Photo-Identification of Fin Whales (*Balaeanoptera physalus*) along the US West Coast, Baja California, and Canada: Final report for order number JFI 3F09SE 516

Erin Falcone, Bethany Diehl, Annie Douglas, and John Calambokidis

Cascadia Research Collective
218 ½ W. 4th Ave.
Olympia, WA, 98507
efalcone@cascadiaresearch.org

14 January 2011

Introduction

The fin whale (*Balaeanoptera physalus*) is a large baleen whale with a broad geographic distribution. Fin whales were subjected to commercial whaling until the mid-twentieth century and were severely depleted throughout their range by the time they received protection in the late 1970's (Mizroch *et al.* 1984). While there is evidence that many populations are recovering, the extent of recovery has varied regionally and proven difficult to quantify; based on capture records they likely remain far below pre-exploitation levels in all or most areas where they occur (Perry *et al.* 1999). Subsequently they remain listed under the United States Endangered Species Act and subject to regulation to encourage continued population growth (Reilly *et al.* 2008).
In general fin whales have proven more difficult to study than related species such as blue and humpback whales, and subsequently they are less well described throughout most of their range. Population assessments in many regions where they occur lack precision, related to several challenging aspects of their biology and life history. Not all fin whale populations appear to undergo predictable latitudinal seasonal migrations like most other large whales, a factor which complicates stock assessments in several regions, but particularly so in the North Pacific (Watkins *et al.* 2000). They tend to favor offshore habitat that is less accessible to routine surveys making data collection challenging and costly throughout much of their range (Reilly *et al.* 2008). Additionally, they are not as distinctively and consistently marked as some other large baleen whale species, for which photo-identification studies have proven invaluable in documenting population structure, size, and growth as well as migratory patterns. Despite these challenges, there are several populations in the world that are being studied with a variety of

emerging methods, including photo-identification (Agler *et al.* 1993, Tershy *et al.* 1993, Zanardelli *et al.* 1992) and genetics (Bérubé *et al.* 1998). These better-known populations are mostly regionally isolated and/or in closer proximity to the coast (the Northeastern United States, the Mediterranean Sea, and the Sea of Cortez), and thus may not be representative of the species in other areas. Nevertheless, many of the methods being used are broadly applicable and can inform research in less studied regions.

The eastern North Pacific is a region where fin whales appear to be recovering in some areas, but for which data to document the extent of recovery are sparse (Mizroch *et al.* 2009). NOAA/NMFS currently recognizes three fin whale stocks in US waters based primarily on whaling data and the results of discovery tagging: the Northeast Pacific stock (including the Gulf of Alaska and Bering Sea), the California/Oregon/Washington stock (extending west 300 nmi), and the Hawaii stock (central North Pacific at lower latitudes, documented primarily acoustically) (Caretta *et al.* 2005). A comprehensive review of available North Pacific fin whale data by Mizroch *et al.* (2009) called into question the accuracy of these designations, and underscored the importance of incorporating additional data to better characterize the complex distribution of fin whales in the ocean basin. While genetic studies are currently underway as one means of addressing this, photo-identification is another low-impact method potentially available to document stock boundaries and trends.

Opportunistic photographs of fin whales have been collected by a number of research organizations during the course of other studies since the 1980's (please see the acknowledgements section for contributor details). Cascadia Research Collective (Olympia, WA) is one such organization, and throughout this time had amassed an archive of fin whale photographs from the US West Coast, as well as smaller numbers of photos from peripheral regions including the pacific coast of Baja California, Mexico and the Queen Charlotte Islands, British Columbia. This collection grew considerably with the inception of an ongoing marine mammal study at the SCORE range beginning in 2006, an active naval training range centered around San Clemente Island approximately 100 nmi off the coast of southern California. Fin whales occur regularly in this offshore area, occasionally in dense aggregations, and this study has provided increased opportunities to collect photos of fin whales in recent years.

Historical photographs from this region had not been thoroughly cataloged previously in part because sample sizes were insufficient, but also because North Pacific fin whales appear to be

even less distinctively marked than other studied populations making cataloging that much more difficult. In many other populations the blaze and chevron pigmentation patterns are reliably bright and well-defined, with enough individual variation to serve as a primary identifying feature along with the shape of the dorsal fin, which can vary considerably in fin whales (Agler *et al.* 1990). For many whales sighted along the US West Coast these pigmentations patterns are often muted and do not photograph well, and thus are not consistently available to match by. Part of any photo-ID study of these whales should ultimately involve a close look at mark rates, mark change, and the reliability of available features relied upon for matching, since other studies have shown many marks on fin whales to be transitory over sometimes relatively short periods (Agler *et al.* 1991).

The purpose of this contract has been to compile all available photographic data for fin whales from the US West Coast and adjacent areas through 2008, develop a reliable method for cataloging these whales which incorporates measures of both photo quality and individual distinctiveness, and internally reconcile these photographs into a catalog of unique individuals with an associated database of their sightings. Results presented here include resighting rates of individual whales both within and between designated regions and across years, and a preliminary assessment of regional variation in several physical characteristics.

Methods

Data collection and processing

Photographs of the left and right sides of the body including the dorsal fin were collected from fin whales encountered during marine mammal surveys beginning in 1987. The majority of photographs contributed to this study were collected from small vessels (<8m in length), though a smaller proportion of photos were collected from large vessels used for offshore line transect surveys, such as those conducted by the Southwest Fisheries Science Center (SWFSC), or other ship-based efforts in which Cascadia Research participated. Prior to August 2003, 35mm SLR film cameras equipped with telephoto lenses and high speed (> 400 ISO) black and white film were used as has been described previously for photo identification of fin whales in the Northwestern Atlantic (Agler *et al.* 1990). In most cases, acceptable quality photographs were printed in a dark room and these prints were archived, with some preliminary reconciliation of

whales across sightings, in addition to the negatives. Beginning in mid-2003, all photos were collected in full color using digital SLR cameras and stored as high resolution jpeg images. Data and photos were processed in batches in reverse chronological order, beginning with photographs from the SCORE study. Effort and sighting data from the SCORE study were entered into an Access database used to correlate photographic data (termed "identifications") with spatial and behavioral observations of groups of whales encountered ("sightings"). All available photographs from each sighting of fin whales were reviewed, and the best quality photos of the left and/or right sides were selected for each whale present in the sighting and entered into the database. A copy of each best-of-sighting photo was cropped to include just the whale and exposure was corrected necessary to enhance visibility of marks.

Photographic comparisons and catalog development

The sample of whales from SCORE 2006-2008 was utilized to develop the matching method used for creating the complete catalog. Prior to reconciliation, these photographs were printed with a photographic quality printer and scored for quality and distinctiveness criteria described in Table 1 (only values of two scored features are assessed in this report). They were also assigned to the fin shape categories described by Agler *et al.* (1990). Then they were manually compared to one another using traditional matching methods which relied primarily on the shape of the dorsal fin and any available marks or patterns on the sides of the body. Matches were confirmed by at least two experienced matchers based on the occurrence of at least three unambiguous shared features, including the curvature of the leading and trailing edges of the fin and any visible scars or pigmentation patterns on the body or fin. Left side-right side matches were made using photos of the same whale from within a sighting, and could be made across sightings for whales which had highly distinctive dorsal fins with disfigurements or multiple notches that were clearly visible from the left and right sides.

Once completely matched, all available photos of each whale were quality assessed for inclusion in the catalog. To be included, a whale had to have at least one photograph of either side that scored 2 or better in all four quality criteria (Table 1). Once individuals with only insufficient quality images were removed, catalog ID numbers ("CRCID") were assigned to the remaining whales and updated into all identification records of the individual. A review of the Agler *et al.*

(1990) fin categories assigned to each whale was conducted to determine if different images of the same whale were consistently assigned to the same category, and these designations could thus serve to organize individuals within this catalog in the future. Fin category assignments were not consistent across images of the same individual, therefore a new series of hierarchical categories was created for this catalog that we felt resulted in fewer ambiguities in category assignments (Table 2).

Though the initial match of whales from SCORE was conducted using printed photos, a decision was made to forgo printing the next batch of images to be compared and conduct the entire match digitally instead. To manage this comparison, an Access digital catalog program was designed in-house to facilitate the rapid and orderly comparison of new images against each other and the existing catalog (Figure 1). The first batch of images to be processed in this fashion were whales identified along the US West Coast, Canada, and northern Baja California from 2003-2008, which were originally digital images. Identification records referencing the best-of-sighting images for each whale photographed during this period were imported into the digital catalog program, and an edited copy of each referenced image placed in a common network folder. Each identification record (which could contain left side, right side, or both side images of a whale from a given sighting) was presented to an initial matcher in a form where they could assign the whale to a fin category and give each image a general distinctiveness score to reflect the number of marks visible on the body (not including fin notches, which were captured in the fin category code): 1. No obvious scars or marks on the fin or body, 2. A few obvious marks, 3. Many obvious marks. From this form, the matcher could trigger a search of the whales in the concurrent batch that had already been matched once (termed the "Annual Catalog", although in this case it contained a collection spanning several years), beginning with whales in the same fin category in descending order of distinctiveness, and then expanding to additional categories until all whales in the current annual catalog had been searched. If the whale was found in the annual catalog, the identification record was updated with the annual ID number (TempID) and the historical ID number (CRCID) if the whale had already also been matched to the historical catalog. In this way, images from the identification being processed would be linked to other annual sightings of the same whale and displayed in the annual catalog record for that whale. If the whale was not found in the annual catalog, it was assigned a new TempID, and a similar search was triggered for the "Historical Catalog" (in this case the SCORE

catalog, though typically this would be whales cataloged from previous years). If the whale was found in the historical catalog, the identification record was assigned its CRCID number, and added to the annual catalog as a new whale for that year. In this way, the annual catalog would grow to contain a reconciled collection of all unique individual in the current batch of new images, some with links to historical sighting records. Independent of matching, these photos were scored for detailed quality and distinctiveness features described in Table 1.

Following an initial comparison of all new images in the active batch of photos, a second experienced matcher would compare all whales in the annual catalog that were not found in the historical catalog during the initial comparison. Whales not found in this second comparison whose annual best images met minimum quality standards described previously were assigned new CRCIDs and added to the historical catalog in preparation for the next comparison. CRCIDs for the images just processed were updated into the original sighting records and the annual catalog was emptied, with annual best images moved into the historical catalog in preparation for the next comparison.

The final stage of matching for this study was the collection of whales originally photographed with black and white film from 1986-2003. Sighting data for these older records were compiled from earlier sighting databases, with best-of-sighting photo frames verified as required. For those images that had already been printed in the darkroom, these prints were digitized using a flatbed scanner and saved as high resolution jpg images. In cases where best-of-sighting frames had not been printed, the original negatives were scanned with a film scanner. Once the collection was completely digitized, these images and identification data were imported into the digital catalog program and they were compared, and integrated into the historical catalog as described previously. These images did not undergo the detailed mark scoring applied to collections that were originally digital images, as the fundamental differences in image resolution and detail inherent in these older images made fine scale mark comparisons more difficult.

Data analysis

For analyses, sightings were assigned to five regions based on latitude from north to south (Table 3). They were also defined as “inshore” (less than 50 nmi from the coast) versus “offshore”, to

assess interchange between regions that are feasibly sampled during routine coastal small vessel surveys (the primary mode of data collection for this study) and those that are not. Identification rates and movements of cataloged individuals were characterized both regionally and inter-annually. Because fin shape was the primary feature used to organize the catalog and a key feature in matching, and because some fin categories were more distinctive than others by definition, a Kruskal-Wallis ANOVA was run to determine whether there were differences in match rates associated with fin category. A chi-square test of the distribution of fin categories between regions was also conducted.

To assess regional variation in two of the other more common marks observed on the body and dorsal fin of whales (pock marks and linear scars, Figures 2a and 2b), a sub-sample was selected of identification photographs with a proportion visible score of 1 and scores of 2 or better in all other quality criteria (Table 1). These photographs were grouped by CRCID and region and assigned the maximum overall degree of scarring on the body score (categorical, ranging from 1-3), maximum number of pock marks visible, and maximum number of linear scars visible across all photographs of the whale in that region. ANOVAs were run to assess regional variability in these mark rates. This sub-sample was not controlled for inter-annual resightings as the number of photos was relatively small following quality screening, there were few inter-annual matches contained in it, and those it did contain did not differ greatly in their scoring between years. Given the small sample size of suitable quality photographs, a detailed analysis of inter-annual mark change was not conducted for whales photographed in more than one year.

Results

A total of 545 fin whale identifications were processed for this study. Total number of identifications by region and month are summarized in Table 3, and mapped in Figure 3. Identifications were available from all months of the year except February and March, though only very small numbers of whales were photographed during winter and spring. Of the total identifications reviewed, 379 (69.5%) were of sufficient quality to receive a CRCID and be cataloged. Of these, 147 were photographed from the left side only, 149 from the right side only, and 83 contained images of both sides of the whale. These identifications represented 274 unique individuals, for an average of 1.38 identifications per individual, or 1.24 daily

identifications per individual (range = 1-6) when 40 same-day resightings were removed from the sample. The average number of days individuals were seen varied regionally (Table 4); however these differences fell short of significance (Kruskal-Wallis ANOVA of ranks, corrected for ties, $p = 0.062$). Forty-six cataloged whales were sighted on more than one day (17%) and 22 were sighted in more than one study year (8%).

The majority of identifications in this study were collected from offshore regions more than 50 nmi from the mainland coast. Of the total individuals identified, 216 were seen offshore and 66 were seen inshore. Only 8 (17%) of the 46 whales seen on more than one day were seen in both coastal and offshore waters. There was insufficient data from both inshore and offshore areas across regions to characterize inshore-offshore movements more broadly or with test of significance, however such exchanges were observed in the Southern California Bight (6 whales), Northern California (1 whale), and between inshore Northern Baja California and offshore Southern California (1 whale).

There were 22 whales identified in more than one year of study, up to a maximum of three separate years. The number of years between first and last identifications for these whales ranged from 1-11. There were only two whales seen in more than one study region, and both of these cross-regional identifications occurred in separate years. The whale CRCID 83 was first identified offshore in the Southern California Bight in August 2003, and was subsequently identified inshore off the coast of Northern Baja California on two consecutive days in October 2006. CRCID 113 was first identified in coastal Southern California during June 1999, and was subsequently identified in coastal Northern California (Monterey Bay) in September 2003, then again in coastal Northern California (Point Saint George, just south of the Oregon Border) in October 2004.

The sample of identified whales, including resighting rate, is summarized by fin category in Table 5. A significant difference in the number of days sighted was detected for at least one fin category (Kruskal-Wallis ANOVA, $df= 7$, $H=18.526$ corrected for ties, $p=0.01$); however a Dunn's test indicated this difference was due entirely to the effect of fin category 2. While whales with fin category 2 were identified on significantly more days than other fin categories, this category was very small (only 4 individuals- one of which was CRCID 113, detailed previously). If this category was excluded from the analysis there were no significant differences detected among the sighting rates of whales in the other seven categories.

The sample was also assessed for evidence of regional variation in fin category and other features used in the comparison. The regional distribution of whales in each fin category is summarized in Table 6. A chi-square test of this data detected no significant differences in the number of whales in each fin category across regions (df =28, chi-square=33.847, p=0.21). The sample of whales used to assess variation in other types of marks on the body was small for several study regions; however, significant regional variation was evident in the overall level of marks on the body, and suggested latitudinal trends in the occurrence of both pock marks and linear scars (Table 7). Whales identified in British Columbia-Southeast Alaska (BC-SEAK) had significantly higher overall body marks scores than did whales from Baja California, though neither of these regions were significantly different from the intermediate geographic regions in overall mark scores (Tukey-Kramer Multiple Comparison, df=86, Critical Value=3.941, $p < 0.05$). A closer inspection revealed that this pattern was driven largely by the number of pock marks on the body, which could be quite high in some individuals and which was significantly higher in whales from BC-SEAK than in both Baja California and the Southern California Bight (Kruskal-Wallis One-Way ANOVA, df=4, H=25.52, $p << 0.01$) with a general declining trend to the south (Figure 4a). Linear scars were much less frequently observed on whales than were pock marks in general and showed a reversed trend, with higher numbers seen on whales from Baja and Southern California than BC-SEAK and to a lesser degree Oregon-Washington with a declining trend to the north (Figure 4b), though the differences were less significant than for pock marks (Kruskal-Wallis One-Way ANOVA, df=4, H=9.09, p=0.06).

Discussion

While the sample sizes across regions, months, and years included in this study are insufficient to characterize movement patterns and stock boundaries for fin whales along the US West Coast and adjacent areas, this study has provided the groundwork for using photo-identification data to begin to do so. The results presented here do suggest the possibility that a higher degree of site fidelity may exist for some subareas along the US West Coast during summer and fall, and do not refute the currently proposed stock boundary that exists between the US West Coast and waters to the north, though this sample is too small to draw any firm conclusions. The often patchy and offshore distribution of fin whales along the US West Coast will always present a

data collection challenge in this region; however the level of daily and inter-annual resightings of whales found in even this limited opportunistic sample support the continued use of this methodology toward more robust stock assessments, potentially including mark-recapture population estimates to refine those currently available from line-transect studies. Previous studies of blue and humpback whales, which also have a variable inshore-offshore distribution along the US West Coast, have underscored the importance of using both survey methodologies to overcome the limitations of each in accurate population estimation for such populations (Calambokidis and Barlow 2004).

At the outset of this study, there were very real questions as to whether it would be productive at all, given the relatively limited sample size relative to the current population estimates (2,000-3,000 individuals, Barlow and Forney 2007, Forney 2007), broad geographic and temporal range of the data used, and inherent challenges of conducting photo-ID with any minimally marked species. There was consensus among staff involved with this project, all of whom were experienced with photo-ID across a range of cetacean species, that matching fin whales almost exclusively by the shape of the dorsal fin is exceptionally challenging; however, with practice matchers also felt they began to recognize the much more subtle characteristics that distinguish these whales from one another. While many, if not most, photo-identification studies of small cetaceans rely exclusively on the shape of the dorsal fin, these studies typically involve much larger samples and often much smaller populations than this study. In the cases where photo-identification is being used to study large odontocete populations there is often enough data that minimally marked individuals can be excluded from comparisons and the mark rate within the population accounted for and applied as a correction factor later. We did not feel we would have an adequate sample if only marked (i.e. notched, scarred, or disfigured) dorsal fins were included in this study, and since it was essentially an exploratory exercise we opted to include all identifications of adequate quality, regardless of distinctiveness. The relative consistency in match rates across all fin categories, from the most distinctive to those that could not be easily categorized, confirmed our sense that there is adequate variability to identify fin whales using the shape of the dorsal fin alone in this population, provided matchers are experienced and there are at least a few marks on the fin and/or body with which to confirm the ID. Ultimately, if these data are to be used for statistical methods that require assumptions about equal capture probability, then the least marked individuals should probably be excluded from those analyses,

particularly if samples are drawn across longer periods where transitory marks on the body may have been gained or lost. But to identify movement patterns and stock boundaries, all whales should be included to maximize sample size. Further, while we opted to include both left and right sides for whales in this study and did not partition results presented here with respect to left side and right side data sets, more detailed assessments of this or future datasets should do so. There are very likely some whales with duplicate records in this catalog which could not be reconciled across their left and right sides (and therefore the catalog may actually contain fewer individuals with a correspondingly higher resighting rate than is reported); however we maintain these individuals in the catalog so that they might be unified via a future sighting of the same whale.

Because individual variation in North Pacific fin whales can be quite subtle, it is vitally important that future efforts to collect identification photos of fin whales strive for high quality data in the field. By far the most essential aspect of photo quality for identifying these whales is the angle of the photographer to the whale. Any photograph taken at more than 30 degrees from perpendicular distorts the dorsal fin shape beyond usefulness in all but the most distinct dorsal fins, thus oblique photos should be avoided. Secondarily, the proportion of the body visible (to increase the availability of additional marks), the photographic exposure, and the image clarity are all also very important- much more so than they are for better marked species. Any study focused on fin whale photo-ID data collection should expect to invest more field time per whale identified. In addition to being less reliably encountered, additional time should be taken with each whale encountered to get the best possible images given conditions, as photos that would suffice for use with blue whales, for example, might well be inadequate for identifying a fin whale.

Ultimately, it will require a variety of methodologies to elucidate the true stock structure and movement patterns of fin whales in the North Pacific. Concurrent to this study, Cascadia has been providing tissue samples from many photographed whales to the SWFSC for genetic studies, and hopefully one day mitochondrial data can be used to augment sighting histories as a tool to differentiate populations and stocks. Cascadia Research has also been deploying medium-duration LIMPET style satellite transmitters on the dorsal fins of fin whales in southern California since 2008 as part of the SCORE project, and has deployed a smaller number of tags on fin whales outside of southern California with support of the SWFSC and the Alaska

Fisheries Science Center, including several off the Washington coast in 2010- a region for which very little fin whale data has been available previously. These tags can provide movement data with several locations a day over periods of up to 6 months on large whales. A detailed analysis of the movements and habitat use of tagged whales is anticipated in the coming year.
An additional 150 fin whale identifications were collected by Cascadia Research in 2009, and these data are in the final stage of comparison to the catalog created by this study. Preliminary results of that match suggest a match rate of 5-10% is likely. A sizeable collection of fin whale identification data was also collected in 2010 and is in the early stages of processing. We have been coordinating our fin whale methodologies with researchers from the Department of Fisheries and Oceans Canada to facilitate an eventual comparison with that much larger dataset of whales from Canadian waters than was included here, and have also been in touch with researchers from Alaska about an eventual comparison to that population. While these studies are likely to be challenging, they may finally provide the level of detail needed to characterize North Pacific fin whale populations with confidence.

Acknowledgements

This report has relied on the efforts of many organizations and photographers over the years. We wish to specifically credit the following for their contributions to this study:

- Past and present staff, interns, and research associates of Cascadia Research Collective for their efforts in both the field and the office, including Gregory Schorr, Lisa Schlender, Jessie Huggins, Todd Chandler, Dominique Camacho, Gretchen Steiger, Kristin Rasmussen, Jeff Jacobsen, Daniel Webster, and Erin Keene.
- The volunteers and staff of the Channel Islands National Marine Sanctuary Naturalist Corps for their contribution of photos from the Santa Barbara Channel and surrounding areas
- Staff and associates of the Department of Fisheries and Oceans Canada, including John Ford, Lisa Spaven, and Rob Williams, for their collaboration in surveys of the Queen Charlotte Islands, BC and additional photographic contributions.

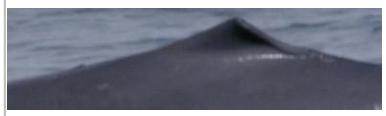
- Nancy Black, Peggy Stap, and naturalists aboard whale watching charters in the Monterey Bay, California area for their photographic contributions.
- Past and present staff and students from Scripps Institution of Oceanography, including Elizabeth Henderson, Megan McKenna, Erin Oleson, and Greg Campbell for their collaboration in field efforts in southern California and additional photographic contributions.
- Staff and observers of the Southwest Fisheries Science Center for large vessel support during collaborative survey efforts and photographic contributions, especially from the far offshore areas of the US West Coast and Baja California. We also wish to thank Barbara Taylor, Jay Barlow of SWFSC and Christina Fahy of the NMFS SWR for their interest and support of this project.
- Staff of UC Santa Cruz and Cornell University for photographic contributions from the southern California LFA study in 1995 and 1997.
- Frank Stone of the US Navy's N45 program for supporting much of the recent fieldwork in southern California during which fin whale photographs have been collected.

Tables

Table 1. Photographic quality and physical characteristic scores applied to fin whale identification photos. Fields marked with an asterisk* are analyzed in this report.

Type	Field Name	Score 1	Score 2	Score 3	Description
Quality	Angle	60-90 degrees to whale	30-60 degrees to whale	0-30 degrees to whale	Degree of angle to whale, with 1 being perpendicular, 3 being from nearly ahead or behind whale
	Exposure	Well-lit, good contrast, faint marks and variations easily seen	Lighting/contrast would prevent some markings conditions from being seen	Poor light/contrast, would obscure all but very obvious marks	
	Proportion Visible	High arch, with dorsal surface visible from roughly midway between blowhole and DF to middle of CP	Some of dorsal surface visible but marks low on side of body likely obscured by water	Only a small portion of the body immediately adjacent to the dorsal fin visible	Indication of total amount of the whale's body visible in the photograph
	Sharpness	Crisp, good detail	Loss of focus may obscure small markings, or make some features difficult to assess	Poor focus, only very obvious features visible	
Physical Features	Body Condition	Healthy, robust, crown of back broad and even extending forward from dorsal fin	Possible signs of emaciation, dorsal ridge visible extending forward from dorsal fin	Clearly emaciated, vertebrae visible, post-cranial depression evident if photos forward on body	
	Bumps	None seen	1-5 seen	more than 5	Smallish, round, skin-colored raised areas on the skin
	Dermal Parasites	Scored as a total count of visible dermal parasites rather than a categorical feature			
	Human Impact	Vessel	Entanglement	Other	For animals with signs of injury, potential anthropogenic source
	Linear scars*	Scored as a total count of discreet linear scars on the body and dorsal fin rather than a categorical feature			Thin, straight or curvilinear scars, of any size, usually with some degree of depigmentation
	Pigmentation	Even skin tone	Some mottling or limited areas of discoloration	Extensive discoloration	
	Pock Marks*	Scored as a total count of visible marks for this study rather than a categorical feature			Smallish circular or oval depressions in the skin which may be light or dark pigmented at center
	Pock Type	White	Dark	Both	Appearance of pock marks, if presence
	Overall marks	Few, if any, marks on the body that are likely to be persistent	A small number of obvious and likely persistent marks	Many obvious and likely persistent marks	General level of marks visible on the body and dorsal fin
	Rake Marks	Scored as presence/absence of killer whale rake marks on the body or dorsal fin			
	Serious Injury	No evidence of injury seen	Definite injury but not apparently life-threatening	Serious injury, potentially life-threatening	
	Skin Condition	Smooth, unblemished	Some irregularities	Many irregularites	Overall skin condition
	Sloughing	No sloughing seen	Some sloughing	Obvious sloughing over large areas of body	Skin sloughing, as evidenced by large, ragged-edged patches of irregular pigmentation on the body surface
	Xeno	Scored as a total count of *xenobalanus* parasitic attachments on the dorsal fin, rather than a categorical feature			

Table 2. Hierarchical fin categories used to organize whales in the catalog. Whales are assigned to lowest category number for which they meet the criteria described below.

FinCat	Description	Example
1	Disfigured, significant portions of the fin missing, or fin obviously bent or distorted	
2	One or more notches in both the leading AND trailing edges	
3	One or more notches in the leading edge only	
4	One or more notches in the trailing edge only	

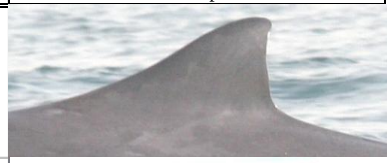
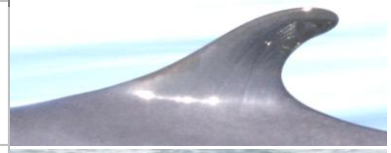
FinCat	Description	Example
5	Fin distinctly triangular in shape, with minimal concavity in trailing edge. Insertion of trailing edge at or posterior to fin tip.	
6	Fin tip distinctly broad and rounded in shape	
7	Fin tip distinctly narrow and pointed in shape	
8	Ambiguous fin shape, can't be easily classified	

Table 3. Regional sample description, including the number of fin whale catalog identifications from each month by region.

			Month									
Region	First Year	Last Year	1	4	5	6	7	8	9	10	11	12
British Columbia-Southeast Alaska	2004	2007						83	3			
Oregon-Washington	2005	2008					2	18				
Northern California (Pt. Conception to Oregon border)	1987	2008			1		3	10	25	10	2	
Southern California Bight (US-Mexico border to Pt. Conception)	1992	2008	2	1		15	11	78	9	65	28	
Baja California (Pacific coast to Cabo San Lucas)	2003	2006						1		11		1

Table 4. Regional summary of fin whale identification data, including resighting rates.

Region	Total Identifications	Identifications assigned a CRCID	Unique individuals	Avg days sighted per individual	Individuals sighted in > 1 year
British Columbia-Southeast Alaska	104	86	46	1.87	3
Oregon-Washington	21	20	20	1.00	0
Northern California	76	51	45	1.13	2
Southern California Bight	326	209	154	1.36	18
Baja California	17	13	11	1.18	1

Table 5. Summary of identification data by fin category.

FinCat	Unique IDs	Daily Sightings	Avg days per ID	Left Side Only	Right Side Only
1	24	32	1.33	7	9
2	4	10	2.50	0	2
3	12	14	1.17	3	5
4	70	91	1.30	21	21
5	23	30	1.30	7	8
6	13	17	1.31	5	3
7	72	82	1.14	26	27
8	58	64	1.10	29	20

Table 6. Regional distribution of individuals by fin category.

	Fin Category							
Region	1	2	3	4	5	6	7	8
British Columbia-Southeast Alaska	4		3	14	2	2	9	12
Oregon-Washington	2			8	1		6	3
Northern California	6	3		10	6	1	10	9
Southern California Bight	11	2	9	36	14	10	43	29
Baja California				1			4	6

Table 7. Regional summary of the occurrence of marks on the body in a sub-sample of identified individuals with adequate quality photographs for detailed mark scoring.

Region	Individuals in Sample	Mean (range) overall body marks score	Mean (range) pock marks	Mean (range) linear scars
British Columbia-Southeast Alaska	28	2.4 (1-3)	55 (5-161)	0.9 (0-6)
Oregon-Washington	8	2.0 (1-3)	31 (5-64)	0.5 (0-2)
Northern California	6	2.0 (1-3)	25 (10-48)	2.2 (0-9)
Southern California Bight	43	1.9 (1-3)	19 (0-84)	3.0 (0-23)
Baja California	6	1.5 (1-2)	20 (4-35)	4.8 (0-13)

Figures

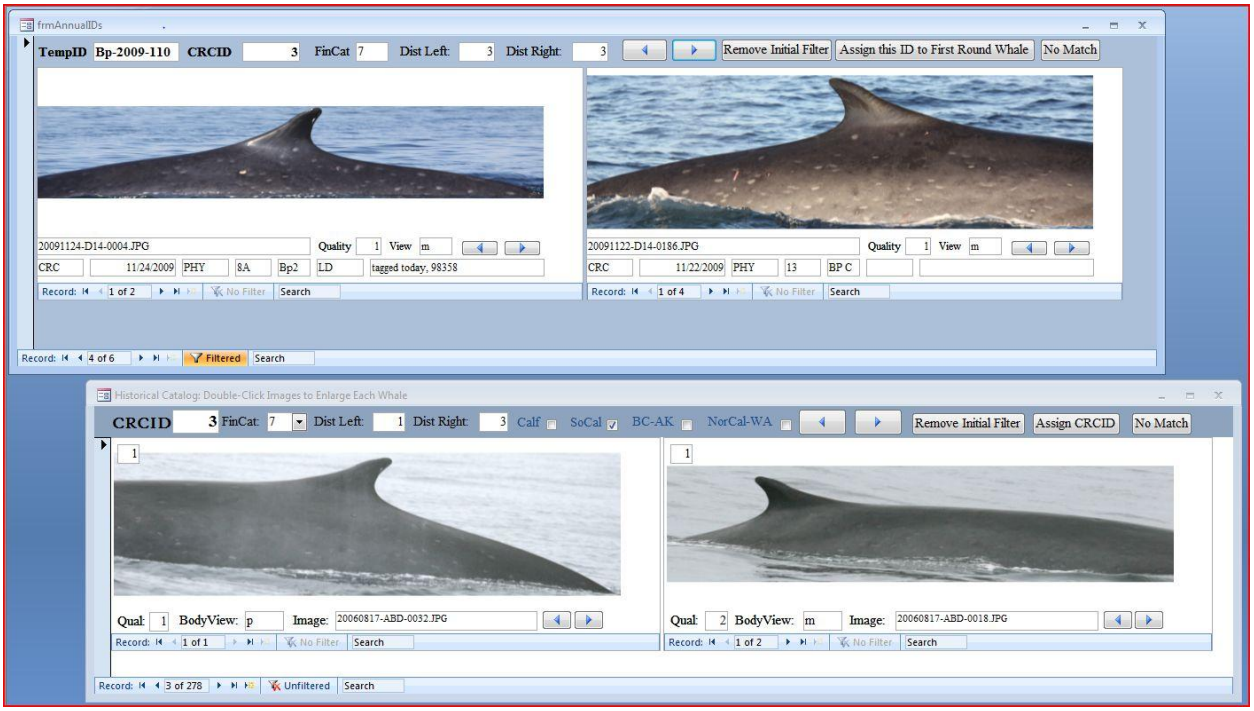


Figure 1. Screen shot of the MS Access digital catalog matching system designed for managing image comparisons. The upper form displays the Annual Catalog record for CRCID 3 in 2009, with all left and right side images from that year presented in subforms in ascending order of quality, along with the corresponding sighting data for each photograph. The lower form is the Historical Catalog record for the same whale, displaying the older photos to which the 2009 photos were successfully matched.


2a

2b

Figures 2a and 2b. Examples of two of the more common marks observed on the bodies of fin whales in the study: "pock" marks (2a) on a whale photographed off Northern British Columbia, and irregular linear scars (2b) on a whale from Southern California.

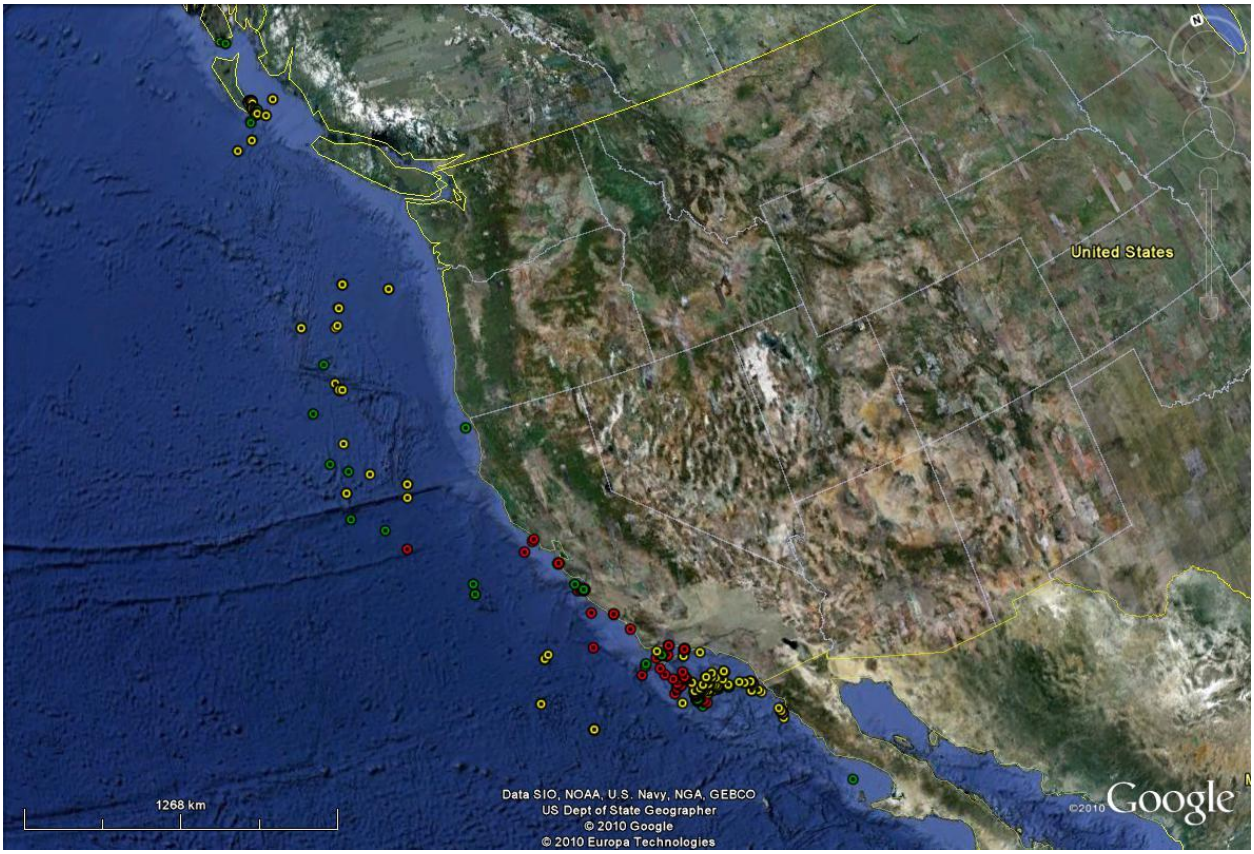
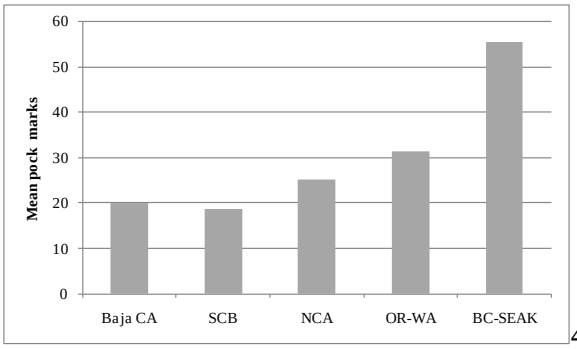
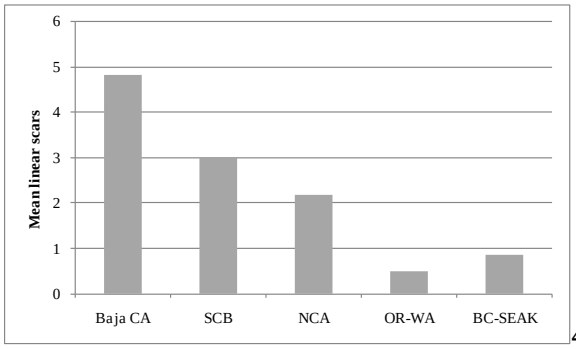


Figure 3. Map of fin whale identification locations, with identifications from 1997-2002 in red, 2003-2005 in green, and 2006-2008 in yellow.



4a



4b

Figures 4a and 4b. Trends in the mean number of pock marks (4a) and linear scars (4b) observed in whales across study regions.

References

AGLER, B.A., J.A. BEARD, R.S. BOWMAN, H.D. CORBETT, S.W. FROHOCK, M.P. HAWVERMALE, S.K. KATONA, S.S. SADOVE, AND I.E. SEIPT. 1990. Fin Whale (*Balaeanoptera physalus*) photographic identification: Methodology and preliminary results from the western North Atlantic. Report of the International Whaling Comminssion (Special issue 12): 349-356.

AGLER, B. A.; D. DENDANTO; S. E. FROHOCK; K. A. ROBERTSON AND I. E. SEIPT. 1991. Scars: Are these marks reliable enough to be used for fin whale photo-identification? In: Ninth Biennial Conference on the Biology of Marine Mammals. 5-9 December, Chicago, IL. p.1. 1991.

AGLER, B.A., SCHOOLEY, R.L., FROHOCK, S.E., KATONA, S.K. AND SEIPT, I.E. 1993. Reproduction of photographically identified fin whales, *Balaenoptera physalus*, from the Gulf of Maine. *Journal of Mammalogy*, **74**,577–587.

BARLOW, J. AND K.A. FORNEY. 2007. Abundance and population density of cetaceans in the California Current ecosystem. *Fishery Bulletin* 105:509-526.

BÉRUBÉ, M., AGUILAR, A., DENDANTO, D., LARSEN, F., DI SCIARA, G.N., SEARS, R., SIGURJONSSON, J., URBAN-R, J. & PALSBOLL, P.J. 1998. Population genetic structure of North Atlantic, Mediterranean Sea and Sea of Cortez fin whales, *Balaenoptera physalus* (Linnaeus 1758): analysis of mitochondrial and nuclear loci. *Molecular Ecology*, **7**, 585–599.

CALAMBOKIDIS, J. AND BARLOW, J. 2004. Abundance of blue and humpback whales in the eastern north pacific estimated by capture-recapture and line-transect methods. *Marine Mammal Science*, 20: 63–85. doi: 10.1111/j.1748-7692.2004.tb01141.x

CARRETTA, J.V., FORNEY, K.A., MUTO, M.M., BARLOW, J., BAKER, J.D. & LOWRY, M.S. 2005. U.S. Pacific Marine Mammal Stock Assessments: 2004. US Department of Commerce. NOAA Technical Memorandum, NMFS-SWFSC-375, La Jolla, California, USA.

FORNEY, K.A. 2007. Preliminary estimates of cetacean abundance along the U.S. west coast and within four National Marine Sanctuaries during 2005. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-406. 27p

MIZROCH, S.A., RICE, D.W. & BREIWICK, J.M. 1984. The fin whale, *Balaenoptera physalus*. *Marine Fisheries Review*, **46**, 20–24.

MIZROCH, S. A., RICE, D. W., ZWIEFELHOFER, D., WAITE, J. and PERRYMAN, W. L. (2009), Distribution and movements of fin whales in the North Pacific Ocean. Mammal Review, 39:193–227. doi: 10.1111/j.1365-2907.2009.00147.x

PERRY S. L., DEMASTER D. P. AND SILBER G. K. 1999. The fin whale. *Marine Fish Review* 61(1): 44-51.

REILLY, S.B., BANNISTER, J.L., BEST, P.B., BROWN, M., BROWNELL JR., R.L., BUTTERWORTH, D.S., CLAPHAM, P.J., COOKE, J., DONOVAN, G.P., URBÁN, J. & ZERBINI, A.N. 2008. *Balaenoptera physalus*. In: IUCN 2010. IUCN Red List of Threatened Species. Version 2010.4. <www.iucnredlist.org>. Downloaded on 14 December 2010.

TERSHY, B.R., URBÁN-RAMÍREZ, J., BREESE, D., ROJAS-BRACHO, L. & FINDLEY, L.T. 1993. Are fin whales resident to the Gulf of California? *Revista de Investigación Científica*, 1: 69–72.

ZANARDELLI, M.; G. NOTARBARTOLO DI SCIARA, AND M. JAHODA. 1992. Photo-identification and behavioural observation of fin whales summering in the Ligurian Sea. European Research on Cetaceans 6:86-89. 1992. Proceedings of the Sixth Annual Conference of the European Cetacean Society, San Remo, Italy, 20-22 February 1992.