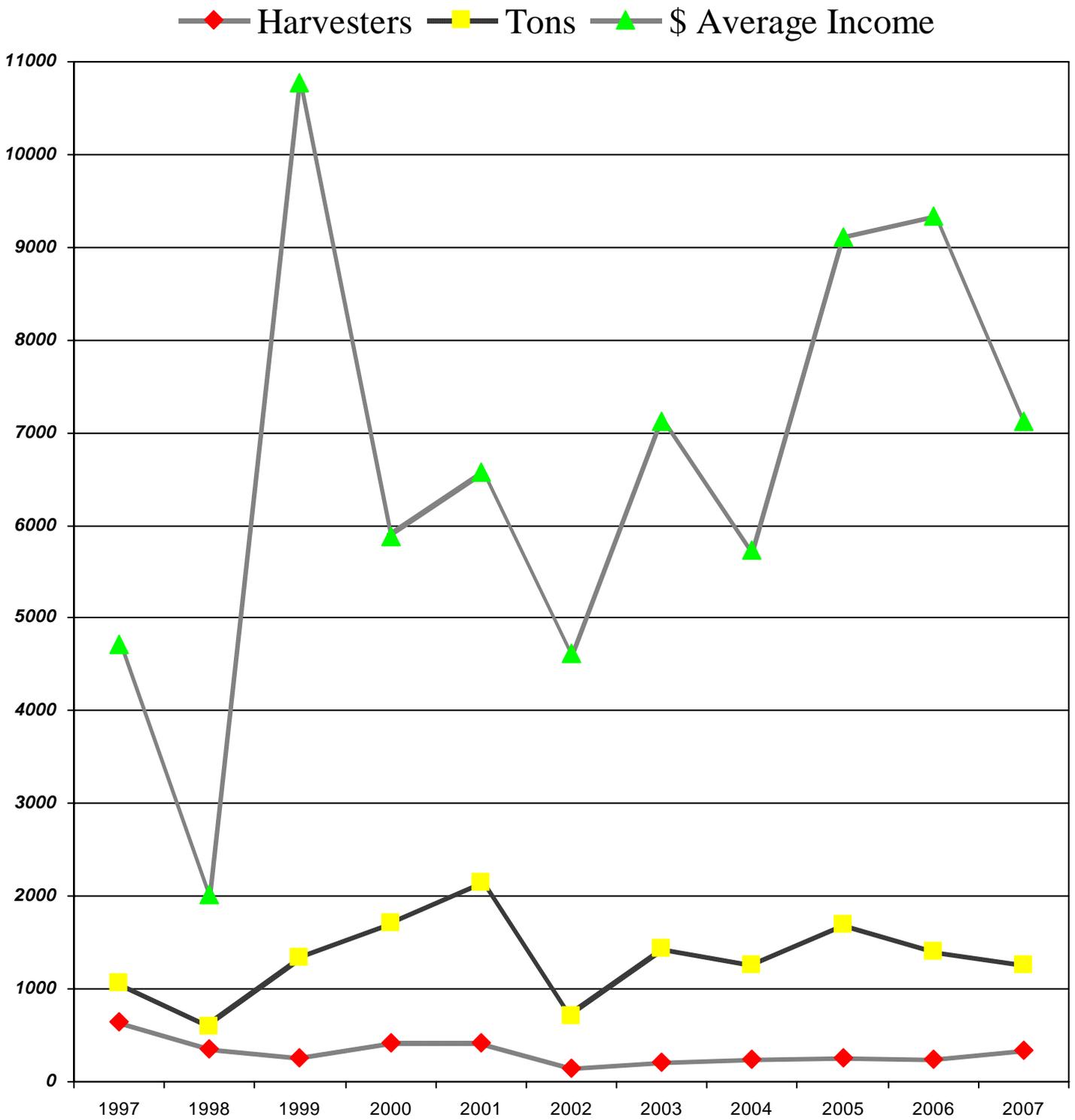
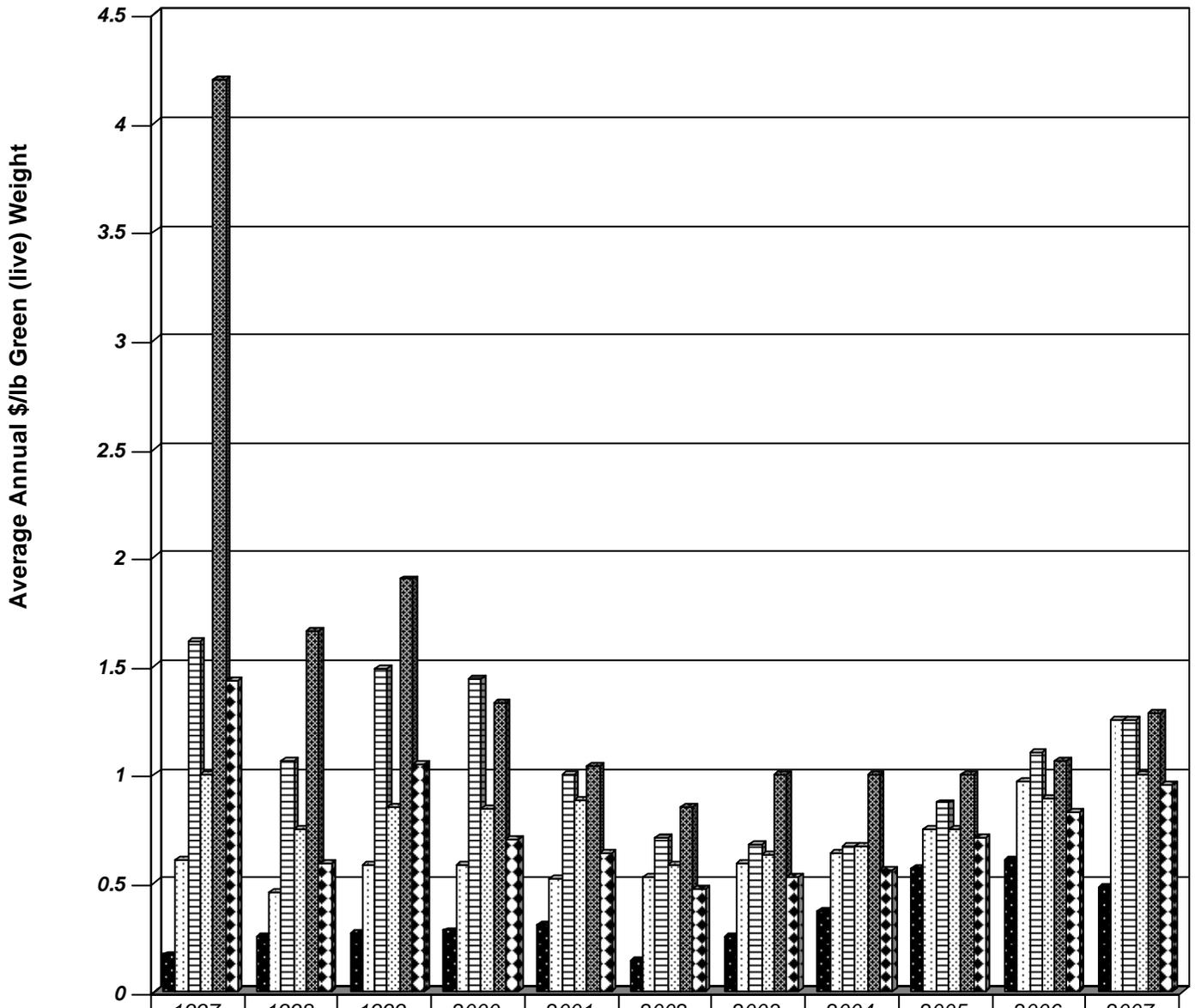


Figure 1. Tennessee mussel shell harvest trends, 1997 - 2007.



	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
■ 2 3/8" Ebony	0.17	0.25	0.27	0.28	0.31	0.14	0.25	0.37	0.57	0.61	0.48
□ 2 5/8" Lake Mix	0.61	0.46	0.58	0.58	0.52	0.53	0.59	0.64	0.75	0.97	1.25
▨ 2 3/4" Lake Mix	1.61	1.06	1.49	1.44	1	0.71	0.68	0.67	0.87	1.1	1.25
▩ 2 3/4" Ebony	1	0.75	0.85	0.84	0.88	0.58	0.63	0.67	0.75	0.89	1
▤ 4" Washboards	4.2	1.66	1.9	1.33	1.04	0.85	1	1	1	1.06	1.28
⊞ Weighted Average	1.43	0.59	1.05	0.7	0.64	0.47	0.53	0.56	0.71	0.83	0.95

Figure 2. Tennessee wholesale shell price trends, 1997 - 2007.

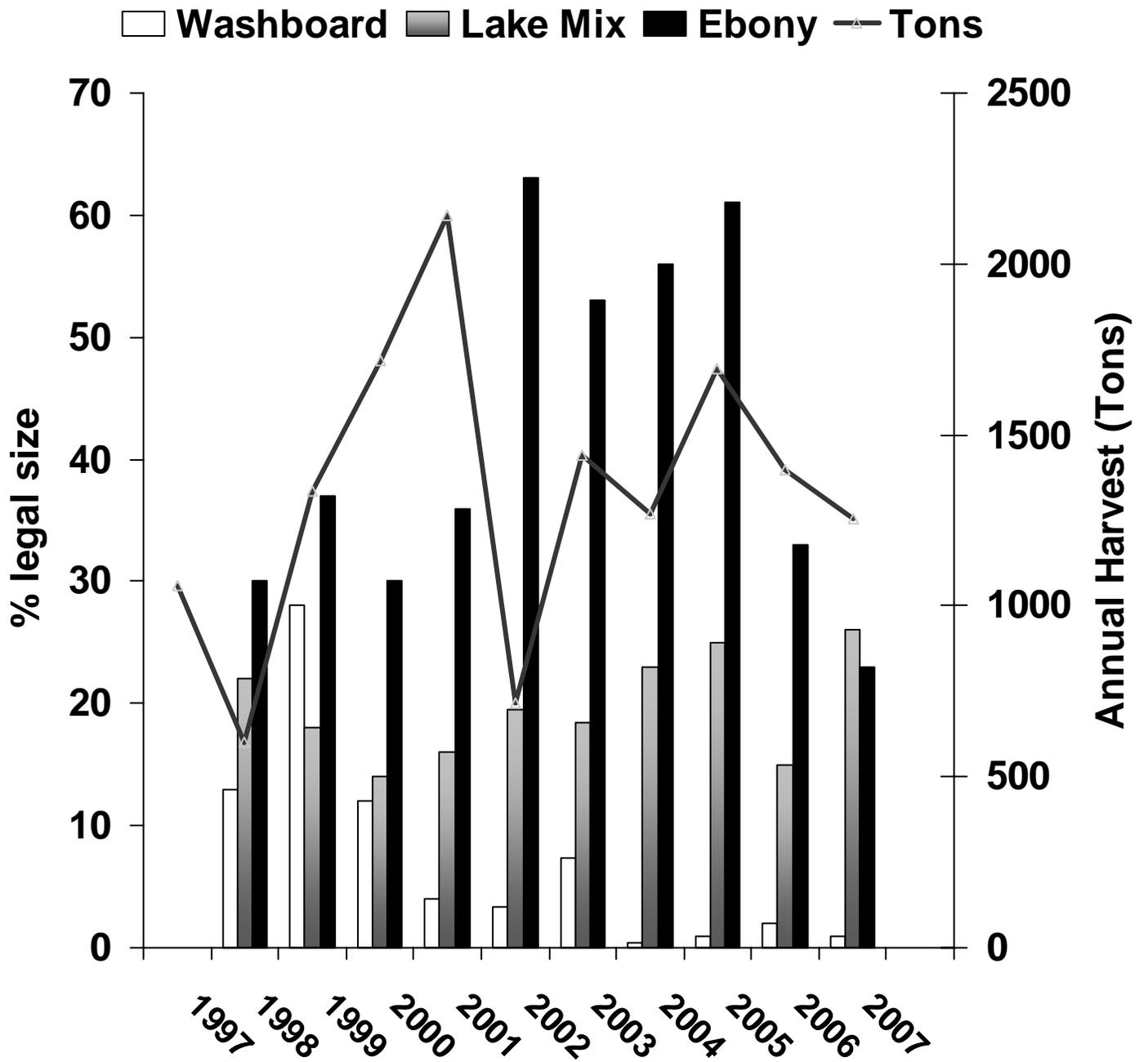


Figure 3. Legal sized mussel shell in Kentucky Reservoir population, 1997 - 2007.

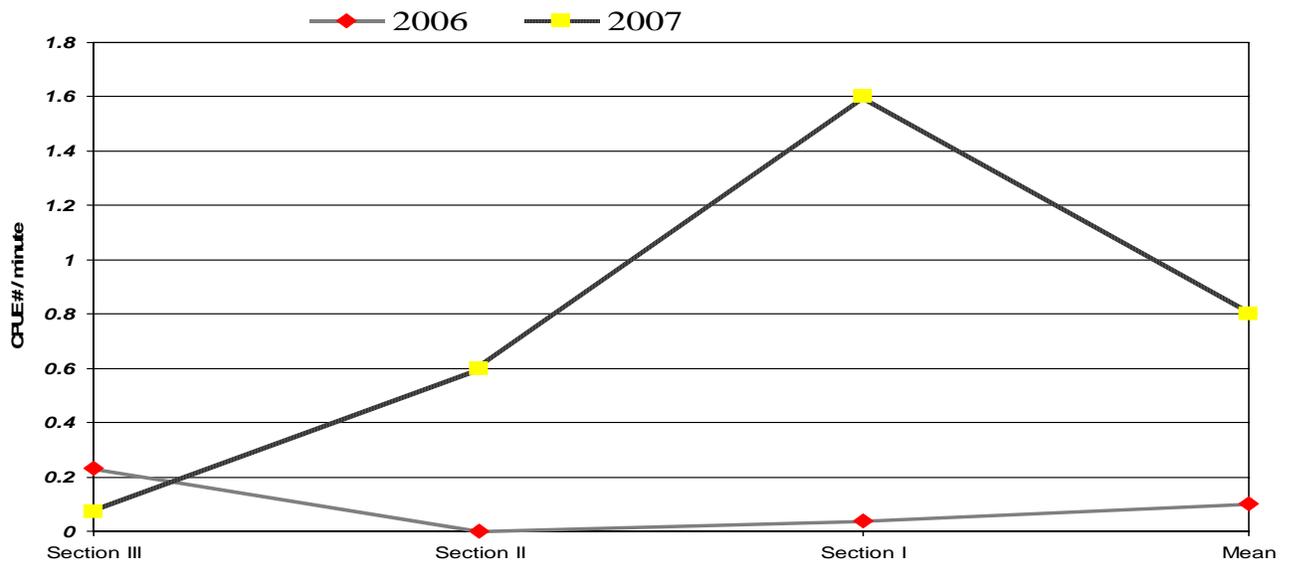


Figure 4. Zebra mussel collection rate at Kentucky Reservoir commercial mussel assessment sites during August 2006 and 2007.

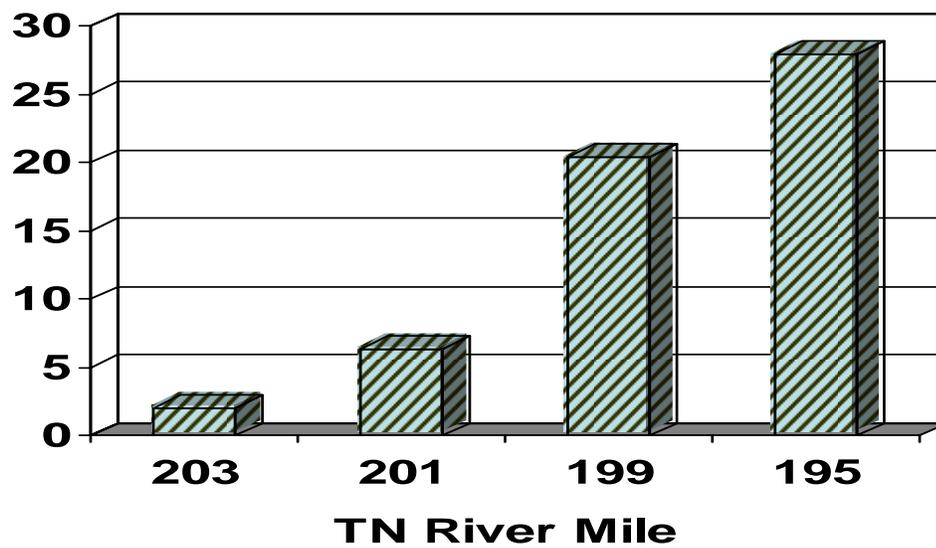


Figure 5. Zebra mussel density (#/m²) measured during mussel die-off below Pickwick Dam.

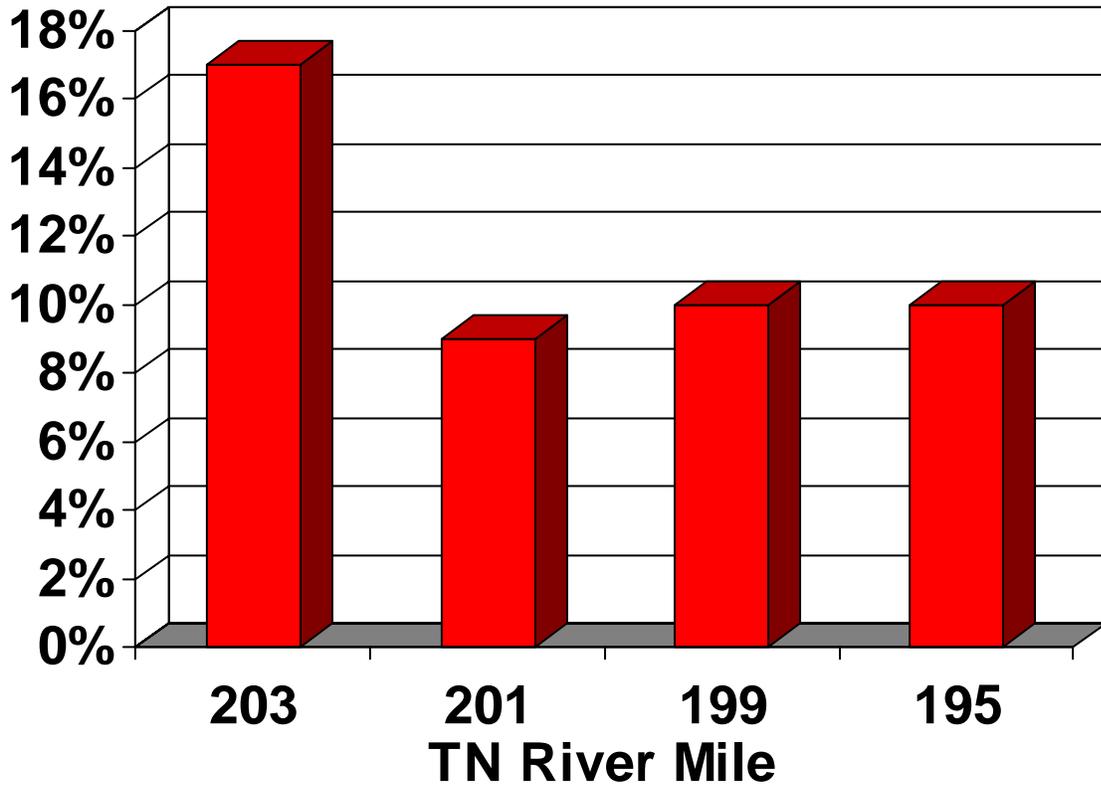


Figure 6. Mussel die-off below Pickwick Dam % fresh dead Unionid mussels.

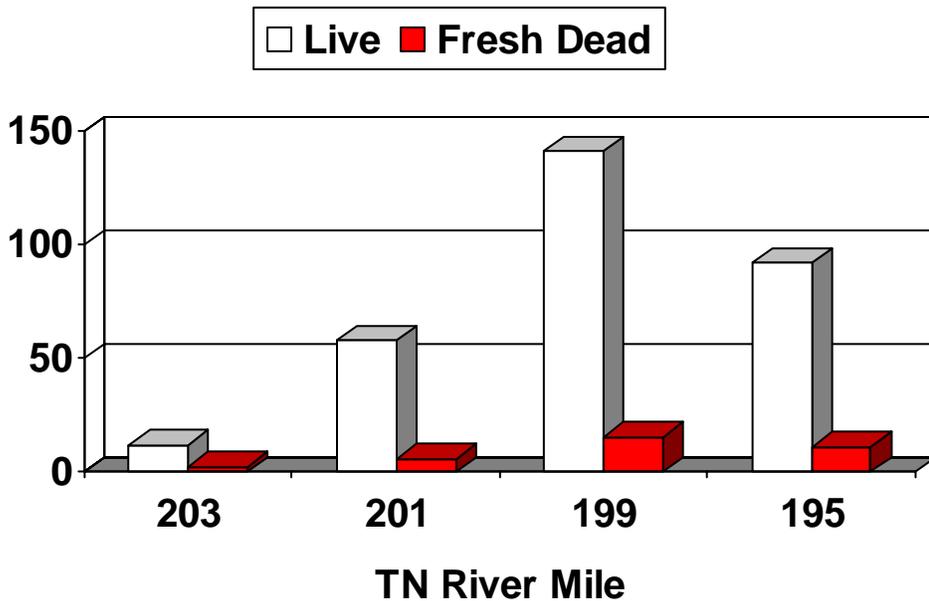


Figure 7. Mussel die-off below Pickwick Dam Unionid mussel density (#/m2).

TABLES

Table 1. Harvest volume, value, license and shell fee revenue, 1992-2007.

Year	Tons of Mussels	Pounds of Mussels	Wholesale Value	License Revenue	Shell Fee	Total Revenue	Revenue as % of Wholesale Value
1992	2,258	4,516,416	\$4,613,120	\$75,330	\$56,533	\$131,863	2.86%
1993	1,643	3,286,373	\$4,572,810	\$113,165	\$41,382	\$154,547	3.38%
1994	2,707	5,414,238	\$8,492,090	\$135,850	\$67,773	\$203,623	2.40%
1995	3,881	7,761,235	\$14,731,777	\$223,625	\$103,666	\$327,291	2.22%
1996	2,362	4,723,088	\$6,820,139	\$189,195	\$65,731	\$254,926	3.74%
1997	1,061	2,121,907	\$3,024,779	\$101,875	\$33,140	\$135,015	4.46%
1998	601	1,201,514	\$709,133	\$57,000	\$15,185	\$72,185	10.18%
1999	1,335	2,669,716	\$2,800,239	\$39,125	\$38,187	\$77,312	2.76%
2000	1,717	3,434,087	\$2,412,133	\$71,875	\$50,946	\$122,821	5.09%
2001	2,144	4,287,072	\$2,734,081	\$62,625	\$53,625	\$116,250	4.25%
2002	714	1,429,293	\$665,326	\$25,625	\$15,759	\$41,384	6.22%
2003	1,439	2,878,808	\$1,531,327	\$33,375	\$35,049	\$68,424	4.47%
2004	1,267	2,533,947	\$1,417,753	\$48,375	\$31,786	\$80,161	5.65%
2005	1,693	3,386,254	\$2,404,375	\$69,500	\$32,985	\$102,485	4.26%
2006	1,400	2,800,901	\$2,336,027	\$60,900	\$31,174	\$92,074	3.94%
2007	1,253	2,505,205	\$2,378,398	\$96,900	\$33,924	\$130,824	5.51%
TOTAL	27,475	54,950,205	\$61,643,507	\$1,404,340	706,845	\$2,111,185	
Average	1,717	3,434,378	\$3,852,719	\$87,771	\$44,178	\$131,949	3.42%

Table 2. Average wholesale price paid for various categories of commercial shell during 2007.

CATEGORY	CONDITION	AVERAGE PRICE (\$/LB)	SPECIES
LAKE MIX 2 5/8"	GREEN	\$1.25	<i>A. plicata, F. flava, Q. quadrula, Q. apiculata</i>
LAKE MIX 2 3/4"	GREEN	\$1.25	<i>A. plicata, F. flava, Q. quadrula, Q. apiculata</i>
EBONY 2 3/8"	GREEN	\$0.48	<i>F. ebena</i>
EBONY 2 1/2"	GREEN	\$0.50	<i>F. ebena</i>
EBONY 2 5/8"	GREEN	\$0.88	<i>F. ebena</i>
EBONY 2 3/4"	GREEN	\$1.00	<i>F. ebena</i>
LAKE WASHBOARD 4.0"	GREEN	\$1.28	<i>M. nervosa</i>
LAKE WASHBOARD 5.0"	GREEN	\$1.28	<i>M. nervosa</i>
RIVER WASHBOARD 4.0" & Larger	GREEN	\$1.28	<i>M. nervosa</i>
PINK HEELSPLITTER 4.0" & Larger, Grade #1	OPEN	\$1.12	<i>P. alatus</i>

GREEN = Shell with meat

OPEN = Shell without meat

Table 3. 2007 wholesale commercial shell harvest by size category, as estimated from Tennessee waters.

	WEIGHT LBS	PERCENT WEIGHT	ESTIMATED VALUE	PERCENT VALUE
CATEGORY				
Lake Grade Washboards 4.0" to 4.5"	125,738	5.02%	\$160,945	6.77%
Lake Grade Washboards 5.0"	5	0.00%	\$6	0.0%
River Grade Washboards ≥ 4.0"	360	0.01%	\$461	0.02%
Pink Heelsplitter ≥ 4.0"	582	0.02%	\$652	0.03%
Ebony 2 3/8"	587,737	23.46%	\$282,114	11.86%
Ebony 2 1/2"	232,417	9.28%	\$116,209	4.89%
Ebony 2 5/8"	290,359	11.59%	\$255,516	10.74%
Ebony $\geq 2 3/4$"	90,050	3.59%	\$90,050	3.79%
Lake Mix 2 5/8"	750,111	29.94%	\$937,639	39.42%
Lake Mix $\geq 2 3/4$"	427,846	17.08%	\$534,808	22.49%
Total	2,505,205	100%	\$2,378,398	100%
Tons	1,253			

Table 4. Tennessee commercial mussel shell industry volume and value, 2003-2007.

Year	2003	2004	2005	2006	2007
Harvesters	215	247	264	250	334
Dealers	13	14	15	15	15
Tons	1,439	1,267	1,693	1,400	1,253
Millions \$	\$1.5	\$1.4	\$2.4	\$2.33	\$2.38
Shell Fee	\$35,049	\$31,786	\$32,985	\$31,174	\$33,924
Average Wholesale price/lb	\$0.53	\$0.56	\$0.71	\$0.83	\$0.95

Table 5. Tennessee's commercial mussel shell harvest size class distribution by weight, 2003-2007.

	YEAR				
SIZE CLASS	2003	2004	2005	2006	2007
2 3/8"	10.6%	17.1%	21.1%	18.4%	23.5%
2 1/2"	24.9%	24.1%	21.2%	22.6%	9.3%
2 5/8"	33.3%	27.6%	32.4%	27.4%	41.5%
2 3/4"	26.1%	26.1%	18.4%	26.7%	20.7%
3 7/8"					
3 15/16"					
=>4"	5.1%	5.0%	6.8%	4.9%	5.0%

Table 6. Summary of commercial mussel species data, Kentucky Reservoir sections I, II, and III.

Section I - Paris Landing	Legal	Sub-Legal	Total	%Legal	%Abundance
Amblema plicata	75	105	180	42%	16%
Elliptio crassidens	1	1	2	50%	0%
Fusconaia ebena	259	275	534	49%	48%
Fusconaia flava	4	29	33	12%	3%
Megaloniaias nervosa		209	209	0%	19%
Potamilus alatus		10	10	0%	1%
Pleurobema cordatum					
Quadrula quadrula		8	8	0%	1%
Quadrula apiculata	5	127	132	4%	12%
Quadrula metanevra	2		2	100%	0%
Sites Sampled			3		
CPUE = mussels per minute	2.31	5.09	7.40		
Total	346	764	1110	31%	100%
<i>Dreissena polymorpha</i>			240		
CPUE <i>D. polymorpha</i> / minute			1.6		

Section II - Camden	Legal	Sub-Legal	Total	%Legal	%Abundance
Amblema plicata	64	134	198	32%	21%
Elliptio crassidens	1	1	2	0%	0%
Fusconaia ebena	51	475	526	10%	55%
Fusconaia flava	6	24	30	20%	3%
Megaloniaias nervosa	5	128	133	4%	14%
Potamilus alatus	11	21	32	34%	3%
Pleurobema cordatum					
Quadrula quadrula		3	3	0%	0%
Quadrula apiculata	2	35	37	5%	4%
Quadrula metanevra					
Sites Sampled			3		
CPUE = mussels per minute	0.93	5.47	6.41		
Total	140	821	961	15%	100%
<i>Dreissena polymorpha</i>			92		
CPUE <i>D. polymorpha</i> / minute			0.6		

Section III - Savannah	Legal	Sub-Legal	Total	%Legal	%Abundance
Amblema plicata	2	3	5	40%	1%
Elliptio crassidens	6	27	33	18%	5%
Fusconaia ebena	54	485	539	10%	78%
Fusconaia flava					
Megalonaias nervosa		7	7	0%	1%
Potamilus alatus					
Pleurobema cordatum	8	9	17	47%	2%
Quadrula quadrula					
Quadrula apiculata		2	2	0%	0%
Quadrula metanevra	23	63	86	27%	12%
Sites Sampled			2		
CPUE = mussels per minute	0.93	5.96	6.89		
Total	93	596	689	13%	100%
<i>Dreissena polymorpha</i>			7		
CPUE <i>D. polymorpha</i> / minute			0.07		

Section I, II, & III combined	Legal	Sub-Legal	Total	%Legal	%Abundance
Amblema plicata	141	242	383	37%	14%
Elliptio crassidens	8	29	37	22%	1%
Fusconaia ebena	364	1235	1599	23%	58%
Fusconaia flava	10	53	63	16%	2%
Megalonaias nervosa	5	344	349	1%	13%
Potamilus alatus	11	31	42	26%	2%
Pleurobema cordatum	8	9	17	47%	1%
Quadrula quadrula		11	11	0%	0%
Quadrula apiculata	7	162	169	4%	6%
Quadrula metanevra	25	63	88	28%	3%
Sites Sampled			8		
CPUE = mussels per minute	1.45	5.45	6.90		
Total	579	2179	2758	21%	100%
<i>Dreissena polymorpha</i>			339		
CPUE <i>D. polymorpha</i> / minute			0.8		

Closed Mussel Mgmt Area in Section II	Legal	Sub-Legal	Total	%Legal	%Abundance
<i>Amblema plicata</i>	19	33	52	37%	12%
<i>Elliptio crassidens</i>		2	2	0%	0%
<i>Fusconaia ebena</i>	137	211	348	39%	77%
<i>Fusconaia flava</i>	1	15	16	6%	4%
<i>Megalonaias nervosa</i>	2	5	7	29%	2%
<i>Potamilus alatus</i>	2	6	8	25%	2%
<i>Pleurobema cordatum</i>					
<i>Quadrula quadrula</i>		2	2	0%	0%
<i>Quadrula apiculata</i>		16	16	0%	4%
<i>Quadrula metanevra</i>					
Sites Sampled			1		
CPUE = mussels per minute	3.22	5.80	9.02		
Total	161	290	451	36%	100%
<i>Dreissena polymorpha</i>			5		
CPUE <i>D. polymorpha</i> / minute			0.1		

Table 7. Kentucky Reservoir percentage legal-sized commercial mussels by category, 2007.

	TWRA Population Samples, Sections I, II and III combined			
	N	Open Waters Legal-Sized	N	Closed waters Legal-Sized
Ebony $\geq 2 \frac{3}{8}$"	1599	23%	348	39%
Lake Mix $\geq 2 \frac{5}{8}$"	643	26%	86	23%
Washboards ≥ 4"	344	1%	7	29%

Table 8. Quantitative samples collected during mussel die-off below Pickwick Dam, August 1 and 2, 2007.

RIVER MILE	TRM195.2R			TRM199.0R			TRM201.2R			TRM203.0R			
COLLECTORS:	170, 43, 1307			43, 1307, 245, 45			45, 245, 43			45, 245, 43			
Bottom Time:	10 - 0.25 m2 quads			10 - 0.25 m2 quads			10 - 0.25 m2 quads			10 - 0.25 m2 quads			
DEPTH ft.	16 to 29 ft			15 to 20			10 ft			3 to 10 ft			
LATITUDE	35 11.426N			35 07.987N			35 06.526N			35 04.864N			
LONGITUDE	88 18.538W			88 18.576W			88 17.858W			88 17.566W			
SUBSTRATE	sand, gravel, clay			gravel rock sand			gravel, sand			gravel			
Species	SIZE	FD	LG	SL/NC	FD	LG	SL/NC	FD	LG	SL/NC	FD	LG	SL/NC
<i>Amblyma plicata</i>				1									1
<i>Arcidens confragosa</i>					1					1			
<i>Cyclonaias tuberculata</i>				4			11			11			4
<i>Elliptio crassidens</i>				1			6						
<i>Elliptio dilatata</i>													
<i>Ellipsaria lineolata</i>	2			6	1		22	1		1			1
<i>Fusconaia ebena</i>	25	6		177	32	6	174	13	8	66	3	5	3
<i>Leptodea fragilis</i>													1
<i>Ligumia recta</i>				2			1						
<i>Megalonaias nervosa</i>							2			2			
<i>Obliquaria reflexa</i>				4	1		10			11			
<i>Pleurobema cordatum</i>									1	1		2	
<i>Potamilus alatus</i>				2			2		1	1	1		
<i>Quadrula apiculata</i>							2						
<i>Quadrula metanevra</i>				3			6			1		1	
<i>Quadrula pustulosa</i>				23	3		109			40	2		12
<i>Truncilla truncata</i>				1			2						
TOTAL	27	6		224	38	6	347	14	10	135	6	8	22
Density #/m2	10.8	2.4		89.6	15.2	2.4	138.8	5.6	4.0	54.0	2.4	3.2	8.8
Percent	10%	2%		88%	10%	2%	88%	9%	6%	85%	17%	22%	61%
<i>Dreissena polymorpha</i>				70			51			16			5
Density #/m2				28.0			20.4			6.4			2.0

FD = Fresh Dead, LG = Legal Size,
 SL = SUBLEGAL SIZE,
 NC = NONCOMERCIAL

* = FEDERALLY LISTED ENDANGERED SPECIES

Table 9. Cumberland River Old Hickory Reservoir Hunter's Point mussel sanctuary, September 5, 2007.

CRM 264 to 265	Non-Commercial	Legal	Sub-Legal	Total	%Legal	%Abundance
<i>Elliptio crassidens</i>		1		1	100%	4.5%
<i>Fusconaia flava</i>						
<i>Megaloniaias nervosa</i>						
<i>Lasmigonia complanata</i>	1			1		4.5%
<i>Ptychobranchnus fasciolaris</i>	1			1		4.5%
<i>Pleurobema cordatum</i>		10	4	14	71%	63.6%
<i>Quadrula pustulosa</i>	3			3		13.6%
<i>Quadrula metanevra</i>		2		2	100%	9.1%
<i>Tritogonia verrucosa</i>						
Sites Sampled	80 minutes total			5		
CPUE = mussels per minute	0.06	0.16	0.05	0.28		
Total	5	13	4	22	76%	
D.O. 5.0 mg/l, 21.2°C at 40 ft.						

Table 10. Cumberland River Old Hickory Reservoir Rome Landing mussel sanctuary, December 14, 2007.

CRM 297.9 & 302.8	Non-Commercial	Legal	Sub-Legal	Total	%Legal	%Abundance
<i>Elliptio crassidens</i>		relic				
<i>Ellipsaria lineolata</i>	1			1		1.7%
<i>Megaloniaias nervosa</i>		25	8	33	76%	56%
<i>Leptodea fragilis</i>	1			1		1.7%
<i>Ptychobranchnus fasciolaris</i>	1			1		1.7%
<i>Pleurobema cordatum</i>		5		5	100%	8.5%
<i>Quadrula pustulosa</i>	14			14		23.7%
<i>Quadrula metanevra</i>		3		3	100%	5.1%
<i>Lampsilis abrupta*</i>	1 live, 3 relic			1		1.7%
Sites Sampled	55 minutes total			3		
CPUE = mussels per minute		0.6	0.14	1.1		
Total	18	33	8	59	80%	

* Federal Endangered Species

APPENDICES

**APPENDIX
I
2007 Wholesale Mussel Dealer
& Receipt Report Summary Data**

Mussel Harvest by Lake 1/1/2007 through 12/31/2007

Lake BARKLEY RESERVOIR											
shl	meat	g500	g450	g400	g375	g300	g275	g268	g250	g238	Shell Total
LWB	O	0	0	5	0	0	0	0	0	0	5
REB	G	0	0	0	0	0	0	3715	9007	11696	24418
RMB	G	0	0	0	0	0	0	0	0	79	79
RMF	G	0	0	0	0	0	0	0	221	1136	1357
Totals		0	0	5	0	0	0	3715	9228	12911	25859

Lake KENTUCKY RESERVOIR											
shl	meat	g500	g450	g400	g375	g300	g275	g268	g250	g238	Shell Total
DEA	G	0	0	0	0	0	0	0	0	18	18
DEB	G	0	0	0	0	0	0	0	0	724	724
EBD	G	0	0	0	0	0	0	0	0	13	13
EBL	G	0	0	0	0	0	0	241	228	0	469
EBS	G	0	0	0	0	0	41	0	67	1853	1961
HS	G	0	0	43	0	0	0	0	0	0	43
KEB	G	0	0	0	0	0	0	12	0	0	12
L3R	G	0	0	0	0	5	312	0	0	0	317
LEB		0	0	0	0	0	36	125	131	136	428
LEB	G	9	0	77	78	101	89074	220175	218930	356008	884452
LEB	O	0	0	0	0	0	26	252	163	1385	1826
LED	O	0	0	0	0	0	0	0	0	548	548
LEG	G	0	0	0	0	0	36	39	0	88	163
LEW	G	0	0	0	0	0	0	18	0	0	18
LHS	G	0	0	11	0	0	0	0	0	0	11
LHS	O	0	0	74	0	0	0	0	0	0	74
LML		0	0	0	0	0	35	532	0	0	567

LML	G	6	0	67	0	899	425424	743341	1091	1972	1172800
LML	O	0	0	0	0	0	1098	5459	0	0	6557
LNH	G	0	0	0	0	0	35	0	0	0	35
LRB	G	0	0	8	0	0	0	0	0	0	8
LWB		0	0	34	0	0	0	0	0	0	34
LWB	G	5	66	124364	112	13	453	775	0	680	126468
LWB	O	0	0	245	0	0	4	0	0	8	257
OEB	G	0	0	0	0	0	0	0	0	21	21
ONH	G	0	0	0	0	0	0	0	0	16	16
PHS	G	0	0	328	0	0	0	0	0	0	328
PHS	O	0	0	126	0	0	0	0	0	0	126
REB	G	0	0	6	0	0	33	63647	359	124535	188580
REB	O	0	0	0	0	0	0	1339	285	47577	49201
RER	G	0	0	0	0	0	41	0	0	0	41
RMF	G	0	0	0	0	0	0	21	39	34799	34859
RMF	O	0	0	0	0	0	0	0	0	638	638
RWB	G	0	0	360	0	0	0	0	0	0	360
ZZZ	G	0	0	0	0	0	0	0	131	1676	1807
ZZZ	O	0	0	0	0	0	0	0	0	109	109
Totals		20	66	125743	190	1018	516648	1035976	221424	572804	2473889

Lake NICKAJACK RESERVOIR

shl	meat	g500	g450	g400	g375	g300	g275	g268	g250	g238	Shell Total
LEB	G	0	0	0	0	0	0	0	0	942	942
LEB	O	0	0	0	0	0	0	0	0	219	219
LML	G	0	0	0	0	0	0	44	0	0	44
LWB	G	0	0	451	0	0	0	0	0	0	451
Totals		0	0	451	0	0	0	44	0	1161	1656

Lake OUT-OF-STATE

shl	meat	g500	g450	g400	g375	g300	g275	g268	g250	g238	Shell Total
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BLF	O	0	0	21	0	0	0	0	0	0	21
BLU	O	0	0	625	0	0	0	0	0	0	625
L3R	G	0	0	0	0	0	12969	0	8	0	12977
L3R	O	0	0	0	0	0	33	0	0	0	33
LEB	G	0	0	0	0	0	547	430	3946	45	4968
LEB	O	0	0	0	0	0	31	0	77	0	108
LER	G	0	0	0	0	0	148	0	0	0	148
LML	G	0	0	0	0	0	251	0	337	0	588
LNH	G	0	0	0	0	0	94	0	0	0	94
LNH	O	0	0	0	0	0	0	0	17	0	17
LWB	G	0	0	621	0	0	0	25	0	0	646
R3R	G	0	0	0	0	0	6035	0	0	0	6035
R3R	O	0	0	0	0	0	2849	2106	0	0	4955
RBR	O	0	0	0	0	0	50	0	0	0	50
RCB	O	0	0	46	0	0	0	0	0	0	46
REB	G	0	0	0	0	0	0	0	0	1828	1828
REB	O	0	0	10	0	0	0	0	0	0	10
RML	G	0	0	0	0	0	0	1423	0	0	1423
RWB	G	0	0	226	0	0	0	0	0	0	226
RWB	O	0	0	1939	0	0	0	0	0	0	1939
RWC	O	0	0	293	0	0	0	0	0	0	293
Totals		0	0	3781	0	0	23007	3984	4385	1873	37030

Report total	20	66	129980	190	1018	539655	1043719	235037	588749	2538434
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**APPENDIX
II
Freshwater Mussel Species
Collected From Kentucky Reservoir
During 2007 Sampling and Observations**

2007 Mussel species collected from Kentucky Reservoir all sites and supplemental sampling, 1 = collected live.

Species		
1	<i>Anadonta suborbiculata</i>	1
2	<i>Pyganodon grandis</i>	1
3	<i>Utterbackei imbecillis</i>	1
4	<i>Amblema plicata</i>	1
5	<i>Arcidens confragosa</i>	1
6	<i>Cumberlandia monodonta</i>	
7	<i>Cyclonaias tuberculata</i>	1
8	<i>Cyprogenia stegaria</i>*	1
9	<i>Elliptio crassidens</i>	1
10	<i>Ellipsaria lineolata</i>	1
11	<i>Fusconaia ebena</i>	1
12	<i>Fusconaia flava</i>	1
13	<i>Lampsilis abrupta</i>*	1
14	<i>Lampsilis cardium</i>	
15	<i>Lampsilis ovata</i>	1
16	<i>Lampsilis teres</i>	1
17	<i>Lasmigonia complanata</i>	
18	<i>Leptodea fragilis</i>	1
19	<i>Ligumia recta</i>	1
20	<i>Megaloniaias nervosa</i>	1
21	<i>Obliquaria reflexa</i>	1
22	<i>Plectomerus dombevanus</i>	1
23	<i>Plethobasus cooperianus</i>*	1
24	<i>Plethobasus cyphus</i>	
25	<i>Pleurobema rubrum</i>	
26	<i>Pleurobema cordatum</i>	1
27	<i>Pleurobema sintoxia</i>	
28	<i>Potamilus alatus</i>	1
29	<i>Potamilus ohioensis</i>	1
30	<i>Quadrula apiculata</i>	1
31	<i>Quadrula c. cylindrica</i>	1
32	<i>Quadrula metanevra</i>	1
33	<i>Quadrula nodulata</i>	1
34	<i>Quadrula pustulosa</i>	1
35	<i>Quadrula quadrula</i>	1
36	<i>Toxolasmus parvus</i>	1
37	<i>Toxolasmus lividus</i>	
38	<i>Truncilla donaciformis</i>	1
39	<i>Truncilla truncata</i>	1
40	<i>Tritogonia verrucosa</i>	1
	TOTAL	33
	EXOTIC SPECIES	
	<i>Dreissena polymorpha</i>	1
	<i>Corbicula fluminea</i>	1

***Federal Endangered species**

**APPENDIX
III
Zebra Mussel Distribution
In Tennessee**



Since the first documented collection of the zebra mussel in Tennessee occurred on the Tennessee River at Savannah, Hardin Co., Tennessee during February 1992, reports of one to several individuals have become more numerous. Clusters of zebra mussels have been discovered on the lock walls of most TVA and Army Corps of Engineer facilities open to commercial navigation traffic on the Tennessee and Cumberland rivers. Barge and boat traffic are believed to be the primary vectors of dispersion of this exotic species. Summer water temperature extremes, fish predation and water chemistry characteristics may be limiting the expansion of the zebra mussel population in some areas, particularly the lower Tennessee River.

Zebra mussel sightings continue to be reported by commercial musselers working the Kentucky Reservoir portion of the Tennessee River system. While it has yet to develop densities that endanger the native mussel fauna, frequency of occurrence and number of individuals are on the increase, the CPUE measured during TWRA's annual commercial mussel site assessments on Kentucky Reservoir increased from 0.1 to 0.8 individuals per minute between 2006 and 2007. Quantitative sampling at four sites below Pickwick Dam between river miles 203 to 195 resulted in zebra mussel density estimates of two to 28 per square meter, increasing in a downstream direction.

Zebra mussel densities in the upper Tennessee River system increased during the late 1990's through 2001. An established colony of zebra mussels below Watts Bar Dam, at TRM527.1, increased from 600 to just over 5,000 per square meter in late 2001. At TRM558.2, zebra mussels reached an even higher density of 23,166 per square meter. A large population was also noted below Chickamauga Dam, at TRM 470.0. Density at this site was estimated at 11,613 per square meter (Tennessee Valley Authority, 2002). However, the hot and dry summers of 2004, 2005 and 2007 significantly limited these populations. Only two live zebra mussels were encountered at nine TWRA freshwater mussel assessment sites below Watts Bar Dam during sampling conducted in 2005, resulting in a CPUE of 0.45 zebra mussels per hour.

Zebra mussels have colonized the Mississippi River along the western border of Tennessee. They are abundant and attached to surfaces of concrete and rock bank stabilization structures below the water line. Some native mussels collected from the Mississippi River have been covered with zebra mussels.

TWRA personnel will continue to monitor zebra mussel populations through cooperation with commercial harvesters, and other government agencies. While accurately predicting what ultimate effect this exotic species will have on native mussel stocks and other aquatic species is difficult, the potential for devastation does exist. For more on zebra mussels and their current distribution in the United States go to http://www.glsc.usgs.gov/_files/factsheets/2000-6%20Zebra%20Mussels.pdf.

APPENDIX
IV
Commercial Mussel Program Funding Status
2003 -2007

Commercial Mussel Program Statistics	2003	2004	2005	2006	2007	TOTAL	Average
Harvester Licenses	215	247	264	250	334	1310	262
Shell Dealers Licenses	13	14	15	15	15	72	14
Pounds Harvested	2,878,808	2,533,947	3,386,254	2,800,901	2,505,205	14,105,115	\$2,821,023
Wholesale Harvest Value	\$1,531,327	\$1,417,753	\$2,404,375	\$2,336,027	\$2,378,398	\$10,067,880	\$2,013,576
Shell Fee Revenue collected	\$35,049	\$31,786	\$32,985	\$31,174	\$33,924	\$164,918	\$32,984
Proposed Shell Fee @ \$0.10/lb	\$287,881	\$253,395	\$338,625	\$280,090	\$250,520	\$1,410,511	\$282,102
Proposed Shell Fee @ \$0.05/lb	\$143,940	\$126,697	\$169,313	\$140,045	\$125,260	\$705,255	\$141,051
License Revenue by Fiscal Year	\$32,500	\$48,375	\$47,725	\$32,126	\$78,500	\$239,226	\$47,845
Total Revenue	\$67,549	\$80,161	\$80,710	\$63,300	\$112,424	\$404,144	\$80,829
Mussel Program Expenditures Fiscal Year	\$178,196	\$229,654	\$275,324	\$277,046	\$259,037	\$1,219,257	\$243,851
Program Funding Balance	-\$110,647	-\$149,493	-\$194,614	-\$213,746	-\$146,613	-\$815,113	-\$163,023
Program Funding Balance @ \$0.10/lb	\$177,234	\$103,902	\$144,011	\$66,344	\$103,908	\$360,497	\$119,080
Program Funding Balance @ \$0.05/lb	\$33,293	-\$22,796	-\$25,301	-\$73,701	-\$21,353	-\$109,857	-\$21,971