APPENDIX O
MONITORING APPROACH FOR THE ARROYO TOAD

Introduction to the Monitoring Approach

This proposed approach to monitoring in support of the Southern NCCP/MSAA/HCP Habitat Reserve Management Program (HRMP) and its Adaptive Management Program (AMP) component will include elements articulated in and closely follow the monitoring framework promulgated by the U.S. Geological Survey (USGS) in its recent publication "Designing monitoring programs in an adaptive management context for regional multiple species conservation plans" (Atkinson et al. 2004). Much of that approach has emerged from a series of critiques of historical attempts at drawing useful knowledge from environmental monitoring, which have virtually always fallen short of providing the information needed by land and resource managers to respond to environmental changes that affect species of concern (Noon 2003, NAS 1997, etc).

Here we provide an example of the AMP's intended monitoring approach using a single example, that of the federally threatened arroyo toad and its riverine habitats. It is understood that while the monitoring approach is proposed to be implemented within the construct of the AMP, it will, at various points in time, be applied in other portions of the Habitat Reserve subject to the overall HRMP (that is, monitoring will, with the permission of the County, also occur within County-owned lands not designated as part of the AMP). The species happens to have been used in the USGS document as an example as well. This choice then allows interested parties to consider the resource assessment approach in this NCCP/MSAA/HCP in the context of other suggested means of data acquisition, analysis, and interpretation.

A generally accepted approach to monitoring in support of adaptive management has become de rigeur in conservation planning, especially in southern California; however, NCCP programs with defined approaches to adaptive monitoring have only been recently approved, thus examples of successful implementation are few and long-term data sets emerging from the recent efforts, not surprisingly, are fewer yet. The adaptive management approach usually requires a clear articulation of project/program goals, development of conceptual models that describe the relationship between targeted species and their environments, selection of defensible indicator attributes of the species and their habitats to a measured articulation of a sampling scheme, and description of a process for synthesizing new information into adaptive management.

Although it is expected that monitoring data accrued in support of the AMP may prove additionally useful in species and ecosystem planning well beyond the Southern Habitat Reserve, the approach to monitoring will be designed to assess the performance of the AMP in meeting the discrete goals of the NCCP/MSAA/HCP Conservation Strategy. To that end, the proposed AMP monitoring program emphasizes the assessment of conservation actions pursuant to a specific operational adaptive management program. That assessment will utilize explicit performance measures, which will include appropriate attributes of Covered Species, as well as co-occurring Focal Species that are believed to provide valuable indications of ecosystem well-being, and certain physical and biotic attributes of the environment that are likely to be closely related to ecosystem health in ways directly important to sustaining populations of species of concern. As the preliminary monitoring plan for the arroyo toad describes below, a rigorous monitoring scheme that is attentive to both contemporary data collection techniques employed elsewhere and to issues beyond the immediate planning boundaries will serve to maximize and accelerate the potential learning monitoring that can be harvested under the AMP.

Certain steps are necessary to the development of a reliable monitoring program that can help inform and measure AMP performance. These steps include:

1. Identifying target resources. Determining the historical state of targeted resource(s), if information is available, and reference variability of resource attributes (distribution, abundance, vigor etc.) to use in identifying realistic program goals.

2. Describing existing conditions of resources.

3. Identifying a desired (future) condition for targeted resources, and recommending a range of acceptable variability in resource attributes. Using resource condition targets to define

(and refine) goals and objectives of management effort or policy in quantified (or quantifiable) terms, including desired spatial extent of managed targeted resources, temporal context, and condition of resources (composition, density, etc.),

Linking program goals to management actions, the process then

4. Develops conceptual (or, if possible, parameterized) models, which describe how the targeted ecosystem operates; integrate known system attributes, stressors, and linkages among system elements; and identify key uncertainties regarding system structure and function. Major controlling factors will be included. Fine details may not always be necessary, but embedded submodels that elucidate key relationships (e.g., relationship between water temperature and growth rates in fairy shrimp) can prove useful in performance measure selection.

5. Identifies opportunities and options for management actions.

6. Identifies potential performance measures (indicator or surrogate variables, including Focal Species) from inventory of candidate measures derived from conceptual model(s) and anticipated management actions. Performance measures can be found in any component of the conceptual model(s) – drivers, linkages, outcomes, and endpoints. The list will be inclusive, but not necessarily exhaustive. Due to uncertainties about how the targeted system operates, legitimate candidates in cases may be few.

7. Selects among potential performance measures, culling the list by considering their relevance to program goals and anticipated management actions, logistics and costs of measurement, variability and potential precision in differentiating between signal and noise, and desired versus undesired conditions or outcomes. Given inevitable program constraints (from funding limitations to overarching uncertainties regarding ecosystem function) the number of performance measures selected may be few; but the program recognizes that multiple measures increase the opportunity to learn about the system and targeted resources as management actions are assessed.

To determine the monitoring approach and data collection scheme, the process then

8. Develops sampling tools that: (a) use estimates of expected values (or trends) of the selected performance measures to assess the state of these measures following management actions; (b) identify measure values that will trigger a management response; and (c) consider fully issues of spatial context (including heterogeneity), temporal resolution and extent, and sample size and units of measure. Reference back to program and project goals, and conceptual models, is necessary in developing a sampling design that will detect pertinent changes in performance measure and ecosystem attributes. Sampling frequency and replication needed to detect trends should be based on historical data where possible and power analyses that interrelate the percentage change that can be detected, variance of the parameter, and replication in space and time.

To move from data handling to adaptive management the process requires

9. Development of a field data and meta-data handling and archive capacity with a spatial (GIS) component.

10. Development of an analytical capability to reduce information from the field to pertinent findings. Reduced data and results should link directly to identified performance measures and conceptual models.

11. Identification of a means of information transfer to recipients who will receive monitoring results. Identify the form in which results should be transferred – as analyzed and interpreted data sets, narrative results and conclusions, etc.

12. Description of AMP elements and authorities that allow for amendment of conceptual models, monitoring schemes, and performance measures, as well as planned and ongoing management activities and priorities.

The bases of biological information that exist for certain species, such as the California gnatcatcher, are substantial and allow for ready application to monitoring plan development in the structure above. But, for most species that will be directly or indirectly targeted for assessment, historical data from on-site or from the literature may be limited to differing degrees, and inference will have to be drawn in the identification of realistic desired future conditions. For those species, reliable conceptual models may be constrained by substantial uncertainties that generally relate to the life history of the species. Focused surveys or pilot studies may be needed before initial phases of long-term monitoring are carried out.

A Monitoring Program for the Arroyo Toad

The above considered, the intention here is not to present a monitoring protocol in its final, field-ready form, or to step down through the detailed vetting process described. The discussion below focuses on the technical challenges described in steps six through eight above for one of the proposed Covered Species – the arroyo toad (*Bufo californicus*). The purpose is to illustrate the approach, rigor, and technical considerations that will be used for each Covered or Focal Species that ultimately is selected as an element in the monitoring program to inform adaptive management. For those species the AMP will support the twelve-point approach to measuring HRMP performance with a two-step action plan. The first step is to assess the distribution of currently suitable habitat for the species of interest in map form using the NCCP/MSAA/HCP Conservation Worksheets for Covered Species and available information for Focal Species that are not Covered Species. The map will then serve as the baseline for subsequent assessment of changes in the amount and spatial distribution of habitat. Second, a monitoring scheme is developed to assess temporal trends in the status of the species populations within suitable habitat.

The following outlines a design and methods of analysis for monitoring the status and trend of the arroyo toad. The protocol draws on the monitoring program for the toad that has been developed for use on Marine Corps Base Camp Pendleton (USGS 2003). Camp Pendleton is directly adjacent to the proposed Southern Habitat Reserve, and appears to have habitat conditions for the toad very similar to those found in the Habitat Reserve. Also, a portion of the proposed Southern Habitat Reserve and Camp Pendleton share a common boundary along Talega Creek that supports an identified *major population* in a *key location* of the arroyo toad. As such, the conceptual model of arroyo toad presented in the USGS monitoring program is directly applicable to the AMP, and is compatible with both the riparian and toad conceptual models presented in these documents. Additional information on arroyo toad habitat characteristics has been obtained from the report titled "Geomorphic and Hydrologic Needs of Aquatic and Riparian Endangered Species" (PCR/Dudek, 2002) prepared for the Southern NCCP/MSAA/HCP.

The Camp Pendleton plan focuses on estimating the extent of toad habitat on the base and monitoring the "proportion area occupied" (PAO; see MacKenzie 2002) by toad egg masses and tadpoles within areas likely to provide suitable habitat. PAO is an estimation protocol that adjusts survey data for the possibility of failing to detect animals at a survey site because of imperfect detectability. PAO is estimated on the base by first partitioning suitable habitat (watersheds) into 50 blocks, and subsequently subdividing each block into 5-7 200 meter-long stream segments. The individual stream segment represents the sample unit, the occupancy status (occupied/unoccupied) of which is determined on the basis of multiple surveys within a given breeding season. Segments are surveyed for toad presence (eggs or tadpoles) in a rotating panel design using a 5-6 year rotation. One segment within each block will be surveyed every year (a permanent sampling site), and a second, rotating segment will be sampled within each block in different years (rotating).

Objectives of the Monitoring Program

The primary objective of the proposed monitoring protocol is to provide the Rancho Mission Viejo Land Conservancy (RMVLC) Reserve Manager with information on the current spatial distribution and conservation status of arroyo toads in the Habitat Reserve and to estimate baseline conditions for long-term monitoring. A related objective is to provide information on the environmental factors associated with changes in population status in the Habitat Reserve. Specific objectives of the monitoring program are:

1. Estimate the proportion of stream segments (see below) occupied by arroyo toads in the Habitat Reserve using rigorous sampling methods and statistical estimators that adjust for imperfect detectability (MacKenzie et al. 2002);
2. Estimate temporal trends in occupancy rate (ψ), and extinction and colonization rates of local populations using the methods of MacKenzie et al. (2003);
3. Test the null hypothesis that $\lambda = \frac{\psi_{t+1}}{\psi_t} = 1.0$ (that is, no temporal trend in occupancy rate);
4. Relate patterns of occupancy, and extinction and colonization rates to environmental covariates at the scale of the individual stream segment and segments within watershed units (see below); and
5. Evaluate broad-scale changes in habitat amount and distribution by means of a map-based, change-detection algorithm.

Methods

<u>Establish the Sample Frame</u>

A sampling frame that delineates suitable (current and potential) toad habitat will be developed on the basis of existing survey information, as well as new aerial photography, digital elevation data, soil maps and field reconnaissance. Since toad habitat is largely restricted to riparian/streamcourse areas, existing maps of hydrologic units (i.e., watershed sub-basins) in the Habitat Reserve can serve as a logical starting point for frame delineation. Watersheds naturally exist in a spatial hierarchy that can be used to define nested sampling units. Currently, the toad is known from the San Juan Creek Watershed in the upper San Juan Creek, middle San Juan Creek (the Central San Juan and Trampas Canyon sub-basin), and Bell Canyon sub-basin, and from the San Mateo Creek Watershed in the lower Gabino, Cristianitos and Talega sub-basins. Additional field work may be required to establish the toad's status in upper Arroyo Trabuco Creek, for which there have been unconfirmed anecdotal reports of the arroyo toad. An early decision is required on how suitable habitat will be mapped and how it will be spatially structured.

Given a fixed protocol for frame delineation, changes in the amount and spatial distribution of suitable habitat over time will become part of the monitoring program. This measure of habitat is of course not a direct population measure, but in combination with population monitoring, it can be used to identify non-habitat factors that may be putting the toad at risk. A suggested time frame for habitat change detection is about every five years.

Sample Unit Selection

Conceptually, sample units should be randomly selected and representative of the range of habitat conditions and management impacts in the Habitat Reserve. Usually this random/representative sample is achieved by means of an appropriate pre-stratification of the habitat frame prior to sample unit selection. In the case of the Southern Subregion Habitat Reserve, because of the limited distribution of the arroyo toad, it is unknown at this time whether there is enough habitat heterogeneity in the system to pre-stratify and randomly select sample units from the pre-stratified areas as would be desirable. Based on current mapping of occupied habitat, there are about 32,000 linear meters (m) total of occupied habitat in the Habitat Reserve: Bell Canyon is about 3,700 m; San Juan Creek about 14,500 m; lower Gabino Creek about 6,900 m; and lower Cristianitos Creek about 6,300 m. Talega Creek along the RMV/Camp Pendleton boundary is an additional 6,100 m. Using the Camp Pendleton example, at 200 m/segment there are only 160 total segments in the Habitat Reserve, not including Talega Creek. At 5 segments/block, there would about 32 blocks total from which to select a sample set of, for example, 20 blocks, resulting in about 60% sampling coverage of the total occupied habitat.

Although 20 blocks, or 100 segments, is suggested as an example of the sampling effort, the number of segments actually selected for sampling would be based on the desired statistical power of the trend estimator (see below). This will translate into the necessary precision of the estimate of PAO (ψ) in order to achieve the power objectives. In addition, it is imperative that the monitoring sites not be treated in any way different from the general Habitat Reserve landscape. Trends across monitoring sites must be reflective of trends in the larger landscape.

As noted above, the Camp Pendleton plan is based on stream segment lengths of 200 m, the segment length used in the above example to estimate the number of available sample blocks.

This length may, or may not, be appropriate for the PAO estimator in the Southern Subregion Habitat Reserve. The key point is that toad abundance should not be so high within a typical 200 m segment that it is unlikely that a segment will be unoccupied. Segment lengths that are excessively long (that is, contain too many animals) make it unlikely to detect a declining trend until population size has become very small. A pilot study may be required to determine appropriate segment length.

Sampling Protocol and Frequency

The well-resolved conceptual model that describes the life history of the arroyo toad that has been generated by USGS staff and colleagues (USGS 2003) supports defensible field sampling methods for egg masses and tadpoles. It is envisioned that sample sites used for long-term monitoring will be surveyed each year, serving as primary sites used to estimate temporal trends in occupancy rate. In addition, a set of secondary sites can be sampled each year in a rotating fashion (see USGS 2003). The advantage of both permanent and rotating sites is that the permanent sites provide a precise estimate of trend and the rotating sites provide additional spatial coverage and improved estimates of the state of occupancy in the Habitat Reserve in any given year (McDonald 2003).

Estimation of Proportion of Stream Segments Occupied (PAO)

Recently, MacKenzie et al. (2002) developed a survey strategy and statistical method for estimating the proportion of sample units occupied (ψ), a state variable for use in large-scale monitoring of animal populations. Traditional methods of monitoring species over large spatial scales have relied on presence-absence data. These methods often fail to account for imperfect detection of the species of interest, thus provide negatively biased estimates of the proportion of sites occupied (MacKenzie et al. 2002, 2003). The model of MacKenzie et al. (2002) uses presence-absence data from multiple visits to each site to estimate p, the conditional detection probability, and ψ, the proportion of sites occupied. The U.S. Amphibian Research and Monitoring Initiative (ARMI; United States Geological Survey) is using this estimator to monitor amphibians on Department of Interior lands across the country (http://armi.usgs.gov).

The PAO model has several key assumptions that must be considered in the design of the AMP's toad monitoring program; that –

1. sampled sites (stream segments) are closed to immigration and emigration during the survey period. That is, the occupancy status of a segment does not change following the first survey;
2. no false positive occurrences are recorded;
3. detection probabilities are constant across sites; and
4. covariates (see below) for stream segments are constant and site specific.

On Camp Pendleton, the PAO model is being used to estimate the proportion of stream segments occupied by arroyo toads (USGS 2003); the AMP proposes to use a similar protocol.. In the context of the proposed monitoring program, a stream segment in the Habitat Reserve is considered a site. A site is occupied if it contains one of more egg masses or tadpoles. Each designated survey year, surveys would be conducted at an appropriate number of sites to attain the objectives for statistical power of the trend estimator (see below). It is anticipated that annual surveys would be conducted in the early years of the AMP but the frequency of surveys likely will be adjusted as information is collected and toad population dynamics within different parts of the Habitat Reserve and through contacts with other survey efforts (including other NCCPs and other non-NCCP programs) throughout the overall range of the species in Southern California. To obtain reliable estimates of occupancy rate and detection probabilities, segments should most likely be surveyed ≥ 3 times annually during any survey year (MacKenzie et al. 2002). Again, as information is collected the frequency of within-year surveys may be adjusted.

Program PRESENCE (MacKenzie et al. 2003) can be used to analyze the data and estimate site occupancy (ψ) and its standard error. With this program it is also possible to estimate time, method, or specific detection probabilities; for example, it may be that egg masses and tadpoles have different detection probabilities and these can be included in parameter estimation methods.

<u>Trends in PAO Over Time and Estimation of Extinction and Colonization Rates</u>

Annual estimates of PAO can be used to estimate temporal trend. In this case a linear regression of ψ_t on time (*t*) would be based on the model, $\psi_t = \psi_0 + rt$, where ψ_0 is the initial occupancy rate and *r* is the annual rate of change in ψ. The appropriate statistical test would test the null hypothesis that $r = 0$. Test of this null hypothesis would occur only after a formal statement of monitoring objectives and an appropriate analysis of statistical power as described below.

Tests for temporal trend are of limited value without a formal structure with which to evaluate the temporal dynamics of the state variable. MacKenzie et al. (2003) present a model that provides this structure. The model uses data from within-year surveys to estimate *p* and ψ (as described above), and data from surveys across years to estimate population extinction and colonization rates (Figure 1).

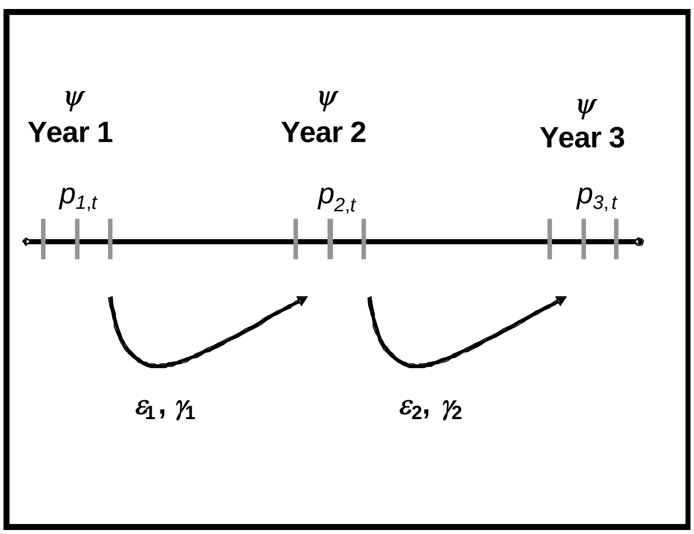

Figure 1: The model of MacKenzie et al. (2003) uses data from surveys across years to estimate the vital rates affecting change in PAO (represented by ψ), extinction (ε) and colonization (γ) rates. The $p_{i,t}$ represent detection probabilities for surveys (*t*) within years (*i*).

In this model, population extinctions and colonizations cause change in PAO over time. Thus, the probability of occupancy at time, *t*, can be represented as

$\psi_t = \psi_{t-1} - [\psi_{t-1} * \varepsilon_{t-1}] + [(1 - \psi_{t-1}) * \gamma_{t-1}]$,

where the probability of extinction at a breeding pool between t – 1 and t is ε_{t-1} and the probability of colonization of a previously unoccupied breeding pool between t – 1 and t is γ_{t-1}. Extinction of occupied segments reduces PAO (left-hand term in brackets), and colonization of previously unoccupied segments increases PAO (right-hand term in brackets; MacKenzie et al. 2003).

This model can be used in program PRESENCE to estimate extinction and colonization rates in the Habitat Reserve for the toad and to evaluate hypothesized relationships between these parameters and habitat covariates. Hypothesized relationships that could be evaluated include:

- The probability of extinction for an arroyo toad population along a stream segment(s) is negatively related to rainfall in the preceding winter.
- The probability of colonization of an unoccupied stream segment is negatively related to the distance of the segment from the nearest occupied segment.

<u>Statistical Power for Trend Estimation</u>

To compute the power (1- β, probability that the null hypothesis will be rejected when it is false) of the test of the null hypothesis $\lambda = \frac{\psi_{t+1}}{\psi_t} = 1.0$ requires specification of: 1) the probability of rejecting the null hypothesis when it is true (α), 2) the probability of failing to reject the null hypothesis when it is false (β), 3) the rate of change in the annual occupancy rate that is to be detected, 4) the number of years of sampling required to detect the specified rate of change, and 5) and the variance of coefficient of variation (CV) in the estimate of ψ (Thompson et al. 1998). Using the first four requirements we can compute the fifth. For example, one possible monitoring objective would be to have an 80% probability of detecting a 25% decline in occupancy rate over a 10 year time period with an type I error rate (α) equal to 0.05. The unknown in this case is the CV of ψ.

To compute the required sample size to reach the target CV for the estimate of ψ requires prior estimates of its standard error. This may necessitate a pilot study to be conducted in the Habitat Reserve. These calculations can be performed with program TRENDS (Gerrodette 1987) which is available as freeware over the internet. In general, the accuracy and precision of the estimate of ψ will increase with the: 1) per visit detection probability (*p*); 2) number of times sites are sampled; and 3) the number of sites sampled (MacKenzie et al. 2002).

Estimating Cause-Effect Relationships

Species-focused monitoring programs are of limited utility if they do not provide insights into causal explanations for any observed population trends. In this context, monitoring should measure factors (e.g., stressors) that are believed to drive a species population dynamics and patterns of site occupancy. It is reasonable to expect that the occupancy status of any given segment (ψ_i), or the likelihood that it will experience an extinction or colonization event (ε and γ, respectively) will be a function of site characteristics. Similarly, detection probability (*p*) may also vary as a function of measurable variables such as weather or observer. Covariate information (**X**) can be introduced into the occupancy model by using the logistic equation for either ψ, p, ε, or γ (MacKenzie et al. 2002, 2003).

$$\theta = \frac{\exp(XB)}{1+\exp(XB)}$$

In the logistic model above the parameter of interest is denoted as θ and the vector of model parameters as **B** (that is, the regression coefficients associated with the covariates).

Therefore, in addition to deriving estimates of PAO, *a priori* models that reflect hypothesized relationships between the occupancy status of a stream segment and the physical characteristics of the segment and its surrounding landscape (habitat covariates) can be specified and evaluated. These models can be viewed as habitat relationship models and will identify environmental attributes associated with amphibian presence (Pellet and Schmidt 2005). Studies of other amphibian species have identified habitat covariates associated with occupancy and density (e.g., Knapp et al. 2003; Herrmann et al. 2005; Welch and MacMahon 2005). The results of previous studies can be used to generate hypotheses to be tested using data from the Habitat Reserve. Some example habitat covariates that could be estimated for each segment include the amount of sandy substrate, gradient, water sources for breeding pools, and/or hydroperiod. These measures could be linked to environmental stressors, such as invasive species or cattle-related impacts, road construction and fire. Selection of a "best" model(s) from a complete set of *a priori* models could be based on an AIC information criterion (Burnham and Anderson 2002).[1]

Direct Relevance to Habitat Reserve Planning and Assessment

Information on the status of arroyo toad populations on Habitat Reserve lands consists of basic spatial distribution and relative population abundances, as well as basic information regarding habitat characteristics from the "Geomorphic and Hydrologic Needs" report and the arroyo toad critical habitat designation. The proposed monitoring protocol will provide important information on the spatial distribution of toads in the Habitat Reserve, changes in those distributions over short time scales, and relate changes to possible environmental factors. It will contribute to the conservation and management goals of the AMP by providing the Reserve Manager with:

1. a more precise map of the distribution of suitable habitat (current and potential) for arroyo toads in the Habitat Reserve. This map will be useful for informing the conceptual model for the arroyo toad, particularly evaluating the identified/hypothesized stressors for the arroyo toad.
2. habitat characteristics that are correlated with occupancy, extinction and colonization probabilities for populations within discrete watersheds. This information will identify habitat characteristics that may be required by the species and can be manipulated to achieve arroyo toad conservation goals of the proposed Southern Conservation Strategy.
3. credible estimates of proportion of stream segments occupied (PAO). These estimates will provide a landscape-scale measure of the current state of the toad populations in the Habitat Reserve. It will also provide baseline data that can be used to identify significant changes in those populations in the future.
4. rigorously derived estimates of contemporary extinction and colonization rates of individual populations, and how these relate to landscape composition and pattern. These

[1] The Akaike Information Criterion, or AIC criterion, has become a standard tool in time series model fitting.

estimates will be important for evaluating the long-term viability of arroyo toads in the Habitat Reserve.

5. estimates of the status and trend of an amphibian species over time and varying climate conditions that may serve as a broad indicator and provide the basis for assessing specific indicators of watershed integrity in relation to other monitoring information such as that provided through the implementation of the Water Quality Management Program (see Welsh and Ollivier 1998; Welsh and Droege 2001).

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