Evaluating the Connectivity between Central California Marine Protected Areas (MPAs) Using CODAR HF-Radar Measurements

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ABSTRACT

To investigate the connectivity between the Point Buchon marine protected area (MPA) and other oceanic Central California MPAs, back-projections were calculated using the ocean surface currents measured by the network of CODAR high-frequency (HF) radar stations operated along the California coast by the member institutions of the Coastal Ocean Currents Monitoring Program with funding provided by California voters through Propositions 40 & 50 and administered by the State Coastal Conservancy. Trajectories of a 1 km resolution grid of water particles were back-projected from the Pt. Buchon MPA each hour, out through 40 days in the past, from 365 starting-days, producing a map of where surface waters travel over a 40-day period to reach the Pt. Buchon MPA – and a visualization of the length of time the waters travel along these paths. By comparing the travel times of those back-projected track-points that fell within other central California MPAs, the connection time between the Pt. Buchon MPA and adjacent MPAs was calculated. Repeating these calculations for the other Central California MPAs would result in a connectivity matrix between all the MPAs in the region.

INTRODUCTION

Where does the water in the Point Buchon MPA come from, and how long does it take to get there (e.g., from other MPAs…)

To investigate the connectivity between the Point Buchon MPA and other oceanic central California MPAs (Figure 1), the trajectories of a 1 km resolution grid of water particles were back-projected each hour, out through 40 days in the past (Figure 2). These back-projected trajectories were calculated from the beginning of each of the 365 days from October 2006-October 2007.

Figure 1. Central California MPAs.

Figure 2. Shown is an aerial view of the Point Buchon region off the San Luis Obispo, California county coast with the boarder of the Pt. Buchon MPA (SMCA/SMR) outlined in yellow. Inset within the Pt. Buchon MPA boundary are red dots at each of the 45 grid-points, spaced 1 km apart, where the paths of the surface waters into the MPA were back-projected from.

MEASUREMENTS & METHODS

Calculated with HF Radar Surface Currents: Hourly back-projections of water particles, out through 40 days in the past, from the Pt. Buchon SMCA/SMR; repeated daily with surface currents measured from October 2006 – October 2007

Needed to perform these calculations were time-series from October 2006 – October 2007 of ocean surface current vectors measured hourly throughout the Central California coastal ocean (Figure 3). These measurements were recorded by the CODAR SeaSonde® HF-radar stations operated along the California coast by the Coastal Ocean Currents Monitoring Program – Northern California (COCMP-NC) as a program of the Central & Northern California Ocean Observing System (CeNCOOS).

Back-projecting the trajectories of the water particles was a straightforward process with the HF-radar measurements –

<u>Example</u>: If the currents at a given location flowed south at a speed of 10 cm s^{-1} over the course of an hour (1 hour = 3600 seconds), then the waters at that location would have been 360 m to the north the previous hour (3600 s × 10 cm s^{-1} = 36,000 cm = 360 m). Continuing to "step backwards" each hour in this fashion provides the means to calculate the trajectories of source waters and their transit times.

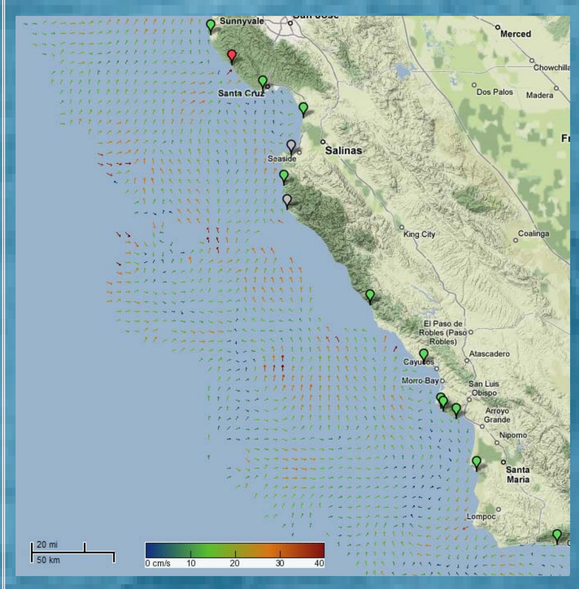

Figure 3. Map of 6 km resolution ocean surface currents measured by the COCMP-NC long-range HF-radar array on February 10, 2009 0000 UTC (vectors are shaded according to their speed in cm s^{-1} per the color-bar). The HF-radar network provides measurement coverage of all the Central California MPAs which extend 6 km or more out to sea.

RESULTS

Connection time between Pt. Buchon SMCA/SMR and other central California MPAs

The connection times between the Pt. Buchon MPA and other central California MPAs were then calculated by comparing the number of days taken by any back-projected track-points falling within those other MPAs to reach the Pt. Buchon MPA (Table 1; Figure 4).

Graphing the back-projected points yielded a map of where surface waters traveled over 40 days before entering the Pt. Buchon MPA, and a visualization of how long it took those waters to travel along these paths (Figure 5).

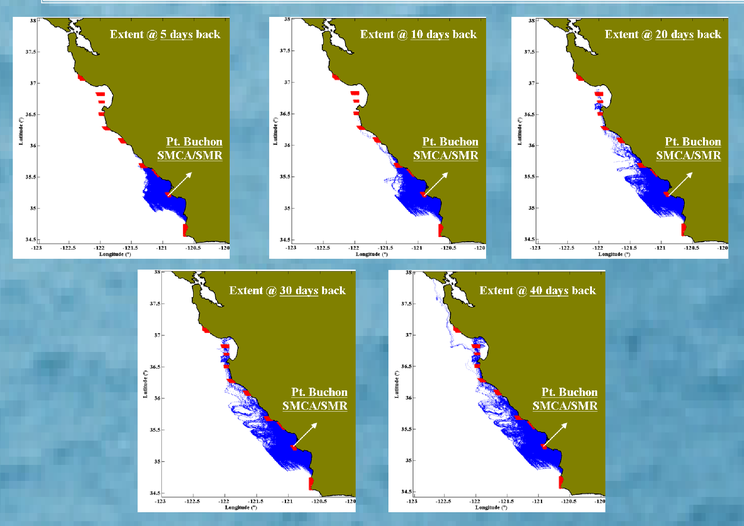

Figure 4. Graphs of the positions of the particles (in blue) back-projected from the Pt. Buchon MPA at 5, 10, 20, 30, and 40 days. The extent of the excursions at these durations demonstrates the time it took the particles to reach a given density of observations within the regions of the other MPAs (in red) along the Central California coast.

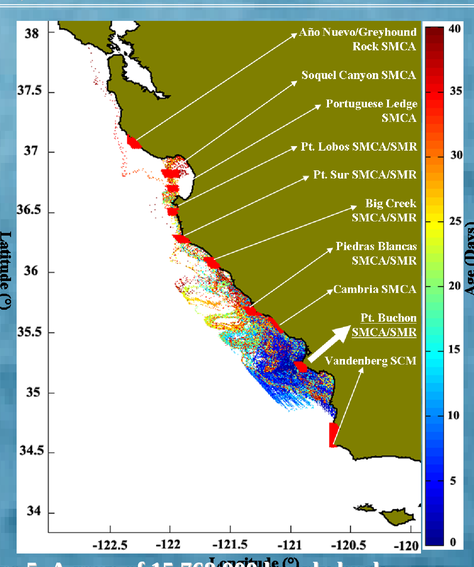

Figure 5. A map of 15,768,000 hourly back-projections of water particles, out through 40 days (960 hours) in the past, into the Pt. Buchon MPA; repeated daily for each of the 45 1-km grid-points with surface currents measured from October 2006-October 2007 (45 trajectories × 960 time-steps × 365 start-days = 15,768,000 back-projected points). These water particle track-points are color coded to show the travel time (up through 40 days) the waters took to reach the Pt. Buchon MPA.

Table 1. Percentage of the 16,425 trajectories (45 traj. × 365 days) back-projected through 40 days intersecting the Pt. Buchon MPA and the average connection time.

MPA	% of trajectories to the Pt. Buchon MPA backprojected to have gone through the given MPA	Mean number of days until intersection
Año Nuevo/Greyhound Rock SMCA	0%	--
Soquel Canyon SMCA	1.5%	31.9
Portuguese Ledge SMCA	1.6%	30.1
Pt. Lobos SMCA/SMR	1.8%	25.9
Pt. Sur SMCA/SMR	2.0%	25.4
Big Creek SMCA/SMR	1.7%	23.5
Piedras Blancas SMCA/SMR	14.8%	24.1
Cambria SMCA	31.3%	16.6
Vandenberg SCM	0%	--

CONCLUSIONS

Management Applications: Larval duration; seeding between MPAs, …

Repeating the calculations performed for the Pt. Buchon MPA for the other Central California MPAs would result in a connectivity matrix between all the MPAs in the region. A challenge central to the design and management of the MPA network is accurately understanding the larval transport which links the MPAs. Single-point measurements from current meters and buoys don't provide the measurement coverage necessary to do this, but the HF-radar network provides the density of continuous measurements necessary for developing a data-based understanding of larval transport and connectivity between MPAs.

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