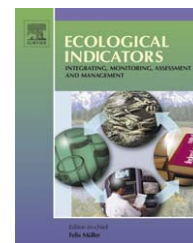


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Invasive exotic plant indicators for ecosystem restoration: An example from the Everglades restoration program

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ABSTRACT

We have developed a comprehensive ecological indicator for invasive exotic plants, a human-influenced component of the Everglades that could threaten the success of the restoration initiative. Following development of a conceptual ecological model for invasive exotic species, presented as a companion paper in this special issue, we developed criteria to evaluate existing invasive exotic monitoring programs for use in developing invasive exotic performance measures. We then used data from the selected monitoring programs to define specific performance measures, using species presence and abundance as the basis of the indicator for invasive exotic plants. We then developed a series of questions used to evaluate region and/or individual species status with respect to invasion. Finally, we used an expert panel who had answered the questions for invasive exotic plants in the Everglades Lake Okeechobee model to develop a stoplight restoration report card to communicate invasive exotic plant status. The report card system provides a way to effectively evaluate and present indicator data to managers, policy makers, and the public using a uniform format among indicators. Collectively, the model, monitoring assessment, performance measures, and report card enable us to evaluate how invasive plants are impacting the restoration program and how effectively that impact is being managed. Applied through time, our approach also allows us to follow the progress of management actions to control the spread and reduce the impacts of invasive species and can be easily applied and adapted to other large-scale ecosystem projects.

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1. Introduction and background

Invasion by exotic species is an ecosystem level problem in restoration (Pimentel, 2002; Cox, 1999; Cronk and Fuller, 1995). Exotic species present a threat to the restoration of many natural areas and often drive ecological changes that may be irreversible and thus preclude successful restoration. Invasion prevention, early detection and removal of exotics are key to their control and management (Hulme, 2006). Understanding trends in the spread and density of invasive

exotic species, including the impact of control and management activities, is necessary to manage invasive species and needs to be a vital part of large-scale ecosystem restoration programs (Hulme, 2006; Fridley et al., 2004; D'Antonio and Meyerson, 2002). To date, developing effective strategies that include invasive species management in large landscape-scale ecosystem restoration programs has posed a particular challenge (Sheley et al., 2006; Doren et al., 2002). Here, we present a conceptual model (see Doren, Richards and Volin, 2009), performance measures, and communication tools that

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can be used as fundamental components of strategies for assessing restoration success.

1.1. Applicability of indicator to the Everglades

An indicator for invasive exotic plants is not similar in nature or context to the other indicators presented in this journal issue because exotic species are not good indicators of ecological function, process or structure, especially for restoration. In addition, measurements of their biological performance do not provide any insight into how they may or may not impact other biological functions or restoration. While invasive exotic plants may result in changes in ecological function and structure, they do not necessarily "indicate" anything regarding ecological condition, or restoration success except as pertains to their level of invasion and adverse impacts on the ecosystem (Doren, Richards and Volin, 2009). However, without control and management of exotic species, there is the potential that restoration could fail, since exotics have the capacity to drastically alter the natural environment (Mack et al., 2000). Therefore, this exotic plant indicator was developed to report regularly on the status of and progress controlling invasive species in a restoration context. The invasive exotic species that are monitored as part of this indicator may change over time as new invasive species arrive and others come under control.

To address this challenge, we present an approach that incorporates invasive exotic species monitoring and management into ecosystem restoration programs, focusing on invasive exotic plants and using the 50-year, multi-billion dollar Everglades ecosystem restoration program in southern Florida, USA, as our example. The foundation of our approach is a conceptual model that establishes the framework for evaluating both the impact of invasive exotic plants and our knowledge about that impact on an ecosystem; this model is presented as a companion paper in this special issue (see Doren, Richards and Volin, 2009). The invasive exotic plant indicator we present here is one of an integrated set of eleven ecological indicators developed for Everglades restoration and also presented as companion papers in this special issue. Evaluations of the ecological indicators are based on individual performance measures that are assessed through individualized monitoring programs. Typically, performance measures are specific metrics (e.g. chicks per nest) that have measurable targets (e.g. 2.5 chicks per nest per year) that, when reached, indicate that restoration goals are being met. However, performance measures available for exotic species account only for the numbers of species present and area infested. Targets for invasive exotic species are generally meaningless since there is insufficient science, except for a few species (e.g., melaleuca in South Florida), to be able to set meaningful non-zero targets. As control and monitoring programs continue to collect data on additional species, we may be able to set target levels that account for reductions in exotic species presence – without total eradication – that are documented to result in significant ecological and biological restoration of habitats and communities. Such targets should be able to be documented as meeting biologically meaningful restoration goals (Tipping et al., 2008).

The methods used to collect and analyze the data in each of the indicator programs affect the possible formats that we could use to communicate the results. In recognition of this interrelationship, we developed a methodology for evaluating the invasive exotic plant indicator that is functionally integrated with all the other Everglades ecosystem restoration indicators. We use a communication tool (the stoplight restoration report card) to report the results of this evaluation; this tool reports the status of exotic plant invasions and the results of control and monitoring programs to policy-makers, managers and the public in a meaningful and easily understood format.

2. Indicator development and regions this indicator covers

2.1. Performance measure development

Development of performance measures for the Everglades exotic plant indicator was constrained to the use of information on invasive exotic plants collected by existing monitoring and research. Given the costs of collecting such information, this constraint may be common to other ecosystem restoration programs. Most large managed ecosystems have existing monitoring and management activities, however, and these can provide valuable data to assist in restoration assessments. The challenge in using these data, which are collected for a variety of purposes, is integrating information of different types collected by different groups for different purposes. To aid in this process, we developed and applied the criteria in Table 1 to evaluate data from monitoring programs; we used this evaluation to select programs that could supply appropriate input for an invasive exotics indicator. Using the selection criteria (Table 1) to review the existing monitoring programs for invasive exotic plants in south Florida, it was clear that even using a set of the most comprehensive programs, much less using only a single program, would still not provide an exhaustive, rigorous and geographically inclusive database that met all the criteria (Table 1). While combining several monitoring programs has limitations, other

Table 1 – Criteria that were used to assess the elements of different exotic plant monitoring programs to determine if they would be useful in developing an invasive exotic plant indicator for Everglades restoration

- (1) How many different invasive exotic plant species does the program monitor?
- (2) How large is the geographic coverage of the monitoring program?
- (3) Are new species detectable by this monitoring program?
- (4) Are existing species detectable when they invade previously uninvaded areas or habitats?
- (5) How accurately are the locations and densities of invasive exotic plants able to be determined?
- (6) Can the rate of invasive exotic plant spread be determined?
- (7) Can the effectiveness of control actions/programs for invasive exotic plants be measured using the monitoring program?
- (8) Can the overall spatial extent of the exotics be measured?

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