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Aerial monitoring of endangered whales in the Santa Barbara Channel to enhance and inform whale conservation

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Abstract.—NOAA Channel Islands National Marine Sanctuary (CINMS), located off Santa Barbara and Ventura Counties in California, maintains a consistent marine mammal aerial monitoring program to improve understanding of endangered baleen whale species distribution and applies these findings to better inform whale conservation management actions in the Santa Barbara Channel. Ongoing boat-based research surveys and tagging efforts take place in this region, offering valuable broadscale spatial and temporal data. However, they occur too infrequently and not at relevant spatial or temporal scales to accurately inform policy measures. From 2017 to 2022, CINMS conducted systematic monthly survey flights focused on the heavily trafficked shipping lanes in the Santa Barbara Channel. Aerial survey data show that endangered humpback (*Megaptera novaeangliae*), fin (*Balaenoptera physalus*), and blue (*B. musculus*) whales are concentrating in areas of the Santa Barbara Channel that are not included in current predicted density models based on data from ship-based research surveys. Additionally, endangered whales are present in the region during times of the year that fall outside of historical seasons suggested by ship-based surveys and modeling efforts. The current coastwide density models predict that the highest density of whale aggregation sites are farther west and offshore, while the aerial monitoring data identify additional whale hotspots within the Santa Barbara Channel. Integration of the aerial whale monitoring data in conservation management actions at finer spatial and temporal scales is important for mitigating the risk of fatal ship strikes on these endangered whales.

Resumen.—El Santuario Marino Nacional de las Islas Channel (“CINMS”, por sus siglas en inglés) de la Administración Nacional Oceánica y Atmosférica (“NOAA”, por sus siglas en inglés), ubicado frente a las costas de los condados de Santa Bárbara y Ventura en California, mantiene un programa constante de monitoreo aéreo de mamíferos marinos, con el objetivo de entender mejor la distribución de las especies de ballenas barbadas en peligro de extinción y aplica estos hallazgos para informar de mejor manera las acciones de gestión de conservación de ballenas en el Canal de Santa Bárbara. En esta región se llevan a cabo estudios de investigación y esfuerzos continuos de marcado desde embarcaciones, los cuales ofrecen valiosos datos espaciales y temporales a gran escala. Sin embargo, estos estudios se llevan a cabo con muy poca frecuencia y no en escalas espaciales o temporales relevantes, como para recabar información precisa que pueda ser aprovechada para crear medidas o políticas de conservación. Desde el año 2017 hasta el 2022, el “CINMS” realizó vuelos de estudio sistemáticos mensuales enfocados en las rutas de navegación de mayor tráfico en el Canal de Santa Bárbara. Los datos de los estudios aéreos muestran que las ballenas jorobadas (*Megaptera novaeangliae*), rorcuales comunes (*Balaenoptera physalus*) y ballenas azules (*B. musculus*) en peligro de extinción se concentran en áreas del Canal de Santa Bárbara que no están incluidas en los modelos de densidad prevista actuales, basados en datos de estudios de investigación marítima. Asimismo, hay ballenas en peligro de extinción en la región durante épocas del año que caen fuera de las temporadas históricas sugeridas en los estudios y esfuerzos de modelado realizados en barco. Los modelos de densidad actuales a lo largo de la costa predicen que los sitios de conglomerado de ballenas tienen la mayor densidad al oeste y en alta mar, mientras que, los datos de monitoreo aéreo identifican focos adicionales de ballenas dentro del Canal de Santa Bárbara. La integración de los datos de monitoreo aéreo de ballenas en las acciones de conservación a escalas espaciales y temporales más específicas es importante para mitigar el riesgo de colisiones fatales de barcos con estas ballenas en peligro de extinción.

Cetaceans are globally and regionally protected to enhance recovery from historic whaling, yet they still face a number of threats that inhibit their recovery (Laist et al. 2001, Freedman et al. 2017, Rockwood et al. 2017, Peel et al. 2018, Schoeman et al. 2020, Morten et al. 2022). While these populations are protected under the Marine Mammal Protection Act (50 C.F.R. Part 218), habitat-wide protections and management actions are difficult to enact or enforce.

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Responsibilities fall to regional and local managers who can make impactful decisions in areas where there is risk to cetaceans; however, these managers often lack spatially appropriate data to make fine-scale policy decisions, as most research effort has been geared toward population-scale efforts (Redfern et al. 2013, Falcone et al. 2022). Managers need a strong understanding of how actual regional habitat use compares to large spatial models and what types of data (e.g., regional overflights, localized acoustics, and other methods) can provide decision-makers with scale-appropriate information.

One region where this issue is prevalent is the Santa Barbara Channel (SBC or channel) off the coast of California, USA. The unique geography, oceanographic conditions, and biological productivity in the region make it an important habitat for many marine mammal species that migrate through and feed in local waters, especially 3 large endangered baleen whale species: humpback (*Megaptera novaeangliae*), fin (*Balaenoptera physalus*), and blue (*B. musculus*) whales (Bailey et al. 2009, Redfern et al. 2013, Irvine et al. 2014, Calambokidis et al. 2015, Abrahms et al. 2019). However, the SBC sees high rates of large vessel activity that threaten cetacean habitat because of busy shipping lanes that lead to the ports of Hueneme, Long Beach, and Los Angeles (Freedman et al. 2017, Hazen et al. 2017, Rockwood et al. 2021, Morten et al. 2022). The spatial overlap between areas of high human use and endangered whale habitat poses challenges for managers balancing the protection of these species with maintaining the economic vitality of the region.

Given that ship strikes pose high risk to whales in the SBC and can even cause mortality (Laist et al. 2001, Panigada et al. 2006, Vanderlaan and Taggart 2007, Wang et al. 2007, Berman-Kowalewski et al. 2010, Wiley et al. 2011, de Vos et al. 2016, Carretta et al. 2016, Rockwood et al. 2017, NOAA National Marine Fisheries Service 2019), the National Oceanic and Atmospheric Administration (NOAA), the U.S. Coast Guard (USCG), and the Environmental Protection Agency (EPA) publish seasonal requests for vessels over 300 gross tons (GT) to slow to below 10 knots when whales are present to mitigate and reduce this risk (Freedman et al. 2017, Rockwood et al. 2021, Morten et al. 2022). These vessel speed reduction (VSR) requests are critical to conservation but require an understanding of where and when animals are aggregating so that informed policy decisions about enacting VSRs can be made. Each whale population is highly dynamic and has unique habitat use patterns, so knowing when endangered whale species are present is an ongoing challenge to VSR enactment. While large-scale species predictive models, including the California Current density predictions (Becker et al. 2020), provide a crucial baseline for assessing whale presence across the California Coast, the data driving these models are collected on broad geographic and temporal scales, impeding finer-scaled management actions such as seasonal VSR zones.

Since 2017, the Channel Islands National Marine Sanctuary (CINMS), the California Marine Sanctuary Foundation (CMSF), and The Volgenau Foundation have collaborated to organize monthly aerial whale surveys to detect large whales in the Santa Barbara Channel. In 2017, the location and timing of VSR requests were based on sightings data collected during these monthly aerial surveys. In 2018, monthly aerial survey data were used to set the seasonal duration of VSR requests. Since 2019, the temporal and spatial parameters of the VSR requests have been static and determined from historical flight records but have depended heavily on survey data to justify the timing and duration to best protect endangered species (Morten et al. 2022).

The overall goal of this study was to qualitatively assess any spatiotemporal differences between density predicted by the broadscale California Current models, which utilize ship-based surveys, and density obtained from more frequent small-scale aerial surveys. While we acknowledge inherent differences between the survey methods and tradeoffs between spatial breadth and temporal frequency, identifying these seasonal or locational differences ensures that local management and conservation actions, including the timing and location of the VSR requests, are targeted to the specific region. We aimed to identify time windows of whale presence that fall outside of the boat-based surveys and to highlight spatial differences in whale activity hotspots in the SBC during the time windows in which the 2 survey types overlap.

METHODS

Aerial Survey Program

From 2017 to 2022, aerial survey flights were scheduled in the middle of the month, every month, pending weather conditions and pilot

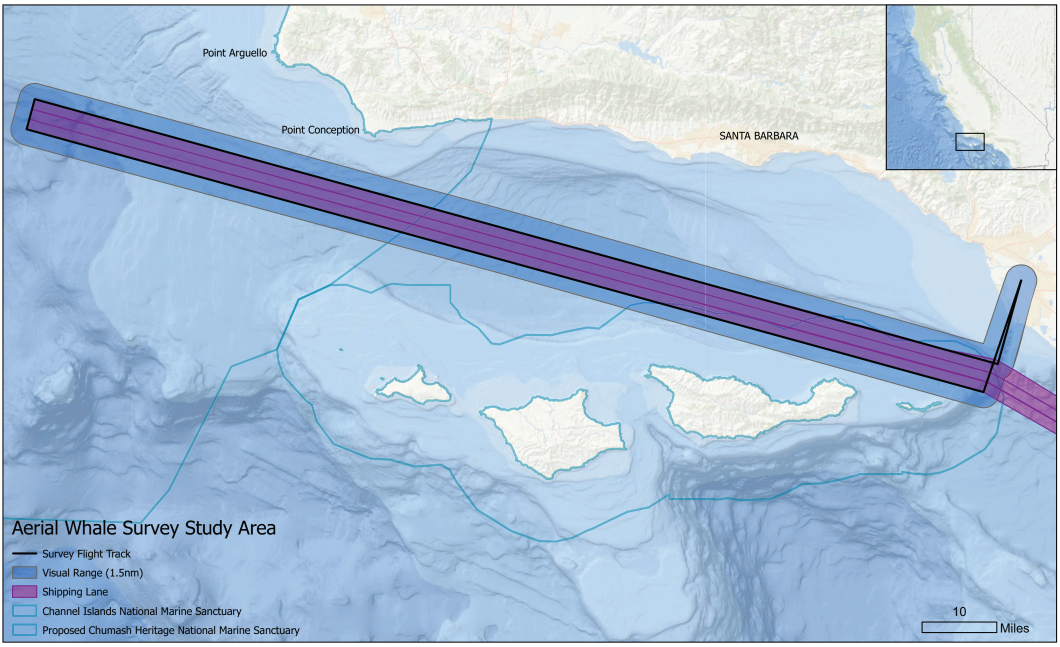

Fig. 1. Flight path from Oxnard Airport along north- and southbound shipping lanes.

availability. Two trained observers documented sighting data on Whale Alert and Spotter Pro data collection platforms from either side of a Partenavia fixed-wing, twin-engine airplane. The survey started at Oxnard Airport on a flight trajectory heading northwest along the northbound shipping lane at 1000 ft (~300 m) elevation and 100 knots (~185 km/h) and then turning off the coast of Point Arguello (34.5014827N, 121.1099609W) to follow the southbound shipping lane back to Oxnard Airport (Fig. 1). Visual range was estimated to be 1.5 nautical miles (2.8 km) in either direction of the flight path.

When whales were sighted, the survey plane broke track from its survey transect and circled over sighted whales to allow observers to record their exact locations, estimate the number of individuals present, and take photographs of each whale for individual identification whenever possible.

California Current Ecosystem Models

A commonly cited standard for wide-scale habitat models for blue, fin, and humpback whales is the cetacean density estimates in the California Current Ecosystem (Becker et al. 2020). This study uses survey data from 1991 to 2018 collected via ship-based line transect surveys. During the surveys, cetaceans were identified at the species level. Environmental data such as sea surface temperature, sea surface height, and chlorophyll-a concentrations were derived through remote sensing. The researchers employed generalized additive models to model the relationship between cetacean densities and environmental covariates.

Seasonal and Interannual Metrics Assessment

Aerial sighting data were downloaded from the SpotterPro data platform and aggregated across 2017–2022, omitting 2020 due to a low number of flights (n = 3). We focused on blue, fin, and humpback whale species for this analysis. All other species, including unidentified individuals, were omitted from the analysis.

Using R (R Core Team 2021) and RStudio (Version 4.3.1, RStudio Team 2021), survey data were grouped by month and species across 2017–2022 for all months (January–December). Next, using the same dataset, months which overlapped the boat-based surveys used in modeled predictions were selected (July–November).

Density Comparison

When making direct, qualitative comparisons between California Current densities from models and aerial survey data, we *only* selected sightings

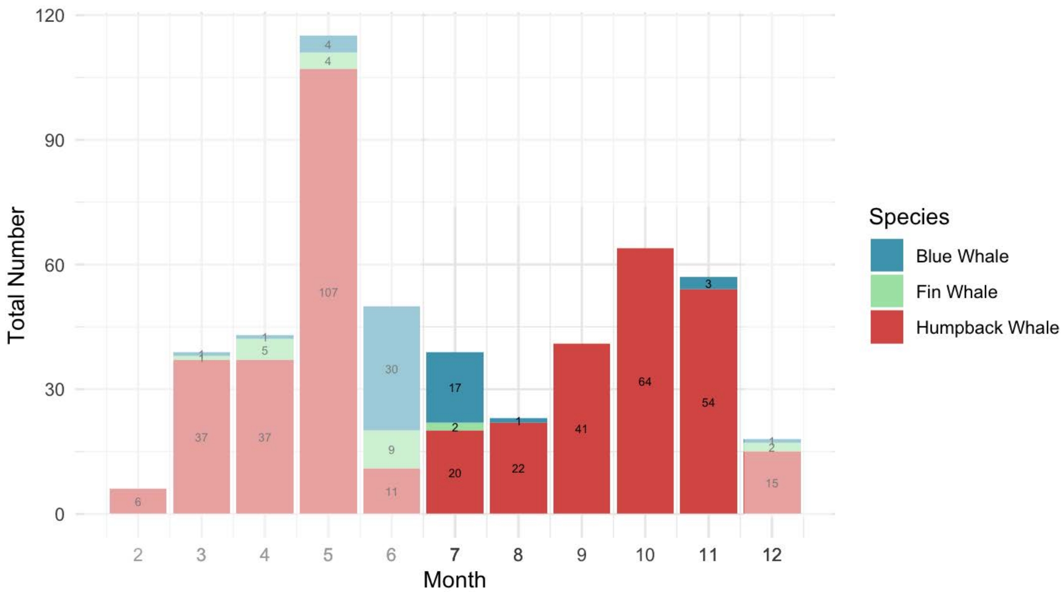

Fig. 2. Sightings records summed by month from 2017 to 2022. Faded bars illustrate months not reflected by the California Current density estimates, while bold bars show records used in the density comparison between aerial and California Current density estimates.

records in months overlapping with California Current model predictions (July–November), and we retained the same 1° grid resolution from the California Current density estimates. Assessing each species individually, we summed the number of sightings in each corresponding model cell to obtain the count estimate for each species and then divided by the area of each cell and number of surveys covering that grid cell to get the density for survey data. While this is *not* a quantitative comparison because California Current models incorporate other environmental variables to form their predictive density, this method gives us a way to qualitatively compare relative densities across the 2 data sets. Cells with no sightings data were omitted from the analysis. We maintained the symbology and spatial grid from the California Current paper (Becker et al. 2020) for visual comparison, keeping the number of bins the same, and applied them to the aerial sightings data in ArcGIS Pro (Version 3.0.2, ESRI).

RESULTS

Temporal and Seasonal Dynamics

Analysis of the aerial survey data shows that endangered whales are present in the Santa Barbara Channel throughout the year, not just from July to November, the months included in current predicted density models based on data from boat-based research surveys (Fig. 2). Humpbacks were sighted in all months except January, with the highest number of humpbacks recorded in May. Blue whales were present in all months except January, February, September, and October. Blue whales were sighted in highest numbers in June and July. Fin whales were least sighted but were present from March through July, and in December.

Density and Spatial Dynamics

The most notable difference between the California Current models and the aerial whale survey program is the difference in spatial aggregations of humpback whales. Humpback sighting records (n = 201) show that there is a hotspot of activity in the SBC between Santa Rosa and Santa Cruz Islands. This density hotspot is not reflected in the California Current predictions, which show instead a decrease in density moving eastward through the channel and do not reflect the nuanced but important detail of high density between the 2 islands (Fig. 3). Furthermore, additional hotspots emerged except for 1 grid cell which already showed relatively high density closer to San Miguel Island.

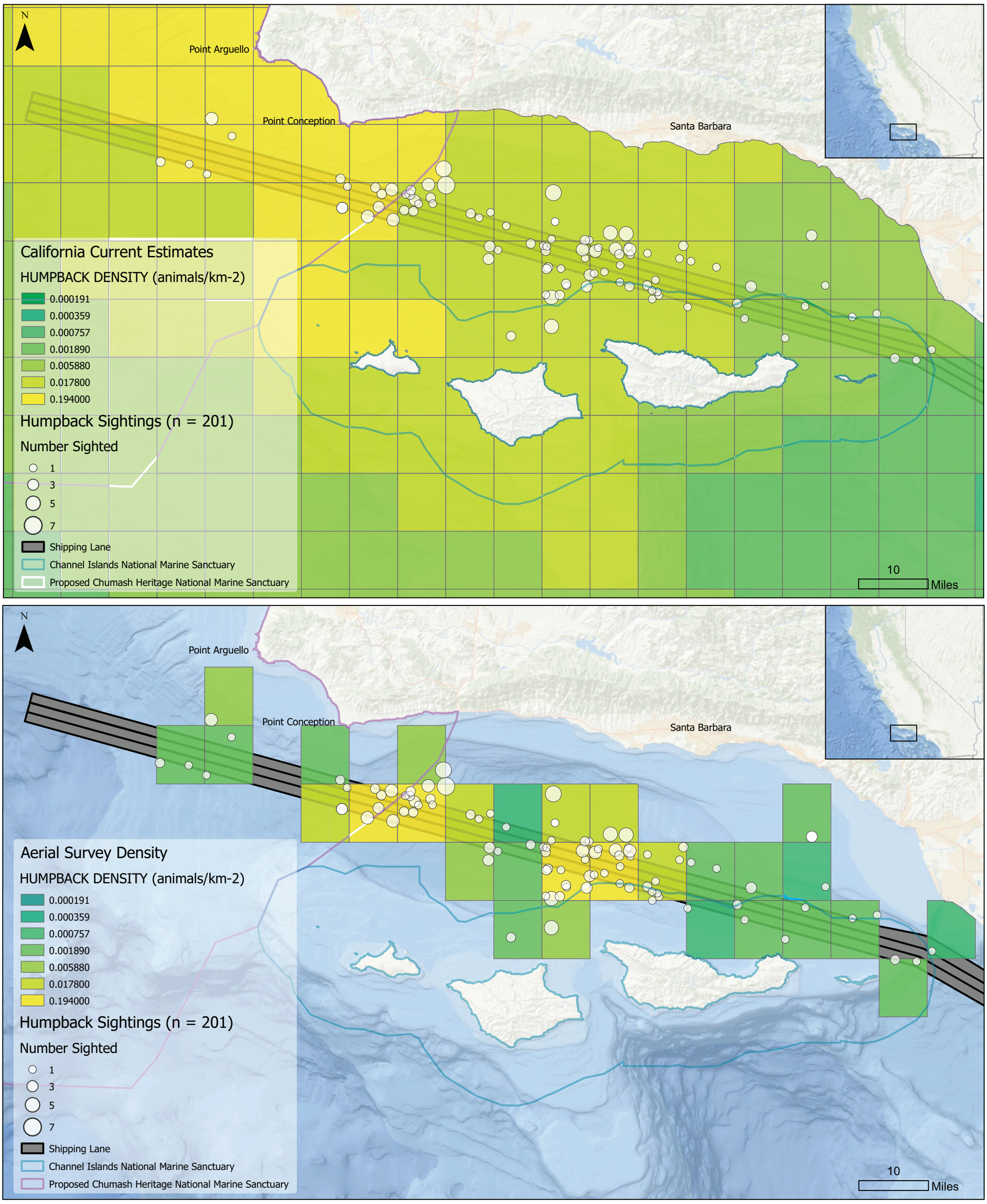

Fig. 3. Comparison between relative California Current density estimates (Becker et al. 2020) and density derived from 2017–2022 aerial sightings. *Top panel*: California Current 2020 model density predictions. *Bottom panel*: Aerial survey density calculations.

DISCUSSION

Temporal and Seasonal Dynamics

The seasonal dynamics recorded in the aerial survey suggest that, when designating shipping lanes or VSR zone placement and timing, managers may lose valuable data denoting temporal dynamics of whale presence when only consulting models that consider limited seasonal data (i.e., only summer and fall months). Figure 2 highlights this trend by showing seasonality of blue, fin, and humpback whales throughout the year from the survey program, illustrating how temporally restricting aerial survey data to the large-scale model months results in an incomplete picture of whale presence in the channel.

Notably, there are months in the spring that are very important for whales in the SBC, especially for blue and humpback whales. The aerial surveys documented the highest number of blue whales in June, which is a month not reflected in the seasonal limits of the large-scale models. This is similar for fin whales, where all months but one of data containing fin whale sightings are lost when the aerial survey data is limited to months covered by the large-scale model. Finally, the aerial survey data shows that spring is a significant time for humpback whale presence in the channel, but the large-scale models do not incorporate May, the month with the highest record of humpback whale presence, into model projections. These patterns highlight the importance of and need for a year-round monitoring program to capture important temporal patterns in endangered whale presence in the SBC.

CONCLUSIONS

The relationship between large-scale California Current models and smaller-scale localized monitoring data reveals important, policy-relevant differences in cetacean population level dynamics and habitat use in the Santa Barbara Channel, even if the comparison is not quantitative or one-to-one. It is necessary for managers to utilize localized monitoring data like the sightings data from the monthly aerial survey program alongside large-scale models in order to protect the whale populations in this unique region. The role of aerial programs in understanding fine-scale movements of cetaceans is not unique to this study, and previous research has demonstrated the benefit of supplemental monitoring (Forney et al. 2012, Roberts et al. 2016). Surveys and models that are larger than the operation areas impacted by conservation actions require finer-scale estimates (Forney et al. 2012).

This study highlights the need for a range of spatial and temporal monitoring scales and strategies to fully capture the spatiotemporal trends of populations of endangered, large-bodied whales. Large-scale models achieve different goals than small-scale monitoring, and both have important uses in resource management. Managers should use large population models for large-scale management but should work with regional and local managers that have more nuanced localized monitoring programs to inform and design a network of protection measures that are biologically relevant. These combined scales of monitoring efforts can incorporate additional systems and sensors to expand how whale presence is tracked. For example, acoustic detections can provide key information about whale presence when adverse weather conditions prevent ship and flight surveys (DeAngelis et al. 2022, Pearson et al. 2023). While specific locational data is not retained through acoustic detection, the combination of multiple monitoring efforts can provide a more wholescale picture of whale presence in an area. Similarly, advances in automated detection of large-bodied whale species using high-resolution satellite imagery and drone footage can increase the geographic range of monitoring efforts.

The aerial surveys in the Santa Barbara Channel provide data critical to understanding endangered whale species' movement patterns within a limited geographic scope as compared to the ship-based surveys. The spatial and temporal extent of the VSR zones and requests rely heavily on data from the aerial whale survey program and justify the survey program's maintenance and expansion. Notably, this study shows that we would not capture the full seasonality of whale presence for which we have data if we relied solely on large-scale models for regional management policies. Year-round monthly surveys are important for understanding the seasonal dynamics of when each species is present and most prevalent in the channel. Spatial nuance of whale habitat in the Santa Barbara Channel is another key detail that is not fully encapsulated by large-scale models. It is important for ocean managers and marine spatial planners to understand fine-scale areas of aggregation and high predicted density for endangered species in order to create effective conservation and management measures including adjusting shipping lanes; establishing Areas To Be Avoided, future offshore shipping fairways, and VSR zones; and establishing national marine sanctuaries.

Finally, as climate and ocean conditions change, whale behavior and density will likely shift. An aerial survey program operating on a monthly basis allows managers to incorporate and consider more recent sightings data and better understand changing spatial and temporal patterns across species. Combining past knowledge and predictive environmental conditions with current sightings data offers a more comprehensive analysis for informing whale conservation.

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