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On the road again: A study valuing wildlife crossings for wetland mitigation on State Road 40 in Volusia County, Florida

Benjamin J. Shepherd[1] | **Jason Houck**[1] | **Casey Lyon**[2]

[1]Inwood Consulting Engineers, Inc., Oviedo, Florida, USA

[2]Florida Department of Transportation, DeLand, Florida, USA

Correspondence
Benjamin J. Shepherd
Email: bshepherd@inwoodinc.com

Funding information
Florida Department of Transportation

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Abstract

Over the past few decades, wildlife crossings have effectively reduced wildlife–vehicle collisions and improved habitat connectivity and genetic exchange for animals. However, wildlife crossings are expensive to construct, and the cost may discourage transportation agencies from implementing new wildlife crossings on public roadways. Additionally, transportation agencies and planners rarely consider the permitting and mitigation costs that wildlife crossings can require. A road profile must be raised to accommodate a wildlife underpass on many Florida roadways, particularly in low-lying areas. Raising the road can result in new wetland impacts that would not occur but for the wildlife crossing. Consequently, new or more compensatory wetland mitigation may be required to satisfy § 404 of the Clean Water Act—a cost to the transportation agency and taxpayers. We used Florida's Uniform Mitigation Assessment Method (UMAM) to calculate the value of functions in habitats before and after planned wildlife crossings on State Road 40 in Volusia County, Florida. The results of our analysis show that wildlife crossings will enhance the functions in remnant habitats adjacent to the wildlife crossings, generating wetland mitigation credits that reduced the amount of compensatory wetland mitigation required by the U.S. Army Corps of Engineers. Our case study provides a novel application of the UMAM in valuing wildlife crossings. We believe the UMAM can be used in cost–benefit models and transportation planning to determine the functional value of new wildlife crossings, thereby producing a monetary value that can incentivize new wildlife crossing projects.

KEYWORDS
compensatory mitigation § 404 permitting, road ecology, Uniform Mitigation Assessment Method, wildlife crossings

INTRODUCTION

Roads have an outsized and often negative impact on the natural environment (Coffin, 2007; Forman & Alexander, 1998; Forman et al., 2003). Specifically, roads increase habitat fragmentation (Nellemann et al., 2001; Smith & Dodd, 2003) and create artificial barriers to wildlife movement that can disrupt seasonal migration patterns, foraging opportunities, and reproductive success (Coffin, 2007). In extreme cases, roads can restrict gene flow to isolated tracts of land that, in turn, increases the potential for inbreeding and local extirpation (Reh & Seitz, 1990; Wilcox & Murphy, 1985).

Research on wildlife movements has shown that roads can profoundly impact animals in Florida. Habitat fragmentation has decreased fitness and increased the risk of physical abnormalities for two large, wide-ranging mammal species: the Florida black bear (*Ursus americanus floridanus*) and the Florida panther (*Puma concolor coryi*). The former is restricted to a few subpopulations that occupy just 49% of their historical range (Florida Fish and Wildlife Conservation Commission [FWC], 2019). The genetic isolation between bear subpopulations and the limited landscape connectivity is problematic for the species (Dixon et al., 2007; Maehr & Wooding, 1992). Additionally, roads facilitate traffic, creating the opportunity for wildlife–vehicle collisions (WVCs). WVCs pose a serious risk to motorist safety and increase the likelihood of animal injury and mortality (Bissonette et al., 2008; Joyce & Mahoney, 2001). For example, WVCs are a significant cause of death for Florida black bears and other large animals in the state (Harris & Scheck, 1991).

Transportation agencies have deployed more than 40 mitigation measures to reduce WVCs and improve motorist safety, road permeability, and habitat connectivity (Forman et al., 2003). The most common strategies include animal detection systems and wildlife warning signs, operations to reduce traffic volumes and/or speeds, and new wildlife crossing structures with or without exclusionary fencing (Clevenger & Ford, 2010; Huijser & McGowen, 2010). The combination of wildlife crossings and fencing has been particularly successful because they reduce WVCs and improve road permeability without requiring changes to traffic flows or speeds (van der Grift et al., 2013). Some reports estimate that wildlife crossings with fencing reduce WVCs by 80%–97% (Clevenger et al., 2001; Gagnon et al., 2015; Sawyer et al., 2012).

The inherent value of wildlife crossings appears to be known. However, their value in terms of compensatory wetland mitigation under § 404 of the Clean Water Act remains unexplored till now. This wetland mitigation-for-wildlife crossing concept addresses a major drawback of the crossings themselves: cost. Wildlife crossings are expensive to build and maintain, costing up to $1 million or more for a single structure and eclipsing more than 10% of an entire road project budget (Glista et al., 2009; Kintsch et al., 2019; van der Grift et al., 2015). For example, the cost of constructing double 18.6-m-wide × 88.4-m-long parallel bridges on Interstate 4 in Central Florida exceeds $3.2 million in FY 2021–2022. However, the total construction cost will exceed $10 million when accounting for the new, higher road profile needed to accommodate the structures, the maintenance of traffic during construction, and more than $41,500/km in fencing (B. Setchell, Florida Department of Transportation, personal communication, June 15, 2022). These costs do not include the design and construction engineering inspection services, which can be an additional 10% of the total construction costs.

An unforeseen cost of incorporating a new wildlife crossing onto an existing roadway can be the wetland impacts and associated compensatory wetland mitigation required to obtain a construction permit. Permit programs exist in Florida and around the United States to protect wetlands. These permit programs often require compensatory mitigation for the lost ecological values and functions for most adverse wetland impacts due to construction activities. Florida has more wetlands and surface waters than most other states because of its relatively flat topography, abundant rainfall, and high water table (Dahl, 1990). When incorporating a new wildlife crossing under an existing road, the Florida Department of Transportation (FDOT) must often raise the existing roadway to accommodate the structure while maintaining positive drainage and line of sight for motorist safety. Raising the road will often increase the project footprint, resulting in new or additional wetland impacts that would not occur but for adding a new wildlife crossing. These wetland impacts may require compensatory mitigation from state or federal regulatory agencies, an unanticipated cost that can exceed $81,000/ha.

Our case study aimed to address the following question: what is the amount of compensatory mitigation that can be generated by a wildlife crossing and authorized by a federal permit? Any compensatory mitigation created by a wildlife crossing would be a cost-saving to the FDOT and taxpayers, incentivizing new wildlife crossing projects. First, we summarize the road project and the federal permitting that authorizes wetland impacts and compensatory mitigation. Second, we describe the methodology used in Florida to determine the functional value of wetlands and how we applied it to our project. Finally, we discuss how our concept could be applied to future road projects.

CASE STUDY

State Road 40

State Road (SR) 40 is an important two-lane east–west arterial road and a designated emergency evacuation route in northern Central Florida (Figure 1, inset). The road bisects large tracts of otherwise contiguous natural habitats, including conserved lands with significant usage by Florida black bears and other protected species. Consequently, SR 40 has been designated as the Florida Black Bear Scenic Byway. Any improvements (e.g., road widening) to the Byway must consider the potential impacts on public safety, native habitat, and ecological resources, including regional wildlife populations.

SR 40 is classified by the FDOT as Rural Principal Arterial with an average annual daily traffic (AADT) volume between 6000 and 10,000 trips and a moderate level of service in the morning. Based on accepted future land use maps and projected population growth, the AADT volume has been forecasted to be between 7000 and 28,400 trips, with a failing level of service in the morning by 2040 (Ghyabi & Assoc., 2011). The AADT in 2040 could make SR 40 an impenetrable barrier to wildlife movement and exacerbate WVC on the corridor. To reduce the negative impacts of the current and future road conditions on wildlife, FDOT plans to widen an 11.25-km segment of SR 40 in Volusia County and incorporate the following new wildlife crossings:

1. Three pairs of 3.6–4.6 m wide wildlife shelves at existing bridges over Little Haw Creek and the braided Middle Haw Creek tributaries.

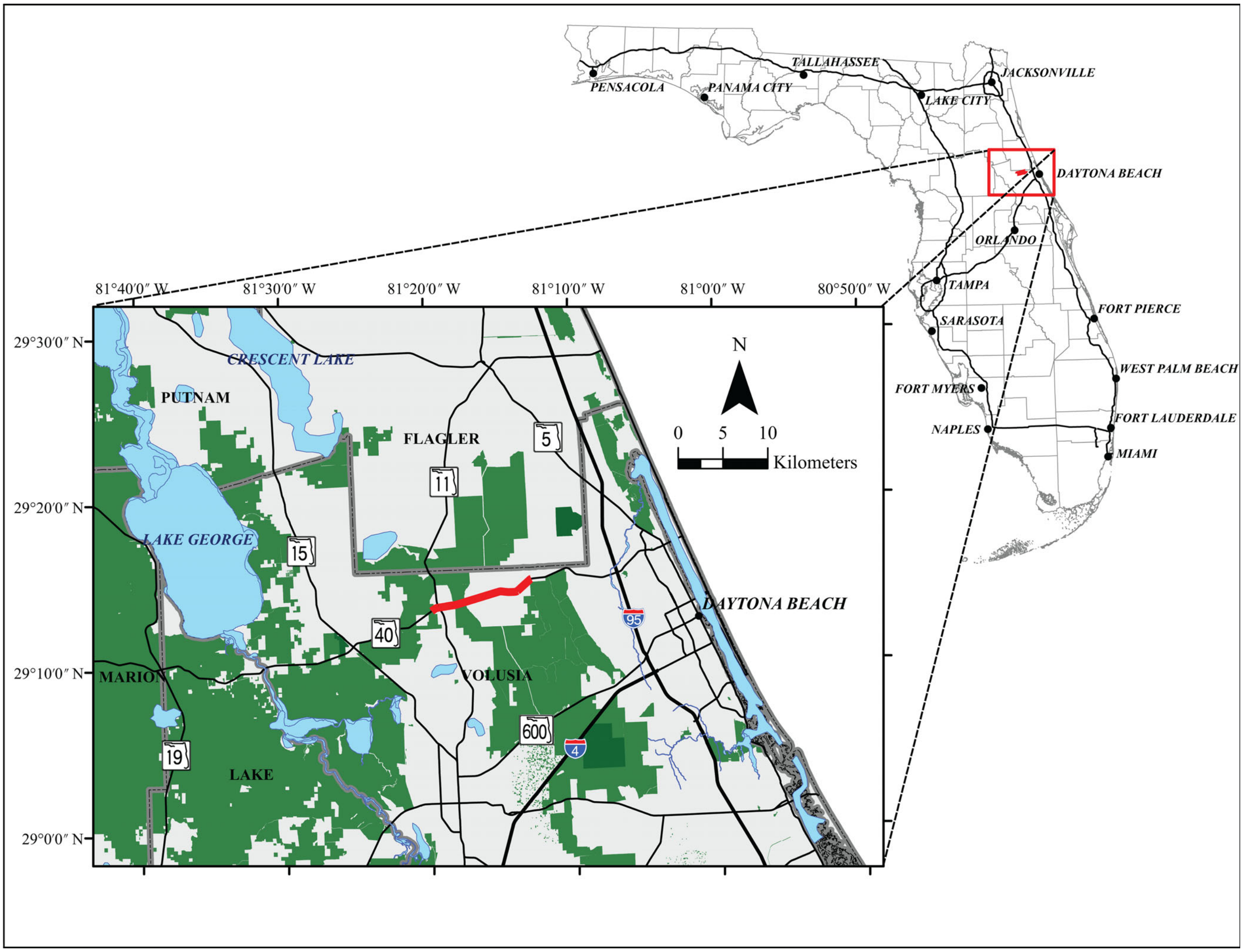

FIGURE 1 State Road 40 case study area. The 11.26-km road segment (red line) is part of a designated emergency evacuation route. It bisects an extensive conservation network (green) that provides habitats for many wildlife species, including the Florida black bear (*Ursus americanus floridanus*). Scale 1:500,000. Data layers from the Florida Geographic Data Library (https://fgdl.org/info/cite-fgdl/).

2. A 2.4-m-high × 5.8-m-wide concrete box culvert centered within a large (4745 ha) conservation easement contiguous with other federal, state, and local conserved lands. The interior of the culver will include refugia for herpetofauna and meso-mammals.
3. Install 1100 m of Type A fencing parallel with the roadway from Little Haw Creek to the concrete box culvert. The fencing will be 3 m high, topped with three-strand barbed wire, and affixed near the ground with 0.9-m-high "herp" mesh.

Floor elevations for the new wildlife crossings are set approximately 0.3 m above the seasonal high-water level, allowing for wildlife movement by most species throughout the year (Figure 2). However, FDOT must

FIGURE 2 Images of wildlife crossings similar to those proposed on State Road 40. (a) A pair of 2.43-m-wide shelves under State Road 80 near the C-1 Canal, east of LaBelle, Florida. Photo credit: Florida Department of Transportation. (b) A 3.04-m-wide × 1.67-m-high concrete box culvert under State Road 60 at Padgett Branch, near Fort Drum Wildlife Management Area. Photo credit: fStop Foundation.

also raise the base elevation of the road by 2–3 m to maintain positive drainage and line of sight for motorists and accepted engineering standards in the state. The proposed typical roadway section will extend beyond the current FDOT right-of-way, impacting natural habitats, including wetlands.

Section 404 permitting

Congress established a permit program under § 404 of the Clean Water Act (33 USC § 1251 et seq) to regulate the discharge of dredged or fill material into waters of the United States, including wetlands. Congress delegated the permit program to the U.S. Environmental Protection Agency (EPA) and tasked the U.S. Army Corps of Engineers (Corps) with the day-to-day administration of the permit program, including decision-making and permit issuance. The permit program requires applicants to evaluate alternatives that avoid and minimize wetland impacts. Only when unavoidable wetland impacts remain does the Corps require compensatory mitigation for the potential loss of wetland functions.

In 2008, EPA and the Corps published their final rule on compensatory mitigation under the § 404 permit program (33 CFR Parts 325 and 332, 40 CFR Part 230). Their rule formalized and expanded upon existing mitigation concepts, including the mitigation sequencing and the watershed approach for mitigation (BenDor & Riggsbee, 2011). The watershed approach emphasized the need to select mitigation sites more likely to achieve the desired ecological results. The mitigation sequencing established a hierarchical preference for wetland mitigation banks over in-lieu fee or permittee-responsible mitigation, except on a case-by-case basis where a watershed plan will improve an outstanding aquatic resource in the watershed.

In order to determine whether compensatory mitigation is required for a project, an applicant (in our case, FDOT) must first determine whether and to what extent the project will result in unavoidable wetland impacts. First, we delineated the extent of wetlands in the project footprint, noting that wetland areas support a prevalence of vegetation adapted for life in saturated soil conditions (Corps, 2010). We collected data points of the wetland/upland transition zone in a Trimble 6000 Series GeoXH handheld GPS with submeter accuracy. We projected those wetland data points onto the road construction plans and detail sheets. By overlaying the wetland points with the project footprint, we could determine the unavoidable wetland impact areas and calculate the compensatory mitigation required by the Corps.

Uniform Mitigation Assessment Method

Per the 2008 mitigation rule, an applicant must calculate and offset a project's lost wetland functions. There exist several methods for quantifying wetland function: the Hydrogeomorphic Method (Brinson, 1993), the Habitat Evaluation Procedure (U.S. Fish and Wildlife Service, 1980), the Wetland Rapid Assessment Procedure (Miller & Gunsalus, 1999), and the California Rapid Assessment Method (California Wetlands Monitoring Workgroup, 2013) to name a few. In Florida, the legislature directed Florida's Department of Environmental Protection (FDEP) to "develop a Uniform Mitigation Assessment Method … for determining the amount of mitigation required to offset impacts to wetlands and other surface waters" in the state (373.414(18), Florida Statutes). FDEP worked closely with the state's five water management districts to prepare and approve the Uniform Mitigation Assessment Method (UMAM) in 2004. After some analysis, the Corps adopted the UMAM for § 404 permitting in 2005.

UMAM provides a standardized procedure for assessing the ecological functions provided by habitats, including wetlands and surface waters. This procedure is divided into a qualitative description (Part I) and a quantitative evaluation (Part II) for each assessment area. Part I provides context for anticipated wildlife usage, particularly by protected or managed species; significant nearby features, including conserved lands, major rivers, water bodies, and aquatic preserves; and the geographic relationship and hydrologic connection between the assessment area and adjacent habitats, particularly conserved lands and/or wildlife corridors. Part II quantifies the current or anticipated functional value of the assessment area based on the following parameters:

1. Landscape and location support
2. Water environment
3. Community structure

Parameters are scored between 0 and 10, based on criteria in Rule 62-345, Florida Administrative Code (FAC), and best scientific judgment. The total score for all three parameters is divided by 30, generating an interval between 0 and 1. The functional value for an assessment area is determined by multiplying the interval and its acreage (Figures 1 and 2; Reiss & Hernandez, 2018). This process is conducted for the current condition and repeated for the with-project condition. The functional loss is the difference between the current and post-construction conditions (Equation 3).

$$D = (L + W + C)/30, \quad (1)$$

$$F = D \times A, \quad (2)$$

$$F_L = (F_C - F_P), \quad (3)$$

where D is the interval between 0 and 1, derived from the total score for L, landscape and location support, W, water environment, and C, community structure, parameters in either the current or anticipated post-construction condition. A is the assessment area, expressed in acres, typically within the project footprint. F refers to the functional value of the assessment area, where F_L is the anticipated functional loss, based on the difference between the current functional value, F_C, of the assessment area and the anticipated functional value, F_P, of that same area in the post-construction condition. F_P will be zero for most wetland assessment areas in the project footprint.

FDEP established a similar formula for calculating the anticipated functional value of a mitigation assessment area. However, the mitigation formula incorporates (1) the level of uncertainty that the anticipated functional value will not be achieved (i.e., risk factor); (2) the time expected to achieve the anticipated functional value (i.e., time lag); and (3) the extent and homogeneity to which mitigation benefits can be evaluated as a single assessment area (Equations 4 and 5), in some cases combining upland and wetland habitat types, even outside of the project footprint.

$$F_M = (D_M / RT) \times A_M, \quad (4)$$

$$F_G = [F_M - F_C], \quad (5)$$

where F_M is the anticipated functional value for a mitigation assessment area following the implementation of a mitigation project. D_M is the anticipated mitigation interval derived from the sum of scores for the three parameters (Equation 1). L is the most important parameter for a wildlife crossing project, where documented evidence of wildlife movement and landscape linkages to conserved lands can increase the with-mitigation project score. A_M is the anticipated mitigation area, in acres, that will benefit from a mitigation project. A_M is the single most important component determining the amount of relative functional gain, F_G, produced by a wildlife crossing. R is the risk factor to achieve D_M, ranging from one (*de minimis*) to three (high risk) in 0.25-point increments. T is the time lag adjustment factor assumed to achieve D_M, based on a table provided by the Corps. FDOT assumed that T would be 1.00 with fencing and 1.07 without fencing (i.e., a minor risk that wildlife will habituate to a crossing structure within three years). F_G is the relative functional gain for the entire project based on the difference between the current and anticipated functional values in a mitigation assessment area.

A_M typically follows a well-defined wetland or property boundary; however, the benefits of a wildlife crossing to animals extend beyond the structure itself (Forman et al., 2003). Most wildlife requires myriad habitat types to complete their life history requirements. Home ranges for Florida black bears and the Florida panthers are >2000 ha, with male ranges for either species extending >20,000 ha (Maehr et al., 1992; McCown et al., 2004). Even the small Florida gopher frog (*Lithobates capito*) can travel >4500 m from ephemeral ponds where they breed and spawn to uplands where they spend most of their adult lives (FWC, 2013). Based on this information and other studies, FDOT reasonably assumed that A_M included habitats next to new wildlife crossings, even if those habitats were located outside the FDOT right-of-way.

Section 404 permitting results

In 2016, FDOT applied for a § 404 permit for road improvements to SR 40. The project will impact 12.96 ha of nontidal freshwater wetlands and other surface waters within the FDOT right-of-way, including newly acquired property for ponds and floodplain compensation. The functional value of the wetland and other surface water impact areas equaled 8.46 UMAM ha-units (or 20.91 UMAM ac-units; Table 1). The scores for each parameter were less than optimal, reflecting that the original road construction in the 1940s had altered these systems. The habitats experience noise and light pollution from vehicles on the road and periodic maintenance by FDOT.

In our application to the Corps, we noted that the state's wildlife agency had emphasized the importance of new wildlife crossings on SR 40 for reducing WVC, promoting gene flow, and enhancing habitat connectivity (Gilbert et al., 2001; McCown et al., 2004). FDOT expected the new wildlife crossings would provide secondary benefits and relative functional gains for the remnant habitats adjacent to the wildlife crossings and beyond the FDOT right-of-way. However, the extent of those benefits for wildlife was unclear. We tailored the mitigation assessment areas according to the proposed wildlife crossing opening size and the mean spatial distances for a suite of semiaquatic and wetland-dependent species in Central Florida (Brown et al., 1990). We excluded Florida black bear and Florida panther home ranges from our calculations after ad hoc analyses

TABLE 1 The proposed impact areas and their functional losses (F_L), calculated with Florida's Uniform Mitigation Assessment Method, for direct or indirect impacts (D_P) for State Road 40 improvements from State Road 11 to Cone Road, Volusia County, Florida.

ID	Impact area (ha)	Type	Current condition			Interval (D_C)	With project			Interval (D_P)	Delta ($D_P - D_C$)	F_L
			L	*W*	*C*		*L*	*W*	*C*			
NW	0.35	Direct	5	7	7	0.63	0	0	0	0.00	0.63	0.22
	2.32	Indirect	5	7	7	0.63	3	7	5	0.50	0.13	0.30
S1, S9	1.44	Direct	5	7	7	0.63	0	0	0	0.00	0.63	0.91
S2, S3, S10a	0.69	Direct	5	5	5	0.50	0	0	0	0.00	0.50	0.35
S5	0.01	Direct	6	9	9	0.80	0	0	0	0.00	0.80	0.01
S6a	1.08	Direct	6	8	8	0.73	0	0	0	0.00	0.73	0.79
S6b	1.50	Direct	6	7	7	0.67	0	0	0	0.00	0.67	1.00
S6c	0.89	Direct	5	8	7	0.67	0	0	0	0.00	0.67	0.60
S7	0.75	Direct	5	4	4	0.43	0	0	0	0.00	0.43	0.32
S8	1.76	Direct	5	7	6	0.60	0	0	0	0.00	0.60	1.06
S10	0.56	Direct	5	7	5	0.57	0	0	0	0.00	0.57	0.32
S10b	0.02	Direct	7	9	7	0.77	0	0	0	0.00	0.77	0.02
S11	0.17	Direct	6	7	6	0.63	0	0	0	0.00	0.63	0.11
S12	1.13	Direct	5	6	6	0.57	0	0	0	0.00	0.57	0.64
S13	1.18	Direct	4	7	5	0.53	0	0	0	0.00	0.53	0.63
S14	0.24	Direct	4	4	4	0.40	0	0	0	0.00	0.40	0.10
S15, FPC2w	0.13	Direct	4	5	5	0.47	0	0	0	0.00	0.47	0.06
S	4.51	Indirect	5	5	5	0.50	3	5	3	0.37	0.13	0.59
FPC2	0.47	Direct	7	5	6	0.60	0	0	0	0.00	0.60	0.28
Pond 9	0.29	Indirect	5	7	7	0.63	5	5	5	0.50	0.13	0.04
Pond 10	0.88	Indirect	5	7	7	0.63	5	5	5	0.50	0.13	0.11
Pond 19	0.11	Indirect	5	7	7	0.63	5	5	5	0.50	0.13	0.01
Total												8.46

Abbreviations: *C*, the community structure score for the wetland area; D_C, the current functional interval; D_P, the proposed functional interval after the project; F_L, the proposed functional loss to wetlands because of the project; *L*, the landscape and location support score for the wetland area; *W*, the water environment score for the wetland area.

showed these areas would generate too many UMAM credits for permit authorization. We worried that using the bear or panther home ranges would completely offset F_L for the project and create additional UMAM credits in direct competition with private wetland mitigation banks.

The Corps agreed that A_M for the concrete box culvert should radiate 304 m (1000 ft) into the adjacent conservation easement, which provides ecological connectivity to an extensive network of conserved lands, including the Ocala National Forest. A smaller A_M of 223 m (732 ft) would radiate from the shelves at Little Haw Creek and an even smaller A_M of 98 m (322 ft) for the pair of shelves at Middle Haw Creek (Figure 3). The A_M for the concrete box culvert was the largest because the structure can accommodate large and small species and would be enhanced by fencing, with the adjacent habitats under long-term conservation. The A_M at Little Haw Creek was smaller because the adjacent habitats were not under long-term conservation but were also unlikely to be developed because they were within the 100-year floodplain. The A_M for the pair of shelves at Middle Haw Creek was the smallest because the structures were located near private development and would not be enhanced by fencing.

The Corps assigned risk and time lag factors to the pair of shelves at Middle Haw Creek. In the "with-mitigation" scenario, there can be uncertainty about whether the mitigation can achieve the desired functional value. The risk factor increases as the level of uncertainty increases. The Corps agreed that the level of risk was low for our project. The wildlife crossings had

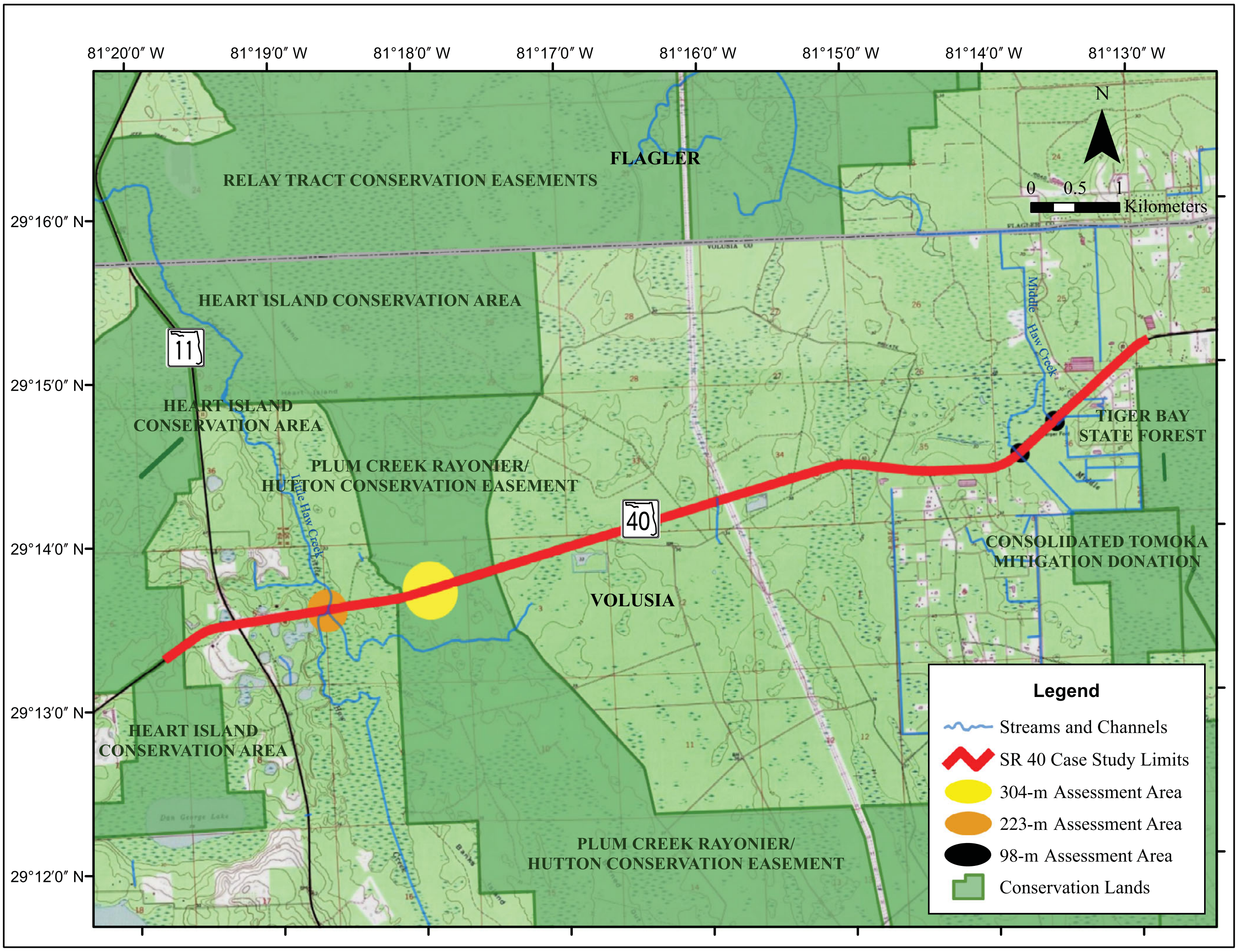

FIGURE 3 State Road 40 project limits (red line) and the compensatory mitigation assessment areas (yellow, orange, and black) where functional benefits from the new wildlife crossings were calculated. Scale 1:50,000. Data layers: Florida Geographic Data Library: county boundaries, roads, and managed lands. Base layer: USA Topo Maps, © 2014 National Geographic Society, i-cubed.

undergone a siting analysis and peer review by other agencies, including the state's wildlife agency. A time lag factor can be applied when mitigation is required but has not occurred, accounting for the amount of time in years it will take for the mitigation area to achieve the desired functional value in the A_M. Research has shown that animals can acclimate to a new wildlife crossing within three years, even without the aid of fencing (Land & Lotz, 1996; Seidler et al., 2018). However, animals will more than likely benefit immediately from a wildlife crossing with fencing (Clevenger et al., 2001). Using this information, we applied a time lag factor of 1.07, equating to three years under Rule 62-345.600, FAC. Table 2 shows our UMAM findings, where the total functional loss and the relative functional gain were 8.46 and 2.09 UMAM ha-units (or 20.91 and 5.17 UMAM ac-units), respectively. The net wetland mitigation was a functional loss of 6.37 UMAM ha-units (or 15.75 UMAM ac-units), for which we purchased credits from a wetland mitigation bank within the same basin.

DISCUSSION

Our case study provides one of the only examples in the United States, and the first in Florida, to quantify the functional value of a wildlife crossing into wetland mitigation (National Academy of Sciences, 2020). Understanding the value of wildlife crossings is important. In a prior study, Huijser et al. (2009) compared the cost–benefits of nearly 40 mitigation measures to reduce WVC; however, they found only 13 effective at reducing collisions with large ungulates (e.g., white-tailed deer). Their break-even threshold for deer—a genus common throughout the

TABLE 2 The proposed functional gain (F_M), calculated with Florida's Uniform Mitigation Assessment Method, for four different wildlife crossing structures on State Road 40 from State Road 11 to Cone Road, Volusia County, Florida.

ID	Mitigation area (ha)	Current condition			Interval (D_C)	With mitigation (wildlife crossing)					Interval (D_M)	Delta ($D_M - D_C$)	F_M
		L	*W*	*C*		*L*	*W*	*C*	*R*	*T*			
Little Haw	15.64	7	8	8	0.77	8	9	8	1	1	0.83	0.07	1.09
Box Culvert	29.18	6	6	6	0.60	7	6	6	1	1	0.63	0.03	0.88
Middle Haw no. 1	3.03	7	6	7	0.67	8	6	7	1.25	1.07	0.70	0.02	0.06
Middle Haw no. 2	3.03	7	6	7	0.67	8	6	7	1.25	1.07	0.70	0.02	0.06
Total													2.09

Abbreviations: *C*, the community structure score for the wetland area; D_C, the current functional interval; D_M, the anticipated mitigation interval; F_M, the anticipated functional gain for a mitigation assessment area because of the project; *L*, the landscape and location support score for the wetland area; *R*, the risk factor to achieve D_M; *T*, the time lag adjustment factor assumed to achieve D_M, based on a table provided by the Corps; *W*, the water environment score for the wetland area.

USA, including Florida—was 3.2 deer km^{-1} $year^{-1}$ for an underpass with jump-outs and fencing, at a discount rate of 3% in 2007 US$. However, a new road tunnel increased the break-even threshold to nearly 1200 deer km^{-1} $year^{-1}$. That threshold may be worse today with rising material and road construction costs and inflationary pressures (Federal Highway Administration, 2022).

Wetland mitigation banking has been the Corps' preferred method of compensatory mitigation since 2008. A wetland mitigation bank receives wetland credits based on the value of functions provided by the establishment, restoration, enhancement, and/or preservation of aquatic resources within their property. The credits can be sold for profit to transportation agencies and other developers seeking to offset adverse wetland impacts. Again, these functions are determined by the UMAM in Florida.

The cost of a single UMAM credit from a wetland mitigation bank in Central Florida can exceed $150,000 per ac-credit. In our case study, FDOT had pre-purchased a surplus of UMAM credits from a wetland mitigation bank in the same drainage basin as our project for $53,000 per ac-credit. With our project generating a relative functional gain of 2.09 UMAM ha-credits (or 5.17 UMAM ac-credits), the cost savings in less wetland mitigation needed by the FDOT was equivalent to $274,010. The same 2.09 UMAM ha-credits have a current market value of >$500,000 in today's private wetland credit market. With this in mind, we offer four recommendations for regulatory and transportation agencies:

1. Update cost–benefit analyses like those in Huijser et al. (2009) by including wetland mitigation costs in the calculations. The potential cost for wetland mitigation may change the break-even threshold for a new wildlife crossing, potentially delaying these improvement projects while transportation agencies seek additional funds to account for the cost of wetland mitigation. Alternatively, any relative functional gains generated by a new wildlife crossing may reduce overall mitigation cost and incentivize more wildlife crossing projects.
2. Develop a standardized approach for determining the value of functions provided by wildlife crossings to adjacent habitats. In our case study, we used three different A_M depending on the size of the crossing structure, fencing, and proximity to conserved land. However, a few years after our case study, FDOT, District One, permitted a wildlife crossing with the Corps and regional water management district. Those agencies approved A_M for the crossings that were different than the three A_M we had used, despite applying the same UMAM. These remain the only two projects in Florida to receive wetland mitigation credit for a new wildlife crossing and highlight the need for a standardized approach for determining A_M from a wildlife crossing.
3. Similarly, identify a set of metrics that practitioners may use to measure the value of functions provided by a new wildlife crossing. This could include known wildlife movement corridors and/or roadkill hotspots (FDOT, 2020, 2022), which could demonstrate movement patterns across the landscape worth enhancing and help to identify and prioritize new wildlife crossing locations. The focus on metrics could also include existing habitats, the size of the proposed structure, and population dynamics for key wildlife species, particularly for animals that are highly valued by society (Clevenger & Waltho, 2000; Dixon et al., 2006; National Academy of Sciences, 2012). For example, a model could place greater ecological value on rare or designated critical habitats that provide important landscape linkages for wide-ranging or rare species (University of Florida, 2021). Florida's legislature adopted this approach for the Florida Wildlife Corridor Act (Section 259.1055, Florida Statutes), allocating $400 million to protect and enhance 7.28

million ha of Priority 1 and 2 habitats around the state. Until the resource agencies agree to a set of metrics that can reasonably quantify the ecological benefit of a wildlife crossing, our concept for receiving wetland mitigation credit for a new wildlife crossing will be determined by the best scientific judgment and whims of review staff.

4. Another option would be exploring the Corps' Nationwide Permit (NWP) program. These pre-issued permits have general and specific conditions to which a project must adhere, in many cases including a maximum wetland impact area where wetland mitigation would not be required (typically <0.20 ha of wetland impacts). However, NWP 27 authorizes unlimited wetland impacts for aquatic habitat restoration, enhancement, and establishment activities that demonstrate a restoration benefit. Our case study and the subsequent Interstate 4 project demonstrated that a new wildlife crossing would provide restoration and ecological benefits to adjacent habitats. Using the NWP program would eliminate the need to provide a wetland mitigation analysis and reduce the time required to receive construction authorization because these permits are pre-issued. In other words, the NWP program could accelerate the construction of new wildlife crossings on the state and US highway systems.

Our case study addresses an important part of the 2008 mitigation rule: a watershed approach to wetland mitigation that considers the habitat requirements for important species and corridors. While the same rule established a hierarchical preference for wetland mitigation banks, the watershed approach requires applicants to consider whether the project will affect the landscape position and habitat connectivity. Our project will occur >48.28 km from the nearest wetland mitigation bank. Meanwhile, the ecological benefits and relative functional gains emanating from the new wildlife crossings will occur in habitats immediately adjacent to the project. The wildlife crossings may also serve as a conduit for reconnecting wetlands and floodplains in the watershed, thus enhancing W (Equation 1; Table 2). This dual-use approach of the structure could be a cost savings to the FDOT, too, after proper drainage analysis and floodplain modeling demonstrate the action will not adversely impact adjacent property owners or habitats.

We believe that our case study provides a framework for valuing wildlife crossings in terms of wetland mitigation, which can be used to defray total project costs for specific roadway projects. Transportation agencies commonly identify the lack of funding as a major hurdle in preventing the construction of new wildlife crossings (Ament et al., 2015; Kociolek, 2014). Our results indicate that Florida's current methodology for evaluating wetland mitigation can be used for determining the ecological benefits provided by these crossings. However, we recognize that the UMAM and our application for this case study are not without limitations, namely the lack of defined metrics that would improve predictability. Similar methodologies around the United States for evaluating habitat function may also be applied to new wildlife crossing projects. Consequently, our framework provides potential cost savings for transportation agencies that could incentivize new wildlife crossing projects while improving motorist and animal safety.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

No new data were collected for this study.

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