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Conservation planning for climate change vulnerability across the islands of the Californias

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ABSTRACT.—Climate change poses threats to island ecosystems worldwide. Despite widespread recognition of the significance of islands in the global biodiversity extinction crisis, comprehensive climate vulnerability assessments and adaptation strategies for islands remain limited. Here, we present the outcomes of a climate vulnerability planning workshop for the loose archipelago of islands of California (USA) and Baja California (Mexico). Scientists and resource managers engaged in discussions to identify climate sensitivities and suggest management actions using the Resist-Accept-Direct (RAD) framework. Breakout sessions identified widespread climate-driven impacts on the islands of the Californias, including habitat loss, population declines, invasive species impacts, impaired ecosystem function, phenological mismatch, and range shifts/contractions. Participants proposed a suite of management actions that could improve climate resilience, including bolstering existing populations and habitats, translocating species, reducing risk of fire, controlling invasive species, and creating refugia. Although participants expressed more confidence in actions designed to resist the effects of climate change, the workshop provided a venue to discuss implications of directing ecosystems along new trajectories and accepting changes that managers are unwilling or unable to prevent. The workshop facilitated discussions that transcended individual islands, scientific disciplines, and land management entities, and contributors produced a suite of "no regrets" actions that managers can implement immediately, even in the face of uncertainties. We highlight the value of collaboration in planning and implementing responses to climate change and discuss next steps in the adaptive management of this globally significant archipelago.

RESUMEN.—El cambio climático representa amenazas para los ecosistemas insulares a nivel mundial. A pesar del amplio reconocimiento de la importancia de las islas en la crisis global de extinción de biodiversidad, las evaluaciones integrales de vulnerabilidad al cambio climático y las estrategias de adaptación para las islas continúan siendo limitadas. En este trabajo presentamos los resultados de un taller de planificación de vulnerabilidad climática para el archipiélago disperso de las islas de California (en Estados Unidos) y Baja California (México). Los científicos y gestores de recursos participaron en discusiones con el objetivo de identificar las sensibilidades climáticas y sugerir acciones utilizando el marco Resistir-Aceptar-Dirigir (RAD, por sus siglas en inglés). En las sesiones de trabajo se identificaron los impactos generalizados impulsados por el clima en las Islas de las Californias, incluyendo la pérdida de hábitats, el declive de las poblaciones, los impactos de las especies invasoras, el deterioro de la función del ecosistema, el desajuste fenológico y los cambios/contracciones en el área de distribución de las especies. Los participantes propusieron acciones de gestión que podrían mejorar la resiliencia climática, incluyendo el fortalecimiento de las poblaciones y hábitats existentes, la translocación de especies, la reducción del riesgo de incendios, el control de las especies invasoras y la creación de refugios. Aunque los participantes expresaron mayor confianza en las acciones diseñadas para resistir los efectos del cambio climático, el taller brindó un espacio para discutir las implicaciones de dirigir los ecosistemas hacia nuevas trayectorias y de aceptar cambios que los gestores no están dispuestos o no pueden prevenir. El taller facilitó discusiones que trascendieron las islas individuales, las disciplinas científicas y las entidades de gestión de tierras, y produjo un conjunto de acciones "sin arrepentimientos" que los gestores pueden implementar de forma inmediata, incluso frente a las incertidumbres. Destacamos el valor de la colaboración en la planificación e implementación de respuestas al cambio climático y discutimos los próximos pasos en la gestión adaptativa de este archipiélago de importancia global.

Understanding the direct and indirect ecological effects of climate change is essential for conservation planning, i.e., setting natural resource management goals and developing strategies to achieve them (Foden et al. 2019). Climate change vulnerability assessments are a

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common tool used in estimating and evaluating those effects. Vulnerability assessments aim to identify current climate change impacts and project future conditions, providing a range of possible outcomes that managers can use as a foundation to identify, prioritize, and implement appropriate management actions for conservation (Glick et al. 2011). The first step in an assessment involves identifying potential impacts based on exposure (the magnitude or rate of change that a species or system will experience) and sensitivity (the system's innate ability to tolerate change) (IPCC 2007, 2014, Dawson et al. 2011, Foden et al. 2013). Sensitivity and adaptive capacity, which is the ability of a species or system to adapt to climate change impacts, are then examined to provide an overall understanding of vulnerability (IPCC 2007, 2014). Climate change vulnerability assessments can be applied across ecological scales and allow flexible approaches that can vary depending on the scope of the assessment and data availability. Climatological projections can be linked with existing data on species' distributions and biological processes to inform likely impacts (Rowland et al. 2011, Foden and Young 2016). However, expert opinion is also valuable, particularly when models and data are unavailable (Case et al. 2015).

Vulnerability assessments generally enter the conservation planning process between gathering knowledge and taking action (Pacifici et al. 2015). However, even with a relatively good understanding of current and near-term vulnerabilities, conservation decision-makers can find it difficult to set long-term goals for ecosystems in rapid transition toward uncertain new states. Land managers increasingly report that traditional planning paradigms that aim to restore ecosystems toward historical baselines are no longer adequate to address the challenges presented by climate change (Lynch et al. 2021, Dunham et al. 2022). Responding to this universal challenge, the U.S. National Park Service and partners developed a climate planning tool for framing the decision-making space that managers encounter when grappling with uncertainty and limited resources: the Resist-Accept-Direct (RAD) triad (Schuurman et al. 2020). When using this framework to address climate vulnerabilities, managers can choose actions that "Resist" the trajectory of change, "Direct" the trajectory toward desired new conditions, or "Accept" change by choosing not to intervene.

Climate Vulnerability Planning on Islands

Climate change poses a significant threat to island ecosystems and biodiversity around the world, often compounding the impacts of invasive species and habitat degradation (Veron et al. 2019). Yet predicting climate change impacts on islands can be especially difficult. A lack of downscaled data at appropriate scales, coupled with highly variable, pronounced, and often difficult-to-model marine influences, increases uncertainty in projections. As a result, few vulnerability assessments have been conducted on island systems outside of socioeconomic evaluations, even though there is a recognized, urgent need for frameworks that can help island managers prioritize action in the face of uncertainty (Zulhaimi et al. 2023).

Islands present unique contexts for climate change planning, with many distinct challenges and opportunities for management. Because islands are spatially segregated and their natural communities have evolved with some degree of isolation, island ecosystems are often less diverse than mainland systems and are associated with high rates of endemism and threatened species (Kier et al. 2009, Tershy et al. 2015). Island species may be dispersal limited and thus constrained in their ability to shift their ranges to track suitable climate conditions (Harter et al. 2015). However, climate impacts may vary within islands, especially on those with marked topographic variability, creating the potential for microclimatic refugia (Hannah et al. 2014, Harrison and Noss 2017, Cartwright 2019). Island ecosystems may also be amenable to management actions that remove other key stressors, such as the eradication of invasive species (McLaughlin et al. 2022, Spatz et al. 2022), as well as to interventions that restore habitat and species, such as reintroducing seabirds (Spatz et al. 2023)—all of which may have the added benefit of increasing climate change resilience (Spatz et al. 2017).

The loose island archipelago of Alta and Baja California (USA and Mexico, respectively; Fig. 1) hosts a globally significant diversity of species (McEachern et al. 2016). Despite having similar ecological characteristics, human histories, and anthropogenic threats (Rick et al. 2014), the islands of the Californias (hereafter, the California Islands) lack an archipelago-wide assessment of climate change exposure, vulnerability, or opportunity for action, which has limited planning at scales beyond that of the

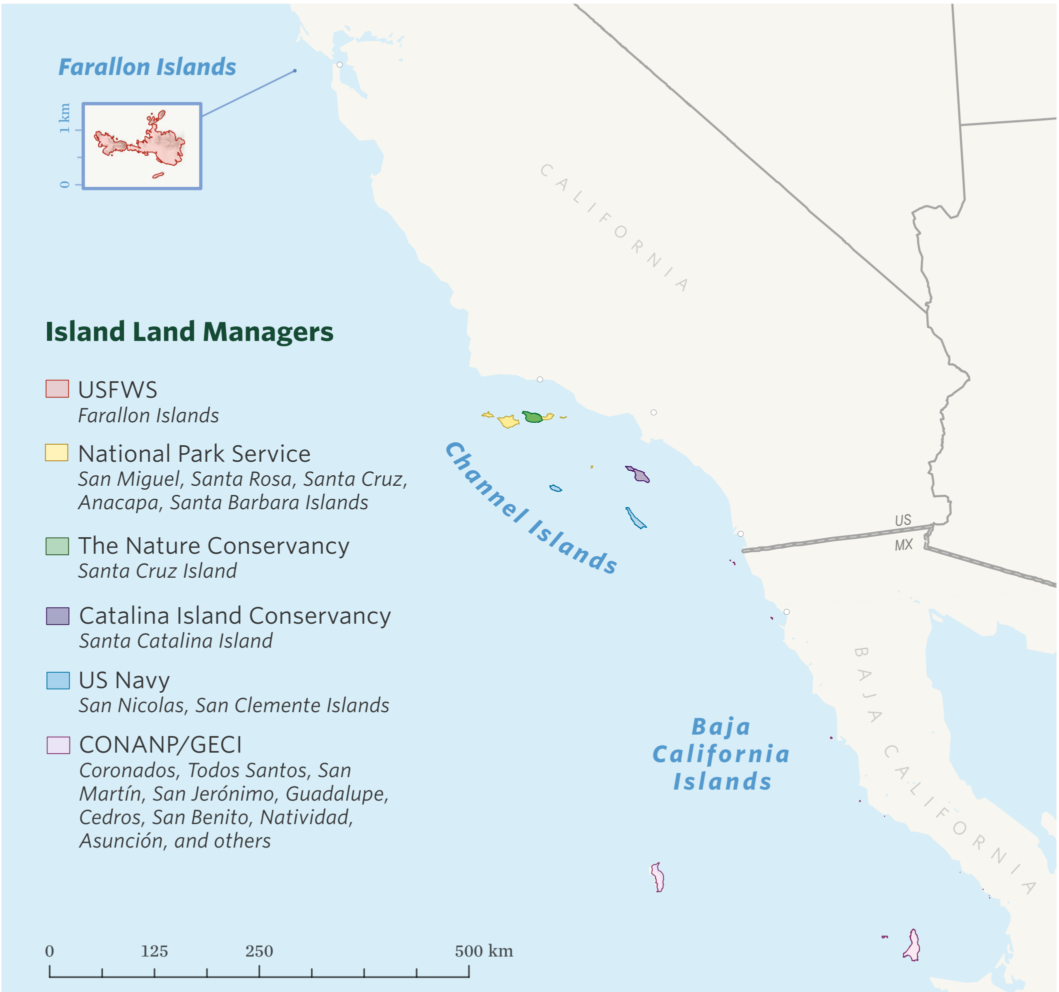

Fig. 1. Map of the California Islands (as defined herein) and their primary land managers.

individual island managers (e.g., Gonzalez 2020, Clemesha et al. 2021). While island-specific plans will certainly be critical for effective conservation management, especially for taxa with highly restricted ranges and limited dispersal ability, an evaluation at the multi-island scale is ecologically intuitive given the many shared habitats, species, processes, and threats. For example, there may be opportunities to set conservation goals at an archipelago scale: perhaps a species is projected to be less vulnerable on one island than elsewhere in its range, and a multi-island context can provide opportunities for conservation translocations. A shared understanding of climate change impacts on conservation priorities across the system may also illuminate opportunities for collaborating, finding efficiencies in management, and synergizing efforts across islands and land management units.

To that end, we convened a workshop of California Island managers and researchers to discuss climate vulnerability planning for the archipelago and seek opportunities for cross-island collaboration in analysis, planning, and action. Here, we present outcomes from that workshop, which include a preliminary assessment of climate exposure, sensitivity, and overall vulnerability across the archipelago, as well as a candidate set of management actions that could be prioritized by managers. We also describe the general method we used to facilitate the group and assessment, as it may provide a template for generating rapid progress toward preliminary climate vulnerability plans in other systems.

METHODS

Study System

The climate change planning workshop was aimed at scientists and conservation practitioners who work on the California Islands, which include the Farallon Islands near San Francisco Bay, the Channel Islands in the Southern California Bight, and the Pacific Islands off Baja California in Mexico (Fig. 1). These islands span approximately 1300 km from their northernmost to southernmost points, but many share species (including island endemics), habitat types (especially those in the California Floristic Province), and conservation agendas. The California Islands are managed by 7 major landowners. In the United States, islands are managed by the Fish and Wildlife Service (Farallon Islands), the National Park Service (San Miguel, Santa Rosa, Anacapa, Santa Barbara, and the eastern 24% of Santa Cruz Island), The Nature Conservancy (the western 76% of Santa Cruz Island), the Catalina Island Conservancy (88% of Santa Catalina Island), and the U.S. Navy (San Nicolas and San Clemente Islands). Islands in Mexico are managed by the Comisión Nacional de Áreas Naturales Protegidas (CONANP), in conjunction with the Grupo de Ecología y Conservación de Islas (GECI). Because the scope of the workshop spanned a large geographic area and diversity of landowners, we chose a more narrow focus of climate change impacts on resources that were (1) shared across the archipelago; (2) terrestrial or coastal (i.e., not marine); and (3) native habitats and species (i.e., not anthropogenic infrastructure or resources).

Climate Change in the California Islands

Prior to the workshop, we conducted a literature search to identify the primary drivers of climate change likely to affect the California Islands in the future: rising temperatures, increasing variability in precipitation/water availability, increasing fire severity and frequency, sea-level rise, and altered marine influences (including rising sea surface temperatures, variability in the El Niño–Southern Oscillation (ENSO), ocean acidification, and changes in upwelling). The California Islands are already experiencing deviations from historic patterns of interannual variability, making climate predictions difficult. Furthermore, mainland datasets typically used to understand climate change impacts in this region of North America often exclude the California Islands, especially smaller islands. However, an understanding of the range of potential scenarios can be used to identify a suite of management actions to take in preparation.

The California Islands occupy a large latitudinal range, but generalized climate impacts are summarized as follows. The California Islands are projected to experience increases in daily temperatures and greater frequency of extreme heat events, although expected maximum temperatures differ across models and islands (Gonzalez 2020). Water availability is expected to become much more variable, with swings between extreme precipitation events and increased drought severity and duration (Gonzalez 2020). Changes to fog patterns (frequency, duration, and location) are also likely to occur, which can impact temperature ranges, humidity, availability of microclimates, and ecosystem services (Clemesha et al. 2021). Fire prevalence and severity will differ between climate scenarios, although an overall increase is likely, especially in the northern islands (Batllori et al. 2013, Westerling 2018). Most of the California Islands are topographically complex and are not expected to lose a significant proportion of their land area to sea-level rise (Barnard et al. 2018). However, low-lying areas—including rare and sensitive habitats like wetlands and sea caves—will be especially vulnerable to flooding, storm surges, and erosion (Pendleton et al. 2010). Sea surface temperature is expected to increase, leading to more powerful marine storms, while ocean pH and productivity are both expected to decrease, the latter caused by predicted shifts in upwelling and ENSO patterns in the California Current ecosystem (Doney et al. 2012, Bakun et al. 2015, Pozo Buil et al. 2021). These possible climate impacts in the California Islands are summarized in Table 1.

Workshop Structure

The climate change planning workshop was held on 6 November 2023, at the 10th California Islands Symposium (henceforth, the Symposium) in Ventura, CA. The Symposium is a longstanding, quadrennially recurring meeting of island natural resource managers, scientists, and stakeholders. While some portions of the workshop were open to all Symposium attendees, we also conducted targeted outreach to encourage participation from

TABLE 1. Relevant climate drivers in the California Islands and a range of possible exposures that may result through the year 2100.

CA Islands Climate Driver	Possible Exposures (1980–2100)
Temperature	Increase in average daily temperatures across all seasons (+1–3 C) Increase in average daily maximum temperature (+ 1–2.5 C) Increase in extreme heat days above the historical 99th percentile
Freshwater Availability	Increase in average annual precipitation by ~5 cm (Warm/Wet future) Decrease in average annual precipitation by ~10 cm (Hot/Dry future) Increase in number of extreme rainfall days above the historical 95th percentile Increase in 50-year storm interval Increase in drought duration, intensity, frequency, and severity Increase in interannual variability in precipitation Decreased overall fog cover and altered fog patterns Increase in summer precipitation Decrease in average relative humidity and soil moisture content
Sea Level Rise	Increase in erosion rates near coastal areas Inundation of low-lying areas 0.5–1.5 m above current sea level More severe storm surges Saltwater intrusion in coastal water sources
Fire	Increase in number of high fire danger days per year Increase in fire return interval Increase in average fire intensity and total area burned Entire island burns from shore to shore Change in wind patterns that facilitate fire spread and persistence Decrease in average relative humidity
Marine	Increase in average sea surface temperatures More frequent and more severe marine heat waves Changes to upwelling patterns Decrease in pH of seawater Increased likelihood and intensity of tropical cyclones

key decision-makers, land managers, researchers, stewards, and climate experts. Ultimately, 163 individuals from 50 organizations (including governmental agencies, universities, for-profit organizations, and nonprofit organizations) registered for the workshop (see Supplementary Material 1 for a list of organizations represented).

Prior to the start of the workshop, we asked registrants to complete a short online survey intended to help us tailor the program to attendees' needs and backgrounds. A total of 74 of 163 registrants (45%) completed the survey. Participants who completed the survey reported having worked on the California Islands for between 3 months to 55 years, and the median duration of work experience on the islands was 11 years. Most of the participants worked on the Northern and/or Southern Channel Islands (79% and 61%, respectively), while fewer participants reported working on the Baja California islands (11%) or Farallon Islands (9%). We also asked registrants the following open-ended questions: "In what ways has climate change most visibly impacted your work on the California Islands?" and "What are the biggest areas of uncertainty that currently limit your ability to plan for climate

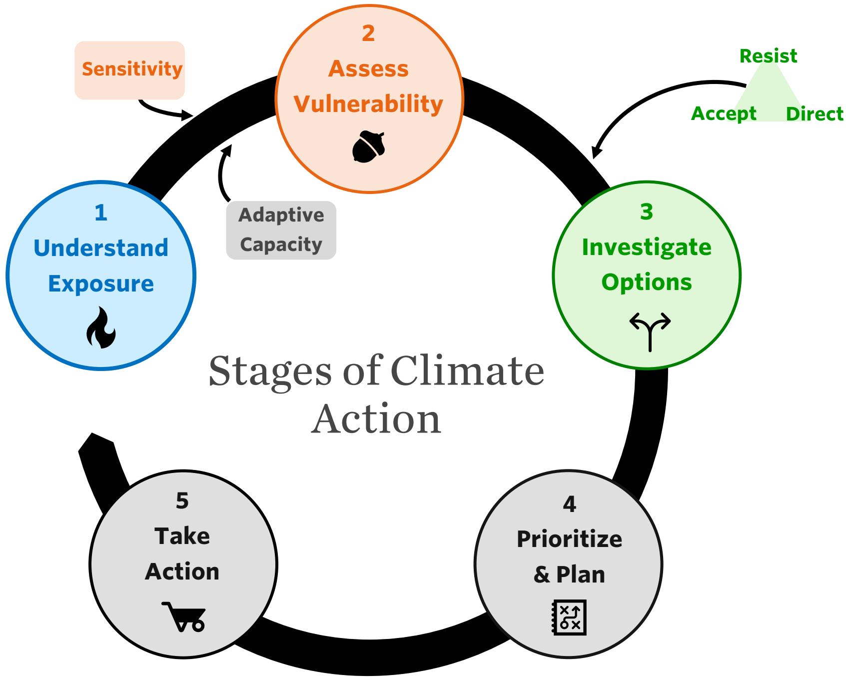

Fig. 2. The 5 stages of climate action, modified from Gardiner et al. (2022). At the workshop, step 1 ("Understand Exposure") took the form of a series of presentations by climate experts outlining likely climate exposures relevant to the California Islands. In step 2 ("Assessing Vulnerability"), participants in breakout groups developed a list of relevant climate sensitivities. Adaptive capacity was not considered due to limited available time and a lack of empirical data available for most focal natural resources. In step 3 ("Investigating Options"), participants used the Resist-Accept-Direct triad to brainstorm a list of possible management actions to address important climate sensitivities. Steps 4 and 5 were outside of the scope of the day-long workshop.

change impacts on the California Islands?" Results of those questions are summarized and reported in Supplementary Material 1.

The structure of the workshop was drawn from recommendations outlined in *Implementing the Steps to Resilience: A Practitioner's Guide*, a guidebook for climate change planning for vulnerable communities and ecosystems (Gardiner et al. 2022). During the day-long workshop, we facilitated an accelerated walkthrough of the first 3 steps of the guidebook (Fig. 2).

During step 1 ("Understand Exposure"), we aimed to foster a shared understanding of current and future climate change impacts to California Islands resources. To that end, we invited expert speakers to present talks and serve on a panel covering (1) historical, contemporary, and projected climate trends for the islands; (2) available datasets and planning tools; and (3) possible mitigation/management options for a variety of climate hazards, including hydroclimate whiplash (i.e., abrupt shifts between wet and dry extremes), increasing temperatures, ocean variability, changes to fog and fire regimes, and sea-level rise.

Following the presentations, we led participants through steps 2 ("Assessing Vulnerability") and 3 ("Investigating Options"). Prior to the workshop, selected attendees were asked to serve as group facilitators and received training on climate vulnerability assessments and the Resist-Accept-Direct Framework. Participants separated into 9 breakout groups with between 9 and 12 members each, including one trained facilitator and one notetaker. Breakout groups were organized around the following pre-identified, shared natural resources with known climate change vulnerabilities: (1) Grasslands and Coastal Scrub; (2) Native Mammals; (3) Oaks and Conifers; (4) Intertidal Communities; (5) Seabirds; (6) Island Chaparral and Woodland; (7) Rare Plants; (8) Landbirds; and (9) Herpetofauna (see Supplementary Material 1 for a list of participants in each working group). Two groups (Rare Plants and Landbirds) chose to focus on a single, highly vulnerable taxon: island ironwood (*Lyonothamnus floribundus*) and Loggerhead Shrikes (*Lanius ludovicianus* ssp.), respectively. Other breakout groups chose broad definitions of their resource that included a variety of species within each system.

Each breakout group received an information packet that included definitions of climate drivers (see Table 1), maps of sea-level rise scenarios, climate and precipitation predictions, and fog/marine layer trends for the California Islands. Notetakers transcribed key points into a worksheet that provided structure and guidance to facilitators leading the discussion (see Supplementary Material 1 for the worksheet template with detailed instructions). Within their breakout groups, participants jointly brainstormed (1) desired future conditions for their resource; (2) key sensitivities to climate drivers; (3) major uncertainties that influence decision-making; and (4) management actions to Resist, Accept, or Direct the impacts of climate change for the resource under discussion. We also asked participants to highlight "no regrets" management actions that could be pursued immediately, regardless of continued climate uncertainty. In this brainstorming phase, facilitators guided discussion away from possible financial, regulatory, or bureaucratic constraints that could impede management actions, and toward open consideration of all options, regardless of novelty or feasibility. After the workshop, we summarized the results of the breakout group brainstorming session using the worksheets provided by each group's notetaker, requesting clarification from group facilitators where needed.

Results

Assessing Vulnerability

In total, breakout group participants developed a list of 56 sensitivities likely to be experienced by their focal natural resources. Across groups, common trends in sensitivities emerged, which we categorized as follows: (1) habitat loss; (2) species declines, extirpations, and extinctions; (3) invasive species impacts; (4) impaired ecosystem function; (5) phenological mismatch; (6) range shifts and contractions; and (7) pathogen susceptibility. Key points discussed in each group are briefly summarized in the narrative below and in Table 2; complete summarized results can be reviewed in the Supplementary Material 1, while specific notes from each breakout group can be viewed on the California Islands website (https://www.californiaislands.net/tnc-workshop-1).

Habitat loss.—Many of the California Islands have experienced rapid recovery of sensitive habitats following the removal of feral ungulates (e.g., Beltran et al. 2014). However, participants noted that in some cases, climate change had begun to slow or even undo the habitat gains realized in previous decades. All breakout groups independently highlighted high-intensity, high-frequency fires that could burn through critical habitat and prevent recovery as a possible outcome of concern across the California Islands (Oberbauer et al. 2009, Jacobsen et al. 2018). Relatedly, habitat erosion brought on by fire, drought, storms, sea-level rise, and the continued legacy of overgrazing was universally identified as an important issue limiting the recovery of habitat on the California Islands (Chaney and McEachern 2000, Jazwa and Johnson 2018).

Species decline, extirpation, and extinction.—Long-term monitoring datasets collected and evaluated by California Islands researchers have identified species declines that can be attributed, at least in part, to the effects of climate change (Kushner et al. 2013, Anderson et al. 2017). A reduction in available resources caused by drought was widely thought to limit reproduction, recruitment, and survival among vulnerable species like the Channel Islands fox (*Urocyon littoralis*; Bakker et al. 2021). Many practitioners reported observing direct mortality from high temperatures in their study system (e.g., crops of oak [*Quercus* spp.] acorns desiccated during a period of extreme heat). Participants also outlined scenarios in which stochastic events could eliminate small populations of endemic species like the island malacothrix (*Malacothrix squalida*), which is so limited in range that it could be destroyed by a single fire, landslide, or storm surge (McEachern et al. 2009a).

Invasive species impacts.—Impacts from established invasive species, in addition to the risk of new human-aided incursions, are a common concern across the California Islands, and their impacts can be amplified through complex interactions with climate change (Donlan et al. 2003, Boone and McCleery 2023). Participants noted that often, novel climatic conditions favor invasive species over native species, as the former may be better adapted to cope with climate change outcomes like frequent disturbance, extreme temperatures, and atypical summer precipitation (Russell et al. 2017). In

TABLE 2. The most commonly discussed climate sensitivities among 8 breakout groups and related climate exposure types (in color; less relevant exposure types in light gray). From left to right, icons represent temperature (red), water availability (dark gray), sea-level rise (blue), fire (orange), and marine influences (green). *n* = the total number of independent breakout groups that discussed each sensitivity.

Sensitivity	Examples	Exposures	*n*
Habitat Loss	Erosion of critical habitat		8
	Increased fire frequency prevents habitat recovery		8
Species Decline, Extirpation, and Extinction	Direct mortality from high temperatures and low water availability		7
	Reduced recruitment and survival caused by resource limitations		6
	Small populations extirpated by stochastic events		6
Invasive Species Impacts	Novel climatic conditions and increased disturbance favor invasive species		6
Impaired Ecosystem Function	Reduced summer fog and loss of vegetation leads to reduction in fog capture		5
	Loss of biodiversity as sensitive/specialized species are extirpated		5
Phenological Mismatch	Early, late, or missed cues for germination, flowering, fruiting, and reproduction		5

particular, multiple breakout groups independently discussed the ways in which drought intensifies competition between invasive and native species by limiting the resources available to either (Levine et al. 2010), and how annual grasses and other invasive plant matter fuel fires that may have burned at lower intensities in habitats dominated by native plants (Knapp 2014).

IMPAIRED ECOSYSTEM FUNCTION.—Climate change will continue to alter and inhibit key ecosystem processes at work in the California Islands. Across groups, participants expressed concern about reduced ecosystem resiliency caused by loss of functional roles as climate-vulnerable species decline or become extirpated from the islands. In particular, many groups identified fog capture as a critical ecosystem process in the California Islands, particularly during drought and dry summer months when other forms of precipitation fall to near zero. A reduction in summer fog, and mortality of plants like bishop pines (*Pinus muricata*) with necessary vegetative structures to capture fog and convert aerosolized droplets into usable water (Taylor et al. 2019, Clemesha et al. 2021), was thought to be a crucial point of sensitivity across habitats and species groups.

Phenological mismatch.—Island flora and fauna have evolved to synchronize events in their life cycles with those of closely linked species and with the timing of favorable environmental conditions (Harter et al. 2015). Participants widely noted that climate change had led to early, late, or missed reproductive cues in some organisms (e.g., spring nights that are now too warm to induce germination in the island-endemic softleaf paintbrush, *Castilleja mollis*; McEachern et al. 2009b). As productive seasons are delayed, shortened, or fail completely, animal life cycles become out of sync with the timing of dietary resource availability, leading to observed disruptions in migrations, recruitment failures, and mass mortality among sensitive species like the California Brown Pelican (*Pelecanus occidentalis californicus*; Jaques et al. 2016).

Range shifts and contractions.—California Island species are likely to shift their ranges to some extent to cope with novel environmental conditions (Lenoir et al. 2020). However, limited elevational gradients, steep topography, and restricted total land areas bounded by ocean were all thought to impede the ability of vulnerable species to migrate to more suitable climates within and across islands (Butt et al. 2021). Across breakout groups, participants expected to see sensitive species contract in range to climate refugia like north-facing slopes and deep drainages to avoid hotter and drier microclimates. Participants also speculated that species sensitive to salinity (like amphibians) may follow the saltwater gradient inland as sea-level rise proceeds, while mobile organisms like seabirds may migrate to northern islands as the climate envelopes shift (indeed, this has already been observed—tropical Blue-footed and Brown Boobies [*Sula* spp.] have begun to nest off the coast of Santa Barbara Island [Howard et al. 2024]).

Pathogen susceptibility.—Climate change can interact with and amplify the negative effects of disease-causing pathogens in sensitive island ecosystems (Buttke et al. 2021). Participants consistently noted that individuals stressed by extreme environmental conditions become more susceptible to disease (e.g., bishop pines succumb to infestation by a native bark beetle after prolonged drought [Fischer et al. 2009]). Many of the downstream effects of climate change (including rising temperatures, unseasonal precipitation, and overcrowding due to habitat loss) combine to create conditions that encourage disease transmission (Ben-Horin et al. 2013); for example, warming conditions may increase the prevalence of mosquito-vectored pathogens such as West Nile virus, which can have significant adverse effects on some bird taxa (Bakker et al. 2020).

Investigating Options

During the final stage of the workshop (step 3), breakout groups brainstormed options for management actions that could be considered to address climate vulnerabilities identified in step 2. Participants then evaluated whether each potential action could be considered part of a "Resist," "Accept," or "Direct" strategy for addressing climate change on the islands. Finally, participants highlighted "no regrets" actions that would benefit California Islands ecosystems regardless of which climate scenario materializes (i.e., actions that can be initiated immediately despite uncertainty). During this session, participants identified 84 management actions that island managers could consider to directly respond to climate sensitivities experienced by their natural resource of interest. We categorized these actions as follows: (1) bolster existing populations/habitats; (2) translocation/assisted migration; (3) reduce risk of catastrophic fire; (4) prevent and control invasive species; (5) protect and create refugia; (6) ex-situ species management; (7) genetic management; (8) manage food, cover, and water for wildlife; and (9) reduce human impacts. Common results across breakout groups are summarized in narrative form below, with the relevant RAD strategies for each tactic shown in parentheses. Fig. 3 also provides an illustrative example of the Resist-Accept-Direct framework as applied to a climate-sensitive resource on Santa Cruz Island: the bishop pine community. Complete results can be reviewed in Supplementary Material 1 and on the California Islands website (https://www.californiaislands.net/tnc-workshop-1).

Bolster/enhance existing populations and habitats.—Tethering restoration targets to historical conditions may no longer be possible or practical in the face of climate change; however, traditional habitat management actions can still improve climate resilience in island ecosystems by introducing redundancy, protecting key ecosystem processes, and reducing multiplicative stressors. Preventing erosion by installing structures that stabilize soil, slow runoff, and encourage infiltration (Resist) was identified by the majority of breakout groups as a "no regrets" climate action that could have tangible benefits without requiring high levels of perpetual

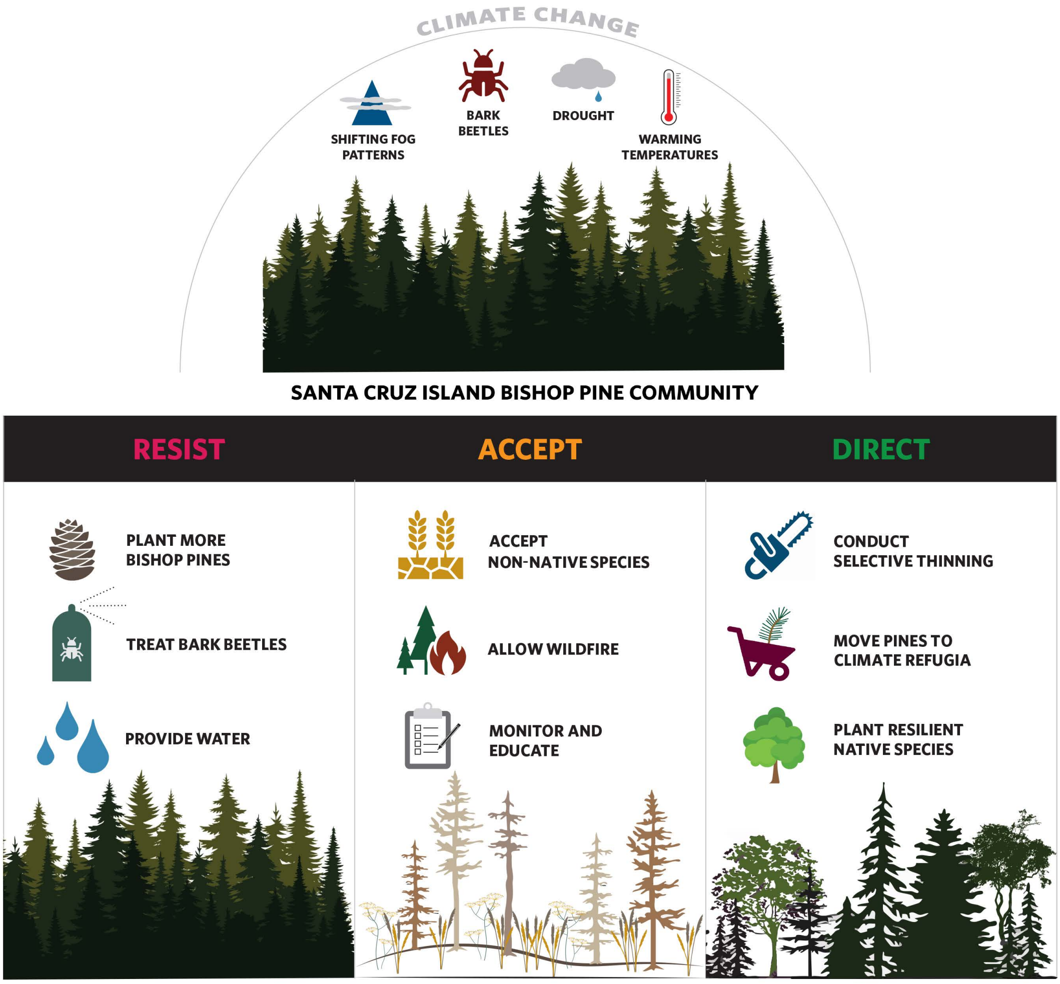

Fig. 3. A diagram illustrating management options discussed by the "Oaks and Pines" breakout group, using the Santa Cruz Bishop Pine Community as an example. Shifting fog patterns deliver reduced summer moisture, while extended heat and drought stress create conditions for pathogens like bark beetles to thrive. Participants explored the decision-making space available to managers in this scenario, from "Resisting" the trajectory of change (replacing lost pines, treating beetles, and irrigating during drought) to "Accepting" the change (allowing wildfire and nonnative species encroachment, monitoring and educating island users), to "Directing" the change (encouraging community shift to mixed chaparral with selective thinning and planting of resilient shrubs, translocating pines to enduring climate refugia).

investment. While groups also discussed irrigating vulnerable habitats and restoration areas during periods of extreme drought (Resist), the logistical costs and limited scalability of this practice were also identified as a major challenge to its wide-scale adoption.

TRANSLOCATION/ASSISTED MIGRATION.—Each of the 8 breakout groups debated the potential risks and benefits of intentionally translocating species outside of their historic ranges in the California Islands as a climate mitigation action. Several strategies were considered, including translocating species in danger of extinction to refugia within an island (Resist/Direct), between islands (Direct), or from the islands to the mainland (Direct). Participants also considered introducing populations that are better adapted to warmer and drier climates (Direct) to either hybridize with or replace species with similar ecosystem functions that have lost fitness in a novel climate regime. Because of uncertainty, lack of precedent in the California Islands, and perceived risks associated with translocation (including potential invasiveness and loss of unique genetics, subpopulations, and species) participants did not consider any of these tactics to be "no regrets."

MANAGE FIRE.—With limited firefighting infrastructure and extensive tracts of wildlands on each of the California Islands, participants felt that preventing human-caused ignitions and creating realistically defensible spaces (e.g., with fuel breaks around sensitive resources; Resist/Accept/Direct) were the best options for reducing the frequency and intensity of fire in a new climate regime. Several groups weighed the potential risks and benefits of using prescribed fire to reduce fuel loads and invasive plant cover (Resist/Direct); however, participants also expressed uncertainty regarding the natural and human history of fire on the islands and the ecological relationships between island species and fire, which may differ from those found on the mainland. Consistently, implementing best management practices to reduce human-caused ignition risk, such as equipping vehicles with fire extinguishers (Resist), was viewed as a "no regrets" tactic.

PREVENT AND CONTROL INVASIVE SPECIES.—Invasive species risk profiles change continuously as climatic conditions shift (Mainka and Howard 2010), contributing to a dynamic and constantly growing list of nonnative and potentially problematic species present on or likely to be introduced to the California Islands. Breakout group participants felt that in the face of limited resources, it was important (and a "no regrets" action) that managers prioritize biosecurity and control of invasive species that alter ecosystem processes in sensitive habitats (Resist/Accept/Direct), carefully considering whether nonnative organisms present on the islands are likely to become more or less damaging as the climate continues to change.

PROTECT AND CREATE REFUGIA.—Exposure to climate impacts is not uniform across the California Islands; thus, managers may be able to identify areas of refugia (e.g., north-facing slopes, deep drainages, offshore islets, or cooler/wetter islands in the archipelago) where vulnerable populations can persist despite generally unfavorable climatic conditions elsewhere. Several breakout groups suggested that managers may choose to focus restoration efforts in known refugia (Resist/Accept/Direct) while accepting habitat loss in more exposed regions. Participants also suggested that managers may attempt to create new areas of refugia through actions intended to increase water availability and retention on the landscape, such as through fog harvesting (Resist/Direct) using vegetation or artificial structures.

EX SITU SPECIES MANAGEMENT.—In the interest of safeguarding the long-term persistence of island species through climatic regime shifts, managers may consider preserving genetic material, propagules, or self-sustaining populations of endemic plants and animals outside of their natural habitat. Partnering with mainland and island-based nurseries to seed bank and bulk (Resist/Accept/Direct) diverse species collected across islands, wet/dry years, and habitat characteristics was identified as a "no regrets" action that would aid the restoration of rare species and hedge against extirpation of small populations. If climatic conditions across the islands become unsuitable for some endemic species (e.g., the Santa Cruz Island ironwood, *Lyonothamnus floribundus* spp. *aspleniifolius*) and extinction in the wild is imminent, establishing mainland populations (Resist/Accept) in preserves, zoos, or gardens may be the only option remaining to island managers.

GENETIC MANAGEMENT.—The recent proliferation of low-cost DNA sequencing methods enables conservationists to consider genetic and genomic information more readily in their management decisions. At the workshop, participants debated the trade-offs between maintaining the unique genetic characteristics of long-isolated island populations and actively encouraging adaptation toward more climate-resilient forms. Several breakout groups discussed whether the practice of assisted gene flow (Resist/Direct), or purposefully introducing individuals with climate-adapted genotypes to either hybridize with or replace extant, less-adapted populations, should be considered as a tool for species management in a novel climate regime. Regardless, participants agreed that genome banking (Resist/Accept/Direct) of samples and propagules across ecotypes, islands, and hydroclimatic conditions was a "no regrets" action that could aid in future decision-making.

MANAGE FOOD, COVER, AND WATER FOR WILDLIFE.—In some cases, wildlife populations of concern may become conservation dependent and require additional support to persist through periods of extreme weather, enhanced competition, and novel predation threats. Temperature-induced mortality was a concern for several wildlife species, so creating shade with vegetation or artificial structures (Resist/Direct) was identified by several groups as an action that island managers could consider. Multiple groups also discussed the practice of providing microhabitat structures (Resist/Direct)—e.g., nest boxes for seabirds, rock piles for herpetofauna, artificial reefs for intertidal organisms, and woody debris for island spotted skunks (*Spilogale gracilis amphiala*)—to serve as thermal refuges and to encourage colonization of previously identified climate refugia.

REDUCE HUMAN IMPACTS.—When climate vulnerabilities cannot be directly addressed, reducing other stressors (like human disturbance) can improve species' adaptive capacities and increase their likelihood of persistence at a site despite climate change. Compared to mainland sites, human disturbance on many of the California Islands is relatively low; however, participants thought that instituting seasonal or permanent visitation closures (Resist/Accept/Direct) in sensitive times and places (e.g., beaches with active pinniped rookeries) could improve the recruitment and survival of populations over the long term. Managing roads (Resist/Direct) to reduce runoff, erosion, roadkill, fire risk, and spread of invasive species was also considered an important tactic for reducing human impacts to climate-threatened ecosystems.

SUMMARY OF TACTICS.—In total, participants brainstormed roughly equivalent numbers of tactics compatible with the Resist ($n = 63$) and Direct ($n = 57$) strategies. Tactics that required managers to Accept at least some climate change impacts to their resource of interest were less frequently discussed ($n = 28$). Among the "no regrets" tactics that participants felt could be initiated immediately despite uncertainty, about twice as many were Resist actions ($n = 24$) compared to Accept ($n = 12$) or Direct ($n = 13$) actions (Fig. 4a). The majority of actions addressed climate exposures related to temperature or water availability, while fewer addressed sea-level rise, fire, and/or marine influences (Fig. 4b).

DISCUSSION

Because of their concentration of range-restricted and imperiled resources, as well as uncertainty about how global climate change will affect their highly bounded and idiosyncratic systems, the California Islands pose a variety of distinct challenges for conservation managers. Thus, understanding the relative vulnerability of these resources is essential for effective conservation management planning. We found the Resist-Accept-Direct framework to be a useful and accessible tool for facilitating focused discussion of key issues and for elucidating management recommendations, including identification of 27 "no regrets" actions (Table 3). We also found that even a relatively short convening of experts, representing multiple disciplines and including both scientists and managers, can be a productive means of not only generating helpful insights, but also fostering a shared understanding of climate change vulnerability assessments and how they can be applied in this system of interest. We anticipate that familiarizing key actors across the archipelago with a common framework for organizing the complex, myriad issues associated with managing climate vulnerability will make future discussions, planning, and collaboration more efficient and effective.

Workshop participants identified sensitivities for a wide range of natural resources, including habitats, ecological communities, groups of taxa, and endemic species. They also identified potential management options to directly mitigate the effects of climate change, as well as actions to increase climate resiliency by reducing interacting stressors, such as invasive species, pathogens, and human disturbance. Notably, participants readily discussed possible Resist and Direct actions, but tended to suggest fewer Accept actions overall. This difference could reflect an unwillingness to consider choices that were perceived to allow continued ecosystem degradation (Clifford et al. 2022), or simply a paucity of options available to explore within this strategy. There was widespread agreement that additional research and monitoring would aid climate change planning. However, participants also recognized that the pace and scale of climate change on the California Islands demanded prompt decision-making even with limited available data. It was noted that waiting to gather additional data can be a *de facto* Accept strategy.

When asked to highlight "no regrets" actions that could be initiated immediately despite uncertainty, participants tended to gravitate toward Resist actions, perhaps indicating continued hesitancy to pursue actions perceived to be actively shaping the trajectory of change, such as assisted migration of climate-vulnerable species. Concepts such as these may diverge with long-held conservation strategies on islands where there is, for example, a well-documented history of nonnative

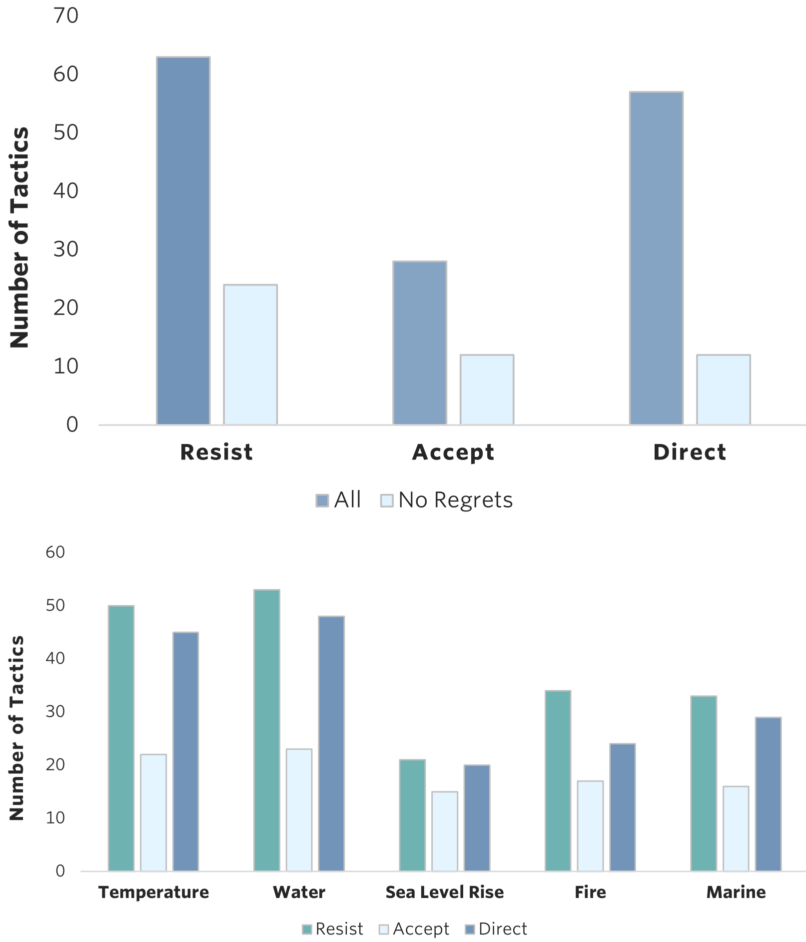

Fig. 4. ***A*,** Comparison of the total number of Resist-Accept-Direct tactics and total number of "no regrets" RAD tactics brainstormed by breakout groups. ***B*,** Comparison of the total number of Resist-Accept-Direct tactics brainstormed for each exposure type.

species introductions leading to undesired consequences (Russell et al. 2017). Nevertheless, conservation translocations and other Direct actions require additional consideration on islands, where natural movement is unlikely or impossible and the only reasonable alternative may be extinction (Rivera at al. 2021). Mainland climate planning exercises often center improved landscape connectivity as a vital mitigation action (Nuñez et al. 2013), yet this strategy was not discussed in most of the breakout groups. While many island landscapes are relatively undisturbed and thus already permeable to species movement, further exploration could identify opportunities to connect intra-island climate refugia. Participants also discussed how Resist strategies can lead managers down unsustainable pathways or toward unachievable solutions despite good intentions. Creating conditions that support ecosystem function and biodiversity will require island managers and researchers to be open-minded to new future states and to articulate a range of desired and feasible outcomes within these new parameters.

We consider the overall effort described herein to be just one of the starting points to climate change planning in the California Islands. We note that the vulnerabilities and potential actions discussed here are not comprehensive, and are likely biased by overrepresentation from the Channel Islands (and particularly the Northern Channel Islands) compared to the Farallon Islands or the Baja California islands. Moreover, a lack

TABLE 3. A complete list of Resist-Accept-Direct actions identified as "no regrets" by workshop participants, with related climate exposure types (in color; less relevant exposure types in light gray). From left to right, icons represent temperature (red), water availability (dark gray), sea-level rise (blue), fire (orange), and marine influences (green). *n* = the total number of independent breakout groups that discussed each tactic.

Management Action	"No Regrets" Tactics	Exposures	RAD Strategy	*n*
Bolster/Enhance existing Populations and Habitats	Install structures that reduce run-off in erosion-prone areas		R	7
	Conduct baseline monitoring to identify change & define management thresholds		A	6
	Irrigate restoration areas during droughts and heat waves		R	5
	Head-start seedlings in nurseries to improve survival		RD	1
Ex-Situ Species Management	Conduct seed banking and bulking in mainland nurseries		RAD	3
	Establish populations in mainland zoos or gardens		RA	3
Genetic Management	Collect samples for genome banking/biobanking		RAD	2
Manage Food, Cover, and Water for Wildlife	Protect and restore core habitat for vulnerable wildlife		RD	5
Manage Human Impacts	Enforce visitation closures to avoid disturbance to vulnerable species		RA	3
	Time human activities to reduce impacts to sensitive species		RA	3
	Manage roads to reduce runoff, erosion, roadkill, fire risk, and invasive species		RD	3
	Adaptively manage fisheries and marine protected areas		RD	2
Prevent and Control Invasive Species	Control invasive plants that alter ecosystem function in refugia		RAD	6
	Remove nonnative wildlife that negatively impact island ecosystems		R	6
	Implement biosecurity to prevent introduction of invasive species		R	2
	Prioritize control of invasive species likely to flourish in warmer/drier conditions		RAD	1
	Build barriers that exclude invasive species from refugia		RAD	1
	Survey highly visited areas regularly for new invasive species (and respond)		R	1
	Survey former infestation sites regularly to ensure invasive species do not re-emerge		R	1

TABLE 3. Continued.

Management Action	"No Regrets" Tactics	Exposures	RAD Strategy	*n*
Protect and Create Refugia	Encourage fog capture with vegetation or structures		RD	6
	Plant a buffer of resilient native vegetation around vulnerable resources		RD	5
	Manage water sources to encourage water retention		RD	5
	Conduct baseline climatic monitoring to identify refugia		A	3
Manage Fire	Implement best management practices to reduce human-caused ignitions		R	4
	Restore native vegetation post-fire and prevent weed takeover		RD	2
	Monitor burned areas and assess vegetation/wildlife response		A	2
	Identify defensible refugia and prioritize for fire suppression		RA	1

of empirical data about climate vulnerabilities for most of the imperiled taxa on the California Islands required us to rely primarily on expert solicitation. However, there is ample precedent for relying on expert knowledge to conduct climate vulnerability assessments as a means to enable rapid information synthesis and prompt decision-making (e.g., Case et al. 2015, Ofori et al. 2017).

Our workshop illustrated that management planning for climate change in the California Islands benefits from thinking at both the individual island and the multi-island scales. For example, management options for even single island endemics may be expanded by including additional islands as potential future habitat (e.g., the Island Scrub Jay [*Aphelocoma insularis*]; Bakker et al. 2020), and for evaluating conservation strategies of species endemic to the archipelago (e.g., island oak [*Quercus tomentella*]; Mead et al. 2024). It is worth noting that compared to other Pacific islands and nearby mainland areas, the California Islands may serve as climate refugia for other species at risk from climate change (e.g., Pacific albatrosses; VanderWerf et al. 2024). Yet because these islands are managed by a multitude of land management agencies and organizations, each with varying priorities and political landscapes (Fig. 1), such planning may require setting up new fora for discussing how best to set and meet conservation management priorities for the overall system. Fortunately, the California Islands have been a case study of cross-island collaboration in the past, with initiatives that include biosecurity and species recovery efforts (Boser et al. 2014, Coonan et al. 2014). These experiences—and the trajectory of improved ecological resilience they produced—provide a critical foundation to build upon as managers face the unprecedented challenges ahead.

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SUPPLEMENTARY MATERIAL

One online-only supplementary file accompanies this article (https://scholarsarchive.byu.edu/wnan/vol85/iss2/18).

SUPPLEMENTARY MATERIAL 1. Workshop materials, including lists of climate sensitivities, management options, and uncertainties, as well as preworkshop survey results, worksheet templates, and attendee affiliations.

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