

Poster Presentations

THE AFTERMATH OF HURRICANE IVAN: RECONSTRUCTING ROADWAYS WHILE RECOVERING SPECIES

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Abstract

Reconstructing roadways following Hurricane Ivan presented both challenges and opportunities for protected-species recovery. A major challenge was balancing the desire for rapid restoration of major transportation linkages with the regulatory need to minimize harm to rare coastal species. Animals like the Perdido Key beach mouse (PKBM) were already severely impacted by the storm and additional losses could have affected their continued survival. Lessons learned from Ivan will assist state and federal transportation agencies, state resource agencies, the Federal Emergency Management Agency (FEMA), and the U.S. Fish and Wildlife Service (FWS) in responding to future natural disasters.

Hurricane Ivan made landfall as a Category 3 storm on September 16, 2004, passing between the cities of Mobile, Alabama and Pensacola, Florida with the eye located just west of the Alabama-Florida line. Storm surge, winds, and waves resulted in heavy damage to many miles of coastal roadway, major bridges, numerous residential and commercial structures, state and federal park facilities, and coastal habitat for federally protected species. Winds were in excess of 111 mph. The tidal surge was 12-14 feet, with a peak wave height of 53 feet. Erosion occurred inland for up to 200 feet. Road damage in Florida included the collapse of a portion of the I-10 bridge, damage to bridge approaches, and extensive pavement destruction on SR 292, SR 399, and US 98 in Santa Rosa and Escambia counties. Some of the protected species and their critical habitat that occur in the area include the Gulf sturgeon, PKBM, piping plover, and nesting beaches for sea turtles.

Road repairs began after the storm using Endangered Species Act (Act) Emergency Consultation Procedures. Recognizing that emergency road work could affect remaining beach mouse habitat, the FWS and Florida Fish and Wildlife Conservation Commission (FWC) distributed road-repair guidance for county, state, and federal transportation agencies. After initial contact by the Florida Department of Transportation (FDOT) for specific projects, the FWS provided recommendations to minimize effects on listed species or their critical habitat. In situations where listed species or critical habitat may have been adversely affected by the emergency response, formal consultation takes place after the emergency work is completed. Normal consultation procedures on repair work began once the emergency situation was past. In preparation for future emergencies, guidance on Emergency Consultation Procedures is provided on the FDOT Central Environmental Management Office's website at: <http://dot.state.fl.us/emo/> as well as the FDOT's Permitting Handbook.

The framework of Florida's new Efficient Transportation Decisions Making (ETDM) process assists in providing a rapid response to emergencies. ETDM designates specific personnel within the natural resource agencies to coordinate transportation-project review. Having a central point of contact prevents time lost in determining consultation responsibility.

Emergency restoration funds received by counties, state agencies, the Federal Highway Administration (FHWA), and FWS have greatly assisted in hurricane and endangered-species recovery efforts. State park facilities at Perdido Key and Big Lagoon are being rebuilt as an interagency cooperative effort between the Florida State Parks, FHWA, and FDOT. Roads are being repaired or replaced as needed. Sea oats and other dune vegetation are being planted to re-establish dunes, providing both improved habitat and protection from future storms. New fencing along park boundaries will help control parking and direct visitor access, preventing the continual "wear and tear" on dunes by pedestrian traffic. Control of predators attracted by storm-debris piles is also underway.

In states prone to fire, flood, hurricanes, and other catastrophic events, it helps to have a plan in place before a natural disaster strikes! Resource agencies should have a central point of contact for transportation projects, which often require coordinating multi-species and multi-county concerns. Rapid completion of damage assessments by state and federal biologists is needed to acquire the emergency funds critical for restoring habitat after a natural disaster. Finally,

a willingness to cooperate between agencies is essential to achieving multi-agency goals in emergency situations. The experience of Hurricane Ivan demonstrates that crucial transportation systems can be restored rapidly while incorporating measures to protect our invaluable natural resources.

Biographical Sketch: Mary Mittiga is an ecologist and has worked since 1998 with the U.S. Fish and Wildlife Service in Panama City, Florida. Her current position as transportation liaison is dedicated to review of transportation projects and policies, including NEPA review, ESA consultations, streamlining initiatives such as ETDM, regional-conservation planning, and Clean Water Act Section 404 review. Mary holds a bachelor's degree in biology from the College of Wooster in Wooster, Ohio and a master's degree in environmental engineering from Florida State University, Tallahassee, Florida.

Vicki Sharpe currently works in the Central Environmental Management Office of the Florida Department of Transportation (FDOT) as the State Transportation Ecologist. Since 1989, she has been employed by state government agencies in Florida to manage environmental programs involving a broad range of ecological issues related to phosphate mining, surface-transportation planning, and large-scale development projects. She has more than 10 years of emergency-management experience serving various functions in response to hurricanes and other natural disasters. Vicki manages the statewide wildlife and ecology programs for FDOT. Her primary interests include wildlife and fish-habitat initiatives, habitat connectivity, landscape ecology, long-term regional conservation planning, and overall natural-resources and ecosystems management. She is also the Project Manager for environmental-research projects funded by the agency pertaining to wildlife and habitat research.

ASSESSING FUNCTIONAL LANDSCAPE CONNECTIVITY FOR SONGBIRDS IN AN URBAN ENVIRONMENT

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Abstract: Worldwide, urbanization is recognized as a leading cause of species extinction because of its role in rapid and permanent habitat loss and fragmentation. This study investigates how habitat fragmentation caused by urbanization and transportation corridors affects the movements—and ultimately, the occurrence—of songbirds within a human-impacted landscape.

In spring and summer 2005, I used audio playbacks to measure the willingness of birds to cross small-scale features such as roads, railways, rivers, and transportation bridges over riparian corridors within the urban landscape of Calgary, Alberta, Canada. Preliminary results indicate a negative correlation between the likelihood of forest-dependent birds crossing roads, rivers, and bridges over riparian corridors and the width of the gap in vegetation associated with these features. In contrast, railways appeared to be highly permeable for forest birds, probably due to their relatively narrow width.

This study is still in its earliest stages. Subsequent phases of the project include: (1) using translocations to measure the permeability of larger-scale elements of the landscape such as freeways and neighbourhoods of various ages and densities, (2) developing individual-based, spatially explicit models aimed at depicting functional landscape connectivity among the city's natural areas, and (3) exploring the relationship between landscape connectivity and bird species occurrence within these natural areas.

Background and Purpose

In fragmented landscapes, biodiversity is often dependent on habitat connectivity because without it, the exchange of genes and individuals is constrained and small, isolated populations become at greater risk of extinction (Soule 1986). Movement is a process of central importance to the persistence of species in fragmented landscapes because it underlies dispersal and colonization (Belisle and Desrochers 2002).

In the past decade, a limited number of studies have attempted to elucidate the effects of linear features and gaps between habitat patches on the movement of birds. Taped playbacks of mobbing calls have been successfully used to lure birds across selected small-scale features such as roads or meadows (Rail et al. 1997, Desrochers and Hannon 1998, St. Clair et al. 1998, Belisle and Desrochers 2002, St. Clair 2003). In larger-scale experiments, territorial birds have been translocated and their return trip documented (Belisle and St. Clair 2001). Both playback and translocation techniques have made it possible to standardize the motivation of birds to cross different landscape elements so that their permeability can be quantified and compared.

The primary purpose of this research project is to investigate how habitat fragmentation caused by urbanization and transportation corridors affects the movements—and ultimately, the occurrence—of songbirds within a human-impacted landscape. The study is being carried out in Calgary, Canada's fastest growing city.

Methods

I used an audio recording of a Black-capped Chickadee (*Poecile atricapillus*) and a Red-breasted Nuthatch (*Sitta canadensis*) to lure birds across selected small-scale features of the urban landscape and thus assess their willingness to cross these features. Each trial involved attracting birds to an origin speaker and then to a destination speaker located on either side of a potential barrier. Immediately upon turning the origin tape off, the destination tape was turned on and the response of each bird noted. A response was considered positive if a bird moved from the origin to the destination within six minutes from the time the destination tape was turned on.

This year's playback experiments, conducted from May 2 to August 26, 2005, focused on four features: (1) roads of varying widths and traffic volumes, (2) railways (including transit lines), (3) transportation bridges over riparian corridors, and (4) rivers. Each trial across a feature was paired with a control trial conducted in similar habitat conditions, but in continuous forest cover.

Preliminary Results

Only data collected during the breeding season (May 2 to June 15, 2005) have been analyzed thus far. During this time, a total of 325 birds responded to playback experiments in 103 separate trials. Black-capped Chickadees were the most common species to respond, representing 63% of the total responses. Only chickadees and nuthatches were included in the analyses, as they were the only family groups represented by a sample size of at least 25 individuals. Logistic regression showed that the probability of chickadees and nuthatches crossing roads quickly decreased as the trial distance exceeded 30 m. At 50 m, these birds were 60% less likely to cross roads than they were to travel through continuous forest. At 80 m, this difference increased to 80%.

A similar, but slightly less pronounced, pattern was found for bridges over riparian corridors and rivers. In contrast, chickadees and nuthatches were equally as likely to move across railways as they were through continuous forest.

Discussion

These preliminary results suggest that gap width is one of the most important factors affecting the willingness of forest-dependent birds to cross features in the urban context. For most features, as the gap in vegetation increased, the likelihood of a positive response decreased. The high permeability of railways was likely due to their narrow width, which resulted in a vegetation gap of less than 20 m.

Vegetation height also appeared to be a key factor affecting movement, particularly in relation to bridges and roads. The presence of tall trees on either side of a bridge appeared to facilitate movement as birds typically attempted to cross over the structure, from treetop to treetop. Chickadees and nuthatches almost never flew under a bridge. Tall trees on either side of busy roads also appeared to make it easier for these birds to cross above moving traffic.

Next Steps

In the next several months, I will conduct multivariate analyses to better elucidate the factors affecting the permeability of urban features to the movements of forest-dependent songbirds. I will then compare the breeding-season playback data to more recently collected post-fledging data to examine seasonal differences in movement behavior. Playback experiments will also be conducted in winter 2006 to further explore seasonal-movement patterns.

Because the spatial scale of playback experiments is constrained by the distance at which sound will carry, starting in spring 2006 I will use translocations to assess the permeability of larger landscape features such as freeways or residential neighborhoods of different ages and densities. Each translocation experiment will consist of capturing a territorial male bird in a mist net, moving it a distance of 200 m to 2 km and documenting its return trip to its home territory. Using these empirical data, I will then determine functional landscape connectivity among natural areas through the use of individual-based movement modeling within a GIS environment.

A final component of the project will be to examine the relationship between functional landscape connectivity and species occurrence. To this end, breeding bird surveys are being conducted over multiple years to determine the presence or abundance of bird species within selected natural areas. Through regression analysis, I will then explore how functional connectivity and patch-specific attributes (such as area and habitat quality) affect the composition of songbird communities within the city's natural areas.

Significance

Through the use of playbacks and translocations this study will provide novel, empirically-based information on the permeability of urban-landscape elements (including transportation corridors) to the movement of birds. Anticipated applications of the study's results include the development of guidelines aimed at facilitating the movements of songbirds across transportation corridors and urban areas, as well as the identification of priorities for restoration or preservation of habitats important to the movements of songbirds.

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Biographical Sketch: Marie holds a master's degree in environmental design (environmental science) from the University of Calgary, in addition to undergraduate degrees in education and engineering. In fall 2004, she undertook a Ph.D. in ecology at the University of Alberta. Her research focuses on the movements of songbirds in the urban landscape of Calgary, Alberta and is supported by several prestigious scholarships including a National Science and Engineering Research Council Postgraduate Scholarship and an Alberta Ingenuity Studentship Award.

Marie has over 11 years of teaching experience, including almost five years as an instructor of biology, ecology, environmental science, physical geography, and geology at Mount Royal College and the University of Lethbridge. She has also worked part-time as a wildlife consultant over the past several years, focusing on the effects of human activities and facilities on the movements of wildlife. Her most important contributions include modeling wildlife-movement corridors for elk, bighorn sheep and grizzly bears in the Radium Hot Springs area in southeastern British Columbia (her master's work), and developing a management strategy aimed at facilitating movements of large- to mid-sized mammals in the Lake Louise area in Banff National Park. Most recently, in 2004 she co-authored a report addressing the effects of exclusionary fencing on the movements of mammals in the Lake Louise area of Banff National Park, Alberta.

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BIRD-PROTECTION WALLS: AN INNOVATIVE WAY TO PREVENT BIRD STRIKES?

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Abstract: Bird strikes have been known for a long time as a severe negative effect of vehicular traffic. While the phenomenon has been studied for a couple of decades, the prevention of road kills has not been solved yet reassuringly. Of the several methods applied to reduce the collision risk, this study examined solid bird-protection walls that are pitched to raise the flight path of the small songbirds that cross the road.

Most specifically, the study examines the effects of applying bird-protection walls on the number of bird strikes and on the behavior of birds. The research area was situated along a four-lane motorway in Eastern Hungary, Central Europe. Extensive fieldwork was carried out in order to map the local breeding and migrant avifauna and to learn their substantial reactions to the barriers in their flying path. In parallel with observing live birds, road kills were also registered during the whole period of the study. The collected data were analyzed in function of the location of walls, of the relevant bird habitats, and of the technical parameters of the examined road section.

The results? Some issues related to road kills and identified the group of the most-threatened bird species. Several causes of the high risk of bird strikes could be determined and, surprisingly, none of them seemed to be handled efficiently by building these types of physical barriers.

The final results of the study are expected to become public at the end of the year.

Introduction

Several researchers have been discussing the patterns and ecological significance of road kills (Briggs et al. 1994, Primack and Standovar 2001, Hirvonen 2001, Erritzoe 2002), some have also studied those factors that seemed to give rise to the collisions (Erritzoe et al. 2003). Although it would have been a logical approach, crossed migration routes have not been mentioned in European studies so far among the main reasons of the high number of bird strikes. In Central and Eastern Europe, a significant number of passerine species migrate in large volume. They fly from tree to tree at a height of 5-10 meters from the ground surface. Their migration paths usually run along watercourses or long strips of forests and the birds flock together during their movement. Since (theoretically) a migration path crossed by a road can result in numerous road kills, the examined bird-protection instruments were designed at the intersections of the motorway and ecological corridors that were considered relevant in the migration of small songbirds. The walls are simply meant to raise the flight path of migrating birds that cross the roads at the height of the vehicles.

This study examines how effective these bird-protection walls are as regards to both the total number of bird strikes and the behavior of birds. In the paper we address several issues related to the ecological impacts of transportation on birds, especially those that are closely connected with road kills.

We report on: (1) what bird species are especially threatened by road hits, (2) which birds tend to avoid the motorway, (3) how birds react to the walls, (4) whether the number of bird strikes is lower behind the walls than anywhere else, (5) what species can really profit from this protection, and (6) whether the efficiency of the walls differs significantly in case of different types of habitats.

The study was funded by the Hungarian National Motorway Company (NA Rt.), who built the walls at the examined road sections. The project is divided into two phases; the first phase was the present research, while the second phase is expected to corroborate and refine the results of the first phase and it will aim at estimating the future risk level of bird strikes on the next, newly built road sections.

Study Area

We conducted this phase of the survey along a 7-km-long section of a four-lane East Hungarian motorway. This motorway is the only fast connection between the capital city and the Eastern part of the country, with an increasing traffic volume of around 5,000 to 11,000 vehicles per day.

The study area belongs to the ancient flood plain of River Tisza and it is occupied primarily by ploughlands, saline grasslands, and riparian vegetation. The first bird-protection walls in the country were built here, at four points of this road section, in December 2002.

Except for a short section of a few hundred meters length, the motorway was placed on an embankment here. It crosses the River Tisza that is belted by a riparian forest, a smaller watercourse in the midst of the study area, and a few pastures with a fishpond in the background.

Methods

In similar studies, the number of bird strikes are compared before and after the implementation of the examined measure. As the bird-protection walls and the motorway were constructed at the same time, another approach had to be chosen to evaluate the level of protection provided by the walls.

Our hypothesis, initiated from the planned function of the walls, was: if the transportation threatens the migrating birds and the walls were placed exactly at the migration routes, there must not be road-killed migrant birds anywhere along the whole road section. Naturally, non-migrant, e.g., feeding birds may still be hit behind the walls or at the unprotected sections.

If a significant number of migrating birds were killed at the unprotected sections and none of them were killed behind the walls, migrant birds would indeed be at a high risk of road kills, but the walls would not entirely secure their migration routes. In the third case, i. e., if there were a number of road-killed migrant birds behind the walls, that would indicate the incapability of the barriers, provided there were not other road kills along the unprotected sections.

Considering the potential discrepancy between numbers counted and numbers killed (Slater 2002), the initial hypothesis needed further indirect reinforcement based on other type of data than the sheer number and distribution of bird casualties. Primarily, a better understanding of the local migration paths and the migrant bird species, as well as their behavior, seemed to be essential. Similarly to the vagrant and migrant species outside the migration period, the role of the resident fauna could not be disregarded either. Also, several studies have demonstrated the vulnerability of breeding birds in the vicinity of roads (Reijnen and Foppen 1995, Reijnen et al. 1996).

To get an insight into all the above-mentioned issues, the study area was determined as a 400-400 m wide zone along each side of the road. Within this area, the bird habitats were classified and all the migrant, vagrant, and resident species were observed. The study area was divided into four easily recognizable zones (corresponding zones on both sides of the highway were combined): from the mid-line of the road up to the wildlife fence (on a par 10 m from the edge of the road), from 10 m to 50 m, from 50 m to 100 m, and from 100 to 400 m. We monitored and categorized the behavior of birds near the motorway in the zones within 100 m and tried to identify those human and non-human factors (e.g., traffic disturbance, habitat qualities) that significantly influenced their move. Behavior covered both birds' reaction to the traffic and characteristics of their move near the motorway. Their typically observed behavior was feeding, resting, breeding, crossing the road on their daily routes, and avoiding cars in motion.

From the point of view of the study, the most relevant factors were the typical approach distance and the typical height of the flight over the road.

The comparison of bird-counting data for sections farther than and within 100 m from the road helped us to select those species that are disturbed heavily by the traffic; these did not come closer to the motorway. According to our hypothesis, the crossing heights above the road surface were regarded as species-specific and a distinctive part of the behavior of birds. To select those species that tend to fly low over the road, we also recorded how many times and at what height (below 3 m, below 10 m, or higher) each perceived individual bird crossed the road above the walls and at the sections without walls.

The road-killed birds comprised the last source of data, which were registered in the function of the road sections. The data came from two sources. In the survey, we checked the roadside on foot one to three times every week during the whole study period. Technicians from the Hungarian National Motorway Management Companies also ran over the motorway by car at least twice a day, every day. They looked for animals bigger than a dove and only on the pavement. Thus, only a limited amount of valuable data was gathered during their work. Despite the different sampling method, their database helped us to obtain a quite-useful overview about road hits of larger birds like raptors and owls throughout the whole year.

Data Analysis

Since we managed to collect more than 5,000 occurrences and behavior data altogether through the autumn and spring migration term, the database could be analyzed statistically. Both spatial and temporal distribution of the collected data was assumed to have great relevance, according to our examination approach.

The 3D spatial distribution of birds was drawn around the examined road section. As several authors (Briggs et al. 1994, Reijnen et al. 1997, Hirvonen 2001, Gutzwiller and Barrow 2003) have already pointed out, bird occurrences perpendicular to the road are related to traffic disturbance. The second axis of spatial distribution (parallel with road) explains how the habitats of various quality influence the abundance of birds which are affected by the traffic. The typical flight height of the birds not only helps to estimate the theoretical risk of collisions, but we can obtain data on niche segregation among birds or on an aspect of species-specific behavior, i.e., how birds react to the traffic (they can be halted abruptly when they perceive the approaching cars and fly higher or can fly very high, excluding the possibility of any interference with ground transportation).

When more than 50 distinct occurrences data were available for a particular species, we set up three diagrams for the spatial distribution of the given birds around the road (as described above). The results were further refined by the perceived individual behaviors and the uncertainty in perception.

Despite the relatively large amount of data, the qualitative evaluation seemed to have a similar significance in those cases where we had little quantitative information on a given species or when a specific behavior form

was experienced equivocally in the case of several species, but with no statistical significance. If these findings corresponded to our preliminary background knowledge of the given bird species, limited consequences could be drawn from the perceived individual, except for characteristic behavior.

The road kills were evaluated in function of the road length, of nearby habitats, and of the location of walls. The number of bird strikes was calculated for the protected and unprotected sections in the proportion of the total length of the examined motorway section.

Results

Altogether, the shorter or longer presence of 123 bird species could be demonstrated on this small area. Most of these species crossed the motorway at least once. The overwhelming majority of data was collected in spring, because of the favorable weather.

The spatial distribution of birds around the examined road section clearly indicated which birds approach the motorway and tend to cross at the height of the vehicles in motion and which birds avoid the busy traffic at a safe height.

From the three diagrams of spatial distribution, collision risk could be estimated for each species, as summarized briefly in the following. If the given bird approached the road frequently and if it mostly preferred crossing below 3 meters, it could be considered potentially threatened. The hot spots of high risk were selected on the basis of the distribution data along the road section.

The protection walls were considered efficient in the case if these potentially threatened birds all raised their flight path above 3 meters at the walls and if they did not dip down behind the walls onto the road. Also, in those road sections where there were not any walls, the threatened species could not usually fly over the road above 3 meters.

After the analysis, we found no proof that any of the four walls could prevent the striking of birds. On the contrary, the present structure of walls contributed to the slight increase of road kills. First of all, the solid walls formed windproof places for birds behind the walls at open grasslands (two documented hits). Secondly, raptors could sit on top of the walls and wait for the road-killed victims and small rodents that looked for dropped crop seeds on the road (two documented cases). Thirdly, birds could not see behind the walls, so flying over and dipping down abruptly behind the walls resulted in high-risk situations (one documented case of hits of 28 barn swallows in one group just before our study).

Road kills could be divided into three groups of birds: birds of prey, feeding passerines, and casual victims from other taxons. The birds most frequently hit in the survey period are listed below.

Table 1. List of most-frequently hit birds in the survey period

	Bird species	Latin name	Number of road killed birds
Tree Sparrow			
Barn Swallow	<i>Hirundo rustica</i>	20	
House Sparrow	<i>Passer domesticus</i>	12	
Long-eared Owl	<i>Asio otus</i>	4	
White Wagtail	<i>Motacilla alba</i>	4	
Corn Bunting	<i>Miliaria calandra</i>	4	
Buzzard	<i>Buteo buteo</i>	3	

As initially expected, the distribution of road kills showed no evenness. The highest number of victims, however, was found at the only resting place in the examined section. The number of road kills behind the walls was lower than anywhere else, but the difference cannot be regarded as significant. The migrant species accounted for half of the total number of road-killed birds, but the majority of these birds were killed before or after their migration.

Discussion

In conclusion, at this phase of the study, the following can be stated:

1. Unlike the initial assumption, migrant passerines are not threatened directly by the traffic. It is true that migrating birds were killed by cars at certain points of unprotected road sections, but they gave only less than 3% of total road kills. The majority of the species in migration were observed flying at a safe height over the motorway. Daily moves between breeding/resting and feeding place led to more victims from this group of birds before and after their migration.
2. The present structure of walls does not fulfil the original bird-protection goals. They are not efficient protection instruments at all for any bird species in an open landscape, but with a slight modification they can be useful in those sites where dense, tall vegetation (e.g., a forest) is located close to the road at both sides.
3. The number of road kills itself proved an insufficient source of information in the survey. The number of road kills varies year by year. The victims can be found and identified statistically only in an unreliable way. The reasons for bird strikes can be numerous, in addition to the crossed migration routes. The risk of road kills can be estimated more precisely from a combined analysis of the classified behavior of types of birds and a habitat survey.
4. In the measured range of traffic density (3,500-10,500 cars/ day) the available resources relevant for birds (e.g., food) have a more-significant role in the presence and abundance of birds than traffic. Several bird species prefer the embankment, road surface, and bridges to the surrounding habitats for feeding and breeding. These birds will be killed by the vehicles in higher number than those birds that cross the motorway by chance.

While several results of the study have been outlined, further in-depth analysis of the database is needed to conclude the research. It is expected at the end of the year, after the present and upcoming field-work phase.

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Biographical sketch: Csaba Varga is a conservation consultant and coordinator of projects, including ecological impacts of transportation, for BirdLife Hungary Land Stewardship Advisory Service. He obtained a M.Sc. in ecology in 1994 and he has been involved in environmental-impact studies ever since. Csaba's current research focus include niche segregation of birds on motorways and population biology of owls affected by the traffic. Akos Monoki is the leader of a biodiversity-saving target program for the Nimfea Environment and Nature Conservation Association. Bence Barsony is a dedicated voluntary conservationist and member of the Nimfea Environment and Nature Conservation Association.

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CALIFORNIA INNOVATION WITH HIGHWAY NOISE AND BIRD ISSUES

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Abstract

The California Department of Transportation (Caltrans) and environmental-resource agencies such as the U.S. Fish and Wildlife Service have been concerned for many years with highway construction and operation noise impacts to birds, especially to species listed under the Federal Endangered Species Act (FESA). Mitigation implemented to date in California is conservatively estimated in the tens of millions of dollars, without clear evidence of need or benefit. This issue frequently occurs with high-profile species such as the marbled murrelet (*Brachyramphus maroratus*) in Northern California, as well as the least Bell's vireo (*Vireo bellii pusillus*) and California gnatcatcher (*Polioptila californica*) in the southern part of the state. Other transportation agencies in the United States, such as the Oregon State Department of Transportation, have also been working to resolve the issue in their state. Our approach involves an integrated partnership with the Federal Highway Administration, federal and state resource agencies, and the scientific community that is based upon recent successful experience by Caltrans in fisheries hydroacoustics.

The 60 dB (A-weighted) Leq (1 hr) criterion is usually applied as a threshold to assess impacts without scientific justification. For many projects, mitigation (e.g., seasonal work restriction) for noise impacts to birds has been required, resulting in delays to project delivery for Caltrans and other transportation agencies in California. Other types of mitigation have included attenuation at the source, noise barriers to intercept the path, and out-of-kind compensation such as invasive exotic-vegetation removal. To ensure compliance with both the letter and spirit of applicable statutes, more information and scientifically justifiable noise thresholds are needed, particularly for FESA-listed species. These data and thresholds will facilitate coordination with our funding partners and resource agencies, provide guidance to Caltrans' staff, and better inform the public and other stakeholders.

We intend to identify existing data gaps and the research necessary to bridge them. The process is beginning with a literature synthesis by bioacoustic experts Drs. Arthur Popper and Robert Dooling of the University of Maryland, who are part of the interagency expert panel. Next, we will develop interim noise thresholds, as well as FESA consultation and compliance protocols. This will also involve the interagency working and management groups—the other two of the three integrated panels. A key role of the management panel will be to make final decisions in case of dispute. Based on our efforts, we will develop a strategic research plan to provide data needed to address key uncertainties related to bioacoustic impacts on birds, including refined effect thresholds, metrics for effect criteria, and protocols for monitoring noise sources.

We expect that our integrated partnership will develop cost-effective, scientifically credible noise thresholds, and evaluation protocols in a timely manner applicable throughout the United States and possibly elsewhere. These thresholds and protocols will provide mechanisms to avoid, minimize, and compensate for adverse effects to birds, as well as to facilitate efficient and economic implementation of highway-related activities.

COLORADO WILDLIFE ON THE MOVE: A WILDLY SUCCESSFUL ROAD ECOLOGY AWARENESS CAMPAIGN

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Abstract

In Fall 2003, the Southern Rockies Ecosystem Project (SREP), in partnership with the Federal Highway Administration, the Colorado Department of Transportation (CDOT), and Colorado State University, initiated Linking Colorado's Landscapes to identify and prioritize wildlife linkages in the state of Colorado. As the education and outreach component to Linking Colorado's Landscapes, SREP launched "Colorado Wildlife on the Move," a driver-awareness campaign. The goal of the campaign was to educate the motoring public in Colorado about the hazard of wildlife moving across roads and to improve driver awareness, thereby reducing the number of collisions with animals.

To assess the magnitude of animal-vehicle collisions (AVCs) in the state of Colorado, SREP worked with CDOT to analyze data from 1993 to 2004, identifying where and when the most AVCs occurred. With the help of SREP, CDOT was also able to pull out species-specific AVC data. With this information, SREP designed a media campaign in partnership with CDOT, the Colorado State Patrol, Rocky Mountain Insurance Information Association, and Enterprise Rent-A-Car. The campaign was based on data that identified November as the most dangerous month for drivers and wildlife due to the extremely high number of AVCs. A media event was then timed for the beginning of November to bring greater attention to this issue during this critical time. SREP developed two outreach tools for the event: a driver safety tip sheet and an awareness poster, featuring photographs from famed Colorado wildlife photographers.

The campaign was a wild success: all five Denver TV stations were present and the story was aired 12 times on local TV over the next 36 hours. In addition, both local and national papers covered the story. Over the next two months, articles featuring information from the "Colorado Wildlife on the Move" campaign reached over three million people. To date, 58,000 driver safety tip sheets and 500 posters have been distributed in welcome centers, national parks, and Enterprise Rent-A-Car offices in 85 cities and 175 locations. The tip sheets have already been reprinted three times to meet these needs.

Because of the great success of this campaign and the obvious interest and need for additional safety tip sheets, SREP intends to continue its media events and tip sheet distribution on an ongoing basis. Press events will be held in November and June, the two most dangerous months for drivers and wildlife.

COMBINING THREE APPROACHES TO QUANTIFY THE BARRIER EFFECT OF ROADS: GENETIC ANALYSES

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Abstract

The movement and dispersal of animals between populations is an important component of wildlife ecology and has been described as “the glue that holds local populations together.” Without adequate ability to disperse, the rate of movement of individuals and DNA between populations is reduced and these populations become isolated, increasing the risk of local extinction.

Most research addressing the barrier effect of roads and traffic has focussed on the use of crossing structures by wildlife. Our study is a first for Australia and represents a unique collaboration to quantify the barrier effect in a highly fragmented landscape and (subsequently) the success of mitigation.

The aims of the project are to use genetic techniques and empirical observations to quantify the barrier effect of roads on the movement and dispersal of mammals, reptiles, birds, and invertebrates and to assess the effectiveness of structures and road designs intended to mitigate the barrier effect. Quantitative modeling will also be implemented to predict the effects of reduced movement on population viability.

A range of genetic markers is available for use in population biology to measure dispersal. Microsatellites are hypervariable and sensitive enough to be able to detect genetic differentiation in the short term and at small spatial scales, and are therefore appropriate to investigate genetic substructuring due to the presence of roads. Genetic analyses will be used at different scales of resolution. The genic approach will be employed for identifying population substructuring and patterns of gene flow at the population level. The genotypic approach will be used for finer-scale observations of dispersal of individuals.

Direct methods still provide highly reliable data on dispersal parameters, although they rely on logistically difficult field observations. Trapping and radio tracking will be used in the present project to be combined with and strengthen the results obtained from genetic analyses.

Repeated trapping will provide life history information which can aid in understanding the genetic data and contribute to the population viability models. Radio tracking will be used to collect information on daily movements of mammals in relation to foraging as well as dispersal and to assess the effectiveness of mitigation structures.

Finally, quantitative population modelling will be conducted to estimate the effects of inhibited dispersal on population viability. Data from observations and genetic studies will be used to characterise populations in terms of age and stage structures, fecundity, survival, and dispersal. Data collected over three years will be used to characterise variability in the parameters to improve population modelling.

Biographical Sketch: Dr. Rodney van der Ree is the ecologist at the Australian Research Centre for Urban Ecology (ARCUE). He obtained his Ph.D. in 2000 from Deakin University, where he studied the impacts of habitat fragmentation on arboreal marsupials in northeastern Victoria. He used the principles of landscape ecology to investigate the response of fauna to a landscape where the habitat was arranged as a network of linear strips along roads and streams. Rodney now brings this knowledge and skill to ARCUE to investigate the response of mammals to urbanization. Rodney will be investigating the distribution and abundance of mammals within the greater Melbourne area, with a focus on the rate of species decline, their habitat requirements, and survival prospects.

COMBINING TRANSPORTATION IMPROVEMENTS AND WILDLIFE CONNECTIVITY ON FREEWAY REBUILD IN WASHINGTON'S CASCADE MOUNTAINS

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Abstract

Interstate 90 over the Cascades is a significant barrier to over 250 species of wildlife, including cougar, elk, deer, mustelids (otters, fishers, badgers, etc.), amphibians, and reptiles. In the vicinity of Snoqualmie Pass, urban development to the west and agriculture and resort development on the east has shrunk the forest connecting the north and south Cascades to less than 64.6 kilometers wide.

The Washington State Department of Transportation (WSDOT) is proposing to expand a 24.15-kilometer stretch of Interstate 90 just east of Snoqualmie Pass through a particularly critical zone for north-south wildlife corridors. Absent effective wildlife-crossing structures, the expansion would worsen the barrier by increasing roadkill and further isolating populations, thus inhibiting genetic exchange. However, the state has made ecological connectivity a project goal, along with increasing capacity, straightening curves, and repaving.

The I-90 Wildlife Bridges Coalition has been working with WSDOT, other public officials, transportation interests, and the public to promote high-quality wildlife-crossing structures. Such structures can also improve safety for motorists by reducing collisions that are sometimes fatal to humans, as well as wildlife.

Good data is available to inform where to build crossing structures. WSDOT and the US Forest Service collaborated on a study entitled I-90 Snoqualmie Pass Wildlife Habitat Linkage Assessment (Singleton and Lehmkuhl 2000) that used tracking and road-kill counts to map existing crossing activity. Additional relevant information comes from analysis leading to the Snoqualmie Pass Adaptive Management Area Plan and I-90 Land Exchange (US Forest Service, 1997 and 1999) and Washington State Dept. of Fish and Wildlife studies of cougar movements using radio collars.

Recent land acquisitions and national forest-management changes have dramatically improved the outlook for habitat quality near the project. In recent years, purchases, donations, and exchanges have brought more than 50,000 acres of land valued at \$200 million into public ownership and protection. The Forest Service is committing to additional habitat restoration, such as road removal.

Two of the distinguishing features of the I-90 project are the prevalence of wetlands associated with the Yakima River and the variation in habitat as precipitation and elevation decline from west to east. A variety of structure types—from extended vehicle bridges, to box culverts, to overpasses specifically for wildlife—is required to allow both hydrological connectivity and connections for a diverse array of species. Preferred habitat conditions and existing movement patterns are balanced with site-specific design considerations, including cost, to establish a range of possible solutions to be presented in a draft environmental-impact statement due in spring 2005.

Given the intense competition for transportation funds, particularly big-ticket projects near urban areas, the I-90 Snoqualmie Pass East project will need broad-based support to obtain funding. To overcome the environmental community's general opposition to expanded freeways, the project will need to provide a high level of wildlife connectivity. Project proponents will also need to navigate anti-tax politics by joining in a diverse coalition of agencies, conservation groups, and shipping interests. The recent partnership to acquire habitat north and south of the project points the way.

The coalition has grown out of a history of grassroots activism and collaboration around the Central Cascades region. Citizen involvement has played a critical role in the management policies of this area. The I-90 project will be a greater success due to the high level of attention and input received from the public. Public involvement will have peaked in the spring of 2005 with the release of the Draft Environmental Impact Statement followed by five public comment hearings throughout Washington State. This input will be considered throughout the summer of 2005 and (hopefully) brought to a successful completion in the fall/winter of the same year.

CONTROLLING WHITE-TAILED DEER INTRUSIONS WITH ELECTRIC FENCE AND MAT

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Abstract

White-tailed deer (*Odocoileus virginianus*) pose a significant threat to human health and safety. During 1990-2003, the average cost of a deer/aircraft collision was \$38,000. Various methods of fencing and gating exist to reduce deer intrusions onto airports. We tested one style of electric fence (ElectroBraid) and an electric mat in separate tests on free-ranging deer in northern Ohio by measuring deer intrusions and corn consumption at 10 sites. The fence reduced mean daily deer intrusions by 88-99 % in each test when the fence was powered. When power was turned on and off within a four-week period, intrusions decreased 57%. Mean corn consumption differed between treated (< 2-6.4 kg/day) and control sites (15-32 kg/day). In the electric-mat test, deer intrusions at treated sites decreased 95% for the six-week treatment period. Control site intrusions initially decreased by 60%, but returned to pretreatment levels by week 3. Mean corn consumption was similar between treated (16.2 kg/day) and control sites (15.7 kg/day). Results suggest that the electric fence and electric mat, under the conditions of the tests, may significantly reduce deer intrusions.

Biographical Sketch: Thomas W. Seamans is a certified wildlife biologist for the USDA/Wildlife Services/National Wildlife Research Center field station in Sandusky, Ohio. Tom has spent the last 18 years conducting research focused on finding biologically sound solutions to conflicts between people and wildlife. He received a B.S. degree in wildlife science from Cornell University and a M.S. in wildlife management from Ohio State University.

EMPOWERING STEWARDSHIP WITH TECHNOLOGY—THE OREGON STATEWIDE BRIDGE DELIVERY PROGRAM

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Abstract

The OTIA III State Bridge Delivery Program is part of the Oregon Department of Transportation's 10-year, \$3 billion Oregon Transportation Investment Act (OTIA) program. In 2003, the Oregon legislature enacted the third Oregon Transportation Investment Act, or OTIA III. The package includes \$1.3 billion for bridges on the state highway system. During the next eight to 10 years, ODOT's OTIA III State Bridge Delivery Program will repair or replace hundreds of aging bridges on major corridors throughout Oregon.

Oregon Bridge Delivery Partners (OBDP) is a private-sector firm that has contracted with the Oregon Department of Transportation to manage the \$1.3 billion state bridge program. OBDP, a joint venture formed by HDR Engineering Inc. and Fluor Enterprises Inc., will ensure quality projects at least cost and manage engineering, environmental, financial, safety, and other aspects of the state bridge program.

Technology is a key factor in the ability to deliver over 350 bridges in eight years. Charged with seeking cost-effective delivery solutions as part of the state's Context Sensitive and Sustainable Solutions (CS³) initiative, OBDP is developing a suite of tools that will aid the program in its different disciplines. Tools include a mobile, PDA-based field reporting tool, a web-based comprehensive permitting form, and a comprehensive GIS database. Unifying these projects and the program is an electronic document management system (EDMS). This is the program's document repository. It is web-accessible, extendible to agency and contractor staff, and acts as a "backbone" for other information-development projects.

Not only do such initiatives streamline standard delivery practices, but they provide a project database on which metrics can be derived to measure the impacts of the program from a number of perspectives. For example, the environmental database can be queried to measure the ecological "footprint" of one project or all.

ENGINEERED LOGJAM TECHNOLOGY: A SELF-MITIGATING MEANS FOR PROTECTING TRANSPORTATION INFRASTRUCTURE AND ENHANCING RIVERINE HABITAT

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Abstract

Transportation projects set within river valleys are susceptible to incurring economic and environmental costs when they fail to recognize and accommodate geomorphic processes. For example, overlooking natural processes such as channel migration can lead to costly protection measures that adversely impact aquatic habitat and further exasperate problems elsewhere. In situations where proposed protection measures may adversely impact endangered species, the resulting regulatory constraints can result in major delays and cost overruns. River-reach assessments and new engineering technologies can provide transportation managers with valuable tools to find sustainable solutions to develop and maintain transportation infrastructure in sensitive environments. Reach assessments provide valuable scientific information on how a river has changed through time and how it is likely to change with or without the implementation of a particular project. New "biomimicry" technologies such as engineered logjams, which emulate natural conditions, offer a self-mitigating approach that successfully achieves project goals and regulatory requirements. Since transportation corridors occupy significant portions of stream and river valleys, the cumulative affect of implementing this type of approach presents a cost-effective opportunity for sustaining and restoring ecological integrity throughout the world.

Scientific advancements in the understanding the role of woody debris in river ecology has led to increased efforts and regulations to restore natural wood function to rivers. There are numerous benefits and advantages of strategic, well-designed wood placement in rivers, such as: food-web support, increased hyporheic connectivity and exchange, creation of salmonid spawning and refuge-habitat rehabilitation, bank protection, grade control, and debris retention. Wood is often a required element in bank-protection design for obtaining environmental permits in the PNW. However, there are currently no industry standards and protocols for the re-introduction and management of wood in rivers. Wood placement for habitat enhancement has largely been done without adequate scientific and engineering design and little or no consideration of consequences such as future debris accumulation, channel change, flood inundation, and safety hazards. The lack of engineering standards and information on the structural performance and longevity of wood-debris habitat structures has hindered the development and application of wood-based structures to treat traditional river-engineering problems.

The long-term success of river restoration efforts will depend on well-designed projects and how human encroachment into fluvial domains is managed to tolerate natural processes such as channel migration and wood loading. Functional wood loading can have significant effects such as channel avulsions and increased flood frequency. While these processes have important ecologic benefits, they can adversely impact human development that is not prepared to deal with the consequences. Efforts to expand protection of riparian forests, delineate channel migration zones, and in-stream habitat restoration will all lead to more wood in rivers. Thus the hydrologic and geomorphic consequences will increase in the coming decades. We present a design protocol that includes geomorphic analysis of channel dynamics and riparian conditions, force balance (stability), hydraulics, scour, constructability, material specifications, cost projections, risk assessment, and liability. Engineered logjam technology presents a rigorous alternative for reintroducing woody debris and natural complexity to rivers, while also treating traditional problems such as bank erosion. Engineered log jam projects constructed over the last 10 years demonstrate that this technology is capable of providing sound solutions that protect highways and restore aquatic and riparian habitat.

Biographical Sketches: Timothy B. Abbe, Ph.D., L.E.G., L.H.G., director of river science and geomorphology, Herrera Environmental Consultants. Tim Abbe has 17 years of experience in geology, geomorphology, environmental restoration, applying engineering principles in environmental project design, and solving problems in urban fluvial and coastal environments. He has pioneered the development of engineered logjams, which are artificial structures that emulate naturally occurring stream structures to achieve particular purposes (e.g., bank protection, grade control, and sediment trapping). His work on engineered logjams has offered new technology to professionals who must comply with environmental regulations while solving traditional problems such as runoff and bank erosion.

Jennifer Black Goldsmith is a senior scientist with Herrera Environmental Consultants in Seattle. Ms. Goldsmith has 14 years of experience conducting natural-resource assessments throughout the Pacific Northwest. Her professional expertise includes water resources, water quality, geomorphology, and forestry. Ms. Goldsmith has extensive experience preparing water-resource analysis documentation for a variety of environmental impact statements, reach analysis, environmental assessments, and permit applications for a variety of projects.

EVALUATING HYDRODYNAMIC SEPARATORS

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Abstract: With the advent of both federal and state storm water management regulations, state and municipal highway departments must consider a broad array of Best Management Practices (BMPs) for meeting storm water treatment objectives for both new road construction and roadway-improvement projects. In recent years, a number of manufacturers have entered the marketplace with a variety of proprietary devices for treating storm water. One of the most common types of devices is the hydrodynamic separator (also referred to as innovative water-quality inlet, particle separator, or swirl concentrator). Evaluating these technologies for application in the highway setting requires consideration of a number of factors relative to these devices' treatment performance, inspection and maintenance requirements, and installation and operating costs.

The Massachusetts Highway Department (MassHighway), under a cooperative agreement with the U.S. Geological Survey, recently conducted a detailed field study of water-quality inlets (WQIs) located on the Southeast Expressway in Boston. That study provided valuable lessons regarding storm water sampling protocols and data analyses used to evaluate hydrodynamic separators. (These products generally consist of refinements in the design of the standard WQI.) This paper discusses the lessons learned and offers recommendations for evaluating the performance of proprietary designs within this class of BMP.

A variety of findings came out of the Southeast Expressway (SEE) Study that should be considered when evaluating "hydrodynamic separators." The study evaluated two separate WQIs, each of which received storm water discharges from deep-sump (four-foot) catch basins. It was found that the one continuously monitored deep-sump catch basin had an annual suspended sediment removal efficiency (SSRE) of 39%, whereas the annual average SSRE for two WQIs was 32% (based on the remaining load after flow through the catch basins).

Captured sediments were comprised predominantly of sand-sized particles. Residence time was the primary factor controlling the SSRE. To a lesser degree, antecedent conditions and volume of rain also affected the SSRE. Other findings were that metals and nutrients tend to concentrate on particles smaller than sand and that sediment resuspension occurred in both the catch basin and the WQIs.

In addition to the limited suspended sediment removal efficiency of the WQIs, the SEE Study found that the WQIs were ineffective at removing soluble pollutants, fine particles, floatable solids (debris and litter), and oils and grease. Prior to installing hydrodynamic separators, the operators of drainage systems and environmental regulators should obtain scientifically supportable data on the field performance of hydrodynamic separators. Based on the findings and experience obtained over the course of the SEE Study, MassHighway recommends the following key elements for validating the field performance of hydrodynamic separators:

- Collect field data that is both representative of the range of rainfall events and that is applicable to the conditions (e.g., ambient particle-size distributions) under which the BMP likely will be installed;
- When sampling, differentiate between the effects of "supernatant displacement" and active-particle removal by the separator (i.e., "hydrostatic" versus "hydrodynamic" separation). This requires flow-proportional sampling throughout each storm event;
- Account for antecedent conditions, bypass flows, and resuspension when calculating the SSRE;
- Sample a sufficient number of storms not only to obtain statistically significant data, but to include the full range of operating conditions to which the device will be subject;
- Analyze treatment performance by "Summation of Loads," which is the preferable method for accuracy and quality control;
- Sample storms sequentially, to allow for a mass-balance calculation;
- Include measurements of particle-size distribution in the sampling and analysis program to assess the removal efficiency of Total Suspended Solids (or, preferably, Suspended Sediment Concentration), as well as that of other contaminants associated with various particle-size fractions.

Hydrodynamic separators should also be evaluated relative to other potential limitations. For example, if these underground structures function to contain fuel spills, then they have the potential to create an explosion hazard. In addition, according to the literature, hydrodynamic separators also may create conditions suitable for breeding mosquitoes and bacteria or conditions that result in liberating nutrients and metals from captured sediments.

Based on its evaluation of WQIs and on the literature MassHighway has reviewed to date, further scientifically sound evaluation is necessary to demonstrate the effectiveness of hydrodynamic separators as primary-treatment devices. Although MassHighway has documented the limitations of the WQIs used along the Southeast Expressway (e.g., low overall removal of suspended sediment, particularly fine particles), hydrodynamic separators may be appropriate for pre-treatment and retrofit applications where sand is the target contaminant and where the operator has adequate maintenance capabilities.

Abbreviations

BMP: Best Management Practice

DOT: Department of Transportation

EMC: Event Mean Concentration

EPA: Environmental Protection Agency
 PSD: Particle-Size Distribution
 SEE: Southeast Expressway
 SSC: Suspended Sediment Concentration
 SSRE: Suspended Sediment Removal Efficiency
 TSS: Total Suspended Solids
 USGS: U. S. Geological Survey
 WQI: Water-Quality Inlet

Introduction

The focus of this paper will be on a specific category of storm water Best Management Practices (BMPs) known as hydrodynamic separators (also known as innovative water-quality inlets, particle separators, or swirl concentrators). Hydrodynamic separators are flow-through structures with a separation unit to remove sediments and other pollutants. The separation of sediments depends primarily on settling and may be enhanced by the swirling action of flowing water and/or by modifying the flow path with a system of baffles. A number of devices accumulate and store settled solids in a manner designed to minimize resuspension of previously captured particulates.

In recent years, hydrodynamic separators have become increasingly common. MassHighway has considered this class of BMP for application in a number of settings and has had experience in the application and evaluation of these and similar devices. Based on this experience, MassHighway has identified a number of issues that should be considered by drainage-system operators and environmental regulators when assessing the performance of these devices and ultimately choosing the most cost-effective BMP (including both structural and non-structural methods) for treating storm water.

BMP Performance Evaluation

USGS-MassHighway study: evaluation of BMPs along the Southeast Expressway

During 1999-2000, MassHighway conducted a field study with the U.S. Geological Survey (USGS) to evaluate the treatment effectiveness of a deep-sump catch basin and two conventional water-quality inlets (WQIs) located along the Southeast Expressway (I-93) in Boston. The objectives of the Southeast Expressway (SEE) Study were to characterize the concentrations and loads of suspended sediment during a multitude of sequential storm events and to define the suspended sediment removal efficiency of two 1,500 gallon WQIs and one deep-sump catch basin (Smith 2002).

Water-quality analyses included metals, nutrients, organics, bacteria, and suspended sediment along with particle size. Two WQIs were sampled, using automated samplers to capture storm water events continuously—one for 10 months and the other for 14 months—for a total of 133 storms. A mass balance was computed based on measurements of the material captured (i.e., the measured inlet loading plus the mass of material captured equaled the measured outlet loading). Removal efficiencies were estimated using the “summation of loads” method.

Figure 1 presents a schematic diagram of the drainage BMPs evaluated by the SEE Study. As is typical of hydrodynamic separators, each had a bypass weir in order to minimize high velocities and the resuspension of sediment from within the device.

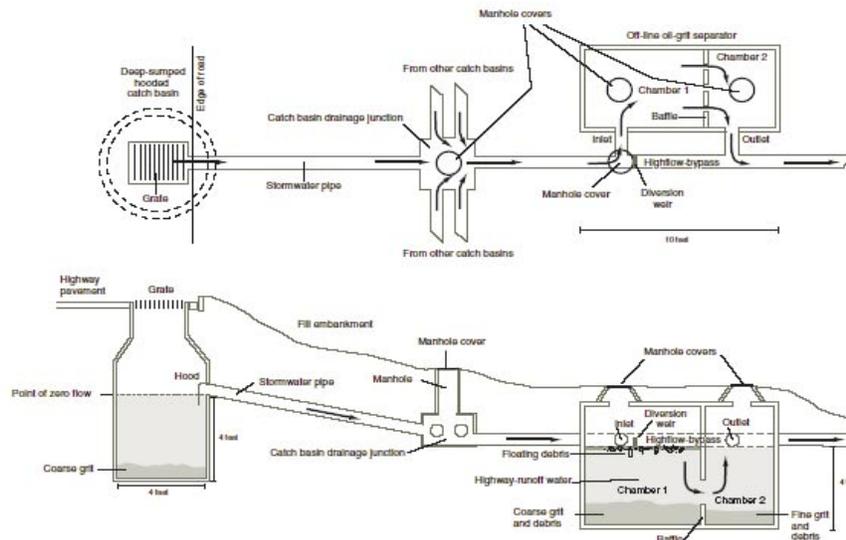


Figure 1. Schematic section of a deep-sump hooded catch basin and a 1,500-gallon off-line water-quality inlet.

Summary of Findings

1. The suspended sediment removal efficiency (SSRE) of the deep-sump hooded catch basin was found to be 39% over a 14-month period. The WQIs achieved a SSRE of 35 and 28%, for an average of 32%. However, if the removal efficiency of the catch basin is factored into this BMP “treatment train,” then the SSRE of the WQIs averaged only 18% of the influent’s *total* suspended sediment load.
2. WQIs and the deep-sump hooded catch basin captured predominantly sand-sized particles (i.e., greater than 0.062 mm). This finding has been attributed to the short residence times within the WQIs (fine particles have long settling times). The average retention times for the 1,500 gallon WQIs ranged from one hour to less than a minute. Therefore, residence time was the primary factor controlling suspended sediment removal efficiency.
3. Other factors affecting SSRE included: antecedent conditions (i.e., length of time between storms, which in turn affects particle settling time), rainfall intensity (i.e., if high, then large particles became dislodged and entered the runoff flows), and the volume of rainfall. The SEE Study found that for small events (< 0.2 inches of rain, where the total rainfall volume was less than 1,500 gallons) and also when there had been no rain for at least five days, that the WQIs removed more than 80% suspended sediment. When the antecedent dry period was only two days, then less than 40% of suspended sediment was removed. These observations again demonstrate the importance of residence time between storms.
4. Sediment resuspension occurred in both the catch basin and the WQIs, which reduced their sediment-removal effectiveness. Sediment capture also was reduced when high flows bypassed the WQIs. Resuspension and bypass flows each accounted for a similar level of total sediment loading: approximately 2 to 3%.
5. Metals and nutrients tend to concentrate on particles smaller than sand (<0.062 mm), in part due to their greater surface area (per unit weight). The WQIs were found to remove only 5 to 15% of most metals and nutrients from the influent.
6. The WQIs also were ineffective at removing dissolved pollutants, particle sizes finer than sand, floatable solids, and oils and grease (as well as total petroleum hydrocarbons).

BMP evaluation by manufacturers

BMP manufacturers offer a variety of supporting documentation regarding the treatment effectiveness of their devices. However, inconsistent sampling methods, lack of associated design information, and different reporting protocols make comparisons between devices difficult (Federal Highway Administration 2001). For example, individual studies often include the analysis of different constituents and do not use the same methods for data collection and analysis, and do not report equivalent information on BMP design and flow characteristics. This results in a range of BMP “efficiencies” reported in manufacturers’ literature. In addition, the effectiveness of a hydrodynamic separator is oftentimes based on a low number of select storms or on limited sampling within each storm event. Thus, the available data for the various hydrodynamic separators do not appear to allow for comparison between other similar devices or other types of BMPs.

The SEE Study provided valuable experience in sampling and analysis methodology for a device that has a limited residence time. The following discussion highlights several sampling and analysis protocols that should be applied to future field-performance studies of other hydrodynamic separators in order to provide valid and comparable scientific basis for evaluating these devices’ pollutant removal performance.

Storm Water Data—Quality Control and Analysis

Representative storms

The monitoring requirements of the National Pollutant Discharge Elimination System (for industrial activities) identify key characteristics that result in a “representative storm.” According to these requirements, the total precipitation and duration of a “representative storm” should be within 50% of the average event for a given location, produce equal to or greater than 0.1 inches of precipitation, and have an antecedent dry period (i.e., less than 0.1 inches precipitation) of at least 72 hours (GeoSyntec et al. 2002). This sets up a worst-case scenario, where the runoff has a relatively high concentration of pollutants that have built up during the antecedent dry period. Unfortunately this sampling criterion can lead to bias in calculating the removal efficiency of storm water BMPs (as described further below, Displacement versus Treatment).

For BMP monitoring purposes, strict adherence to these criteria is not necessary and likely not desirable because there is no truly “representative storm.” It is preferred that monitoring be performed under a wide variety of conditions and storms such that the storm water data represents the annual range of rainfall events (GeoSyntec et al. 2002). Different site conditions, such as seasonality, temperature, ambient particle sizes, runoff rates, precipitation volumes, durations, and intensities, all contribute to “make each storm a unique event” (Church et al. 1999). Therefore, all these variations should be considered when determining the period over which the monitoring program will be run, and are key to interpreting BMP monitoring data and predicting effectiveness (Muthukrishnan et al. 2004).

WQIs are particularly sensitive to variations in influent water quantity and quality, due to their small volumes and the relatively short retention times during flow events. Therefore, when evaluating any hydrodynamic separator, the sampling program should include an extended and continuous period of study covering the full range of events that would affect the unit's operation. For example, it was found during the SEE Study that about 90% of the sediment loading was carried in 10% of the storm events. Figure 2 illustrates the inlet and outlet sediment loads and how the SSREs varied from storm to storm, and were sometimes below zero when effluent loads exceeded influent loads (representing sediment resuspension, further discussed below).

In addition, any BMP monitoring programs also should provide a description of the statistical error and confidence of its findings. Obtaining statistically valid results requires a sufficient number of storms sampled to draw valid conclusions at high levels of confidence (Muthukrishnan et al. 2004). As described above, the SEE Study monitored a total of 133 storms—74 and 59, respectively, at two separate sites. Nonetheless, the USGS corroborated that a relatively high statistical confidence could be derived from just 15 to 20 sequential and continuously monitored storms. For example, by calculating the SSRE of 20 storms, a BMP monitoring program could predict (with 89% confidence) that the SSRE of the BMP will be lower than the minimum SSRE (of the 20 events) less than 10% of the time for all future storm events. For 15 and 10 storms, the confidence drops to 79% and 65%, respectively. Still, although sampling 15-20 sequential storms allows for a mass-balance computation, it may not be adequate for deriving contaminant loading estimates and average BMP performance on an annual basis because of the variability in hydrologic factors in the Northeast U.S.

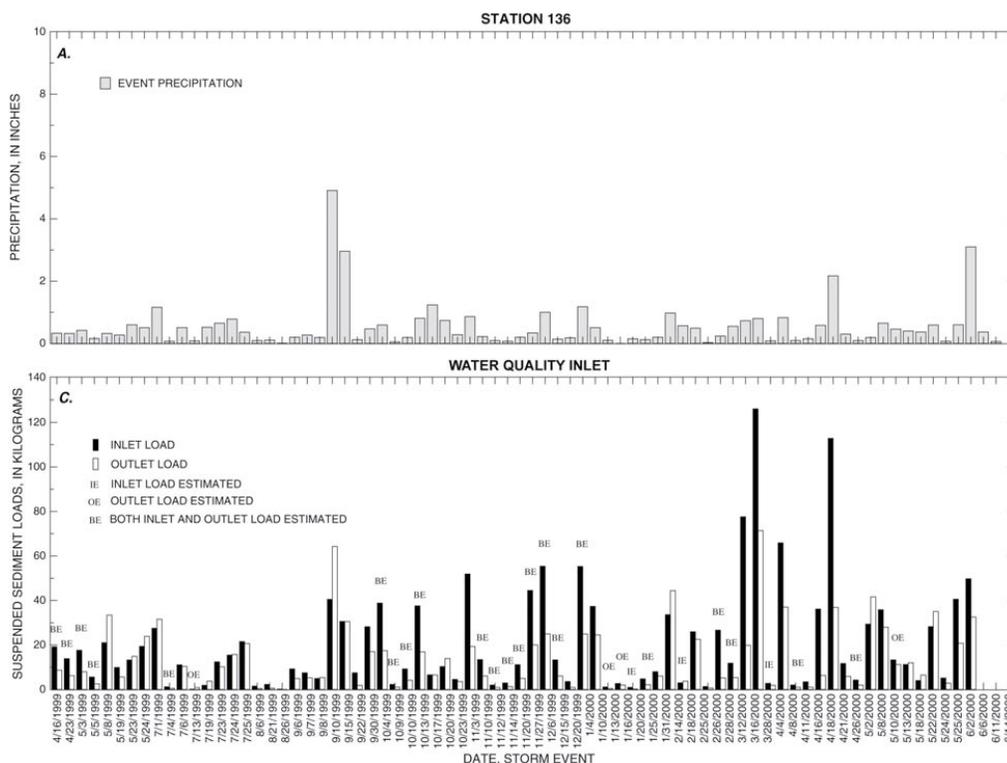


Figure 2. Precipitation and suspended sediment loading for long-term sampling period at a WQI.

Sampling frequency

The SEE Study measured the concentrations of various contaminants in the influent and effluent flows, which were observed to vary widely during the events sampled. If influent and effluent water quality were sampled only once at random during a storm (i.e., grab sample), or even at a preset time interval following the onset of a storm, the variations in water quality over the course of the storms could not have been measured. This would have been a significant source of error in calculating sediment loading, and therefore the treatment performance of the WQIs.

In addition, the SEE Study employed automatic sampling equipment to collect flow-proportional samples over the entire duration of each storm. The samples were analyzed to accurately calculate sediment loading and capture throughout the storm. This sampling methodology should always be used to evaluate hydrodynamic separators so as to account for all the variability in storm water quality and treatment performance.

Applicability of BMP performance to other sites

Site conditions can vary significantly from one location to another, which can affect storm water treatment performance by BMPs. Geographic variables such as climate, geology, hydrology, land use, and local water quality make each site unique (Berg 2002). Therefore, field studies should take place in settings that are representative of those where the respective BMP will most likely be used. This will increase the likelihood that the performance results will be authentically transferable to similar sites.

Examples of particular test sites of interest include a DPW maintenance yard with outdoor storage of sand, a well-maintained parking lot, a road with an eroding edge of pavement, a high-volume expressway, and a local service road. Note, however, how each of these sites may have varying types and volumes of sediment loading and other pollutants and that the treatment-evaluation results for a device at one type of site may not be readily transferable to another type of site (at least not without careful study design).

BMP performance historically has been evaluated in the context of a particular device being a stand-alone system. This probably does not reflect actual applications, however, because storm water BMPs almost always are used in conjunction with various upstream controls, most typically catch basins. According to the SEE Study, it was found that the upstream catch basins captured the bulk of the drainage area's coarse sediments. Specifically, if the WQIs were used as stand-alone BMPs, they would have captured up to 57% of total suspended sediment load. However, since the upstream catch basins captured 39%, the WQIs captured only 18% of the total annual sediment load. Therefore, to make findings comparable, all BMP evaluation studies should be designed in a way to correctly account for how the BMP performs when pre-treatment occurs upstream (e.g., through the use of catch basins). If the effects of pre-treatment are not incorporated into the BMP findings, then the calculations for total removal efficiencies will be incorrect.

Another variable that affects the comparability of BMP studies is the size of the area that drains to, and the flow rates that pass through, the BMP (particularly hydrodynamic separators). A smaller drainage area implies smaller storm flows, greater average device-residence times, and a likely reduction in rates of resuspension. All of these effects could result in a higher treatment efficiency for the hydrodynamic separator. The field study of a particular BMP should therefore be designed to reflect the drainage areas, flow rates, volumes, and other conditions that characterize the full range of circumstances anticipated for actual future application of the device.

Bypass flows and resuspension

Early discussions of storm water treatment theorized that if a storm water BMP is designed to treat the first 0.5 inch or inch of rainfall, then the majority of pollutants will be captured. Under this scenario, runoff volume in excess of this "first-flush volume" might be allowed to bypass the BMP untreated, under the assumption that the water is relatively clean (Berg 2002). However, for certain pollutants, such as nitrate, ortho-phosphate, bacteria, and sediment, the first-flush theory is weak or absent altogether (Schueler 1994). One major criticism of the first-flush theory is that it overlooks the effects of rainfall intensity. High-velocity flows resulting from high-intensity rainfall events are capable of transporting larger sediment particles and debris that is not often mobilized by more frequent, but less intense, storm events (Berg 2002).

Regardless, bypasses (such as a control weir within the drainage structure located just upstream of the BMP) are often considered necessary to diminish high flows that would otherwise move through storm water BMPs, especially hydrodynamic separators, and resuspend captured material. Bypasses can have a measurable effect on the ability of a BMP to remove constituents and, if set too low, may reduce the overall capture efficiency of the system as a whole. On the other hand, providing insufficient high-flow bypass risks the potential for resuspension of captured sediments and associated pollutants from within a separator. Minimizing resuspension is important because of the propensity of finer particles, which are associated with relatively higher concentrations of contaminants, to become resuspended selectively.

During the SEE Study, resuspension was observed within the WQIs during storm events with high flows and/or rainfall intensities (as depicted in figure 2 above). As illustrated in table 1, the amount of sediment resuspended from the WQIs was about 8% of that captured (2 to 3% of the total sediment loading at the drainage-outfall pipe). Coincidentally, the sediment load that bypassed the WQIs represented about 2 to 3% of the total loading.

Table 1. Conditions and frequency of resuspension and bypass

Description	Station 136 WQI	Station 739 WQI
Range of flows when resuspension was observed	0.46 to 0.97 cfs	0.41 to 2.81 cfs
Range of maximum 5-minute rain intensities during these storms	0.04 to 0.23 in	0.04 to 0.18 in
Number of events exceeding resuspending flows and intensities	33 (of 74)	22 (of 59)
Percentage of captured SSC resuspended	8%	8%
Percentage of total SSC load resuspended	2.8%	2.2%
Percentage of total SSC load bypassed	3%	2%

Disregarding bypass flows when evaluating BMP performance will result in misleading conclusions (Muthukrishnan et al. 2004). Comprehensive inflow and outflow measurements should be used in calculating the mass balance of contaminant loading, which includes the loading in bypass flows. This mass-balance calculation will provide the most accurate estimation of the BMP's overall efficiency.

Displacement versus treatment

As discussed above, the volume of storm water passing through the separator is a critical parameter in estimating the performance of hydrodynamic separators and differentiating between active contaminant removal and hydrostatic settling prior to the storm. For this reason, evaluations should avoid the use of random sampling or single-event sampling at a fixed time period of the storm. Flow-proportional sampling should be conducted over the full duration of each event (as well as over a full range of events) to account for the wide variability of influent and effluent water quality.

This potential source of bias was observed in the SEE Study when the WQI influent and effluent were sampled at the initial onset of a storm event. After the suspended sediment in the WQI had settled over the course of several days, the incoming turbid storm water pushed the clarified water out. The resulting effluent was cleaner than the influent because of "displacement" and not because of the dynamic removal of sediment within the WQI. In fact, in almost every case, as samples were taken later into the storms, there was much less difference in the suspended sediment concentrations between the influent and effluent samples.

In addition, assessing the performance of hydrodynamic separators based solely on very small rainfall events can lead to erroneous findings because of the "displacement" phenomenon. When a storm's volume (to the device) is less than device volume, the monitored effluent will reflect the storm water that had been stored from the previous event, rather than from the event under study. This would not represent the "flow through" operating characteristics of the device and could bias the estimate of overall performance. This bias can be overcome by monitoring a full range of storm events over an extended period and by taking flow-proportional samples throughout each event.

Laboratory partitioning error—SSC versus TSS

There currently is debate over the most appropriate analytical method for measuring the concentration of solids in storm water samples. The Total Suspended Solids (TSS) analysis requires extracting an aliquot from the original sample, which is then analyzed to determine the sediment concentration, whereas the Suspended Sediment Concentration (SSC) method uses the entire sample for the analysis. Although TSS has been widely used as a parameter in water-quality analyses (dating back to the 1970s and 1980s in the wastewater-treatment industry), the SSC method ensures that all material present in the sample is represented in the results.

In a study by the USGS, it was determined that in samples containing 25% or more of sand-sized particles, the TSS method consistently under-reported sediment concentrations when compared to the corresponding SSC samples. Because of its high settling velocity, sand-sized material is often under-represented in the aliquot drawn for the TSS analysis (Gray et al. 2000). Thus a new measurement of sediments, SSC, was developed and is now a standard water-quality analysis for the USGS (GeoSyntec et al. 2002). This method has been proven to measure sediment loads more accurately, and therefore BMP removal efficiencies (Berg 2002).

Since the SSC test is biased toward heavier particle sizes, TSS will provide a much more conservative measure of BMP performance. Therefore, it can be assumed that the average SSRE of 32% would have been even lower if the SEE Study had measured for TSS rather than SSC.

BMP efficiency computation

A number of different methods can be used to estimate the efficiency of BMPs. The most common method is the Efficiency Ratio method (GeoSyntec et al. 2002). The SEE Study used the summation of loads method, which was determined to be more appropriate for the evaluation of sediment removal efficiency of the WQIs. Based on the findings of this study, MassHighway recommends that this approach be used for evaluating the performance of other hydrodynamic separators.

Efficiency Ratio Method

The "efficiency ratio" is an estimate of the average event mean concentration (EMC) of pollutants over a given time period. EMCs are determined from flow-weighted composite samples in the field or derived from discrete samples. The method weights EMCs from all storms equally, regardless of the volume of the storm or the concentration of the parameter under study. The method is most useful where loads are directly proportional to storm volume.

Summation of Loads Method

The "summation of loads" method estimates efficiency based on the ratio of the sum of all influent loads to the sum of all effluent loads. The method assumes that the removal of material over the entire period of analysis is most relevant. The method also assumes that monitoring data are sufficient to represent the actual entire volume of loads into and out of the BMP under study for a long enough period to account for temporary storage and export of the study parameter.

In the SEE Study, where there was an extensive data set (based on 133 storm events), the summation of loads method was used because it accounted for the wide variation of concentrations over the course of storm events and among

storm events, as well as the temporary storage and export of sediment from the WQIs. Further, the difference between inlet and outlet loads were directly estimated from this method (i.e., a mass balance could be determined) and compared with field measurements of sediment accumulation in the WQIs. This provided an ideal method for corroborating the test results.

By sampling every sequential storm throughout the SEE Study and then measuring total mass of sediment captured within the WQIs at the end of the study, a critical element of quality assurance was added to the data. This technique clearly showed the limitations of the WQIs in capturing sediment particles smaller than 62 μm and also was used to develop an accurate annual SSRE for these devices.

It also was found that the overall treatment efficiency of a BMP is a more meaningful measure than the average efficiency. The Massachusetts Department of Environmental Protection's Storm Water Management Policy requires that storm water management systems remove 80% of TSS on an average annual basis. Given this requirement and based on the experience from this study, the most appropriate measure of BMP effectiveness for long-term sediment removal is the summation of TSS (i.e., SSC) loads, provided that the storms sampled are generally representative of Massachusetts' typical storm distribution.

Particle-size distribution

The SEE Study indicated that residence time was a key factor in the sediment removal efficiency of the WQI. This conclusion was expected, given that the device depends on settling as its primary treatment process. Since the performance of a hydrodynamic separator is particularly sensitive to particle size and specific gravity and given the short residence time of most storm flows within such a device, any suspended sediment removal claim should include the particle sizes associated with the stated removal rates. Washington's guidance for evaluating innovative storm water BMPs provides a good example of the method for qualifying sediment removal rates (Washington State Department of Ecology 2004).

When BMPs are evaluated under laboratory conditions to determine their suspended sediment removal rates, the use of an appropriate particle-size distribution (PSD) representative of storm water becomes a pivotal component of the study. But without a standardized definition for PSD in "typical urban runoff," the TSS removal rate claims made by various manufacturers may not be comparable to one another. Particle-size determinations are especially important when testing the effectiveness of hydrodynamic separators because the larger the average particle size used for evaluation, the higher the treatment efficiency.

To address this issue, it is recommended that all BMP evaluations address removal rates by particle size, and that the particle-size fractions should comprise a standardized distribution established by the U.S. Environmental Protection Agency (Driscoll et al. 1986). The EPA report, based on an analysis of the National Urban Runoff Program data, presents a typical settling-velocity distribution for sediment found in urban runoff. Converting the settling-velocity distribution to particle sizes (using Stoke's Law and assuming a specific gravity of 2.65) shows that 90% of sediment particles in storm water are smaller than 69 μm and only 20% of particles are larger than 40 μm (the size of very fine sand).

Since larger particle sizes settle more quickly than smaller ones (i.e., greater settling velocities), they are easier to remove from storm water. Therefore, the sediment removal performance of a BMP is highly dependent on the PSD. For example, several performance studies of hydrodynamic separators have been conducted in the upper Midwest and Northeast where deicing sand is commonly used. The sand, washed off during spring and summer storms, skewed the PSD to larger sizes not commonly found in the storm water that occurs in other parts of the country. Consequently, a lower level of efficiency may be observed if the same BMP is installed in areas where deicing sand is used less or not at all (California Stormwater Quality Association 2003).

The importance of the PSD in storm water was demonstrated in the SEE Study, where particle sizes in the sand range generally were not mobilized under low-flow conditions, but were under high flows. Hence, the WQIs were often most effective during the larger storms because there were more sand-sized particles in the storm water flows to remove.

It was estimated that throughout the SSE Study, more than half of the total sediment loads contained in the storm water fell below the 50- μm particle size range. Hence, it is unlikely that the WQIs could achieve 80% TSS removal when they are virtually incapable of capturing particles less than 50 μm in size. In addition, since pollutants have a higher affinity for absorption to finer sediment due to the fine particles' large surface area per unit volume (Horowitz and Elrick 1987), WQIs are presumed to also have low removal efficiencies for pollutants.

Other performance factors of concern

This paper has addressed the evaluation of WQIs in particular and future assessment of hydrodynamic separators primarily with respect to treatment removal effectiveness of suspended sediment. However, there are a number of other performance factors that must eventually be addressed to document the effectiveness of this class of storm water BMP. Some (but not all) of these factors were considered in the SEE Study, but all warrant further analysis by future research. These factors include:

1. Removal of dissolved pollutants and fine particles

Little information is available for hydrodynamic separators treating pollutants other than suspended solids. As was found in the SEE Study, pollutants such as nutrients and metals, which adhere to fine particulates, as well as dissolved solids, were not significantly removed by the WQI device. Moreover, heavy storms may cause mixing and subsequent resuspension of any captured fine particles. More information is needed on hydrodynamic separators' ability to remove both fine particles and dissolved pollutants.

2. Removal of oil and grease

Oil and grease in storm water typically are in the range of 5-10 mg/l. There is no comparative data that these units are capable of trapping oil and grease. The Utah Department of Transportation (DOT) does not recommend that hydrodynamic separators be used for treating and/or reducing oil and grease concentrations in typical urban storm water runoff for two reasons: by the time the oil reaches the device, it will have adhered to sediment and/or will have emulsified in the runoff, making it too difficult to separate. Further, oil and grease exist in very low concentrations in storm water, making it very difficult for these devices to treat them to even lower levels. Nonetheless, the Utah DOT will consider these systems for capturing oil and grease in high-loading areas ("hot spots") (Nichols et al. 2005).

Silverman and Stenstrom (1989) also acknowledge the relative ineffectiveness of hydrodynamic separators in capturing oil and grease. They cite that 40% to 60% of oil and grease associated with urban runoff are in a dissolved or colloidal state. Thus, baffled BMPs that are designed to separate free-floating oil and grease may not provide effective treatment for this pollutant.

3. Removal of floatable solids

During the course of the SEE Study, it was found that floatable debris was readily discharged from the WQIs. These devices might be more effective at floatable-solids removal if cleaned regularly (e.g., monthly), before the floatables become neutral-buoyant and flush out of the WQI. General performance of hydrodynamic separators for floatable-solids removal appears to require further study.

4. Containment of hazardous spills

Spill containment should be considered carefully in coordination with local fire department personnel (and/or other "first spill response" entity) before installing a hydrodynamic separator. For example, trapping a large quantity of spilled gasoline in an underground structure may constitute a safety hazard that could outweigh the apparent benefits of "containment." MassHighway is not aware of studies that have addressed this concern.

5. Incubation of bacteria

With a nutrient-rich medium, relatively stable temperatures, and a lack of UV light, hydrodynamic separators may breed bacteria. It is documented that storm-drain sediments can function as a reservoir of Fecal Coliform and Fecal Streptococci bacteria under warm conditions. This implies that displacement of collected storm water may release bacteria into the receiving water bodies (Marino and Gannon 1991). MassHighway is not aware of any studies that specifically address the potential for bacterial growth and export associated with this class of BMP.

6. Potential breeding habitat for mosquitoes

An issue associated with storm water management that is receiving more and more attention is the potential public-health risk created by the use of certain BMPs. If not designed and managed properly, they can provide habitat conditions suitable for the propagation of mosquitoes. This is an issue of prime concern because of the existing and widespread presence of endemic vector-borne diseases (e.g., West Nile virus, eastern equine encephalitis). Statistically, as vector populations increase, so does the risk of disease transmission (Metzger 2003, Metzger et al. 2002).

In 1998, the California Department of Health Service's Vector-Borne Disease Section, in cooperation with the California Department of Transportation, conducted a two-year study of vector production associated with the 37 operational storm water BMP structures in southern California. The study found that a variety of vector species, particularly mosquitoes, utilize the habitats created by storm water BMP structures throughout the U.S. With easy access, no predators, and constant water levels, mosquitoes can easily propagate within hydrodynamic separators.

7. Liberation of metals and nutrients

Due to the relatively quiescent conditions inside the separators, there is little oxygen exchange and the material captured within the sump of the device can develop conditions with low dissolved oxygen (DO). During periods of low DO concentrations, metals and nutrients adsorbed to sediments can become desorbed and dissolve into solution (Breault and Granato 2000, Rushton 1998). This means that storms accompanying

this process would displace the captured storm water containing these dissolved nutrients and metal ions. Further analysis of this class of BMPs is warranted to characterize their effects on the release of metals and nutrients from captured sediments into the water column.

8. Operation and maintenance considerations

Regular maintenance is critical to the proper function of storm water BMPs. Hydrodynamic separators pose particular requirements for maintenance. Without regular clean-outs the devices may be prone to the following: accumulated sediment reducing available treatment volume, sediment resuspension during high-flow storm events, and accumulated floating material becoming entrained into the water and ultimately discharged during subsequent storm flows.

In the SEE Study, MassHighway found that inspection and maintenance of the WQI is much more difficult than with open systems (e.g., detention basins, drainage swales) or even catch basins. Routine inspection and the determination of sediment accumulation were constrained by the limited access and physical size and configuration of the device.

Physically cleaning the WQI also was difficult and required using personnel to access the device under “confined-space protocol” to ensure effective cleaning of the device. Cleaning and disposal costs are anticipated to be much higher for this type of device than for “open” BMPs.

The assessment of any particular hydrodynamic separator should include an evaluation of the procedures, cleaning frequencies, and associated costs, as well as the treatment effectiveness, in order to determine if their use is warranted in a particular setting.



Figure 3. Vacuum truck employed during the cleaning operation of a water-quality inlet along the Southeast Expressway in Boston (left) and a maintenance worker pushing sediments to a vacuum hose while exercising “confined-space entry” protocol (right).

Conclusions and Recommendations

The field evaluation of the treatment performance of hydrodynamic separators requires careful planning and appropriate study methodology to secure representative storm water data. Without such data, the results from these studies will lack scientific credibility and/or statistical confidence. Scientifically valid data is essential for the selection and design of BMP technologies and for assessing whether these technologies are capable of meeting regulatory requirements. This paper has presented some primary factors that should be incorporated into the design of a scientifically valid BMP test study.

Based on the findings and experience gained during the Southeast Expressway Study, MassHighway recommends the following for validating the field performance of hydrodynamic separators:

- Collect field data that is both representative of the range of rainfall events and that is applicable to the conditions (e.g., ambient particle-size distributions) under which the separator likely will be installed;
- Sample a sufficient number of storms to obtain statistically significant data and cover the full range of operating conditions to which the device is subject;
- Sample storms sequentially, with complete data acquisition to allow for a mass-balance calculation;
- When sampling, use flow-proportional sampling throughout the duration of each storm event to determine the active-particle removal by the separator (i.e., “hydrostatic” vs. “hydrodynamic” separation) and not bias the results because of “supernatant displacement;”
- Account for antecedent conditions, bypass flows, and resuspension when calculating the SSRE;
- Analyze treatment performance by “Summation of Loads” to characterize long-term overall effectiveness; and
- Include measurements of particle-size distribution in the sampling and analysis program to assess the removal efficiency of TSS (or preferably SSC) as well as that of other contaminants associated with various particle-size fractions.

In light of MassHighway's evaluation of WQIs and on the literature discussed herein, further evaluation—using scientifically sound methods that generate data with high statistical confidence—is necessary to demonstrate the effectiveness of hydrodynamic separators as primary-treatment devices. Although MassHighway has documented the limitations of the WQIs used along the Southeast Expressway (e.g., low overall removal of suspended sediment, particularly fine particles), hydrodynamic separators may be appropriate for pre-treatment and retrofit applications where sand is the target contaminant and where the operator has adequate maintenance capabilities.

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HABITAT RESTORATION PLAN AND PROGRAMMATIC BIOLOGICAL ASSESSMENT FOR *POTAMILUS CAPAX* (GREEN 1832) IN ARKANSAS

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Abstract

The fat pocketbook, *Potamilus capax* (*Mollusca: Unionidae*), was designated as “Endangered” in June 1976 by the USFWS in the entire range of the species. The present general distribution of *P. capax* has been reported from the upper Mississippi River on the borders of Minnesota, Wisconsin, Iowa, Illinois, and Missouri, the Ohio River System on the borders of Indiana, Illinois, and Kentucky, especially its tributary the Wabash River in Indiana and Illinois, the White River of Missouri and Arkansas, and the St. Francis River system in Arkansas. Relocation of freshwater mussels prior to large-scale bridge construction, repair, or replacement has been broadly utilized for conventional management of construction impact. The success of that practice related to long-term viability of relocated specimens, however, has not been fully validated. This research was jointly funded by the Federal Highway Administration (FHWA) and the Arkansas State Highway and Transportation Department (AHTD) in 2003 as an Environmental Streamlining Initiative to provide more information regarding the likelihood of specific impacts to mussels attributed to sediment plumes downstream of highway construction activities. The research proposes to support a programmatic Biological Opinion for *P. capax*, which will provide a protocol for highway projects that may impact the species. Relocation can then be assessed for its ability to minimize loss of endangered freshwater mussel species, and in particular, *P. capax*.

The objectives of this project are: 1) to determine the success of relocation efforts for *P. capax* associated with highway construction projects by investigating survival, movements, mortality, fitness (as indicated by condition factor), and fecundity of relocated and non-relocated adults and sub-adults, 2) to determine the success of propagation efforts resulting from highway construction projects by investigating the survival of juveniles returned to identified habitats and used for population enhancement (recruitment), and 3) to determine relative impacts at highway construction sites to *P. capax* and associated mussel assemblage by comparing pre- and post-construction abundance and composition, sediment deposition downstream of the construction, and individual mussel fitness. Data acquired will be submitted to the Fish and Wildlife Service as documentation of the likelihood of impacts for the programmatic Biological Assessment. These data will be utilized by the Fish and Wildlife Service in crafting the programmatic Biological Opinion.

Initial observations have indicated relocated *P. capax* and *Quadrula quadrula* exhibit very different movement patterns post-relocation. For example, many resident and relocated *P. capax* are capable of moving 10 miles or more over a 12-hour period, while resident and relocated *Q. quadrula* have remained stationary up to four months after relocation. A continuation of this pattern may reveal that species-specific life history characteristics potentially influence movement patterns following relocation. Fatalities have occurred in the resident, relocated, and propagation animals of both species, though time to and cause of fatality are not known.