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Cover: View of Tomales Bay, California, USA, showing tidal reintroduction into previously leveed dairy pastures to restore historic tidelands of the Giacomini Wetlands (credit: Robert Campbell)

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RESEARCH ARTICLE

Tidal marsh restoration stimulates the growth of winter shorebird populations in a temperate estuary

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The regional responses of winter shorebird populations in the nearly 3,000 ha estuary of Tomales Bay, California, to the restoration of 223 ha of historic tidal wetlands were evaluated for 27 years: 19 years prior to tidal reintroduction and 8 years after tidal reintroduction. We used interrupted time series analyses to measure the spatial extent of the restoration effect and to model the magnitude and length of time associated with the gradual, restoration-induced growth of winter shorebird populations in the bay. Expanded, regional benefits of the restoration were revealed by consistent patterns of winter shorebird population growth. Eight years after tidal reintroduction, overall shorebird abundances in southern Tomales Bay nearly tripled in response to the restoration. Substantial winter population growth by most species in southern Tomales Bay was evident within 3 years after tidal reintroduction, and maximum responses to the restoration were estimated to be predominantly achieved within 8 years. In contrast to strong effects of tidal marsh restoration on winter shorebird populations in southern Tomales Bay, no significant overall responses were exhibited by shorebirds in the northern portion of the bay, although marginal evidence of expanded effects on a few species in northern Tomales Bay were suggested. The results illustrate the importance of accounting for restoration effects beyond the spatial and temporal boundaries of the restored habitat, to consider both the potentially expanded benefits and the spatial limits of those benefits to regional wildlife populations.

Key words: estuarine restoration, population dynamics, spatial scale, tidal reintroduction, waders

Implications for Practice

- The sizes of wintering shorebird populations may not be affected by tidal marsh restoration beyond their daily foraging range.
- Wintering shorebird populations within foraging range of a tidal marsh restoration may increase in size within 3 years of tidal reintroduction, with most of the expected increases achieved within the first 8 years.
- The removal of constraints imposed by constructed levees, on tidal flow, freshwater run-off, and estuarine circulation, is likely to enhance winter shorebird numbers in temperate tidal marshes, but the impacts of winter storms may continue to result in midwinter declines in abundance.

Introduction

The success of tidal marsh restoration projects, measured by the numerical and behavioral responses of shorebirds (Scolopacidae, Charadriidae, Recurvirostridae, Haematopodidae), is usually evaluated in the immediate vicinity of the project area (Armitage et al. 2007; Patten & O'Casey 2007; Mander et al. 2013). However, the dynamics of winter shorebird abundances may operate at spatial scales that exceed the boundaries of restoration areas or the supported scope of restoration monitoring (Neckles et al. 2002; Atkinson 2003). Consequently, little is known about the extent to which local tidal marsh restoration efforts lead to the growth of surrounding winter shorebird populations versus opportunistic shifts in local foraging distributions or habitat use.

Shorebird populations at regional and larger scales may be strongly influenced by habitat conditions encountered in wintering and migration-stopover areas (Thomas et al. 2006; Bart et al. 2007; Aharon-Rotman et al. 2015; Xu et al. 2015). The restoration of previously lost or degraded tidal or nontidal wetlands, or the protection of key habitat features in tidal wetlands, have been associated with numerous benefits to wintering shorebirds. These benefits include increases in the extent of suitable foraging areas (Atkinson 2003; Armitage et al. 2007; Patten & O'Casey 2007), including seasonally available habitat (Colwell & Dodd 1995; Warnock & Takekawa 1995); landscape position and proximity to natural wetlands (Brusati et al. 2001; Reiter et al. 2015); increased food supply or availability (Atkinson 2003; Miller & de Rivera 2014); reestablishment of the natural hydroperiod and water levels suitable for foraging (Bellio & Kingsford 2013; Brand et al. 2014); development of roosting opportunities or other conditions that facilitate improved predator avoidance (Rogers et al. 2006; Huang et al.

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