

Functional Outcomes of Unstable Ankle Fractures in Adolescents

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Background: The purpose of this study was to describe the functional outcomes and complications of unstable supination external rotation (SER) and pronation external rotation (PER) ankle fractures in adolescents. A secondary outcome was to compare functional outcomes of SER stage IV injuries that were treated definitively with closed reduction and cast application to a similar group of minimally displaced fractures treated with open reduction and internal fixation (ORIF).

Methods: A retrospective review of adolescents aged 10 to 18 years with unstable ankle fractures treated at a single institution between 2009 and 2017 was conducted. All patients had functional outcomes data from the Foot and Ankle Ability Measure obtained at a minimum of 1-year follow-up.

Results: In total, 67 adolescents (41 SER, 26 PER) were included (mean follow-up: 52.3 ± 24.8 mo). A total of 56 were treated with ORIF and 11 were closed reduced and casted. No patients treated nonsurgically had a loss of reduction and none required subsequent surgical intervention. Preoperative radiographic predictors of syndesmotic injury (>6 mm of tibiofibular clear space or <2 mm of tibiofibular overlap) were not sensitive and only moderately specific predictors of intraoperative syndesmotic injury. There was no difference in functional outcome between the 11 SER stage IV fractures treated nonoperatively and a group of minimally displaced SER injuries treated with ORIF. Patients with open or partially open physes had better functional outcomes. Patients with syndesmotic injuries, medial malleolus fractures, or fracture-dislocations were not associated with lower functional outcome scores in our adolescent cohort.

Conclusions: Unstable SER and PER injuries in adolescents have favorable functional outcomes at intermediate-term follow-up,

though a minority continue to have impaired ankle function. Minimally displaced SER stage IV injuries with near anatomic alignment after closed reduction can be successfully treated with continued closed management, and have no difference in functional outcomes compared with similar injuries treated with ORIF.

Level of Evidence: Level III.

Key Words: ankle fracture, pediatrics, adolescent, syndesmosis, Lauge-Hansen, growth plate, supination external rotation, pronation external rotation, SER IV, PER IV

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Ankle fractures account for about 5% of all fractures in children, and unstable fractures are a common indication for surgical intervention.^{1,2} About 60% of ankle fractures are Lauge-Hansen supination external rotation (SER) injuries, whereas pronation external rotation (PER) injuries account for about 20%.^{3,4} Lauge-Hansen SER stage IV and PER stages III or IV fractures are considered to be unstable as both the lateral and medial sides of the mortise have failed.^{5,6} Although outcomes of these fractures have been described for adult populations, there is minimal data on the functional outcomes of unstable ankle fractures in adolescents who are at or nearing skeletal maturity.

In the adult population, open reduction internal fixation (ORIF) of unstable ankle fractures is preferred, though whether ORIF leads to better functional outcomes compared with cast treatment of anatomically closed-reduced fractures has not been well demonstrated. The only prospective, randomized study of ORIF versus continued closed treatment of adequately reduced unstable SER and PER fractures found a benefit to ORIF, but only in patients greater than 50 years of age or those with a fracture of the medial malleolus.⁷ A systematic review of operative versus nonoperative management of SER stage IV fractures also found conflicting results as to the benefit of ORIF in younger patients or patients with a deltoid ligament injury.² There are no studies that we are aware of that have compared closed versus operative treatment of these fractures in the pediatric population.

The purpose of this study was to describe the functional outcomes of unstable, closed SER and PER injuries in the adolescent population, and to identify factors associated with

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a successful outcome. A secondary outcome was to compare the functional outcomes of SER stage IV injuries that were treated with closed reduction and casting to a similar group of fractures treated with ORIF.

METHODS

Institutional Review Board approval was obtained. Using CPT codes, ~3000 adolescents aged 10 to 18 years that were treated for closed distal fibular fractures between 2009 and 2017 were identified. A retrospective review was performed to identify those with Lauge-Hansen SER stage IV and PER stages III or IV injuries. SER stage IV was defined as a spiral or oblique Weber B fibula fracture, and any one of the following: a transverse medial malleolar fracture, a Salter-Harris IV fracture of the medial malleolus, or medial clear space widening ≥ 5 mm at the level of the talar dome.⁶ PER III or IV fractures were defined by the presence of a spiral or oblique Weber C fibula fracture and any medial injury as described above. Pretreatment ankle radiographs, or computed tomography scans (when available), were used to identify the injuries. Medial clear space was measured on pretreatment radiographs. Gravity and manual stress views were measured if available. Other inclusion criteria were pretreatment and posttreatment ankle radiographs and functional outcome data from the Foot and Ankle Ability Measure (FAAM) questionnaire obtained a minimum of 1 year postinitiation of treatment. Each subject's clinical course, complications, and additional surgeries or procedures were documented by review of the electronic medical record.

After radiographic review, 110 patients initially met inclusion criteria. Two were excluded because of tibial comminution consistent with a Pilon type fracture. One patient was excluded because of treatment of the fibula fracture with percutaneous pinning. In total, 40 of the remaining 107 patients did not have functional outcome data available and were excluded, leaving 67 study subjects.

The treating surgeon determined the need for surgery. If a near anatomic reduction of the fracture and syndesmosis was obtained after a closed reduction, some surgeons elected to treat these patients with continued casting. Other surgeons decided to proceed with surgery despite anatomic closed reduction because of the instability visualized on the pre-reduction radiographs. If surgical stabilization was pursued, the fibula and medial malleolus underwent ORIF when displaced, whereas small avulsion fractures of the posterior malleolus were never repaired. Repair of a deltoid ligament tear was not part of the protocol for any child. The syndesmosis was fixed with either a screw or suture button fixation device when indicated by a positive intraoperative Cotton/Hook or external rotation test. The Cotton/Hook test was performed by applying a lateral force on the distal fibula with a bone hook and assessing for >2 mm of lateral translation of the fibula and widening of the mortise on the anteroposterior view.

Postoperative management consisted of a short period of immobilization to protect the soft tissues, generally 3 to 6 weeks, followed by progressive range of motion in a controlled ankle movement boot.

A subset of SER stage IV fractures were determined to be suitable for continued closed management. Closed management consisted of reduction with or without conscious sedation and placement of a below-knee or above-knee, non-weight-bearing cast for 3 to 6 weeks, followed by conversion to a short-leg walking cast for 3 to 4 weeks. After immobilization, patients were recommended to begin physical therapy.

Assessment of Radiographic Findings

Pretreatment films were evaluated for presence of a medial malleolar fracture or fracture-dislocation, and to determine the physal status of the tibia. Two previously published radiographic predictors of syndesmotic injury on the anterior-posterior ankle view were used to determine their utility in predicting the need for syndesmotic fixation: either >6 mm tibiofibular clear space (between the lateral border of the posterior tibia to the medial border of the fibula)⁸ or <2 mm of tibiofibular overlap (between the lateral edge of the anterior tibial tubercle and the medial border of the fibula).⁹ Subjects with fracture-dislocations were not measured. All available radiographs and clinic notes were reviewed to confirm fracture healing and document any complications.

Assessment of Functional Outcomes

To assess subjective ankle function, the FAAM was administered to the patients, which is composed of an Activities of Daily Living (ADL) section and a Sports section.¹⁰ The ADL section assesses difficulty with walking, climbing stairs, and working, whereas the Sports section assesses difficulty with running, jumping, lateral movements, and other sports-related activities. Only patients with functional outcome data obtained a minimum of 1-year postinitiation of treatment were included.

Statistical Methods

Basic descriptive statistics are reported. The Shapiro-Wilk test of normality and Levene test of homogeneity of variances was performed on all continuous data. All continuous data were found to be non-normally distributed and therefore analyzed with the Mann-Whitney test. Categorical data were analyzed with Pearson χ^2 or Fisher exact test. No a priori power analysis was performed. Statistical analysis was conducted using SPSS (version 24; IBM, New York, NY). Statistical significance was defined as $P < 0.05$.

RESULTS

Clinical Results

A total of 67 adolescents were included [mean follow-up: 52.3 ± 24.8 mo (range, 12 to 106 mo)] (Table 1). A total of 56 patients were treated with ORIF (mean age: 15.8 ± 1.7 y; 30 male, 26 female), and 11 patients all with SER injuries were treated with closed reduction and cast application (mean age: 14.6 ± 2.3 y; 7 male, 4 female). Sample radiographs can be found in Figures 1 and 2. Eight patients, all with SER injuries, had open or partially open tibial physes (Fig. 3). There was 1 case of premature physal closure treated with bilateral epiphysiodeses. There were no cases requiring secondary surgery and no instances of implant failure [with

TABLE 1. Demographics

	N (%)	
Sex		
M	37 (55)	
F	30 (45)	
Treatment		
Operative	56 (84)	
Nonoperative	11 (16)	
Physis status		
Open	8 (12)	
Closed	59 (88)	
Medial malleolus Fx		
Medial malleolus Fx	33 (49)	
No medial malleolus Fx	34 (51)	
Fx dislocation		
Dislocation	9 (13)	
No dislocation	58 (87)	
Fx type		
SER	41 (61)	
PER	26 (39)	
Tibiofibular overlap (mm)		
<2	15 (26)	
≥2	43 (74)	
Tibiofibular clear space (mm)		
≤6	39 (67)	
>6	19 (33)	
	Mean ± SD	Range
Age at injury (y)	15.6 ± 1.9	10.0-18.0
Follow-up (mo)	52.3 ± 24.8	12-106

FAAM indicates Foot and Ankle Ability Measure; F, female; Fx, Fracture; M, male; PER, pronation external rotation; SER, supination external rotation.

the exception of broken syndesmotom screws ($n=5$)). There were no major surgical complications. Three patients were treated with a short course of antibiotics for superficial wound infections, with no cases of deep infection. In the closed group, no patients had a loss of reduction observed on follow-up radiographs, and none required subsequent surgical intervention. One patient in the closed group was found to have bilateral osteochondritis dissecans lesions and ultimately underwent chondroplasty and retrograde drilling of the lesion on the side of their fracture.

We observed a higher percentage of syndesmotom injuries in operatively managed PER than SER fractures (57.7% vs. 36.7%, $P=0.18$). The 2 radiographic predictors of syndesmotom injury were not sensitive and only moderately specific for intraoperative syndesmotom injury: >6 mm of tibiofibular clear space was 40% sensitive and 76% specific, whereas <2 mm of tibiofibular overlap was 30% sensitive and 81% specific.

Functional Outcomes

There was a weak correlation between FAAM Sports score and follow-up time ($r_s=0.27$, $P=0.03$). There was no significant correlation between age and FAAM Sports or FAAM ADL score. Both SER and PER fractures had similar scores, and there was no association between a fracture of the medial malleolus and either of the outcome scores. Fractures that required syndesmotom fixation had similar mean FAAM Sports score compared with operatively treated fractures without syndesmotom injuries

(86.2% vs. 92.1%, $P=0.79$). The 9 fracture-dislocations, which were all treated with surgery, had similar functional outcomes to patients without a dislocation. Patients with open or partially open tibial physes had a higher mean FAAM Sports than their skeletally mature counterparts (99.6% vs. 88.2%, $P=0.014$) (Table 2).

A comparison was made between the 11 non-operatively treated SER stage IV fractures and 13 SER stage IV injuries treated with ORIF that had either a nondisplaced fracture of the medial malleolus or a deltoid ligament injury. In the surgical group, 11/13 patients had deltoid ligament injuries, compared with 8/11 patients in the closed group. Follow-up time was similar (ORIF: 50.1 mo vs. nonoperative: 58.0 mo, $P=0.46$). The surgical group had a higher mean age at time of injury (ORIF: 16.1 y vs. non-operative: 14.6 y, $P=0.07$). There was 1 skeletally immature patient in the surgical group and 3 in the non-operative group. There was no difference in mean FAAM ADL or Sports score between the 2 treatment groups (Table 3). This group of minimally displaced surgical patients had similar outcome scores to the rest of the surgical patients that had more significant displacement or dislocation ($P>0.3$).

DISCUSSION

The literature on unstable adolescent SER and PER fractures is quite limited, and no studies that we are aware of have collected patient-centered, functional outcomes for these injuries. Our study found that both SER and PER fractures have favorable functional outcomes at a mean follow-up of over 4 years. There were no major complications, and other than implant removals and 1 bilateral epiphysiodesis, there were no subsequent surgeries or procedures. There was a weak, positive association between follow-up time and FAAM Sports score, and no association with FAAM ADL score, indicating that the good outcomes of these injuries was durable through the follow-up period. We also sought to determine what fracture characteristics might be associated with functional outcome. Although previous adult studies had found bimalleolar fractures to be associated with a worse outcome than a fibular fracture with a deltoid ligament injury,¹¹ we found that the type of medial injury had no impact on functional outcome. Fracture-dislocations of the ankle have been shown to be associated with a worse functional outcome,^{12,13} but surprisingly, the 9 fracture-dislocations did similarly well on both outcome measures to nondislocated ankles in our young patient population.

Patients with intraoperatively determined syndesmotom injuries (57.7% of all surgically managed PER fractures and 36.7% of SER fractures) had a slightly lower mean FAAM Sports score (86.2% vs. 91.6%, $P=0.81$) than the rest of the cohort. This is consistent with Litrenta et al's¹⁴ study, which found that SER stage IV fractures with syndesmotom injuries had slightly lower mean outcome scores. We examined whether >6 mm of tibiofibular clear space or <2 mm of tibiofibular overlap on the anterior-posterior view was a reliable test for intraoperatively determined syndesmotom injury in this



FIGURE 1. A–C, Radiographs of a 13-year-old male who sustained a supination external rotation stage IV injury with disruption of the deltoid ligament demonstrated on stress views (inset image) (A) while playing football. He underwent closed reduction with conscious ketamine sedation and was treated with a short-leg non-weight-bearing cast for 4.5 weeks followed by a short-leg walking cast for 3.5 weeks. At 7-year follow-up, the patient scored 96.4% on the Foot and Ankle Ability Measure Sports subscale.

adolescent population. Although the above parameters afforded moderate specificity, the markedly low sensitivity of 30% for <2 mm of tibiofibular overlap and 40% for >6 mm of tibiofibular clear space indicates that these parameters alone are insufficient to rule out syndesmotom injury in the adolescent population. This is consistent with Nielson et al's¹⁵ magnetic resonance imaging (MRI) study, which found that conventional radiographic measurements had minimal correlation with syndesmotom injury on MRI in adults. Bozic et al's¹⁶ study of the normal pediatric syndesmosis found that 23% of uninjured children with a detectable incisura fibularis had ≥ 6 mm of tibiofibular clear space, which may explain the low specificity of this measurement in our study. Given the low sensitivity of the analyzed radiographic predictors of syndesmotom injury, and the high incidence of syndesmotom injury even in SER pattern fractures (36.7%), we recommend stress testing of the syndesmosis if nonoperative management is being considered.

Whether ORIF of SER stage IV fractures yields better functional outcomes than continued casting when satisfactory anatomic alignment of the ankle mortise was

achieved by closed reduction has not been well demonstrated. In the only randomized trial comparing ORIF with continued cast management of anatomically reduced unstable ankle fractures, only patients >50 years of age or those with a fracture of the medial malleolus had better functional outcomes with ORIF.⁷ Yang et al¹⁷ compared closed management versus ORIF of SER stage IV fractures, but found that the surgical group had worse functional outcomes at mean follow-up of 20 months. They attributed this to the surgical group containing more severe fractures. To address this issue, we compared only minimally displaced SER stage IV fractures treated with ORIF to those treated with closed reduction and cast application, and found no difference in functional outcome. The injuries treated nonoperatively had predominantly deltoid ligament injuries, or less commonly nondisplaced fractures of the medial malleolus. No patients in the nonoperative group had a loss of reduction, and no patients underwent secondary surgical treatment, indicating that the reduction achieved by closed manipulation was maintained by casting.

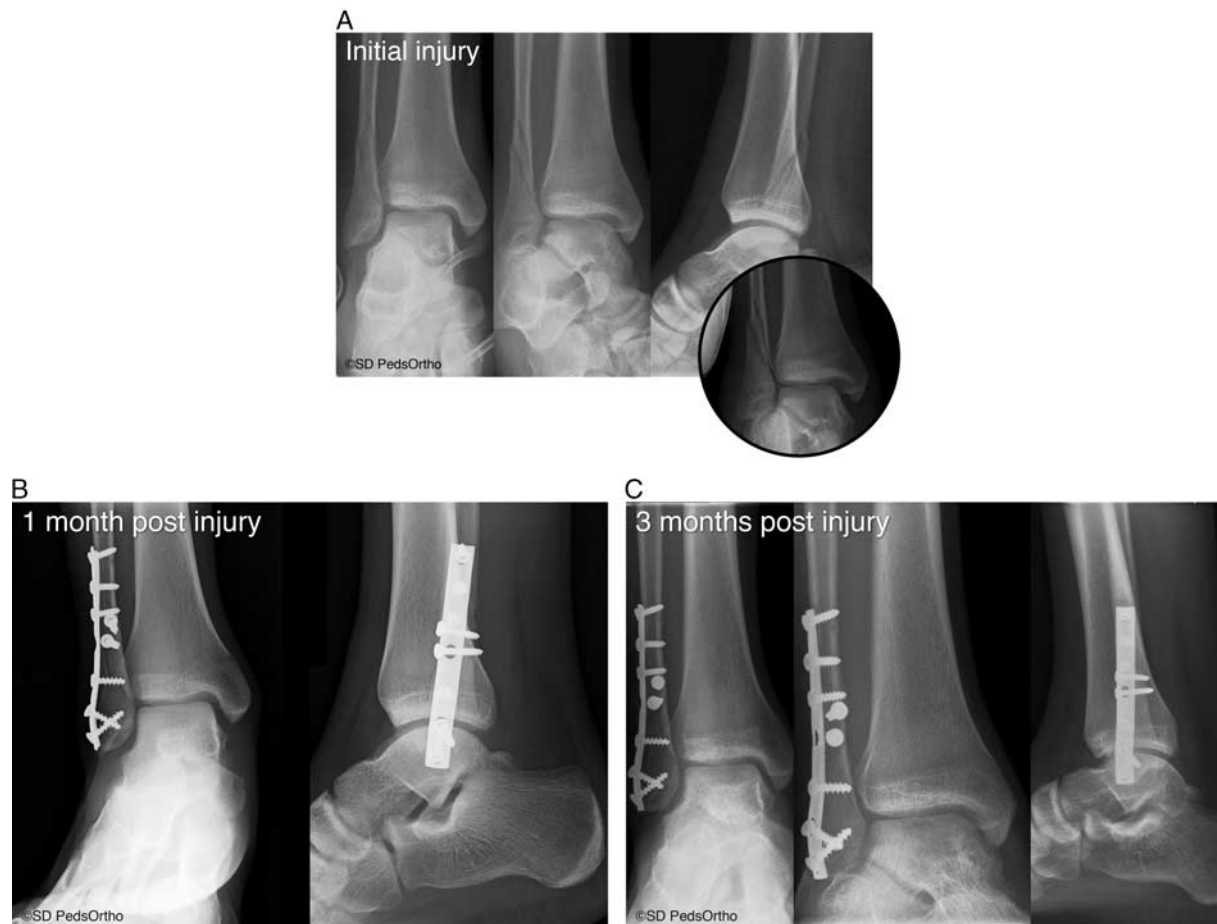


FIGURE 2. A–C, Radiographs of a 17-year-old male who sustained a supination external rotation stage IV injury with disruption of the deltoid ligament demonstrated on stress views (inset image) (A) while riding a motorcycle. He underwent open reduction internal fixation and was placed in a short-leg non-weight-bearing cast for 3.5 weeks followed by a short-leg walking cast for 4 weeks. At 4-year follow-up, the patient scored 100% on the Foot and Ankle Ability Measure Sports subscale.

This study is consistent with the results of Tornetta et al,¹⁸ who managed half of their 114 stress-positive SER stage IV fractures with continued casting and reported no cases where subsequent surgical intervention was needed. Koval et al¹⁹ provide a possible explanation for why SER stage IV injuries with a deltoid ligament tear can be successfully treated with closed management. They used MRI to evaluate the deltoid ligament complex in 21 SER stage IV injuries with ≥ 5 mm medial clear space widening and found that 19/21 patients had incomplete rupture of the deltoid. Patients with incomplete rupture were treated with casting and had excellent functional outcomes on the American Orthopaedic Foot and Ankle Score. Although their study had no comparison group, their results may explain why SER stage IV fractures with ligamentous medial injuries fare well with conservative treatment. In our study, a small number of patients with a nondisplaced fracture of the medial malleolus were also treated with continued closed management, demonstrating that an incomplete deltoid ligament tear is not the only situation where nonoperative treatment of SER stage IV injuries can be successful.

This study has some limitations that should be considered. Because of the retrospective design, there was no randomization and the need for surgery was determined solely by the treating surgeon. This introduces selection bias as to which treatment patients received. To try to account for the propensity for more severe fractures to be managed surgically, the closed group was compared against a group of patients with minimal displacement and a high proportion of deltoid ligament injuries. The sample size for the subanalysis was small. A larger sample size might allow for detection of differences between the closed and surgical groups. Another limitation may be that our mean follow-up of 4 years is inadequate to capture the development of early degenerative joint disease.

In conclusion, unstable SER and PER injuries generally have favorable functional outcomes and few complications in the adolescent population at intermediate-term follow-up. Fracture-dislocations, syndesmotic injuries, and fractures of the medial malleolus all did similarly well, despite having been identified as poor prognostic features in the adult population. The SER stage IV fractures treated with continued casting when



FIGURE 3. A–C, Radiographs of a 12-year-old male patient with open growth plates that sustained a fracture-dislocation classified as a supination external rotation stage IV injury. He was reduced and splinted in the emergency room and underwent open reduction internal fixation 12 days after initial injury to allow for his swelling to improve. At 3-year follow-up, the patient scored 100% on the Foot and Ankle Ability Measure Sports subscale.

TABLE 2. Functional Outcomes

	N	FAAM Score					
		ADL			Sport		
		Mean \pm SD	Range	P	Mean \pm SD	Range	P
All patients	67	96.0 \pm 7.6	64.3-100	NA	89.5 \pm 16.7	21.4-100	NA
Operative	56	95.7 \pm 8.1	64.3-100	0.806	89.4 \pm 17.5	21.4-100	0.822
Nonoperative	11	97.9 \pm 3.1	90.5-100		90.3 \pm 12.6	60.7-100	
Medial malleolus Fx	34	96.7 \pm 6.5	66.7-100	0.439	89.3 \pm 14.8	45.8-100	0.656
No medial malleolus Fx	33	95.3 \pm 8.5	64.3-100		89.8 \pm 18.7	21.4-100	
Physis open	8	99.3 \pm 1.1	97.6-100	0.202	99.6 \pm 1.3	96.4-100	0.014
Physis closed	59	95.6 \pm 7.9	64.3-100		88.2 \pm 17.4	21.4-100	
Syndesmotic fixation	26	94.5 \pm 10.1	64.3-100	0.694	86.2 \pm 22.1	21.4-100	0.806
No syndesmotic fixation	41	97 \pm 5.3	72.6-100		91.6 \pm 12	53.6-100	
SER	41	96 \pm 7.8	64.3-100	0.278	89 \pm 17.8	21.4-100	0.864
PER	26	96.1 \pm 7.3	72.6-100		90.4 \pm 15.1	39.3-100	
Fx dislocation	9	95.2 \pm 7.5	77.4-100	0.601	87.3 \pm 21.6	39.3-100	0.853
No Fx dislocation	58	96.2 \pm 7.6	64.3-100		89.9 \pm 16	21.4-100	

Bold value indicate statistical significance $P < 0.05$.

ADL indicates Activities of Daily Living; FAAM, Foot and Ankle Ability Measure; Fx, fracture; NA, not applicable; PER, pronation external rotation; SER, supination external rotation.

TABLE 3. Subanalysis of Minimally Displaced SER Stage IV Injuries

	N	FAAM Score					
		ADL			Sport		
		Mean \pm SD	Range	P	Mean \pm SD	Range	P
Operative	13	96.0 \pm 9.1	66.7-100	0.955	90.6 \pm 17.5	45.8-100	0.608
Nonoperative	11	97.9 \pm 3.1	90.5-100		90.3 \pm 12.6	60.7-100	

ADL indicates Activities of Daily Living; FAAM, Foot and Ankle Ability Measure; SER, supination external rotation.

closed reduction achieved adequate reduction of the ankle mortise had comparable functional outcome to those with minimal displacement treated with ORIF. Because of the risks of surgery, SER stage IV injuries with good anatomic reduction following closed reduction cast application could be considered for continued conservative management.

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