FEEDING HABITATS, MIGRATIONS AND WINTER REPRODUCTIVE RANGE MOVEMENTS DERIVED FROM SATELLITE-MONITORED RADIO TAGS ON EASTERN NORTH PACIFIC GRAY WHALES.

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Introduction

This study is an efficacy test of two new Argos location-only tags using Wildlife Computers Spot-5 tag technology and Oregon State University attachments on the abundant eastern North Pacific gray whale (*Eschrichtius robustus)* stock, before this technology is considered for use on western gray whales. Prior tagging of eastern gray whales by Mate in 2005 led to the determination by IUCN's Western Gray Whale Advisory Panel (WGWAP) and the IWC BRG subcommittee that Telonics ST-15 tags would be adequate for western gray whales. However, more modern technologies could allow smaller and more efficient tags to be used.

The tracking of whales equipped with satellite-monitored radio tags has proved very helpful in identifying critical habitats and migration routes for many large baleen whale species (Watkins *et al*. 1996, Mate *et al*. 1997, 1998, 1999, 2000, 2003, 2007, Heide-Jørgensen *et al*. 2001a, 2001b, 2003a, 2003b, Mate and Urban-Ramirez 2003, Wade *et al*. 2006, Zerbini *et al*. 2006, Heide-Jørgensen and Laidre 2007, Mikkelsen *et al*. 2007, Dalla Rosa *et al*. 2008, Lagerquist *et al*. 2008, Bailey *et al*. 2009), and could prove very useful in addressing some of these questions for western gray whales.

In the 2005 study, 17 female eastern gray whales (one single and 16 mothers with calves) were tagged in Baja, Mexico with Telonics ST-15 tags. Six of those whales made it to the feeding grounds in the Chukchi Sea 100 or more days after tagging and subsequently averaged 223 days of tracking (Mate and Urban 2005). The longest running tag transmitted 321 days after tagging, at which time the whale was southbound off Monterey California.
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The current study used more contemporary tags developed in collaboration with Wildlife Computers with funding from the Office of Naval Research (ONR) in the hopes that they would meet or exceed the performance of the Telonics tags. Efforts were made to provide both longer operational life and a smaller, potentially less invasive size than previous

tags. Two tag designs were tested using contemporary electronics and similar attachments to the Telonics tags: a short version containing 2 batteries, and a long version containing 3 batteries.

Tags were deployed on eastern gray whales off Oregon and northern California, known to be part of the Pacific Coast Feeding Aggregation (PCFA). The PCFA is well studied with frequent inter- and intra-annual re-sightings of the same individuals and is thus ideal for follow-up studies. Besides our own team traveling to where tagged whales were located during the summer/fall, we enlisted the help of other researchers currently studying gray whales to obtain as many sightings of the tagged whales as possible. The other researchers had access to tagged whale locations to facilitate this process and re-sighting information from them will be included in the follow-up evaluation process.

This study also addresses the issue of how important depth of penetration is to the overall duration of tag attachment and whether or not this influences any visible differences in tag effects or healing. This experiment is meant to address interests expressed by the IWC co-ordination group in applying the smallest size tag practicable to achieve future western gray whale research objectives and be potentially less invasive. Given the general concern about potential effects of satellite tagging on the health of individual whales and the need for follow-up data on tagged individuals (see Weller, 2008), this project serves the dual purpose of testing new tag technology as well as being the first study to look at the effects of tag attachment on whales during their attachment and over an extended time period.

Methods

Eighteen satellite tags were applied to gray whales in the PCFA off the coast of Oregon and California from September to December 2009. Tags were applied near Seal Rock, OR (n = 3), Cape Foulweather, OR (n = 6), Lincoln City, OR (n = 1), and near Pt. St. George, CA (n = 8). Tagging dates and locations varied because of poor weather conditions and local whale abundance.

Tags consisted of Wildlife Computers Spot-5 transmitters cast in stainless steel cylinders (2.0 cm in diameter) with a whip antenna on one end and a four-bladed tip with attachments on the other. Two battery configurations were tested; a short tag with 2 Saft A cells (22.8 cm long, weighing 172 g), and a longer tag with 3 Saft A cells (27.8 cm long, weighing 210 g). The tags provided Argos locations of varying quality and were set to transmit for four 1-h periods each day. Transmission times were scheduled during daylight hours to aid with tag relocation.

Tags were applied on the dorsal surface of non-calf whales that appeared to be in good health (not emaciated or heavily infested with cyamids) following the protocols described by Mate *et al*. (2007). Biopsy samples were collected using a Barnett crossbow and ID photos were taken during and after tagging. Follow-up observations and photographs of tagged whales were undertaken opportunistically during the course of additional tagging attempts as well as on dedicated re-sighting trips based on Argos locations from September 2009 to April 2010.

Tag durations (time from deployment to last transmission) were compared between short and long tags and linear regression was used to test the effect of deployment position and penetration on log transformed tag longevity. Locations in the winter-feeding area were examined for differences in the amount of time spent inside and outside the breeding lagoon. The narrowest point in the mouth of the lagoon was used as the boundary between inside and outside the lagoon. Only good quality (LC 1, 2, & 3) locations were used and any locations that were within their associated error radius of the boundary were discarded to reduce the possibility of location error falsely influencing the number of locations inside vs. outside. Days spent inside or outside the lagoon were determined using the location dates. If only one location was received in a day, that location was counted as a 'day' in that position. If two locations were received in a day, one inside and one outside, it was counted as 0.5 d in each location. If two or more consecutive locations were received in a location, the number of days elapsed from the first location to the last location was used as the number of days in that location.

Results

Between September 3 and December 4 2009, eighteen tags were applied to gray whales off the coast of Oregon and Northern California (Table 1). Nine tags of each battery configuration were deployed. Twelve tags (six of each type) were fully deployed or protruded <1.3cm from the whale's body and were considered 'good' deployments (Table 1). The six tags that protruded 5-10cm from the whale's body were considered 'poor' deployments. Biopsies were obtained from 14 of the tagged whales and used to determine sex (five females and nine males). ID photographs taken during or after the tagging approach enabled all but one whale to be identified using a combination of photo ID data bases and all were confirmed to be part of the PCFA. Six whales were tracked through their entire southerly migration and three of those were tracked for their northerly migration.

Tag Duration

At the time this report was written three tags were still transmitting; one of the nine short tags and two of the nine long tags. Results apply to the duration of tags up to April 28, 2010. Until the last three tags stop transmitting, differences in tag durations will be influenced by different deployment dates (ranging over three months), rather than actual duration differences.

Overall tag duration ranged from 3-238 d with an average of 73 d (SD = 70.9 d, n = 18, Table 1). Tag duration ranged from 9-238 d ($\bar{x}$ = 87 $\pm$ 92.1 d, n = 9) for long tags, and from 3-145 d ($\bar{x}$ = 58 $\pm$ 41.0 d, n = 9) for short tags.

The average duration of all long tags that were well deployed (<1-3 cm exposed) was 124 d (SD = 93.4 d, n = 6), while all well-deployed short tags averaged 75 d (SD = 38.2 d, n =

6). The trend suggests that long tags lasted longer than short tags, but because of the high variability in tag durations and the small sample size, average tag duration was not significantly different between the two tag types. Power analysis revealed that a minimum sample size of 18 for both tag types would be necessary to statistically detect a 30% difference with 90% power.

For comparison, the 11 Telonics ST15 tags that were well deployed on gray whales in Ojo de Liebre Lagoon in March 2005 lasted an average of 87 d (SD = 107.2 d, range = 6-321 d). Tag duration was not significantly different between the Telonics ST15's and the tags described here (both long and short types together).

Tag Exposure vs. Duration

Tag exposure was the best predictor of the duration of a tag ($p<0.001$, multiple linear regression) with distance from the midline and distance from the dorsal hump having no further effect after accounting for tag exposure ($p = 0.45$ and $p = 0.92$ respectively). For every 2.5 cm increase in tag exposure, longevity was decreased by 55% (95% CI: 34 – 76%). Tag exposure was affected by both the distance of the tag from the midline and the distance of the tag from the dorsal hump ($p<0.001$ and $p=0.014$, respectively; linear regression). For every 2.5 cm from the midline, tag exposure decreased by 0.9 cm (95% CI: 0.53 – 1.28), and for every 1 m forward of the dorsal hump, tag exposure decreased by 2.23 cm (95% CI: 0.63 - 3.8).

Summer foraging range

While on the summer/fall foraging grounds, tagged whales showed a high degree of variability in their movements, both in the location of the areas visited and in the number of areas frequented by each animal. Of the first six whales tagged, which were tagged within a period of three consecutive days, four whales (827, 831, 847, and 1385) departed the tagging area immediately after tagging (Figure 1). All four whales moved south, with two of the whales (827 and 831) spending time in the area of Yachats, Coos Bay, and Cape Blanco, OR in the first 2 weeks after tagging. The third whale (847) also moved south to Cape Blanco, but then immediately turned north and reached Vancouver Island, BC two weeks after tagging. The fourth whale traveled to Pt. St. George, CA and was last heard from in this area on September 12, 2009. Two of the other tagged whales (4171 and 5670) remained in the tagging area for the duration of their tag life (10 d and 18 d respectively). Later, two more whales (5801 and 5923) tagged on the same day, in the same area, again showed different movement behavior with 5923 immediately departing the tagging area, traveling to Pt. St. George, CA, then turning north and spending 2 weeks near Florence, OR, while 5801 remained within 30 km of the tagging area for almost 1 month.

The area near Point St. George, CA (PSG) was heavily used by tagged whales later in the fall and through the winter. By November 20, all six whales with functioning tags (out of 10 deployed by that date) were located within a 10 km radius of PSG. During a resighting effort in that area on Nov 25 an estimated 35–40 gray whales were observed, including three whales which had been previously tagged, but the tags had come off, meaning that at least nine of the 10 whales which had been tagged were at PSG at the end of November. The two whales which spent the most time in the PSG area were whale 827, which arrived at the start of October and remained there for over 15 weeks before migrating south in late February, and whale 831 which arrived at PSG one week later, and, aside from two brief trips to Cape Mendocino 70 miles south, has remained there all winter and is currently in that area at the time of this report. Re-sight efforts consistently observed relatively large numbers of gray whales in a tight aggregation (15-20+ whales in an area <500 radius) throughout the winter. The whales appeared to be foraging as defecation was observed and the whales would often surface from a deep dive and turn 180 degrees before diving again. Groups of sea lions and various sea birds were often observed in the immediate area, and there was often a dense scattering layer on the boat's echo sounder (sometimes in the bottom third of the water column, or throughout the entire water column).

Southward migration

The start of the southerly migration was captured for eight individuals. All whales began their migration from the area near PSG, but the start dates varied widely, ranging from Dec 4 to Feb 13 (Table 3), and all six whales tracked to the end of their southerly migration arrived at Laguna Ojo de Liebre near Guerrero Negro, BCS Mexico. Migratory routes were typically close to shore and followed the coastline, however, much like the northbound migration of a satellite-monitored gray whale from San Ignacio Lagoon to San Francisco (Mate and Urban-Ramirez 2003), whale 23038 traveled directly across the California Bight, through the outer Channel Islands (Santa Rosa and Santa Cruz), rather than following the coastline directly (Figure 2). Most whales traveled continuously after starting their migration, until they reached their destination; however whale 827 stopped for 9 d in the area of San Miguel Island in the Channel Islands, CA before continuing its journey (Figure 2).

Tagged whales took an average of 18.6 d (SD = 3.19 d, n = 6) to migrate from PSG to Ojo de Liebre, resulting in an average speed of 4.3 km/h (SD = 0.74, Table 3). The whale recording the slowest migratory speed (23033) provided only four locations during the southerly migration. If that whale is excluded, migrations lasted an average of 17.5 d (SD = 1.98 d) and averaged speeds of 4.6 km/h (SD = 0.46).

As of the writing of this report (April 28, 2010), whale 831 has not migrated at all, and it is possible that other whales which had shed their tags may also not have migrated or migrated very late. A resight effort on January 27, 2010 photographed seven tagged whales in the PSG area, four of which (831, 1385, 10842, 23029) had been photographed at PSG with no more than 33 d between any of the photographs (Table 2). The last re-sight effort on April 15, 2010 photographed two tagged whales in the area (831 and 1385)

Winter range and lagoon use during the breeding season

Arrival time at Ojo de Liebre varied greatly between individuals reflecting consistent migration speeds, but differing departure dates from California. Upon arriving, whales typically spent time in the area immediately outside the mouth of the lagoon before entering.

The entire stay in the winter breeding area was recorded for three whales (827, 5938, 23041). The whales stayed in the area of Ojo de Liebre for 21, 26 and 20 days, respectively, before starting their northward migrations (Table 3). Three other whales (23033, 23035, 23038) were recorded arriving in the area of Ojo de Liebre but their tags stopped transmitting before recording the start of their northward migration. These whales spent a minimum of 3, 17, and 8 d, respectively, in this area before their tags stopped transmitting.

While whales were in the winter breeding area, locations were recorded both inside and outside the lagoon for five individuals (Figure 3, Table 4). Both males spent a larger portion of their time outside the lagoon with one (23035) almost exclusively staying outside the lagoon. One of the females (5938) also spent a larger portion of its time outside the lagoon, and the other female recorded an equal amount of time spent inside and outside. Whale 827 (a female) recorded a large number of locations (>25) outside the lagoon and three inside the lagoon, but only two locations (both outside the lagoon) fit the criteria to be included in the comparison, so the whale was left out of the table and figure.

Northward migration

Three of the tagged whales were tracked migrating north from Ojo de Liebre (827, 5938, 23041). As with the start dates of southbound migration, the start of northbound migration varied widely, with departure dates ranging from January 27 to March 29, 2010.

During its northward migration, 5938 did not stop at PSG, where it was tagged, but traveled directly to the central coast of Vancouver Island (arriving at Hesquiat Harbor on February 23, 2010) where the majority of its photo identifications occurred prior to tagging. There were still tagged whales present at PSG at the time 5938 passed on its northward migration. Migratory speed from Ojo de Liebre to Vancouver Island for 5938, a female, was the same as its southerly migration speed (Table 3). Whale 5938 left Hesquiat Harbor on March 23, 2010, traveled northwest along the coast, and arrived at Icy Bay, AK, on April 3. The animal was still in that area as of April 28.

Whale 23041 began its northward migration on February 27, 2010, and arrived at the Olympic Peninsula coast in Washington on March 29. Similar to whale 5938, whale 23041, a male, passed the PSG area, where it was tagged and at least one other tagged whale (831) was currently located, without stopping. Whale 23041 traveled 0.7 km/h slower on its northward migration (Table 3) than on southward migration. Shortly after arriving at the Washington coast, whale 23041 traveled south again to Lincoln City, OR, before heading north again to the Olympic Peninsula. This whale spent the month of April moving between these latter two areas, at one time spending approximately one week near Cape Foulweather, OR, which prompted further re-sight efforts.

Whale 827 was tracked as far north as Cape Mendocino, CA, before its tag stopped transmitting on April 16, 2010. During its northward migration, this female traveled a minimum of 1770 km at an average speed of 4.1 km/hr, which is over 1 km slower than its southerly migration speed, but close to the average for the other whales.

Resighting efforts

Resighting efforts conducted during tagging and later as separate efforts were very successful. Twelve of the 18 tagged whales were re-sighted and photographed at least once after tagging. Ten of the whales were photographed post tagging with their tags still attached. Seven whales were photographed after their tags had come off, six of which had been previously photographed with the tag on. Ten whales were photographed multiple times subsequent to tagging (Table 2). One whale (10838) was photographed with the tag still attached but the tag had a broken endcap and was non-functional.

Discussion

Tag duration

It appears there may be a difference in attachment longevity between well-deployed short and long tags, despite the small sample size and high variability preventing the detection of this difference statistically. The most likely explanation of the observed differences in duration between tag types is that the short tags worked their way out faster and fell off. Of the 15 whales whose tags have stopped transmitting, seven were observed later without their tags and one was observed with a broken, non-functional tag (10838). While the observation of a non-functional tag on a whale makes it possible that unobserved tags might have failed, the preponderance of whales observed without their tags makes it more likely that they simply came off. Based on battery power and transmission schedule, the life expectancy of both tag styles was over one year, so it is very unlikely that the short periods of operation were the result of battery exhaustion.

Both tag styles were the same diameter and used the same blades and attachments. The only functional difference between the two tag types was the 5 cm difference in length. It is possible that the tags work their way out at the same rate, and, therefore, the longer ones take longer to come out, however, this is unlikely as the tags on whales which were re-sighted most recently did not appear to have started migrating out at all. This suggests that the added length of the long tag allowed its attachments to engage tissues that held better than the short tag, such as the fascia layer between the blubber and muscle. It is also possible that increased blood flow in the muscle mass below the fascia may have contributed to wound healing for the deeper-penetrating long tags and increased their duration. These ideas are also supported by the short duration of poorly deployed tags.

Another interesting observation is that two whales were observed with functional tags that were still well deployed, then within a week the tags stopped transmitting and the whales were later observed without their tags. It is interesting that a tag could have come off so quickly and may suggest that the whale rubbed against the bottom or another whale, which expedited tag loss.

The results also show that depth of tag penetration has a close relationship to the duration of attachment, and that accurate placement is important to ensure full deployment. While care is always taken to place the tags as well as possible in any field season, these results further emphasize how critical the act of deploying the tag is to the longevity of the tag and therefore the success of the project.

Movements/migration

Despite being tagged relatively late in the summer/fall foraging season, the tagged whales were highly mobile and showed considerable variability both in the locations they visited and especially in the amount of time spent in those locations. This mobility was also noted in the past using photo ID methods (Darling 1984, Darling *et al*. 1998, Calambokidis *et al.* 2002), however the majority of the field work in these studies took place before mid-November. Calambokidis *et al*. (2002) noted some patterns in the movements of PCFA whales, with numbers peaking in the Clayoquot Sound area of Vancouver Island in August, followed by southerly transits from this area in late August/early September. Resightings of gray whales in Oregon and California were primarily made late in their season, in August and October, respectively (Calambokidis *et al*. 2002). One of the tagged whales in this current study moved north from Oregon to Vancouver Island in September. Perhaps the El Nino conditions in 2009 contributed to whales searching widely and in the case of one whale, against the typical direction of travel, for suitable concentrations of prey species. Travel speeds during these transits were similar in speed to migrations, suggesting the whales moved directly from one spot to the next without much en route “sampling”.

Gray whales have been shown to use the northern California area late in the summer foraging season (Mallonee 1991, Calambokidis *et al.* 2002), however, surveys did not typically take place in November and December when the majority of tagged whales from this study were occupying the PSG area. The high use of PSG by tagged whales, as well as the relatively large number of untagged whales also observed in the area, suggests it was an important area for whales prior to migration, at least this year. Our observations of apparent foraging combined with how the whales were grouped very closely suggest a very dense and long lasting food source in 2009/2010. It is notable that all the tagged whales spent time at PSG, either having been tagged there, or traveling there from

Oregon, and it may suggest that this is a staging area for the PCFA prior to southbound migration.

The migratory timing for most south-bound tagged whales observed in this study generally matched the December/January peak of the overall southerly migration passing the central Oregon coast (Herzing and Mate 1984) but revealed departures as late as 13 February, over a month after the southern migratory peak. The individual variability in arrival times at the breeding lagoon suggests that individual gray whales do not use these lagoons for the entire reproductive season. Rather the tagged whale data show that whales stay only for a portion of the time, with some individuals arriving after others have already left. A similar 'rapid turnover' in the breeding area was suggested for humpbacks around Hawaii (Mate *et al.* 2007), where the timing of humpback arrivals and departures was shown to vary with sex, age, and reproductive condition (Craig *et al*. 2003). Of the seven whales for which the start of southerly migration was recorded, three were females (without calves) and their migrations were spaced throughout the entire winter season with the last one (827) arriving at Ojo de Liebre on March 8. Thus, researchers calculating population estimates from surveys in the breeding areas would severely underestimate the population, given our observed variability in migratory timing.

It is possible that the whales that migrated later were in poorer health/body condition and therefore chose to remain on the foraging grounds longer in an effort to maximize fat reserves before the long migration. Whale 827 arrived quite "late" at the wintering area, and we do not know how to interpret that presently. One mother with a calf that was tagged in Mexico in 2005 was last heard from 11 February 2006, just south of Monterey Bay still migrating south. Knowing that this female was not expected to calve in 2006 (two years in a row), we think some of the whales going south to breed may have wider latitude to do so than females going south to calve (calving dates are primarily in January and February). These results suggest that some female gray whales may mate during the latter part of the breeding season (late February and beyond). Breeding activities have also been observed for gray whales during their northbound migration along the Oregon coast (observations by Whale Watch Volunteers and B. Mate). Such late season mating, combined with the synchrony observed in calving dates on the breeding grounds suggests the possibility for delayed implantation and a shorter effective gestation period than previously thought. Whale 827 stayed just 21 d in Ojo de Liebre, before heading north again. We were unable to resight this animal before its tag stopped transmitting, but presume that it did not give birth to a calf this year, given the late migration and quick turn-around time in the breeding area.

At the date of this report, whale 831 was still in the PSG area and had not migrated. It has been hypothesized that female gray whales may not complete the migration to Mexico if their calves are born further north (Shelden *et al.* 2004). Gray whale calls have been recorded throughout the winter in the Beaufort Sea (Stafford *et al*. 2007), suggesting some whales do not migrate, or there is some variation in the timing of those migrating in and out of the region. This study provides the first unequivocal evidence of a gray whale not participating in the migration to Mexico. The resight photographs showed that other tagged whales were also in the PSG area very late in the season (1/27/10) and the time between photographs was short enough that it is extremely unlikely these whales migrated to Mexico and returned in such a short time period. Whale 827, however, demonstrated that it is possible that some of the whales observed around PSG in late January might still have migrated after that resighting expedition. In any case it indicates that a relatively large percentage of the population may arrive at the breeding lagoons much later in the season than previously thought or not at all, which, again, may skew population estimates made in the reproductive areas.

The prevalence of our tagged whales migrating to Ojo de Liebre Lagoon suggests that gray whales in the PCFA may have site fidelity to this breeding lagoon. While interchange of humpback whales between the Hawaiian islands is frequent (Mate *et al*. 1998), and has been documented across hundreds of miles between breeding areas at Isla Socorro, MX, the Baja Peninsula, and the Mexico mainland (Lagerquist *et al.* 2008), none of the six tagged gray whales visited the nearby breeding area at San Ignacio Lagoon (160 km to the south), Magdalena Bay (270 km south) or offshore areas as far south as Cabo San Lucas during their tracking periods. Three of the six tagged whales that traveled to Ojo de Liebre began their northbound migration after spending 20, 21, and 26 days, respectively, in the lagoon, confirming that these animals did not visit other breeding lagoons while in Mexico. The remaining three tags stopped transmitting while the whales were in the vicinity of Ojo de Liebre.

It is possible that this apparent site fidelity to Ojo de Liebre Lagoon may be a feature of the PCFA whales, and that they may represent a genetic subset of the larger eastern North Pacific population. Steeves *et al*. (2001) compared mtDNA from 16 summer 'resident' whales from Clayoquot Sound, Vancouver Island, B.C. to whales from the overall population and found no significant difference in mtDNA patterns between the two groups. This finding may be a result of small sample size, too short a time frame for isolation to develop detectable differences, or a true lack of isolation of this PCFA group (Calambokidis *et al*. 2002)

The previous tagging study in 2005 tracked six gray whales tagged in Ojo de Liebre to the Chukchi Sea, showing they were part of the much larger subpopulation which summers in the Arctic (Mate and Urban 2005). With the PCFA estimated to be composed of approximately 200 individuals, they would be a small percentage of whales using that lagoon, and thus, in 2005, it would have been quite possible to have tagged only whales that migrate to the Arctic, even if the PCFA whales were there.

While Ojo de Liebre lagoon is by far the most heavily used of the three Mexican breeding lagoons, the high use by tagged whales in 2010 may also represent a shift in overall gray whale distribution based on environmental factors. Gray whale distribution in the wintering areas along the western Baja Peninsula has been shown to fluctuate with sea surface temperature (Urbán R. *et al.* 2003), with distribution moving north during warm water years and south during cold-water years. The NOAA Climate Prediction Center has declared an El Nino watch (NOAA 2010 El Nino/Southern Oscillation (ENSO) Diagnostic Discussion, available at; http://www.cpc.noaa.gov/products/analysis_monitoring/enso_advisory/ensodisc.html) meaning sea surface temperature anomalies greater than +0.5 degrees were observed and expected to continue. The numbers of calves and adult whales in San Ignacio Lagoon were lower this year than during the last decade (Kuyima staff personal communication), which may be a reflection of a northward distribution shift in response to warmer water temperatures. It may also be the result of an El Nino event during the 2009 feeding season, making many individual females re-absorb their fetuses or have such a low "fitness" that they decided not to migrate south even for breeding this year.

It has often been noted that the total number of gray whale calves found in the three main Mexican breeding lagoons was smaller than the total calf production in the population. Tagged whales spent time both inside and outside Ojo de Liebre lagoon during the breeding season, with a greater amount of time spent outside the lagoon. In the case of whale 23035, all but one of its good quality locations were outside the lagoon. If some whales rarely, if ever, enter the lagoon, and others spend a large percentage of time outside the lagoon, it would be necessary to include offshore surveys to estimate population size during the breeding season.

Northbound migration was documented for three whales in this study, with two of them reaching PCFA feeding destinations. Whale 23041 exhibited a great deal of mobility, moving back and forth repeatedly between the OR and WA coasts. Whale 5938, on the other hand, traveled initially to Vancouver Island where it remained for one month, prior to moving to Icy Bay, AK, where it has stayed for five weeks (as of April 28). Although their sample size was small, Calambokidis et al. (2002) documented an inter-annual resighting of one animal between southeast Alaska and Washington, and suggested that either the range of the PCFA extends farther north than the efforts of their study, or that there are other feeding aggregations along the west coast with some interchange among them.

Tag Effects

The re-sighting of tagged whales was very successful and will provide the first detailed information on the effects of implantable tags on whales. Two whales were photographically re-sighted 5 and 6 times respectively after tagging, providing documentation of the tag sites over a period of six months. By photographing seven whales with tags on, then again at various times over a period of months after the tags had fallen off we will be able to describe some of the healing process that occurs after a whale loses its tag. Photographs of tags while they were attached to the whales and photos of the tag sites after the tag had come off will be sent to marine veterinarians for analysis and evaluation of any observable effects.

Summary

While three of the tags are still transmitting, the longer, three-battery style tags have out-performed the shorter, two-battery tags. The depth of tag penetration strongly affected tag life, and it is likely that the difference in duration between the tag types results from the longer tags being better able to engage tougher tissue with their attachments. Photographs of tag sites over periods of up to 8 months are being analyzed to determine any potential effect to the whales. Tagged whales exhibited a high degree of variability in their movements on the foraging grounds as well as with the timing of their southerly migrations. Pt. St. George, CA was a potentially important late season foraging area. Large numbers of tagged and untagged whales were observed there late into the winter with at least one tagged whale remaining there throughout the winter and not migrating south. Six tagged whales migrated south to Laguna Ojo de Liebre, Baja, MX at an average speed of 4.4 km/h in just 18.5 days. After a stay in the reproductive area for an average of 22 days, three whales migrated north at an average speed of 4.0 km/h. This project has tested two new tag types and will provide valuable information about the effects of tag attachment to whales. It has also added valuable detail to what is known of the Pacific Coast Feeding Aggregation of eastern gray whales.

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Table 1. Deployment information, tag durations, and location information received from satellite-monitored Eastern North Pacific gray whales, tagged off central Oregon and northern California in September - December 2009.

Tag #	Tag Style	Deployment Date and Time (UTC)	Deployment Location	Biopsy (Yes/No) - Sex	Amount of Tag Protruding at Deployment (inches)	Distance from Whale's Midline (inches)	Known Attachment Time (d)	# Good-Quality Locations*
827**	Long, 3 batteries	9/2/2009 21:59	Seal Rock	Y - F	0	8	225.8	551
831	Long, 3 batteries	9/2/2009 23:25	Seal Rock	Y - M	0.5	4	237.9	688
847**	Long, 3 batteries	9/3/2009 18:26	Seal Rock	N	0	6	26.1	53
1385***	Long, 3 batteries	9/4/2009 19:07	Cape Foulweather	Y - M	3	2	13.0	6
4174***	Long, 3 batteries	9/4/2009 20:18	Cape Foulweather	N	4	2	9.2	31
5670***	Long, 3 batteries	9/4/2009 22:04	Cape Foulweather	Y - M	4	3-4	18.1	57
5801**	Short, 2 batteries	9/21/2009 19:24	Cape Foulweather	Y - F	0	9	83.2	160
5923**	Short, 2 batteries	9/21/2009 20:17	Cape Foulweather	Y - M	2	5	52.2	204
23029**	Short, 2 batteries	10/5/2009 20:24	Cape Foulweather	Y - M	0.5	8	43.9	123
10838***	Short, 2 batteries	10/6/2009 21:44	Lincoln City	N	3	6	20.1	72
10836**	Short, 2 batteries	11/14/2009 17:08	Pt. St. George	N	4	4	3.3	13
23032**	Short, 2 batteries	11/14/2009 21:16	Pt. St. George	Y - M	0	8	49.0	189
10842***	Short, 2 batteries	11/15/2009 19:50	Pt. St. George	Y - F	0	8	49.2	169
23033**	Short, 2 batteries	11/15/2009 20:36	Pt. St. George	Y - M	0	11	79.2	11
23041	Long, 3 batteries	12/1/2009 18:21	Pt. St. George	Y - M	0	12	147.8	480
23035**	Long, 3 batteries	12/1/2009 18:56	Pt. St. George	Y - M	0	6	43.1	119
23038**	Long, 3 batteries	12/3/2009 17:40	Pt. St. George	Y - F	0	5	64.2	228
5938	Short, 2 batteries	12/4/2009 19:04	Pt. St. George	Y - F	0	12	144.7	352

* Represents locations that have met our error filtering criteria.
** Tag(s) we are no longer hearing from
***Tag(s) we are no longer hearing from and have been re-observed without their tag

Table 2. Resight information for satellite-monitored Eastern North Pacific gray whales, tagged off central Oregon and northern California in September - December 2009.

Tag #	Deployment Date and Time (UTC)	Biopsy/Sex Yes/No M/F	Known Attachment Time (days)	# Times Resighted	# Times Photographed	Dates Resighted Only	Dates Photographed
827**	9/2/09 21:59	Y - F	225.8	6	6		11/3, 11/13, 11/25, 12/1, 12/28, 1/27
831	9/2/09 23:25	Y - M	237.0	8	6	11/3, 12/2	11/13, 11/14. 11/25, 12/28, 1/27, 4/15
847**	9/3/2009 18:26	N	26.1	0	0		
1385***	9/4/2009 19:07	Y - M	13.0	5	5		12/1, 12/2, 12/28, 1/27, 4/15
4174***	9/4/2009 20:18	N	9.2	3	3		9/11, 9/17, 11/25
5670***	9/4/2009 22:04	Y - M	18.1	6	6		9/17, 11/3, 11/14, 11/15, 11/25, 1/27
5801**	9/21/2009 19:24	Y - F	83.2	2	0	11/25, 12/2	
5923**	9/21/2009 20:17	Y - M	52.2	2	2		11/3, 11/15
23029***	10/5/2009 20:24	Y - M	43.9	4	4		11/13, 11/25, 12/28, 1/27
10838***	10/6/2009 21:44	N	20.1	6	6		10/20, 11/13, 11/14, 11/15, 11/25, 1/27
10836**	11/14/2009 17:08	N	3.3	1	1		11/15
23032**	11/14/2009 21:16	Y - M	49.0	0	0		
10842***	11/15/2009 19:50	Y - F	49.2	3	3		11/25, 12/28, 1/27
23033**	11/15/2009 20:36	Y - M	79.2	1	1		12/2
23041	12/1/2009 18:21	Y - M	147.8	3	2	12/4	12/2, 12/3
23035**	12/1/2009 18:56	Y - M	43.1	0	0		
23038**	12/3/2009 17:40	Y - F	64.2	0	0		
5938	12/4/2009 19:04	Y - F	144.7	0	0		

** Tag(s) we are no longer hearing from

***Tag(s) we are no longer hearing from and have been re-observed without their tag

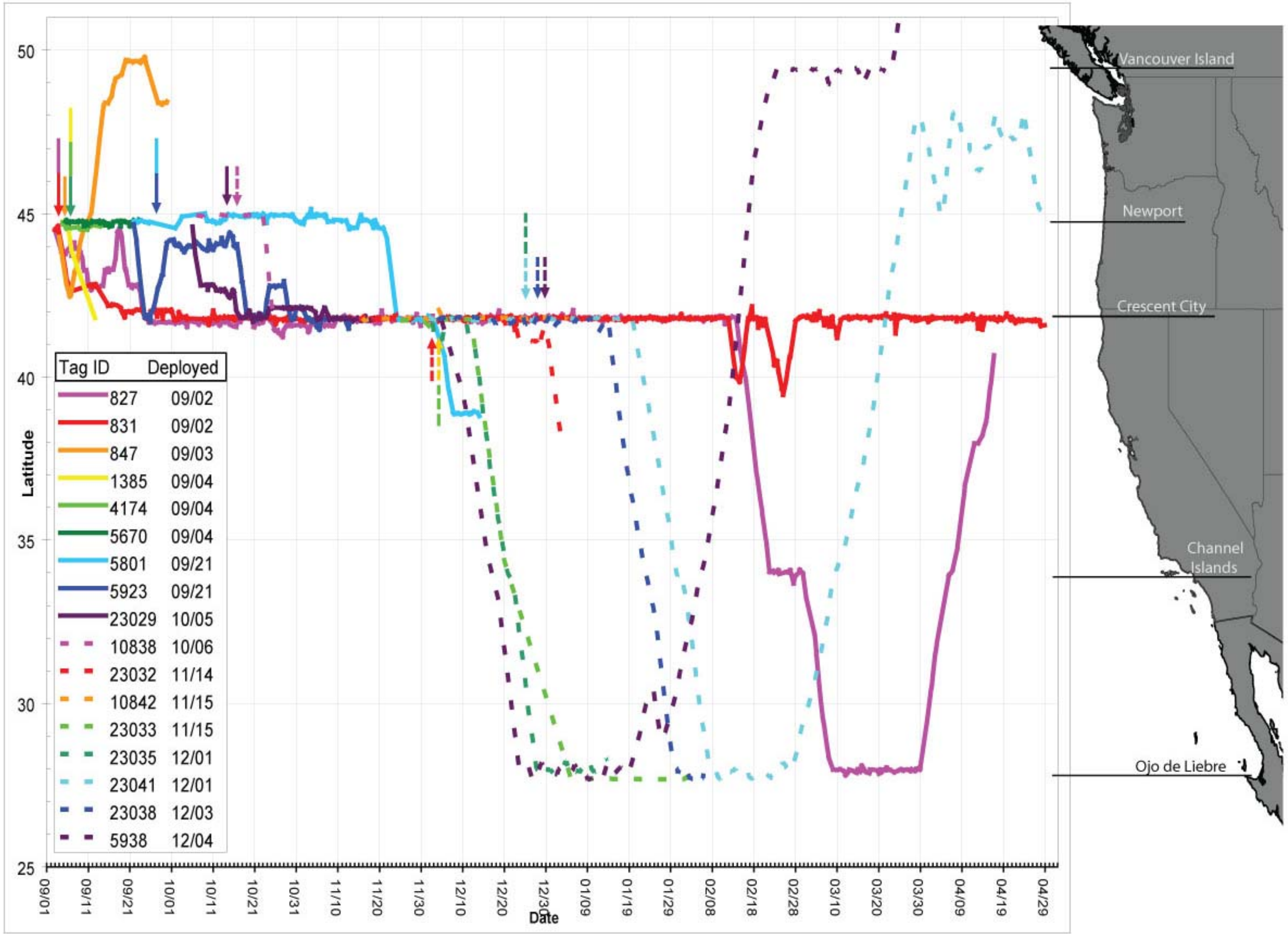

Figure 1. Latitude versus date of satellite-monitored locations of Eastern North Pacific gray whales tagged off central Oregon and northern California from September – December 2009. Arrows point to deployment dates for the corresponding tag colors. The map's scale would not allow depiction of the full migration to Icy Bay, Alaska for whale 5938.

Table 3. Migration timing, distances traveled, and speeds for satellite-monitored Eastern North Pacific gray whales tagged off central Oregon and northern California, September – December 2009.

	Southbound Migration						
Tag #	**Departure**	**Arrival / Progress**	**Dist (km)**	**Days**	**Speed (km/h)**	**Sex**	**Notes**
827*	2/13/2010	3/8/2010	2680	14.0	5.4	F	Crescent City to Ojo de Liebre excluding 9 d @ San Miguel Island
5801	11/20/2009	12/7/2009	653	8.50	3.2	F	Crescent City to Pt. Arena only
5938*	12/4/2009	12/23/2009	1874	18.6	4.2	F	Crescent City to Ojo de Liebre (6 locations)
23032	12/29/2009	1/2/2010	454	4.2	4.5	M	Crescent City to Pt. Reyes
23033*	12/12/2009	1/5/2010	1794	24.0	3.1	M	Crescent City to Ojo de Liebre (4 locations)
23035*	12/10/2009	12/28/2009	1953	18.0	4.5	M	Crescent City to Ojo de Liebre
23038*	1/10/2010	1/28/2010	2030	18.7	4.5	F	Crescent City to Ojo de Liebre
23041*	1/20/2010	2/7/2010	1920	18.2	4.4	M	Crescent City to Ojo de Liebre
			Mean:	15.5	4.2		
			Mean complete migrations	18.5	4.35		

	Northbound Migration						
Tag #	**Departure**	**Arrival / Progress**	**Dist**	**Days**	**Speed (km/h)**	**Sex**	**Notes**
827	3/29/2010	4/16/2010	1770	18.0	4.1	F	Ojo de Liebre to Cape Mendocino
5938*	1/27/2010	2/23/2010	2714	27.2	4.2	F	Ojo de Liebre to Vancouver Island
23041*	2/27/2010	3/29/2010	2680	30	3.7	M	Ojo de Liebre to Olympic Peninsula
			Mean:	25.1	4.0		

* Complete migration

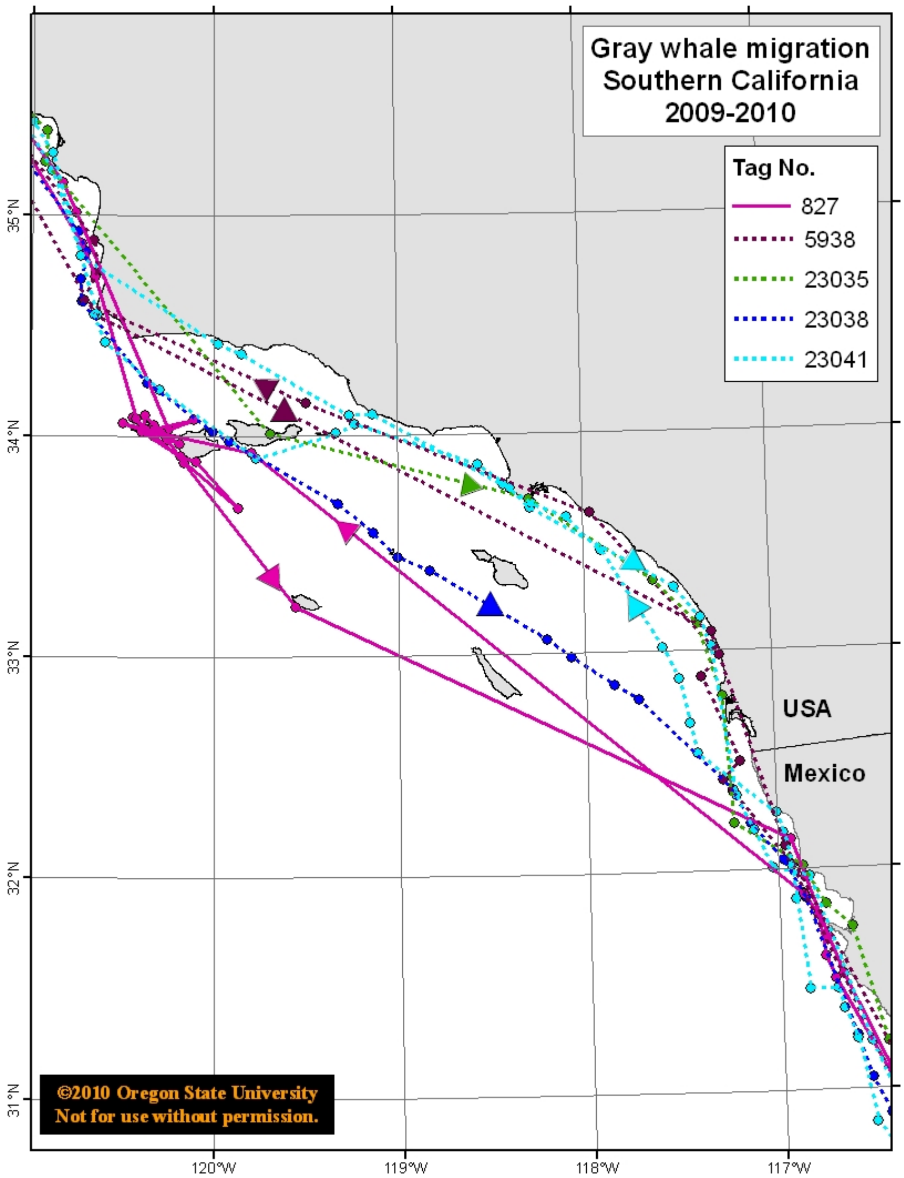

Figure 2. Satellite-monitored tracklines of migrating gray whales tagged off Oregon and northern California, September - December 2009. Arrows depict the migratory direction (southbound or northbound). Tagged whale tracklines revealed that both nearshore and offshore routes (through or outside the channel islands) were taken during both the south-bound migrations. Two whales, which migrated in both directions through the southern California Bight, used nearshore routes. Whale 827 stopped at San Miguel Island in both directions.

Table 4: Comparison of the number of good quality locations (LC 1, 2, & 3), and days spent inside and outside Ojo de Liebre Lagoon for four satellite-monitored Eastern North Pacific gray whales tagged off northern California, in early December, 2009.

Tag # - Sex	# Locs inside	# Locs outside	# Days Inside	# Days Outside
5938-F	6	6	5	11
23035-M	1	21	0.5	16.5
23038-F	16	12	4	4
23041-M	21	25	8.5	12.5

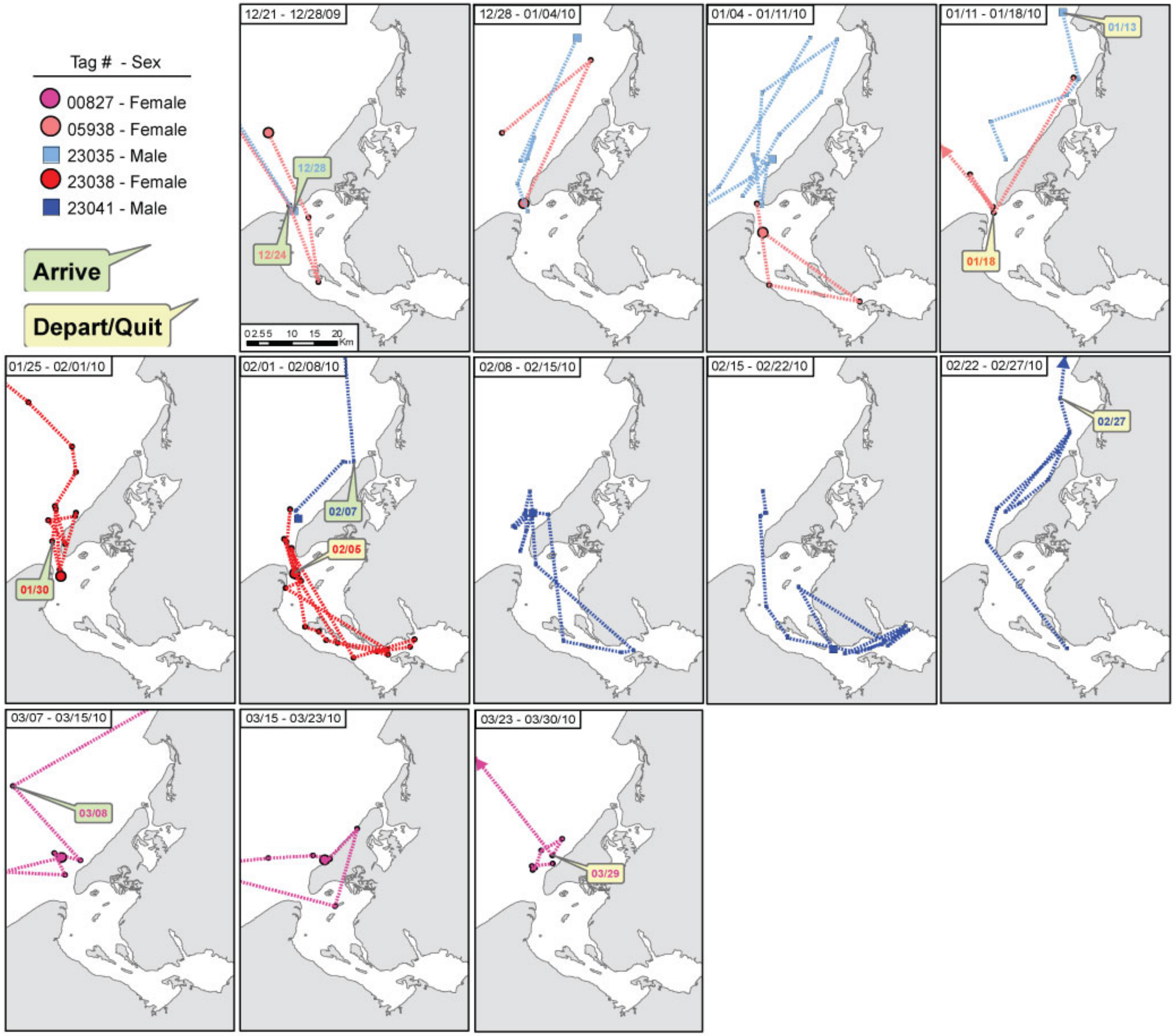

Figure 3. Satellite-monitored tracklines of Eastern North Pacific gray whales around Ojo de Liebre Lagoon, Mexico. This figure depicts only locations through April 13, 2010. The locations reveal variability between whales in the amount and percentage of time spent inside the lagoon compared to the time spent in the open ocean.