Jaguar Habitat Modeling and Database Update[1]

Eric W. Sanderson* and Kim Fisher
Global Conservation Programs
Wildlife Conservation Society
2300 Southern Blvd
Bronx NY 10460 USA

Contact info for Eric Sanderson*
Phone: 718-220-6825
Email: esanderson@wcs.org

Summary

All project objectives and outcomes, as outlined below, were accomplished, including revising the jaguar database and habitat model created in 2011 in coordination with the technical subgroup of the Jaguar Recovery Team (JRT). We updated the database with additional observations obtained since July 2011 through July 2012, conducted analyses of how different selections of jaguar "events" (as explained herein) influenced the choice of habitat variables, and produced five revised versions of the habitat model (designated versions 9 – 13 below). For each version, under the advice of the JRT, we selected habitat variables, constructed a simple habitat model, and translated that habitat model into potential carrying capacity in northern Mexico and the southwestern United States (over the area designed as the "Northwestern Recovery Unit" or NRU, described herein). Model versions were revised in each case to match the expert assessments of the JRT regarding the current status of jaguars in the NRU. The final habitat model (version 13) suggests a potential carrying capacity of more than 3,400 jaguars over an area of over 226,000 square kilometers. This capacity can be further broken down into smaller geographic areas or "subunits" of the NRU which, from south to north, may have the potential to contain: ~1,318 jaguars in the Jalisco Core Area, ~929 jaguars in the Sinaloa Secondary Area, ~1,124 jaguars in the Sonora Core Area, and ~42 jaguars in the Borderlands Secondary Area. Note that current populations are substantially below these carrying capacities, but are not zero according to recent observations in all four subunits. Accompanying this report is a data package consisting of a CD containing GIS files and a revised Microsoft Access database described below.

Project Objectives and Outcomes

The overall objective of this project was to assist the U.S. Fish and Wildlife Service (FWS) in digital mapping aspects of recovery planning for the northern jaguar. For this round of database and habitat model updates, the Wildlife Conservation Society (WCS) agreed to:

1. Prior to the technical subgroup meeting: coordinate with the JRT leaders and Arizona Ecological Services Office – Tucson (AESO) prior to the technical subgroup on task items as described in the Performance Work Statement; provide an initial audit of the FWS jaguar location database; input additional jaguar locations provided by FWS; with the JRT and AESO, develop criteria for "Class I" jaguar records and possible selections deemed useful; and create fields in the database for rapid application and extraction of records using criteria from the technical subgroup meeting.

[1] Final report to the USFWS in response to Solicitation F12PS00200, submitted March 12, 2013.

2. At the technical subgroup meeting (April 24 – 26, 2012): attend and advise the technical subgroup meeting; based on input from the technical subgroup, identify potential errors in and revise the jaguar location database; and re-run the habitat modeled developed last year, as described in Sanderson & Fisher (2011).
3. Prior to the full recovery team meeting: coordinate with the JRT and AESO on follow-up from the technical subgroup meeting; input additional locations identified by the technical subgroup; complete the audit of the jaguar database; revise the previous habitat model and prepare presentations for the full recovery team meeting; and make calculations and summaries from the model and database as instructed by the JRT and AESO.
4. At the full recovery team meeting (July 31 – August 2, 2012): attend the full recovery team meeting; present the audited revised database and revision of the habitat model; and lead the recovery team in developing a new habitat model.
5. Following the full recovery team meeting: prepare a final report describing the audited and revised database and the new JRT habitat model; and, with the report, deliver an audited and revised database and JRT habitat model by DVD to AESO office within 15 days of receiving comments.

Objective 1: Preliminary database audit and additions and criteria

Eric Sanderson and Kim Fisher had a conference call with Erin Fernandez, Marit Alanen, Howard Quigley, and Carlos López González on April 13, 2012 to discuss the Performance Work Statement.

In prior work WCS created a jaguar "event-record" database based on input from the JRT (Sanderson and Fisher 2011). An event refers to the experience of a person observing a jaguar. Events happen at a given place, at a given time, and vary in kind. Kinds of events include mortalities (when a person kills a jaguar), sightings (when a person observes a jaguar), observations of scat or sign attributed to a jaguar, or no observations (when a qualified person looks for a jaguar but does not see one). Events result in a memory on behalf of the observer(s) and may also result in physical evidence (like a skull, skin or photograph). Events are also commonly recorded, resulting in a record. A record is a written, graphical or verbal account of a jaguar event. Written records occur in newspapers, books, scientific journals, and ideally can be cited and rest in the public domain. Graphical records include photographs, paintings, or other human created representations of a jaguar (like a figurine of a jaguar). Verbal records are accounts of the event, either by someone with firsthand experience, or someone who heard the story from someone else.

In the event-record database, each record is described according to a standard set of fields (see Sanderson and Fisher 2011), and then assigned to an event. The same event can have multiple records, derived from different bibliographic references, and often with slightly different versions of the event, different levels of precision, and so forth. At the level of the event, the best available scientific information is summarized with a pre-defined classification system to describe the most precise locality, date, identity, and evidence associated with that event (described in Appendix 1 and explained below). Collecting the data in this structure enabled the JRT to have a fine level of control over which events (and via the event, which records) were admitted into the habitat analysis described below.

Based on feedback from the FWS and JRT, we audited the previous jaguar event-record database, correcting a number of typographical errors and two locations related to the 1996 and 2006 Glenn records.

We added these additional data to the database:

- 186 records of track and camera trap photos of jaguars from the studies reported in McCain & Childs (2007), with data provided to FWS by the Arizona Game and Fish Department
- 1 photograph record from the Ajos Bavispe Reserve in Sonora forwarded by Carlos López González

Objective 2: Revise database and habitat model at technical subgroup meeting

Kim Fisher attended the technical subgroup meeting on April 24 – 26, 2012, in Tucson, Arizona. Eric Sanderson participated by phone for portions of the meeting. Fisher presented a review of the database and habitat model developed by WCS and the JRT in 2011, as described in Sanderson and Fisher (2011).

Further revisions of the jaguar event-record database

The technical subgroup did not identify any errors in the database. However they did reveal additional sources of records from camera traps and telemetry to be included in the analysis, and they requested a different treatment of camera trap and radiotelemetry observations in the event-record framework. Camera trap and radiotelemetry studies often have many locations of the same animal in close proximity in time and in space. It was recognized that to include each camera trap record or each radiotelemetry record as a separate event could create pseudo-replication and bias the resulting habitat model. To avoid this problem, the technical subgroup advised us to apply the following rules:

- For camera trap studies, to create a single record for each individual camera trap location that assimilates all observations made over time at that location (i.e., to generate only one event per camera trap location).
- For radiotelemetry studies, to create a single event for all telemetry locations for a single animal more than 3 km from other observations.

Application of the revised event-record database to the habitat model

At this meeting, the subgroup discussed how to select jaguar events for use in the habitat model. In terms of scientific analysis and recovery planning, it is desirable to have high confidence in the event locations used for habitat modeling. It is also important to understand how different selections of events lead to different habitat maps. To deal with the issue of confidence in a systematic way, previous work by the Arizona Game and Fish Department, the New Mexico Department of Game and Fish and the Arizona-New Mexico Jaguar Conservation Team adapted a system developed by Tewes and Everett (1986) for ocelot and jaguarundi for the jaguar. For example, in the Jaguar Recovery Outline (FWS 2012), these classes are defined as:

- Class I records include those records [note that “record” in this context is analogous to the term “event” as used in this report] with physical evidence for verification. Class I reports are considered “verified” or “highly probable” as evidence for a jaguar occurrence.

- Class II records have detailed information of the observation but do not include any physical evidence of a jaguar. Class II observations are considered “probable” or “possible” as evidence for a jaguar occurrence.

- Class III reports are considered unreliable as account details are vague, observer reliability is questionable and/or the animal described is something other than an ocelot, jaguar or jaguarundi.

The technical subgroup recognized and discussed some difficulties in applying these particular definitions across the entire NRU (see Figure 1) and over the full length of the data record in a consistent manner. For example, many jaguar events, especially pre-1970 observations in the United States and nearly all the observations in Mexico, do not have physical evidence that can be verified by a third party. Typically such verification requires a photograph, DNA evidence, or museum voucher specimens (e.g., a skull or skin). Using only events with a verifiable voucher specimen or photograph would strongly bias the observations set to those made since 1970.

There are also problems with establishing a precise geographic location and a precise date associated with each event from the available records. Although most recent records may have modern global positioning system (GPS) locations, prior to 1990 such locational accuracy is rare. For older records, and therefore events, locations are assigned based on locality name (e.g., Santa Rita Mountains, Pima County, etc.). Exacerbating the problem from the perspective of database quality and analysis, some record locations and dates may be obscured by government agencies and/or data compilers who fear that releasing precise locations may lead to harm to the animal. For example, state agencies often report to the public observations only within the nearest mountain range or county. Also, historical observations may have more generalized locality descriptions according to the conventions of geographic naming at the time the observation was made or use names that are no longer recognized.

There may be questions related to what kind of animal is actually observed (as suggested in the definition of Class III above). Observations of "large black cats" are relatively common, but probably rarely represent jaguars, especially in recent times. Other wild animals, including mountain lions, coyotes, and bears, even large domestic dogs may be mistaken for jaguars in poor light. Without corroborating evidence it is difficult to verify that what was seen was actually a jaguar, especially for records of jaguars from the historical record.

The technical subgroup recognized the value of treating these different kinds of information systematically, so that intelligent and consistent selections can be made of jaguar events for use in habitat modeling. In the event-record database framework, every event (based on compilation of one or more records) is attributed a code reflecting the precision of that event's:

- Geographic precision (e.g., point location with geographic coordinates, a named place, a named county, etc.)
- Date precision (e.g., an exact date, a month within a year, a season within a year, within a decade, etc.)
- Identification accuracy (e.g., did the observe describe it as a jaguar, or a large cat, or some other animal)
- Evidence type (e.g., was there any physical evidence? If so, what kind was it?)

Appendix 1 describes this system of attribution for these database fields.

After extensive discussion, the technical subgroup decided to define a subset of events for inclusion in the NRU habitat model for which they had confidence reflected reliable jaguar records. These events had to meet all of the following criteria (the full set of codes is provided in Appendix 1):

- Have localities that are defined by geographic coordinates (e.g., from a GPS) or come from a determined area, with locality descriptions sufficient to place the location with certainty within 10 km of its actual location. [Locality type code < 3]
- Have a date, at least to the nearest century. [Date type code < 11]
- Have been attributed specifically to a jaguar. [Identity code = 1]
- Some evidence. The technical subgroup considered three different filters by evidence type:
    - Evidence Filter 1: "Physical evidence only": use events with evidence types 4, 6 and 7 and 8 only (physical evidence other than fossils).
    - Evidence Filter 2: "Physical and sign evidence": use events add evidence types 13, 14, and 98 (tracks and kills) to the above.
    - Evidence Filter 3: "All evidence types" scenario: include every evidence type from 0-99 (see Table 1.4 in Appendix 1 for full list).

Application of the new filters yielded 102 events for Filter 1, 128 events for Filter 2, and 203 events for Filter 3. The other criteria were all the same.

At the technical subgroup's direction, the WCS team analyzed these three different filtered subsets of the event localities with respect to geographic data on tree cover, terrain ruggedness, human influence, and distance from water (Table 1; described below). These factors were determined by the JRT to be important factors in jaguar habitat during the previous year's work (Sanderson and Fisher 2011; also see below).

We produced histograms showing the frequency distributions of these variables for each filtered set of events, as shown in Appendix 2. The goal was to discover if varying the selection resulted in a different selection of habitat variables to be included in the habitat model. In all three filtered subsets, the overall patterns in frequencies of observation relative to habitat factors were similar, i.e., the selection of event localities did not produce qualitatively different selection of habitat variables (Appendix 2). The technical subgroup hypothesized that this result accords with their expert opinion because jaguars are habitat generalists – in general, the definition of jaguar habitat is cover, prey, and limited human persecution within the NRU. For the habitat modeling it was decided to use all the criteria above and evidence filter 3, because that resulted in the largest number of events for inclusion in the model. Having made this determination, the technical subgroup moved to considering revisions to the jaguar habitat model within the NRU.

Habitat Model

The purpose of the habitat model is to determine potential areas of jaguar habitat and make an estimate of the potential carrying capacity of various subunits of the NRU (Figure 1).

The jaguar habitat modeling approach for the NRU follows a variant of the Hatten et al. (2005) method as described in Sanderson and Fisher (2011). Previously, the JRT determined a set of habitat factors to characterize potential jaguar habitat. They include: percentage of tree cover, ruggedness index, human influence, ecoregion, elevation (some model versions only, see below) and distance from water. Sources of geographic data describing these habitat factors are listed in Table 1.

Table 1. Data sources for habitat factors for the recovery team potential jaguar habitat model.

Habitat Variables	**Recovery Team Potential Jaguar Habitat Model**
Vegetation (Tree cover)	MODIS Tree cover (continuous field data) (https://lpdaac.usgs.gov)
Terrain Roughness (or Ruggedness)	ASTER DEM (https://wist.echo.nasa.gov)
Distance to Water	Derived from HydroSHEDS (http://gisdata.usgs.gov/)
Human Influence (to exclude cities, agricultural and developed rural areas)	Human Influence Index (http://sedac.ciesin.columbia.edu/wildareas/)
Ecoregions	WWF Ecoregions (http://www.worldwildlife.org/science/data/item6373.html)

Thirteen iterations of the habitat model were run using different input variables since the establishment of the recovery team. The first models are described separately in Sanderson and Fisher (2011); the final models from last year's work were designated versions 8 (draft report)/8.1 (final report). This report covers development of version 8 (for reference) through version 13. In each model version, the following basic steps were followed. Appendix 3 contains the details of each model version, including maps showing the results.

(1) Subunit definition: Define the spatial extent of the subunits over which calculations will be made (see Figure 1 for NRU map and small changes in Appendix 3 for subunit areas for each iteration).

(2) Habitat factors: Compare selected jaguar event locations to potential habitat factors to determine which classes or ranges of each habitat factor to include within the model and which to exclude from the model (see Appendix 2).

(3) Habitat weights: Determine weights for habitat types representing how quality of habitat for jaguars varies by ecosystem type (e.g., tropical dry forest, thorn-scrub, pine-oak forest, etc.). In version 8, these weights were arrived at via consensus among JRT technical subgroup experts; starting in version 9, habitat weights were calculated from the average density estimates available for each habitat (see Appendix 3).

(4) Habitat equation: Formulate an equation to combine the selected habitat factors (from step 2) and the weights (step 3) into a habitat score for every 1-sq-km area within the NRU.

(5) Mask: Mask out areas considered unsuitable. Unsuitable factors considered include human influence, elevation, and patch size. In model versions 8/8.1, no habitat factors were used as masks; in later models, a variety of different masks were applied, as described in Appendix 3.

(6) Translation to density: Available studies conducted within the NRU that measure jaguar density were used to translate habitat suitability scores into density. The polygonal boundaries of each study area (in the few cases where boundaries were not explicitly identified, they were estimated by JRT experts or study authors) were used to average the values of the habitat scores within that area. These average habitat scores were then plotted against the respective

density estimates to produce a regression equation that was applied to arrive at jaguar density across the entire NRU.

(7) Sum: Sum the potential number of jaguars (i.e., determine the carrying capacity) based on step 6 over the areas of each subunit and for the recovery unit in total. These data were provided to the population viability analysis described elsewhere.

In general, the net effect of the versions of the habitat model was to bring the results into closer alignment with the expert opinions of the JRT and recent studies of jaguars across the NRU, which reflect low densities of jaguars across the entire region and a general trend of diminishing numbers from south to north, particularly north of the US-Mexico border within the NRU.

Objective 3: Complete database and habitat model revisions based on technical subgroup feedback and meeting output

Database

After the meeting, we received and entered additional jaguar records into the database:

- 95 camera trap photos and telemetry observations from Rodrigo Núñez
- 174 camera trap photos and telemetry observations from Carlos López González
- 67 observations (18 tracks, 1 photo, 1 unknown, and the others predation events) from Octavio Rosas-Rosas
- 27 various records from the team, forwarded from Erin Fernandez, or documented by Sanderson from primary sources (for example, press reports of the 2011 observation in the Whetstone Mountains, Arizona)

We applied the radiotelemetry and camera trap rule sets as described above to generate records and events.

Habitat Model

Kim Fisher and Eric Sanderson met with Marit Alanen, Howard Quigley and Carlos López González at the WCS headquarters in the Bronx, NY, on June 25 – 26, 2012 to further refine the habitat model and discuss density estimates within the study area. Prior to the meeting, a series of emails and phone conversations resulted in revised histograms and a new north/south bifurcation of the model (see Appendix 2). Based on these discussions, several further iterations to the model were made (versions 10-11), to incorporate changes to habitat weights, input variable parameters, subunit definitions, the new north/south bifurcation of the model, and masks (see Appendix 3). Subsequent work after their visit led to version 12.

Objective 4: Present revised database and habitat model to full recovery team meeting

Eric Sanderson and Kim Fisher attended the full JRT meeting July 31 – August 2, 2012, and presented the revised database and habitat model (through version 12). We received feedback from the full team. There were no comments about the form of the habitat model or the data input.

The full team did express concern that the habitat/density trendline used to determine the equation for converting habitat scores to jaguar density (step 6, as described above) should be forced through (0, 0),

under the assumption that a zero habitat score translated to zero potential for jaguar density. Not forcing the y-intercept through zero meant that large areas with zero habitat scores still had very low, but non-zero, contributions of jaguars to the carrying capacity estimates for the subunits. The effect can be seen by comparing model versions 12 and 13, particularly for the Borderlands Secondary Area, where habitat is quite patchy and lots of "non-habitat" area is contained within the subunit boundaries. The JRT discussed extensively whether these "non-habitat" areas could still be used by jaguars in some way. For example, it is known that in the Borderlands Secondary Area, jaguars move between mountain ranges, presumably by crossing areas marked as "non-habitat" in the valleys. Eventually the team decided that for purposes of carrying capacity estimation, these areas of "non-habitat" should not be included in the model estimation, and therefore the density regression should be forced to have a zero-intercept.

We revised the approach accordingly to produce the final model, version 13. The general effect of modifications to the model over the course of this year has been to decrease the number of predicted potential jaguars across the study area from versions 8 – 13. These decreases in numbers are in keeping with the expert knowledge, observations, and expectations of the recovery team as to "what is on the ground" today within the NRU (Appendix 3). The JRT discussed the question of whether what is currently the case is an appropriate scientific guide to "carrying capacity", which reflects the potential jaguar population if threats were alleviated. No consensus was reached on this question and so the habitat model stands with version 13 as the "final habitat model" form within the NRU.

New subunit geometry names were decided upon at the July 2012 meeting and are shown on the maps used in this report. Please note that the subunit boundaries were slightly altered between various model versions (see notes under each model version in Appendix 3) and the names are slightly different from previously used terminology (e.g., Sanderson and Fisher 2011). In the tables in Appendix 3, we maintain the old names for purposes of backwards compatibility. The new names are shown on Figure 1. From south to north, they are: Jalisco Core Area, Sinaloa Secondary Area, Sonora Core Area, and Borderlands Secondary Area. Areas outside of the NRU were not analyzed for jaguar carrying capacity in the summary tables.

Note that the Borderlands Secondary Area includes a US portion from the US-Mexico border north to Interstate-10, and a Mexico portion from the US-Mexico border south to the Sonora Core Area. The Borderlands Secondary Area contains the border fence.

Objective 5: Prepare report describing final database and model and provide supporting datasets

This report with attachments (including appendices and DVD with GIS data and database) fulfills this objective. The draft report was submitted on September 17, 2012. Comments on the draft report were received on December 3, 2012. This final report was submitted on March 12, 2013.

Literature Cited in Main Report and Appendices

Coronel-Arellano, H., N. E. Lara-Díaz, C. N. Moreno-Arzate, y C. A. López-González. *In press*. Density of jaguar (*Panthera onca*) in the Meseta de Cacaxtla, Sinaloa, México. *Western North American Naturalist*.

Gutiérrez-González, C. E., M. Á. Gómez-Ramírez, y C. A. López-González. *In press*. Jaguar (*Panthera onca*) density in arid lands of North America using an open population model. *Oryx*.

Hatten, J. R., A. Averill-Murray, and W. E. Van Pelt. 2005. A spatial model of potential jaguar habitat in Arizona. *Journal of Wildlife Management* 69 (3): 1024–1033.

Lara-Díaz, N. E. 2010. La comunidad de mamíferos previa a la liberación de Canis lupus baileyi en sonora2, Mexico. Tesis de Maestria Posgrado en Recursos Bioticos – Universidad Autonoma de Queretaro. Queretaro.

López González, C. A., and E. Moreno Arzate. 2011. Jaguar abundance and density in Rosario de Tezopaco, Sonora, Progress Report presented to Northern Jaguar/Naturalia/CENJAGUAR-CONANP.

McCain, E. B, and J. L. Childs. 2008. Evidence of resident jaguars (*Panthera onca*) in the Southwestern United States and the implications for conservation. *Journal of Mammalogy* 89 (1): 1–10.

Núñez-Pérez, R. 2011. Estimating jaguar population density using camera-traps: a comparison with radio-telemetry estimates. *Journal of Zoology* 285 (1): 39–45.

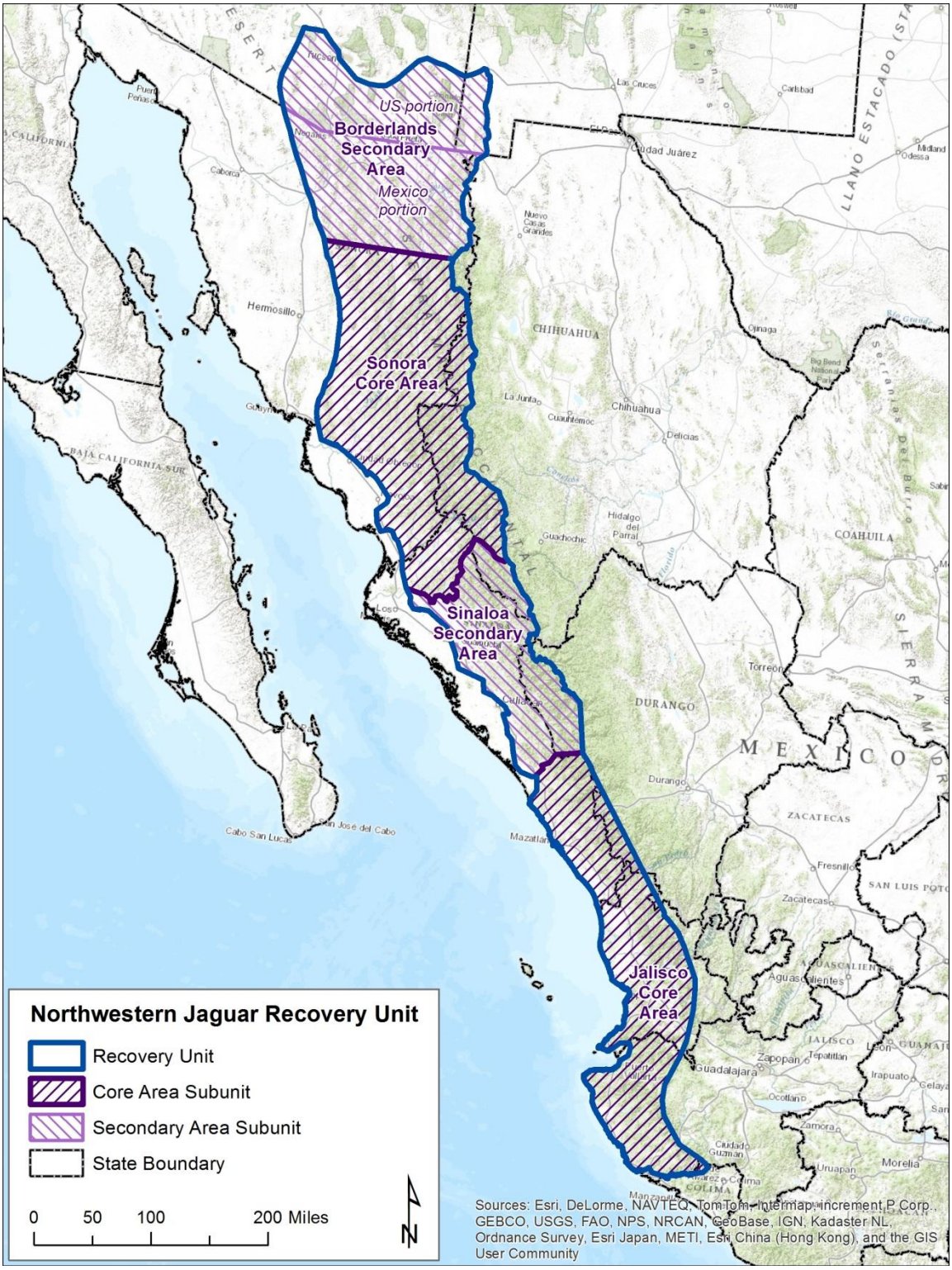
Rosas-Rosas, O. C., and L. C. Bender. 2012. Estado de la población de jaguares (*Panthera onca*) y pumas (*Puma concolor*) en el noreste de Sonora, México. *Acta Zoológica Mexicana (n.s.)*, 28 (1): 86–101.

[Rubio] Yamel Gpe. Rubio Rocha y Horacio V. Bárcenas. 2011. Sitio 9: San Ignacio, Sinaloa. CENJAGUAR. Reporte presentado a la CONANP-SEMARNAT.

Sanderson, E. W., and K. Fisher. 2011. Digital mapping in support of recovery planning for the northern jaguar: report submitted to the US Fish and Wildlife Service. Bronx, NY: Wildlife Conservation Society.

Tewes, M. E., and D. D. Everett. 1986. Status and distribution of the endangered ocelot and jaguarundi in Texas. In: Cats of the World: Biology, Conservation and Management. S.D. Miller and D.D. Everett (Eds.), 147–158. Washington D.C.: National Wildlife Federation.

Figure 1: Revised Northwestern Jaguar Recovery Unit



Appendix 1: Systems for identifying precision in the jaguar event-record database

Table 1.1. Locality type codes for the northern jaguar event-record database.

LocalityType Code	LocalityType Text	Description	Examples	Number of Events
1	Defined Point	Geographic coordinates describing locality provided to within 1 km of the location of the event		102
2	Determined Point	Locality description is sufficient to describe locality as point location to within 10 km of the event	Grand Canyon Village, AZ; near the base of Old Baldy, Santa Rita Mountains	121
3	Defined Area	Locality description within 25 km of known place (e.g., mountain range, ranch, town, etc.) or within a named geographic area (e.g., mountain range, county) with an area less than 2000 sq km (~750 sq miles)	Rincon Mountains, near Globe AZ	207
4	Wide Area	Locality description within 100 km of known place (e.g., mountain range, ranch, town, etc.) or within a named geographic area with an area less than 30,000 sq km (~12,000 sq miles)	southeastern Arizona, northern Sonora	58
5	Very Wide Area	Locality description >100 km of known place (e.g., mountain range, ranch, town, county, etc.) or within a large geographic area (e.g., state or states)	Arizona, Sonora, Texas	9
6	Undetermined Area	Locality cannot be determined from description		0

Table 1.2. Date type codes for the northern jaguar event-record database.

DateTypeCode	DateTypeText	Description	Examples	Number of events
0	Unknown			10
1	Exact Date	described to day, month and year	March 9, 1902	138
2	Month-Year	described to month and year	January 1912	47
3	Season within a Year	described to a season within a year or to a few months time	fall of 1910	17
4	Year	described to a year	1946	118
5	Few Years	described to within a three year period; most recent year cited	1904-1907; around 1907; about 1860	44
6	Decade	described to within a ten year period, most recent year cited	1909-1918; 1920s	17
7	Prior to a given year	described at some point in time prior to the year cited, usually used when event time is not given, but record year is known	prior to 1856; until 1900	81
8	Half a Century	described to a 50 year period	early 19th century	2
9	Nearest Century	described to a 100 year period	1800s	2
10	More than a Century but less than a Millennium	described to a period between 100 and 1000 years long (usually multiple centuries)	1540 - 1931, AD 1000 - 1700	8
11	One or more millennia, but less than 10,000 years	described to a period between 1000 and 10,000 years long (to a millenia)	7,000 - 3,800 BP	2
12	Geological Ages	described to a geological age, which vary in length, but are typically more than 10,000 years long	Pleistocene, Miocene	11

Table 1.3. Identity type codes for the northern jaguar event-record database.

IdentityCode	IdentityText	Description	Possible Identity	Number of events
-5	Not culturally significant	Cultural accounts do not claim special significance for the jaguar		3
-4	Wrong country	Record locality has been mistakenly identified within the study area		1
-3	Released	A jaguar was known to have been brought from elsewhere and released for a "canned" hunt		3
-1	Absence	Qualified observer looks for but does not find jaguar or evidence of jaguar		5
0	Unknown or unattributed			1
1	Jaguar	Records claim observation of a jaguar, tigre, el tigre, Panthera onca, Felis onca, or other synonym of jaguar	Jaguar	452
2	Spotted cat	Records claims observation of spotted cat that may be a jaguar	Jaguar, ocelot, bobcat or mountain lion cub	6
3	Cat	Records claims observation of cat of some kind that may be a jaguar	Jaguar, mountain lion, ocelot, bobcat, jaguarundi or domesticated or feral cat	23
4	Large quadruped	Records claims observation of large quadruped that may have been a jaguar	Jaguar, mountain lion, deer, elk, coati, fox, dog, or other similarly sized four legged animal	2
5	Other	Records claim some other creature other than a large quadruped or a cat of some kind and yet which might have been a jaguar		1

Table 1.4. Evidence type codes for the northern jaguar event-record database.

EvidenceCode	EvidenceText	Description	Physical Evidence	Number of events
0	Unknown or unattributed		0	5
1	First hand report	A person who witnessed or participated in the event created the record	0	55
2	Second hand report	A person who witnessed or participated in the event gave an account to someone who recorded it	0	59
3	Third hand report	A person who witnessed or participated in the event gave an account to someone who gave it to someone else who recorded it	0	156
4	Photograph or video		1	102
6	Skull		1	24
7	Hide		1	17
8	Carcass measured		0	1
12	Fossil	Fossilized bone or track found, attributed to jaguar	1	11
13	Tracks seen and/or measured		0	27
14	Prey animal killed jaguar style		0	2
18	Cultural artifact made of jaguar seen		0	7
19	Linguistic evidence		0	5
20	Cultural story or myth		0	5
21	Cultural representation of jaguar		0	12
22	Subfossil	Incompletely fossilized remains	1	1
98	Other physical evidence		0	1
99	Other documentary evidence		0	1

Appendix 2: Frequency histograms of habitat variables based on different selections of jaguar events within the Northwestern Recovery Unit (NRU)

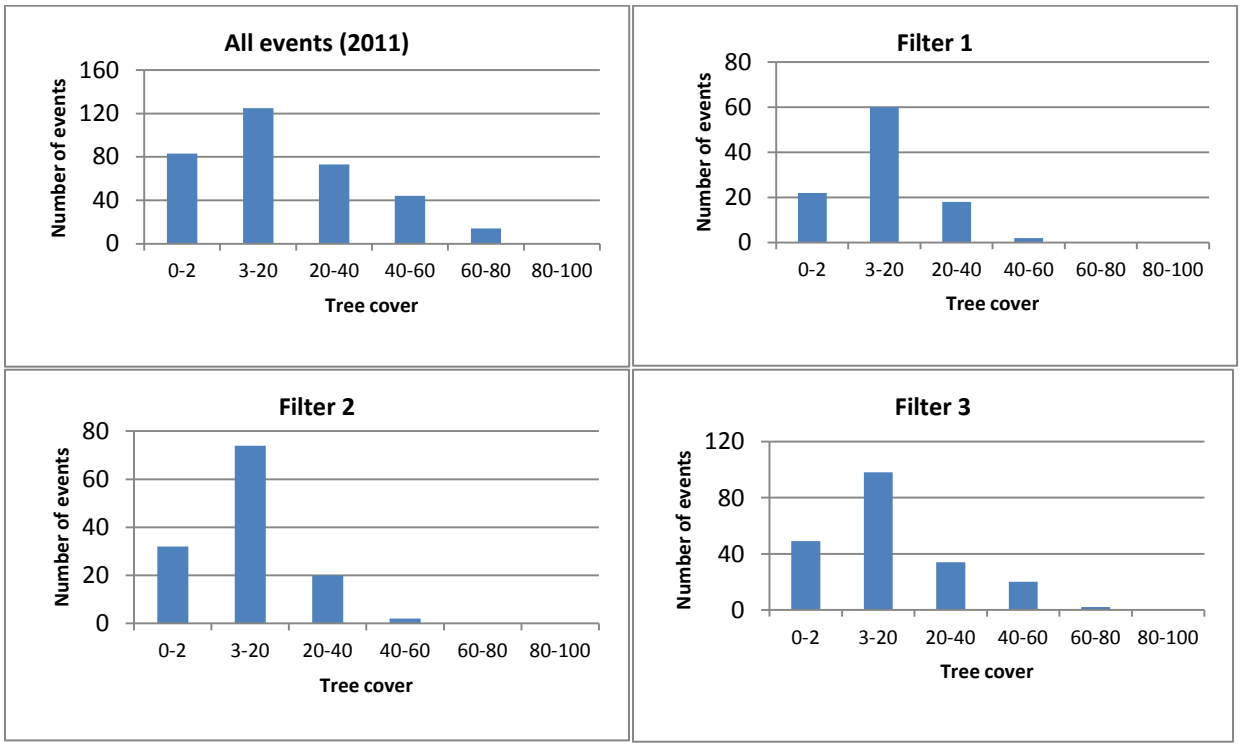
Under the direction of the technical subgroup of the JRT, we examined the consequences of different selections of events on the habitat variables relevant to jaguars: tree cover, terrain ruggedness, human influence and elevation. The technical subgroup also requested analyses of the events in the two southern subunits (Jalisco Core Area and Sinaloa Secondary Area) separate from the two northern subunits (Sonora Core Area and Borderlands Secondary Area). These analyses are presented below without further statistical analysis. Decisions by the technical subgroup about which portions of the habitat variables to include were made based on visual examination of the histograms. In the histograms below, "All events (2011)" refers to the histogram reported in Sanderson and Fisher (2011). The other three histograms refer to event subsets based on filters described in the main report. (Recall that all filters use localities known within 10 km, dates known within a century, observations that were certainly assigned to jaguars, and three different selections of events based on evidence: Filter 1 = physical evidence only, Filter 2 = physical evidence plus tracks and sign, Filter 3 = no filter based on evidence type.)

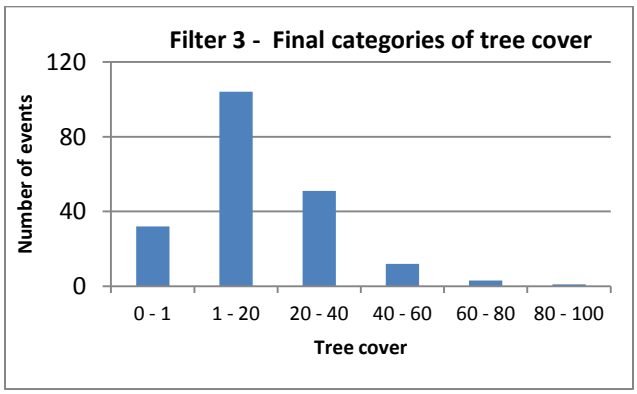
Tree cover

Visual examination of Figure 2.1 suggests that the selection of events using these different criteria makes little qualitative difference in the shape of the tree cover histogram. Most jaguar events were recorded in areas of moderate tree cover.

Note that, after further discussion, the technical subgroup also decided to create finer categories of tree cover, separating out for 0-1% tree cover and 1-20% tree cover, as shown in the fifth histogram. In the models below, the JRT advised us to use categories of tree cover from 1-40% based on these categories.

Figure 2.1. Comparison of subsets of jaguar events against jaguar habitat variable: tree cover



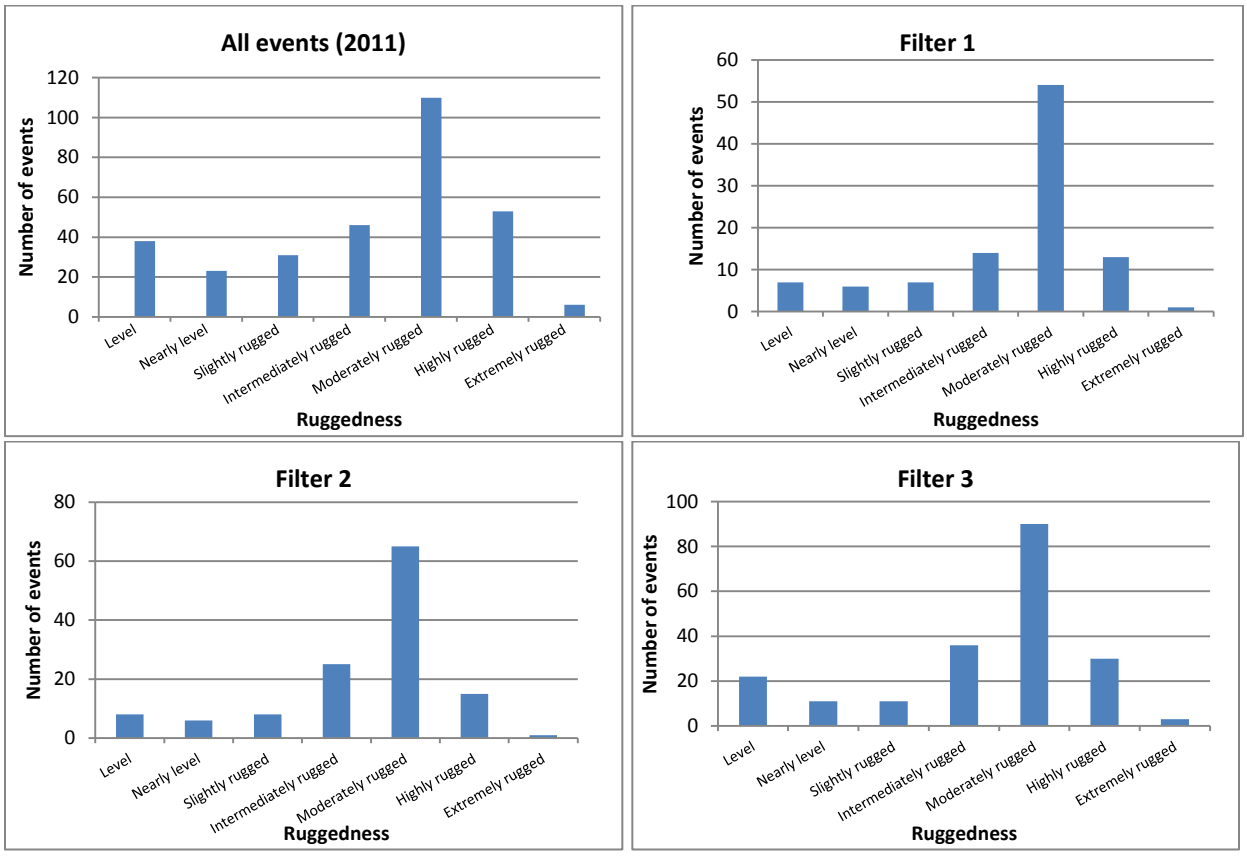


Terrain Ruggedness

Under the advice of the technical subgroup of the JRT, we also examined the frequency distributions of different selections of events for terrain ruggedness. Visual examination of Figure 2.2 suggests that the selection of events using these different criteria makes little qualitative difference in the shape of the terrain ruggedness histogram. Most jaguar events were located in areas of moderate ruggedness, with smaller numbers of events in the intermediately rugged and highly rugged categories.

In the models below, the JRT advised us to use the following categories of ruggedness: intermediate, moderate, and highly rugged categories (no change).

Figure 2.2. Comparison of subsets of jaguar events against jaguar habitat variable: terrain ruggedness

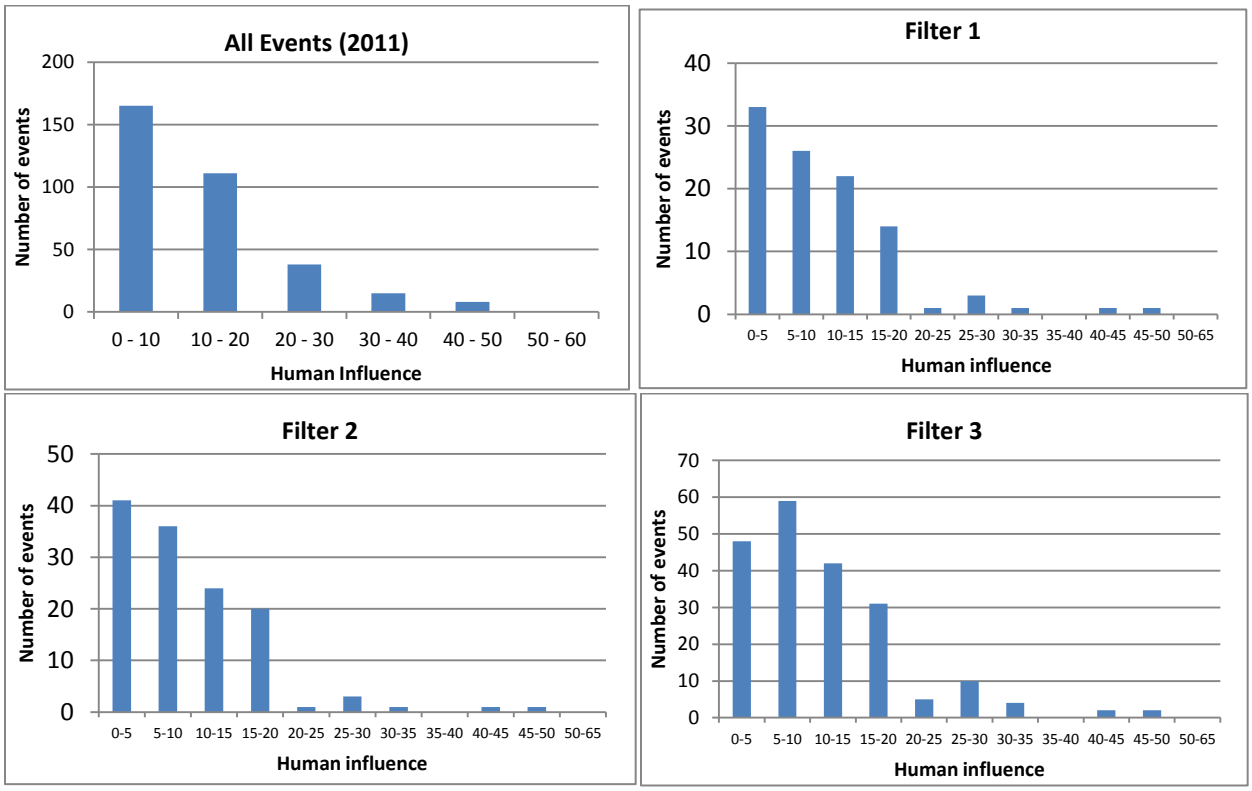


Human Influence

Under the advice of the technical subgroup of the JRT, we also examined the frequency distributions of different selections of events for human influence, based on the human influence index (Sanderson et al. 2002). Visual examination of Figure 2.3 suggests that the selection of events using these different criteria makes little qualitative difference in the shape of the human influence histogram. Most jaguar events were located in areas of low human influence, typically less than a score of 20 on the human influence index.

In the models below, the JRT advised us to mask out areas of human influence greater than 20.

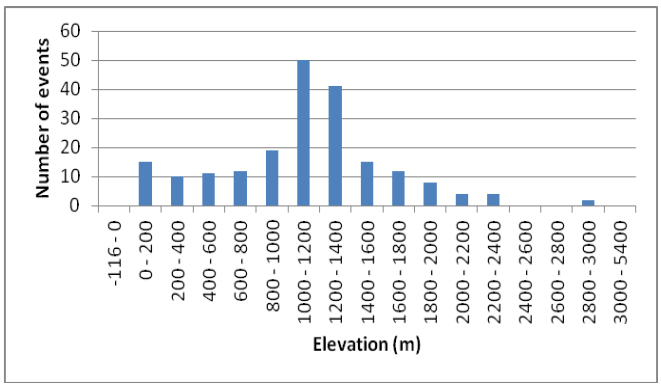
Figure 2.3. Comparison of subsets of jaguar events against jaguar habitat variable: human influence.



Elevation

Figure 2.4 shows the distribution of Filter 3 events by elevation. Because only 20 events occurred above 2000 m, the JRT technical subgroup decided to mask out areas above 2000 m. Because so few events were involved even with the most expansive filter, the technical subgroup decided it was not necessary to examine the other filters for their effect on elevation.

Figure 2.4. Comparison of the Filter 3 subset of jaguar events against elevation



North/South Comparisons

During the development of model versions 10-11, the technical subgroup, via Carlos López González, Howard Quigley, and Marit Alanen, asked us to consider whether separate models for the two northern subunits and the two southern subunits might provide results more in keeping with the technical subgroup's expertise, especially as there is a major habitat shift from the dry tropical forest of Jalisco to the thornscrub vegetation of Sonora. Below we present comparisons of frequency histograms, separating out events from the northern two subunits (shown in blue) and from the southern two subunits (shown in red) for tree cover and human influence. Although there were some differences with respect to these two variables, ultimately the technical subgroup decided that this approach was not useful because it split an already small number of density estimates into two even smaller pools – see notes in Appendix 3 for versions 10-11.

Figure 2.5. Comparison of frequency histograms for jaguar events in the northern and southern parts of the NRU with respect to tree cover.

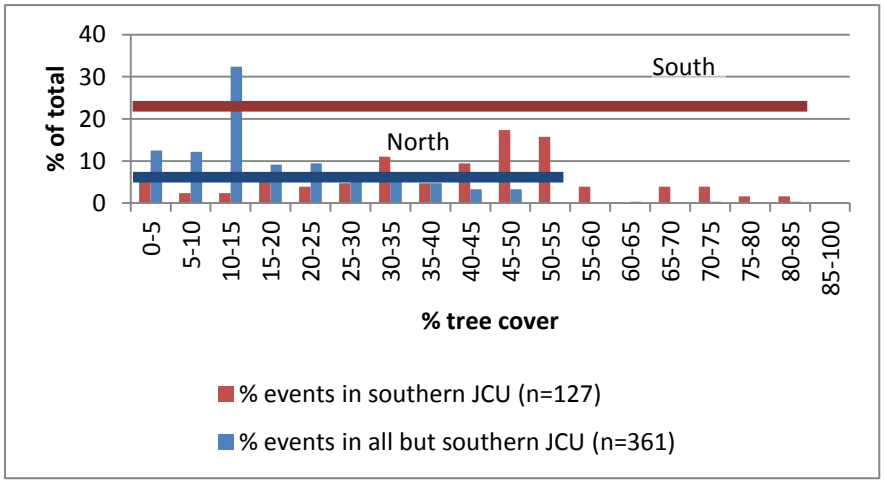
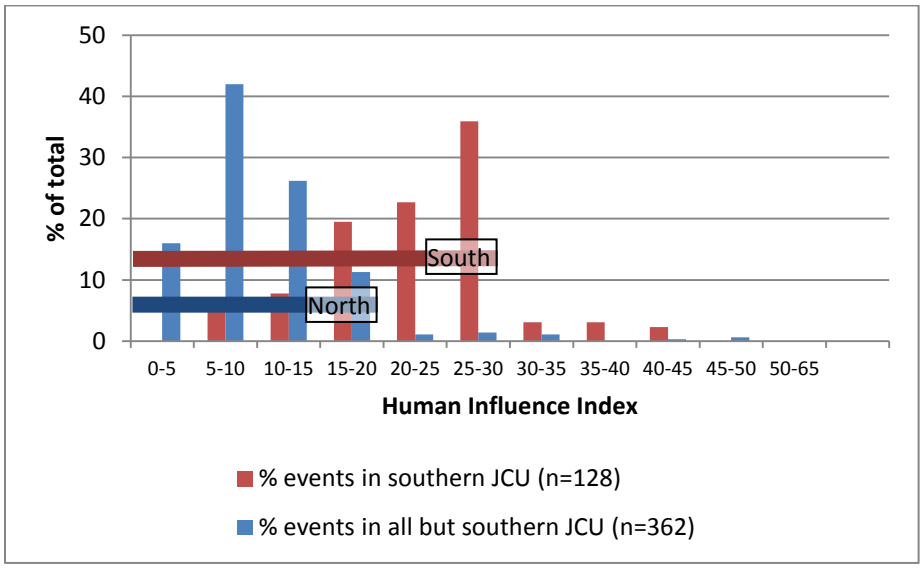


Figure 2.6. Comparison of frequency histograms for jaguar events in the northern and southern parts of the NRU with respect to human influence.



Appendix 3: Habitat model history

The habitat model eventually adopted by the JRT represents an evolution. With a few small noted exceptions, each step was essentially a refinement of the parameters of the same basic conceptual process described in the main text under Objective 2, based on ongoing discussion amongst the technical subgroup of the JRT and the JRT at large. Each description in this appendix begins with a version number, starting from version 8.0 as the starting point for this contract, and specifies:

1. Subunit definition: The geographic extent of each subunit changed slightly from model to model. In some cases names changed as well. Where the subunits changed in area, we produced a summary table of the areas. Former names are listed in a column beside the final names to allow for easy cross-referencing. Where subunit definitions remained the same between model versions, a note to that effect is given rather than providing an additional (duplicative) table.

2. Habitat factors: The model is driven by a simple combinatorial model of habitat factors considered important for jaguars in the NRU. In our descriptions here, we provide a table of each of the environmental factors used, including ranges of values, as necessary. Note the selection of ranges of values is discussed in Appendix 2, based on analysis of the selected jaguar events against the various factors. Where habitat factors remained the same between versions, a note to that effect is given rather than providing an additional (duplicative) table.

3. Habitat weights: In some models, the habitat type is weighted based on the potential ecoregion type. The ways these weights were arrived by the JRT are noted below, and when they did not change between versions, a note to that effect is given rather than providing an additional (duplicative) table.

4. Habitat equation: The formula used to calculate habitat suitability across the NRU given the set of inputs is shown and explained where changes occurred, or a note about lack of change included.

5. Mask: As the model was refined, the JRT determined in a few cases that certain values of individual variables ought to be used to omit areas from consideration during or after calculating habitat suitability. These areas are referred to as “masks” because they exclude associated areas entirely, rather than assign them low or 0 values. These cases, or else a note about the lack of change, are included in this item.

6. Translation to density: For each model version, a table lists each available density study with the average modeled habitat suitability calculated within its extent, along with the source and density value for that study. These values were then correlated as described under Objective 2, producing the regression equation and graph shown under the table in this item (or else lack of change is noted).

7. Sum: Finally, the results of multiplying density by area over each subunit are listed to arrive at jaguar population numbers.

8. Maps: A map of the potential carrying capacity predicted by the model is provided, with an inset map in the upper right corner focused on the northern portions of the Borderlands Secondary

Area in the United States. Note that the definition of the colors on the map indicating potential jaguar carrying capacities vary slightly between model versions.

Potential Jaguar Habitat Model, version 8.0 (March 3, 2011)

(1) Subunit definition:

Population subunit	Former subunit name	Area of subunit (km2)
Jalisco Core Area	MX Sinaloa Sub-Population	53,446
Sinaloa Secondary Area	MX North Sinaloa Connector Area	41,260
Sonora Core Area	MX Sonora Sub-Population	83,472
Borderlands Secondary Area – Mexico portion	MX Northern Sonora Connector Area	36,237
Borderlands Secondary Area – US portion	US South of I-10 Highway	29,754
	US North of I-10 Highway	38,073

(2) Habitat factors:

Variable	1	0
Tree cover	3-60% tree cover	< 3% or > 60% tree cover
Ruggedness	intermediate, moderate, and high ruggedness	Level, nearly level, and extreme ruggedness
Distance from Water	<= 10 km of water	> 10 km from water
Human influence	HII < 30	HII >= 30

(3) Habitat weights: In version 8.0, the relative weight assigned to each habitat type was determined by JRT consensus and was meant to reflect expert opinion about the relative suitability of each kind of environment, independent of the other variables in the model. In later versions this expert opinion was replaced with a quantitative approach.

Habitat type	Relative weight
Jalisco dry forest	2.5
Sinaloan dry forest	2
Northern Mesoamerican Pacific mangroves	1.5
Sonoran-Sinaloan transition subtropical dry forest ("thornscrub")	1
Trans-Mexican Volcanic Belt pine-oak forests	0.25
Sierra Madre Occidental pine-oak forests	0.25
Arizona Mountains forests	0.25
Chihuahuan desert	0.1
Sonoran desert	0.1

(4) Habitat equation:

([3-60% tree cover] + [intermediate, moderate, and high ruggedness]) (0-2)
*
[Within 10km of water] (0-1)
*
[HII < 30] (0-1)

*

[Habitat type weight] (0.1-2.5)

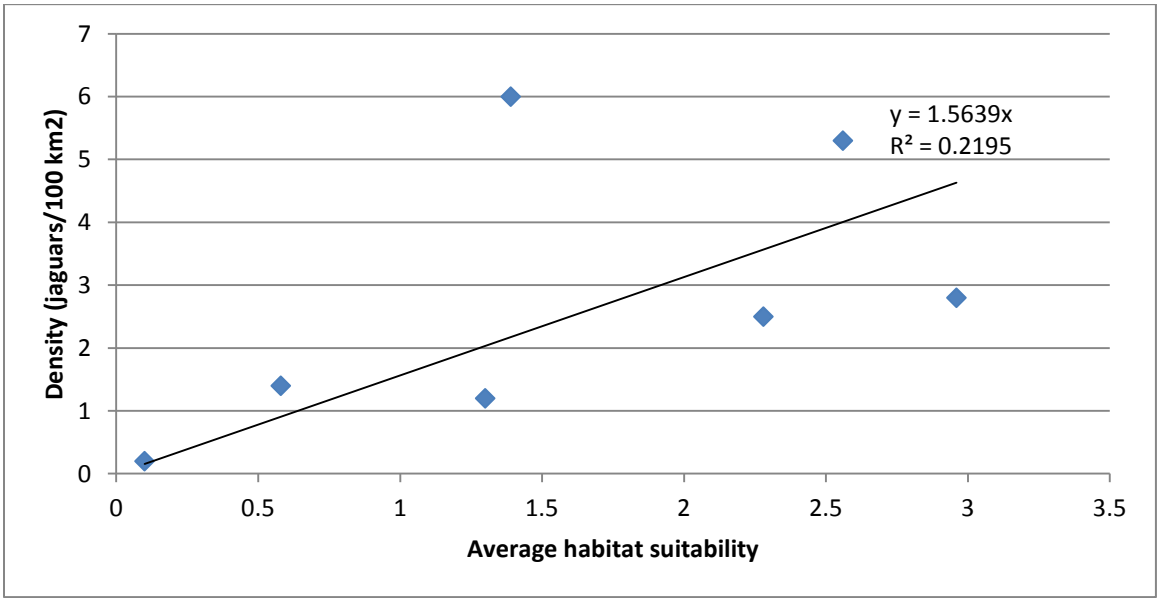
(5) Mask: no additional mask.

(6) Translation to density:

Study ID	Study	Average habitat suitability	Density (jaguars /100 km2)	Source
1	Jalisco-Sinaloa I	3.0	2.8	Núñez-Pérez 2011
2	Jalisco-Sinaloa II	1.4	6.0	R. Núñez (pers. comm.)
3	Jalisco-Sinaloa III	2.6	5.3	R. Núñez (pers. comm.)
4	Jalisco-Sinaloa IV	2.3	2.5	Coronel-Arellano et al., *In press*
5	Sonora I	0.6	1.4	Gutiérrez-González et al., *In press*
6	Sonora II	1.3	1.2	López González and Moreno Arzate 2011
7	Arizona I	0.1	0.2	McCain and Childs 2008

The regression equation: density (jaguars / 100 km2) = (1.5639 * habitat score) / 100.

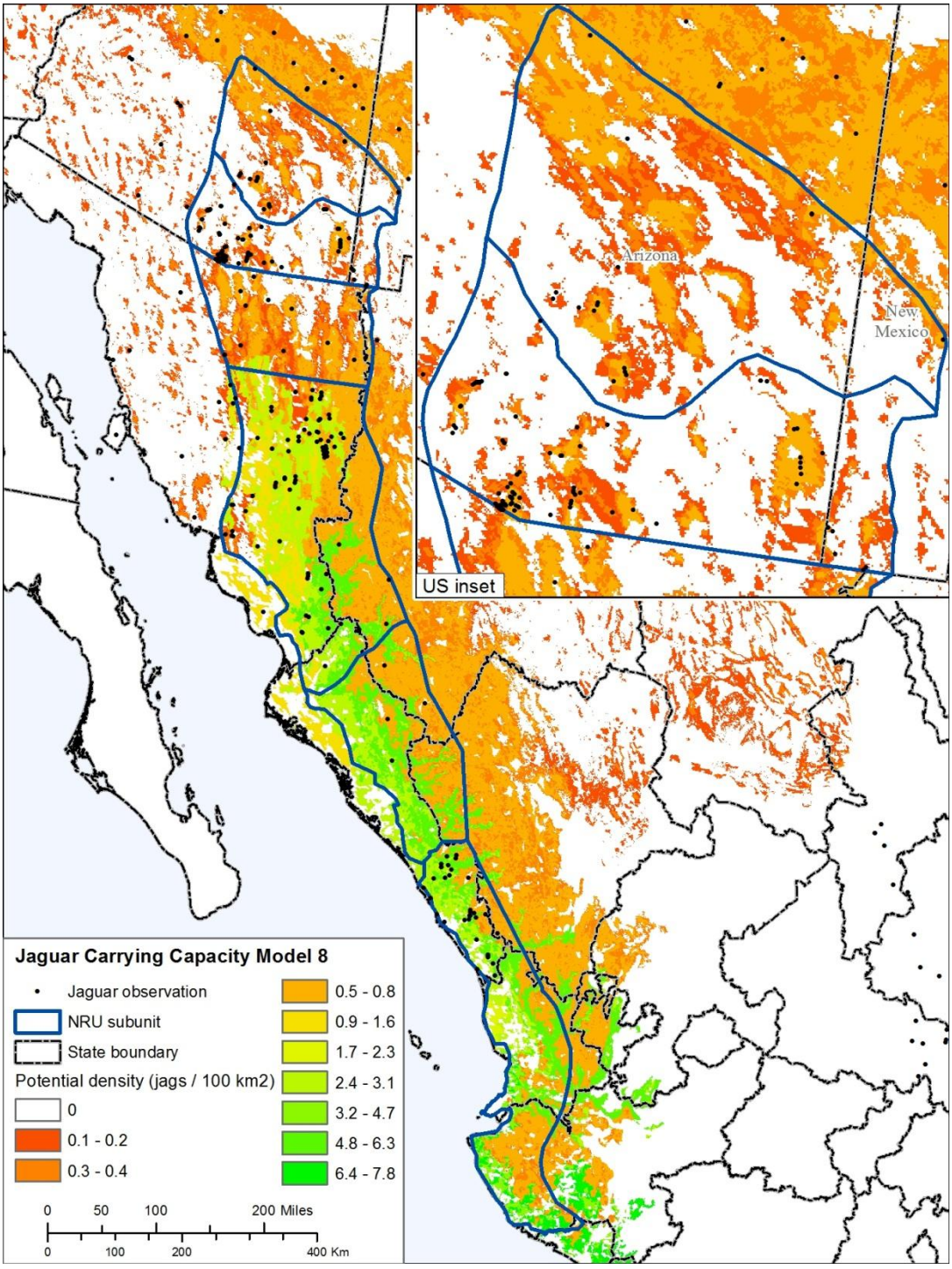
Note that the regression equation forced the y-intercept through zero (see discussion in Objective 4).



(7) Sum: The number of potential jaguars in each subunit and in the NRU (total). Habitat area includes all the areas with non-zero, positive habitat scores within each subunit.

Population subunit	**Former subunit name**	**Estimate of habitat area (km^2)**	**Estimated number of potential jaguars**
Jalisco Core Area	MX Sinaloa Sub-Population	44,510	1,410
Sinaloa Secondary Area	MX North Sinaloa Connector Area	39,501	1,198
Sonora Core Area	MX Sonora Sub-Population	76,271	1,670
Borderlands Secondary Area – Mexico portion	MX Northern Sonora Connector Area	24,394	135
Borderlands Secondary Area – US portion	US South of I-10 Highway	7,663	27
[this subunit was subsequently deleted from analysis by the JRT]	US North of I-10 Highway	17,269	74
Total		**282,604**	**4,513**

(8) Map of potential carrying capacity.



Potential Jaguar Habitat Model, version 8.1 (August 4, 2011)

Version 8.1 of the model was described in the final report from the WCS to the FWS on August 4, 2011, under agreement F11AC00036 (and modification #0001).

(1) Subunit definition: The area north of Interstate 10 in the United States was removed from the recovery unit definition at the request of the JRT at the meeting March 1 – 3, 2011. Also, a small area (approximately 342 km^2) was removed from the definition of the US South of I-10 Highway subunit in New Mexico.

Population subunit	**Former subunit name**	**Area of subunit (km^2)**
Jalisco Core Area	MX Sinaloa Sub-Population	53,446
Sinaloa Secondary Area	MX North Sinaloa Connector Area	41,260
Sonora Core Area	MX Sonora Sub-Population	83,472
Borderlands Secondary Area – Mexico portion	MX Northern Sonora Connector Area	36,237
Borderlands Secondary Area – US portion	US South of I-10 Highway	29,528

(2) Habitat factors: same as version 8.0.

(3) Habitat weights: same as version 8.0.

(4) Habitat equation: same as version 8.0.

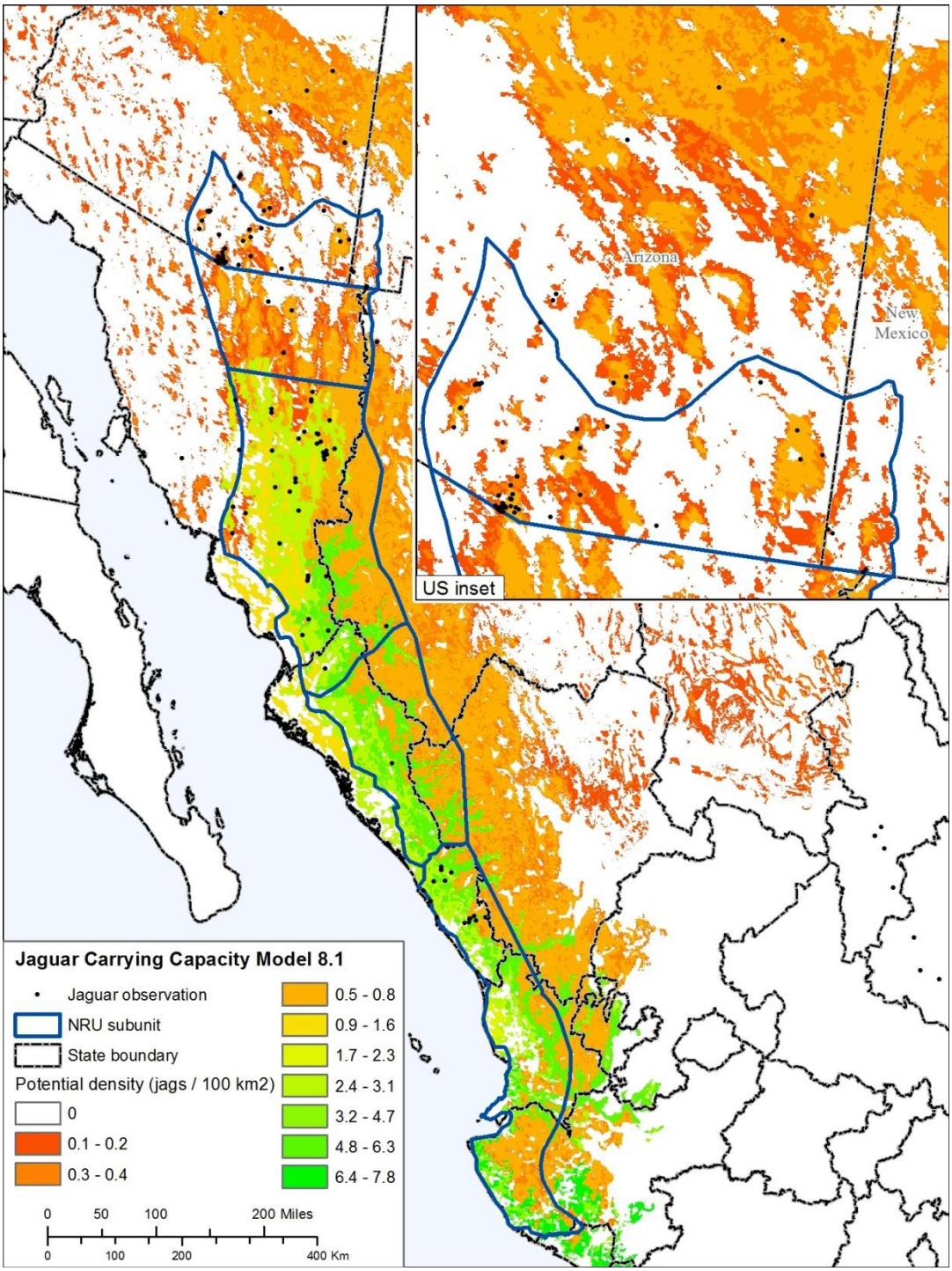
(5) Mask: same as version 8.0.

(6) Translation to density: same as version 8.0.

(7) Sum: same as version 8.0 with the US north of I-10 Highway removed.

Population subunit	**Former subunit name**	**Estimate of habitat area (km2)**	**Estimated number of potential jaguars**
Jalisco Core Area	MX Sinaloa Sub-Population	44,510	1,410
Sinaloa Secondary Area	MX North Sinaloa Connector Area	39,501	1,198
Sonora Core Area	MX Sonora Sub-Population	76,271	1,670
Borderlands Secondary Area – Mexico portion	MX Northern Sonora Connector Area	24,394	135
Borderlands Secondary Area – US portion	US South of I-10 Highway	7,663	27
Total		**192,339**	**4,440**

(8) Map of potential carrying capacity.



Potential jaguar habitat model, version 9 (April 26, 2012)

(1) Subunit definition: Same as version 8.1.

(2) Habitat factors: At the request of the JRT technical subgroup during the meeting April 24 – 26, 2012, WCS produced a set of three histograms for each habitat factor (see Appendix 2) based on jaguar observations filtered by three sets of criteria. The overall histogram patterns proved very similar across the filtered subsets; while the total in each category was lower in the more restrictive scenarios, the histograms were qualitatively similar, and the thresholds suggested were the same. Therefore, the JRT technical subgroup agreed that the "filter 3" subset of events should be used to revise the thresholds used for the habitat factors based on histogram analysis.

In addition, the JRT technical subgroup requested that a new habitat factor be added for elevation, and that areas above 2000 m be considered unsuitable habitat, since only a limited number of records occurred above that height (see Figure 2.4).

Habitat Factor	**1**	**0**
Tree cover	> 1 and <= 40% tree cover	<= 1 or > 40 and <= 100% tree cover
Ruggedness	intermediate, moderate, and high ruggedness	Level, nearly level, and extreme ruggedness
Distance from Water	<= 10 km of water	> 10 km from water
Human Influence	HII <= 20	HII > 20
Elevation	<= 2000 m	> 2000 m

(3) Habitat weights: At the request of the JRT technical subgroup, WCS added density estimates occurring in the different ecosystem types to the weights table, so that the group could evaluate correlations. In the table produced below, the first column shows the original values, the second column shows existing density estimates falling within each habitat type, and the third column shows the average of the values in the second column. These density estimates were provided from by the technical subgroup or derived from the published literature. The JRT technical subgroup decided to use the values from the third column as new ecosystem weights.

Ecoregion	**Relative weight**	**Density estimates (literature sources and technical subgroup*)**	**Density estimates (expert)**
Jalisco dry forest	2.5	2.8, 5.3, 5.6	4.57
Sinaloan dry forest	2	2.5	2.5
Northern Mesoamerican Pacific mangroves	1.5	6, 2.5	4.25
Sonoran-Sinaloan transition subtropical dry forest ("thornscrub")	1	1.2, 1.1, 1.4	1.23

Trans-Mexican Volcanic Belt pine-oak forests	0.25		0.1
Sierra Madre Occidental pine-oak forests	0.25		0.1
Arizona Mountains forests	0.25		0.1
Chihuahuan desert	0.1	0.2	0.08
Sonoran desert	0.1		0.08

* Data provided by R. Núñez, C. López González, and O. Rosas-Rosas based on studies of jaguar density in Mexico. The only US estimate is drawn from McCain & Childs (2008) by estimating the number of jaguars observed (i.e., two) over the reported sampling area.

(4) Habitat equation:

[Tree cover (> 1 and <= 40%)] +
[intermediate, moderate, and high ruggedness] (0-2)
*
[Within 10km of water] (0-1)
*
[HII < 20] (0-1)
*
[Elevation <= 2000 m] (0-1)
*
[Habitat type weight] (0.08-4.57)

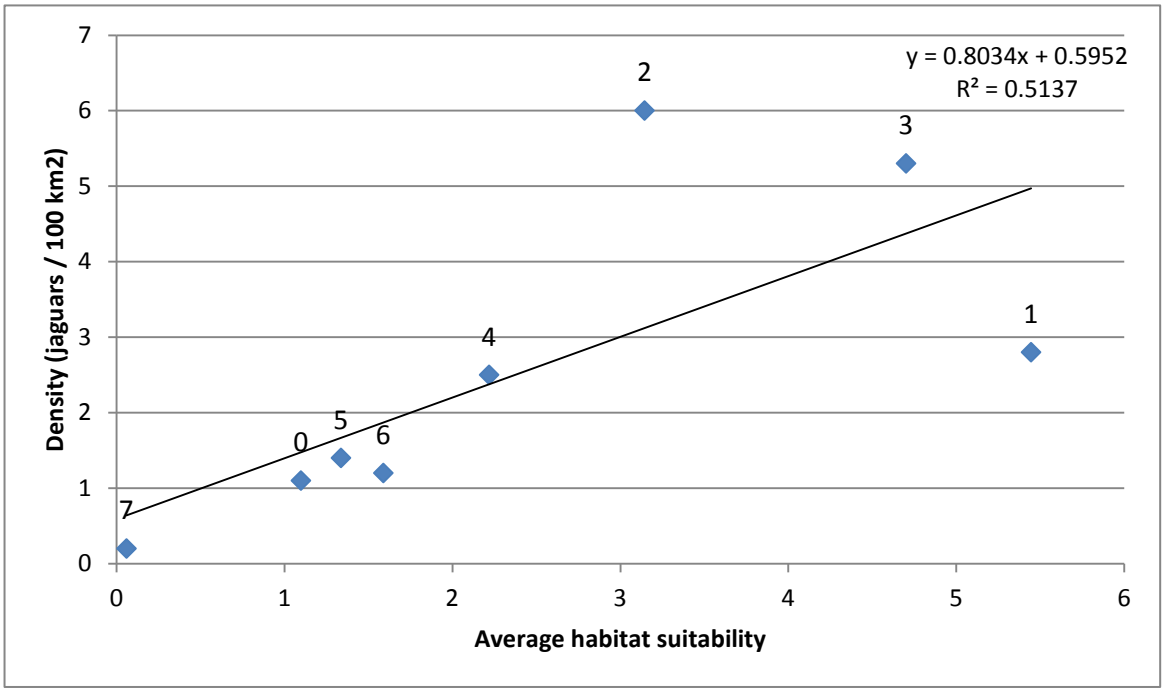
(5) Mask: After habitat suitability was calculated, resulting contiguous areas of less than 100 sq km were removed throughout the northwest jaguar recovery unit, because the JRT technical subgroup consensus was that areas smaller than this are too small to support a jaguar.

(6) Translation to density: One additional density study data point, from Octavio Rosas-Rosas, was added.

Study ID	**Average habitat suitability**	**Density (jaguars /100 km2)**	**Source**
0	1.1	1.1	Rosas-Rosas 2011
1	3.0	2.8	Núñez-Pérez 2011
2	1.4	6.0	R. Núñez (pers. comm.)
3	2.6	5.3	R. Núñez (pers. comm.)
4	2.3	2.5	Coronel-Arellano et al., *In press*
5	0.6	1.4	Gutiérrez-González et al., *In press*
6	1.3	1.2	López González and Moreno Arzate 2011;
7	0.1	0.2	McCain and Childs 2008

The regression equation: density (jaguars / 100 km2) = ((0.8034 * habitat score) + 0.5952) / 100.

Note that the regression equation did not force the y-intercept through zero (see discussion in Objective 4).

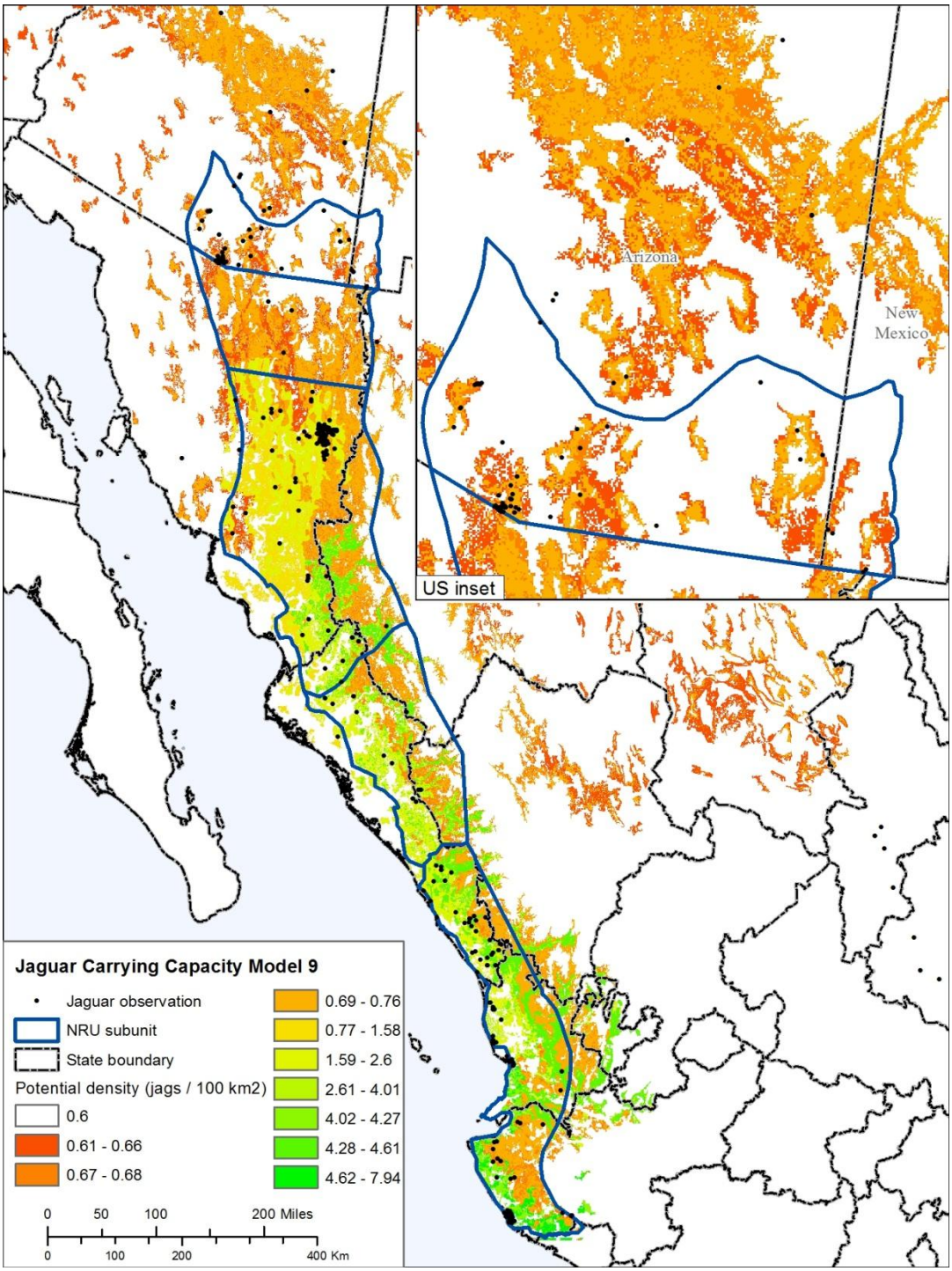


(7) Sum:

Population subunit	Former subunit name	Estimate of habitat area (km2)	Estimated number of potential jaguars
Jalisco Core Area	MX Sinaloa Sub-Population	52,899	1,253
Sinaloa Secondary Area	MX North Sinaloa Connector Area	41,129	675
Sonora Core Area	MX Sonora Sub-Population	82,994	1,316
Borderlands Secondary Area – Mexico portion	MX Northern Sonora Connector Area	36,200	254
Borderlands Secondary Area – US portion	US South of I-10 Highway	29,534*	182
Total		**242,756**	**3,680**

* Slightly larger than subunit polygon area because of rounding.

(8) Map of potential carrying capacity.



Potential jaguar habitat model, versions 10-11 (June 25-26, 2012)

Versions 10 and 11 are here combined, because version 10 was effectively an intermediate step to 11, produced during a meeting of a subgroup (hereafter the "coleaders") of the JRT technical subgroup (Carlos López González and Howard Quigley, with Marit Alanen acting as the FWS liaison) at the WCS Headquarters in Bronx, NY, during June 25 – 26, 2012.

(1) Subunit definition: The western boundary of the Jalisco Core Area was redefined to fit the area of potential jaguar habitat more closely by making the boundary follow the coast except around Puerto Vallarta.

Population subunit	**Former subunit name**	**Area of subunit (km2)**
Jalisco Core Area	MX Sinaloa Sub-Population	54,949
Sinaloa Secondary Area	MX North Sinaloa Connector Area	41,260
Sonora Core Area	MX Sonora Sub-Population	83,472
Borderlands Secondary Area – Mexico portion	MX Northern Sonora Connector Area	36,237
Borderlands Secondary Area – US portion	US South of I-10 Highway	29,528

(2) Habitat factors: The coleaders investigated the disparity between results of the model in the northern and southern parts of the NRU. The histogram-based thresholds used to calculate habitat suitability removed large areas from the southern part where jaguar observations occurred. After some discussion, the coleaders decided that a broad north-south ecological divide between and human influence and the types of habitat used by jaguars in the southern two subunits (Sinaloa Secondary Area and Jalisco Core Area) compared to habitat types used by jaguars in the northern three subunits (US and Mexico portions of the Borderlands Secondary Area and Sonora Core Area) was the cause of the poor fit. Jaguars in the southern subunits appear to use areas of higher tree cover compared to jaguars in the northern subunits, and so to improve the model, the tree cover habitat factor was treated differently in the three northern subunits and in the two southern subunits, as elaborated below.

Similarly, human influence thresholds were adjusted, but the coleaders decided to use HII as a post-calculation mask, rather than a habitat factor (see (5) Mask, below).

Habitat Factor	**1**	**0**
Tree cover	> 1 and <= 50% tree cover (north) / > 1 and <= 100% tree cover (south)	<= 1 or > 50 and <= 100% tree cover (north) <= 1% tree cover (south)
Ruggedness	intermediate, moderate, and high ruggedness	Level, nearly level, and extreme ruggedness
Distance from Water	<= 10 km of water	> 10 km from water
Elevation	Elevation <= 2000 m	Elevation > 2000 m

(3) Habitat weights: An additional four density estimates were added to the analysis and one was removed (see (6) Translation to density, below), and these were used to adjust habitat weights based on recalculated density averages. In addition, the two desert habitat types, for which no density studies were available to average, were assigned further reduced weights based on expert opinion about the relative suitability of these environments (i.e., very low) compared to the revised set of density estimates from the other habitat types.

Habitat type	**Density estimates**	**Relative weight**
Jalisco dry forest	2.8, 5.3, 5.6	4.6
Sinaloan dry forest	2.5, 6.7	4.6
Northern Mesoamerican Pacific mangroves	6, 2.5	4.3
Sonoran-Sinaloan transition subtropical dry forest ("thornscrub")	1.2, 1.1, 1.4	1.2
Sierra Madre Occidental pine-oak forests	0.2, 0**, 0**, 0.45**	0.2
Arizona Mountains forests		N/A
Trans-Mexican Volcanic Belt pine-oak forests		0.2
Chihuahuan desert		0.01
Sonoran desert		0.01

** Density estimates provided by C. López González reflecting unpublished estimates from the Chihuahuan pine forests of the Sierra Madre in Mexico.

(4) Habitat equation:

[Tree cover (> 1 and <= 50% north / > 1 and <= 100% south)] +
[intermediate, moderate, and high ruggedness] (0-2)
*
[Within 10km of water] (0-1)
*
[Elevation <= 2000 m] (0-1)
*
[Habitat type weight] (0.08-4.57)

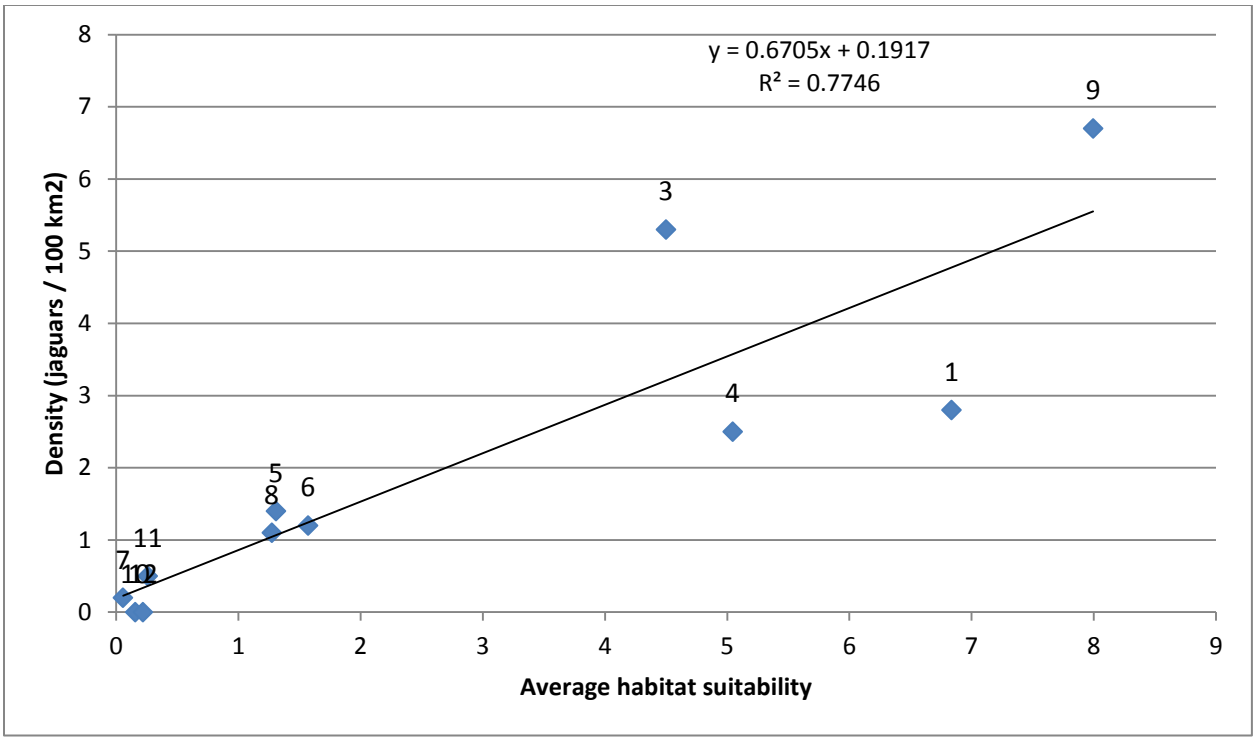
(5) Mask: Application of the thresholds derived from the histograms for jaguar observations against human influence in the previous iteration was removing large areas from the southern end of the NRU where observations had been made; but raising these thresholds was including large areas in the northern portion where observations had not been made and where habitat suitability was clearly poor according to expert opinion. Recognizing that jaguars may respond more tolerantly to human influence in the south than they do in the north, (as defined in (2) Habitat factors, above), the JRT coleaders during their meeting in New York suggested lower thresholds (HII < 20) than in the south (HII < 30) for inclusion in the model. The coleaders further suggested that areas not meeting the HII threshold in each area should be masked out, rather than set to 0 as in previous models. As with the small-fragment mask applied earlier, these masks have the effect of completely removing low-HII areas from consideration.

(6) Translation to density: Four new density studies were added (see table below). Additionally, after examining the habitat models and discussing the outlier results in the southern portion of the NRU in generally and in the Northern Mesoamerican Pacific mangroves specifically, the team coleaders decided to remove density study #2 (see model 10/11) because it occurred in an anomalous mangrove ecological setting, in a protected area surrounded by high human influence, and so was not considered representative of densities elsewhere in the NRU.

Study ID	Average habitat suitability.	Density (jaguars /100 km2)	Source
1	6.8	2.8	Rodrigo Núñez (pers. comm.)
3	4.5	5.3	Rodrigo Núñez (pers. comm.)
4	5.0	2.5	Carlos López González (pers. comm.)
9	8.0	6.7	Rubio 2011
5	1.3	1.4	Carlos López González (pers. comm.)
6	1.6	1.2	Carlos López González (pers. comm.)
7	0.1	0.2	McCain & Childs 2008
8	1.3	1.1	Rosas-Rosas 2011
10	0.2	0	Lara-Díaz 2010 (Master's thesis)
11	0.3	0.5	Lara-Díaz 2010 (Master's thesis)
12	0.2	0	Lara-Díaz 2010 (Master's thesis)

The regression equation: density (jaguars / 100 km2) = ((0.6705 * habitat score) + 0.1917) / 100.

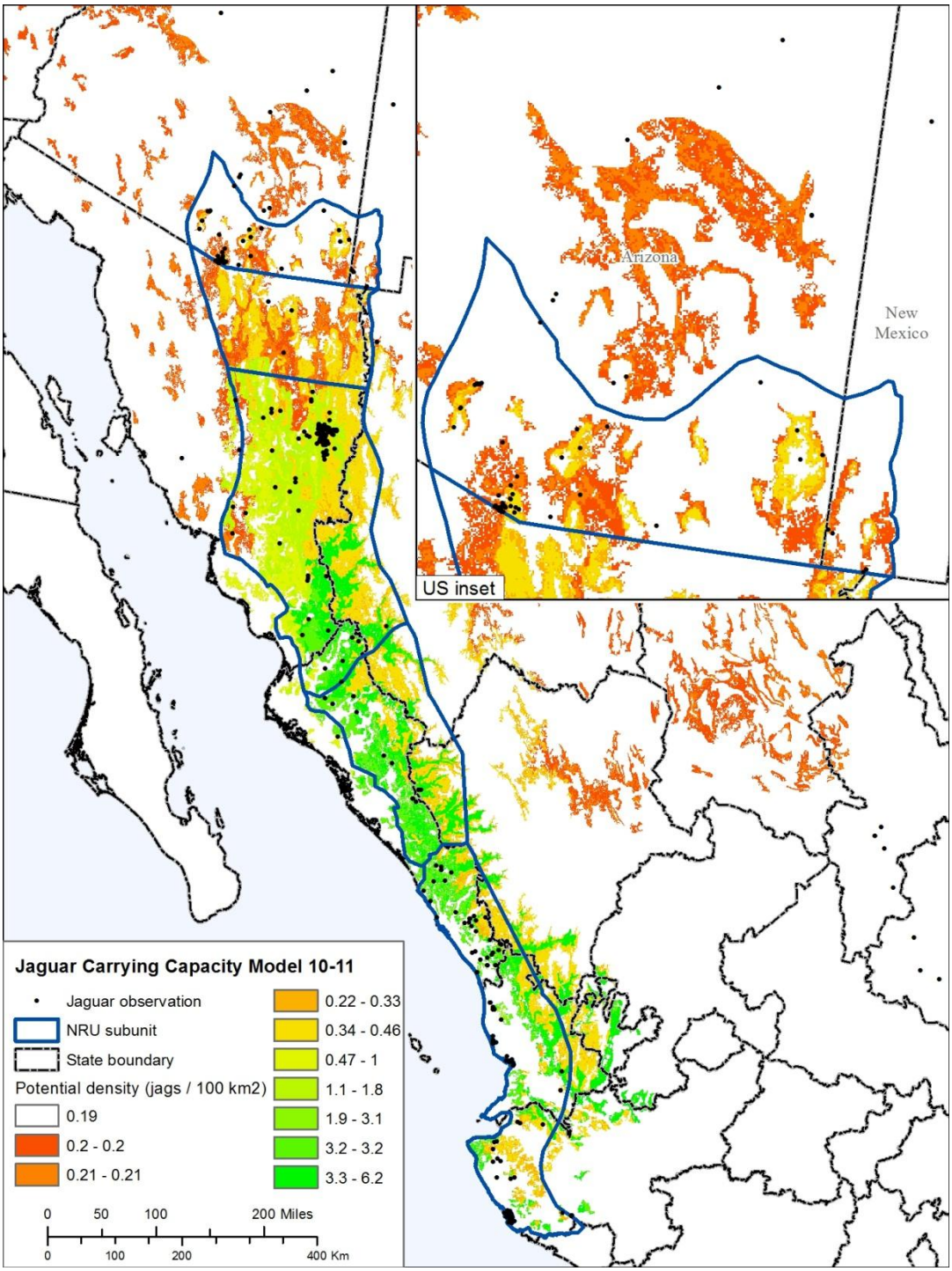
Note that the regression equation did not force the y-intercept through zero (see discussion in Objective 4).



(7) Sum:

Population subunit	Former subunit name	Estimate of habitat area (km2)	Estimated number of potential jaguars
Jalisco Core Area	MX Sinaloa Sub-Population	51,732	1,350
Sinaloa Secondary Area	MX North Sinaloa Connector Area	30,822	982
Sonora Core Area	MX Sonora Sub-Population	76,996	1,277
Borderlands Secondary Area – Mexico portion	MX Northern Sonora Connector Area	33,286	101
Borderlands Secondary Area – US portion	US South of I-10 Highway	27,737	59
Total		**220,573**	**3,769**

(8) Map of potential carrying capacity.



Potential jaguar habitat model, version 12 (July 31, 2012)

This version of the potential jaguar habitat model was presented at the meeting of the full JRT meeting in Tucson, Arizona on July 31, 2012.

(1) Subunit definition: The eastern boundary of the Mexico portion of the Borderlands Secondary Area, the Sonora Core Area, and the Sinaloa Secondary Area was moved westward to more closely match the western edge of the pine-oak forests and the 2000 m elevation line. In addition, the extreme northwest corner of northernmost unit, which extended into Pinal County, was removed.

Population subunit	**Former subunit name**	**Area of subunit (km2)**
Jalisco Core Area	MX Sinaloa Sub-Population	54,949
Sinaloa Secondary Area	MX North Sinaloa Connector Area	31,191
Sonora Core Area	MX Sonora Sub-Population	77,710
Borderlands Secondary Area – Mexico portion	MX Northern Sonora Connector Area	33,955
Borderlands Secondary Area – US portion	US South of I-10 Highway	29,021

(2) Habitat factors: same as version 11.

(3) Habitat weights: same as version 11.

(4) Habitat equation: same as version 11.

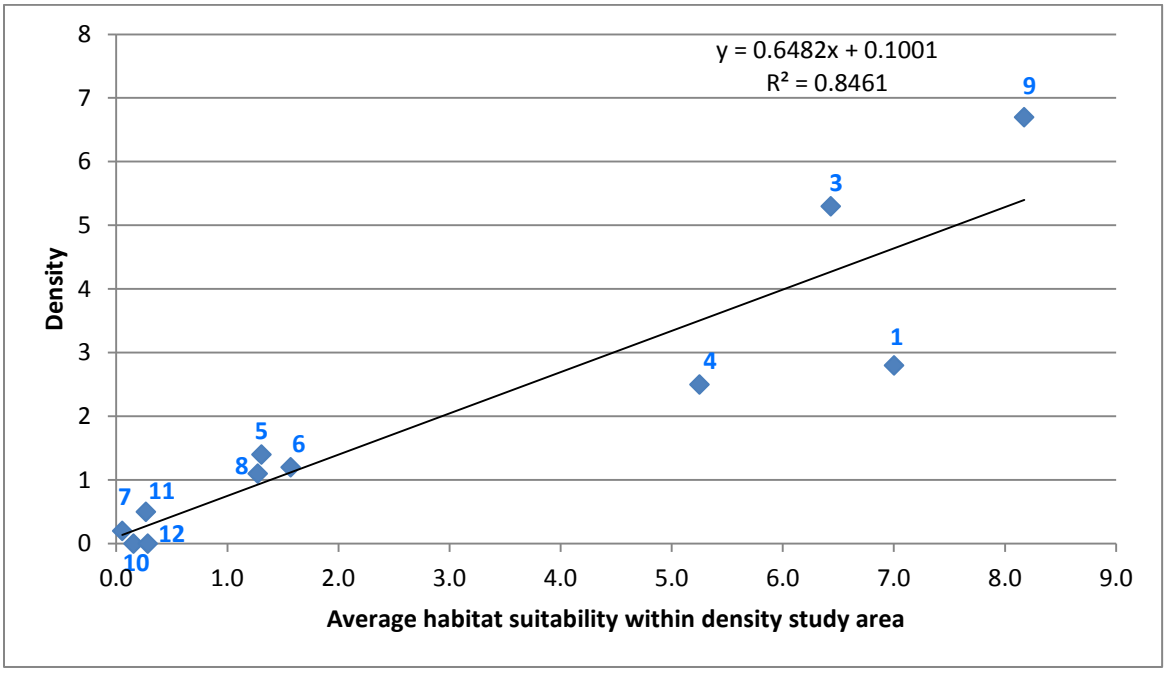
(5) Mask: same as version 11.

(6) Translation to density:

Study ID	**Average habitat suitability**	**Density (jaguars /100 km2)**	**Source**
1	7.0	2.8	Rodrigo Núñez (pers. comm.)
3	6.4	5.3	Rodrigo Núñez (pers. comm.)
4	5.3	2.5	Carlos López González (pers. comm.)
9	8.2	6.7	Rubio 2011
5	1.3	1.4	Carlos López González (pers. comm.)
6	1.6	1.2	Carlos López González (pers. comm).
7	0.1	0.2	McCain & Childs 2008
8	1.3	1.1	Octavio Rosas 2011
10	0.2	0	Lara-Díaz 2010 (Master's thesis)
11	0.3	0.5	Lara-Díaz 2010 (Master's thesis)
12	0.3	0	Lara-Díaz 2010 (Master's thesis)

The regression equation: density (jaguars / 100 km2) = ((0.6482 * habitat score) + 0.1001) / 100.

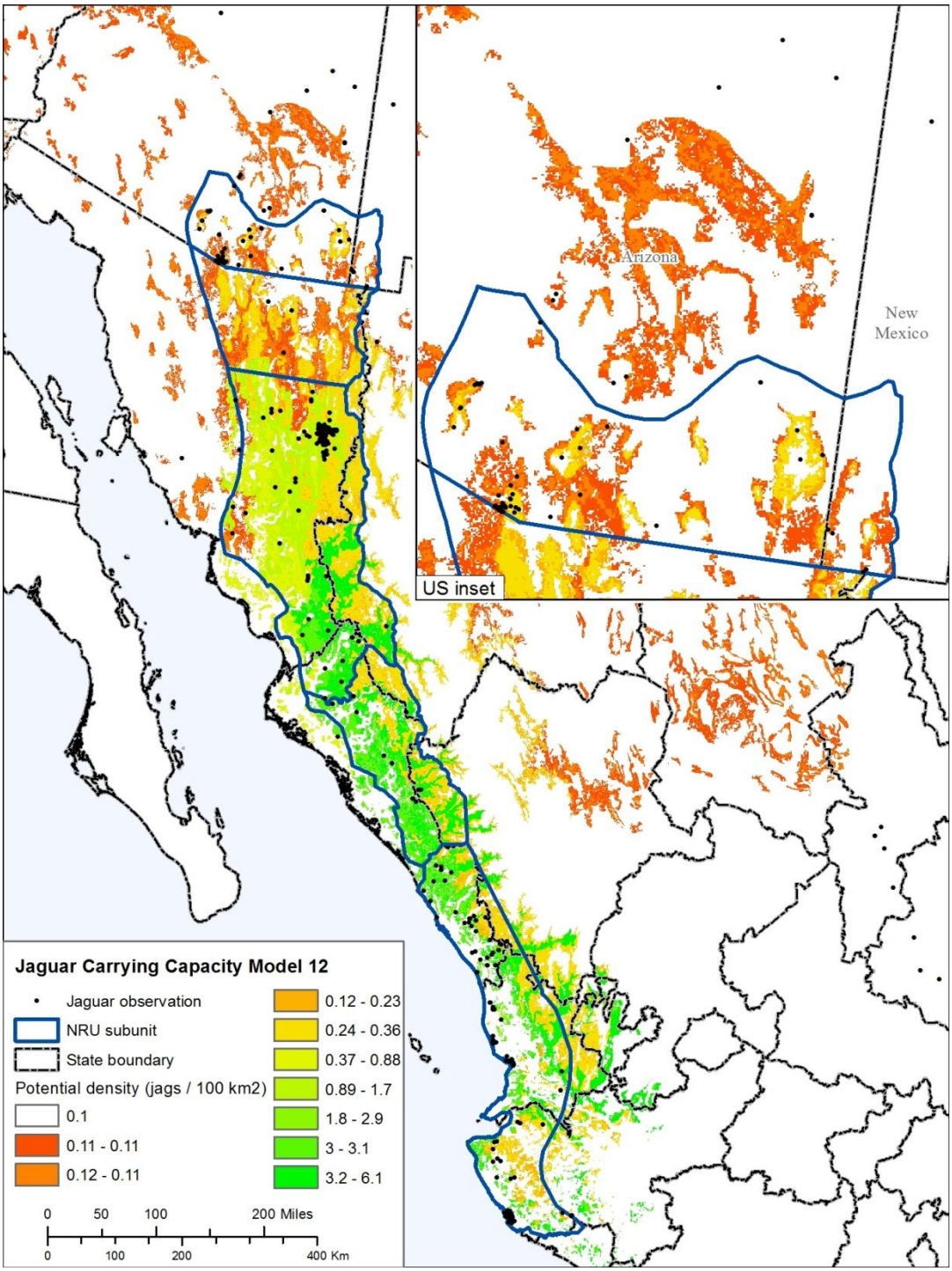
Note that the regression equation again did not force the y-intercept through zero, although the intercept is very small. As a result, this model, as in previous ones with non-zero y-intercepts, predicted a very low jaguar density everywhere in the NRU that had not been masked out, even in areas with "zero" habitat. See Objective 4 for further discussion.



(7) Sum:

Population subunit	**Former subunit name**	**Estimated number of potential jaguars**
Jalisco Core Area	MX Sinaloa Sub-Population	1,342
Sinaloa Secondary Area	MX North Sinaloa Connector Area	949
Sonora Core Area	MX Sonora Sub-Population	1,181
Borderlands Secondary Area – Mexico portion	MX Northern Sonora Connector Area	66
Borderlands Secondary Area – US portion	US South of I-10 Highway	31
Total		**3,569**

(8) Map of potential carrying capacity.



Potential jaguar habitat model, version 13

(1) Subunit definition: same as version 12.

(2) Habitat factors: same as version 12.

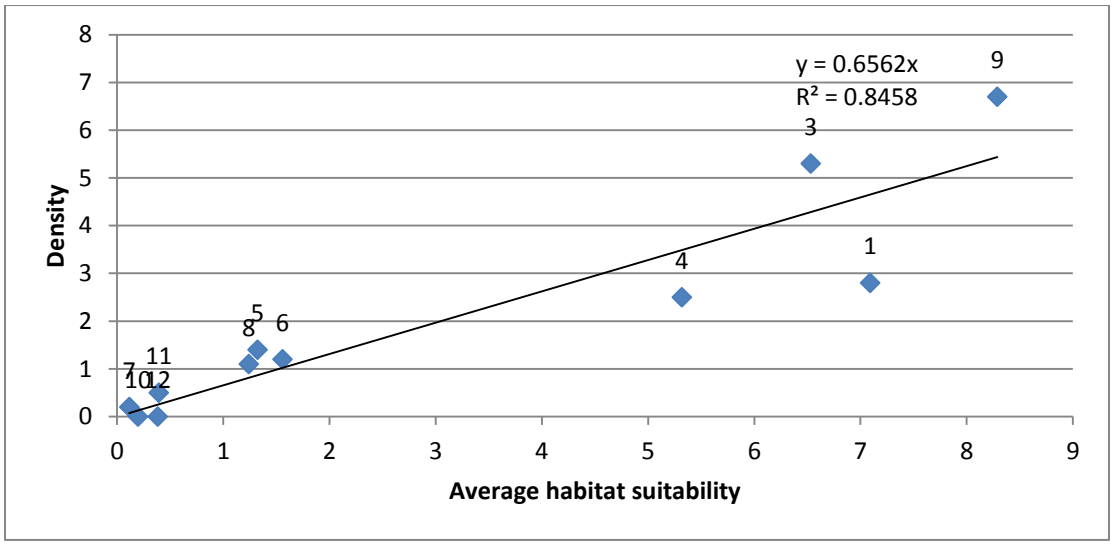
(3) Habitat weights: same as version 12.

(4) Habitat equation: same as version 12.

(5) Mask: same as version 12.

(6) Translation to density: The density studies and habitat values were the same as for version 12, but at the request of the Recovery Team the regression line was forced through 0. Forcing the regression line for zero meant that areas with a zero habitat score would not contribute to jaguar carrying capacity, in effect lowering the total estimated jaguar carrying capacity.

The regression equation: density (jaguars / 100 km2) = (0.6562 * habitat score) / 100.



(7) Sum:

Population subunit	Former subunit name	Estimated number of potential jaguars
Jalisco Core Area	MX Sinaloa Sub-Population	1,318
Sinaloa Secondary Area	MX North Sinaloa Connector Area	929
Sonora Core Area	MX Sonora Sub-Population	1,124
Borderlands Secondary Area – Mexico portion	MX Northern Sonora Connector Area	37
Borderlands Secondary Area – US portion	US South of I-10 Highway	6
Total		**3,414**

(8) Map of potential carrying capacity.