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THE USE OF QUANTITATIVE DATA ON FRESHWATER MUSSELS TO ASSESS THE ENVIRONMENTAL IMPACTS OF COMMERCIAL NAVIGATION TRAFFIC IN WATERWAYS OF THE UNITED STATES

by

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1. USE OF WATERWAYS FOR COMMERCIAL PURPOSES

BACKGROUND

In the United States three projects are responsible for initiating concern over the environmental effects of commercial navigation traffic. These are the Tennessee-Tombigbee Waterway, a connecting link between the Tennessee and Tombigbee Rivers in Alabama and Mississippi; replacement locks and dam in the Mississippi River near Alton, Illinois; and construction of a new lock in the Ohio River at Gallipolis between Ohio and West Virginia. However, during the last 10 years environmental groups and state conservation agencies have directed attention toward impacts of vessel movement. As a result, much speculation and discussion on this topic has appeared, most in the government or nonrefereed literature, Virginia Polytechnic Institute and State University (1975); Academy of Natural Sciences of Philadelphia (1980); Berger Associates, Ltd. (1980); Sparks et al. (1980): U.S. Army Corps of Engineers (1980); Lubinski et al. (1980, 1981); Environmental Science and Engineering (1981, 1988); Kennedy et al. (1982); Rasmussen (1983); Simons et al. (1981, 1987); Wuebben et al. (1984); and Nielsen et al. (1986). Much of this writing has been considered speculative, Wright (1982). Regardless, the increasing use of inland waterways to transport bulk commodities, Dietz et al. (1983), and the recent articles on impacts of waterway use in Europe, Brookes and Hanbury (1990) and Haendel and Tittizer (1990), suggest that this issue will remain important well into the 21st century.

PHYSICAL EFFECTS OF VESSEL PASSAGE

A review of the literature indicates that the pulse of velocity and turbulence associated with vessel passage has been a major concern. It has been suggested that vessel-induced change in magnitude and direction of flow negatively affects benthic organisms by scouring substrates and resuspending fine-grained sediments. Figure 1 illustrates the change in magnitude and direction of flow, caused by passage of a commercial vessel. The vessel was an 800-hp (597-kW) workboat with a 7.5-ft (2.286-m) draft and twin 60-in. (1.524-m) propellers operating at 900 rpms. It was pushing a single loaded barge upriver in water 4 m deep. The tow, which requires a 9-ft (2.7-m) draft, passed directly over a velocity sensor positioned approximately 23 cm above the substrate-water interface. Passage caused the ambient

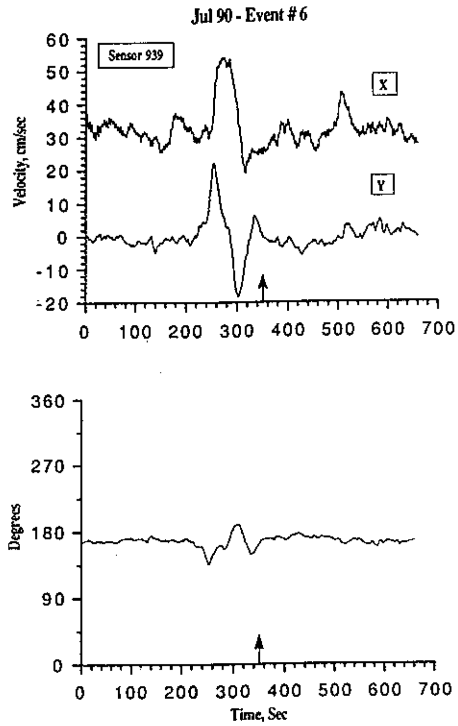

Fig. 1 - Change in ambient water velocity parallel to flow (X) and at right angles to flow (Y), and change in flow direction, caused by passage of an 800-hp workboat moving upriver in the east channel of the Mississippi River, RM 635.0. The vessel passed directly over the sensor of a Marsh McBirney 527 sensor positioned 23 cm above the substrate-water interface. Water depth = 4 m.

velocity to approximately double for about 100 sec; a change of about 30 cm/sec to slightly more than 50 cm/sec and a slight alteration in flow direction.

Miller et al. (1990b) measured changes in velocities caused by tugs pushing loaded barges in the main channel of the upper Mississippi River. He reported that a single downbound tow could cause a complete 200-sec current reversal 120 m from shore. Physical effects of traffic in the main channel were measured at a mussel bed along the shoreline. The velocity change was comparable to that which occurred in the event illustrated in Figure 1. Miller et al. (1990b) concluded that movement of a commercial vessel in the main channel can cause measurable velocity change, but usually not of a magnitude to disrupt the substrate or negatively affect the biota. Details on techniques used to measure these changes in velocity can be found in Miller at al. (1990b), Bogner et al. (1988), and Bhowmik et al. (1990 and references cited therein). Other physical effects of traffic that could affect aquatic biota are: formation of surge waves, turbulence from hull friction or propeller action, water drawdown that briefly exposes shallow-water habitats, and increased shoreline erosion, Johnson (1976), Camfield et al. (1979), Environmental Science and Engineering (1981), and Brookes and Hanbury (1990).

EVALUATING THE BIOLOGICAL IMPACTS OF VESSEL MOVEMENT

Tolerances of many aquatic organisms to sustained, specific levels of turbulence, water velocity, or suspended solids is known either from laboratory or field studies. Since vessel passage causes a brief and sometimes minor physical disturbance (Figure 1), most laboratory tolerance studies or field observations are not applicable. Intermittent disturbances caused by vessel movement, pulses of suspended sediments, changes in water velocity, and periods of desiccation can be simulated in the laboratory. Navigation-related studies have been conducted on fish eggs, Morgan et al. (1976) and Holland (1987), fish larvae, Killgore et al. (1987), Holland (1987), and Payne et al. (1991), plankton, Stevenson et al. (1986), and freshwater mussels, Aldridge et al. (1987) and Payne and Miller (1987). Results of most studies demonstrated that mortality or physiological stress could be measured under conditions corresponding to high traffic intensity. In the field, discharge, flow patterns, bathymetry, and sediment characteristics have complex influences on vessel-induced disturbances. It is extremely difficult to estimate an organismal response to these intermittent physical effects, and even more difficult is accurate prediction of long-term responses of natural populations to such disturbances. Results of the few navigation-related field studies that have been conducted are characterized by extreme spatial and temporal variability, so that clear patterns of navigation effects often cannot be discerned, Sparks et al. (1980); Bhowmik et al. (1981a, 1981b); Seagle and Zumwalt (1981); Eckblad (1981); Eckblad et al. (1984); Environmental Science and Engineering (1981); and Holland (1986). Ambient hydrologic conditions often overwhelm navigation effects, Johnson (1976).

Consideration has been given to using Habitat Suitability Index (HSI) models, developed primarily for the Habitat Evaluation Procedures, U.S. Fish and Wildlife Service (1981), to predict the environmental effects of increased traffic. However, commercial traffic does not permanently affect habitat conditions such as water depth and velocity, presence of cover, and substrate type. Examination of requirements that variables must meet to be included in an HSI model, Schamberger and O'Neil (1986), indicate that these procedures are not suitable for analyzing or predicting traffic effects.

Planners and biologists must evaluate the effects of man's activities on populations of species in their natural habitats. Whether as an alternative to, or in validation of laboratory simulation, field studies should be used to evaluate the biological effects of tow-induced disturbances. Field studies should provide quantitative data on biotic parameters such as density, relative species abundance, community composition, population demography, and rate of growth. Adequate baseline data should be established, and then additional studies can be used to determine whether commercial navigation causes measurable change. Since commercial traffic affects an entire waterway, planners and conservation groups frequently desire a « system-wide » quantification of environmental impacts. It is more practical to identify and study specific sites with special biological value that are among the most likely to be affected by commercial traffic. Results can then be extrapolated to similar sensitive sites.

2. IMPORTANCE OF FRESHWATER MUSSELS IN RIVERS OF THE UNITED STATES

Freshwater mussels (Family: *Unionidae*) dominate the benthic biomass in most large rivers in the United States, Fuller (1974). Their sedentary lifestyle and reliance on suspended particulate organic matter as food makes them particularly susceptible to turbulence, sedimentation, and fluctuating water levels. Sparks (1975), Sparks et al. (1979), and Lubinski et al. (1981) suggested that decline of freshwater mussels in navigation channels could be caused by commercial traffic. Assumptions were based largely on the knowledge that mussels require stable gravel shoals free of sedimentation.

Shells of common unionids (principally *Amblema plicata plicata* (Say, 1817), *Megalonaias nervosa* (Rafinesque, 1820), *Quadrula quadrula* (Rafinesque, 1820), and *Fusconaia ebena* (I. Lea, 1831)) are used in the cultured pearl industry, Fuller (1974), Sweaney and Latendresse (1982), and Sitwell (1985). Commercially valuable species are collected by divers or with a brail, Coker (1919), and then shipped to the Orient and processed into inserts. In the United States 25 species are listed as endangered by the U.S. Fish and Wildlife Service (1987). Willful destruction of these species or their habitat by a Federal Agency is prohibited.

3. USE OF QUANTITATIVE DATA ON MUSSELS TO ASSESS HABITAT QUALITY

Because they are long-lived and relatively nonmotile, regular quantitative assessments of freshwater mussel populations and communities provide an index of habitat quality. This, in conjunction with their ecological and commercial value and the protected status of the endangered species, makes them ideal monitoring tools. At the U.S. Army Engineer Waterways Experiment Station, the primary research facility for the U.S. Army Corps of Engineers, we have been studying freshwater mussels since the early 1980s. Research has been conducted at historically prominent mussel beds in major rivers in the central United States (Figure 2). Studies are conducted to determine whether endangered species are present and likely to be affected by proposed developments, and to evaluate the environmental effects of commercial traffic, dredging, or other water resource developments. These data will also be used to evaluate the effects of the spread and colonization of zebra mussels, *Dreissena polymorpha*, Roberts (1990). Quantitative techniques have been used for all studies, which are described in Miller and Payne (1988), Payne and Miller (1989), and Miller et al. (1990a). The following examples illustrate the use of quantitative data on freshwater mussels to monitor aquatic habitats and evaluate the environmental impacts of commercial navigation traffic.

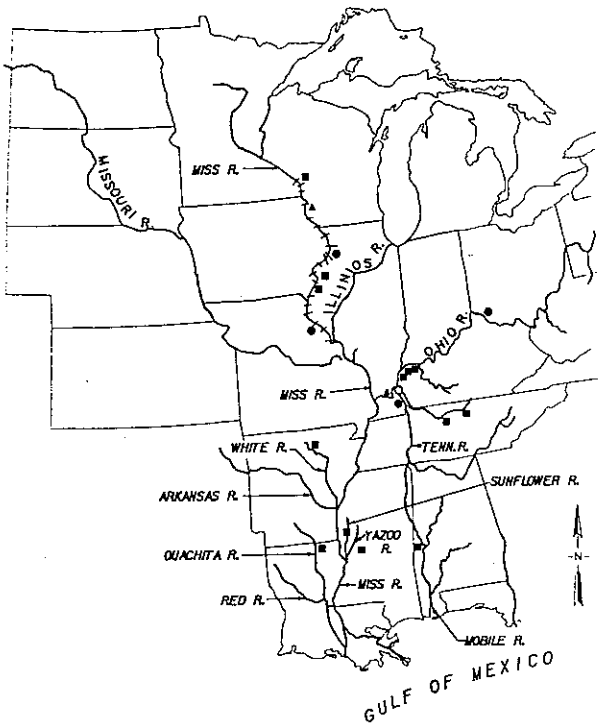

Fig. 2 - Detailed studies of freshwater mussels undertaken on major rivers in the United States. Sites identified with a solid circle have been sampled more than one year; sites identified with a solid square have been sampled one year only. Sites described in this article, the Upper Mississippi and Lower Ohio Rivers, are marked with a solid triangle.

DEMOGRAPHIC ANALYSIS OF FUSCONAIA EBENA IN THE LOWER OHIO RIVER

The Louisville District of the U.S. Army Corps of Engineers is planning to replace the last two locks on the lower Ohio River, Lock and Dam 53 (River Mile (RM) 962.6) and Lock and Dam 52 (RM 938.9) with a single lock and dam at RM 964.4. The replacement will be located immediately upriver of a dense and diverse bed of freshwater mussels, first identified by Williams (1969). The mussel bed is approximately 6 km long and occurs on the channel border adjacent to the navigation channel. *Fusconaia ebena* is the dominant species, comprising approximately 70 percent of the unionid fauna. The position of the new structure will cause vessels entering and exiting the lock to pass near the mussel bed. Quantitative studies on mussels were initiated at this site in 1983; more details appear in Miller et al. (1986) and Payne and Miller (1989).

Replicate quantitative 0.25-sq.m substrate samples were collected by scuba divers in the fall of 1983, 1985, and 1987. Sediments were sieved (finest mesh size 6.4 mm) to obtain all mussels, regardless of size. The total shell length (SL) of each mussel was measured, and SL frequency histograms were plotted. Seventy-one percent of all *F. ebena* collected in 1983 belonged to a single cohort of 1981 recruits with an average SL of 16 mm (range 13 to 20 mm) (Figure 3). By the fall of 1985, this cohort had increased to an average SL of 30 mm (range 23 to 38 mm), and still comprised 71 percent of the population. Continued linear growth led to an average SL of 47 mm by late September 1987 (range 36 to 56 mm). The relative abundance of the cohort remained high (74 percent). Its sustained high relative abundance was a result of low mortality and lack of extensive new recruitment.

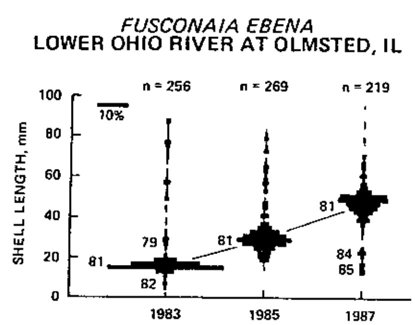

Fig. 3 - Shell length frequency histograms for **Fusconaia ebena** *collected in the Lower Ohio River (modified from Payne and Miller (1989)).*

Fusconaia ebena has existed in this reach of the river for decades, Williams (1969), in a shoal bordering the commercial navigation lane. Data clearly demonstrate that recruitment success is the principal determinant of abundance. Survival of the 1981 recruits has been high despite proximity of the shoal to a major commercial navigation lane.

The continued existence of unionids in large inland rivers depends on protection of remaining beds from impoundment, dredging, or sustained degradation of water quality, Stansbery (1970), and prevention of overharvesting. Assessments of the health of remaining mussel beds must be based on long-term quantitative studies of recruitment, growth, and survival of cohorts of dominant populations. Quantitative samples were also obtained in 1988 and 1990. The cohort continues to grow and there is evidence of only limited recruitment since the study began.

ANALYSIS OF RECRUITMENT OF AMBLEMA PLICATA IN THE UPPER MISSISSIPPI RIVER

Techniques similar to those described above are also being used to study mussels in a side channel due east of the Mississippi River near Prairie du Chien, Wisconsin (RM 635.0). A barge loading facility is in the north end of the 4.8-km-long east channel. The loading facility and dock principally handle grain and other agricultural products and has operated since the early 1960s. The east channel and an extensive reach of the main river support dense and diverse mussel populations, including an endangered species, *Lampsilis higginsi*, Havalik and Stansbery (1977). Only the north end of the east channel is navigated, although the remainder is suitable for commercial traffic. Traffic must make a sharp turn in a turning basin as they approach or exit the loading facility. The basin is only 9-12 ft deep; it and adjacent areas were dredged in 1976.

The loading facility is serviced by a workboat that draws only 2.3 m, although loaded barges require a 2.7-m channel. (The physical effects of passage of this workboat with a loaded barge were illustrated in Figure 1). In 1988 and 1989, 230 and 248 barges, respectively, were loaded and moved through the north end of the east channel (Robert Read, Wisconsin Department of Natural Resources, personal communication). Because the turning basin is shallow, the bottom is often scraped by loaded barges. Approximately 20-50 percent of the live mussels in the turning basin show evidence of abrasion. The workboat also transports barges to and from another loading facility and dock that is reached without making a sharp turn in the north end of the channel.

Quantitative mussel samples were obtained in 1984-85 and 1987-90 using divers equipped with scuba or surface air supply. An experimental site was in the barge turning zone, and a reference site relatively unaffected by vessel movement was located about 0.8 km downriver. The purpose was to determine whether vessels passing through the turning basin affected recruitment of *A. plicata*. This commercially valuable species usually comprises more than 50 percent of the fauna in this reach of the upper Mississippi River. *Amblema plicata* was separated into groups less than and greater than 30 mm total SL. Smaller individuals are three years old or less and evidence of fairly recent recruitment. The larger group contained individuals up to 120 mm SL; such large specimens could be 20 or more years old. The maximum age of large unionids is difficult to determine using shell ring counts.

Density of mussels greater than 30 mm SL in the turning basin was significantly less ($p < 0.05$ for unpaired t test) than at the reference site for all years except 1989 (Figure 4a). Intersite density differences can be attributed to dredging in the turning basin in 1976 which removed substrate and live specimens. However, there were no significant intersite density differences for mussels less than 30 mm total SL ($t < 0.65$, $p > 0.05$ for all six years). This indicates that recruitment is proceeding at a similar rate at both sites, regardless of earlier dredging and the continued use of the turning basin. Figure 4 suggests that intersite density differences are decreasing partially because of recruitment and growth of younger cohorts. The density decline after 1985 of large individuals at the reference site is unrelated to traffic, and is probably the result of mortality of older cohorts.

Pygott et al. (cited by Brookes and Hanbury (1990)) studied fish community structure in four British canals

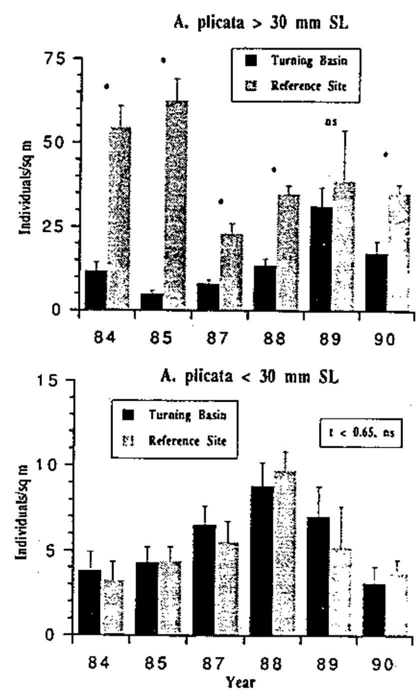

Fig. 4 - Total density (individuals/sq m) for **Amblema plicata** *greater (4a) and less (4b) than 30 mm total SL in a barge turning basin and a reference site located downriver (a). For mussels greater than 30 mm total SL, all intersite differences were significant ($p < 0.05$, denoted with an asterisk) except for 1989 (ns). For mussels less than 30 mm total SL all intersite density differences were nonsignificant.*

where traffic events ranged from 500 to 10,000 movements per year. Heavily trafficked waterways with high turbidity had the lowest fish species diversity. Murphy and Eaton (1983) reported that low traffic levels (less than 2,000 passages per year) had little effect on abundance and composition of aquatic plant communities. When the number of events exceeded 2,000 per year, the plant communities were negatively affected by water turbulence, turbidity, and suspended sediments. Payne and Miller (1987) exposed the freshwater mussel *Fusconaia ebena* to continuous low velocity (7.11 cm/sec), continuous high velocity (27.2 cm/sec) and a 5-min pulse of high-velocity water (26.4 cm/sec) every 60 minutes. A condition index (tissue dry mass/shell dry mass) was reduced in all treatments, but significantly decreased ($p < 0.05$) in the continuous high-velocity treatment. Major findings were: 1) Analysis of tissue condition provided a useful index of stress, 2) laboratory-held organisms (the control group) also exhibited a loss in physical condition; and 3) significant differences in tissue condition were found only in organisms subjected to continuous turbulence. A single 5-min pulse of turbulence (corresponding to one vessel event per hour) did not elicit a measurable change in physical condition. The above-cited field and laboratory studies clearly corroborate results of the field experiment and suggest that existing traffic levels in the turning basin (currently less than 300 events per year) are not measurably affecting population structure of the dominant species, *A. plicata*.

4. EVALUATION OF THE EFFECTS OF INCREASED TRAFFIC IN THE UPPER MISSISSIPPI RIVER SYSTEM

In the late 1980s the U.S. Army Engineer District, St. Louis began construction of the Melvin Price Locks and Dam to replace Locks and Dam 26 located on the Mississippi River near Alton, Illinois. The new structure will have two chambers, one 1200 ft (366 m) long for commercial tows, and a 600-ft (183-m) auxiliary lock (currently under construction). Since the original structure consisted of a 600-ft (183-m) lock and a smaller auxiliary lock (360 ft, 110 m), the new facility will greatly reduce traffic congestion. Previously, delays up to 72 hours were common. This is at a critical segment of the waterway; 24 km north is the confluence of the Illinois River which leads through the Chicago Ship Canal to Lake Michigan, and 16 km south is the confluence of the Missouri River. The lock is 322 km upriver of the confluence of the Ohio River which ultimately connects to the Tennessee, Cumberland, Allegheny, and Monongahela Rivers.

The U.S. Fish and Wildlife Service and state conservation groups indicated that the potential for increased traffic above the new lock could negatively affect aquatic resources, especially the endangered *L. higginsi*, U.S. Fish and Wildlife Service (1986). In accordance with the Endangered Species Act, Section 7, Consultation, in 1988 a monitoring program was initiated to assess the effects of projected traffic increases. Research was designed to obtain data on physical effects of commercial vessel passage (changes in water velocity and suspended solids near the substrate-water interface) at dense and diverse mussel beds where *L. higginsi* was found. In addition, important biotic parameters (such as species richness, species diversity, density, growth rate, and population structure of dominant mussel species) are being monitored every second year. Data are being collected on community and population parameters to determine whether commercial navigation traffic is negatively affecting *L. higginsi*. This surrogate species concept is being used since it is extremely difficult to obtain information on density, recruitment, and other items for uncommon species. In addition, intensive collections of *L. higginsi* would be detrimental to its continued existence. Baseline data are being collected from 1988-94. If appropriate, additional studies will be conducted every fifth year until 2040.

The relationship between cumulative species of mussels (Y) and cumulative individuals (X) at one of these study sites provides a measure of the difficulty of obtaining uncommon species such as *L. higginsi* (Figure 5a). In 1988, ten quantitative (0.25-sq.m) samples were collected at RM 504.8; 20 species were obtained after nearly 250 individuals had been collected. In 1989, 30 quantitative samples were collected. Additional effort yielded nearly 900 individuals and only three additional species. *Lampsilis higginsi*, which comprises about 0.5 percent of the mussel fauna at this site, was found both years. With appropriate sampling, the mussel fauna was found to have a fairly even distribution, and spanned four orders of magnitude (Figure 5b).

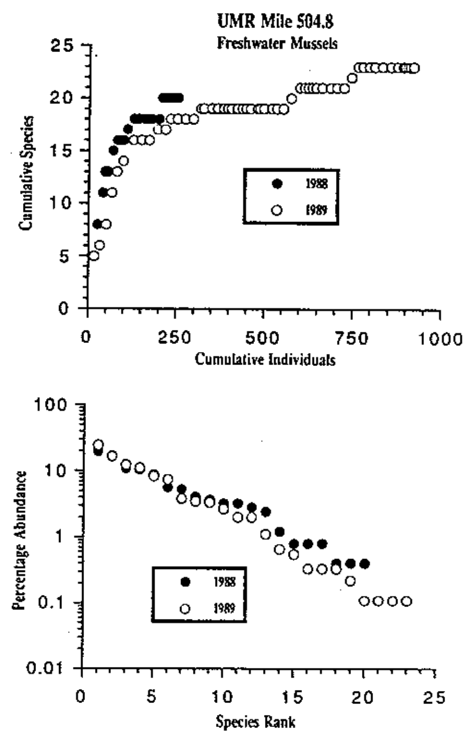

Fig. 5 - The relationship between cumulative species and cumulative individuals (5a), and percent abundance and species rank (5b) for freshwater mussels collected in 1988-89. See text for details.

Continuing studies will provide information to assess the effects of traffic on community composition and distribution, and the effort required to collect *L. higginsi.*

5. CONCLUSIONS AND RECOMMENDATIONS

Conservation agencies in the U.S. federal and state governments have expressed concern over the environmental effects of commercial vessel movement. This has resulted in the publication of many reports, some speculative and without substantial data, Wright (1982). Part of the problem is the extreme difficulty and expense of conducting field studies on traffic effects. Many species of freshwater mussels (any many fish species) live 20 or more years. At a minimum, definitive cause-and-effect studies should span a sizable segment of their life cycle.

At sites where important biotic resources exist, side channels or sites outside the navigation channel, the direct physical impacts of commercial vessel passage are usually minor (Figure 1). This information is not new, Environmental Science and Engineering (1981) published data similar to these. In shallow water commercial vessels can dislodge, scrape, or even kill aquatic organisms. However, in studies conducted near Prairie du Chien, Wisconsin, the number of traffic events per year, less than 300, is not negatively affecting structure of the *A. plicata* population. Results of heavily trafficked waterways in Europe, Murphy and Eaton (1983) and Brookes and Hanbury (1990), and laboratory experiments by Payne and Miller (1987) suggest that extremely high traffic intensities would be needed to affect certain aquatic organisms.

Although laboratory experiments provide insight into possible impacts of physical stress to natural populations, definitive empirical data can only be obtained by long-term field studies. In the United States, and certainly in most developed countries, Federal Governments are in a position to sponsor such research. Their established missions with respect to waterways and potentially stable funding bases are important components of monitoring programs. Predictions on the impacts of controlled use of natural resources should not be based on results of a single laboratory experiment or one-time field observations. Key biotic parameters should be regularly monitored similar to the manner in which data are assembled on river discharge, precipitation, or air temperature.

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RESUME

L'EMPLOI DE DONNEES QUANTITATIVES SUR LES POPULATIONS DE MOULES D'EAU DOUCE POUR L'EVALUATION DES IMPACTS SUR L'ENVIRONNEMENT DU TRAFIC COMMERCIAL SUR LES VOIES NAVIGABLES DES ETATS-UNIS

Les projets de navigation récents aux Etats-Unis se doivent aussi d'attirer l'attention des organismes de défense de l'environnement sur les impacts du mouvement des navires commerciaux. Il a été suggéré que les changements d'amplitude et de direction du courant induits par les navires pourraient avoir des impacts négatifs sur la croissance, la reproduction et la survie des organismes benthiques. Des études en laboratoire ont démontré qu'il était possible de mesurer la mortalité ou la tension physiologique dans les larves de poissons ou dans les moules d'eau douce (de la famille des *Unionidae*) dans des conditions correspondant à un trafic à haute densité. Il est cependant difficile d'évaluer la réponse d'un organisme aux tensions physiques intermittentes. Il est encore plus difficile de prédire avec précision la réponse à long terme des organismes à de telles perturbations. Les effets biologiques du passage du trafic commercial devraient être mesurés dans les populations d'espèces vivant dans leur habitat naturel. Les études devraient fournir des données quantitatives sur les paramètres biotiques tels que la densité, l'abondance relative des espèces, la composition de la communauté, la démographie des populations et le taux de croissance. Il convient de recueillir en premier lieu des données de base adéquates, puis de conduire des études additionnelles pour déterminer si le mouvement des navires commerciaux est à l'origine d'un changement mesurable dans les communautés biotiques naturelles.

Les données quantitatives sur les populations et communautés de moules d'eau douce fournissent un indice de la qualité de l'environnement, car ces moules ont une longue durée de vie, sont dotées de relativement peu de motilité, et forment l'élément dominant de la biomasse benthique de la majorité des grands cours d'eau des Etats-Unis. La structure de la population de moules d'eau douce *Fusconaia Ebena* d'un haut-fond avoisinant un couloir de navigation sur le Bas Ohio, près de Cairo, Illinois, a été étudiée dans le cadre d'un programme de monitorage des impacts sur l'environnement du trafic commercial sur les voies navigables. Les données recueillies démontrent clairement que le succès du recrutement est la déterminante principale de l'abondance des populations. Le taux de survie de la population récente était élevé en dépit du voisinage de la voie de navigation.

Une étude similaire a été conduite dans le Haut Mississippi, au Wisconsin, où des échantillons quantitatifs de moules ont été recueillis, d'une part dans une zone de manœuvre de barges draguée en 1976, et, d'autre part, dans un site de référence relativement peu affecté par le mouvement de navires, situé en aval. Les résultats indiquent que le recrutement de moules *Amblema plicata* progresse au même taux sur les deux sites, et ce malgré l'usage du bassin de manœuvre par des navires commerciaux ou le dragage précédent.

Fusconaia ebena has existed in this reach of the river for decades, Williams (1969), in a shoal bordering the commercial navigation lane. Data clearly demonstrate that recruitment success is the principal determinant of abundance. Survival of the 1981 recruits has been high despite proximity of the shoal to a major commercial navigation lane.

The continued existence of unionids in large inland rivers depends on protection of remaining beds from impoundment, dredging, or sustained degradation of water quality, Stansbery (1970), and prevention of overharvesting. Assessments of the health of remaining mussel beds must be based on long-term quantitative studies of recruitment, growth, and survival of cohorts of dominant populations. Quantitative samples were also obtained in 1988 and 1990. The cohort continues to grow and there is evidence of only limited recruitment since the study began.

ANALYSIS OF RECRUITMENT OF AMBLEMA PLICATA IN THE UPPER MISSISSIPPI RIVER

Techniques similar to those described above are also being used to study mussels in a side channel due east of the Mississippi River near Prairie du Chien, Wisconsin (RM 635.0). A barge loading facility is in the north end of the 4.8-km-long east channel. The loading facility and dock principally handle grain and other agricultural products and has operated since the early 1960s. The east channel and an extensive reach of the main river support dense and diverse mussel populations, including an endangered species, *Lampsilis higginsi*, Havalik and Stansbery (1977). Only the north end of the east channel is navigated, although the remainder is suitable for commercial traffic. Traffic must make a sharp turn in a turning basin as they approach or exit the loading facility. The basin is only 9-12 ft deep; it and adjacent areas were dredged in 1976.

The loading facility is serviced by a workboat that draws only 2.3 m, although loaded barges require a 2.7-m channel. (The physical effects of passage of this workboat with a loaded barge were illustrated in Figure 1). In 1988 and 1989, 230 and 248 barges, respectively, were loaded and moved through the north end of the east channel (Robert Read, Wisconsin Department of Natural Resources, personal communication). Because the turning basin is shallow, the bottom is often scraped by loaded barges. Approximately 20-50 percent of the live mussels in the turning basin show evidence of abrasion. The workboat also transports barges to and from another loading facility and dock that is reached without making a sharp turn in the north end of the channel.

Quantitative mussel samples were obtained in 1984-85 and 1987-90 using divers equipped with scuba or surface air supply. An experimental site was in the barge turning zone, and a reference site relatively unaffected by vessel movement was located about 0.8 km downriver. The purpose was to determine whether vessels passing through the turning basin affected recruitment of *A. plicata*. This commercially valuable species usually comprises more than 50 percent of the fauna in this reach of the upper Mississippi River. *Amblema plicata* was separated into groups less than and greater than 30 mm total SL. Smaller individuals are three years old or less and evidence of fairly recent recruitment. The larger group contained individuals up to 120 mm SL; such large specimens could be 20 or more years old. The maximum age of large unionids is difficult to determine using shell ring counts.

Density of mussels greater than 30 mm SL in the turning basin was significantly less ($p < 0.05$ for unpaired t test) than at the reference site for all years except 1989 (Figure 4a). Intersite density differences can be attributed to dredging in the turning basin in 1976 which removed substrate and live specimens. However, there were no significant intersite density differences for mussels less than 30 mm total SL ($t < 0.65$, $p > 0.05$ for all six years). This indicates that recruitment is proceeding at a similar rate at both sites, regardless of earlier dredging and the continued use of the turning basin. Figure 4 suggests that intersite density differences are decreasing partially because of recruitment and growth of younger cohorts. The density decline after 1985 of large individuals at the reference site is unrelated to traffic, and is probably the result of mortality of older cohorts.

Pygott et al. (cited by Brookes and Hanbury (1990)) studied fish community structure in four British canals

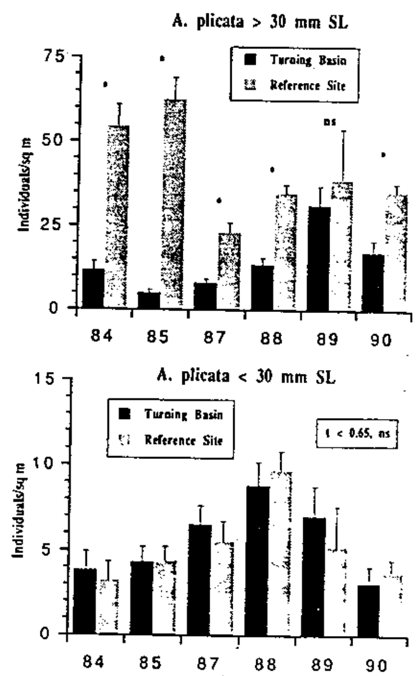

Fig. 4 - Total density (individuals/sq m) for **Amblema plicata** *greater (4a) and less (4b) than 30 mm total SL in a barge turning basin and a reference site located downriver (a). For mussels greater than 30 mm total SL all intersite differences were significant (p < 0.05, denoted with an asterisk) except for 1989 (ns). For mussels less than 30 mm total SL all intersite density differences were nonsignificant.*