

FINAL REPORT

HUMPBACK AND BLUE WHALE PHOTO-IDENTIFICATION RESEARCH OFF CALIFORNIA, OREGON AND WASHINGTON IN 1999

Prepared for:
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EXECUTIVE SUMMARY

Surveys were conducted in 1999 to continue long-term research studies of humpback and blue whales off California, Oregon, and Washington. Primary objectives of this work have included examining the abundance of these two species, trends in population size, movement and migration patterns, and reproduction and mortality rates. In 1999 several other objectives were undertaken including deployment of an underwater video/instrument package on blue whales and testing a new method for measuring the sizes of whales. Support for this research in 1999 came from Southwest Fisheries Science Center, Olympic Coast National Marine Sanctuary, the Channel Islands National Marine Sanctuary, and several individual contributors.

Photographic identification studies of humpback and blue whales were conducted off California, Oregon, and Washington during dedicated surveys by Cascadia personnel on 64 days between 20 May and 3 November 1999. These were conducted using Cascadia's 5.3m RHIBs and on a few occasions other boats. Collaborating researchers and work from opportunistic platforms provided additional effort and identification photographs especially in Monterey Bay. Identification photographs were taken using standard procedures employed in past research (Calambokidis *et al.* 1990a, 1990b, 1999a, 2000). Both the right and left sides of blue whales in the vicinity of the dorsal fin were photographed as well as the ventral surface of the flukes. For humpback whales, photographs were taken of the ventral surface of the flukes.

There were 449 sightings of 1,018 humpback whales approached in 1999 off California, Oregon, and Washington with an estimated 646 identifications made which yielded 348 unique individuals. Photographic identification of blue whales conducted in 1999 yielded 414 identifications of 178 unique individuals out of 361 sightings of 540 whales. Locations of sightings in 1999 were more clumped than in past years with most blue whale identifications made in the Santa Barbara Channel and more than half the humpback whale identifications coming from the Monterey Bay area.

Abundance estimates for humpback whales show that the population has continued to increase, the estimates using 1998 and 1999 samples is 1,024 (CV 0.097). These are the highest estimates we have obtained to date. Inexplicably, sightings of humpback whales calves remained low, likely indicating a bias in our observations. Long-range movement patterns of blue whales were examined in 1999 with the help of comparisons to identification photographs gathered by Cascadia in a 1999 cruise to the Costa Rican Dome and identification photographs from Mexico gathered by Diane Gendron (CICIMAR). These comparisons have revealed extensive movements of blue whales from California down to Mexico and the Costa Rica Dome in winter and spring.

Several other components of the research proved promising in 1999. We successfully attached a CRITTERCAM underwater camera (including a hydrophone and pressure and temperature sensor) to a blue whale in collaboration with National Geographic. This yielded excellent images of blue whale swimming behavior and contributed to an analysis of marine mammal diving strategies. We documented an anomalously pigmented white blue whale. Estimated sizes of humpback whales were determined using a laser range-finder and calibrated camera system. We also obtained biopsy samples of humpback and blue whales for determination of gender and genetic patterns.

INTRODUCTION

This report summarizes the results of field work conducted by Cascadia Research and collaborators in 1999 on humpback and blue whales off California, Oregon, and Washington. The purpose of the research has been to examine distribution, abundance, movements, and population dynamics of humpback and blue whales in the eastern North Pacific. A central method to this research is the use of identification photographs of humpback and blue whales to track individual whales.

Field research in 1999 focused primarily on obtaining as large and representative a sample as possible of humpback and blue whale photographic identifications for use in the examination of movements, mark-recapture abundance estimates, and examination of reproductive and mortality rates. Secondary field activities included: 1) examining whale use of several specific regions including two national marine sanctuaries, 2) testing and obtaining size measurements of humpback and blue whales using a photogrametric system based on sizes of flukes, and 3) obtaining data on the underwater behavior of blue whales utilizing National Geographic *Crittercams*.

Support for this research has come from a number of sources in 1999:

- Primary support for the overall research effort aimed at assessing population size and trends as well as reproductive and mortality rates came from Southwest Fisheries Science Center under Purchase Order #40ABNF901105.
- The Olympic Coast National Marine Sanctuary contributed support for conducting surveys off northern Washington and provided space for a researcher on their Rigid-Hull Inflatable Boat (RHIB) under Purchase Order #40ABNC901489.
- The Channel Islands National Marine Sanctuary provided support for conducting research in the southern California Bight under Purchase Order #40ABNC0S0460.
- National Geographic Television provided support during filming efforts documenting the research off California.
- Several private contributors provided support for conducting the research.

METHODS

Photographic identification methods

Identification photographs were taken with *Nikon* 8008 35mm cameras equipped with a 300mm *Nikkor* telephoto lenses and databacks that recorded date/time on the exposed film. High-speed black-and-white film (*Ilford HP-5+*) was exposed with camera settings pushed 1½ stops so that exposure times were generally 1/1,000 or 1/2,000 sec.

Identification photographs were taken using standard procedures employed in past research off California and Washington (Calambokidis *et al.* 1990a, 1990b, 2000). Both the right and left sides of blue whales in the vicinity of the dorsal fin were photographed as well as the ventral surface of the flukes. For humpback whales, photographs were taken of the ventral surface of the flukes.

Humpback and blue whale identification photographs taken in 1999 were compared internally to identify resightings of individual whales. They were then compared to our catalogs of all humpback and blue whales identified along the West Coast. These catalogs consisted of 1,071 different humpback whales and 1,166 different blue whales identified during annual surveys between 1986 and 1998 (Calambokidis *et al.* 1999a). Individual whales identified in 1999 that did not match past years and which were of suitable quality were assigned a new unique identification number and were added to the catalogs.

Survey regions and coverage

Surveys off Washington and Oregon

Surveys off outer coast waters of Washington and Oregon were conducted on 14 days and were primarily focused on humpback whales west of Cape Flattery, Washington and Newport, Oregon (Table 1). These surveys included coastal survey effort for gray whales. An additional 12 days of surveys were conducted in inland waters but are not included in Table 1 because they focused on gray whales and did not have any humpback or blue whale sightings. Components of this effort in and around Washington and Oregon included:

1. Photographic identification of humpback and gray whales conducted off Washington north to the British Columbia border from 20 May to 20 October using Cascadia boats and the Olympic Coast Sanctuary rigid-hull inflatable (RHIB).
2. Surveys from 6 September to 13 October to identify gray and humpback whales off Oregon. This included surveys in more offshore waters on 12 and 13 October when a large concentration of humpback whales were found off Newport. A few additional surveys off northern California included some effort north of the California/Oregon border but all sightings were in California waters and are included below.
3. Photographs of a humpback whale seen in Puget Sound on 1 July 1999 were provided by Mark Sears.

4. Identification photographs of humpback whales photographed incidentally to gray whale research off Vancouver Island near the Washington/BC border have also been taken by Brian Gisborne and Volker Deeke, although these have not yet been examined and are therefore not included in this report.

Dedicated photographic identification surveys off California

Photographic identification of humpback and blue whales were conducted off California by Cascadia personnel on 49 days between 16 June and 2 November 1998 (Table 2). These were conducted using Cascadia's 5.3m RHIBs and with other larger boats on a few occasions. This survey effort had several components including:

- Surveys from 16 June to 12 July using Cascadia's RHIB in the Santa Barbara Channel to sample large concentrations of blue whales. Some survey effort was also conducted in late August.
- Surveys conducted in association with National Geographic Television using both Cascadia's RHIBs from 14 to 21 September in the Gulf of the Farallones and off Bodega Bay.
- Late season surveys conducted using Cascadia's RHIB off northern California out of Eureka and Crescent City between 9 September and 30 October 1998.
- A survey conducted using the schooner *Russamee* from Ventura to Moss Landing from 24 to 27 August.
- A survey along the coast (from Washington) conducted by the *Raven* transiting California waters in mid-September.
- Intermittent surveys using Cascadia's RHIB off central California waters on a periodic basis between 13 July and 2 November, especially from Monterey Bay to Bodega Bay.

Monterey Bay surveys conducted with Oceanic Society

A collaborative research program with Nancy Black and the Oceanic Society yielded additional dedicated photographic identification surveys in the Monterey Bay area on 24 days from 19 July to 17 October 1999 (Table 3). These surveys were conducted aboard the *Point Sur Clipper* out of Monterey and were directed by Nancy Black. Nancy and other naturalists also obtained additional photographs opportunistically from whale-watch vessels but these data are not included in Table 3.

Other contributors for photographs off California

A number of other researchers and naturalists provided photographs of humpback or blue whale off California obtained incidental to other activities. These included:

- Eric Martin of the Marine Mammal Study Center obtained identification photographs of humpback and blue whales in the Santa Barbara Channel on 10-13 July 1999.
- Yuki and Michuru Ogino provided photographs of blue whales taken in the Santa Barbara Channel from four days (9 & 12 July and 5-6 August 1999).
- Bob Pitman provided photographs of blue whales taken off San Diego on 10 June 1999.
- Sue Lynn Konopka-Reif provided photographs of a humpback whale in Monterey Bay on 18 May 1999.

Comparisons to photographs taken outside the region

Additional comparisons were made between photographs taken up through 1998 and those taken through 1999 off Mexico and Central America (Rasmussen *et al.* 1999, Chandler *et al.* 1999, Calambokidis *et al.* 1999b). These include examination of photographs taken off Mexico and Central America by Cascadia Research in winter 1999 and by SWFSC in the summer and fall of 1998 and 1999.

A major effort was undertaken to compare blue whales identified through 1999 in California with those compiled from Mexico by Diane Gendron of CICIMAR. A comparison between these catalogs was made several years ago but since then the size of both catalogs has expanded considerably.

RESULTS AND DISCUSSION

Sightings and photographic identification

There were 449 sightings of 1,018 humpback whales approached in 1999 off California, Oregon, and Washington with an estimated 646 identifications made which yielded 348 unique individuals (Table 4). Identifications were made from southern California to the Washington/BC border between April and November 1999 (Table 5). Photographic identification of blue whales conducted in 1999 yielded 414 identifications of 178 unique individuals out of 361 sightings of 540 whales (Table 4). No identifications were made north of California (Table 6).

Humpback whale photographic identification off California

The locations of sightings and identifications of humpback whales in 1999, especially the high proportion around the Monterey Bay area, was different than in most previous years (Table 7). Over half the identifications were made in the Monterey Bay area. This is a result of both the large amount of effort and the high concentration of humpback whales in this area. The high effort in this area included dedicated surveys by Cascadia Research, Oceanic Society research expeditions in this area (lead by Nancy Black), and opportunistic identifications from whale-watching (organized by Nancy Black).

Identifications in a number of other areas off California were also obtained but not as many as in some past years. Just over 244 identifications of 148 unique individuals were obtained in July, September and November in the Gulf of the Farallones region (including off Bodega Bay) (Table 5). Identifications outside Monterey Bay and the Gulf of the Farallones were somewhat hampered by our failure to find high concentrations of whales in other areas off California in 1999. Animals along most of the California coast seemed more widely dispersed than in other recent years. Smaller samples of animals were identified in the Santa Barbara Channel, off San Luis and Morro Bay, off Half-Moon Bay and off Pt. St. George.

Total humpback whales identified in our research for all areas of California, Oregon, and Washington now totals 1,173 (Table 7). These identifications span a 15 year period and so do not represent individuals that were alive at the same time. A majority of these animals have been identified in the Gulf the Farallones at some point in time (Table 7).

Humpback whale photographic identification off Oregon and Washington

Additional identifications of humpback whales were obtained north of California in 1999. Thirty-two identifications of 21 humpback whales were made by Cascadia personnel off the northern Washington coast in August and October. Additional opportunistic identifications were also obtained in this same area (but mostly on the British Columbia side of the border) throughout the summer by Brian Gisborne who operates a ferry service along Vancouver Island. Fifty identifications of 26 humpback whales were obtained in two days off Newport, Oregon in mid-October 1999. The primary objective of our photographic identification off Oregon and Washington has been to examine the northern border of the apparent boundary between aggregations of humpback whales that feed off California and those off British Columbia

(Calambokidis *et al.* 1996). During photo-identification surveys between 1988 and 1999, 156 whales were individually identified in the Washington/BC border area (Figure 1).

A new effort was conducted in 1999 to compare the 921 humpback whales that were photographed off California with those off Oregon and Washington (Steiger *et al.* 1999). A high degree of interchange was seen between whales off California and those identified from southern Oregon to central Washington (59-82% of whales were seen in both regions). A sharp decrease in interchange rate occurred with the whales that were identified near the Washington/British Columbia border (n=110), of which only 7% were seen off California. These results initially suggested that the northern limit of the California-Washington feeding range should be defined as central Washington or at about 47°30'N. This was also consistent with evidence that the WA/BC area was used by a small number of whales showing high site fidelity (Figure 2).

There were several surprises in the photographic identification data from 1999. An unexpectedly high proportion of whales identified in the WA/BC area in 1999 had not been identified previously in this area. In past years resighting rates have been high with 21 of 29 (72%) of whales identified in 1998 seen in this region previously. The 1999 resighting rate was lower with only 33% of whales identified having been seen in this region previously. As in past years a very low proportion of these whales (1 of 21 had been seen previously off California). We did find a higher degree of interchange within 1999 between whales identified in the summer near the WA/BC border and those seen in the fall off the Oregon coast (Figure 3). Three of 21 whales identified off WA/BC in 1999 were resighted among these 29 whales identified off central Oregon in mid-October. This higher matching rate than indicated in past data may be the result of several factors:

1. The overall distribution of humpback whales appeared different in 1999. We had less success finding large concentrations of humpback whales off California in 1999 compared to previous years. We also had greater success than past years identifying whales off Oregon and Washington despite fairly limited effort.
2. The higher matching rate we found in 1999 between WA/BC and Oregon could have been the result of our sampling off Oregon later in the season in 1999. These Oregon whales were identified later in the season than our previous samples and indicate more overlap may occur between these regions late in the season when some WA/BC whales begin their movement toward southern wintering areas.

Blue whale photographic identification

As with humpback whales, blue whale identifications collected in 1999 were more concentrated in a few regions and time periods than in most years. Our largest sample came from a concentration of blue whales in the Santa Barbara Channel in June, July, and August (Table 6). In June alone this area accounted for 272 identifications (66% of our identifications for the year). A large number of identifications (69) were also made off Bodega Bay in September (Table 6). Blue whales were encountered less frequently in other areas such as Monterey Bay and Pt. St. George compared to past years.

Identified blue whales from all years off California total 1,213 (Table 8). A high proportion of the individual blue whales (535 or almost half) have been seen in some year in the

Santa Barbara Channel where we had good success in 1999. This is higher than for any other region.

Sightings of cows and calves

Of 584 humpback whales approached during Cascadia surveys, 20 or 3.4% were judged to be calves (including tentative determinations). A higher proportion of calves were sighted during surveys in Monterey Bay conducted by Nancy Black (21 of 413 whales or 5.1%). This is consistent with observations in past years off California, Oregon, and Washington but remains below that expected for growing population or that found in other humpback whale populations (Steiger and Calambokidis 2000).

Identifications were obtained of 12 different humpback whale mothers with calves; there were 5 additional identified animals that were tentatively considered mothers due to some ambiguity in the data from sightings (Table 9). Four of the twelve known mothers had been identified with a calf in at least one previous year (three of them in two previous years). Of the individuals tentatively identified as mothers, none had been seen previously with a calf. Six definite and three tentative calves were also successfully identified. One of the mothers was seen with a calf in northern Costa Rica in March 1999 before being sighted with a calf in September in the Gulf of the Farallones.

In one sighting of a mother and calf humpback whale made on 18 July 1999 off Pt. Sur, both animals appeared to be entangled in netting. The calf (only marginal ID photograph) had the netting on the front of its body and on the fluke, while the mother (ID# 9031) appeared to have netting on the fluke only. Both animals appeared to be swimming normally and the netting did not appear to restrict their movements. The entanglement on the calf was fairly severe, however, and would pose a long term problem (see photographs below). Neither animals has been resighted as yet.



Photographs of entangled humpback whale calf seen on 18 July 1999 off Pt. Sur.

Only four confirmed sightings of blue whale mothers with calves were made off California in 1999. These were all in the Santa Barbara Channel in June. Two of these sightings made two days apart were of the same cow/calf pair. For all three distinct pairs, the mother was an animal with a sighting history from past years and as expected, the calf was new. One of these (ID#12) has been seen almost every year since 1985 and was documented with a calf in 1992. Another cow with a long-term sighting history was ID#15, first identified in 1975 in Monterey

Bay (by Gary Friedrichson). She was identified as a mother with a calf in the Sea of Cortez on 1 April 1999 by a collaborator (Michuru Ogino). On 28 June 1999 when she was seen in the Santa Barbara Channel, she was alone, suggesting she had already weaned or had lost the calf. She had also been identified with a calf off California in 1992.

Our low sighting rate of blue whale mothers and calves is not surprising. Blue whale calves grow rapidly and wean from their mothers in early to mid-summer. After weaning it is no longer possible to reliably determine which animals were born that year. Our low sightings of blue whale calves likely represents the high proportion of calves that are either too large or have weaned from their mothers by the time we conducted our observations.

Tagging of blue whales off California

Following a pilot effort in 1998, we worked in collaboration with National Geographic Television in 1999 to attach an instrument package to blue whales. The 'critter-cam' instrument package included a Hi-8 video camera, hydrophone recording to tape, and a depth and temperature sensor. All attempts in 1999 were made off Bodega Bay on 3 days (19-21 September) with a suction-cup attachment on the end of pole and used Cascadia's RHIB.

We approached nine blue whales and made physical contact with eight resulting in one successful deployment (Table 10). Most unsuccessful deployments were the result of the difficulty of getting a tight seal for a sufficient period to allow the suction cup to fully attach. There was typically a very short time window before the whale dove in which to achieve good placement of the tag such that the system used to evacuate the air could be effective in sucking the tag into place.

The one successful deployment was made on the lead whale of a pair of whales on 20 September at 1413 (Figure 4). The whales were tracked from 1206 until 1650. The tag was attached for about 1½ hours from 1413 to about 1540. During the entire observation period, the whales were traveling at about 4 knots in a generally SW direction. There were only small deviations from the southerly course and speed during the entire observation period. The whales remained in the same orientation to each other with the lead whale several body lengths ahead of the other animal.

The tag yielded data on the dive patterns of the blue whale and provided underwater video images, sounds and temperature. Major dive intervals were generally 5 to 14 minutes (Figure 5). Dive depths ranged down to more than 80 m on two occasions. Shallower dives occurred near the middle of the record where the whales traveled over Cordell Banks and the end of the record when the whales were in deep water. The video record yielded images of the whale swimming, surfacing, and turning. Water was clear and there was no evidence of feeding. Information on the fluke beat rate was apparent from the video and these data (in relation to depth and rate of descent) have been incorporated into a comparative analysis of marine mammal swimming behavior that was recently published in *Science* (Williams *et al.* 2000).

The animal on which the critter-cam was placed was at least 10 years old. It is a previously identified whale (ID#576) and has been seen 10 times in 5 different years from 1990

through 1998. Sighting locations have included off San Miquel Island, in Monterey Bay, off Half Moon Bay, and in the Gulf of the Farallones. The trail animal in the pair was also a previously identified whale (ID#006) that we have identified and seen many times since 1986. A sample of sloughed skin was also obtained from the suction cup and should allow genetic determination of sex.

Sightings of a white blue whale

Resightings of one blue whale was easily accomplished in the field due to its virtually all-white coloration. This animal was first seen on 20 June amongst the large concentration of blue whales in the Santa Barbara Channel (34°07N 120°08W). On 26 June a biopsy sample was obtained from this animal, it was surface feeding sometimes singly and other times in a pair among a concentration of blue whales in the same area (34°09N 119°55W). It was again seen multiple times in the same area on 27 and 28 June. We ended our sampling of this area at that time and did not see the whale again during trips in the following months.

Published accounts of anomalously white-pigmented individuals have been documented in a number of whale species including the closely-related fin whale but not in blue whales (Hain and Leatherwood 1982). Richard Sears of Mingan Island Cetacean Study, however, reported seeing a similar colored white blue whale in the Sea of Cortez several seasons earlier. The whale we saw did not appear to be an adult. At this point we cannot confirm whether this is the same individual. Photographs of some faint markings may allow this evaluation in the future.

Measurements of the sizes of whales

During field effort in 1999 we experimented with determining the relative sizes of humpback whales by measuring the width of the flukes of animals. In conjunction with identification photographs, the distance to the whale was measured using a *Bushnell* laser range-finder. The range finder and lens focal-length were calibrated by taking sets of measurement of known size targets on land. The range finders yielded consistent measurements of distance with relatively little error and only a slight bias that was adjusted in the calibration (Figure 6). Measurements of whales were only made when directly behind the whale so that the flukes were perpendicular to the photograph angle.

A total of 42 usable images and measurements were obtained in 1999 off California. Repeated measurements of the same individual yielded fairly consistent results in most cases. The few large deviations in measurements were primarily the result of unrealistically close distance readings from the laser range finder (apparently from false targets) or when only a partial or distorted fluke image was photographed. Measurements provided a realistic distribution of fluke widths (Figure 7).

While this method appears promising for determining the relative sizes of identified whales, there are several aspects of this evaluation still in progress to verify its usefulness. These include:

1. A more complete analysis of potential sources of bias in these measurements.

2. A better determination of reproducibility from an increased sample of repeated measurements of the same individual.
3. Compilation of data on the relationship between fluke width and animal length and age class.

Central America comparisons

A major effort was undertaken by Cascadia Research in 1999 to survey potential Central America wintering grounds for the humpback and blue whales that feed off California. Humpback whale surveys were conducted in January and February in coastal waters off Costa Rica, an area where we have conducted annual effort in conjunction with Oceanic Society Expeditions (Calambokidis *et al.* 1999b). An extensive survey was conducted using the schooner *Russamee* that included a search for humpback whales in coastal waters from southern Mexico to Costa Rica (Rasmussen *et al.* 1999) and a search of waters around the Costa Rica Dome for blue whales (Chandler *et al.* 1999) (Figure 8).

Although the humpback whale photographs from Central America have not yet been compared with 1999 California sightings, matching to previous years was completed and yielded new insights into humpback whale use of this area (Rasmussen *et al.* 1999). The humpback whale survey in the *Russamee* off southern Mexico and Central America covered over 600 nmi in 14 days. We made 19 sightings of 31 humpback whales distributed widely in all areas surveyed. The highest sighting rate of animals was found in northern Costa Rica. Of 18 individuals identified photographically during this survey, 14 of these had also been seen feeding off California through 1998 (78%). Surveys off southern Costa Rica in 1999 and previous years have identified a total of 35 individuals (including one off Panama), with 30 of these also identified off California (86%). This high rate of matching suggests that southern Mexico and Central America are used almost exclusively by humpback whales that feed off California. Humpback whales that feed off California appear to utilize a broad region from southern Mexico to Panama as a wintering area. Although densities are low, this region is a more significant wintering area for North Pacific humpback whales than previously thought.

Similarly, over 1,300 nmi of offshore waters out to the Costa Rica Dome were surveyed in two 2-3 week periods between 13 January and 22 March 1999 (Chandler *et al.* 1999). We made 24 sightings of 28 blue whales, with most (18) from 12-15 March 1999. Of 14 whales that were individually identified, 7 were animals previously seen off California. We estimate that we have identified about half (1,000) of the blue whales that feed off California, so the proportion of matches we found indicates whales seen on the Costa Rica Dome at this time of year are comprised primarily of whales that feed off California. There were no matches between the whales seen off California or in winter at the dome and those identified during summer months by SWFSC near the dome or by Daniel Palacios near the Galapagos Islands. The high match rate between the winter sightings off the dome and California and the absence of matches between the winter/spring and summer/fall identifications on the dome suggests there is not a resident population on the dome or if there is one it is relatively small. This would mean that whales seen near the dome in the summer/fall are either migrants from Southern Hemisphere waters, part of a small resident population, or possibly some animals leaving late or arriving early from their summer migration to northern waters. We observed blue whales defecating on several occasions suggesting blue whales feed on this wintering ground.

Satellite tag data on blue whales seen off California in the summer and fall have also documented the movements of animals to wintering areas off Mexico and one animal to the area near the Costa Rica Dome (Mate *et al.* 1999). Vocalizations typical of those made by northeast Pacific blue whales were most numerous in the Eastern Tropical Pacific in the winter/spring although some calls were heard year-round (Stafford *et al.* 1999).

Comparison of blue whales to Mexico

Comparison of Cascadia's catalog to that maintained by Diane Gendron of CICIMAR yielded new information on exchange of whales between California and Mexico (Table 11). The CICIMAR catalog contained 285 individual whales, from this 191 were judged to be of suitable quality for comparison. Of these 191 individuals 67 (35%) matched Cascadia's catalog with 60 representing animals seen in both California and Mexico. Some of these were already known as matches to Mexico based on data gathered previously by Cascadia or collaborators and previous comparisons with the catalog maintained by Mingan Island Cetacean Study. For 31 individual whales, however, these matches provided the first documentation of their being seen in both California and Mexico. Some potential internal matches and reconciliations were identified in this comparison that are currently being double-checked.

There appeared to be a slightly higher matching rate to California for those whales identified on the Pacific coast of Baja, Mexico and those identified in the Sea of Cortez. Of the whales that CICIMAR had identified in the Sea of Cortez only 33% matched to Cascadia's catalog while 50% of those identified off the Pacific coast of Baja matched. The 50% match rate is consistent with what we find for our new annual identifications off California and in some new areas like the Costa Rica Dome. The lower match rate for the whales seen in the Sea of Cortez could indicate that some of these whales tend to go to places other than the California coast in the summer.

Abundance estimates of humpback whales

Revised estimates of humpback whale abundance were made incorporating 1999 identifications (Tables 12 and 13). New abundances for blue whales were not calculated because of the need for a systematic sample covering the more offshore waters where this species occurs. Petersen mark-recapture estimates using the adjacent years of 1998 and 1999 yielded an estimate of 1,024 humpback whales with a CV of 0.097 (Table 12). This is considerably higher than any other estimates but is consistent with the steady increase that has been observed in this population. For the pairs of samples from adjacent years from 1991 to 1999 the annual rate of increase has been 8.6% (based on regression of the log abundance from 8 pairs of observations, $r^2=0.90$).

Humpback whale abundance estimates obtained with the multi-year Jolly-Seber model yielded similar results; the estimate for 1998 was 817 (Table 13). This model estimated an annual survival/emigration rate of 0.94 and predicted a birth/immigration rate of well over 10%. This is consistent with the observed rate of increase based on the Petersen estimates but is higher than the observed rate of calf sightings.

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Numerous collaborating researchers provided photographs of humpback and blue whales from California in 1999 that were obtained incidental to their research activities:

- Nancy Black and Peggy Stapp provided photographs from Monterey Bay conducted primarily as part of Oceanic Society Expeditions trips and whale watching trips. Natasha Bodorff provided identifications from one of the Monterey Bay surveys.
- Brian Gisborne and Volker Deeke provided humpback whales photographs taken incidental to gray whale research off Vancouver Island near the Washington/BC border.
- Photographs of a humpback whale seen in Puget Sound on 1 July 1999 were provided by Mark Sears.
- Eric Martin of the Marine Mammal Study Center obtained identification photographs of humpback and blue whales in the Santa Barbara Channel on 10-13 July 1999.
- Yuki and Michuru Ogino provided photographs of blue whales taken in the Santa Barbara Channel from four days (9 & 12 July and 5-6 August 1999) as well as photographs taken in Mexico in March and April 1999.
- Bob Pitman provided photographs of blue whales taken off San Diego on 10 June 1999.
- Sue Lynn Konopka-Reif provided photographs of a humpback whale in Monterey Bay on 18 May 1999.
- Heather Harding and Graeme Ellis provided opportunistic identification photographs taken off Baja, Mexico in January and February 1999.

A number of people assisted in the field effort, the printing and matching of photographs, and the data analysis. Julia Erickson assisted in the field and analysis work including making measurements of humpback whale flukes. Annie Douglas assisted in field work and coordinated photographic analysis and matching effort. Sheryl Lapp, Hilary Dorinson, and Annie Douglas gathered opportunistic data and photographs during the trip of the *Raven* from Washington to California and across to Hawaii. Anne Nelson, Heidi Faken, Celva Boon, Kristine Endsley, and J.R. Veldink assisted in matching and data compilation. Dave Ellifrit conducted surveys off Washington State and assisted in blue whale matching. Diane Gendron of CICIMAR provided her catalog of blue whales in Mexico for comparison. Jay Barlow provided a review of the draft report.

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Table 1. Summary of field effort by Cascadia Research personnel off Oregon and Washington in 1999.

Date	Vessel	Region	Time		Dist nmi	Latitude		Gray whale			Humpback whale			
			Start	End Duration		South	North	Sit #	An #	Pho #	Sit #	An #	Pho #	
Oregon														
6-Sep-99	RAV	Southern	12:52	19:44	6.9	46	44.184	44.608						
8-Sep-99	RAV	Southern	8:33	18:33	10.0	49	42.908	43.370						
13-Sep-99	N1	Central	11:37	19:54	8.3	82	44.488	45.598	9	12	10			
12-Oct-99	N2	Central	8:17	19:15	11.0	96	44.411	44.837	12	20	16	12	33	26
13-Oct-99	N2	Central	8:03	18:10	10.1	90	44.399	44.651				19	46	32
Washington outer coast														
20-May-99	N1	OC	8:20	18:05	9.8	70	47.849	48.390	61	86	66			
28-Jun-99	OOS	OC	8:00	17:06	9.1	80	47.995	48.398	3	4	2			
3-Aug-99	OC2	OC	8:47	18:23	9.6	97	48.229	48.395				5	7	5
4-Aug-99	OC2	OC	13:10	19:58	6.8	58	48.159	48.387	2	3	3	2	2	1
5-Aug-99	OC2	OC	8:55	18:03	9.1	74	48.083	48.394						
30-Aug-99	RAV	OC	6:22	16:45	10.4	39	48.218	48.502				3	7	1
2-Sep-99	RAV	Southern	6:46	18:43	12.0	79	45.657	46.857						
10-Oct-99	N2	OC	8:45	19:00	10.3	108	48.305	48.498	2	2	1	5	16	15
20-Oct-99	N2	OC	8:04	18:05	10.0	150	47.859	48.385				8	15	12
Total		14	days		133.2	1,118			89	127	98	54	126	92

Table 2. Summary of field effort by Cascadia Research personnel off California in 1999.

Date	Vessel	Region	Time			Dist nmi	Latitude		Gray whale			Humpback whale			Blue whale			
			Start	End	Duration		South	North	Sit #	An #	Pho #	Sit #	An #	Pho #	Sit #	An #	Pho #	
16-Jun-99 N2	CA	7:39	8:50	1.2	2	34.242	34.250											
20-Jun-99 N2	CA	7:54	18:33	10.7	79	34.104	34.408									41	53	50
22-Jun-99 N2	CA	7:19	20:37	13.3	142	34.105	34.250				8	17	12		38	42	39	
25-Jun-99 N2	CA	8:30	17:38	9.1	75	34.088	34.408				1	3	3		30	44	39	
26-Jun-99 N2	CA	7:15	16:27	9.2	54	34.134	34.408								33	47	41	
27-Jun-99 N2	CA	7:30	21:10	13.7	105	34.109	34.407								68	106	88	
28-Jun-99 N2	CA	8:08	18:15	10.1	56	34.127	34.407				2	4	3		24	36	27	
10-Jul-99 N2	CA	7:48	12:59	5.2	67	34.123	34.408				1	1	1		1	1	1	
12-Jul-99 N2	CA	6:43	15:03	8.3	139	34.798	35.672								1	1	1	
13-Jul-99 N2	CA	6:40	18:12	11.5	129	37.110	37.719				14	41	33					
14-Jul-99 N2	CA	7:16	21:18	14.0	100	36.553	37.501				12	24	20					
16-Jul-99 N2	CA	6:00	13:26	7.4	88	36.603	36.964				8	17	13		1	2	1	
17-Jul-99 N2	CA	7:01	16:16	9.3	127	36.603	37.332				3	5	2					
18-Jul-99 N2	CA	6:42	16:51	10.2	100	36.218	36.964				15	32	30		7	9	8	
19-Jul-99 N2	CA	7:27	18:12	10.8	167	36.078	36.964				18	27	27		5	5	5	
20-Jul-99 N2	CA	7:11	12:56	5.8	78	36.537	36.963				13	27	17					
22-Jul-99 N2	CA	6:23	18:56	12.6	145	37.454	37.786				14	32	27		16	22	20	
24-Aug-99 RUS	CA	8:15	19:37	11.4	56	34.237	34.448											
25-Aug-99 RUS	CA	6:35	20:00	13.4	57	34.448	34.893				3	4	4					
26-Aug-99 RUS	CA	10:02	19:41	9.7	54	35.614	36.107				2	5	4					
27-Aug-99 RUS	CA	6:44	19:40	12.9	52	35.919	36.301				3	6	4		1	2	2	
3-Sep-99 N2	CA	7:20	16:52	9.5	109	37.961	38.317				2	4	4		2	3	1	
4-Sep-99 N2	CA	7:19	17:55	10.6	112	37.481	37.917				14	26	20		3	6	6	
5-Sep-99 N2	CA	8:21	13:49	5.5	60	36.706	36.919											
8-Sep-99 N2	CA	7:25	18:22	11.0	127	37.481	38.001				14	22	17		8	9	9	
9-Sep-99 RAV	CA	6:44	19:18	12.6	62	41.257	41.785				2	4						
11-Sep-99 RAV	CA	12:31	19:19	6.8	43	40.353	40.853											
12-Sep-99 RAV	CA	8:53	18:51	10.0	33	38.639	39.039				1	1	-					
14-Sep-99 N1	CA	11:00	13:15	2.3	10	41.742	41.790											
15-Sep-99 N1	CA	8:30	9:30	1.0	4	38.293	38.323											
15-Sep-99 N2	CA	11:56	14:24	2.5	16	38.282	38.323											
16-Sep-99 N1	CA	8:40	19:30	10.8	108	38.289	38.718				2	4	3		7	11	12	
16-Sep-99 N2	CA	9:55	19:45	9.8	109	37.722	38.323				9	15	9					
17-Sep-99 N1	CA	15:14	19:19	4.1	30	38.280	38.323								3	6	4	
17-Sep-99 N2	CA	9:39	19:20	9.7	40	38.256	38.323				3	8	5		20	38	28	
18-Sep-99 N1	CA	9:04	19:14	10.2	128	37.899	38.521				3	5	6		1	2	2	
18-Sep-99 N2	CA	10:42	20:00	9.3	77	38.222	38.515				4	6	3		2	6	2	
19-Sep-99 N1	CA	10:37	19:45	9.1	144	38.257	39.455				5	12	10		1	1	1	
19-Sep-99 N2	CA	9:30	19:35	10.1	43	38.149	38.323				2	6	4		6	13	10	
20-Sep-99 N1	CA	9:01	20:03	11.0	106	37.914	38.312	1	1	1	8	11	9		2	3	1	
20-Sep-99 N2	CA	9:00	19:58	11.0	82	37.862	38.323	1	1	1	5	7	4		7	17	10	
21-Sep-99 N1	CA	8:05	18:00	9.9	140	36.802	38.323				6	12	11		1	1	1	
21-Sep-99 N2	CA	9:46	15:58	6.2	43	38.059	38.323				5	10	7		4	7	4	
22-Sep-99 JM	CA	6:00	16:00	10.0	16	36.717	36.805				1	4	4					
23-Sep-99 N2	CA	16:48	19:41	2.9	37	41.737	41.872				3	5	3					
2-Oct-99 RUS	CA	11:30	18:30	7.0	18	36.705	36.822				2	7	5					
11-Oct-99 N2	CA	7:51	18:13	10.4	124	41.449	42.107	1	1	1	9	19	15					
30-Oct-99 N1	CA	10:17	17:46	7.5	112	41.516	42.083	3	4	3								
2-Nov-99 N1	CA	6:39	16:54	10.3	87	37.903	38.311				21	46	34		4	6	5	
3-Nov-99 N1	CA	7:00	9:44	2.7	36	38.081	38.311											
Total	50	days		443	3,928			6	7	6	238	479	373	337	499	418		

Table 3. Summary of effort by Nancy Black and Peggy Stapp in Monterey Bay during Oceanic Society expeditions.

Date	Vessel	Time			Dist nmi	Latitude		Humpback whale			Blue whale		
		Start	End	Duration		South	North	Sit #	An #	Pho #	Sit #	An #	Pho #
19-Jul-99	PSC	8:00	15:00	7.0	NA	NA	NA	13	47	23	3	4	2
20-Jul-99	PSC	7:40	14:50	7.2	NA	NA	NA	12	36	18	2	4	2
21-Jul-99	PSC	7:40	14:50	7.2	NA	NA	NA	5	9	4	1	1	0
22-Jul-99	PSC	7:40	15:20	7.7	NA	NA	NA	2	10	5	3	4	2
23-Jul-99	PSC	7:35	15:00	7.4	NA	NA	NA	6	15	7	4	9	4
20-Sep-99	PSC	8:00	15:00	7.0	40	37	36.820	2	5	5			
21-Sep-99	PSC	7:30	15:15	7.8	40	37	36.785	5	8	3	1	2	1
22-Sep-99	PSC	7:35	15:00	7.4	64	37	36.742	2	3	3			
23-Sep-99	PSC	7:33	15:50	8.3	52	37	36.831	3	5	4			
24-Sep-99	PSC	7:30	15:00	7.5	44	37	36.826	4	10	4			
26-Sep-99	SOM	9:13	14:50	5.6	34	37	36.784	2	3	2			
28-Sep-99	PSC	9:09	14:40	5.5	33	37	36.761	3	5	2			
30-Sep-99	PSC	9:08	15:15	6.1	28	37	36.814	4	10	4			
2-Oct-99	ZOD	12:00	19:19	7.3	52	36	36.755	8	18	7	1	1	1
3-Oct-99	SOM	9:03	14:32	5.5	34	37	36.708	2	5	5			
4-Oct-99	PSC	7:35	15:30	7.9	48	36	36.720	5	9	9			
5-Oct-99	PSC	7:40	15:00	7.3	36	37	36.827	7	14	14			
6-Oct-99	PSC	7:35	15:15	7.7	51	37	36.841	10	17	13			
7-Oct-99	PSC	7:34	15:25	7.9	33	37	36.769	1	1	0			
8-Oct-99	PSC	7:30	15:30	8.0	38	37	36.817	14	26	18			
10-Oct-99	PSC	9:04	14:57	5.9	24	37	36.777	4	7	4			
11-Oct-99	PSC	9:01	15:01	6.0	40	37	36.840	5	10	7			
14-Oct-99	PSC	9:15	15:30	6.3	33	37	36.769	2	7	0			
17-Oct-99	PSC	9:10	15:15	6.1	38	37	36.797	2	6	4			
Total		24 days		131.0	762			123	286	165	15	25	12

July trip data not complete, number photographed estimated based on sightings

Table 4. Summary of total sightings, approaches, and identifications by species and region during dedicated surveys.

	Blue whales	Humpback whales		
	CA	CA	OR	WA/BC
Sightings approached	361	398	31	20
Number approached	540	897	79	42
Good quality identifications	414	564	50	32
Unique IDs	178	302	29	21

Table 5. Number of humpback whales identified off California, Oregon, and Washington in 1999.

Region	Code	Month									Total
		4	5	6	7	8	9	10	11		
Santa Barbara Channel	33			15	3	4					22
Off San Luis	41					2					2
Pt. Buchon to Sur	42				1	8					9
Monterey Bay area	51	2	13	1	179	12	45	103	3		358
Ano Nuevo to HMB	52				14						14
G. Farallones to Bodega	53				35		84		29		148
Bodega to Pt Arena	54						2				2
Pt. St. George	63							9			9
central Oregon	72							50			50
WA/BC border	76					6		26			32
All areas		2	13	16	232	32	131	188	32		646

Table 6. Number of blue whales identified off California in 1999.

Region	Code	Month							Total
		6	7	8	9	10	11		
Santa Barbara Channel	33	272	15	10					297
Pt. Buchon to Sur	42		4	2					6
Monterey Bay area	51	2	13		1	2			18
Ano Nuevo to HMB	52		6						6
G. Farallones to Bodega	53		11		69		2		82
Bodega to Pt Arena	54				5				5
All areas		274	49	12	75	2	2		414

Table 7. Number of unique humpback whales identified by Cascadia and collaborators by year and region for California, Oregon and Washington through 1999.

REGION	Code	Number of individuals identified															All
		>86	86	87	88	89	90	91	92	93	94	95	96	97	98	99	
S Ca. Bight (south)	31	0	0	0	0	0	0	1	0	5	3	0	0	4	0	0	12
S. Ca. Bight (north outside SBC)	32	0	0	0	1	0	1	0	3	1	6	18	0	0	5	0	33
Santa Barbara Channel	33	0	0	0	4	0	6	15	97	9	13	136	22	27	101	18	254
S. California (offshore)	39	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	4
Pt Concepition to Buchon	41	0	0	8	58	0	0	78	4	1	14	20	0	23	3	2	158
Pt Buchon to Pt. Sur	42	0	0	0	2	0	2	12	0	0	0	0	8	13	16	9	60
S Monterey Bay Sanc.	51	3	0	4	15	2	13	13	65	45	59	33	89	90	146	175	469
N Monterey Bay Sanc.	52	0	0	0	2	0	20	0	0	26	4	42	82	47	30	12	225
Farallones/Cordell	53	16	90	140	134	110	161	89	172	181	164	127	168	34	89	117	701
Bodega Bay to Pt. Arena	54	0	1	0	5	0	0	0	63	6	0	0	4	5	22	2	104
C. California offshore	59	0	0	0	0	0	0	0	0	3	1	0	0	0	0	0	4
Pt. Arena to C. Mendocino	61	0	0	0	0	0	0	4	73	2	0	0	0	23	22	0	119
C Mend. to Klamath Riv.	62	1	0	0	8	0	0	4	0	4	0	12	8	26	6	0	61
N California to Oregon	63	0	0	0	3	0	0	85	50	16	0	1	0	14	69	6	185
S Oregon	71	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2
C. Oregon	72	0	0	0	0	0	22	0	0	0	0	0	7	0	0	29	56
N Oregon	73	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	6
Washington	75	0	0	0	0	0	5	0	0	0	0	0	0	0	1	0	6
Wash/BC border	76	0	0	0	1	1	10	13	0	3	16	34	34	22	29	21	106
Puget Sound	79	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2
All		20	91	150	214	111	218	282	398	257	260	364	366	287	418	348	1,173

Table 8. Number of unique blue whales identified by Cascadia and collaborators by year and region for California through 1999.

REGION	Code	Number of individuals identified															All
		>86	86	87	88	89	90	91	92	93	94	95	96	97	98	99	
S Ca. Bight (south)	31	1	0	0	0	0	5	17	0	7	0	33	16	11	43	0	128
S. Ca. Bight (north outside SBC)	32	2	2	0	0	0	0	1	19	5	34	91	9	22	0	0	177
Santa Barbara Channel	33	0	0	0	0	0	0	0	106	0	145	102	77	102	77	122	535
S. California (offshore)	39	3	1	0	0	0	0	20	0	32	0	0	8	0	0	0	64
Pt Concpetion to Buchon	41	0	0	0	0	0	0	4	0	2	6	5	2	8	0	0	27
Pt Buchon to Pt. Sur	42	0	0	0	0	0	0	0	0	2	0	0	7	0	0	6	15
S Monterey Bay Sanc.	51	9	42	62	25	15	0	0	6	18	18	8	21	10	85	16	280
N Monterey Bay Sanc.	52	0	0	0	0	0	2	0	1	45	0	3	4	4	1	5	64
Farallones/Cordell	53	9	36	74	95	64	102	27	109	25	29	7	26	40	22	42	392
Bodega Bay to Pt. Arena	54	0	0	0	17	1	0	0	20	0	1	0	4	5	0	3	47
C. California offshore	59	0	0	0	0	0	0	3	0	9	0	0	2	0	0	0	14
Pt. Arena to C. Mendocino	61	0	0	0	0	0	0	2	93	0	0	0	0	4	7	0	103
C Mend. to Klamath Riv.	62	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	4
N California to Oregon	63	0	0	0	0	0	0	4	4	0	0	0	0	0	7	0	15
All		24	79	129	122	77	109	76	280	126	208	231	168	182	228	178	1,213

Table 9. Summary of sighting histories of humpback whales seen as mothers with calves in 1999.

Identification #		Dates seen in 1999						Regions	1st yr	Other yrs	Comments
Mother	Calf						seen 1999	seen	w/ calf		
9031		18-Jul					Pt. Sur	1996		Both entangled	
9038	11315	2-Sep	20-Sep	2-Oct	3-Oct	6-Oct	11-Oct	Monterey Bay	1988		
9505	11335	31-Aug	22-Sep	23-Sep	20-Oct	21-Oct		Monterey Bay	1988		
10164	11295	14-Mar	4-Sep					N Costa Rica and Gulf of Farallones	1987	1991, 1997 Seen w/ calf in N Costa Rica then California	
10233		20-Jul	26-Aug					Monterey Bay and San Luis	1987	1987, 1996 Costa Rica in 1996	
10243	11339	3-Sep						Gulf of Farallones	1988	1992, 1994	
10402	11340	11-Oct						Pt. St. George	1990		
10539		19-Jul	20-Jul	23-Jul				Monterey Bay	1991	1996, 1997 Tentative in 1996	
10582	11389	2-Nov						Gulf of Farallones	1991		
11354		13-Jul	8-Sep					Gulf of Farallones	1999		
11375		13-Jul						Half Moon Bay	1999		
14029		3-Aug						WA/BC border	1991		
Tentative determinations											
10010	11390	27-Aug						San Luis	1986	Revillagigedoes in 1991	
10079	11352	14-Jul						Monterey Bay	1986		
10850		18-Jul	19-Jul	22-Jul				Monterey Bay and Gulf of Farallones	1995		
11244		19-Jul	1-Aug	18-Sep	20-Sep	22-Sep	24-Sep	17-Oct	1998		
11325		24-Sep						Monterey Bay	1999		
	11341	2-Oct						Monterey Bay	1999		

Table 10. Attempts to place "critter-cam" tags on blue whales in 1999 (under permit #838). All deployment attempts are off Bodega Bay.

Date	Time	Snum	Num	Latitude	Longitude	Type of sampling	Reaction	Photo	Comments
19-Sep	1540	N2-7	2	38 09.7	123 18.37	Suction-cup contact w/ 1, no atchmt.	Quick dive	JAC-39/30-end	
19-Sep	1638	N2-8	2	38 10.92	123 18.71	Suction-cup contact w/ both, no atchm	No chng in feeding, 1 does c	JAC-40/3-9	
20-Sep	1240	N2-7	2	38 04.77	123 22.02	Cup contact w/ both, attach to one	Quick sink and acceleration	JAC-40/27-end	Stays on 1413 to 1540, get skin
21-Sep	1317	N2-11	2	38 07.00	123 14.64	Suction-cup contact w/ both, no atchm	Sink, turn, and accelerate	JAC-42/20-24	
21-Sep	1401	N2-13	1	38 08.38	123 14.15	Suction-cup contact, no atchmt.	Turn and dive then back to r	JAC-42/25-33	

Table 11. Summary of new matches found between CICIMAR catalog for Mexico and Cascadia catalog (primarily from California).

ID#	CICIMAR data							Cascadia data				
	Quality			Photos	Region	Years seen		CRC ID #	Years seen		Regions seen	
	L	R	F			Start	End		Start	End	Start	End
35	1	2	2	11	S Cortez	1991	1998	6	1986	1999	22	53
180	2	3		1	S Cortez	1997	1997	11	1986	1999	24	53
29	2	2	1	3	S Cortez	1989	1993	34	1986	1999	33	53
101	2	1	1	1	Pacific	1995	1995	102	1987	1999	24	53
183	2	1		2	S Cortez	1997	1998	122	1981	1999	22	53
187	2	1		2	S Cortez	1997	1997	144	1987	1995	32	61
139	2	2	2	4	S Cortez	1996	1999	154	1982	1999	22	54
213	2	1	3	1	S Cortez	1997	1997	201	1988	1995	33	53
98	3			1	Pacific	1995	1995	229	1988	1999	24	61
250	1	1		3	S Cortez	1998	1999	243	1988	1997	22	53
171	1	2		1	S Cortez	1995	1995	246	1985	1994	22	53
292	2		2	1	S Cortez	1999	1999	246	1985	1994	22	53
111	2		3	1	Pacific	1995	1995	253	1988	1998	51	54
33	2	2		1	S Cortez	1994	1994	283	1988	1992	24	61
120	1	1		1	S Cortez	1991	1991	322	1984	1996	22	53
4	3	2	3	3	S Cortez	1988	1995	345	1987	1999	22	61
152	2	2		2	S Cortez&Pac.	1996	1997	348	1982	1995	32	51
142	1	1	2	6	S Cortez	1988	1999	382	1981	1998	22	53
84	2	2	3	1	Pacific	1994	1994	395	1988	1988	24	24
6	2	1	1	21	S Cortez	1988	1996	401	1985	1992	22	61
124	2	2	2	13	S Cortez	1996	1999	423	1984	1995	22	53
136	1	1	2	4	S Cortez	1996	1997	459	1985	1998	22	61
221	2	1		1	S Cortez	1997	1997	475	1984	1999	22	33
127	2	1		5	S Cortez	1996	1999	486	1989	1995	24	33
8	3	2	1	3	S Cortez	1989	1993	525	1979	1992	22	51
278	1	2	3	1	S Cortez	1999	1999	559	1989	1999	22	61
36	2	2		1	S Cortez	1994	1994	573	1990	1999	22	61
17	2	2		1	S Cortez	1990	1990	581	1987	1996	22	53
204	1	3		1	S Cortez	1997	1997	610	1985	1995	22	33
107	2	2		1	Pacific	1995	1995	616	1990	1992	31	33
259		2		1	S Cortez	1998	1998	682	1992	1999	32	51
39	3	2		1	S Cortez	1994	1994	743	1990	1999	22	61
43	2	2		2	S Cortez	1991	1998	743	1990	1999	22	61
50	2	1		2	S Cortez&Pac.	1994	1995	763	1992	1997	33	53
160	2	2	3	2	Pacific	1996	1996	772	1992	1998	32	33
260	2	2	2	1	S Cortez	1998	1998	775	1984	1999	22	33
96	2	2		1	Pacific	1995	1995	794	1992	1992	33	33
223	2			1	S Cortez	1997	1997	926	1994	1997	33	33
28	1	2		2	S Cortez	1993	1995	938	1994	1999	33	33
249	2	3		1	S Cortez	1998	1998	939	1993	1997	24	33
268	3	2		2	S Cortez	1999	1999	939	1993	1997	24	33
80	1	2		1	S Cortez	1995	1995	959	1994	1995	32	33
122		2		1	S Cortez	1991	1991	1047	1991	1991	22	22
123		2		1	S Cortez	1991	1991	1047	1991	1991	22	22
42	2	1	2	2	S Cortez	1994	1994	1057	1995	1997	32	33
48	2			1	S Cortez	1994	1994	1057	1995	1997	32	33
253	2	1	2	1	S Cortez	1998	1998	1060	1995	1996	31	51
112		2		1	Pacific	1995	1995	1122	1995	1995	33	33
246	3	1		1	S Cortez	1998	1998	1149	1995	1997	31	33
117	3	2		1	S Cortez	1991	1991	1167	1995	1999	32	33
25	1	1		1	S Cortez	1993	1993	1173	1995	1995	33	33
106	2	2	3	1	Pacific	1995	1995	1201	1995	1995	32	32
251	2			1	S Cortez	1998	1998	1236	1996	1996	39	39
280	1		3	1	S Cortez	1999	1999	1262	1996	1996	33	33
282	1	1		3	S Cortez	1999	1999	1292	1996	1997	33	33
189	1	1		1	S Cortez	1997	1997	1339	1997	1998	33	41
113	1			2	S Cortez&Pac.	1995	1999	1340	1997	1997	33	33
271	2	2	1	1	S Cortez	1999	1999	1346	1997	1997	53	53
73	1	2		3	S Cortez	1994	1994	1365	1997	1999	32	33
141	2	2		3	S Cortez&Pac.	1996	1997	1436	1998	1998	31	31
290		1	3	2	S Cortez	1999	1999	1460	1998	1999	22	33
288	2	1		1	S Cortez	1999	1999	1467	1998	1998	51	51
286	2	2	2	1	S Cortez	1999	1999	1514	1999	1999	22	22
134	2	1	2	2	S Cortez	1996	1999	1529	1999	1999	22	22
40	2	2		3	S Cortez	1994	1999	1530	1999	1999	22	22
12	2	1	2	9	S Cortez	1990	1998	1543	1999	1999	33	33
74	1	2		3	S Cortez&Pac.	1994	1998	1575	1998	1998	24	24

Table 12. Humpback whale abundance off California, Oregon, and Washington using Peterson mark-recapture estimates with paired samples based on either adjacent annual samples or on survey type during pooled years.

Period	Sample 1			Sample 2				Match	Est.	CV1	CV2	
	Year	Subs.	Ident.	n	Year	Subs.	Ident.					n
Annual samples using all data												
1991-92	1991	7	668	269	1992	8	1023	398	188	569	0.03	0.051
1992-93	1992	8	1023	398	1993	6	512	254	173	584	0.03	0.057
1993-94	1993	6	512	254	1994	6	402	244	108	572	0.05	0.148
1994-95	1994	6	402	244	1995	9	661	331	100	804	0.06	0.166
1995-96	1995	9	661	331	1996	7	564	331	144	759	0.05	0.078
1996-97	1996	7	564	331	1997	7	383	265	104	840	0.06	0.164
1997-98	1997	7	383	265	1998	8	854	389	116	886	0.06	0.129
1998-99	1998	8	854	389	1999	6	613	330	125	1024	0.06	0.097
Pooled years using survey type as samples												
1991-93	Systematic	6	87	68	Other	12	2116	523	57	622	0.05	0.074
1995-97	Systematic	8	91	75	Other	11	1516	601	49	914	0.08	0.129

Ident.-Number of identifications during period

n-Number of unique individuals in sample used in mark-recapture estimate

Est.-Estimated abundance

CV1-Coefficient of variation based on Chapman

CV2-Alternate estimate of coefficient of variation using Jackknife procedure (see Methods)

Table 13. Humpback whale model parameters and population estimates from Jolly-Seber mark-recapture method using California, Oregon, and Washington (not incl. WA/BC border) for 1990-99.

Year	IDs	Prev IDs	r	z	Sur- vival	Births	Marked available	Popul. estimate	SE
1990	208	0	184	0	0.91				
1991	269	105	252	79	0.97	88	189	482	25
1992	398	245	345	86	0.93	56	344	558	14
1993	254	204	222	227	0.96	75	464	577	17
1994	244	191	210	258	0.98	152	491	626	21
1995	331	230	260	238	0.97	57	533	766	28
1996	332	255	223	243	0.93	45	616	802	31
1997	265	216	154	250	0.90	103	645	791	40
1998	389	298	125	106			626	817	49
1999	330	231	0	0					
Mean	302	198	198	149	0.94	82	489	677	
SD	63	86	92	105	0.03	37	157	131	

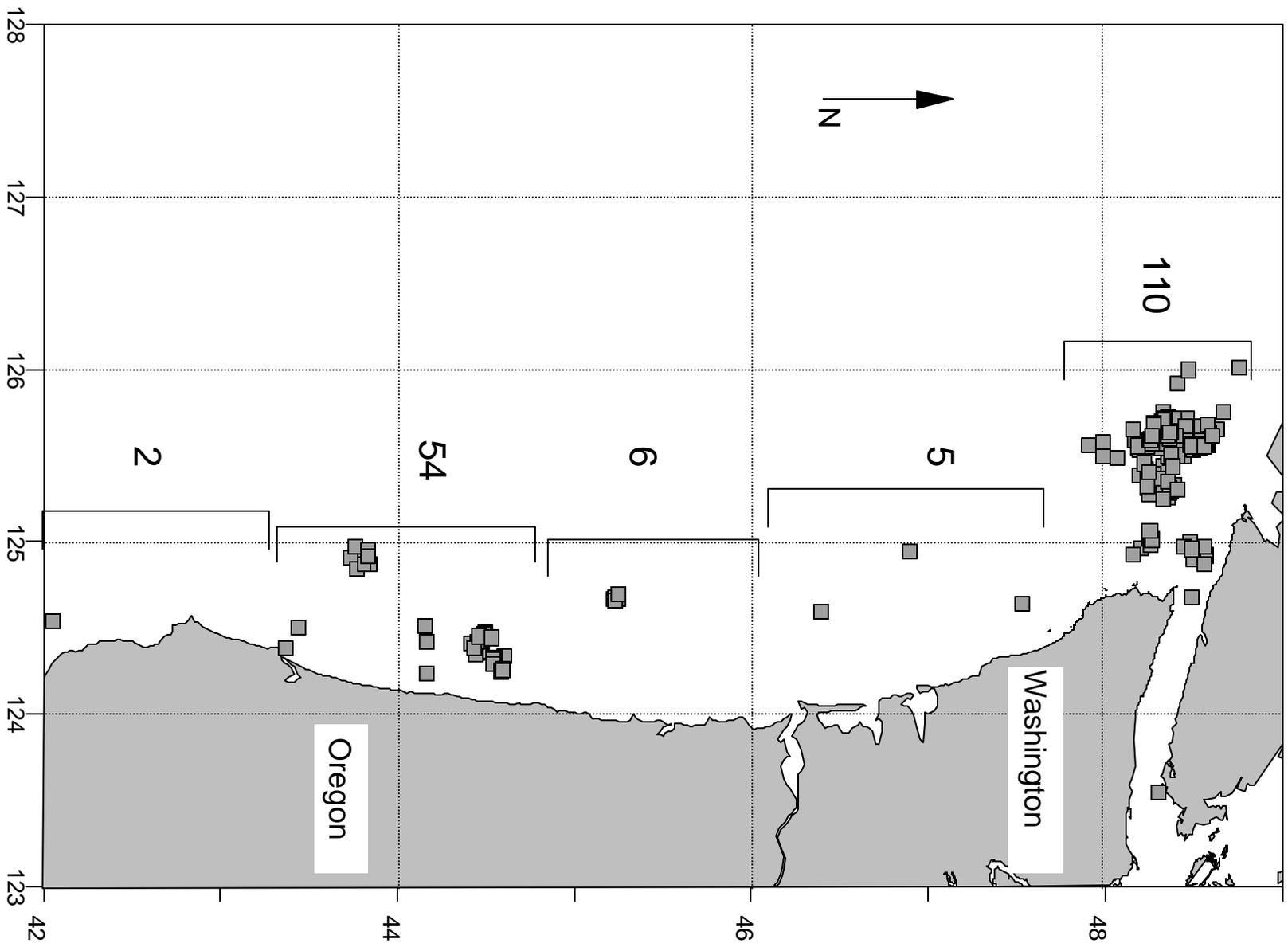


Figure 1. Number of humpback whales identified photographically along Oregon and Washington coast 1988-1999. The coastline was divided into sub-regions to examine interchange rates.

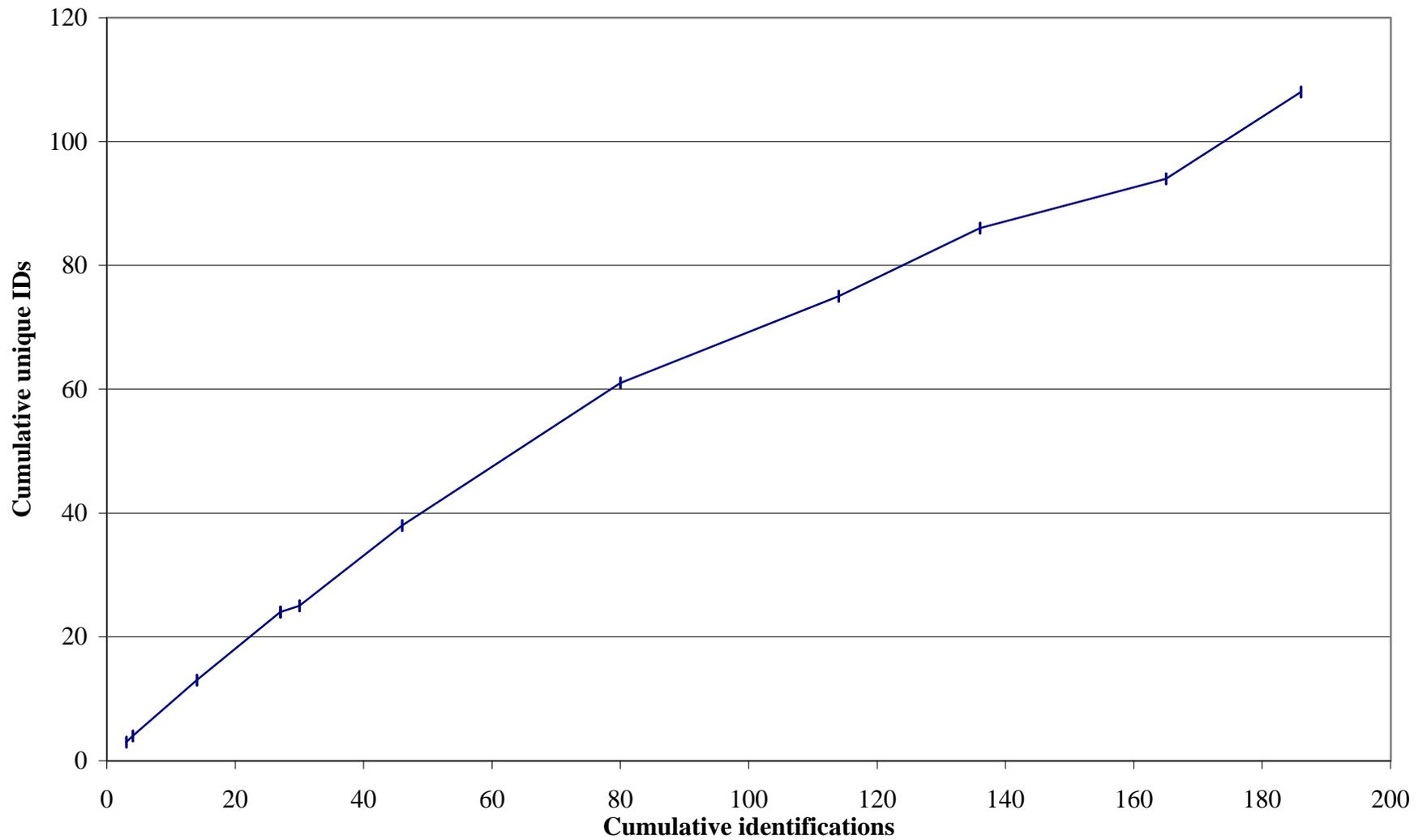


Figure 2. Rate of discovery of new humpback whales near WA/BC border by year 1990-99. Results from 1999 deviate from the pattern and indicate a higher proportion of whales not seen in this region in past years.

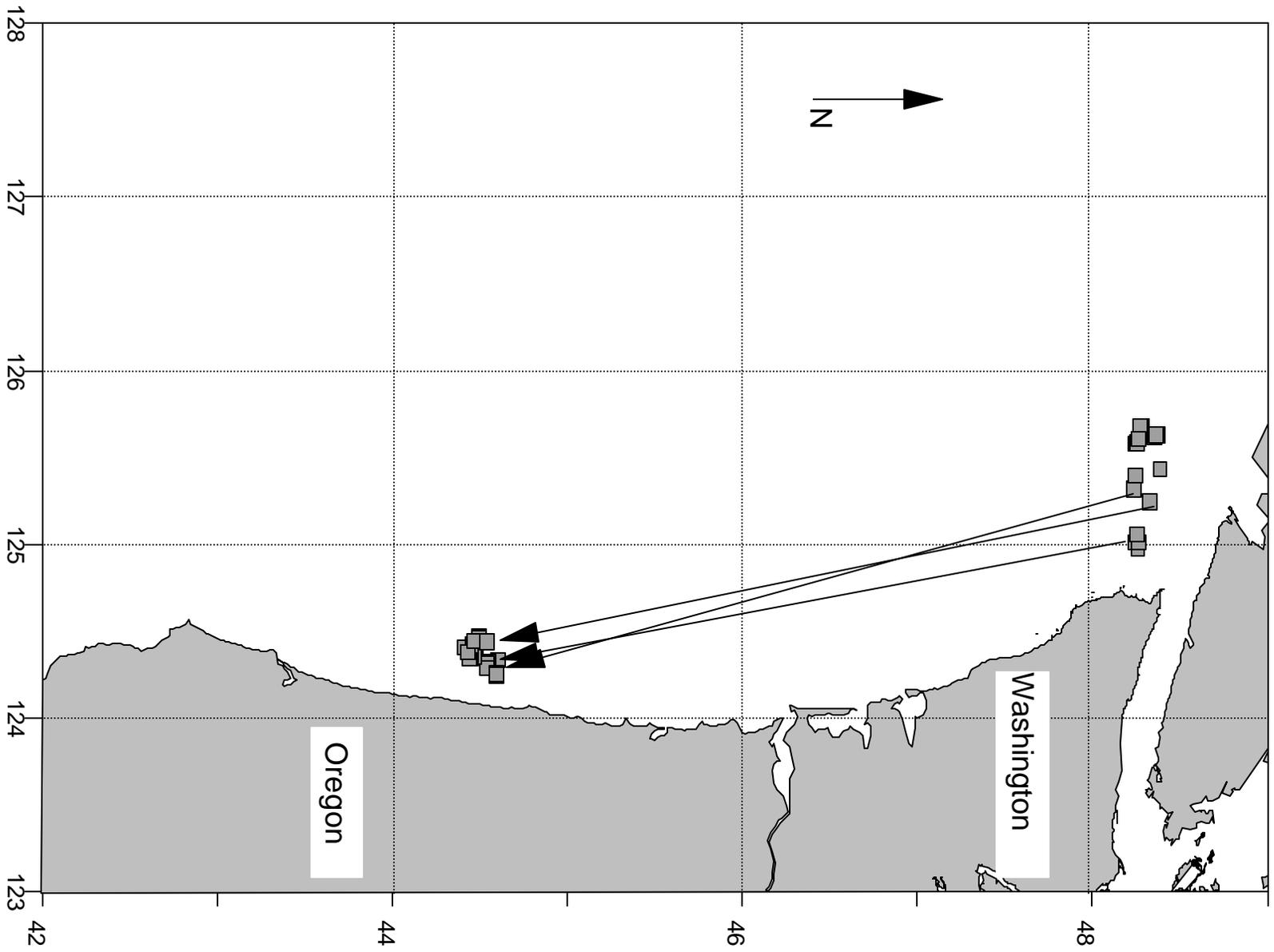


Figure 3. Preliminary results from 1999 showing location of identifications off Washington and Oregon. Movements are shown of 3 of 21 whales identified off WA/BC in August which were resighted among 26 whales identified off central Oregon in mid-October 1999.

Movements of blue whales during tagging

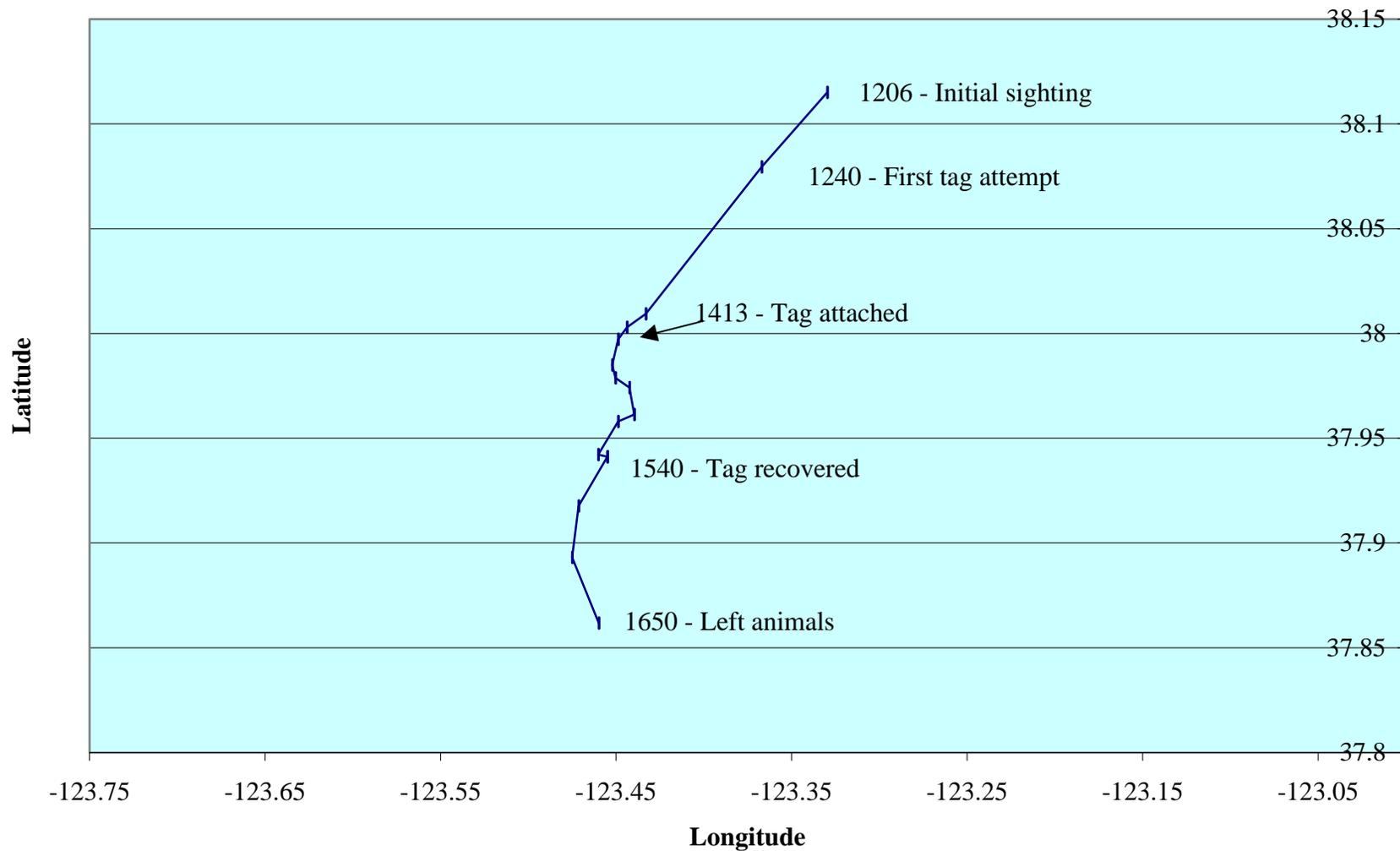


Figure 4. Geographic track and times two blue whales were followed during critter-cam deployment on 20 September 1999.

Dive profile of tagged blue whale

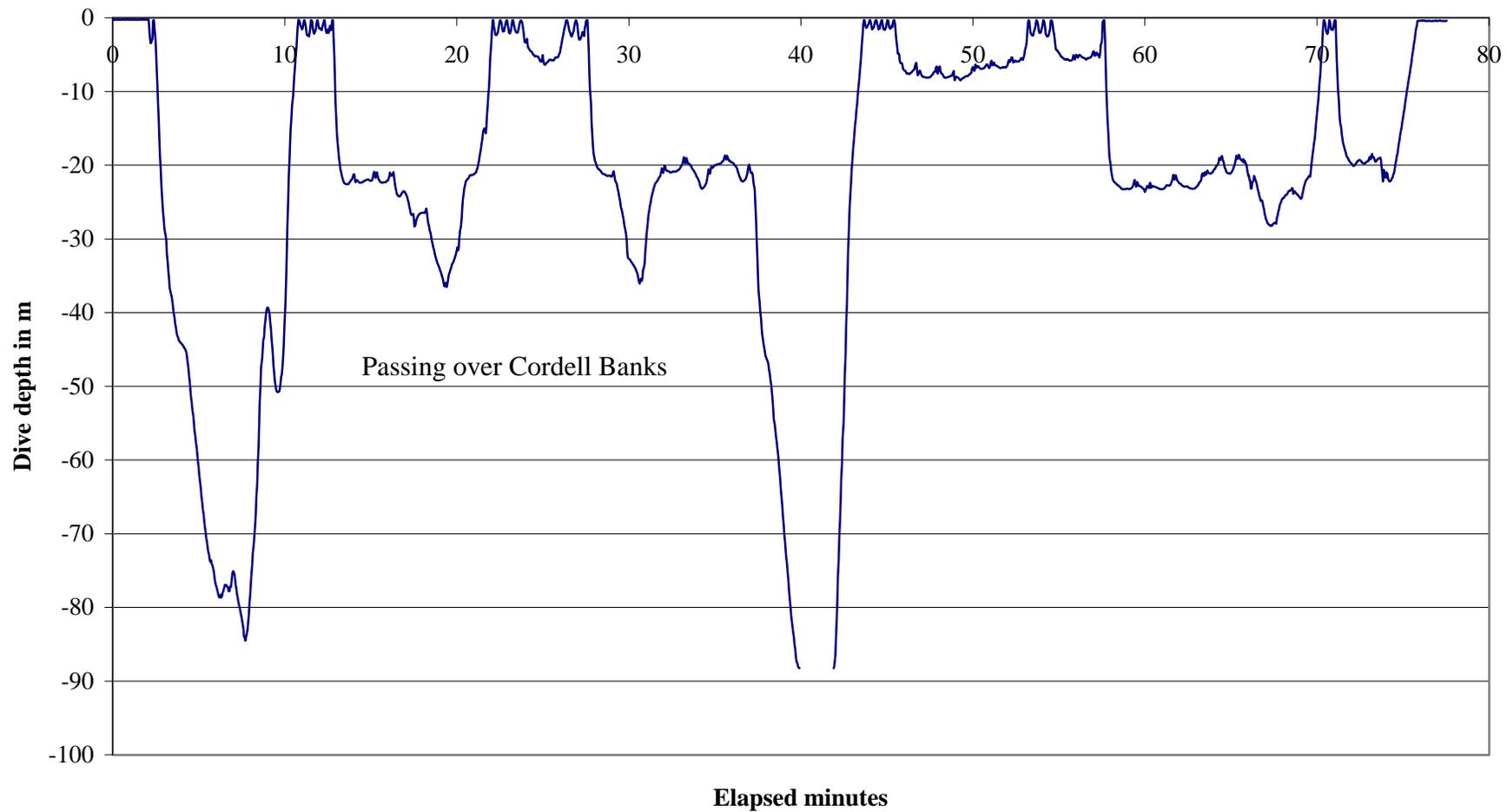


Figure 5. Dive profile of blue whale tagged with Crittercam on 20 September 1999.

Measured distance versus range-finder estimates

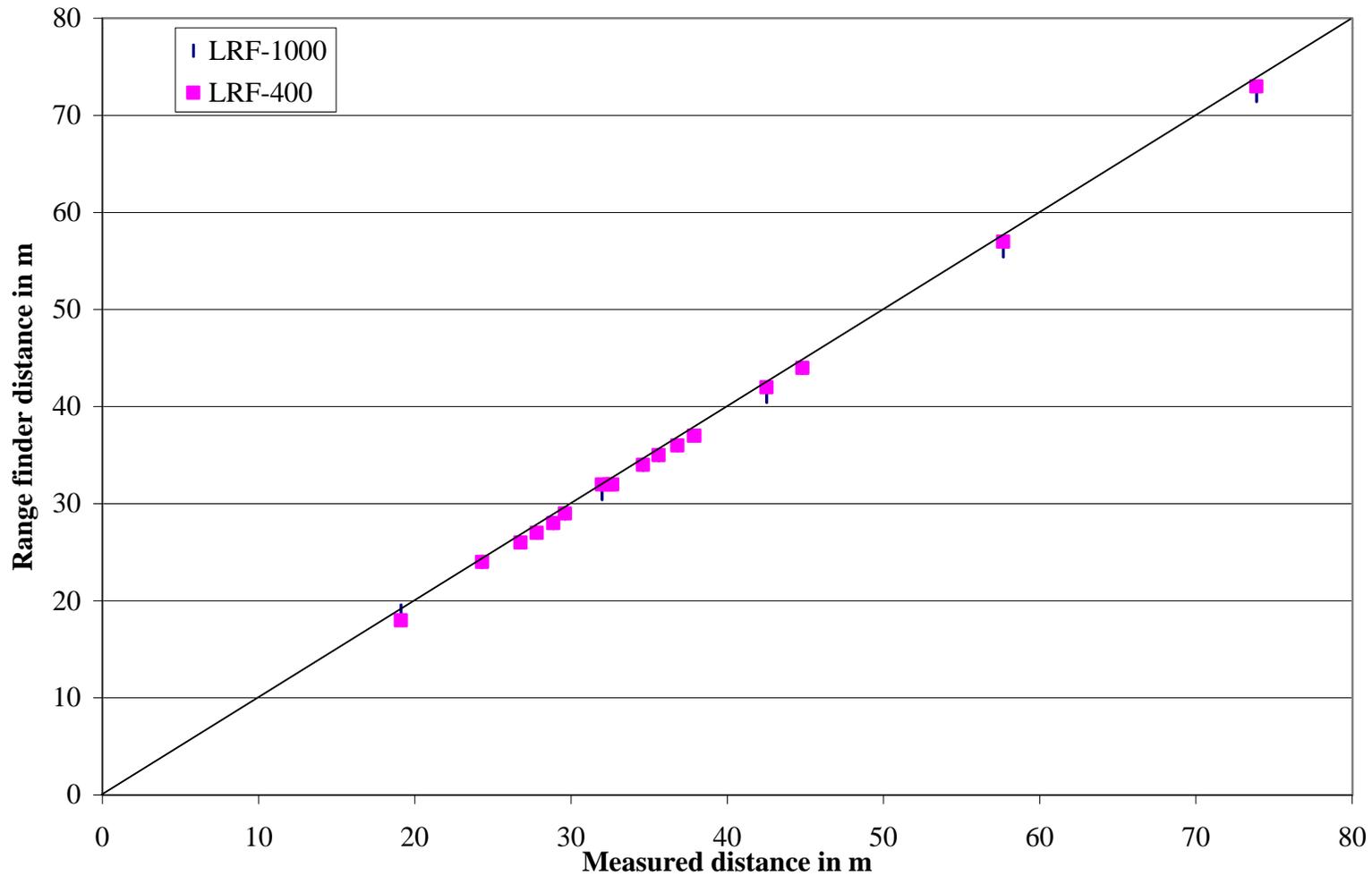


Figure 6. Relationship between distance determined by two laser range-finders and measured distance to a target on land.

Histogram of fluke widths

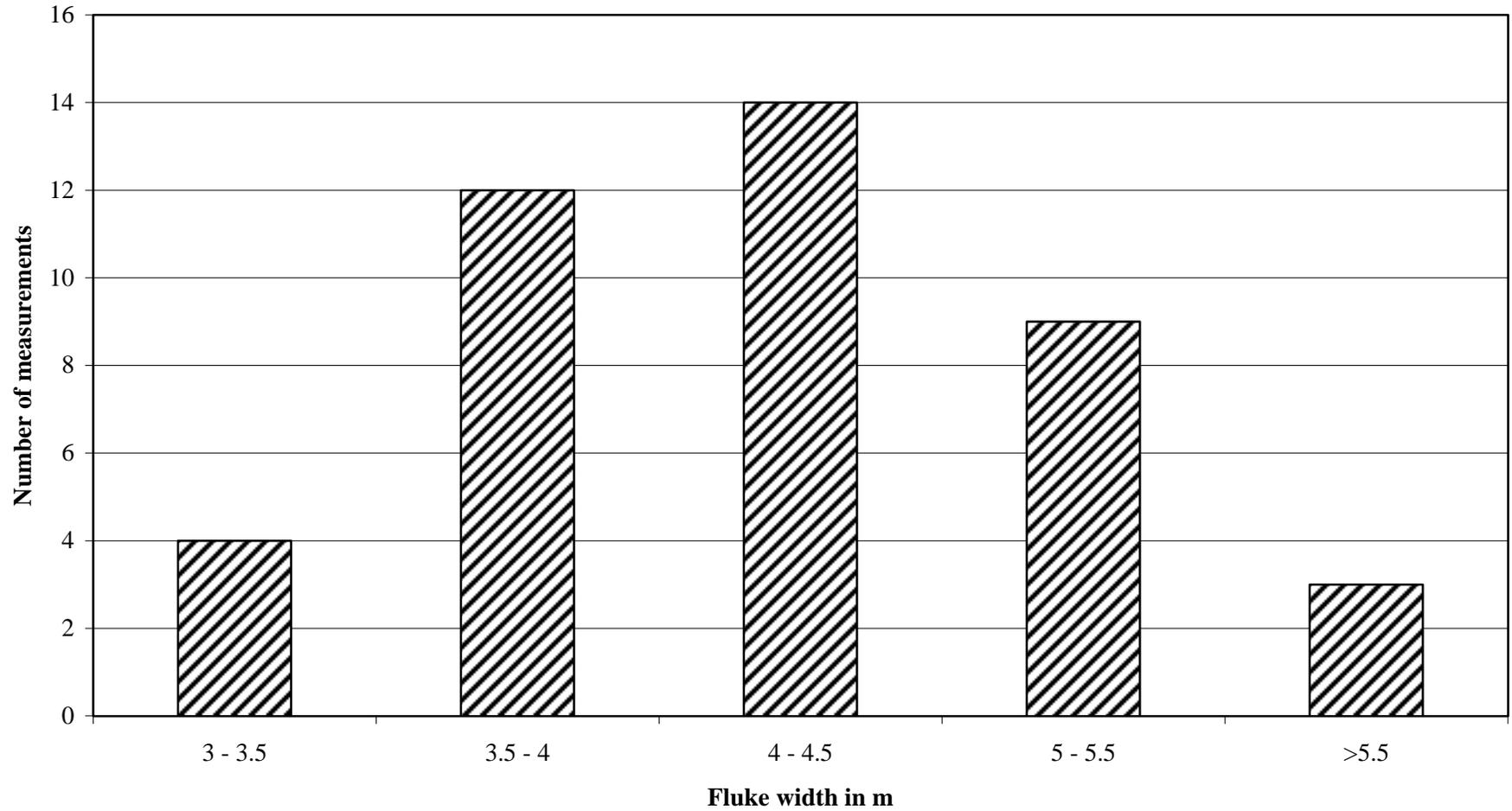


Figure 7. Frequency distribution of fluke widths from 42 measurements of humpback whales taken off California in 1999.

