National Fish and Wildlife Foundation
Final Programmatic Report

Project Name and Number: Status of Humpback Whales & Human Impacts #2003-0170-019

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EXECUTIVE SUMMARY

This report summarizes overall SPLASH results completed through the end of 2006 as well as reporting on the human impact assessment funded by NFWF. SPLASH is an international collaborative research program on the abundances, population structure, and potential human impacts on humpback whales in the North Pacific involving more than 50 research groups and 300 researchers. The National Fish and Wildlife Foundation provided two years of support to SPLASH which filled some key gaps in funding. This report summarizes findings of both the overall SPLASH photo-ID effort including the results of matching and analysis from the first three seasons of SPLASH effort, and three different measures of human impacts and health based on analysis of photographs of the tailstock, flank, and flukes of whales.

SPLASH field effort was conducted at all known feeding and wintering areas for humpback whales in the North Pacific and consisted of five field seasons, three winter breeding seasons (Winter 2004, 2005, and 2006) and two summer feeding seasons (Summer 2004 and 2005). Identifications of over 10,000 individual humpback whales (some matching still underway) represent the largest photo-ID catalog of whales conducted. Over 5,000 skin samples were collected over the five seasons. Comparison of SPLASH identification photographs collected in Winter 2004, Summer 2005, and Winter 2005 yielded 5,348 different humpback whales. There were almost 500 migrations of individual whales documented from wintering grounds in 2004 and 2005 to the summer feeding areas in 2004. This represents the largest and most complete examination of humpback whale migrations in the North Pacific and revealed a far more complex pattern of movements than had been documented previously. For the first time, migrations were documented between feeding areas off Russia and all three Asian wintering areas. These initial data also suggest that there was an additional wintering area for humpback whales not previously documented between Asia and Hawaii.

Human impacts and other injuries were documented from photographs of the tailstock, flanks, and flukes of whales. Incidence of entanglement of humpback whales was primarily documented from the examination of scarring on the tailstock. This was the first systematic effort to quantify entanglement rates across an ocean basin and results to date indicate significant variation among North Pacific areas. Southeastern Alaska produced the largest sample of high quality images and 50% of whales showed signs of entanglement. This was higher than some of the other North Pacific feeding areas and is similar to estimates for the Gulf of Maine, where entanglement is a management concern. Small sample sizes were a limitation for some of the other feeding areas

and inclusion of images from the later SPLASH years (2005 and 2006) will allow improved estimates.

Examination of the flanks and flukes of humpback whales also provided important information on human injuries and health status. Analysis of flanks provided measurements of serious injuries including ship strikes and these varied by region with some of the coastal feeding areas (i.e., those closer to ship traffic) showing higher rates. Analysis of flanks also provided important insights into seasonal and regional patterns in body and skin condition, as well as incidence of various skin disorders. Body condition did steadily improve during the feeding season but skin condition deteriorated. Injuries on flukes revealed higher rates of scars from killer whale attacks in some areas and also revealed a geographic pattern in the incidence of non-killer whale-related injuries that was similar to that seen in the analysis of flanks.

SPLASH sampling to date has been extremely successful and exceeded expectations. Even though matching is not yet completed it has provided important new information on the status of humpback whales in the North Pacific. Analysis of health and human impacts on humpback whales from visual examination of flanks, tailstocks, and flukes was also more successful than anticipated. While all aspects of SPLASH are going extremely well, funding is still needed to complete the analysis of SPLASH data including completion of matching, analysis of skin samples collected, and completion of the analysis for human impacts and health assessment for the final seasons of SPLASH. SPLASH will be requesting a third year of funding from NFWF (only the first two years of our three-year proposal were funded) to help complete this work.

INTRODUCTION

SPLASH is an international collaborative research program on the abundances, population structure, and potential human impacts on humpback whales in the North Pacific. More than 50 research groups and 300 researchers participated in SPLASH data collection. Fieldwork began in winter 2004 and continued through Winter 2006, encompassing three winter breeding seasons (2004, 2005, and 2006) and two summer feeding seasons (2004 and 2005).

The National Fish and Wildlife Foundation provided two years of support to SPLASH which filled key gaps in funding. NFWF support helped fund the continuation of SPLASH data collection especially in the winter field seasons and in the visual assessment of human impacts. NFWF funded two-years of the three-year proposal for funding (a request to NFWF to fund the 3^{rd} year is pending). This reports summarizes the findings and accomplishments to date related to the areas NFWF helped to fund, which included the overall, SPLASH sampling and matching as well as the assessment of human impacts. This report is divided into four sections:

1) Overall SPLASH photo-ID results,
2) Entanglement rates of humpback whales based on analysis of photographs of stalks,
3) Assessment of health from examination photographs of the flanks of whales, and
4) Assessment of injuries based on scars on the flukes.

OVERALL SPLASH PHOTO-ID

Sample sizes of both identifications and skin samples collected during the five seasons of SPLASH effort exceeded expectations (Table 1). Identifications of over 10,000 individuals (some matching still underway) represent the largest photo-ID catalog of whales in existence. Over 5,000 skin samples were collected over the five seasons.

Table 1. Summary of identifications and samples collected during SPLASH.

Season	Unique IDs	Skin samples
Winter 2004	1,594	1,063
Summer 2004	2,785	1,047
Winter 2005	1,702	1,106
Summer 2005 (does not reflect some inter-regional matches)	2,081	868
Winter 2006 (estimate, screening and matching underway)	2,000	1,579
Total (does not reflect inter-season matches)	**10,162**	**5,663**

Comparison of SPLASH identification photographs collected in Winter 2004, Summer 2005, and Winter 2005 has been completed. During the first three seasons of SPLASH, 5,348 different humpback whales were identified with high quality photographs. Unique individuals identified each season were from 1,594 to 2,785 (Table 1). Overall, the humpback whales identified in the initial three seasons were widely distributed throughout the North Pacific (Figure 1).

Overall there were 234 migrations of individual whales documented from wintering grounds in 2004 to the summer feeding areas in 2004 and 255 migrations from the feeding grounds to wintering areas in 2005 (Figures 1-2, Table 2). Grouped by regions, these migrations between winter and summer areas showed some clear patterns in movements (Table 2). At feeding areas, humpback whales feeding off Russia were documented going to all three Asian wintering areas and one individual was resighted in Hawaii. Feeding areas in the Aleutians, and Bering Sea showed links to Hawaii, Asia and Mexico without a clear pattern; the number of matches was low due to both low numbers of identifications from some of these regions and also an overall lower matching rate to wintering grounds. Whales from these feeding areas may be going to winter areas that were either not sampled or were undersampled in SPLASH. Feeding areas in the Gulf of Alaska showed primary links to Hawaii and the Revillagigedos, Mexico, but also included a lower number of matches to Asia and other areas in Mexico. Humpback whales identified in Southeastern Alaska and northern BC showed a very strong connection to Hawaii with a small number of matches to the three Mexico wintering areas. Southern British Columbia/Northern Washington showed links to Hawaii and all three areas of Mexico. California/Oregon matched to mainland Mexico, Baja, and Central America with no matches to Hawaii, Asia, or the Revillagigedos.

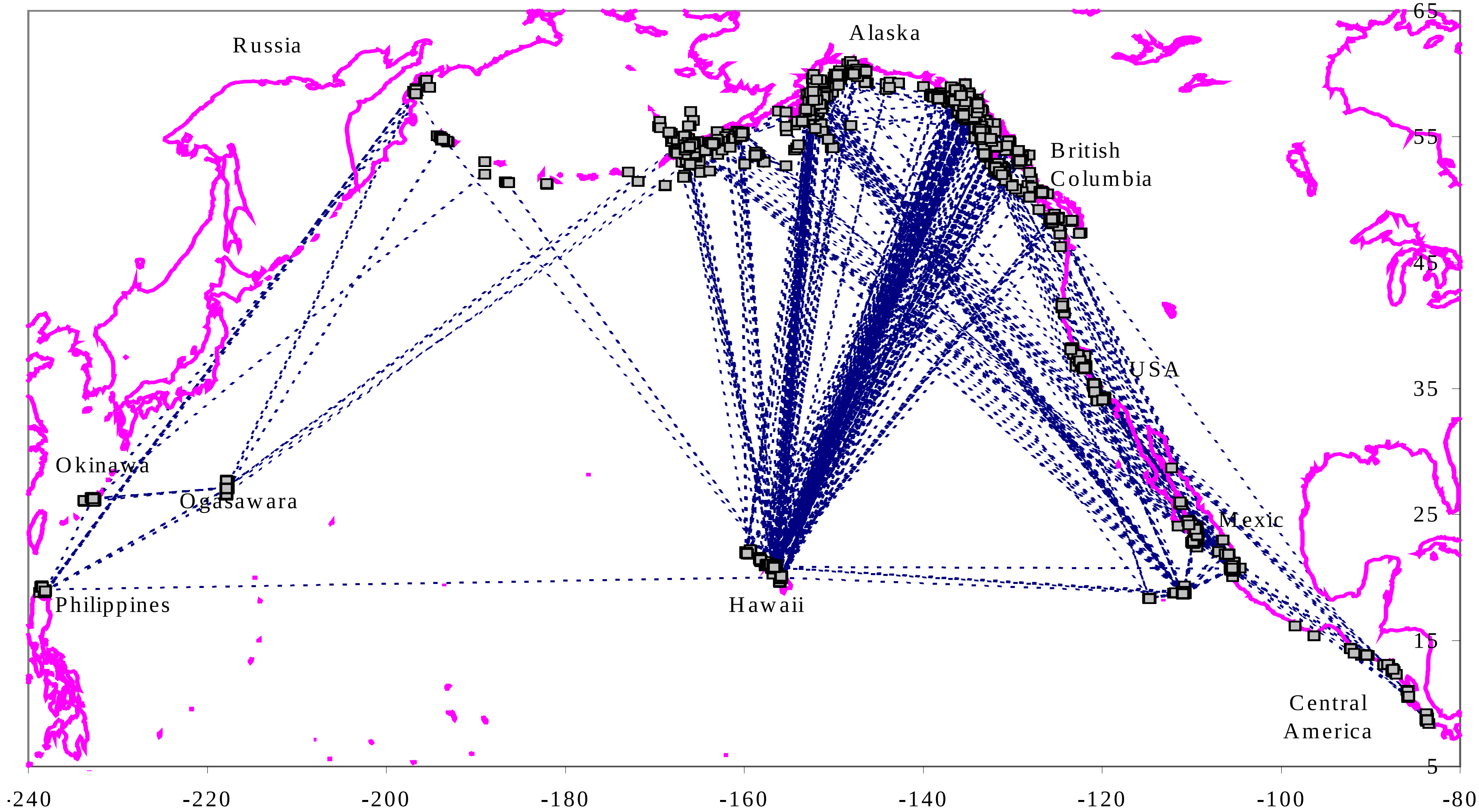

Figure 1. Locations of SPLASH identifications for winter 2004 and 2005 and summer 2004. Lines connect resightings of the same individual.

Table 2. Summary of matches of identified whales from feeding areas in Summer 2005 (listed across top rows).

		Rus	W Al	E Al	Ber	WGOA	NGOA	SEAK	NBC	NWA	CA-OR
	IDs	40	12	51	228	224	726	795	421	75	253
Winter 2004 to Summer 2004											
Ogas.	114	2			1						
Okin.	43		1								
Phil.	27	2									
Hawaii	697		1		8	10	35	66	20	3	
MX-Rev	317				1	7	22	3	2	1	
Mx-MnId	223				2	1	4	1		2	29
Mx-Baja	182				1	2	4	2	1	1	3
Cent Am.	18										3
Winter 2005 to Summer 2004											
Ogas.	123	1			1	2					
Okin.	55	1									
Phil.	35	2									
Hawaii	846	1	1	1	4	4	31	77	38	4	
MX-Rev	193				2	1	11	4	3		
Mx-MnId	266				2		2	2	2	5	28
Mx-Baja	157			1	1	4	6	2	1	2	7
Cent Am.	48									1	7

The overall percentage of whales from different 2004 feeding areas that matched to wintering areas showed a geographic gradient that suggested the existence of a new previously undescribed wintering area for humpback whales somewhere between Hawaii and Asia. Completion of the SPLASH matching will allow more definitive evaluation of this intriguing possibility.

Resightings of whales between winter 2004 and 2005 revealed a fairly low level of interchange among the principal wintering regions (Table 3). A total of 296 whales were seen on wintering grounds in both 2004 and 2005. Even when examined by subregion (except Hawaii), most resighted whales were seen in the same wintering subregion that they had been seen previously (Table 3). One whale seen in the Philippines in 2004 was seen in Hawaii in 2005; there were a total of five whales seen in Hawaii one year and in the Revillagigedos in the other year (three seen first in the Revillagigedos and two first seen in Hawaii). There were also three whales that were resighted between Hawaii and either Baja or mainland. There were frequent matches between Baja and both mainland and Revillagigedos, Baja was one of the few areas where whales seen there one year were almost as likely to be seen at one of the other Mexico subareas as they were to be seen again in Baja. Despite the small sample for Central America, there were six whales seen there that were also seen in either mainland or Baja Mexico.

Table 3. Matches between breeding areas sampled in Winter 2004 (rows) and 2005 (columns).

2004	IDs	Ogas. 123	Okin. 55	Phil. 35	Hawaii 846	MX-Rev 193	Mx-Mnld 266	Mx-Baja 157	Cent Am. 48
Ogas.	114	21	2	1					
Okin.	43	1	9						
Phil.	27	2		3	1				
Hawaii	697				100	2	1		
MX-Rev	317				3	61	5	8	
Mx-Mnld	223					1	50	9	2
Mx-Baja	182				1	1	9	12	2
Cent Am.	18						2		3

ENTANGLEMENT SCAR ANALYSIS

Entanglement scar analysis was conducted by Jooke Robbins of the Center for Coastal Studies under a subcontract from Cascadia Research. Entanglement in fishing gear is a documented source of injury and mortality to humpback whales and other cetaceans. However, entanglement frequency is not known for most areas of the North Pacific because only a small fraction of events are witnessed and reported. Observer effort varies among areas and individual whales may encounter gear in more than one part of their range. Humpback whales are most commonly entangled at the flukes and caudal peduncle (Johnson *et al.* 2005) and even short-term, mitigated events produce persistent scars (Robbins and Mattila 2000; 2001). Systematic sampling and scar analysis can therefore be used to compare entanglement rates geographically and over time (Robbins and Mattila 2000; 2001). In the present study, scar analysis techniques developed in the North Atlantic were used to estimate entanglement rate across 10 North Pacific feeding regions and four breeding regions sampled during SPLASH in 2004.

A total of 1,484 SPLASH images were screened for documentation of the lateral and dorsal caudal peduncle to the insertion point of the flukes (Figure 2). The quality of each image was evaluated based on a combination of focus, lighting, coverage, distance and angle to the subject. In total, 763 were considered useful for one or more aspects of entanglement scar analysis. Regional entanglement rates were estimated based on the best quality images in the data set (n=437), after excluding high quality within-day duplicates of the same individual. An additional 326 images were of lower quality, but were retained for an entanglement index and for future estimates of inter-annual entanglement rate.

Each image was examined for scar evidence of a previous entanglement, including wrapping scars, notches and more extensive tissue damage. Analysis focused on six parts of the caudal peduncle and flukes, and an entanglement status code was assigned to all images in which at least two areas were successfully scored (Figure 2). Animals with wrapping scars or injuries in two or more areas were considered to have a high probability of a prior entanglement. Those with no diagnostic injuries or scars were considered to have a low probability of prior entanglement. When wrapping injuries were detected in only one coded area, entanglement could neither be strongly supported nor necessarily ruled out. In such cases, the animal was assigned an ‘uncertain’ probability of previous entanglement. Examples of scar interpretation are shown in Figure 2. Minimum entanglement rates were estimated for each geographic region as the percentage of images with high probability scarring out of the total number of images scored.

a) a) Low probability of prior entanglement

b) Uncertain entanglement history

c) High probability of prior entanglement

d) High probability of entanglement, unhealed severe injury

Figure 2. Examples of high quality caudal peduncle images and scar interpretation.

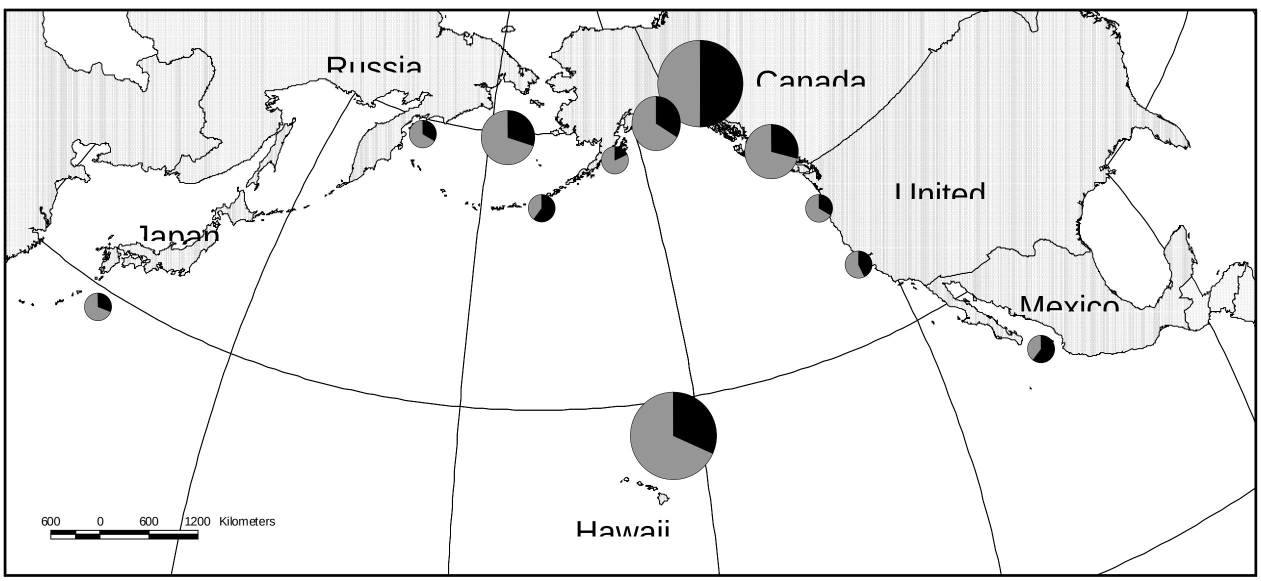

Figure 3. Comparison of entanglement rates across the North Pacific. Black wedges indicate the percentage of the regional sample with a high probability of previous entanglement. The size of the circle indicates the relative sample size and degree of confidence in the results to date. Sample sizes and estimate precision will increase when data from 2005 and 2006 are analyzed.

This was the first systematic effort to quantify entanglement rates across an ocean basin and results to date indicate significant variation among North Pacific areas (Table 4, Figure 3). Southeastern Alaska produced the largest sample of high quality images and an estimated entanglement rate of 50% (95% CI: 43-58%). This result is consistent with estimates for the Gulf of Maine, where entanglement is a management concern (Robbins and Mattila 2000; 2001). Hawaii exhibited a significantly lower rate (32%, 95% CI: 23-42%) despite the fact that it is a known migratory destination for Southeastern Alaska whales. Three other feeding areas with exchange to Hawaii exhibited more similar entanglement rates: the Bering Sea (30%, 95% CI: 15-49%), northern Gulf of Alaska (33%, 95% CI: 16-54%) and northern British Columbia (29%, 95% CI: 13-51%). Thus, the lower entanglement rate observed at Hawaii likely reflects a mixing of high latitude feeding populations with different levels of entanglement risk. Small sample sizes for the remaining areas produced a wide range of less precise estimates (Table 4, Figure 3). Images obtained by SPLASH in 2005 and 2006 should greatly improve sample sizes and corresponding estimates for those regions.

Scar-based techniques produce minimum entanglement estimates because some injuries heal beyond recognition, some entanglements do not involve the caudal peduncle and some individuals die before they can be sampled. True entanglement rates are expected to be even higher than those reported here. In addition, despite the advantages of scar-based methods, regional and inter-ocean comparisons are only valid if entanglements in all areas are equally likely to involve the caudal peduncle. At present there are few independent data with which to evaluate this assumption. However, the types of caudal peduncle injuries observed in the 2004 data were not substantially different among North Pacific areas, and were also generally consistent with what has been observed to date in the North Atlantic. The method also assumes that entanglement mortality is proportional to entanglement frequency across areas. If animals are more likely to die before they can be sampled, then scar-based techniques will under-estimate entanglement rates relative to other areas. At present, the only insight into mortality rate is the frequency of severe entanglement-related injuries (see Figure 2d for an example). These occurred in less than 1% of North Pacific cases, a result that is comparable to what has been reported for the Gulf of Maine (Robbins and Mattila 2000; 2001). The few cases that were observed also occurred in areas with relatively high estimates of entanglement: California, Southeastern Alaska and Mexico (Table 4, Figure 3). In the future, larger sample sizes will allow us to evaluate whether severe injuries increase proportionally with entanglement rate and whether they vary between North Pacific areas. However, lethal entanglements do not necessarily produce outwardly severe injuries and so the results should be taken with some caution.

In conclusion, scar analysis to date confirms significant differences in humpback whale entanglement rate among North Pacific areas. Through the use of systematic protocols and with the addition of data from 2005 and 2006, we anticipate being able to identify North Pacific areas in greatest need of management attention. Furthermore, we expect to produce final estimates that can be compared to the Gulf of Maine, an area where entanglement mitigation efforts are already well established. Entanglement inference will also benefit from the results of other planned SPLASH analyses, such as estimates of regional exchange and molecular genetic determination of sex.

Table 4. Regional entanglement rates and 95% confidence intervals (CI) for 2004 data. Entanglement rates were limited to the highest quality images in the data set. Sample sizes and estimate precision will increase when data from 2005 and 2006 are analyzed.					
Region	**# Screened Images**	# High Quality **Images**	**Minimum Entanglement Rate**	**95% CI**	
				Lower bound	**Upper bound**
FEEDING GROUNDS					
Calif.-Oregon	46	7	43%	18%	90%
N Wash.- S British Col.	36	6	33%	4%	78%
N British Col.	98	24	29%	13%	51%
Southeastern Alaska	465	194	50%	43%	58%
N Gulf of Alaska	137	27	33%	16%	54%
W Gulf of Alaska	81	11	18%	2%	52%
Bering Sea	138	30	30%	15%	49%
Aleutians (East + West)	46	8	62%	24%	91%
Russia	39	3	33%	0%	71%
BREEDING GROUNDS					
Asia	93	13	31%	9%	61%
Central America	5	1	0	0%	97%
Hawaii	249	98	32%	23%	42%
Mexico	54	15	60%	38%	88%

INJURY AND HEALTH ASSESSMENT FROM FLANK PHOTOGRAPHS

As discussed in the previous section, tailstocks of whales were used to examine rate of entanglement. An additional goal of SPLASH was to evaluate use of photographs of the flanks of animals taken in SPLASH to measure indications of health and some additional human impacts. While this is not thought to be as effective in detecting entanglement as the use of tailstocks, it was thought to be a better indicator of ship strikes and possibly other indications of health. Visual health assessment has not been attempted in humpback whales previously, in part because the feature most often used to identify them is the ventral surface of the tail fluke, which is often raised at the start of a deep dive. At the inception of the SPLASH study, participants were requested to collect photographs of the sides of the body ("flanks") as well as the tailstock of whales (used in the previous section to evaluate entanglement rates), in addition to the fluke photographs that would ultimately be used to identify each individual. Although not an initial intent, it became apparent that the flank photos might be useful as a means of assessing the overall health of whales, as has been done for other species like North Atlantic right whales (Pettis et al. 2004). For some whales, good quality photographs were obtained of all features (flanks, tailstocks, and fluke photographs) in many cases only some features were obtained of adequate quality for a whale.

In this summary, we present the results of a review of flank photos collected across all summer feeding areas in the first year of the SPLASH study. We summarize the frequency of injury rates (as inferred from scarring/wounds on the body) throughout the population and regionally, and attempt to identify trends in human impacts where the cause of the scarring can be determined. We also assess several aspects of health regionally, and look for detectable changes in health throughout the season.

Methods

To measure health and injury rates in individuals, flank photos from whales that were identified by a good quality fluke photograph were rated for quality in four areas: angle of the whale, proportion of the body visible, photographic exposure/lighting, and sharpness/focus. Flank photos were then scored on a scale of one to three for the following characteristics (the result of those in **bold** are presented in this report):

- **Overall body condition** (1- Healthy, 2- Possible emaciation, 3- Clearly emaciated) based on appearance of dorsal ridge and presence of depressed areas or visible ribs.
- **Overall skin condition** (1- Healthy, 2- Superficial or limited irregularities, 3- Severe or extensive irregularity)
- **Evidence of serious injury** (1-None, 2-Significant but not life-threatening, 3-Potentially life-threatening). Any evidence of injury was further classified by probable source: Entanglement, Vessel Collision, Other
- Overall scarring on the body (1-No scarring, 2, Some scarring, 3-Extensive scarring)
- Dorsal fin condition (1-Unmarked/intact, 2- Minimal scarring, small notches, 3-Heavily scarred/damaged)
- **"Pock" marks on the body** (1-None, 2- one to five, 3-more than five). Pocks are distinctive round/ovoid indentations in the skin, the exact cause has not been determined; the source may be cookie-cutter shark bites
- "**Bumps" on the body** (1-None, 2- one to five, 3-more than five). Bumps are discreet, skin-colored, round raised areas on the skin, cause unknown
- Barnacles on the dorsal fin and body (1-None, 2- one to five, 3-more than five)
- Killer whale rake mark scars on the body (1-None, 2-Possible rakes, 3-Obvious rakes)
- "Knuckle" pattern (1-None/smooth, 2-Few or small, 3-Many or distinct)

A total of 1,934 flank photos from 1,228 different whales were scored from all feeding areas. For the following analyses, sub-samples of flank photos were selected based on the specific quality criteria, which most affect the ability to accurately assess the condition of the photographed whale (Table 5). To assess geographic trends, sightings were assigned to the regions listed in Table 5.

Results and Discussion

Serious Injury and Human Impact Rates

Preliminary analysis of the incidence of injuries and human impacts on the flanks of humpback whales revealed geographic patterns. The number of these whales with evidence of a life-threatening injury of any type on their body was relatively low (6 whales, or less than 1%). The number of whales with evidence of injuries that were deemed significant but probably not life threatening was considerably higher (45 whales, 7%). Injury rates appear to vary regionally, and this trend is more evident when quality criteria are relaxed slightly (Figure 4), although this rate has a negative bias because some whales might have injuries that were not visible in the photos scored. The most notable regional trend was an unusually high rate of injury for whales off Russia and California-Oregon. Although the Russian sample was small, 20% of whales identified there had evidence of serious injury. Whales from Southeastern Alaska and the Aleutians also had slightly higher rates of injury than most other regions.

Table 5. Number of flank photos scored and unique individuals included in the preliminary analysis, and the number meeting quality criteria for that particular condition.

Region	Flank photos examined	Different whales	Body condition	Skin condition	Serious injury	Pocks & Bumps
Bering	90	65	41	53	40	39
CA-OR	115	75	31	50	29	29
E Aleut.	48	34	15	28	15	15
NBC	169	110	72	89	70	69
NGOA	317	230	107	173	101	100
NWA-SBC	51	32	19	31	19	19
Russia	68	36	20	28	20	20
SEAK	932	547	341	433	327	327
W Aleut.	19	11	7	10	7	7
WGOA	125	95	42	64	41	39
Total	1,934	1,235	695	959	669	664

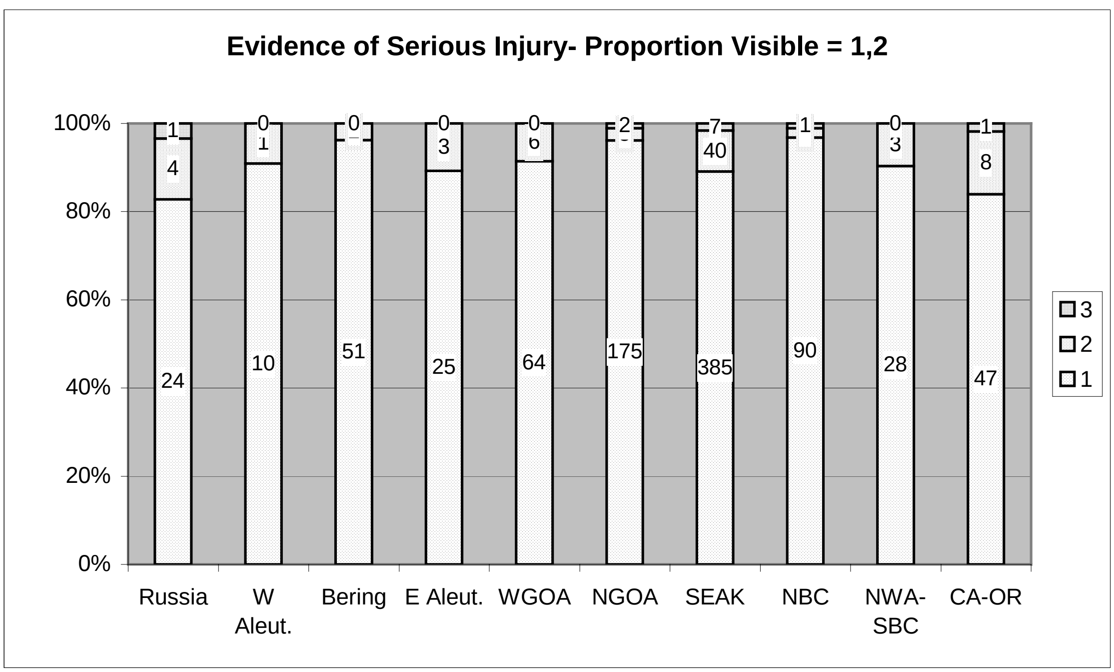

Figure 4. Proportion of whales from each region with evidence of injury on the body. A score of 1 indicates no evidence of injury, 2 is evidence of an injury that was probably not life-threatening, and 3 denoted evidence of a life-threatening injury.

While not all injuries observed could reliably be classified as anthropogenic in nature, in 39 whales in the sample, the scarring observed was consistent with entanglement in fishing gear or other lines or with vessel collision. Entanglement scars, generally identified as linear scars that wrapped across the back or caudal peduncle, or around the dorsal fin or hump, accounted for 36 of these 39 cases. Of all whales included in the entire flank analysis study (irrespective of photo quality), 73 whales had evidence of entanglement on their body, six of which had scarring that indicated the entanglement might have been life-threatening. These rates of scarring from entanglement are much lower than those documented from tailstocks and confirm that the tailstock analysis is better for calculating incidence of entanglement since the incidence of sisible scarring on flanks was so much lower.

Of all whales in the flank analysis study (irrespective of photo quality), seven had evidence of having survived a vessel collision, as typified by a series of propeller scars often associated with a moderate to deep linear gash (Figure 5). In five of these seven whales, the injury appeared to have been life threatening. Although there are too few whales with vessel collision scars in this sample to statistically assess the impact regionally, all seven of these whales were sighted in Alaska (five in Southeastern Alaska, and one each from the Northern and Western Gulf of Alaska).

Figure 5. Scarring from a vessel collision on a whale sighted in Southeast Alaska on 3 December 2004.

While it is difficult to accurately assess the impact human activity has on humpback whales on a population-wide basis, it is clear that whales in regions where they are in closer proximity to high levels of human activity are experiencing elevated levels of injuries from entanglement and ship strikes. This type of assessment does not estimate the number of animals that are injured and do not survive the encounter; many vessel collisions presumably occur offshore and are not reported or their carcass recovered.

The current analysis demonstrates the capability of using photographs to effectively identify populations at risk of high levels of human impacts. The analysis reported here only used a portion of the SPLASH photographs (one season, Summer 2004) and therefore had a limited sample for many areas and only included feeding areas. This analysis will improve dramatically with the expanded sample of photographs available from the full SPLASH collection. As the populations of both whales and humans continue to increase, it is likely that these interactions will increase, and the understanding gained through the SPLASH study may prove valuable to mitigate these impacts in the future.

Overall Body Condition

There was a detectable improvement in the average body condition of all whales as the season progressed, with whales sighted after October appearing healthier on average than whales sighted in June and July (Figure 6). Average body condition varied regionally, and when this overall seasonal trend was controlled for, there remained significant differences in the average body condition for whales in some areas. Whales from the Eastern Aleutians and the Gulf of Alaska had significantly poorer body condition overall than whales from Russia, Southeastern Alaska and California/Oregon, which tended to appear healthiest on average.

It was somewhat surprising that the flank photographs proved as effective as they were in assessing overall body condition. Where visual health assessment has been attempted in other whale species, researchers have generally used views of the post-cranial region. This has been used especially in northern right whales where photographic identification also relies on markings near the head (Pettis et al. 2004). The detectable improvement in body condition demonstrated throughout the season here, as whales are feeding after their annual winter fast, was not unexpected. The ability to detect this change in a broad seasonal sample of flank photos demonstrates that this is a viable technique to assess the health of whales on both an individual and population-wide basis. This is encouraging because historically flank photos of humpback whales and other species are more likely to have been collected than post-cranial photos and these older photos could be incorporated into future visual health assessments. It also means that we will be able to continue this process with the sample of flanks collected in the subsequent four seasons of SPLASH.

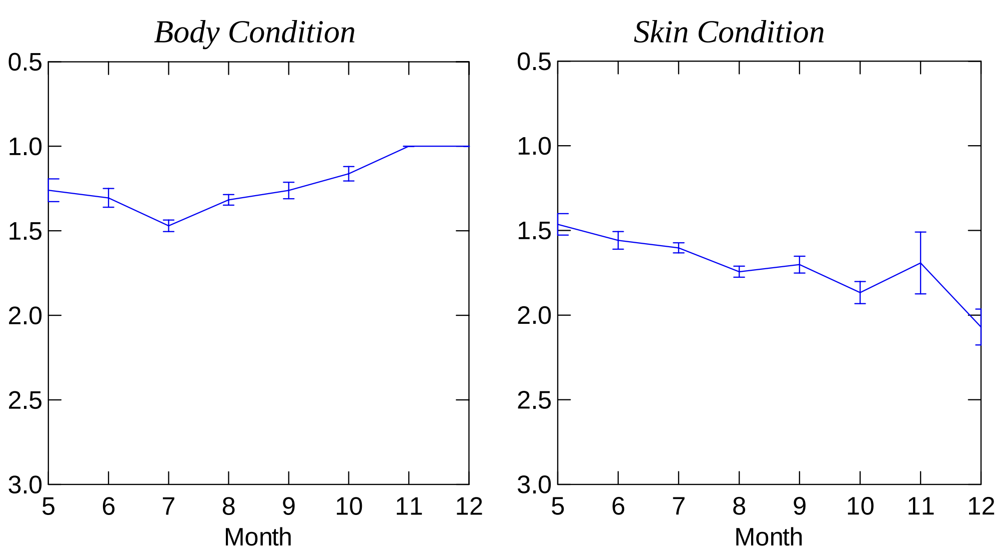

Figure 6. Average score for body and skin condition of humpback whales by month during Summer 2004 showing improvement in body condition and deterioration in skin condition over the course of the season.

Overall Skin Condition

Most whales were found to have some skin irregularity, however, there were detectable trends in average skin condition over the season (Figure 6). Whales sighted early were more likely to have smooth, evenly pigmented skin whereas by late fall most whales sighted had skin irregularities, often in the form of sloughing and/or pitting of the skin surface over much of the body, or slightly raised, grayish patches. There were also several significant regional differences in skin condition. Whales from the S. British Columbia/N. Washington area had the poorest overall skin condition; whales from the Bering Sea had better than average skin condition. Skin condition trends did not generally correlate with body conditions trends regionally, however it is notable that whales in the Eastern Aleutians had both poorer body and skin condition than most areas, although the difference in skin condition was not statistically significant.

The change observed in the skin condition of whales throughout the season has not been described before. Because skin condition appeared to decline even as overall body condition improves, poor skin condition alone does not seem to reflect a serious health issue. However, considering that by December most whales still in the feeding areas had very poor skin does raise the question whether declining skin condition might relate to seasonal migration in humpback whales. It also suggests that there is an additional cost to remaining in the feeding area longer, especially as productivity in those areas decreases.

"Pock" Marks and "Bumps"

There was a decline in the frequency of both pocks and bumps on whales through the season, although this trend was clearer in pocks than in bumps (Figure 7). Early in the season, pocks are more commonly observed than bumps, but in the fall this trend changes as the frequency of pocks continues to decline but there is an increase in bumps in October and November.

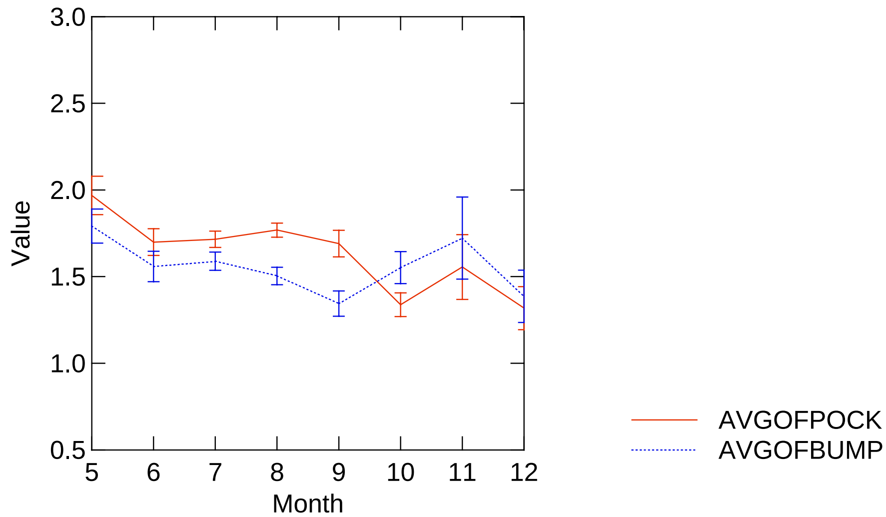

Figure 7. Seasonal trends in the average frequency of pocks and bumps on whales.

There was also regional variation in the frequency of pocks and bumps observed with fewer whales in California-Oregon with pock marks than in all other areas except the adjacent N.

Washington/S. British Columbia region (which also had significantly fewer pocks than most other regions). The frequency with which pocks were observed was fairly consistent throughout most of the Alaska regions, but showed a slight increase to the west, with animals in Russia most frequently observed with at least a few pocks, however this trend was not significant. Although there was variability in the frequency of bumps between regions, and the California-Oregon region also appeared to be lower than other regions.

Although the exact causes of the conditions we refer to as pocks and bumps are not known, the results of this study provide insight. Both the seasonal decline and the regional distribution of pocks support the theory that they are caused at least in part by cookie cutter sharks. Cookie cutter sharks are primarily found in very deep water, and are often associated with islands potentially explaining the lower rates in California whales that primarily breed off mainland Mexico and Central America. The cause of bumps on whales remains unclear from this study.

INDICATIONS OF INJURIES ON FLUKES

In addition to examining the tailstock for entanglement and the flanks of photographs for injuries and health assessment, it was also possible to examine injuries on the flukes themselves. While it was not uncommon for whales to have small nicks and injuries to the trailing edge of the tail fluke, some whales were missing significant portions of the fluke, and there have even been whales of several species identified that have little or no fluke remaining at all.

There are a number of ways a whale can lose parts of its flukes, some naturally occurring and others a result of human activities. The most obvious and easily attributed source of injury is attack by killer whales. Previous studies have documented regional patterns in the proportion of whales with killer whale rake marks (Steiger et al. In press). Killer whale predation on large whales has become an important and controversial issue in recent years because shifts in killer whale predation from large whales to pinnipeds and otters has been suggested as the cause of wide-spread declines of many species in Alaskan waters (Springer et al. 2003) although this finding has been disputed (Wade et al. In press). There are also whales that are missing large pieces of the fluke that have little or no associated scarring, so the injury cannot easily be attributed to any cause. An encircling entanglement around one blade of the fluke by a relatively fine line or rope, with enough time and drag, may eventually cleanly sever the distal portion of the fluke. A large propeller blade may also cleanly slice away a significant piece.

One advantage of using the fluke to assess serious injury in humpback whales is that it is the feature typically used to identify individuals; the basis for a whale's inclusion in the SPLASH study is at least one suitable quality fluke photo. This means that the feature can be scored for every individual whale in the collection, thus allowing the maximum possible sample size. Here, we summarize the number of whales with significant fluke damage for the entire North Pacific and look for regional variations from each of ten summer feeding areas and six winter breeding areas (treating sub-area areas in Mexico separately) included in the SPLASH study.

Of the 5,342 individual whales identified in the first three seasons of the SPLASH study, 561 (11%) were missing significant pieces of the trailing edge of the fluke. While about half of these had killer whale rake marks suggesting the injury likely came from these predatory attacks, 286 of the 561 (or 5.4% of all whales) had no killer whale rake marks, suggesting the injury came from some other cause including human interaction (see Table 6 for sample sizes by region).

There was considerable regional variation in the percentage of whales with missing pieces of the fluke, as well as those that also had killer whale rake marks (Figure 8). There was a lower rate of overall fluke damage, but a much higher proportion of damaged flukes without rake marks, in whales from the far west (Asia, Russia, and the W Aleutians, although the sample from both western feeding areas were small). The lack of rake marks on these whales increases the chance that the fluke damage is from a potentially anthropogenic source. The highest rates of fluke damage overall are from the central feeding areas and Mexico, especially the Revillagigedos. In all of these areas, a much higher percentage of whales with damaged flukes also have rake marks, suggesting the damage is the result of killer whale attacks.

Table 6. Total whales with damaged flukes both with and without killer whale rake marks.

REGION	Total Whales	Total Damaged Flukes	Total Damaged Flukes with Rakes	Total Damaged Flukes without Rakes
Winter breeding areas				
Asia	364	26	3	23
Hawaii	1443	134	58	76
Revillagigedo	449	73	52	21
Baja California	327	33	27	6
Mainland, Mex.	439	48	30	18
Cent Am	63	6	2	4
Summer feeding areas				
Russia	40	1	0	1
W Aleutians	12	1	0	1
Bering Sea	228	24	17	7
E Aleutians	51	7	5	2
W. Gulf of Alaska	224	33	18	15
N. Gulf of Alaska	726	95	44	51
Southeast Alaska	795	74	20	54
N. British Col.	421	21	8	13
N. WA & S. BC	75	5	3	2
Calif. & Oregon	253	22	11	11

Information from feeding grounds was a little more inconsistent possibly due to the more limited sample sizes for some areas. The California-Oregon feeding area, for example did not show as higher rate of killer whale attacks that has been found in some previous studies (Steiger et al. 2005, In press). A higher rate of human impacts in the far western and eastern portions of the summer range was also noted in the review of flank injuries presented in this report. These populations of whales migrate closer to continental shelves and hence spend much of their lives, including feeding, breeding, and migration, in closer proximity to higher levels of human activities than whales migrating between more remote areas and across open oceans. Southeastern Alaska and to a lesser degree northern Gulf of Alaska were regions with a high incidence of whales with flukes with missing pieces but no rake marks.

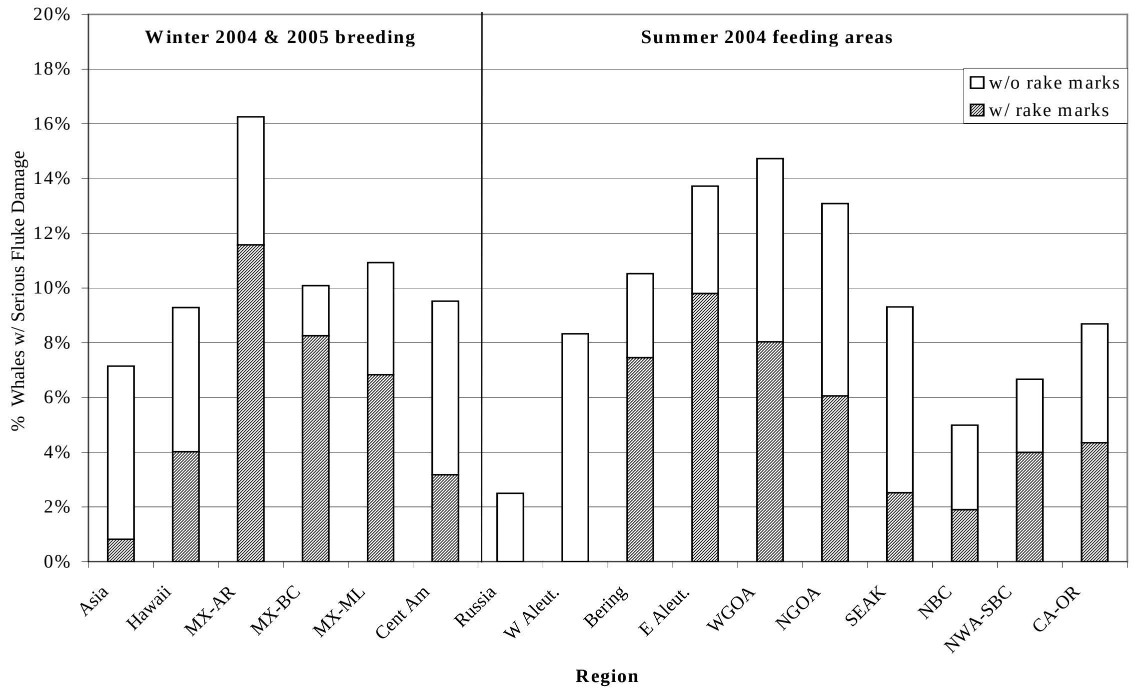

Figure 8. The percentage of whales from each region, with significant missing pieces of the fluke, and the proportion of these whales that also had killer whale rake marks, suggesting a killer whale attack is the likely source of the damage.

In attempting to determine whether observed fluke damage is naturally occurring or anthropogenic, it should be noted that human impacts and killer whale attacks might not occur independently in some areas. In recent years, whale-watching activity has increased dramatically in coastal Mexico and some researchers there have noted an apparent rise in the frequency with which breeding humpback whales are being attacked by killer whales and have suggested that the increase in whale-directed vessel traffic may be driving mothers with calves further offshore where they are more susceptible to attack. Time-series analyses for changes in the percent of whales showing signs of attacks off California (where many of the coastal Mexico whales go) have not detected an increase in the animals showing signs of having been attacked (Steiger et al 2005).

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