Hawaiian Islands Humpback Whale National Marine Sanctuary

ANNOTATED RESEARCH BIBLIOGRAPHY

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Abileah, R., D. Martin, et al. (1996). "Long-range acoustic detection and tracking of the humpback whale Hawaii-Alaske migration." IEEE Journal of Oceanic Engineering **1996**: 373-377.

Au, W. W. L. and K. Andrews (2001). Feasibility of using acoustic DIFAR technology to localize and estimate Hawaiian humpback whale population. Paper prepared for HIHWNMS. Available at http://www.hihwnms.nos.noaa.gov/.

The objective of this project was to determine if the DIFAR (directional frequency analyses and recording) sonobuoy technology could be applied to estimate the population size of humpback whales singing in chorus. In order to accomplish this objective, the project was divided into two phases. The first phase consisted of obtaining high quality recordings of singing humpback whales at close ranges to determine the characteristics of their songs. The second phase consisted of deploying two DIFAR sensors to obtain directional information from chorusing humpback whales. Eight different singers were recorded at ranges from 20 to 40 m. The songs consisted of burst of sounds called units, and units were organized into phrases. Some of the units had higher order harmonics that extended to 15 kHz. The amplitudes of the higher frequency harmonics of some units were within 18 to 24 dB of the fundamental or highest level harmonics up to a frequency of 13.5 kHz. These results indicate a broadband quality of humpback whale songs that has not been previously reported. The source levels were based on the rms value of the maximum level for each different phrases used by each whale. Source levels varied between 171 to 189 dB re 1 mPa. Two DIFAR sensors, each coupled to a microcontroller for remote recording of the acoustic information, were deployed in the waters outside of the Hawaiian Humpback Whale National Marine Sanctuary office in Kihei, Maui. Unfortunately, the DIFAR system did not function properly. One unit flooded, destroying the electronics and microcontroller. The other unit had a hard disk crash. However, the analysis of the humpback whale songs provided strong evidence that the DIFAR would probably not have accurately localized humpback whales singing in chorus since the likelihood of finding short intervals of time during which only the sound from one whale was received while the other whales were silent would be extremely small. Therefore, with chorusing humpback whales, a DIFAR sensor would probably provide erroneous information. A better acoustic localization technique would be to use two beam-steerable arrays of hydrophones.

Au, W. W. L., A. Frankel, et al. (2001). "Against the humpback whale sonar hypothesis." IEEE Journal of Oceanic Engineering **26**(2): 295-300.

This article is a rebuttal to the Frazer and Mercado sonar model. Arguments regarding noise-limited form of the sonar equation, behavioral attributes of humpback whales,

known characteristics of whale songs, and evolutionary perspectives are cited to disprove the Frazer and Mercado model.

Au, W. W. L. and M. Green (2000). "Acoustic interaction of whales and whale-watching boats." Marine Environmental Research **49**: 469-481.

The effects of boat noise on humpback whales was studied off the waters of West Maui. Noise levels were measured for five representative whale watching boats, concluding that noise levels produced by the boats cause no serious effects on humpback whale's auditory system.

Au, W. W. L., J. R. Mobley Jr., et al. (2000). "Seasonal and diurnal trends of chorusing humpback whales wintering in waters off western Maui." Marine Mammal Science **16**(3): 530-544.

Recordings of humpback whale chorusing were taken during the 1998 wintering season in Maui, Hawaii. Peaks in sound levels as well as diurnal patterns were detected which may reflect mating advertisement and relative numbers at a particular site.

Baird, R. W. (2001). Update COSEWIC status report on humpback whale (Megaptera novaeangliae). Ottawa, Committee on the Status of Endangered Wildlife in Canada (COSEWIC)**:** 1-18.

This report evaluates the endangered status of humpback whales populations that frequent Canadian waters.

Baird, R. W. and S. M. Burkhart (2000). Bias and variability in distance estimation on the water: implications for the management of whale watching, IWC Meeting Document.

Baird, R. W., A. D. Ligon, et al. (2000). Sub-surface and night-time behavior of humpback whales off Maui, Hawaii: a preliminary report. Kihei, Hawaii, Hawaiian Islands Humpback Whale National Marine Sanctuary**:** 1-11.

Provides a better understanding of humpback whale behavior in their wintering grounds by utilizing TDR/VHS radio tags. The results provide a better understanding of tagging feasibility, diving behavior, and management implications for Hawaii's humpback whale population.

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

During the 19977-1979 winter season, researchers conducted aerial surveys to determine trends in whale sightings. Annual changes in migratory timing observes for all three years. The data indicated a progressively later date for peak abundance. Data collected supports the hypothesis of a southeast to northwest movement pattern.

Baker, C. S. and L. M. Herman (1984). "Aggressive behavior between humpback whales (*Megaptera novaeangliae*) wintering in Hawaiian waters." Can. J. Zoology **62**: 1922-1937.

Aerial surveys and boat observations were conducted during the winter and spring seasons of 1979-1981. The observations suggest male-male competition for mature females. Guess characteristics are scaled by intensity and show seasonal changes correlated to average pod size. Observations also demonstrated singing and escorting are interchangeable reproductive roles of mature males.

Baker, C. S. and L. M. Herman (1984). "Seasonal contrasts in the social behavior of the humpback whale." Cetus **5**(2): 14-16.

Observations of whale associations and agonistic behavior were reported in Alaska and Hawaii. The social structure in Hawaii is observed as "extremely fluid and individuals transient". On Alaska feeding grounds two distinct behavioral patterns were observed: fluid association between individuals feeding on plankton and stable associations when feeding on schooling fish. These findings support cooperative feeding associations have implications for overall structure of populations.

Baker, C. S. and L. M. Herman (1985). "Whales that go to extremes." Natural History: 52-60.
This article provides a brief overview of the current studies that have provided evidence of whale social behavior. In addition, it details breaching behavior as well aggressive behaviors.

Baker, C. S. and L. M. Herman (1987). "Alternative population estimates of humpback whales (*Megaptera novaeangliae*) in Hawaiian waters." Can. J. Zoology **65**: 2818-2821.
To examine the population abundance findings presented by Darling and Morowitz in their 1986 report, the researchers conducted an independent study during the 1980-1983 season. Findings were analyzed using two additional frequency of recapture distributions, the Poisson and geometric. Substantial differences in abundance estimates were shown suggesting a need for further research tools to estimate abundance for these endangered species.

Baker, C. S., L. M. Herman, et al. (1986). "Migratory movement and population structure of humpback whales (*Megaptera novaeangliae*) in the central and eastern North Pacific." Marine Ecology Progress Series **31**: 105-119.
Photographic identification was used to collect data on migratory movements between season habitats in the central and eastern Pacific during 1977 to 1983. Extensive movements were observed between whales wintering near Hawaii that traveled to summer feeding grounds of the coasts of Alaska and whales wintering near Mexico feeding in Alaska and the Farallon Islands of California. Fidelity to a given region was demonstrated by a high proportion of migratory return. Analysis of regional return, migratory destinations, and fluke coloration indicate these whales form several geographically isolated 'feeding herds'. Mark-recapture analysis indicates the Hawaiian wintering congregation is 4 to 6 times larger than Alaskan feeding herd, which has important implications for managing these whale.

Baker, C. S., L. Medrano-Gonzalez, et al. (1998). "Population structure and nuclear mitochondrial DNA variation among humpback whales in the North Pacific." Molecular Ecology **7**: 695-708.

Baker, C. S. and S. R. Palumbi (1994). Which whales are hunted? A molecular genetic approach to monitoring whaling. Science. **265:** 1538-1539.
This article presents a brief overview of the international whaling moratorium and current and historic management of whales. Genetic analysis of sample taken from Japanese retail markets suggest illegal whaling is being conducted. This demonstrates the need to better management to verify catch reports and can include molecular genetic tests to track meat through international trade.

Baker, C. S., A. Perry, et al. (1993). "Abundant mitochondrial DNA variation and world-wide population structure in humpback whales." Proceedings of the National Academy of Science **1993**: 8239-8243.

Baker, C. S., A. Perry, et al. (1987). "Reproductive histories of female humpback whales *Megaptera novaeangliae* in the North Pacific." Marine Ecology Progress Series **41**: 103-114.
Photographic identification and on-site observation was used to infer gender and reproductive status of female whales. Interbirth or 'calving' intervals of adult females were on average longer and more variable than previously reported. Intervals ranged from 1 to 5 years, with an estimated calving rate of 0.58 in Hawaii. This study suggests that Hawaiian Island calf rate estimates are inflated and lower estimates obtained from southeastern Alaska are better measure of reproductive rates. Documenting behaviors associated with calf survival and migratory return is essential to develop complete life table for humpback whales in the North Pacific.

Baker, C. S., W. Slade, et al. (1994). "Hierarchical structure of mitochondrial DNA gene flow

among humpback whales world-wide." Molecular Ecology **3**: 313-327.
230 whales collected by biopsy in 11 seasonal habitats which represent six subpopulations or 'stocks' world-wide were analyzed. These studies revealed significant partioning of world-wide of genetic variation. This suggests among other things, support for the division of the North Pacific population into a central stock which feeds in Alaska and winters in Hawaii. Results show that humpback whales are a suitable demographic and genetic model for the study of gene flow within the marine ecosystem.

Bauer, G. B. (1986). The behavior of humpback whales in Hawaii and modifications of behavior induced by human intervention. Honolulu, University of Hawaii.

Bauer, G. B. and L. M. Herman (1986). Effects of vessel traffic on the behavior of humpback whales in Hawaii. Honolulu, National Marine Fisheries Service**:** 1-151.
Correlational studies of whales off Maui indicates alterations in behavior associated with vessel traffic. Changes in respiration, diving, swimming speed, social exchange, and various aerial behaviors were found to correlate with vessel speed, proximity and direction. This report represents a literature review to provide evidence that distributional patterns of whales may be disturbed by vessel traffic.

Bryant, P. J., G. Nichols, et al. (1981). "Krill availability and the distribution of humpback whales in southeastern Alaska." Journal of Mammalogy **62**(2): 427-430.
This report examines the possibility that distribution of humpback whales in southeastern Alaska is dependant on food availability. Stomach samples indicate the major food source of whales is krill. Krill availability was assessed by a series of plankton tows. Low counts of krill at all 5 stations suggests that whales may have abandoned the Glacier Bay area during the 1978 and 1979 season due to scarcity of food in the area.

Calmabokidis, J., G. H. Steiger, et al. (1996). "Interchange and isolation of humpback whales off California and other North Pacific feeding grounds." Marine Mammal Science **12**(2): 215-226.
Fluke photographs of whales identified off California between 1986 and 1992 were compared with those off other known feeding grounds of the eastern North Pacific. A high degree of interchange was observed for the whales off California, Oregon and Washington. It is noted that because of this high degree of interchange as compared to other areas, whales off California, Oregon and Washington form a single intermixing feeding aggregation with only limited interchange from other areas. These findings are consistent with other photographic identification studies and genetic studies.

Calmabokidis, J., G. H. Steiger, et al. (1997). Abundance and population structure of humpback whales in the North Pacific basin. Olympia WA, Cascadia Research Collective**:** 1-72.
This report provides new insights into the movements and population structure of humpback whales in the North Pacific region. This provides results of a collaborative effort by 16 independent researchers to understand abundance and geographic stratification. New insights on the extent of interchange among three wintering regions showed a low correlation. Considerably more mixing occurred off the Hawaiian Islands than seen on the Mexican and Japanese regions. The best estimate of abundance for the North Pacific population was 6,010 based upon average estimates from the Darroch method. Thus showing a dramatic increase since estimates made at the end of whaling in the 1960's.

Cartwright, R. The impact of escort associations on the behavior of humpback whale calves whilst in nursery waters - A cost and benefit analysis.

Cartwright, R. (1999). Factors affecting the behaviour of humpback whale calves whilst in Hawaiian waters. MSc Conservation Biology, Manchester Metropolitan University.
Impact of escort associations and the influence of season were investigated to their affect on the behavior of calves in nusery waters in the Hawaiian Islands. This study provides a

cost and benefit analysis of natural behavior patterns in calves.

Cerchio, S. (1993). Geographic variation and culturaleEvolution in songs of humpback whales in the eastern North Pacific. Moss Landing Marine Laboratories. Moss Landing, CA, San Jose State University**:** 72.

Songs of humpback whales off the coast of Mexico and Hawaii were examined to determine changes that occur during the breeding season in both areas. 24 individual's songs were recorded during the winter and spring of 1991. Variable were identified and grouped into six categories. Results indicate that all but three variables changed between winter and spring in at least one area. Thus indicating that whales may be predisposed to gradually change certain features of song independent of cultural influences.

Cerchio, S. (1994). Population characteristics of humpback whales off the Hawaiian island of Kauai. Moss Landing, CA, Moss Landing Marine Laboratories**:** 14pp + appendices.

Research was conducted during the winter and spring of 1989-1993 in their breeding area off Kauai and this study provides the analysis of research collected during 1993 field season. Research collected focused on individual photographic identification, pod characteristics, song recordings, and behavioral observations. To collect effort data for analysis, the island was divided into 12 zones from Niwiliwili Harbor to Kilauea Point. A total of 395.9 hours were spend during the 60 survey days. Results indicate pods of whales were distributed throughout the study range and tended to clump within the 100 fathom depth contour. In addition, the North region has the highest mean pod size, greater proportion of large pods (>4 whales), and the greatest proportion of surface active pods of the regions examined.

Cerchio, S. (1998). "Estimates of humpback whale abundance off Kauai, 1989 to 1993: evaluating biases associated with sampling the Hawaiian Islands breeding assemblage." Marine Ecology Progress Series **175**: 23-34.

Photographic identification of humpback whales off the island of Kauai were collected during mid-January to mid/late-April in 1989-1993. This data was used to estimate population abundance of wintering whales in Hawaiian waters. In addition, several mark-recapture procedures were used to determine abundance estimates. Biases due to temporary emigration and non-random mixing were considered in estimating range of abundance. The author suggests that population abundance is between 3000 and 5000, but likely close to 4000. These estimates are considerable greater than those generated in the 1970 and early 1980's. Thus suggesting increase in abundance of this decade.

Cerchio, S., C. M. Gabriele, et al. (1998). "Movements of humpback whales between Kauai and Hawaii: implications for population structure and abundance estimation on the Hawaiian Islands." Marine Ecology Progress Series **175**: 13-22.

Photographic identification and mark-recapture data collected during the 1989-1991 whale wintering season off the islands of Kauai and Hawaii were analyzed. This study documents individual movements across the entire island chain. A total of 1072 individual whales were identified by recapture off both islands. Recapture data indicate a more wide-range of males movements associated in active courtship behaviors. This report suggests that complete random mixing of whales within the Hawaiian Islands is unlikely and some degree of segregation does occur. Further studies with larger samples which including the Northwestern Hawaiian Islands will need to be conducted to elucidate movements patterns of the population.

Cerchio, S., J. K. Jacobsen, et al. (2001). "Temporal and geographical variation in songs of the humpback whale, Megaptera novaeangliea: synchronos change in Hawaiian and Mexican breeding assemblages." Anim. Behav. **62**: 313-329.

Chaloupka, M. and M. Osmond (1999). Spatial and seasonal distribution of humpback whales in

the Great Barrier Reef region, American Fisheries Society Symposium 23**:** 90-107.
Spatial and seasonal distributions of humpback whale populations were analyzed from aerial survey data. Trends in sightings for the Austrian substock were consistent with low levels of juvenile recruitment.

Clapham, P. J. (1996). "The social and reproductive biology of Humpback Whales: an ecological perspective." Mammal Review **26**(1): 27-49.
A review of social organization, mating, and reproduction is used to assess how our current understanding of humpback whales fits into the framework developed from ecological studies on terrestrial animals. Population chance and behavior can be attributed to their lack of predation, availability and abundance of food resources, and level of kinship associations.

Coleman, R. J. (1994). Aerial behavior of the Hawaiian humpback whale. Honolulu, University of Hawaii.

Craig, A. S. (1995). Site fidelity and reproductive histories of humpback whales in the Hawaiian Islands and Southeast Alaska. Honolulu, University of Hawaii.

Craig, A. S. (2001). Habitat utilization, migratory timing, and male escorting strategies of humpback whales in the Hawaiian Islands. Honolulu, University of Hawaii.

Craig, A. S. and L. M. Herman (1997). "Sex differences in site fidelity and migration of humpback whales (*Megatera novaeanglie*) to the Hawaiian Islands." Can. J. Zoology **75**: 1923-1933.
Photographic observations of humpback whales between 1976 and 1991 were examined investigate gender-related site fidelity. This paper proposes that females may not complete or undertake yearly migrations between summer feeding grounds and winter breeding grounds. This is based on the results that indicate higher probability of males being re-sighted in consecutive years.

Craig, A. S. and L. M. Herman (2000). "Habitat preferences of female humpback whales in the Hawaiian Islands are associated with reproductive status." Marine Ecology Progress Series **193**: 209-216.
Identification photographs of individual whales were collected from waters off the islands of Maui and Hawaii between 1977 and 1994. Female and calf sightings were significantly higher on Maui than off the Big Island. It was concluded that habitat utilization by females varies between Maui and the Big Island, and appears to depend upon reproductive status.

Craig, A. S., L. M. Herman, et al. (2001). Estimating residence times of humpback whales in Hawaii. Paper prepared for HIHWNMS. Available at http://www.hihwnms.nos.noaa.gov/.
A review of previous literature on humpback whales in the Hawaiian Islands revealed that relatively few whales were identified on more than one day within the same season, but there was little information about the residence times of different classes of whale. We addressed this information gap by examining the sighting histories of individual whales photographed by Kewalo Basin Marine Mammal Laboratory off west Maui and the Kohala Coast of the Big Island from 1976 through 1996. Our analyses of resighting rate (the proportion of individual whales identified on more than one day within the same season) showed that (a) overall resighting rates were low (11.94%), (b) resighting rates did not differ significantly among males, mothers, females without calf, and juveniles for the Big Island, Maui, or all data combined, and (c) resighting rates were significantly greater off the Big Island than off Maui. Our analyses of the resighting intervals (intervals between first and last identifications within the same season) of all whales identified on more than day showed that (a) most whales (65.98%) had an interval of 2 weeks or less, (b) no juvenile had an interval of more than 4 weeks, and no mother or female without calf had an interval of more than 5 weeks, but some males (N = 10) and adults of unknown sex (N

= 2) had intervals of 8 weeks or more, the longest interval being almost 11 weeks (76 days), (c) differences in resighting intervals among classes of whale were not significant overall or for the Big Island, but off Maui resighting intervals for females without calf were significantly shorter than resighting intervals for males and adults of unknown sex, and (d) inter-island resighting intervals tended to be longer than intervals recorded off a single island. Our results suggest that in Hawaii, humpback whales of all classes rarely remain resident in the same locale for long periods. Whales may be more transient off Maui than the Big Island, but it is also likely that differences in the extent of preferred habitat caused sampling differences between these two areas. Resighting rates and resighting intervals of females without calf relative to other whales off Maui and the Big Island suggest that these females may spend more time off the Big Island than off Maui, although further research is required. Finally, inter-island resighting intervals appear to be more representative of residency in the Hawaiian Islands as a whole than are intervals based on resightings of whales in the same location. Future studies combining photo-identification and large-scale satellite telemetry may provide the most precise data on humpback whale residency in the Hawaiian Islands, although obtaining sample sizes sufficient to compare different classes of whale would be financially and logistically challenging.

Craig, A. S., L. M. Herman, et al. (2002). "Male mate choice and male-male competition coexist in the humpback whale (Megaptera novaeangliae)." Can. J. Zool. **80**: 745-755.

Male humpback whales (Megaptera novaeangliae) outnumber females on the winter grounds and compete physically for proximity to females. Analyses of identification photographs collected in Hawai'i from 1976 through 1995 and scan samples collected in 1998 showed that (i) reproductive potential (calving rate) for the following winter was greater for females without a calf than females with a calf, (ii) females without a calf were less likely to be found alone and more likely to be found in large pods than females with a calf, (iii) individual females were found in larger pods when without a calf than when with a calf, (iv) the probability of females with a calf being escorted by one or more males increased as the reproductive season progressed, and (v) head lunges occurred more commonly in all-adult pods than in pods containing a calf. We concluded that male humpback whales associate preferentially with females with high reproductive potential, that the attractiveness of individual females varies with their status (with a calf versus without a calf), that males become progressively less choosy over the course of the reproductive season as females without a calf become increasingly rare on the winter grounds, and that males expend more energy in competition over females without a calf than females with a calf.

Darling, J. D. (1983). Mating behavior of Hawaiian humpback whales. Fifth Biennial Conference on the Biology of Marine Mammals, Boston, MA, Society for Marine Mammalogy.

Darling, J. D. (1983). Migrations, abundance, and behavior of Hawaiian humpback whales. Santa Cruz, University of California**:** 147 pp.

Darling, J. D. (2000). Study of the Function of the Humpback Whale Song. Maui, Hawaii, The Humpback Whale National Marine Sanctuary.

This study investigated the hypothesis that whale song is a male display of dominance status. Rather than occurring between age class or behavior pattern, as hypothesized, variation in song occurred within one age class. This leads to a second hypothesis that aspects of song may be subject to short-term variation due to surrounding environment. Further work is being conducted to test other hypotheses.

Darling, J. D. (2001). Characterization of behavior of humpback whales in Hawaiian waters. Video and photographs by Charles "Flip" Nicklin. Paper prepared for HIHWNMS. Available at http://www.hihwnms.nos.noaa.gov/.

Humpback whales make annual migrations to winter assembly areas in subtropical and

tropical waters to mate and, after a year gestation, give birth. The main Hawaiian Islands are the largest such assembly area in North Pacific. Since the late 1970s humpback whale research in Hawaii has been at the forefront of the investigation of reproductive behavior patterns of this species. This report reviews available information and summarizes our current understanding of the behavior of humpback whales in Hawaii. Humpback behavior patterns in Hawaii represent a continuum of reproductive activities that begin on late season feeding grounds and occur throughout the migration. In Hawaii, whales are found around all the main islands, with concentrations on shallow banks within the Four Island Group, Penguin Banks and to a lesser degree off the Kona coast and Kauai. It is apparent whales circulate freely throughout the islands, although questions remain as to if differential use of specific locations occurs. Cows with newborn calves are more likely to be found in shallow, inshore waters than the general population. Humpback whale abundance peaks in February-March, but whales are common from December through May and seen as early as September and as late as June. The arrival and departure of whales is segregated to some degree by age, sex and reproductive condition, with strong suggestions that, with the exceptions of some males, many whales are present for short periods relative to a five-six month long season. Female reproductive cycles govern much of the humpback whale behavior in Hawaii. Humpback whales give birth on the average every two-three years, although postpartum estrus is common with annual birth occurring in some portion of the population. The sexual cycle peaks during the three-five winter months, with peak ovulation in January-February. Females are seasonally polyestrus, undergoing several cycles if pregnancy does not occur. Peak ovulation period coincides with most behavioral activity in Hawaii including the peak of singing, male competitive and aggressive behavior, and transience of individuals among groups. With a 50:50 sex ratio, and the average birth rate two-three years, many more mature males than fertilizable females are present in any one breeding season, leading to increased competition among males. It is generally agreed that humpbacks follow a polygynous or promiscuous mating system. The former implies that males monopolize females in some way; in the latter they do not. Mating system hypotheses include dominance polygyny where males develop and maintain, through display and fighting, a hierarchy for access to females; and lek polygyny where males assemble and advertise to females through song. A further emerging hypothesis proposes formation of male coalitions and cooperation to access females. All these hypotheses require further testing. Most male behavior patterns, interactions and associations are short-lived, lasting only minutes to hours, with the animals apparently orienting to any female in estrus. Earlier studies emphasized male antagonism and avoidance of each other; more recent studies report non-agonistic male-male interactions. Male behavior patterns include singing; interaction with singers, at times forming all male pairs, trios or larger groups; and escorting or guarding females, defending or challenging the escort position with a variety of agonistic behavior including displays, sounds and physical clashes that may result in bloody wounds. There are some suggestions of cooperative and even care-giving behavior amongst some males. Female behavior patterns are set in two contexts: mating or birth and newborn care. Some portion of females undergoes postpartum ovulation and are involved in both activities in one season. Little is known about female mating strategies and behavior; however, this likely includes maximizing contact with males, minimizing contact and potential competition with females, and accomplishing mating in as short time as possible for energetic considerations. Female behavior may include acceptance of the male escort, leading or being chased by multiple competitive males, and mating. Female-female associations are rare on the breeding grounds. A typical behavior flow begins with a female-male pair in apparent calm union; this pair joined by other males often leading to competitive groups; and eventually the group breaking up leaving a pair again, which may or may not include the original male. Female behavior may influence the selection of a mate through encouraging competition and accepting/rejecting copulation. It has been proposed that females select males based on song but there is no evidence to support this hypothesis. Female humpbacks in Hawaii are involved in birth, nursing and

protection of young. These cows with newborn often occupy shallow, inshore waters presumed to separate them from mating activity and harassment of males, more turbulent offshore conditions, and predators. Birth has not been observed, although circumstantial evidence indicates it peaks at the time of year whales are in Hawaii. With sightings as early as December, cows with newborn peak in numbers in February-March, and are usually the last groups seen in May and June. Cow/calf pairs usually maintain an active separation from each other. Cows with calves apparently travel and circulate through the region like other whales. Travel is the most cow/calf common behavior. When resting the cow often lies in a horizontal position at 30-70 feet below the surface with calf under her head or body. The calf surfaces every five to six minutes, circles, and dives back towards the cow, with the cow surfacing every 10-20 minutes. Suckling occurs when cow/calf is either stationary or traveling. Play is a common activity with the calf mimicking most adult actions and postures. Some sounds by the calf and between cow and calf have been documented, but relative to males they are quiet. It has been proposed that the single male escort is accepted by the cow as it may offer indirect protection from groups of males. Juveniles, ranging from yearlings to four to five years old, make up a portion of the Hawaiian humpback population; little is known of their behavior patterns. They are found on the periphery of adult groups, in association with adult males including involvement in apparent sexual activity, in juvenile pairs, and alone. One observation reports a sub-adult attempting to feed in Hawaii. We may have a greater understanding of humpback whale reproductive behavior than other whales; however, overall, our knowledge is still young and dynamic with many aspects at the hypothetical stage and others barely described. Streams of important investigation include the relationship of habitat and behavior, male and female reproductive strategies, and factors that affect birth and newborn success.

Darling, J. D. and M. Berube (2001). "Interactions of singing humpback whales with other males." Marine Mammal Science **17**(3): 570-584.

Recordings and monitoring of 42 singers were conducted fin 1997 off Maui, Hawaii. Researches were evaluating two non-mutually exclusive hypotheses on the function of humpback whale song 1) it attracts females to the male singer; 2) it is a male-male display, that may indicate status. In 76% of the observations a lone non-singing adult joined the singer, and in 81% of these cases the pair split after brief interaction. All joiners were determined to be males. These observations appear to support speculation that song may be a function of social ordering.

Darling, J. D. and S. Cerchio (1993). "Movement of a humpback whale between Japan and Hawaii." Marine Mammal Science **9**(1): 84-89.

This report documents the first record of a humpback whale observed between Japan and Hawaii. This whale was identified on two occasions both times it was the "escort" for a cow and calf, and thus presumably male. This whale was photographically identified in Japan in April 1990 and the following winter in Hawaii, February 1991. This provides indications of migration and helps to define breeding stocks and population characteristics.

Darling, J. D., K. M. Gibson, et al. (1983). Observations on the abundance and behavior of humpback whales of West Maui, Hawaii 1977-79. Communication and behavior of whales. R. Payne. Boulder, CO, Westview Press**:** 201-222.

Darling, J. D. and C. M. Jurasz "Migratory destinations of North Pacific humpback whales." 359-368.

This paper reported the first connection between Hawaii and a Northe Pacific feeding ground with photoidentification matches between Maui and S.E. Alaska. These connections suggested more of a northeast-southwest component in migrations than previously thought. Also reported was a whale indentified in Mexico one winter and in Hawaii another, indicating an interchange of whales between these regions.

Darling, J. D. and D. McSweeney (1985). "Observations on the migration of North Pacific humpback whales." Can. J. Zool. **63**(63): 308-314.

Migratory destinations of northeast humpback whales were determined by repeat sightings using photographic identification and fluke pigmentation. Whales identified between the years 1975 and 1982 in Hawaii, Canada, and Alaska. This study suggests separate summer feeding areas may exist in the northeast Pacific, where individuals prefer to feed. Migratory observations suggest all whales are of one stock.

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

Humpback whale abundance was estimated in Hawaiian waters by counting the numbers of individual whales derived from photographs of identified whales between 1977-1981. Calculations based upon the number of repeat sightings were used to estimate total population size. A Bernoulli distribution was used to estimate total numbers from multiple sightings of individuals. The best estimates generated were 1000 in one winter and 2100 over 5 years. This suggests that population fluctuates from year to year and that the population increases in size over the wintering period. The authors also suggest that a small subpopulation of whales may stay in Hawaii longer than the majority of the population.

Forestell, P. H. (1989). Assessment and verification of abundance estimates, seasonal trends, and population characteristics of the humpback whale in Hawaii. Washington, DC., Marine Mammal Commission.

Forestell, P. H. and E. K. Brown (1992). Description of humpback whale use of Maalaea Bay, Maui Hawaii. Honolulu, US Army Engineer District**:** 1-18.

This report provides a description of humpback whale use of Maalaea Bay. The rational for this is to provide stricter approach limits in the Bay and along the coast of Lanai to protect distinct calving areas. Analysis provides compelling evidence that current boat activity in the area influences whale distribution and behavior.

Forestell, P. H. and E. K. Brown (1992). Cetacean abundance and distribution patterns off West Hawaii: Winter 1992. Kohala Coast, Hawaii, Mauna Lani Resort, Inc.

Forestell, P. H. and E. K. Brown (1992). Survey of humpback whales (Megaptera novaeangliae) in the vicinity of Kahoolawe, Hawaii during the winter of 1992, USDOC/NOAA Marine Sanctuaries Division.

Forestell, P. H., E. K. Brown, et al. (1990). Relative frequency and distribution of humpback whales and boats near Maui, Hawaii during the 1990 winter season. Maui, Hawaii**:** 1-57.

An analysis of six years of aerial survey data between 1978 and 1990 showed no evidence that the distribution of whales between Maui and Lanai have changed significantly over the past 12 years. Whales have avoided Lahaina since surveys in 1976, and still due today. No evidence supports the whales are being pushed offshore nor a difference in average offshore distance of calf pods.

Forestell, P. H., E. K. Brown, et al. (1994). Observations of humpback whales and other cetaceans off West Hawaii: Year Two (1993). Honolulu, Hawaii, Marine Research Consultants.

Forestell, P. H. and G. D. Kaufman (1991). The history of whalewatching in Hawaii and its role in enhancing visitor appreciation for endangered species. Proceedings of the 1990 Congress on Coastal and Marine Tourism, Volume II, Newport OR, National Coastal Resources Research & Development Institute.

Forestell, P. H. and G. D. Kaufman (1996). Development of whale watching in Hawaii and its

application as a model for growth and development of the industry elsewhere. Encounters with Whales '95. K. C. a. A. J. (eds.). Canberra, Australia, Australia Nature Conservation Agency.

Forestell, P. H. and J. R. Mobley Jr. (1991). Humpback whale aerial survey throughout the major Hawaiian Islands during the 1991 season.

Forestell, P. H., J. R. Mobley Jr., et al. (1996). Aerial survey of humpback whales near Kahoolawe, Hawaii: 1995, Report for the USDOC/NOAA Marine Sanctuaries Division.

Aerial surveys were carried out throughout the Main Hawaiian Islands during a portion of the winter of 1995. Data collected supports the present assessment that Kahoolawe is not a major aggression site for humpback whales. However, the findings do suggest that the near-shore waters surrounding the island are used by whales at least some of the time.

Frankel, A., S. (1987). Sound playback experiments with humpback whales in Hawaiian waters. Honolulu, University of Hawaii.

Frankel, A., S. and C. W. Clark (1998). "Results of low-frequency playback of M-sequence noise to humpback whales in Hawaii." Can. J. Zool. **76**: 521-535.

Researchers exposed whales to playback of low-frequency sounds to examine whether they would respond to sound levels exceeding 120 dB. Using an M-sequence signal behavior and movements were described before, during and after playback. Comparisons revealed no difference in whale tracks and bearings between control and playback condition. Vessels had a larger impact and affected more behavioral variables than playback. Although subtle responses to M-sequence playbacks were detected statistically, their biological significance is still uncertain.

Frankel, A., S., C. W. Clark, et al. (1995). "Spatial distribution, habitat utilization, and social interactions of humpback whales, *Megaptera novaeangliae*, off Hawaii, determined using acoustic and visual techniques." Can. J. Zoology **73**: 1134-1146.

Humpback whales were observed using acoustic and visual methods off the island of Hawaii. This report supports the hypothesis that a function of song is to maintain space between singers. Depth of singing whales were observed at depths between 10 and 305 fathoms. These observations provide important acoustic data in tracking singing whales.

Frankel, A., S., J. R. Mobley Jr., et al. (1995). Estimation of auditory response thresholds in humpback whales using biologically meaningful sounds. Sensory Systems of Marine Mammals. R. A. Kastelein, J. A. Thomas and P. E. Nachtigall. Woerden, De Spil Publishers**:** 55-69.

Sound playback is used to estimate thresholds of response to biologically meaningful sounds. Using conspecific vocalization playbacks, researchers observed and tracked whales form shore. Estimates of response thresholds are potentially biased however, they provide a feasible method for behaviorally estimating auditory detection.

Frankel, A. S. (1994). Acoustic and visual tracking reveals distribution, song variability and social roles of humpback whales in Hawaiian waters. Honolulu, University of Hawaii.

Gabriele, C. M. (1991). The behavior and residence characteristics of reproductive classes of humpback whales in the Hawaiian waters. Honolulu, University of Hawaii.

Gabriele, C. M., J. M. Straley, et al. (1996). "Fastest documented migration of a North Pacific humpback whale." Marine Mammal Science **12**(3): 457-464.

The shorted documented migration of a humpback whale between Alaska and Hawaii was reported at 39 days. This demonstrates that migrating whales can travel at relatively high speeds over long distances. It also suggests that whales may stay on feeding grounds longer than previously believed without compromising the breeding season. A longer feeding season is suggested to increase strength and body size thus linking it with

successful male competitiveness and in meeting energy demands of pregnant females.

Gabriele, C. M., J. M. Straley, et al. (2001). "Estimating the mortality rate of humpback whale calves in the central North Pacific." Can. J. Zoology **79**: 589-600.

Data collected by various researchers between 1979 and 1995 was used to estimate mortality rates in humpback whale calves. Indications of calf mortality were studied by conducting longitudinal studies conducted between Hawaii and Alaska. The proportion of mothers sighted with known calves between these two important habitats was used as an estimate of calf mortality. While an important parameter for evaluating calf mortality, the researcher note some bias in estimates.

Gardner, E. A. (1996). Swimming through a sea of sovereign states: A look at the whale dilemma. Honolulu, Law of the Sea Institute**:** 61-81.

This report provides an overview of the legal framework currently in place for the management of whale throughout the world's oceans. The tension that exist between pro and anti-whaling states represented on the International Whaling Commission (IWC) to effectively manage the whaling industry is used to stress the difficulty of managing these marine species. The author presents a more effective international regime for the regulation of whaling acknowledging that the present framework, that is IWC, is in serious danger of dissolution.

Gisiner, R. C. P. D. (1998). Workshop on the effects of anthropogenic noise in the marine environment, Office of Naval Research**:** 141 PP.

A panel of experts convened for a 3-day workshop on the role ocean acoustics and anthropogenic sounds affect the natural behavior of marine mammals. These proceedings provide an in-depth analysis of current finding in the area of acoustical ocean research and the effect of noise on marine mammals in general but not specifically humpback whales.

Glockner, D. A. (1983). Determining the sex of humpback whales in their natural environment. Communication and behavior of whales. R. Payne. Boulder, CO, Westview Press**:** 447-464.

Glockner-Ferrari, D. and M. Ferrari Reproduction of the humpback whales in Hawaiian waters, Report to the International Whaling Commission**:** 237-242.

Individual lactating females and calves were photographically identified in the waters off Maui. Calf suckling behavior was observed, in addition to body pigmentation. Pigmentation of cow and calf were similar to that of whales in Ryukyuan waters. Sex differences and reproductive characteristics of calves identified in this study are important to better understand whale behavior in Hawaiian waters.

Glockner-Ferrari, D. and M. Ferrari (1989). Reproduction in the humpback whale in Hawaiian waters, 1975-1988: the life history, reproductive rates, and behavior of known individuals identified through surface and underwater photography, International Whaling Commission**:** 161-167.

Using surface and underwater photographs of body pattern, whales were identified off the coast of Maui during the period 1975-88. By compiling resighting histories and calving intervals, a decrease in the occurrence of mother and calves in nearshore waters off Maui during the 1975-88 period was demonstrated.

Glockner-Ferrari, D. and S. C. Venus (1983). Identification, growth rate, and behavior of humpback whale cows and calves in the waters off Maui, Hawaii 1977-1979. Communication and Behavior of Whales. R. Payne. Boulder, Westview Press.

Individual whales were identified through photographs of fluke pigmentation patterns. By utilizing this technique, the researchers detail movement and behavioral patterns of cows, calves and escorts, as well as present evidence for growth rate of calves during their first two years.

Glockner-Ferrari, D. A. and M. J. Ferrari (1985). Individual identification, behavior, reproduction, and distribution of humpback whale, *Megaptera novaeangliae*, in Hawaii. Washington DC, Marine Mammal Commission**:** 1-36.

Underwater and surface photographic analysis was used to estimate abundance of the west coast of Maui, Hawaii. Whales were categorized according to pigment patterns and spatial-numerical patterns. A total of one hundred and fifty adult whales, 15 subadult and 42 calves were identified during the 1982-83 season. Previous sightings data from 1975-1981 were used to identify resident whales. Using data during the period of 1977 to 1983, female reproductive intervals were identified. Behavioral attributes for calves, subadults and adult males and females were also observed. In addition, population abundance estimates showed a decrease in mother and calves sightings since the 1977-1979 period.

This report provides insight into individual whale behaviors, reproductive intervals, and records changes in abundance over successive years.

Green, M. L. (1991). The impact of parasail boats on the Hawaiian humpback whale. Honolulu, Marine Mammal Commission**:** 1-11.

This is the first of 2 reports on the impact of vessels on Hawaiian humpback whales. Shore-based observational data was collected on 12 mornings in January 1990. It isolates the effects of parasail operations on the natural behaviors of whales in the region. The site is believed to be an preferred cow-calf resting spot. The complete absence of whale during the operation of parasails in the region indicate a displacement from their desired near-shore resting habitat.

Green, M. L. (1998). The Impact of vessels on the Hawaiian humpback whale: an experimental study, Ocean Mammal Institute.

This is report 2 of an ongoing investigation to understand the affects of parasail on whale behavior. Data collected from observation and theodolite in January 1990 indicate a displacement of cow calf pods in areas with parasail boat's operating. Vessel disturbance is also believed to impact the natural behavior of whales. This report provides information on type of boat and engine to determine their effect on whale behavior.

Green, M. L. and R. G. Green (1990). Short-term impacts of vessel traffic on the humpback whale. Annual meeting of the Animal Behavior Society, SUNY, Buffalo NY.

Due to the increasing levels of tourism in the past decade researchers are placing more attention on the affect of boat interaction on whales. Indirect evidence shows changes in whale distribution, indicating an immediate impact by boat traffic. Data is collected by shore observers to record behavior changes in relation to proximity of boats. This study supports previous findings that boats have several short-term effects on whales

Guinee, L. N., K. C. Chu, et al. (1983). Changes over time in the songs of known humpback whales. Communication and behavior of whales. R. Payne. Boulder, Westview Press.

Hain, J. H. W., G. R. Carter, et al. (1981). "Feeding behavior of the humpback whale in the western North Atlantic." Fishery Bulletin **80**(2): 259-268.

This paper reports on the feeding behavior of humpback whales in the waters off the northeastern United States. Data was collected from aerial and surface platforms from 1977-1980. Principal catalogued behavior include swimming/lunging behaviors and bubbling behaviors. Many of these behaviors are believed to be utilized to maintain naturally occurring concentrations of prey.

Helweg, D. A. (1989). The daily and seasonal patterns of behavior and abundance of humpback whales (*Megaptera novaeangliae*) in Hawaiian waters. Department of Psychology. Honolulu, University of Hawaii- Manoa**:** 133.

Helweg, D. A., G. B. Bauer, et al. (1992). "Observations of an S-shaped posture in humpback whales." Aquatic Mammals **18**(3): 74-78.

This report attempts to assess the function of observed S-shaped postures in humpback whales. This posture is characterized by upward aching of the tail stock, lowering the flukes, raising the rostrum, and spreading the pectoral fins. This posture is held for several seconds, after which the whale resumes normal activity. Interpretation of this posture is believed to be a threatening behavior, however, courting cannot be ruled out.

Helweg, D. A., A. Frankel, et al. (1992). Humpback whale song: our current understanding. Sensory Abilities of Aquatic Mammals. R. K. J. Thomas, and and A. S. (eds.). New York, Plenum Press**:** 459-483.

Despite the many detailed reports of humpback whale songs, its exact function remains elusive. This paper provides a literature review of whale songs; describes general methods for collecting data on free-ranging whales, and presents results of current studies to shed light on the function of whale song.

Helweg, D. A. and L. M. Herman (1994). "Diurnal patterns of behavior and group membership of humpback whales wintering in Hawaiian waters." Ethology **98**: 298-311.

Visual and acoustic observations of humpback whale behavior was studied in relation to time of day. Behavioral changes is escorting, pod size, male-male competition can be correlated to diel variations. The data suggests that whales rest in the dawn hours, behavior relating to mating begins shortly after sunrise, and male-male competition peaked in the afternoon.

Helweg, D. A., L. M. Herman, et al. (1990). "Comparison of songs of humpback whales (*Megaptera novaeangliae*) recorded in Japan, Hawaii and Mexico during the winter of 1989." Scientific Report Cetacean Research **1**: 1-20.

During the March-April 1989 humpback whales song recordings were obtained from the Bonin Islands and the Ryukyuan Islands of Japan, the Hawaiian Islands, and the southeastern Baja Peninsula of Mexico. Analysis of songs identified theme similarities across these regions. This data suggests acoustic contact among these whale populations during migration.

Herman, L. M. (1977). Humpback whales in Hawaiian breeding waters II. Behaviors, United States Marine Mammal Commission.

Herman, L. M. (1978). The Hawaiian humpback whale problem, Marine Mammal Commission and Committee of Scientific Advisors on Marine Mammals.

Herman, L. M. (1979). "Humpback whales in Hawaiian waters: A study in historical ecology." Pacific Science **33**(1): 1-15.

This report provides historical evidence into Hawaiian whale populations. It suggest humpback whales invaded Hawaiian waters within the last 200 years. Evidence suggests that humpback whales were unknown to Hawaiians prior to 1778. Possible reason for invasion into Hawaiian waters include dispersion from other habitats by increased whaling activities and long-term changes in North Pacific water masses affecting preferred water temperature chance. Short-term changes have also occurred with the Hawaiian Islands in response to whale pressure and post WWII offshore construction. These changes are seen as an adaptive response of whales to important physical or physiological characteristics in habitat preference.

Herman, L. M. (1979). Temporal and spatial distribution of humpback whales at the island of Hawaii and relations to the OTEC-1 project., Environmental Impact Report to TRW Inc.

Herman, L. M. (1994). "Hawaiian humpback whales and ATOC: A conflict of interests." The

Journal of Environment and Development **3**: 63-76.

Herman, L. M. and R. C. Antinoja (1977). "Humpback whales in the Hawaiian breeding waters: population and pod characteristics." Scientific Report Whales Research Institute **29**: 59-85.
During the 1976 spring breeding season, observation of population characteristics were made by aerial survey, shipboard and underwater methods. Most of the whales were observed within the 100-fathom contour surrounding the islands. Estimated yields of 200-250 whales were observed with low birth rates less than 10%. Approximately 73% of the animals were observed in pods of 2 to 9 animals, the remaining observed alone. Calves were typically observed in multiple-pods; consisting of a mother and 'escort' whale. A large percentage of adult pods (76%) seemed 'determined' suggesting considerable local migration. This report details the adverse effect whale-watching activity may have on humpback whale reproductive success.

Herman, L. M., P. H. Forestell, et al. (1980). The 1976/77 migration of humpback whales into Hawaiian waters: composite description. Honolulu, Hawaii, US Department of Commerce**:** 1-55.
Surveys were conducted on humpback whales during their 1976/77 residency season. Majors findings include peak in adult and calf abundance in February; subregions of high calf density; decline abundance in regions of high vessel and human activity; and deference responses to marine and air traffic. These findings have direct implications for management of traffic or whale-watching activities.

Hudnall, J. (1978). "A report on the general behavior of humpback whales near Hawaii, and the need for the creation of a whale park." Oceans(2): 8-17.
This report develops a conceptual plan of a marine reserve to protect their nursery habitat and provide a means of public education. This is developed in response to their endangered species status as well as a need to monitor existing boating activity to determine its affects on humpback whale behavior.

Laist, D. W., A. R. Knowlton, et al. (2001). "Collisions between ships and whales." Marine Mammal Science **17**(1): 35-75.
Historical databases, stranding reports, and evidence of ship strikes involving great whales was investigated. This report provides detailed accounts of types of whales hit most commonly (which includes humpback whales) as well as the timing of these events. Ship speeds are also indicated which as management implications.

Mate, B. R., R. Gisiner, et al. (1998). "Local and migratory movements of Hawaiian humpback whales tracked by satellite telemetry." Can. J. Zoology **76**: 863-868.
Inter-island movements and offshore migrations of six humpback whales radio tagged during March and April 1995 off Kaua'i were examined. This study provides increased knowledge of seasonal distribution and movements for Hawaii overwintering whale population.

Maybaum, H. L. (1988). Effects of a 3.3 kHz sonar system on humpback whales in Hawaiian waters. Honolulu, University of Hawaii.

Mazzuca, L., S. Atkinson, et al. (1998). "Death and entanglements of humpback whales, *Megaptera novaeangliae*." Pacific Science **52**(1): 1-13.
Reports of humpback Whales, *Megaptera novaeangliae*, that either died or were entangled in Hawaiian waters from 1972 through October 1996 were analyzed to determine age, location, frequency, and seasonal distribution of occurrence.

McSweeney, D., K. C. Chu, et al. (1989). "North Pacific humpback whale songs: A comparison of southeast Alaskan feeding ground songs and Hawaiian wintering ground songs." Marine Mammal Science **5**: 139-148.
Recording of humpback whales were done on their Alaska feeding grounds during 25

August 1979 and 3 September 1981. Firstly, samples from Alaska were first evaluated to determine if they were songs. They were determined to be songs because of their repeated cyclical sound patterns and that they follow the same structure for humpback whale song. Thus, the songs recorded in Alaska contain the same material sung in the same order as songs heard off known Mexican and Hawaiian wintering grounds. Secondly, researchers evaluated the difference between the Alaskan songs and the Hawaiian songs, they determined that no significant difference existed. Thirdly, Alaska songs were evaluated to determine if they were more like the songs sung the preceding or subsequent winter. No consistent trends for theme or phase duration were apparent.

Mercado, E. Computational models of sound production and reception. Department of Engineering. Honolulu, University of Hawaii.

Mercado, E. (1995). An Acoustic Analysis of humpback whale song units. Honolulu, University of Hawaii.

Mercado, E. (1998). Humpback whales bioacoustics: From form to function. Honolulu, University of Hawaii.

Mercado, E. and A. Kuh (1998). Classification of humpback whale vocalizations using self-organizing neural network. IJCNN.

Mobley Jr., J. R. (1998). Preliminary results of 1998 Hawaiian Island marine mammal aerial survey. Mililani, Hawaii, Marine Mammal Research Consultants.

This report was performed to determine the distribution and abundance of all marine mammals sighted, with particular focus on humpback whales. The majority of sightings (79%) were humpback whales. This paper represents the first survey based estimate of humpback whales since 1979.

Mobley Jr., J. R. (1999). Distribution and abundance of humpback whales in the Hawaiian Islands: Results of 1993-98 aerial surveys, University of Hawaii-West Oahu**:** 1-7.

Results of aerial surveys conducted four times a year for the main Hawaiian islands increases understanding of Hawaii's wintering humpback whales. Relative abundance, critical habitat, and abundance trends were analyzed from the 5 year data collection.

Mobley Jr., J. R. (2001). Results of 2001 aerial surveys of humpback whales north of Kauai. Hawaii, North Pacific Acoustic Lab.

Mobley Jr., J. R., G. B. Bauer, et al. (1999). "Changes over a ten-year interval in the distribution and relative abundance of humpback whales (*Megaptera novaeangliae*) wintering in Hawaiian waters." Aquatic Mammals **25**(2): 63-72.

Analysis of aerial survey data gathered during the 1990 wintering season along with consistent methods used performed during 1977-80 indicate changes of relative abundance. The data indicate significant increase of total whale and calf abundance over the ten-year period. Data collected from 5 major regions supporting a general increase in northwest movements through the island chain. This data suggests that the wintering population may be spilling over form previously preferred habitats and supports the notion that this endangered population may be recovering.

Mobley Jr., J. R. and B. A. Dell (1985). Humpback whales in Hawaii: A guide for the amateur whale-watcher. Honolulu, University of Hawaii Sea Grant College Program**:** 13 p. ill.

Mobley Jr., J. R., P. H. Forestell, et al. (1994). Results of 1993 aerial surveys in Hawaiian waters. San Diego, CA, Advance Research Projects Agency.

This is a report of aerial surveys in response to the lack of systematic research on Hawaii's resident cetacean species. Humpback whales were the most commonly

observed.

Mobley Jr., J. R., P. H. Forestell, et al., Eds. (1997). Preliminary results of 1993 and 1995 aerial surveys of Hawaiian waters. Report of the Workshop to Assess Research and Other Needs and Opportunities Related to Humpback Whale Management in the Hawaiian Islands, NOAA Technical Memorandum NMFS-OPR-11.

Mobley Jr., J. R., R. Grotefendt, et al. (1999). Results of aerial surveys of marine mammals in the major Hawaiian Islands, Acoustic Thermometry of Ocean Climate Program**:** 34 pp.

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

Shore-based and small boat observations were conducted in 1980 to examine pod size and membership. Social affiliations in this study were consistent with polygynous mating systems.

Mobley Jr., J. R., L. M. Herman, et al. (1986). "Sound playback experiments with humpback whales in the Hawaiian wintering grounds." University of Hawaii Sea Grant Quarterly **8**(3): 1-6.

Sound playback experiments were performed during the 1985-1986 wintering season off the northwest coast of the island of Hawaii and off the west coast of Maui. Five sounds were used: Hawaiian wintering song, Hawaiian winter social sounds, Alaska feeding sounds, synthetic sounds, and blank tape. The sounds were played back from a small vessel over a transducer. Results indicate rapid approach response to feeding call playback sounds. This study uncovers some social functions of humpback whale sounds previously unknown.

Mobley Jr., J. R., L. M. Herman, et al. (1988). "Responses of wintering humpback whales (*Megaptera novaeangliae*) to playback of recordings of winter and summer vocalizations and of synthetic sounds." Behavioral Ecology and Sociobiology **23**: 211-223.

Sound playback experiments were conducted during the 1985 and 1986 wintering season in Hawaiian waters. Playback experiments were conducted from a boat using a high precision surveyor's theodolite and underwater speakers system. Three natural sounds and one synthetic sound were testing in a total of 143 playback sessions. The major response observed was rapid approach (velocities up to 9 km/h) by whales to within 50 m or less of the vessel. The majority of whales singleton and, secondly, adult pairs. No cow-calf pairs ever approached. In addition, no response approach was observed for blank tape sound. This report suggests that observed relative attractiveness of feeding sound is related to the activities of mature, prospecting males.

Mobley Jr., J. R., S. Spitz, et al. (2001). Abundance of haumpback whales in Hawaiian waters: Results of 1993-2000 aerial surveys. Paper prepared for HIHWNMS. Available at http://www.hihwnms.nos.noaa.gov/.

This report summarizes the results of aerial surveys of humpback whales conducted throughout the major Hawaiian Islands during the 1993, 1995, 1998 and 2000 winter seasons during their period of peak abundance (late Feb - early Apr). Identical methods were used throughout the series consistent with accepted distance sampling theory, thus permitting estimation of abundance and accurate assessment of trends across years. Densities were calculated using DISTANCE (vers. 3.5) stratified by both depth category (0-99, 100-1000, >1000 fathoms) and year. Respiration data collected from earlier shorestation observations made across a six-year period were used to correct for the probability of detecting whales at the surface (g(0)). Corrected population estimates were as follows: 1993: 2,754 (95% CI: 2,044-3,463); 1995: 3,776 (95% CI: 2,925-4,627); 1998: 4,358 (95% CI: 3,261-5,454); 2000: 4,491 (95% CI: 3,146-5,836). Regression analysis revealed a significant linear trend of increasing densities across the seven-year intervening period [$F(1,2) = 18.72$, $p < .05$] with an average increase of 7% per year.

Comparisons with earlier estimates of abundance based on mark-recapture models applied to fluke identification photographs (e.g., Cerchio, 1998; Calambokidis et al. 1997) generally show the latter to be considerably higher than the survey-based estimates. The means of the estimates by Cerchio (1998) and Calambokidis et al. (1997) are 4,448 and 4,305 based on photographs from years 1989-93 and 1991-93, respectively. If the estimated rate of population increase of 7% per year is applied to these estimates, this suggests the current population to be approximately 6,800 whales. If the same rate of increase is applied to the survey-based estimate for 2000, there are currently about 4,800 whales. The discrepancy may represent over-estimates on the part of the mark-recapture estimates, perhaps deriving from violations of model assumptions (e.g., heterogeneity of sighting probabilities across regions) or from under-estimates on the part of the aerial survey estimates due to relatively short residency times on the part of individual whales. More data on average residency times of humpbacks in the Hawaiian Islands are needed to resolve this issue.

Neil, D., M. Orams, et al. (1994). Effects of previous whale watching experience on participants knowledge of, and response to, whales and whale watching. Queensland**:** 182-188.

Participants were surveyed during the 1994 whale watching season off Moreton Island, Australia. A preliminary analysis of the effects of previous whale watching knowledge, expectations, and enjoyment were used to gain greater understanding to the expectations of whale watching participants.

Nitta, E. T. and J. J. Naughton (1989). Species profiles: life histories and environmental requirements of coastal vertebrates and invertebrates Pacific Ocean region #2: humpback whale. Honolulu, US Army Corp of Engineers**:** 1-22.

This report provides an overview of the ecology and human impacts of humpback whales in the Hawaiian Island up to 1989. It provides a brief but comprehensive sketch of how whale populations may be affect by environmental changes and human impacts in Hawaiian waters.

Norris, K. S. and R. R. Reeves (1978). Report on a workshop on problems related to humpback whales in Hawaii. Waimanalo, Sea Life, Incorporated**:** 88 p.

This report is part of a workshop to consider the nature and extent of harassment experience by whales in their wintering grounds in the Hawaiian Islands. Both long and short-term impacts were assessed that could result in measurable life history and behavioral changes as a result of human activity in these regions. Management recommendations include: sanctuary and critical habitat considerations, stronger enforcement presence to monitor human/whale interaction. In addition, this report recommends further studies on abundance, distribution, recruitment rate, and behavioral patterns of whale that frequent Hawaiian waters.

Norris, T. F. (1995). Effects of boat noise on the singing behavior of humpback whales. Moss Landing Marine Laboratories. Moss Landing, CA, San Jose State University**:** 69.

The objective of this study is to determine the effects of boat noise on whales by measuring absolute received noise levels near singing whales before and during boat-passes, and to compare the power spectra of whales to different types/sizes of boats. Songs of whales were recorded when noise from small (5.5m) and large (10-35m) vessels were introduced to the study region off the coast of Kauai. Changes in song tempo and a shift downward in frequencies of some units, could be an indication of disturbance, however further studies on this subject are necessary to verify this hypothesis.

Orams, M. Tourists getting close to whales, is it what whale-watching is all about? Tangalooma, Center for Tourism Research, Massey University**:** 1-11.

Participants from twelve whale-watching cruises were surveyed to determine sat of experience in connection with the importance of proximity to whales during trip. This

report indicates that many motivating factors contribute to participant satisfaction and closeness to whales was not a major influence.

Osmond, M. G. and G. D. Kaufman (1996). "A heavily parasitized humpback whale." Marine Mammal Science **14**(1): 146-149.

This report provides a brief description of observation made by a research team responded to a humpback whale distress call off the coast of Maui. The adult female was completely covered in a thick layer of whale lice. In addition, the animal appeared to have a spinal anomaly of unknown origin.

Pack, A. A., D. R. Salden, et al. (1998). "Male humpback whale dies in competitive group." Marine Mammal Science **14**(4): 861-873.

An adult male humpback whale was found dead in the waters of Lahaina, Maui. Evidence suggests that the whale died as a result of male-male aggression involving at least four whales. Videotape of the aggressive behavior was obtain and information on behaviors typical of competitive groups was observed. Behaviors observed may have involved sexual components, helping behavior and/or dominance displays. This is the only known documentation of a death while engaged in a competitive group.

Palsboll, P., P. Clapham, et al. (1995). "Distribution of mtDNA haplotypes in North Atlantic humpback whales: the influence of behavior on population structure." Marine Ecology Progress Series **116**(1995): 1-10.

Whales representing 5 feeding aggregations in the North Atlantic and Antarctic, were analyzed to understand the sequence variation in the mitochondrial (mt) control region. Significant degrees of heterogeneity were found between the Antarctic and all North Atlantic areas. Results of homogeneity tests and genealogical tree indicate that behavior can influence population structure on an evolutionary time scale.

Payne, K., P. Tyack, et al. (1983). Progressive changes in the songs of humpback whales (*Megaptera novaeangliae*): A detailed analysis of two seasons in Hawaii. Communication and Behavior of Whales. R. Payne. Boulder, Westview Press**:** 9-57.

This report analyzes the process by which the rapid and synchronous changes in songs occurs within 2 singing seasons. Seasons were divided into six periods and songs were compared in terms of duration, number, frequency, spacing, and configuration of units, phases, themes, and songs. These comparisons reveal significant monthly evolution, however, adaptive significance of change remains unclear. However, this study provides evidence for both cultural and natural interpretations of song change.

Payne, R. and L. N. Guinee (1983). Humpback whale (Megaptera novaeangliae) songs as an indicator of "stocks". Communication and Behavior of Whales. R. Payne. Boulder, CO, Westview Press**:** AAAS Selected Symposium 76.

Perry, A., C. S. Baker, et al. (1990). Population characteristics of individually identified humpback whales in the central and eastern North Pacific: A summary and critique, International Whaling Commission**:** 307-317.

This report to the International Whaling Commission reviews methods developed to study population characteristics in the central and eastern North Pacific, specifically Hawaii and southeastern Alaska. Analysis suggests that whales in the North Pacific form geographically isolated herds which intermingle on one or more wintering grounds. Population estimates in both Alaska and Hawaii are introduced as well as social organization and foraging strategies.

Perry, A., J. R. Mobley Jr., et al. (1988). Humpback whales of the central and eastern North Pacific: A catalog of individual identification photographs. Honolulu, University of Hawaii Sea Grant College Program**:** 37pp.

This book catalogs photographs identifying individual whales in Hawaii, Mexico, central

California, southeastern Alaska, and the western Gulf of Alaska. Scientists as well as amateur whale watchers can use this comprehensive collection to where and when whales might have been previously sighted. It provides in-depth information on photographic identification through the use of natural fluke marking and coloration. In addition, it provides photographic identification research findings such as migratory movements, abundance, and social behavior.

Rice, D. W. and A. A. Wolman (1978). Humpback census in Hawaiian waters - February 1977, Honolulu, U.S. Department of Commerce.

Rosenbaum, H. C., P. J. Clapham, et al. (1995). "Geographic variation in ventral fluke pigmentation of humpback whale people worldwide." Marine Ecology Progress Series **124**: 1-7.
Fluke photographs were assessed to determine if pigmentation relates to geographical variations across breeding areas. Ventral fluke patterns were analyzed for southern ocean stocks and north pacific subpopulations. Results show historic and cultural interactions among oceanic subpopulations and reflect sub-division of the species.

Salden, D. R. (1988). "Humpback whale encounter rates offshore of Maui, Hawaii." Journal of Wildlife Management **52**(2): 301-304.
Humpback whale populations were observed to decline from 1981 to 1986 in the Four Islands area around Maui, Hawaii. Observations conducted from commercial whale-watching boats during the peak wintering season showed relative encounter rates differing among the years but no evidence in overall decline in individuals, pod or calf encounters. This report provides evidence that cows and calves are deserting traditional resting areas near Maui shore for waters further offshore.

Salden, D. R. (1990). Apparent feeding by a sub-adult humpback whale in the waters off of Maui, Hawaii. Lahaina, Hawaii Whale Research Foundation**:** 1-5.
In 1989, a solitary sub-adult was observed off Maui, Hawaii. The food source was a Pacific chub mackerel which was observed as an apparent vertical feeding lunge. This event suggests opportunistic feeding occurs on the wintering grounds more frequently that previously thought. This has significant management implications.

Salden, D. R. (1991). Periodicity in humpback whale appearances on the wintering grounds off Maui, Hawaii from 1998-1991. Ninth Biennial Conference on the Biology of Marine Mammals, Chicago, IL.
Photographic identification were analyzed which suggest a pattern of periodicity for humpback migratory appearance in Hawaii. No sexual differences were observed with a maximum range recorded being 55 days.

Salden, D. R. (1992). Humpback whale responses to close approaches by research boats off Maui, Hawaii, 1989-1992. Animal Behavior Conference, Kingston, Ontario, Canada.
This study reports responses to close approaches by research boats operating under federal scientific permits. Responses were not significantly associated with season. Evasions were associated most often with cow-calf pairs in January. Indicating responses associated with pod size and composition.

Salden, D. R., L. M. Herman, et al. (1999). "Multiple visits of individual humpback whales between the Hawaiian and Japanese wintering grounds." Can. J. Zool. **77**(3): 504-508.
Interchanges between three wintering ground located in Hawaii and Japan were documented through photographic identification of whales. Findings demonstrate that individual whales may be highly flexible in relation to their choice of wintering grounds.

Sekiguchi, K. (2001). The Habitat utilization by humpback whales on the northeast coast of the Big Island of Hawaii. Hilo, Pacific Aquaculture and Coastal Resources Center.
Observations of the presence of whales at a viewing point 2Km north of Hilo were

conducted from 15 December 2000 to 30 April 2001. Observers used binoculars to scan the study area and determine species type, group size and behavior. Total observation time from the viewing point was 65 hours and 7 minutes in 120 days. The most frequent sightings occurred in the winter season, between 25 December 2000 and 9 April 2001. Shipboard observations proved that whales do not just concentrate in Hilo Bay but spread themselves north along the coast. In addition, few cow calf pairs were detected, which may indicate these are not preferred nursery grounds.

Silber, G. K. (1986). "The relationship of social vocalizations to surface behavior and aggression in the Hawaiian humpback whale (*Megaptera novaeangliae*)." Can. J. Zoology **64**: 2075-2080.

Social vocalizations (nonsong sounds) were recorded off West Maui in the 1981-1982 whale seasons. Social sounds occur mostly in groups of three or more and were observed to show aggressive behavior among males for social dominance and females. In addition, aggressive surface activity suggesting the establishment of dominance within competing males. Social sounds were rarely heard in nonaggressive situations.

Silvers, L. E., S. Atkinson, et al. (1997). "A large placenta encountered in the Hawaiian winter grounds of the humpback whale." Marine Mammal Science **13**(4): 711-716.

A large placenta found was examined for anatomical features and hormone analysis. It is believed to be of humpback whale origin. A captain of a commercial whale-watching vessel describes what he believes as a birth, noting a small calf and placenta nearby. Photographic and biochemical evidence suggest this to be a placenta from an animal as large a humpback whale. However, direct evidence of humpback whale birth continues to elude the scientific community.

Smultea, M. A. (1991). Temporal and spatial segregation of Humpback whale (Megaptera novaeangliae) off the big island of Hawaii: the influence of behavioral and ecological onstraints, Texas A & M University.

Smultea, M. A. (1992). Habitat utilization patterns of humpback whales off the island of Hawaii. Galveston, TX, Marine Mammal Research Program**:** 1-70.

The distribution of whales off the Island of Hawaii was assessed by tracking whales from shore during the 1988 and 1989 calving season. Groups containing a calf occurred in shallow waters closer to shore more often than did groups observed without calves. No significant relationship was found between the distribution of groups with a calf and the number the number of adults within the calf group. The overall number of whales peaked in mid-February in both years. Theory why calves prefer shallow nearshore waters include (1) to avoid harassment and injury by aggressively courting males, (2) to minimize predation, (3) to reduce exposure to more turbulent offshore sea conditions. These results provide baseline data on the distribution and abundance of whales in Hawaiian waters that can be used to identify management needs.

Smultea, M. A. (1994). "Segregation by humpback whale cows with calves in coastal waters near the island of Hawaii." Can. J. Zool. **72**: 805-811.

During the 1988-1989 winter calving season, whales were tracked to determine habitat use patterns in an area relatively undisturbed by humans on the Big Island of Hawaii. Temporal and spatial distribution of whales differed with group size and composition. The number of whales observed per hour peaked in mid-February, however, rates for various group sizes and compositions varied throughout the year. Groups with a calf occurred mostly in nearshore waters than adult groups. Observations suggest cow-calf use of shallow habitat to avoid competing males as well as predators that occupy deeper waters. This research is important to improve upon the management of humpback whales in Hawaiian waters.

Spitz, S. S. (1999). The functional role of body size in humpback whale social behavior. Honolulu, University of Hawaii.

Spitz, S. S. and L. M. Herman (2000). "Measuring sizes of humpback whales (*Megaptera novaeangliae*) by underwater videogrammetry." Marine Mammal Science **16**(3): 664-676.
This report details a new and inexpensive method to measure body size of living humpback whales. Underwater videogrammetry techniques use a digital camera and a hand-held speedtech Dethmate sonar device to measure distance from camera to animal. A swimmer outfitted in snorkeling equipment is deployed from a boat and positioning in such a way to obtain best video image of whales within the vicinity. In addition to providing data on body size, information obtained from videogrammetry techniques can be used to aid in understanding life history characteristics such as population demographics, social organization, reproductive behavior, and calf growth rates. This report demonstrates the accuracy and reliability of this inexpensive techniques as compared to other photogrammetric techniques employed.

Thompson, P. O. and W. A. Friedl (1982). "A long term study of low frequency sounds from several species of whales off Oahu, Hawaii." Cetology **45**: 1-19.
Sounds were recording from December 1978 through April 1981 off Oahu. Tape was analyzed to determine the frequency and abundance of particular singing whale species. Humpback whales were the most commonly recorded sound. This report provides unique biogeographic information on distribution and acoustic behavior.

Tinney Jr., R. T. (1988). Review of information bearing upon conservation and protection of humpback whales in Hawaii. Washington D.C., Marine Mammal Commission**:** 1-56.
This report highlights recent studies that suggest humpback whales in Hawaiian waters are avoiding formally preferred sites due to human activities. Short and long-term impacts need to be investigated to determine the extent to which whales respond to vessel traffic from fishing, whale-watching, and dive boat operators. In addition, this report calls for better understanding of whale biology and ecology to better protect these animals from human impacts.

Todd, S., P. Stevick, et al. (1996). "Behavioral effects of exposure to underwater explosions in humpback whales (*Megaptera novaeangliae*)." Can. J. Zoology **74**: 1661-1672.
Entrapment rates of humpback whales were recorded in Trinity Bay, Newfoundland. Explosions under 1 kHz showed no behavioral reaction by whales in the region.

Townsend, R. T. (1991). Conservation and protection of humpback whales in Hawaii -- An update. Washington D.C., Marine Mammal Commission**:** 1-47.
This report contains a literature review. interviews with knowledgeable individuals, and a site visit conducted in 1990 to better understand human impact on Hawaii's humpback whale population. It provides recommendations to address activities that affect whales in Hawaiian waters. A recovery plan, increased scientific understanding, as well as better information on whale-watching is cited as necessary to accurately determine human impact on these marine mammals.

Tyack, P. (1981). "Interaction between singing Hawaiian humpback whales and conspecifics nearby." Behavioral Ecology and Sociobiology **8**: 105-116.
this study observed 35 occasions of singing whales to understand the interaction of singing whales and conspecifics nearby. Observations support the hypothesis that song plays a reproductive role similar to bird song. Since whales only sing during the breeding season, it is likely, that singing communicates their species, sex, location, readiness to mate and readiness to engage in agonistic behavior with other males.

Tyack, P. (1983). "Differential response of humpback whales to playback of song or social sounds." Behavioral Ecology and Sociobiology **13**: 49-55.
Song playback experiments were preformed off the coast of Maui. Singing whales usually stopped singing upon playback of songs by researchers. 14 of the 16 groups

exposed to playback moved away. This experiment supports the conclusion that the song and social sounds of whales mediate the responses of approach or avoidance that are made to singing whales or large groups in aggressive behavior situations.

Tyack, P. (1998). Comments on low frequency playback experiments to singing humpback whales in Hawaiian waters, Woods Hole Oceanographic Institution.

Tyack, P. and H. Whitehead (1983). "Male competition in large groups of wintering humpback whales." Behaviour **83**: 132-154.
Observations were conducted in Silver Banks between January and April 1980. Groups of humpback whales were followed visually and in the case of singers, acoustically from a boat. This study identifies Nuclear Animals and Principal Escort. Evidence of desirable escort associations, group interactions, and aggressive behavior were observed.

Utech, D. (1999). Valuing Hawaii's humpback whales: The economic impact of humpbacks on Hawaii's ocean tour industry, Hawaiian Islands Humpback Whale National Marine Sanctuary**:** 34.
The economic impact of commercial whale watching and ocean touring involving humpback whales was estimated based upon surveys conducted in 1999. Number of vesseal participating in whale watching, direct revenues attributed to whale watching, and total economic impact were analyzed to better understand the role it plays in the ocean tour industry as a whole.

Valsecchi, E., D. Glockner-Ferrari, et al. (1998). "Molecular analysis of the efficiency of sloughed skin sampling in whale population genetics." Molecular Ecology **7**: 1419-1422.
A non-intrusive method for obtaining tissue sample for DNA genetic analysis of whales, collecting slough tissue was done in this study. The efficiency of sampling is examined to provide a viable alternative to biopsy darting in regions where darting is either not permitted or otherwise undesirable.

Valsecchi, E., P. Palsboll, et al. (1997). "Microsatellite genetic distances between oceanic populations of the humpback whale." Molecular Biology and Evolution **14**(4): 355-362.
DNA analysis of humpback whales demonstrate strong segregation between oceanic populations and feeding grounds. Microsatellite loci typed across sample of four regions: the North Atlantic. The North Pacific, East Australia, and the Antarctic Peninsula were analyzed. this report suggests a highly structured pattern but does not exclude nuclear gene flow. This technique demonstrates an alternative means of investigating population dynamics.

Wolman, A. A. and C. M. Jurasz (1977). "Humpback whales in Hawaii: Vessel census, 1976." Marine Fisheries Review **39**(7): 1-5.