Report of the Workshop to Assess Research and Other Needs and Opportunities Related to Humpback Whale Management in the Hawaiian Islands

April 26-28, 1995
Kaanapali, Maui, Hawaii

Compiled by

P. Michael Payne
Brady Phillips
Eugene Nitta

This report documents in a timely manner, the communication of preliminary results that were presented at the workshop. It has not undergone external scientific review. Also, the interpretation of the results of the studies presented herein, and the information presented and discussed at the workshop, represent the opinions and views of the participants and not those of either the National Oceanic and Atmospheric Administration, Sanctuary and Reserves Division or the National Marine Fisheries Service. This workshop report is intended to act as a step towards facilitating the completion of a Sanctuary Management Plan for the Hawaiian Island Humpback Whale National Marine Sanctuary, and towards implementing recovery priorities stated in the Final Recovery Plan for the Humpback Whale.

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EXECUTIVE SUMMARY

The National Marine Fisheries Service (NMFS) completed a Final Recovery Plan for the Humpback Whale (Recovery Plan) in December of 1991 (NMFS 1991). Less than a year later, Public Law 102-587 (the Oceans Act of 1992 (the Act)), was signed into law which designated the Hawaiian Islands Humpback Whale National Marine Sanctuary (the Sanctuary). The primary objectives of the Sanctuary are to: protect the humpback whales and their habitat in the waters around the Main Hawaiian Islands; educate and interpret for the public the relationship of the humpback whale and the Hawaiian marine environment; manage human uses of the Sanctuary consistent with the Act; and, identify other marine resources and ecosystems of national significance for possible inclusion in the Sanctuary. The objectives of the Recovery Plan are compatible with those of a Sanctuary Plan and include maintaining and enhancing humpback whale habitat (s); reducing human-related mortality, injury and disturbance; measuring and monitoring key population parameters; and promoting a State/Federal partnership for administration and implementation of the Recovery Plan.

NOAA's Sanctuaries and Reserves Division (SRD) and NMFS convened a workshop on April 26-28 in Kaanapali, Maui to bring together resource managers from county, state 2nd Federal agencies and researchers to help develop research and management objectives for ite Sanctuary's management plan and to help implement provisions of the NMFS humpback whale recovery plan. Recommendations from the workshop will help the NMFS and the SRD develop more closely coordinated and complementary long-term monitoring strategies and programs. In addition, the workshop also provided an opportunity for the research community to interact with the county, state and Federal resource managers having management jurisdiction over and interest in humpback whales.

The workshop consisted of a day of presentations by researchers and resource managers followed by two days of focused working group discussions. Presentations included such topics as humpback whale life history, humpback whale habitat, human and natural impacts, and individual agency management responsibilities. Selected presentations are contained in this part 1 of this report. Workshop participants were divided into one of four working groups. The population assessment and methodology group (Working Group 1) discussed the overall objective of population assessment and monitoring of humpback whales relative to management needs. Working Group II, the habitat characterization group, focused on identifying parameters influencing the habitat use patterns of humpback whales. The behavior and life history group (Working Group 111) discussed research to better assess and monitor humpback whale vital population parameters and behavior, and human activities and their potential affects on humpback whales. Finally, the management needs and covery plan implementation group (Working Group IV) involved discussion among those county, state and Federal agencies that would participate in the implementation of Recovery Plan and the Final Management Plan for the Sanctuary. The individual working groups met over the course of two days, with periodic breaks to share the results with the entire workshop. Part 2 of this report documents the collective recommendations from each of the four working groups. Each of the four reports were generated at the workshop and were subsequently sent out to workshop participants for review and comment. This workshop report provides a summary of the information that was contributed to the workshop by these participants.

ACKNOWLEDGEMENTS

Mahalo Nui Loa to the many individuals who contributed their time, expertise and patience to help make sure this workshop was held and that it would be beneficial to the research and management communities in and outside of Hawaii. Special thanks goes to Naomi McIntosh, Susan Bemrose, Allen Tom and Carol Carey who handled the logistics, travel, organization and made sure the workshop went smoothly. In addition, various staff from NOAA's Sanctuaries and Reserves Division, the National Marine Fisheries Service and the Marine Mamrnal Commission were involved in planning various portions of the workshop.

Funding was provided by NOAA's Coastal Ocean Program and the Sanctuaries and Reserves Division. Special kudos go out to the Whale Center of the Pacific for sponsoring a museum open-house and a National Marine Sanctuary Manager forum and the volunteers of the Hawaiian Islands Humpback Whale National Marine Sanctuary for organizing a post-workshop BBQ at the Kihei Sanctuary Facility.

PART 1: SELECTED WORKSHOP PRESENTATIONS

A. An Overview of Biology and Life History Studies of the Humpback Whale in Hawaii and in the North Pacific Selected Presentations

Preliminary Results of 1993 and 1995 Aerial Surveys of Hawaiian Waters.

Mobley, Jr., J. R., P. H. Forestell and R. A. Grotefendt.

Background: In 1993 and 1995 aerial surveys were conducted as part of the Acoustic Thermography of Ocean Climate (ATOC), Marine Mammal Research Program (MMRP), Kauai portion. The goal of this survey series was to describe the distribution and abundance of marine mammals in waters adjoining the major Hawaiian Islands, with particular attention to endangered humpback whales, Megaptera novaeangliae.

The 1993-95 surveys expanded on earlier surveys performed in Hawaiian waters in three ways: a) increase coverage -- north-south transect lines extended beyond the 1000 fathom contour; b) abundance estimation - distance sampling techniques were used consistent with current theory (Buckland et al., 1993; Burnham et al., 1980); and c) inclusion of all marine mammal species--past surveys focused on humpback whales only.

Earlier surveys of humpback whales in Hawaiian waters (Herman et al., 1980; Baker and Herman, 1981; Forestell, 1989; Mobley and Bauer, 1991; Forestell and Mobley, 1991) focused effort in near-shore waters primarily within the 100-fathom contour isobath. The results of past surveys suggest that the primary habitat of wintering humpback whales to consist of those waters less than 100 fathoms on leeward sides of the islands (Herman and Antinoja, 1977). However, this claim was not well-supported (i.e., by comparisons of whale densities in deeper water) since there was little systematic effort outside of the 100-fathom contour. Highest densities of whales and calves were found during the 1977-80 surveys in the Four Island Region (Maui, Molokai, Kahoolawe and Lanai) and Penguin Bank (shoal extending southwest from Molokai) (Herman and Antinoja, 1977; Herman et al., 1980; Baker and Herman, 1981). Replication of this earlier effort during the 1990 season showed these area preferences to remain robust across the 10-13 yr period, yet additionally showed a substantial increase in densities of adult whales around the Kauai/Niihau region (Mobley and Bauer, 1990). Densities of calf pods around the Kauai/Niihau region remained low, however, with only the Oahu island region lower among a total of five regions.

Methods: During each of the 1993 and 1995 seasons, four survey flights were performed in waters surrounding the major Hawaiian Islands spaced approximately one week apart during the period corresponding to peak densities of whales as shown by past surveys (Table 1) (Herman et al., 1980; Baker and Herman, 1981; Forestell, 1989; Mobley and Bauer, 1991). A complete survey was defined as the amount of time required to cover all five major regions of the Hawaiian chain (Big Island, Four Island, Penguin Bank, Oahu and Kauai/Niihau regions). This involved a minimum of two flights during 1993 when two planes were used, and four flights during 1995 with one plane.

Planes were equipped with Collins ALT 50A radar altimeters and Morrow Apollo GPS receivers which outputted to a Compudyne 386 laptop computer. The computer captured data using software developed by Foster Wheeler Environmental Corp. (FWE) and modified by one of the coauthors (RG). This system automatically recorded position data at 30-sec intervals or manually recorded whenever a sighting was made. Sighting angles to target pods were made using Suunto (Model PM-5) hand-held clinometers with analog displays calibrated to whole degrees. These angles, in combination with altitude data, allowed estimation of perpendicular distance from the sighting to the transect line.

Table 1. Summary of Flight Dates for 1993 and 1995 Surveys

Survey Number	1993 Dates	1995 Dates
1	Feb 21-24, 26	Feb 28, Mar 1-4
2	Mar 4-8	Mar 8-11
3	Mar 15-16	Mar 18, 20, 23-25
4	Mar 24-26	Apr 1-3, 7

Each plane was staffed by three survey personnel including two observers and one data recorder in addition to the pilot. During 1993, specific portions of the the survey area were assigned to each of two teams. However, during 1995, survey personnel were rotated through all regions. All primary staff were experienced in marine mammal identification and distance sampling methods with a minimum of two winter seasons prior survey experience.

Survey tracklines were based on north-south systematic lines spaced 14 nmi apart in channel areas, 7 nmi apart in major island regions, and 3.5 nm apart in areas of particular interest (i.e., vicinity of ATOC source and waters surrounding Kahoolawe) (Figures 1 and 3). Random startpoints were used so that the exact trackline configuration varied on each survey. The systematic lines projected 7 nmi past the 1000-fathom isobath, with random lines connecting endpoints. Portions of the survey involving reduced effort were designated as dead-head lines and not counted in the results.

Results and Discussion: A more complete description of 1993 results is available in an earlier report (Mobley, Forestell and Grotefendt, 1994). These 1995 results are preliminary and a more detailed summary of 1995 and combined results will be forthcoming.

The 1993 and 1995 surveys comprised a total effort of 8,115 nm and 11,253 nm, respectively. The increased effort during 1995 resulted from additional tracklines placed in the vicinity of Kahoolawe (as contracted by the Hawaii Humpback Whale National Marine Sanctuary) and fewer truncations of tracklines due to improved seastate conditions (tracklines are normally truncated when prevailing seastate exceeds Beaufort 4).

Table 2 shows a summary of all sightings for both years. There were a total of 14 different marine mammal species sighted during 1995 (confirmed sightings only), as compared to nine during 1993. For both years, the only mysticete sightings consisted of humpback whales (Note: However, a confirmed fin whale sighting was made during the 1994 ATOC MMRP aerial surveys north of Kauai; the 1994 data are not included here). The number of humpback whale pod sightings doubled from 1993 to 1995. This difference is more than expected based on the 39 percent increase in effort during 1995, and may be due, in part, to better seastate conditions during 1995 (though quantitative analyses of environmental data for 1995 are not yet available).

Distribution of Humpback Whales: Figures 1 through 4 show all 1993 and 1995 humpback whale sightings by region and by year. Effort is indicated by dotted lines. As shown, there is a clear preference for inshore waters less than 100 fathoms in depth, despite the majority of effort in deeper waters. During 1993, 74 percent of all humpback whale sightings occurred in waters less than 100 fathoms, with only 20 percent of effort within this depth stratum (Mobley, Forestell and Grotefendt, 1994). These results provide stronger support for descriptions of inshore waters as preferred habitat for humpback whales (Herman and Antinoja, 1977; Herman et al., 1980).

Humpback Whale Calf Pods: Calves comprised only 5.2 percent of all whales seen in 1993 and 4.5 percent of all whales seen in 1995. This is lower than the typical 7-8 percent noted in previous surveys (Herman and Antinoja, 1977; Herman et al., 1980; Mobley & Bauer, 1991). Calf pods were likely undercounted during the 1993 and 1995 surveys since few pods were orbited to confirm composition, unlike previous surveys. Based on the more complete analyses of the 1993 results, 72 percent of all calf pod sightings occurred in the Penguin Bank and Four Island regions, similar to past surveys.

Status of Abundance Estimation: The 1993 abundance results were analyzed using the DISTANCE (ver. 2.03) program (Mobley, Forestell and Grotefendt, 1994). Results from all four 1993 flights were combined and stratified into three depth categories: 0-100, 101-1000, and greater than 1000 fathoms. An overall abundance estimate of 669 whales was derived using a depth stratified line transect approach based on a hazard rate model with encounter rate and density by stratum, detection probability for all data combined, and a pooled estimate of density from area-weighted stratum. The log-based confidence interval was 536-835 whales, with a C.V. of 11.3 percent. The results of the 1995 season will be analyzed separately, and combined with the

1993 results if appropriate.

The distance sampling theory upon which DISTANCE (developed at the National Marine Mammal Laboratory) and similar programs are based, assumes the probability of detection (g(O)) on the trackline to be unity. This is obviously not true for cetaceans since they are only detectable at the surface for relatively brief periods of time (e.g., Buckland et al., 1993). In order to transform the abundance estimate to a population estimate, one must know the probability that the animals in question will be at the surface at any given time. We propose to use surface/dive time data derived from shore station data (gathered between 1983 and 1993) to derive such a correction factor (Barlow et al., 1988; Calambokidis et al., 1993). A corrected population estimate for humpback whales wintering in Hawaii will hopefully be available in the near future.

Acknowledgements: This work was sponsored by the Advanced Research Projects Agency (ARPA) as part of the Acoustic Thermography of Ocean Climate Marine Mammal Research Program (ATOC MMRP, Principal Investigator: Christopher Clark of Cornell University). We extend our thanks to our observers and data recorders, including Eric Brown, Tim Clark, Alison Craig, Adam Frankel, Christine Llewellyn, Michael Newcomer, Tom Norris, Rob Schick, Mari Smultea, and Dave Weller. Also, mahalo to our pilots, John "Keoni" McFadden, Mike Anderson and Paul Beckham for their great work.

Table 2. Species observed on Hawaii statewide aerial surveys

Species or Species Group	1995		1993	
	N	Groups	N	Groups
Humpback Whale	1,388	837	698	39'/
Spinner Dolphin	573	27	518	13
Spotted Dolphin	367	8		
False Killer Whale	80	12	229	8
Shortfin Pilot Whale	162	18	67	12
Bottlenose Dolphin	125	32	77	*5*
Rough-toothed Dolphin	77	4		
Striped Dolphin	76	2		
Stenella spp.	36	3	2	1
Sperm Whale	22	9	4	1
Melon Headed Whale	21	1		
Mesoplodon spp.	13	3		
Grampus	13	2		
Cuvier's Beaked Whale	6	3	2	1
Blainville's Beaked Whale	8	3		
Pygmy Sperm Whale	1	1	4	1
Beaked Whale, unid. spp.	8	2	3	2
Dolphin, unid. spp.	209	36	56	13
Whale, unid. spp.	14	10		
Turtles (spp.)	24	20		

1 Total Effort in 1993 = 8,115 nautical miles, 1995 11,253; Number of Humpback whale calves in 1993 = 36, in 1995 = 63 ;

An overview of humpback whale movements within Hawaiian waters.

C., Salvatore

Introduction and Objectives: A large portion of the Pacific population(s) of humpback whales winters each year off the Hawaiian Islands. The purpose of this summary was to review what is currently known about the movements of humpback whales throughout the Hawaiian Island chain and briefly discuss the implications of such movement. Sources included early work conducted from 1979 to 1984 as well as a recent study conducted from 1989 to 1991 by Christine Gabriele and myself.

Background: While wintering off the Hawaiian Islands, humpback whales appear to move throughout the island chain rather than remaining resident off any single island (Baker and Herman, 1981; Darling and McSweeney, 1985; Darling and Morowitz, 1986; Baker et al., 1986). The pattern or extent of this movement is unknown. After three years of aerial surveys over the islands of Hawaii, Maui, Molokai, Oahu and Kauai, Baker and Herman (1981) found peak abundance off each island was staggered temporally through the season from Hawaii to Oahu. They concluded that whales moved through the islands in a general northwesterly direction starting from the island of Hawaii. Timing of peak abundance off Kauai, however, was anomalous from the overall trend, and appeared to be independent from the other islands. Baker and Herman (1981) suggested that Kauai might therefore represent a semi-isolated sub-population, with the deep 125 mile-wide Kauai Channel acting as a partial barrier between Kauai and the other islands. Little evidence from tracking individual whales existed at the time to evaluate their hypotheses of northwesterly movement or potential segregation of whales among the Hawaiian Islands.

Baker and Herman (1981) reported six individual whales moved from Hawaii to the Maui region and one from Maui to Oahu, supporting a general northwest movement trend. However, Darling and Morowitz (1986) reported five cases of whales moving from Maui to Hawaii, refuting a northwest trend, and presented evidence suggesting that the majority of the population was present off Maui through peak season. Furthermore, Darling and McSweeney (1985) found that 33 percent of whales identified off Kona, Hawaii (n = 200) between 1978 and 1981 were also identified off Maui (but did not indicate direction of movement), and "assumed [these areas] to be contiguous, with whales regularly traveling between them."

Estimates of humpback whale abundance off the Hawaiian Islands have been made using a variety of mark-recapture analyses (Darling et al., 1983; Darling and Morowitz, 1986; Baker et al., 1986; Baker and Herman, 1987; Cerchio, 1994). Darling and Morowitz (1986) collected 1,553) photographs of 922 whales during five winters (1977 to 1981) off Maui, and used the rate of discovery of previously unidentified individuals, and a form of the Bernoulli distribution to estimate abundance. They estimated 1,000 whales present during a single winter and 2,100 whales during five winters (no confidence intervals were reported). Due to the difference between these estimates, Darling and Morowitz (1986) suggested the population off Maui was not identical from year to year, and cited evidence that some whales visited different breeding areas in different years as a potential explanation. Humpback whales have been documented switching breeding areas in the southern hemisphere (Chittleborough, 1965; Dawbin, 1966), between Hawaii and Mexico (Darling and Jurasz, 1983; Darling and McSweeney, 1985; Baker et al., 1986), and most recently between Hawaii and Japan (Darling and Cerchio, 1990). Since the sampling of Darling and Morowitz (1986) was restricted to Maui waters, it is possible that individuals may have been present on the Hawaiian breeding grounds, however, off other islands.

Recent Work: Movements of whales between Hawaii and Kauai: Between 1989 and 1991, two independent research projects collected identification photographs of humpback whales off the islands of Hawaii (University of Hawaii/Kewalo Basin Marine Mammal Lab) and Kauai (Moss Landing Marine Labs). Samples were compared to examine exchange between these two areas, approximately 500 km apart on opposite ends of the main Hawaiian Island chain (Cerchio, Gabriele and Frankel, 1991; Cerchio, Gabriele and Herman, 1994). A total of 1,702 individuals were identified, with 40 individuals being captured off both islands (Table 1). There were 15 cases of within-year recaptures (transits between islands) and 31 cases of across-year recaptures between islands (Table 2).

Of the 15 documented transits between islands, nine whales traveled northwest from Hawaii to Kauai, whereas six whales traveled southeast, originating off Kauai (Table 3). This suggested a similar degree of movement in both directions, contrary to the hypothesis of northwesterly flow of movement through the islands. The shortest sighting interval was 8 days, for a whale first sighted off Hawaii on March 18, 1991. The actual transit time may have been shorter than 8 days since the precise days of departure and arrival were unknown. The shortest apparent southeast transit was 17 days of a whale first sighted off Kauai on February 22, 1990. The mean sighting interval for all between island recaptures was 37 days (sd = 19.3 days, range = 8 to 71 days). This demonstrates that whales travel throughout the chain in relatively short periods of time, indicating that mark-recapture data may not be a valid indicator of residency trends off specific islands, even over periods as short as two weeks.

There was some indication of coordinated movement among individuals (Table 4). In 1989, two individuals (ID# 063 and 273) were photographed within 7 days of each other off Hawaii and then photographed later in the season within 4 days of each other off Kauai. In 1990, two individuals (ID# 107 and 159) were photographed within 7 days of each other off Kauai and then within 3 days of each other off Hawaii. In 1991, two individuals (ID# 219 and 296) were photographed off Kauai on the same day and then within five days of each other off Hawaii. ID# 384, photographed off Kauai 18 days prior to ID# 219, was later photographed off Hawaii on the same day as ID# 219. Three additional individuals photographed off Kauai on 27 February 1991 (in the same pods as ID# 219 and 296) were previously photographed off Hawaii between 14 March and 23 March 1990. Two pairs of individuals (ID# 214 and 258, and ID# 314 and 127) were also photographed on the same days off Hawaii, and then later in the season off Kauai, however in different months. These data suggest there may exist loose associations among groups of individuals, however, the sample size is small and difficult to test statistically.

In order to determine whether mixing of animals between the two islands was random, we sought to address two questions: 1) Was the probability of recapture across different years

Table 1. Numbers of individual whales photographed. Values in () indicate number of repeat sightings of individuals photographed more than once that year. Totals are corrected for recaptures among years and between islands.

	1989	1990	1991	ALL YEARS
Hawaii	231 (61)	286 (54)	268 (32)	753
Kauai	80 (4)	91 (5)	198 (31)	359
TOTAL	307 (66)	373 (62)	459 (68)	1072

Table 2. Summary of individuals photographed in both Kauai and Hawaii within the same year and between different years.

	MALES	FEMALES	UNKNOWN	TOTAL
Within Years	8	0	7	15
Between Years	14	1	16	31
Different Individuals				40

Table 3. Direction of travel within year recaptures between Kauai and Hawaii.

	1989	1990	1991	ALL YEARS
Hawaii to Kauai	3	2	4	9
Kauai to Hawaii	1	2	3	6

independent of initial area of capture, and 2) was the probability of recapture within a single year independent of initial area of capture? For recaptures off each island, 2x2 Chi-squared contingency tables were used to test whether the probability of a whale being recaptured (or not recaptured) was independent of original capture area (after Begon, 1979, p.62).

Contingency table analysis did not reject the null hypothesis that recapture probability in subsequent years off each island was independent of area of initial capture (Table 5). Off Hawaii there appeared to be an equal probability of recapturing whales photographed off either island in previous years. Off Kauai, however, the relationship was less clear, considering that the contingency table analysis approached significance. Moreover, the sample size of recaptures was small and power to detect differences was low. It is possible, given the results, that individuals captured off Kauai may be more likely to travel to Hawaii in subsequent years than animals off Hawaii are to travel to Kauai. A larger sample size including animals captured off Maui and Penguin Bank will clarify this, but presently we can not eliminate the possibility of equal mixing of individuals throughout the island chain across years.

Table 4. Within-year recaptures between Kauai and Hawaii, indicating catalogue number of individual (ID# - from Kauai catalogue), island (KI = Kauai, HI = Hawaii) and date of each sighting, sighting interval in days, and sex if known (M = male, F = female)

ID #	First Sighting	Second Sighting	Interval (days)	SEX
063	HI - 20 Feb 1989	KI - 26 Apr 1989	45	M
273	HI - 27 Feb 1989	KI - 30 Apr 1989	62	M
107	KI - 22 Feb 1990	Hi - 11 Mar 1990	17	U
159	KI - 15 Feb 1990	HI - 14 Mar 1990	27	U
219	KI - 27 Feb 1991	HI - 20 Mar 1991	21	U
296	KI - 27 Feb 1991	HI - 25 Mar 1991	26	M
384	KI - 9 Feb 1991	HI - 20 Mar 1991	39	U
214	HI - 4 Feb 1991	KI - 24 Mar 1991	18	U
258	HI - 4 Feb 1991	KI - 24 Mar 1991	48	M
314	HI - 18 Mar 1991	KI - 26 Mar 1991	8	U
127	HI - 18 Mar 1991	KI - 16 Apr 1991	29	M

Contingency table analysis rejected the null hypothesis that recapture probability within years off each island was independent of area of initial capture (Table 6). All within-year, same-island recaptures with an interval of less than 8 days (the shortest observed transit between islands) were excluded from this analysis. Within years, whales tended to have a higher probability of recapture off the same island they were originally captured, indicating there may be some degree of segregation within a season. There is a potential bias in our analysis that must be addressed. When considering probabilities of recapture during a season, the amount of time it takes an individual to travel between islands must be taken into account. We allowed a period of eight days, the shortest observed transit between islands, in our analysis of within-year recapture. Allowing a greater period of time would provide a better indication of degree of mixing among islands, i.e., the mean observed transit time of 37 days or considering recaptures between the first and second half of the season. Unfortunately the number of recaptures in our sample was too small to draw conclusions when reduced to such a time frame. Also, it is likely that there is greater exchange between closer islands, as demonstrated by the high proportion of individuals sighted off both Hawaii and Maui by Darling and McSweeney (1985). As noted for across-year recaptures, a larger sample including the Maui and Penguin Bank regions would clarify distribution of individuals during a season and indicate more clearly any segregation. Presently, this data infers that whales are more likely to visit either Hawaii or Kauai during a given year, rather than both.

Conclusions and Implications: The distribution and mixing of a population throughout its range is an important consideration when estimating abundance using mark-recapture (Hammond, 1986, 1990). Most studies have sampled the Hawaiian population in only a small portion of its overall range (i.e., off Maui or Hawaii) without considering the possible effects of non-random mixing or distribution among the islands. Early work suggested that whales may be segregated among the islands and may not move randomly during a season (Baker and Herman, 1981; Darling and McSweeney, 1985; Darling and Morowitz, 1986). The recent study described here (Cerchio et al., 1991; Cerchio et al., 1994) suggested 1) equal interchange between Hawaii and Kauai between years, with the possibility that additional data might change this conclusion, 2) potential segregation between Hawaii and Kauai within a season, 3) potential loose association and coordinated movement of groups of individuals among the islands, and 4) rapid transit of at least some whales across the island chain during mid-season in both directions.

Therefore, it is likely that movement among the islands is not completely random either during a season or between seasons. Population estimates derived from single island samples, consequently, would be biased either negatively or positively, depending on the character of movement/distribution among the islands. Only an analysis of photographs from all regions of whale concentration will reveal the distribution of individuals and patterns of movements among the islands. This information could then be used to assess the effects of any segregation or temporary emigration on abundance estimation. Furthermore, only a sampling regime covering all islands will insure a representative sample of the population and provide the least biased estimate of abundance. Therefore, it is recommended that existing data from Hawaii, the Maui region and Kauai be pooled and examined to address these issues. Preliminary abundance estimates could then be performed and future field studies could be more properly designed based upon conclusions.

Table 5. Across year probabiliity of capture tests. Chi-squared (X^2) contingency tables (corrected for continuity) were used to test whether probability of recapture across years was independent of original area of capture (see text for details).

	INITIALLY CAPTURED					
	Off Kauai		Off Hawaii			
<u>Off Kauai</u>	OBS	EXP	OBS	EXP	X^2	P
Recaptured	11	6.7	16	20.3		
Not Recaptured	159	163.3	501	496.7	3.0191	0.0823[*]
<u>Off Hawaii</u>						
Recaptured	18	12.9	34	39.1		
Not Recaptured	152	157.1	483	477.9	2.3976	0.1215

[*] When recaptures off Kauai are subdivided by year, significance is attributed to animals initially captured in 1989 ($Xi^2 = 4.184$, $P = 0.041$) but not to animals initially captured in 1990 ($X^2 = 0.0090$, $P = 0.924$)

Table 6. Within year probability of capture tests. Chi^{2}2x2 contingency tables (corrected for continuity) were used to test whether probability of recapture within years was independent of original area of capture (see Text for details). Within year recaptures of eight days or greater only are considered to control for transit time between islands (see text).

	INITIALLY CAPTURED					
	Off Kauai		Off Hawaii			
<u>Off Kauai</u>	OBS	EXP	OBS	EXP	Chi^2	P
Recaptured	18	8.3	8	17.7		
Not Recaptured	350	359.7	777	767.3	15.33	0.0001
<u>Off Hawaii</u>						
Not Recaptured	5	27.4	81	58.6		
Recaptured	363	340.6	704	726.4	27.85	<0.000

Overview of the reproductive parameters of the North Pacific humpback whale based on long-term studies

Glockner-Ferrari, D. A. and M. J. Ferrari.

Abstract: Long-term photo-identification studies in the waters of the Hawaiian Islands and southeastern Alaska have elucidated vital information on the reproductive cycle of the North Pacific humpback whale. In our 1975-93 Hawaii study, 504 known mothers producing 593 calves were identified. Resighting histories were compiled for 74 known mothers sighted in two or more years. The observed reproductive spans ranged from 1 to 17 years. Calculation of the calving rate yielded a minimum estimate of 0.44 calves per mature female per year. Of 89 observed calving intervals, 14 (15.7 percent) were one year. The mean maximum calving interval, based on non-continuous sightings, was calculated to be 3.3 years (SE 1.26). The mean calving interval, determined from 18 continuous intervals, was found to be 1.2 years (SE 0.76). The growth of a male calf to sexual maturity was observed. Six confirmed calf mortalities and one sub-adult mortality and the occurrence of numerous injuries and abnormalities was noted. The results of our study were compared to those of other studies in waters of Hawaii, southeastern Alaska, and the North Atlantic. The results of our study and those in southeastern Alaska support the theory that simultaneous pregnancy and lactation are of common occurrence in this species and suggest that postpartum ovulation is occurring without previous loss of a calf. The survival and recruitment rates of the population remain to be determined. Obtaining further information on the reproductive parameters of the North Pacific humpback whale is essential to aid management in the recovery of this endangered species.

Introduction: To be born into a population is significant. To be recruited into the mature population and produce one's own offspring is vital to the recovery of a species. Are humpback whale calves surviving to the age of maturity, and being successfully recruited into the mature population? This is the major question to keep in mind as we present the following overview of the reproductive cycle of the North Pacific humpback whale.

Humpback whales are an endangered species. Once numbering over 120,000 individuals, today less than 10,000 exist worldwide (Gambell, 1976; Rice, 1974,1978; Braham, 1984; NMFS, 1991). Although protected by the International Whaling Commission since 1966, the humpback whale remains less than 10 percent of its original level (Allen, 1974, 1980).

Prior to its protection in 1966, most of the knowledge of its vital reproductive parameters came from the examination of corpses taken by the whaling industry (e.g. Matthews, 1937; Omura, 1953; Chittleborough, 1954, 1955, 1958, 1965; Tomilin, 1957; Nishiwaki, 1959, 1962; Dawbin, 1966; Mitchell, 1973; see Lockyer, 1984 for summary).

Matthews (1937) analyzed data on the ovaries and mammary glands of 19 humpback whales taken in the South Indian Ocean and suggested that the majority of females breed once every two years and a minority twice every three years. Through examining the ovaries and mammary glands of 390 humpback whales taken at Western Australian whaling stations, Chittleborough (1958) reported that the majority of females breed once every two years. He also found that three females were simultaneously pregnant and lactating. He reported that Norwegian observers found 8.5 percent of 94 females taken in Antarctic waters were simultaneously pregnant and lactating. Van Lennep and van Utrecht (1953) reported one female humpback whale in this condition. Chittleborough (1958) stated that postpartum ovulation with conception may occur commonly in humpback whales. However, obtaining no further evidence of postpartum ovulation, Chittleborough (1965) later decided that it is probably not of frequent occurrence in this species.

Studies of this currently unexploited species, are now conducted on living populations in the wild. The clear, warm, relatively accessible waters of the Hawaiian Islands comprise the major wintering ground for the humpback whale in the North Pacific. This natural environment also provides an excellent laboratory in which to observe whales not only from above the surface of the water, but also below it.

Recent studies in both Hawaii and southeastern Alaska, based on photo-identification of individual whales, have elucidated vital information on the reproductive cycle of the North Pacific humpback whale. In this presentation, we will attempt to compare the results of these long-term studies, emphasizing the recent findings of our own 21 year study off the west coast of Maui.

Methods: Following pilot studies in 1975 and 1976, we began an intensive study of the biology and behavior of humpback whales off the west coast of Maui, in 1977. Our research has differed from that of others in that it focuses on observing individual animals and their behavior over prolonged periods from both above and below the surface of the water (Glockner and Venus, 1983; Glockner-Ferrari and Ferrari, 1984; 1985; 1987; 1990).

Comparison of photographs of the pigmentation pattern of the undersurface of the flukes has enabled individual identification and compilation of resighting histories (Katona, et. al. 1979; Glockner-Ferrari, 1990; Katona and Beard, 1990; Mizroch, Beard, and Lynde, 1990; Perry, Baker, and Herman, 1990). In our own study, we also utilize body patterns to identify individuals, including the pigment patterns of the flippers, throat grooves, and flanks, the shape of the dorsal fin, and the numerical patterns of the lip grooves (Glockner and Venus, 1983, Glockner-Ferrari and Ferrari, 1990). The sex of individual whales was determined through observation of a hemispherical lobe, found only in females, following the genital slit (see Glockner, 1983). Thus far, we have compiled over 120,000 surface and underwater photographs of individual whales.

Definition of Reproductive Parameters: We would now like to define the following reproductive parameters as summarized by Baker, Perry, and Herman (1987), Clapham and Mayo (1990), and Straley (1994):

Crude Birth Rate = percentage of calves in total population;

Calving Interval = Number of years between successive calves of an individually identified female, based on a continuous resighting history;

Maximum Calving Interval = Number of years between successive calves of an individually identified female, based on a non-continuous resighting history;

Calving Rate = Number of calves per mature female per year, calculated by:

A. Dividing the number of calves observed in a year, by the number of known females observed in a given year, or summed across years; or

B. Dividing the number of calves produced by a known female by the number of years of her reproductive span;

Therefore, the Calving Rate = the inverse of the Calving Interval.

Reproductive Span = the length of time in years over which each female has been observed to produce calves.

Results: Resighting Histories: Through a comprehensive analysis of fluke photographs taken during the period 1977 through 1993, 504 known mothers producing 593 calves were identified. Seventy-four known mothers were identified in 2 or more years (Figure 1). Of these, 58 produced more than one calf: 1 had 8 calves, 2 had 7 calves, 2 had 4 calves, 11 had 3 calves, and 42 had 4 calves, totalling 147 calves.

Reproductive Span: The observed reproductive span of the 74 resighted mothers ranged from 1 to 17 years. Ten of the 74 mothers (13.5 percent) had reproductive spans of 10 or more years. One individual had a reproductive span of 13 years, one had a 15 year reproductive span, one a 16 year reproductive span, and one a 17 year reproductive span (Table 1). The whales possessing the longest reproductive spans, whales M22, W128, and W94, produced 7, 3, and 8 calves respectively. Although not included in this data, whale M22 was most recently sighted this year (1995) with yet another calf to exhibit a 19 year reproductive span.

Calculation of Calving Rate: Difficulties have arisen in calculating reproductive parameters such as calving intervals, and calving rates, because of the non-continuous nature of resighting histories of known females photographed in Hawaiian waters. Baker, Perry, and Herman (1987) calculated the calving rate, the number of calves per mature female per year, by dividing the number of calves observed across years, by the number of known females observed in the same period. In a 1980 through 1985 study, Baker, Perry, and Herman (1987) estimated a calving rate of 0.58 calves per year, but stated that this estimate assumes that the chances of sighting a female were not affected by the presence or absence of a calf. They further state that this calving rate may be inflated due to behavior and longer presence of "mothers and calves" on the breeding grounds. In southeastern Alaska, Baker, Perry, and Herman (1987) estimated a calving rate of 0.37 for the same time period (Table 2).

Through aerial surveys conducted in 1976, Herman and Antinoja (1977), found 9.1 and 9.6 percent of the population to be calves, estimating a crude birth rate of 0.091 and 0.096. Converting the crude birth rates to calving rates yielded estimates of 0.36 and 0.38 respectively. Likewise, aerial surveys in 1978-80 conducted by Bauer (1986) produced an estimate of 0.29 calves per mature female per year.

In a 1977-1992 study in southeastern Alaska, Straley (1994) calculated a minimal calving rate of 0.39 calves per mature female per year, and a maximal calving rate of 0.50 calves per mature female per year, and states that the maximal rate is a more reliable estimate since it takes into account only adults known to be sexually mature (method A described above). If we use this same method of determining the calving rate, the number of calves sighted per mature female per year, our study yields an inflated rate of 0.82. These results are biased due to non-random sampling for mothers and calves. Furthermore, our study area off Maui may be geographically stratified as an area which is utilized more frequently by mother/calf pairs than non-mothers.

We therefore calculated the calving rate by dividing the number of calves produced per female, by the number of years of the observed reproductive span, to yield an estimate of 0.44. This calving rate closely compares to 0.43 derived by Clapham and Mayo (1987a) for the North Atlantic population. However, our estimate is a minimum estimate of the calving rate as it is based on non-continuous resighting histories and consequently it is likely that more calves were produced than observed.

Calving Intervals: A total of 200 sightings of 58 mothers during our 1977 through 1993 study, produced information on 89 calving intervals. Of the 58 mothers with two or more calves, 7 (12.1 percent) produced 14 one year calving intervals at an unexpectedly high proportion of 15.7 percent (14 of 89) of the total intervals (Figure 2). Whales M22 and W94 each produced calves on 3 one year calving intervals. Whale W69 produced calves 4 years in a row (Figure 3).

Eighteen of our 89 (20.2 percent) intervals were continuous. Using these continuous intervals only, yielded a mean calving interval of 1.2 years (SE 0.76). This result is negatively biased because of 1 year calving intervals being continuous. However, an earlier study based on underwater photographs taken during 1975-88, used only nine continuous calving intervals. This study yielded the same result of 1.2 years (SE 0.47) (Table 3). Since our resighting histories are often not continuous, we calculated the maximum calving interval defined as the maximum number of years between calving: 14 intervals were 1 year; 23 were 2 years; 20 were 3 years; 13 were 4 years; and 19 were 5 years or more. Calculating the mean maximum calving interval, yielded a result of 3.3 years (SE 1.26). Thus, our study yields a range of 1.2 to 3.3 years. Using an alternative method of calculating the mean calving interval, that is, by determining the inverse of the calving rate, yielded a result of 2.27 years for Hawaiian waters. This estimate compares closely to Straley's observed interval in Alaskan waters of 2.26 years (Table 3).

Due to the non-continuous nature of our study, one-year calving intervals probably occur more frequently than observed. Through analyzing whaling industry data Chittleborough suggested that the occurrence of a one-year reproductive cycle could be the result of postpartum ovulation occurring due to the loss of a calf. However, we postulate that postpartum ovulation is occurring without the previous loss of a calf.

In 1992 and 1993, we observed the presence of mucous secretions in the water near 3 lactating females. Of 2 specimens that were collected, one was found to contain measurable quantities of estrone sulfate (Glockner-Ferrari, et. al., 1993). The second sample did not yield measurable quantities of estrogen, but was significantly degraded. The sample containing estrogen was observed to come from the genital slit area of the mother.

The mother whose specimen was analyzed and found to contain estrogen, and the female whose specimen was not collected, were found in an active group of whales. Active groups are frequently sighted on the wintering grounds as has been documented by Darling, Gibson, and Silber (1983), Tyack and Whitehead (1983), Baker and Herman (1984), and Glockner-Ferrari and Ferrari (1985). These groups consist of a female, a dominant male escort, and one or more male challengers fighting to overtake the position of escort. We previously demonstrated the purpose of these groups is to lead to pair formation between the female and dominant male, which we speculate results in mating (Glockner-Ferrari and Ferrari, 1985).

Of 402 sightings of Active Groups, 201 (50.0 percent) contained a lactating female accompanied by a calf. The presence of estrogen and epithelial cells in the mucous secretions of the lactating females in the active groups, lends support to the theory that the formation of "Active Groups" lead to mating, and that postpartum ovulation is occurring in lactating females without previous loss of a calf (Glockner-Ferrari, et. al., 1993).

We most recently obtained a mucous sample, during our 1995 field season, from a known whale, W199, who has thus far produced 5 calves over a 17-year reproductive span. She most recently produced calves on a one year calving interval in 1994 and 1995.

Straley, Gabriele, and Baker (1994) reported the successful annual reproduction of five females producing 12 calves in southeastern Alaska. Two of the calves were resighted in later years.

Calf Survival and Recruitment: Following the growth of a calf to maturity is difficult, as the pigment patterns of calves can change with age. Thus far we have identified only three known yearlings, that have returned to Hawaii accompanying their mothers (Glockner-Ferrari and Ferrari, 1984). In addition we have observed one known male calf to have reached sexual maturity. This whale was first observed as a calf in 1978, and was distinguished by a "v" shaped cut on its peduncle posterior to the dorsal fin (Glockner, 1978). This whale was subsequently seen five years later as an escort to a female, head lunging in an active group. At the age of ten he was observed singing (Glockner-Ferrari and Ferrari, 1990).

Of 85 calves photographed in southeastern Alaska, Straley (1994) reports that only 21 calves (24.7 percent) were resighted in subsequent years. Eight were at least 5 years old, the presumed mean age of sexual maturity, as estimated by Chittleborough (1958, 1959), Nishiwaki (1959), and Clapham and Mayo (1987b), but only two were observed with calves.

Juvenile and Calf Mortality: One of the most critical components of understanding recruitment to a population, is knowledge of calf and juvenile mortality. The following are known accounts of juvenile and calf mortalities, abnormalities, or injuries in Hawaii:

On 1 March 1995, a sub-adult whale was found entangled in mooring lines off the Maui coast. The Coast Guard cut the whale free, but several lines remained attached. Two hours later the whale beached on a reef off Kihei, Maui. Numerous tiger sharks attacked and killed the whale. The whale was recorded 11.0 meters in length. The whale was 2 to 3 years in age. On 3 April, 1995, a calf was observed being attacked by several tiger sharks (Worthen, pers. comm.). Captain Jeff Worthen reported that the escort was "tail lobbing while the mother attempted to keep the calf above her back." The calf disappeared. In 1992, we observed a similar incident of a tiger shark following a Mother, Calf, Escort group. The escort was exhibiting a multitude of behaviors, including tail throws, tail lobs, breaching, and pec slaps. The mother was trumpet blowing and acting in an agitated manner. She kept the calf close to her body with her pectoral fin. We observed this encounter for approximately 3 hours. These whales were not resighted that year. In 1987 we also observed an apparently sick yearling-sized whale that was covered with lice and barnacles. The yearling would remain stationary underwater, and then float backwards tail first to the surface to breathe. A 14' tiger shark was seen near this whale. On the same day as the sighting off Maui, a yearling-sized whale was reported to be in the same condition off the Big Island. An oceanic white-tip shark was reported with this individual (Glockner-Ferrari, et. al., 1987).

Other incidents have been reported that document potential sources or episodes of juvenile and/or calf mortality or injury. Information compiled by Eugene Nitta, National Marine Fisheries Service, denotes the death of a 4.3 meter calf off Lanai in 1992, 2 female calves 4.0 and 4.7 meters off Oahu and the Big Island respectively in 1991, a calf of unknown sex off Maui in 1990, and a calf off Kauai in 1987. In 1987, a calf was observed with a portion of its flipper cut and its fin serrated by a propeller. In 1981, a male calf washed ashore off the coast of Oahu. This individual was held at Sea Life Park, until it died a week later. We also observed a calf whose flukes were degenerating and a severely emaciated calf trailing the adult that accompanied it in 1980 and 1979, respectively. And in 1976, a yearling-sized whale was seen at Molokini Island, swimming inside the crater. A few days later it was seen without one pectoral fin being followed by several tiger sharks (Shallenberger, 1981; Nitta and Naughton, 1989).

A total of six confirmed calf moralities, and one sub-adult mortality were observed in Hawaiian waters during the 1981-95 period. Throughout our study, calves have been periodically seen with rake marks, missing fluke tips, and other apparent injuries probably sustained from either killer whales, false killer whales, or sharks. Researchers have also documented humpback whale calf mortality in Alaska. Baker, Perry, and Herman (1987) reported the apparent death of a calf in southeastern Alaska during the summer of 1986. Straley (1994) reports 3 cases of presumed calf mortality, one case of possible mortality, and three confin-ned deaths of male calves in 1987, 1991, and 1992.

Discussion: In summary, we have found one year calving intervals to be a frequent occurrence in this species. Our studies, along with those of Straley, Gabriele, and Baker (1994), support Chittleborough's (1958) initial assumption that simultaneous pregnancy and lactation are not uncommon in this species, and that successful postpartum ovulation can occur without previous loss of a calf. We further estimated that females reproduce at a minimum rate of 1 calf every 2.3 years. Reproductive spans of known females ranged from 1 to 19 years. Observations of long reproductive spans lends support to the theory, as evidenced by Mizroch (1981) in fin whales, that reproductive senescence does not occur in baleen whales.

In conclusion, long-term studies have produced a tremendous amount of information on the reproductive cycle of humpback whales. However, we still have yet to determine with certainty the reproductive, survival, and recruitment rates of the population.

In 1986, Mizroch of the NMFS/National Marine Mammal Laboratory, began a computerized photo-identification system to compare photographs of the flukes of humpback whales taken by researchers throughout the North Pacific. This system has the potential to elucidate vital information on the reproductive parameters of the North Pacific humpback whale. In 1991, NMML held a workshop on estimating Calf and Juvenile Mortality. Data presented at this workshop are currently being analyzed.

Current mortality rate estimates are limited to observed mortalities. However, great potential exists in comparing reproductive histories of known mothers in Hawaii with those in Alaska, to determine the survival rate of calves during migration.

Understanding the survival rate of calves and juveniles is vital to determining the recruitment rate of this endangered population in order to aid in its recovery. It is essential that research on the reproductive history of this endangered species continue and that comparative studies be facilitated. The National Marine Mammal Laboratory has done that in the past, and we appreciate and look optimistically forward to their continued support.

Last week Judge Harold Fong, the judge who ruled in favor of humpback whales on the thrillcraft/parasail issue, passed away. Judge Fong's "Summary Judgement" stated that:

> "The public interest in preserving the habitat of the humpback whale is paramount. Congress has intended that endangered species be afforded the highest of priorities (Tennesee Valley Authority v. Hill, 437 U.S. 153, 174, 98 S.Ct. 2279, 2292 (1978)). The Supreme Court has stated that the value of an endangered species is 'incalculable' ID. at 437 U.S. 187-88, 98 S.ct. 2298. The loss of even one member of an endangered species is a loss that cannot be replaced with any amount of money."

The waters surrounding the Hawaiian Islands are critical habitat for the North Pacific humpback whale. Sixteen years ago, the first workshop was held here at Kaanapali to discuss the need and importance of creating a Sanctuary for the humpback whale in Hawaii. Since that time, we have learned a tremendous amount about the whales and their critical needs. However, much more work is needed until we understand the status of this species. Hopefully, the humpback whale will not only survive, but thrive in this unique environment, the waters surrounding the Hawaiian Islands.

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An Overview of the Movements of Humpback Whales in the North Pacific and Evaluation of Stock Structure

Calambokidis, J., J. Straley, S. Mizroch and S. Cerchio.

Introduction and Objectives: This summary reviews information on the movements and stock structure of humpback whales in the North Pacific and make conclusions relative to stock structure and presence of sub-populations. Information reviewed included the following:

- known feeding and wintering areas for humpback whales in the North Pacific;
- migratory destinations between feeding and wintering areas;
- interchange among wintering and feeding areas;
- genetic patterns of mtDNA and nuclear DNA.

Sources of Information: (1) We reviewed available published and unpublished information on movements of humpback whales in the North Pacific. These included historical accounts based on whaling records and discovery tags, whaling records including accounts of where whales were killed (Kellogg, 1928; Tomilin, 1957; Berzin and Rovnin, 1966) and movements based on Discovery tags that were shot into whales and later recovered when the whale was killed and processed (Nishiwaki, 1966; Omura and Ohsumi, 1964; Ohsumi and Masaki, 1975; Ivashin and Rovnin, 1967).

(2) Published accounts of whale movements based on photographic identification. These include some of the early pioneering work done in the late 1970s and early 1980s (Darling and Jurasz, 1983; Darling and McSweeney, 1985; Baker et al., 1986; Perry et al., 1988) as well as more recent accounts of movements (Darling and Mori, 1993; Urban et al., 1987; Calambokidis et al., 1989, in press; Steiger et al., 1991; Darling and Cerchio, 1993; Darling et al., pers. comm.).

(3) Unpublished data including research by the authors on movements involving humpback whales that occur in areas in which we work (California, southeastern Alaska, and Kauai) and information made available to us by other researchers and collaborators. Some of this information is under submission to scientific journals and should be available in the near future.

(4) We also used information on matches found or recorded in the North Pacific Humpback Whale Fluke Catalog maintained by NMFS/NMML (Mizroch et al., 1990). A compilation of matches recorded by the system was prepared by Sally Mizroch for workshop participants.

Use of Feeding and Wintering Areas: Humpback whales make seasonal migrations between low latitude wintering areas used for mating and calving and high-latitude feeding areas. Some animals use feeding areas in winter months (Straley, 1990; Forney et al., 1995) possibly reflecting a staged migration to the wintering grounds. The general distribution of feeding areas in the North Pacific covers coastal waters in the western North Pacific from northern Japan, north throughout the Bering Sea and in the eastern North Pacific as far south as off northern Baja California, Mexico (Figure 1). Although some of the areas are fairly well studied, other areas, including the western North Pacific, are known only from limited data gathered from whaling records.

Humpback whales in the North Pacific use three primary wintering areas (Rice, 1974; Johnson and Wolman, 1984). These consist of the waters near Mexico, Hawaii, and Japan (Figure 1). Within each of these three regions are a number of subareas. In Mexico, humpback whales winter off the southern tip of Baja, around the Revillagigedo Archipelago, and coastal areas off mainland Mexico (Urban and Aguayo, 1987). Humpback whales winter in Japanese waters off Ogasawara (Bonin Islands) and Okinawa (Ryukyu Islands) (Darling and Mori, 1993; Uchida et al., 1993). In Hawaii, humpback whales generally use waters less than 100 fathoms deep extending from the Big Island of Hawaii to Kauai (Herman and Antinoja, 1977; Rice and Wolman, 1980). Additionally northern hemisphere humpback whales have also been observed wintering off Costa Rica (Steiger et al., 1991).

Movement Among Wintering Areas: Humpback whales sometimes move among wintering areas (Figure 2). A few matches have been documented between Hawaii and Mexico (Darling and McSweeney, 1985: Baker et al., 1986; Cerchio and Jacobson, pers. comm.) including one whale that visited both areas in the same year (North Pacific Humpback Whale Working Group, unpublished data). Darling and Cerchio (1993) documented interchange of a single whale between wintering areas off Hawaii and Japan.

Movement of humpback whales among different sub-areas within a wintering ground appears extensive. Frequent exchange has been noted between Ogasawara and Okinawa, 1,600 km apart, with 7 matches recorded (out of a total of 211 identified whales) through 1991 (Darling and Mori, 1993; Uchida et al., 1993). Rates of interchange between Kauai and the Big Island of Hawaii were not significantly different than the inter-year resighting rate at the same location, however, movement among the islands may not be completely random (Cerchio, pers. comm.). Interchange among islands wintering areas in Mexico, however, is not random with infrequent exchange of humpback whales between wintering areas in the Revillagigedos and off mainland Mexico (Urban et al., pers. comm.).

Migratory Movements Between Wintering and Feeding Areas: Humpback whales from specific wintering grounds migrate to numerous feeding areas in the North Pacific (Figures 3 and 4). Because of the limited data gathered from some feeding areas in the Northern Hemisphere, a complete picture of these migratory movements is not yet available. In many cases, however, research conducted to date has identified some of the major migratory destinations of these whales.

Humpback whales wintering in Mexico have been documented migrating to feeding areas off U.S. west coast, British Columbia, and Alaska (Figure 3). Over 100 matches have been identified between Mexico and the waters off California, Oregon, and Washington (Baker et al., 1986; Urban et al., 1987; Calambokidis et al., 1989; Calambokidis and Steiger, 1995). Surprisingly, these matches come almost exclusively from animals wintering along the Mexican mainland coast and Baja California with only a couple from the offshore Revillagigedo Islands.

Humpback whales wintering in the waters of Hawaii migrate to feeding areas off California, Oregon, Washington, British Columbia, and Alaska (Figure 4). Frequent matches have been noted between whales feeding in southeastern Alaska and those wintering in Hawaii (Darling and McSweeney, 1985; Baker et al., 1986). A migration time of as short as 39 days has been recorded between these two areas (Gabriele et al., in press).

Movements from wintering areas in the western North Pacific have primarily come from whaling records (Figure 4). Discovery tag recaptures have indicated movement of whales between the Bonin and Ryukyu Islands wintering areas and feeding areas in the Bering Sea, on the south side of the Aleutian Islands, and in the Gulf of Alaska (Nishiwaki, 1966; Omura and Ohsumi, 1964; Ohsumi and Masaki, 1975). One whale marked at the Bonin Islands in March was captured in June of the same year west of northern Japan, possibly indicating movement up toward the Kuril Is. (Nishiwaki, 1966). A recent match of a humpback whale between the Ogasawara wintering area and a feeding area off southern British Columbia (Darling, et al., pers. comm.), demonstrated a long migration with a larger east-west component than the typical north-south movement.

Although different animals from a given feeding area may migrate to several different wintering areas, the migratory destinations are far from random, as demonstrated by the migratory destinations of humpback whales feeding off California (Figure 5). Almost the entire population of humpback whales from this feeding area has been identified and compared to collections of photographs from all known wintering areas (Calambokidis et al., 1989, 1990, 1993; Calambokidis and Steiger, 1995; Steiger et al., 1991). Although migratory destinations of whales off California include both Hawaii and Costa Rica, the vast majority migrate to wintering areas off mainland and Baja Mexico.

Interchange Among Feeding Areas: Humpback whales appear to form distinct feeding aggregations with only limited interchange among feeding areas. Katona (1986) and Katona and Beard (1990) report on the existence of four to five separate feeding substocks for humpback whales in the western North Atlantic with little interchange among them. Calambokidis et al. (In press) describe the existence of a sub-population of humpback whales feeding off California, Oregon, and Washington with little or no interchange with feeding areas farther north in British Columbia and Alaska (Figure 6). The northern boundary for the feeding area off California, Oregon, and Washington was in the vicinity of the Washington/British Columbia border. Within this feeding area interchange among sites decreased as function of distance (Figure 6).

Although the number and boundaries of other feeding grounds in the North Pacific are not defined, interchange among adjacent regions has been documented (Figure 7). A few matches have been found between British Columbia and southeastern Alaska (Darling and McSweeney, 1985; G. Ellis and J. Straley, pers. comm.). Six matches have been made between southeastern Alaska and Prince William Sound, both well-studied areas, between 1977 and 1993 (Baker et al., 1986; von

Ziegesar and Matkin, 1989; Perry et al., 1990; J. Straley, unpubl. data). Baker et al. (1992) reported no interchange between whales identified in southeastern Alaska in 1986 and other areas in the western Gulf of Alaska. Matches have also been found between 104 whales identified off Kodiak Island and both Prince William Sound (2) and southeastern Alaska (3) (Waite and Dahlheim, unpubl. data, Dahlheim and Waite, 1993).

Discovery tags applied during commercial whaling also demonstrated some movements among feeding areas in Alaska. Omura and Ohsumi (1964) report on the movement of a humpback whale tagged on 21 July 1962 in the Gulf of Alaska south of Prince William Sound, west to the south side of Akutan on the Aleutians (a distance of over 700 nmi) on 19 October 1962. Other smaller movements within and among feeding areas in the Gulf of Alaska and Bering Sea were also found through the Discovery tags (Nishiwaki, 1966; Omura and Ohsumi, 1964; Ohsumi and Masaki, 1975; Ivashin and Rovnin, 1967).

Genetic Indicators of Stock Structure: Patterns of mtDNA and nuclear DNA in North Pacific humpback whales have also revealed some differences, particularly among feeding areas. Significant differences in mtDNA haplotypes were found between 38 humpback whales biopsied in southeastern Alaska and 20 from central California, suggesting a long-term migration rate of less than one female per generation (Baker et al., 1990, 1994). However, differences in nuclear DNA were not found between humpback whales off California and southeastern Alaska (Baker et al., 1993; Palumbi and Baker, 1994), suggesting some reproductive interchange, recent or historical.

Similar differences in mtDNA have been found among feeding areas in the North Atlantic. Though no differences were found among the western continental feeding grounds (Baker et al., 1994; Palsbϕll et al., 1995), recent studies have revealed significant differences in mtDNA patterns between feeding areas in the western North Atlantic and those in the central and eastern North Atlantic (Palsbϕll et al., 1995, Larsen et al., 1994).

The occurrence of distinct feeding herds, as indicated by photographic identification and mtDNA, does not necessarily indicate an absence of some interbreeding among these sub-populations. Because mtDNA is maternally transmitted, mtDNA differences among feeding grounds may only indicate that offspring return to their mother's feeding ground. Mattila et al. (1989) and Clapham et al. (1993) have reported that breeding groups in the West Indies have included males and females from different feeding grounds. Similarly, humpback whales from feeding areas in both Alaska and California migrate to both Hawaii and Mexico although with very different frequencies (Darling and McSweeney, 1985; Baker et al., 1986; Perry et al., 1990; Urbán et al., 1987; Calambokidis et al., 1989), hence, the opportunity for whales to interbreed exists. Although the frequencies of mtDNA haplotypes on Mexican and Hawaiian wintering grounds are significantly different, they are not as marked as between California and Alaska (Baker et al., 1994). This may reflect the mixing of whales from different feeding areas on the wintering grounds or migration from as yet unsampled feeding grounds (Medrano et al., 1995).

Conclusions: Humpback whales show a strong affinity to particular feeding areas and the interchange among feeding areas is limited. The number and boundaries of feeding areas has not been described for all areas of the North Pacific. All whales from a feeding area do not travel to the same wintering area and there is some interchange among wintering areas. Though animals from a specific feeding area may differentially travel to a specific wintering area, there is not a clear stock structure that includes both specific feeding and wintering areas. The existence of dramatic mtDNA differences among some feeding areas demonstrates that offspring generally adopt their mothers feeding area. The mixing and likely interbreeding of animals from different feeding areas on the wintering grounds explains the less dramatic differences in mtDNA among wintering areas as well as the apparent absence of differences in nuclear DNA among feeding areas.

A number of areas of research are needed to resolve our understanding of humpback whale migrations and stock structure. A better understanding is needed of the number and boundaries of feeding sub-populations off Alaska and the western North Pacific. A more quantitative assessment of interchange rates is needed for most areas. This along with basin-wide estimates of abundance will provide a perspective on the proportion of animals using different feeding and wintering areas. Research on both mtDNA and nuclear DNA differences among feeding and wintering areas needs to be expanded.

FIGURE CAPTIONS

Figure 1. Range of feeding areas of humpback whales in the North Pacific (cross hatching) and primary wintering areas (circled).

Figure 2. Documented interchange of humpback whales among North Pacific wintering areas. Thickness of connecting lines indicates relative rate of interchage.

Figure 3. Migratory connections of humpback whales between wintering areas off Mexico and feeding areas in the North Pacific. Thickness of connecting lines indicates relative rate of interchage.

Figure 4. Migratory connections of humpback whales between wintering areas off Hawaii and Japan and feeding areas in the North Pacific. Thickness of connecting lines indicates relative rate of interchage.

Figure 5. Migratory destinations of humpback whales feeding off California. Thickness of connecting lines indicates relative rate of interchage.

Figure 6. Interchange rate of humpback whales among feeding locations to the north and south of the Gulf of the Farallones.

Figure 7. Interchange of humpback whales among feeding areas along the eastern North Pacific. Lines connect most distant regions with documented interchange and thickness indicates relative rate of interchange.

Comparison of Humpback Whale Group Dynamics Between Hawaii and Alaska

Gabriele, C. M.

Introduction: Sighting histories of individually-identified North Pacific humpback whales (Megaptera novaeangliae) were used to summarize and compare the size and composition of humpback whale pods in Hawaii and southeastern Alaska. Sighting intervals, calf return and site fidelity provide context for the pod composition comparisons. The analyses presented were modified and updated from work on humpback whales in the Hawaiian islands (Baker 1985, Gabriele 1992), and ongoing work conducted by National Park Service staff in and around Glacier Bay National Park and Preserve, southeastern Alaska.

Humpback whales are found in tropical waters for several months each winter, where females raise their newborn calves and adult males compete for proximity and presumably mating access to estrous females (Tyack and Whitehead, 1983; Baker and Herman, 1984; Clapham et al., 1992b). Humpback whales feed on schooling fish and zooplankton in high-latitude waters primarily in summer (Jurasz and Jurasz 1979). Although varying numbers of humpbacks are present in high-latitudes throughout the year, it is unknown whether some individuals remain in southeastern Alaska waters for the entire year (Straley 1994, Gabriele et al. in press). The longest documented humpback whale residence time in southeastern Alaska is 219 days (Straley 1994). Whales move among the Hawaiian islands in winter (Baker and Herman, 1981; Darling and McSweeney, 1985; Cerchio et al., 1991) and throughout southeastern Alaska during the year (Baker et al., 1990; Straley, 1994). Humpback whale social behavior varies between summer and winter. Little overt aggression among whales is observed in summer feeding areas, while in wintering areas, agonistic behavior is relatively common (Tyack and Whitehead, 1983; Baker and Herman, 1984; Baker, 1985). Humpback whale song is a vocalization produced by mature males and occurs in the wintering grounds only; characteristics of groups with a singer in Hawaii have been described by Frankel (1994). Humpback whale pods in winter and summer habitats are unstable, frequently gaining or losing members (Mobley and Herman, 1985; Baker, 1985).

Methods: In Hawaii and southeastern Alaska, humpback whales were observed and photographed from 14-17' skiffs powered with outboard engines. Whale fluke photographs were taken with a 35mm SLR camera equipped with a 300 mm lens. High speed (400 ASA) black and white film was used to obtain clear photographs of the ventral surface of the tail flukes of each whale, for the purpose of individual identification (Jurasz and Palmer, 1981; Katona et al., 1979). Photographs were matched to catalogs to determine the identity of the whale (Perry et al., 1988).

The NPS Humpback Whale Monitoring Program has been conducted annually in Glacier Bay and Icy Strait from late May through August since 1985. In 1982-1984, humpback whale studies in Glacier Bay were conducted by the University of Hawaii, under contract to the NPS and National Marine Fisheries Service (NMFS). Vessel surveys of Glacier Bay were conducted approximately 3 days per week, and Icy Strait was surveyed 1-2 days per week. Glacier Bay/Icy Strait data from 1982 to 1994 were analyzed for the analyses presented here. The University of Hawaii humpback whale research team has photographically identified humpbacks in Maui or Big Island waters each winter since 1976. Hawaii survey effort and locations varied, but occurred primarily from mid-January to late-March beginning in 1980. Hawaii data from 1976 to 1989 were used for the analyses presented here (Gabriele, 1992).

A 'group', or 'pod' of whales contained one or more individuals within approximately five body-lengths of one another, in behavioral synchrony with respect to direction of travel, respiration and diving. Sighting histories of recognized individual whales were used to determine their age/sex class, using the following criteria: An adult whale closely and consistently accompanied by a calf in Alaska or Hawaii was considered to be female. In pods with a calf and more than one adult, the adult that remained consistently closest to the calf was presumed to be the mother. Once an individually-identified whale was determined to be a mother, she was denoted as female in previous or subsequent years within the database. A whale observed as a singer or an escort was considered to be male. The term 'escort' refers to an adult whale accompanying a cow/calf pair in the wintering grounds (Herman and Antinoja, 1977). A whale was determined to be a 'singer' if singing was heard underwater using a hydrophone in the vicinity of a whale and if the surfacings of this whale correlated with marked attenuation in song intensity. A whale less than 20 feet long, gray or black in color, usually closely accompanied by an adult whale was considered to be a calf.

Pod size denotes the number of individuals in a pod, despite whether all animals were individually identified with a fluke photograph. Annual return and residence times were measured because of their effects on the composition of pods. Annual return or site fidelity was measured by determining the number of years that individuals were identified in southeastern Alaska or Hawaii. Sighting intervals or residence times were determined by calculating the number of elapsed days between the first and the last sighting of an individual in one season. Whales were not assumed to be present in the study area for all the intervening days; this method provides an index of minimum occupancy in winter or summer grounds. Associations among individuals occurred when individuals were identified in the same group. Sighting histories were used to determine the identity, age-sex class and relatedness of individuals.

Results: Pod size: Pod sizes in summer and winter grounds were generally small, although larger pods occurred (Fig. 1). In southeastern Alaska, calves were infrequently found alone (2 percent), and the majority of calf pods were composed of just the cow/calf pair (Fig. 1a). In Hawaiian waters, the majority of cow/calf pairs were accompanied by a single escort. In the southeastern Alaska feeding grounds, most pods contained a single adult whale (Fig. 1b). In Hawaii, 40 percent of whale pods contained two adults, and 20 percent single whales. Very rarely did a pod in Hawaii or southeastern Alaska contain more than one calf.

Annual Return: In southeastern Alaska, more than 70 percent of whales were identified in more than one year, with approximately one third sighted in 10 or more years (Fig. 2). In contrast, 70-80 percent of Hawaii whales have been identified in only one year (Fig. 2), with very few individuals identified in 6 or more years. No pronounced differences in annual return between males and females emerged in Alaska or Hawaii (Fig. 2), although no statistical analyses were done.

Residence Times: Most whales in Hawaiian waters were identified on one day only (Fig. 3), with very few animals documented to remain greater than 2 weeks. Sighting intervals of Hawaii females appear to be significantly shorter than those of males (Table 1). In southeastern Alaska, 75 percent of whales were identified on more than one day, with over 50 percent of these animals present for greater than 30 days (Fig. 3).

Associations Among Age/Sex Classes: Males and females in Hawaii associated frequently in cow/calf/escort pods, surface active pods and pairs (Fig 1, Gabriele, 1992). No pod in Hawaii has been observed to contain more than one adult female (Baker, 1985; Gabriele, 1992) and Clapham et al. (1992b) observed only one competitive group that briefly contained more than one female. Many pods in Hawaii contained more than one male (Baker, 1985; Gabriele, 1992). Most non-parous females were accompanied by a single adult, or many adults, but were very rarely alone (Gabriele 1992). In southeastern Alaska, whales of all age/sex classes intermixed, with juvenile and adult male-male, female-female and male-female pods common (Baker, 1985; NPS unpublished data).

Table 1. Sighting intervals of male and female humpback whales in Hawaii

	< 1 Week	1-2 Weeks	2-3 Weeks	3-4 Weeks	> 4 Weeks	TOTAL
Females						
OBS	20	8	2	3	2	35
EXP	12.9	8.2	5.2	2.7	5.9	35
Males						
OBS	37	28	21	9	24	119
EXP	44.0	27.8	17.8	9.3	20.1	119

$X^2 = 10.9$, df = 4, $P = 0.0274$

Associations Among Relatives: Detecting associations among related individuals is possible to a limited degree in Glacier Bay/Icy Strait, where 14 of 36 photographically identified calves were re-sighted in subsequent years. Four of these individuals are male, one is female, and nine are of unknown sex (Gabriele, 1994). No post-weaning associations between cows and their offspring were observed, nor were associations between half-siblings, although these individuals concurrently inhabit the same feeding ranges (NPS, unpubl. data ; Straley, 1994). In Hawaii, detecting associations among related whales was not possible with available data; site fidelity is very low (Fig 2), photo-identification of calves is often impossible because newborn calves rarely raise their flukes above water, and fluke coloration may change within the first year of life (Carlson et al., 1990).

Stable Associations Among Individuals: In Hawaii, only seven pairwise repeat associations within season have been observed (Baker, 1985; University of Hawaii unpubl. data). Between seasons, no repeat associations were detected. In southeastern Alaska, whales appear to have preferred feeding partners (Baker, 1985; Perry et al., 1985), with numerous pairs of individuals sighted together repeatedly within and between seasons (NPS, unpubl. data). A 'core group' of 4-7 whales, first documented by Perry et al. (1985), fed together on herring (Clupea harengus) annually in Icy Strait (1981-1994). In some seasons the group appeared to associate continuously over a period of weeks (Perry et al. 1985, Gabriele 1991). A 'core group' sighting was defined as a pod containing 3 or more whales, with at least 3 of the individuals being those identified as core group members. A 'core group member' was defined as an individual that was sighted in the group for more than 25 percent of the group's sightings in a given year, in more than one year. Using those definitions, three new core group members (ID# 186, #353, #193) have joined since 1990, and 43 other whales associated briefly (on one to five occasions) with the group. Male #186 and female #353 are the offspring of well-documented cows (#530 and #581) who have infrequently associated with this group since 1985. The pod appears to be less stable when the female pod members have a calf (Perry et al., 1985), although cows with a calf sometimes associate with the group (Straley, 1990; Gabriele, 1994).

Discussion: Life history data from long term photographic-identification studies are a powerful tool in gauging the population parameters and recovery of humpback whales. The data presented here largely corroborate and expand upon other published reports from the North Pacific, North Atlantic and Eastern Australia on humpback whale pod size (Nemoto, 1964; Whitehead, 1983; Bauer, 1986; Mattila and Clapham, 1988; Weinrich and Kuhlberg, 1991; Clapham et al., 1993; Smultea, 1994) composition (Nemoto, 1964; Darling, 1983; Tyack and Whitehead, 1983; Whitehead, 1983; Baker and Herman, 1984; Clapham et al., 1992b; Weinrich and Kuhlberg, 1991; Clapham et al., 1993, 1994; Corkeron et al., 1994), site fidelity (Mattila and Clapham, 1988; Clapham et al., 1992a, 1993; Mattila et al,. 1994), residency (Whitehead and Moore, 1982; Darling, 1983; Corkeron et al., 1994; Mattila et al., 1994) and stability (Darling, 1983; Whitehead, 1983; Weinrich, 1991; Weinrich and Kuhlberg, 1991; Clapham et al., 1993), but also contribute some new insights into annual return, sex differences in sighting intervals and long-term associations among individual whales.

Observations of long-term, repeated associations in southeastern Alaska are distinctly more prevalent than reported in the North Atlantic feeding grounds (Whitehead, 1983; Weinrich, 1991; Clapham et al., 1993). Refinement and standardization of the definitions of 'stable' associations and more comprehensive analyses of pod characteristics and dynamics are necessary.

Well-designed, collaborative studies will be necessary to advance our collective knowledge of humpback whale natural history. This important point is illustrated by the differences in site fidelity between winter and summer habitats (Fig. 2). The low site fidelity in Hawaii may be a sampling artifact indicating that the home range sizes of individual whales in Hawaii are large in comparison with the size of the study areas. This assertion makes sense given what is known about inter-island movement (Baker and Herman, 1981; Darling and McSweeney, 1983; Cerchio et al., 1991) and within-season resighting rates of only roughly 15 percent (Whitehead and Moore, 1982; Darling, 1983; Gabriele, 1992; Corkeron et al., 1994; Mattila et al., 1994) in various wintering grounds. North Pacific humpbacks sometimes switch wintering grounds (Baker et al., 1986) but seem likely to return consistently to the Hawaiian islands as a whole, although single research groups may fail to detect site fidelity on that scale.

Similarities and differences in whale behavior between seasonal habitats may influence a whale's susceptibility to various impacts and management actions, and/or influence researchers' ability to measure important life history traits. Data such as those presented here should be taken into account in designing future studies of population size, habitat use, reproductive rates, survival and recruitment. For example, given humpback whale resighting rates, researchers may choose to conduct a particular study preferentially in the summer vs. wintering grounds and consider resighting rates in determining the sample sizes and study area sizes needed to obtain the necessary data. Collaboration, standardization of methods, consideration of the accumulated knowledge and use of applicable new techniques will undoubtedly improve future understanding of the humpback whale biology and behavior.

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B. POTENTIAL HUMAN IMPACTS AND MITIGATION

Overview of the Final Humpback Whale Recovery Plan as it Relates to Hawaii and the North Pacific

P. Michael Payne

The Endangered Species Act (ESA) requires Federal agencies to use all reasonable methods available to conserve endangered and threatened species, including planning and actions to prevent further decline of the species, to facilitate an increase in its population and to improve the quality of its habitat. Section 4(f) of the ESA requires the National Marine Fisheries Service (NMFS) to develop and implement a recovery plan for any species listed as either threatened or endangered, if it is determined that such a plan will promote conservation of the species. The Final Recovery Plan for the Humpback Whale (Recovery Plan) was written by the Humpback Whale Recovery Team at the request of the Assistant Administrator for Fisheries, and was completed in November 1991. The recovery team included members from the private sector, academia, and state and Federal agencies.

The Recovery Plan is organized into five major sections. Following a review of the natural history of the humpback whale, the Recovery Plan provides details on populations in the North Atlantic and the North Pacific Oceans. The Recovery Plan concentrates on populations of humpback whales that occur seasonally or permanently in the U.S. territorial waters. A discussion of known and potential impacts to the species and its habitat(s) is followed by recommended recovery actions to restore and maintain populations of the humpback whale, and recommended management activities to assist the species to increase in numbers, and further research needed to monitor rates of population change. The Recovery Plan outlined the following objectives:

- to maintain and enhance habitat,

- to measure population change, and.

- to reduce human-related injury and mortality.

Additionally, the Recovery Plan recognizes that public education is important in implementing the actions proposed and recommended the following objective towards that goal:

- to promote education and cooperation to achieve the recovery goal of this Plan.

The Recovery Plan recommended and ranked management/recovery actions considered necessary to reach each of the stated objectives. With the completion of the Recovery Plan, the intent of NMFS is to focus implementation efforts on those issues which are considered as having the greatest priority. Relative to this workshop the following action items were considered as having the greatest priority in the Recovery Plan:

1. Recovery Plan Objective: Maintain and Enhance Habitats Used by Humpback Whales Currently or Historically.

a) Provide detailed description of habitats used by humpback whales. Differences in spatial and/or temporal use of habitat by sex, age, or different reproductive classes need be described. Sampling on the summer range should extend through the winter, where possible, to ascertain the number, age, sex, reproductive state and behavior of humpback whales that do not migrate to the breeding grounds. The resulting data should.be incorporated into methods for population estimation and other management decisions.

b) Designate critical habitat. As required in Section 4 of the ESA, the NOAA Fisheries should use information gathered above to characterize, identify and possibly designate as Critical Habitat any areas that appear to be essential to survival or population growth of existing humpback whale populations. Waters around the Hawaiian Islands that are used by humpback whales were specifically mentioned.

c) Identify and monitor human-related activities that mav affect habitat suitability and population recovery. Modifications to or destruction of essential habitat from pollution and/or other human activities may already be, or may soon become, a major limiting factor for humpback whale populations. It is necessary to monitor the occurrence and abundance of human-related activities that could decrease the ability of habitats to support humpback whales. Evaluation of these factors should also consider cumulative or synergistic interactions between various factors.

Long-term monitoring for comparison against initial baseline values for such factors were recommended in the Recovery Plan.

d) Investigate responses of humpback whales to human-induced habitat changes and the effects of underwater noise on humpback whales. Investigate short- and long-term responses of humpback whales to human-induced habitat changes near known feeding or breeding areas. Use information to predict potential effects of future changes and to identify previous modifications to habitat that may have affected distribution or population size of the humpback whale. Federal agencies that oversee activities in humpback whale habitat(s) should take the lead in research in this area.

2. Recovery Plan Objective: Measure and Monitor Key Population Parameters.

a) Standardize methods for estimating humpback whale population size. Accurate assessments of humpback whale populations throughout the range of the species are necessary for evaluating the success of this Recovery Plan. Consistent long-tenn data are needed to identify spatial and temporal trends in abundance. Interpretation of data is hampered by inconsistent methodology and high variance surrounding estimates of the mean.

Research methods must be designed to provide reliable and comparable results. Particular consideration should be given to improving sampling consistency, precision, accuracy and frequency. Improving comparability between different studies should also be an important goal. Techniques for analysis of relative trends in population size, including the use of index areas, should also be re-evaluated.

b) Perform new field studies on population dynamics. Research to estimate the sizes and rates of change of humpback whale populations should be initiated. The research is essential for evaluating actual and potential rates of population recovery. Some,of these studies will also provide information about habitat use or other topics important for determining management actions.

c) Examine rates of birth and survivorship. Estimates of birth rate and survivorship are important for evaluating the potential rate of recovery of humpback whale populations and comparing reproductive success in different geographic regions. Survivorship rates should be detailed as a function of age, sex, or other characteristics.

d) Extend photo-identification studies. Photo-identification studies should be continued and extended to follow calf survival through recruitment and beyond, in order to provide data on natality, mortality, population size, migrations and habitat use.

e) Encourage multi-agency approaches to research. The Recovery Plan should be distributed to appropriate public and private agencies in states whose activities can, affect humpback whales and their habitat. Such communication will help to create a framework for cooperating on appropriate tasks in this Recovery Plan. The Sanctuary Advisory Council's research working group may help foster greater coordination with other agencies and the research community.

3. Recovery Plan Objective: Identify and Reduce Direct, Human-related Mortality, Injury and Disturbance.

Identify Sources and Rates of Human-Induced Injury and Mortality. NOAA- NMFS should investigate and identify sources and rates of injuries and mortality attributed to human activities. Recent amendments to the Marine Mammal Protection Act require reports of incidental take of any marine mammal by U.S. fisheries. All dead humpback whales should be photographically identified to provide information on variation in mortality by age, reproductive class or other variables.

4. Recovery Plan Objective: Improve Administration and Coordination of Recovery Program for Humpback Whales.

a) Develop Federal-State Partnerships to Protect Humpback Whales. Although management of the humpback whale is primarily a Federal responsibility delegated to the NOAA/NMFS, other federal agencies such as NOAA's Sanctuaries and Reserves Division (SRD) and the states should be partners in reviewing recovery needs and cooperating to carry out appropriate actions. NMFS and SRD should continue efforts to coordinate so that Sanctuary actions remain complementary to broader NMFS humpback whale recovery actions throughout the North Pacific.

States can aid the recovery of humpback whale populations by:

(1) reviewing relevant local laws and making changes where appropriate to enhance habitats;

(2) identifying potential impacts of proposed construction and/or habitat modification activities on humpback whales and their habitats; and

(3) using appropriate legislative processes to ensure protection for the whales and their habitats.

Joint Federal-state-municipal meetings to explore ways to protect humpback whale habitats should be implemented.

<u>b) Convene meetings between NOAA and the State of Hawaii</u>. The Recovery Plan recommended that NOAA should work with the State of Hawaii to address problems concerning protection of this species and its winter range in Hawaiian waters. Continued suitability of the Hawaiian wintering range is necessary to meet the goals of this Plan. Among other things, action should be taken to upgrade habitat water quality by providing adequate sewage treatment or transfer facilities at Hawaiian marinas. Other topics requiring discussion include speed limits for boats and potential location of new marinas in areas used frequently by humpback whales.

<u>c) Promote Public Education and Cooperation to Achieve Recovery Goal</u>. Public awareness of the recovery planning process and the objectives of this Recovery Plan in particular will help achieve recovery objectives. NOAA should develop and distribute information materials in coordination with states and other Federal agencies, and other public and private groups to:

(1) advise the public of the protected status of humpback whales;

(2) summarize Recovery Plan recommendations and ongoing recovery efforts;

(3) solicit appropriate involvement of the public in actions related to this Plan;

(4) provide instructions for field identification of humpback whales to facilitate

reporting of injured, entrapped or dead specimens; and

(5) foster attitudes that will enhance the habitats used by this species.

d) Produce and Distribute Educational Materials. NOAA should consult with persons experienced in education and public relations to plan the most effective instruments for stimulating public cooperation, including brochures, pamphlets, media presentations and others.

e) Distribute Synthesis of Biological Data. Synthesis of biological and ecological information for humpback whales need be distributed to enforcement officers, researchers and managers involved in management activities and decisions that may affect humpback whales.

f) Improve Availability of Information on Humpback Whales. A comprehensive library of publications and information on humpback whales should exist in order to facilitate tasks called for in this Plan. NOAA should implement such a collection or assist in maintaining and extending an existing collection.

g) Improve Cooperation with Marine Resource Users. NOAA should work to facilitate information exchange and coordination with appropriate commercial and recreational marine users to ensure that their activities will not cause direct or indirect adverse affects to the humpback whale.

The Recovery Plan is subject to modification as determined by completion of actions described in the plan. Many recovery actions in the Recovery Plan have been, and are continuing to be, addressed through the ESA, Section 7 consultation process, through regional meetings and, most recently, through a review of Recovery Plan research and management activities by NMFS that addresses recovery needs.

The intent of NMFS is to provide a long-term commitment to the implementation of the actions outlined in the plan to affect the recovery of the humpback whale [in Hawaii and the North Pacific]. The results of discussion groups conducted in this workshop will further focus recovery and management efforts needed in Hawaii and the North Pacific. Implicit in this workshop is the recognition by NMFS and other workshop participants that achievement of this long-term commitment goal will require the continuous cooperation of Federal, State and private organizations, throughout the recovery period.

OVERVIEW OF OCEAN WATER QUALITY IN HAWAII[1]

Wiltse, W.

Abstract

Coastal waters of Hawaii, while generally of good water quality, have numerous localized areas where problems of turbidity, nutrient enrichment, and toxic contamination exist. These problem areas are all coastal embayments or semi-protected nearshore waters. Signs of degradation in these areas include nuisance algal blooms, loss of corals, decline of fisheries, and spread of introduced species. Most ocean pollution in the state is due to polluted runoff from urban and agricultural lands. The main pollutant sources that whales are likely to encounter are turbidity plumes (common) , ocean discharge outfalls for treated wastewater, vessel discharges, and oil or chemical spills (rare). Note: This analysis is based on Hawaii Department of Health, "305(B) Water Quality Report for the State of Hawaii" (1994).

Water Quality

Overall, the quality of ocean waters in the State is very good with the exception of numerous localized areas where water quality problems including turbidity, high bacterial counts, and toxic contamination exist. These problem areas are all coastal embayments or semi-protected nearshore waters. signs of degradation in these areas include nuisance algal blooms, loss of corals, decline of fisheries, and spread of introduced species. Some suggest that high incidence of turtle tumors and deaths at specific localities may be related to declining water quality.

The water quality data for Hawaii lack comprehensive coverage in space and time. The Department of Health regularly samples a network of fixed shoreline stations for water quality parameters. No comprehensive assessment exists for offshore waters.

One of the best data sets available is f or enterococcus bacteria in shallow beach waters. These data are used by Department of Health staff to assess the water quality at beaches. Based on these data, water quality at 7 beaches on Oahu, 10 on Hawaii, 8 on Kauai, and one each on Maui, Molokai, and Lanai is rated poor or very poor. Since whales generally stay in deeper water outside reefs, they rarely encounter these nearshore waters with elevated bacterial counts.

In the absence of comprehensive data, we can look to common indicators of coastal water quality problems observed throughout the world to see that Hawaii's water quality is very good. Reported anoxia events, fish consumption advisories, and major oil spills are absent in Hawaii. Compared with national coastal waters, Hawaii also reports few fish kills and beach closures.

Causes of water quality and environmental degradation in Hawaiian waters are complex and poorly studied. Polluted runoff, point source discharges, habitat destruction, overfishing, introduced species, and diseases probably interact to cause degradation.

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[1] Based on "305(B) Water Quality Report for the State of Hawaii," Hawaii Department of Health (1994).

Runoff from urban and agricultural land, groundwater seepage, and boat wastes are the major sources of pollution in areas with poor water quality. Most of these sources are not currently regulated, although a new state program mandated by the Coastal Zone Management Act will begin to control runoff quality through a combination of voluntary and regulatory approaches.

Point source discharges to Hawaiian waters include wastewater and thermal discharges. There are five wastewater outfalls in deep water off Oahu (2 primary treatment, 3 secondary treatment) , a secondary treatment outfall at Hilo, and a secondary treatment outfall at Wailua, Kauai. Thermal discharges exist on all islands where powerplants, sugar mills, and refineries discharge cooling water, generally close to shore. All point source discharges are regulated under the Clean Water Act through National Pollutant Discharge Elimination System (NPDES) permits.

Sediment is the most broadly distributed pollutant in Hawaiian waters. Sediment runoff smothers reefs, causes high turbidity in the water column, and transports nutrients. Agricultural lands are the major sources of sediments transported to nearshore waters. Runoff from forests disturbed by ungulates and from urban areas, especially construction sites, also contribute to coastal turbidity.

Nutrients, especially nitrogen and phosphorus, enter the ocean via runoff and groundwater seeps. Whether or not land-based nutrients from fertilizers and wastewater injection wells encourage growth of the nuisance algae Hypnea and Ulva along Maui's coastline is still being debated.

Problems with high levels of toxic contaminants occur in a f ew protected harbors and streams including Hilo (arsenic), Manoa Stream (lead), Pearl Harbor and Ala Wai Canal (metals and hydrocarbons). Some drinking water wells also show elevated levels of agricultural chemicals.

The following is the list of sites identified by the Department of Health as "Water Quality Limited Segments", i.e., sites not meeting state water quality standards:

OAHU: Ala Wai Canal, Honolulu Harbor, Kahana Bay, Kaneohe Bay, Keehi Lagoon, Kewalo Basin, Pearl Harbor, Waialua-Kaiaka Bays;
KAUAI: Hanapepe Bay, Nawiliwili Bay, Waimea Bay;
MAUI: Kahului Bay, West Maui, Kihei;
HAWAII: Hilo Bay;
MOLOKAI: South Molokai.

There are other bays and protected coastal waters (e. g. Maalaea Harbor, Maui) that would likely qualify for this list if adequate data were available to characterize water quality.

Water Quality Concerns for Whales

Whales experience very good water quality in their Hawaiian habitat. They are generally reported in water depths ranging from 60-600 feet, seaward of the reefs. Their range is outside of the localized polluted waters and degraded nearshore habitats described above. The few pollutant sources they may encounter include turbidity plumes, vessel discharges, wastewater discharges and oilspills. Of these, turbidity plumes are probably the most frequently encountered because of runoff that occurs during the winter rainy season in Hawaii.

A first step in assessing water quality within the whale's habitat could be compiling GIS plots of "water quality indicators" such as turbidity plumes, oil and chemical spills, vessel traffic, wastewater outfalls, thermal discharges, and degraded nearshore habitats. Information for this data base could be collected inexpensively through volunteer monitoring efforts.

Winter Breeding Habitat Characteristics of the Humpback Whale

Naughton, J. J.

Introduction: The well known coastal habitat of the humpback whale made it one of the most vulnerable species to modern whaling, resulting in worldwide depletion of most stocks. Preference for coastal habitat also subjects them to increasing encounters with man-induced impacts; including seabed mining, oil and gas recovery, nearshore pollution, ocean dumping, entanglement in fishing gear, and coastal and tourist-related development such as marinas, harbors, resorts, and vessel traffic.

Why do the humpback whales come to the Hawaiian Islands? What is it about this habitat that attracts them and compels them to return year after year?

An attempt was made by NMFS to characterize the humpback whale winter breeding habitat in the Hawaiian Islands through an extensive literature search. This was done under funding by the U.S. Army Corps of Engineers to aid in management decisions concerning potential loss or modification of nearshore habitat. The following is a summary of this effort, as reported in Nitta and Naughton (1989), as well as new information reported since publication of the report.

Habitat Parameters

I. Water Depth. Water depth has been determined to be one of the most important habitat characteristics of the humpback whale wintering habitat. Numerous studies have found at least 90% of sightings between 10-100 fathoms of water, with the majority shallower than 40 fathoms. Cow-calf pairs are usually sighted in the shallower range, often segregated from other whales. Very small percentages of humpback whales are sighted in deeper inter-island channels where they apparently are only transiting. Whales are strongly migratory, however they are relatively sedentary over shallow water once they arrive at their seasonal destinations.

2. Bank Characteristics. In addition to water depth, the size of the bank appears to be of importance to humpback whales on their wintering grounds, with the largest banks supporting the greatest concentration of whales. Examples include Silver and Navidad Banks in the West Indies, Cape Taputapu in American Samoa, and Penguin Bank in Hawaii

Another bank characteristic investigated was leeward banks versus windward banks. Despite the commonly held belief that lee, protected waters are critical to humpback whales, particularly cows with calves, a number of studies have found a fairly even distribution on leeward and windward banks.

Bottom substrate of the banks was also investigated. Very little work has been done on substrate characteristics of the banks where humpback whales are consistently found during the winter breeding season. Little or no feeding occurs, therefore substrate is not believed to be important for attracting prey species. In the West Indies, the highest whale song densities occurred on banks with virtually flat bottoms, thereby enhancing sound transmission. No comparisons have been done in

Hawaii, however highest concentrations of whales occur in areas with expansive banks of flat, sandy bottom (Penguin Bank, Four-island Bank).

3. **Sea Surface Temperature (SST)**. Sea surface temperatures (SST) range from 23.2°c to 24.2°c in the main Hawaiian Islands during the winter months. These temperatures are slightly cooler than those found in other known humpback whale winter habitats. Winter SST in the West Indies range from 24°c to 28°c and is approximately 25°c in Australia). This may explain why humpback whales are not found on the huge bank complexes in the Northwestern Hawaiian Islands, which are further north than the Main Hawaiian Islands and consequently a few degrees colder in SST. However, recent data from Chichi-Jima in the Bonin Islands indicate that during the peak February-March humpback whale season, SSTs are 19-20°c (J. Darling, 1995, pers. commun.).

4. **Surface Salinity.** Surface salinity in the Hawaiian Archipelago during the winter breeding season is between 35 ppt and 35.2 ppt. This seems to be consistent with other wintering habitats. Considering the low salinity found in much of the whales' summer feeding grounds, it is improbable that salinity plays a major role in selection of wintering areas.

5. **Surface Currents**. The Hawaiian Archipelago has a net surface current flow to the west, with bank areas influenced by tidal currents and eddies. Early studies suggested a general movement of the whales southeast to northwest through the Hawaiian Islands, entering at Hawaii and departing from Oahu and Kauai. However, recent studies have found whales traveling from northwest to southeast. This would indicate that surface currents may not play a major role in movement of whales within the Hawaiian Islands.

6. **Turbidity**. Considering turbidity levels of glacial runoff waters and nutrient rich conditions on the whales' summer grounds, turbidity would not appear to have a negative impact on the whales. However, a number of observations have been made in Hawaii of whales avoiding turbid coastal waters. There is a concern that they may be abandoning preferred coastal habitat because of persistent turbidity and water quality problems. It is unknown whether they are avoiding the turbidity itself or chemical pollutants in the runoff.

7. **Association with Other Biota.** Humpback whales are often observed with other cetaceans, particularly spinner dolphin (Stenella longirostris) and bottlenose dolphin (Tursiops truncatus). At least one species of fish, the la`e (Scomberoides lysan), has been observed swimming with humpback whales, possibly feeding on particles of skin. The importance of these associations are unknown.

Isolated observations of apparent feeding and of defecation by humpback whales has been noted in Hawaii. The only potential prey species in Hawaiian waters are two schooling carangids (opelu, Decapterus macarellus and akule, Selar crumenopthalmus). However, there have been no confirmed sightings of humpback whales feeding on these potential prey species.

The tiger shark (Galeocerdo cuvier) is the major predator of humpback whales in the Hawaiian wintering habitat, particularly on calves and injured or ailing adults. Large tiger sharks have been observed attacking injured and entangled adults and calves, and there are a few reports of presumably healthy calves being attacked despite attempts by adults to fend off the sharks. However, if tiger sharks were routinely successful in killing calves, calf mortality on an annual basis would be exceedingly high. It has been suggested that selection of calving areas may be dictated by tiger shark distribution.

Habitat Impacts

In the Hawaiian Islands resource managers are required on a day-to-day basis to provide recommendations on projects and activities which potentially may alter habitat important to the humpback whale. Regulations under a number of federal laws (i.e. Endangered Species Act, Fish and Wildlife Coordination Act, Clean Water Act, River and Harbors Act, Ocean Dumping Act) mandate these reviews, primarily through permit actions required by the U.S. Army Corps of Engineers and the U.S. Environmental Protection Agency. The recent designation of the Hawaiian Islands Humpback Whale National Marine Sanctuary, under the Oceans Act of 1992, mandates additional protection of humpback whales and their habitat in Sanctuary waters.

Examples of management decisions which must be made based on existing data as to potential impacts to humpback whale habitat include:

1. Should any loss or alteration of humpback whale habitat, whether substrate or water column, be allowed?

2. What are the impacts to humpback whales and their habitat from dredge and fill activities, particularly from turbidity? What are the differences between, and impacts from, construction generated turbidity versus land runoff?

3. Should blasting for construction or explosive ordinance clearing be permitted in humpback whale habitat?

4. Should sewage outfalls be constructed and operated in humpback whale habitat? If so, at what level of sewage treatment?

5. What are the real impacts of vessels and associated noise pollution on the humpback whale? Will the whales abandon preferred habitat because of increased vessel traffic?

6. Should offshore vessel moorings and fixed fishing gear be permitted in humpback whale habitat? Are recent whale entanglement incidents the result of local gear or high seas gear and/or debris?

7. Are there negative impacts to humpback whales and their habitat from alteration of the sea bottom through such activities as sand mining, pipeline deployment, ocean dumping, and artificial reef construction?

These few examples of the types of questions resource managers must deal with clearly reveal the need for additional research on humpback whale habitat. Much more information is needed as to what the environmental and habitat parameters are that make these wintering areas so desirable to the whales.

Hopefully this workshop will be able to add additional information to more accurately characterize the humpback whales' habitat and uses, and, more importantly, whether loss or alteration of this habitat will negatively impact the whales.

The Acoustic Environment of Hawai'i

Adam S. Frankel, Ph.D.

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Abstract: A description of the acoustic environment of the Hawaiian Islands is largely a discussion of the sources, levels and variability of ambient noise. Ambient noise is the combination of numerous distant sources. They include diffuse sources, such as wind noise and point sources, such as distant ships and earthquakes. Occasionally, some of these point sources are close enough to a receiver so that they become a signal, audible above the background ambient noise. These acoustics sources can be biological or man-made. Much of the debate about effects of sound on marine mammals is centered on the '120 dB criterion,' which is imperfect and unrealistic as the single predictor of response. Some other important factors which are likely to affect responsiveness include sound gradient, the behavior of the sound source, and the duration of the sound.

Units: What is a dB?: Sound levels are commonly reported in decibels. However, the word 'decibel' by itself, is insufficient and more information must be specified, just a temperature is not reported in degrees, but as degrees Fahrenheit or Celsius. Very briefly, a decibel is a ratio of acoustic intensity level (IL) or sound pressure level (SPL). It is defined as:

dB IL = 10 * log10 (measured intensity/reference intensity)

or

dB SPL = 20 * log10 (measured pressure/reference pressure)

The reference level must be specified, and the common reference in water is 1 = uPa; hence the common term 'dB re 1 = uPa.'

The second consideration of a sound measurement is its bandwidth. Since sound is distributed across a spectrum of frequencies, one should specify for which frequencies energy is being reported. As the bandwidth of the measurement increases, then the dB level calculated will tend to rise. Common bandwidths that are reported include spectrum level, 1/3-octave band, octave band and 'broad-band' measurements. Spectrum level is defined as the amount of sound in a 1 Hz-wide band, and it is reported in dB/Hz. 1/3-octave and octave band measurements are measurement bands 1/3 or 1 octave-wide, based on a center frequency, e.g. the 1/3-octave band centered on 100 Hz. Broad band measurements have no formal definition. They are typically used for animal sound measurements, and encompass the entire range of the animal's vocalization. However since that range can be 20 Hz for blue whales and 10,000 Hz for humpback whales, it is important to specify the measurement range when presenting measured values.

Underwater Sound Propagation: It is also important to consider the effects of sound propagation on ambient noise and signals. To call underwater sound propagation a complex subject would be a gross understatement. Nevertheless the basic concepts can be described and appreciated.

Sound sources are typically described as an ideal point source, a physics buzzword meaning a very small vibrating point, which is actually a good approximation of reality. Sound radiates spherically (in all directions in 3D space) from the source - this produces spherical spreading transmission loss, Transmission loss is the loss of sound pressure (or intensity) with distance and the surface area of the expanding sphere of the sound wave front increases. It is defined as:

Transmission Loss (TL) = 20 * log10 R

where R is the range from the source.

When sound reaches an impedance boundary, like the ocean bottom or the water's surface, it is either reflected, scattered or absorbed. In an ideal situation, with very good reflecting surfaces, the spreading loss becomes cylindrical, defined as:

TL = 10 * log10 R

However, the reflecting surfaces are often imperfect, and additional scattering losses are present. Therefore, it is always best to validate any shallow-water transmission loss modeling efforts with empirical transmission loss measurements.

In addition to spreading losses, the water itself absorbs sound energy. This effect is negligible at low frequencies and becomes more significant at higher frequencies.

Examples of how propagation can affect ambient noise are surface decoupling and downslope conversion. Surface decoupling is a destructive interference effect which keeps ships in deep water from contributing strongly to ambient noise at long ranges. Conversely, downslope conversion accentuates the propagation of noise sources located above the continental shelf. This is seen by the increase in ambient noise received on hydrophones at Kaneohe, O'ahu, Hawaii that was attributed to increases in vessel traffic during the weekends at San Francisco harbor (Ross, 1993).

Frequency Ranges: Many writers divide the ambient noise into different frequency ranges. Urick (1986) divided them as follows: 0-20 Hz; 20-200 Hz; 200-50,000 Hz; and 50,000 Hz +.

Another division has been suggested by Ross (1993). He divides the noise into the following frequency bands:

0-10 Hz	Dominated by wave action above the receiver;
10-150 Hz	Absorption loss is so low that it has no effect, and sources at the ocean margin may make important contributions;
150-1.5k Hz	Under local control, predominately windspeed (or local vessels) (dominant sources in shallow water are within 50-100 km);

1.5 + kHz

Based on these and other sources, I synthesized a new set of frequency bands:

0-10 Hz	Dependent on wave action overhead;
10-150 Hz	Distant ships and storms important;
150-1500 Hz	Extremely variable local effects;
1.5-50kHz	Static local effects;
> 50 kHz	Thermal noise.

Spectral Characteristics of Ambient Noise: Figure 2-17 from Urick (1986) shows a typical shallow water ambient noise spectrum. Above about 1 kHz, sound level generally decreases with frequency, which is the general pattern in ambient noise and is largely a function of wind speed. Below about 1 kHz, local and vessel effects dominate, and can be much more variable.

Natural Sources of Ambient Noise: **Physical Wind**: The Knudsen Curves are very reliable predictors of ambient noise above 1 kHz (Urick 1986) (see fig 2-10). However, below 1 kHz, there are many other factors that affect ambient noise, and these should be measured at the site of interest (e.g. Urick fig. 2-8b). Wind driven noise mechanisms include wind turbulence, surface motion, wave interactions, spray and cavitation noise (Urick 1986). In shallow water in the absence of local vessel traffic, wind noise dominates because of the poor low frequency propagation of distant vessel traffic noise into shallow water (Urick, 1986). This is probably representative of the situation in Hawai'i. Recordings of ambient noise (at other locations) at 200 fathoms showed a strong dependence on wind speed, whereas deep-water recordings (900 fathoms) did not, indicating the effect of vessel noise in deep water.

Waves: In experimental mesaurements, weak spilling breakers had a spectrum level of ~60dB re 1 uPa2/Hz @ 2 kHz, moderate spilling breakers had a spectrum level of ~85 dB re 1 uPa2/Hz at 600 Hz, and ~85 dB re 1 uPa2/Hz at 200 Hz was measured for a weak plunging breaker (Kolaini and Crum 1994) .

Surf: Breaking waves can raise the ambient noise level by as much as 10 dB at distances 8.5 km offshore in the frequency range of 100-700 Hz, the lower limit probably being due to limitations in low-frequency propagation (Wilson et al., 1982) .

Distant Storms: One study found distant storms to have a spectrum level of 70-75 dB at 165 Hz (Wilson 1983).

Rain: Light rain had a measured spectrum level of ~ 50 dB re 1 uPa^2/Hz. Heavy rain had a spectrum level of ~ 80 dB re 1 uPa2/Hz (Nystuen et al., 1993) . Rain noise is broadband in the 4-21 kHz region (for heavy rain), spectral peak at 15 kHz for light rain. At frequencies up to 10 kHz, the spectral level correlates with rainfall rate. At wind speeds > 15 m/s, a wind driven bubble injection creates a bubble layer that isolates the rain noise from the water column.

Thermal Noise: This is not often considered, but at frequencies above 50 kHz, the thermal noise of molecular bombardment becomes a factor (Anderson and Gruber, 1971). The only measurements of noise in this range have been made in busy harbors, so its real-world contribution to ambient noise is uncertain.

Biological: There are three primary biological sources of ambient noise: Snapping shrimp, fishes and whales. Snapping shrimp sounds range from 1-10 kHz, with spectrum levels between 65 - 95 dB re 1 uPa2/Hz (Urick, 1986; fig 7-4). Examples of other fish that contribute to ambient noise include grunts, damselfish, and parrotfish. Damselfish (Pomacentrus partitus) have a broadband source level of 110 dB re 1 uPa and Toadfish (Opsanus tau) can be 140 dB re 1 u5Pa (Myrberg, 1990) . Whales, such as finbacks and blues, produce source levels of sound between 14-200 Hz at 180-195 dB re 1 u5Pa (broadband). Other species are less loud. Humpbacks are probably 170-175 dB re 1 u5Pa (broadband).

Geological: Seismic noise is concentrated between DC and 100 Hz, with spectral levels of 71 - 116 dB re 1 =B5Pa (Wenz, 1962). Volcanic activity has been measured at 130 - 140 dB re 1 uPa at a range of 1800 NM (Northrop, 1974) , with most sound energy between 0-20 Hz.

Human-made Sources of Ambient Noise

Vessel Noise: The mechanisms of vessel sound production are primarily propeller cavitation (bubble formation and breaking) and propeller singing (when vortex shedding occurs at a resonant frequency of the blade). Ambient noise is increased if the prop is out of balance or if it is bent, for it will then resonate at many frequencies. Propulsion machinery noise is the remaining major noise source.

Vessels: Nearshore and small vessels typically have a broadband source level of 175 dB re 1 =B5Pa (Richardson et al., 1991b) . Specific examples include:

Whaler with 2 x 90 hp motors:	spectral level of 131-136 dB re 1 uPa2/Hz;
5 m zodiac:	spectral level of 120 dB re 1 uPa2/Hz;
7 m outboard drive:	135 dB re 1 uPa2/Hz spectral peak.

In shallow water (< 200 m) there is no contribution from the deep SOFAR channel, so distant shipping noise and other loud sound sources will not contribute to the ambient noise (Urick 1986). In Hawai'i, the estimated traffic density is: (ATOC EIS, 1994)

Vessel Type	**Number of ships/ 1000 NMi^2**
Merchant Ship	0.1-0.3
Tankers	0.05-0.18
Larger Tankers	0.003-0.005
Super Tankers	0.002-0.003

The effect of large and offshore vessels can be seen in the difference in ambient noise between the South and North Pacific. The South Pacific is 15 dB quieter than the North Pacific, due to shipping noise (Kibblewhite et al., 1976) . The mean spectrum level for average-sized merchant ships is 175-150 dB (Scrimger and Heitmeyer, 1991). Supertankers can have spectral levels reaching 205-165 dB (Richardson, 1991).

Oceanographic sources are found throughout the oceans. A typical example is the ATOC source, which has a 180 dB re 1 uPa2/Hz spectral peak level (195 dB re 1 uPa broadband).

Aircraft are an interesting case. They can project sound into the ocean, but only within a 26=B0 cone centered beneath the aircraft. Sound rays directed at angles greater than 13=B0 (on either side) are reflected back into the air. (Richardson, 1991). Some specific examples include:

Helicopter spectral source levels:	111-93 dB re 1 uPa2/Hz;
Fixed wing aircraft:	90-105 dB re 1 uPa2/Hz for twin otter class;
Navy P-3:	124 dB re 1 uPa2/Hz;
Navy Sonar:	small commercially available sonars have a source level of 219 dB re 1 uPa2/Hz spectral peak. Urick (1983) cites naval sonars operating in the ranges of 210-240 dB re 1 uPa.

Seismic Exploration: Air guns have a pulse level of 215 dB re 1 uPa, with a repetition rate of 6 Hz. This translates to a mean source level of 205 dB re u5Pa. This has been responsible for measured increases of up to 20 dB in the ambient noise. It should be noted that this means that 1 airgun is the acoustic equivalent of 100 merchant ships (185 dB re 1 uPa).

Variability in Ambient Noise: A survey of ambient noise data recorded under wind-dominated conditions in shallow water shows substantial differences in spectrum level (often greater than 10 dB) under the same wind speed and sea-state conditions. This area-dependent effect is evident even in long-term averaged data, and results from differences in ocean bottom properties, water depth and sound-speed profile. This is primarily a local propagation effect (Ingenito and Wolf, 1989). Temporal effects appear to be related to tidal events (Bourke and Parsons 1993). There is a depth dependence on the quality of ambient noise. Deep water ambient noise tends to be only 5 dB lower than surface levels. This is likely due to the fact that sources of ambient noise are largely a surface phenomenon, and the downward propagation of sound is very good. Other variation in ambient noise with depth is likely due to variability in sound propagation.

Factors Affecting Humpbacks' Reactivity to Sound: I don't think that anyone would argue that the 120 dB response or disturbance criterion is valid only as a first approximation. One consistent finding in vessel effect studies has been a great deal of variability in animals' responsiveness. Individual animals respond to sound at different source levels, and at a given received level (RL), some animals will tolerate it and others will react. This variability suggests that RL is not the only factor in determining responsiveness. Other factors that probably influence an animal's response to sound include:

a) The "behavior" of the noise source. Vessels moving faster and with more frequent course changes appear to be more disturbing to whales (Richardson et al., 1985) . Some bowheads have been shown to tolerate vessels nearby that produced RL of 110-115 dB re 1 uPa, However when presented with lower but increasing levels, an avoidance reaction was noted (Miles et al., 1987) .

b) Sound gradient vs. received level. In many cases, the reactions observed to sound stimuli occur at ranges < =3D = 1 km from the sound source. One could ask what is the critical parameter: Is it received level or sound field gradient? Given the nature of sound transmission loss, a sharp sound gradient indicates proximity to the source and that may be a factor in determining response. It is worth noting that while most reactions to sound playback were within 1 km, there are exceptions such as the gray whale response to drillship noise at 2 km. Additionally some of the air gun xperiments with full arrays produced reactions at several kilometers. This suggests that both factors of received level and sound gradient may be affecting the response. An experiment with two levels of sound playback could address this issue by presenting animals with the same received sound level at different ranges, and therefore different sound gradients.

c) Signal duration. The apparent response threshold to long duration, continuous wave signals is around 120 dB re 1 uPa. Short impulsive sounds, such as those produced by airguns seem to have a response threshold of circa 160 dB re 1 uPa. It has been demonstrated in humans that short duration sounds are less annoying than continuous sounds of the same amplitude. Annoyance appears to be related to the average acoustic energy of the sound. In human work, the 'equivalent sound level' or Leq is used to describe short impulsive sounds. Leq represents a temporal integration of the total energy output of an intermittent sound source. Malme (1990) calculated equivalent sound levels for the playback and air gun data. The resulting curve of Equivalent level vs. Duty cycle was nonlinear, indicating that the acoustic energy of the signal was not the only factor determining the responses. This may be explained by a general trend for hearing threshold to increase as signal duration decreases. The relationship between signal duration and threshold has been investigated in *Tursiops*

(Johnson, 1968) and harbor seals (Terhune, 1988; Terhune, 1989) . Generally thresholds increase as signal duration drops below one second at a rate between 5 and 10 dB per decade in signal duration.

d) Behavioral context. This undoubtedly affects the response of individual animals in a specific situation. However the results of air gun studies conducted with both migrating and summering gray whales, were similar. The California studies found that a 50 percent probability of avoidance occurred at 170 dB re 1 uPa, whereas the study in the Bering sea concluded that the same level of avoidance would occur at 173 dB re 1 uPa (Malme et al., 1988). Richardson et al. (1991a) performed playback experiments to bowheads along the spring migratory route. They found responses occurring at received levels and distances from the sound projector that were similar to previous work. Possible reactions were observed at 4 km and 107 dB re 1 uPa. Increased turns were observed as far away as 2 km (117 dB re 1 uPa) and definite strong reactions were observed out to 1 km (125 dB re 1 uPa).

e) The importance to the animal of remaining in the area. This may affect its response to noise. Animals may tolerate a sound level that they find disturbing, because the need to remain in an area is great. An example might be an animal that remained in a high productivity area to continue feeding in the presence of high noise levels. This might explain the observation of bowhead whales near to operating dredges. However, the 'abandonment' of the Negro Guerro lagoons by gray whales during a time of high vessel traffic suggests that there are limits to the ability of necessity to overcome noise.

f) Habituation. This is another unknown in attempting to assess the effect of persistent sounds. Observations of whales in the presence of long-term sounds, such as drilling platforms, sometimes reveal whales tolerating high source levels. Other whales when exposed to similar source levels avoid them. Perhaps the presence of animals in high noise environments can be attributed to habituation.

g) Variation in responsiveness. Perhaps the greatest uncontrollable variable is the inherent seasonal and individual variability in responsiveness to sound. This can be addressed with high sample sizes, but it always needs to be remembered when interpreting these data.

h) Repeated exposures to sound. Baker and Herman (1989) found a tendency for whales to react strongly to vessels when there where multiple vessel pass-bys. They suggested that repeated exposures can lead not to additive effects or habituation, but instead may have a cumulative effect. This probably needs to be considered when whales migrate through a dense aggregation of industrial platforms or in waters where vessel density is great, such as California and Hawaii.

Summary/Take Home Message: In conclusion, several studies have shown about 50 percent of gray and bowhead whales produce short-term reactions to continuous man-made noise at received levels of 115-125 dB re 1 UPa broadband or at a level of about 20 dB SNR. Response thresholds to impulsive noise such as air guns are typically 40-50 dB higher. As shown by gray whale reactions to orca calls at 0 dB SNR, whales are most likely able to detect these sounds at levels lower than those producing visible reactions. There is also considerable variation in the response to these noise levels. It is almost certain that other factors influence the reactivity of an animal to a given noise level.

The studies and results described here represent very good efforts to explore the effects of sound on marine mammals. But our understanding is incomplete. More work is needed to resolve some of the questions that have been raised both by the authors of the papers covered and in this review. As a final note, we probably need more interaction between biologists and physical acousticians, in order to better understand the acoustic environment through which whales swim.

ADDENDUM - Sound measurements

Measurement of sound level in the ocean is one of the more puzzling operations in the life of a bioacoustician. This is intended as an introduction and a review of the relevant concepts. There are two frequently overlooked considerations in reporting a sound level as a dB: these are the reference level and the bandwidth of measurement. Decibels are defined as:

dB IL =3D 10 * log10 (intensity/reference intensity).

This is equivalent to the pressure formulation of:

dB SPL =3D 20 * log10(pressure/reference pressure),

because sound pressure is proportional to intensity, as shown by:

I=3Dp2/rc

where I is Intensity, p is root mean square (rms) pressure, r =3D density of the medium, and c =3D speed of sound in water. The term rc is known as the acoustic impedance. Different acoustic impedances yield different values of the sound pressure level for a given sound intensity.

The term 'dB' is meaningless unless the reference pressure or intensity is specified. It is best if the acoustic impedance is also specified, at least by indicating whether measurements were made in air or water. Because of differing reference levels and acoustic impedances we have this relationship between water and air dB SPL:

dB re 1 uPa in water =3D dB SPL (in air) + 61.5 dB.

The second parameter of the measurement that must be specified is the bandwidth of the measurement. Consider the calculus example of approximating the area underneath a curve by finding the area of a column. The wider the column, the greater the area. The same applies to acoustic measures, the wider the bandwidth, the more acoustic energy is measured, the higher the dB value. Thus the bandwidth of your measurement must be reported. Typical bandwidths include

1) spectrum level: the amount of energy in a 1 Hz wide band. The frequency of this

1 Hz wide band must also be reported. This is typically used for man-made noise or pure tones;

2) 1/3 octave or 1 octave bands. This is typically the output of an old-style analog spectrum analyzer;

3) "broadband" which can mean almost anything. The essence of this statement is that it the measurement includes all of the acoustic energy of the signal. It is best to define what frequency range is represented by the term 'broad band'.

What type of value are we measuring?

Power - (energy/time) produced by the source: This does not vary with range, but it can vary with time. Power is reported in watts.

Intensity - (power/area): This is the power, divided by the surface area of a sphere of radius r. Thus is power / 4 * r2. The sphere represents the expanding wavefront from the ideal point source of sound. Intensity is reported in Watts/m2.

Pressure - (force/area): A sound wave of a given intensity exerts a pressure on objects in its path. If that object is a hydrophone, the pressure of the sound wave is measured. In most underwater bioacoustic references, this is reported as sound pressure level of X dB re 1 uPa. This value is actually an intensity measurement. More explicitly it is "dB re 'the intensity of a plane wave of pressure equal to' 1 uPa." (Urick, 1983, p. 15).

Intensity spectral density: This is the intensity of a sound in a 1 Hz wide bin. It is reported in Watts/m2/Hz.

Pressure spectral density (Spectrum level): This is the sound pressure level in a 1 Hz wide bin. It is reported in dB re 1 uPa2/Hz.

For more specific information, consult: Urick, R.J. 1983. Principles of Underwater Sound. McGraw-Hill. 3rd Edition.

Responses of Humpback Whales to Vessel Traffic

Bauer, G. B.

This paper briefly reviews the research concerning the impact of boats and ships on humpback whale behavior and notes some of the limitations of these studies. Because of the migratory nature of humpbacks, vessel effects in both Alaska and Hawaii are discussed. Humpback whales were studied in southeast Alaska during the summers of 1981 and 1982 (Baker et al., 1982, 1983; Baker and Herman, 1989) and in Hawaii during the winters of 1983 and 1984 (Bauer, 1986). Shore-based observation methods are reported in these references.

One methodological point should be noted. Alaska had relatively few boats, which allowed for control observations, when no vessels were present, and analysis of whale behavior in response to single vessels. In Hawaii, there were numerous vessels for almost all observations. It was therefore difficult to identify any single vessel as a causal agent. For analysis purposes group means were used of vessel speed, vessel separation from whales, and vessel changes of direction.

The analyses for both Alaska and Hawaii are too detailed to go through comprehensively, so I have provided a rough summary and a few examples of vessel correlates. In Hawaii, the most stable predictor of changes in whale behavior was the number of vessels within 1000 meters of a focal pod. In Alaska, vessel numbers, speed, and distance from whales were all important. I expect that this difference between the Hawaii and Alaska studies was probably due to the use of group vessel statistics as a unit of analysis for the Hawaii data.

We looked at three (3) general classes of behavior - respiratory behavior (which includes diving), aerial or surface active behavior (which includes breaches, head slaps, head lunges, fluke and pec slaps), and movement behavior (which includes speed and orientation).

Respiratory and dive variables (blow rates, dive intervals, number of dives, etc.) were the most sensitive measures of vessel disturbance. In Hawaii there were significant increases in the rate of fluke-up dives. There were a variety of other changes which varied depending on pod size and composition. In Alaska effects were most apparent in the whales of Frederick sound where vessel traffic was infrequent. For example, shorter median blow intervals were observed in the presence of vessels. Effects in the more heavily trafficked Bartlett Cove were significant, but of lesser magnitude, perhaps suggesting some habituation to vessel traffic.

Aerial behaviors occurred infrequently in Alaska, and were therefore not particularly amenable to statistical analysis. Correlations using group averages in Hawaii tended to show weak, but significant, relationships between some aerial behaviors and vessel traffic. For example breaches increased as vessel speed increased.

Whale swimming speed was affected by a variety of factors including pod composition, size of vessels, and number of vessels. In general, pod speeds were slower compared to normal in the presence of small vessels, but faster than normal in the presence of large (cruise ship) vessels. In the low vessel density area of Frederick Sound, whales would turn away from vessels at distances of 8,000 meters.

Subsequent studies indicate significant changes in behavior associated with vessel passbys. For example, Green and Green, (1990) report longer downtimes and slower swimming speeds after a passby of boats in Hawaii.

Analyses of group data were critical for establishing vessel effects in Alaska and Hawaii, but I think they probably under-represent short-term vessel effects even when described in substantial detail. There are several reasons for this conclusion. The measurement error in these types of studies is substantial and the lack of observational access to underwater behavior severely restricts the range of behavior that can be observed. Also, the critical acoustic characteristics of boats were not assessed in most of our observations. For these reasons, case studies can be helpful additional aids in illuminating vessel effects. I will report two such case studies.

The first involves an observation in Hawaii of a mother, calf, and escort. Only three vessels were present, unusually few for this area. Initially, passbys of a speed boat traveling within 22 meters (at 44 km/hour) and of a Zodiac passing within 225 meters (at 20 km/hour) resulted in small displacements of the pod. A U.S. Navy Torpedo Retriever, traveling between 26-28 km/hour approached the pod on a straight line route. When the vessel was within 700 m of the pod, the calf started breaching, followed by mother and escort, and then simultaneous breaches (the closest point of approach for the vessel was 365 m). Within about 15 minutes the calf breached 43 times and head-slapped 5 times. The two adults breached 6 times between them.

After a period of 20 minutes calm by the calf our Zodiac started its engines - within 10 seconds the calf started breaching, 16 times in 5.5 minutes. The Zodiac was 775 meters away and no other boats were in the vicinity. The Zodiac cut its engines for several minutes and then 14 minutes after the calf's last breach, started the engine again. Within 10 seconds the calf breached twice and headed in the direction of the Zodiac - engines were cut off. Distance at this point was about 500 meters. It is important to note that vessel activities by the smaller Zodiac which had not previously elicited any activity, did come to elicit activity after the passby of the larger vessel. The responses to sequential passbys suggest cumulative effects through sensitization, and the distance at which they occurred indicates an acoustic impact.

The second observation occurred in Alaska and included sound level recordings made by Miles and Malme of Bolt, Beranek and Newman (Baker et al., 1983). There was a pod of 3 whales - two adults and a calf- residing in Bartlett Cove as a 177 m cruise ship approached. As the ship approached the pod moved away, into Bartlett Cove (Figure 1). As the vessel moved away the mother and calf returned to the mouth of Bartlett Cove. The move away from the vessel coincides with increases in the estimated received sound levels, and the return of the mother and calf follows a substantial decrease. Other behavioral responses show the impact of vessel noise even more clearly (Figure 2). During its approach, the ship engaged in several engine changes and a shift in the pitch of the propeller. Over a one minute period this resulted in three abrupt rises sound level, the last rise of over 12 dB, re 1 micro-Pascal. This last rise was followed within 20 seconds by three breaches and a head slap by the calf. About 6 minutes later the ship made further engine and propeller pitch changes resulting in a drop from 134 dB to 118 dB and back, which was followed immediately by 11 breaches and other behaviors (lasting about 5 minutes). The closest this ship came to the pod was 2 km.

The case studies in conjunction with the group analyses indicated that boats and ships had a significant and at times dramatic effect on short-term humpback whale behavior. At the time these studies were done, we concluded that these changes were a potential threat to the recovery of humpback whales in the North Pacific. These concerns were supported by aerial surveys which indicated a lower density of whales in heavily trafficked areas (Herman, Forestell and Antinoja, 1980; Forestell, 1985) . Also, Glockner-Ferrari and Ferrari (1985) reported that whales were moving further offshore as the development of the Kaanapali area increased.

Despite these early concerns, recent evidence suggests some reasons to be cautious in interpreting these findings. Mobley, Bauer, and Herman (1990) conducted a set of aerial surveys which used the same observation techniques that had been used for a set of surveys conducted on consecutive years between 1977 and 1980. Many of the same personnel were involved in both sets of observations. The observations did not allow for an estimate of abundance, but they did suggest a substantial change in whale numbers. We observed over 50 percent more whales during our surveys in 1990. Although whale densities have increased most noticeably in the low vessel density area around Kauai, they have also increased substantially, in the high vessel density areas on Penguin Bank and the Four-Island Region.

There has also been an increase in numbers of whales in Glacier Bay and Icy Strait in the years since the vessel studies. Recent communications with Chris Gabrielle (pers. comm., 1994), a Glacier Bay biologist, suggest that this trend is continuing.

Conclusions: Overall, we conclude that short-term humpback whale behavior is changed by vessels. The ultimate meaning of these changes remains obscure. The following factors limit the interpretation of these results:

1) inconsistent or statistically weak results;

2) a lack of understanding of the function of many surface behaviors; and

3) little direct evidence that vessels affect behaviors critical to survival and reproduction.

Although case studies indicate dramatic changes in whale behavior, the enormous variance in many behaviors over nurmerous observations produces weak correlations between vessel movements and whale behavior. In turn this high variance makes detection of effects unlikely, (e.g., Green and Green (1990) report no significant correlation between vessels and aerial behaviors). Frankel (pers. comm., 1995) reports that vessel numbers, our most stable predictor of behavioral change, was not a significant factor in his recent studies off Kauai. This may be, primarily, a matter of statistical power. For example, the sample size needed to detect the effect of vessel speed on breaches, if the population correlation matched my sample correlation, would be N = 215 (i.e., 215 observation sessions based on correlation of 0.18, an alpha of 0.05, and a desired power of 0.75 - i.e., 3 to 1 odds of rejecting the null hypothesis). That addresses the zero-order correlation. This is more usable observations than we had over two years.

To detect the semi-partial correlation, in which variation in breaching is explained by other variables as well, would demand a considerably larger sample size. Although the variance might be reduced by more careful attention to reliability assessments, a greater influence is undoubtedly attributable to the basic difficulties of observing whales (observation limited to brief surface intervals, identification of age and sex classes, determination of antecedent behaviors and vents, etc.).

Many of us have taken a conservative stance. Because humpbacks are an endangered species, we assumed that any change in their behavior is potentially harmful. I think we need to be more critical in our assessment, especially since recent aerial surveys and observations of other researchers at this conference have suggested an increase in abundance. Suggestions for the directions of future research concerning human impact on humpback whale behavior and population recovery are discussed in the Behavior and Life History Report for this conference.

C. AGENCY PROFILES: ACTIVITIES, RESPONSIBILITIES AND PLANS FOR PROTECTING HUMPBACK WHALES AND THEIR HABITAT IN HAWAII

An Overview of the Responsibilities and Activities of the National Marine Fisheries Service - Section 7 Consultations, Approach Regulations, and Research

Nitta, E.T..

Background: Four stocks of humpback whales have been recognized in the North Pacific basin based on genetic and photo-identification studies: two Eastern North Pacific, Central North Pacific and Western Pacific. The Central North Pacific stock of humpback whales winters in the waters of the Main Hawaiian Islands and feeds on the summer grounds of Southeast Alaska and Prince William Sound. A population estimate of 1,407 whales was derived using capture-recapture methodology (95 percent CI 1,113 - 1,701) for data collected in 1980-83 (Baker and Herman, 1987). Current abundance is unknown, although the stock has likely been increasing for the last 12 years. A reliable estimate of trend in abundance is unavailable. In Hawaiian waters, their distribution is almost exclusively within the 1,000 fm isobath and usually within 100 fm.

Much of the past and ongoing research in Hawaii has resulted in a better understanding of humpback whales. It has not, however, directly addressed NMFS' priority management needs for information on population dynamics and trends, distribution, abundance, stock composition, harassment, and habitat. Without better information on the status of the Hawaiian breeding aggregation, reproductive parameters, habitat usage and distribution, and its relationship to the North Pacific population of humpback whales, we have an incomplete measure of the health and status of the Hawaiian stock and of the effectiveness or adequacy of present and proposed management and protective measures.

Impacts: Coastal Development: Known humpback whale habitat is affected by harbor and boat ramp construction, nearshore resort development, alternative energy development, wastewater discharge and outfall construction, permanent vessel moorings, agricultural runoff, and recreational water sports activities. Water dependent construction activities by themselves result in highly visible primary impacts such as blasting, dredging and filling which could result in displacement, injury and mortality. However, these adverse effects can be reduced or eliminated through seasonal timing or construction design modifications and the actual physical loss of habitat is small in comparison to the total available. It is the secondary and tertiary impacts associated with the initial habitat modification that may likely have significant consequences on the distribution and reproductive success of humpback whales.

Examples of such activities are increased vessel traffic associated with harbors, ramps, moorings and hotels. Although effects are not evident, water quality degradation resulting from increased sewage effluent and surface runoff (agricultural, industrial and residential) may also adversely affect the distribution or physical well-being of humpback whales utilizing nearshore waters.

Vessel Traffic: In Hawaii, humpback whales are subject to physical and acoustic disturbance by large numbers of recreational boaters as well as an increasing number of whale watching vessels. Commercial shipping and commercial fishing do not appear to pose a significant problem at this time. The Navy occasionally conducted vessel firing exercises off Kaho'olawe Island until late 1990 when federal legislation was passed setting up a commission to develop the terms of returning the island to the state. In 1994 Kaho'olawe Island was returned to the State of Hawaii and is now administered by the Kaho'olawe Island Reserve Commission.

Normal whale behavior (the energetic and often acrobatic behaviors associated with pod formation and disassociation and competitive activities) has made the concern of effects of vessel traffic difficult to address in Hawaii.

<u>Whale Watching</u>: Organized whale watching in Hawaii is generally thought to have its origins on Oahu in the 1950's when interested individuals in the community formed the Wailupe Whale Watchers Association. Though non-commercial, the effort was coordinated with press coverage of sightings and incorporation of whales in logos, signs, and advertisements in the area. Interest waned as whale sightings declined. These reductions in sightings may be correlated with the large commercial harvests of humpback whales in the North Pacific in the early 1960's, development along the south shore of Oahu and increasing nearshore vessel traffic. It was not until the mid 1970's and later that whale watching in Hawaii became a viable commercial activity, which interestingly coincides with the first efforts to study the Hawaiian wintering population of humpback whales. It is likely that research efforts utilizing photography to popularize its goals in concert with shrewd entrepreneurship and a history of whale watching in California combined to create the beginnings of a multi-million dollar industry. Spectacular photos of breaching humpback whales, underwater stills and films from numerous sources such as National Geographic, World Wildlife Fund, and independent filmmakers contributed to the public appetite for whale watching and a flourishing industry.

There are two groups of users that actively pursue whales to observe them, researchers and whale watchers (private and commercial). Although researchers operate under Federal permit which allows them to "take" an animal for scientific purposes, whale watchers do not have that allowance or exemption. By definition, then, whale watch activities may lawfully be allowed only if "take" or more specifically "harassment" does not occur.

It should be recognized that there are many factors that affect humpback whale behavior and distribution in Hawaiian waters. Although specific measures may be required to mediate potential problems associated with commercial whale watching, issues such as other vessel traffic, coastal development and water quality degradation are also important factors to consider in any management actions undertaken.

Management: <u>State Management</u>: The State of Hawaii has declared the humpback whale its official state marine mammal. State law recognizes Federally listed endangered species and directs the Department of Land and Natural Resources (DLNR) to establish programs for ensuring the "continued perpetuation of indigenous wildlife and plants and their habitats for human enjoyment, for scientific purposes, and as members of ecosystems..." The State, through the DLNR, requires permits for research on endangered species and further requires the possession of a federal permit as a prerequisite for issuance of the state permit. Within DLNR, the Division of Aquatic Resources (DAR) is responsible for marine endangered species management. DAR currently has no formal conservation program for humpback whales in Hawaiian waters.

The Hawaii State Department of Transportation (DOT) is authorized to regulate vessel operations including whale watching vessels and their use in state waters. The DOT placed signs (supplied by NMFS) at virtually every boat ramp in the state in 1986 warning boaters of the protected status of marine mammals. The DOT is also re-evaluating statewide mooring designations. Such designations would limit potentially disturbing vessel moorings which are proliferating, especially in the Maui area. The DOT can also establish special rules governing specific activities within the state shorewaters, but its regulations must be related to the public safety, health, and welfare.

In response to a proliferation of commercial water-related recreational activities and conflicts between users of nearshore waters the DOT promulgated rules controlling the operation of recreational water craft (e.g. jetskis, para-sails, sailboards, canoes and kayaks etc.) under the authority of the State of Hawaii Ocean Recreation Management Plan (ORMP). Because there was evidence of displacement of certain age and sex classes of humpback whales from nearshore areas by vessel traffic, NMFS recommended seasonal area closures in reported cow-calf habitat to the DOT. The DOT and the NMFS worked closely on identifying specific areas for protection. Despite a legal challenge by the parasail industry the courts have affirmed the need and validity of the Ocean Recreation Management Rules which banned jetskis and parasails from Maui waters during the winter humpback whale season.

<u>Section 7 Consultation</u>: Section 7 consultations, required under the Endangered Species Act of 1973, as amended (ESA), continue to provide checks on federally funded or regulated activities determined to be detrimental to humpback whales. In Hawaii, this primarily entails reviewing marine construction permits for the U.S. Army Corps of Engineers under Section 10 of the River and Harbor Act of 1899, and U.S. Navy and Marine Corps activities at various amphibious, underwater, and aerial target training areas.

If consultation reveals that a proposed activity may jeopardize a listed species or population, then reasonable and prudent alternatives are offered to avoid jeopardy. If consultation reveals that an activity is likely to adversely affect, but not jeopardize, a listed species or population, then conservation recommendations are provided to the consulting agency to minimize the adverse effects of the activity. The federal agency, however, is not required to accept or implement conservation recommendations.

<u>National Marine Sanctuary</u>. The Hawaiian Islands Humpback Whale National Marine Sanctuary (the Sanctuary) was designated by an Act of Congress (Title 11, Subtitle C, Public Law 102-587, Hawaiian Islands National Marine Sanctuary Act or Act) to recognize the importance of Hawaii's nearshore waters which serve as the winter breeding, calving and nursing habitat essential to the long-

term survival and recovery of the North Pacific stock of the endangered humpback whale (Megaptera novaeangeliae). As designated the Sanctuary encompass the waters, from the shoreline to the 100-fathom isobath, around the islands of Maui, Molokai, and Lanai; Penguin Banks; the Pailolo Channel; and a small area off the Kilauea Point National Wildlife Refuge on Kauai. The Act allows NOAA to modify the boundary as necessary to fulfill the purposes of the Act. At this time NOAA has proposed in the Draft Environmental Impact Statement/Management Plan (DEIS/MP), to expand the Sanctuary boundary to include additional areas on Kauai, Oahu and the Big Island. Final boundaries will be identified in the final EIS/MP.

The Act established the Sanctuary to: (1) protect the North Pacific population of Humpback Whales and their habitat within the Sanctuary; (2) educate and interpret for the public the relationship of Humpback Whales to the Hawaiian Islands marine environment; (3) manage human uses of the Sanctuary consistent with the Act and the NMSA, as amended; and (4) provide for the identification of marine resources and ecosystems of national . significance for possible inclusion in the Sanctuary. The Act also called upon the NOAA to develop a comprehensive management plan for the Sanctuary that shall:

(1) facilitate all public and private uses of the Sanctuary (including uses of Hawaiian natives customarily and traditionally exercised for subsistence, cultural, and religious purposes) consistent with the primary objective of the protection of humpback whales and their habitat;
(2) set forth the allocation of Federal and State enforcement responsibilities, as jointly agreed by the Secretary and the State of Hawaii;
(3) identify research needs and establish a long-term ecological monitoring program with respect to humpback whales and their habitat;
(4) identify alternative sources of funding needed to fully implement the plan's provisions and supplement appropriations under section 2307 of this subtitle and section 313 of the NMSA (16 U.S.C. §1444);
(5) ensure coordination and cooperation between Sanctuary managers and other Federal, State, and local authorities with jurisdiction within or adjacent to the Sanctuary; and
6) promote education among users of the Sanctuary and the general public about conservation of humpback whales, their habitat, and other marine resources.

NMFS and the SRD have worked together to develop portions of the DEIS/MP. NMFS will continue to play a integral role in the Sanctuary as both NOAA offices continue to work closely together to ensure that their efforts are coordinated and complementary.

The Federal Research Permit System. There are currently six active NMFS research permits governing humpback whale research in Hawaiian waters. The permits, issued by the NMFS, specify dates and conditions under which legal exceptions to the prohibition on "taking" whales may occur. Permits are granted after review by the Marine Mammal Commission, internal NMFS review, publication in the Federal Register for public comment, and an internal Section 7 process. A number of special conditions are added to research permits valid in Hawaii to clarify notification procedures and alleviate possible duplication of effort problems. To date, these special conditions have not impaired the conduct of research in Hawaiian waters.

Humpback Whale Recovery Plan. The Final Recovery Plan for the Humpback Whale was published in November 1991. Research and recovery actions for all stocks of humpback whales, with emphasis on stocks within U.S. jurisdictons were proposed for implementation by NMFS and other relevant parties. Although an implementation schedule was included as an appendix to the Plan, and implementation plans for specific stocks or geographic areas have not yet been completed, recovery activities such as those illustrated above have been ongoing in Hawaii.

Regulations. Interest in whales and whale watching grew rapidly to such intensity in the early and mid 1970's that the U.S. Marine Mammal Commission in cooperation with NMFS sponsored a workshop in Honolulu to consider "problems related to humpback whales . . . in Hawaii" (Norris and Reeves, 1978). These problems were related to the popularization of whales and increasing attempts by growing numbers of groups and individuals to emulate the researchers and photographers that gained widespread exposure and acclaim by getting into the water and pursuing and approaching whales. The resulting workshop report provided a biological definition of harassment, and made two primary recommendations which directly followed from a recognition of the growing level of human-whale interaction and the potential for adverse impact on the humpback whale population. The first recommendation urged "study and monitoring of the population." The second recommendation was for "a management plan that promotes both public education and understanding of whales, and that regulates potentially destructive human interaction . . ."

A second workshop was convened by the NOAA Marine Sanctuaries Program Office in December 1979. The charge of this workshop was to "consider the adequacy of present management of the endangered humpback whales . . . and to explore possible additional means of protection." The recommendations of the 1979 workshop restated those of the earlier meeting regarding the need for continued monitoring of the population's current status and future prospects, and the importance of public education.

Notice of Interpretation of Harassment. On January 4, 1979, in response to the earlier workshop recommendations and recommendations from within the agency, and an exponential growth in humpback whale related activities, NMFS and NOAA General Counsel published a Notice of Interpretation (NOI) of Harassment pertaining to humpback whales in Hawaii (Federal Register 44(3):1113-1114). The NOI designated certain calving and breeding grounds, set guidelines for approach limits of 100 or 300 yards (depending on the area) for vessels, swimmers, divers, and aircraft, and otherwise defined "harassment" as any act that substantially disrupted or altered the normal behavior of a whale. This was the first attempt by NMFS to interpret the biological definition of "harassment" and translate it into an easily understood and recognizable rule. Even though the relationship between the distance restrictions and actual biological or behavioral parameters was unclear in some cases, these rules offered the best compromise for enforcement purposes because it was felt that much of the interpretation of variable humpback whale behavior would not be required.

While the NOI served notice that NMFS was concerned about the possible effects of human activities on the whales and acted to address them, additional distributional and behavioral data were acquired after its publication. Normal whale behavior such as joining, splitting, mating, and competitive behavior patterns, was more completely described, and in some instances is indistinguishable from reactions to vessels. These findings again complicated the elucidation of harassment in relation to human activities in Hawaii.

Studies designed specifically to investigate short-term reactions of whales to vessel traffic have shown a definite sensitivity of humpback whales to vessels from distances greater than previously noted. Bauer and Herman (1986) found humpback whales off Maui to significantly alter behaviors in response to vessels out to at least 1,000 m. Increases in dive times and some threat behaviors were found. Short-term impacts of reduced fitness due to excessive energy expenditure during the non-feeding season were suggested. The need for mediating these possible short-term impacts is also linked to the potential for long-term negative effects such as displacement, reduced reproductive success, and reduced recruitment.

Baker et al. (1983) found significant changes in humpback whale respiratory rates in response to vessel proximity, speed, and presence of large ships and noted avoidance behavior as far as 8000 m from vessels in Southeast Alaska studies. These results prompted the National Park Service to regulate vessel traffic in Glacier Bay National Park. A continuing decline in the percentage of cow/calf pairs sighted in nearshore waters off west Maui has been noted by Glockner-Ferrari and Ferrari (1987). Possible factors suggested in this apparent decline were direct interactions between whales and vessels, increased usage of specific areas by boaters and concessionaires, increased land runoff, and the occurrence of changing water quality and pollution.

During a series of aerial surveys (Herman et al., 1980: Forestell, 1989), significant numbers of vessels in proximity to whales were noted, and suggested a preference of whales for subregions removed from areas of dense human habitation or activity. Whales were noticeably absent in the Lahaina, Maui area - an area of high vessel density. Aerial surveys in 1985 also noted this "hole" at Lahaina as well as one off Keawakapu, Maui, where a public boat ramp was built in 1983. It was theorized that rather than total avoidance by whales of these areas, selective avoidance by cow/calf pods and groups of larger animals may have been indicated. Single animals, which typically stay underwater for longer periods, may frequent these areas yet be missed by aerial surveys.

Interim and Final Rule on Approaching Humpback Whales in Hawaiian Waters: By 1985, NMFS found that the NOI was losing its effectiveness as an enforcement tool in that harassment cases were very difficult to prosecute because NMFS enforcement agents had to document acts that substantially disrupted the normal behavior of a whale under the terms of the NOI, requirements almost identical to those found in the statutes without interpretation. With new information on humpback behavior and biology being developed, human activity increasing in preferred humpback whale habitat, and with the recognition of the inadequacy of the NOI, NMFS published an Interim Rule regulating the approach to humpback whales in Hawaiian waters in 1987 (Federal Register 52(225):44912-44915). This Interim Rule prohibited approaching humpback whales within prescribed distances which provided for more effective and efficient enforcement in a environment of increasing human activity. The regulations established a minimum approach distance of 100 yards from a humpback whale within the EEZ around the Hawaiian Archipelago and special cow/calf areas on

Maui and Lanai where the approach distances were 300 yards. The final rule (50 CFR 222.31, as follows) with modifications required by the 1994 amendments to the Marine Mammal Protection Act were published on January 19, 1995 (Federal Register 60(12):3775-3776). The final rule deletes the Cow/Calf areas and the 300 yard distance requirement from the Interim Rule as required by the amendment.

Humpback whale approach regulations in Hawaii (50 CFR 227.31)

Except as provided in subpart C (Endangered Fish or Wildlife Permits) of this part it is unlawful for any person subject to the jurisdiction of the United States to commit, or to cause to be committed, within 200 nautical miles of the Islands of Hawaii, any of the following acts with respect to humpback whales (Megaptera novaeangliae):

(a) Operate any aircraft within 1,000 feet (300 m) of any humpback whale; or
(b) Approach by any means, within 100 yards (90 m) of any humpback whale; or
(c) Cause a vessel or other object to approach within 100 yards (90 m) of a humpback whale; or
(d) Disrupt the normal behavior or prior activity of a whale by any other act or omission. A disruption of normal behavior may be manifested by, among other actions on the part of the whale, a rapid change in direction or speed; escape tactics such as prolonged diving, underwater course changes, underwater exhalation or evasive swimming patterns; interruptions of breeding, nursing, or resting activities; attempts by a whale to shield a calf from a vessel or human observer by tail swishing or by other protective movements; or the abandonment of a previously frequented area.

The Role of Hawaii Department of Land and Natural Resources-Division of Aquatic Resources

Oishi, F.

The Hawaii Department of Land and Natural Resources (DLNR) has many diverse responsibilities including Aquatic Resources, Boating, Ocean Recreation, Forestry, Wildlife, Land and Water Management, Parks, and Historic Sites, to name a few. Organizationally, the DLNR is advised by various commissions: Animal Species, Fisheries, Historic Places, Aquaculture, Natural Area Reserves, Water, and a recently established Reserve Commission for the island and surrounding waters of Kahoolawe.

The DLNR, Division of Aquatic Resources (DAR), manages the State's aquatic resources in both marine and freshwater. This is accomplished through three programs: a commercial fisheries and aquaculture program, an environmental protection program, and a recreational fisheries program.

Traditionally, we are known for managing of fisheries through licensing, seasonal closures, minimum sizes, bag limits, and marine life conservation districts, to name a few. However, we have recently become involved with educational efforts towards conservation, involvment in land management issues that affect aquatic ecosystems, and management plans involving threatened/endangered species.

With regards to humpback whales, the only direct involvement that the DAR has is to issue scientific collecting permits (SCPs) for whale research. The DAR is authorized to issue this permit under two state statutes: the Hawaii Revised Statutes (HRS) 187A-6 and 195D-4. The state statute (HRS) 187A-6 regulates the taking of aquatic life for scientific, educational, or propagational purposes. State statute (HRS) 195D-4 covers threatened and endangered species and exempts permit holders for scientific study and/or propagation purposes. For example, this permit allows the researcher to approach whales closer than specified minimum distances by Federal and State law and exempts the permitee from take (harassment) prohibitions. However, in order for the state permit to be valid, the State permittee is also required to possess a NMFS-issued, Federal research permit. Therefore, the DAR coordinates the issuance of these permits with the NMFS, regional Protected Species Program.

During Fiscal Years (FY) 1992 and 1993 (July 1 - June 30), 40 such permits were issued. In FY 1993-1994, 47 permits with amendments were issued. Most permits are issued to researchers and educators to collect marine organisms, that are neither threatened nor endangered, with gear that would be otherwise prohibited for the purposes of education and/or research. In FY 1994-1995, eight (8) permits were issued to various prinicple investigators for humpback whale research. This permitting process fulfills, in part, statutory requirements and provides an initial screening process for applicants desiring to conduct research on whales.

An Overview of the Responsibilities and Activities of the U.S. Army Corps of Engineers as They Pertain to the Protection of Humpback Whales in Hawaii

Lennan, W.B.

The U.S. Army Corps of Engineers (Corps) has two major subdivisions: the Engineer units of the regular army, Army Reserves and Army National Guard; and the largely civilian Corps Engineer Divisions and Districts with military upper level management. In Hawaii there is the Pacific Ocean Division (POD), with its subordinate units, the Honolulu Engineer District (HED), the Japan Engineer District (JED) and the Far East Engineer District (FED). The overseas Districts, JED and FED, do only planning and construction for military projects of the Army and Air Force, and occasionally the Navy.

The Honolulu District also does planing and construction for the military services, such as Tripler Hospital, various military housing projects and the Johnston Atoll Agent Disposal System. In addition, HED has a Civil Works mission. In Hawaii and the U.S. flag Pacific islands, HED plans and constructs water resources development projects when requested by the local governments. Projects such as deep draft harbors, small boat harbors, flood control and shore protection projects are sponsored and cost shared by the state or local government. The Honolulu District also has regulatory authority under the Clean Water Act, the River and Harbors Act of 1899, and the Ocean Dumping Act. In Hawaii and the U.S. Pacific islands the Corps issues permits for work in the water and transportation of material for ocean dumping.

The Corps has no direct responsibilities toward humpback whales as does NOAA; however, strong indirect responsibilities are generated by both militaty and Civial Works projects and permits actions under the Endangered Species Act (ESA), especially section 7 consultation and coordination. For military construction projects the Corps provides technical assistance in section 7 coordination actions to the service owning the land, but the basic responsibility for compliance with the ESA belongs to the owning service. For Civilian Works projects and the regulatory program the Corps is directly responsible for compliance with the ESA. The regulatory program assures compliance by distributing a Public Notice for each individual permit actions, which elicits comments from the public and various agencies including the NMFS. Measures recommended by NMFS to mitigate impacts on protected species become conditions of the permit, which are enforceable in Federal courts.

Protection of humpback whales becomes an integral part of the planning process for civilian works projects. The environmental documentation required by the National Environmental Policy Act (NEPA) reports the existing conditions and expected impacts to protected species, and includes appropriate correspondence between the Corps and NMFS concerning formal or informal section 7 consultation. Recommended mitigation actions become part of the specifications for the construction contract, and are enforced by Corps on -site inspectors. Failure by a contractor to comply with these requirements can have serious consequences.

As the population increases, more development is needed to keep pace with the desires of the community for infrastructure improvements such as flood protection, navigation improvements and shore protection. The Corps is a developer of these types of water resources projects, but we strive to make the project as environmentally benign as possible within the framework of the project purpose.

PART II. DISCUSSIONS OF WORKING GROUPS AND RECOMMENDATIONS

In order to facilitate the discussion of a variety of topics, workshop participants were placed in one of the following working groups, each group with a specific focus: Population Assessment and Monitoring Methodology; Humpback Whale Habitat Characterization; Behavior/Life History Research; and Risk Assessment and Management Needs.

Working Group I - Population Assessment and Monitoring Methodology: To evaluate the effectiveness of recovery efforts for the humpback whale, it is necessary to develop and implement a program that monitors the distribution, abundance, age-sex composition, movement patterns, and behavior of whales within the Sanctuary and adjacent Hawaiian waters. The purpose of this working group was to (1) identify the variables that should be monitored; (2) describe any additional information that would be required and recommend how frequently the identified variables should be monitored to provide the required data at minimum cost; (3) rank the identified research and monitoring tasks with respect to their relative importance for meeting the objectives of the Sanctuary Management Plan and the Humpback Whale Recovery Plan; and (4) estimate what it would cost to carry out the recommended baseline research and long-term monitoring programs.

Working Group II - Humpback Whale Habitat Characterization: At present there is not a clear understanding of the relationship between specific biological, chemical and physical parameters of the marine environment and the distribution of humpback whales in Hawaii. To effectively manage and protect the humpback whale it is necessary to obtain data regarding habitat use and potential threats to these habitats. This working group was assigned to summarize what is presently known about humpback whale distribution and habitat use in Hawaiian waters, including a description of the characteristics of these areas (temperature, salinity, currents, water quality, substrate, depth, acoustic properties, etc.); to identify information needs regarding the distribution of humpback whales in Hawaii, their use of selected habitat(s), and potential threats to these habitat(s); to identify needed research, long-term monitoring and education programs that can be developed and implemented that will begin to answer some of these questions.

Many of the data necessary to monitor the co-occurrence between the distribution of humpback whales and their habitat might be archived and analyzed most effectively through a geographic information system (GIS). Therefore, this working group also identified the types of data with geographic attributes that are likely to be required to meet the objectives of the Sanctuary and the Recovery Plan; determined whether access to, and utilization of, such data might be facilitated by using an existing or new GIS system or other data information system; identified other state and Federal agencies, and private organizations, that might benefit from, and thus might be asked to support the development of a cooperative GIS system-sharing program; and as appropriate, recommend steps that might be taken to facilitate development of a GIS system which would assist in archiving and analyzing information required to meet Sanctuary objectives.

Working Group III- Behavioral/Life History Research: Research on humpback whale behavior and life history is crucial to understanding individual whales and population dynamics. This type of research will be an important component in the research components of the Sanctuary management plan and to implement portions of the NMFS Humpback Whale Recovery Plan. The purpose of this working group is to assess past and current research on humpback whale behaviors and life histories, and to help determine the types of research that are needed to effectively manage the whales.

Working Group IV - Risk Assessment and Management Needs: The SRD and NMFS are responsible for developing and implementing two complementary programs for the protection of humpback whales in the Hawaiian Islands, and their habitat. The purpose of this Working Group is to review all potential threats to humpback whales and their habitat in the Hawaiian Islands. The Working Group also assessed those threats identified in the Recovery Plan and reviewed management measures contained in the Recovery Plan which may help identify, monitor or mitigate some of the impacts. This assessment will be used to develop complementary long-term monitoring strategies and programs by both the Sanctuary program and by NMFS.

REPORT OF WORKING GROUP I - POPULATION ASSESSMENT AND MONITORING METHODOLOGY

Douglas DeMaster, Chair	Jeff Laake, co-chair
John Calambokidis	Sally Mizroch
Sal Cerchio	Joe Mobley
Phil Clapham	Gene Nitta
Paul Forestell	Jan Roletto, co-chair
Rich Grotefendt	Jan Straley
Terry Jackson	

Introduction: The working group discussed the overall objective of population assessment and monitoring of humpback whales in the North Pacific relative to the management needs of the Sanctuaries and Reserves Division (SRD) of the National Ocean Service, and the National Marine Fisheries Service (NMFS). There was general agreement that the focus of the group's recommendations should be relative to the information needed to evaluate the status and recovery of humpback whale populations in the North Pacific, with special emphasis on animals in the central and eastern North Pacific.

Background on Status and Trends: The status of a population, in the context of the information needs of the SRD and NMFS, is relative to the maximum number of individuals the environment can support on a long term basis. That is, status refers to the size of the current population relative to the carrying capacity (referred to as K) of the environment. The traditional approach to estimating status for populations of large whales is to "back-calculate" historical abundance, based on the following information: 1) current population size, 2) history of removals (e.g., catch history), 3) maximum rate of increase (per capita rate), and 4) functional relationship between density and the population's growth rate. Typically for marine mammal populations, developing a reliable estimate of the carrying capacity is extremely difficult because of the lack of information on catch history and the relationship between growth rate and density. Further, in interpreting estimates of K, based on back-calculation techniques, it is necessary to assume that K has remained constant over time. Therefore, alternative approaches were developed, such as "dynamic response techniques" and "K and P" indexing (see Gerrodette and DeMaster 1990). These latter two approaches have been used to determine whether a population is above its maximum net productivity level (approximately 50-75 percent of K) and when K is declining, respectively.

It is important to recognize that, while the status of a population is used to determine whether a population of marine mammals should be classified as depleted under the Marine Mammal Protection Act, status is not a particularly important parameter in classifying animals as endangered or threatened under the Endangered Species Act (ESA). Rather, classification under the ESA is more a function of current population size, trends in abundance, and the status of regulations protecting the population from further reductions. Therefore, relative to evaluating the recovery of humpback whales in the North Pacific as discussed in the Humpback Whale Recovery Plan, it is important to have information on current population size and trends in abundance.

Regarding the estimation of recovery rates for marine mammals, two basic approaches have been applied: 1) analysis of index counts and 2) population modeling. The former approach requires a relatively long time series (e.g., 10 years) of index counts, where the precision of each data point is relatively high. This is because the life history of marine mammals is such that maximum rates of increase rarely exceed 4-8 percent per year for cetaceans, polar bears, and manatees, and 12-20 percent for pinnipeds and sea otters. Regarding the latter approach, the basic information required to estimate recovery rates include calf survival, non-calf survival, age at first birth, fecundity, and longevity. For long-lived animals in general and marine mammals in particular, it has been shown that estimates of population growth rate are extremely sensitive to the value of non-calf survival. Therefore, this particular parameter must be estimated very accurately (i.e., ± 0.02) to use this approach in estimating recovery rates.

Information Needs Regarding Status and Trends: The working group identified five general categories of information needs relative to assessing the status of humpback whales in the North Pacific: 1) abundance, 2) trends in abundance, 3) distribution, 4) life history parameters and 5) stock structure.

After some discussion, it was agreed that information on abundance, trends in abundance, life history parameters, and stock structure was most critical to evaluating the status of humpback whale populations (i.e., whether populations were recovering and what the status of the various populations were relative to carrying capacity). Each of these four topics were then discussed. For each topic, the following were identified: 1) specific research activities (see Table 1), 2) advantages and disadvantages of each activity, and 3) the cost of each activity (see Table 2). In addition, the working group also agreed that because of the potential for bias in estimating the status or rates of recovery of humpback whales, it was important to have a second, independent estimate of abundance and trends in abundance. Finally, the working group identified a subset of the activities list, which were considered to be absolutely essential in evaluating the status and recovery of humpback whales in the North Pacific, which are presented in Table 2.

Abundance: Estimating abundance of humpback whales in the central and eastern North Pacific requires sampling feeding areas or wintering areas or both. Estimates of abundance of humpback whales using the feeding area off California, Oregon and Washington are already available from photo-identification and line transect vessel surveys (Calambokidis and Steiger, 1995). Discussion centered on two primary techniques: aerial surveys and mark-recapture from photo-identification. Four different topics were identified and discussed:

<u>Aerial surveys of abundance in Hawaiian wintering areas</u>: Aerial surveys of abundance of humpback whales in Hawaiian waters have been conducted intermittently for the past decade with the most extensive surveys conducted in 1993 and 1995 (Mobley, Forestell and Grotefendt, this volume). Aerial surveys provide an efficient means of obtaining abundance and distribution of whales at a point in time. Two problems were identified in estimating the population size in Hawaiian waters: 1) the length and pattern of residency time are unknown, and 2) correction factors need to be developed for the proportion of whales not at the surface. Age, sex and group size-specific respiration and dive

data, which have been collected from shore-based observations, need to be analyzed and examined for intra- and inter-annual variation.

Photo-identification surveys of abundance in Hawaiian waters: Coordinated photo-identification surveys throughout the Hawaiian Islands at weekly intervals during the winter season were conducted in 1995. (Mizroch, pers. comm.) The objectives of this study were to: 1) estimate abundance of whales which visit Hawaii during a single year, and 2) provide information on length and patterns of residency during the winter season. Multiple-year surveys of humpback whales in the entire range in Hawaii, which have not been attempted to-date, would also provide information on trends in abundance and variability in numbers of whales that migrate to Hawaiian waters. Mark-recapture estimates of abundance are sensitive to heterogeneity and particular attention must be given to following a strict sampling protocol to assure whales have an equal probability of capture. This will require adequate sampling across all areas and throughout the entire mating and calving season.

Within-year surveys conducted in 1995 followed a strict sampling protocol, and data on variables such as sex, age, presence or absence of calf, and fluke capture rates were collected. For future studies, protocols developed by researchers conducting the Year(s) of the North Atlantic Humpback Whale (YONAH) project should be evaluated in order to refine existing survey protocol for Hawaiian waters. The goal of future studies should be to photograph a sufficiently large proportion of the population using the winter ground to minimize the effects of selection bias that cannot be controlled and to provide an adequate level of precision.

North Pacific basin-wide abundance estimate: Estimating abundance of humpback whales for the entire North Pacific basin from photo-identification studies is currently being considered and this approach was discussed by the working group. Certain advantages and disadvantages exist with surveying the feeding or winter grounds. Based on broad regional fidelity, feeding areas provide a natural unit for population estimation; however, feeding areas in the North Pacific are challenging logistically. The strong tendency of humpback whales from different feeding areas to concentrate on traditional wintering grounds, such as Hawaii, potentially facilitates the estimation of abundance in such locations. However, it is not clear whether all or most whales migrate to specific wintering areas and therefore, whether estimates developed truly reflect abundance across the high latitude range of the population. Basin-wide estimates based on existing data would have to be robust to the lack of a sampling protocol and incomplete nature of the sampling effort across areas. Data from some feeding/wintering areas that have been extensively sampled in the past may yield minimum abundance estimates. In addition, evaluation of existing photo-identification data may provide information on exchange rates between each of the feeding and winter grounds and survival rates. These data may help guide future efforts in designing a sampling scheme to estimate basin-wide abundance.

Vessel surveys: Vessels were considered as an alternative platform to aircraft for distance sampling surveys. It was noted that vessels have a number of disadvantages although they may be useful in some circumstances (e.g., remote areas) and the correction factor for submerged animals is smaller relative to correction factors applied to aerial survey data. However, it was noted that vessel surveys of humpback whales have the potential problems: 1) double counting, 2) responsive movement of whales to the vessel, and 3) errors in distance estimation from sightings beyond the horizon. Also, aircraft enable more extensive coverage in a short time frame and, therefore, are better suited to taking advantage of good sighting conditions.

The following activities were considered essential to evaluating the status and recovery of humpback whales in the central and eastern North Pacific: 1) aerial surveys in Hawaiian waters, 2) photo-identification surveys in Hawaiian waters with more extensive coverage and a defined sampling protocol, 3) North Pacific basin-wide studies, where existing photographs would be analyzed to estimate rates of exchange between the various feeding and winter grounds (see recommendations on Stock Structure), estimate non-calf survival rates (see recommendations on Life History), and evaluate the potential for estimation of humpback whale abundance in the North Pacific based on existing data, and 4) photo-identification surveys along the coast of British Colombia and Alaska.

The cost of conducting and reporting the results of an aerial survey comparable to the 1995 effort in Hawaiian waters was estimated at $80K. An additional $15K would be required to derive correction factors based on respiration and dive data. Conducting photo-identification surveys in Hawaiian waters for the purpose of providing information on stock structure, abundance, and life history was considered a single activity in determining cost. The cost of conducting and reporting the results of a comprehensive photo-identification survey in Hawaiian waters was estimated at $170K. A precise estimate of cost for the basin-wide study will be forthcoming. The estimated cost of conducting and reporting the results of photo-identification surveys off British Columbia and Alaska was $150K.

Trends in Abundance: The working group identified four activities related to assessing trends in abundance:

<u>Index counts based on aerial surveys</u>: A time series of data from aerial surveys in Hawaiian waters already exists because consistent protocols were followed in some areas in Hawaii during at least six winter seasons between 1985 and 1992 (analysis cost: $15K). The working group considered this an important advantage. It was further recognized that, for the purpose of identifying trends in abundance, biases in estimates of abundance (e.g., probability of sighting animals on the track line is not unity) would not affect the estimates of trends, assuming the bias was constant over time. However, the working group noted that trend data based on surveys in Hawaiian waters were somewhat difficult to interpret because of the use of winter grounds by animals from several different feeding areas, and that changes in sighting rates could reflect shifts in distribution within the Hawaiian wintering areas. Again, the group recommended that at least two independent estimates of trends be determined.

<u>Index counts based on estimates of abundance from photo-identification studies</u>: A time series of mark-recapture based abundance estimates for animals in Hawaiian waters was presented in Cerchio (this volume). Using photo-identification to estimate trends was considered cost-effective because of the continued need for photo-identification studies in monitoring the recovery and status of humpback

whales in the central and eastern North Pacific. However, it was noted that possible heterogeneity in return rates from year-to-year would increase the variability and possibly the bias, in any estimate of rate of change.

Index counts of abundance estimates from feeding areas in California,Oregon and Washington:The working group agreed that a time series of abundance estimates of whales in feeding areas could be used to evaluate the potential for recovery rates in specific feeding areas. Trends in abundance in Hawaii (#1 and 2 above) would largely exclude whales feeding off California, Oregon and Washington. Initial abundance estimates are currently available from on-going studies in the eastern Pacific. Continuing studies would cost $70K.

Population modeling: Trends in abundance can be derived from population modeling based on life history parameters (calf survival, non-calf survival, age at first birth, fecundity, and longevity). The group agreed that modeling-based estimates of trends in abundance were unlikely to be reliable because of a lack of precision in estimates of non-calf survival. However, it would still be valuable to examine differences in life history parameters and recovery rates among different populations (see sections on Life History Parameters and Ancillary Information Needs) even in the absence of having precise estimates of all of the parameters needed to estimate trends in abundance.

The working group considered all of the above activities, except section 4, Population modeling, to be essential for evaluating the status and recovery of humpback whales in the central and eastern North Pacific. The cost of the three essential activities are summarized in Table 2, Section 2.

Life History Parameters: Six specific activities were identified by the working group: 1) determine reproductive rates of mature females, 2) determine calf mortality, 3) determine non-calf mortality, 4) determine age at first birth, 5) determine distribution of size classes of animals within Hawaiian waters, 6) determine longevity. The first three activities were considered essential by the working group for evaluating the status and recovery of humpback whales in the central and eastern North Pacific. The latter three activities were considered unlikely to produce reliable results over the next few years. It was noted that in the absence of commercial whaling, it would be extremely difficult to estimate longevity (the oldest humpback whale observed based on whaling data was reported to be 48 years old (Chittleborough 1965)).

Determine reproductive rates of mature females: Annual re-sightings of females on the wintering grounds are needed to calculate appropriate reproductive rates and birth intervals. Obtaining complete sighting histories is difficult because it appears that small-scale geographic site fidelity is less strong in wintering areas than in feeding areas. This may be addressed through increased sampling and continued cross-matching of fluke photos in Hawaiian waters.

Because of increased site fidelity on the feeding grounds, there are more complete sighting histories of females with calves in Alaskan waters than in Hawaiian waters. Cumulative observations in Alaska give an indication of reproductive rate and birth interval, but do not include any pre-migration calf mortality. In addition, unless long-term sighting histories are used, these studies can be biased towards shorter birth intervals, since there is a better chance of seeing a whale each year for 2-3 years than for 5-6 years.

Summarized information on reproductive rates and birth intervals for whales photographed in Hawaii and Alaska from 1976-1992 will be a product of the calf mortality workshop. However, costs for future efforts to collect additional sightings in feeding areas in Alaska, British Columbia, and the U. S. west coast would be shared with the overall cost estimates shown in Table 2, sections 1.4 and 2.3.

Determine calf mortality: Migration mortality of calves can be determined by comparing sightings of mothers and calves in the winter grounds to sightings of those same mothers with or without a calf later that season on the feeding ground. A workshop was held to begin the analysis, and the follow-up workshop to finish the analysis will cost $25K.

Non-calf mortality: The assessment of non-calf mortality will require long-term observations and photo-identification of individual whales. Data already collected from long-term studies can be used to begin the assessment of non-calf mortality, and would cost $75K. However, costs for future efforts to collect additional data would be shared with the overall cost estimates shown in Table 2, sections 1.2, 1.4 and 2.3.

Although age at first birth was not listed by the group as an essential activity, it was noted that there may be differences in age at first birth between the North Atlantic stock and the central North Pacific stock (though sample size of known-age animals is very small in the central North Pacific), which may indicate differences in the recovery rates between these two populations. With increased monitoring, sample size of known-age animals in the North Pacific will increase, and comparisons of age at first birth among stocks will be possible.

Stock Structure: Three specific activities were identified regarding the stock structure of humpback whales in the North Pacific. It was recognized that there were no participants in the working group with considerable expertise in population genetics and, therefore, recommendations concerning genetic studies should be considered preliminary.

Exchange rates based on photo-identification: Use of movement patterns based on uniquely identified individuals to estimate exchange rates between putative stocks was considered the primary information source for determining stock structure (see Calambokidis, Straley, Mizroch and Cerchio, this volume). It was recognized that survey effort varied considerably by area, but the working group considered the relative frequency of observed movements to be representative of humpback whales in the North Pacific. It was further recognized that additional matches of animals from different areas with currently available data were likely. Because this would benefit from the utilization of the North Pacific Fluke Collection (NPFC),it was agreed that problems in fully utilizing the NPFC should be resolved immediately.

Genetic differences: Use of tissue samples to determine genetic diversity and stock structure based on mtDNA and nuclear DNA analyses was considered an essential, independent source of information. The working group agreed that tissue samples for genetic analysis needed to be collected from all of the currently recognized feeding and wintering aggregations in the North Pacific. Minimum sample sizes necessary for this study could not be identified without additional information concerning the expected level of genetic diversity among populations.

Song structure: Examining song structure from the three wintering areas in the North Pacific has provided mixed results concerning the degree of similarity of song among these areas, possibly due to the temporal variability in song structure and the difficulty in quantifying differences in dialects. These results may also be attributable to small sample size, in that, given current methodology, songs are easy to collect and difficult to analyze. However, progress is being made in song analysis using automated feature recognition, which, if successful, will increase the sample size of analyzed songs and thereby potentially increase the ability to clarify stock structure based on small differences in song structure.

There was general agreement that the first two activities should be included in the list of essential activities. The working group noted that the actual cost of assessing stock structure of humpback whales in the North Pacific based on photo-identification studies was difficult to separate from the overall need for analyzing existing photo-identification data and for collecting and analyzing additional photo-identification data, as the analyses would provide information on the abundance and life history as well. Therefore, after some discussion, it was agreed that a reasonable estimate of cost for all of the essential activities related to photo-identification studies was roughly $390K per year. In addition, the working group estimated that it would take $40K per year to maintain the NPFC (note: this estimate does not include funding to support data analysis, oversight or development of educational materials). Regarding the analysis of tissue samples for genetic studies to assess the stock structure of humpback whales in the entire North Pacific, the working group agreed that a preliminary estimate of cost was $260K (which includes cost of logistics to get samples from areas where additional samples are needed).

Ancillary Information Needs for Humpback Whales in Hawaii: The working group noted that once information on trends in abundance are available for all of the stocks in the North Pacific, the logical next step would be to compare the stock-specific rates of growth. Should the recovery rate of the central stock or any of the eastern Pacific stocks be significantly less than recovery rates of other humpback whale populations (including those in the Atlantic Ocean and Southern Hemisphere), the following ancillary information from Hawaiian waters will be needed to evaluate whether anthropogenic effects were important, where all of the following variables would be available as time-series type data sets: 1) sea surface temperature, 2) ambient noise levels, 3) vessel traffic, 4) water quality (e.g., turbidity, pollutants), 5) humpback whale stranding data, 6) incidence of predation, and 7) fishery interactions. Depending on the scope of considerations, additional variables (e.g., prey availability in high latitudes) may also need to be considered.

Conclusion: Evaluating the status and recovery of humpback whales in the central and eastern

North Pacific would be greatly enhanced by additional focus, direction and funding by NMFS and SRD in coordinating ongoing research activities in waters off Hawaii, Alaska, British Columbia, the U. S. west coast, and Mexico. There is currently no permanent source of funding to support long-term research on humpback whales in the North Pacific. In addition, there is no long-term support for the NPFC, which was originally envisioned as a vehicle for enable researchers to cooperatively study humpback whale abundance, stock structure, and life history in the North Pacific. The NPFC would be a valuable tool to educate the public and develop awareness of the value of research on humpback whales for the protection of this species.

The working group recommended a set of specific activities that it considers essential over the next 2-3 years to evaluate the status and recovery of humpback whales in the central and eastern North Pacific. The cost of these activities is approximately $1 million dollars. Without this level of investment, it seems clear that the reliable assessment of the status and recovery potential of humpback whale populations in the North Pacific will not be possible. The cost of humpback whales not recovering or not recovering in a timely manner is difficult to assess. However, based on recently developed techniques for valuating the “worth” of recovering endangered megafauna, it is likely that the cost of documenting the recovery of humpback whale populations in the North Pacific is trivial compared to the value of enabling this population to recover to its optimal status. It was the consensus of the group that the importance of developing an immediate scientifically-determined basis for assessing the current status of this endangered species warrants the costs involved.

Table 1. Initial List of Potential Variables to Monitor

Abundance	- aerial survey with correction factor
	- within season photo-ID
	- basin-wide
	- development of a reconciled fluke catalog from the NPFC
	- analysis of bias in mark-recapture estimates
	- development of protocol for abundance estimate based on photo-identification.
	- development of protocol for abundance estimate based on aerial surveys.
	-feasibility study on using acoustic arrays to estimate abundance.
Stock Structure	- analysis of genetic diversity.
	- photo-identification analysis of exchange rates.
Distribution	- all age and sex classes (current)
	- all age and sex classes (changes over time)
	- calves (current)
	- calves (changes over time)
Life History	- reproductive interval (current)
	- reproductive rate (changes over time)
	- percent calf (current)
	- percent calf (changes over time)
	- percent>length (SM) (current)
	- percent>length (SM) (changes over time)
	- age at sexual maturity (current)
	- age at sexual maturity (changes over time)
	- calf mortality
	- non-calf mortality
Archive Photographs used for Photo-identification Studies	

Table 2. List of research activities considered essential to the evaluation of the status and recovery of humpback whales in the central and eastern North Pacific. Annual cost estimates should be considered preliminary and will be reviewed after 3 years. Actual costs may vary among years.

RESEARCH ACTIVITY	**COST**
1. Abundance	(Costs in Thousands)
Aerial Surveys of whales in Hawaii	80
Correction Factors for line transect estimate	15
Photo-identification of whales	
in Hawaii	170
in Alaska and British Columbia	150
North Pacific basin-wide studies	25-50
2. Trends in Abundance	
Aerial Surveys of whales in Hawaii	(see above)
Analyses of existing survey data	15
Photo-identification of whales	
in Hawaii	(see above)
in California, Oregon and Washington	70
3. Life History	
Reproductive Rates (from photo-ID data)	(see above)
Calf Mortality Rates	25
Non-calf mortality (from phoo-ID data)	(see above)
Analyses of existing non-calf mortality data	75
4. Stock Structure	
Photo-identification (from photo-ID above)	(see above)
Genetic Differences	260
NPFC (studies conducted annually)	40

REPORT OF WORKING GROUP II: HUMPBACK WHALE HABITAT CHARACTERIZATION

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Introduction: Why do the humpback whales come to the Hawaiian Islands? What is it about this habitat that attracts them? The goals of the working group were twofold: to identify parameters influencing the habitat use patterns of humpback whales and to assess whether analysis of this information would be facilitated through development of a Geographic Information System (GIS) or other data base management tool. The primary goals relative to habitat use were to identify (1) the parameters characterizing wintering habitat of humpback whales in Hawaii, (2) potential human impacts to humpback whale habitat, (3) what is known about the importance of these parameters in habitat selection by humpback whales, and (4) recommended research needs.

The limited results of studies to date do not allow us to clearly identify all factors influencing habitat selection by humpback whales wintering in Hawaii. Thus, we attempted to classify habitat variables based on associated level of scrutiny (i.e. published analyses versus anecdotal observations). Much of the available data is summarized by Nitta and Naughton (1989), and was also addressed at the workshop (Mobley et al.; Cerchio; Payne; Frankel; Bauer). We recognize that additional information and data are needed before a thorough assessment of humpback habitat utilization patterns can be completed.

These analyses should begin with compilation of existing relevant datasets. This approach would be best facilitated with the use of a GIS. Recommendations for research and implementation of GIS techniques for these data are summarized.

Natural Biological, Chemical and Physical Habitat Characteristics: The working group began by listing potential habitat characteristics that may affect humpback distribution in the wintering grounds. These characteristics were subsequently grouped into three categories and are presented below.

Parameters <u>strongly suspected</u> to influence habitat use by humpbacks based on existing published data:

- water depth (less than 100 fathoms(183m); cow/calf pairs may prefer shallower waters)
- topography (bank size and location, bottom complexity and slope)
- sea surface temperature

- acoustic environment (sound transmission, ambient noise)

Parameters <u>suspected</u> to influence habitat use by humpbacks but for which limited data are available relative to humpback distribution:

- wind speed, direction (leeward, windward)
- turbidity (sediment, plankton, water quality/chemistry, oxygen, metals, chemicals, nutrients)
- sea floor characteristics (rugosity, substrate type)
- other biota (other species distribution and/or interactions (predatory, symbiotic, parasitic))

Parameters which may <u>potentially</u> influence habitat use by humpbacks but for which correlative studies have not been conducted:

- salinity
- density
- current structure (fronts, eddies, oceanographic features)
- tides (tidal circulation)
- surface waves, internal waves
- thermocline depth, stratified versus well mixed
- magnetic field
- light (intensity,duration)/latitude

Potential Human Impacts: The working group listed potential human impacts that may affect humpback distribution in the wintering grounds. These impacts were subsequently grouped into three categories and are presented below.

Factors <u>strongly suspected</u> to impact habitat use by humpbacks based on existing published data:

- acoustic sources/noise (vessels, aircraft, research, construction, industrial)
- vessels as physical obstructions and intrusions (type, density, activities)

Factors suspected to impact habitat use by humpbacks but for which limited data are available relative to humpback distribution:

- non-point source pollution (agricultural, urban development, runoff, groundwater)
- point source pollution (sewage outfall, canals, warm water discharge, industrial discharge)
- oil/hazardous material spills

Factors which may <u>potentially</u> impact habitat use by humpbacks but for which correlative studies have not been conducted:

- dredging/dumping
- sand mining
- artificial reefs
- coastal obstruction (jetties, breakwaters, piers)
- other physical obstruction (fishing gear, moorings, scientific equipment, military equipment)
- changes to biological components of ecosystem (reduced biodiversity, biomass, potential prey, predators)

Potential global impacts briefly discussed by work group members which should be monitored for local implications:

- global warming
- ozone depletion, increased UV-A/UV-B
- El Niño/Southern Oscillation, Pacific North American pattern

Working Group Recommendations: Geographic information systems (GISs) are integrated software mapping and database storage programs that allow datasets with spatial coordinates to be plotted and analyzed. The power of a GIS lies in the flexibility of the software to organize and combine disparate datasets. For example, whale distributions from aerial surveys and photo identification studies can be combined with a variety of habitat datasets to determine characteristics that are most important to wintering humpback populations in Hawaii. Data from a GIS can also be extracted to other software packages for more complex statistical and plotting analyses. The habitat group recommends that ongoing and new research projects collect precise spatial coordinates in conjunction with other data attributes to ensure that a comprehensive data library be developed. In addition, the group recommends that a working group be convened to establish standardized collection and reporting methodologies, and address database design issues based on both historical and potential datasets. The following research recommendations are predicated with the initial recommendation of establishing a central library for compilation, coordination and management of data.

<u>Recommended analyses using either existing data or data from ongoing projects:</u> The following recommendations were provided:

- Compare and contrast winter habitat characteristics for all stocks of humpbacks based on a review of existing literature (see page 78 of Recovery Plan to identify stocks wintering grounds).

- Inventory comprehensive list of available data (analyzed or unanalyzed) for habitat use analysis (including whale distribution and physical and environmental parameters).

- Continue standardized aerial population assessment surveys and include 1) aerial expendable bathythermograph surveys to obtain synoptic thermal structure of water column concomitant with sightings, 2) vessel traffic distribution, 3) locations of turbidity plumes, 4) sightings of other species (i.e. other cetaceans, sharks).

- Use results from behaviorial studies to define relationship between habitat and whale behaviors (i.e. nursing, resting, singing, diurnal movements) (see working group III report).

<u>Recommended management and research activities:</u> The following management and research recommendations were suggested by this working group:

- Form scientific advisory committee for sanctuary, including interactions with other sanctuary teams (other sites); membership should include appropriate habitat expertise.

- Designate a lead agency to establish a central data library for compilation, coordination and management of databases.

- Utilize telemetry devices to characterize temporal patterns of three dimensional habitat use by age group/class (e.g. information on depth of dives, dive duration, site fidelity).

- Use acoustic arrays in regions of high and low whale density to compare intensity and frequency of ambient noise.

- Conduct sound playback experiments and controlled vessel approach experiments to assess effects of vessels on behavior, movement and distribution of humpbacks.

- Determination of habitat required for birth, maturation, and survival of calves including use of telemetry to augment existing data.

- Define the relationship between humpback distribution (by group class and composition) and habitat parameters using the following methodologies: GIS, canonical correspondence analysis, spatially explicit population models.

- Monitor water quality in order to assess effects of runoff events on local distribution and movements of humpbacks; sample associated water quality in areas of historical documented use by humpbacks and high likelihood of runoff.

- Examine AVHRR (advanced very high resolution radiometer) images prior to and in conjunction with population assessment surveys to ensure inclusion of oceanographic features within line transects; extend surveys outside 100 fathom (183m) contour during episodes of extended suitable habitat.

- Determine the distribution of tiger sharks and other potential predators of humpbacks in Hawaii and the incidence of predation.

Recommendations for Education: Following are recommended educational needs regarding habitat characterization.

- Share results of research with agencies and other interested parties (i.e., Coastal Zone Management agency, Army Corps of Engineers) to identify sensitive humpback whale habitat relative to their databases.

- Incorporate results of habitat analyses into educational outreach programs to advise on possible loss of suitable humpback habitat due to human activity in the nearshore and coastal waters of Hawaii (i.e. inclusion in boater's guides).

- Establish training programs for interpreters on humpback observation vessels where possible; utilize whale watching vessels to collect habitat related data and report significant events (i.e. turbidity, predation, entanglements).

Potential data sources identified by the working group: The working group identified several potential sources of data for inclusion in a sanctuary data library. The working group notes that this list is by no means exhaustive but represents several known local resources.

- GMT (spatial mapping program available from University of Hawaii)
- U.S. Navy
- USGS
- NOAA
- State (OSP, DLNR)
- University of Hawaii
  School of Ocean and Earth Science Technology:
    Hawaii Institute of Geophysics;
    Department of Oceanography;
    Department of Ocean Engineering
    Joint Institute of Marine and Atmospheric Research
    Hawaii Institute of Marine Biology
- Independent investigators
- U.S. Fish and Wildlife Service
- County governments
- Environmental/conservation organizations

REPORT OF WORKING GROUP III - BEHAVIOR AND LIFE HISTORY RESEARCH

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The Role of Behavior and Life History Data in Humpback Whale Management: Knowledge of humpback whale behavior and vital population parameters is critical to effective management. Significant variations in humpback whale behavior, distribution, or vital rates may be linked to changes in the physical or biological environment or anthropogenic stressors. Measured changes in these aspects of humpback whale biology will be useful to managers in detecting and attempting to mitigate adverse effects of human activities.

The relationship between short-term impacts on individuals and long-term consequences for the population is often complex and subtle. Therefore, investigations are needed which (a) provide baseline information on vital rates and naturally occurring behavior; (b) track changes in behavior patterns and vital rates through systematic and rigorous monitoring; and (c) when possible, address hypotheses through an experimental approach that yields data suitable for statistical analysis.

Working Groups Objectives: The objectives of this working group were to identify what could and should be done to better assess and monitor humpback whale vital population parameters and behavior, and human activities and their potential affects on humpback whales in the waters surrounding the Hawaiian Islands.

We determined that the desired information could be obtained by (a) organizing, reviewing, and assessing existing data found in published and unpublished reports, and held as raw data; (b) continuing ongoing basic research and initiating studies to address applied research questions; and (c) ensuring that research results are analyzed, interpreted, and disseminated. To help reach these goals, we identified, and provide here, a series of recommendations to the Sanctuary. They are categorized as high-priority recommendations; research recommendations; and general recommendations.

Human Activities That May Affect Whales: To focus our discussion, we first identified human activities within the Sanctuary that might potentially affect humpback whales. The following list of activities reflects the content of our discussion, but is not intended to be exhaustive.

<u>Boat, Aircraft, and Recreation-Related Activities</u>: This category includes whale-oriented activities (e.g., whale watching and research), commercial shipping, fishing boats, and water recreational activities. Adverse effects may vary depending on how boats and aircraft are operated and on their acoustic signatures;

Non-vessel Noise: Including noise such as introduced sources and military activities;

Pollution and Habitat Degradation: This includes coastal development, point and non-point source pollution, contaminants, and marine debris; and

Catastrophic Events: Which includes oil and hazardous waste spills.

High Priority Recommendations: This working group identified general recommendations, other than those involving specific research, that are high priority.

- Basic life history and behavior research, especially long time series studies, is vital to management of humpback whales because it can provide long-term data bases to track possible changes in the ecology or biology of the whales and provide baseline data to which experimental work can be compared. Also, behavioral data are useful in identifying responses to and providing assessments of potential disturbances (e.g., reactions to boats and aircraft) on relatively short time scales. Therefore, efforts should be made to continue and encourage ongoing basic research on behavior, life history, and related variables.

- In the last decade, a considerable amount of information on humpback whale behavior and life history has appeared in the peer-reviewed literature and in conference presentations. This information could be more useful to managers if it were compiled and reviewed. Reviewing this information was one of the goals of this working group set forth by the workshop organizers. However, there was insufficient time to conduct such a review. Therefore, we recommend that existing humpback whale behavior and life history information reported in the literature be reviewed, summarized, and assessed to identify (a) what is known; (b) the questions that remain; (c) ways to address the questions; and (d) prioritized research goals (see working group II report).

- Extensive data, provided by many researchers, reside in the humpback whale photo-identification database currently housed at the National Marine Mammal Laboratory. When analyzed, the data will provide much information about the life histories of individual humpback whales and the population as a whole. Therefore, the working group recommends that the data in the photo-identification database, and the ways in which the data are maintained and analyzed, be reviewed and assessed. The review should provide recommendations regarding, among other things, ways to improve access to, and steps needed to facilitate analysis of, the photographs (see working group I report).

Research Recommendations: To address the issues concerning the protection of humpback whales, effects of human activities, and other management concerns, a broad range of research areas should be pursued. Understanding the biology of humpback whales is inseparable from the development of sound management policies. Investigations suggested by our working group are consistent with the "Research & Long-Term Monitoring" component of the "Draft Sanctuary

Management Plan," and point to a few new directions.

Review of Existing Information and Studies: A vast array of data on humpback whales exist in government reports, in graduate student theses, and as raw data held by various individuals, organizations, or laboratories. For example, unanalyzed individual identification photographs and basic behavioral data collected in Hawaii, Alaska, and other Pacific areas can provide important information on group affiliations, migrations, age and sex classes, abundance, and distribution. Therefore the available information should be compiled and analyzed to determine if it is sufficient to answer questions and, if not, what would be required to resolve any uncertainties. This task might be accomplished by (a) contracting with one of more individuals or organizations to compile and prepare a report summarizing the adequacy of the data; and/or (b) organizing and holding a workshop of invited experts to obtain and evaluate the data (also see working group II report).

Vital Rates: The most critical issue in managing the humpback whale is the assessment of recovery of the species. In order to meet this need, studies must be pursued on birth rates, recruitment rates, mortality, and population size. In addition, a serious effort should be made to assess sources of mortality, including disease and predation. Human-related mortality remains an ambiguous area. Obviously, illegal hunting is a concern, but the magnitude of this phenomenon remains largely anecdotal and needs to be assessed.

Reactions of Whales to Specific Stimuli: Rigorous, well-designed experiments are needed to assess the reactions of whales to specific stimuli, both natural and anthropogenic. For example, carefully designed playback experiments can help to elucidate the functions of song and the impact of potential masking by vessel noise. Similar studies can be designed to investigate the critical features of sounds generated by various sources (e.g., vessels, geological testing) that affect whale behavior.

Behavior Patterns and Social Organization: As noted earlier, behavioral and social organization data are needed to identify and assess responses to potential distributions on relatively short time scales. A substantial effort has been made over the last two decades by numerous researchers to understand behavioral functions and the social organization of humpback whales. However, much remains to be done.

1) Description and Function of Behavior: An important area for investigation is reproductive behavior, but the lack of observations of mating makes this a particularly difficult area to pursue. More accessible research goals lie in the functional assessment of behavior as determined from correlations of behavior with age/sex classes and social structure, as well as the further study of the composition of active pairs and larger groups (with and without calves).

The majority of past efforts has been based on observations of surface behavior. Recent emphasis on underwater observation will help to describe relationships between underwater and surface behavior, and provide a more complete view of social behavior. This work should be continued and expanded. The study of behavior at night has been a virtually neglected area; it should be investigated.

2) Surface and Diving Patterns: Surface and diving patterns (e.g., dive times, surface times, blow intervals, synchrony, and depth) have traditionally been one of the easier areas to monitor. Substantial information of this topic may already exist, with the possible exception of depth of dives, in the archival record and as unanalyzed data. Although some of these data may exist with age/sex class identifications, greater specificity will be needed in future studies.

3) Vocal and Acoustic Communication: One of the least understood, but most accessible, characteristics of humpback whales is their vocalizations. Song is largely a mystery, but we have the technology to monitor song in a much more thorough fashion than we can study other types of behavior, which are observed primarily in brief surface intervals. Understanding humpback whale vocal behavior, the natural acoustic environment in which it occurs, and the impact of introduced noise on social behavior are critical issues. Specifically, investigations are needed on the following topics: location, spacing, and distribution of singers; characteristics and functions of song; social sounds and non-vocal acoustic communications; cow-calf vocalizations; effects of songs and other sounds on non-singing individuals; characterization and monitoring of ambient noise; and infra-sound.

4) Group Associations: Although most researchers acknowledge the potential for long-range communication among humpback whales, the parameters for "groups" have been largely based on spatial proximity. It is time to re-examine the definition of "groups" that omits consideration of the probably long-range communication capabilities of whales. In this context there is a need to further investigate the possible long-term affiliations of individuals other than cow/calf pairs.

Behavioral Development: The cow/calf pair has been recognized by biologists and managers as a social group critical to recovery. For example, areas thought to be calving and nursery areas have in the past had more restrictive rules with respect to vessel approaches (Nitta, this volume). Unfortunately, recognition as a critical unit has not been accompanied by a comparable emphasis on developmental studies. Changes in the cow-calf relationship over time in both Hawaii and Alaska are central to understanding responses to stressors. Of equal importance is characterization of species-typical chronological development of calves (i.e., the timing and nature of stages of maturation) and acquisition of social behavior. A complete understanding of the ontogenetic stages preceding sexual and physical maturity also require investigations of juveniles, a substantially neglected group.

Distribution and Movements: Evaluation of the effects of future regional events (e.g., heavy vessel traffic, deteriorating water quality, coastal development) are impossible without knowledge of how humpback whales currently use the waters of the Hawaiian Islands. Questions concerning whale behavior include the timing and location of arrival and departure, as well as movement among the islands. Localized stressors may be quite important if whales are found to remain in circumscribed areas, but of little consequence if whales are traditionally transient. In this context, it will be critical to assess the age/sex classes and social groupings when determining residence, distribution, and movement characteristics.

A particularly difficult area of study, but one which will be important for protecting whales during transits between Alaska and Hawaii, is the determination of migration routes. Hawaii is the most isolated land mass on earth. How humpback whales navigate the expanses of open ocean presents an intriguing navigational problem. Identifying the navigational cues used by humpback whales and the routes they take may have important management implications. For example, if sound is used as a navigational cue, anthropogenic noise may impede effective location of the islands.

Behavioral Indices of Change: The research topics discussed previously have for the most part not addressed human impact directly. One method for assessing possible human influence would make use of relatively stable behavioral features as indices by which to assess change, i.e., a behavioral bioassay. Assessment of the impact of putatively harmful events has been quite difficult to accomplish because there is little in the behavioral record offering contrast, i.e., we do not know what is normal. Many types of behavior are highly variable, and therefore unlikely to be of much use to investigators looking for signs of disturbance. A search of the archival record plus studies of behavior, distribution, and abundance should be initiated to identify low variance characteristics that might be useful as behavioral indices of stress. In captive settings, behavioral changes are frequently early warning signs of later health problems. The search for indices can make use of data collected for other purposes, and therefore does not require additional field effort.

Whale song and related behavior offer possible sources for effective indices. Unlike brief surface episodes and periodic observations by divers, song can be monitored continuously. Although songs vary over time, certain characteristics might remain stable in undisturbed environments, e.g., distribution of emphases on certain frequencies, distance between singers, rate of change in various parameters. These characteristics can be investigated in conjunction with more general studies of humpback whale acoustic behavior.

Genetic and Physiological Studies: Two other topics that our group recognized as highly important were genetic and physiological studies. Genetic studies, used to assess relatedness, parentage, and stock discreteness, were addressed by the Population Assessment Working Group. Therefore, while we believe such studies should be pursued, they are not discussed further here.

With regard to physiological studies, we did not feel that we had the expertise to comment conclusively. However, in many mammals, reproductive and adrenal hormones as well as other aspects of blood chemistry are used as indicators of health, stress, reproductive status, and social role. In addition, various contaminants, such as organochlorines, are stored in fatty tissues. We suggest consulting with marine mammal physiologists to discuss the feasibility of meaningful assessment of blood and blubber chemistry in free-ranging or stranded whales.

General Recommendations: A number of additional topics and recommendations were discussed by the working group. Some of these were outside the specific scope of our charter. However, we believe the following recommendations will be useful to Sanctuary managers.

Hawaiian Islands Stranding Network: It is possible that valuable information is being lost because tissue relevant to life history and other types of analyses are not being systemically collected from stranded animals. Therefore, a review should be conducted to assess, and provide suggestions on ways to improve, the marine mammal stranding network in the Hawaiian Islands. The review, perhaps in the form of a workshop and workshop report or a contractor's report, should (a) identify for researchers and the public the organization(s) that should be contacted in a stranding event; (b) identify what actions should be taken in a stranding event; (c) describe the types of tissue that should be collected; and (d) identify the locations and affiliations of investigators interested in cooperative analysis of data collected from stranded animals. Efforts should be made to ensure that the network extends to all Hawaiian Islands.

Availability of Data Held by Federal Agencies: The Sanctuary should help to improve the availability of federally held data (e.g., NOAA satellite data) that might be useful in humpback whale studies (also see working group II report).

Decision-Making and Communication Channels: It was not clear to members of the working group how scientific information gets to, or is used by, decision-makers. Therefore, the group recommended that the Sanctuary prepare, or have prepared, a report on the ways in which biological data make their way to decision-makers, the types of information that are important to the decision-making process, and how scientific information is used to make decisions. The report should provide recommendations on ways to improve channels of communication (see working group III report).

Coordination Among Humpback Whale Researchers: Communication among researchers facilitates collaboration, allows the various researchers to avoid duplication of research, and promotes cooperation when related studies are being conducted. The group recommends that the Sanctuary examine the mechanisms of information exchange among researchers and suggest ways to improve communication among researchers and between researchers and federal agency personnel (see working group IV report).

Scientific Advisory Board: There is a need for independent review of activities within the Sanctuary. The Sanctuary should establish an independent scientific advisory board that reports to the Sanctuary manager, assesses research and other human activities, and provides recommendations on information needed (see working group IV report).

REPORT OF WORKING GROUP IV - MANAGEMENT NEEDS AND RECOVERY PLAN IMPLEMENTATION

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Introduction: This group discussed various management needs as they relate to humpback whales in their Hawaiian habitat. Discussions centered on the management of the Hawaiian Islands Humpback Whale National Marine Sanctuary, implementation of the NMFS Humpback Whale Recovery Plan, and other areas of concern to group participants. The group collectively decided to focus management strategies in the following four topic areas: (1) education, (2) research, (3) enforcement and (4) adminstration and management, including regulation.

At the present time, there is not enough information to indicate that any natural or human-induced impacts are occurring in Hawaii that are a detriment to the recovery of the humpack whale. However, there are indications that problems could potentially arise as the population of whales grows, and as their range in Hawaii expands, and as human uses of ocean and coastal areas associated with whales increases.

Management Goals Identified by Working Group IV: Management goals were stated as follows:

- Ensure the recovery and continual protection of humpback whales and their habitat in Hawaiian waters, while allowing for compatible economic, recreational, traditional, and educational activities afforded by the whale's seasonal wintering in these waters.

- Identify and minimize impacts to the humpback whale (see working group II report).

- Develop partnerships and improve coordination between Federal, State, County agencies and Non-Government organizations (see working group III report).

- Increase the benefits of Sanctuary and humpback whale management policies and actions for the people of Hawaii,

- Work with the local community to formulate and implement management programs.

- Improve administration and coordination of the overall recovery effort for this species.

Educational Goals Identified by Working Group IV: In order to avoid and help mitigate adverse impacts to the humpback whale and its habitat and to enhance the public's appreciation of them, we suggest the following recommendations in support of educational efforts:

A. Disseminate basic information on the natural history of the humpback whale and the regulations protecting them to visitors and hawaiian residents

<u>Implementing Actions</u>:

- Assist the visitor industry and government agencies in enhancing educational and outreach about the humpback whale and efforts to protect it.

- Enhance recreational value of whale watching activities through interpretive education programs and materials.

- Inform visitors and residents of regulations that protect the humpback whale and its habitat, and the purpose of these regulations. Include in educational materials, programs and workshops reasons why the humpback whale should be protected (e.g., it is an endangered species and without assistance from us it may not recover, etc.), and that it has an economic value to Hawaii as a tourist attraction.

- Standardize existing programs as to content and accuracy and offer certification through the Sanctuary Program.

- Create an information certification program to standardize and assure accuracy of information in curriculum development about the humpback whale.

- Integrate, coordinate and facilitate the existing educational efforts (including curriculum development) by non-Governmental organizations, County and State governments, and other agencies regarding the humpback whale.

- Ensure that the visitor industry information about whales is at least bilingual (Japanese/English), and perhaps multilingual where possible.

B. Enhance the utilization of research findings by agencies for management, enforcement, education, and planning

Implementing Actions:

- Initiate or support training workshops for various agency personnel that incorporate latest research findings of humpback whales.

- Create an archival repository and reference center for research results and educational materials associated with the humpback whale.

- Transfer knowledge gained from significant findings on current whale research for dissemination to interested agency personnel.

Research Goals Identified by Working Group IV: There is a need to direct more research towards meeting management objectives by:

A. Assemble what is known about the humpback whale and its habitat

Implementing Actions:

- Characteristics, bibliographic references, reseach institutions, principle investigators, research results

- Summarize existing research results.

- Summarize long-term research efforts and determine which areas need additional long-term research studies.

B. Develop a comprehensive long-term monitoring program with committment level of funding to fill knowledge gaps and to address management related issues related to the Humpback whale and its habitat.

Implementing Actions:

- Coordinate research to develop a baseline study of all land and water activities that may or potentially impact the humpback whale (vessel traffic, point and non-point source pollution, ambient noise, whale-watching operations, recreation and water activities) (see working group II and III reports).

- Determine what characteristics of the marine environment are important for humpback whales (corals, substrate, etc.) (see working groups II and III reports).

- Monitor population and life history of whales to determine long-term cumulative effects of potential human-related impacts (see working group II and III reports).

- Determine whether increasing vessel traffic and the associated increase in ambient noise adversely impacts the whale's fitness, vital rates and ultimate population recovery (see working group II and III reports).

- Encourage the collection of baseline acoustic signature profiles of Hawaii's marine environment and determine the relationship between various acoustic noises and whale behaviors (see working group II and III reports).

- Measure the ambient noise levels at whale relative to surrounding levels to determine if whales are avoiding areas with certain noise levels.

- Formulate and model a long-term whale-watching and whale population dynamic interaction scenario to ascertain whether, and at what level, limitations on the number of whale watching vessels might eventually be required (see working group II and III reports).

- Continue photo-identification of whales to increase the proportion of "tags" in the popululation, while structuring the research design to account for the known difference in behavior of whales in Hawaii and those in Alaska that affects recapture probabilities and unbiased estimates of population abundance and vital rates (see working group I reports).

- Develop an assessment program to improve low recapture/resighting rate (see working group I and III reports).

- Determine movements of whales within Hawaiian Islands using satellite-tagging or other technologies (see working group I and III reports).

C. Increase benefits of research activities for Hawaii's people

<u>Implementing</u> <u>Actions</u>:

- Provide opportunities for local residents to participate in humpback whale research in Hawaii and to learn more about whale research activities in Hawaii and elsewhere.

●Encourage further development of internship programs involving Hawaii's residents to fulfill research and management objectives.

D. Encourage coordination and collaboration with local and regional research teams and individuals, and local residents.

Implementing Actions:

●Encourage and facilitate all research efforts. However, direct Sanctuary and NMFS-funded research to answer management-related questions.

Enforcement Goals Identified by Working Group IV: There is a need to increase the effectiveness of enforcement of existing rules and regulations in a multi-pronged approach.

A. Coordinate interagency efforts

Implementing Actions:

●Establish a review panel for regulations and laws under law enforcement jurisdiction (e.g., MMPA and ESA vs. state, city and county laws).

●Expand and develop more comprehensive interpretive-enforcement programs that establish close linkages with education.

●Investigate the feasibility of a volunteer interpretive enforcement program and volunteer office administrative support program.

Develop a statewide enforcement action plan for MMPA and ESA programs.

Standardize training and education materials within law enforcement agencies

Implementing Actions: Secure funding for research and education

Expand enforcement efforts to statewide and ensure that enforcement is consistent throughout the state

Develop process/mechanism for enforcement personnel to obtain and distribute resource management and educational material (signage at boat ramps, pamphlets, etc.), particularly to the visitor industry, the major source of non-compliance problems.

Expand enforcement personnel to all islands statewide and at all levels of government

Implementing Actions: Consider cross-deputation, increase hiring, usage of reserve officers, volunteer observers, expand usage of outside assets (e.g., USCG planes, vessels, helicopters; DOD assets such as airforce and navy crafts, etc.).

Identify a liaison office to coordinate all activities (enforcement and education operations) between all levels involved, including interaction with the media.

ADMINISTRATION/MANAGEMENT/REGULATION Goals Identified by Working Group IV: There is a need to establish institutional arrangements linking affected government agencies and the public

Direct research programs toward management objectives.

Focus initial education and encourage risk-averse management regarding humpback whales.

Base regulations on the results of research programs

Implementing Actions: Identify specific management needs and formulate regulations after analyzing the available surveys/research studies and monitoring data.

Seek strong linkage between regulation and enforcement. Any regulations devised must be implemented and enforceable.

Evaluate the impacts of proposed management policies and actions on the people of Hawaii.

Implementing Action: Formulate Sanctuary managment which involves community input, should include all islands and user groups in the Sanctuary Advisory Council, and avoid an overly bureaucratic system.

LITERATURE CITED

LITERATURE CITED

Allen, K.R. 1974. Recruitment to whale stocks. pp. 352-358. In: W. E. Schevill, W.E (Ed.), The Whale Problem: a status report. Harvard University Press, Cambridge.

Allen, K.R. 1980. Conservation and Management of Whales. University of Washington, Seattle, 107 p.

Anderson, A.L. and G.J. Gruber. 1971. Ambient-noise measurements at 30, 90 and 150 kHz in five ports. J. Acoustical Soc. America 49: 928.

Baker, C.S., and Herman, L.M. 1981. Migration and local movement of humpback whales (Megaptera novaeangliae) through Hawaiian waters. Can. Zool. 59: 460-469.

Baker, C.S., L.M. Herman, B.G. Bays and W.S. Stifel. 1982. The impact of vessel traffic on the behavior of humpback whales in southeast Alaska: 1981 season. Final Report to the National Marine Fisheries Service, Contract No. 80-ABC-00114.

Baker, S.C. and L.M. Herman. 1984. Aggressive behavior between humpback whales, Megaptera novaeangliae, wintering in Hawaiian waters. Can. J. Zoology 62: 1922.

Baker, C. S. 1985. The population structure and social organization of humpback whales (Megaptera novaeagliae) in the central and eastern North Pacific. PhD. dissertation, University of Hawaii, Honolulu.

Baker, C.S., L.M. Herman, A. Perry, W.S. Lawton, J. M. Straley, A.A. Wolman, G. D. Kaufman, H. E. Winn, J. D. Hall, J. M. Reinke and J. Ostegman. 1986. Migratory movement and population structure of humpback whales (Megaptera novaeangliae) in the central and eastern North Pacific. Marine Ecol. Progress Series 31:105-119.

Baker, C.S., A. Perry and L.M. Herman. 1987. Reproductive histories of female humpback whales, Meqaptera novaeangliae, in the North Pacific. Mar. Ecol. Prog. Ser. 41: 103-14.

Baker, C. S. and L. M. Herman. 1987. Alternative population estimates of humpback whales (Megaptera novaeangliae) in Hawaiian waters. Canadian J. Zoology 65: 2818-2821.

Baker, C. S. and L. M. Herman. 1989. Behavioral responses of summering humpback whales to vessel traffic: experimental and opportunistic observations. Tech. Report NPS-NR-TRS-89-01.

Baker, C.S., and L.M. Herman. 1989. The behavioral responses of summering humpback whales to vessel traffic: Experimental and opportunistic observations. Kewalo Basin Marine Mammal Laboratory, Final Report June, 1989.

Baker, C.S., J.M. Straley and A. Perry. 1990. Population Characteristics of Humpback Whales in Southeastern Alaska: Summer and Late-Season 1986. Final Report. Marine Mammal Commission., PB90-252487, 23 p.

Baker, C.S., S.R. Palumbi, R.H. Lambertson, M T. Weinrich, J. Calambokidis and S J. O'Brien. 1990. Influence of seasonal migration on geographic distribution of mitochondrial DNA haplotypes in humpback whales. Nature (London) 344: 238-240.

Baker, C S., J.M. Straley and A. Perry. 1992. Population characteristics of individually identified humpback whales in southeastern Alaska: summer and fall 1986. Fisheries Bull. 90: 429-437.

Baker, C.S., D.A. Gilbert, M.T. Weinrich, R. Lambertsen, J. Calambokidis, B. McArdle, G.K. Chambers and S.J. O'Brien. 1993. Population characteristics of DNA fingerprints in humpback whales (Megaptera novaeangliae). J. of Heredity 84: 281-290.

Baker, C.S., R.B. Slade, J.L. Bannister, R.B. Abernethy, M.T. Weinrich, J. Lien, J. Urbán-R., P. Corkeron, J. Calambokidis, 0. Vasquez and S. R. Palumbi. 1994. Hierarchical structure of mitochondrial DNA gene flow among humpback whales, world-wide. Molecular Ecol. 3: 313-327.

Barlow, J., Oliver, C.W., Jackson, T.D. and Taylor, B.L. 1988. Harbor porpoise, Phocoena phocoena, abundance estimation for California, Oregon and Washington: II. Aerial surveys. Fishery Bull. 86: 433-444.

Bauer, G.B. 1986. The behavior of humpback whales in Hawaii and modification of behavior induced by human interventions. Ph.D. dissertation, Univ. of

Hawaii, Honolulu.

Bauer, G. B. and L. M. Hennan. 1986. Effects of vessel traffic on the behavior of humpback whales in Hawaii. Contract Report to National Marine Fisheries Service, Honolulu, Hawaii.

Begon, M. 1979. Investigating animal abundance: capture-recapture for biologists. University Park Press, Baltimore, MD.

Berzin, A.A. and A.A. Rovnin. 1966. The distribution and migrations of whales in the northeastern part of the Pacific, Chuckchee and Bering Seas. In K.I. Panin (Ed.), Soviet Research on Marine Mammals in the Far East, p. 179-207.

Bourke, R.H. and A.R. Parsons. 1993. Ambient noise characteristics of the northwestern Barents Sea. J. Acoustical Soc. America 94: 2799-2808.

Braham, H.W. 1984. The status of endangered whales: an overview. Mar. Fish. Rev. 46: 2-6.

Buckland, S. T., D. R. Anderson, K. P. Burnham and J. L. Laake. 1993. Distance sampling: Estimating abundance of biological populations. New York: Chapman and Hall.

Burnham, K.P., D.R. Anderson and J.L. Laake. 1980. Estimation of density from line transect sampling of biological populations. Wildlife Monograph, No. 72.

Calambokidis, J., G.H. Steiger, J.C. Cubbage, K.C. Balcomb and P. Bloedel. 1989. Biology of humpback whales in the Gulf of the Farallones. Final report to Gulf of the Farallones National Marine Sanctuary, San Francisco, California, 93p.

Calambokidis, J., J.C. Cubbage, G.H. Steiger, K.C. Balcomb and P. Bloedel. 1990. Population estimates of humpback whales in the Gulf of the Farallones, California. Rept. International Whaling Commn (Special Issue 12): 325-333.

Calambokidis, J., J.R. Evenson and J.C. Cubbage. 1993. Calibration of sighting rates of harbor porpoise from aerial surveys. Final Report, Contract No.

43ABNF202319, to National Marine Mammal Laboratory, National Marine Fisheries Service, Seattle, Washington.

Calambokidis, J., G. H. Steiger and J. R. Evenson. 1993. Photographic identification and abundance estimates of humpback whales off California in 1991-92. Final Report, Contract No. 50ABNF110137, to the Southwest Fisheries Science Center, National Marine Fisheries Service, La Jolla, California, 67p.

Calambokidis, J. and G.H. Steiger. 1995. Population estimates of humpback and blue whales made through photo-identification from 1993 surveys off California. Report to Southwest Fisheries Science Center, National Marine Fisheries Service, LaJolla, California, 36p.

Calambokidis, J., G.H. Steiger, J.R. Evenson, K.R. Flynn, K.C. Balcomb, D.E Claridge, P. Bloedel, J.M. Straley, C.S. Baker, 0. von Ziegesar, M.E. Dahlheim, J.M. Waite, J.D. Darling, G. Ellis, and G.A. Green. In press. Interchange and isolation of humpback whales off California and other North Pacific feeding grounds. Marine Mammal Science.

Carlson, C.A., C. A. Mayo and H. Whitehead 1990. Changes in the ventral fluke pattern of the humpback whale (Megaptera novaeangliae), and its effect on matching; evaluation of its significance to photo-identification research. Rept. Int. Whaling Commn (Special Issue 12): 105-111.

Cerchio, S. 1994. Estimates of humpback whale (Megaptera novaeangliae) abundance off Kauai, Hawaii using mark-recapture techniques. Draft Report to NOAA, Sanctuaries and Reserves Division. 40 pp.

Cerchio, S., C. M. Gabriele and A.S. Frankel. 1991. Inter-island movements of humpback whales in the Hawaiian Islands: three seasons off Hawaii and Kauai. Proc. Biennial Conf. Biology of Marine Mammals (Abstract), Chicago, Illinois.

Cerchio, S., C. M. Gabriele, and L.M. Herman, 1994. Movements of humpback whales between Kauai and Hawaii, 1989-1991: implications on population structure and abundance estimation in the Hawaiian Islands. Draft Report to NOAA, Sanctuaries and Reserves Division.

Chittleborough, R.G. 1954. Studies on the ovaries of the humpback whale, Megaptera nodosa (Bonnaterre), on the western Australian coast. Aust. J. Mar. Freshw. Res. 5: 35-63.

Chittleborough, R.G. 1955. Aspects of reproduction in the male humpback whale, Megaptera nodosa (Bonnaterre). Aust. J. Mar. Freshw. Res. 6: 1-29.

Chittleborough, R.G. 1958. The breeding cycle of the female humpback whale,
Megaptera nodosa (Bonnaterre). Aust. **J.** Mar. Freshw. Res. 6: 3-29.

Chittleborough, R. G. 1959. Determination of age in the humpback whale, Megaptera nodosa (Bonnaterre). Aust. J. Mar. Freshw. Res. 10: 125-43.

Chittleborough, R.G. 1965. Dynamics of two populations of the humpback whale, Megaptera novaeangliae, (Borowski). Aust. J. Mar. Freshw. Res. 16: 33@128.

Clapham, P.J., L.S. Baraff, C.A. Carlson, M.A. Christian, D.K. Mattila, C.A. Mayo, M.A. Murphy and S.Pittman. 1992a. Seasonal occurrence and return of humpback whales Megaptera novaeangliae, in the southern Gulf of Maine. Can. J. Zoology 71: 440-443.

Clapham , P.J., P.J. Parsboll, D.K. Mattila and 0. Vasquez. 1992b. Composition and dynamics of humpback whale cometitive groups in the West Indies. Behavior 122: 182-194.

Clapham, P.J. 1993. Social organization of humpback whales on a North Atlantic feeding ground. Symp. Zool. Soc. London 66: 131-145.

Clapham, P. J. 1994. Maturational changes in patterns of association in male and female humpback whales, Megaptera novaeangliae., J. Zool. Soc. London 234: 265-274.

Clapham, P.J. and C.A. Mayo. 1987a. Reproduction and recruitment of individually identified humpback whales, Megaptera novaeangliae, observed in Massachusetts Bay, 1979-1985. Can. J. Zool. 65: 2853-2863.

Clapham, P.J. and C.A. Mayo. 1987b. The attaimnent of sexual maturity in two female humpback whales. Mar. Mamm. Sci. 3: 279-83.

Clapham, P.J. and C.A. Mayo. 1990. Reproduction of humpback whales (Megaptera novaeangliae) observed in the Gulf of Maine. In P. Hammond, S. Mizroch, and G. Donovan (Eds.), p. 171-176, Rept. Int. Whal. Comirym (Special Issue 12).

Clapham, P.J., D.K. Mattila and P.J. Palsboll. 1993. High-latitude-area composition of humpback whale competitive groups in Samana Bay: further evidence for parunixis in the North Atlantic population. Can. J. Zoology 71: 1065-1066.

Corkeron, P.J., M. Brown, R. Slade and M. Bryden. 1994. Humpback whales, Megaptera novaeangliae (Cetacea: Balaenopteridae), in Hervey Bay, Queensland.

Dahlheim, M. E. and J. M. Waite. 1993. Abundance and distribution of killer whales (Orcinus orca) in Alaska, 1992. Laboratory Report, National Marine Mammal Laboratory, National Marine Fisheries Service, Seattle, Washington, 32p.

Darling, J. 1983. Migrations, Abundance and Behavior of Hawaiian Humpback Whales Megaptera novaeangliae (Borowski). PhD dissertation, University of California, Santa Cruz, California.

Darling, J.D., K.M. Gibson, G.K. Silber. 1983. Observation on the abundance and behavior of humpback whales, Megaptera novaeangliae, off West Maui, Hawaii, 1977-79. In R. Payne (Ed.) Communication and Behavior of Whales, p. 210-222, Amer. Acad. Advance. Sci., Symposia Series. Westview Press, Boulder, 643 p.

Darling, J.D. and C.M. Jurasz. 1983. Migratory destinations of North Pacific humpback whales (Megaptera novaeangliae). In R. Payne (Ed.), Communication and behavior of whales, p. 359-368, Amer. Acad. Advance. Sci., Symposia Series. Westview Press, Boulder, Colorado, 643 p.

Darling, J.D. and D.J. McSweeney. 1985. Observations on the migrations of North Pacific humpback whales (Megaptera novaeangliae). Can. J. Zoology 63: 308-314.

Darling, J.D., and Morowitz, H. 1986. Census of "Hawaiian" humpback whales (Megaptera novaeangliae) by individual identification. Can. J. Zool. 64: 105-111.

Darling, J.D, and K.Mori. 1993. Recent observations of humpback whales (Megaptera novaeangliae) in Japanese waters off Ogasawara and Okinawa. Can. J. Zoology 71: 325-333.

Darling J. D. and S. Cerchio. 1993. Movement of a humpback whale (Megaptera novaeangliae) between Japan and Hawaii. Mar. Mamm.Sci. 9: 84-89.

Dawbin, W.H. 1966. The seasonal migratory cycle of humpback whales. In :K. Norris (Ed.), Whales, Dolphins, and Porpoises, p. 145-170, University of California Press, Berkeley. 789 p.

Forestell, P.H. 1985. Assessment and verification of abundance estimates, seasonal trends, and population characteristics of the humpback whale in Hawaii. Interim Report to Marine Mammal Commn..

Forestell, P. H. 1989. Assessment and verification of abundance estimates, seasonal trends, and population characteristics of the humpback whale in Hawaii. Final Report to the Marine Mammal Commn., Washington, D.C., Available as NTIS Publication PB90-190273, Springfield, Virginia. 66 p.

Forestell, P.H. and J.R. Mobley, Jr. 1991. Humpback whale aerial survey through the major Hawaiian Islands during the 1991 season. Report to the National Marine Fisheries Service, December 1991.

Forney, K.A., J. Barlow and J.V. Carretta. 1995. The abundance of cetaceans in California waters. Part II: aerial surveys in winter and spring of 1991 and 1992. Fisheries Bull. 93: 15-26.

Frankel, A.S. 1994. PhD dissertation, University of Hawaii at Manoa, Honolului.

Gabriele, C.M. 1991. Population characteristics of humpback whales in Glacier Bay and adjacent waters: 1991. Report to the National Park Service, Glacier Bay National Part, Gustavus, Alaska. 24 p.

Gabriele, C.M. 1992. The behavior and residence characteristics of reproductive classes of humpback whales (Megaptera novaeangliae) in the Hawaiian Islands. M.S. thesis, University of Hawaii, Honolulu, Hawaii. 99 P.

Gabriele, C. M. 1994. Population characteristics of humpback whales in Glacier Bay and adjacent waters: 1994. Report to the National Park Service, Glacier Bay National Park, Gustavus, Alaska. 20 p.

Gabriele, C.M., J.M. Straley, L.M. Herman, and R.J. Coleman. In press. Fastest documented migration of a North Pacific humpback whale. Mar. Mamm. Sci.

Gambell, R. 1976. World whale stocks. Mammal Rev. 6: 41-53.

Gerrodette and D. DeMaster. 1990. Mar. Mamm. Sci. 6: 1-16.

Glockner, D.A. 1978. The humpback whale, Megaptera novaeangliae; Underwater with mothers and calves. Waters: J. Vancouver Aquar. 3: 19-25, Vancouver, British Columbia, Canada.

Glockner, D.A. 1983. Determining the sex of humpback whales, Megaptera novaeangliae , in their natural environment. In R. Payne (Ed.), Communication and Behavior of Whales, p.447-64, Amer. Acad. Advance. Sci., Symposia Series. Westview Press, Boulder, Colorado, 643 p.

Glockner, D.A. and S.C. Venus. 1983. Identification, growth rate, and behavior of humpback whale, Megaptera novaeangliae, cows and calves in the waters off Maui, Hawaii, 1977-79. In R. Payne (Ed.), Communication and Behavior of Whales, p. 223-58, Amer. Acad. Advance. Sci., Symposia Series. Westview Press, Boulder, Colorado, 643 p.

Glockner-Ferrari, D.A. and M.J. Ferrari. 1984. Reproduction in humpback whales, Megaptera novaeangliae, in Hawaiian waters. In W.F. Perrin, R.L. Brownell, Jr., and D.P. DeMaster (Eds.), Rept Int. Whal. Comtnn (Special Issue 6), p. 237-242, Cambridge, United Kingdom.

Glockner-Feffari, D.A. and M.J. Ferrari. 1985. Individual identification, behavior, reproduction, and distribution of humpback whales, Megaptera novaeangliae, in Hawaii. Final Report to the Mar. Mamm. Commn., available as NTIS, Report No. PB85-200772, Springfield, Virginia. 36 p.

Glockner-Ferrari, D.A. and M.J. Ferrari. 1987. Identification, reproduction, and distribution of humpback Laboratory, National Marine Fisheries Service, Seattle, Washington. 33 p.

Glockner-Ferrari, D.A., M.J. Ferrari and D.J. McSweeney. 1987. Occurrence of abnormalities, injuries, and strandings of humpback whales in Hawaiian waters (Abstract). Proc. Seventh Biennial Conf. Biology of Marine Mammals, Miami, December 1987.

Glockner-Feffari, D.A. and M. J. Ferrari. 1990. Reproduction in the humpback whale (Megaptera novaeangliae) in Hawaiian waters, 1975-1988: the life history, reproductive rates, and behavior of known individuals identified through surface and underwater photography. In P. Hammond, S. Mizroch, and G. Donovan (Eds.), Rept Int. Whal. Commn. (Special Issue 12), p.

161-170, Cambridge, United Kingdom.

Glockner-Ferrari, D.A., M.J. Ferrari and S. Atkinson. 1993. Reproductive physiology and calving intervals of humpback whales based on mucous secretion and observational data. Proc. Tenth Biennial Conf. Biol. Marine Mammals (Abstract), Galveston, November 1993.

Green, M. L. and R. G. Green. 1990. Short-term impact of vessel traffic on the Hawaiian humpback whale (Megaptera novaeangliae). Proc. Ann. Meeting Animal Behavior Soc., June, 1990, State Univ. New York, Buffalo, New York.

Hammond, P. S. 1986. Estimating the size of naturally marked whale populations using capture recapture techniques. In Behavior of Whales in Relation to Management. (Eds.) G. P. Donovan. Rep. Int. Whal. Commn. Spec. Issue No. 8, p. 253-282.

Hammond, P. S. 1990. Heterogeneity in the Gulf of Maine? Estimating humpback whale population size when capture probabilities are not equal. In Individual Recognition of Cetaceans: use of Photo-identification and Other Techniques to Estimate Population Parameters. (Eds.) P. S. Hammond, S. A. Mizroch, and G.P. Donovan Rep. Int. Whaling Commn. Spec. Issue No.12. pp. 325-333.

Herman, L.M. and R.C. Antinoja. 1977. Humpback whales in Hawaiian waters: population and pod characteristics. Sci. Rept. Whales Res. Inst., Tokyo, 29: 59-85.

Herman, L.M., P.H. Forestell and R.C. Antinoia. 1980. The 1976/77 migration of humpback whales into Hawaiian waters: Composite description. Contract No. MMC-77/19, Marine Mannnal Commission, Washington, D. C.

Ingenito, F. and S.N. Wolf. 1989. Site dependence of wind-dominated ambient noise in shallow water. J. Acoust Soc. America 85: 141-145.

Ivashin, M.V. and A.A. Rovnin. 1967. Some results of the Soviet whale marking in the waters of the North Pacifc. Norsk Hvalfangst-Tidende 57: 123-129.

Johnson, C. S. 1968. Relation between absolute threshold and duration of tone pulses in the bottlenosed porpoise. J. Acoustical Soc. America 43: 757-763

Jurasz, C. M. and V. P. Jurasz. 1979. Feeding modes of the humpback whale, Megaptera novaea, in southeastern Alaska. Sci. Rept. Whales Res. Inst.

31: 69-83.

Jurasz, C.M. and V.P. Palmer. 1981. Censusing and establishing age composition of humpback whales (Megaptera novaeangliae), employing photodocumentation in Glacier Bay National Monument, Alaska. Rept. to the National Park Service, Anchorage, Alaska. 44p.

Katona, S., S. Baxter, 0. Brazer, S. Kraus, J. Perkins and H. Whitehead. 1979. Identification of humpback whales by fluke photographs. In H.E. Winn and B.L. Olla (Eds.), Behavior of Marine Animals - Current Perspectives in Research, Vol. 3 Cetaceans. Plenum Press, New York.

Katona, S.K. 1986. Biogeography of the humpback whale, Megaptera novaea , in the North Atlantic. In Pelagic biogeography, Proc. UNESCO International Conf., p. 166-171, May 29 May- June 5, 1985, Netherlands.

Katona, S.K. and J.A. Beard. 1990. Population size, migrations and feeding aggregations of the humpback whale (Megaptera novaeangliae) in the western North Atlantic Ocean. In P. Hammond, S. Mizroch, and G. Donovan, (Eds.), Rep. Int. Whal.Commn (Special Issue 12), p. 295-306, Cambridge, United Kingdom. 440 p.

Katona, S. K. and J. A. Beard. 1990. Population size, migrations and feeding aggregations of the humpback whale (Megaptera novaeangliae) in the western North Atlantic. Rept. Int. Whal. Commn (Special Issue 12): 295-305.

Kellogg, R. 1928. What is known about the migrations of some of the whalebone whales. In Annual Report of the Smithsonian Institution, p. 467-94.Washington D.C.

Kibblewhite, A. C., J. A. Shooter and S. L. Watkins. 1976. Examination of attenuation at very low frequencies using the deepwater ambient noise field.J.Acoustical Soc. America 60: 1040.

Kolaini, A.R. and L.A. Crum. 1994. Observations of underwater sound from laboratory breaking waves and the implications concerning ambient noise in the ocean. J. Acoustical Soc. America 96: 1755-1765.

Johnson, J.H. and A.A. Wolman. 1984. The humpback whale, Megaptera novaeangliae Mar. Fisheries Rev. 46: 30-37.

Larsen, A.H., P.J. Palsbfll, N. Fien, G. Vikingsson, and J. Sigurjonsson. 1994. Analysis of the mitochondrial control region of Norwegian and Icelandic humpback whales (Meagptera novaeangliae). Proc. International Symp. on Marine Manimal Genetics (Abstract), La Jolla, California.

Lockyer, C. 1984. Review of baleen whale (Mysticeti) reproduction and implications for management. In W.F. Perrin, R.L. Brownell, Jr., and D.P. DeMaster (Eds.). Rep. Int. Whal. Commn (Special Issue 6), p. 27-50, Cambridge.

Malme, C.I., B. Wursig, J.E. Bird and P. Tyack. 1988. Observations of feeding gray whale responses to controlled industrial noise exposure. In: Sackinger WM, Jeffries MO (eds) Port and Ocean Engineering under Arctic Conditions, The Geophysical Institute, Fairbanks, AK. p 55-73

Malme. C. I. 1990. Prediction of potential disturbance of baleen whales by low frequency acoustic transients. Report No. 1059, June 1990, by Bolt, Beranek and Newmann, Inc., Cambridge, Massachusetts.

Matthews, L.H. 1937. The humpback whale, Megagptera nodosa. Discovery Rept.17: 7- 92 + 1 plate.

Mattila, D.K. and P.J. Clapham 1988. Humpback whales, Megaptera novaeangliae , and other cetaceans on Virgin Bank and in the northern Leeward Islands, 1985 and 1986. Can. J. Zoology 67: 201-2211.

Mattila, D.K., P.J. Clapham, 0. Vasquez, R.S. Bowman 1994. Occurrence, population composition and habitat use of humpback whales in Samana Bay, Dominican Republic. Can. Journal of Zoology 72: 1989-1907.

Mattila, D.K., P. J. Clapham, S. K. Katona and G. S. Stone. 1989. Population composition of humpback whales, Megaptera novaeangliae, on Silver Bank, 1984. Can. J. Zoology 67: 281-285.

Medrano, L., J. Urbán and C. S. Baker. 1995. Short and long terrn population structure of humpback whales in the eastern North Pacific: the definition of management units and evolutionary significant units revisited. In XX Reunion Internacional para el Estudio de los Mamiferos Marinos, 18-22 April 1995, p. 35, La Paz, Mexico.

Miles, P.R., C.I. Malme, W.J. Richardson. 1987. Prediction of drilling site-specific interaction of industrial acoustic stimuli and endangered whales in the Alaskan Beaufort Sea. Bolt, Beranek and Newman, Final Report No. 6509, Cambridge, Massachusetts.

Mitchell, E. 1973. Draft report on humpback whales taken under special scientific permit by Eastern Canadian land stations, 1969-1971. Rept. Int. Whal. Commn. 23: 138-154.

Mizroch, S.A. 1981. Analyses of some biological parameters of the Antarctic fin whale (Balaenoptera acutorostrata). Rept. Int. Whal. Commn. 31: 425-34.

Mizroch, S., J. Beard, J. and M. Lynde. 1990. Computer assisted photo-identification of humpback whales. In P. Hammond, S. Mizroch, and G. Donovan (Eds.) Rept. Int. Whal. Commn (Special Issue 12), p. 66-73, Cambridge, United Kingdom. 440 p.

Mobley J.R. and L.M. Herman. 1985. Transience of social affiliations among humpback whales (Megaptera novaeangliae) on the Hawaiian wintering grounds. Can. J. Zoology 63: 762-772.

Mobley, J. R., G. B. Bauer and L. M. Herman. 1990. Changes in distribution of Hawaiian humpback whales. Presented at the Annual Meeting of the Marine Mammal Commission, March, 1990, Honolulu, Hawaii.

Mobley, J.R. and G.B. Bauer. 1991). State-wide aerial surveys of "Hawaiian" humpback whales (Megaptera novaeangliae). Final Report to University of Hawaii Sea Grant College Program, July, 1991, Sea Grant Publication UNIHI-SEAGRANT-JC-91-01.

Mobley, J.R., P.H. Forestell and R. Grotefendt. 1994. Results of 1993 aerial surveys in Hawaiian waters. In A. Bowles (Ed.), 1993 Annual Report, ATOC Marine Mammal Research Program. 39 p.

Myrberg, A.A. 1990. The effects of man-made noise on the behavior of marine animals. Env Int 16: 575-586.

National Marine Fisheries Service. 1991. Final Recovery Plan for the Humpback Whale (Megaptera novaeangliae). Prepared by the Humpback Whale Recovery Team for the National Marine Fisheries Service, Silver Spring, Maryland. 105 p.

Nemoto, T. 1964. School of baleen whales in the feeding areas. Sci. Rept. Whales Res.Inst. Tokyo 18: 89-110.

Nishiwaki, M. 1959. Humpback whales in Ryukyuan waters. Sci. Rept.Whales Res. Inst. Tokyo 14: 49-87.

Nishiwaki, M. 1962. Ryukyuan whaling in 1962. Sci. Rept.Whales Res. Inst Tokyo 16: 19-28.

Nishiwaki, M. 1966. Distribution and migration of the larger cetaceans in the North Pacific as shown by Japanese whaling results. In K. S. Norris (Ed.), Whales, Dolphins, and Porpoises, p. 171-191. University of California Press, Berkeley.

Nitta E.T. and J.J. Naughton. 1989. Species Profiles: Life Histories and Environmental Requirements of Coastal Vertebrates and Invertebrates, Pacific Ocean Region; Report 2, Humpback Whale, Megaptera novaeangliae. Technical Report EL-89- 10, prepared by NMFS, NOAA, Honolulu, HI for the US Army Engineer Waterways Experiment Station, Mississippi.

Norris, K. S. and R. R. Reeves. 1978. Report on a workshop on problems related to humpback whales (Megaptera novaeangliae) in Hawaii. Report to the Marine Mammal Commission, Washington, D.C. Available as NIS PB-280 794, Springfield, Virginia.

Northrop, J. 1974. Detection of low-frequency underwater sounds from a submarine volcano in the Western Pacific. J. Acoust. Soc. America 56: 837-841.

Nystuen, J.A. and C.C. McGlothin. 1993. The underwater sound generated by heavy rainfall. J. Acoust. Soc. America 93: 3169-3177.

Ohsumi, S. and Y. Masaki. 1975. Japanese whale marking in the North Pacific, 1963-1972. Bull. Far Seas Fish. Res. 12: 171-219.

Omura, H. 1953. Biological study on humpback whales in the Antarctic whaling
Areas IV and V. Sci. Rept. Whales Res. Inst. Tokyo 8: 81-102. -

Omura, H. and S. Ohsumi. 1964. A review of Japanese whale marking in the North Pacific to the end of 1962, with some information on marking in the Antarctic. Norsk Hvalfangst-Tidende 4: 90-112.

Palsbfll, P.J., P.J. Clapham, D.K. Mattila, F. Larsen, R. Sears, H.R.Siegismund, J. Sigurjonsson, 0. Vasquez and P. Arctander. 1995. Distribution of mtDNA haplotypes in North Atlantic humpback whales: the influence of behavior on population structure. Mar. Ecol. Progr. Series 116: 1-10.

Palumbi, S.R. and C.S. Baker. 1994. Contrasting population structure from nuclear intron sequences and mtDNA of humpback whales. Molecular Biology and Evol. 11: 426-435.

Perry, A., C.S. Baker, and L.M. Herrnan. 1985. The natural history of humpback whales (Megaptera novaeangliae), in Glacier Bay. Final Report to the National Park Service, Alaska Regional Office, Anchorage, Alaska. 41 P.

Perry, A., J.R. Mobley, Jr., C.S. Baker, and L.M. Hennan. 1988. Humpback whales of the central and eastern North Pacific. University of Hawaii Sea Grant Miscellaneous Report UNIHI-SEAGRANT-MR-88-02, Honolulu, Hawaii.

Perry, A., J.R. Mobley, Jr., C.S. Baker and L.M. Hennan. 1988. Humpback whales of the central and eastern North Pacific. A catalog of individual identification photographs. University of Hawaii Sea Grant Program, Honolulu, Hawaii.

Perry, A., C. S. Baker, S.C., and L. M. Herman,. 1990. Population characteristics of individually identified humpback whales in the central and eastern North Pacific: a summary and critique. In P. Hammond, S. Mizroch, and G. Donovan (Eds.), Rep. Int. Whal.Commn. (Special Issue 12), p. 307-318, Cambridge, United Kingdom.

Rice, D. W. 1974. Whales and whale research in the eastern North Pacific. In W. E. Schevill, D. G. Ray, K. S. Norris (Eds.), The Whale Problem, p. 170-195, Harvard University Press, Cambridge, Massachusetts.

Rice, D.W. 1978. The humpback whale in the North Pacific: Distribution, exploitation, and numbers. In K.S. Norris and R.R. Reeves (Eds.), Report on a Workshop on Problems related to Humpback Whales, (Megaptera novaeangliae), in Hawaii, p. 29-44, Final Report to the Marine Mammal Commission, available as NTIS PB-280-274, Springfield, Virginia.

Rice, D.W. and A.A. Wolman. 1980. Census of humpback whales wintering around the Hawaiian Islands 1976-1979. Int. Whal. Commn, Report to the Scientific Advisory Committee, Document SC/31/38.

Richardson, W.J., M.A. Fraker, B. Wursig, R.S. Wells. 1985. Behaviour of Bowhead Whales (Balaena mysticetus) summering in the Beaufort Sea: Reactions to industrial activities. Biol. Conserv. 32: 195-230.

Richardson, W.J., C.R. Greene, W.R. Koski and M.A. Smultea. 1991a. Acoustic Effects of Oil production activates on bowhead and white whales visible during spring migration near Pt. Barrow, Alaska - 1990 Phase. Final Report No. TA848-5LGL, October, 1991, by LGL Ecological Research Associates, Ltd., Kingstown, Ontario.

Richardson, W.J., C.R. Greene, C.I. Malme and D.H. Thompson. 1991b. Effects of noise on marine mammals. Final Contract Report No.14-12-0001-30362 to the Minerals Management Service, No. MMS 90-0093, by LGL Ecological Research Associates, Ltd., Bryan, Texas.

Ross, D. 1993. On ocean underwater ambient noise. Acoust. Bull. 18: 5-8.

Scrimger, P. and R.M. Heitmeyer. 1991. Acoustic source-level measurements for a variety of merchant ships. J. Acoust. Soc. America 89: 691-699.

Shallenberger, E.W. 1981. The status of Hawaiian cetaceans. Final Contract No. MM7AC028 to the Marine Mammal Commission, Available NTIS, Contract No. PB82-109398, Springfield, Virginia. 79 p.

Smultea, M. 1994. Segregation by humpback whale (Megaptera novaeangliae) cows with a calf in coastal habitat near the island of Hawaii. Can. J. Zoology 72: 805-81 1.

Straley, J.M. 1990. Population characteristics of humpback whales in Glacier Bay and adjacent waters: Summer 1990. Report to the National Park Service, Glacier Bay National Park, Gustavus, Alaska. 20 p.

Straley, J. M. 1990. Fall and winter occurrence of humpback whales (Megaptera novaeangliae) in southeastern Alaska. Rept. Int. Whal. Commn, Special Issue 12: 319-323.

Straley, J.M. 1994. Seasonal characteristics of humpback whales (Megaptera novaeangliae) in southeastern Alaska. M.S. Thesis, University of Alaska, Fairbanks, Alaska. 121 p.

Straley, J. M., C. M. Gabriele and C. S. Baker. 1994. Annual reproduction by individually identified humpback whales (Megaptera novaeangliae) in Alaskan waters. Mar. Mamm. Sci.10: 87-92.

Steiger, G. H., J. Calambokidis, R. Sears, K. C. Balcomb, and J. C. Cubbage. 1991. Movement of humpback whales between California and Costa Rica. Mar. Mamm. Sci. 7: 306-310.

Terhune, J.M. 1988. Detection thresholds of a harbour seal to repeated underwater high-frequency, short-duration sinusoidal pulses. Can. J. Zool. 66:1578-1582.

Terhune, J.M. 1989. Underwater click hearing thresholds of a harbour seal, Phoca vitulina. Aquat. Mamm. 15: 22-26.

Tomilin, A.G. 1957. Zveri SSSR i Prilezhaschikh stran. Vol. IX. Kitoobraznye. (Mammals of the USSR and Adjacent Countries Vol. IX. Cetacea) Akad. Nauk. SSSR, Moscow (Translated by the Israel Program for Scientific Translations, Jerusalem, 1967). 717 p.

Tyack, P. and H. Whitehead. 1983. Male competition in large groups of wintering humpback whales. Behaviour. 83: 132-154.

Uchida, S., N. Higashi and A. Takemura. 1993. Preliminary report of humpback whale of Okinawa, Japan. Rept. Int. Marine Biol. Res. Inst. 4: 57-67, Kamogawa, Japan.

Urbán, J. and A. Aguayo. 1987. Spatial and seasonal distribution of the humpback whale, Megaptera novaeangliae, in the Mexican Pacific. Mar. Mamm. Sci. 3: 333-344.

Urbán, **J.,** K.C. Balcomb, C. Alvarez, P. Bloedel, **J.** Cubbage, **J.** Calambokidis, G. Steiger and A. Aguayo. 1987. Photo-identification matches of humpback whales (Megaptera novaeangliae) between Mexico and central California. Proc. Seventh Biennial Conference of the Biology of Marine Mammals

(Abstract), Miami, Florida.

Urick, R.J. 1983. Principles of Underwater Sound, 3rd Edn. McGraw-Hill Book Company, New York.

Urick, R.J. 1986. Ambient Noise in the Sea. Peninsula Publishing, Los Altos, California.

van Lennep, E. W. and W. L. van Utrecht, W. L. Preliminary report on the study of the mammary glands of whales. Norsk Hvalfangst Eid. 5: 249-258.

von Ziegesar, 0. and C. Matkin. 1989. A catalogue of Prince William Sound humpback whales identified by fluke photographs between the years 1977 and 1988. North Gulf Oceanic Society, Homer, Alaska.

Weinrich, M.T. 1991. Stable social asociations among humpback whales (Megaptera novaeangliae) in the southern Gulf of Maine. Can. J. Zoology 69: 3012-3018.

Weinrich, M.T. and A.E. Kuhlberg. 1991. Short-term association patterns of humpback whale (Megaptera novaeangliae) groups on their feeding grounds in the southern Gulf of Maine. Can. J. Zoology 69: 3005-3011.

Wenz, G.M. 1962. Acoustic Ambient noise in the ocean: spectra and sources. J. Acoust. Soc. America 34: 1936-1961.

Wilson, J.H. 1983. Distant stonn noise versus local wind noise at 165 Hz in the northeastern Pacific Ocean. J. Acoust. Soc. America 74: 1500.

Wilson, O.B., S.N. Wolf, F. Ingenito. 1982. Measurements of acoustic ambient noise in shallow water due to breaking surf. Naval Postgraduate School No. NPS 61-83-006.

Whitehead, H. 1983. Structure and stability of humpback whale groups off Newfoundland. Can. J. Zoology 61: 1391-1397.

Whitehead, H. and M.J. Moore, 1982. Distribution and movements of West Indian humpback whales in winter. Can. J. Zoology 60: 2203-221 1.

APPENDICES

Appendix I: Agenda for the Workshop to Assess Research and Other Needs and Opportunities Related to Humpback Whale Management in the Hawaiian Islands.

Wednesday, April 26

0830 Welcome - Review of Workshop Objectives and Agenda

PART I: SELECTED WORKSHOP PRESENTATIONS

A. An Overview of Biology and Life History Studies of the Humpback Whale in Hawaii and in the North Pacific

0850 Mobley, Jr., J.R., P.H. Forestell and R. Grotefendt. Preliminary Results of 1993 and 1995 Aerial Surveys of Hawaiian Waters

0910 Cerchio, Sal. An overview of humpback whale movements within Hawaiian waters

0930 Glockner-Ferrari, D. and M. Ferrari. Overview of the reproductive parameters of the North Pacific humpback whale based on long-term studies

0950 Calambokidis, John, J. Straley, S. Mizroch and S. Cerchio. An overview of the movements of humpback whales in the North Pacific and evaluation of stock structure

1010 Gabriele, Chris. Comparison of humpback whale group dynamics between Hawaii and Alaska

1030 BREAK

B. Potential Human Impacts and Mitigation

1050 Payne, P. Michael. An overview of threats identified in the Humpback Whale Recovery Plan

1110 Wiltse, Wendy. The Status of Hawaii's Water Quality - Point and Non-Point source Pollution

1130 Naughton, John. A review of winter breeding habitat characteristics

1150 Frankel, Adam. A review of the acoustic environment of humpback whales in Hawaiian waters

1210 Bauer, Gordon. An overview of the effects of vessel approaches on humpback whale behavior in Hawaii

1230 LUNCH

Matilla, David. An overview of Project YONAH (Year of North Atlantic Humpback Whale)

C. Agency Profiles: Activities, Responsibilities and Plans for Protecting Humpback Whales and Their Habitat in Hawaii

1330 Nitta, Gene. An overview of the responsibilities and activities of the National Marine Fisheries Service - section 7 consultations, approach regulations, and research

1350 Oishi, Francis. The role of the Hawaii Department of Land and Natural Resources, Division of Aquatic Resources

1410 Eisen, Tom. The role of the Environmental Protection Agency/Hawaii Department of Health and Coastal Zone Management Program in addressing water quality issues - Enforcement, research permits, CDUAs, endangered species,

1430 BREAK

1450 Johnson, Bob. The role of the counties - Maui County - planning, permitting, business, economic development, education and outreach

1510 Lennan, Bill. An overview of the responsibilities and activities of the U.S. Army Corps of Engineers as they pertain to the protection of humpback whales in Hawaii.

1530 Hommon, Rebecca. The role of the U.S. Navy as a Sanctuary user and Federal agency

1550 BREAK

1610 Workshop participants break into specific Working Groups and discuss priorities for the following days meetings (note: paricipants should sign up for a working group when they register)

1700 Reception - Whalers Village Museum, Kaanapali

Thursday, April 27

0900 Break into individual Working Groups

(I) Population Assessment and Monitoring Methodology
(II) Humpback Whale Habitat Characterization
(III) Behavior and Life History Research
(IV) Management Needs and Recovery Plan Implementation

1200 LUNCH

1330 Present and discuss progress of Working Group I

1350 Present and discuss progress of Working Group II

1410 Present and discuss progress of Working Group III

1430 Present and discuss progress of Working Group IV

1450 BREAK

1510 Working groups reconvene and draft reports and recommendations

1700 DINNER

1900 Working groups reconvene and continue discussions and drafting reports

2000 Evening SRD Sanctuary Managers Public roundtable discussion - OPEN TO PUBLIC

2100 Working Groups Adjourn

Friday, April 28

0900 Morning and remainder of day available to complete and prepare group reports.

1200 Reports on small working group meetings distributed and available for all participants to review.

1200 LUNCH

1300 Present and discuss report of Working Group I

1330 Present and discuss report of Working Group II

1400 Present and discuss report of Working Group III

1430 Present and discuss report of Working Group IV

1500 BREAK

1530 Summarize and discuss principle workshop findings and conclusions

1630 ADJOURN

1700 Barbeque at Hawaiian Island Humpback Whale National
Marine Sanctuary Office (optional)

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