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EFFECTIVE MANAGEMENT OF ENDANGERED BLANDING'S TURTLE *(EMYDOIDEA BLANDINGII)* POPULATIONS IN NOVA SCOTIA, CANADA, REQUIRES CONSIDERATION OF THREATS POSED BY LEGACY GOLD MINE CONTAMINATION

BRIANNA L. BOWES[1*] AND TONY R. WALKER[1]

[1]*School for Resource and Environmental Studies*
Dalhousie University, Halifax, NS

ABSTRACT

The Nova Scotia, Canada, Blanding's turtle (*Emydoidea blandingii*) population is designated as endangered both federally and provincially. Currently, its range is confined to five disjunct sub-populations in the province's southwestern interior. With fewer than 500 breeding adults in the wild, current recovery efforts are focused on reducing mortality risk to adult and juvenile turtles. However, little is being done to address the cumulative impacts of environmental contamination on species fitness and reproductive capacity. This paper focuses on legacy impacts of Nova Scotia's gold mining industry within present-day Blanding's turtle critical habitat, with a focus on mercury and arsenic contamination. To date, previous studies have not considered the impacts of legacy gold mining contaminants on Blanding's turtle recovery and conservation. Three historical gold mining areas were identified as overlapping with Blanding's turtle ranges (West Caledonia District, Brookfield District, and Pleasant River Barrens District). To address the current knowledge gap, site assessments for Blanding's turtle presence, food web contamination surveys, turtle claw tissue sampling, and overall site remediation are recommended to complement existing recovery efforts.

Keywords: Blanding's turtle, critical habitat, environmental contamination, gold mine tailings

INTRODUCTION

Legacy gold mine tailings in Nova Scotia

Large-scale gold mining in Nova Scotia began in the mid-1800's and continued in abundance until the mid-1900's; in that period

* Author to whom correspondence should be addressed: brianna.bowes@dal.ca

over 300 individual gold mines were constructed across 64 separate mining districts (Bates 1987, Parsons *et al.* 2012). The primary gold extraction method used involved a mercury-gold amalgamation process, in which extracted and crushed ore-containing host rock would be washed over mercury (Hg) coated copper plates (Parsons *et al.* 2012). Once any present gold was removed, the remaining waste bedrock would then be washed into nearby wetlands as tailings, now significantly contaminated with elemental Hg (Parsons *et al.* 2012). Gold mine tailings are also known to be highly contaminated with arsenic (As), which is commonly found in association with gold ore-containing host rock in Nova Scotia (Drage 2015). Although naturally occurring, the process of crushing and spreading bedrock into surface wetlands allows As to exist in a more mobile, bioavailable form (Lengke *et al.* 2009, Parsons *et al.* 2012).

By the early 1940's, ongoing gold extraction became too difficult and sparse to remain economically viable on a large scale, and the industry became largely dormant (Parsons *et al.* 2012). However, in the past two decades, given the advancement in mining extraction technology, there has been som , 2015). This involves the potential to resume operations at previous mining sites, as well as initiate mining at new sites (Drage 2015).

Despite inactivity at most of the province's historic gold mines for at least 80 years, legacy tailings remain contaminated to the present day (Drage 2015, LeBlanc *et al.* 2020). While As, a known carcinogen, is the primary concern from a human health perspective, Hg, a potent neurotoxin, is also highly dangerous, particularly if methylated into its organic form (O'Driscoll *et al.* 2005, Drage 2015). In this lipophilic form, methylmercury (MeHg) can readily cross the blood-brain barrier in animals, where it is then prone to bioaccumulation and trophic biomagnification (LeBlanc *et al.* 2020). MeHg forms in acidic and anaerobic environments in the presence of methylating sulphate or ferric reducing bacteria (O'Driscoll *et al.* 2005). Such conditions commonly occur within wetlands in Nova Scotia, including those observed at legacy gold mine tailings sites (LeBlanc *et al.* 2020).

Management and mitigation

Most gold mine tailings sites have undergone little to no remediation efforts to date (LeBlanc *et al.* 2020). Since the 1970's, numerous studies have investigated As and Hg concentrations in groundwater,

sediments, and plant and animal tissues, both within the tailings themselves, as well as in adjacent residential areas and wells (Parsons *et al*. 2012, Drage, 2015). Parsons *et al*. (2012) summarized the findings of a 2003-2006 multi-disciplinary investigation of Hg and As concentrations in tailings and sediment samples from 14 Nova Scotian mining districts. Based on their findings, 99% of samples exceeded Canadian Council of Ministers of the Environment (CCME) soil and sediment guidelines for As, while at least 20% exceeded those set for Hg in soils, and 71% exceeded for Hg in sediments (Parsons *et al*. 2012). Current CCME freshwater Interim Sediment Quality Guidelines (ISQG) for the protection of environmental and human health for As and Hg are 5.9 and 0.17 mg/kg, respectively, whereas Probable Effects Levels (PEL) for As and Hg are 17 and 0.486 mg/kg dry weight, respectively (CCME 2023). For soils in residential areas, CCME guidelines for As and Hg are 12 and 6.6 mg/kg dry weight, respectively, representing an integrative Soil Quality Guideline for Human Health (SQGHH) and Environmental Health (SQGE) (CCME 2023).

LeBlanc *et al*. (2020) conducted a review of 23 studies examining Hg and As exposure and bioaccumulation in terrestrial and aquatic organisms from legacy gold mine tailings sites in the province. The review outlines all organism sampling studies conducted at gold mine tailings sites in Nova Scotia to the time of publication, covering a diverse array of plant, invertebrate, fish, amphibian, and mammal species (LeBlanc *et al*. 2020). Overall, the review concluded that organisms found in and around tailings sites typically have Hg and As tissue concentrations elevated above background concentrations typical for individuals from non-contaminated sites, or exceeding CCME tissue consumption guidelines (LeBlanc *et al*. 2020). The authors also noted that there are currently no CCME guidelines regarding safe levels of Hg and As occurrences in animal tissues with respect to wildlife health and wellbeing (LeBlanc *et al*. 2020).

Warning signs regarding high As contamination have been posted on crown land gold mine tailings since the early 2000's, with recommendations for the public to avoid exposure to such sites as much as possible (Parsons *et al*. 2012). Additional water and food As level advisories for adjacent residential areas have been issued since the first recorded occurrences of well water contamination were observed in the 1970's (Parsons *et al*. 2012). Mercury contamination of gold

mine tailings is a concern for human health in areas where fish and seafood may be collected for human consumption (LeBlanc & Halfyard 2010, Parsons *et al*. 2012). These cases are similarly managed with region-specific food advisories and restrictions on fishing or harvesting species of interest within contaminated watersheds (LeBlanc & Halfyard 2010, Parsons *et al*. 2012).

Blanding's Turtle in Nova Scotia

Blanding's Turtle (*Emydoidea blandingii*) is a medium-sized, freshwater species that primarily consumes small aquatic invertebrates, fish, worms, insects, and some plant materials (Rowe 1992). It is long-lived, with a natural life expectancy of 80 years, taking at least 18 years to reach maturity in Nova Scotia (McNeil *et al*. in rev.). As such, the population is susceptible to any increase in adult mortality from anthropogenic activities (*e.g.*, roads) as well as increased juvenile mortality from elevated predator populations (*e.g.*, raccoons), which reduces recruitment of juveniles to breeding adults (Parks Canada 2012, ECCC & Parks Canada 2020).

Nova Scotia's Blanding's turtle population is geographically isolated and genetically distinct from the remainder of the species range (ECCC & Parks Canada 2020). Within the Nova Scotian population, there are currently five identified, genetically distinguishable subpopulations (Congdon *et al*. 2008, COSEWIC 2016). This genetic isolation is largely attributed to significant habitat fragmentation and small population size, with limited movement among the fragments (ECCC & Parks Canada 2020). All five present day subpopulations are found in the southwestern interior of the province; the range of each has been designated Critical Habitat (CH) as outlined in the *Action Plan for Blanding's Turtle (Emydoidea blandingii), Nova Scotia Population, in Canada* (ECCC & Parks Canada 2020). The turtles inhabit a variety of seasonal habitats within their larger range and show significant fidelity to their preferred sites (Parks Canada 2012).

Species conservation efforts

The species was originally assessed as 'Threatened' by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in 1993 (Parks Canada 2012, ECCC & Parks Canada 2020), predating the establishment of the Species at Risk Act (SARA) in Canada by 10 years (Government of Canada 2019). In 2005 the species' status was

changed to 'Endangered', which it retained after a 2016 re-evaluation by COSEWIC (ECCC & Parks Canada 2020). In 2016 COSEWIC estimated the province's population to exist in a state of ongoing decline, consisting of fewer than 500 mature adults (COSEWIC 2016).

As a federally listed Endangered species under SARA, Nova Scotia Blanding's turtle recovery efforts are the joint responsibility of Environment and Climate Change Canada (ECCC) and Parks Canada where the turtles are found on federal/crown land (ECCC & Parks Canada 2020). Currently, the turtle's presence on federal land is restricted to the Kejimkujik National Park subpopulation (ECCC & Parks Canada 2020). All other turtles found on provincial land are the responsibility of the Nova Scotia Department of Natural Resources and Renewables (DNRR) (DNRR 2020). The Nova Scotia DNRR has also adopted the federal *Action Plan for Blanding's Turtle (Emydoidea blandingii), Nova Scotia Population, in Canada* (hereby referred to as the '*Action Plan'*) (ECCC & Parks Canada 2020, DNRR 2020) as well; therefore, the recovery efforts at both provincial and federal levels would be expected to be consistent.

Most of the activities and objectives outlined within the *Action Plan* are designed to address three threats to species' recovery: habitat loss and degradation; accidental mortality of adults; and changes in ecological dynamics (ECCC & Parks Canada 2020). Additional threats identified in the *Action Plan* include pollution and environmental contaminants, including specific references to historical mine sites, for which the impact severity is classified as 'unknown'. Current and planned recovery activities include creating management plans for more developed areas within critical habitat ranges, restoring natural habitat where it has been lost or severely altered, encouraging public reporting of turtle sightings, and constructing protective barriers around nests and nesting sites (ECCC & Parks Canada 2020).

While these activities do address short term threats to species recovery, for example mortality due to vehicular collisions, they do not consider the multi-generational effects that can result from chronic contaminant exposure and failure to recruit juvenile turtles to adulthood (Hopkins 2012, Meyer 2014, Landler 2017, Benjamin *et al.* 2018). Given this lack of attention directed towards facilitating multi-generational success, the *Action Plan's* long-term goal of achieving "…a self-sustaining population of Blanding's turtles in Nova Scotia, over the current range, and to maintain sufficient gene flow to prevent

any single population from becoming genetically isolated" may be unattainable (ECCC & Parks Canada 2020).

Threat posed by environmental contamination

The *Action Plan* does not outline any current or past activities to address the knowledge gap surrounding the impacts of environmental contamination on Blanding's turtles (ECCC & Parks Canada 2020), despite acknowledging that turtles are known to nest within historical mine tailings sites in the province (ECCC & Parks Canada 2020). However, specific mines or mining districts where the turtles have been recorded were not disclosed.

Turtles in general are prone to bioaccumulation of environmental contaminants, including Hg, due to their longevity and trophic level (Hopkins 2012, Slimani *et al*. 2018, Benjamin *et al*. 2018). Turtles are also known to be useful bioindicators of Hg contamination in soils and sediments, presenting a direct relationship between concentrations stored in their keratinized tissues and those found in the environment (Slimani *et al*. 2018). In freshwater turtles, long-term exposure to Hg has been linked to thyroid dysfunction, interference with magnetic geo-orientational capacity, maternal infertility, and reduced hatchling success due to maternal Hg transfer (Hopkins 2012, Meyer 2014, Landler 2017). Aside from the obvious consequences of reduced fecundity and hatchling failure, these health impacts can also hinder turtle growth and development, further reducing overall population fitness (Benjamin *et al*. 2018).

While the impacts of long-term As exposure to turtle health remain largely unknown, the general scientific consensus is that chronic exposure to any toxic trace element causes continuous stress on the animal (Rowe 2014, Zavala-Félix *et al*. 2022). Therefore, long-term exposure to As, in tandem with the other factors contributing to decreased fitness in Blanding's turtles, should also be recognized as a significant threat. No study of Hg or As concentrations in the tissues of turtles or other reptiles in NS gold mine tailings sites has been conducted to date (LeBlanc *et al*. 2020).

MATERIALS AND METHODS

Location data obtained from the *Historical gold mining areas in Nova Scotia* map series (Smith & Goodwin 2009) were used to determine potential for overlap between Blanding's turtle habitat

and legacy gold mine tailings habitat in Nova Scotia. The map series details all 64 historical gold mining districts in the province as aerial photos overlain with property boundaries and the approximate locations of tailings ponds and mine shafts as identified by previous studies and reviews. These maps, created by Smith and Goodwin (2009), were not confirmed by field checks.

Maps of the Western Meguma Group formation from this series show the approximate mining activity areas for six mining districts (West Caledonia, Whiteburne, Molega, Leipsgate, Brookfield, and Pleasant River Barrens) determined most likely to overlap with Blanding's turtle critical habitat; these were georeferenced and digitized using ArcGIS Pro software. Nova Scotia Blanding's turtle critical habitat areas were also georeferenced and digitized from the federal *Action Plan* species overview map (ECCC & Park's Canada 2020). All original figures were generated in ArcGIS Pro using the North American Datum 1983 (NAD83) geodetic reference system and the Universal Transverse Mercator (UTM) Projection, Zone 20. Base layers were obtained from the Government of Nova Scotia's geographic data directory.

RESULTS

Of the six legacy gold mining sites investigated, the Brookfield, Pleasant River Barrens, and West Caledonia mining areas were identified as overlapping with present day Nova Scotia Blanding's turtle critical habitat (Fig 1). The West Caledonia mining area overlaps with a portion of the Kejimkujik turtle population within Queens County, Nova Scotia. Meanwhile, both the Brookfield and Pleasant River Barrens mining areas overlap with the Pleasant River turtle population, in Queens and Lunenburg counties, respectively.

DISCUSSION

Two of the five current Blanding's turtle critical habitat areas in Nova Scotia definitively overlap with three legacy gold mine sites in Nova Scotia (Fig 1). The West Caledonia Mining area overlaps with the only subpopulation currently found on federally designated land in Kejimkujik National Park, while the remaining two legacy sites both overlap with the provincially managed Pleasant River subpopulation.

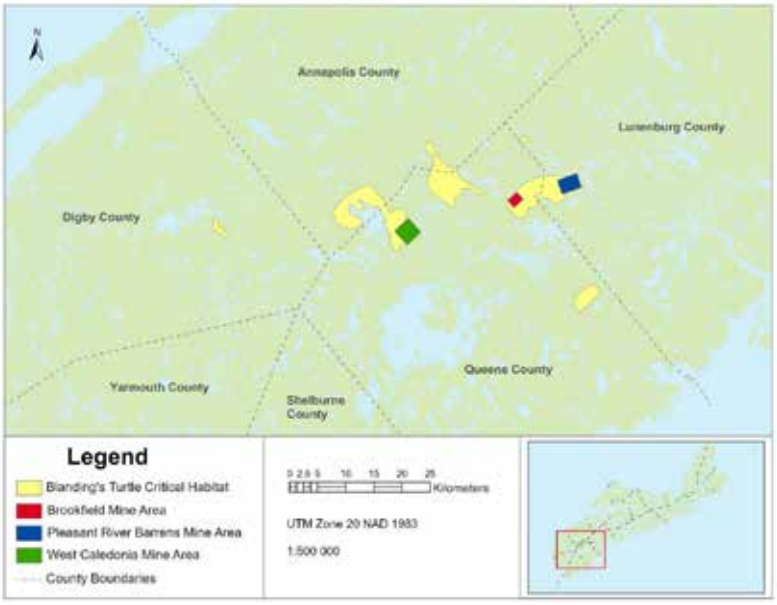

Fig 1 **Three legacy gold mine sites in Nova Scotia that overlap with current Blanding's turtle critical habitat, as digitized from Smith & Goodwin (2009) and ECCC & Parks Canada (2020).**

Therefore, a joint federal-provincial approach, with collaboration from turtle health researchers, would be suitable to investigate and manage the potential for Hg and As contamination in the Nova Scotia population of Blanding's Turtle.

Site level population surveys

To establish the degree of Blanding's turtle presence within the three overlapping mining sites, extensive population surveys should be undertaken. A model for this process is described in the 2012 federal species recovery plan (Parks Canada 2012), and was used to identify and characterize the two new critical habitat ranges in 2015 and 2016 (ECCC & Parks Canada 2020). Techniques employed include visual sightings of individuals, live-trapping, identification of Blanding's turtle nests, and VHF radio-tracking of a subset of juvenile and adult turtles. These activities often engage citizen scientists, in collaboration with Parks Canada, DNRR, the Mersey Tobeatic Research Institute, the Blanding's Turtle Recovery Team, and the Nova Scotia Amphibians and Reptiles Recovery Team (Parks Canada

2012, ECCC & Parks Canada 2020). In recent years GPS-enabled radio-tracking has also been employed; its use would be particularly relevant to any examination of turtle use of former mine sites.

The study should also establish mining area suitability for Blanding's turtle inhabitation based on biophysical characteristics. For the active season (April to September) preferred Blanding's turtle sites in Nova Scotia contain freshwater wetlands characterised by slow moving tannin-rich acidic water, beaver dams, abundant aquatic and overhanging vegetation, and muddy, organic-rich substrate with little rock presence (Congdon *et al.* 2008, Parks Canada 2012). Nesting sites, which are accessed intermittently mainly during June and July, require semi-loose, exposed substrate such as sand, gravel, or soil with large amounts of sun exposure (BTRT 2006, Parks Canada 2012). For the overwintering period from October to March, sites contain deep muddy substrate found within wooded pools, channels, railway trenches, portions of streams or wetlands, and undercut banks (Parks Canada 2012, Canadian Herpetological Society 2023).

Based on site characteristics, further surveys should be conducted during the seasons they are most likely to host Blanding's turtles. Any portions of the mine sites deemed unsuitable for Blanding's turtle habitation in any season could be excluded from further analysis on a site-by-site basis.

Use food web contamination as a proxy for Blanding's turtle health

To establish a precedent for contamination in Blanding's turtles themselves, food web studies investigating Hg and As concentrations should first be conducted as a proxy. Sampling should be done in CH in areas both overlapping and not overlapping mining sites. If such studies confirm significant contamination of the species' food sources, they would support direct sampling of the turtles themselves.

Blanding's turtles are omnivorous, feeding on freshwater and terrestrial invertebrates, small fish, amphibians, and small amounts of vegetation (Rowe 1992, BTRT 2006, ECCC 2020). To date, several studies have examined Hg and As contamination in lower and mid trophic level organisms in Nova Scotia's gold mine tailings sites (LeBlanc & Halfyard 2010, Walker & Grant 2015). Consensus supports elevated levels of contaminants in organisms within and around legacy tailings sites, although with high degrees of variability between sites, media, and organisms examined (LeBlanc *et al*. 2020).

LeBlanc and Halfyard (2010) found elevated As levels in fish from tailings associated lakes compared to those without gold mine tailings in their watersheds. Moriarty *et al.* (2013) found significantly elevated As levels in frogs at a gold tailings contaminated site, which they attributed both to contamination within their diet (mainly consisting of terrestrial invertebrates) and adsorption from water. Eaton and Clair (1985) found that Hg concentrations in fish exceeded Canadian Food Inspection Agency (CFIA) guidelines in over half of their samples. Eaton *et al.* (1978) found significant Hg concentrations in freshwater vegetation, which were also significantly elevated above levels in terrestrial plants at the same site. LeBlanc and Halyard (2010) additionally measured Hg concentrations in fish, with variable results; however, at least one fish per site exceeded CFIA guidelines.

However, CFIA guidelines are designed as metrics for human health risk based on consumption of contaminants, and do not apply to risk for Blanding's Turtle. Given the lack of suitable metric for the latter, the consistent record of elevated As and Hg levels in prey species from different Nova Scotia gold mine tailing sites supports the need for a comprehensive food web study.

Determine Hg and As tissue concentrations in living Blanding's turtles

To establish current contamination levels in living Blanding's turtles, non-lethal tissue samples should be collected from an array of individuals of varying age from locations overlapping and non-overlapping with mining areas. This will help to assess the current risk to the population's recovery and inform the urgency and nature of additional conservation efforts required.

Multiple studies of Hg in turtles have confirmed that claw tissue sampling provides reliable samples with no harm to the animals (Hopkins *et al.* 2013a,b, Van Dyke *et al.* 2016, Slimani *et al.* 2018, Benjamin *et al.* 2018). At the time of writing, only one study (Benjamin *et al.* 2018) has quantified Hg levels in Blanding's Turtle. That study, using claw tissue from a population across four wetland sites in Illinois, United States of America, reported significantly lower Hg concentrations in Blanding's Turtle than in other turtle species of similar trophic levels in the area. Further, the authors did not identify any deleterious effects on the population attributable to Hg contamination (Benjamin *et al.* 2018).

Methodology in Benjamin *et al.* (2018) can also provide a model for a Nova Scotian study. Clipping turtle claws is both easy and harmless (Hopkins *et al.* 2013b); clippings reflect cumulative dietary Hg exposure for several months prior to sampling (Benjamin *et al.* 2018). In that study the distal 2-3 mm of three claws were collected from each back foot using dog nail trimmers; turtle size (mass, straight carapace and plastron length) was also recorded (Benjamin *et al.* 2018). The authors specifically selected gravid turtles (confirmed with field x-rays) to characterize the likelihood for maternal Hg transfer to offspring. However, for this proposed study it may be more appropriate to sample turtles of all ages and sexes, to both increase sample size and develop a broader picture of population-wide contamination.

Remediate legacy gold tailings sites while reducing risk to Blanding's Turtle

The crown corporation Build NS is facilitating the remediation projects of historic gold mines on crown land in Nova Scotia (Build NS 2022). Currently, only five mining districts in the Halifax Regional Municipality and Guysborough County have completed Phase 1 & 2 Environmental Site Assessments under this program, with remediation efforts reportedly underway for at least one site since Fall 2022 (Build NS 2022). None of these sites currently targeted for remediation overlap with the range of Blanding's Turtle, which is restricted to the southwestern interior of the province. However, the remediation plans developed for these sites could be used as a proxy for remediation at sites inhabited by Blanding's turtles, with appropriate modifications to address needs specific to preserving turtle health and safety.

A brief review of two Phase 2 ESAs (Gold Brook Lake/Seal Harbour, Mooseland) reveals similar remediation plans (AECOM Canada Ltd. 2022a,b): an initial phase with construction of engineered wetlands near residual tailings ponds to act as 'filters' preventing contaminants from spreading further in the watershed, followed by extensive excavation of 'dry' tailings to be consolidated and stored *in situ* and under a cap on site (AECOM Canada Ltd. 2022a,b). Based on these activities, potential risk to Blanding's Turtle would include accidental mortality from dredging and vehicle collisions. However, such risks can be reduced by restricting activity to seasons when turtles are likely absent from the area; if turtles are identified

within the site while work is underway, all remediation activities can be temporarily halted.

LIMITATIONS

This study does not provide a comprehensive analysis of Blanding's turtle range overlap with legacy gold mining sites in the province. The species is known to travel significant distances between seasonal habitats and to take advantage of newly created nesting sites; because of the latter some individuals may venture out of their traditional ranges. This presents the possibility for individuals to cross into mine sites that do not overlap with currently designated critical habitat.

Additionally, two of the five current critical habitat ranges for the species were also not identified until the mid-2010's, and the *Action Plan* itself identifies current critical habitat ranges as "likely incomplete" (ECCC & Parks Canada 2020). Therefore, it is possible that unidentified Blanding's turtle sub-populations may reside within legacy gold mine areas not identified in this study.

CONCLUSIONS

Current management plans for the Nova Scotia population of Blanding's Turtle do not adequately address potential impacts of environmental contamination on species recovery. To address such impacts, the threats posed must first be quantified through comprehensive study and review, as discussed above. However, successful recovery and conservation of the species will require ongoing, adaptive, and collaborative effort on the part of all involved management bodies. While the authors present a preliminary framework to begin addressing the current knowledge gap, future management of this SARA species will be most successful if shaped by a double-looped system characterised by ongoing scientific study and monitoring.

Declaration of competing interest
The authors declare no competing conflicts of interest.

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Data availability

Data will be made available upon request.

CRediT authorship contribution statement

Brianna L. Bowes: Conceptualization, Methodology, Writing – Original Draft, Writing – Review and Editing. Tony R. Walker: Writing – Review and Editing.

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