The use of regional advance mitigation planning (RAMP) to integrate transportation infrastructure impacts with sustainability; a perspective from the USA

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Abstract
Globally, urban areas are expanding, and their regional, spatially cumulative, environmental impacts from transportation projects are not typically assessed. However, incorporation of a Regional Advance Mitigation Planning (RAMP) framework can promote more effective, ecologically sound, and less expensive environmental mitigation. As a demonstration of the first phase of the RAMP framework, we assessed environmental impacts from 181 planned transportation projects in the 19 368 km² San Francisco Bay Area. We found that 107 road and railroad projects will impact 2411–3490 ha of habitat supporting 30–43 threatened or endangered species. In addition, 1175 ha of impacts to agriculture and native vegetation are expected, as well as 125 crossings of waterways supporting anadromous fish species. The extent of these spatially cumulative impacts shows the need for a regional approach to associated environmental offsets. Many of the impacts were comprised of numerous small projects, where project-by-project mitigation would result in increased transaction costs, land costs, and lost project time. Ecological gains can be made if a regional approach is taken through the avoidance of small-sized reserves and the ability to target parcels for acquisition that fit within conservation planning designs. The methods are straightforward, and can be used in other metropolitan areas.

Keywords: regional planning, spatially cumulative impact assessment, environmental mitigation, RAMP, transportation, metropolitan regions

Introduction
Over half of all humans live in cities, (UNPF 2007) with 1.75 billion more people expected by 2030 (McDonald et al 2011). Urbanization associated with the growth of cities transforms natural landscapes and impacts biodiversity, ecosystem processes and agriculture (Theobald et al 2000, Schwartz et al 2006, Grimm et al 2008a, 2008b, McKinney 2008, Satterthwaite et al 2010). Expanding transportation infrastructure is linked to the functionality of these expanding urban areas (Barthelemy et al 2013, Schneider and Mertes 2014). However, transportation structures have adverse impacts to the natural environment (Trombulak and Frissell 2000, Forman et al 2003, National Research Council 2005), including: direct and cumulative mortality to species hit by vehicles (Seo et al 2013), reduced dispersal capacity (Forman and Alexander 1998), impediments to gene
flow (Epps et al. 2005), the spread of invasive species (Gellard and Belnap 2003), the generation of greenhouse gas emissions (Fuglesvedt et al. 2008, Kennedy et al. 2009), and landscape fragmentation (Jaeger et al. 2005, Girvetz et al. 2008). Concern over the rapid growth of cities and transportation infrastructure highlights the need to reduce environmental impacts associated with this growth (Thorne et al. 2005, 2006, 2009a) by initiating or improving requirements to offset those impacts via conservation or restoration of other lands, here termed environmental mitigation.

Finding a balance between new transportation infrastructure and preservation of land for biodiversity conservation, ecosystem processes, agriculture, and other needs is most effectively assessed and implemented using planning principles at a regional level (Kark et al. 2009, Huber et al. 2010, Gordon et al. 2013, Moilanen et al. 2013). We used the first part of a framework called Regional Advance Mitigation Planning (RAMP, figure 1), that uses a regional planning approach to estimate the spatially cumulative impacts from multiple projects. RAMP is part of emerging practice for transportation officials in local, state, and federal government in many areas in the United States (Brown 2006, Marcucci and Jordan 2013). Using the San Francisco Bay Area as a study area, we asked, “Can early regional assessment of impacts from multiple future transportation projects create added benefits for conservation?” We assessed potential impacts to species, habitats, agriculture and streams from 181 planned road and railroad projects. We show that the early quantification of the impacts, done in aggregate as opposed to the typical project-by-project impact assessment approach can provide the foundation for more ecologically effective and cost effective environmental mitigation strategies. We assert that the methods of the RAMP framework can be applied to many other urbanizing regions of the world.

### Background

RAMP can be thought of as a set of guiding policies, a framework, and a method.

The policy component of RAMP emerges when government bodies make conscious decisions to use the framework to address impacts from regional transportation (or other infrastructure) development. Motivations to adopt the framework are available because RAMP addresses several known inefficiencies in the way transportation and other infrastructure projects have typically been implemented in the United States. Inefficiencies that local, state and federal government transportation agencies have historically experienced include: project-by-project environmental mitigation, usually toward the end of a project’s timeline, which exposes the agencies to increased costs due to real estate appreciation, and also to losing potential land acquisition opportunities to encroaching development and speculation (Thorne et al. 2006). In addition, project-by-project mitigation often overlooks regional and ecosystem scale impacts to species, habitats and ecosystem services, a recognized need in environmental impact assessment (EIA) approaches (Jay et al. 2007). Further motivation arises from the possibility that bundling environmental mitigation from several projects in

![Figure 1. The RAMP framework. This framework allows the integration of environmental impact assessment and environmental mitigation (blue box) with regional conservation concerns (dotted box).](image-url)
RAMP may permit the acquisition of fewer properties (with larger area) with consequent lower transaction and long-term land management costs, and by potentially reducing the time needed for environmental review, required under US environmental laws (Marcucci and Jordan 2013). Larger parcels are also more ecologically effective (Soule et al 2003, Gaston et al 2006), meaning a RAMP approach can be better both environmentally and economically. In support of these concepts, the US Federal Highways Administration endorses federal, state and local government applications of RAMP in transportation planning through a program called ‘Eco-Logi-cal’, (Brown 2006). In California, our study area’s state, RAMP approaches are being used by a few individual county-level governments, and efforts to implement a state-level program are ongoing (Greer and Som 2010). A similar approach has been developed by The Nature Conservancy called ‘Development by Design’ that combines scientific assessment of infrastructure impacts with landscape-level conservation planning.

As a framework, RAMP engages multiple parties, including transportation infrastructure developers (governmental or private), government agencies that enforce environmental laws, and research and environmental groups that have identified critical lands for conservation. This cooperation between multiple stakeholders permits the incorporation of planning principles and environmental considerations early in the development of transportation infrastructure and other construction plans and projects (Thorne et al 2009a, 2009b).

The framework used in RAMP is similar to EIA, which is an internationally recognized and often required tool for environmental management, with global (Wanders forde-Smith 1980) and regional reviews (EU: Barker and Wood 1999, Middle East and North Africa: El-Fadl and El-Fadel 2004, Brazil: Glasson and Salvador 2000). The EIA process requires proposed projects to comply with sustainable development goals. Initially EIA focused on the impacts on the natural environment. Today, and because of suggestions that give EIA a more deterministic role in planning processes (Jay et al 2007), EIA also includes impacts on the human environment (social and economic). RAMP deals with ecological and environmental concerns, as in the earlier forms of EIA.

Claims that EIA as a process was unable to include the three factors of sustainability (environmental, economic and social), and that these should be addressed earlier in the planning phase have led to the development of strategic environmental assessments (SEA, Partidário 2000). The SEA can be thought of as the counterpart to the framework component of RAMP. In Europe, the SEA framework is intended to be used to ensure that impact assessment and sustainability are accounted for during planning phases. The SEA framework advocates early EIA, and suggests that it can (1) elevate environmental concerns to the same level as other aspects of development, (2) promote multi-organizational communication and collaboration, (3) be scaled from project to region, and (4) develop codes of conduct for mitigation and compensation. To do so, the SEA framework strengthens and streamlines the EIA process by the early identification of potential impacts and cumulative effects (Partidário 2000). The SEA process has been widely applied (Chaker et al 2006, Alshhuwaikhat 2005, Briffet et al 2003); however, SEA procedures are not yet fully functional because they often do not progress beyond the planning phase to implementation (Bina 2007, Wallington et al 2007). In a SEA planning phase there is a need to do spatially cumulative assessments of multiple projects (cumulative effects assessment)—CEA, Gunn and Noble 2011). One possible way by which SEA could progress from strategy to implementation would be through the use of a RAMP framework. RAMP’s project-based impact assessments are intended to both integrate environmental information into project planning and development to potentially reduce impacts on the environment from planned transportation projects and, as a basis for identifying what regional areas could be used to compensate for the estimated impacts during environmental mitigation. This process can be implemented early in, or prior to, the implementation of the transportation projects.

The RAMP framework also provides a way to integrate funds, when those are required of road developers (governmental or private) for environmental mitigation, with regional ecological and conservation goals. This coordination between transportation development and other regional objectives can be implemented for example, by pooling environmental mitigation funds from several transportation projects, to enable the purchase of larger parcels, which produces better results for ecosystem processes, viable species populations and their habitats (Soule et al 2003, Gaston et al 2006). The ecological effectiveness of the environmental mitigation can be further enhanced by coordinating mitigation actions, such as targeting the purchase of lands for preservation, within regional conservation priorities, here called a Greenprint (figure 1).

The RAMP methods use spatial assessment tools to determine regional environmental impacts from multiple transportation projects (left-hand column of figure 1), and to coordinate the locations of environmental mitigation for those projects with regional conservation objectives. The regional impact assessment can be compared and contrasted to impacts assessed on a project-by-project basis, to determine whether a regional approach will be ecologically and economically beneficial. RAMP includes a method to project the environmental mitigation needs for each individual and the aggregate impacts; for example, by including how much area of different land cover types may be needed, and where (within the region) mitigation sites can be found for acquisition. This step requires a map of the region that portrays land that has been targeted for conservation, restoration, ecosystem services or other objectives (right-hand column of figure 1).

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4 http://www.environment.fhwa.dot.gov/eco/index.asp.
5 https://rampcalifornia.water.ca.gov/web/guest.
6 http://www.nature.org/ourinitiatives/urgentissues/smart-development/publications/index.htm.
7 http://www.unep.org/regionalseas/publications/reports/RSRS/pdfs/rsrs122.pdf.
8 http://www.imperial.ac.uk/pls/portallive/docs/1/21559696.PDF.
integration of mitigation with conservation needs can provide an opportunity for better regional outcomes for environmental and social goals. This paper demonstrates the implementation of the first part of the RAMP approach for the transportation network in the Bay Area, and discusses the utility of the approach for environmental mitigation under different contexts, including whether a RAMP approach can help link SEA and EIA.

Methods

The San Francisco Bay Area (hereafter called ‘the Bay Area’) region’s nine-county population reached 7.15 million in 2005 from 1.73 million in 1940 (Department of Finance 2013), and is projected to grow to 10.22 million by 2050 (Public Policy Institute of California, PPIC 2009). In the Bay Area, regional government comprised of the Metropolitan Transportation Commission and the Association of Bay Area Governments (MTC and ABAG), is charged with developing a regional urban growth and transportation strategy. They published the ‘Plan Bay Area’ report, which identifies Bay Area transportation needs and a transportation infrastructure growth strategy over the next 25 years9. This report identifies 698 road and railroad transportation projects that are planned for construction in the 19 369 km² region (figure 2). We used the first phase of a RAMP framework (figure 3) to assess the potential aggregate impacts to protected species and their habitats, and regional concerns, by assessing impacts to agricultural lands (food security and economy) and wetlands (ecosystem process).

We reviewed the 698 planned transportation projects identified in GIS files provided by the MTC, using aerial imagery (Google Maps 201310), and identified 181 road and railroad projects that crossed non-urbanized land or significant streams for inclusion in the regional impacts assessment (figure 4). Projects with predominantly urban impacts were excluded. We used ArcGIS v10 (ESRI, Redding CA) to assess aggregate environmental impacts. For each project, we identified impacts to species of concern and their habitats, to major natural vegetation types, and to agricultural lands.

Calculation of transportation project footprints was accomplished in two ways. For new projects, the width and length of the new project was used to obtain a map of the area that may be impacted (figure 5). For modifications to existing transportation infrastructure (the majority of projects in our area), we used two buffers from the project’s centerline or center point (figure 6). For the inner buffer, we used one meter square aerial imagery11 to measure the typical distance from the centerline to the edge of the paved surface for each project. The centerline was then buffered by this distance. The second buffer is the distance from the edge of the inner buffer to the edge of the new project, which is the zone of new impact that different types of projects (e.g. adding highway lanes) will occupy when constructed (Thorne et al 2009a).

The inner area was then buffered by the second distance to arrive at a total project footprint (e.g. figure 6(a)). For rail projects, we consulted an engineer from the Bay Area Rapid Transit (BART) program, to determine what the typical widths of impacts for different types of rail and terminal projects would be and applied those as buffers.

We then overlaid the transportation project footprints on a conservation greenprint to determine the suitable habitat that may be impacted within the project footprints (second row of figure 3). In order to develop the conservation greenprint, we compiled spatial data on the documented locations of threatened and endangered species, maps of their habitats, maps of natural landcover types and streams, and the locations of important agricultural lands. We obtained the recorded locations of threatened and endangered species, maps of their habitats, maps of natural landcover types and streams, and the locations of important agricultural lands. We obtained the recorded locations of threatened and endangered species, maps of their habitats, maps of natural landcover types and streams, and the locations of important agricultural lands. We obtained the recorded locations of threatened and endangered species, maps of their habitats, maps of natural landcover types and streams, and the locations of important agricultural lands. We obtained the recorded locations of threatened and endangered species, maps of their habitats, maps of natural landcover types and streams, and the locations of important agricultural lands.

![Figure 2. The nine-county San Francisco Bay region.](image)

9 http://onebayarea.org/pdf/Draft_Plan_Bay_Area_3-22-13.pdf.
10 https://maps.google.com/maps.
11 http://www.fsa.usda.gov/Internet/FSA_File/naip_2009_info_final.pdf.
12 http://www.dfg.ca.gov/biogeodata/cnddb/.
The appropriate habitats for each species were then selected from the landcover maps to portray the suitable locations for each species across our study area. For plant species, we used a similar process to identify suitable habitats, with a floristic database, Calflora.

Various online sources for invertebrate species were used to define appropriate habitat types. Plant and invertebrate species’ habitat requirements were then linked to the CWHR types represented in the maps of the region, so that their potential locations on the landscape could be identified using the reference maps. Using the following list of landcover maps, maps of suitable habitats for every terrestrial species were developed: the Conservation Lands Network, the National Wetlands Inventory, the San Francisco Estuary Institute’s Inventory of wetlands, and the Great Valley Vernal Pool Distribution (Holland 2009).

Once the project footprints and habitat extents were established, we could measure the types of impacts and their

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13 http://www.dfg.ca.gov/biogeodata/cwhr/wildlife_habitats.asp.
14 http://www.calflora.org/.
15 cln_veg; http://www.bayarealands.org/.
16 http://www.fws.gov/wetlands/.
17 http://www.sfei.org/ecoatlas/gis.
extent. We buffered the known locations of each species by 3.2 and 6.4 (two and four miles), and selected the suitable habitat map area inside these areas (figure 5). These buffered habitat maps were then intersected with the footprints of the transportation projects to project the extent of habitat in each transportation project’s footprint to be labeled as impacted-area habitats (figure 5). When the length of a transportation project extends beyond the area identified by the species buffer, there could be additional suitable habitat inside the transportation footprint, but beyond the species location buffer. Since we do not have actual evidence that the habitat is occupied, we limited the extent of suitable habitat selected to inside the species location buffer. This makes our projections of impacts more conservative than by selecting all suitable habitat regardless of its distance from a point of known occurrence, and recognizes that not all suitable habitat for a species is occupied. Species habitat and agricultural location data were overlaid with project footprints to derive likely location and extent of impacts to species and habitats due to project construction (figure 5). Impacts were summed by species and aggregated to county and regional scales.

In addition, species-specific habitat maps for aquatic species were assembled. These included Delta smelt (*Hypo<sub>mesus transpacificus*)) and salmonid fish distribution data and critical habitat requirements from the US Fish and Wildlife Service<sup>18</sup>. We examined impacts to anadromous fish habitat by reviewing the number of times planned projects crossed waterways designated as critical habitat for these fish species. Typically, impacts to fish from transportation projects occur not from habitat loss but from direct mortality to individuals, especially juveniles, during the construction period itself. While temporary habitat loss on site is generally restored, additional offsite actions to mitigate for loss of individuals is usually required. Often, these actions include removal of in-channel barriers to fish movement in the vicinity of the impacts. If there are multiple impacts within a watershed, mitigation requirements and funding could conceivably be bundled for several projects, potentially leading to a greater ecological return on the mitigation investment. While the identification of aquatic mitigation locations is beyond the scope of this paper, a critical first step is the assessment of the impact locations, which we have included.

Finally, impacts to agricultural lands<sup>19</sup> and to some natural vegetation types (oak woodlands, riparian forest, and wetlands) were identified because these landcover types require mitigation regardless of the presence of listed species. In addition, loss of agricultural land is potentially a food security issue and reduces regional agricultural economic output; and loss of water habitats has consequences for ecosystem processes and biodiversity. For these, we calculated the full extent of impacts within the boundaries of each transportation project.

**Regional versus individual project impact assessment**

Typically, environmental impacts are assessed on a project-by-project basis, and subsequent mitigation to offset any impacts is also conducted on this basis. We present impact assessments from three individual projects for comparison with the regional assessment. The impacts were assessed using the same approach as for the regional assessment, and the results are also part of the summed regional results. The first project is RTP 22175, located in Santa Clara county titled, ‘Widen Almaden Expressway from Coleman Avenue to Blossom Hill Road’ (figure 6(a)). This project is 1.1 km in length. The assigned buffers were 12 m (existing road) and 50 m (proposed project). The second project, RTP 22400 is located in Contra Costa county titled, ‘Conduct environmental and design studies to create a new alignment to Blossom Hill Road’ (figure 6(b)).

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<sup>18</sup> [http://ecos.fws.gov/crithab/](http://ecos.fws.gov/crithab/).

<sup>19</sup> [http://conservation.ca.gov/dlrp/fmmp/Pages/Index.aspx](http://conservation.ca.gov/dlrp/fmmp/Pages/Index.aspx).
SR239 and develop corridor improvements from Brentwood to Tracy—project development (figure 6(b)). This project is 17.5 km in length, among the larger projects assessed overall. The assigned buffers were 20 m (existing road) and 152 m (proposed project). The third project is RTP 240114, located in San Mateo county titled, ‘Implement operational and safety improvements on route 1 between half Moon Bay and Pacifica (includes acceleration lanes, deceleration lanes, turn lanes, bike lanes, and enhanced crossings)’ (figure 6(c)). This project is 28.8 km in length. The assigned buffers were 7 m (existing road) and 15 m (proposed project).

### Results

We analyzed 181 transportation projects that will cross natural lands and streams (table 1, figure 4), and found that 107 (59%) will have impacts to listed species, ecosystems, or agriculture. Of these, eight are rail and the others road projects. The aggregate rail projects’ footprint area is 1551 ha as compared with 3372 ha for roads.

The estimated impacts from the 107 projects include 43 terrestrial threatened and/or endangered species were recorded within 6.4 km of the project extents, and 30 within 3.2 km (table 2), including 20 plant species, seven birds, five amphibians and reptiles, four insects, two mammals, and four aquatic invertebrates. Impacted species were affected by an average of 8.4 projects using the 6.4 km buffer and 6.4 projects using the 3.2 km buffer (table 2).

### Discussion

#### Regional and project level assessments

Nearly 24% (1175 ha) of the planned transportation projects analyzed in the Bay Area are projected to impact landcover types that require mitigation in California. Additionally, there are spatially cumulative impacts to habitats that support between 30 and 43 threatened and endangered species,
| Area impacts by species habitat | Impacts—3.2 km (in hectares) | Impacts—6.4 km (in hectares) | No. projects—3.2 km | No. projects—6.4 km |
|---------------------------------|-----------------------------|-------------------------------|---------------------|---------------------|
| Acantomintha duttonii San Mateo thorn-mint | 1.66 | 2.75 | 2 | 3 |
| Agelaius tricolor Tricolored blackbird | 278.2 | 552.36 | 23 | 32 |
| Ambystoma californiense California tiger salamander | 474.21 | 509.38 | 38 | 44 |
| Anisincia grandiflora Large-flowered fiddleneck | 8.54 | 19.8 | 1 | 3 |
| Athene cunicularia Burrowing owl | 344.4 | 493.5 | 41 | 53 |
| Blennosperma bakeri Sonoma sunshine | 7.7 | 7.7 | 1 | 1 |
| Brachinecta conservatio Conservancy fairy shrimp | 0.73 | 13.4 | 1 | 1 |
| Brachinecta longistriata Longhorn fairy shrimp | 0.0 | 1.5 | — | 3 |
| Brachinecta lynchi Vernal pool fairy shrimp | 41.8 | 41.8 | 6 | 6 |
| Buteo swainsoni Swainson’s hawk | 324.4 | 559.5 | 20 | 23 |
| Caloprys mossii bayensis San Bruno elfin butterfly | 6.1 | 7.6 | 3 | 3 |
| Castilleja affinis ssp. neglecta Tiburon paintbrush | 1.6 | 25.2 | 2 | 9 |
| Ceanothus ferrisiae Coyote ceanothus | 0.0 | 0.04 | — | 1 |
| Chlorogynum molle ssp. molle Soft bird’s-beak | 0.0 | <0.01 | — | 1 |
| Chlorogynum palustre Palmate-bracted bird’s-beak | 2.2 | 7.9 | 3 | 7 |
| Cirsiun fontinale var. fontinale Fountain thistle | 0.0 | <0.01 | — | 1 |
| Dudleya abramsii ssp. setchellii Santa Clara valley dudleya | 0.04 | 0.04 | 1 | 1 |
| Elaphrus viridis Delta green ground beetle | 0.0 | 6.8 | — | 1 |
| Eriophyllum latilobum San Mateo woolly sunflower | 0.0 | 0.45 | 1 | 2 |
| Eryngium racemosum Delta button-celery | 0.0 | 3.36 | — | 1 |
| Hesperolinon congestum Marin western flax | 0.08 | 0.08 | 1 | 1 |
| Lasthenia burkei Burke’s goldfields | 0.0 | 0.04 | — | 1 |
| Lasthenia conjugens Contra Costa goldfields | 21.5 | 21.5 | 2 | 2 |
| Laterallus jamaicensis coturniculus California black rail | 43.1 | 45.9 | 12 | 21 |
| Lepidurus packardi Vernal pool tadpole shrimp | 15.4 | 21.5 | 2 | 2 |
| Limnanthes vinculans Sebastopol meadowfoam | 0.0 | 0.12 | — | 2 |
| Masticophis lateralis euryxanthus Alameda whipsnake | 0.0 | 0.32 | — | 1 |
| Navarretia leucocephala ssp. pleiantha Many-flowered narretia | 5.9 | 7.4 | 1 | 1 |
| Plebejus icarioides missionensis Mission blue butterfly | 5.5 | 6.4 | 2 | 3 |
| Pleurodophus hooverianus North Coast semaphore grass | 0.0 | 0.04 | — | 1 |
| Potentilla hickmanii Hickman’s cinquefoil | 0.16 | 0.24 | 1 | 1 |
| Rallus longirostris obsoletus California clapper rail | 121.3 | 215.3 | 19 | 25 |
| Rana draytonii California red-legged frog | 250.9 | 345.9 | 42 | 51 |
| Reithrodontomyx raviventris Salt-marsh harvest mouse | 10.9 | 19.7 | 7 | 7 |
| Riparia riparia Bank swallow | 0.0 | 0.16 | — | 1 |
| Speyeria callipe callipe Callipe silverspot butterfly | 0.0 | 5.6 | — | 2 |
| Sterula antillarum browni California least tern | 0.24 | 6.5 | 1 | 5 |
| Streptanthus albidus ssp. albidus Metcalf Canyon jewel-flower | 0.04 | 0.04 | 1 | 1 |
orders of magnitude smaller). For example, burrowing owls only minor impacts to species and habitats (three to four km²). In contrast, the project-by-project analysis indicated impacts will likely require considerable open space (>30 ha). Regulatory representatives will potentially multipliers for impacts to calculate mitigation needs. These multipliers vary by the type of impact and the reasons to consider the impacts from a spatially cumulative perspective, which offer the possibility to conduct better environmental practice. Government regulatory representatives will find environmental mitigation better meeting the needs of species, and transportation agencies will potentially find economic savings through the purchase of fewer, larger properties, as well as recognition for improvement in environmental practice.

The use of a RAMP framework for providing compensatory mitigation for transportation projects appears justified because of the large number of projects and the extent of the expected impacts. Further, the mitigation required by government environmental regulation agencies to permit the development of these projects will likely be more than just the area of direct impacts we quantified. Regulatory agencies often require multipliers for impacts to calculate mitigation needs. These multipliers vary by the type of impact and the ecological context, with (in the US) no net loss laws requiring a minimum of 1 ha of wetlands constructed for every 1 ha developed, and typically additional extant wetlands protected (US Clean Water Act 197220). In California, many habitat types for endangered species may require a higher ratio. For example, blue oak woodlands (Quercus douglassii) are frequently assessed at a 3:1 ratio, whereby three hectares must be purchased or restored for each hectare impacted.

The development of regional EIAs, and subsequent identification of appropriate locations to accommodate the

Table 3. The projected area of suitable habitat impacted (ha) within the buffered footprints for the three example projects, listed by their project identification number.

| Species                          | Project 22175 (ha) | Project 22400 (ha) | Project 240114 (ha) |
|----------------------------------|--------------------|--------------------|---------------------|
| California red-legged frog       | 0.0–4.17           | 71.99–73.69        | 15.5                |
| Tricolored blackbird             | —                  | 146.8–312.9        | —                   |
| California tiger salamander      | —                  | 164.38             | —                   |
| Burrowing owl                    | —                  | 119.9–163.3        | —                   |
| Vernal pool fairy shrimp         | —                  | 18.6               | —                   |
| Swainson’s hawk                  | —                  | 208.78–350.58      | —                   |
| Delta butter-celery              | —                  | 0.0–3.4            | —                   |
| San Joaquin kit fox              | —                  | 163.3              | —                   |
| San Bruno elfin butterfly       | —                  | —                  | 5.63–6.07           |
| Mission blue butterfly           | —                  | —                  | 0.0–0.85            |
| Hickman’s cinquefoil             | —                  | —                  | 0.16–0.24           |
| San Francisco garter snake       | —                  | —                  | 2.75–3.76           |
| Open water                       | <0.04              | 0.16               | —                   |
| Wetlands                         | 0.12               | 3.92               | 0.24                |
| Oaks                             | —                  | —                  | 0.12                |
| Riparian forest                  | —                  | —                  | 0.08                |
| Farmland                         | —                  | 278.3              | 5.58                |
| Vernal pools                     | —                  | 1.86               | —                   |

Table 2. (Continued.)

| Species                          | Impacts—3.2 km (ha) | Impacts—6.4 km (ha) | No. projects—3.2 km | No. projects—6.4 km |
|----------------------------------|--------------------|--------------------|---------------------|---------------------|
| Suaeda californica               | California seablite| 5.02               | 5.3                 | 1                   |
| Thamnophis gigas                 | Giant garter snake | 0.0                | 0.24                | —                   |
| Thamnophis sirtalis tetrataenia  | San Francisco garter snake | 3.68           | 7.28                | 3                   |
| Trifolium amoenum                | Showy rancheria clover | 0.65             | 10.08               | 4                   |
| Vulpes macrotis mutica           | San Joaquin kit fox| 249.9              | 332.41              | 15                  |
| Total species impacts            | —                  | 2411.4             | 3490.2              | 107                 |

20 Title 33 U.S.C. Part 1344.  http://www.epw senate.gov/water.pdf.
environmental offsets, is at the heart of California’s RAMP framework. An interesting phenomenon is that groups using the approach are emerging at several spatial scales and administrative levels, such as federal initiatives advanced through Eco­logical (Brown 2006) and two county­level initiatives in California. One measure of success of the approach is where conservation lands have actually been acquired to offset transportation infrastructure impacts, in other words by the completion of the RAMP steps. The two county­level initiatives in California are doing this to offset spatially cumulative impacts from multiple transportation projects well in advance of transportation project delivery. San Diego county has a program that uses funds from a county sales tax measure to pay for offsets from transportation project impacts21, while Orange county (near Los Angeles) has acquired at least four properties to address similar impacts, also funded through a county sales tax measure.22 This suggests the utility of the approach, and that it would be possible to implement it elsewhere, even while other areas have different environmental laws, administrative systems and capacities.

RAMP and SEA

The implementation of RAMP in some counties in California, the results from the Bay Area impact assessment, and the national guidelines promoting a RAMP framework may be informative for European groups that are attempting to implement SEAs. The challenge for the EU has been how to implement spatially cumulative effect assessments (CEAs) which are the phase of a SEA where implementation occurs. The RAMP framework shows one way that this integration of planning, environmental impact analysis, project construction and environmental mitigation can be operationalized. While the specifics of environmental laws, business practice, and environmental practice differ between the EU and the US, the underlying needs and challenges are the same.

This study illustrates how RAMP could act as the operationalization tool to bring SEA from a strategic to an implementation level. We show that RAMP addresses spatially cumulative impacts (for example cumulative impacts on California red­legged frogs and burrowing owl, for which project­specific impacts are much smaller than those of the RAMP spatially cumulative estimated impacts). We also demonstrate that RAMP is more than that. It can be the step at a regional level that is necessary to bridge between the planning level of SEA and the project­by­project level of an EIA. In the Bay Area assessment, we show that 58% of the threatened and endangered species are projected to be impacted by more than one project. Thus, the scaling from individual to multiple project assessments of impact for those species allows for a regional planning of mitigation and compensation measures, likely more effective than project­by­project planning from both a transportation delivery and ecological perspective. RAMP can thus be coupled with the assessment of mitigation and compensation needs (how much is required from the sum of all projects); it can be used in partnership with systematic conservation planning tools for conservation land identification (where best can we meet those requirements); and because of this regional perspective, RAMP can identify the best strategy for conservation land acquisition and designation (how to best use mitigation funds to acquire land for conservation).

RAMP in other metropolitan regions

The population growth projections in the Bay Area (PPIC 2009), and for cities globally, (McDonald et al 2011) suggest that cities will continue to expand. Further, the urban extent in the Bay Area has expanded by over 1842 km² since 1940, as population grew from 1.7 to 7.1 million (Thorne et al 2013), trends that are similar to hundreds of other cities globally, where populations have on average doubled and area used has tripled (Schneider and Mertes 2014) or quadrupled over the past 20 years (Deto et al 2011). The pressures these trends and associated transportation infrastructure will put on natural ecosystems suggest the need is urgent, and that a RAMP framework may be an attractive option for planners in other metropolitan regions who seek better outcomes for conservation and infrastructure development. Infrastructure agencies are a promising group for environmental groups to work with to initiate this type of planning because of their long planning horizons (Thorne et al 2009b), and it is hoped that by setting an example, these agencies may also be able to influence environmental mitigation practices from other types of urban growth impacts, particularly housing construction. The Bay Area implementation of the RAMP framework will need to involve multiple jurisdictions, which may be typical of what would be encountered in other metropolitan regions.

In many developing countries there are fewer legal obligations for environmental offsets (Kuokkanen 2002), and in many cases, less digital data are available about the locations of the resources and species of concern. In such areas, a RAMP approach could potentially still be useful as a way to develop regional planning. First, its use would require an evaluation of the data that are lacking to conduct an EIA of a road network, which could provide government and environmental NGOs with an agenda about what type of information is needed to be developed. Second, even without specific information on the locations of species, impacts to landscape connectivity, to linear features such as rivers, and to the general landcover types, as identified by coarse­resolution landcover maps (for example, the CORINE program from the European Environmental Agency, or MODIS products), can be assessed. The RAMP approach can even be applied in regions that have very little data or capacity, through recognition that the development of road networks has spatially cumulative impacts. This recognition can provide the basis to develop partnerships between those responsible for the implementation of roads, and those with the knowledge and expertise to assess what impacts might arise.

21 http://www.sandag.org/uploads/publicationid/publicationid_1138_4880.pdf.
22 http://www.octa.net/Measure-M/Environmental/Freeway-Mitigation/Overview/.
**RAMP shortcomings/limitations**

Barriers to the application of a complete RAMP framework include data and knowledge, skills and capacity building, institutional configurations and legislative power. Like SEA (João 2007), RAMP can be a data hungry platform and the spatial extent of RAMP projects needs to be defined, to understand the issues that are at stake. This data need is exacerbated by the assessment of cumulative effects (Therivel and Ross 2007) and the across-scales interactions emerging from this regional approach (Partidário 2007). Local or federal governments, universities, and NGOs are the primary repositories of such data and knowledge, and need to be engaged in the process. Some federal US agencies are interested in putting these data online to promote this type of planning, for example, the US Federal Highways ESA WebTool\(^{23}\), and the Environmental Protection Agency’s NEPAssist tool\(^{24}\). However, such tools are relatively new, are not populated with data or the data are incomplete depending on the state, or are not yet widely available.

The RAMP framework requires some investment in planning and design that is typically earlier in the cycle of project development than is the case under business as usual. Therefore, a key consideration for convincing regional governments to adopt the approach is to demonstrate that there are enough biological and environmental impacts from new infrastructure projects to justify implementing a regional environmental mitigation, by identifying suitable environmental offsets to satisfy obligations from multiple projects. This can be hindered by institutional configurations and legislative power. Institutions have agendas of their own and clear jurisdictional boundaries necessary to track accountability in decisions. Cross-institutional collaboration is rare, but RAMP provides a framework for involvement of multiple stakeholders in the planning process, wherein each group has something to gain through the collaboration. The challenge ahead is how to promote institutional configurations that allow for collaboration while preserving accountability. Different agencies comply differently to legislation and regulation at different governance levels (for example international conventions like the Ramsar convention, US national laws like the Endangered Species Act, or local policies like the California Lands Act). The lack of environmental regulation need not to be a barrier to RAMP, as a code of best conduct can be implemented, or NGOs can play a significant role in managing environmental needs.

**Conclusion**

This analysis demonstrated the screening of 698 transportation projects in a major metropolitan area to identify 181 that cross open space, and found that 107 of those will have cumulative biological and environmental impacts of 3586–4655 ha. These impacts will affect at least 30 threatened or endangered species, over half of which will be impacted by more than one project. These results point to the need to address the environmental mitigation for these impacts in aggregate. The RAMP framework offers an opportunity to do so, with potential for better ecological results, and that the implementation may be less expensive than project-by-project mitigation. In the Bay Area, assembling a round table of transportation agency and environmental regulation agency representatives will permit discussion of steps for implementation of a RAMP. In other parts of the world, the RAMP framework offers a model for development of cooperative regional planning that can result in better environmental outcomes.

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\(^{23}\) [http://www.environment.fhwa.dot.gov/esawebtool/](http://www.environment.fhwa.dot.gov/esawebtool/).

\(^{24}\) [http://nepassisttool.epa.gov/nepassist/entry.aspx](http://nepassisttool.epa.gov/nepassist/entry.aspx).
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