INTRODUCTION

Since 1902 the commercial harvest of freshwater mussels has occurred in the upper Mississippi River (UMR) bordering the state of Wisconsin (Carlander, 1954). In the early half of this century, this harvest was used to produce buttons. In 1917 Wisconsin clammers were first regulated. They were required to purchase a $50.00 license, limited to a single boat and dredges were prohibited. In 1919, a minimum size limit of 1 3/4 inches in the greatest dimension, a resident license of $5.00 and nonresident for $50.00 were established. Clamming licenses were available only to state residents from 1947 to 1951 after which none were required.

In the 1930's, the harvest all but ceased due to the paucity of harvestable shells (Perry, 1979) and the introduction of plastic buttons (Bates and Dennis, 1985; Knott, 1980). From 1946 to 1950, the number of Wisconsin clamming licenses issued dropped from 68 to six. In 1964 mussel harvest resumed (Finke, 1966) with the processed shells used primarily for the Japanese cultured pearl industry and later for jewelry and novelties. Additional mussels were also harvested for pearls.

Recently the two principal species harvested were the washboard (Magnonaias nervosa) and the three ridge (Amblema plicata plicata). Species that were taken in a much lesser amount included the mapleleaf (Quadrula quadrula), pigtoe (Fusconaia flava) and pimpleback (Quadrula pustulosa pustulosa). Within the past few years the pink heel splitter

(Potamilus alatus) has been harvested for use as a host organism in the production of freshwater pearls cultured in this country. In the 1960's and early 1970's other thick-shelled species were taken for non-pearl culture use.

Since the early 1900's and particularly within the last decade, concern has been expressed by resource managers, citizens, commercial shellers and buyers over the increasing number of non-resident shellers and over exploitation of the mussel stocks in the UMR. In response, the Wisconsin Department of Natural Resources (WDNR) in coordination with neighboring states implemented significantly revised Statutes and emergency Administrative Rules in the spring of 1986 to regulate clamming, commercial clamming and related activities by establishment of seasons, minimum size limits, restricted mussel species and waters, reciprocal license privileges, restricted harvest methods and harvest reporting. During 1986, the season extended from ice-out in the spring to 30 September. The minimum legal size limit in height was 3 1/2 inches for washboard and 2 5/8 for three ridge. A three ridge minimum size limit of 2 3/4 inches, greater than the state's legal limit was used by the industry.

Until now basic biologic and economic data on mussels and their exploitation was inadequate to fully assess the impact of harvest on the resource. Recent information on the mussel population status in the UMR is limited. Several qualitative mussel investigations from generally small and scattered localities have been conducted (Cawley, 1984; Clymer and Eberley, 1980; Coon et. al., 1977; Havlik, 1977a,

1977b, 1978, 1983; Havlik and Stansbery, 1978; Heath, 1982; Larsen and

Holzer, 1978; Lewis, 1986; Mathiak, 1979). Other more extensive studies were conducted in recent years (Ecological Analysts, 1981; Fuller, 1978, 1980a, 1980b; Perry, 1979; Thiel, 1981). However only a few quantitative studies descriptive the unionid community in the UMR have been done (Cawley, 1984; Duncan and Thiel, 1983; Miller and Payne, 1987). Quantitative work descriptive of the harvest does exist (Thiel, 1981; Trimberger, 1967) but is limited in detail. The primary objectives of this investigation were to describe the basic population parameters of the three ridge and washboard mussels in Navigation Pools nine and 10 and to characterize their commercial harvest and its effect. To meet these objectives, several aspects were examined during 1986 and 1987: population density and size; size and age class structure; age, growth and gravidity; catch composition by species, size and age; total amount harvested; monies transacted and finally harvest methods and effort.

STUDY AREAS

Population estimate sampling was conducted at four localities: Lynxville (Pool 9), Harper's Slough, East Channel and Indian Isle (Pool 10). The Lynxville area (3,054,389 sq. m) was located immediately upriver of Lock and Dam 9 in the navigation channel upstream to near the Cold Springs Public Boat Landing in Winneshiek Slough (FIGURE. 1). Harper's Slough study area (2,830,675 sq. m) included the navigation channel near the mouth of the Yellow River upstream into the slough

near the town of Harper's Ferry, Iowa (FIGURES 2 & 3). The East

Channel area (1,265,557 sq. m) included the side channel near Prairie du Chien, Wisconsin from river miles 633.5 to 636.0 (FIGURE. 4) and the Indian Isle area (1,103,123 sq. m) included the main navigation channel from river mile 631.4 just above the mouth of the Wisconsin River upstream to the boundary of the East Channel study area (FIGURE. 5).

METHODS

Age, Growth and Gravidity

All mussels used for age, growth and gravidity determinations were first preserved in a mixture of ETOH, glycerol and water. Lengths and heights were measured to the nearest millimeter (mm) using a standard fish rule. Length was the greatest distance parallel to the hinge line and height was the greatest distance from the dorsal to ventral margin roughly perpendicular to the length.

Mussels were aged by counting external growth rings (checks) using criteria similar to those of Moyer (1984) and Stansbery (1961). The average of three ring counts per individual was recorded as the age. To verify the external counts, annuli were also counted by personnel at the National Fisheries Research Center - La Crosse (NFRC) on a washboard subsample using a thin sectioning technique described by Clark (1980).

Gravidity was determined by gross examination of the gills and contents. A mussel was considered gravid if the marsupia showed any

evidence of contents, either eggs, zygotes or glochidia. In most cases

identification of gravid females was easy; in cases where it was not, the gills and excurrent opening were pricked and probed to determine if contents were present.

Washboards were collected from April to November 1986 by diving in Pools nine and 10 . Additional specimens were collected in July and placed in wire cages for later removal. A total of 50 cages containing 22 mussels each were anchored in Pool 10. At least one cage per month was removed from November 1986 through August 1987 and the washboards examined for gravidity.

All three ridge were collected by diving and brailing from April through November 1986. These specimens were obtained from Pools seven through 10.

Population Estimates

Roving instantaneous sheller boat counts were conducted by the Iowa Department of Natural Resources twice a month in the main channel and sloughs of Pools nine, 10 and 11 in June, July and September 1986. Using these counts and sheller interviews, the four beds that yielded the greatest three ridge and washboard harvest were chosen for a post-season population estimate and exploitation study.

Study area boundaries were drawn on aerial photographs based on boat counts and results of shellers' reports. Sampling stations were selected randomly using a grid overlay and surface areas determined digitally using the WDNR Graphic Data Entry System. A minimum of 20

stations were sampled in each area. The density variances of these

were analyzed to determine statistical reliability. If needed, additional samples were then collected within the required areas.

A total of 98 stations were sampled by SCUBA divers and/or a petite Ponar. Ponar samples were used to determine whether or not diving was required at 65 stations. Stations having the following characteristics were not dove and assumed to contain no three ridge or washboards: absence of shells or fragments; fine silt or loose, coarse sand substrate; depth less than 0.5 m; very high current velocity and loose, coarse sand substrate.

A SCUBA diver placed all articulated shells and substrate into a four mm mesh size bag removed from a one-quarter square meter metal frame. Frames were cleared to a depth at which no shells could be found. Four frames were sampled at each station, one three meters off each corner of a 18 ft. boat. Total length and height of the mussels were measured. The condition of the mussels were recorded as living, dying or fresh dead. All mussels greater than 22 mm in any dimension were collected.

Raw data collected in 1980, which was summarized by Duncan and Thiel(1983), was sorted for washboard lengths sampled from the 1986 study areas. These lengths were then used to generate a 1980 age distribution using the age/length regression equation presented in this report.

The 1986 three ridge population age structure was generated by first calculating the percent age contribution to each one mm length class in a sample of 997. This was then used to convert the post

season population density sample lengths (N = 620) to ages. The

washboard age structure was based on a sample within which all specimens were aged by counting external annuli.

Population size estimates were calculated by expanding the mean density within each study area to its surface area. A combined population estimate for all study areas used weighted means from each area.

Harvest Assessment

Estimated weight and number of mussels harvested were made for two portions of the UMR: one for the population estimate study areas and another for the entire river bordering the state of Wisconsin. Estimate data came from four sources: sheller interviews, shellers' reports, buyers' reports and verbal information given voluntarily by two buyers operating in Iowa. The study area estimate came from sheller interviews and voluntary reporting. Shellers', buyers' and voluntary reports were used for the entire UMR estimate.

From 6 June through 26 September 1986, sheller interviews were conducted at the three Wisconsin shell buyers who purchased mussels harvested from the UMR. Locations were selected randomly for each of two consecutive three hour time slots per day. The schedule placed greater weight on the last two slots (3:00 p.m. to 9:00 p.m.) than on the first two (9:00 a.m. to 3:00 p.m.) and on the week days than on the weekend days because more transactions occurred at these times. A week day stood a four times better chance of being scheduled than a weekend

day and the 3:00 to 9:00 slots stood a four times better chance of

being scheduled than the remaining slots. Every sheller that sold shells during the time slot at the scheduled location was interviewed.

Interviewers recorded the pounds of living and dead mussels of each species or a combination as weighed on the buyer's scale. Total hours, date(s), location shelled, gear, name and which state issued the sheller's license were noted. During each interview a subsample of 50 randomly selected mussels were measured by height. From 4 August to 12 September the subsample was separated into species and weighed. Data was then expanded to arrive at a harvest estimate for the study areas and the UMR bordering Wisconsin.

Beginning 1 June, each sheller holding a Wisconsin license was required to record their daily activities and transaction on a form provided by the WDNR. Required information included date, location, method of harvest, weight, percent composition of each species by weight, weight sold, money received and the identification of their buyer.

Wisconsin licensed buyers were required to report beginning 20 July 1986. These reports included the sheller's name, address and license number, date of the transaction, pounds of fresh (living) and dead mussels, amount paid for fresh and dead mussels each and the total amount paid. Interview results, shellers' and buyers' reported weights were directly extrapolated to a common time period.

EXPLOITATION ASSESSMENT

Since population density sampling began in the four study areas after the season closed, the following formula was used to calculate a point estimate for exploitation:

$$\% \text{ EXPLOITATION} = \frac{\text{ESTIMATED \# HARVESTED}}{\text{ESTIMATED POPULATION} + \text{ESTIMATED \# HARVESTED}} \times 100\%.$$

Sheller interview data was sorted for harvest information from the four population estimate areas. Intermediate statistics were then calculated to obtain exploitation rates and variance estimates. Then the weight of mussels purchased by Iowa buyers caught from within the study areas was added to arrive at the final rates. Since no statistical information was available on the additional catch, exploitation rate variance estimates were assumed to be similar.

Statistical analyses were done using the SAS Version 5.16 computer program (SAS Institute Inc. 1985a, 1985b).

RESULTS

Age, Growth and Gravidity

Analysis by the NFRC of 118 washboard specimens aged by counting thin section and external growth checks indicated a significant relationship ($P \leq 0.001$, R-square = 0.81) between the external count and

the thin section count (Holland Pers. Com. to Thiel).

Washboard mean height at age is given in FIGURE 6 (N=747). Of the three regression methods attempted for an age-height relationship: linear, logarithmic and exponential the latter had the best fit and association. This equation was:

LOG 10 AGE = 0.0121 (HEIGHT mm) + 0.0907 (R square = 0.89).

According to this equation, a 3 1/2 inch (=88.9 mm) and a 4 inch (101.6 mm) washboard are on average, 14.7 and 20.9 years old respectively.

The washboard age-length equation was:

LOG 10 AGE = 0.0089 (LENGTH mm) + 0.0776 (R square = 0.90).

Three ridge mean height at age is given in FIGURE 7 (N = 997). The three ridge age-height equation was:

LOG 10 AGE = 1.6097 (LOG 10 HEIGHT mm) - 1.5846 (R - square = 0.87).

According to this equation the average age reached at legal size of 2 5/8 inches (=66.7 mm) is 22.5 years and the age reached at 2 3/4 inches (=69.9 mm) is 24.2 years.

The three ridge age-length equation was:

LOG 10 AGE = 1.5354 (LOG 10 LENGTH mm) - 1.6246 (R - square = 0.89).

The period of washboard gravidity for 1986 and early 1987 is given in TABLE 1. Gravid females were observed on 25 August through 19 November 1986. The peak gravidity period extended from approximately 27 August through 27 October in which 49.1% of the population was gravid. No specimens under six years of age were found gravid at any time of the year. During the peak gravidity period, 10.8% of the age six , 34.1% of the age seven, 57.9% of the age eight and 60.0% of the age nine individuals were gravid compared to an average of 65.7% gravid

for ages 10 and greater (TABLE 2). The percent contribution to the

gravid population by age class during the peak gravidity period is given in TABLE 2. The age at which washboards reach their maximum percent gravidity was calculated to be 10.2 years and the age at which half of their maximum percent gravidity is reached was 7.3 years.

A total of 807 three ridge was sampled for gravidity determination. The first gravid individual was observed on 9 June (TABLE 3). Three ridge sampling ceased on 26 June and was not continued until 24 October. Of the 804 in which external age counts were made, age 10 was the youngest found gravid.

1986 Population Density and Size Estimates

Living washboard and three ridge population densities within the four population estimate study areas are given in TABLES 4 and 5. Washboard densities were highest within Harper's Slough. The highest three ridge density was found in the East Channel while the greatest density of legal-sized three ridge occurred in Harper's Slough.

Total estimated number (in millions) of washboards in all four areas was 7.86 of which 2.2 were legal-sized. Estimated population size of three ridge was 78.8 of which 12.2 were legal-sized and 7.8 were greater than the market size limit.

Population Age and Height Structures

The washboard population sample height distribution is given in

FIGURE 8. Of 748 individuals measured, 36.4% were greater than the

present legal minimum size limit while 9.5% were greater than four inches. Included between these two heights was 26.9% of the sample. Heights ranged from 17 to 117 mm with a mean of 77.9 mm (SD = 21.1).

Three ridge population sample heights (N = 627) ranged from six to 83 mm with a mean of 47.3 (SD = 18.6). Nearly 10% were greater than the market size limit and 15.8% greater than the legal size limit (FIGURE 9).

The age class structure of washboards is given in FIGURE 10. Ages zero, one and two were under represented due to the sampling method. Frequency peaks occur approximately every seven years at ages seven, 14, 20 and 28. Ages ranged from one to 45. The proportion younger than age six was 15.8% while 38.9% were less than ten years of age. Total mortality calculated from a catch curve (Ricker, 1975) using the average age at which the minimum legal size is reached (14 years) and greater was 14.16% (R-square = 0.87). Natural mortality derived from fresh dead and dying washboard data was 5.43%.

The age class structure of three ridge is given in FIGURE 11. Frequencies for ages zero, one two and three were biased due to the sampling method. Ages ranged from zero to 38. The portion of the population sample younger than age 11 was 42.1%.

Harvest Assessment - UMR

A total of 227 sheller interviews were conducted from 6 June through 26 September. Since one buyer purchased three ridge near La

Crosse, Wisconsin and interviews were conducted only at the three

Prairie du Chien buyers, interview harvest assessment data did not include some catch information on this species from approximately Stoddard, Wisconsin upstream.

In the live mussel subsamples (N = 9666) 60% of the catch in numbers of individuals were washboards followed by three ridge (38.2%), Mapleleaf (1.7%) and Pimple Back (<0.1%). No Pig Toes were subsampled but interviewers noted a very small number in the catch.

Information used to calculate the total amount harvested is presented in TABLE 6. From 6 June through 26 September 473,247 Lbs. of living washboard, 140,722 Lbs. living three ridge, 262,930 Lbs. dead washboard and 13,141 Lbs. dead three ridge were estimated to have been harvested (TABLE 7) based on interviews. Estimated value from the three harvest information sources is given in TABLE 8.

Living washboard catch height distribution (N = 5806) based on sheller interviews is given if FIGURE 12. The mean height of the harvest sample was 99.01 mm (SD = 8.0) and heights ranged from 50 to 128 mm. A total of 4.1% of the catch was under the legal size limit, 36.4% was over four inches and 59.53% was between 3 1/2 and four inches inclusive. The most frequently harvested size was 90 mm, just over the minimum legal size limit.

Living three ridge catch height distribution based on sheller interviews is given in FIGURE 13. A total of 2.22% of the catch was under the legal size limit of 2 5/8 inches, 25.32% was under the industry size limit of 2 3/4 inches and 23.1% of the catch was between these two sizes. The majority of the catch (57.17%) was between 2.68

and 2.8 inches inclusive. The mean height was 72.06 mm (SD = 4.1) and

ranged from 59 to 101 mm. The most frequently harvested size was 70 mm, just over the market size limit.

Of the three harvest methods reported from sheller interviews, diving accounted for the largest portion of the catch by weight (68.1%) followed by brailing (28.0%) and hand picking (3.9%) (TABLE 9).

The percent weight composition of harvested living and dead three ridge and washboard is presented in TABLE 10. No washboards were harvested upstream of Pool nine since Wisconsin regulations prohibit harvest there.

Harvesting based on shellers' reports occurred in Navigation Pools four, seven, eight, nine and 10. The highest percent catch by weight came from Pool eight followed by nine, seven, 10 and four (TABLE 9). Of specific harvest locations reported Goose Island accounted for the largest percent catch by weight followed by Lynxville, Stoddard, Trempealeau, St. Paul Slough and Indian Isle (TABLE 11). Lynxville and Indian Isle were included in the population estimate study areas. Harvest methods for each Pool and percent of total reported weight by month are given in TABLES 12 and 9. Approximately 15.3% of the catch by weight from June through September occurred after 15 August.

Catch per unit effort (CUE in Lbs./Hour) computed from sheller interview data was 77.9 of which 49.7 was living and 27.8 dead (TABLE 13). Diving had the highest CUE followed by hand picking and brailing. Pool eight had the highest total CUE followed by nine, seven and 10. August had the highest CUE followed by June, September and July.

Exploitation Assessment

It was estimated that 240,366 living washboards and 160,989 living three ridge were caught from 6 June through 26 September within the four study areas. Within this same time period it was estimated that 3.1% of the washboards and 0.20% of the three ridges were harvested from the four population estimate study areas. A total of 9.89% of the legal washboards and 1.32% of the legal three ridge were caught (TABLE 14).

DISCUSSION

Population Age and Height Structures

The 1986 washboard population age structure appears weakly represented from ages three to 12 and normally distributed from ages 13 and greater. The corresponding year classes in 1980 are weakly represented as well (1980 ages three to six) while the remaining year classes appear fairly normal (FIGURE 14).

Using the calculated natural and total mortality rates, expected ages frequencies in our sample population were plotted and compared to

the observed (FIGURE 15). The observed frequency summation was 56.5%

of the expected from ages three to 14 indicating less than expected age class strength. Duncan and Thiel (1983) reported low levels of recruitment in Pool 10 from data collected six years earlier. This evidence suggests that washboard young-of-the-year recruitment has been relatively weak since at least 1974.

The observed frequencies in the washboard population height distribution gradually increases from the minimum height to 91 mm and then abruptly drops. This inflection point corresponds with the minimum legal size limit and the height most frequently harvested (90 mm). Although middle-aged and older mussels have gradually decreasing growth rates the more they age (Stein, 1973; St. John, 1974; Moyer, 1984); the abrupt change observed is not characteristic of an unexploited population. This evidence suggests that commercial harvest of washboards has an effect on their population structure in the UMR.

In contrast, the three ridge population height distribution does not show a dramatic drop in observed frequencies at the legal (67mm) or market (70mm) size limit. Frequencies decrease gradually as would be expected with slowing growth rates of the older individuals. Harvest has had less impact on the three ridge population height structure. This is apparently due to two reasons. Three ridge are very abundant; outnumbering washboards 10 to one. Secondly, the three ridge exploitation rate (1.32%) is much lower than that of the washboard's (9.89%). The three ridge population age structure is weakly represented from ages six to 17 but strong elsewhere. Young-of-the-year recruitment seems to have rebounded as evidenced by ages four and

five.

Population Density Comparisons

A comparison of mean number of mussels per square meter in 1980 and the present study was made. The earlier densities were calculated from raw data which was summarized by Duncan and Thiel (1983). In 1980 quantitative samples were not taken in the Lynxville study area, so comparisons were only possible in the remaining three areas. Due to the non-normality of both sets of sample data, the information was Log 10 transformed before doing Student's t tests.

Results of these tests are given in TABLES 15 and 16. Washboard population densities in all three size classes and areas have dropped significantly in six years. Individuals of all sizes decreased about 65% while legals and sublegals declined 80% and 53% respectively.

Three ridge densities dropped less dramatically. All sizes of this species declined 39% while legal and sublegal densities of this species were reduced by 11% and 42% respectively. Within each study area, all densities were significantly reduced except legal three ridge in two areas.

The greater relative decline in sublegal three ridge is supported by the 1986 population age structure. The weak age classes (six to 17) are all sublegal and have contributed to a wider range of classes since 1980 (FIGURE 11). Legal density has declined little or none because these weak classes have not reached legal size and their exploitation rate is comparatively low. Three ridges of all sizes may have declined less than washboards of all sizes because a smaller portion of the

three ridge population is harvested. A total of 36.4% of the

washboards and 10% of the three ridge were of salable size in 1986.

In contrast, greater relative drop in legal washboards could be due to exploitation since apparently there were no weak age classes moving into the minimum legal size (ages $\geq$ 14) (FIGURE 10) as there were in the sublegal three ridge population. In 1981 the Prairie du Chien mussel buyers reduced their minimum size limit from four to 3 1/2 inches thus increasing exploitation within this half inch range of the washboard population. The drop in sublegal density is most likely due to the weak age class strength in ages 12 and younger as demonstrated previously. In the East Channel Miller and Payne (1987) also documented weak recruitment during 1984 and 1985. For both species, documented natural mortality events since 1982 (Havlik, 1987; Thiel, 1987) may have contributed greatly to density reductions in all size classes.

Harvest Assessment

The differences between the three information sources of harvest weight estimates (TABLE 7) can be explained. Interviews were not conducted outside of the Prairie du Chien area. At least one buyer was purchasing mussels near La Crosse, Wisconsin. These mussels were caught from approximately Stoddard, Wisconsin upstream. Shellers reported harvest included only those shellers holding a Wisconsin

license, not ones licensed only by reciprocal states. The harvest

estimate based on buyers' reports included mussels purchased at locations where interviews were not conducted as well as non-Wisconsin licensed shellers' catches. In addition, results of statistical tests to determine whether buyers reported accurately compared to interview information concluded that they did. During 1987, WDNR conservation wardens cited shellers 42 times for non-compliance with reporting regulations. No buyers were cited. In conclusion, for estimating total weight harvested from the UMR bordering Wisconsin, weight reported by buyers (1,333,706 Lbs.) seems to be the most accurate; although this figure, as with all others, does not include harvest that occurred from March through May.

Total harvest weight has increased since 1977 and 1978. Thiel (1981) estimated that during these years, 150 and 124 tons of living mussels were purchased. This compares to the 1986 June through September harvest of living mussels of 460 tons. This harvest increase is due to increased effort, not larger mussel stocks. Since 1977, the number of buyers in the area has increased from one to five and the price per pound has more than quadrupled from $0.05 to $0.22. These increases have encouraged and corresponded to a greater number of shellers. In fact the initiation of the revised 1986 harvest regulations was done by shellers and buyers who were concerned about the increasing number of shellers, particularly non-residents. Greater harvest pressure and declining stocks may have prompted the industry to reduce its washboard minimum size limit in 1981 from four to 3 1/2 inches. Fritz (1986) also noted a significant increase in harvest

weight from the Mississippi River bordering Illinois. He attributed

this to increased price, not larger stocks.

Exploitation Assessment

To determine likely future effect of observed exploitation and mortality on washboard populations, the 1986 age structure was projected forward six years to 1992. The total mortality rate was applied to legal mussels and the natural mortality rate to the sublegals. Three different projections were done using varying total mortality and exploitation rates. Percent of the sample population change was then calculated. A relationship was found from which steady state was estimated (R - Square = 0.98).

Results of these projections are given in FIGURE 16. At the observed exploitation rate of 9.89%, 14.25% of the washboards in ages 10 to 45 were lost by 1992. At no exploitation, 14.2% was gained in six years. Steady state was estimated at 4.56% exploitation and 10% total mortality. The population changes were not due to the peaks or troughs of the seven year age structure periodicity since the projections included six years, enough to cover a cycle. Very similar changes were found when the average age of legal size and older (14 to 45) were used. It is not surprising to see these population changes with the manipulated exploitation rates since the observed exploitation comprises 70% of total mortality. Using the washboard harvest height di limit was estimated that would correspond to the steady state exploitation rate. This limit was 3.86 inches. Several assumptions

were made in deriving this. Total effort would remain the same and the catch height distribution would be similar in future years to that of 1986. Also, the reduction in the harvestable stocks was proportional to the decreased exploitation.

Note that this steady state exploitation rate is based on projections that extend until 1992 only. In 1986, the strongest sublegal age classes were recruiting into harvestable size leaving increasingly weaker ones to follow beyond 1992. In other words, although reductions were observed by 1992 in ages 10 to 45, beyond this year a greater reduction is likely to be seen in legal-sized stocks. In addition, even under a higher size limit the loss of brood stock can only worsen young-of-the-year recruitment.

Historic and Present Geographic Ranges

Mussel surveys conducted in the early half of this century have documented the presence of washboard and three ridge in the entire UMR bordering Wisconsin (Baker, 1905,1928; Dawley, 1947; Grier, 1922, 1926; Grier and Mueller, 1922; Shimek, 1921; Van der Schalie and Van der Schalie, 1950; Wilson and Danglade, 1914). Results of recent surveys indicate a dramatic reduction in washboard range and no reduction in the three ridge range (Coon et. al., 1977; Finke, 1966; Fuller, 1978, 1980a, 1980b; Mathiak, 1979 and Thiel, 1981). Washboards have essentially disappeared from 57% of its historic range in Wisconsin. If this trend continues as it has in the last 80 years, this species

will be entirely absent from state waters.

Causes of Poor Recruitment

As evidenced by both species population structures and population density declines, in general the present basic problem is poor recruitment of legal and sublegal stocks. Factors affecting recruitment may be environmental and/or harvest related.

Since harvesting occurs during the gravidity seasons of both species, premature glochidial abortion caused particularly by brails is a potential source of low recruitment. Numerous observations can be found in the literature of mussels aborting or being unable to rebury themselves after being handled or brailed. (Fuller, 1974; Imlay, 1972; Miller, 1972). Coker et. al. (1921) noted that summer breeders, like the three ridge, abort easily and that washboards "when removed from the water...quickly abort the contained glochidia.". During our own field work these observations were verified. The effect of premature abortion on glochidial survival is unknown but if abortion occurs early in development when their structures are not fully formed, attachment to a host fish is not possible.

Paucity of fish hosts does not seem to be a causative agent. Fuller (1978) listed 16 and 15 common and wide-ranging fishes that have been recorded to serve as glochidial hosts for washboard and three ridge respectively. Changes in water quality, sediment load and siltation may have caused sterility or increased glochidial and juvenile mortality (Bates, 1962; Crossman et. al., 1973; Isom, 1969;

Scruggs, 1960). River channel maintenance for navigation, impoundment

as well as direct and indirect effects of barge traffic may have significantly influenced these species survival and reproduction (Coon et. al., 1977; Fuller, 1974; Isom, 1969; Starrett, 1971). Recurring die-off events from unknown causes could also be blamed.

The harvest of washboards at 3 1/2 to four inches may have seriously impacted recruitment. Assuming the oldest age achieved by an individual is 45 and sexual maturity occurs at age 10, harvesting at a minimum size of four inches reduces the potential reproductive years by 30%. At 3 1/2 inches, reproductive years are reduced by almost 60%. This half inch size class comprised 59.5% of the catch and accounted for 41.5% of the gravid population during the peak gravidity period of 1986. In populations of long-lived organisms, shortening reproductive potential can only reduce recruitment for these animals whose strategy is to propagate slowly but do so over many years. A closed season for washboards during their gravidity period would certainly improve recruitment but alone may be inadequate to bring population densities and recruitment back to historic levels.

Although it is unclear what extent harvest has contributed to washboard population declines as documented in this report, the commercial mussel industry must accept some responsibility. Others have blamed commercal harvest as a major cause of mussel declines as well (Isom, 1969; Oesch, 1984; Starrett, 1971; van der Schalie, 1938; Wetzel and Kasprowicz, 1985). Contrary to what the industry has repeatedly insisted upon, mussel populations have drastically dropped during a time of increased harvest pressure. Conditions at present are

severe enough that a population collapse is possible. Future harvest

at present levels will seriously affect populations of this species. It is obvious that present regulations are grossly inadequate to protect this species in Wisconsin-Iowa boundary waters. Until adverse environmental factors can be fully understood and controlled, harvest restrictions are the most practical vehicle to stabilize or reverse population declines.

To insure survival of this species in state waters and to increase future chances of a sustained yield, washboard management goals should attempt to rebuild this population. Therefore a season closed to commercial harvest is recommended. Rules pursuant to this should remain in place until future studies demonstrate that recruitment has improved and stocks are more abundant. Then a framework for sustained harvest should be carefully developed.

Three ridge recruitment and population trends are not as well understood as the washboard. Although some of the same factors affecting washboards also threaten three ridge, its exact status remains unclear. Recruitment appears inconsistent and densities of all but legal-sized mussels have declined, however the geographic range has not changed. A precautionary measure to allow continued harvest would be to increase the legal minimum size limit to the present salable size limit of 2 3/4 inches.

SUMMARY

1) A mussel study was done during 1986 and 1987 in the Upper Mississippi River (UMR) bordering Wisconsin. The primary objectives were to describe the basic population parameters of the three ridge and washboard mussels and to characterize their commercial harvest and its effect.

2) Population data was collected primarily by the use of SCUBA. Shellers' and buyers' reports as well as a "creel" census were used to gather harvest information.

3) An estimated total of 667 tons were harvested from the UMR bordering Wisconsin from 1 June through 30 September 1986. Since 1977 and 1978, there has been a 335% increase in live weight harvested.

4) In four mussel beds studied, it was estimated that there were 7.86 million washboards and 78.8 million three ridge present.

5) Based on these estimates and "creel" survey information, a total of 9.89% and 1.32% of the legal washboards and three ridge respectively were harvested from these beds. Washboard natural mortality was 5.43%. Exploitation accounted for 70% of the total mortality rate of 14.16%.

6) From data collected in 1980, mussel population densities were calculated and compared to densities from the same beds in 1986. Since 1980, washboard population densities have decreased 65% while legal and sublegals have declined 80% and 53% respectively.

Three ridge have declined 39% while densities of sublegals have

decreased 42%. Legal-sized three ridge densities have changed little.

7) The 1986 washboard height distribution shows a dramatic drop corresponding with the minimum legal size limit and the most frequently harvested size indicating that harvest does have an impact on this population. Harvest of three ridge does not have an effect on its height distribution.

8) The 1986 washboard age distribution indicated poor recruitment in ages three to 12. Three ridge age structure was weakly represented from ages six to 17 but strong elsewhere.

9) According to our population projection of the washboard age distribution, at the observed exploitation rate of 9.89%, 14.25% of the washboards in ages 10 to 45 were lost by 1992. At no exploitation, 14.2% were gained. Steady state was estimated at an exploitation rate of 4.56%.

10) Implementation of the calculated washboard steady state size limit of 3.86 inches would only delay legal sized stock loss until 1992. After which a dramatic loss would occur and poorer young-of-the-year recruitment would be expected due to the loss of this brood stock.

11) In the last 80 years, washboard range in Wisconsin has reduced 57%. Three ridge range has not changed.

12) During the two year study, gravid washboards were found from 25 August through 19 November 1986 and the youngest found fully sexually mature was age 10. Gravid three ridge were found during

the summer and the youngest found was age 10.

13) The present basic problem is poor recruitment of sublegal and legal-sized mussel stocks, particularly washboard.

14) Population density reductions and recruitment problems may have been due to several factors. Changes in water quality, sedimentation load and siltation may have caused mussel sterility or increased glochidial and juvenile mortality. Channel maintenance, impoundment, recurring die-off events as well as direct and indirect effects of barge traffic may have significantly affected mussel survival and reproduction.

15) Commercial harvest of sexually mature stocks particularly in the 3 1/2 to four inch size range may have caused reduced recruitment. This half inch accounted for 59.5% of the catch and 41.5% of the sexually mature population. Disturbance of gravid mussels during the reproductive seasons may have caused reduced recruitment and abortion of larvae.

16) The commercial mussel industry must except some responsibility for past and present washboard population declines. Increased harvest pressure since 1977 and reduced stocks since at least 1980 prompted the industry to reduce its own washboard size limit making the problem more severe. Clearly exploitation has had a deleterious effect on this species abundance and present harvest regulations are grossly inadequate to protect it. Although adverse environmental factors have surely contributed to this species decline, the only practical method to halt present and future trends is to reduce washboard harvest.

17) Management goals for washboard should attempt to rebuild the

population. Therefore a closed season in Wisconsin-Iowa boundary waters is recommended.

18) Precautionary measures should be taken for the three ridge population. An increase in the present minimum size limit to 2 3/4 inches is recommended.

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AN ASSESSMENT OF THE 1986 COMMERCIAL HARVEST OF FRESHWATER MUSSELS IN THE MISSISSIPPI RIVER BORDERING WISCONSIN

by

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SUMMARY REPORT

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FINAL

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