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I. Wetlands, Streams, and Coastal Issues

CHAPTER IV-I
........................*Wetlands, Streams, and Coastal Issues*

COMPARISON OF TWO VEGETATION MONITORING STRATEGIES IMPLEMENTED ON FOUR WASHINGTON STATE DEPARTMENT OF TRANSPORTATION WETLAND MITIGATION SITES

Fredrick S. Bergdolt, Field Coordinator, Wetland Monitoring Program, Washington State Department of Transportation, Environmental Affairs Office, P.O. Box 47332, Olympia, Washington 98504-7332, Phone: 360-570-6645, Fax: 360-570-6633, Email: bergdof@wsdot.wa.gov

James R. Thomas, Remediation Coordinator, Wetland Monitoring Program, Washington State Department of Transportation, Environmental Affairs Office, P.O. Box 47332, Olympia, Washington 98504-7332, Phone: 360-570-6646, Fax: 360-570-6633, Email: thomasbo@wsdot.wa.gov

Abstract: The Washington State Department of Transportation (WSDOT) creates, restores, and enhances wetlands to mitigate for impacts that occur during highway construction projects. Monitoring data provides information on the development and success of these wetland mitigation sites. Valid monitoring data is critical to the adaptive management of site remediation and maintenance activities. In 2000, biologists surveyed wetland vegetation using two different sampling strategies on four mitigation sites in western Washington. Vegetative aerial cover data were collected using both the agency's historical, standardized monitoring approach, and an alternative method that combines changes in sampling design with new methods of data collection. Cover estimates were calculated for each data set and compared. Post-monitoring data analysis shows the alternate methods generate more reliable aerial cover estimates for target plant populations.

Introduction

A well-planned and effectively executed monitoring program can be used as the cornerstone of an adaptive management strategy designed to guide mitigation site remediation and maintenance activities. Valid monitoring data is central to the success of this strategy (Thom and Wellman 1996; Elzinga et al.1998) (Fig. 1a). A monitoring program that provides consistent and reliable information can be used to make management decisions that will improve the condition of a wetland mitigation site and ensure compliance with regulatory permits. Sound management decisions based on credible monitoring data can save resource management dollars when implemented in a timely fashion as part of an effective adaptive management strategy (Shabman 1995).

Frequently, however, monitoring results are inconclusive and fail to provide information necessary to evaluate the success of a wetland mitigation project (Peyre et al. 2001). When this occurs, the adaptive management cycle breaks down (Fig. 1b). Staff time and resources are wasted on an ineffective and inconclusive monitoring effort. Additionally, costs to the resource manager may climb as management decisions are based on inaccurate, ambiguous, or potentially misleading monitoring information (Shabman 1995; Elzinga et al. 1998).

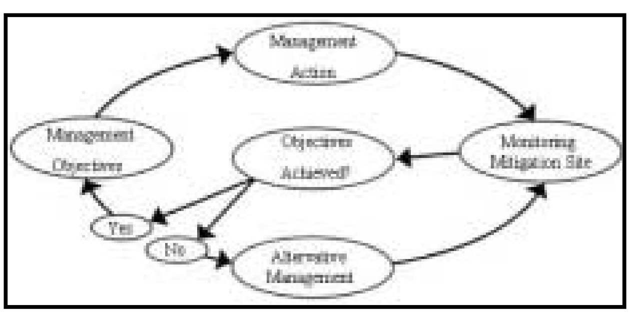


Fig. 1a. Successful Adaptive Management Cycle. Monitoring data was reliable and conclusive (Redrawn from Elzinga et al. 1998).

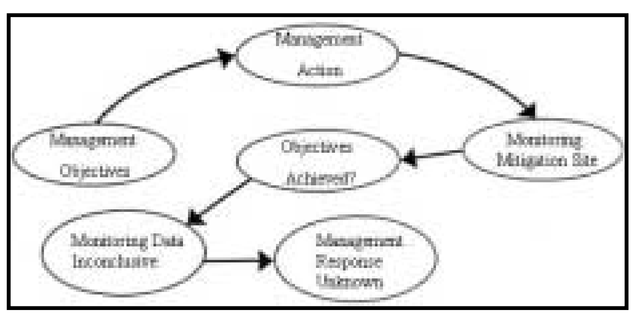


Fig. 1b. Unsuccessful Adaptive Management Cycle. Monitoring data was inconclusive (Redrawn from Elzinga et al. 1998).

In July and August 2000, WSDOT biologists surveyed vegetative communities using two different sampling strategies on 4 wetland mitigation sites in western Washington. On each site, aerial cover data were collected using both the agency's historical, standardized set of monitoring techniques, and an alternative approach that combines changes in sampling design and statistical analysis with new methods of data collection. The following provides a summary of these findings.

Methods

Using the historical, standardized monitoring techniques, two methods were used to collect and calculate vegetative cover on wetland study sites. For woody species, cover data was collected along sampling transects using the line intercept method (Canfield 1941; Bonham 1989). All woody vegetation intercepting a tape measure stretched the length of each sampling transect was identified and the length of each canopy intercept was recorded. The sum of the canopy intercept lengths was divided by the total length of all transects to calculate a mean aerial cover value. With this method, permanent sampling transects were placed along a baseline in a systematic, non-random manner. Sampling transects were angled through perceived vegetation planting zones prior to the first year of monitoring.

In the herbaceous plant community, ocular estimates of vegetative cover were made within one-meter diameter circular quadrats using the Daubenmire (1959) cover class method. Permanent quadrats were located along each sampling transect in a systematic, non-random manner. Plant species, bare soil, and structures (logs, etc.) were assigned cover class values based on the subjective, best professional judgment of the monitoring biologist. Using the Daubenmire method, the following cover class (CC) values were used for this study; CC1 (5% or less), CC2 (5-25%), CC3 (25-50%), CC4 (50-75%), CC5 (75-95%), and CC6 (95% or greater). Summary statistics were based on midpoint cover class values. Cumulative cover values were normalized to approximate herbaceous species aerial cover

Concurrent with the implementation of the historical methods, alternate sampling design and data collection techniques were employed on the 4 study sites. Stratified, systematic, and restricted random sampling designs were implemented using macroplots and microplots in multiple configurations, as appropriate. Using a random numbers table (Zar 1999), sample units (lines, point-lines, or quadrats) were randomly positioned along temporary transects. When necessary, sampling designs were stratified to address site-specific monitoring objectives for different vegetative zones. Both herbaceous and woody species cover data were collected along sampling transects.

Cover data for the woody species plant community was collected using the line intercept method, as in the historical methods. With the alternate techniques, however, temporary sample units (line segments) were randomly positioned along sampling transects. Woody species aerial cover values were calculated for each sample unit. Cover values were summed to calculate a sample mean and standard deviation.

For the herbaceous plant community, the point-line technique (Bonham 1989; Coulloudon et al. 1999) was used to collect aerial cover data. With this method, a vertical rod tipped with a pin was lowered from above the tallest vegetation. All plant species intercepted by the pin were recorded. If the pin intercepted no plant species, the ground surface was recorded as bare soil or structure. Temporary point-line sample units (series of points along a randomly located line segment) were positioned along sampling transects. Aerial cover values for each sample unit were summed to calculate a sample mean and standard deviation.

Use of sample size equations is predicated on the assumption that a sampling design is fully randomized and methods are objective (Elzinga et al. 1998). Due to the non-random, subjective nature of the historical methods, sample size analysis was deemed inappropriate.

With the alternate methods, however, sample size analysis was able to confirm that sufficient sampling had been completed based on sampling objectives and the desired level of statistical confidence. The following equation was used to perform this analysis (Elzinga et al. 1998). In this equation, the precision level equals half the maximum acceptable confidence interval width multiplied by the sample mean.

$$n = \frac{(z)^2 (s)^2}{(B)^2}$$

z = standard normal deviate
s = sample standard deviation
B = precision level
n = unadjusted sample size

Study Site 1: Wetland Pond

In July 2000, WSDOT biologists assessed scrub-shrub, invasive, and emergent plant species cover on a created wetland in southwest Washington.

Historical Sampling Design

Three permanent transects of various length were subjectively angled off an 80-meter baseline (Fig. 2a). Wetland scrub-shrub and emergent plant communities were identified along each sampling transect.

Two methods were used to collect and calculate cover values for plant communities in the emergent and scrub-shrub wetland zones. For woody species in the scrub-shrub zone, cover data was collected using the line intercept method. In the scrub-shrub and emergent zones, biologists used the Daubenmire method to estimate herbaceous species cover.

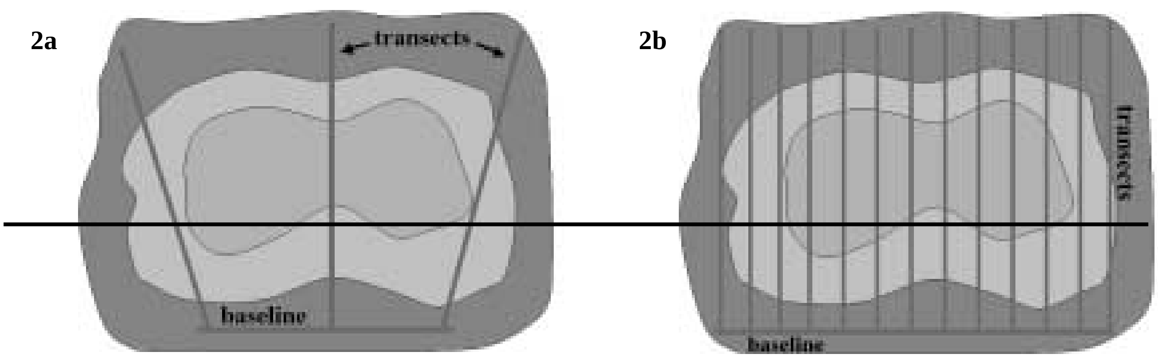


Fig. 2 . Sampling designs for study site 1, wetland pond (not to scale)

Thirty-four permanent, one-meter diameter circular quadrats were systematically positioned in a non-random manner along sampling transects. Summary statistics were based on midpoint cover class values. Cumulative cover values were normalized to estimate aerial cover.

Alternate Sampling Design

A temporary, 125-meter baseline was established along the length of the wetland mitigation site. Twenty-four transects were positioned perpendicular to the baseline using a systematic random sampling method (Elzinga et al. 1998) (Fig. 2b).

The line intercept method was used to collect woody species aerial cover data in the scrub-shrub zone. To achieve the desired statistical confidence interval specified in the site sampling objectives, data was collected from 24 22-meter sample units (line segments) randomly positioned along sampling transects in this zone.

The point-line technique was used to collect herbaceous species cover data. To achieve the desired statistical confidence interval, 26 10-meter sample units (point-lines) were randomly positioned in vegetation zones across the entire site.

Study Site 2: Estuarine Wetland

In July and August 2000, biologists collected scrub-shrub and saltmarsh plant species cover data at a restored, estuarine wetland mitigation site.

Historical Sampling Design
Five permanent transects of various length were subjectively angled off a 105-meter baseline (Fig. 3a). Using vegetative and topographic cues, wetland scrub-shrub and saltmarsh plant communities were identified along each sampling transect.

As in the previous study, two methods were used to collect and calculate plant species cover values. For woody species in the scrub-shrub zone, cover data was collected using the line intercept method. In the saltmarsh zone, biologists used the Daubenmire method to collect herbaceous species cover data from 30 permanent, one-meter diameter circular quadrats. Quadrats were systematically positioned in a non-random manner along sampling transects in this zone.

Alternate Sampling Design
A macroplot (100m × 75m) was strategically placed to include all vegetation zones in the estuary. The macroplot was divided along its length into 24 equal segments (Fig. 3b). One 75-meter sampling transect was randomly positioned in each segment of the

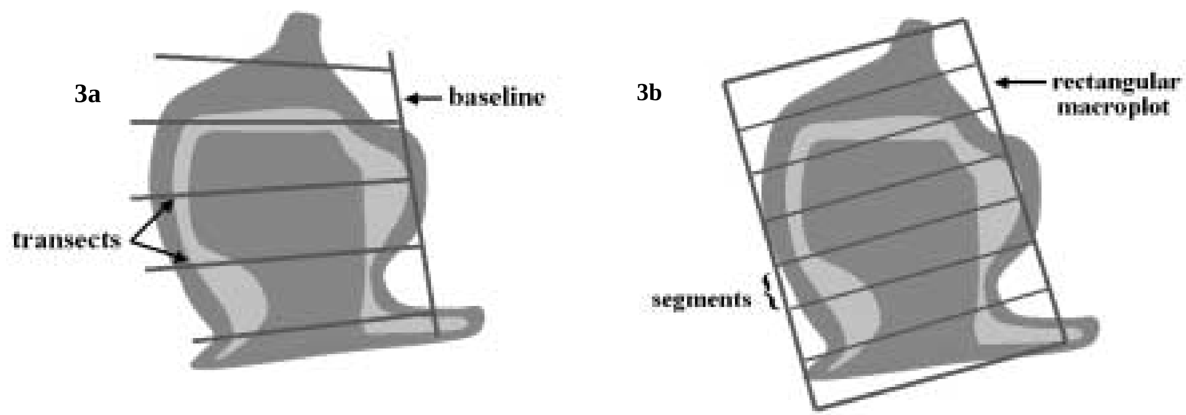


Fig. 3. Sampling designs study site 2, estuarine wetland (not to scale).

macroplot using a restricted random sampling method (Elzinga et al. 1998). Transects were broken into smaller sampling units to address zone-specific monitoring objectives.

For the herbaceous plant community, the point-line technique was used to collect aerial cover data in the saltmarsh. To achieve the statistical confidence interval specified in site sampling objectives, 51 10-meter sample units (point-lines) were randomly positioned along sampling transects.

The line intercept method was used to collect woody species cover data. To achieve the desired statistical confidence interval, data was collected from 36 13-meter sample units (line segments) randomly positioned along sampling transects in the scrub-shrub zone.

Study Site 3 and 4
Monitoring was conducted along a restored stream (site 3) and in a forested wetland (site 4). Using historical and alternate methods, similar sampling designs and monitoring methods were implemented on these study sites.

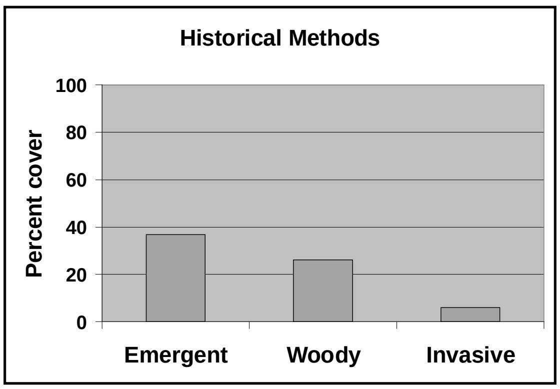
Results

Study Site 1: Wetland Pond

Using the historical, standardized methods, data analysis shows 8 native herbaceous wetland species provide 37% aerial cover in the emergent zone of the wetland pond. Analysis of data collected using the alternate methods shows 19 native wetland species provide 97% (CI 0.99 ± 0.05) aerial cover in this same zone (Fig. 4).

With historical methods, data analysis shows 6 native wetland woody species provide 26% aerial cover in the scrub-shrub zone that surrounds the pond. The alternate methods also show native wetland woody species in the scrub-shrub zone provide 26% (CI 0.80 ± 0.20) aerial cover (Fig. 4).

The historical methods show the emergent and scrub-shrub wetland zones support 6% aerial cover of reed canarygrass (*Phalaris arundinacea*). By contrast, the alternate techniques show aerial cover of reed canarygrass is 34% (CI 0.80 ± 0.20) in these same zones (Fig. 4).



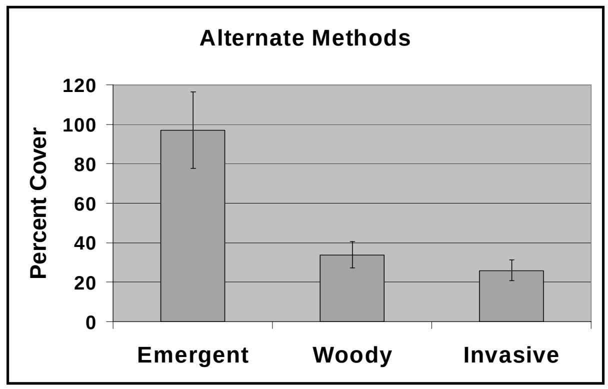


Fig. 4. Percent cover values for emergent, woody, and invasive species

Study Site 2: Estuarine Wetland

Using the historical, standardized methods, data analysis shows 15 native herbaceous saltmarsh species provide 48% aerial cover in the emergent wetland zone. Analysis of data collected using the alternative methods reveals that 20 species of native saltmarsh plants provide 56% (CI 0.95 ± 0.10) aerial cover in this zone.

With historical methods, data analysis shows 7 native wetland woody species provide 25% aerial cover in the scrub-shrub wetland zone. By comparison, the alternate methods indicate the scrub-shrub buffer area supports the same 7 species, but they provide 44% (CI 0.80 ± 0.20) aerial cover.

Study Sites 3 and 4

Table 1 summarizes data analyses for study sites 3 and 4. Forest species in site 4 are red alder (*Alnus rubra*), Oregon ash (*Fraxinus latifolia*), and red osier dogwood (*Cornus sericea*).

Table 1
Data summary for study sites 3 and 4

Study Site	Species	Aerial Cover (%) Old Method	Aerial Cover (%) New Method
3: Wetland Stream	Native emergent	0.50	0.65 (CI 0.80 ± 0.20)
	Native woody	0.10	0.17 (CI 0.80 ± 0.20)
4: Forest Wetland	*Alnus rubra*	0.53	0.37 (CI 0.90 ± 0.10)
	Fraxinus latifolia	0.11	0.08 (CI 0.90 ± 0.10)
	Cornus sericea	0.16	0.34 (CI 0.90 ± 0.10)

Discussion

Post monitoring data analysis shows the historical and alternate monitoring methods provide different aerial cover values for herbaceous and woody species. Using historical sampling strategies, sample size analysis cannot be used to confirm sufficient sampling has been completed. Therefore, cover values calculated using historical techniques are of unknown reliability and should not be reported with statistical confidence. In 10 of the 11 surveys, values calculated using these methods fall outside the confidence interval range for values calculated using the alternate techniques. By comparison, data collected using alternate methods can be reported with a statistical confidence interval and can be defended using accepted statistical tools.

Differences in historical and alternate sampling designs and resultant differences in cover values for two of the study sites would probably result in a different management or regulatory response. For the wetland pond (site 1), cover values for reed canarygrass (*Phalaris arundinacea*) are 6% and 34% using historical and alternate techniques, respectively. Considering the invasive nature of this species, from a resource management perspective, this difference is important. Where a value of 34% would likely trigger a management response, a value of 6% may fall below the threshold and indicate no management response is necessary. In this case, a decision to suspend or implement a weed control program will have serious implications for the future condition of the mitigation site.

Site goals and performance standards require a mixed tree and shrub community on the forest wetland mitigation site (study site 4). Though woody species cover estimates using the historical methods show a community dominated by a single species, alternate techniques indicate a mixed species distribution with similar cover values for red alder (*Alnus rubra*) and red osier dogwood (*Cornus sericea*). These results may generate a very different regulatory response in each case.

On all study sites, estimates of aerial cover calculated using the alternate methods were consistent with observations made in the field. Values calculated using both methods show alternate techniques are more statistically reliable and better demonstrate wetland site characteristics.

While federal, state, and local jurisdictions require mitigation at increasing levels, many agencies and municipalities are faced with static or decreasing resources. Environmental mitigation monitoring activities should be driven by statistically valid data to ensure good information is available for site management decisions. Reliable monitoring information is essential to efficiently utilize the resources available to manage wetland mitigation sites in a cost effective manner.

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DARK BEACHES – FDOT'S APPROACH TO RESOLVING COASTAL ROADWAY LIGHTING AND ITS IMPACTS TO ADJACENT SEA TURTLE NESTING BEACHES

Ann Broadwell, Florida Department of Transportation, District Four Office, 3400 West Commercial Blvd, Fort Lauderdale, FL 33309, Phone: 954-777-4325, Email: ann.broadwell@dot.state.fl.us

Dr. Michael Salmon, Department of Biological Sciences, Florida Atlantic University, 777 Glades Road, Boca Raton, Florida 33431, Phone: 561-297-2747, Fax: 561-297-2749, Email: salmon@fau.edu

Dr. Ralph Ellis, College of Civil Engineering, University of Florida, Phone: 352-392-3730, Email: relli@ce.ufl.edu

Abstract: The effects of artificial lighting on nesting female sea turtles and their offspring have been well documented in Florida for years. While federal and state regulatory agencies have pursued dark beaches to protect sea turtle habitat, Florida's coastline has continued to develop and degrade nesting beaches with artificial light. Currently, Florida Department of Transportation (FDOT) Design Standards do not take into account the biological conditions of adjacent properties. Transportation-related impacts caused by coastal roadway lighting affect sea turtle behavior by deterring nesting females from utilizing an otherwise suitable beach for nesting and incubation purposes. Coastal roadway lighting affects sea turtle habitat by forcing the nesting female to utilize inferior beaches that may not provide the best environment for hatching and emergence success of the clutch. Lastly, coastal roadway lighting impacts sea turtle populations when emerging hatchlings are attracted landward toward light sources. These 'disoriented' hatchlings usually die from predation, dehydration, heat exposure after sunrise, or getting crushed by vehicles. Hatchlings depend on visual cues from the beach in order to find their way to the ocean. With fewer hatchlings successfully making it to the ocean, fewer hatchlings make it to adulthood. This paper will discuss the development of Sea Turtle Lighting Zones, the proposed changes to the FDOT Lighting Standards for these zones, and the use of innovative lighting technology to illuminate the road for the traveling public and at the same time reduce impacts to adjacent sea turtle nesting beaches.

Introduction

Five species of sea turtles (loggerhead, *Caretta caretta*; leatherback, *Dermochelys coriacea*; green turtle, *Chelonia mydas*; hawksbill, *Eretmochelys imbricata*; and Kemp's ridley, *Lepidochelys kempi*) are found in U.S. coastal waters. Of these, four species (all but the Kemp's ridley) nest on U.S. shores. Loggerheads (the second largest population of this species in the world) place about 90% (70,000 annually) of their nests on the east coast of Florida. In addition, about 2000 green turtles, and more than 120 leatherbacks, also nest on Florida's beaches each year (Meylan, Schroeder, and Mosier 1995).

"Photopollution" (the negative influence of stray, artificial lighting on the survival and /or reproductive activities of nocturnally active organisms) is a major factor degrading sea turtle nesting beaches in Florida. It arises as a consequence of 40 years of intense immigration to the state, and settlement along its coastline. Stray light from homes, businesses and municipalities reaches the beach where it repels gravid turtles that nest at night. Today, most Florida sea turtles nest within the few remaining areas where light levels are low. However, a significant minority continues to place nests at sites where the beach is exposed to lighting. At such sites, extraneous lighting affects their hatchlings that emerge from nests at night. Hatchlings depend primarily upon visual cues to locate the ocean. Artificial lighting can either prevent turtles from detecting natural cues or, in extreme cases, attract them landward to the light source. Attracted hatchlings usually die from predation [capture by raccoons and foxes], dehydration, crushing by cars on roadways, or heat exposure after sunrise (Salmon 1998).

Habitat alterations associated with FDOT coastal highways contribute to many beach lighting problems. In 1998, FDOT entered into a research study with Florida Atlantic University (FAU) that would address the impacts of coastal roadway lighting on adjacent sea turtle nesting beaches. Originally, the purpose of this study was to (i) identify coastal roadway lighting problems, (ii) determine how they can be corrected, and (iii) use this information to develop new and improved lighting standards for roadway design engineers, coastal communities and utility companies. It has since been expanded to include an embedded roadway lighting demonstration project as well as an evaluation of the safety and roadway user response to embedded roadway lighting.

The purpose of this paper is to provide an overview of each FDOT sponsored research study. All studies are works in progress. The final report is scheduled for completion in April 2002.

Study 1: Coastal Roadway Lighting Impacts on Nesting Endangered and Threatened Marine Turtles and their Hatchlings

The first objective for this study was to conduct a coastal lighting survey of Florida's roadways. FDOT coastal roadways were inspected in order to identify existing lighting problems. Local conditions such as presence/absence of lighting system, presence/absence of sea turtle nesting activity on the adjacent beach, and adjacent land use were recorded. The Sea Turtle Lighting Zones were established from the survey. Coastal roadways will be classified into four types:

- Type I – Roadway is without lights and the surrounding area (as well as the adjacent beach) is dark.
- Type II – Roadway is furnished with lighting fixtures, some or all of which are visible at the beach. Other lighting is rarely present.
- Type III – FDOT luminaires and other sources illuminate the beach, either directly or indirectly. Modification of roadway lighting is likely to significantly reduce this illumination, but in some areas, is unlikely to render the beach totally dark.
- Type IV – Lights from streets and roadways make a relatively insignificant contribution to an already serious lighting problem (caused by extensive coastal development).

The information from this objective will be used to develop a geographically referenced database. This database will be displayed as a map and will provide information on existing roadway lighting conditions, the Sea Turtle Lighting Zone classification and the alternative lighting standards that a design engineer would be allowed to use in that particular Sea Turtle Lighting Zone. It will be part of the Florida Geographic Database Library (FGDL).

In order to determine what modifications to existing lighting fixtures and FDOT Design Standards are necessary, several roadways on the east and west coast were selected as experimental sites. These sites were used to document hatchling disorientation before and after modifications were made to the light source. Disorientation occurs when hatchlings can not maintain a constant directional movement toward the ocean because of a light source interfering with the their sea-finding ability (Witherington and Martin 1996). Modifications to light sources included shielding of fixtures, repositioning fixtures, and turning off lights. It was determined that some of these solutions were beneficial to the turtles but did not consider public safety. Filtered lens, developed by Florida Power and Light Company (FPL), were also tested. The filters were designed to exclude the transmission of the shorter light wavelengths, allowing the longer light wavelengths to be transmitted to the environment. Sea turtles are most sensitive to short light wavelengths. It was thought that it might be possible to illuminate coastal roadways for humans with spectral hues that the turtles ignore (Cowan and Salmon 2000). Both adult nesting females and hatchlings were studied using the filtered lens on streetlights in Palm Beach County, Florida that were located on a Type II coastal roadway. The FDOT study indicates that filtered lighting is ignored by nesting loggerheads but cautions that other species may respond differently (Pennell and Salmon 2000). Comparative studies have shown that both spectral sensitivity and perception vary among hatchling species (Witherington 1992; Lohmann et al. 1996). This may persist into adulthood. Similar conclusions were drawn concerning loggerhead hatchling response to filtered lighting (Cowan and Salmon 1998).

Study 2: Design, Installation and Maintenance of an Embedded Roadway Lighting System for Turtle Nesting Protection

FDOT has furthered its research efforts by funding a demonstration project that allowed for the research, design, installation, and maintenance of an embedded roadway lighting system. The system would be utilized in the summer when sea turtle nesting activity occurs. It is interesting to note that marine turtle nesting activity is seasonal. Modifications to existing lighting systems and the design of new lighting systems along coastal roadways should take this into consideration. This type of lighting system is under consideration for use in the Sea Turtle Lighting Zones.

The location of the embedded roadway lighting system is a Type II one half-mile stretch of State Road A1A in Boca Raton, Florida. The site was selected for the following reasons - the presence of vegetation between the road and the beach, known sea turtle nesting activity on the beach, documented hatchling disorientation events, and a desire by the City of Boca Raton to correct the problem. The product selected for installation is an illuminated raised pavement marker (RPM). The unit contains light emitting diodes (LED) that are energized by induction. A low voltage cable with energy nodes is trenched into the asphalt. The trench is resealed and the illuminating RPM is placed on top of the energy node. These units assist in delineating the pavement markings and were installed to enhance the centerline and outside lane markings. In addition to illuminating the pavement markings, low-level bollards were installed 3 feet from the edge of the paved shoulder. These louvered units disperse light horizontally across the pavement. This type of lighting should transfer bright, elevated light sources from tall poles to the street itself, thereby placing the light where it is needed while reducing its scatter to other areas of the environment (Hughes and Salmon 2001).

Study I has been supplemented to include beach surveys to determine the effects of low level lighting on adjacent sea turtle nesting beaches. Arena assays or staged hatchling emergences will be conducted on the adjacent sea turtle nesting beach. The experimental design allows for three light conditions to be researched—street lights on, embedded lights off; street lights off, embedded lights on; street lights off, embedded lights off. These arena assays are being conducted in the summer of 2001.

Study III: Evaluation of the Safety and User Response to Embedded Roadway Lighting Systems on an FDOT Demonstration Project

In order to evaluate the safety aspects of the embedded roadway lighting system that was installed summer 2001, FDOT entered into a research agreement with the University of Florida (UF). It is essential that the embedded roadway lighting system provide for the safety of the motorist, bicyclists and pedestrians.

A survey instrument was designed to obtain input from users of SR A1A. Motorists, pedestrians and cyclists were asked to give their opinion on the light levels of the new system, the location of the low level light fixtures in reference to safety, and whether or not impacts to sea turtles should be taken into consideration when designing a roadway lighting system. Approximately 2000 surveys were distributed in August 2001. Currently, UF is collecting and analyzing the data on the returned surveys. The results of the UF study will assist in determining just how innovative the traveling public will allow FDOT to be when it comes to alternative roadway lighting.

Conclusion

The above referenced research studies will provide FDOT with the information necessary to resolve coastal roadway lighting and it's impacts on sea turtle nesting beaches. Revising lighting standards within the Sea Turtle Lighting Zones will allow civil engineers to consider the biological conditions of adjacent property when designing roadway projects.

Biographical Sketch: Ann Broadwell has worked for the Florida Department of Transportation for 9.5 years as an Environmental Specialist. Ann has conducted environmental impact reviews to ensure NEPA compliance on Roadway and Bridge projects. She has worked on Environmental Resource Permitting activities for the US Highway 1 South project to the Florida Keys; this included the construction of the upfront mitigation activities for the USFWS Crocodile Refuge restoration project. Ann's interest in Sea Turtle Biology is a carryover from Graduate School, where her Master's Thesis was on Beach Renourishment and its effects on Loggerhead sea turtle hatchlings. She graduated from Florida Atlantic University with a Master of Science Degree, with an emphasis on Marine Biology.

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IMPACTS OF HIGHWAY CONSTRUCTION AND TRAFFIC ON A WETLAND BIRD COMMUNITY

Heikki Hirvonen, Department of Ecology and Systematics, Division of Population Biology, P.O. Box 17, FIN-00014 University of Helsinki, FINLAND, Phone: + 358-9-19128774, Fax: + 358-9-19128701,
Email: heikki.hirvonen@helsinki.fi

Abstract: Here I report the ecological impact assessment of a section of European Highway E18 east in Helsinki, Finland. This two-lane section of highway was constructed through the shore pastures of the Pernajanlahti Bay, which is one of the most important nature conservation areas on the southern coast of Finland. It is a wetland area characterized by extensive shore meadows and reed swamps offering habitats to a diverse and abundant birdlife. Wetland bird populations in the target area as well as in a control area were monitored before, during, and after the road construction. The results indicated that after the highway had been opened for traffic, the mean conservation value of the wetland bird community in the target area had decreased by 25 % as compared with the control area. The decline in conservation value was mainly due to the loss of several habitat specialist species, such as European bittern (*Botaurus stellaris*), ruff (*Philomagnus pugnax*) and little gull (*Larus minutus*). Abundance of breeding wader birds also declined in areas near the highway, where the traffic noise level exceeded 56 dB, but did not change much in areas with lower noise load. In contrast to wader birds, population abundance of passerine birds did not show any directional response to disturbance by the highway, regardless of noise level. Despite the negative effects of the highway on conservation value and on many bird populations in the Pernajanlahti Bay, the highway is currently being expanded with another two-lane roadway. The effects of traffic noise could be to some extent mitigated by noise barriers.

Introduction

Environmental impact assessment (EIA) is currently part of the road design process in Finland. However, when the Highway 7, which is part of the international Highway E18, was planned along the southern coast of Finland, no ecological assessment of the alternative routes was implemented. Therefore, the route chosen for the two-lane section of this highway 70 km east of Helsinki was taken through the shores of a wetland nature reserve with high conservation value. This area, the Pernajanlahti Bay, is protected mainly due to its abundant and diverse bird community where wetland birds are especially well represented.
Here I report on preliminary results of a post-project analysis (PPA) of ecological impacts (Wathern 1992) of the construction of the highway on the bird populations of the wetland area. In addition to their conservation value in this area, birds were chosen as the target taxon because they are particularly useful indicators of the ecological state of the environment in which they live (Furness & Greenwood 1993). This is partly due to the fact that the habitat and other ecological requirements as well as population status of most European bird species are well known (Tucker & Heath 1994) and bird monitoring methods are well-developed (Bibby et al. 2000).

Study Areas and Methods

Pernajanlahti Bay (the target area) is one of the most valuable nature conservation areas on the southern coast of Finland. It is characterized by shallow brackish water with submerged vegetation surrounded by extensive reed swamps and shore meadows. The highway was built through the shore pastures on the northern edge of the Bay.

Wetland and marshland bird populations in the Pernajanlahti Bay were monitored by standard bird census methodology (Koskimies & Väisänen 1991). Bird censuses were conducted before the road was built, during the construction, and after the highway had been opened for traffic. The number of monitoring years before, during and after the road construction were two, one and two, respectively. At the same time bird populations were monitored with similar methods in the control area, which is situated about 20 km from the target area. Habitats and bird species composition in the control area (Pieni Pernajanlahti Bay) were very similar to the target area. Possible changes in bird populations as well as in conservation value and diversity of the bird communities in the two areas were compared. Furthermore, changes in bird abundances in the target area were related to the level of traffic noise (Lahti 1994).

The index of conservation value of the bird community is based on species-specific indices of population size, species endangerment, and rarity in the particular biogeographical area in question. It was calculated separately for the two years of each period, i.e. before and after the road construction. Hence it is a comparable value for comparison between the two periods. Factorial analysis of variance (ANOVA) and repeated measures ANOVA (Zar 1996) were used for the statistical analysis of the data. Prior to the analyses the data were log_{10}-transformed.

Results

Conservation value

Road construction caused habitat changes and disturbance, and traffic noise accounted for extra disturbance. The mean conservation value of the wetland bird community in the target area declined by 25 % as compared with the control area after the highway had been opened for traffic. This reduction is derived from 23.3 % reduction in the target area (from 79.5 ± 3.5 to 61 ± 5.6 points) and 2.4 % increase in the control area (from 60.5 ± 6.4 to 62 ± 1.4 (mean ± SD)) over the same period of time. This difference in the change of the mean conservation value through time in the two areas was statistically significant (ANOVA, interaction between period and noise level, $F_{1,4} = 9.195$, $P = 0.039$). Much of the decline in conservation value in the target area was due to the loss of several habitat specialist species with high conservation value, such as European bittern (*Botaurus stellaris*), marsh harrier (*Circus aeruginosus*), crane (*Grus grus*), ruff (*Philomachus pugnax*) and little gull (*Larus minutus*) during and after the road construction. These species are restricted to wetland and marshland habitats and all but marsh harrier have declining population trends in Europe (Tucker & Heath 1994).

Population changes of waders and passerines

The abundance of wader birds breeding in the shore meadows near the highway (up to 200 meters) dropped by 50 % during the road construction and the decline was almost 80 % after the highway had been opened for traffic (Fig. 1). Farther off from the highway the decline in the wader populations was less steep and it leveled off when the distance from the road was more than 800 meters (Fig. 1). In addition to habitat destruction, the

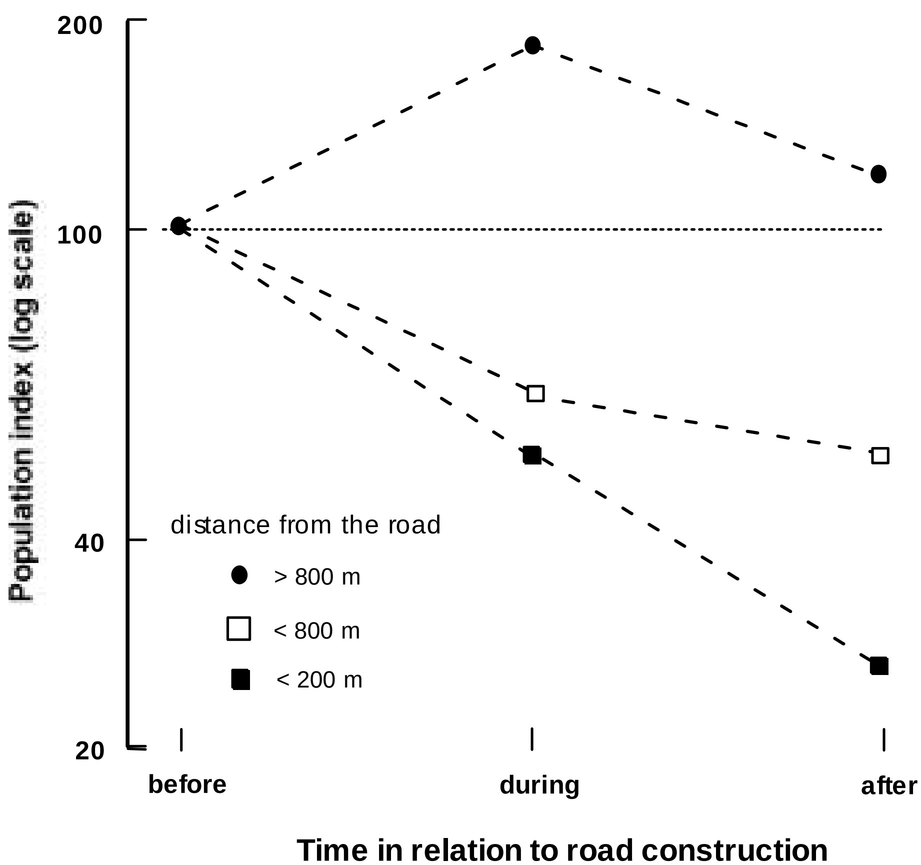

Fig. 1. Changes in population index (log scale) of breeding waders in relation to the distance (in meters) of from the highway before (index value 100), during and after the construction.

main reason for the severe decrease in the number of breeding waders near the highway was probably traffic noise. This is demonstrated when wader populations are compared before and after the highway was opened for traffic in the zones where traffic noise was more than 56 dB and less than 56 dB (Table 1). In the zone where traffic noise was > 56 dB, the number of breeding waders declined, whereas in areas where traffic noise was < 56 dB wader abundance remained fairly constant (Table 1). The wader population changes in the two noise zones were significantly different from each other (Table 1; repeated measures ANOVA, interaction between period and noise level, $F_{1,8} = 5.434$, $P = 0.048$).

On the contrary, the passerine birds breeding in the meadows did not show any clear responses to the highway and traffic noise (Table 1). Therefore, there was no significant difference in the population trends in the two traffic zones (Table 1; $F_{1,4} = 0.156$, $P = 0.713$). Thus, passerine birds seemed to be less vulnerable to disturbance caused by road construction and traffic disturbance than waders.

Table 1
Population indices of waders and passerines in the zones of traffic noise load of > 56 dB and < 56dB before and after the highway (see text for details).

	Noise load	> 56 dB	< 56 dB
Waders	before	100	100
	after	38	100
Passerines	before	100	100
	after	90	105

Discussion

Reduction in wader populations

The results of this long-term monitoring study indicate that habitat changes and disturbance caused by road construction and traffic noise had considerable effects on breeding populations of waders, while passerine populations showed minor responses. In the open shore meadows, through which the highway was built, the number of breeding wader birds declined considerably due to the highway and the consequent increased disturbance to the distance of 800 m. Although it is not possible to tell apart the effects of habitat changes and traffic noise completely, it is probable that the latter factor was more important here. This finding is in accordance with the results reported by van der Zande et al. (1980). They found that road traffic reduced the densities of the waders lapwing (*Vanellus vanellus*) and black-tailed godwit (*Limosa limosa*) up to two kilometers away from the road in open field habitats.

Similar results have been demonstrated by correlative studies in the Netherlands. For example, in a study based on regression between traffic load and bird densities, Reijnen et al. (1996) showed that out of the four wader species studied, three species showed a decrease in density adjacent to the road. Disturbance distance caused by traffic load for Oystercatcher (*Haematopus ostralegus*) was found to be as high as 3000 m along roads with high traffic densities (50,000 cars per day). In the Pernajanlahti Bay the traffic density was approximately from 15,000 to 20,000 cars per day, and therefore the disturbance distance for the wader species was probably found to be most significant up to 200 meters, though clear disturbance effects were found up to 800 m away from the highway.

No directional change in passerine populations

In the present study waders responded to the highway and traffic noise, but passerine species showed no effect. Earlier studies have also shown a similar difference between these groups of birds. For example, Haworth and Thompson (1990) found that many wader species avoided areas with strong human disturbance, but the occurrence of passerine birds was more clearly related to habitat quality than to human disturbance. However, the response to traffic noise and other disturbance caused by roads and their construction can vary depending on the bird species (e.g., Ferris 1979). In fact, in the abovementioned study Reijnen et al. (1996) found that passerines skylark (*Alauda arvensis*) and meadow pipit (*Anthus pratensis*), which breed in open landscapes, also suffered from disturbance by traffic. Their disturbance distances were roughly half of that of the wader species. Both species also occur in the shore meadows of the Pernajanlahti Bay, but because of low breeding densities and short disturbance distance, no significant effect of the car traffic was observed in this study.

Mechanisms of traffic disturbance

One finding of the present study was that the bird species specialized in wetland habitats proved to be most vulnerable to disturbance. For example, territories of European bitterns used to be located in the reed beds considerably far off from the road line. Therefore, habitat changes probably had no effect on their disappearance, but disturbance by car traffic is the most probable reason. Bittern males attract females by a deep and loud mating call. Frequency range of the call (Cramp & Simmons 1977) is similar to the most dominant part of the traffic noise spectrum in the Pernajanlahti Bay area (Lahti 1994). In the areas where the bittern territories were located before the highway the level of the traffic noise is now about 53-55 dB in the summertime (Lahti 1994), which exceeds the loudness of the mating call by male bittern (40 dB; Cramp & Simmons 1977). This means that bittern mating calls are masked by the traffic noise and remain inaudible for the females, and maybe therefore the males abandoned the area.

Mitigation of disturbance

On the basis of this study, extra care should be taken in planning new roads in open wetland areas. Despite the fact that the present highway has been shown to have negative effects on conservation value and on many bird populations in the Pernajanlahti Bay, the highway is currently being expanded with another two-lane roadway. From a conservation point of view, it is also important to explore how the present effects could be reduced. As the most severe disturbance here is caused by traffic noise, it seems that noise barriers could be used to mitigate the existing disturbance.

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MITIGATION OF LIGHT RAIL TRANSIT CONSTRUCTION ON JURISDICTIONAL AREAS IN THE WHITE ROCK CREEK FLOODPLAIN, DALLAS, TEXAS

Emily Schieffer (eschieffer@wendylopez.com); and Jerry Smiley, (jsmiley@wendylopez.com),
Wendy Lopez & Associates, Inc., 1825 Market Center Boulevard, Suite 510, Dallas, Texas 75207,
Phone: 214-741-7777, Fax:: 214-741-9413

Abstract: In 1994, Dallas Area Rapid Transit (DART) began planning for an 11.8-mile extension of its light rail transit (LRT) system from Dallas to Garland, Texas. The proposed alignment of the LRT extension traversed approximately 1.2-miles of the White Rock Creek floodplain near the confluence of three creeks and adjacent to approximately eight acres of wetlands. Because of the extensive development that has occurred within the watersheds of these creeks over the last 50 years, the conveyance of flood waters within this urban floodplain has been severely constrained. In order to adequately protect the new rail bed from flooding, it needed to be elevated as much as 12 feet above the existing rail bed, nearly 20 feet above the natural surface.

This area also serves as part of the Olive Shapiro Nature Preserve and White Rock Park – one of the largest, intact natural areas in the City of Dallas. Thousands of park users cross the proposed alignment daily. In addition to protecting the jurisdictional areas found adjacent to the rail alignment and to preserving the park's existing flood water storage, project designers wanted to maintain park users' access to the bike paths and natural areas of the park. All of these concerns were taken into account when evaluating the project design alternatives.

The first alternative suggested placing the new alignment on fill with bridges located at the creek crossings. This alternative would restrict park users' access, destroy adjacent wetlands, and further restrict floodplain storage. The second design option recommended placing the rail line on an aerial structure through the length of the floodplain. This option would minimize permanent impacts to the adjacent jurisdictional areas, maintain the public's access to all areas of the park, and avoid impacts to floodplain storage within the park. Although the construction costs for this option were higher, DART selected this alternative.

The true success of this project, though, was found not in innovative engineering, but in the cooperative efforts between DART, USACE, USFWS and the City of Dallas Parks and Recreation Department. These groups collaborated to develop a mitigation plan that was acceptable to all interested parties, including the general public. The fact that this mitigation occurs within the same watershed and within one-mile of the original impact area is a significant accomplishment.

The final mitigation plan has four components:
- post-construction restoration of the wetland areas adjacent to the new alignment;
- construction of two "educational" wetlands next to the park's hike-and-bike trail;
- restoration of a ten-acre historical wetland within White Rock Creek Park; and
- creation of a mitigation monitoring plan to review construction activities.

It is our hope that this project will serve as a model for future cooperative work between DART, USACE, USFWS, and the City of Dallas.

Problem Statement

In 1994, Dallas Area Rapid Transit (DART) began planning for a $293 million, 11.8-mile extension of its light rail transit (LRT) system from Dallas to Garland, Texas – known as the Northeast Corridor – along the former MKT railroad. One of the more interesting issues that were addressed during project planning and design was the consideration of impacts to jurisdictional areas in the White Rock Creek floodplain. A portion of the proposed alignment of the LRT extension traversed approximately 1.2-miles of floodplain near the confluence of White Rock Creek, Jackson Branch and McCree Branch. This floodplain also serves as part of the Olive Shapiro Nature Preserve and White Rock Park – one of largest, intact natural areas in the City of Dallas.

Because of the extensive development that has occurred within the watersheds of these creeks over the last 50 years, the conveyance of floodwaters in these urban floodplains has been severely constrained. The creeks often flood their banks during storm events and overtop portions of the old rail line by as much as 10 feet. In order to maintain rail operations during these events, it is necessary to design a system where the track or low chord of structures is at least two feet above the 100-year floodplain. Critical to the planning and design of the system is the potential impacts to jurisdictional areas within the floodplain – bottomland, hardwood forests complete with a mosaic of wetlands.

Additionally, hundreds of park users cross this alignment daily at the White Rock Creek Hike-and Bike Trail and other equestrian trails. Maintaining these trails during construction and assuring openings for equestrian users became an important issue during the planning process.

Project Objective

The primary objective of this project was to minimize LRT construction impacts on the surrounding floodplain.

Methodology

During the planning phase of the Northeast Corridor, jurisdictional delineation identified ten wetland areas, totaling more than eight acres that could be impacted along the former freight line. The majority of these were located within the White Rock Creek floodplain. Isolated jurisdictional areas were also identified in areas where urban runoff was collected. Many of these areas were formed because the rail bed causes seasonal impoundments. These floodplain wetlands represent a diverse, mature closed-canopy of hard and soft mast-producing species. These bottomland hardwood forests tend to be rare in metropolitan areas and function as a refuge for urban wildlife and migrating birds and waterfowl.

Within the White Rock Creek floodplain, the top of rail was, on average, six feet above the natural grade of the floodplain. It was completely built on fill material with openings at White Rock Creek, the White Rock Creek Overflow Channel and Jackson Branch. Field investigations revealed that the existing track bed served an important function in influencing hydrologic conditions for the bottomland, hardwood forest. Overtime, low-lying areas developed near the rail bed due to scouring action during flooding. As a result, these areas experienced an enhanced hydroperiod.

In order to locate the LRT line two feet above the 100-year floodplain, as required by DART design standards, several options were considered. One design option would require placing the new alignment on fill with bridges located at each of the creek crossings. Nearly 48,000 cubic yards of fill would be required to raise the rail structure 12 feet above the existing rail bed (nearly 20 feet above the natural ground surface). At a 3:1 side slope, the new rail bed would be approximately 135 feet wide at its base.

There were several adverse impacts of this option. First, most of the available ROW would be impacted, permanently displacing adjacent jurisdictional areas and thousands of trees. Second, because of the flooding issues already associated with urban watersheds, City of Dallas policy limits the amount of development in the floodplain. Any DART development would not be allowed to raise the 100-year flood elevation. Mitigation for this amount of fill would be extremely costly. Third, to accomplish the construction of this option, construction roads would be required on both sides of the rail line, causing further impacts to the surrounding jurisdictional areas and limiting park users' access to the ROW.

Retaining walls, instead of sloped fill, were also considered; however, it was determined that the structural integrity could be in jeopardy due to the scouring action of the floodwaters.

A second design option recommended placing the LRT line on an aerial structure through the length of the floodplain. This option would limit the width of impact, requiring only a temporary construction road along one side of the embankment. Further analysis also determined that placing the support piers for this structure on the existing rail bed would minimize the hydraulic impact and maintain the existing 100-year flood elevation.

During the NEPA process, Wendy Lopez & Associates, Inc. (WLA) conducted an evaluation of these alternatives to determine their impact on the jurisdictional areas in the park and to compare the costs of mitigation and construction.

Summary of Findings

Cost/benefit analyses revealed that the direct construction costs of placing the new rail on fill was less expensive, but the overall impacts and indirect costs of mitigation made it unfavorable. The direct construction costs of the structural alternative were much higher, but the mitigation costs were negligible relative to the fill option. Additionally, the direct impacts to the wetlands adjacent to the ROW were lessened and the hydrology of the area and the volume of the floodplain storage largely unchanged. Finally, the freedom of visitors to wander through the park would be unimpaired once the aerial structure was completed. DART concurred with this finding and coordination with affected agencies was initiated to determine mitigation for the temporary impacts to the jurisdictional areas.

In addition to restoring the wetland areas along the temporary construction road, it was the desire of the USACE for DART to identify additional potential mitigation areas within the White Rock Creek watershed. The City of Dallas Parks and Recreation Department owns much of the surrounding land in the watershed including several thousand acres around White Rock Lake located approximately ½-mile south of the DART LRT line. DART approached the Parks and Recreation Department about identifying areas for potential mitigation. They agreed to let DART research parkland and make recommendations where potential mitigation could occur.

DART identified three areas for potential off-site mitigation: an area along the hike-and-bike trail; one along the White Rock Lake shoreline; and an isolated area that was historically an open-water wetland. The City of Dallas Parks Department suggested that the area along the hike-and-bike trail be developed as an educational wetland. Additionally, the hydroperiod of the isolated area would be enhanced to restore its historic function as a wetland.

As a result of field studies, the proposed mitigation plan included the following components:

- restoration and enhancement of the wetland areas adjacent to the new structure;
- construction of two "educational" wetlands located next to a heavily traveled hike-and-bike trail that will teach the public about the characteristics and benefits of wetlands;
- off-site restoration of a ten-acre wetland area located in White Rock Creek Park; and
- quarterly monitoring of construction activities to ensure protection of the surrounding environment from further degradation.

The mitigation plan was strengthened by the fact that the mitigation occurred in the same watershed. The USACE and USFWS concurred with the findings and approved the proposed mitigation measures.

Implications for Future Research/Policies

The true success of this project was found in the cooperative efforts between DART, USACE, USFWS and the City of Dallas Parks and Recreation Department to develop a plan that was acceptable to all interested parties, including the general public. DART received land for mitigation at no cost; the City of Dallas Parks Department received two educational wetlands for the general public; the USACE obtained mitigation within the same watershed; and the enhanced wetland areas met the USFWS desire for improved habitat. Additionally, this seven-year project was the impetus for DART to develop Mitigation Monitoring Policies for all projects where mitigation is required through the NEPA process.

Biographical Sketch: Ms. Schieffer has experience in a broad range of projects within the field of Conservation Biology. She has worked with state and federal agencies, non-profit organizations, community groups and private companies, both in the United States and abroad, on projects ranging from tracking endangered species occurrences, to maintaining trails and implementing erosion controls, to researching the effects of oak wilt. She has also designed, organized and led workshops for college and high school students, serving as both leader and team member, overseeing quality control and reviewing the success of each workshop. Ms. Schieffer spent 1½ years in Bolivia with the Peace Corps, working as an environmental educator, where she collaborated with community groups, non-governmental organizations and government officials on a variety of projects. Currently, she is working as an Environmental Scientist for Wendy Lopez & Associates, an engineering and consulting in Dallas, Texas. In this capacity, Ms. Schieffer has gathered data and prepared documents for NEPA compliance, completed Section 404 jurisdictional determinations (for wetlands/waters of the US), conducted noise surveys, and carried out mitigation monitoring for wetland restoration projects.

PREVENTION OF UNWANTED SPECIES IMMIGRATING TO ISLANDS ON STRAIT CROSSINGS

Bjørn Iuell, Environmental Strategy Division, Directorate for Public Roads, Norwegian Public Roads Adminstration, P.O. Box 8142 Dep, N-0033 Oslo, NORWAY, Phone: +47 22 07 30 19, Fax: +47 22 07 36 79, Email: bjorn.iuell@vegvesen.no

Abstract: When islands are connected to the mainland by bridges or tunnels it becomes possible not only for humans to travel back and forth but also for wildlife, which uses these new means of access as migration corridors. The results can be disastrous, as can be seen from the example of the island of Tautra in the north of Norway (North Trøndelag).Tautra was proclaimed a wetlands area of international importance under the Ramsar convention in 1985. Parts of the island perform the multifunctional purpose of a breeding, migration, wintering and molting area, and have been used over the years by countless numbers of waterfowl. In the late 1970's a road to the island was built over a stone-fill embankment. Predators, such as foxes, badgers, martens and others, began appearing on the island, using the new road as a migration corridor. The most abundant species of waterfowl on the island, which was the reason for the island receiving its Ramsar wetlands status, declined sharply in numbers after the construction of the road. Indeed, today some species on the island have been reduced to barely 10% of their original populations before the road was built. This drop in numbers is due not only to the introduction of mammalian predators but also to the deterioration of the area as a wetland feeding ground, an effect resulting from the blocking of the ocean stream when the embankment was constructed. A predator extermination program for the island was established. Also, to prevent predators from using the road, loudspeakers were set up in the hope that the noise from the speakers would be enough to scare the predators away. However, after a time the deterrent effect of the loudspeakers weakened, possibly as a result of the animals becoming used to the sound and no longer associating the sound with danger. In regard to roads and bridges, little research has been done on wildlife deterrent methods, which employ no physical barriers. Noise, light and smell have been used in different ways, but these measures seem to lose their effect over time. In tunnels, however, noise deterrents have proven successful. It has now (2001) been decided to replace 350 metres of the road out to Tautra with a bridge; a measure, which it is hoped will restore the natural water currents around the island. To ensure the success of this project, which will cost nearly 50 million Norwegian crowns, an effective wildlife barrier must be set in place. The Public Roads Administration has therefore initiated a development project with the aim of producing a wildlife barrier device that is 100% reliable. The device will be tested out on foxes, martens and badgers in captivity. The trials will be carried out at the University of Oslo during the course of the year 2001. Specifically, the tests are designed to demonstrate how well these three species cope with different kinds of grids (width of mesh, wire-thickness, length, breadth).

Introduction

Roads and road building can have an impact on the natural environment in many different ways. Traditionally, we have been concerned by the land use itself; however, in more recent years we have also begun to focus upon a range of effects which, to a greater or lesser degree, are indirect; for example: pollution, road kills, the disturbance of vehicular traffic (noise, vehicle-lights, movement) and the erection of barriers that close off the paths used by different kinds of wildlife and divides the patterns of their natural living areas. The negative effects of these factors are many and complex, but the building of roads and other transport infrastructures can also create new migratory opportunities for wildlife. Areas beside the road can serve as linear habitats or corridors, which allow wildlife to migrate across unsuitable territory, joining together habitats and wildlife populations, which would otherwise have remained separate. Road building can also serve to protect habitats; remnant areas, for example, after construction can be left closed off, out of reach of undesirable human interference.

The Problem

However, when wildlife gains entry to areas from which it has previously been cut off, it can in some cases have particularly undesirable effects. This applies mainly to the building of road bridges to islands, but it can also be a problem when roads connect two areas on the mainland where the wildlife of the areas has remained isolated due to insuperable natural barriers; for example, high mountains or wide rivers. In the following discussion I will concentrate on the problems associated with islands, which have acquired, in one form or another, a link with the mainland, be it a bridge, a tunnel or a road on a landfill embankment.

The flora and fauna of an island can be quite different from that of the adjacent mainland. The difference in the range of species found on the island depends upon its distance from the mainland and from other islands, ice conditions in winter, the ocean streams and the different abilities of each species to bridge the gap posed by the water barrier. Many bird species have little trouble making their way out to even far out-lying islands and the same is true for some mammals capable of swimming moderate distances. In a somewhat broader perspective, both geographically and historically, we might say that the range of species on an island is determined by the situation at the time the island was still a part of the mainland.

Over time the plants and animals on isolated islands can develop in quite distinctive directions. The absence of natural enemies can mean that some species find themselves in a very favourable position; ground-nesting birds, for example, are especially attracted to such islands. There are opportunities too for humans to influence and exploit the special range of species to be found on isolated islands. On islands without larger predators, for example, game animals can be introduced for hunting purposes, while predator-free islands are also well suited for the raising of domesticated animals. On islands along the Norwegian coast porcupines have been introduced as part of a campaign of “biological warfare” against snakes and small rodents.

On islands with only limited immigrations, be these of reptiles, rodents, ungulates or carnivores, an active combative campaign can be an effective measure in controlling or completely exterminating vermin and other unwanted creatures. Problems occur when migrations become so large that it becomes difficult or extremely costly to control groups of undesirable species. Moreover, for especially vulnerable areas the introduction of even a small number of new animals can be damaging. Predators pose the biggest problems; they are by nature more opportunistic and more curious than other animals. They move over wide areas and are capable of overcoming most barriers, both natural and man-made.

The Solutions

Little available documentation exists on the kinds of devices that have been used in the past to or on what effect these different measures have had. Fences and traditional cattle grids can usually effectively stop most hoofed animals, domesticated and wild. With regard to predators, however, finding effective barriers has proved much more difficult. Some of the measures employed to deter wildlife from using roads include the use of noise, light and smell, both singly and in combination. While we may, nevertheless, have our own opinions as to how effective these measures have been, no scientific follow-up programmes as such have been carried out on the deterrent devices. Nor, moreover, has the problem of wildlife migration to islands via roads been given high priority abroad. The following discussion of the different types of wildlife deterrent therefore will be based primarily upon the undocumented experience from a small number of Norwegian wildlife deterrent installations.

The use of *smelling agents* has been employed to repel both ungulates and predators. The artificially produced scent of predator urine, for example, has been used to frighten away ungulates from roads where they might be run over. The general conclusions from such attempts, however, are that smells alone are not enough to deter animals from crossing the road. The measure is also sensitive to wind. A degree of repulsion can be registered immediately after the smelling agent has been placed out, but the effect begins to weaken a short time later, even with regular renewals of the smelling agent.

The *lighting* of roads, bridges and tunnels has generally little deterrent effect upon animals. Indeed, for certain species light can have precisely the opposite effect by attracting insects and other small creatures that can serve as food for other animals.

Noises have been employed in various forms. It is most commonly used to frighten away birds from airports or food production plants. In such cases the noises employed are usually those of the enemies of the unwanted species – for example, the sounds made by a bird of prey. More monotone and sustained sounds of different frequencies are also used in a variety of situations and upon a range of species, from insects to rodents and from seals to land predators. The effect of these measures has been reported as varied. With regard to deterring predators from roads, sound-creating devices that produce strong sound signals are employed. In the tunnels out to the islands of Hitra (1994) and Frøya (2000) in South Trøndelag, Norway, loudspeakers were set up which produce sounds in the frequency ranges 5,000 Hz (from 07:00-16:00) and 7,000 Hz (from 16:00-07:00). In the Hitra Tunnel three pairs of speakers were set up 15m, 21m, and 27m from the mouth of the tunnel. In the Frøya Tunnel one pair of speakers was set up 100m from the mouth of the tunnel. Here the problem species are primarily badgers, martens, red foxes and stray farm foxes. The installations have been relatively dependable and results so far have been good. No sightings of the unwanted species have been made on Hitra, although a fox was spotted in the Hitra Tunnel, probably as a result of temporary equipment failure.

Fig. 1. A wildlife noise deterrent device on the road to Tautra, North Trøndelag, Norway. (Photo: Bjørn Iuell)

On the road out to the island Tautra in North Trøndelag, attempts have also been made using noise to keep out martens, badgers and foxes; but the results here have not been as good as in Hitra and Frøya. Loudspeakers were set up on poles on either side of the road approximately 50m from the shore (fig. 1). The equipment is the same brand as that used in the Hitra and Frøya tunnels, but the sound produced fluctuates within the 5,000-30,000 Hz frequency range. During outside tests on domesticated foxes the animals exhibited obvious signs of stress when exposed to sounds between 5,000-10,000 Hz. During the first 3-4 years the deterrent device appears to have had good effects; however, after this time the effect seems to have fallen off, with repeated sightings of the target species made since then. Shooting of mink, martens, badgers and foxes has therefore been introduced as a supplement to noise deterrent. During the period 1991-2000 a total of 64 animals were shot.

A noise deterrent device has also been set up on the Dyrøy Bridge in Troms County, primarily to stop the immigration of foxes. However, this deterrent device also exhibited reduced effect after only a few years of operation. The frequency range in the beginning was in this case between 20,000-30,000 Hz, but this was adjusted to 17,000 Hz after tests on dogs.

The conclusion then, when it comes to the use of sound deterrents, is that they seem to be more effective in tunnels than in open country. Moreover, something that can be said in general for all wildlife deterrents that are not physical barriers, is that there is a danger that a certain immunity to them will develop over time. Another problem is that the installations are prone to breakdown, either as a result of technical problems or because of vandalism.

Fig. 2. The Island of Tautra, with a 3 km road constructed in 1976. (Map: Cappelens kart)

The New Approach

Based on experience gained from the above cases the Norwegian Public Roads Administration has initiated a smaller development project with the objective of coming up with effective, dependable and lasting barrier devices for a wide range of species. Tautra Island in the municipality of Frosta in North Trøndelag County has been mentioned earlier. The island is approximately 3.5 km long and is situated in the Trondheim Fjord (fig. 2).

This is a unique island, which in addition to its national cultural and historical significance, is of strategic importance for migrating and nesting birds, with a highly productive wetlands area. This has led to large parts of the island being declared a national reserve under the Environment Act in 1984. Tautra is an important feeding and resting place for migrating birds nesting in the Arctic, as well as a nesting place for many other bird species. In all, 202 different bird species have been registered on the island, and in 1985 the area was proclaimed a Ramsar-area under the Convention on wetlands of international importance, especially as waterfowl habitat (Ramsar, Iran, 1971).

In 1976 the island was connected to the mainland with a 3km road (fig. 3). It was built to on a stone embankment, which has led to the silting-up of the wetlands area and to a considerably reduced level of food availability for the birds on the island. Furthermore, as mentioned earlier, there has been immigration of predators to the island in spite of the wildlife noise deterrent devices set up on the road in 1991.

Fig. 3. The road to Tautra, seen from the island. (Photo: Bjørn Iuell)

The situation has seen dramatic developments over recent years, with the most important bird species now reduced in number to just 10% of their original population before the road was built. To improve the flow of water around the island it has now been decided that the mid-section of the stone embankment where the strait is at its deepest will be removed and replaced by a bridge of approximately 350m in length. As part of this work, which has been estimated to cost almost 50 million Norwegian Crowns, an important consideration will also be the setting up of effective wildlife barrier devices in connection with the new bridge.

A project group with representatives from Frosta Municipality, the Regional Administration of North Trøndelag County, the North Trøndelag University College, the Directorate for Nature management, the University of Oslo and the Norwegian Public Roads Administration was set up in 2000 to consider wildlife barrier alternatives. After assessing the experience to date with existing deterrent installations, it was concluded that if the bridge emplacement project were to be effective, then deterrent methods other than noise, smell and light needed to be found.

Moreover, as any proposal would entail the exposure of equipment to harsh climatic conditions such as strong winds, ice formation and the effects of salt water, the demands upon technology and its reliability were great.

It was also concluded that the task of deterring wildlife from the road should be approached from two angles. Firstly, rather than the mainland end of the road and embankment virtually leading animals out onto the road as it does today, it should be constructed in such a way as to lead animals away from the road. The second way of tackling the problem is to stop those animals, which do manage to get onto the road from making their way any further out towards the island.

Leading-fence

As it stands today the embankment emerges on both sides of the road as a natural extension of the shoreline, which leads animals along the beach sands and thus out onto the road (fig.4). That is to say, the embankment appears to wildlife as the continuation of the shoreline, and they can end up on Tautra without ever intending to go there. It is therefore possible to repel animals from the island before they even get as far as the road by placing appropriate constructions between the shoreline and the road, which will lead the animals away from the road.

This should be possible by setting up a simple leader-fence that leads the animals back and over the road, somewhat like an inverted fish-trap. However, as the sea floor on either side of the embankment slopes away very gradually, an added challenge will be finding an effective deterrent method that also functions at low tide. Water recedes from large expanses of the shore area on both sides of the embankment at low tide thus allowing animals to pass freely (fig. 5). Another consideration, moreover, is that any wildlife deterrent emplacements must blend in aesthetically with the natural environment.

Fig. 4. The embankment emerges as a natural continuation of the shoreline, thus leading animals out to the island. (Photo: Bjørn Iuell)

Fig. 5. At low tide, shore areas are exposed on both sides of the embankment, thus allowing animals free passage. This presents a challenge when it comes to finding a wildlife deterrent method that blends in with the natural environment. (Photo: Bjørn Iuell)

Wildlife barrier device

The Norwegian Public Roads Administration in North Trøndelag, in conjunction with the North Trøndelag Department of the Environment and the North Trøndelag University College, has drawn up a proposal for a wildlife deterrent device consisting of a gate with an automatic opening mechanism combined with a grid. The plan is to place the device over the crossing between the existing body of the road and the new bridge. There should be a height difference between the existing road and the bridge of approximately 2m, and a grid should be built into the apron of the road that slopes up to the bridge. A grid combined with an automatic gate should be enough to prevent animals from gaining access to the road. It is important, moreover, to ensure that animals cannot gain access by using other parts of the emplacement.

Gate

Badgers are quite poor at climbing and jumping, while foxes on the other hand can jump over barriers up to 1.5m high without difficulty. Martens, however, pose the greatest challenge, being extremely good climbers. The gate should therefore have a smooth surface and sit flush within the emplacement, and should be between 1.5 and 2.0m high. It must be ensured, moreover, that animals cannot gain access under the gate, while at the same time the gap under the gate must be large enough to prevent foreign objects from becoming wedged under it, thus preventing it from closing properly. The gate must therefore stand as close to the body of the road as possible and preferably have a stiff brush attached to its bottom edge. The gate must open out over the grid so that snow, ice or other material lying in front of the gate is pushed out over the grate so that it falls to the ground or water below.

The automatic opening function of the gate must be adapted to climatic conditions, take pedestrians and cyclists into account and be operable manually in the event of breakdown or power failure.

Grid

The most effective placement of the grid and gate is where the bridge and road join; firstly because at this junction it will be easier to prevent animals from gaining entry by use of other parts of the installation, and secondly because it is important to have a good depth under the grate. Animals will be less inclined to make their way out onto the grid, for example, if they can see water flowing at some distance beneath. Moreover, in the event of the gate remaining open, it is important that the grate function as an effective barrier in itself.

A certain level of maintenance will be necessary to ensure the effective operation of the automatic closing mechanism of the gate and to prevent the grid from becoming clogged.

The grid must be placed on the road apron between the existing road and the bridge, thus creating an inclined approach to the gate. However, the grid must not be too smooth, so that it becomes, as it were, “a hill-start under slippery conditions”. A traditional cattle grid with a row of cross-pipes, for example, would not be particularly practical. The gate must perform the dual purpose of allowing walkers and cyclists to get through, while at the same time keeping the unwanted species in question out. Work has been carried out on different wildlife barrier devices on Tautra since 1988. For example, traditional cattle grids were used with animals in captivity. It became evident from these attempts that red foxes had no particular difficulty getting past this kind of grid. Nor, in our case, is an electrified grid an option, the emplacement being constantly exposed to salt water spray. Trials will therefore be run of the “pressure-welded lattice” type grid.

These grids will be tested out on foxes, martens and badgers in captivity. The trials will be carried out at the University of Oslo during the course of the year 2001. Specifically, the tests are designed to demonstrate how well these three species cope with three different kinds of grid (width of mesh, wire-thickness, length, breadth).

Conclusions

When islands are connected to the mainland by roads, bridges or tunnels it is necessary to evaluate to what extend the new connection can create unwanted ecological changes like immigration of new species. If necessary an effective wildlife barrier must be incorporated in the construction, adjusted to the local situation.

A certain level of supervision on the island will be necessary after these measures have been implemented both to ensure that the wildlife deterrent device is working as planned, and to remove any animals, which find their way out to the island in spite of the device. A camera monitor should also be set up on the road to document, if possible, how animals respond to the new deterrent device, and if any animals are able to gain entry past it. This is the only way to improve our knowledge about the behaviour of the animals and the effectiveness of the barrier devices.

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ROAD TECHNOLOGIES TO MAINTAIN AND RESTORE RIPARIAN AREA FUNCTIONS

Anthony Edwards, Project Leader and Civil Engineer, U.S.D.A. Forest Service, San Dimas Technology and Development Center, San Dimas, CA. Phone: 909-599-1267, ext. 235.

Roy Jemison, Research Hydrologist, U.S.D.A. Forest Service, Rocky Mountain Research Station, Albuquerque, NM,. Phone: 505-724-3664, Email: rjemison@fs.fed.us.

Terry Warhol, Assistant Forest Engineer, U.S.D.A. Forest Service, Umatilla National Forest, Pendleton, OR., Phone: 541-278-3716, Email: twarhol@fs.fed.us.

Abstract

The current management of roads on national forests, as well as, other public and private roads in forested areas across the United States are being reviewed. Along with public safety, a major concern is how roads impact riparian areas and wetland values such as animal populations and water quality. The effects of roads can directly and indirectly affect fish and wildlife species, some of them federally listed as threatened and endangered. Nationally there is an urgent need to communicate successful road restoration techniques and treatments (applicable to riparian areas and wetlands), and to promote the development and application of new technologies

The U.S.D.A. Forest Service alone manages an estimated 611,534 km of classified roads. In recent years, forest service personnel have recognized how traditional road construction and maintenance practices can be detrimental to riparian areas. Our ability to best manage these areas continues to evolve as our understanding of the linkages between landscape processes and human perturbations expands. Resource managers working in interdisciplinary teams, have traced the sources of a variety of problems, such as decreased fish spawning habitat, back to roads and related features (i.e., surface treatments, culverts, and ditches). Working with road engineers, they have developed solutions to restore and enhance natural processes and functions to riparian ecosystems, and maintain road passage.

Solutions to some road-related problems can be as simple as diverting surface runoff to the side of the road away from a bordering stream, thus reducing sediments deposited into the channel. Hardening of road surfaces can also reduce sediment detachment and movement. These techniques and others can hydrologically break the continuous flow paths of water and sediments, reduce the negative effects of roads on the environment, and in a sense make the impacts of roads on the environment seem invisible.

USDA Forest Service engineers and scientists in partnership with other federal agencies (FHA, EPA, BLM, F&WS, NMFS, NRCS, BIA, ACOE) state agencies, and organizations such as Ducks Unlimited and Trout Unlimited are working together to protect, maintain, and restore riparian areas and wetlands influenced by roads in varied environments across the country. This partnership is formally known as the Riparian, Roads, Restoration Team. Through field evaluations, assessments, and literature reviews, over the past 18 months, this interdisciplinary team has identified, documented and developed a training program to communicate to others, successful, tested, experimental, and leading-edge technologies designed to restore and maintain riparian areas and wetlands. An overview of the findings of this committee will be given in this presentation. Additional information about Riparian, Roads, Restoration team related links are available on our website at: www.fs.fed.us/albuq/RRR.html.

ROAD-KILLED ROYAL TERNS (*STERNA MAXIMA*) RECOVERED AT SEBASTIAN INLET STATE PARK, FLORIDA, USA: A 23-YEAR ANALYSIS OF BANDING DATA

Alice M. Bard, Florida Department of Environmental Protection, Florida Park Service, 1800 Wekiwa Circle, Apopka, Florida 32712; Phone: 407-884-2000; Fax; 407-884-2014; Email: alice.bard@dep.state.fl.us

Henry T. Smith, Florida Department of Environmental Protection, Florida Park Service, 13798 S.E. Federal Highway, Hobe Sound, Florida 33455

Terese V. Harber and Gayle W. Stewart, Florida Department of Environmental Protection, Florida Park Service, Sebastian Inlet State Park, 9700 South A-1-A, Melbourne Beach, Florida 32951

John S. Weske, Box 234, Sandy Spring, Maryland 20860-0234

Micou M. Browne, North Carolina State University, Department of Entomology, Raleigh, North Carolina 27695

Steven D. Emslie, University of North Carolina, Department of Biological Sciences, 601 S. College Road, Wilmington, North Carolina 28403-3297

Abstract: Large numbers of Royal Terns (Sterna maxima) from breeding colonies in North Carolina and Virginia migrate to Sebastian Inlet, Florida for a winter residence. A road and two-lane bridge at the site result in many road-kills from collisions with motor vehicles. At least 148 Royal Terns have been killed in this manner since formal surveys were initiated in 1989; while opportunistic collection of dead, banded birds has been sporadically conducted since 1979. Recoveries of 82 bands during the 23-year period 1979 to 2001 have supplied considerable demographic data. Eleven Royal Tern breeding colonies were differentially represented among the band recoveries. Most banded mortalities were 0.5 yr age class juveniles, with an overall range of 5 months to 12 yr 7 months. Most mortalities occurred December through February. These trends and additional data are discussed.

Introduction

Royal Terns (*Sterna maxima*) winter along the Atlantic Coast of the United States from North Carolina south through Florida (Clapp et al. 1983). In addition, Royal Terns breed in the estuarine habitats along both the Atlantic and Gulf coasts of Florida (Egensteiner et al. 1996). Although the species is fairly common along both coasts of Florida throughout the year, local populations are greatly augmented in winter by terns migrating from breeding colonies farther north (Van Velzen 1968; Van Velzen 1971; Clapp et al. 1983; Robertson and Woolfenden 1992; Smith et al. 1994). Nonbreeding and wintering Royal Terns can also be found at inland freshwater lakes and rivers in central and southern Florida (Barbour and Schreiber 1978; Lohrer 1984; Egensteiner et al. 1996). Many Royal Tern nesting colonies are found on islands of dredged materials (Egensteiner et al. 1996). Florida recoveries of banded migrants from Virginia (Van Velzen 1968; Smith et al. 1994) and the Carolinas (Van Velzen 1971; Smith et al. 1994) have been previously reported. This paper reports the data obtained from 82 Royal Tern bands recovered by Florida Park Service staff from Sebastian Inlet State Park (SISP) during the period 1979-January 2001.

SISP is an approximately 324.5 ha park located in Melbourne Beach, Florida, USA, about 22.6 km north of Vero Beach, at the juncture of Brevard and Indian River counties. The Sebastian Inlet essentially bisects SISP from east to west. The area is managed by the Florida Department of Environmental Protection (FDEP), Florida Park Service.

SISP is further subdivided north to south by approximately 5.0 km of State Road A-1-A. In response to high numbers of road-killed birds, predominantly Royal Terns, bird mortality reduction structures were installed on the two-lane bridge on State Road A-1-A over the Sebastian Inlet in late 1994 (Egensteiner et al. 1998). These were 3-meter high poles attached vertically 3.7 meters apart on both sides of the bridge (Egensteiner et al. 1998). The purpose of the poles was to direct birds up and away from bridge traffic.

Methods

Opportunistic collection of dead, banded birds at SISP has been sporadically conducted since 1979. A formal, daily road-kill survey procedure was initiated in 1989 consisting of slowly driving the road and bridge surfaces while scanning for dead wildlife. Road-kills are identified to species when possible and bands are recovered from birds if present. Bands were recovered at the bridge site as well as at the adjacent Atlantic coast beach.

Results and Discussion

Road-kills have been monitored regularly since 1989; although these data are variable between years, a general reduction in the number of road-killed birds within the park has been noted. Whereas Smith et al. (1994) reported 84 Royal Terns road-killed in the period 1989-1992, only 64 birds were killed during 1993-2001. Royal Tern bands were recovered mostly in winter.

Eighty-two bands were recovered from terns banded at eleven locations (Table 1). A subset of the data reported by Smith et al. (1994) reflecting the period of 1979-1992 included recoveries (n=41) from eight sites (Table 1). Differences in banding localities and relative distribution are noted in the data set recoveries (n=41) encompassing 1993-2001 (Table 1).

All of the Royal Terns recovered near the inlet were banded as immature (too young to fly) birds in their northern colonies. Ages of birds recovered during 1979-1992 ranged from approximately 5 months to 3 yr 10 months (Smith et al. 1994). Ages of birds recovered (n=23) during a subset period of more intensive surveys (1989-1992) ranged from approximately 5 months to 1 yr 6 months, with a preponderance of approximately 0.5 yr (n=11) and 1.5 yr (n=7) age class birds (Smith et al. 1994). In the more recent data (1993-2001), ages ranged from 5 months to approximately 12 yr 7 months. Thirty-four (82.9%) of the animals were aged approximately 5 months to 8 months (0.5 yr). Smith et al. (1994) reported that most of the band recoveries between 1989-1992 occurred in December (30.4%) and January (47.8%). The majority of the band recoveries for the 1993-2001 data occurred in January (48.8%) and February (29.3%).

The trend toward band recovery from juvenile Royal Terns in winter also has been noted in previous studies. Van Velzen (1968) reported that recoveries in Florida occurred from November through June, with 35% of these obtained in January; all birds were younger than one year old. In another study, Van Velzen (1971) reported that most Royal Terns were recovered in the initial fall and winter after banding. The band recoveries noted thus far from Sebastian Inlet show similar patterns of seasonal use and age class structure.

The data we present indicate that Sebastian Inlet is a well-frequented wintering area for some Royal Terns migrating southward from more northern banding locations. There also appears to be a temporal abundance of first and second year birds from these locations during winter, particularly December through February. Because much older birds also have been noted, the recoveries may be more of an indication of high juvenile mortality than local age class wintering. Additionally, more intensive banding efforts at some breeding grounds during various years and increased survey frequency during some months may affect band recovery patterns. Additional research is needed to determine why the area is frequented by these migratory birds. Buckley and Buckley (1972) reported that Royal Tern breeding colonies in Virginia and North Carolina were consistently located “at or very near an inlet between bay and ocean.” A similar attraction for inlets may influence some Royal Terns to winter at Sebastian Inlet (Smith et al. 1994).

At some sites in Florida, buffer zones have been implemented to protect breeding (Rodgers and Smith 1995) as well as foraging and loafing (Rodgers and Smith 1997) marine birds from anthropogenic disturbances. Similar buffer zone strategies may need to be developed for marine birds interacting with the road and bridge structure at Sebastian Inlet.

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Biographical Sketch: Alice M. Bard is an Environmental Specialist II with the Florida Department of Environmental Protection, Division of Recreation and Parks (Florida Park Service). The district she works in encompasses thirteen counties in the central and east-central area of the state. Alice is involved in a diverse array of projects, including restoration of upland communities, listed plant and animal species,

prescribed fire, human impacts on ecological communities, and exotic species. Alice received both her B.S. and M.S. from the University of Central Florida.

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Table 1
Band locations of Royal Terns recovered at SISP, Melbourne Beach, Florida, from 1979-2001.

Approximate Location*	Number of bands recovered (a)	Percent**	Number of bands recovered (b)	Percent **	Total Number of bands recovered	Percent
Kure Beach, North Carolina	12	29.3	19	46.3	31	37.8
Beaufort, North Carolina	11	26.8	3	7.3	14	17.1
18 km S of Wanchese, North Carolina	5	12.2	3	7.3	8	9.8
Kiptopeke, Virginia	4	9.8	2	4.9	6	7.3
Lola, North Carolina	3	7.3	5	12.2	8	9.8
Hatteras, North Carolina	2	4.9	1	2.4	3	3.6
Cape Lookout, North Carolina	2	4.9	0	0.0	2	2.4
14.5 km E of Birdnest, Virginia	2	4.9	0	0.0	2	2.4
Portsmouth Island, North Carolina	0	0.0	6	14.6	6	7.3
Accomac, Virginia	0	0.0	1	2.4	1	1.2
Ocean City, Maryland	0	0.0	1	2.4	1	1.2
Total	41	100.1	41	99.8	82	99.9

* All locations obtained from individual USFWS recovery certificates.
** All percentages are rounded up.
(a) Smith et al. (1994): Data covers 1979-1992.
(b) Data covers 1993-2001.

STREAM RESTORATION CASE STUDIES IN NORTH CAROLINA UTILIZING NATURAL CHANNEL DESIGN TECHNIQUES

William A. Harman and Gregory D. Jennings, Principal Hydrologist and Principal Engineer, respectively, Buck Engineering PC, 1152 Executive Circle, Suite 100, Cary, NC 27511; Phone: 919-463-5488; Email: wharman@buckengineering.com

Abstract: Many rural North Carolina streams are degraded due to historic channelization, dredging, and loss of riparian vegetation. The resulting incised channels have poor habitat and unstable bed features and streambanks. Stream restoration options for incised channels include constructing a new stable channel at the floodplain elevation, enhancing the floodplain at the existing channel elevation, or stabilizing streambanks in place. This paper describes three North Carolina stream projects completed since 2000 that make use of a variety of techniques to restore incised streams. Components of each project include channel geometry modification, in-stream structures, streambank stabilization, and riparian corridor restoration. Project objectives are to improve water quality and habitat, reduce streambank erosion, and enhance floodplain functions. The Stone Mountain project is a Priority 1 restoration in which an incised stream was relocated at a higher elevation on the adjacent floodplain. The South Fork Mitchell River project is a Priority 2 restoration in which channel geometry was modified at the existing elevation to create a new meandering stream with enhanced floodplain. The Mitchell River project is a Priority 3 restoration in which the floodplain of an incised straightened channel was widened and boulder structures were used to protect streambanks. The planning, design, construction, and monitoring of these projects are described along with lessons learned about effective restoration techniques.

Introduction

Natural stream functions in many areas of North Carolina are threatened by changes in watershed hydrology and land use. Impacts include impaired habitat, fish kills, unsafe water supplies, flooding, and reservoir siltation. Causes of impairment include impoundments, diversions, urbanization, agriculture, forestry, transportation, and loss of riparian vegetation. All of these affect stream stability, which is defined as the ability of a channel to carry the water and sediment delivered by its watershed, such that over time it maintains its dimension, pattern, and profile while neither aggrading nor degrading. Stream restoration is defined as the process of improving the conditions in and around the channel such that natural biological and hydrologic stream functions occur in stable channels. Restoration project components include channel geometry modifications, in-stream structures, streambank stabilization, and riparian corridor management.

Over the past decade, natural resource management organizations in North Carolina have adopted a natural channel design approach to restoring unstable streams. This approach is based on the use of regional relationships for bankfull channel dimension and reference reach geometry. Permitting agencies evaluating the hydrologic, water quality, and wildlife impacts of stream restoration and mitigation projects are now requiring that designers use natural channel design approaches. These requirements have facilitated interest among many government and private organizations in learning what stream restoration techniques are most appropriate for local watershed conditions.

Since 1996, numerous stream restoration projects have been funded by the NC Department of Environment and Natural Resources, NC Department of Transportation, NC Wildlife Resources Commission, USDA-NRCS, US EPA, USGS, US Fish and Wildlife Service, local Soil and Water Conservation Districts, private industries, citizen groups, and local landowners. The purpose of this paper is to describe several restoration projects addressing rural incised streams and lessons learned from stream restoration experiences in North Carolina.

Project Steps

Each stream restoration project requires site-specific management, assessment, and design to adequately address local conditions. The steps leading to successful stream restoration projects are:

1. Establish a multi-disciplinary team with knowledge of local hydrology and landowners;
2. Assess watershed and stream conditions to determine problems, causes, and potential for restoration;
3. Design stream restoration options including various construction and management strategies;
4. Select and implement viable design options working with local landowners and resource managers;
5. Evaluate stream restoration efforts and adjust construction or management as necessary.

Project Team

Successful stream restoration teams include engineers, hydrologists, and biologists with knowledge of local watersheds and familiarity with local landowners. Successful projects typically begin with a few cooperating landowners who have a strong interest in improving stream conditions on their property and who are willing to try innovative approaches. It is not necessary that these landowners have severely impaired streams, but more importantly that they are excellent demonstration sites for other nearby landowners. In the South Fork Mitchell River Watershed, the initial cooperating landowner was a beef cattle farmer who had a strong interest in protecting the trout streams on his property. After four years, more than 20 landowners throughout the watershed have requested assistance for stream restoration.

Before beginning detailed assessment work, the project team must agree on specific objectives for each stream reach under consideration. The general goal of the South Fork Mitchell River Project is to restore quality trout habitat to mountain streams degraded by livestock and eroding streambanks. For each stream reach, we identified specific restoration needs and measures that should be implemented. These include livestock exclusion, riparian vegetation establishment, and natural channel construction. Not all measures are necessary at each site depending on need. The project team works with individual landowners to determine stream restoration components that fit the needs of each site.

The leader of the South Fork Mitchell River Project team is Dick Everhart, USDA-NRCS District Conservationist, who has extensive knowledge of local environmental conditions and good working relationships with many private landowners. The other 15 members of the project team include biologists with expertise in fish habitat and riparian vegetation, hydrologists with expertise in sediment monitoring and geomorphology measurements, and engineers with expertise in livestock best management practices and stream restoration design and construction. The team meets bi-monthly to select new project sites, discuss monitoring results, develop design options, and plan education programs to enhance the project.

Assessment

The goal of assessment is to identify specific problems, their causes, and the restoration potential for each stream reach. Watershed land uses are inventoried to determine pollution sources and changes in hydrology that may affect stream quality. Project teams also measure water quality, habitat, and the channel's departure from stability. The types of water quality and habitat monitoring depend on the specific problems in the watershed. In the Mitchell River Project, sediment is the major water quality problem affecting trout habitat. Therefore, the monitoring program includes sediment transport in addition to fish and macroinvertebrate sampling. In other watersheds, water quality problems include sediment, nutrients, and bacteria resulting from cattle farms and urban development. In some cases, monitoring is more comprehensive with less emphasis on habitat and more on drinking water supply issues. Each project must have a targeted monitoring program to identify critical areas for restoration and to evaluate success.

Departure from stability is measured using physical measurements of channel dimension, pattern, and profile (Knighton 1984; Leopold et al 1992; Newbury and Gaboury 1993; Simons 1992). A naturally stable channel is one that transports the water and sediment delivered by its watershed while maintaining its dimension, pattern, and profile, such that over time it neither aggrades nor degrades. Channel dimension is defined as the width, depth, and cross-section area. Pattern is the plan view, including sinuosity, meander wavelength, and radius of curvature. Channel profile refers to the slopes of riffles, pools, runs, and glides (Leopold 1994). The first step in the stability departure assessment is to classify the stream according to its physical features. The standard stream classification system in North Carolina is that developed by Rosgen (1994), which is valuable in determining the physical stability of the stream and its restoration potential. The most important physical feature in the Rosgen stream classification system is the bankfull (or channel-forming) stage. Physical indicators such as top of bank, top of point bar, scour line, and vegetation changes are used to estimate bankfull stage in the field. Regional relationships for bankfull dimension related to watershed drainage area are used to verify field bankfull indicators (Harman et. al. 1999). Natural channels may vary from the expected values shown by the regression lines depending on channel shape and sediment supply. Narrow and deep channels (Rosgen type E) are more efficient than wide and shallow channels (Rosgen type C), thus resulting in typically smaller cross section areas for the same discharge. These relationships should only be used to verify bankfull stage in the field and not to design new channel cross-sections. Local reference reach measurements should be used for channel design.

Stream potential is a quantitative and qualitative assessment of the stream's current stability condition versus what the stream should be based on the morphological setting. A wide array of morphological monitoring techniques are used to quantify stability including, permanent cross sections, longitudinal profiles, stream bank erosion surveys, substrate sampling, bed scouring, sediment transport, and others (Kellerhals and Bray 1971). Once the cause of the instability is identified, a solution can be formulated and a reference reach can be selected that matches the degraded stream's valley slope and morphology.

Design

Stream restoration design must address specific problems with a system of construction and management measures. The design process should address watershed influences such as agriculture, forestry, or urban stormwater in addition to natural channel relocation or reshaping where necessary. Design information is collected from reference reaches located in the same hydrophysiographic province as the degraded stream. Reference reaches are stable stream segments that represent a stable dimension, pattern, and profile. A reference reach is not always a pristine stream, but it is a naturally stable stream. The following field survey data are collected at a reference reach with the same morphological valley type and slope as the design stream:

- Stream type
- Bankfull cross-section area, width, and mean depth
- Bankfull maximum depth
- Floodprone area width
- Valley slope and stream slope
- Sinuosity
- Channel and point bar materials
- Drainage area
- Bankfull velocity and discharge
- Slopes of riffles, pools, runs, glides
- Widths and depths of riffles, pools, runs, glides
- Spacing of riffles, pools, runs, glides
- Meander length
- Radius of curvature
- Belt width
- Bank height

The variability found in naturally stable reference reaches demonstrates the large differences observed in natural channel morphology. Designers should make use of this variability in creating or reshaping channels within the ranges observed in naturally stable channels. In this way, designers can avoid creating "cookie cutter" restored channels.

For incised stream channels, designers have several restoration options to consider (Rosgen 1997). In a Priority 1 restoration project, the incised channel is replaced by a new meandering channel located at a higher elevation on the floodplain. The new channel is sized such that the bankfull stage is at the land elevation of the existing floodplain. In the Stone Mountain project, a Priority 1 restoration was implemented to replace the F4 channel with a meandering C4 stream. The surrounding land use was agricultural, and the upstream channel was not incised, making this type of restoration relatively straightforward. Soil excavated from the new channel was used to fill the former channel after water was turned into the new stream. Some areas of former channel were left unfilled to serve as floodplain pond habitat.

The South Fork Mitchell River project is an example of a Priority 2 restoration in which it was not feasible to create a new channel at a higher elevation. Instead, the channel geometry was modified at the existing elevation to create a new meandering stream with a widened floodplain. In these projects, streams classified as F4 were changed to C4 channels.

The Mitchell River project is an example of a Priority 3 restoration in which the floodplain of an incised straightened channel was widened and boulder structures were used to protect streambanks. The Mitchell was converted from an incised C4 channel to a C4 with lower bank heights.

In addition to channel geometry, designs must consider bank and bed stabilization, riparian management, and watershed management. Stream channel and bank stabilization practices include rock vanes, log vanes, j-hook vanes, cross vanes, root wads, shrub and sod transplants, willow stakes, and erosion control fabrics. Each restoration project requires a unique set of practices depending on site conditions.

Implementation

Natural channel design is a new concept for most earth moving contractors. Therefore it is essential that a professional familiar with the design be on-site during channel construction for the job. Many projects with technically sound designs fail because they were improperly installed by an unqualified contractor. Much of this work involves placing individual rock boulders and root wads. A trackhoe with a hydraulic thumb and a skilled operator works well for implementing most designs. Because large storms often occur soon after construction, it is important to install devices that provide immediate stability.

Evaluation and Adjustment

The measurements discussed under the assessment section are also made after construction to evaluate the success of stream restoration efforts. Often times adjustments and modifications are required and should be made as soon as possible to prevent further damage.

Summary

Stream restoration using natural channel design procedures is being used throughout North Carolina to improve water quality and aquatic habitat. Many projects are currently being implemented with multi-agency teams of hydrologists, engineers, and biologists with the objectives of improving water quality and aquatic habitat, demonstrating effective stream protection measures, and evaluating the effectiveness of implemented measures. Projects are initiated by landowners and watershed stakeholders who identify unstable stream reaches with potential for restoration. Project teams then assess watershed land uses to determine sources of pollution and hydrologic changes and monitor streams to determine channel stability, aquatic habitat, and pollutant impacts. Restoration design options are developed using relationships for bankfull channel dimension and reference reach geometry. Project teams then work with landowners and local resource agencies to select the preferred restoration option and develop a construction plan. Components of successful projects include constructed stream beds and banks, instream structures such as rock vanes, stabilized banks using vegetation and root wad revetments, and protected stream corridors with livestock exclusion and riparian plantings. The effectiveness of these projects is evaluated using sediment sampling, stream channel measurements, water chemistry, and biological assessment. Educational programs are used to share experiences in order to improve future projects.

Lessons learned from North Carolina projects include:

- Successful stream restoration results when teams of hydrologists, engineers, and biologists begin with clear objectives.
- Cooperative landowners are necessary for innovative approaches and demonstration sites.
- Stable reference reaches must be used to determine appropriate natural channel design parameters.
- Natural channel design must address both hydraulic capacity and sediment transport such that stability is maintained.
- Stream restoration designs must include systems of measures to prevent pollution, establish riparian vegetation, and address channel stability.
- On-site construction management is essential to ensure that earth-moving contractors follow design specifications.
- Monitoring is essential to develop designs, measure success, and determine if follow-up work is needed following initial construction.

Biographical Sketch: Will Harman is Vice President and co-founder of Buck Engineering. Will has 10 years of experience in watershed management, stream geomorphology and hydrology, water quality monitoring and data analyses, and geographic information systems. Will served as Program Leader for the NC Stream Restoration Institute at NC State University from 1998-2000. He has utilized natural stream channel design technologies on over 75 projects in North Carolina and surrounding states. Will developed a series of training workshops and educational materials for private consultants and natural resources management professionals on channel forming flows, morphological assessments, sediment transport, and natural channel design technologies. He provides expertise on stream restoration to agencies, nonprofit organizations, and landowners.

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TRANSPORTATION INFLUENCES ON WETLAND DIVERSITY

Edward H. Frantz, Regional Environmental Coordinator/Environmental Specialist II, New York State Department of Transportation, 207 Genesee St., Utica, N.Y. 13501, Phone: 315-793-2722, Fax: 315-793-2400, Email: efrantz@gw.dot.state.ny.us

Abstract

Transportation systems have been critical to the development of most societies. These systems form large networks and require large areas of land. Over the passage of time most transportation systems will continue to expand and technological advances will lead to new forms of transportation. Thus, our understanding of their effects on the environment and the best way to build, reconstruct, maintain, and mitigate these systems needs to be a priority. This presentation will focus on roadbed transportation systems and their effects on wetlands. The presentation will look at their direct and indirect influences on wetlands.

Direct impacts from filling wetlands have been well documented for many land uses. Many existing transportation corridors developed from what were early trails and passages. These early routes often followed waterways due to the ease of travel. Even with passage of time many new transportation corridors have been built along waterways and in valley bottoms to take advantage of gentle grades. Most wetlands also are found in these landscape positions, thus transportation systems can contribute a higher rate of direct losses from filling per area of development. Further, wildlife mortality, pollutant runoff, and vegetation management are examples of other direct influences these corridors have on wetlands adjacent to them.

Indirect impacts have not been well documented and further research is necessary. A wide array of factors such as ditching, design criteria, change to drainage patterns, fill effects, soil compaction, bridge location, culvert invert elevations, traffic patterns, and pollutant spills have influences on wetlands. Further, these factors influences depend on certain parameters of the adjacent wetlands such as soil type, hydrologic regime, depth to bedrock, water chemistry, plant community, and flow patterns. Some resulting indirect influences include changes in plant communities, species richness, water chemistry, wildlife habits, sediment transport, hydrologic changes, and increase of invasive plant species. This presentation will consider these effects resulting from transportation construction, maintenance, design, and policies (past, present, and future) that have and will influence future wetland diversity. An overview of key literature, and personal experience will be presented.