Field Testing a Surgical Technique for Intracoelomic Satellite Transmitters with Percutaneous Antennae to Assess Post-Release Survival and Movement of Western Grebes

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ABSTRACT

Western Grebes (*Aechmophorus occidentalis*) are in decline along the western coast of the United States. Often they are impacted by oil spills and natural seeps when wintering along the Pacific coast, however little data are available on Western Grebe winter site fidelity, which can be important when determining potential exposure to oil spills. In addition, post-oiling mitigation of Western Grebes has previously focused on improving summer breeding grounds, however migration patterns between wintering and summering grounds are not well known. We used a captive-tested surgical procedure to implant Western Grebes with intracoelomic satellite transmitters with percutaneous antennae to field test this technique as well as to gain more information on winter site fidelity and migration. Birds were captured in early December 2010 in San Francisco Bay, California and implanted with transmitters. Nine birds survived surgery and were released, and with the exception of one bird, all survived at least 25 days suggesting a lack of surgery-related complications for 8 of the birds, however the 44-56% mortality seen within the first year post-surgery is believed to be related to the transmitter or antenna and necessitates more work before this surgical technique is used widely. Post-release winter movement of released birds showed that birds mostly remained within San Francisco Bay suggesting high winter site fidelity. Two complete migrations were documented: one bird traveled from San Francisco Bay to Upper Klamath Lake in Oregon in July and returned to San Francisco Bay in November, and another traveled south to San Diego and then back to San Francisco Bay in December the 2nd winter post-release. More studies are needed to further characterize the winter site fidelity and migration of Western Grebes and improving the surgical technique and transmitter design should enable implanted satellite transmitters with percutaneous antennae to be used for this work.

Keywords: Aechmophorus occidentalis, migration, site fidelity, surgery, telemetry, transmitter, Western Grebe.

Western Grebe (*Aechmophorus occidentalis*) populations are declining along the west coast of North America (Anderson et al. 2009, Burger 1997, Ivey 2005) where they are one of the most commonly impacted species in oil spills (Ivey, 2004, OWCN, unpub. data). Numerous larger spills have had significant impact on Western Grebes off the coast of Washington, Oregon and California (Carter 2003; Smail et al. 1972; Page et al. 1990; and other citations) and there is strong evidence that low volume oil spills chronically kill small numbers of wintering Western Grebes (Burger 1993, Speich and Wahl 1986, L. Henkel unpub. data). The majority of grebe mortality caused by oil injury happens between November and February (OWCN, unpub. data), when the number of grebes is high along the western coast of North America (Storer and Nuechterlein 1992). Little information is available on Western Grebe migratory patterns between summer and wintering habitats, as well as winter site fidelity, which can be important when determining potential exposure to oil spills or when mitigation after oil spills. Response efforts have focused on capture and rehabilitation of oiled birds and post-spill mitigation efforts have focused on restoration of summer nesting habitat (*American Trader* Trustee Council 2001; *Luckenbach* Trustees Council 2006).

Post-release tracking and evaluation of rehabilitated grebes after rehabilitation from oiling and actual linking of Western Grebe wintering sites with summer breeding habitat have both been hindered by a suitable technique for implanting transmitters (Gaydos et al. 2011). The goal of this study was to field test a technique for monitoring post-release survival and movement of

Western Grebes impacted by oil spills. A prior study (Gaydos et al. 2011) determined that with minor surgical modifications, a common surgical technique for implanting intracoelomic transmitters with percutaneous antennae could be used successfully to implant Western Grebes with satellite transmitters in a captive setting. We used the modified surgical procedure that was successful in a captive setting, this time releasing the birds back into the wild post-surgery. Additionally, this project was designed to learn about Western Grebe winter movements and migration patterns between marine wintering sites to summer breeding grounds on freshwater lakes.

MATERIALS AND METHODS

Capture, Care and Housing

Ten Western Grebes were captured from several locations around San Francisco Bay, California over a two-day period in December 2010 using a modified neutrally-buoyant gill net technique (Breault and Chang 1990). All birds were after hatch year, and sex was determined based on measured bill length. Of the captured birds, four were female, five were male, and two were of unknown sex (Table 1). Body weights were obtained at the time of capture and daily thereafter. Captured birds were temporarily housed on elevated, netted platforms within plastic transport crates and provided oral fluids. On the day of capture, all birds were taken to a research facility at the University of California, Davis, California where they were housed indoors in 3 m-diameter fresh water rehabilitation pools. Water was maintained at 16º C and depth at a minimum of 1.3 m to allow birds to swim, dive, and forage. Air temperature was maintained at 18º C. Birds were force-fed 3-6 whole freshly-thawed Night Smelt (*Spirinchus starski*) or Capelin (*Mallotus villosus*) twice daily (approximately 120 gm total / day). To prevent aspergillosis infection, which often is associated with housing birds in captivity, grebes were given 15 mg/kg of Itraconazole (Sporanox, Amerisource Bergen, Valley Forge, PA 19482, USA) orally at the time of capture and once daily until released. Birds also received Meloxicam orally (0.5 mg/kg; Metacam, Boehringer Ingelheim Vetmedica, Ridgefield, CT 06877, USA) when captured and once daily until released. Grebes were individually identified with a plastic leg band and a U.S. Fish and Wildlife Service metal leg band. All birds were given one dose of an oral multivitamin supplement containing thiamine (Sea Tabs, Pacific Research Laboratories, San Diego, California USA). Birds were clinically evaluated daily by a veterinarian and housed in captivity for 24-48 hours post-surgery, after which they were released close to their capture locations.

Clinical Pathology

On the day of capture birds were bled via jugular venipuncture for evaluation of blood parameters including complete blood counts (total granulocyte count, packed cell volume, total white blood cell count, heterophil number and percent of total, lymphocyte number and percent of total, basophil number and percent of total, eosinophil number and percent of total, and monocyte number and percent of total), plasma chemistries (fibrinogen determined using heat precipitation method, glucose, blood urea nitrogen, creatinine, sodium, potassium, total carbon dioxide, amylase, lipase, calcium, phosphorus, cholesterol, triglycerides, uric acid, aspartate aminotransferase, alanine aminotransferase, lactate dehydrogenase, creatine phosphokinase, and gamma-glutamyl transpeptidase), plasma protein electrophoresis profiles (total protein, pre-albumin amount and percentage of total protein, albumin amount and percent, alpha-1 globulin amount and percent, alpha-2 globulin amount and percent and gamma globulin amount and percent), and corticosterone levels.

Surgery

All birds were mask-induced with isoflurane, intubated, and maintained on isoflurane with 100% oxygen. Using a previously described procedure (Gaydos et al. 2011), birds were implanted with ARGOS platform terminal transmitters (PTT-100; Microwave Telemetry Inc., Columbia, Maryland, USA) with external percutaneous whip antennae. All grebes had a 1cm^2 piece of porcine small intestine submucosa (SIS) (Vet BioSISt, Smiths Medical North American, Wankesha, Wisconsin, USA) placed over the base of the transmitter antenna prior to implantation, with the exception of one bird (# 97617). Six of ten birds (#'s 97615, 97616, 97618, 97620, 97621, 97622) received 10cc Lactated Ringers Solution IV pre- or intra-operatively.

Platform Terminal Transmitters

The implanted PTTs weighed 26 g, representing 1.8 – 2.5% of adult body mass (Table 1), and were equipped with batteries that had 400 hours of transmission time. The PTTs had a duty cycle of 6 h on/19 h off for the first 25 cycles (30 d), then switched to 6 hrs on/75 h off for the remainder of the life of the battery. The expected battery life was about one year, however, two PTTs continued transmitting past the one-year mark. In addition to location, the PTTs also had sensors for temperature and battery voltage. This allowed distinction between mortality (when the temperature sensor went from that of a live grebe and dropped steeply, remaining below

100^{o}F), or battery failure, when the sensor was below 3.73 volts. Transmitter temperature reading in conjunction with PTT transmission days was used to determine post-release mortality.

Locations of the PTTs were processed using an algorithm based on the Kalman filtering approach (Argos Service 2011), which provides a greater number of positions and has improved position accuracy compared to the least squares method. Locations are classified based on type of location, estimated error, and the number of messaged received. Based on these criteria, data were excluded from analyses that were of class type Z, A, B, 0 (>1500m error, <= 4 messages; Argos User's Manual 2011). We also excluded positions that fit the above criteria but were obviously incorrect (i.e., more than 200 miles offshore). In addition, we filtered the raw location data based on temperature, using 100°F as our cut-off point for temperature, (the temperature at which medical intervention would be warranted). The number of final locations used in the analyses (after the filters were applied) was 1,629.

Statistical Analyses

All statistical analyses were performed using appropriate software (SPSS 17.0 and STATA v.12), and p-values < 0.05 were considered significant. We examined the correlation between the number of days of post-release survival and the weight of the bird at capture to assess any relationship between these two variables. We used a kernel density estimator (Seaman and Powell 1996) with MATLAB R2012a software to estimate the winter home range size for each of the nine individuals from release on 12 December 2010 to 21 March 2011 (the first winter).

RESULTS

Nine of ten birds were successfully implanted with transmitters and subsequently released. Post-release, all birds survived at least 25 days. Mortality (as deduced from the internal temperature sensor) occurred on days 5, 25, 39 and 123 post-release (Table 1). The PTTs in two of the birds had suspected battery failure after transmitting for 68 and 143 days; two birds survived until battery depletion of the PTT, transmitting for 436 and 454 days post-release (Table 1). The fate of one of the grebes (# 97615) is undetermined, as both the battery voltage and temperature were within normal range when it stopped transmitting abruptly at day 47 post-release. If this bird survived, post-release survival was 56% (5/9), if it died, survival was 44% (4/9). There was a positive but non-significant correlation between post-release survival and capture weight ($F_{1,7} = 3.81$, $r^2 = 0.35$, $n = 9$, $p > 0.05$; Fig. 1). Of the four heaviest birds (one male and one female), two were among the bird that transimtted the greatest number of days post-release (over 400 days). However, based on the PTT temperature sensor readings, the other two heaviest birds (both males) are suspected to have died, (Table 1, Fig. 1).

Of the nine study birds, only three of them left the San Francisco Bay area. The first grebe to leave the Bay was grebe # 97615 on 27 January 2011 when it traveled directly south to the southern end of Monterey Bay (total cumulative distance was 572 km, Table 1), at which time transmission ceased. Grebe # 97622 remained in the Bay throughout the first winter, and then departed on 13 July 2011 traveling north. It stopped at Clear Lake (California, 39°3’42” N, 122°49’38” W) and then continued to Upper Klamath Lake (Oregon, 42°23’32” N, 121°52’49” W). The total distance covered during this migration was 1620 km in 10 days (Fig. 2). This individual remained in Upper Klamath, presumably to breed, then returned to San Francisco Bay 4 November 2011 for a total cumulative migration distance of 2144 km (Table 1). Grebe # 97617 remained in San Francisco Bay through the first winter, spring, and summer (2010). Almost exactly one year post-release, on 10 December 2011, this bird traveled 757 km south to the San Diego Bay (California, 32°38'53" N, 117°11'28" W), then returned to San Francisco Bay four days later for a total round-trip distance of 1514 km. This bird went on to transmit for 65 more days, remaining in San Francisco Bay until the PTT battery was depleted on day 436 post-release (Table 1).

In general, post-release movement of the grebes followed a relatively similar pattern, with birds remaining within San Francisco Bay, for the greatest majority of the tracking period. Some grebes spent most time restricted to a very small area (see grebes # 97617 and 97622; Fig. 4); while others had a wider range (see grebe # 97613 and 97615; Fig. 4). In general, however, bird movement within the Bay was mostly concentrated within the north-central portion, spanning from the Sausalito/Tiburon region on the west side of the Bay to Richmond/Berkeley area on the east side.

DISCUSSION

San Francisco Bay is an important area for wintering, migrating, and breeding birds, supporting a great number and diversity of both freshwater as well as marine birds. In particular, grebes of various species use the Bay during several months of the year (Warnock et al. 2002; Takekawa et al. 2006). Western Grebes are known to winter on marine waters and migrate to summer inland freshwater lakes (Storer and Nuechterlein 1992), however little data exist on site fidelity of wintering Western Grebes. This study suggests that in general (Grebe # 97615 being a rare exception), Western Grebes wintering on San Francisco Bay remain there between December and March. Grebes are often impacted by oil spills during the fall and winter, after they breed, and when they are found mostly along the Pacific coast of North America. During this time, they are especially vulnerable to oil impacts as a great majority of them undergo molt when they arrive along the coast of California (Storer and Nuechterlein 1985), and a proportion of the population undergoes a full wing molt in the winter (Sibley 1970). The Cosco Busan oil spill in November 2007 heavily impacted Western and Clark's Grebes, with an estimated 1133 killed (Dept. of Fish and Game 2009).

This study successfully tracked one grebe (# 97622) from its wintering range and its summer range and back to its wintering habitat. To our knowledge, this is the first ever real-time recording of a complete winter-summer-winter migration for this species. It is interesting that this bird visited two known Western Grebe breeding locations (Storer and Nuechterlein 1992), Clear Lake and Upper Klamath Lake, although it is unknown if this individual bred at Klamath Lake (where it remained the majority of time before traveling back to San Francisco Bay).

The present study represents the first satellite date available for Western Grebe movements within and outside of San Francisco Bay, however we are cautious about over-interpretation of our results as we have no control to compare them to. Our results show that the grebes exhibited strong site fidelity within San Francisco Bay during the non-breeding period. Of those birds that did migrate, 2 out of 3 returned to San Francisco Bay, once again, showing strong site fidelity. Availability of predictable and plentiful food supply, especially during an energetically costly activity such as molt, is especially important and the Bay apparently provides sufficient resources to maintain such large numbers of aquatic birds (Warnock and Takekawa 1996), including Western Grebes.

Surgically implanted intracoelomic satellite and VHF transmitters with percutaneous antennae have been used to successfully track the movements of many bird species (Korschgen et al. 1984, 1996 and other citations), including unraveling migratory patterns for some species such as the Spectacled Eider (*Somateria fischeri*, Petersen et al. 1999). A prior study (Gaydos et al. 2011), demonstrated that a modified surgical technique could be use to successfully implant satellite transmitters in Western Grebes in a captive situation. Those data showed that Western Grebes implanted with satellite transmitters had healed by postoperative day 9, suggesting that the 44-56% mortality associated with this current study was not related to the immediate surgical procedure. It is impossible to know the causes of mortality because none of the birds that died were recovered; however, all birds exhibited high post-release movement within San Francisco Bay, which would not be expected of birds that were debilitated and dying. External to the surgical operation and recovery, possible causes of death related to surgical implantation of satellite transmitters post-surgery and healing include prolongation of impaired waterproofing, chronic low-grade infection, increased energy requirements due to transmitter weight, antenna drag or increased preening, increased predation or more likely, some degree of multifactorial interaction. Although not well described in birds, there is likely an interactive effect between stress, thermoregulation, behavior, nutrition, and immunity that conspires against survival after capture, handling, and surgical implantation of transmitters (Gaydos et al. 2011). Waterproofing issues and increased energy requirements could result in negative energy balance and cause death directly, or they could result in increased foraging or preening time and decreased vigilance, leading to increased predation (Wilson et al. 2004).

Although not statistically significant, it is interesting that there was positive, but non-significant, correlation with bird weight and post-release survival, which suggests that bird size might have permitted larger birds to overcome some energy cost-associated with the transmitter weight and/or antennae drag. Transmitter weight ranged from 1.8-2.5% of Western Grebe body weight, well within the general standards (Caccamise and Hedin 1985). There might be something about Western Grebes where this doesn't apply. More likely, with Western Grebes being strictly aquatic birds, spending little if any time on land and being adapted only for brief flights during migrations, is that antenna drag while diving for foraging and traveling was a more significant energy burden. Future work should calculate the potential energy requirements of antenna drag and should investigate the use of shorter antennas if the cost appears to be substantial.

It is impossible to know if the behavior of the grebes in this study was affected by the transmitters. Several studies with other species suggest that birds that have devices, such as dataloggers, radios or satellite transmitters, whether external or internal, have altered behavior and/or survival (Burger et al. 1991, Bannasch et al. 1994, Latty et al. 2010, Fast et al. 2011, among others). We did, however, receive several reports of a Western Grebes from our study (percutaneous antennae visible) from members of Richardson Bay Audubon Sanctuary conducting winter bird surveys in the Bay in mid and late January 2012. This bird was seen in the NE corner of Richardson Bay, and by this date it would have been in its second winter since the implant of the transmitter.

The miniaturization of satellite transmitters (< 5 g) may offer new opportunities for testing external attachment without the typical problems associated with larger externally attached instruments, such as drag in water and air. One of the great advantages of internally placed transmitters is the retention of the transmitter that would normally not last more than a few months for externally placed devices. To a certain degree, retention can be increased with subcutaneous anchors (Lewis and Flint 2008, Newman et al. 2009), and we will continue to explore other promising new attachment methods.

This study demonstrates that just because a novel surgical technique is effective in a laboratory setting, it does not guarantee success when birds are released into the wild. The high level of site fidelity within San Francisco Bay highlights the importance of protection for this important bird area, in particular because of the recent declines in the population and their vulnerability to oil pollution. More work is needed before this surgical technique is ready for widespread use.

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Table 1. Outcomes of the nine PTTs deployed on Western Grebes in San Francisco Bay.

Bird ID	Sex	Body Mass (g)	% Body Mass[a]	Maximum No. Days Alive	Total Cumulative Distance (km)	Final Status
97620	Male	1134	2.29	5	129.7	Suspected mortality
97614	Female	1225	2.12	25	218.2	Suspected mortality
97621	Male	1435	1.81	39	246.6	Suspected mortality
97615	Unknown	1025	2.54	47	571.7	Unknown
97618	Male	1102	2.36	68	295.6	Battery failure
97613	Male	1385	1.88	123	624.3	Suspected mortality
97619	Unknown	1190	2.18	143	283.8	Battery failure
97617	Female	1378	1.89	436	2940.4	Battery depleted
97622	Male	1455	1.79	454	2143.6	Battery depleted

[a]PTT implant as percentage of body mass.

FIGURE LEGENDS

Fig. 1 – Relationship between capture weight (grams) and post-release survival (days).

Fig. 2 – Track lines for grebe # 97622 showing migration to Klamath Lake, Oregon, July – October 2011.

Fig. 3 – Track lines for grebe # 97617 showing migration to San Diego, California, December 2011.

Fig. 4 - Kernel density estimator overlaid on maps of the San Francisco Bay area for 4 grebes (#s 97613, 97615, 97617, 97622).

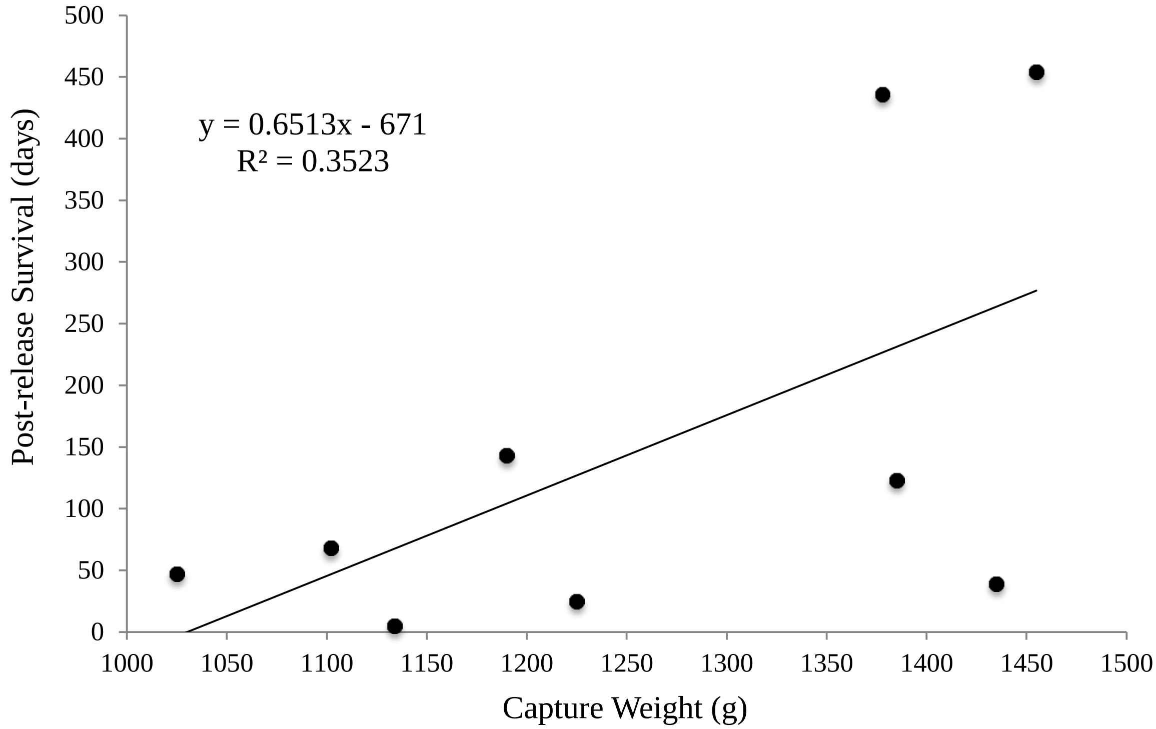
y = 0.6513x - 671
R² = 0.3523
Post-release Survival (days)
500
450
400
350
300
250
200
150
100
50
0
1000
1050
1100
1150
1200
1250
1300
1350
1400
1450
1500
Capture Weight (g)

Fig. 1

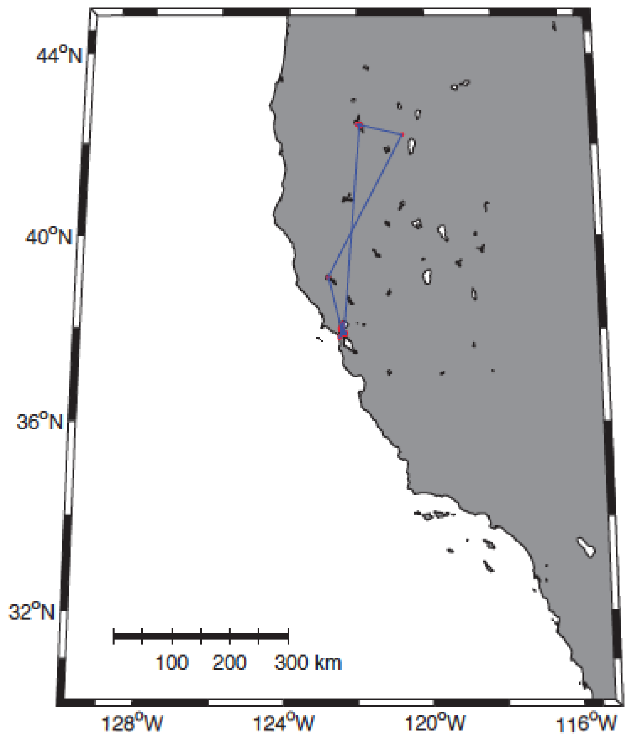

Fig. 2

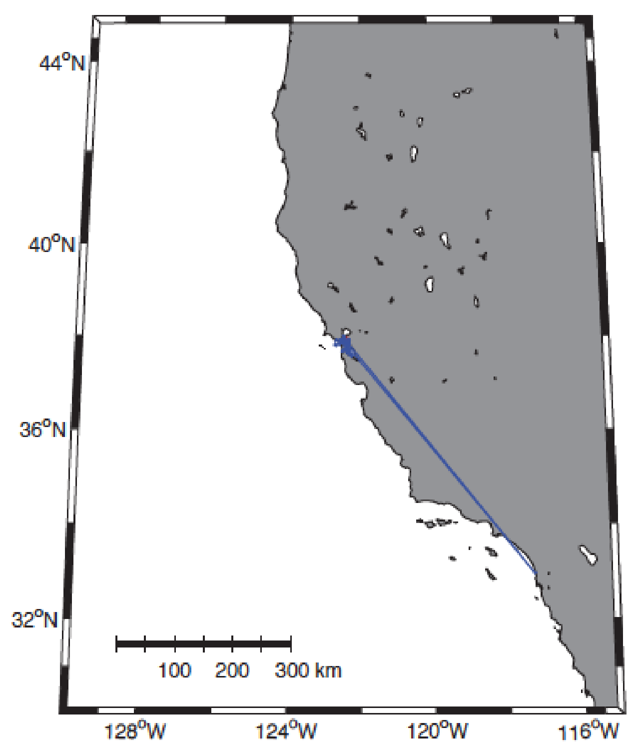

Fig. 3

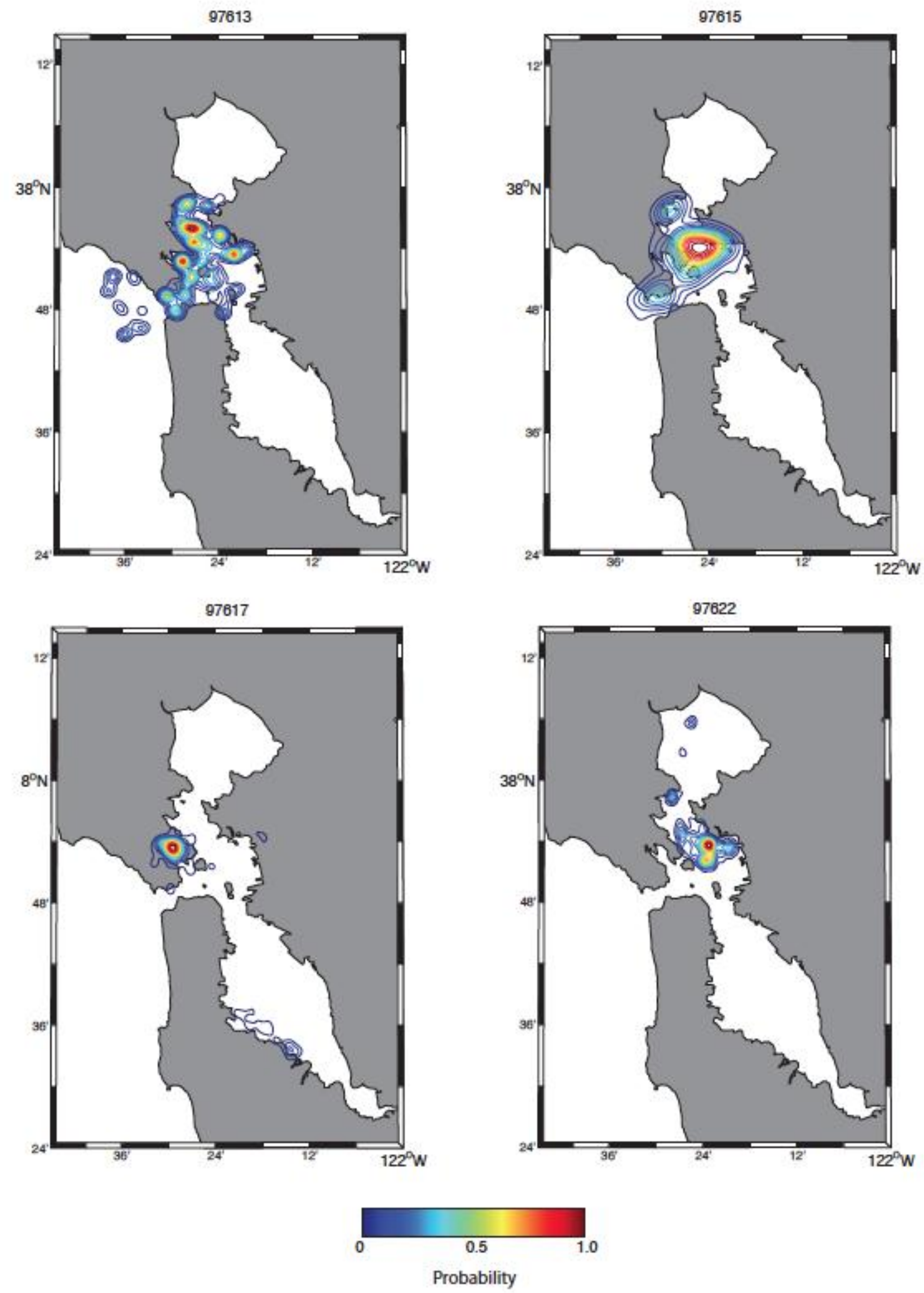
97613
97615
97617
97622
12'
38°N
8°N
48'
36'
24'
36'
24'
12'
122°W
0
0.5
1.0
Probability

Fig. 4