Ecological Engineering 74 (2015) 337–344

Contents lists available at ScienceDirect

Ecological Engineering

journal homepage: www.elsevier.com/locate/ecoleng

# Sea-level rise and refuge habitats for tidal marsh species: Can artificial islands save the California Ridgway's rail?

C.T. Overton [a,*], J.Y. Takekawa [b], M.L. Casazza [a], T.D. Bui [b], M. Holyoak [c], D.R. Strong [d]

[a] U.S. Geological Survey, Western Ecological Research Center, Dixon Field Station, 800 Business Park Drive, Suite D, Dixon, CA 95620 USA
[b] U.S. Geological Survey, Western Ecological Research Center, San Francisco Estuary Field Station, 505 Azuar Drive, Vallejo, CA 94592 USA
[c] Department of Environmental Science and Policy, University of California – Davis, 1 Shields Avenue, Davis, CA 95616 USA
[d] Department of Ecology and Evolution, University of California – Davis, 1 Shields Avenue, Davis, CA 95616 USA

ARTICLE INFO

*Article history:*
Received 8 June 2014
Received in revised form 22 September 2014
Accepted 6 October 2014
Available online 7 November 2014

*Keywords:*
Artificial habitat
Camera
Ridgway's rail
Limitation
Sea level rise
Saltmarsh
*Rallus obsoletus obsoletus*

ABSTRACT

Terrestrial species living in intertidal habitats experience refuge limitation during periods of tidal inundation, which may be exacerbated by seasonal variation in vegetation structure, tidal cycles, and land-use change. Sea-level rise projections indicate the severity of refuge limitation may increase. Artificial habitats that provide escape cover during tidal inundation have been proposed as a temporary solution to alleviate these limitations. We tested for evidence of refuge habitat limitation in a population of endangered California Ridgway's rail (*Rallus obsoletus obsoletus*; hereafter California rail) through use of artificial floating island habitats provided during two winters. Previous studies demonstrated that California rail mortality was especially high during the winter and periods of increased tidal inundation, suggesting that tidal refuge habitat is critical to survival. In our study, California rail regularly used artificial islands during higher tides and daylight hours. When tide levels inundated the marsh plain, use of artificial islands was at least 300 times more frequent than would be expected if California rails used artificial habitats proportional to their availability (0.016%). Probability of use varied among islands, and low levels of use were observed at night. These patterns may result from anti-predator behaviors and heterogeneity in either rail density or availability of natural refuges. Endemic saltmarsh species are increasingly at risk from habitat change resulting from sea-level rise and development of adjacent uplands. Escape cover during tidal inundation may need to be supplemented if species are to survive. Artificial habitats may provide effective short-term mitigation for habitat change and sea-level rise in tidal marsh environments, particularly for conservation-reliant species such as California rails.



## 1. Introduction

Animals living in seasonal or otherwise variable environments often experience temporary limitation in resources leading to reduced survival or reproduction (Elton, 1927; Fretwell, 1972; Payne and Wilson, 1999). These critical periods may create short-term population bottlenecks that influence population dynamics, particularly when seasonal resource limitation increases intra-specific competition or predation (Ekman, 1984; Roy and Thomas, 2003). Resource supplementation using artificial structures is common practice in conservation, particularly for management of birds and game species (Hinsley and Bellamy, 2000; Stoate and Szczur, 2001). Artificial structures are credited with increasing populations of waterfowl, osprey (*Pandion haliaetus*), and cavity nesting birds through provision of nest sites (Corrigan et al., 2011; Ewins, 1996; Newton, 1994). Management of Light-footed Ridgway's Rail (*Rallus obsoletus levipes*; formerly Light-footed clapper rail, *Rallus* longirostris levipes Chesser et al., 2014) in Southern California involves floating nest structures to augment reproduction (Zembal, 1990).

Artificial habitats have also been constructed to improve species' survival rates in a variety of terrestrial and aquatic environments. Artificial floating islands are being used to increase water quality and enhance biodiversity (Chang et al., 2014). Artificial floating islands provided as nesting substrate are also used to improve recruitment of black–throated loon (*Gavia arctica*) in Scotland, red–throated loon (*Gavia stellata*) in Finland, and were associated with greater hatching success of Black Terns (*Chlidonias niger*) in Wisconsin (Hancock, 2000; Nummi et al., 2013; Shealer et al., 2006). Hedgerows providing escape cover often increase

* Corresponding author. Tel.: +1 530 669 5083; fax: +1 707 678 5039.
*E-mail address:* coverton@usgs.gov (C.T. Overton).

http://dx.doi.org/10.1016/j.ecoleng.2014.10.016
0925-8574/Published by Elsevier B.V.

survival of game birds species and promote greater bird abundance and diversity (Hinsley and Bellamy, 2000). Cottontail rabbits (*Silvilagus* sp.) and snowshoe hare (*Lepus americanus*) used supplemental refuge habitats heavily, but with no apparent change in survival rates (Cox et al., 1997). Artificial rocks increased survival and abundance of velvet geckos (*Oedura lesueurii*; Croak et al., 2013). Artificial nesting mounds were used more than expected by freshwater turtles as nesting substrate and nests on artificial mounds had greater hatching success than natural nests (Paterson et al., 2013). Artificial sea grass habitats decreased efficiency of predators and increased survival of juvenile walleye pollock (*Theragra chalcogramma*) (Heck and Thoman, 1981; Manatunge et al., 2000; Sogard and Olla, 1993). Rearing fish in artificially vegetated hatchery pools may increase survival after stocking (Einfalt et al., 2013). Submerged reef structures may be the most globally widespread artificial habitat enhancement (Seaman, 2000). As a management tool, artificial habitats may be a more attractive option than restoration of natural habitat due to the relative flexibility of implementing actions and the immediacy of resultant change in habitat condition or characteristics. However, artificial habitats may also create ecological traps if predators cue into them and increase their overall capture efficiency (Shochat et al., 2005). Alternatively, avoidance of artificial habitats by target species may result in no net population change and result in costly conservation actions with no tangible results (Smith and Rule, 2002).

The consequences of climate change, particularly sea level rise, are likely to decrease the ability of natural habitats to provide salt marsh species with refuge cover. Much of the California coast is projected to experience 42 –167 cm of sea level rise this century (National Research Council, 2012). The natural processes that maintain zones of marsh vegetation, accretion of sediment and organic matter, are not likely to keep pace with this rise. In San Francisco Bay 96% of the tidal marsh is projected to convert to mudflat by 2100 (Takekawa et al., 2013). Saltmarsh habitats which do remain will be more frequently inundated and by higher water levels, jeopardizing terrestrial intertidal species that are unable to cope with the combined effects of habitat loss, habitat conversion, and compression of the vegetated zone between hardscaped (e.g., levees) upper boundaries and rising tides (Erwin et al., 2006; Flick et al., 2003). San Francisco Bay currently contains the greatest amount of estuarine saltmarsh along the Pacific Coast (Josselyn, 1983; Nichols et al., 1986) despite the loss, fragmentation, or conversion of 80% of this critical habitat (Takekawa et al., 2006). Historic filling and urban expansion from adjacent upland habitats are likely to have affected the highest elevation marshlands, resulting in disproportionate loss of historic tidal refuge habitat and leading to the potential shortage of contemporary refuge habitat (Overton et al., 2014). Lack of tidal refuge habitat is particularly problematic for species like the California Ridgway's rail (*R. obsoletus* obsoletus; formerly *R. longirostris* obsoletus, the California clapper rail Chesser et al., 2014; hereafter California rail) and California black rail (*Laterallus jamaicensis coturniculus*) that have small ranges and highly fragmented populations.

**Fig. 1.** Photograph of floating artificial island. Floating artificial islands made of a recycled plastic polymer and high density foam were installed at Arrowhead Marsh, Oakland, CA in September 2010 and monitored using time elapse and motion triggered cameras through March 2012. Woven palm leaves attached to a PVC frame provided vertical and lateral cover. Each island was anchored just off the marsh plain using augur anchors and braided nylon rope of sufficient length to allow floatation during maximum tide heights (2.5 m). Water level in photo is approximately 1.2 m for comparison.

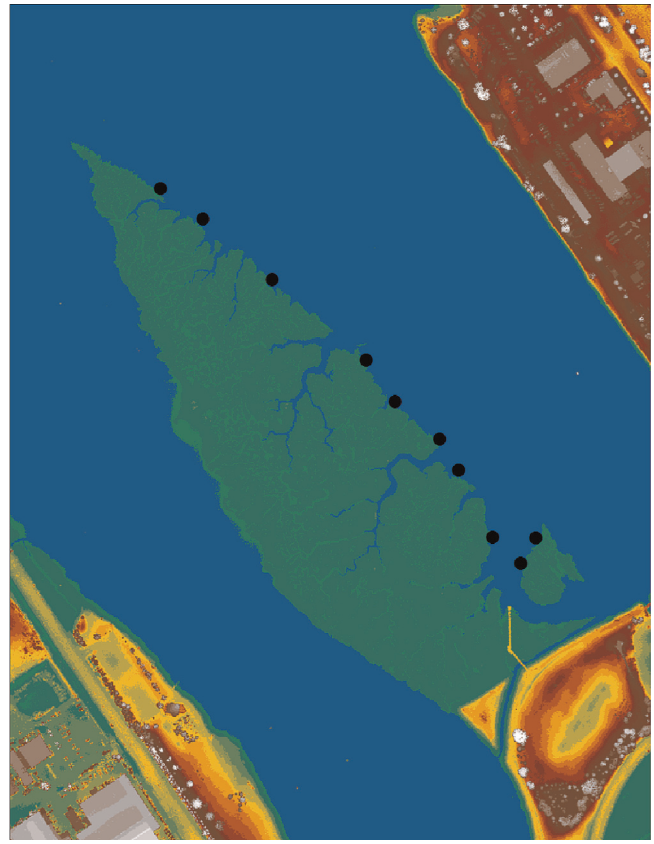

**Fig. 2.** Map depicting locations of floating artificial islands. Ten floating artificial islands (black circles) were deployed on the northeastern shoreline of Arrowhead Marsh in San Leandro Bay Oakland, California in September 2010. Ground elevations below mean sea level indicated in blue, and above mean higher high water in yellow to white.

The California rail is particularly sensitive to availability of tidal refuge habitats. The state and federally endangered California rail is a tidal-marsh obligate species that inhabits primarily lower elevation tidal salt and brackish marshes in San Francisco Bay California (Albertson and Evens, 2000; Gill, 1979) and is dependent on refuge cover during high tides for protection from predation. Habitat loss and fragmentation are the major contributors to California rail endangerment (Albertson, 1995; U.S. Fish and Wildlife Service, 2010). Radio-telemetry studies found that California rail survival rates were lowest when tide heights were greatest and during the winter when much of the intertidal vegetation used as refuge habitat (e.g., *Spartina* sp.) had senesced (Albertson, 1995; Overton et al., 2014). An invasive hybrid plant, *Spartina foliosa x alterniflora*, which grows taller and more densely than native vegetation, increased California rail survival rates