SANTA PAULA CREEK SEEP SSEP: Bird Oiling

Final Report, Volume 2

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Executive Summary and Overview

The January 2005 Ventura Oiled Bird Incident (VOBI) was an extremely devastating oiled bird incidents with at least 1500 dead or injured birds (CDFW/OSPR, 2013). The VOBI affected 21 species of birds along nearly 250 miles of southern California coastline with ultimate response costs of over $1 million. Most heavily impacted were *western grebes*, which commonly raft just off the shoreline during their winter migration. Estimated loss was 5% of the west coast western grebe population (a total of 1329 injured western grebes were collected during the VOBI). Oiled bird locations were mapped and showed a spatial distribution, which extended primarily southward from the vicinity of Ventura with a significant concentration near the mouth of the Santa Clara River (SCR), suggesting a terrestrial source from the SCR watershed. Almost 59% of the affected birds (alive and dead combined) were collected within a 25-mile stretch of coastline from Ventura to Mugu Lagoon.

Volume 1 of this two-volume final report presents:

1) The investigations, which led to discovery of the oil source;

2) The analytical studies conducted by the California Department of Fish and Wildlife–Petroleum Chemistry Laboratory (CDFW-PCL) to identify the oil source;

3) Efforts to quantify oil emissions and determine factors affecting their release seasonal and spatial, and introduction into the waterway.

Volume 2 of this two-volume final report summarizes:

1) The distribution and species of oiled birds affected; and

2) The field and wildlife care operations required to rescue and rehabilitate oiled birds.

3) How real-time spatial-temporal mapping of bird capture and recovery can improve future oil spill response.

The use of spatial-species bird information to deduce a likely oil source location was a novel aspects to this study, but this information also was used to deduce bird movement mechanisms, proposing that *Aechmophorus* grebes flew rather than as has been generally suggested, swam to distant areas of safe harbor. Additional information in terms of bird oiling and mortality provided further insight into bird movements. Furthermore, *Aechmophorus* grebe movements were surmised to be influenced by migratory patterns, with the spatial distribution showing strong southerly asymmetry.

The finding that birds tended to seek out protected coastal areas after being oiled, suggests that initial wildlife rescue and recovery for future oil spills should focus on inlets and harbors and protected beaches. Priority should be given in the downcurrent direction or in the case of migratory birds, the direction of migration. Clearly, this latter factor depends on the species and time of year.

For birds that are not in a migratory pattern, such as the brown pelicans during VOBI, initial response and recovery focus should be on inlets and harbors and protected beaches in either direction.

Importantly, the spatial analysis in this study could be adapted to real-time, improving response asset allocation and alerting local observers (e.g., harbor personnel, etc.). Key was GPS data, which should be stressed in future response protocols.

This report acknowledges the important contributions of Bryan Gollhofer, Paul Hamdorf, Steve Hampton, Laird Henkel, Diana Humple, Bruce Joab, Dr. Massey, Michael Sowby, Susan Sugarman, and Dr. Ziccardi.

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1 Introduction

1.1 The Ventura Oiled Bird Incident

Incidences of oiled birds and/or bird mortalities unrelated to reported oil spills are common in central and southern California, occurring virtually every year. Oiled birds are regularly reported along the coast from Orange County to San Luis Obispo County, often during the winter and spring months. Total annual casualties usually number ~200 obviously oiled individuals (Laird Henkel, personal communication, 2012). Although these casualties may be attributable to natural oil seepage, little is known. Rarely is a responsible party found for these lesser but recurrent events.

Two of the largest ‘mystery’ bird oiling incidents in recent years included the S/S *Jacob Luckenbach* (Luckenbach Trustee Council, 2006), which occurred in multiple winters prior to 2003 and the Ventura Oiled Bird Incident (VOBI), which occurred in January 2005.

The *Luckenbach* incident began as a ‘mystery’ bird oiling event off San Francisco Bay during which increased incidence of oiled marine birds was noted over a several year period, although the source of the oil was not identified until Feb. 2002. The source was found to be a 468-foot freighter that sank ~17 miles southwest of the Golden Gate Bridge, on 14 Jul. 1953. Leakage from this vessel killed or injured over 51,000 birds (Luckenbach Trustee Council, 2006), mostly common murres (*Uria aalge*), and eight sea otters (*Enhydra lutris*). In an intensive response operation, the residual oil was removed from the vessel thereby eliminating the continued threat to wildlife (Hampton et al., 2003).

The Ventura Oiled Bird Incident (VOBI) began in the second week of Jan. 2005 (Leifer and Wilson, 2015). The first oiled birds sightings were reported on 12 Jan. 2005 along the Ventura County coastline (**Fig. 1**). Lt. Paul Hamdorf and Warden Bryan Gollhofer (Department of Fish and Game–Office of Spill Prevention and Response - DFG-OSPR) investigated these reports and, in turn, reported the event to OSPR headquarters. The DFG–OSPR responded quickly activating OSPR staff, the Oiled Wildlife Care Network (OWCN) including the International Bird Research Rescue Center (IBRRC).

By the end of the day of 12 Jan. 2005 rescuers had captured 68 birds, virtually all were *Aechmophorus* grebes. Captures clustered mostly along the central Ventura County coastline, near Ventura Harbor and the mouth of the SCR and near Mugu Lagoon. By the morning of 13 Jan. 2005, the effort had ramped up with 25 rescue workers capturing live oiled birds and delivering them to rehabilitation centers. By 18 Jan. 2005, a week after the first oiled bird sightings/rescues, 1033 oiled birds had been collected from along the Ventura, Los Angeles, and Santa Barbara coastlines. Most of the oiled birds were found between the Ventura Harbor and the Naval Station - Ventura County, near Point Mugu. The numbers of live oiled birds eventually rescued reached over 1,200 individuals. An additional 312 dead oiled birds were recovered during this incident. Based on population estimates the VOBI affected a few percent (Wilson et al, 2013) to up to 5% (Steve Hampton, Pers. Comm.) of the west coast population of western grebes. In fact, VOBI could have affected up to 25% of California's western grebe breeding population (Paul Kelly, Pers. comm., 1/18/2005). The total cost of the incident exceeded **$1,000,000** (Sandy Potstada, OSPR Sacramento, Pers. Comm. 2010). An additional and unrelated bird-oiling incident, termed Ventura Birds II, was significantly smaller in magnitude, and occurred in central and southern California in Feb. 2005.

Fig. 1. Google earth image of VOBI study area showing location of focused study site near Thomas Aquinas College just north of Santa Paula. The study area was centered on a feature informally named "Cactus Slump Seep." Also labeled are the Santa Clara River (SCR), Santa Paula Creek (SPC), and Sisar Creek (SC). Inset shows coastline where oiled birds were found from Morro Bay to Long Beach, California.

1.2 Biological Effects of Petroleum on Birds

The effects of crude and refined petroleum products on birds can vary considerably depending upon the amount, type of oil and level of refinement, mixture or composition, and type of spill, such as from a pipeline, vessel, etc. (Oiled Wildlife Care Network, 2000; Welte and Frink, 1990). Likewise, the response of birds exposed to the same oil varies among species, within species by age and condition of the animals (e.g., the presence of bacterial and/or fungal infections, and/or sub-lethal levels of toxic substances), and with conditions associated with captivity during rehabilitation (Beer, 1968). The effects of oil exposure on most marine birds require one to three days to become evident; depending upon the sensitivity of affected species, degree of oiling, and the oil type (*Steve Hampton, DFG OSPR*, Pers. Comm. 2012).

There are multiple mechanisms that cause wildlife morbidity and mortality due to oil exposure, including physical (direct contact on skin, feathers, etc.), toxicological effects (Jessup and Leighton, 1996) and through ecosystem alteration (food source loss).

Oil on the feathers causes loss of insulation (resulting in hypothermia), loss of buoyancy, and, in extreme cases, loss of ability to fly, dive, swim, feed, and escape predators (Leighton, 1993). Marine birds primarily maintain their body temperature 102-106ºF (39-41ºC) by the insulation of their plumage (Oiled Wildlife Care Network, 2000). This can be critical because southern California winter ocean waters - 10 to 15.5°C - are significantly cooler than their body temperatures (NOAA, 2013). Wildlife care workers have found that

> "for ocean-going birds that forage at sea, a spot of oil the size of a nickel may be sufficient to cause death. Like a hole in a wetsuit, the oil destroys the feathers' ability to insulate the bird, thus allowing cold ocean water to spread against the bird's skin. Oiled birds most typically die of hypothermia and starvation (Moskoff 2000)."[1]

Furthermore, different birds exhibit different sensitivity to oil from physical effects. Eventually, affected birds may die or be highly debilitated due to oiling (Leighton, 1993).

Beyond the physical effects, the volatile components of oil include many potent toxins that affect almost all species (Aguilera et al., 2010), leading to severe stress(Smith, 1975). Where there is sufficiently high oil exposure, there can be damage to the reproductive, renal, hepatic, and digestive systems that metabolize toxins and produce carcinogens, thus ingestion is a significant exposure pathway Further, oil may suppress the immune response and disrupt or suppress red blood cell formation. These include irritation of skin, oral, ocular, respiratory, and gastrointestinal mucous membranes (Aguilera et al., 2010). In severe cases, gastrointestinal irritation leads to starvation, and dehydration can also be a problem (Smith, 1975). The impact of oil can be multi-generational, by affecting bird embryos when oil is transferred to the shell (Jessup and Leighton, 1996; Leighton, 1993).

In many cases, a majority of rescued birds do not survive despite intensive rehabilitation efforts (Smith, 1975). For example in the 1971 San Francisco oil

[1] California Department of Fish and Game, US Fish and Wildlife Service, Kure/Humboldt Bay Oil Spill: Final Damage Assessment and Restoration Plan/Environmental Assessment, 2008, pp. 36, 143 Pages.

spill, 95% of 4686 rehabilitated birds died. In 1973, IBRRC treated 543 birds, of which 25% of 40 western grebes died, while 35% of common murre (190 individuals) survived. Thus, some oiled bird species are more likely to survive than others. Furthermore, there are different survival rates for different oil spills for the same species, indicating oil type and other factors also are important (Smith, 1975). Important to understanding the rehabilitation rates, as well as numbers of birds killed by oil spills has been standardization of total mortality estimates with the passage of federal and state oil pollutions acts in 1990. These acts also led to improvements in rehabilitation programs.

Fig. 2. Four oiled western grebes, roosting in the bottom and left quadrants of the photo on a Ballona Creek seawall, Los Angeles County on 16 Jan. 2005. Photos courtesy of Ed Boyes, DFG-OSPR – Los Alamitos.

1.3 VOBI Wildlife Response and Rehabilitation

Activated by OSPR's incident command system through the Wildlife Branch of the Operations Section, the Oiled Wildlife Care Network (OWCN), OSPR personnel, and others responded to rescue/recover the wildlife casualties arising from this incident. At times, almost 500 people from OWCN, DFG, and others were involved in the VOBI coordination, capture, transportation, and rehabilitation efforts. Stabilization, cleaning, rehabilitation, and release activities were overseen by the OWCN at the Los Angeles Oiled Bird Care and Education Center in San Pedro, California.

The first birds began to arrive at OWCN facility for rehabilitation on 14 Jan. 2005 with the bulk collected before 24 Jan. 2005 although some oiled birds, possibly unrelated to VOBI were collected through mid-February 2005. A total of 1204 live birds of 12 taxa were rescued, of which 80% (960) died in captivity or were euthanized a majority of which were *Aechmophorus* grebes (PRBO/OWCN, 2005), despite intensive efforts by rescue and rehabilitation workers.

Approximately 80% of the *Aechmophorus* grebes affected were adults; without a significant difference in mortality related to sex (Humple, 2009; Humple et al., 2011). A total of 239 (20%) birds were successfully rehabilitated and released. Release numbers, among the top four species of live birds rescued were, in descending order: 95% of the brown pelicans, 25% of the common loons, ~19% of the western grebes, and ~10% of the Clark's grebes. A summary of all the birds captured (live) or recovered (dead) discussed in this report from 3 Jan. 2005 to 15 Feb. 2005, which covered the VOBI, 12-18 Jan. 2005.

Wildlife response efforts were intensive and involved 24-7 operations to save oiled birds (**Fig. 2**). There were 476 volunteers and 54 paid staff involved in the capture and rehabilitation efforts conducted in the field and at the Oiled Bird Care and Education Center in San Pedro, California (*Yvette Hernandez*, pers. comm., OWCN, 2010). Rehabilitation workers came from 13 OWCN member organizations and five non-member organizations.

After activation of the OWCN by the incident command on 12 Jan. 2005 when OSPR personnel deemed a wildlife response was necessary, VOBI response efforts included search, collection, and transportation of birds to the nearest OWCN facility, then intake and stabilization, followed by cleaning and assessment prior to their release or euthanasia (*Yvette Hernandez*, pers. comm., OWCN, 2010). Trained personnel who recorded data on location, date, and time of capture.

Rehabilitation stays ranged from as little as 1 day for lightly affected birds to as long as 78 days for more severely impacted individuals. Approximately 63% of the rehabilitated birds were treated and released within 5 to 10 days of arriving at the facility, with 14 days the average duration of rehabilitation.

Each bird was photographed (**Fig. 3**). Samples of oiled feathers were collected during the intake and stabilization process. Birds were temporarily tagged, and a physical examination was performed (blood sampling and evaluation of physical condition) during triage. Birds were triaged and those with an unfavorable prognosis were euthanized, while those with a favorable prognosis for rehabilitation were fed and hydrated up to eight times per day. Once their conditions were assessed as stable (usually 2-5 days after intake), they were cleaned (**Fig. 3C**) by washing in warm, softened water with a dilute solution of dishwashing detergent (Dawn®). Then, they were rinsed and placed in pens with pet dryers.

Cleaned individuals were placed into outdoor pools to groom and feed during recovery with condition and behavior frequently monitored and assessed (**Fig. 3E**). Birds were held until assessed ready for release (**Fig. 3F**). Their grooming habits and feeding were part of the assessment.

Prior to release, birds were re-banded with permanent identification bands. Birds were released into non-oiled, species appropriate, habitat. Where feasible, follow-up observations were done to ascertain the survival of released individuals.

Fig. 3. A. An irate oiled *western grebe*, **B.** Force feeding, **C.** Hydration, **D.** Bird cleaning with dishwashing detergent (Dawn®). **E.** Cleaned grebes awaiting release, and **F.** Bird release of a rehabilitated grebe, Mike Ziccardi-DVM shown. Photo A. courtesy Chris Thixton, OSPR, Los Alamitos, Photo B courtesy Alison Kent. Wildlife Health Center, UC Davis.

1.4 Temporal variability and species of oiled birds collected during VOBI

The VOBI response began on 12 Jan. 2005 and continued through late Feb. 2005, with 68 oiled birds captured by the end of the first day (**Fig. 4**), which was approximately 2 days after oil was observed entering the ocean. Live bird captures rapidly increased, peaking at 267 live birds rescued on 14 Jan. 2005. Thereafter, captures decreased approximately exponentially over the next week, with just a few birds captured after 21 Jan. 2005. The first dead birds were recovered on 13 Jan. 2005. The number of dead birds recovered rose more slowly than that of live birds, reaching a maximum on 15 and 16 Jan. 2005 of ~50 birds each day. Thereafter, dead bird recovery decreased slower than for live birds.

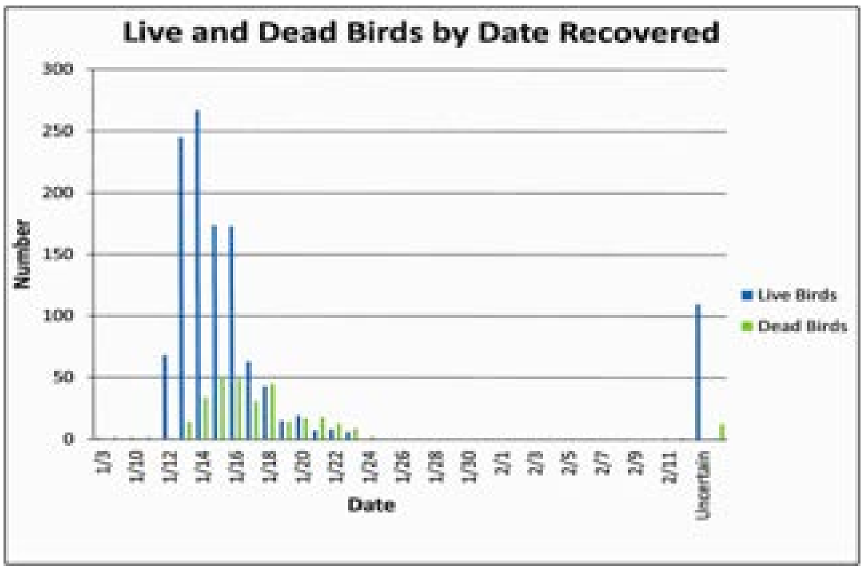

Fig. 4. Recoveries of live and dead oiled birds during the VOBI incident.

These trends represent a combination of bird locations, responder efforts and focus, and bird mortality. There were 26 field responders on 12 Jan. 2005 whose focus primarily was on live birds. The number of responders increased to 40 on 14 Jan. and 44 on 15 Jan. 2005. The number of responders decreased on 16 and 17 Jan. 2005 to ~30, gradually decreasing over the next week during demobilization of the VOBI rescue phase.

A total of 21 confirmed species of birds either were captured/rescued (alive) or recovered (dead), see **Tables 1 and 2**. A total of 1204 live marine birds representing 12 species (**Table 1, Fig. 5**) were collected during the VOBI and transferred to the OWCN facility in San Pedro, California, for cleaning and/or rehabilitation. The locations of capture could not be ascertained for 50 of these individuals. These species represent those normally found in nearshore waters, coastal lagoons, and harbors during winter months in Southern California (Fig. 5A). *Aechmophorus* grebes, including Western grebes, WEGR, and Clark's grebes, CLGR, accounted for ~96% of the live birds rescued. WEGR and CLGR accounted for ~94% and 5%, respectively of the *Aechmophorus* grebes, the remainder being unidentified (Appendix 1 Live Bird Logs &

Appendix 2 – Dead Bird Logs). Clearly, *Aechmophorus* grebes dominated bird capture and rehabilitation activities during the VOBI.

Table 1. Confirmed bird species captured and/or recovered during the VOBI*

1. Cassin's Auklet
2. ***Rhinoceros Auklet***
3. American Coot
4. ***Pelagic Cormorant***
5. ***Brandt's Cormorant***
6. Double Crested Cormorant
7. Rock Dove
8. Ruddy Duck
9. Pie-billed Grebe
10. ***Eared Grebe***
11. ***Western Grebe***
12. ***Clark's Grebe***
13. ***Western Gull***
14. ***Red Throated Loon***
15. Pacific Loon
16. ***Common Loon***
17. ***Hooded Merganser***
18. Red-Breasted Merganser
19. ***Brown Pelican***
20. ***Surf Scoter***
21. Plover (unid)

****Bold Italic*** indicates live individuals.

Table 2. Unidentified bird groups captured and/or recovered during the VOBI

1. Plover Unid
2. Gull Unid
3. Dove Unid
4. Grebe Unid
5. Aechmophorus Grebe

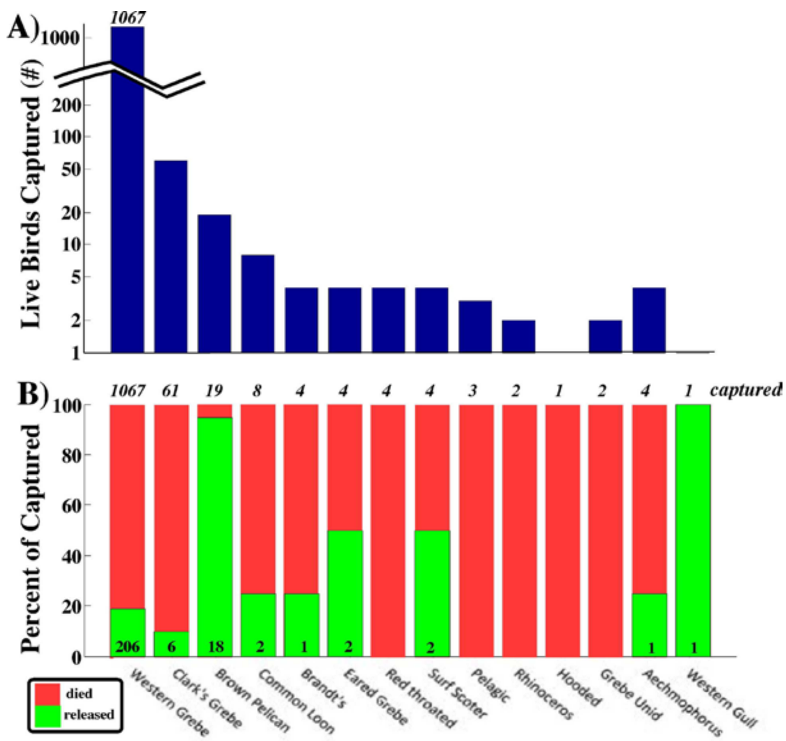

Fig. 5. A) Live birds captured by species. **B)** Percent of captured birds released or died during rehabilitation. Legend on plot. See **Table 1** for full names.

Successful bird rehabilitation varied widely among species (**Fig. 5B**). Grebe rehabilitation was extremely challenging, with ~20% of Western grebes released (more western grebes died than Clarks' grebes). Also challenging was rehabilitation of common loons (25% released); however, the numbers oiled and captured were low and thus statistics are questionable. By contrast, brown pelican rehabilitation was highly successful, with 95% released.

1.5 Capture Locations

Live bird captures were highly spatially heterogeneous (**Fig. 6**). The data appear to show that most injured birds preferentially selected sheltered shorelines and/or beaches in or near lagoons, harbors, and estuaries (Appendix 1 Live Bird Logs & Appendix 2 – Dead Bird Logs).

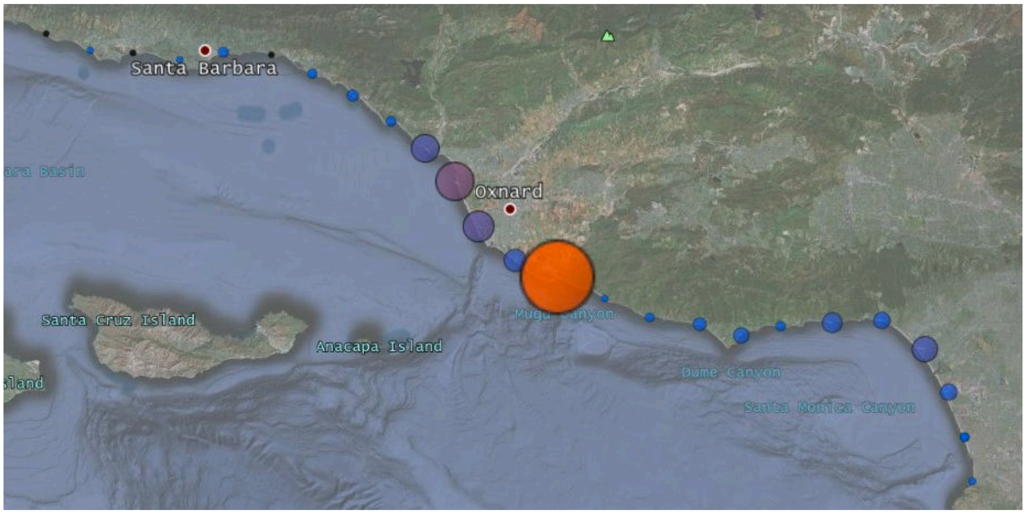

Fig. 6. Spatial location map of live oiled birds. Circle size is number of birds per 5 miles of beach. Large red circle represents 285 birds.

To investigate in greater detail whether there was a correlation between shoreline features and bird recoveries, further analysis was performed on birdlog capture data (PRBO/OWCN, 2005). These logs recorded bird species, number captured, date and time of capture, rescuer name, location, degree of oiling, and whether birds were alive or not. All data were thoroughly quality controlled, which occasionally revealed confusion in the capture location. In such cases, secondary confirming information was used to determine more correctly capture locations. Such information included collection team composition, location data, and times of capture (e.g., a team could not concurrently be in Santa Barbara and Santa Monica Bay (SMB) at a given date and time).

Finally, if questions still existed, we contacted team members directly to confirm data. Where only general locations were recorded or determined for the capture/recovery of birds, such as a beach, harbor, inlet or other local location name, a general coordinate for the particular location was assigned. The location analysis described below did not use capture data for which the location could not be confirmed.

Birds were recovered/captured as far north as Montana de Oro State Beach in San Luis Obispo County, and as far south as Corona del Mar, just south of the City of Newport

Beach in Orange County. VOBI rescue and recovery efforts encompassed a total coastline distance of nearly 260 statute miles. Clearly, bird captures and recoveries were affected by shoreline access and the number of bird rescuers.

Table 3. Segment locations for segregating bird rescue/recovery data*

Segment Number*	Coastal Location/Feature
+10+	**Montana De Oro**, Avila, Pismo Beach, Vandenberg, Hollister Ranch, and Gaviota Coast
+10	El Capitan Ranch, Naples to Eagle Creek
+9	Eagle Creek, Bacara, Venoco, Sandpiper GC, Devereux Lagoon, Coal Oil Pt. and W. Isla Vista
+8	East Isla Vista, UCSB, Goleta Beach, Moore Mesa, and West end of Hope Ranch
+7	Las Olas Dr. (Hope Ranch), Arroyo Burro, Mesa Beach and shoreline Park Beach
+6	Shoreline Park Santa Barbara, Santa Barbara Harbor, West and East Beaches, Butterfly Beach, and Miramar
+5	1/3 mi. west of Fernald Pt, Lookout Park, Loon Pt. to NW end of salt marsh
+4	NW end of Carpinteria Salt Marsh, Carpinteria Beaches, Rincon Beach (W) and Rincon Pt.
+3	Rincon Cove, La Conchita, Rincon Island to Seacliff
+2	Hobson Co and Faria Parks, Pitas Pt., Solimar, to vicinity of Emma Woods State Beach
+1	~1 mi. South of Solimar, Ventura River mouth, City of Ventura (north), to 0.2 mi. S. of entrance to San Buenaventura State Park
0	City of Ventura (south), Ventura Harbor, SCR mouth, McGrath Bch, to Mandalay Beach
-1	W. 5th St, Mandalay Beach, Hollywood Beaches, Channel Island Harbor, Silver Strand Beach Port of Hueneme
-2	0.4 mi SE of So Jetty of Port of Hueneme, Ormand Beach to NW end of Mugu Lagoon
-3	West Holiday Beach, Entire Mugu Lagoon and sand flats, spits, to 0.36 mi. S of Pt. Mugu
-4	0.36 mi S. of Pt. Mugu, Thornhill Broome, Big Sycamore Canyon, 0.5 mi S. of Deer Creek Rd.
-5	Little Sycamore Canyon, Solromar, Leo Carrillo St. Beach, Malibu
-6	Robert Meyer, Lechuza Pt., Trancas/Broad Beach, Zuma North
-7	Zuma Beach, Pt. Dume', Paradise Cove, Escondido Beach
-8	Latigo Pt., Corral, Puerco, Malibu Bluff and Lagoon
-9	Malibu Pier, Carbon, Big Rock and Las Tunas
-10	Topanga, Will Rogers State Beach, Las Olas and Chautauqua
-11	Santa Monica State Beach, Venice, Marina del Rey
-12	Ballona Creek, Playa del Rey, Dockweiler Beach to Manhattan Beach
-13	Manhattan and Hermosa to Redondo Beaches
-14	Redondo Beach, King Harbor, Torrance, Palos Verdes Estates
-15-	Palos Verdes Estates, Abalone Cove, Long Beach, Newport, Corona del Mar

***Positive segment numbers are north of the SCR mouth. Negative values are located to the south. Significant locations and features are listed for each coastal segment (5 mile length, except for segments +10+ and -15-).

A spatial segmentation approach was used to aggregate bird recovery data for 25, five-mile-long shoreline segments (miles along shoreline). The origin of the coordinate system (Segment 0) was centered on the SCR mouth, where the oil was proposed to have entered the ocean. Positive numbered segments extending northwards, and negative extending southwards (**Table 3**). The regular segmenting scheme extended from 10 to -14; however, catchall segments were added for birds outside this range, designated, +10+ and -15, for more northerly beaches and more southerly coast, respectively. Birds were found as far as 110 miles to the north, and 45 miles to the south, of the origin, respectively. Thus, each rescued/recovered live and dead bird was assigned to a coastal segment if the data were determinate.

2 Findings - Capture Locations

Prior to ~12 Jan. 2005 (before VOBI), few bird recoveries were recorded with no discernible spatial or temporal pattern (**Fig. 7**). A total of three individuals were captured between 1 Jan. 2005 and the beginning of VOBI from Santa Monica, Zuma, and El Segundo coast, and all appeared to be *Aechmophorus* grebes. One additional *Aechmophorus* grebe was captured, but the location and date of capture could not be confirmed, and was not included in the location analysis. Similarly low bird recoveries rates were found for the post-VOBI time period, with two birds captured in February (**Fig. 7**); a rhinoceros auklet at Montana de Oro State Beach in San Luis Obispo County and a surf scoter at Corona Del Mar in Orange County. We propose these birds' recoveries were unrelated to the VOBI.

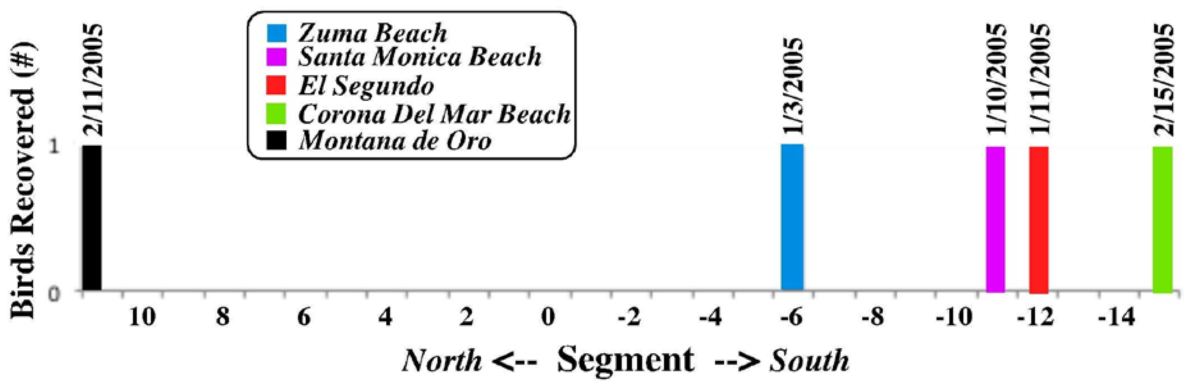

Fig. 7. Coastline segment locations of individual birds that were determined to not relate to the VOBI live bird recovery dates. Specific locations noted in key.

Beginning 12 Jan. 2005, approximately two days after oil was observed entering the Pacific Ocean from the SCR, there was a dramatic increase in oiled bird captures (**Fig. 8A**). Moreover, bird recoveries exhibited a definite spatial pattern, with the greatest numbers clustered around the mouth of the SCR and the Mugu Lagoon, the Ventura Bird Aggregation (VBA).

By 13 Jan. 2005 (**Fig. 8B**), live bird captures again tripled over those of the previous day, with two nexi of bird captures, one near the mouth of the SCR and Mugu Lagoon, and a second in the Marina Del Rey/Ballona area, termed the Marina del Rey Bird Aggregation (MBA). This increase reflects rescue personnel mobilization, their location, and number of oiled birds. One oiled bird was recovered as far south as Redondo Beach in southern SMB (**Fig. 8B**). The highest number of birds recovered on a single day during the VOBI was at Mugu Lagoon on Jan. 14 (Segment -3). Thereafter, the number of captured birds steadily decreased with the first no-capture day being 19 Jan. Mugu Lagoon dominated until 16 Jan. but remained important throughout the VOBI – this likely reflects rescue personnel attention.

A total to 1154 birds for calculations whose location of capture could be ascertained. Only 7% of the live birds captured during the VOBI were rescued from locations north of the City of Ventura (Segments +2 to +10 and north) of these, only 0.3% of the birds were captured north of Santa Barbara Harbor (Segment +6).

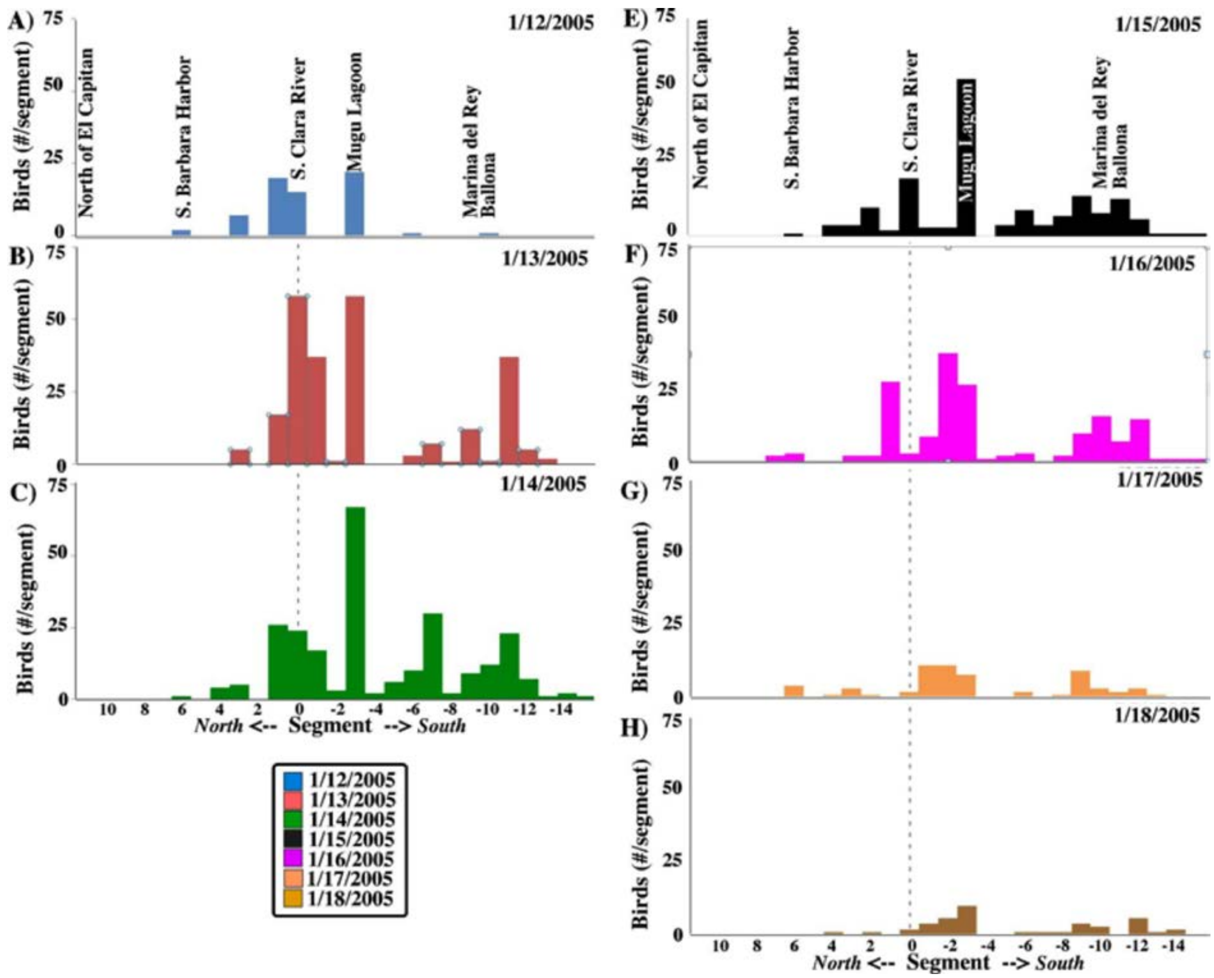

Fig. 8. Oiled birds captured by segments from 12-18 Jan. 2005. Date on panels. For segment locations see **Fig. 6** and **Table 3**.

There were strong clusters of recoveries of live birds from the vicinity of Ventura Harbor and the Santa Clara River mouth (VBA), the coastline near the Channel Islands Harbor and Port of Hueneme with the greatest number of live birds, which is associated with Mugu Lagoon (**Fig. 6, Table 3**). This 25-mile stretch of Ventura County coastline (Segments +1 to – 3) accounted for 61% of the live birds captured during the VOBI.

Approximately 9% of the live rescued birds were captured along the northern Malibu coast (Segments - 4 to -8). Nearly 21% of the birds collected during the VOBI were rescued from 20 miles of the southern Malibu coastline south to Manhattan Beach (Segments - 9 to -12), MBA. Within the latter area was a significant secondary peak in bird recoveries in northern and central SMB (Segments -11 and -12, **Table 3**) in which approximately 12% (179 individuals) of the live birds were collected from the coastal inlets associated with Marina Del Rey and Ballona Creek, 55 to 60 miles south of the Santa Clara River. Only 2% of the live birds were captured south of Manhattan Beach in SMB.

2.1 Spatial Pattern and Degree of Bird Oiling

The presence/absence of oiled plumage was recorded for only 1021 (85%) of the 1204 live individuals collected for rehabilitation. However, 48 of the 183 individuals for which oiling was not recorded, were designated as “washed” in the OWCN/PRBO log (PRBO/OWCN, 2005) and, thus, were inferred to have been oiled. This raises the total estimate of oiled birds to 1067. Two of the live birds collected during the VOBI were assessed as unoiled. Using the ratio of 2 unoiled birds to 1069 live birds among the individuals for which oiling was assessed/inferred, it can be extrapolated conservatively that less than one bird (0.25 bird) out of the 135 individuals, for which oiling was not recorded/inferred, was likely to have been un-oiled. Therefore, for this discussion, we assume all but two of the 1204 live individuals captured were oiled.

Feather samples from seven oiled were collected from the more than 1500 live and dead VOBI birds and the Ventura Weather Buoy were analyzed by the DFG Petroleum Chemistry Lab and compared for consistency/similarity to oil seeps within the SPC Study area. The oiled feathers were collected on 13 Jan. from Santa Barbara, Ventura, Pt. Mugu, Zuma Beach, Malibu, Venice, and Long Beach. This subsample included at least five WEGRs (No specific information was given which would allow us to identify two birds for which the species was not recorded - one from Zuma Beach and one from Santa Barbara). These birds were captured by field personnel from Ventura (L-102), Point Mugu (L-184), Malibu Lagoon (L-293), and Venice/Santa Monica (L-33) on 12 Jan. 2005. These birds were surrogates for and reflected movements of individuals away from the coastal section where oil was contacted.

Oil on the feathers. was consistent with oil on the Ventura Weather Buoy and similar to oil in our SPC study site. Oil chromatograms were classified as ‘Consistent’ among all seven oiled birds, from which feathers were analyzed, and the Ventura weather buoy (Leifer and Wilson, 2015). This oil was classified as ‘Similar’ to the oil from seeps within our study area (S. Sugarman, pers. comm., California Dept. Fish and Game, Petroleum Chemistry Laboratory, 2009). For two of the oiled feather samples, species, location, date and time of capture could not be determined (PRBO/OWCN, 2005).

Lt. Bryan Gollhofer collected the oiled bird feathers from the OWCN facility in San Pedro on 14 Jan. 2005. To the best of his recollection, all the feather samples were taken from WEGRs and all had to have been rescued, transported, and feathers collected on or before that date. The birds from Mugu Lagoon, Malibu Lagoon, and Long Beach had 26-50% oil cover on their feathers, while the birds from the Ventura and Venice had 51-

75% oil cover on their feathers.

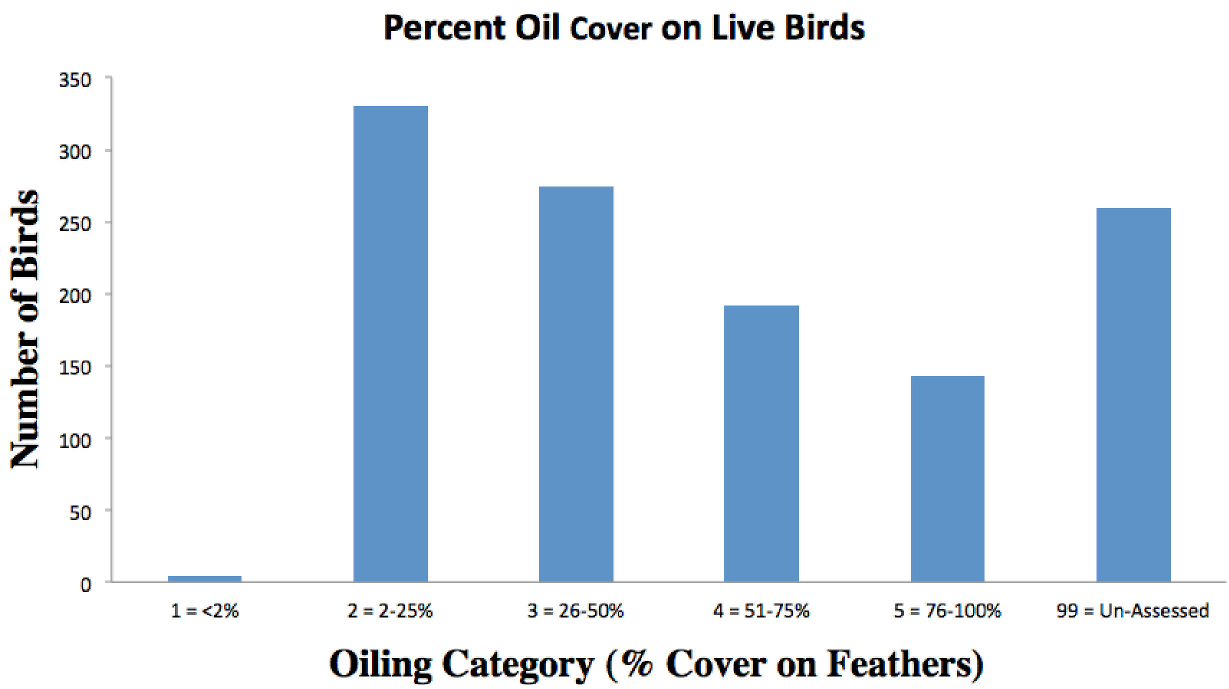

Fig. 9. Percent cover of oil on live birds.

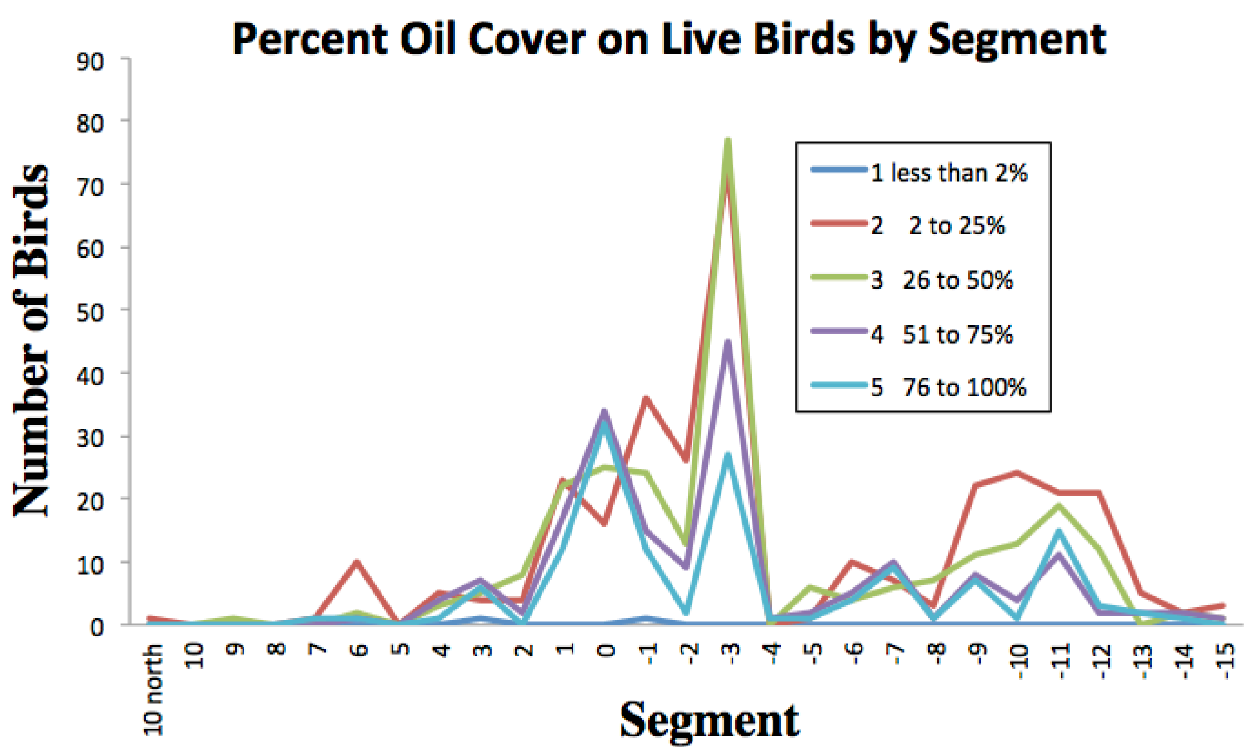

Fig. 10. Percent oil cover on live birds (captured) by segment number. See **Table 3** for segment descriptions.

Oiling status and percent oil cover on the plumage were noted by OWCN for ~78% of the captured birds according to six category intervals: Category 1 (< 2% cover) 0.3%; Category 2 (2 to 25% cover) 27.3%; Category 3 (26 to 50% cover) 22.8%; Category 4 (51 to 75% cover) 15.9%; Category 5 (76-100% cover 11.9%; and Category 99 (oiling not assessed or unoiled) 21.6% (**Fig. 9**).

Most oiled birds were recovered along the 25 miles of coastline from Ventura to Pt. Mugu (Segments +1 to -3). Oiled birds recovered along the Malibu coast and in SMB were fewer in number and less oiled. This is reflected in a comparison between heavily (light blue) and lightly oiled (red) birds around Mugu Lagoon (Segment -3) versus Santa Monica (Segment -11).

Of the affected birds, 61% with all degrees of oiling were captured from Ventura Harbor to Mugu Lagoon (VBA), primarily in harbors and inlets in the immediate vicinity of the spill. However, ~30% of the affected birds were not found in these nearby sheltering locations. Many of these oiled individuals were captured from areas to the south of Mugu Lagoon while roosting along the central and southern Malibu coastline, SMB, Palos Verdes Peninsula, as far as Long Beach. A smaller number were found to the north along the coastlines of northern Ventura County and near Santa Barbara Harbor, again in locations of shelter.

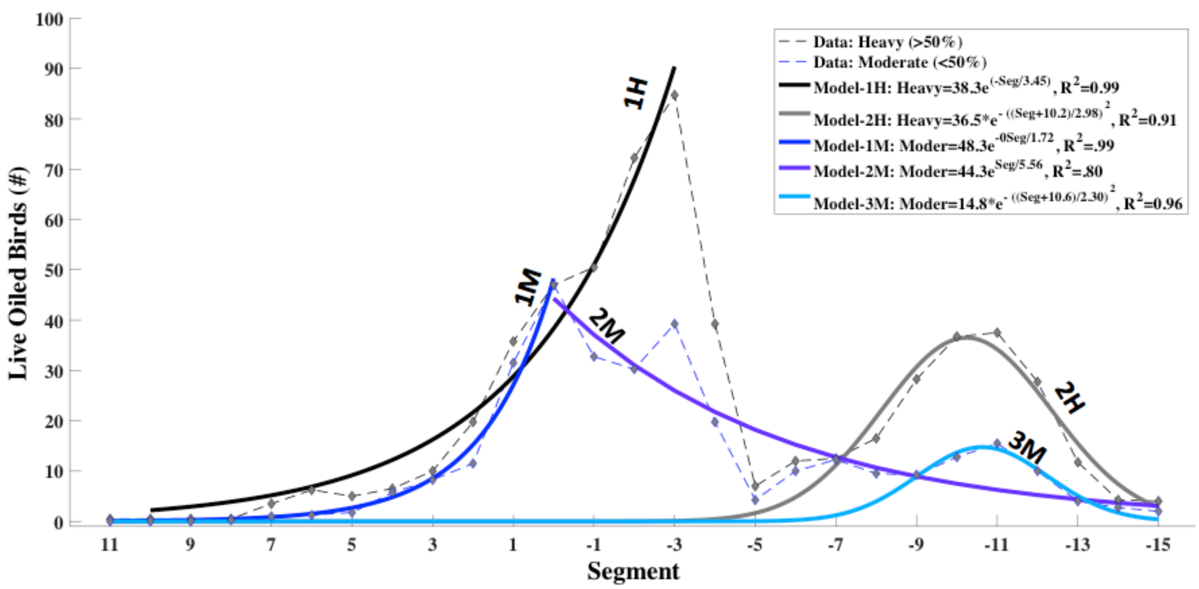

Fig. 11. Percent oil cover on live birds (captured) by segment number for moderate (2-50%) and heavy (51-100%) bird oiling classes (i.e., Fig. 10) and data models by least squares linear regression analysis. See legend on figure. Data models labeled on figure. See text for details. See **Table 3** for segment descriptions.

As noted, birds primarily were found in two nexi with the nexus closer to the source (SCR) exhibiting significantly greater percent coverage of oil on the plumage was (about double) than for the Marina del Rey area (**Fig. 8**). This pattern was found in all classes of oiling (the less than 2% category had too few individuals to discern a pattern). The spatial pattern is consistent with the oiled birds choosing locations of safety, for example, Mugu Lagoon, or Ballona Creek. Clearly, many heavily oiled birds chose to relocate to the Marina Del Rey area, implying significant and rapid movement.

The shift with time of the spatial pattern of rescued (live) birds suggested an overall movement of *Aechmophorus* grebes in a southward direction and aggregation in the Marina Del Rey / Ballona Creek area. This was demonstrated by modeling the segment data for two aggregated bird oiling classes - moderate (2-50%) and heavy (51-100%) for all collected live birds (**Fig. 10)** after applying a nearest neighbor smoothing filter. This smoothing filter removes some uncertainty associated with geo-location of birds near the edges of beach segments. Trends were close to exponential or Gaussian with clearly different length scales to the north versus to the south of the SCR mouth. A piecewise least squares linear regression analysis (Curve Fit Tool, MatLab, Mathworks, MA) was applied to the data and found correlation coefficients of 0.91 to 0.99 for most of the segments (**Fig. 11**).

The length scales to the north were 3 segments (15 miles) for heavy, and 1.7 segments (8.5 miles) for moderate oiling. By comparison there was an exponential decrease to the south for moderate oiling of 5.6 segments scales (28 miles). No exponential fit could be done for heavy oiling to the south due to the dominance of a Gaussian centered at -10.2 (segment). This estimates the asymmetry in tendency of WEGRs to continue moving in the direction of their southwards migration route at a factor of 3.3 (28 miles/8.5 miles). Alternatively, this indicates about of the moderately oiled birds that reversed course, they traveled a third as far opposite to their migration route (i.e., north). The length scale to the north for heavily oiled birds is further (15 miles). Although this could be real, it also is possible that the small Gaussian distribution at segment +6 (Santa Barbara Harbor, approximately split between brown pelicans and WEGRs) s lengthened the curve fit and may have represented a safe haven target for these birds.

There was a aggregation of birds around Marina Del Rey and area (segments -10 to -11, which was well modeled for heavy and moderately oiled birds (R^2=0.91, R^2=0.96, respectively) by Gaussian functions centered at between segments -10 and -11 (10.2 and 10.6, respectively). The heavy distribution was broader (3 segments = 15 miles) than the moderately oiled distribution (2.3 segments). A Gaussian distribution reflects different process(es) than the process(es) associated with the exponential decrease.

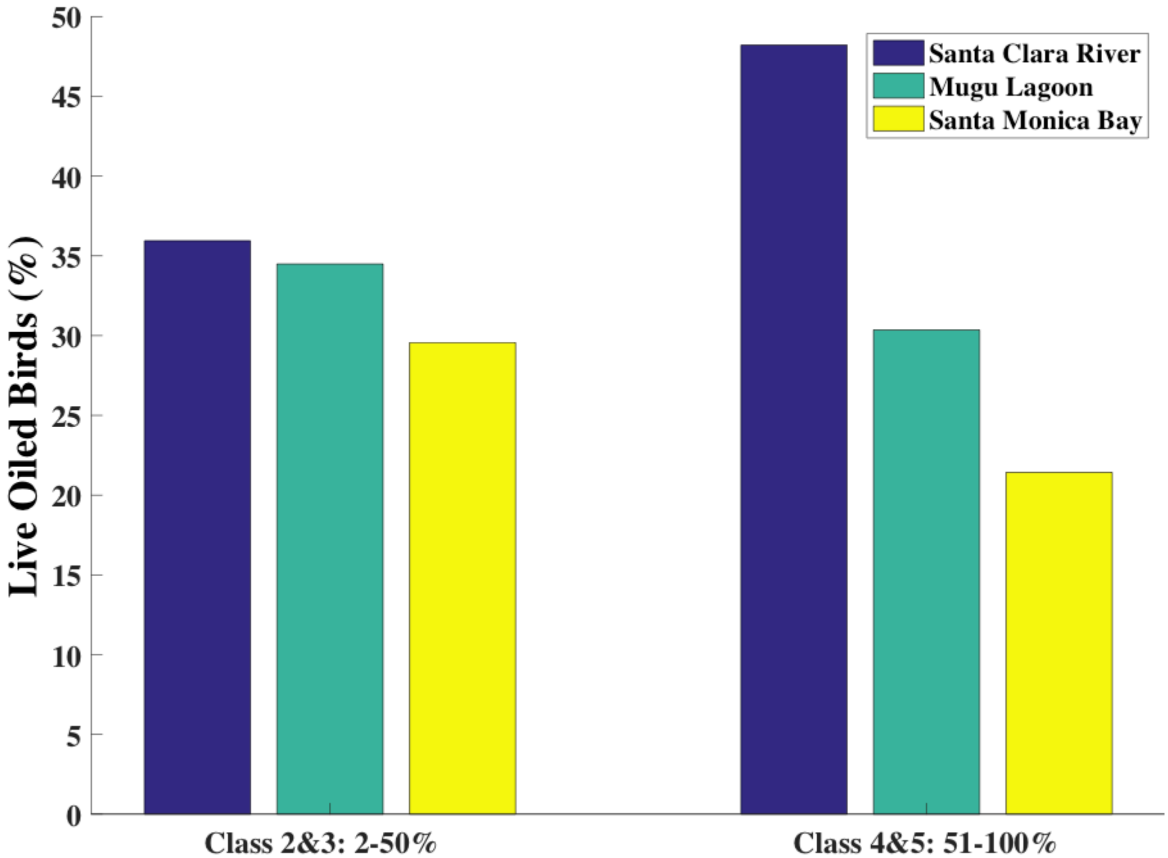

Fig. 12. Normalized bird aggregations in Santa Clara, Mugu Lagoon and Santa Monica Bay for moderate (2-50% bird oil coverage) and heavy (51-100% bird oil coverage). Data key on figure.

Bird aggregations were observed in harbors, embayment's, and estuaries such as those associated with the Santa Clara River, Mugu Lagoon SMB (**Fig. 10 and 11**). The effect of oiling on bird aggregations in these locations (**Fig. 12**) was analyzed by summing birds for segments 2 to -2, -2 to -4, and -8 to -14, respectively. The analysis considered the two aggregated bird oiling classes - moderate (2-50%) and heavy (51-100%) for all collected live birds. Birds less than 2% were too few (one) for this analysis.

For moderately oiled birds, there was no significant difference in aggregation at these three areas. Santa Clara River was significantly more likely to have heavily oiled birds than Mugu Lagoon which was more likely than SMB – i.e., inversely related to distance.

The VOBI data provides new insights into migratory movements during winter for Southern California *Aechmophorus* grebes. Specifically, southward movements were prevalent for the vast majority of *Aechmophorus* grebes from SCR to the Santa Monica Bay and further south. These data suggest the reported westward migration in fall to the coast and inland migration in spring may be followed by a southward migration during winter along the southern California coastline. These data area consistent with the limited observation from the SeaDoc 2007 study (SeaDoc, 2013), which documented a southward migrating bird along the California coast. Overall, this shows a continuation of the westward fall movements as interior winter weather develops (Feerer and Garrett, 1977) in a southward direction along the coast. Furthermore, oiled birds were not found in inland lakes or significantly more northward than the central California coast.

As the dominant oiled bird species, the WEGR distribution defined the spatial and temporal pattern of VOBI (**Fig. 13**). Locations were identified for 97% of the 1087 live WEGRs rescued during the VOBI Only 6% of the live WEGRs were taken north of the Ventura River (Segment +1). (*Aechmophorus* grebes were graphed separately so that trends could be observed).

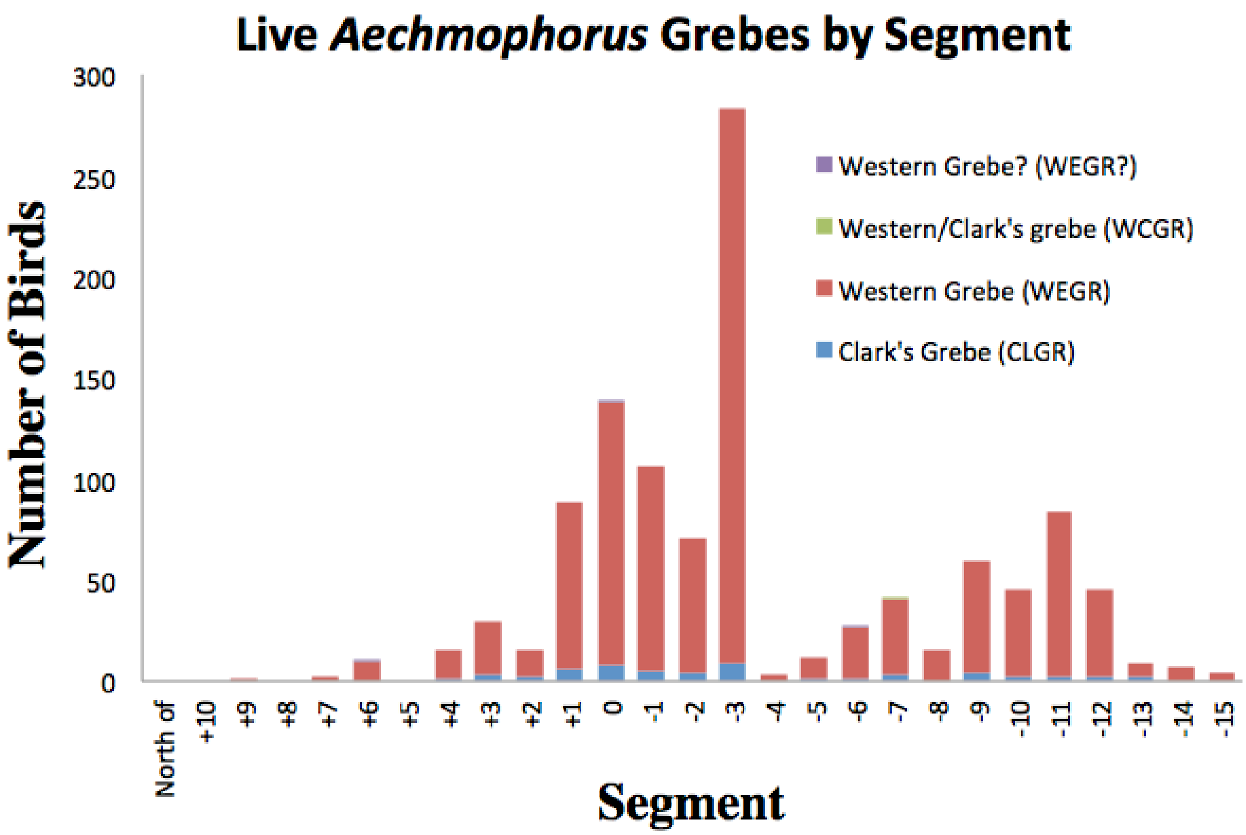

Fig. 13. Live *Aechmophorus* grebes recovered with respect to location. Bird species shown on figure. See **Table 3** for segment descriptions.

Approximately 61% of the WEGRs were recovered along Ventura County beaches, in/near harbors and in Mugu Lagoon (Segments +1 to -3). Almost 32% of the live WEGRs were recovered from beaches and lagoons along the Malibu coast, Marina Del Rey Harbor and Ballona Creek, south, to Manhattan Beach with 2/3 of these collected from (Segments -9 to -12). Less than 2% were collected south of Manhattan Beach (**Fig. 13**). In fact, by 14 Jan. 2005, only two days after the first significant numbers of oiled birds were discovered and approximately four days after the oil was observed entering the ocean on 10 Jan. 2005, a WEGR (log number L-496) confirmed to have oil on its feathers similar to oil in our study area, was recovered from Long Beach.

Locations were identified for 90% of the 61 live CLGRs captured during the VOBI. This species, closely related to WEGRs, displayed a distribution pattern similar to WEGRs. Only 11% of the live CLGRs were taken north of Segment +1 (Ventura River). Approximately 58% of the CLGRs were recovered from the 25 miles of coastline from north Ventura to just south of Pt. Mugu (VBA). Another 31% of the live CLGRs were recovered from beaches and lagoons along the Malibu coast, Marina del Rey Harbor and Ballona Creek, south to Manhattan Beach.

A total of fifty live birds of ten species other than *Aechmophorus* grebes were captured (**Fig. 14**). These accounted for just over 4% of the total number of live birds collected during the VOBI. Locations were recorded for 40 (80%) of these individuals.

The spatial distribution of species other than *Aechmophorus* grebes was somewhat different with an additional nexus noted in the vicinity of Santa Barbara Harbor (Segment +6). Birds also were found in the 15-mile section of coast from the City of Ventura south into Oxnard (Segments +1,0, and -1); and in the SMB (Segments -11 to -14). Note, no birds of species other than *Aechmophorus* grebes were collected from Mugu Lagoon (**Fig. 14**, Segment -3).

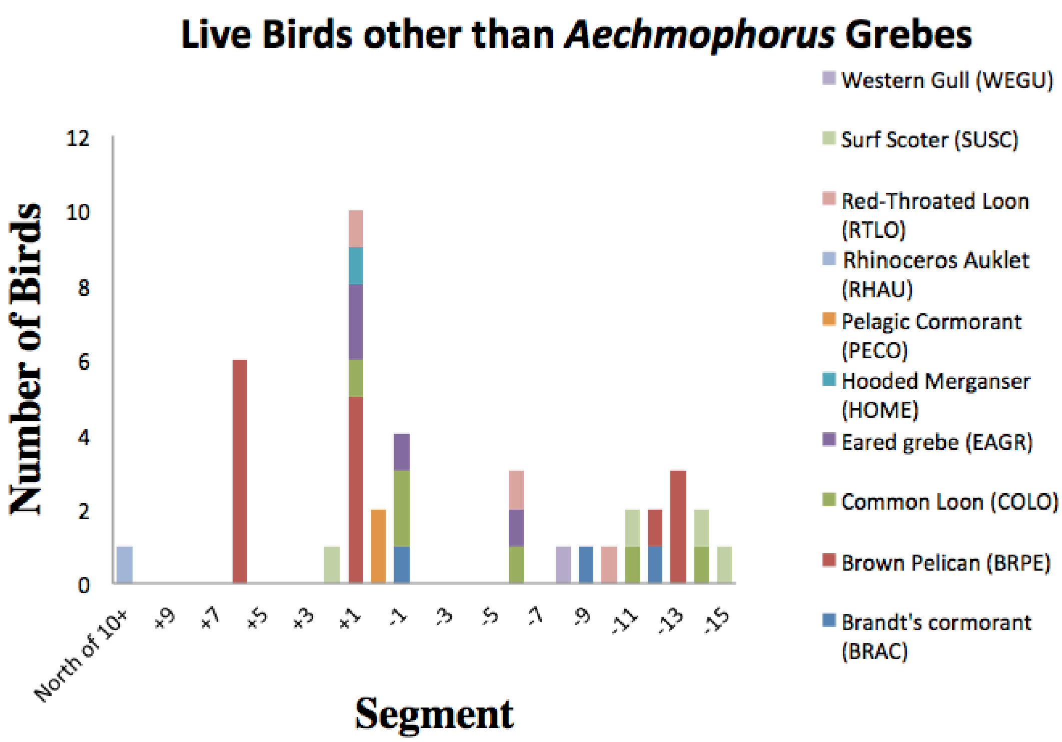

Fig. 14. Captured bird species (live) other than *Aechmophorus* grebes. Species on figure. See **Table 3** for segment descriptions.

Brown pelicans (BRPE) were the second most common species captured, after *Aechmophorus* grebes, accounting for only 1.6% (19 individuals) of the total live birds rescued during the VOBI. Two thirds of the BRPEs were taken in the vicinity of Santa Barbara Harbor and along the Ventura coast just north of the Ventura River (Segments

+6 and +1, respectively). The remaining BRPEs were captured along the central and southern SMB coastline with riprap harbors, docks, and breakwaters between Marina Del Rey and Redondo Beach (Segments -12 and -13).

Only eight common loons (COLO) were rescued. Although COLOs were the fourth most numerous species captured, they accounted for only 0.7% of the total live birds recovered. Locations were recorded for 6 of 8 individuals captured, three of which were rescued along 15 miles of coastline surrounding the SCR. The remaining three individuals were taken from SMB and the Malibu coast (**Fig. 14**). The remaining eight species accounted for a little over 2% of the total live birds collected during the VOBI (**Figs. 13 and 14**).

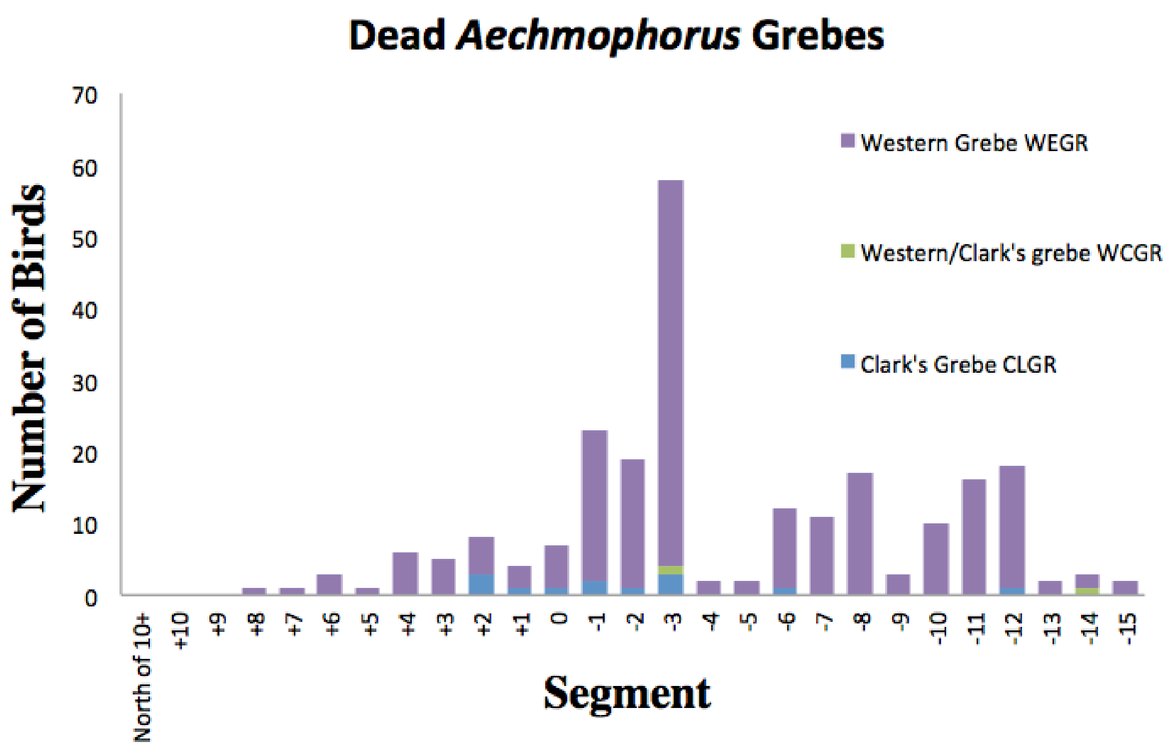

Fig. 15. *Aechmophorus* grebes recovered (dead). Bird species on figure. See **Table 3** for segment descriptions.

2.2 Birds Recovered (Dead)

The array of species of dead birds (23 – see **Figs. 15 and 16**) was more diverse than that of live species (12). Clusters of dead birds, other than *Aechmophorus* grebes were noted near Santa Barbara Harbor (Segment +6); City of Ventura to just south of Mugu Lagoon (Segments +1 to -3); and in central and southern SMB (Segments -11 to -15).

In total, 312 dead birds were collected during the VOBI of which collection locations were recorded for 92%. Of the dead birds, 82% were recovered from the mouth of the SCR, south, with ~42% collected along the 15 mile stretch of coast from Oxnard to just south of Pt. Mugu (Segments -1 to -3); 16% from the northern and central Malibu coastline (Segment -3 to -8); and 20% from north and central SMB (Segments -10 to -12). *Aechmophorus* grebes (**Fig. 15**) accounted for over 80% of the dead birds (by numbers) recovered. There are some differences between live and dead *Aechmophorus* grebes. For example while few *Aechmophorus* grebes were captured (live), most were recovered (dead) from Malibu Pier (**Table 3**, Segment 9). Dead *Aechmophorus* grebes included 236 WEGRs, 13 CLGRs, and 2 western/Clark's grebes.

Four bird species accounted for ~10% of the birds recovered dead and included BRPE (16), unidentified grebes (7), Brandt's cormorants (5), and double crested cormorants (4). The remaining 17 species accounted for only ~9.4% of the dead birds recovered. All of the dead birds but one were collected over a 13-day period between 12 and 24 Jan. 2005, and likely were unrelated to the VOBI.

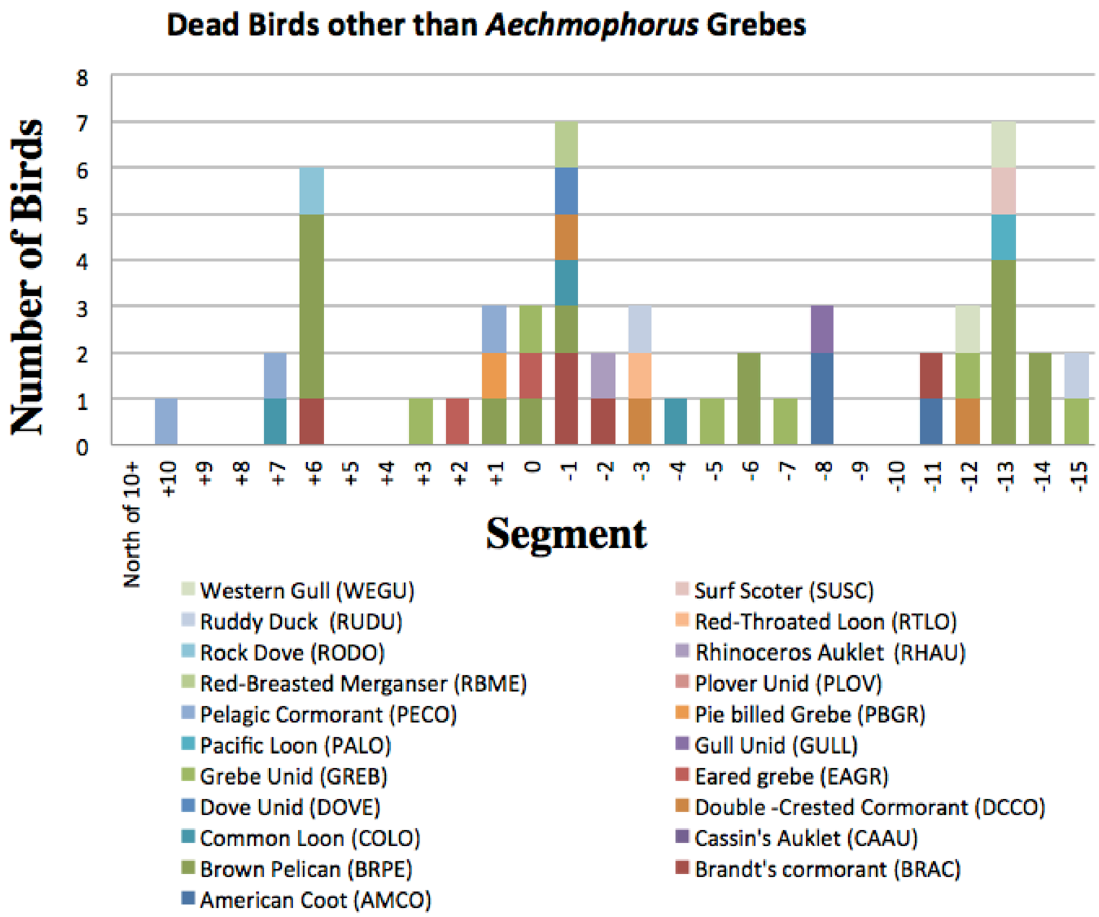

Fig. 16. Bird species recovered (dead) other than *Aechmophorus* grebes. Species listed on figure. See **Table 3** for segment descriptions.

3 Discussion

3.1 Overview

OSPR and the OWCN have responded to many large bird oiling events related to human activities: fuel oil lightering, sunken or leaking vessels, pipeline breaks, overflowing petroleum tanks or tankers, transportation accidents, etc. Bird oiling incidents and casualties occur on a regular basis; however, most are related to unknown sources of oil. In the case of VOBI, new approaches were used in this study to analyze the observations of captured and recovered birds based that considered spatial patterns. These were used to deduce factors of exposure, source, and oiled bird behavioral patterns.

Although this analysis was conducted well after the event, these approaches could and should be implemented in real time as part of future oiling event response.

3.2 Existence of a Spatial Pattern for Bird Rescue & Recovery

Because 96% of the oiled VOBI birds were *Aechmophorus* grebes (Western and Clarks grebes), the following discussion will relate primarily to the relationship of these birds to where the oil entered the Pacific Ocean.

Normally, healthy *Aechmophorus* grebes winter in sheltered coastal areas of central California on or near the shoreline, never coming ashore. Instead, they prefer to swim on the ocean surface, diving for and feeding upon small marine fishes. *Aechmophorus* grebes generally are found aggregating in coastal inlets and along shorelines, which has been substantiated by tracking data (SeaDoc, 2013).

Based on the available literature details on *Aechmophorus* grebe migration and movements are poorly understood particularly during the winter months. Typical movements are from inland lakes in California, Nevada, Utah, and Canada to maritime climates in California, Oregon, and Washington in fall, wintering along the Pacific Coast, then returning to inland lakes in the spring (Feerer and Garrett, 1977; Gericke, 2006; Kucera, 2005). Some grebes may winter in inland lakes in California (e.g., Berryessa Lake) rather than the coast (Kucera, 2005). *Aechmophorus* grebes winter as far north as central British Columbia, and as far east as west Texas, primarily along southern California, the San Francisco Bay, and the Puget Sound. Over the last three decades, there has been a growth in southern California populations and a decline in Puget Sound based on Christmas bird counts (Wilson et al., 2013). These movements correspond to moving to more moderate maritime climates from further eastward as winter develops (Feerer and Garrett, 1977). This migration can increase coastal grebe populations a hundredfold during the wintering period (Feerer and Garrett, 1977), who also proposed that some of more interior populations may nest in California lakes, based on recovery of decimated grebe populations. However, these reviews did not discuss movements during the wintering season along the Pacific Coast.

A recent study by *SeaDoc (2013)* provides some tracking data. A total of nine *Aechmophorus* grebes, had intra-coelomic VHF transmitters successfully inserted (Gaydos et al., 2011) and were released in early December 2010 with at least one individual tracked as late as Feb. 2012. The tracking data from SeaDoc (2013) showed most individuals tracked showed only local movements during the study period. Only a few survived until the fall when the two individuals were observed to migrate from the release location and return. One went inland in the fall (potentially the Upper Klamath

Lake, Oregon), and one migrated south in the fall to San Diego. Also, one individual survived into the fall but did not migrate, but remained in the San Francisco Bay area.

One possible explanation for the lack of knowledge is that most migration is thought to occur at night, although *Aechmophorus* show diurnal activity (Kucera, 2005). Furthermore, bird movement data is highly limited due to the difficulty of surgery to install transmitters until recently (SeaDoc, 2013), with the possibility that the surgery weakened birds affecting normal movements.

Oiled birds often are observed in aggregations on protected beaches and breakwaters near coastal inlets and harbors. In general, fewer oiled birds are expected with increasing distance from the oil source and/or from the area where the birds came into contact with the oil, particularly in the upcurrent and/or upwind direction(s). It is known that when disturbed, oiled grebes will fly short distances to avoid disturbances, if not too weak *(Steve Hampton and Laird Henkel,* Pers. comm., OSPR, 2008). We also hypothesize that the spatial distribution of oiled birds should reflect several factors rather than being uniform,

1. Slick extent
2. Effects of winds and currents and waves
3. Bird behavior (e.g., sheltering)
4. Bird movements (migratory, short distance, swimming)

Also affecting the spatial distribution of captured birds is the timing and focus of the wildlife response. In the case of the VOBI, the response shifted along the coast based on oiled birds observations, the number and location of wildlife response personnel, and beach access. Thus, we propose that the likely oil source can be deduced from the spatial and temporal distribution of oiled birds, and that the earliest spatial distribution of oiled birds provides insight into where the birds first came into contact with oil and thus the source.

During the Jan. 2005 VOBI response, oiled birds were collected primarily from coastal inlets and secondarily from beaches stretching from Pismo Beach, in the north, south to Corona del Mar from 12 - 18 Jan. 2005. Most birds were found from Emma Woods State Beach in mid-Ventura County to mid-SMB, in Los Angeles County. Data were logged carefully for virtually all oiled birds that were captured and/or recovered. Data included species, location, collection date and time, and amount of oil coverage. These data allowed investigation of the oiled birds' spatial and temporal distribution.

3.3 Source from the distribution

Analysis of the oiled bird logs revealed that beginning 12 Jan. 2005, large numbers of oiled birds were discovered at the Ventura Harbor and southeast to Mugu Lagoon. For this discussion, we consider these locations as a single aggregation, termed "the Ventura Bird Aggregation (VBA)." The first oiled birds were captured from Ventura Harbor near the Santa Clara River (SCR) mouth to Mugu Lagoon. By 13 Jan. 2005, the number of oiled birds in VBA doubled, and a second area of bird aggregation developed in the northern Santa Monica Bay (SMB) area, termed the Marina del Rey Bird Aggregation (MBA) (**Fig. 8**). For both aggregations, birds mostly were captured and recovered in or near harbors and coastal inlets. It is worth noting that on 12 Jan. 2005, virtually no oiled birds were found in the SMB area, which is used heavily by the public. Thus, it seems inevitable that if oiled birds had been present in unusual (i.e., significant) numbers, OSPR would have been notified quickly and directed the response accordingly.

3.4 Bird movement from temporal distributions

The shift with time of the spatial pattern of rescued (live) birds suggested an overall movement of *Aechmophorus* grebes in a southward direction. This trend was reflected in the wildlife response – i.e., where personnel were mobilized. As noted, a distinct second bird aggregation (MBA) developed on 13 Jan. 2005, where captures increased over the next two days. Moreover, the MBA grew in importance relative to the SCR mouth area (VBA) over the duration of the VOBI (**Fig. 8**). In contrast, no significant oiled bird aggregations were observed to the north of SCR. For example in inlets near Santa Barbara, such as Santa Barbara Harbor, just a few birds, primarily oiled brown pelicans, were captured.

Again, heavy public use of beaches along the Los Angeles beaches and coastal inlets would argue that if large numbers of oiled birds were present in the SMB area during the first day of the VOBI, i.e., 12 Jan. 2005, they would likely have been reported.

The VOBI data provides new insights into migratory movements during winter for Southern California *Aechmophorus* grebes. Specifically, southward movements were prevalent for the vast majority of *Aechmophorus* grebes from SCR to the SMB and further south. These data suggest the reported westward migration in fall to the coast and inland migration in spring may be followed by a southward migration during winter along the southern California coastline. These data area consistent with the limited observation from the SeaDoc 2007 study (SeaDoc, 2013), which documented a southward migrating bird along the California coast. Overall, this shows a continuation of the westward fall movements as interior winter weather develops (Feerer and Garrett, 1977) in a southward direction along the coast. Furthermore, oiled birds were not found in inland lakes or significantly more northward than the central California coast.

These studies do not preclude a separate population of grebes that remain at coastal wintering sites without further migration. Thus, some of the captured and recovered grebes could be part of a non-migrating grebe population. Supporting the hypothesis that some *Aechmophorus* grebes may be non-migratory was data on one individual bird in the SeaDoc study that did not migrate (SeaDoc, 2013).

3.5 Spatial asymmetry of oiled birds

Although currents and prevailing winds were to the south and east (Leifer and Wilson, 2015)**,** distances to the SMB and the southern Malibu coastline are significant, likely too far for birds, primarily *Aechmophorus* grebes, to have drifted passively or to have swam in the few days between oiling and capture. Therefore, we hypothesize that they must have flown much of the distance to their capture locations. We evaluated this hypothesis by reviewing the distances involved for both coastline distance and straight-line distance from the presumed southernmost extent of the spill (near Pt. Mugu) to their points of capture. This analysis is conservative, because these distances probably should be calculated from the SCR mouth or midway between Mugu Lagoon where most of the oiled birds were rescued and the SCR mouth where the oil presumably entered the ocean.

Movements of oiled birds toward their capture locations likely occurred starting during the timeframe from 9 to 10 Jan. 2005, shortly after oil was presumed to have entered the Pacific Ocean and birds became oiled. Movements of affected birds continued until individual birds became too weak to move and began to seek shelter, were captured, or died. Birds were observed first to the south of Mugu Lagoon on 13 Jan. allowing a maximum of about three days for transit. Thus, birds, specifically *Aechmophorus* grebes, would have had to have moved 22 to 25 miles from Pt. Mugu area to Malibu Lagoon, 33 to 36 miles between Venice and City of Santa Monica, and 57 to 76 miles to Long Beach in just three days. These capture locations suggest movements of as much as 20-30 miles per day, which assumes an unreasonable non-stop swimming speed of 2 miles per hour, assuming the birds rest, groom, and feed during daylight hours when they are not observed to fly, or drifting if surface currents were in the southeast direction. However, coastal current data contained data gaps in the key area between Santa Monica Basin and Santa Barbara during this time period (Leifer and Wilson, 2014, **Fig. 10**). Specifically, sea surface currents on 12 Jan. were weak, but favorable for southeast bird movements, but on 13 Jan. persisting became unfavorable, coinciding with winds that shifted from the west to from the north (offshore) on 11 Jan. (Leifer and Wilson, 2015). Thus, overall, it seems more probable that oiled individuals flew from their oiling location to SMB, rather than swimming, particularly, given that migration of grebes by flight has been documented (to and from interior lakes).

Only 0.6% of the 1204 live birds captured during the VOBI were examined to determine the state of molting of wing feathers. The VOBI dead bird log was statistically far more significant and showed that wing feather molting was observed on 86% of the 248 *Aechmophorus* grebes recovered during the VOBI. Just fewer than 31% of the dead grebes displayed evidence of molting flight feathers (and thus could not have flown prior to their demise); just over 16 percent showed varying degrees of molt; and no data were gathered on 14 percent of the individuals.

Although inland to coastal migration of *Aechmophorus* grebes involves flight, migratory flight in coastal areas has not been documented. Some observers have noted that much of the grebes migratory movements occur on the water surface. For example, SeaDoc (2013) concluded for three birds that left the San Francisco area,

> “The grebes are ONLY SWIMMING. (They fly just twice a year, to migrate) [original emphasis],”

however, for one individual that migrated from San Francisco to San Diego, they note

> "Update 12/12/11: Bird #97617 flew south to the outer coast of California near San Diego. Crazy bird! This is unexpected, as we thought birds stayed put during the winter".

One possible explanation is that movement by flight could occur nocturnally, when migration is thought to occur (Kucera, 2005). This is consistent with a lack of daytime flight observations (Steve Hampton, Pers. comm., OSPR, 2012).

3.6 Bird oiliness consistent with bird movements and distance

The spatial distribution of live birds was related to the percent oil coverage on their plumage (**Fig. 10**), of which most oil-affected birds during VOBI were *Aechmophorus* grebes. There were more birds that were more heavily oiled in the proximity of SCR mouth. This reversed for Mugu Lagoon, where there were more birds that were less heavily oiled. Specifically, birds with more than 50% oil coverage were less common in Mugu Lagoon than those with less oil. The number of birds in Mugu Lagoon with 2-25% and 26-50% oil coverage were the same, while more heavily oiled birds were relatively less common. This suggests birds with less than 50% coverage made it to Mugu Lagoon but more heavily oiled birds had increased difficulty in moving far from the oiling location. Consistent with this was greater number of dead birds immediately south of SCR mouth (**Figs. 15 and 16**), than at the mouth despite large numbers of heavily oiled birds captured at the SCR mouth. The highest number of dead *Aechmophorus* grebes (58 individuals) were recovered from Mugu Lagoon (**Fig. 15**), compared to 285 live individuals (**Fig. 13**). The ratio of dead birds near SCR was higher than in SMB, reflecting the weakened state of the population of birds.

In comparison, at the SCR mouth a population of 141 live birds was twenty times that of the recovery of seven dead birds. This increasing mortality likely reflects the weakened state of birds being captured at Mugu versus SCR.

This observed spatial distribution became more clear in the SMB area, where there was an inverse relationship between number of live oiled birds and percent cover of oil on the plumage for all birds. Specifically, there were more lightly to moderately oiled birds in the SMB area and fewer heavily oiled birds than in locations nearer the mouth of the SCR.

This demonstrates that while few heavily oiled live birds and some moderately oiled birds could make it as far south as Mugu Lagoon, a lower percentage of heavy to heavy/moderately oiled birds moved south of there. Birds that moved as far as SMB tended to have lesser amounts of oil on their plumage. Relatively few heavily to heavy/moderately oiled birds were observed in the SMB area.

The relationship between bird oiliness and movements shows that weakened birds were more likely to remain closer to where they were affected, either due lack of energy or motivation. This behavior suggests that birds weakened for other reasons, such as surgery, may have reduced movements. These insights demonstrate the value of analysis of the very large data set collected during a major oil event to provide insight into bird behaviors.

After nearest neighbor filtering, it was noted that the distribution of live oiled birds appeared to vary along a natural law, investigated by observational modeling. Data for dead recovered birds was too noisy, and no modeling was attempted. These distributions are overwhelming represented by *Aechmophorus* grebes and thus reflects the patterns and responses and behavior of a single species rather than many species. Specifically, either Gaussian functions or exponential functions were fit to the data with the correlation coefficient R^2, for one exponential fit 0.8, and the other four had R^2>0.91, up to 0.99 (**Fig. 12**).

In general, exponential functions are the solution of an equation of form “dn/dz=-kn,” where n is number, and z is beach segment or distance and k is a constant, which is the progressive fractional loss rate. For example, this implies if a population of free birds starts with 100 birds, 10% are lost in the first beach segment, leaving 90 birds – 10 captured or recovered along the segment). Then an additional 10% are lost (captured or recovered) on the next beach segment, leaving 81, and so on.

Thus distributions that were well fit by exponential function are indicative of this type of continuous percent loss of individuals. The heavy and the moderately oiled bird spatial distributions to the north of the SCR mouth decreased exponentially with length scales of 3.4 and 1.7 segments, respectively – i.e., these are birds whose movement was opposite the direction of migration. It may be notable that the more heavily oiled birds went further against the direction of migration the moderately oiled birds.

Secondly, the Moderate and Heavily oiled bird spatial distributions were well fit by Gaussian functions centered on Santa Monica Bay. Both exhibited similar half widths of 3.0 and 2.3, respectively. Gaussian functions are typically used in nature to describe spreading and diffusion by turbulence – specifically, the transport away from the center depends on the gradient. This is indicative that the bird distribution related to the suitability of habitat in each beach segment, which decreased with distance from segment -10.

In future oil spills, improved GPS location and better oil coverage estimates will improve the ability to model the spatial distribution of oiled recovered and captured birds. Clearly these distributions relate to the behavior of the birds. Therefore, better data and modeling in future spills are a largely untapped potential to improve our understanding of the behavior of different bird species.

3.7 No Evidence for a Second VOBI Oil Source

Another possibility that was considered is if there was a second oil source in the Santa Monica watershed of Ballona Creek that could have been related to a second but nearly concurrent incident. However, the relatively gradual increases in reports and capture of oiled birds and the type of oil occurring on analyzed feathers argues against a second oil source.

Although there are known oil sources in the Santa Monica watershed, some of which are in the La Brea area (Hodgson, 1987), chemical fingerprinting from all the bird feathers analyzed, confirmed a Santa Clara River watershed origin for the oil. This was consistent with the spatial distribution analysis that concluded the oiled birds originated from the vicinity of the Ventura Bird Aggregation. Note, the oil fingerprinting sample size was small (seven birds).

Additional evidence against a local oil source of significance to the VOBI in the Santa Monica area comes from the spatial distribution of captured *Aechmophorus* grebes as related to the percent oil coverage on their plumage. If there had been a significant oil source in the Santa Monica watershed, there likely would be a positive relationship between bird oiliness and number of live birds in the Santa Monica area. Specifically there likely would be greater numbers of more heavily oiled birds than of moderate to lightly oiled birds, as observed for areas near the mouth of the SCR. Other oiled birds such as brown pelicans moved both north and south of the mouth of the Santa Clara River.

3.8 Oiled birds were near slick (Ventura-Mugu) and went to inlets

Approximately 61% of the live and dead oiled birds along the southern California coast for were found between Ventura Harbor and Mugu Lagoon (**Fig. 6**, **Table 3**). Thus, we hypothesize that the surface slick (never directly observed by responders) was advected seaward from the SCR mouth (at least three-quarters of mile or more) by currents in a southeast direction extending as far south as Mugu Lagoon before it dissipated. The predominance of heavily oiled birds compared to lightly oiled birds along this 20 mile stretch of coast suggests that most were affected by the heavier parts of the surface slick.

The long-distance movements of *Aechmophorus* grebes were primarily inferred to be from flight, although some of the distance likely was covered by swimming. This is based on the timing, oil slick exposure, and percent cover of oil on the plumage. However, if currents were favorable, swimming and drifting oiled birds could have moved longer distances without flying. Another affecting factor is molting.

The live bird sample size was too small to assess reliably the ability that captured *Aechmophorus* individuals would have had to fly between the time of oiling and the time of capture. However, the dead bird log suggested a significant fraction of the population (or at least the dead population) was in some state of molt. The absence of flight feathers in *Aechmophorus* grebes, a seasonal phenomenon, certainly precludes flight until the feathers have regrown. The presence of flight feathers does not, however, provide definite assurance of the ability of oiled birds to fly.

Only a small percentage of oiled birds, which primarily were *Aechmophorus* grebes, moved north of the City of Ventura (**Figs. 6 & 8**). These live and dead birds primarily were found along the coastline north of the City of Ventura and into southern Santa Barbara County. Aside from *Aechmophorus* grebes, these live birds here consisted of several brown pelicans and a *Rhinoceros* auklet (**Fig. 14**), while dead birds found northwards comprised a few individuals from a range of species (**Fig. 16**).

Normal grebe activity includes swimming and foraging in nearshore coastal waters and lagoons (Steve Hampton and Laird Henkel, OSPR, *Pers. comm.,* 2011) and southward movements (SeaDoc, 2013). The analysis presented in this report suggested that many heavily and moderately oiled birds altered their normal activities. Specifically, debilitated birds ceased feeding and rafting activities and moved to areas where they roosted on pocket beaches in lagoons, harbors, and estuaries–i.e., protected coastal areas. Such environs would facilitate ‘warming up’, and were observed resting or actively preening their plumage in an effort to remove the oil from their feathers.

3.9 Time Delay for Appearance of Oiled Birds

The major oil mass likely entered the ocean between the 9-10 Jan. 2005 (Leifer and Wilson, 2015). The delay before the first recovery or capture of oiled birds (**Fig. 8**) relates to the species, the amount and type of oil to which the birds are exposed, the time for birds to encounter the oil, and environmental conditions. Depending upon their susceptibility, birds eventually weakened, become debilitated and eventually found their way to protected areas. The delay also relates to the presence of observers – i.e., for reports to reach spill response agencies. This gap was several days. However, the increase in number of birds found on 13 Jan. 2005 compared to 12 Jan. 2005 and the evolving spatial distribution, suggested most of the delay was not due to a lack of observers – in part because many southern California beaches are heavily trafficked by the general public and individuals from governmental agencies. Note the number of wildlife response personnel peaked on 14 Jan. 2005.

3.10 Santa Barbara Bird Rescue (Brown Pelicans)

As noted, some birds, primarily brown pelicans, moved northwards to the vicinity of Santa Barbara Harbor, while other brown pelicans remained at the SCR mouth area, and a few flew south to the Ballona Creek - Redondo beach areas (**Figs. 14 and 16**). Furthermore, dead pelicans were recovered almost entirely at these locations rather than points in between (**Figs. 14 and 16**). This is in contrast to the spatial distribution of *Aechmophorus* grebes (**Fig. 13**), which as noted, shifted southwards with time, consistent with their possible migration pattern. We hypothesize that the brown pelican distribution was less directional because oiled birds moved all directions from the mouth of the SCR showing no evidence of migratory behavior, although the statistics are poor. Furthermore, they clearly preferred to move to areas with breakwaters, estuaries, and harbors.

3.11 Response Mobilization

The VOBI initiated a major bird oiling response involving 530 wildlife responders from start to finish. Activities involved the complete spectrum of wildlife response efforts including deployment, search, capture, transportation, intake, stabilization, cleaning, feeding, monitoring, and release. Search and capture occurred during daylight hours and rapidly ramped up after the appearance of the first oiled birds. Oiled bird observations were diligently logged in terms of species, location, date, and time in virtually all cases, and often amount of oil on the plumage. This enabled the analysis in this study, which was used to deduce oiled behavior and patterns of movement, as well as the likely distribution of oil on the sea surface.

Most of the VOBI response effort focused on areas where the largest number of birds were reported the previous day, with some responders providing rapid surveys of distant beaches to identify new areas where oiled birds were reported. Thus, there is a lag between identifying a new area of bird oiling and the response. Reports from the public and local agencies played an important role particularly in areas of active public use or official observation (such as harbors) and aided the response to identify areas for focus.

3.12 Response Effectiveness

Of the 1204 birds captured, a total of 239 birds (~20%) were rehabilitated and released. Approximately, 63% of the rehabilitated birds were treated and released within 5-10 days of arrival. A total of 8% of the birds were under care between 30 and 78 days prior to being considered sufficiently healthy for release.

The survival rate was poor, only 20%, and was driven by the low survival rate of *Aechmophorus* grebes, the dominant oiled birds species (**Fig. 5**). In contrast, although few (19) brown pelicans were captured, survival rates were high (95%). This demonstrates a high sensitivity to oil for *Aechmophorus* grebes, but also relates to other factors like oil composition, and environmental factors that would affect bird stress (Aguilera et al., 2010). Still, this represents a significant improvement over earlier rehabilitation rates. For example, Smith (1975) reports that of 4686 captured birds, which were mostly “grebes and ducks” [the latter probably being scoters] from the 17 Jan. 1971 Standard Oil tanker spill, only 220 were rehabilitated successfully, a 4.7% rate.

4 Recommendations

The finding that *Aechmophorus* grebes tended to seek out protected coastal areas after being oiled, suggests that initial wildlife rescue and recovery for future oil spills should focus on inlets and harbors and protected beaches. Priority should be given in the downcurrent or downwind direction, or in the case of migratory birds, the direction of migration. Clearly, this latter factor depends on the species and time of year.

For birds that do not display migratory behavior (such as brown pelicans during VOBI), initial response and recovery focus should be on inlets and harbors and protected beaches in all directions spreading from the source.

The spatial analysis in this study, performed over nearly a decade, could in principle, be conducted in near real-time, which would improve allocation of response assets. For example, as soon as a spatial pattern was detected that suggested migratory directionality, local observers (e.g., harbor personnel, Audubon Society and other bird societies, etc.) could be recommended to keep a watch at harbors and protected inlets in advance of the predicted likely arrival of oiled birds.

The analysis would have been improved if GPS positions had been recorded for all oiled birds. GPS tagged photos such as now are common on smart phones, could improve upon this significant record. In general, observers should be cautioned against using local beach names (e.g. “Hendry’s Beach”, “Family Beach” or general names (e.g. “Ventura,” “Santa Monica,” “Boat Ramp”) to identify a location – this created the greatest uncertainty in this study for bird mapping. Moreover, some species were not properly identified, which if a photo was recorded of each bird recovered or captured, could be subsequently analyzed for species identification. Thus we recommend GPS tagged photos should be recorded of all affected birds.

Further support that the locations had a precision of one to two beach segments was shown by the model (Fig. 12), whose fit was dramatically improved by nearest neighbor averaging. GPS tagging would have improved location to a few tens of meters.
Hard copies of beach maps could be made available to field responders, or electronic map copies could be made available online for downloading that could be used to precisely map the individuals’ locations, and mobile phone apps can also be useful in some areas with cell coverage. Finally, the public should be educated as to how they can aid the response by providing accurate and useful information to response personnel in a timely manner.

The analysis of the oil coverage showed a lot of variability between segments and classes, leading the analysis to aggregate classes 2 and 3 and also classes 4 and 5 (**Fig. 13**). Some portion of this variability is natural (stochastic), but a significant fraction is likely observer accuracy (which relates to training). Future spill response protocols should require that photographs be taken of all oiled birds (live and dead) to confirm percent coverage and to allow for later re-analysis. It would be helpful for the lab assessment to have training in this parameter from, for example, a database of oiled bird coverage images on line for reference.

It is understandable why live captured oiled birds were not examined for molting, to avoid adding stress to these birds. However, of the captured birds, most died during the VOBI response, and post mortem photos could have documented important information such as whether the birds were in a state of molting. We recommend photos be logged of all captured birds that died.

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Appendix 1 – Live (Captured) Bird Log

Appendix 2 – Dead (Recovered) Bird Log