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Mojave Desert Tortoise Monitoring Plan in Support of the Recovery and Sustainment Partnership

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Executive Summary

The Department of Defense and Department of Interior (DOI) signed a Memorandum of Understanding (MOU) to establish the Recovery and Sustainment Partnership (RASP) initiative to develop species conservation and recovery initiatives and provide increased flexibility for military missions. Here, we present a monitoring plan in support of the RASP Implementation Plan for the federally threatened Mojave desert tortoise (MDT; *Gopherus agassizii*), currently being developed by the National Fish and Wildlife Foundation.

The overall objective of the RASP monitoring plan is to promote effective coordination among agency personnel involved in data collection and analysis efforts as well as improved guidance on prioritizing MDT management options. The RASP monitoring plan is intended to support efforts by management agencies and key stakeholders in MDT conservation—but specifically the RASP—to effectively monitor MDT population responses to human activities and conservation interventions in a single, coherent, range-wide framework.

The monitoring plan is organized into four principal sections, which are summarized below: 1) review of existing data on RASP monitoring metrics, 2) guidance on population-level monitoring methods and study design, 3) opportunities and guidance for effectiveness monitoring, and 4) data management. We provide overarching guiding principles for the RASP monitoring plan in Box 0.1 and key recommendations in Box 0.2.

Box 0.1. Overarching guiding principles for RASP monitoring plan:

- Focus on short-term indicators linked to longer-term tortoise recovery objectives;
- Whenever possible, leverage potential synergies between new and existing data, research, and monitoring efforts, and associated resources;
- Coordinate RASP implementation and monitoring activities with RASP partners and other stakeholders, in ongoing efforts to inform adaptive management and ensure efficiencies in range-wide tortoise management.

Section 1. Review of existing data on RASP monitoring metrics

First, we reviewed and summarized existing datasets and products, focusing on data sources from the RASP focal areas that support core population-level monitoring metrics outlined in the draft Implementation Plan: adult and juvenile survival rates; reproductive success (e.g., number of eggs produced); tortoise abundance, proportion of juveniles, area occupied, and tortoise density.

The four main sources of existing MDT monitoring data that are directly relevant to the RASP focal areas and objectives include: (1) line distance sampling (LDS) data collected by the USFWS Desert Tortoise Recovery Office (DTRO) from 2000 to present; (2) data collected in relation to DOD expansions at Fort Irwin National Training Center (Fort Irwin) and Twentynine Palms Marine Corps Air Ground Combat Center (MCAGCC) and associated translocation efforts; (3) data regarding juvenile growth and survival from the Tortoise Research and Captive Rearing Site (TRACRS) at MCAGCC; and (4) demographic data from long-term BLM/USGS study plots in the Western Mojave. These datasets could help inform baseline estimates of core tortoise population metrics outlined above, while some continue to be collected and may also help inform ongoing population trends within RASP focal areas.

Additionally, these types of data can be used to identify key drivers of observed tortoise population trends, thus serving as targets both for management and effectiveness monitoring. Our review identified important gaps in available information, highlighting needs for additional data collection. These needs include supplemental data collection or adjustments to monitoring protocols to increase the statistical robustness of available data, as well as additional data types and monitoring efforts that would augment existing data and monitoring.

Section 2: Population-level monitoring guidance to support RASP objectives

Recommendations for monitoring MDT population dynamics have been previously described in detail (DTRPA 2004; USFWS 2011). Tracking progress toward MDT recovery goals (e.g., demography, distribution, and habitat) to determine whether the species can eventually be delisted requires multi-faceted, multi-scale monitoring. Because individual monitoring methods are unable to capture data linked to all life stages of interest, a combination of methods is recommended to develop a monitoring program that can quantitatively track progress towards recovery goals.

Considering the RASP priority strategies and relevant monitoring methods described above, we developed a series of recommendations to guide the RASP monitoring plan, which are intended to provide sufficient guidance for a monitoring program to be developed and implemented in the field, once key details have been confirmed by RASP partners.

Guiding principles for RASP population monitoring include:

- Incorporate multiple monitoring metrics to provide holistic, population-level inferences;
- Ensure robust spatial coverage of monitoring efforts;
- Include sufficient replication of monitoring sites/plots;
- Select monitoring sites using a randomized sampling design (to the extent practicable) to ensure statistical robustness of data;
- Balance statistical robustness with efficient use of limited funding and personnel.

For RASP population monitoring, we recommend a nested, multi-method approach to collect the required data for estimating key metrics needed to robustly monitor MDT demographic rates and population viability at relevant time scales (i.e., multiple tortoise generations). To do this, we recommend:

1. Using the long-term, LDS program coordinated by the USFWS as the foundational monitoring component to continue collecting information on tortoise densities for multiple strata;
2. Implementing standardized (ideally telemetry-based, known-fate) capture-mark-recapture surveys within an array of demographic monitoring plots to collect data on survival and juvenile recruitment, and;
3. Targeted monitoring of reproductive output and success within the same demographic study plots.

In summary, the RASP monitoring plan should focus resources on long-term demographic study plots to track tortoise vital rates, while leveraging ongoing, established LDS surveys to continue monitoring tortoise densities; explore options to co-locate new demographic study plots relative to randomized locations of LDS transect surveys; consider re-initiating monitoring efforts at historic demographic study plots (in addition to new, randomly placed plots) to allow for the possibility of important, long-term time series and trend analyses, should historic datasets become available.

Section 3: Effectiveness monitoring guidance

Effectiveness monitoring is used to measure how successful management actions are at achieving specific restoration or recovery objectives, and to inform adaptive management to increase their effectiveness, where required. Adaptive management of MDT recovery actions should focus on objectively quantifying effectiveness of management actions towards achieving specific, measurable outcomes (Kareiva et al. 1999). Ultimately, to provide meaningful, actionable information, effectiveness monitoring of RASP implementation priorities should focus on short-term indicators that are linked to longer-term tortoise recovery goals and objectives. Because decadal time periods required for MDT and their habitats to respond to recovery actions are typically much longer than recovery planning and implementation time horizons, RASP recovery priorities should be designed, implemented, and evaluated for success within short- to medium-term (<10 yr) periods, to inform adaptive management decision-making. We also recommend that the RASP coordinator seek to take advantage of potential synergies between different implementation priorities.

Key considerations for the RASP's effectiveness monitoring include:

- Use readily available, established protocols for monitoring short-term effectiveness of management activities targeting MDT and their habitats;
- Focus on objective, standardized measures of tortoise recovery indicators;
- Be grounded in statistically robust comparisons of treatments vs. controls;
- Leverage potential synergies between new effectiveness monitoring efforts and existing research and monitoring efforts, whenever possible;
- Facilitate regular communication of new monitoring information and findings to RASP decision-makers and resource managers to inform adaptive management.

Effectiveness monitoring of habitat restoration efforts should be designed to evaluate the degree to which restoration activities recover ecosystem function and community structures similar to those of intact reference sites, by tracking specific habitat indicators (Herrick et al. 2005; Esque et al. 2021). Habitat suitability, connectivity, and occupancy metrics could be used by RASP managers to track successful habitat restoration over time. In the shorter term, monitoring of metrics such as tortoise presence, density, and occupancy in RASP implementation areas could allow evaluation of whether habitat is effectively 'converted' from unsuitable/unoccupied to suitable/occupied, or vice versa.

Reducing sources of mortality, particularly on late-stage individuals (i.e., adults and subadults), is the most effective way to reverse population declines of long-lived species like desert tortoises (Doak et al. 1994; USFWS 2011). Tortoise mortality—specifically of larger, older individuals—resulting from collisions with vehicles on highways as well as off-highway routes is a well-documented factor hindering recovery in the Mojave Desert (USFWS 2011). Thus, highway fencing and OHV closures have been identified as RASP implementation priorities to promote MDT recovery.

In the case of highway fencing, effectiveness monitoring of short-term success is essentially equivalent to implementation monitoring. That is, if installed properly and remaining in place, fencing will provide the expected benefits of reducing (effectively eliminating) tortoise mortality from collisions. Targeted monitoring efforts could also be established before and after installation of highway fencing to document potential short-term changes in presence and density of tortoises in adjacent habitats. Unlike fencing, attempts to close OHV routes are often stymied by continued incursions and trespassing, making the initial closure itself a challenging prospect. Thus, effectiveness monitoring of OHV route closures requires a two-step approach of first confirming the short-term persistence of the closure (< 2 months), and then evaluating the longer-term success of ecological restoration within the closed route or area (from 6 to ≥ 24 months after implementation).

To guide population augmentation efforts (head-starting and translocations), the USFWS strategy (2021a) recommends several criteria be addressed when identifying augmentation sites, such as depleted recipient tortoise population density, presence of suitable habitat, no evidence of disease, and compatible management with continued tortoise occupancy (see USFWS 2020 for complete list). The strategy also summarized several success criteria to measure progress of translocation projects dealing with survival and growth of released and resident individuals, evidence of reproduction in released and resident individuals, population growth, and viable population.

Finally, it is important to acknowledge that the impacts of multiple, simultaneous threats and their relative influence on tortoise populations are still poorly understood (USFWS 2011, 2021b); these uncertainties can hinder or confound interpretation of monitoring results.

Section 4: Data management Plan

Well-planned, effective data management is a critical step to providing relevant, useful data to support MDT adaptive management and recovery. Data management plans are common components of any conservation program that aims to collect and organize data for purposes of analysis and interpretation. Key considerations for RASP monitoring data management include:

- Before data design or collection begins, a critical first step is to identify clear monitoring objectives, metrics, and statistical or analytical needs;
- All phases of data management should be carefully designed to meet specific monitoring objectives and needs;
- Follow standardized data collection and management protocols, ensuring newly generated data can be integrated with existing monitoring data;
- Work closely with existing data custodians to Identify how data should be consolidated and uploaded to federal repositories.

USFWS (2015) described distinct phases in a well-constructed data management process, from initiating data collection to finalization of data products. We recommend the following steps for RASP monitoring data management, which follow general data management guidance from USFWS (2015):

1. Data Design: Determine data fields, types, and formats, including QA/QC protocols, based on specific objectives, metrics, and analytical needs;
2. Data Collection and Delivery: Ensure field data are collected in line with established protocols, and verify data are entered correctly and completely (initial QA/QC by project leads); data then shared with NFWF, the RASP coordinator, and distributed to appropriate federal databases
3. Data Integration: RASP coordinator compiles and combines data from multiple sources into a master database, ensuring data are correctly copied or imported via additional QA/QC;
4. Data Finalization: Generate final data products and make them available to RASP partners.

For habitat restoration data, we recommend that RASP data be included in the BLM California Desert District (BLM CDD) habitat restoration database (Fig. 4.3). The BLM CDD database is designed to collate route disturbance and treatment data (including revisits for monitoring purposes) for sites across the CDD, which encompasses the RASP focal areas. We recommend that new demographic and reproductive output data, as well as data from highway fencing projects, be shared directly with the USFWS DTRO.

Role of RASP coordinator

Dedicated personnel, in the form of a RASP coordinator, is critical to ensuring that the RASP plans are followed, that projects are implemented and monitored successfully and in support of RASP and MDT Recovery Plan priorities, and that information generated the RASP program is efficiently collected, compiled, shared, and analyzed. We summarize the specific responsibilities of a RASP coordinator with respect to the monitoring plan sections.

Existing data and information

- Create and maintain lines of communication with key data collectors, researchers, and managers
- Extract published estimates to generate baselines for key monitoring metrics
- Establish a system for updating baseline values and collate new data collected in study plots developed within RASP monitoring program
- Develop data use/sharing agreements with custodians of relevant datasets, where needed

Methods and design of monitoring activities to support RASP objectives

- Maintain communication with other monitoring program managers and researchers to ensure RASP monitoring initiatives complement existing monitoring efforts
- Ensure new RASP monitoring efforts incorporate vetted protocols and a robust study design
- Verify that RASP monitoring data will be relevant for tracking progress towards MDT recovery goals across multiple time scales, including short-, mid-, and long-term objectives

Opportunities for effectiveness monitoring and adaptive management

- Develop an adaptive management strategy that incorporates monitoring metrics for each recovery priority, establishes pre-planned 'trigger' points where decisions should be made regarding changes to project implementation, and integrates across priorities to deliver a coherent, program-wide plan
- Facilitate the transfer of information gained through effectiveness monitoring to decision-makers and resource managers
- Facilitate annual RASP-partner meetings for evaluation and adaptive management decisions

Data management

- Oversee the appropriate design of field data collection protocols and data QA/QC
- Develop data sharing mechanisms with project PIs, and oversee construction of a master database for population monitoring and effectiveness monitoring data
- Facilitate the flow of data from the field to a common RASP-specific database, and then to key data custodians of related central databases (depending on the project and data type), on a regular basis

Box 0.2. Summary of guiding principles and recommendations for each section of the RASP monitoring plan.

Section 1: Existing data

The four main types of monitoring data that exist to support RASP's population monitoring metrics include:

- line distance sampling (LDS) data managed by the USFWS Desert Tortoise Recovery Office (DTRO);
- data collected in relation to translocation efforts, e.g., at Fort Irwin, Marine Corps Air Ground Combat Center (MCAGCC);
- data regarding juvenile growth and survival from the Tortoise Research and Captive Rearing Site (TRACRS) at MCAGCC; and;
- demographic data from long-term study plots in the Western Mojave.

Section 2: Population-level monitoring

- Incorporate multiple monitoring metrics to provide holistic, population-level inferences;
- Ensure robust spatial coverage of monitoring efforts;
- Include sufficient replication of monitoring sites/plots;
- Select monitoring sites using a randomized sampling design (to the extent practicable) to ensure statistical robustness of data;
- Balance statistical robustness with efficient use of limited funding and personnel.
- For population monitoring strategy:
    1) Use the long-term, LDS program coordinated by the USFWS as the foundational monitoring component to continue collecting information on tortoise densities for multiple strata;
    2) Implement standardized (ideally telemetry-based, known-fate) capture-mark-recapture surveys within an array of demographic monitoring plots to collect data on survival and juvenile recruitment, and;
    3) Use targeted monitoring of reproductive output and success within the same demographic study plots.

Section 3: Effectiveness monitoring

- Use readily available, established protocols for monitoring short-term effectiveness of management activities targeting Mojave desert tortoises and their habitats;
- Focus on objective, standardized measures of tortoise recovery indicators;
- Be grounded in statistically robust comparisons of treatments vs. controls;
- Leverage potential synergies between new effectiveness monitoring efforts and existing research and monitoring efforts, whenever possible;
- Facilitate regular communication of new monitoring information and findings to RASP decision-makers and resource managers to inform adaptive management.
- For highway fencing, implementation monitoring is effectiveness monitoring, so ensure fencing installed properly
- For OHV route closures, a two-phased approach is needed
    1. Short-term (< 2 months of implementation) compliance monitoring to confirm that implemented measure still in place, and route has been closed
    2. Longer-term (> 6-24 months) ecological monitoring to confirm recovery of habitat structure and function.

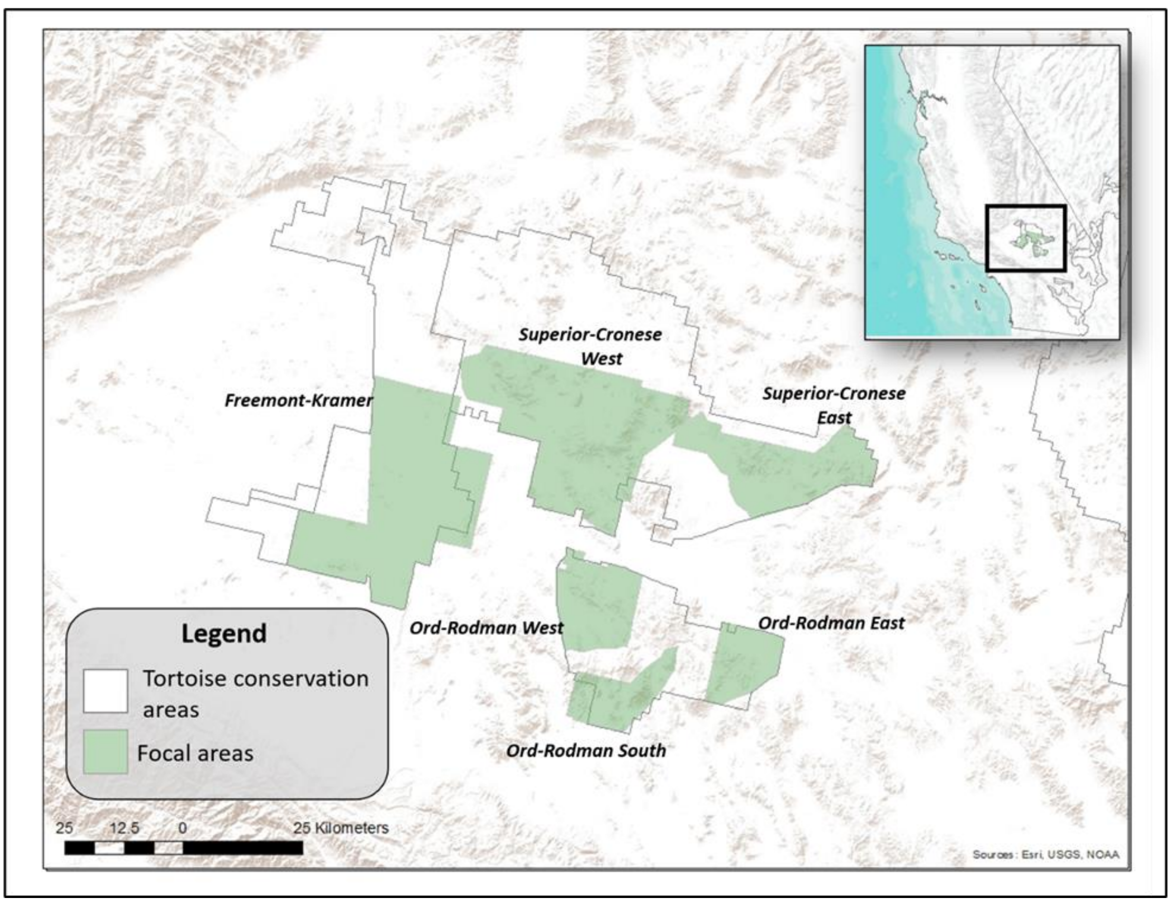
Section 4: Data management

1. Data Design: Determine data fields, types, and formats, including QA/QC protocols, based on specific objectives, metrics, and analytical needs, relying (as appropriate) on available USFWS templates;
2. Data Collection and Delivery: Ensure field data are collected in line with established protocols, and verify data are entered correctly and completely (initial QA/QC by project leads); data then shared with NFWF, the RASP coordinator, and appropriate databases
3. Data Integration: RASP coordinator compiles and combines data from multiple sources into a master database, ensuring data are correctly copied or imported via additional QA/QC;
4. Data Finalization: Generate final data products and make them available to RASP partners.

Introduction: RASP Implementation Plan and Purpose of Monitoring Plan

The Department of Defense and Department of Interior (DOI) signed a Memorandum of Understanding (MOU) to establish the Recovery and Sustainment Partnership (RASP) initiative to develop species conservation and recovery initiatives and provide increased flexibility for military missions. Here, we present a range-wide monitoring plan in support of the RASP Implementation Plan for the federally threatened MDT, currently being developed by the National Fish and Wildlife Foundation.

The overall objective of the RASP monitoring plan is to promote effective coordination among agency personnel involved in data collection and analysis efforts as well as improved guidance on prioritizing MDT management options. The RASP monitoring plan is intended to support efforts by management agencies and key stakeholders in MDT conservation—but specifically the RASP—to effectively monitor MDT population responses to human activities and conservation interventions in a single, coherent, framework across RASP focal areas (see map below).



RASP Mojave desert tortoise focal areas in the Western Mojave.

The RASP monitoring plan is designed specifically to support evaluation of RASP short- and medium-term objectives as described in the Implementation Plan:

- Short-term objectives:
  - Construct 32 miles of MDT exclusion fencing along high-priority highways in the western Mojave Desert
  - Close all unauthorized routes of travel in the identified recovery focal areas
  - Protect and restore up to 250,000 acres of habitat in identified recovery focal areas
- Medium-term objectives
  - MDT adult survival, reproductive success, and juvenile recruitment increases in the focal areas for a period of 5 years
  - MDT density in the focal areas is above minimum viable density (3.9 tortoises per km^2) for a period of 5 years
  - The proportion of juvenile MDT within the focal areas increases for a period of 5 years

The Implementation Plan will guide future investments to achieve targeted conservation goals for the MDT and its habitat in California's Mojave Desert. The RASP priority strategies include:

1. MDT habitat improvement
   1.1. Project existing desert tortoise habitat
   1.2. Improve desert tortoise habitat quality
   1.3. Increase connectivity and continuity of functional habitat
   1.4. Improve understanding of management effectiveness
2. Reduce direct and indirect sources of mortality
   2.1. Construct exclusion fencing along highways
   2.2. Community education
3. Augment depleted MDT populations
   3.1. Head-starting and reintroduction
   3.2. Translocation
   3.3. Address research needs
4. Increase capacity for project implementation and data management
   4.1. Create a RASP Coordinator position
   4.2. Support regulatory compliance
   4.3. Support data collection and data management
5. Monitoring

The RASP priority monitoring metrics described in the Implementation Plan are:

- Adult and juvenile tortoise survivorship
- Tortoise density, area occupied
- Juvenile recruitment, proportion of juveniles
- Reproductive success (e.g., number of eggs/hatchlings produced)

This RASP monitoring plan was designed to provide guidance about how best to support evaluation of successful implementation of RASP priority strategies using the defined population metrics as well as metrics for project-level effectiveness monitoring. The monitoring plan is organized into four principal sections, which are summarized below: 1) review of existing data on RASP monitoring metrics, 2) guidance on population-level monitoring methods and study design, 3) opportunities and guidance for effectiveness monitoring, and 4) data management. The final section of this plan describes the potential role and responsibilities of a RASP Coordinator.

1. Review of existing data on RASP monitoring metrics

1.1. Overview

As a first step in the development of a draft monitoring plan in support of the RASP MDT Implementation Plan, we performed an in-depth review of relevant data sources that could support establishment of Implementation Plan baselines and effectiveness monitoring of tortoise recovery actions. Here, we summarize key findings from this review of existing data sources, appropriate applications of these data, their statistical robustness and availability to the RASP.

Specifically, we reviewed existing data sources that could provide baseline values for key population-level monitoring metrics, data collection programs that may continue to provide relevant data, and gaps in potential baseline and existing data that would need to be filled to support RASP monitoring objectives. In Table 1 below, we summarize a number of existing MDT datasets and products relevant to the Implementation Plan priorities and associated monitoring objectives, focusing on data sources from the RASP focal areas that support core population-level monitoring metrics outlined in Table 4 (Strategy 5) of the draft Implementation Plan: adult and juvenile survival rates; reproductive success (e.g., number of eggs produced), proportion of juveniles/juvenile recruitment, tortoise density, and area occupied. In Appendix A, we provide additional details regarding these data sources, as well as additional data sources outside of the RASP focal areas.

The four main sources of existing MDT monitoring data that are directly relevant to the RASP focal areas and objectives include: (1) LDS data collected by the USFWS DTRO from 2000 to present; (2) data collected in relation to DOD expansions at Fort Irwin and MCAGCC and associated translocation efforts; (3) data regarding juvenile growth and survival from the Tortoise Research and Captive Rearing Site (TRACRS) at MCAGCC; and (4) demographic data from long-term BLM/USGS study plots in the Western Mojave. These datasets could help inform baseline estimates of core tortoise population metrics outlined above, while some continue to be collected and may also help inform ongoing population trends within RASP focal areas.

Additionally, these types of data can be used to identify key drivers of observed tortoise population trends, thus serving as targets both for management and effectiveness monitoring. Our review allowed for identification of important gaps in available information, highlighting needs for additional data collection. These needs include supplemental data collection or adjustments to monitoring protocols to increase the statistical robustness of available information, as well as additional data types and monitoring efforts that would augment existing data and monitoring.

1.2. Existing MDT monitoring data sources within RASP focal areas

Table 1.1. Summary of key data sources within the RASP focal areas: target monitoring metrics, data sources and custodians, focal geographies, static vs. ongoing data sources, time periods, data availability and schedule of data release, if applicable. (See Appendix, Table A1-A3) for further details regarding these data sources in addition to supplemental data sources from outside the RASP focal areas.

Target monitoring metrics	Data source (Custodian)	Focal geography	Static or ongoing?	Time periods (Publications)	Availability
Adult and juvenile survival rates	Fort Irwin Translocation Project (DOD)	Fort Irwin, CA	Static	1997-2003 (Berry et al. 2006) 2006-2008 (Esque et al. 2010) 2008-2011 (Walde and Boarman 2013)	Published estimates
	MCAGCC Translocation Project (DOD)	MCAGCC, CA	Ongoing	2017-present (Henen et al. 2019, 2020, 2021)	Some estimates for 2017-2020 data published in DTC symposium abstracts *Additional analyses currently in progress
	Fort Irwin and MCAGCC Head-starting Program (DOD)	Fort Irwin, CA MCAGCC, CA	Ongoing	2005-present (Nagy et al. 2015, 2020)	Published estimates
	Long-term tortoise demographic plots (USGS-CA)	Various locations within Western Mojave	Some static, some ongoing	1976-2013; *different plots cover different time periods (e.g., Berry 1984, Berry & Christopher 2001, Berry & Yee 2021, Christopher et al. 2003, Berry et al. 2006, 2020, Lovich et al. 2014)	Some estimates published for some sites; NOT publicly available
Reproductive success (# of eggs)	UCLA egg study (with USGS)	Desert Tortoise Natural Area, CA	Static	1992-1993 (Wallis et al. 1999)	Published estimates
	Fort Irwin translocation project	Fort Irwin, CA	Static	2008-2011; (Walde and Boarman 2013)	Egg numbers
	Fort Irwin and MCAGCC Head-starting Program (DOD)	Fort Irwin, CA MCAGCC, CA	Ongoing	2005-present (Nagy et al. 2020)	Egg numbers and emergence success published for MCAGCC; additional data may be available for Fort Irwin, upon request

Table 1.1, continued.

Target monitoring metric	Data source (Custodian)	Focal geography	Static or ongoing?	Time periods (w/ References)	Availability
Tortoise density; ***Proportion of juvenile tortoises***	USFWS Line Distance Sampling (DTRO)	Various locations Range-wide by Tortoise Conservation Areas	Ongoing	2000-present (Allison & McLuckie 2018; DTRO reports online) other estimates may be generated, such as abundance and potentially proportion of juveniles	Published estimates; data publicly available; Surveys conducted Mar-May; Annual reports available Feb-Jun the following year; Trend analyses every ~5 years
Tortoise occupancy	BLM range-wide MDT occupancy model (BLM, CSP)	Range-wide coverage, by Tortoise Conservation Areas	Static	2000-2020 (Kissel et al. <in prep>)	Estimates available upon request; peer-reviewed publication and web-tool currently being developed
Proportion of juvenile tortoises	Fort Irwin Translocation Project (DOD)	Fort Irwin, CA	Static	1997-2003 (Berry et al. 2006) 2006-2008 (Esque et al. 2010)	Published estimates
	MCAGCC Translocation Project (DOD)	MCAGCC, CA	Ongoing	2019-present (Henen et al. 2019, 2020, 2021)	Proportion of juveniles not currently published but may be generated from original data, or potentially by data custodians, by request
	Long-term tortoise demographic plots (USGS-CA)	Various locations	Static	1976-2013; different plots cover different time periods (e.g., Berry 1984, Berry & Christopher 2001, Christopher et al. 2003, Berry et al. 2006, 2020)	Some estimates published for some sites; NOT publicly available

1.3. Summary of existing data and potential applications for RASP monitoring

We identified existing datasets and publications that provide estimates of potential population-level monitoring metrics for the RASP focal areas (Table 1.1). In particular, the DTRO's line-transect monitoring protocol provides a robust foundational dataset that permits estimation of tortoise densities and occupancy at multiple scales (e.g., Allison and McLuckie 2018), including the RASP focal areas (Fig. 1.1). Proportion of juvenile to adult tortoises could also potentially be approximated from this data set, based on rough size class estimates (<180 mm carapace length considered juveniles, >180 mm considered adults); however, this may be a challenging metric to extract from these data given the LDS surveys are not specifically designed to monitor this population metric. These DTRO LDS data are publicly available from 2000-present and are summarized in annual reports. However, analyses of density trends within recovery units and range-wide are performed approximately every five years (e.g., Allison and McLuckie 2018).

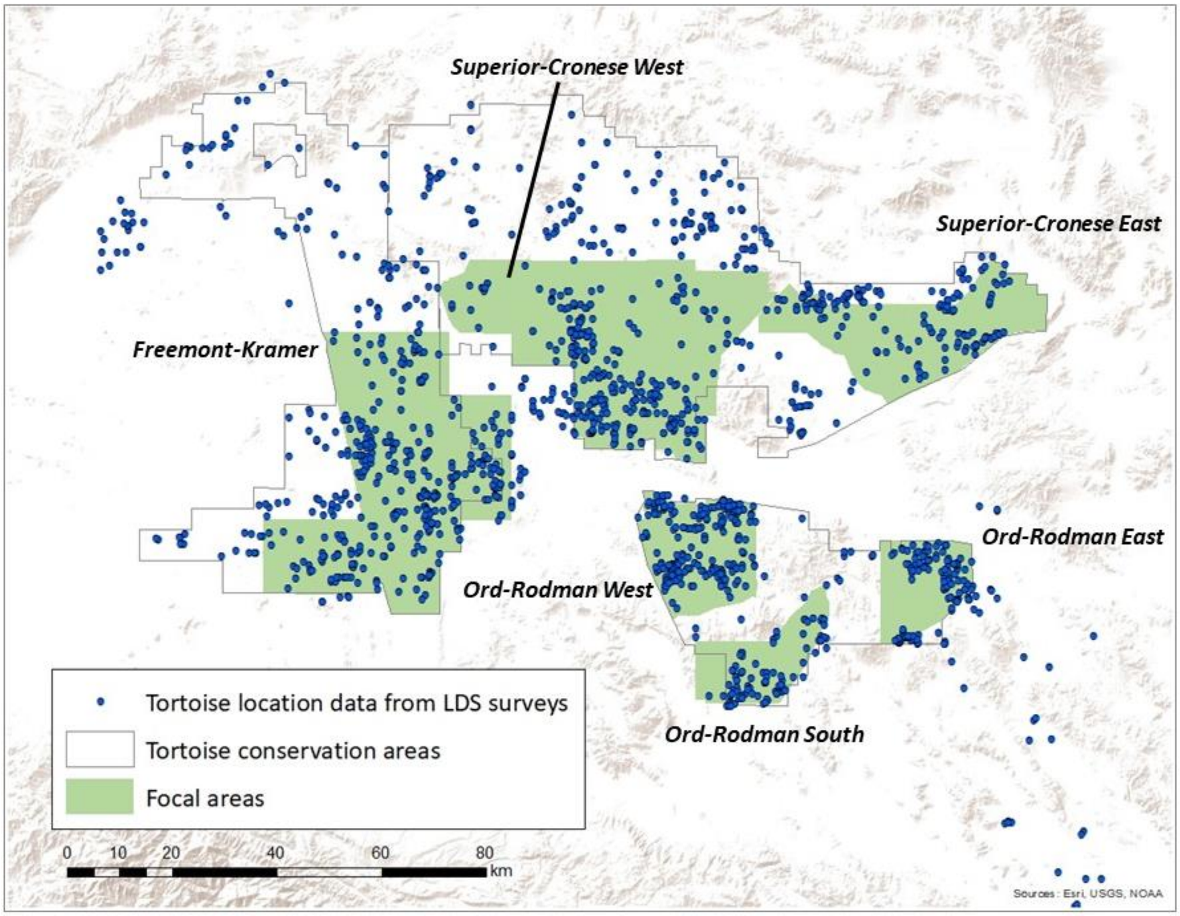


Figure 1.1. MDT observations from USFWS Line Distance Sampling (LDS) within RASP focal areas.

While trends in tortoise densities generated by LDS surveys provide important information for monitoring MDT populations, other metrics are needed to understand underlying dynamics of population trends, such as vital demographic rates (e.g., reproductive success, survival). At the level of the RASP focal areas, two of the most important datasets currently available are those collected in relation to the 2008 Fort Irwin expansion and associated tortoise translocation effort (Esque et al. 2010; Walde and Boarman 2013) and the ongoing tortoise translocation effort associated with the MCAGCC expansion (Henen 2021; Nagy et al. 2020). Post-translocation monitoring at both Fort Irwin and MCAGCC have generated estimates of adult and juvenile survival for translocated, resident (i.e., tortoises already present in recipient areas to which tortoises were translocated), and control groups (i.e., tortoises present in areas adjacent to recipient areas). Esque et al. (2010) also provide summary data on tortoise survival in areas outside of Fort Irwin for 2006-2008 for comparison with survival data collected in association with the translocation, and Berry et al. (2006) provide pre-translocation information about tortoise density and mortality data from 1997-2003 for Fort Irwin. Long-term research on juvenile growth and survival is also being conducted at the head-start facility known as the Tortoise Research and Captive Rearing Site (TRACRS) at MCAGCC (Nagy et al. 2020), in addition to associated head-starting efforts at Fort Irwin (Nagy et al. 2015).

Other important demographic data have been collected by the Bureau of Land Management and U.S. Geological Survey (USGS) periodically since the 1970s at long-term study plots in the CA Western Mojave (*n*=16), approximately 10 of which are located within or adjacent to the RASP focal areas (Fig. 1.2). While these data are not currently available for outside research, several publications have described data collected at some of these plots, and some metrics could be extracted to support the establishment of baselines for monitoring the implementation of RASP strategies (Berry 1984; Berry and Yee 2021; Berry et al. 2020; DTRPAC 2004; Lovich et al. 2014). However, these data have some limitations for robust statistical estimates of key metrics, such as density and survival. For example, the study sites were not selected randomly across tortoise range, and frequency of data collection events varies widely among plots, including cessation of data collection in some plots as tortoise presence appeared to decline (DTRAPC 2004). Thus, it is likely that new efforts will be needed to collect sufficient data to generate robust estimates of these monitoring metrics, perhaps on existing plots and/or on new plots within the RASP focal areas.

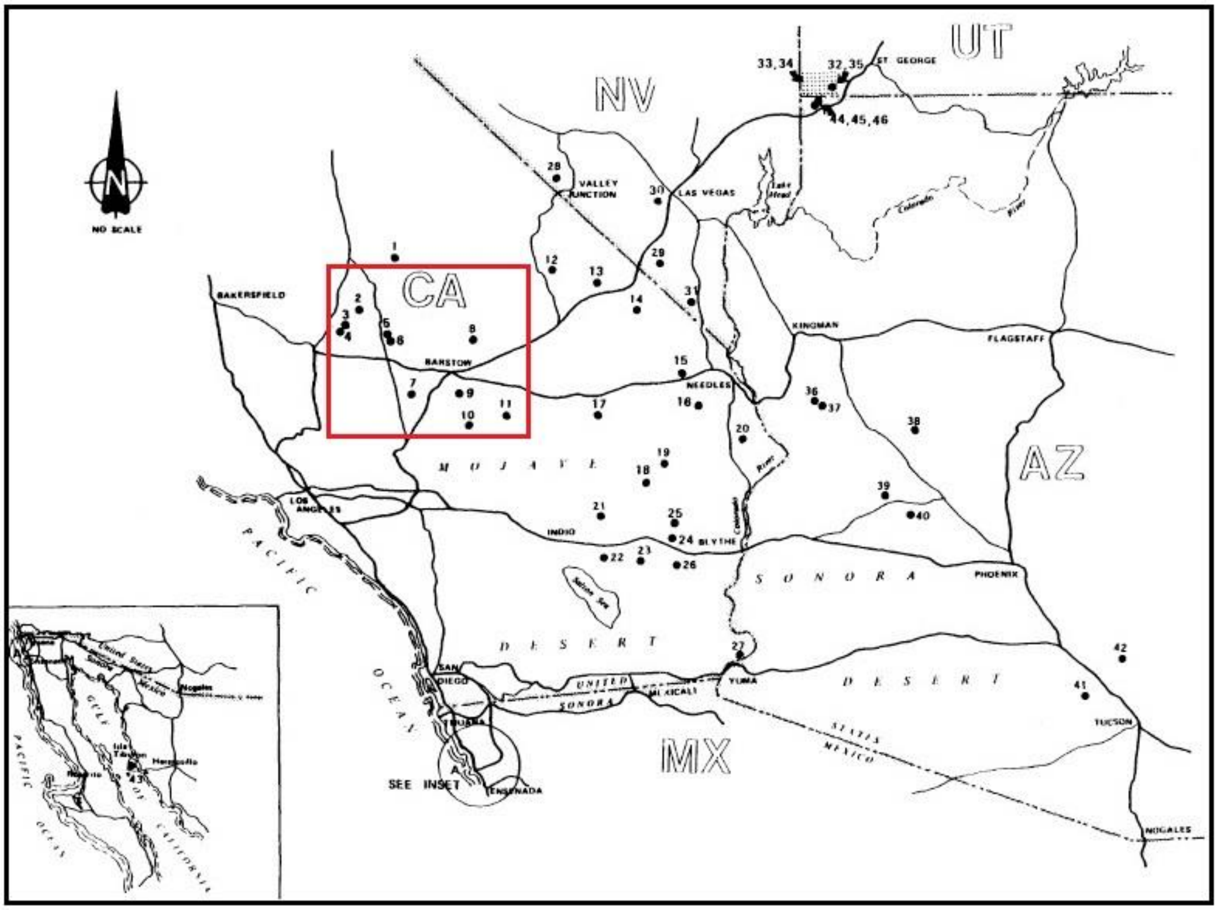


Figure 1.2. Previously published map of long-term MDT study plots in CA, NV, UT, and AZ (Berry 1984). Added red square indicates plots located within or adjacent to the RASP focal areas.

Outside of the RASP focal areas, additional datasets exist that provide estimates of these (and other) monitoring metrics (Table A2). For example, data from other translocation studies in CA (e.g., Dickson et al. 2019) and NV (e.g., Nussear et al. 2012; Nafus et al. 2017) and additional long-term study plots in NV (*n*=23), AZ (*n*=7), and UT (*n*=3) may still be relevant in development of baseline estimates of range-wide demographic and vital rates, against which future data could be compared (Table A2, A3).

Lastly, numerous versions of various environmental and anthropogenic covariate datasets are also available, depending on relevant spatial and temporal scales.

1.4. Processes and schedules to obtain existing monitoring data

Data identified as relevant for establishing baselines and for effectiveness monitoring for the RASP Implementation Plan currently exist in different forms. For example, the USFWS LDS data are collected annually (using the same methodology since 2004), densities and other results are summarized in annual reports, and density trend analyses at range-wide and recovery unit scales are performed approximately every five years. Data collection at MCAGCC is ongoing since 2019, and results are summarized in abstracts presented at the Desert Tortoise Council Symposium (Henen et al. 2019; 2020; 2021). We note that the survival data associated with the Fort Irwin translocation were collected in 2006-2008 (Esque et al. 2010) and 2008-2011 (Walde and Boarman 2013) and other density data were reported from 1997-2003 (Berry et al. 2006), but there are no additional data available for this area. Future translocation efforts associated with further expansion of Fort Irwin will generate new data on adult and juvenile survival and possibly other metrics. Finally, long-term demographic plot data are available for some plots within RASP focal areas in published reports and papers, but are largely unavailable at the moment.

1.5. Key gaps in information needed to track RASP monitoring metrics

While we identified several existing data sources that could help inform important baseline estimates for key population metrics, some of which may continue providing relevant data, we also identified gaps in available information and needs for additional data collection.

Long-term data is particularly important for monitoring this species, given the long lifespans of desert tortoises (~50 years in the wild), delayed reproductive maturity (12-20 years in females), and relatively low annual fecundity (Turner et al. 1986; Medica et al. 2012). Tortoise detection rates also vary widely with annual fluctuations in rainfall (Freilich et al. 2000), and wide variance in population density estimates over relatively short periods of time can make evaluation of population trends difficult for this species (Doak et al. 1994). Thus, while monitoring efforts should have clear objectives to meet current management needs, tortoise surveys should also be designed to provide useful information over longer periods of time that are biologically meaningful for this species (i.e., 25-50 years; DTRPA 2004). As such, new monitoring efforts will benefit from leveraging methods and protocols comparable to those employed by historic and current monitoring efforts, which may enable longer-term assessments of MDT population trends, over time.

The most consistent source of long-term, range-wide monitoring data is LDS data collected and provided by the USFWS DTRO, from 2000 to present (e.g., Allison and McLuckie 2018). Although this is a valuable monitoring program that offers 20+ years of data on tortoise densities and population trends, LDS surveys focusing primarily on tortoise density and abundance and may fail to capture important information about demographic processes (e.g., survival rates for multiple size/age classes, recruitment, reproductive output) that could determine population viability over time (Heppell 1998).

Although there are some existing monitoring data sources of tortoise demographic rates, such as those associated with translocation efforts at Fort Irwin and MCAGCC, these data are limited in both spatial and temporal coverage. Additional demographic data have been collected at long-term USGS study plots distributed throughout the MDT range; however, we identified several potential issues with the long-term study plots in CA, including lack of access to original data, underlying (non-random) sampling design, and inconsistency in data collection at these plots over time.

Thus, new efforts to monitor tortoise demographic metrics, using a statistically robust sampling design and conducted consistently over longer periods of time, would bolster understanding of tortoise population trends and augment existing data and monitoring efforts. New demographic monitoring efforts in the RASP focal areas would ideally include mark-recapture protocols that allow for the estimation of survival and growth rates for multiple life stages as well as reproductive output. Such monitoring efforts might be conducted within established demographic plots in hopes of eventually being able to add new data to existing data collected on those plots over the long-term (i.e., since the 1970s) for analyses of time series datasets on key demographic parameters. These additional efforts are needed to verify the medium- and long-term efficacy of management actions and conservation investments outlined in the draft Implementation Plan. Additional details about monitoring guidance will be provided in the next section.

1.6. Role of RASP coordinator

Compiling existing information and ensuring that such information is updated for the RASP Implementation plan is a key role for a potential RASP coordinator. Specific responsibilities of a RASP coordinator might also include:

- Creating and maintaining lines of communication with key data collectors, researchers, and managers;
- Extraction of published estimates to generate baselines for key monitoring metrics;
- Establishing a system for updating baseline values and collating new data collected in study plots developed within RASP monitoring program;
- Developing data use/sharing agreements with custodians of relevant datasets, where needed.

2. Population-level RASP monitoring guidance

2.1. Overview

Recommendations for monitoring MDT population dynamics have been previously described in detail (DTRPA 2004; USFWS 2011). The recovery goals for MDT include specific criteria on demography, distribution, and habitat. Tracking progress toward these goals over time to determine whether the species can eventually be delisted requires multi-faceted, multi-scale monitoring (USFWS 2011). For example, the 2011 Recovery Plan describes the need for monitoring multiple life stages to understand population dynamics and identify stage-specific management opportunities, rather than focusing solely on a single index (e.g., adult density). In particular, the 2011 Recovery Plan—echoing conclusions from the 2004 assessment (DTRPA 2004) of the initial Recovery Plan (USFWS 1994)—recommended combining inferences from long-term line-transect monitoring that provide adult density estimates with long-term demographic plots that would provide vital rate estimates.

The monitoring guidance provided here is intended to address these priorities by describing a conceptual framework for holistic population monitoring, relevant monitoring methods, and recommendations about key principles and overall structure for a RASP MDT monitoring program.

2.2. Conceptual framework for holistic population monitoring

A conceptual framework encompassing the major life stages of tortoises (Fig. 2.1) illustrates how data collected using a variety of monitoring methods may combine to capture all priority population metrics in support of the overall RASP objectives. Because individual monitoring methods are unable to capture data linked to all life stages of interest, a combination of methods is recommended to develop a monitoring program that can quantitatively track progress towards recovery goals.

For example, ongoing LDS surveys conducted by the USFWS DTRO within RASP focal areas can be leveraged to estimate adult tortoise densities and, potentially, the proportion of juveniles in the population. New demographic monitoring efforts in the RASP focal areas would ideally be implemented using a standardized demographic plot design, including mark-recapture protocols that allow for the estimation of survival and growth rates for multiple life stages. Radio-tracking females and X-ray exams of clutch size would provide additional data on egg production and reproductive success. These additional efforts are needed to monitor the medium- and long-term efficacy of management actions and conservation investments for this long-lived species, as outlined in the draft Implementation Plan.

Such monitoring efforts could also be reinitiated within the handful of established demographic plots within RASP focal areas, in hopes of eventually being able to integrate new data with existing data collected at those plots over the long-term (i.e., since the 1970s) for time series analyses of key demographic metrics. However, new demographic study plots should be established using a randomized sampling design (to the extent feasible) to increase statistical robustness of demographic monitoring data, moving forward.

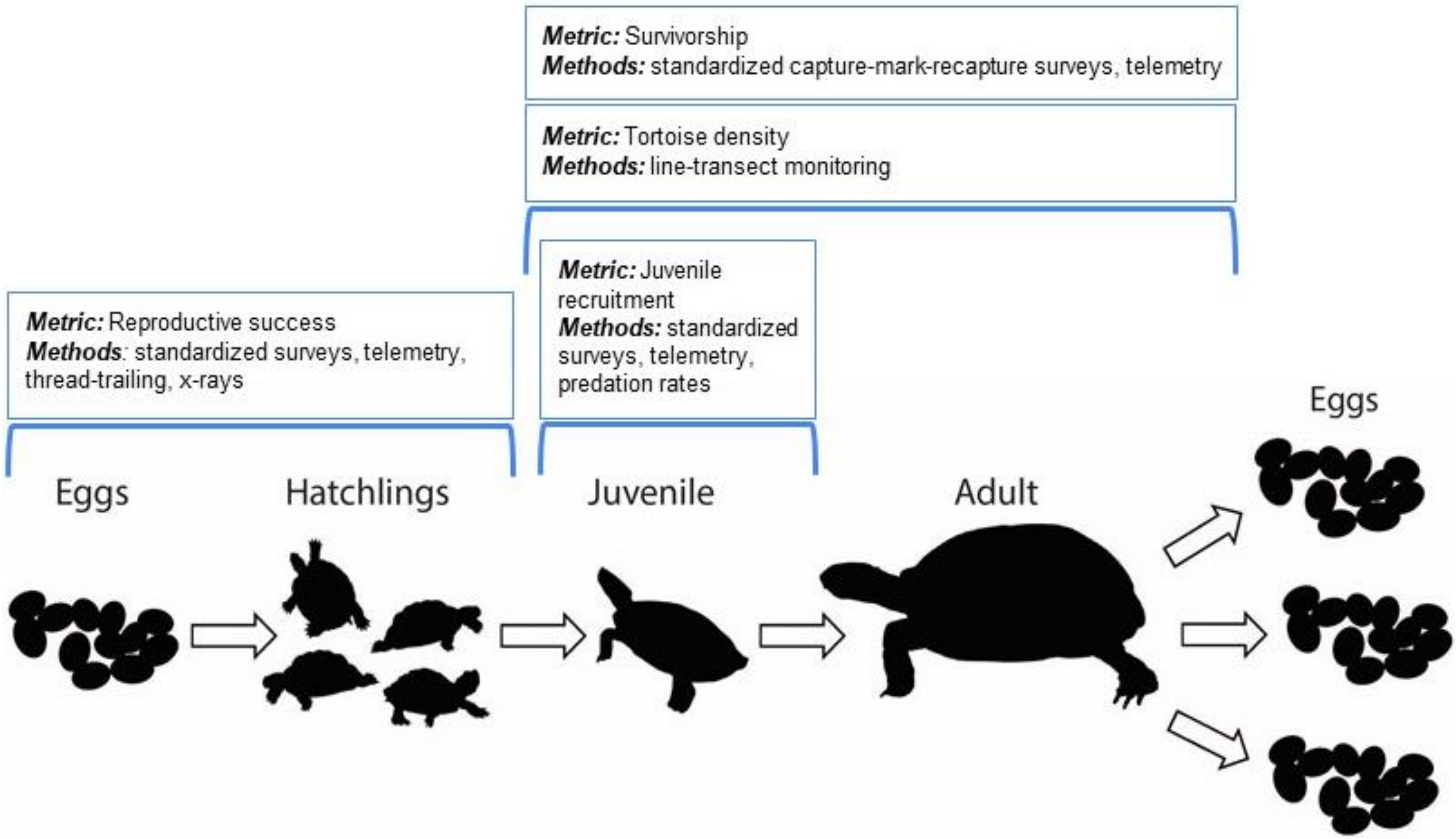


Figure 2.1. Conceptual framework for monitoring key population metrics to provide a holistic population monitoring program.

2.3. Relevant monitoring methods

In the following sections, we describe in greater detail relevant monitoring methods (Box 2.1) and existing datasets followed by a series of monitoring guidelines for study design and survey protocols to estimate priority population metrics, in support of RASP objectives.

Box 2.1. Summary of relevant monitoring methods:

1. Line-distance sampling (LDS) transect surveys >>
   - Tortoise density, (potentially) proportion of juveniles
2. Capture-mark-recapture (CMR) surveys >>
   - Survival rate, juvenile recruitment, proportion of juveniles
3. Radio-tracking females and X-ray exams of clutch size >>
   - Reproductive success

2.3.1. Line Distance Sampling

Ongoing, established LDS surveys conducted annually by the USFWS DTRO can be leveraged to establish baselines and continue monitoring tortoise densities in RASP focal areas. The LDS program was initiated in 2000 and has been conducted using consistent methods across the MDT range since 2004 (Allison and McLuckie 2018). This program was designed to generate statistically robust estimates of tortoise densities at multiple strata, namely at the level of Tortoise Conservation Areas (TCAs) or Critical Habitat Units and Recovery Units (Burnham and Anderson 1996), in support of recovery objectives and criteria (USFWS 1994; 2011).

From 2004 to 2006, LDS transects were randomly placed throughout TCAs across the MDT range; starting in 2007 transects were systematically sited to cover each TCA, with a random subset of these monitored annually. The square-shaped transects are 3-km on each side, with field monitors recording observations of live tortoises (as well as dead tortoises and tortoise sign) along the line transects and at estimated distances from the line itself. Transect surveys are conducted in the morning and completed before the hottest time of day, between mid-March and the end of May each year. LDS is a standard wildlife monitoring technique with well-established estimation procedures, which are embedded in the LDS program's training, oversight, and data analyses (USFWS 2019).

This ongoing monitoring effort has produced annual adult tortoise density estimates and trends for TCAs and recovery units since 2004, which show continuing declines in tortoise densities in all but one recovery unit (Allison and McLuckie 2018). However, the characteristics of the LDS method that make it the established approach for estimating densities—i.e., randomized transect location, consistent monitoring effort along established transects, observations made at estimated distances from line transects—are also what make this method inadequate for mark-recapture-type analyses, or for observing large numbers of cryptic juveniles. For example, tortoises that are observed during transect surveys are marked (i.e., a unique number identifier is glued to a carapacial scute), but the number of recaptures has been too low to permit survival estimates. On any given line transect survey, observers have roughly a 50% chance of encountering a tortoise (L. Allison, pers. comm.). Similarly, juvenile tortoises are observed during transect surveys, but not in sufficient numbers to generate juvenile density estimates. Rather, an alternative metric of juvenile population trends—the proportion of observed tortoises that are juveniles—has been presented (Allison and McLuckie 2018).

The USFWS LDS program is vital for monitoring the MDT population and for tracking management progress toward established recovery goals for the species. However, as currently implemented, the LDS program only produces adult tortoise density estimates, and does not provide inferences about drivers of the observed densities and estimated trends, including underlying processes occurring within nonadult life stages. Thus, the LDS program is ‘bedrock’ for a robust MDT monitoring program, but additional monitoring methods are necessary to provide insights about other life stages.

2.3.2. Capture-Mark-Recapture

Capture-mark-recapture (CMR) methods are another important tool in wildlife monitoring and management. Individuals are given unique identifiers (e.g., external or internal tags, telemetry devices) that allow researchers to construct individual capture histories. These capture histories can then be used to assess vital demographic rates and population dynamics. CMR protocols are typically implemented within an established study area or plot to ensure consistent data collection over time.

For MDT, examples of CMR methods include scute notching or marking and telemetry. As with many turtle species, notches can be made on marginal scutes with a file, or in the case of juveniles, with fingernail/toenail clippers (Berry 1974; 1975; Burge 1977). In the USFWS LDS program, field workers epoxy numbered tags to a carapacial scute or sometimes apply more temporary markings to enable recognition of a previously observed tortoise. To be clear, we do not advise using temporary marking techniques since one of the fundamental assumptions of CMR is that marks are permanent. Another CMR method incorporates telemetry, which has become more widely used for MDT as a method to not only record detailed information on tortoise space use behavior, but also on survival over time (e.g., Nussear et al. 2012; Dickson et al. 2019; Henen et al. 2020).

CMR studies allow for several different types of measurements and information to be recorded in support of multiple monitoring metrics. Some examples include basic location and behavioral information; body size/condition and thus growth over time; repeated capture of individuals over time, and causes of mortality, where possible. These types of data collected in a robust design framework (Kendall et al. 1995) allow for the estimation of stage-, age-, and sized-based survival rates. CMR data collection and analysis methods are extremely well-established in wildlife management, including MDT. However, we note that CMR analyses are data intensive, and—to date—none of the existing long-term demographic study plots in the Mojave Desert were designed to allow for the derivation of robust survival estimates at multiple size- or age- classes (but see survival rates from Sonoran desert tortoise *[Gopherus morafkai]* demographic plots; Zylstra et al. 2013; Campbell 2018). This is largely due to the lack of long-term, consistent implementation of CMR surveys at these existing plots. Thus, CMR approaches should be carefully considered and consistently implemented in the RASP monitoring program, going forward.

2.3.3. Radio-tracking Females and X-ray Exams of Clutch Size

The above methods provide information for monitoring metrics such as tortoise density and survival rates of juveniles and adults, but additional methods are needed to collect information about the earliest life stages: eggs and hatchlings. Studies of MDT reproductive output and success require focused observations of adult female tortoises, including X-ray analyses to confirm whether a female is gravid, and if so, how many eggs she is carrying, as well as radio-tracking females to their nests and monitoring egg incubation and survival of tortoise neonates (Turner et al. 1986; Wallis et al. 1999; Sieg et al. 2015). Information on reproductive output (e.g., fecundity, embryonic survival) can also be obtained from females whose eggs are collected for captive rearing and head-starting purposes (Nagy et al. 2015; 2020). Due to the cryptic location of tortoise nests, gathering information about reproductive output and success requires resource- and time-intensive approaches. Additionally, there is concern that the act of monitoring nests itself may attract potential predators to nest sites (B. Henen and A. Hebshi, pers. comm.). Thus, careful protocols should be followed to reduce human scent trails and minimize time spent at nests (e.g., Bjurlin and Bissonette 2004). However, nest-monitoring efforts are important for generating information about these early life stages, which complement information collected on older life stages via methods described above.

2.4. Long-term demographic plots: history and study design recommendations

As mentioned above, the importance of establishing long-term demographic study plots in a holistic MDT population monitoring program has been recognized previously (DTRPA 2004; USFWS 2011). The focus of this approach is on comprehensive, standardized surveys of fixed areas to generate repeated observations of individual tortoises over time, thus allowing estimation of vital demographic rates, including survivorship and reproductive success.

2.4.1. USGS Long-term Study Plots

An array of long-term study plots was established in the 1970s across the MDT range in UT, AZ, NV, and CA—including within the RASP focal areas in the Western Mojave. Many of these plots have been monitored intermittently since being established, some of which have been monitored in the last ~10 years (Berry 1984; Berry et al. 2020a, b). Of the 8 different Western Mojave plots established between 1976-1980[1], 7 have been visited at least 5 times[2], and 6 have been monitored at least once since 2005[3]. These plots have generated long-term information on tortoise presence, abundance, survival, and causes of mortality (e.g., Berry et al. 2006; Berry et al. 2020a, b, Berry and Yee 2021).

As the Desert Tortoise Recovery Plan Assessment committee pointed out, some methodological aspects of these plots limit statistical applications of data collected (DTRPA 2004). Foremost among these issues is the non-random nature of the selection and placement of plots on the landscape. Researchers used plots of different shapes and sizes, plots were targeted for different purposes (i.e., some plots were non-randomly selected for "management and scientific purposes"), and many plots were selected because they hosted seemingly high abundances of tortoises when first evaluated.

Additionally, a variety of study designs and demographic survey methods were implemented over time at the 8 plots established in the western Mojave between 1976-1980. Further, the methods used to collect data in plots did not account for detectability of tortoises, plots were monitored inconsistently over time, and monitoring ceased in some plots when tortoise numbers declined. Availability of the data collected on these plots, as well as the frequency with which the plots are monitored, varies widely among and within individual states. Nonetheless, these demographic plots represent the longest existing time series of MDT mark-recapture data, and as such, should be considered of fundamental value to MDT population monitoring. Re-initiation of MDT monitoring at 6-8 of these demographic plot locations within RASP focal areas, if possible, would provide key data for long-term comparison with historical data—if and when they become available.

[1] Desert Tortoise Natural Area (interior and visitor center), Fremont Peak, Fremont Valley, Johnson Valley, Kramer Hills, Lucerne Valley, Stoddard Valley

[2] All shown in footnote 1 except Stoddard Valley

[3] All shown in footnote 1 except Stoddard Valley and DTNA interior

2.4.2. Lessons Learned from Existing Long-term Demographic Study Plots

Drawing from lessons learned from established plots as well as best practices for demographic vital rate estimation, there are several recommendations for the study design of long-term study plots that should be considered in the RASP monitoring framework:

- Probabilistic selection of study sites and repeated visits over time; i.e., plots should be randomly placed within critical habitat areas and/or placed to address specific hypotheses concerning threats or management actions, using a stratified random sampling design whenever feasible;
- Sufficient replication within a hierarchical framework to represent the different sizes and scales of management areas (e.g., several plots within each area upon which future analyses are to be conducted);
- Adequate replication of plots within years (typically a minimum of three visits to plots within a year for estimating annual demographic rates) to allow for estimation of detection probability in analyses;
- Ideally, methods selected will produce datasets that are relevant and appropriate for long-term analyses (i.e., spanning a minimum of 25-50 years). Long-term data are essential to understand mechanisms underlying MDT population trends and whether recovery goals are being met.

2.4.3. Additional Demographic Studies and Insights for the RASP Monitoring Plan

More recently, new demographic information has been collected in RASP focal areas through monitoring programs designed primarily to evaluate the effects of mitigation translocation on tortoise survival (e.g., Esque et al. 2010; Henen et al. 2020). Specifically, expansions of military installations at Fort Irwin and MCAGCC required MDT to be removed from expansion areas and translocated to recipient areas. Translocation monitoring data for Fort Irwin are available from 2006-2008, and for MCAGCC from 2019-present. In accordance with USFWS translocation guidance (USFWS 2020), monitoring programs were established to compare short-term effects of translocations on tortoises compared to resident tortoises (i.e., those already living in areas that received translocated tortoises) and tortoises in 'control' areas unaffected by the translocation efforts. These studies used radio telemetry to track individual tortoises in each treatment group (i.e., translocated, resident, control) during the active season to understand short-term behaviors such as space use and to estimate survival rates. The sites that USFWS maintains to estimate the proportion of tortoises available for detection during LDS surveys also contain a large number of tortoises with radio transmitters (> 150), including several sites within the RASP focal areas. Demographic data collected through these various projects for telemetered individuals may provide valuable baseline estimates and ongoing data relevant for monitoring RASP priority demographic metrics.

The MCAGCC translocation project, in particular, also generates information about MDT fecundity (eggs produced per female), and juvenile tortoise biology and ecology through its captive rearing and head-starting program at the Tortoise Research and Captive Rearing Site (TRACRS) (Nagy et al. 2015; 2020). In particular, several cohorts of juvenile tortoises have been reared in predator-resistant, outdoor enclosures, allowing for research into growth, nutrition, and survival of early life stages. Once tortoises reach adequate body sizes to permit attachment of radio transmitters, these 'head-started' juveniles are released and tracked in the wild to provide information about their survival and causes of mortality (Nagy et al. 2015; 2020). These types of data on desert tortoises in early life stages are rare, and are thus a valuable resource for a holistic population monitoring program.

The MCAGCC monitoring plan (Christensen et al. 2016) provides details about how this program has been conducted to ensure robust information is collected to evaluate the effectiveness of translocations. In addition to ongoing monitoring efforts, pre-translocation monitoring included establishment of demographic study plots in and around the proposed expansion areas to collect baseline data on demographics, habitat quality, disease status, behavior and space use, and genetics (Christensen et al. 2016). Ongoing and future translocation studies provide critical information about MDT population dynamics and should be prioritized by the RASP monitoring program going forward.

Additional monitoring efforts on study plots outside the RASP focal areas also provide useful information and examples for a RASP monitoring program. For example, study plots have been monitored in AZ for Sonoran desert tortoises to allow state wildlife managers to track tortoise densities and survival over time (Zylstra et al. 2013; Campbell et al. 2018; Zylstra and Steidl 2020). Several study plots in NV and CA have also been monitored in recent years (see Appendix A, Table A2).

2.5. Monitoring Recommendations

2.5.1. Guiding principles for the RASP monitoring plan

Considering the RASP monitoring metrics and relevant monitoring methods described above, a series of recommendations have been developed to guide the RASP monitoring plan (Box 2.2). These recommendations are intended to provide sufficient guidance for a monitoring program to be designed and implemented in the field, once key details have been confirmed by RASP partners. Here, we describe overarching principles that RASP should use to develop the specific structure and execution of the monitoring program.

Box 2.2. Guiding principles for population-level monitoring plan:

- Incorporate multiple monitoring metrics to provide holistic, population-level inferences;
- Ensure robust spatial coverage of monitoring efforts;
- Include sufficient replication of monitoring sites/plots;
- Select monitoring sites using a randomized sampling design to ensure statistical robustness of data;
- Monitoring program should balance statistical robustness with efficient use of limited funding and personnel.

- ***Principle 1: Incorporate multiple monitoring metrics to provide holistic, population-level inferences.*** As described previously, the RASP monitoring plan will include a suite of monitoring metrics that collectively allow inferences about MDT population dynamics (refer to Fig. 1 conceptual diagram). Monitoring a single or a few life history metrics limits our ability to mechanistically understand the overall viability of MDT populations, and is of limited utility in evaluating efficacy of management actions that may target multiple life stages. Information about clutch size, number of hatchlings emerging each season, and proportion of juveniles within the population provides mechanistic insight into current population trends, as well as implications for future population dynamics (i.e., high hatchling output this year may indicate higher juvenile recruitment in later years). Although estimates of adult tortoise densities can give an indication of the trend and trajectory of the population (e.g., is it declining or increasing?), information about earlier life stages is important for interpreting those trends over time (i.e., are observed declines due to increased mortality of adults? Or poor juvenile recruitment to adulthood in previous years?). By designing a holistic monitoring plan to gather information on multiple life stages, RASP will be able to draw inference regarding the drivers of MDT population dynamics, particularly in response to management actions. At the same time, monitoring multiple life stages will allow decision-makers to identify effects of and adaptively manage distinct management actions that focus on specific life stages.

- ***Principle 2: Ensure robust spatial coverage of monitoring efforts*.** Any wildlife monitoring plan needs to sample available habitat sufficiently to capture important variations that influence patterns of animal distribution and space use. Ideally, placement of monitoring plots/transects should be randomized to ensure robust statistical inference and avoid biases toward certain habitat types or conditions. In addition to considerations of habitat variations, the number and distribution of monitoring sites should also reflect the relevant strata at which inferences need to be made. In the case of the RASP monitoring plan, inferences might be needed at the level of the individual focal areas as well as at the broader Tortoise Conservation Area (TCA) level, within which focal areas are located (i.e., a nested spatial structure). Further, the monitoring plan should allow for comparisons within focal areas where RASP management interventions will occur, as well as outside focal areas as controls for priority monitoring metrics. To address these issues, the RASP monitoring plan might explore co-locating monitoring efforts relative to randomized locations of line transects under USFWS's long-term LDS monitoring program.

- ***Principle 3: Include sufficient replication of monitoring sites/plots*.** Related to Principle 2, ensuring that a sufficient number of monitoring sites are established across a given study area is essential to produce an adequate sample for robust statistical inferences about focal monitoring metrics. Though site replication increases monitoring costs (i.e., more people, more field resources), it also can buffer against unforeseen—but common—challenges in wildlife monitoring that are unrelated to the management actions being evaluated. For example, replication ensures that a monitoring program can continue operating even if catastrophic events force the removal of a site from monitoring efforts, or the loss of animals being monitored, due to fires at a site, massive tortoise die-offs, or widespread predation by badgers, which are not typical tortoise predators.

- ***Principle 4: Select monitoring sites using a randomized sampling design to ensure statistical robustness of data*.** Given dramatic declines in MDT densities and continued degradation of Mojave Desert habitat, simple random sampling of monitoring sites might not be an appropriate approach if selected sites contain zero tortoises to generate robust estimates of monitoring metrics. A stratified random sampling design may be more appropriate, where sites are randomly selected from a targeted subset of occupied or suitable MDT habitat. Multiple factors could be explored for delimiting and stratifying areas for sampling, including gradients of habitat quality (e.g., land cover, topography, human modification), as well as modeled occupancy (CSP 2021) and/or densities of MDT. A more targeted—but still randomized— sampling approach could strike a balance between statistical robustness and efficient allocation of limited resources.

- ***Principle 5: Monitoring program should balance statistical robustness with efficient use of limited funding and personnel.*** Though the RASP monitoring plan will depend in large part on new data collection efforts, and ensuring statistical robustness of inferences based on these monitoring efforts is a primary goal, wildlife monitoring is expensive in terms of people, time, and money. Thus, the RASP monitoring plan should combine new data collection efforts with existing data and ongoing monitoring programs to gain efficiencies in terms of resource costs and existing experience. For example, the RASP monitoring program should rely heavily on the long-term USFWS line transect monitoring program, as well as ongoing and future translocation efforts (e.g., MCAGCC, Fort Irwin), to generate relevant data for priority monitoring metrics. In addition, sites used by USFWS to estimate 'availability' of tortoises for detection during LDS surveys (i.e., g0) contain tortoises that are radio-tracked multiple times a year. Tortoises at these sites also could be used to collect data on vital demographic rates, reducing the number of new tortoises requiring location, capture, and subsequent radio-tracking. In addition, field crews could collect data that support estimation of multiple metrics, or crews performing different monitoring methods (i.e., line transect vs mark-recapture) could be coordinated in time and space to gain further efficiencies.

2.5.2. Specific monitoring components and schema

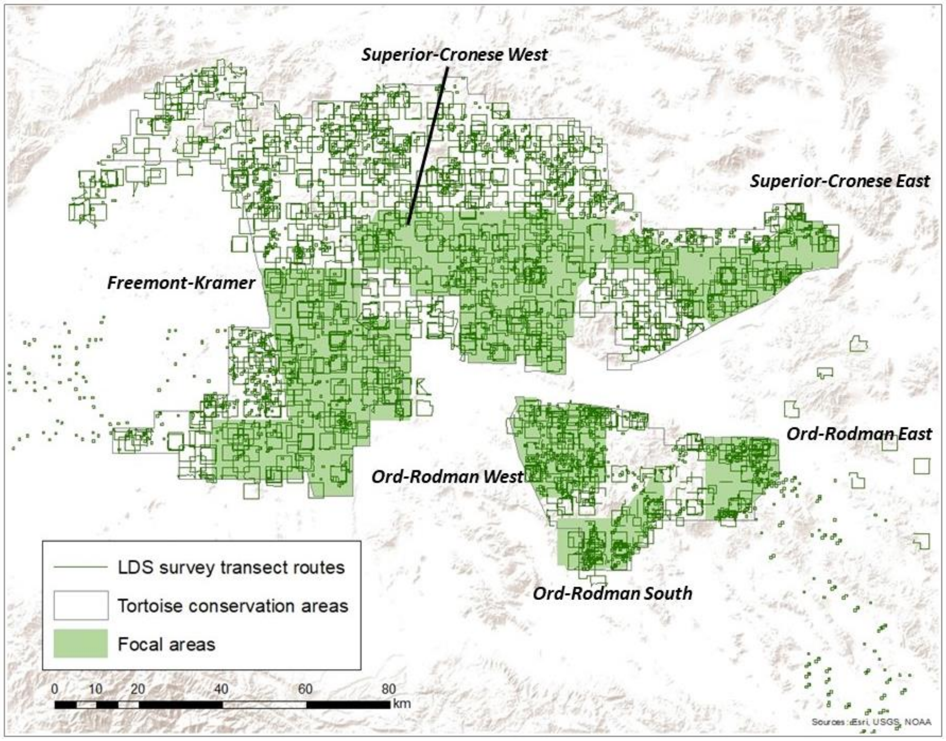
For the RASP monitoring plan, we recommend a nested, multi-method approach to collect the required data for estimating key metrics needed to robustly monitor MDT demographic rates and population viability at relevant time scales (i.e., multiple tortoise generations) (Box 2.3). To do this, we recommend (1) using the long-term, LDS program coordinated by the USFWS as the foundational monitoring component to continue collecting information on tortoise densities for multiple strata, and (2) implementing standardized (ideally telemetry-based known-fate) capture-mark-recapture surveys within an array of demographic monitoring plots to collect data on survival and juvenile recruitment, and (3) targeted monitoring of reproductive output and success within the same demographic monitoring plots.

Box 2.3. Key considerations for RASP monitoring plan:

- Focus RASP resources on long-term demographic study plots to track tortoise vital rates, while leveraging ongoing, established LDS surveys to continue monitoring tortoise densities;
- Explore options to co-locate new demographic study plots relative to randomized locations of LDS transect surveys;
- Consider re-initiating monitoring efforts at historic demographic study plots (in addition to new, randomly placed plots) to allow for the possibility of important, long-term time series and trend analyses, should historic datasets become available.

1) The foundation: Long-term, line transect monitoring

The most consistent, robust source of long-term monitoring data available within the RASP focal areas is the LDS data collected and provided by the USFWS DTRO, from 2000 to present (See: Table 1.1 and Table A3 for additional details on LDS data and key data custodians). This established monitoring program offers 20+ years of data on tortoise densities and population trends and provides relatively comprehensive spatial sampling across the RASP focal areas (Fig. 2.2). However, LDS surveys are primarily designed to estimate tortoise density and abundance and fail to capture important information about demographic metrics (e.g., survival rates for multiple size/age classes, recruitment, reproductive output) that may explain trends over time (Heppell 1998). Again, we recommend that RASP monitoring efforts leverage ongoing LDS surveys to continue tracking tortoise densities and population trends, while bolstering these efforts with new surveys to monitor demographic metrics.



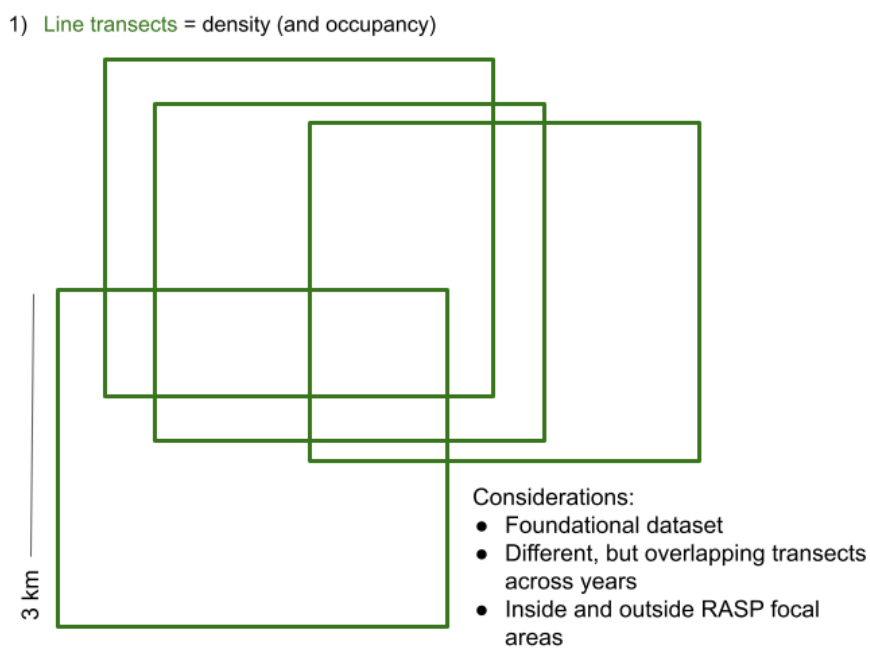


Figure 2.2. Top: USFWS MDT Line Distance Sampling (LDS) transect locations within RASP focal areas; Bottom: schematic showing line transects and considerations for their application within the RASP monitoring framework.

2) Demographic plots for vital rate data

Building on the 'bedrock' dataset of the LDS program, the second component of the RASP monitoring plan should be a suite of demographic plots to collect key vital rate data, specifically juvenile/adult, sex-specific survival rates, which will complement range-wide density and trend data generated by LDS (Fig. 2.3). These plots should be co-located to some extent with LDS transects to ensure that inferences about survival rates can be used to explain patterns in tortoise density in the same general areas and time periods. It is important to emphasize that we are not suggesting LDS surveys can be used to monitor marked individuals in demographic plots; these are separate monitoring efforts with separate objectives and protocols. Co-location of density and demographic monitoring efforts will simply ensure that estimated population metrics overlap spatially within the same focal areas. Most importantly, plots should be placed within RASP focal areas as well as outside focal areas to provide robust 'control vs. treatment' comparisons. In addition, a sufficient number of sites should be established to ensure robust inferences about relevant monitoring strata (e.g., RASP focal area, TCAs).

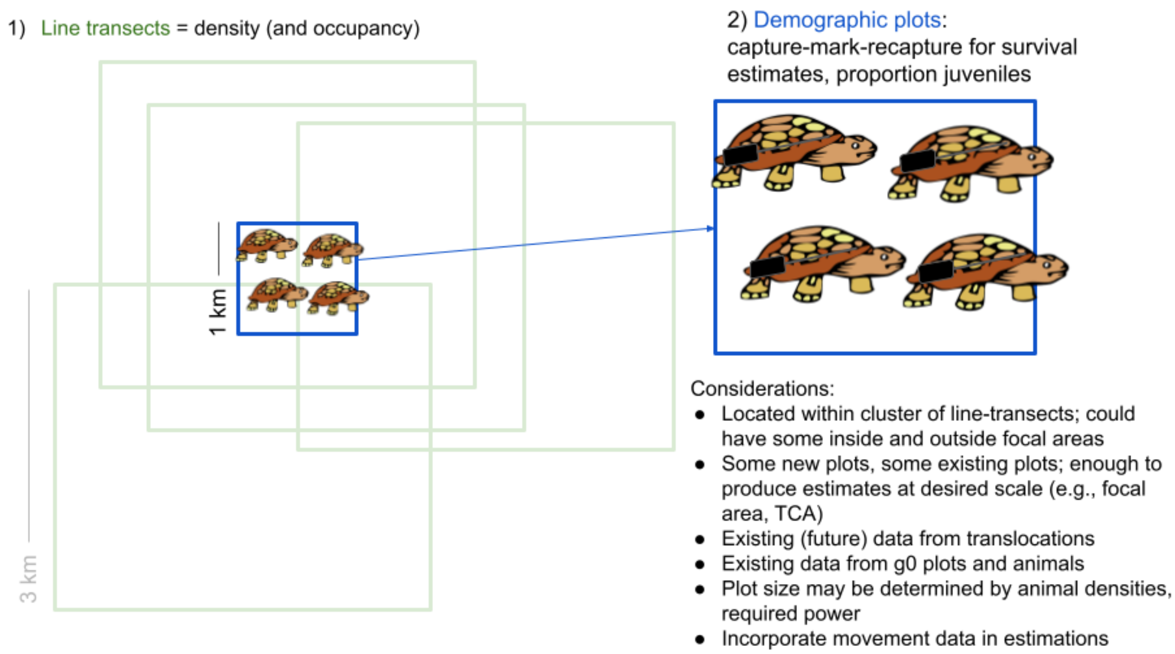


Figure 2.3. Building on recommendation 1 (leveraging USFWS LDS data), recommendation 2 is to establish and maintain demographic study plots to collect data on vital rates, specifically juvenile and adult survival.

While noting the limitations associated with existing study plots in the Western Mojave, we recommend that, to the extent practicable, RASP leverages these plots in addition to new, randomly placed demographic monitoring plots going forward. If the historical data associated with these plots becomes available, these could be integrated with new data to potentially provide rich time series and trend analyses, within the same locations. However, in addition to leveraging the existing plots where possible, the RASP monitoring plan should also include establishment of new demographic plots to ensure methods are consistent and robust.

Plots should incorporate CMR as the overarching monitoring paradigm, likely relying on telemetry—either radio or small GPS transmitters—for data collection. Telemetry-based mark-recapture (e.g., 'known fate' CMR models) is highly valuable not just for confirming survival (or mortality) of individual tortoises, but also for developing analyses of space use that are critical for understanding biotic, abiotic, and anthropogenic drivers of tortoise behavior and survival (Esque et al. 2010; Walde and Boarman 2013; Farnsworth et al. 2015; Brand et al. 2016; Dickson et al. 2019; Henen et al. 2020).

The exact number and location of demographic plots will be determined once the focal areas and boundaries are finalized, and once RASP determines the geographic scale at which it requires monitoring data. Plots should be monitored annually during the active season for the first 3 to 5 years of monitoring plan implementation, and then perhaps every 3 to 5 years thereafter. It is important to highlight that these plots—as with the LDS transects—should be monitored for the long-term (i.e., multiple tortoise generations) to produce meaningful data on key metrics and overall MDT population dynamics.

3) Assessment of reproductive output

The third component of the RASP monitoring plan should include assessment of reproductive output and success, nested within demographic study plots that focus on tracking individual tortoises (Fig. 2.4). First, a subset of telemetered females can be X-rayed to determine whether they are carrying eggs, which will provide data on the proportion of gravid females each season and the number of eggs produced per female. Second, gravid females can be tracked to their nest sites, which can then be monitored intensively during incubation to record information about embryonic survival and number of hatchlings. This will provide data on early life stages to complement data on older life stages collected using other monitoring methods; how many eggs are being laid and how many tortoise hatchlings are emerging each season are important indicators of the immediate health and viability of females in the population and allow for estimation of recruitment into older life stages.

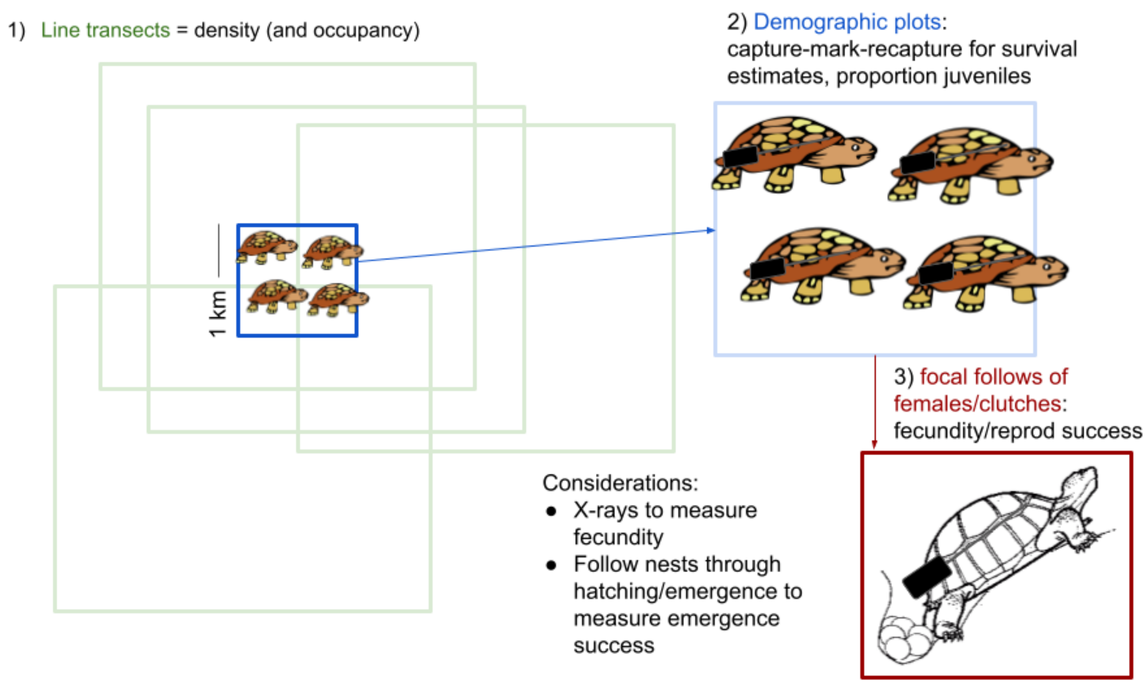


Figure 2.4. Building on recommendations 1 (leverage USFWS LDS data) and 2 (establish demographic study plots), recommendation 3 is to implement focused methods to record information on fecundity and reproductive success. These three, nested methods will ensure collection of data that support monitoring metrics for multiple life stages, thus providing a holistic perspective of MDT population dynamics.

2.6. Summary

Recovery goals for MDT specify criteria on demography, distribution, and habitat. Monitoring progress toward these goals over time to determine whether the species can eventually be delisted requires a holistic, comprehensive monitoring approach (USFWS 2011). Monitoring efforts that focus on a single metric, such as adult tortoise densities, will fail to capture information on multiple life stages important for understanding overall population trends and dynamics for the species. Given that the USFWS DTRO has already invested significant resources to establish the LDS program to monitor MDT densities across their range, we recommend the RASP monitoring program focus on establishing long-term demographic plots to track survivorship, juvenile recruitment, and reproductive success. Locations of new plots should be determined using a robust, randomized study design, which could be layered and integrated relative to randomized locations of LDS transect surveys. In addition to these new, randomized study plots, we also recommend the RASP monitoring program re-initiate monitoring efforts within 6-7 historic demographic study plots within the RASP focal areas. If the historic datasets become available in the future, RASP will then be in a position to facilitate valuable, multi-decadal MDT population trend analyses. Given the long lifespans of desert tortoises, long-term datasets such as this are particularly important for evaluating progress towards recovery goals.

The monitoring guidance provided here describes a holistic population monitoring approach, relevant monitoring methods and protocols, and recommendations about key principles and considerations for a RASP MDT monitoring program. We provide a summary of these recommendations in Table 2.1, below.

2.7. Role of RASP coordinator

A key role for a potential RASP coordinator will include building close partnerships and initiating data sharing agreements with existing MDT monitoring programs. Specific responsibilities of a RASP coordinator might include:

- Maintaining communication with other monitoring program managers and researchers to ensure RASP monitoring initiatives complement existing monitoring efforts;
- Ensuring new RASP monitoring efforts incorporate vetted protocols and a robust study design;
- Verifying that RASP monitoring data will be relevant for tracking progress towards MDT recovery goals across multiple time scales, including short-, mid-, and long-term objectives.

Table 2.1. Summary of priority MDT monitoring metrics from the RASP Draft Implementation Plan, recommended methods to support estimates of monitoring metrics, and key reference studies and protocols for each method.

Target monitoring metric	Specific monitoring metrics	Type of method	Baseline data in RASP focal areas?	Needs for additional data collection for future estimates	Key studies/protocols
Adult and juvenile survival rates	Annual and cumulative survival rates; responses to env and anthro covariates	Capture-mark-recapture via radio telemetry	Yes: Ft Irwin, MCAGCC	• Maintain ongoing efforts (MCAGCC) • Reinitiate efforts in previously monitored sites • Establish new sites	Esque et al. (2010); Walde and Boarman (2013); Henen et al. (2019, 2020, 2021); Dickson et al. (2019)
	Annual and cumulative survival rates, and possibly other vital rates (e.g., growth rates, mortality, and causes of mortality)	Capture-mark-recapture via transect/quadrat surveys within (randomized) study plots	Somewhat, in existing publications	• Reinitiate efforts in previously monitored sites • Establish new sites	Berry (1984); Berry and Christopher et al. (2003); Berry et al. 2006; Berry et al. (2020); DTRPAC (2004); Allison and McLuckie (2018)
Tortoise density	Tortoise densities, trends, other metrics (e.g., occupancy)	USFWS line-transect tortoise observation data	Yes	• Maintain ongoing efforts	Allison and McLuckie (2018)
	Tortoise densities, trends, other metrics (e.g., occupancy)	Capture-mark-recapture via transect/quadrat surveys within (randomized) study plots	Somewhat, in existing publications	• Reinitiate efforts in previously monitored sites • Establish new sites	Berry (1984); Berry and Christopher et al. (2003); Berry et al. 2006; Berry et al. (2020); DTRPAC (2004); Allison and McLuckie (2018); Mitchell et al. (2021)

Table 2.1, continued.

Target monitoring metric	Specific monitoring metrics	Type of method	Baseline data in RASP focal areas?	Needs for additional data collection for future estimates	Key studies/protocols
Reproductive success	Egg size and egg production	Radio-tracking females; Clutch exams via X-ray monitoring of females	Yes: Fort Irwin	• Establish new sites	Walde and Boarman (2013)
	Eggs/nest, nests/female; hatching success; predation rates	Radio-tracking females in (randomized) study plots; nest monitoring	No	• Establish new sites	Sieg et al. (2015)
	Egg production by female, hatching success, early-stage survival estimates	Egg procurement from wild females to population headstarting experiment	Yes: MCAGCC	• Maintain ongoing efforts (MCAGCC)	Nagy et al. (2015, 2020)
Proportion of juvenile tortoises/ juvenile recruitment	Relative proportion of juveniles detected during surveys	Capture-mark-recapture via transect/quadrat surveys within (randomized) study plots	Unknown	• Reinitiate efforts in previously monitored sites • Establish new sites	Berry (1984); Berry and Christopher et al. (2003); Berry et al. 2006; Berry et al. (2020)
	Relative proportion of juveniles detected during line-transect sampling	USFWS line-transect tortoise observation data	Yes	• Maintain ongoing efforts	Allison and McLuckie (2018)
	Annual and cumulative survival rates of juveniles (<180 mm MCL)	Capture-mark-recapture via radio telemetry	Yes: Ft Irwin, MCAGCC	• Maintain ongoing efforts (MCAGCC) • Reinitiate efforts in previously monitored sites • Establish new sites	Esque et al. (2010); Walde and Boarman (2013); Henen et al. (2019, 2020, 2021); Dickson et al. (2019); Nafus et al. (2017)

3. Effectiveness monitoring guidance

3.1. Overview

> **Box 3.1. Key considerations for RASP effectiveness monitoring program:**
> - Use readily available, established protocols for monitoring short-term effectiveness of management activities targeting MDT and their habitats;
> - Focus on objective, standardized measures of tortoise recovery indicators;
> - Be grounded in statistically robust comparisons of treatments vs. controls;
> - Leverage potential synergies between new effectiveness monitoring efforts and existing research and monitoring efforts, whenever possible;
> - Facilitate regular communication of new monitoring information and findings to RASP decision-makers and resource managers to inform adaptive management.

In this section of the RASP monitoring plan, we move down a tier from the population-level monitoring guidance described in previous sections to focus on effectiveness monitoring for specific RASP implementation strategies. Effectiveness monitoring is used to measure how successful management actions are at achieving specific restoration or recovery objectives, and to inform adaptive management to increase their effectiveness, where required. Project-specific monitoring metrics are being developed within the RASP Implementation Plan and will provide primary guidance for effectiveness monitoring for RASP management actions; this section of the RASP monitoring plan is intended to provide programmatic recommendations for effectiveness monitoring from which project-specific guidance can be derived. Here, we provide guidance for monitoring the effectiveness of specific RASP implementation priorities (e.g., habitat improvements, translocations, and reduction of causes of tortoise mortality), and for evaluating the implications of effectiveness monitoring to guide changes in management priorities, strategies, and progress towards RASP Implementation Plan objectives.

Fortunately, several resources already exist to support implementation and monitoring of RASP priority strategies, including habitat restoration guidelines (DeFalco and Scoles-Sciulla 2009; Esque et al. 2021) and a MDT population augmentation strategy (USFWS 2021a). In this section we highlight key considerations for development of effectiveness monitoring priorities (Box 3.1), summarize existing effectiveness monitoring guidance, and describe recommendations for a coherent effectiveness monitoring strategy that will inform adaptive management of RASP project implementation.

3.2. Effectiveness monitoring guidelines

3.2.1. Habitat restoration and improvement (Implementation Plan Strategy 1.2, 1.3)

A primary threat to MDT populations is increasing habitat loss and degradation, driven by a wide range of human activities and climate-related stressors (USFWS 2011, Abella and Berry 2016). In particular, disturbance from off-highway vehicles (OHVs) on public lands has increased dramatically in recent decades (DeFalco and Scoles-Sciulla 2009). Restoring desert habitat and improving habitat connectivity/continuity following vehicle disturbance is a RASP implementation priority.

Effectiveness monitoring of habitat restoration efforts should be designed to evaluate the degree to which restoration activities recover ecosystem function and community structures similar to those of intact reference sites, by tracking specific habitat indicators (Esque et al. 2021). Careful selection of reference sites for comparison with sites that will undergo treatment is a key step in monitoring effectiveness of restoration efforts. Ideally, reference sites should be selected from areas close to treatment sites, and should capture relatively intact, target habitat conditions (Esque et al. 2021). Secondarily, resource-specific benchmarks of the established indicators can be created to evaluate effectiveness of restoration projects in supporting recovery of particular species or resources, such as MDT. Centering effectiveness monitoring first and foremost on ecosystem function and (vegetative) community structure ensures that habitat restoration activities will be evaluated for their benefits for the ecosystem generally, rather than tailored to a single species' ecological needs. Thus, if habitat is restored according to ecosystem indicators, individual species should also benefit.

Along these lines, USGS—in cooperation with BLM—recently developed guidelines for route restoration that provide valuable guidance on several fundamental points, specifically project planning and monitoring design. These include specific indicators and methods, several of which are aligned with and adapted from BLM's Assessment, Inventory, and Monitoring (AIM) core indicators and protocols (Table 3.1, adapted from Esque et al. 2021). This guidance document is a robust resource on several levels, and although designed specifically for route restoration, it identifies ecosystem indicators as well as monitoring methods that could be adapted to other restoration activities in non-linear areas (i.e., interior habitat within defensible polygons).

Table 3.1. Ecosystem indicators and their recommended monitoring methods for restoration of non-routes. Measurement methods adapted from BLM's AIM protocols are indicated. (Adapted from Esque et al. 2021).

Category		Ecosystem Indicators	Measurement Method(s)
Biotic	Core Indicators	Ground cover	Line-point-intercept (AIM)
		Vegetation cover	Line-point-intercept (AIM)
		Vegetation composition	Plot-level species inventory
	Supplemental Indicators	Rodent mounds and burrows, ant nests, lagomorph scat	Ocular counting
Soil	Core Indicators	Bare ground	Gap intercept (AIM)
		Soil bulk density/ compaction	Soil core method or excavation method
		Soil aggregate stability	Soil stability test (AIM)
	Supplemental Indicators	Soil texture	Texture by feel (AIM)
			Hydrometer method
Hydrologic	Core Indicators	Erosion	Gap intercept (AIM); visual
	Supplemental Indicators	Infiltration	Infiltrometer (supplemental)

As for tortoise-specific indicators or benchmarks, USGS and BLM Southern Nevada District Office (SNDO) are collaborating on a project that will serve as an example for other parts of the MDT range. This project is designed to identify benchmark values of AIM indicators (e.g., % cover of invasive plant species) that are linked to tortoise demographic rates. USGS and SNDO biologists are monitoring juvenile tortoises and habitat characteristics in several plots over multiple years to determine the relationships between invasive species cover and tortoise growth and survival. This study could be replicated in other areas to ensure that benchmark values are developed according to local vegetation community conditions and possible variation in tortoise demographic rates.

Current efforts to monitor habitat suitability, connectivity, and occupancy

As discussed in Sections 1 (Existing Data Sources) and 2 (Population Monitoring Guidance), there are several initiatives that provide valuable information on key metrics of tortoise habitat quality, occupancy, and connectivity. Nussear et al. (2009) produced a range-wide MDT habitat suitability model that provides a tool for managers and biologists to estimate acreage of suitable MDT habitat within various jurisdictions. Gray et al. (2019) generated a range-wide habitat connectivity layer that shows varying probabilities of tortoise movements across the landscape, corresponding to habitat features that either promote or hinder tortoise movement and space use patterns.

Recently, MDT habitat occupancy models have been developed to complement the density estimates produced by USFWS DTRO (Harju and Cambrin 2019; Kissel et al., in prep). Such models provide insights about probabilities of MDT colonization and extinction rates across the species' range based on environmental and human land-use covariates. As such, occupancy model outputs provide information that supports evaluation of effectiveness of recovery actions to meet overall recovery goals (USFWS 2011) and of potential consequences of future land uses on MDT habitat occupancy, at multiple geographic scales (CSP 2021).

Habitat suitability, connectivity, and occupancy metrics could be used by RASP managers to track successful habitat restoration over time. However, outputs of existing models are generally produced at coarse geographic scales unlikely to match project- or site-scales, so could be useful for prioritization and for detecting long-term trends in habitat metrics. In the shorter term, monitoring of metrics such as tortoise presence, density, and occupancy in RASP implementation areas could allow evaluation of whether habitat is effectively 'converted' from unsuitable or unoccupied or to suitable and occupied.

Use of remote sensing data to monitor habitat quality

Recent advances in remote sensing technologies and the growing availability of spatially explicit data offer unique opportunities to measure landscape characteristics, across broad spatial extents and in near real-time. There is increasing potential for the development of rapid, reliable methods of tracking disturbance events, vegetation shifts, and other environmental and climatic conditions that may be relevant for MDT monitoring efforts, using remotely sensed data. For example, airborne lidar and high-resolution aerial imagery were combined to identify potential burrow locations for MDT in Nevada, based on a combination of vegetation features and geomorphic characteristics (Young et al. 2017). In a study of MDT habitat connectivity, known locations of a sample of desert washes (preferred MDT habitat features and foraging corridors) were combined with freely accessible, 1-m resolution aerial imagery to model a range-wide, wall-to-wall map of desert washes, using an advanced machine learning approach (Gray et al. 2019). Despite growing interest in such efforts to incorporate remotely sensed data into MDT habitat modeling and monitoring efforts, this is still an ongoing and active area of research.

3.2.2. Reduce direct and indirect sources of mortality (Implementation Plan Strategy 2.1)

Reducing sources of mortality, particularly on late-stage individuals (i.e., adults and subadults), is the most effective way to reverse population declines of long-lived species like desert tortoises (Doak et al. 1994;

USFWS 2011). Tortoise mortality—specifically of larger, older individuals—resulting from collisions with vehicles on highways as well as off-highway routes is a well-documented factor hindering recovery in the Mojave Desert (USFWS 2011). Thus, highway fencing and OHV closures have been identified as RASP implementation priorities to promote MDT recovery.

Priority areas, highways, and OHV routes must first be identified to guide installation of fencing and closures. Fortunately, highway segments within and adjacent to RASP focal areas have been identified as priorities for fencing to reduce tortoise mortality, based on locations relative to washes and other high-transit areas for tortoises (Fig. 3.1). In the case of highway fencing, effectiveness monitoring of short-term success is essentially equivalent to implementation monitoring. That is, efforts should be made to ensure fences are installed properly and remain in place (see USFWS 2009, Chapter 8); properly installed fencing will provide the expected benefits of reducing—and hopefully eliminating—tortoise mortality on highways.

Although somewhat similar to highway fencing, OHV route closures are intended to not only prevent collisions with tortoises but also to promote ecological restoration. Unlike fencing, attempts to close OHV routes are often stymied by continued incursions and trespassing, making the initial closure itself a challenging prospect. Thus, effectiveness monitoring of OHV route closures requires a two-step approach of first confirming the persistence of the closure in the short-term, and then evaluating the success of ecological restoration within the closed route or area in the longer-term. Section 3.3 on Adaptive Management provides a more detailed discussion of short- and long-term effectiveness monitoring OHV route closures.

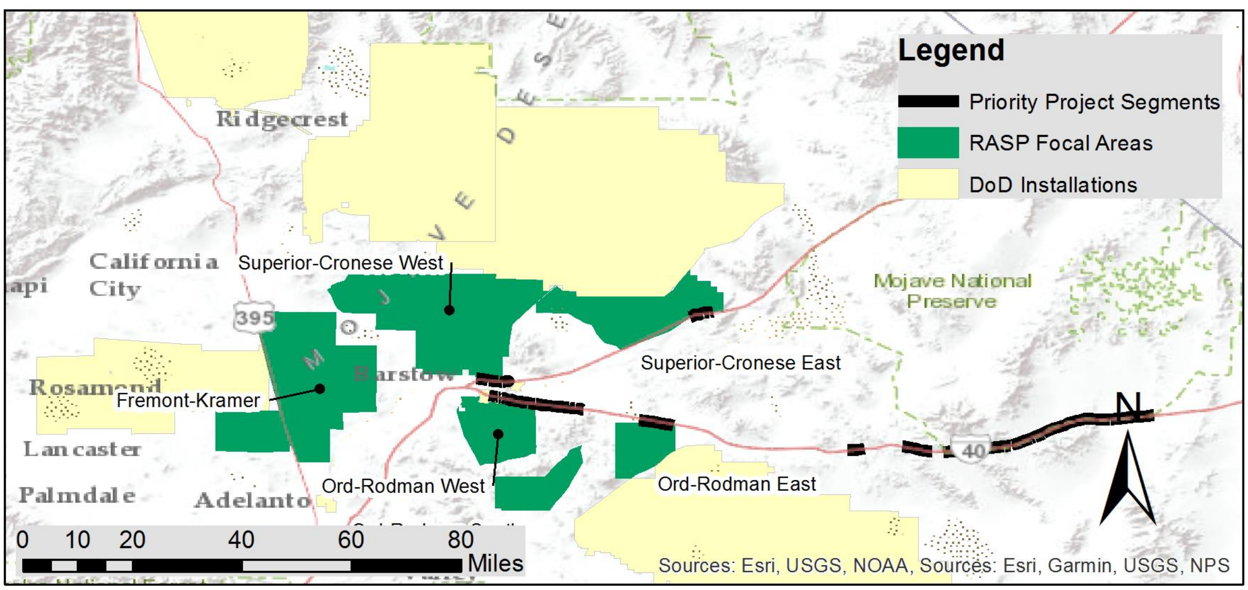


Figure 3.1. Priority highway fencing project segments (black areas along highways [shown as red lines]) in southern CA, relative to DoD installations and current draft RASP focal areas. Figure courtesy of KL Holcomb, USFWS.

However, effectiveness monitoring could also be established before and after installation of highway fencing to document potential short-term changes in presence and density of tortoises in adjacent habitats. Tortoise densities are typically much lower in areas adjacent to unfenced highways compared to areas further away from highway (Peaden et al. 2015), and tortoise home ranges decrease in size, while carapace temperatures increase with proximity to highways (unfenced or fenced) (Peaden et al. 2017) (Fig. 3.2a). Highway fencing could 'restore' these areas, and thus expand the total habitat available to tortoises, especially if combined with other relevant habitat treatments near the newly fenced highway (Fig. 3.2b). Thus, targeted monitoring of tortoises in areas adjacent to highway fences could provide valuable information about short-term space use in response to highway fencing, and increasing tortoise densities near highways relative to densities further from highways could serve as an effectiveness metric. For example, line transects established perpendicular to highways could document changes in tortoise presence, occupancy, and density as a function of distance to highways before and after fence installation (Fig. 3.2). Transects are an established method for sampling desert tortoises near highways (e.g., Boarman and Sazaki 2006), and this particular approach (Fig. 3.2), which has been piloted by DTRO (L. Allison, pers. comm.), could be a promising monitoring tool to provide project-specific information about effectiveness of highway fencing. The same approach could be implemented in a sample of RASP project locations and used to generate estimates of 'tortoises saved' for NFWF's monitoring and evaluation purposes.

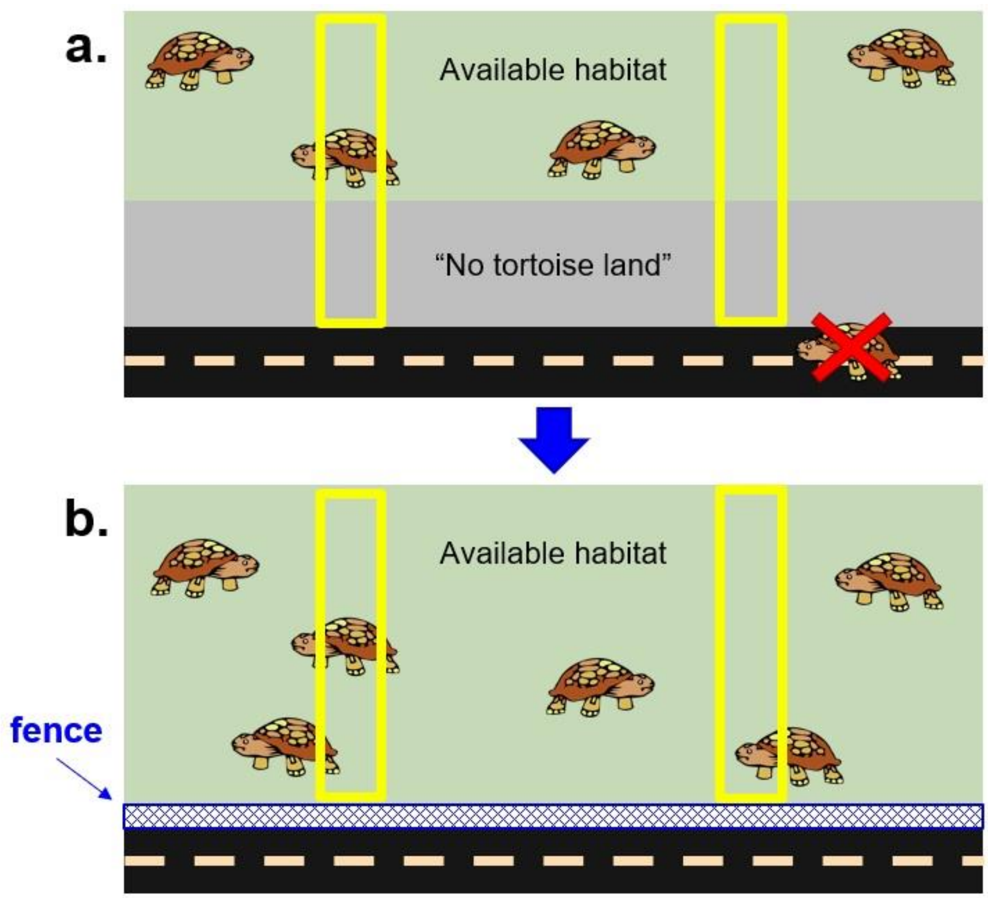


Figure 3.2. Transect surveys (shown in yellow) could also be conducted before (a) and after (b) highway fence installation, to gain additional insights on the effect of fences on movement, survival, and on the effectiveness of fences for measures of tortoise recovery such as density and occupancy.

Long-term monitoring of population metrics can be performed based on the range-wide density monitoring program (see Monitoring Guidance 2.3.1), but these metrics will provide a long-term perspective on the cumulative effects of management actions that address a range of issues, not just fencing. However, demographic plots (see Monitoring Guidance 2.4.1) could be used to monitor tortoise-specific responses to interventions that occur close to plots. For example, if highways near demographic plots are fenced, monitoring data could provide insights about how fences influence tortoises within study plots.

3.2.3. Augment depleted MDT populations (Implementation Plan Strategy 3.2)

Because the 2011 Recovery Plan included population augmentation as a key recovery action in the 2011 Recovery Plan (USFWS 2011), the USFWS developed guidelines for population augmentation activities (USFWS 2021a). This population augmentation strategy is primarily focused on mitigation translocations—i.e., "removal of organisms from habitat due to be lost through anthropogenic land use change and release at an alternative site"—but ultimately focused on the conservation benefit of the recipient site to promote recovery goals of sustained, long-term increases in tortoise abundance and distribution (USFWS 2011). The overall goal of the strategy is to "use population augmentation to help achieve recovery criteria within the recovery units. Individual augmentation plans should include objectives that describe how augmentation at that site will contribute to the overarching goal" (USFWS 2015).

The USFWS strategy (2021a) states that project-specific translocation plans should support regional augmentation plans by tracking health and survival of translocated tortoises compared to tortoises already occupying recipient areas as well as tortoises in control areas outside of the recipient areas. The MCAGCC work plan for translocations provides an example of a project-specific translocation plan that provides details about translocation study design, including monitoring areas, indicators, and methods (Christensen et al. 2016).

The USFWS strategy (2021a) recommends that the following criteria be addressed when identifying augmentation sites (see USFWS 2020, although in this case the criteria also apply to sites that will receive translocatees from captive or head-starting programs).

1. Depleted recipient tortoise population (i.e., < 3.9 adult tortoises/km^2, the threshold below which populations are unlikely to be viable; USFWS 1994, Appendix C) within TCAs or population linkages.
2. Habitat suitable for all life stages.
3. No evidence of an active outbreak of disease, such as high prevalence of clinical signs of disease or seropositive responses to infectious pathogens.
4. A distance of at least 6.5 km from the release area to any major unfenced highways (i.e., high traffic volumes/speed limits and no desert tortoise exclusion fence), highways, or human development that would pose a risk to desert tortoises.
5. No detrimental rights-of-way or other encumbrances that would pose ongoing risks to successful establishment of translocated tortoises.
6. Compatible management with continued desert tortoise occupancy.

The strategy also summarized several success criteria to measure progress of translocation projects (Table 3.2). This framework requires that the success of each stage determines the success of the subsequent stage(s), which provides opportunities for monitoring results to inform adaptive management that can address factors affecting the population, possibly including site-specific threat management.

Table 3.2. Success criteria for tortoise translocation projects (USFWS 2020, USFWS 2021a).

Stage	Indicators/metrics (methods and monitoring intensity may vary)	Time frame (post-translocation)
1. Survival and growth of released and resident individuals	a. Cumulative survival within 20% of controls* b. Increase in carapace length (CL) since release (tortoises released at <180 mm CL)**	a. 5 years b. 5–6 years
2. Evidence of reproduction in released and resident individuals	a. Female reproductive output is similar to controls*** b. Juvenile segment of the size-class distribution is increasing	a. 5 years (for mature releases) b. 9–18 years
3. Population growth	Increasing trend in adult population size	15–20 years
4. Viable population	Adult density > 4 km^2	20–30 years

* Measured via radio telemetry. Survival within 20% of controls is specified as a Stage 1 metric, because high survival is necessary to achieve a self-sustaining population in 20-30 years (Stage 4).

** Measured via periodic (e.g., triennial) mark-recapture surveys.

*** Measured via X-ray examination of females (clutch size) during telemetry-based monitoring

Along these lines, if causes of tortoise population declines are not addressed, population augmentation activities by themselves will not achieve sustained recovery. Therefore, population augmentation actions should identify objectives that will contribute to overarching recovery goals. In particular, augmentation should be implemented synergistically with other recovery actions that reduce threats to tortoise survival. For example, areas adjacent to newly installed highway fencing could also be recipient areas for translocated or head-started tortoises, thus allowing for expansion of occupied tortoise habitat as well as a way of monitoring the success of the other recovery actions. In such a case, space use, survival, and other metrics collected by field monitoring efforts related to the translocation or introduction of head-started tortoises could also support effectiveness monitoring of habitat restoration via highway fencing.

As outlined in the USFWS strategy (2021a), field monitoring should be used to evaluate the effectiveness of implemented augmentation activities to meet the pre-established project goals. For example, field monitoring will provide information about whether project metrics such as survival, habitat use, or changes in numbers of tortoises meet expectations and how to adaptively manage the project in subsequent implementation phases. Thus, as described in the USFWS strategy (2021a), augmentation plans should incorporate adaptive management considerations, such as regular monitoring of key metrics (Table 2) and pre-planned decision points that specify actions to be taken or corrected if monitoring demonstrates deviation from planned project progress.

3.3. Adaptive management guidance

Adaptive management is a dynamic, iterative approach to long-term management of biological resources that is responsive to the results of ongoing monitoring and research. Management objectives and strategies should be evaluated regularly as monitoring efforts provide new information on evolving threats, species responses, and other relevant factors (DTRPAC 2004). Adaptive management of MDT recovery actions should focus on objectively quantifying the effectiveness of management actions towards achieving specific, measurable outcomes (Kareiva et al. 1999). The effectiveness monitoring approach described here is designed to provide information that project implementers and managers can use not just to track progress toward project- and program-specific goals, but also to adaptively manage project design and implementation on a regular, strategic basis (Fig. 3.3).

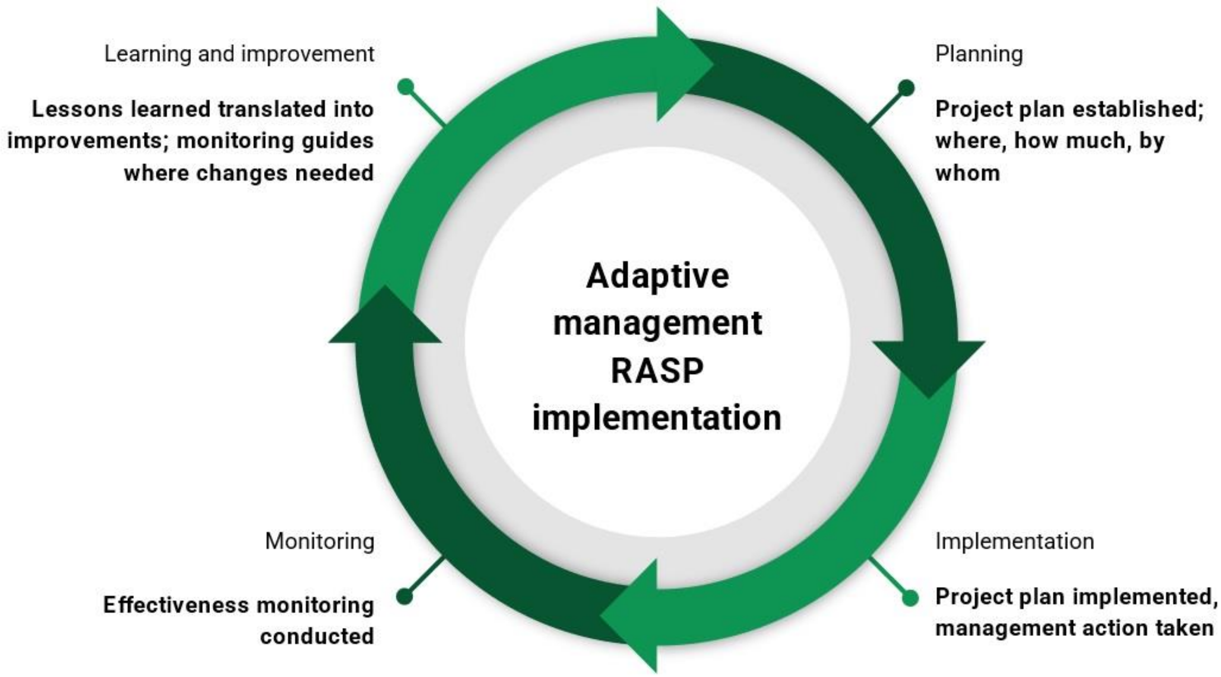


Figure 3.3. Conceptual framework illustrating the role and significance of effectiveness monitoring for informing recommendations for change as they relate to implementation priorities that support adaptive management.

Ultimately, to provide meaningful, actionable information, effectiveness monitoring of RASP implementation priorities should focus on short-term indicators that are linked to longer-term tortoise recovery goals and objectives. MDT, like the Mojave Desert ecosystem generally, respond slowly over many years (or decades) to recovery actions. Because such time periods are typically much longer than recovery planning and implementation time horizons, RASP recovery priorities should be designed, implemented, and evaluated for success within short- to medium-term (<10 yr) periods. Thus, we recommend that RASP effectiveness monitoring should focus on metrics for measuring progress that can be recorded yearly and analyzed within a few years, to inform adaptive management decision-making.

Through this short-term lens, there are important cases in which implementation monitoring actually *is* effectiveness monitoring. For example, once highway fencing or OHV route closures are implemented, there is a need to verify that they were implemented properly, and to verify that they remain in place. If they are in place, tortoise mortality caused by collisions with vehicles should be eliminated. Specifically, monitoring the effectiveness—i.e., the persistence—of OHV route closures warrants a two-step approach (Herrick et al. 2005; Holcomb 2013). First, evaluation of successful implementation of route closures should begin with a revisit to the restoration site within 1-2 months of implementation. Later, site visits should occur within 6 months to 2 years after implementation to evaluate the effectiveness and to confirm the persistence of the original installation. This monitoring would evaluate whether treatments are still intact, whether the closed route was trespassed, and whether positive signs of recovery are observable. Continued long-term monitoring should be conducted to evaluate effectiveness of subsequent recovery of habitat within the closed route and defensible polygons that are the target of the restoration efforts. By revisiting project sites, RASP personnel will be able to determine the effectiveness of the implementation simply by verifying that installed structures are still there. If they are not, managers can adapt implementation strategies to address this issue. Additional monitoring, as described in the sections above, can be used to supplement adaptive decision-making about programmatic priorities as well as project-specific techniques.

As described previously (Monitoring Guidance 2.5.1), a guiding principle for RASP monitoring should include leveraging efficiencies in ongoing or complementary activities, resources, etc., whenever possible. In this vein, we recommend that the RASP coordinator seek to take advantage of potential synergies between different implementation priorities. For example, head-started juvenile tortoises are tracked post-release to evaluate their performance, but these efforts could also be leveraged to evaluate juvenile responses to management actions such as highway fencing (Fig. 3.2). Short-term responses of head-started tortoises can provide insights about the effectiveness of actions for promoting positive outcomes for tortoises, and can inform adaptations regarding how recovery actions are implemented across RASP priority strategies.

Lastly, it is important to acknowledge that the impacts of multiple, simultaneous threats and their relative influence on tortoise populations are still poorly understood (USFWS 2011, 2021b). For example, raven management is not an identified RASP priority, yet it is a source of direct mortality to tortoises that could counteract benefits of RASP priority strategies (USFWS 2011). Thus, RASP could consider including targeted monitoring of raven presence within focal areas and other areas where management actions are implemented. Such monitoring could include focused point counts of ravens and their nests to estimate raven abundance, which could then be related to estimates of raven predation on tortoises.

The effectiveness monitoring recommendations described here provide guidance for measuring progress towards specific recovery goals resulting from specific management actions. However, much remains unknown and unquantified regarding the relative and synergistic effects of various stressors on tortoise populations (e.g., the effects of disturbance and drought on habitat condition, which likely mediates risk of predation and vulnerability to disease). We recommend keeping abreast of relevant research projects and efforts to quantify the relative and interacting effects of particular threats, and re-prioritizing management strategies as needed based on the best available science.

3.4. Role of RASP coordinator

The RASP coordinator's role in promoting effectiveness monitoring across the RASP implementation priorities is straightforward and critical. The existence of several guideline documents will enable the RASP coordinator to identify and extract key recommendations from these guidelines, and translate them to corresponding RASP priority strategies. However, the RASP coordinator will also need to develop an adaptive management strategy that incorporates monitoring metrics for each recovery priority, establishes pre-planned 'trigger' points where decisions should be made about potential changes to project implementation, and integrates across priorities to provide a coherent, program-wide plan. Importantly, the RASP coordinator can support adaptive management by facilitating the transfer of information gained through effectiveness monitoring to decision makers and resource managers. Annual RASP-partner meetings, facilitated by the coordinator, would provide an ideal opportunity for project-to-program evaluation and any needed adaptive management decisions.

A key opportunity for the RASP coordinator to share results of effectiveness monitoring will be at the annual review of the RASP recovery plan by DoD and USFWS. The recovery plan will also be updated at least every 5 years by USFWS and DoD in collaboration with BLM and other recovery partners. Recovery plan updates will apply new information gained through monitoring and incorporate new recovery priorities and recommendations from the Desert Tortoise Management Oversight Group, where applicable. Although these updates may modify the focus of implementation, it will not modify DoD's annual funding commitment under the RASP (see Implementation Plan Funding section).

4. Data management guidance

4.1. Overview

This final section of the RASP monitoring plan will focus on data management guidance describing the format, organization, and storage of acquired and newly generated RASP monitoring data, detailed in sections 1-3 above. Well-planned, effective data management is a key step in providing relevant, useful data to support MDT adaptive management and recovery. Due to the multi-jurisdictional nature of MDT research and recovery efforts, existing data have been collected, organized, and stored in a variety of formats. This presents a challenge for compiling and integrating relevant datasets from different jurisdictions, and has hindered efforts to coordinate the collection, storage, and analysis of MDT monitoring data across management boundaries.

At the same time, this is a unique opportunity for RASP to play an important role in coordinating, compiling, and organizing data from multiple sources, in a standardized format that can help facilitate analysis of MDT population trends and responses, across the RASP focal areas.

Box 4.2. Key considerations for RASP monitoring data management:

- Critical first step is to identify clear monitoring objectives, metrics, and statistical or analytical needs –before data design or collection begins;
- All elements of data management should be carefully designed to meet these specific monitoring objectives and needs;
- Ensure newly generated data can be integrated with existing monitoring data, following standardized data collection and management protocols;
- Work closely with existing data custodians to identify how data should be consolidated and uploaded to federal repositories.

4.2. General guidance on data management

Data management plans are fundamental components of any conservation program that aims to collect and organize data for purposes of analysis and interpretation. Existing guidance on data management for projects focused on MDT can be generalized and adapted to this RASP monitoring plan. In particular, the USFWS (2015) developed a Desert Tortoise Monitoring Data Management Plan for data collected through their LDS surveys. This plan provides an effective and relevant model for the management of other desert tortoise monitoring data. Distinct phases in an effective data management process, from initiation of data collection to finalization of data products, are described below (Fig. 4.1).

Design Phase: Collection Design

There is an initial design phase in which specific data fields, types, and formats are described, based on the monitoring objectives and specific metrics (Fig. 4.1). This important step includes the design of data collection forms and instruments as well as quality control and quality assurance protocols (QA/QC). Given the current lack of standardized, central databases for the types of MDT monitoring data RASP will generate in support of the Implementation Plan (e.g., demographic data, habitat restoration data), this section of the RASP monitoring plan is intended to support this important design phase, specifically. There are current efforts to coordinate more consistent data collection and centralized storage, across the range of MDT; for example, the BLM is working toward a common framework and database for habitat disturbance, treatment, and monitoring data. Thus, a key role of the RASP coordinator will be to work closely with data custodians to stay abreast of these efforts, and to ensure RASP monitoring data can be integrated with central databases, if and when these are finalized.

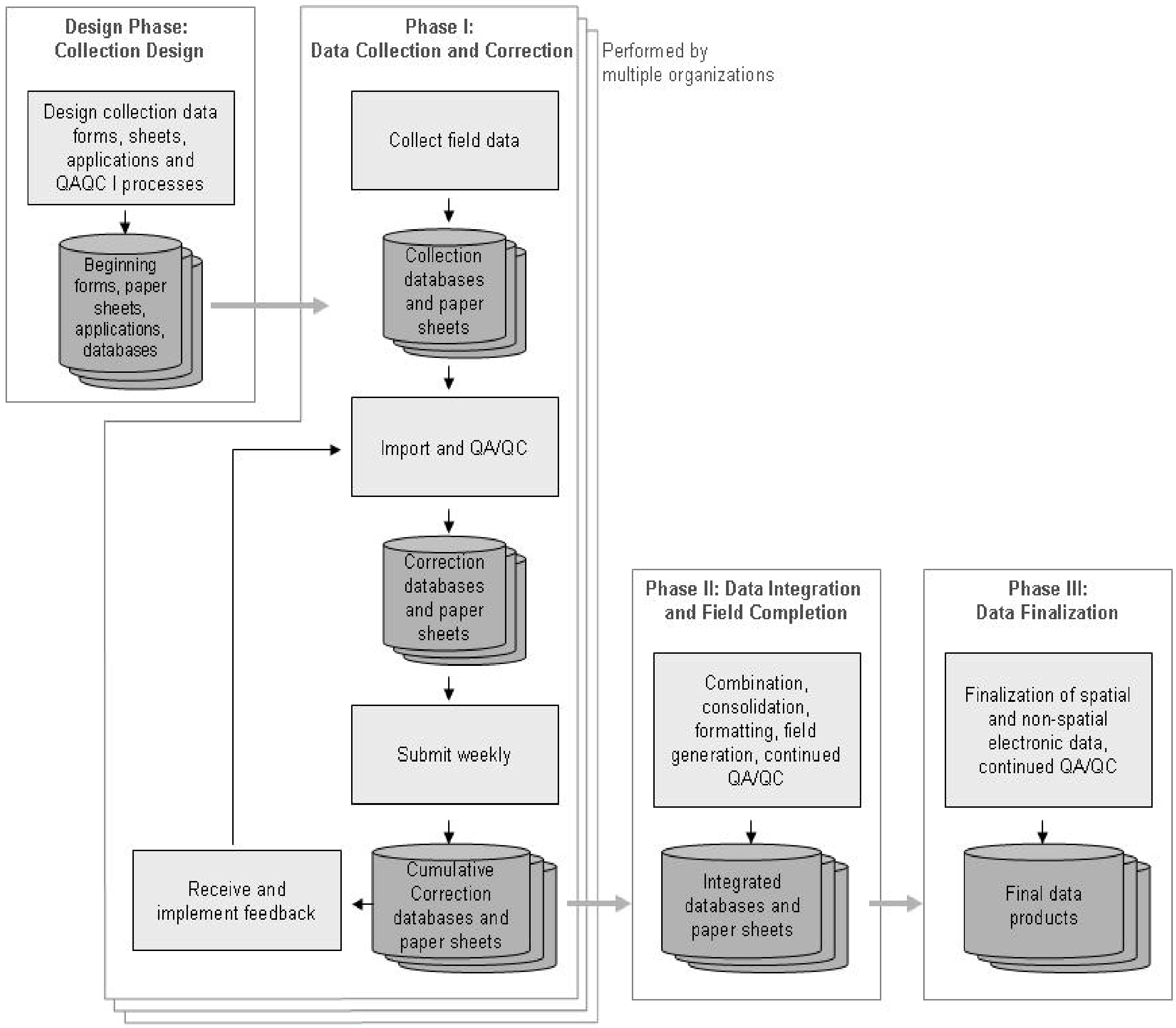


Figure 4.1. Schematic describing generalized data management process from initial data collection to finalized data products (From USFWS 2015).

Phase I: Data Collection and Correction

Phase I involves data collection and correction, which can be performed by multiple organizations depending on the scale and scope of data collection efforts. In the case of the RASP Implementation Plan, it is likely that there will be multiple RASP partners and subcontractors, as well as NFWF grantees, responsible for collecting data. This phase ensures that data are collected according to established protocols and are then filtered through adequate QA/QC protocols to ensure that data can be appropriately analyzed. QA/QC checks should include verification that all required fields are filled properly, according to required formats and relationships to other fields and to the overall database structure (Table. 4.1).

Table 4.1. Example checks in QA/QC protocols for field collected data (USFWS 2015).

Type	Description	Examples of Errors
Database relationships	Identifies orphans or deviations in the expected number of features related to another feature	Waypoints with no transect. More than 22 waypoints related to a transect
Field domains	Identifies values that are not within a specified range or set	Tortoise mcl > 400
Duplicate records	Identifies duplicate records	Duplicate transects
Multi-field attribute conditions	Identifies records that do not meet specific conditions for attribute values	Observer does not match the lead or follow for the last waypoint "Gsub0 = Visible" but no behavior recorded
Spatial conditions	Identifies records that do not satisfy a spatial relationship	Transects that do not intersect their monitoring strata Observations that are more than 50 meters away from their related transect

Phase II: Data Integration and Field Completion

Phase II involves integrating data from multiple sources into a single database. This phase will be relatively efficient if a) there is an existing database into which data will flow upon project start, and/or 2) the data fields selected for data collection match the fields in the master database. QA/QC checks in this phase ensure that data are correctly copied or imported into the master database to maintain their integrity from initial collection to first QA/QC review. Paper datasheets should be preserved for any further QA/QC and as backups to the electronic database.

Phase III: Data Finalization

The final phase of data management involves generating finalized data products. These products could include spatial display and/or analyses of field collected data, as well as analyses of priority monitoring metrics. For example, in the case of the RASP Implementation Plan, effectiveness monitoring of habitat improvements and/or projects to reduce tortoise mortality could be analyzed using field-collected data associated with supported projects.

4.3. Management of newly generated RASP monitoring data

Building on the general guidance described above, we provide specific guidance here for a RASP data management process for the types of newly generated monitoring data described in previous sections of this monitoring plan. The recommended data flow process (Fig. 4.2) provides a management framework for all data collected as part of the RASP monitoring plan. In sections 4.3.1 and 4.3.2, below, we describe considerations specific to habitat effectiveness monitoring and population monitoring, respectively.

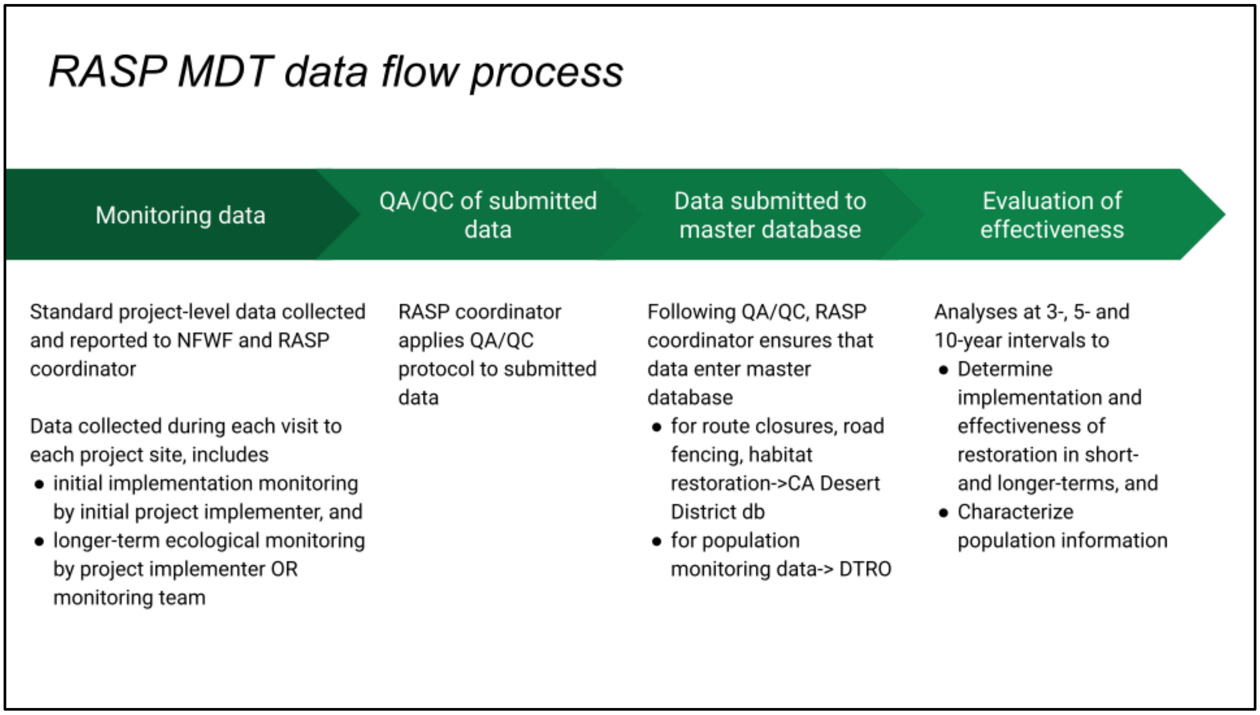


Figure 4.2. Schematic of the recommended RASP MDT data flow process, with a focus on data collected for habitat restoration projects.

First, monitoring data are collected in the field in association with specific projects supported under the RASP Implementation Plan (Fig. 4.2). Data will be collected by NFWF grantees and RASP partners and their subcontractors according to established, required fields. USFWS has developed several data forms and data dictionaries (Appendix B) for data types similar to those recommended for the RASP monitoring plan, and these resources could serve as the basis for designing RASP's data collection requirements. Project PIs will be responsible for initial QA/QC of collected data, using protocols developed by the RASP coordinator using the USFWS's data management plan (2015) as a guide.

Data will then be reported to NFWF as part of grant requirements and then to the RASP coordinator (in the case of projects supported directly by NFWF), or directly to the RASP coordinator in the cases where a project is supported by a RASP partner and not NFWF. Data will also be collected during repeated visits to a project site for the purpose of effectiveness monitoring, either for short-term implementation monitoring to review the 'restoration integrity' (i.e., evaluate the extent to which the treatment remains in place), or longer-term ecological monitoring once implementation is completed (see Section 3 for details).

Next, the RASP coordinator will perform QA/QC of the data collected on RASP Implementation Projects (Fig. 4.2). This QA/QC process verifies that data were entered in all required fields, and that data entry conforms to the required formats of the individual fields. For example, the USFWS DTRO uses an extensive MDT monitoring data dictionary (Appendix B1) to train LDS and translocation surveyors and QA/QC personnel. Data will then be integrated into a master database, a process that the RASP coordinator will oversee in coordination with key database managers (Fig 4.2). Data should also be shared between the RASP coordinator, NFWF, relevant RASP partners and custodians of centralized databases. Data to be shared includes: reporting metrics, spatial data of project footprints, reports, permitting, and raw data if applicable.

Finally, we recommend analyses of RASP monitoring data at regular intervals during the 5 to 10-year lifespan of the RASP Implementation Plan (Fig. 4.2). This will allow for evaluation of progress toward programmatic goals at different intervals, i.e., in the short-term (within 3 years of initial implementation), medium-term (~5 years), and long-term (~10 years). Such periodic evaluation is recommended because Mojave Desert habitat restoration as well as MDT population dynamics occur on long timescales, typically much greater than individual resource management programs, so evaluation is needed at multiple timepoints for different purposes. Additionally, routine analysis of monitoring data and communication of results is an important step in adaptive management of implementation efforts. The RASP coordinator will be responsible for producing data summaries and analyses to share with RASP partners and will coordinate with NFWF as well in this phase. More in-depth geospatial or other analyses could also be conducted by third-party researchers.

4.3.1. Population monitoring data

Existing databases, upload process and availability considerations

As described in Sections 1 and 2 of this monitoring plan, demographic data (e.g., density, survival, reproduction) have been and continue to be collected across the MDT range since the 1970s. However, no single database contains all data collected in these plots.

Given our recommendation of a population monitoring design that nests focused assessments of reproductive output within demographic plots, which themselves should be sited in relation to locations of long-term LDS transects (see Section 2), we recommend that new demographic and reproductive output data be shared directly with the USFWS DTRO. DTRO coordinates the LDS program and maintains the LDS database, and currently holds reports for almost all similar demographic plot surveys in NV, AZ, and UT, from which individual capture histories and other information can be extracted. Thus, housing RASP demographic data within DTRO would ensure consistency and efficiency. This is the most sensible arrangement as DTRO can use these data to track progress toward range-wide MDT recovery goals. Specific data to be collected should be extracted from relevant data fields in the DTRO monitoring data dictionary (Appendix B1).

The RASP coordinator's responsibility in this process will be to coordinate with project PIs, RASP partners, and NFWF to oversee the data flow from the field to a common RASP-specific database, and then to DTRO, as well as conducting all necessary QA/QC, on an annual basis.

Templates, recommended data fields

Just as there is no single database for all MDT demographic data, methods and data fields vary among different demographic studies, depending on project aims and resources. For example, the long-term USGS demographic plots relied on capture-mark-recapture surveys where field observers systematically searched for tortoises (Berry 1984; DTRPAC 2004), whereas more recent plots take advantage of radio tracking data from individual tortoises to estimate survival and other metrics (e.g., Henen et al. 2019, 2020, 2021; Esque et al. 2010; Mitchell et al. 2021). Regardless, depending on the specific methods implemented under the RASP monitoring plan, data fields can be developed in accordance with existing and/or historical datasets.

The DTRO has standard forms for field data collection and reporting that should serve as templates for RASP demographic monitoring efforts. For example, there is a standard reporting form for projects that collect and report data on tortoise movements (Appendix B2) that could be used to develop field data collection forms. The DTRO also has standardized data collection forms for monitoring translocated tortoises (Appendix B3) and for tortoise health assessments associated with translocation monitoring (Appendix B4). These can serve as examples for RASP data collection, although there are project-specific protocols and corresponding data fields that need to be determined during the study design phase. For example, some projects use GPS tracking to document tortoise survey routes rather than collecting waypoints, in which case data fields for spatial locations of survey routes will need to be defined (e.g., only starting and ending points). Additionally, health assessments associated with demographic monitoring require a number of photos; these are collected by USFWS in embedded OLE format, but in the final data these are stored as JPG files following a naming format that links photos to the specific date, transect, tracking and health record. Despite project-specific details that will need to be worked out during the design phase of data management, at a minimum, these standard reporting forms can inform what data needs to be reported to DTRO, where this information will be maintained in a centralized database. See Appendix A, Table A3 for a list of key DTRO data custodians and contact information.

4.3.2. Effectiveness monitoring data

Existing databases, upload processes and availability considerations

In Section 3 of this monitoring plan, we provide guidance for monitoring the effectiveness of specific RASP implementation priorities, including highway exclusion fencing, closure and restoration of unauthorized OHV routes, and population augmentation through translocation and head-starting.

As described in Section 3, due to extremely high success rates of properly installed fencing, effectiveness monitoring of highway exclusion fencing is equivalent to implementation monitoring (i.e., if the fence is installed properly and remains in place, it is effectively reducing tortoise mortality). Thus, data management for fencing monitoring should be fairly straightforward. Data fields should include the date, project site, spatially explicit location, type of fencing, and project-specific metrics required by RASP (e.g., miles of fencing installed or improved, number of acres protected, etc.). These data should then be checked for completeness and QA/QC and reported first to NFWF, then shared by the RASP coordinator with the USFWS DTRO, who maintains range-wide information on highway fencing for tortoises. As described in Section 3, fencing projects should be revisited within approximately two months to confirm that the treatment was properly installed and is still in place; revisit data should be managed following the same collection and reporting process.

A similar data management plan should be used for the installation of unauthorized OHV route closures. However, for habitat improvement projects such as route restoration, there are several points following project implementation at which monitoring data should be collected (Fig. 4.3). Again, projects should be revisited within approximately two months following implementation of a habitat restoration treatment to confirm that the treatment was installed properly and is still in place (Herrick et al. 2005; Holcomb et al. 2013). Later revisits can employ ecological restoration monitoring protocols (Esque et al. 2021). In all cases, standard data types should be collected and reported during each visit to each project site (Fig. 4.3).

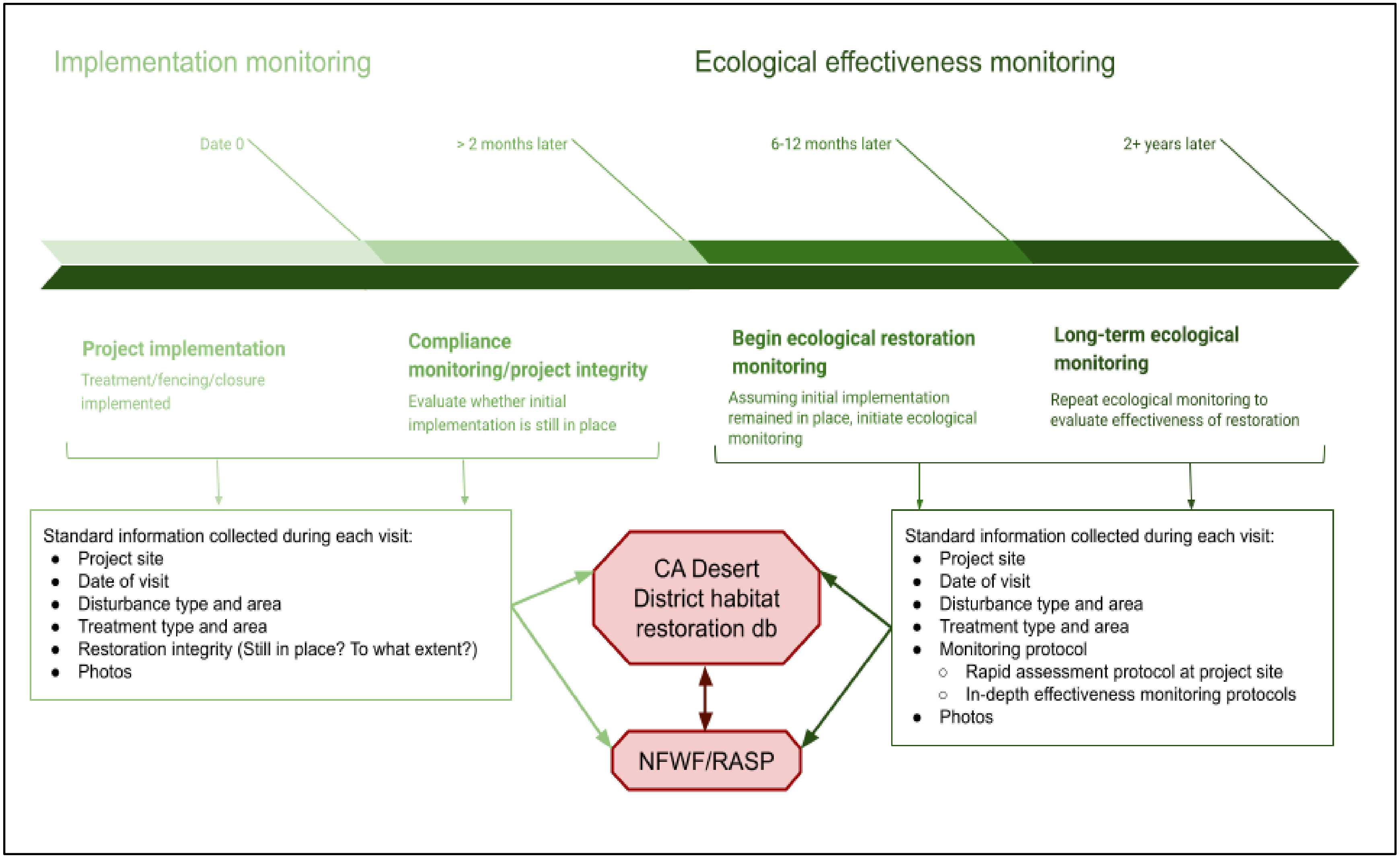


Figure 4.3. Schematic of monitoring data management steps and overall data flow through the life of a habitat restoration project. Note that recommended data fields are also described.

For habitat restoration data, we recommend that RASP data be incorporated into the BLM California Desert District (BLM CDD) habitat restoration database (Fig. 4.3). The BLM CDD database is designed to collate route disturbance and treatment data (including revisits for monitoring purposes) for sites across the CDD, which encompasses the RASP focal areas. This database can also support spatial characterization of project data as well as analyses of treatment information, and BLM is moving toward using this database to standardize data collection and reporting across CA field offices, and perhaps range-wide.

The BLM CDD database is a file geodatabase that is used to post to ArcGIS online for use in the field via mobile application. Although the online service cannot be shared officially with non-BLM personnel, the database itself can be shared, allowing users to copy the database structure to facilitate collection of the same fields. This will ensure that RASP monitoring data collected in the field will conform to the BLM CDD database structure, which will allow these data to be shared with the BLM CDD database managers and integrated into the BLM CDD database itself. This integration should happen at least annually, in coordination with the NFWF reporting schedule.

Lastly, for management of data related to MDT population augmentation projects, we recommend RASP projects follow guidance for data collection and reporting outlined in the USFWS Population Augmentation Strategy for the Mojave Desert Tortoise Recovery Program (2021a). Again, standard data types in addition to project-specific metrics (e.g., survival, growth, and reproductive output of released and resident individuals) should be collected, checked for completeness and QA/QC, and reported to NFWF and key RASP partners, including the USFWS.

Templates, recommended data fields

Because BLM is moving toward using the CDD database as a central repository for habitat treatment data, particularly for route restoration, we recommend that the RASP coordinator work closely with the BLM CDD data custodians to ensure newly generated RASP data conform to this database's existing schema. Standard data fields are straightforward (Fig. 4.3)—i.e., date and location of a project site, disturbance type and area, treatment type and area, and subsequent monitoring information—but should be confirmed upon initiation of RASP project implementation. In the BLM CDD, the same data are collected during each visit to a given project site, whereby data collected on revisits can be used for monitoring purposes. In addition, BLM CDD can include effectiveness monitoring data collected using more in-depth monitoring protocols such as the USGS route restoration guidelines (Esque et al. 2021).

4.4. Role of RASP coordinator

Management of RASP monitoring data presents a unique and important opportunity for the RASP coordinator to develop and facilitate a data management plan based on best practices, described above. Once specific RASP project objectives are established, all subsequent data collection, formatting, and organization should be standardized in accordance with existing data management protocols and scientific/analytical needs. Field data collection and entry should also be standardized to ensure data can be evaluated for completeness, accuracy, and compliance with existing procedures and project requirements.

The RASP coordinator's core responsibilities in this process will be to coordinate with project PIs, RASP partners, and NFWF to oversee the appropriate design of data collection protocols, data QA/QC, and the flow of data from the field to a common RASP-specific database, and then to key data custodians of related central databases (depending on the project and data type), on a regular basis.

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Appendices

Appendix A. Additional information for existing data sources for the Mojave desert tortoise.

Table A1. Additional metadata for existing Mojave desert tortoise (MDT) data sources **within RASP focal areas** (summarized above in Table 1.1), including: focal monitoring metrics that could potentially be extracted from these data, information on statistical robustness and availability.

Target monitoring metric	Data source	Data collection method(s)	Focal monitoring metrics	Statistical soundness/robustness	Wild population or translocation/ head-start?
Adult and juvenile survival rates	Fort Irwin Translocation Project	Mark-recap via Telemetry	Annual and cumulative survival; responses to environmental and anthropogenic covariates	Established, robust methodology	Wild (controls, residents) and Translocated
	MCAGCC Translocation Project	Mark-recap via Telemetry	Annual and cumulative survival; responses to environmental and anthropogenic covariates	Established, robust methodology	Wild (controls, residents) and Translocated
	Fort Irwin and MCAGCC Head-starting Program	Head-starting	Annual survival; responses to environmental and anthropogenic covariates	Established, robust methodology	Head-started juveniles in enclosures
	Long-term tortoise demographic plots	Desert tortoise demographic plots	Estimates of vital rates such as growth rates, fecundity, recruitment, survival (and mortality, and causes)	Presumably robust data collection via mark-recapture and quadrat surveys; some discussion in DTRPAC (2004) re: limitations of these data, esp. non-random sampling design	Wild
Reproductive success (# of eggs)	UCLA egg study (Wallis et al. 1999)	Mark-recap via Telemetry; Clutch exams via x-ray monitoring of females	Egg size and egg production	Published study	Wild
	Fort Irwin and MCAGCC Head-starting Program	Head-starting	Procurement of eggs from wild females for head-starting experiment	Published studies	Eggs from wild females

Table A1, continued.

Target monitoring metric	Data source	Data collection method(s)	Focal monitoring metrics	Statistical soundness/robustness	Wild population or translocated/ head-start?
Tortoise density; *Proportion of juvenile tortoises	USFWS Line Distance Sampling	USFWS line-transect tortoise observation data	Densities, occupancy, trends *other estimates may be generated, such as abundance and potentially proportion of juveniles	Established, robust methodology	Wild
Tortoise occupancy	BLM range-wide MDT occupancy model	MDT habitat occupancy, extinction, colonization probabilities	Probability of habitat occupancy, colonization, and extinction; prioritization of project siting, habitat mgmt, identification of key env and anthro drivers	Robust estimates for Tortoise Conservation Areas, projected to range-wide coverage	Wild
Proportion of juvenile tortoises	Fort Irwin Translocation Project	'Snapshot' surveys of size-age class; Mark-recap via Telemetry	Annual/cumulative survival; responses to env and anthro covariates	Published studies; Established, robust methodology	Wild (controls, residents) and Translocated
	MCAGCC Translocation Project (DOD)	Mark-recap via Telemetry	Annual/cumulative survival; responses to env and anthro covariates	Established, robust methodology	Wild (controls, residents) and Translocated
	Long-term tortoise demographic plots (USGS-CA)	Desert tortoise demographic plots	Estimates of vital rates such as growth rates, fecundity, recruitment, survival (and mortality, and causes)	Presumably robust data collection via mark-recapture and quadrat surveys, though few have first-hand experience with these data; some discussion in DTRPA (2004) re: limitations of these data, esp. non-random sampling design	Wild

Table A2. Summary of additional data sources collected **outside RASP focal areas** (shaded in blue), including focal monitoring metrics that could potentially be extracted from these data, and information on statistical robustness and availability.

Target monitoring metric	Data collection method(s)	Focal monitoring metrics	Statistical soundness/ robustness	Focal geography	Wild pop. or translocated/ head-start?	Availability?	Time period	Reference
Adult and juvenile survival rates	Mark-recap via Telemetry	Annual/cumulative survival; responses to env and anthro covariates	Established, robust methodology	Ivanpah Valley, CA	Wild (control, resident) & Translocated	Published estimates	2013-2018 published; surveys ongoing to present	Dickson et al. (2019)
	Mark-recap via Telemetry	Annual/cumulative survival; responses to env and anthro covariates	Established, robust methodology	Northeast Mojave, NV and UT	Wild and Translocated	Published estimates	1997-2000	Nussear et al. (2012)
	Mark-recap via Telemetry	Annual/cumulative survival; responses to env and anthro covariates	Established, robust methodology	Northeast Mojave, NV	Wild and Translocated	Published estimates	2014-2015	Nafus et al. (2017)
	Long-term tortoise demographic plots, non-CA (USGS-NV, AZ Game & Fish, UT Division of Wildlife)	Estimates of vital rates such as growth rates, fecundity, recruitment, survival, mortality and causes	Robust data collection via mark-recapture and quadrat surveys; potential limitations of data (see DTRPAC 2004)	East Mojave, Northeast Mojave RUs, NV, AZ, UT	Wild	Not publicly available, requires data sharing agreements with data custodians	1979-2003; (different plots cover different time periods)	DTRPAC (2004)
	Long-term tortoise demographic plots (AZ Game & Fish)	Annual/cumulative survival; responses to env and anthro covariates	Robust data collection via mark-recapture	Sonoran Desert, AZ	Wild	Published estimates	1987-2008	Zylstra et al. (2013), Campbell et al. (2018)

Table A2, continued.

Target monitoring metric	Data collection method(s)	Focal monitoring metrics	Statistical soundness/ robustness	Focal geography	Wild pop. or translocated/ head-start?	Availability?	Time period	Reference
Reproductive success (# of eggs)	Nest observation in two field plots	# eggs/nest, nests/female; potentially hatching success and predation rates	Published study	Ivanpah Valley, CA	Wild	Not publicly available, requires data sharing agreements with data custodians	2003	Sieg et al. (2015)
Other metrics	Opportunistic tortoise observation data (BLM, Conservation Science Partners)	Presence, distribution, observations of mortality (and causes)	Not associated with systematic monitoring protocols, can be used to inform species distribution models (e.g., using logistic regression or MAXENT). Also useful for model validation	Range-wide, BLM lands	Wild	CSP has compiled opportunistic observation data from BLM Field Offices; likely other data in existence	2000-present	Described in CSP (2021)
	MDT range-wide connectivity based on Circuitscape method	Prioritization of project siting, habitat management, identification of key movement corridors	Published peer-reviewed manuscript; established methodology	Range-wide	Model outputs	Published paper; dataset and products available from CSP	*Modeled data, based on 2007-2010 relocation surveys	Gray et al. (2019)
	MDT range-wide habitat suitability	Prioritization of project siting, habitat management, identification of key env and anthro divers	Established methodology, updated in 2020	Range-wide	Model outputs	Published paper; 2009 and updated datasets, products available	*Modeled data, based on 1970-2008 presence datasets	Nussear et al. (2009)

Table A3. Key MDT data sources, custodians and contacts.

Data source (Custodian)	Contact(s)
USFWS Line Distance Sampling (DTRO)	**Linda Allison** (USFWS, Reno, NV) Mojave Desert Tortoise Monitoring Coordinator (775) 861-6324 | linda_allison@fws.gov **Roy Averill-Murray** (USFWS, Reno, NV) Desert Tortoise Recovery Coordinator (775) 861-6362 | roy_averill-murray@fws.gov
Fort Irwin and MCAGCC Translocation Projects (DOD)	**Dr. Brian Henen** (USMC, MCAGCC, CA) (760) 830-5720 | brian.henen@usmc.mil **Dr. Todd Esque** (USGS, Henderson, NV) (702) 564-4506 | tesque@usgs.gov
Fort Irwin and MCAGCC Head-starting Program (DOD)	**Dr. Brian Henen** (USMC, MCAGCC, CA) (760) 830-5720 | brian.henen@usmc.mil **Dr. Kenneth Nagy** (UCLA, Los Angeles, CA) (310) 825-8771 | kennagy@biology.ucla.edu
California long-term study plots (*n* = >16) (USGS-CA)	[†] **Dr. Kristin Berry** (USGS, Moreno Valley, CA) (951) 697-5361 | kristin_berry@usgs.gov
Nevada long-term study plots (*n* = 23) (USGS-NV) *	**Dr. Todd Esque** (USGS, Henderson, NV) (702) 564-4506 | tesque@usgs.gov **Dr. Ken Nussear** (University of Nevada-Reno, NV) (775) 784-6612 | knussear@unr.edu
Arizona long-term study plots (*n* = 7) (AZ Game & Fish Department; AZ-GFD) *	**Cristina Jones (AZ-GFD)** Turtles Project Coordinator cajones@azgfd.gov **Tom Jones** (AZ-GFD) Amphibians & Reptiles Program Mgr. tjones@azgfd.gov
Utah long-term study plots (*n* = 3) (UT Division of Wildlife Resources; UT-DWR) *	**Ann McLuckie** (UT-DWR, St George, UT) Wildlife Biologist (435) 680-1062 | annmcluckie@utah.gov

[†] Data from long-term study plots in CA are not yet available to external researchers, however data from a limited subset of CA plots have been published (Berry and Yee 2021; Lovich et al. 2014).

* DTRO has capture histories for all tortoises on non-California (NV, AZ, UT) long-term demographic plots with at least 3 survey visits. Contact **Roy Averill-Murray** at DTRO (see above).

Appendix B. Sample data dictionaries and datasheets from USFWS

See attached documents:

Appendix B1. Data dictionary

Appendix B2. Example transmitter tracking datasheet

Appendix B3. Example translocation datasheet

Appendix B4. Example health assessment datasheet (for use in translocation monitoring)

- Note the health form requires 7+ photos. These are currently included in the data dictionary, and are *collected* by USFWS in embedded OLE format, but in the *final* data they are stored as JPG files following a naming format that links the photos to the specific date/transect/tracking/health record. How these photos will be stored in a centralized database remains an important issue to be addressed.