Short- and Long-term Effects of Whale Watching on Killer Whales (*Orcinus orca*) in British Columbia

Andrew W. Trites[1] and David E. Bain[2]

June 10, 2000

[1] *Marine Mammal Research Unit, Fisheries Centre, University of British Columbia, 2204 Main Mall, Vancouver, BC, Canada V6T 1Z4, Tel: 604 822-8182, Fax: 604 822-8180 e-mail: trites@zoology.ubc.ca*

[2] *Six Flags Marine World Vallejo, Vallejo, CA 94589, e-mail: dbain@u.washington.edu*

Abstract

A number of cetacean studies have shown that whale watching causes short-term behavioral changes in individuals, but none have yet demonstrated long-term population effects. This is particularly true of killer whales (*Orcinus orca*). In British Columbia, killer whales have precisely known population dynamics and there is a well-documented history of whale watching activity. Studies of the effects of vessels on the behavior of northern and southern resident killer whales in British Columbia have been conducted for two decades and have found significant short-term behavioral effects. However, some studies have produced apparently conflicting results, while a couple have not found any significant effects. In general, these studies indicate that killer whales employ a multivariate array of responses to whale watching that are a function of vessel numbers and proximity. Other significant factors may be vessel size, activity and engine noise, as well as age and tolerances of individual killer whales. Further work is needed to assess whether short-term individual behavioral effects can lead to long-term population changes. Three lines of research that may shed light on long-term effects include comparative studies of populations across broad geographic ranges, assessment of physiological changes using indicators of stress, and the development of mathematical models to evaluate possible bioenergetic consequences of whale watching.

Introduction

In the mid-1990s, the resident populations of killer whales in British Columbia numbered about 300 individuals. This was over 100 more whales than were present in 1975 (Ford *et al*. 1994). Over the past 5 years, however, the southern component of the resident populations has declined by 15% (from 98 whales in 1995 to 83 whales in 1999), and growth of the northern portion appears to have leveled off. Possible explanations for the changes in population growth include reduced prey availability, high levels of contaminants, and increased whale-watching activities (Bain and Balcomb 1999, Baird 1999).

The display of killer whales captured in BC from 1965-72 created a desire for people to observe them in the wild during the 1980s and 1990s. In 1990, pods of killer whales in southern BC were accompanied by an average of 4 vessels at any one time during summer daylight hours. By 1997, the number had grown to 25 vessels at one time (of which ¼ were commercial whale watching vessels) (Baird 1999). Numbers of vessels pursuing killer whales will likely continue to grow in parallel with the public fascination for this species (Duffus and Dearden 1993).

If the effect of wildlife viewing on whales is ever to be ascertained, it will likely be achieved with resident killer whales. Every individual in the BC population has been identified and catalogued since photo-identification began in 1973 (Ford *et al*. 2000). There is a wealth of information about their diets, acoustics, movement patterns, social organization, population genetics, survival rates and reproductive rates (e.g., Bigg *et al*. 1990, Ford 1990, Olesiuk *et al*. 1990, Hoelzel and Dover 1991, Ford *et al*. 1998). Resident killer whales are also easily approached by water and observed from shore along the narrow channels of inside passageways where they return each summer.

About a half-dozen studies have been conducted in British Columbia over the past 20 years to measure the response of killer whales to vessel activity. Although quality and rigorousness of the studies vary, most have shown short-term effects of vessels on killer whales. However, none of the killer whale studies completed to date have been able to demonstrate long-term effects of whale watching. This is due in large part to the nature of the beast (i.e., killer whales are long lived with low reproductive rates, and display considerable individual variability in behavior and fitness).

The following provides a brief overview of the short-term studies conducted to date and the types of data sets that might be useful to assess the long-term consequences of wildlife viewing on killer whales. We also consider alternative avenues of research that might be explored to address long-term effects, and propose that mitigating short-term effects might be the best way to ensure that detrimental long-term effects do not occur.

Killer whales

Four populations of killer whales are recognized in British Columbia. They are the southern residents, northern residents, transients, and offshore killer whales. As of 1998, they numbered approximately 600 individuals (~90 southern residents, ~100 transients, ~200 northern residents, and >200 offshores). Further north, there are two additional resident populations – the southeast Alaska residents and the Prince William Sound residents. The populations all appear to be genetically distinct and may be thought of as races with specialized diets, dialects and social patterns (Bigg *et al.* 1990, Ford 1990, Hoelzel and Dover 1991, Ford *et al.* 1998).

There are two prime areas to view killer whales in British Columbia. One is in Haro Strait at the southern end of Vancouver Island (which is frequented by southern residents in the summer), and the other is Johnstone Strait at the northeast end of Vancouver Island (which is frequented by northern residents, also during the summer). Haro Strait encompasses the Gulf Islands of BC and the San Juan Islands of Washington State. Johnstone Strait is a narrow 3-6 km channel with high vantage points for observing the movement of whales and vessels. Johnstone Strait also has a few pebble beaches that the whales use to rub their bodies on. These rubbing beaches form part of the Robson Bight – Michael Bigg Ecological Reserve that was designated to protect the near-shore killer whale habitat. The whales are presumably drawn to Haro Strait and Johnstone Strait because of the high and predictable abundance of migrating salmon that return through these areas each summer. These straits also draw sport and commercial fishermen, and have become the focal points for commercial killer whale watching in British Columbia.

Whales and boats

To a killer whale, most boats must seem noisy. Underwater noise may inflict pain on marine mammals, and may disrupt feeding and communication between whales (Bain and Dahlheim 1994). Similarly, the cumulative effect of inhaling diesel fumes or ingesting oil may prove toxic over time; and of course collisions with vessels can result in injury or death. Killer whales do wake ride occasionally, but in general vessels would seem to provide no benefits to killer whales.

Avoiding vessels may be energetically expensive and require an animal to eat more. Maintaining vigilance against vessels may also reduce the amount of food consumed. In theory, reduced energy balance may stunt growth, delay the onset of sexual maturity and lower pregnancy rates. Severe nutritional deficiencies may even weaken an animal's immune system, increase the likelihood that chronic illnesses will become fatal, or cause death through organ failure.

Short-term effects

Three shore-based studies of the effects of vessels on killer whales began in the early 1980s in Johnstone Strait. One set of behavioral observations made from a blind near the rubbing beaches found whales reacted to three-quarters of the encounters recorded with vessels (76% of 356 encounters, Briggs 1991). Some whales left the rubbing beaches, or rubbed for shorter periods than normal, or simply swam past the rubbing beaches without stopping. However, killer whales did not appear to exhibit any clear behavioral response to vessels away from shore (based on 1,040 encounters when one or more boats were within 300 m of the whales, Duffus and Dearden 1993). The third study of vessel effects on killer whales used a theodolite to record positions of swimming whales and found that killer whales swam 1.48 times faster when vessels were present (speed increased from 5.19 km h^{-1} when no boats were present to 6.37 km h^{-1} when present, Kruse 1991). There was also a correlation between swimming speed and number of boats within 400 m of the whales.

A fourth study was conducted from 1991 to 1994 to document the movement of whales and vessels within the Ecological Reserve (based on 250 days of observations during which 11 pods of killer whales were seen in the Reserve a total of 426 times, and 14,112 vessels were recorded within the borders of the Ecological Reserve, Trites *et al.* 1995). Vessel activity did not appear to have marked effects on the numbers of whales in the Reserve. However, vessels affected the movement of whales. Consistent with the findings of Briggs (1991), whales were more likely to move to another area of the Reserve or to leave the Reserve entirely when vessels were present than when they were absent. Furthermore, the probability of whales leaving the Ecological Reserve increased with the number of vessels that were present. Finally, the whales were more sensitive to disturbance near the rubbing beaches than anywhere else.

In 1992 and 1993, Adimey (1995) studied percussive behavior of killer whales in Johnstone Strait in the vicinity of vessels. She found that rates of surface-active behavior increased between 3-4 times when a single boat closely approached (within 50 m). However, surface activity declined rather than increased when many boats were near whales.

In 1995 and 1996, a sixth study was initiated to experimentally approach killer whales and measure their response with a theodolite (consisting of 117 tracks of 21 identifiable focal animals, Williams 1999). Lone whales were tracked in the absence of boats and during approaches by a 5.2 m powerboat paralleling each whale at 100 m. Variables measured included dive time, swim speed, rate of surface-active behaviors and indices of swimming path (deviation and directness). Female killer whales swam significantly faster when followed by the experimental boat, and increased the angle between successive dives. However, males (which swim faster than females when alone) maintained their speeds but chose a less direct swimming path.

During this same study (Williams 1999), whales were opportunistically tracked in the presence of non-experimental boats (64 tracks of 20 whales). Analyses of these data showed males swam slower as the number of boats approaching the whales increased. They also swam in a more direct line and displayed more surface active behaviors (e.g., tail slapping). Females tended to make longer dives and swam in a more direct and less deviant path as numbers of vessels increased.

A possible interpretation of these results is that whale watching is not perceived by whales along a single, monotonic dimension. They may respond one way to a single vessel that approaches closely (within 50 m), another way at moderate distances (100 m), and another way again when boats are at still greater distances (100-500 m). Likewise, responses to single vessels may be different than responses to groups of vessels (with the response to groups of vessels being more like responses to single vessels at moderate distances than responses to single vessels at short distances).

Layman (1991) monitored changes in acoustical behavior of killer whales as a function of vessel traffic in Johnstone Strait over 54 days. She found no significant effect, although the frequency response of her recording system may have allowed some responses to be masked. Other studies have also failed to find significant behavioral effects, but these null results have not been published or reported (e.g., Otis unpublished data, Kriete unpublished data). Thus it is important to emphasize that while many studies have shown short-term effects, this is not universally the case.

In summary, the studies of killer whales and vessel interactions conducted over the past two decades have tended to show that vessels alter the behavioral patterns of killer whales close to shore. They also show that males and females employ different strategies to avoid vessels when swimming in more open waters, and that the numbers and the proximity of boats that are present alters their responses. However, it is not clear to what extent these results can be generalized to all killer whales, and what the cumulative effect of such interactions might be.

Long-term effects

Over the long-term, vessel activity on killer whales may be expected to increase mortality, reduce reproduction, or lead to a change in distribution patterns. However, to date, killer whales continue to use their traditional core areas despite the rise in whale-watching traffic that has occurred in these waters over the past 15 years (Osborne 1999). Mortality of killer whales in the southern population has increased, and this population does sustain higher levels of whale-watching activity than any other. But it is not possible to draw a causal relationship between the two given that salmon stocks (the principal summer food) have also declined in the coastal waters of British Columbia and Washington (due to over-fishing, poor ocean survival and degradation of spawning habitat), and southern residents have much higher toxin levels than northern resident killer whales (Ross *et al.* in press). Thus, after 25 years of killer whale research and about 20 years of commercial whale watching, there is no clear indication of long-term effects of vessel traffic on killer whales even though there have been significant changes in survival rates during this period (Wade *et al.* 2000).

Future research

One means of assessing long-term effects of vessel traffic on killer whales is to compare variables measured over time, such as swim speeds, activity patterns and behavioral responses. Unfortunately, a considerable amount of information is often lost over time concerning details about the observations and methods used to collect the data. Longitudinal studies need to consider what variables are meaningful and agree on standardized techniques to collect and archive the data.

A case in point is an apparent decadal change in swimming speeds of killer whales in response to vessels. In 1983, Kruse (1991) found whales swam faster as number of boats increased, while in 1994-95 Williams (1999) found no increase in speed as numbers of vessels exceeded one. Comparing these two findings suggests that whales are no longer increasing their swimming speeds in response to vessels, and may have habituated to their presence. Unfortunately, differences in methodologies exist between the two studies, and Kruse's data are no longer accessible 17 years later for re-analysis. However, a third data set was collected in 1985 (Bain and Briggs, unpublished data) using methodologies similar to those applied by Williams. Analysis of these data suggest that whale behavior was no different in 1985 compared with 1995, and that no habituation has taken place (Williams, unpublished analysis), or conversely, no additional habituation has occurred since 1985.

Other avenues of research worth pursuing to address long-term effects fall under the title of comparative 'population' studies. The 5 populations of resident killer whales between Puget Sound, Washington, and Prince William Sound, Alaska, are all subject to different levels of whale watching activity. Comparing the differences in the vital rates of the 5 populations may provide some insights into the potential influence of vessel activity. Differences may also be examined at a finer scale by breaking the populations down into pods and subpods. Of course, environmental factors and genetic differences among populations could confound such studies.

Inferences about long-term effects might also be drawn from studies of terrestrial species. A considerable amount of research is currently being focussed on concentrations of stress hormones produced by species living under different conditions. For example, spotted owls living in clear cuts and re-generated forests have higher levels of stress hormones than spotted owls living in old growth forests (Wasser *et al.* 1997). Measuring stress hormone concentrations in killer whales may prove to be just as useful for assessing relative levels of stress endured by different populations. Fecal hormone assays of many species typically show elevations of glucocorticoid metabolites above baseline after such stressors as translocation to unfamiliar environments, drought, recovery from anesthesia, aggressive interactions, environmental degradation, and social stress (e.g., Kotrschal *et al.* 1998, Monfort *et al.* 1998, Whitten *et al.* 1998, Foley *et al.* in press). While the collecting of feces from killer whales would not be without its challenges, new techniques are being developed that may allow stress proteins to be measured in skin biopsies using molecular techniques. Stress is an important physiological state to measure given that it can potentially reduce birth rates and increase mortality.

Simulation modelling is yet another potentially useful tool for understanding the consequences of vessel activity on whales. For example, models could be used to predict the number of times that whales encounter vessels each day, and could project future rates of encounters based on current rates of growth in whale watching activity. Models could also be developed to determine the energetic cost to animals when vessels disrupt rest patterns or cause animals to swim further or faster. Acoustical models could predict the consequences of noise for foraging efficiency. In turn, these effects on energy flux could be incorporated into population dynamics models to convert short-term disturbance into population level impacts.

As an example of how energetic effects of whale watching could be used to predict population level effects, consider the following. Williams (1999) found males travel 13% farther in the presence of whale watching traffic than when on their own. This extra distance traveled would lead to extra energy consumption (Kriete 1995). In the southern community, the whale-watching season has expanded to about 12 hours a day, six months a year. Thus a whale may be 'watched' as much as 25% of the year, which in turn might increase swimming distance by 3% per year and increase energy requirements accordingly.

With regards to the effects of boat noise, Bain and Dahlheim (1994) found that it could mask killer whale hearing. For a species that relies on echolocation, this could reduce detectability (availability) of prey. Time spent foraging might also be reduced if whales attend to vessel traffic rather than search for prey. Such changes in energy balance caused by the combination of increased energy demand and reduced prey availability might result in a population of killer whales being effectively higher relative to carrying capacity than it would be under natural conditions.

Olesiuk *et al.* (2000) recently fit a generalized logistic model of population growth to killer whales. Extrapolating from this model suggests that the potential 'population' impact of whale watching could depend on how close a population is to natural carrying capacity (K). For example, consider a population that has no whale watching and is at 85% of K. Introducing boats to this system would increase the activity of the whales and thereby require them to increase their food intake. Thus the whale-watched population might consume energy at a level equivalent to a population that is at 90% of natural K. This increase in the effective size of the population would slow population growth by less than one individual every five years (in the case of a population with a K of 100 individuals). However, for a population already at K, whale watching might result in an effective population that is 105% of K. The resulting change in energy budget (although a small percentage) could lead to the loss of one individual per year. Such a loss, however, would be difficult to detect against a background of natural population change.

The scenario we based on the Olesiuk *et al.* model is hypothetical, and we do not claim that such a mechanism has caused the decline of any killer whale population. Our intent is merely to point out that mechanisms might exist for the cumulative effect of small behavioral changes, in combination with limited food availability, to lead to life or death consequences on the population level.

Conclusions

Twenty-five years of research has shown that the relationship between boat traffic and killer whale behavior is complex. In the short-term, killer whales appear to employ a multivariate array of responses to avoid vessels that are in part a function of vessel numbers and proximity. Other influencing variables may be vessel size, activity and engine noise. Killer whales also appear to have a wide range of individual tolerances, which may in turn be a function of prey availability (body condition), age, sex or time of day.

Long-term effects of whale watching on killer whales can be postulated, but have yet to be demonstrated. The killer whale studies conducted to date suggest that killer whales continue to use their core areas despite high levels of whale watching traffic. Generally, populations have continued to increase in the presence of vessel traffic, suggesting that population scale impacts are at most small, and will be difficult to pick out of natural population fluctuations. Assessing such effects will require carefully planned research, which given the longevity of whales could outlast the careers of some whale biologists. However, it may never be possible to conclusively demonstrate long-term effects due to the low numbers of whales, and their low rates of birth and death. Furthermore, there may be too much variability in individual killer whale responses to detect general trends and patterns in numbers and distributions. Such uncertainty thus begs questioning the search for long-term effects when steps can already be taken to mitigate some of the demonstrated short-term responses.

Literature cited

Bain, D. E. and K. C. Balcomb. 1999. Population trends of southern resident killer whales (*Orcinus orca*) from 1960-1999. Report submitted to November 1999 SRG meeting. Maui, Hawaii.

Bain, D. E. and M. E. Dahlheim. 1994. Effects of masking noise on detection thresholds of killer whales. Pages 243-256 in R. R. Loughlin, ed. Marine mammals and the Exxon Valdez. Academic Press, San Diego.

Baird, R. W. 1999. Status of killer whales in Canada. Species Status Report: Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

Bigg, M. A., P. F. Olesiuk, G. M. Ellis and K. C. Balcomb. 1990. Social organization and genealogy of resident killer whales (*Orcinus orca*) in the coastal waters of British

Columbia and Washington State. Reports of the International Whaling Commission (special issue) 12:383-405.

Briggs, D. 1991. Impact of human activities on killer whales at the rubbing beaches in the Robson Bight Ecological Reserve and adjacent waters during the summers of 1987 and 1989. Report to BC Ministry of Environment, Land and Parks.

Duffus, D. A. and P. Dearden. 1993. Recreational use, valuation, and management of killer whales (*Orcinus orca*) on Canada's Pacific coast. Environmental Conservation 20:149-156.

Foley, C., S. Papageorge and S. K. Wasser. in press. Non-invasive stress and reproductive measures of social and ecological pressures in free-ranging African elephants (*Loxodonta africana*). Conservation Biology

Ford, J. K. B. 1990. Vocal traditions among resident killer whales (*Orcinus orca*) in coastal waters of British Columbia. Canadian Journal of Zoology 69:1454-1483.

Ford, J. K. B., G. M. Ellis and K. C. Balcomb. 1994. Killer whales. 1st ed., University of British Columbia Press, Vancouver.

Ford, J. K. B., G. M. Ellis and K. C. Balcomb. 2000. Killer whales. 2nd ed., University of British Columbia Press, Vancouver.

Ford, J. K. B., G. M. Ellis, L. G. Barrett-Lennard, A. B. Morton, R. S. Palm and K. C. Balcomb III. 1998. Dietary specialization in two sympatric populations of killer whales (*Orcinus orca*) in coastal British Columbia and adjacent waters. Canadian Journal of Zoology 76:1456-1471.

Hoelzel, A. R. and G. A. Dover. 1991. Genertic differentiation between sympatric killer whale populations. Heredity 66:191-195.

Kotrschal, K., K. Hirschenhauser and E. Moestl. 1998. The relationship between social stress and dominance is seasonal in greylag geese. Animal Behavior 55:171-176.

Kriete, B. 1995. Bioenergetics in the killer whale, *Orcinus orca*. Ph.D. University of British Columbia.

Kruse, S. 1991. The interactions between killer whales and boats in Johnstone Strait, B.C. Pages 149-159 in K. Pryor and K. S. Norris, eds. Dolphin societies: discoveries and puzzles. University of California Press, Berkeley.

Layman, L. A. 1991. The effects of boat noise on vocal behavior of *Orcinus orca* as an indication of their ability to adapt to human activities in Canadian waters. B.A. University of California.

Monfort, S. L., K. L. Mashburn, B. A. Brewer and S. R. Creel. 1998. Evaluating adrenal activity in African wild dogs (*Lycaon pictus*) by fecal corticosteroid analysis. Journal of Zoo and Wildlife Medicine 29:129-133.

Olesiuk, P., G. M. Ellis, J. Ford and K. Balcomb. 2000. Population dynamics of Southern and Northern Residents. Presentation to the Southern Resident Killer Whale Workshop. Seattle, WA.

Olesiuk, P. F., M. A. Bigg and G. M. Ellis. 1990. Life history and population dynamics of resident killer whales (*Orcinus orca*) in the coastal waters of British Columbia and Washington State. Reports of the International Whaling Commission (special issue) 12:209-243.

Osborne, R. 1999. A historical ecology of Salish Sea resident killer whales (*Orcinus orca*): with implications for management. PhD. thesis, University of Victoria.

Ross, P., G. M. Ellis, M. Ikonomou, L. Barrett-Lennard, and R. Addison. in press. High PCB concentrations in free-ranging Pacific killer whales (*Orcinus orca*): effects of age, sex and dietary preference. Marine Pollution Bulletin.

Trites, A. W., W. Hochachka and S. K. Carter. 1995. Killer whales and vessel activity in Robson Bight from 1991 to 1994. Report to BC Ministry of Environment, Land and Parks.

Wade, P., D. E. Bain and K. Balcomb. 2000. Population dynamics of southern resident killer whales. Report submitted to the Southern Resident Killer Whale Workshop. SRKW11. Seattle, WA.

Wasser, S. K., K. Bevis, G. King and E. Hanson. 1997. Noninvasive physiological measures of disturbance in the Northern Spotted Owl. Conservation Biology 11:1019-1022.

Whitten, P. L., R. Stavisky, F. Aureli and E. Russell. 1998. Response of fecal cortisol to stress in captive chimpanzees *(Pan troglodyte*s). American Journal of Primatology 44:57-69.

Williams, R. M. 1999. Behavioural responses of killer whales to whale-watching: opportunistic observations and experimental approaches. M.Sc. University of British Columbia.