CHANGES OBSERVED IN THE REACTION OF WHALES TO HUMAN ACTIVITIES

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ABSTRACT

A review of our marine mammal observations of more than 25 years indicated that each of the species commonly observed within 35 km of Cape Cod reacted differently to stimuli from human activities. Over the years of exposure to ships, for example, minke whales (Balaenoptera acutorostrata) have changed from frequent positive interest to a general lack of interest, finback whales (B. physalus) have changed from generally negative to uninterested reactions, right whales (Eubalaena glacialis) have apparently continued the same variety of responses with little change, and humpbacks (Megaptera novaeangliae) have dramatically changed from relative disinterest to often strongly positive reactions. These reactions appeared to result mostly from three types of stimuli: underwater sound was the primary cause of reaction, then light reflectivity, and tactile sensation. The reactions of the whales were related to their perception of the stimuli as interesting or disturbing, their perception of the movements of the sources of the stimuli relative to their own positions, and their perception of the occurrence of stimuli as expected or unexpected. The reactions were modified by the whales' previous experience and current activity: habituation occurred rapidly, attention to other stimuli or preoccupation with their own activities overcame their interest or wariness of stimuli, and inactivity seemed to allow whales to notice and react to stimuli that otherwise might have been ignored. The changes over time in the reactions of whales to stimuli from human activities were gradual and constantly varying with increased exposure to these activities and with their levels of habituation.

Report to the National Marine Fisheries Service
Contract 50-eanf-5-00068
"Assessment of Marine Mammal Reaction to Human Activities
from Observations over the Last Twenty-six Years"

CONTENTS

INTRODUCTION

A common impression is that whales have always behaved as they now do toward many human activities, including whale-watching. Actually, the behavior of many whales has changed -- species that formerly were shy of vessels now often approach them without apparent concern. In Cape Cod Bay off Massachusetts, for example, growing numbers of recognizable humpback whales (Megaptera novaeangliae) regularly approach familiar whale-watching boats. Even finback whales (Balaenoptera physalus) that previously could seldom be approached, now appear to be less wary of vessels. The recent increase of concern for marine mammals, the expansion of whale-watching enterprises in the last few years, and the increasing awareness of environmental issues, have all contributed to the assumption that cetaceans are only now being affected by human activity, and that whale behaviors have always been as they are now. In reality, the animal reactions are continually changing, with some radical shifts in behavior over relatively short periods. These changes in whale reactions to human activity may be noticeable in a variety of geographic locations that have relatively high levels of vessel traffic or whale-watching, but we have confined our descriptions to the waters around Cape Cod.

The results presented here stem from our observations of whales over more than 25 years. Systematic investigations of the effects of human activities on whales were not attempted; instead, this information summarizes the responses that we noted during our studies of whales in local waters. Our interest was focused by the need to determine the effects of tracking whales by implanted radio tags (Watkins 1981, Watkins et al. 1984).

We have reviewed our data on the whales we observed to provide general assessments of the changing behavior, to compare responses to human activities during the early years with more recent reactions, and to place the observations of these whale reactions into the perspective of their constantly varying behavioral responses and the changing pressures of human interaction. Although the annotations of whale responses from our records are largely anecdotal and not readily quantifiable, we believe they are representative, and fairly depict the observable differences in the whales' behaviors. These data span enough years of observations so that the differences in whale reactions may be analyzed. Our review has been confined to the species most commonly seen within about 35 km of Cape Cod: minke whales (Balaenoptera acutorostrata), finback whales (B. physalus), right whales (Eubalaena glacialis), and humpback whales (Megaptera novaeangliae). An analysis of this review is presented here.

METHODS

The data for review included observations of whales from before 1958, dovetailing with the previous work of Schevill and Lawrence (1949) since 1947. The base of information included annotations in logs of cruises and experiments, in lists of sightings, with photographic records, on acoustic recordings, and in personal summary notes of observations. These records often indicated assessments of animals' reaction to our presence, to the passage of other vessels, or to other human activities. The notations in these data were reviewed to obtain general assessments and trends in the whale reactions.

A portion of the data from 1957 to 1982 that included 3817 positively identified whales listed in sighting logs were selected to provide a cross section of the observations for more detailed analysis. These sightings were in waters within 35 km of Cape Cod, and they included 122 sightings of minke whales, 2259 finbacks, 833 right whales, and 603 humpbacks. The numbers varied considerably from year to year, depending on the emphases of our work, but they represented approximately equal effort for these species. Of the sighting notations, 129 included comments about the behavior of the whales relative to our presence or to other human activities. These comments from the logs and all accompanying data were transcribed to computer spread-sheet (Lotus 123, Compaq PC) and tabulated chronologically for the

four species. Whale responses before 1975 to 1977 were compared with the more recent observations, since whale-watching activities became common. This provided a small, representative sample of a large amount of generally unquantifiable, unwieldy data.

A summary of the results and analysis of whale reactions are presented first, then the individual subjects are described in that order and illustrated more fully.

RESULTS

Summary of the Data Review --

It was apparent from the data that the reactions by whales to human activity could be categorized as "positive", "uninterested", and "negative". These reactions appeared to result mostly from three kinds of stimuli (see review by Watkins and Wartzok 1985) produced by those activities: underwater sound was apparently the primary cause of reaction, then light reflectivity, and tactile sensation.

Each whale species reacted differently to human activities. Over a few years' exposure to the noise and presence of vessels, including whale-watching boats, minke whales have changed from frequent positive interest to relative lack of interest, finbacks have changed from generally negative to uninterested reactions, right whales have apparently continued the same

variety of responses with little change, and humpbacks have dramatically changed from relative disinterest to often strongly positive reactions. Changes in the reactions of whales to stimuli from human activities were gradual and constantly varying with increased experience and levels of habituation.

The whale reactions seemed to be related to their perception of stimuli produced by the human activity: (1) their perception of the stimuli as interesting, as known and unimportant, or as disturbing, (2) their perception of the movements of the source of the stimuli relative to their own positions, and (3) their perception of the occurrence of stimuli as expected or unexpected.

Reactions to these stimuli appeared to be modified by the whales' experience and current activity: (A) habituation to stimuli occurred rapidly, (B) attention to some particular stimulus or preoccupation with a particular activity overcame animals' interest and wariness so that other stimuli seemed to be ignored, and (C) inactivity seemed to allow whales to notice and react to stimuli that otherwise might have been ignored. These modifications to the whale reactions complicated assessments of their responses. Analysis of a representative cross section of the data demonstrated that these behaviors were consistent, with the same patterns evident for each species. The results from the small data set were similar to our general conclusions based on the overall review.

WHALE REACTIONS

The positive (P) reactions of whales to stimuli from human activities included those of apparent curiosity and those that appeared to provide some desirable reward. During positive reactions, the animals' previous activities were suspended, they became silent, and they permitted close approaches or they approached and interacted with the human activity. After a period of such interest, whales often moved away from the immediate area before returning to their former activities. The humpback whale responses to whale-watching vessels in the Stellwagen Bank area off Cape Cod have been examples of extremely positive reactions.

The uninterested (U) reactions were those in which stimuli from the human activity were apparently ignored, and the whales continued their activities uninterrupted. In our observations, we have consistently tried to achieve such uninterested reactions in order to observe the animals' "normal" behaviors. An uninterested reaction did not mean that the animals were unaware of the human activity, but that their behaviors were not interrupted by it.

The negative (N) reactions by whales to stimuli from human activity appeared to include: a sudden change from activity to inactivity, persistent movement away from the source of the stimuli, turning sharply away, immediate startle responses, avoidance by quickly diving, and occasionally any of these were coupled with agonistic responses (such as the in-air blowhole

trumpeting sounds by humpbacks, Watkins 1967). Animals that already were disturbed appeared to continue negative responses with little provocation.

We have not found that shifts in breathing patterns were a reliable indicator of whale reactions because of the cetacean habit of conducting many activities in bouts, with shifts in behavior and breathing rates occurring naturally (demonstrated by the radio tagged whales, Watkins et al. 1981, 1984).

STIMULI THAT CAUSE REACTION

Sound --

Whales obviously responded to acoustic stimuli within their range of hearing. Sounds that were relatively low amplitude at the whales' location or that had most energy at frequencies below or above their hearing capabilities appeared not to be noticed. Most sounds in the background of ambient noise were ignored, including the sounds from distant human activities, even though these sounds may have had considerable energies at frequencies that could be heard well by whales. Most whales reacted to sounds (therefore we assumed that they were hearing them) in frequency ranges from about 15 Hz to approximately 28 kHz. Even at close range, higher frequency sounds generated by our pingers and sonars at 36, 40, 50, and 60 kHz were apparently not noticed by at least the three larger species of whales, as long as the signals contained little energy in the lower-frequency pulse-envelopes.

There did not appear to be any particular sounds that were attractive to whales, although occasionally sounds that were similar to their own vocalizations seemed to stimulate positive reactions. Occasionally, humpbacks have seemed temporarily curious about series of relatively low amplitude pulsed sounds, such as sounds of the stepping motor in our scanning sonar transducer, or the muffled noises of hands hitting the topsides of boats.

Whales reacted negatively in response to a wide variety of underwater sounds that appeared to be (a) unexpected, (b) too loud, (c) suddenly louder or different, or (d) perceived as being associated with a potentially threatening source (such as the noise of a rapidly approaching ship or outboard on a collision course -- often noticed in both finbacks and humpbacks). Such reactions were variable and seemed to depend on the animals' current activities and their previous experiences. Whales that were already disturbed reacted more quickly in a negative way to sounds that appeared not to be bothersome at other times. There were no specific frequencies or combination of frequencies that were inherently disturbing to whales.

Negative reactions by whales have apparently been caused by the sounds of: an engine starting, a ship's close approach, propeller cavitation when a boat goes into reverse or turns sharply, the start up of echosounder and sonar signals, explosions or hammering on pipes, even the underwater noise of

tools dropped on the deck of a vessel, as well as the underwater components of any loud in-air sounds, such as from the overflight of a noisy airplane or helicopter.

Although such sounds often caused negative reactions by whales, the same sequences often have not elicited this reaction if the sounds were continuing, and therefore, apparently expected -- the sounds of an engine that had been running at a particular rate and at the same received sound levels for some time probably would not cause a reaction, while the starting of the same engine could cause a distinctly negative response.

Whales have often seemed to become accustomed to sounds that at first appeared to be bothersome, so that after a period of repetition, these sounds were tolerated. For example, the whine of a slowly turning propeller shaft seemed to cause a negative reaction whenever we first stopped near animals, but after a few approaches to the same whales, though the shaft was still noisy, we were able to come closer without obvious disturbances.

Light Reflectivity --

Light reflecting off bright objects sometimes appeared to cause startle reactions and avoidance by the whales, limited by the relatively short ranges of visibility. They seemed to avoid brightly reflective objects, such as the unpainted aluminum pressure cases used for underwater instrumentation. Startle reactions were sometimes produced when whales appeared to have

come close enough suddenly to see our boat or underwater instruments. Unexpected notice by whales of our floats and cables has produced startle reactions by all of these species. Yet within a few hours, the same humpbacks that had moved sharply away from the light colored housing of a towed sonar transducer were investigating and touching it -- the periodic, low-frequency pulsing sounds of the stepping motor in the transducer appeared to have aroused the whales' interest, overcoming their wariness of the brightly reflective visual stimulus. (This had been noticed on several previous occasions, so on 28 May 1981 the stepping motor was turned off eight times, and each time the humpbacks left quickly, but returned from 200 to 300 m when it was turned back on.) Whales have also approached apparently without noticing our instruments at night, while in daylight the same reflective objects seemed to cause negative reactions. The use of flat black paint on our instruments has consistently reduced whales' reaction to them.

Tactile Sensation --

The tactile sense in marine mammals has been relatively less important than hearing or vision in their responses to human activity, but on occasion whale reactions have appeared to depend on their expectation of the "feel" of particular objects. Whales generally have appeared to avoid touching unfamiliar objects, and often passed within a few cm without touching new objects and cables. However, increasing

familiarity with the feel of objects has appeared to change these reactions, sometimes within very short periods. Boat hulls usually were not touched, yet after experience, individual whales have been known to rub against and even push or tilt small vessels (as in our experience with Scott Kraus in the Bay of Fundy, when a small right whale gently lifted our 12-m power boat). Familiar objects often have been used in tactile ways -- logs, fishboxes, and seaweed floating at the surface have been touched and lifted repeatedly by individual whales. Our hydrophone cables suspended from floats near the surface usually were avoided by whales, but after some tentative manipulation, individuals have begun touching and lifting the cables so that occasionally we have had to retrieve the hydrophone array for fear of dammage.

PERCEPTION OF STIMULI

The whales' perception of the stimuli from human activities has appeared to dictate the level of their reaction. Most low amplitude sounds appeared to be ignored, except for a few that occasionally seemed to stimulate positive interest. However, those same sound sequences could cause negative reactions when they were too loud or when they began too abruptly.

The whales' assessments of relative movements of a sound source have seemed to influence their reactions -- such as to a source that was perceived to be moving in a direction that would not affect them, or one that would come directly toward them.

For example, a vessel moving on a parallel course with the whales usually caused less reaction than the same vessel at the same distance that was approaching on a collision course. (These effects also may have been complicated by the exponential increase in sound level of an approaching sound source.)

The expectation of the occurrence of a stimulus also appeared to affect the reaction of whales to that stimulus. For example, noises that began abruptly or that were suddenly louder, sometimes any sudden change in sound sequence, or occasionally even the abrupt cessation of a sound, all might cause whales to react negatively, or sometimes positively. Continuing sound sequences were often ignored, perhaps because these sounds were expected to continue, such as echosounder signals that only gradually increased in amplitude as a vessel slowly approached. However, if the same echosounder were suddenly turned on when whales were nearby, it could cause sharply negative reactions. The unexpected, abrupt, or higher amplitude stimuli seemed to trigger many of the negative reactions of whales to human activities.

EXPERIENCE AND OTHER MODIFICATIONS TO REACTIONS

Cetaceans generally appeared to habituate rapidly to most stimuli, consequently their reactions changed with exposure to those stimuli. Only a few encounters were needed sometimes to transform whales' wariness of a stimulus to apparent unconcern. For example, slow-speed, relatively quiet boat maneuvers near

whales for identification photography of individiuals at first may have produced mildly negative reactions, but after three or four passes, the vessel has often been ignored. It has not been possible to establish how quickly habituation occurs (probably highly variable with the experience of individual whales and the nature of the stimulus), but apparently only a few encounters within a short period have been needed for whales to become accustomed to stimuli that were relatively non-disturbing. Individuals that have habituated to such activities have appeared to react less obviously during the next encounter.

Whales' apparent preoccupation with particular stimuli or with their own activities often has appeared to affect their wariness toward other stimuli. For example, a new, louder or more abrupt sound often has seemed to cause whales to ignore other nearby occurrences -- such as the starting of a motor on a more distant boat diverting their attention from a nearby slowly sidling engine. Or, when the attention of whales has appeared to be concentrated on feeding or social activities, they have often ignored other usually disturbing stimuli. Such responses were apparently the result of differences in the relative attention given to these stimuli by the animals, rather than a result of masking by stronger stimuli -- although masking by other sounds at the same frequencies also occurred occasionally. We have taken advantage of such seeming preoccupation to allow closer vessel maneuvering during radio tagging, photography, or detailed observation of individuals.

Conversely, when whales have been relatively inactive, they often were more difficult to approach without causing disturbance. At such times, these animals seemed to be more easily affected, and they have appeared to react more quickly to even low-amplitude stimuli, both positively and negatively.

CHANGING TECHNOLOGIES AND METHODS

There have been two interrelated changes in the methodology associated with these observations that have had some effect on assessments of whale reactions: (A) our developing technologies have allowed more consistent and detailed observations of the animals from greater distances, and (B) we have learned how to approach and work less obtrusively. As improvements in technology became available and silent ship methods were developed, they were gradually incorporated in our studies, beginning in the early years, and therefore contributed some bias to the observations.

Technology Improvement --

Throughout the period of these observations, there has been considerable development in the technologies associated with the studies of whales. For example, improvements in the components of acoustic monitoring systems made it possible to work with lower-amplitude signals, hydrophone arrays permitted localization of underwater acoustic interactions between whales,

and improved photographic gear added detail and confidence in recognition of individuals. Such technological improvements provided more detailed assessments of animal activities at much greater distances.

Silent Ship Methods --

In our study of whales, it was immediately evident that when using engine propulsion, direct, close approaches usually disrupted their activities. It also was clear that whales became silent when disturbed. Although we used sail whenever possible, engine propulsion was usually more practical for maneuvering. Therefore, we emphasized early development of the "silent ship" techniques, summarized here. These have allowed consistent observations of undisturbed whales.

(1) Approaches to the vicinity of whales were made obliquely, on a course that would carry our vessel past the animals. Whales were consistently less disturbed when it appeared that boats would pass beside them, rather than run directly over their position.

(2) The research vessel was gradually slowed in order to keep the underwater engine and propeller noises that were audible to the whales from increasing sharply during an approach. (Sound intensity increases at a rate greater than the inverse square of the difference in distance, so that without a progressive reduction in engine speed as the vessel approached, the crescendo of noise heard by the whales would be tremendous.)

(3) The ship was allowed to stop without reversing propellers or turning sharply, because these maneuvers create extremely loud underwater cavitation sounds, which vary with different vessels. Engines were stopped before reaching the vicinity of the animals, and the ship's way and local winds and currents were calculated in advance and used for final positioning.
(4) The ship was silenced. All machinery on board was turned off, including pumps and refrigerators, and any other sounds such as footsteps on deck were avoided.
(5) Observations continued silently, without restarting machinery until the whales were a considerable distance away.
(6) The ship was always started slowly after the observations, with only gradual increases in engine sound and propeller velocity so that cavitation and noise would be minimal.

These largely common-sense methods for approach and observation of undisturbed animals have continued to be effective, often allowing several sequences of approaches to the same whales. Our consistently successful studies of these vocalizing whales have demonstrated the utility of these methods for providing observations of relatively undisturbed whales.

CHANGES IN WHALE REACTIONS

Some real differences were evident in the observations of whale reactions before about 1975 to 1977, compared with the comments on reactions during later years. The bias introduced by changes in technology and methods would not have been

significant except in the earliest observations, and the patterns of change in reactions have been consistent since then. These changes include the following:

(1) Negative responses were obviously expected from most of the species of whales during the early period -- it was always a surprise when there were positive or uninterested reactions; in the later period, we expected the animals generally to be uninterested in our presence, and we would terminate observations at the first signs of negative responses.

(2) Short observations appeared to be normal during the earlier period, with little hope of returning for other opportunities with the same whales; in the later period, relatively longer and repeated observations of the same individuals were expected.

(3) The development of techniques for approaching animals quietly and monitoring the effectiveness of these methods was a strong emphasis during our early work; in the more recent period, it was expected that most whales could be approached, and that we could observe them closely with little disturbance.

Expectations true of the earlier years have been reversed. The whales near shore have become less wary of boats and their noises. These whales have appeared to be much less bothered by the presence of boats and ship noises in recent years, particularly in areas of higher ship traffic. Even in regions with low traffic, whales have appeared to become less easily disturbed than previously. In particular locations with intense shipping and repeated approaches by boats (such as the

whale-watching areas of Stellwagen Bank), more and more whales have reacted positively to familiar vessels, and they also have occasionally approached other boats and yachts that stopped nearby.

Over the years, the patterns of change noted in the reactions of whales to human activity have proved to be consistent within the different species, especially in these nearshore populations. Animals that have had repeated contact with boating and other human activities have gradually modified their behaviors. In addition, enough individuals in local waters have apparently had sufficient exposure to these activities so that the patterns of changing behavior are not only noticeable in the commonly seen individuals, but also these patterns of change may be observed throughout the larger populations, probably due to relatively wide movememnts of the animals throughout the area.

DIFFERENCES IN WHALE REACTIONS

The whale reactions particularly to vessels and to our presence during the early observations are compared below with the more recent notations of their reactions in these same areas. The differences noted for the four species are summarized from our general review of the data, and then they are related to the results of the tabulation and analysis of the smaller data set compared in Table 1. These whale reactions from the sighting logs, listed in Table 2, were categorized

(column 4) as positive (P), uninterested (U), and negative (N) -- as defined in the preceding section on "Whale Reactions". Although this sample from the data is too small for meaningful statistical treatment, the results of the comparisons in Table 1 agree with the assessments from our broader, general review.

TABLE 1 -- Comparison of Whale Reactions

The whale reactions (in Table 2, column 4) were tallied for comparison of the four species. The reactions were divided into two roughly equal divisions, before and after about 1975 to 1977, and they were categorized by (P) positive reactions, (U) uninterested reactions, and (N) negative reactions to human activities.

	1st Period			/	2nd Period		
B. acuto (total 18) (B. acutorostrata)	P=4,	U=3,	N=1	/	P=2,	U=7,	N=1
B. phy. (total 53) (B. physalus)	P=0,	U=11,	N=15	/	P=1,	U=20,	N=6
Eub. (total 21) (E. glacialis)	P=0,	U=5,	N=5	/	P=0,	U=5,	N=6
Meg. (total 37) (M. novaeangliae)	P=6.	U=4,	N=8	/	P=13,	U=5,	N=1

Balaenoptera acutorostrata --

During the early years, the scattered minke whales usually reacted positively, or they were uninterested in the human activities. Though these animals could seldom be actively approached, they often approached us to look at our ship or equipment. Mostly, they appeared to ignore our presence and moved about unpredictably, surfacing for only one or two breaths

at a time. Only occasionally were their reactions negative. Minke whales were often alone or in small groups, so they usually were silent (lone whales seldom vocalize, Watkins and Wartzok 1985).

In the later years, minke whales continued to appear generally uninterested and undisturbed by passing vessels or by our presence. Although they have not appeared to avoid these activities, they have seemed much less likely to approach closely.

The data set summarized in Table 1 shows general agreement with those assessments. The minke whale reactions in the first period were indicated as more positive, and during the last period, they were relatively uninterested. Generally, little negative reaction was noted for either period.

Balaenoptera physalus --

Finback whales have always appeared to be the most numerous species in these waters, yet in our earlier observations, they were consistently the most wary of ships. They could seldom be approached, even with silent ship procedures. Only occasionally did a finback pass near our vessel, even after long periods of the ship drifting quietly nearby. Finbacks usually moved rapidly away from our approaching ship -- not surfacing again until they were nearly at the horizon. We seldom saw feeding or other near-surface activities, because these whales were actively swimming away. We concluded that it was just about

impossible to study finbacks. Their low-frequency sounds (18 - 75 Hz) travelled well underwater and were often heard in relation to particular behaviors, but these whales were consistently silent for long periods after being disturbed (Watkins 1982).

In later years, finback whales were more likely to ignore vessels, seldom diverting from their activities unless boats passed within about 20 m. They now sometimes swam up to a vessel, apparently just to take a look. Their behavior in local waters has changed so that we have been able to work in relatively close proximity to finbacks and observe details of many activities. However, they have generally continued to be silent when vessels were near, and they have usually interrupted sequences of vocalization as ships passed, even though other activities such as feeding were apparently not affected.

The finback data in Table 1 demonstrate that the whale reactions were uninterested and often negative during the first period. During the later period, finbacks were generally noted to be much more uninterested and less often negative. Only one positive reaction was listed for either period.

Eubalaena glacialis

During our early observations of right whales (Watkins and Schevill 1982), we considered them relatively approachable, compared to finbacks and humpbacks. Right whales generally did not react to low-amplitude engine noises and minor vessel

maneuvering. They were especially approachable when feeding on patches of well concentrated plankton or when interacting with others in social groups. However, they were easily disturbed when not actively engaged in such pursuits, when alone, or when cows were with relatively small calves. Right whales generally moved slowly but consistently away from passing ships, and they dove quickly, often without fluking, when disturbed. They were usually vocal during group activity and between apparent feeding runs at depth, and they were consistently silent when disturbed.

In later years, right whales were still relatively approachable, and their reactions to the presence of vessels have seemed generally unchanged. However, we have the impression that they vocalized less in the nearshore areas.

The right whale data in Table 1 indicate that during both periods responses were nearly equally distributed between uninterested and negative reactions. There was not much change between periods, and these whales did not react positively.

Megaptera novaeangliae

In the early observations, humpback whales could only be approached occasionally, regardless of their activity. Close passages of our vessel often elicited trumpeting sounds (usually an agonistic response of this species, Watkins 1967, Watkins and Wartzok 1985). Humpbacks generally moved away from passing ships and only young animals tended to approach to investigate our activities. The whales seldom remained near boats, and

their surface activity was considerably lessened when ships were nearby. Underwater sounds were often audible from undisturbed groups of humpbacks but disturbed whales usually became silent and moved rapidly away from the area.

In contrast, during recent years, humpback whales in nearshore areas generally have seemed to accept vessels. Many whales that were approached often by whale-watching boats reacted positively -- so much so that these humpbacks acted like trained animals, some of them exhibiting predictable surface behaviors in close proximity to the vessels. These whales were usually silent during these positive reactions, both underwater and in-air, even though there may have been several whales interacting together. The humpback responses to vessels generally had become positive, usually with complete interruption of any other activities.

The humpback whale data in Table 1 show that reactions were mixed during the first period, but in the later period they had become much more positive, with fewer uninterested and negative reactions. The end of those data (Table 2) show these trends more strikingly.

REACTIONS TO WHALE-WATCHING

Our studies of whales near Cape Cod included regular observations from boats and aircraft for more than 17 years before commercial whale-watching began. We happened to be flying above one of the first of Albert Avellar's (1975)

Provincetown whale-watching excursions, and we later participated in many of these cruises. During the first years of whale-watching, it was not usual for the boats to get particularly close to any of the animals. We tried to adapt some of the silent ship methods to the commercial whale-watching -- approaching slowly but more directly, and then stopping engines so that the boat would drift quietly to the whales. These procedures allowed closer approaches, and they were used consistently during the first years of whale-watching. As whales apparently began to recognize and accept these vessels, the skippers have not felt it necessary to approach so carefully.

On several occasions during recent years, when we were hove-to in a sailing vessel, acoustically monitoring and observing humpbacks near Stellwagen Bank, the whales suddenly stopped their underwater activities, became silent, and began slowly swimming at the surface. At the same time, we began hearing the distant sounds of a whale-watching vessel on our hydrophones. The first time we noticed this (21 May 1981), we recognized the characteristic shaft whine of the vessel, DOLPHIN III. Although it was still 8 to 10 km distant, the three humpbacks remained at the surface and appeared to wait for the boat. As it approached, the whales went toward the vessel and swam closely around and under it until engines were restarted. Then, before the boat was away from the area, the whales returned to their previous activities, including vocalization.

Over the last ten years, since whale-watching began off Massachusetts, reactions of whales to this enterprise appear to have changed, with most of the locally resident and even the more transient visiting whales responding more and more positively toward the familiar vessels. Humpback whales have become the focus of whale-watching because they have modified their behaviors so that they now usually react positively, and exhibit considerable aerial activity. This is in striking contrast to the pre-whale-watching period when humpbacks could seldom be approached, few came close unless the boat was lying silently in their path, and surface activities were curtailed when vessels approached. Finback whales also have changed from active avoidance to general acceptance of the vessels' presence, even though they have not often remained near the boats.

CHANGES HAVE BEEN GRADUAL

This review has made it obvious that the differences in whale behavior and reactions have occurred gradually. These have been constantly varying responses by individual whales with relatively small differences form one experience to the next. Yet over a span of years, the whale responses to human activities, such as whale-watching, may be seen to have changed considerably with patterns of habituation emerging. These interrelated changes in behavior have been more noticeable for the consistent local groups of finbacks and humpbacks, while the right whales which have only occasionally come close enough to

experience the heavy vessel traffic have not showed such obvious differences in responses. Some of the same changes in reaction noted in the local animals have also appeared to occur throughout the more extended populations of these species.

ACKNOWLEDGEMENTS

The data for review were collected by many different researchers in whale programs at the Woods Hole Oceanographic Institution, beginning with the studies of William E. Schevill. Support for the data collection was mostly from the Oceanic Biology Program of the Office of Naval Reaserch through a variety of studies (including contract N00014-82-C0019 NR 083-004). The sighting data were analyzed by Karen E. Moore, and the manuscript was helpfully reviewed by William Schevill, Peter Tyack, and Karen Moore. Funds for the review and analysis of these data were provided by the National Marine Fisheries Service, Contract 50-EANF-5-00068 through the Northeast Fisheries Center.

Table 2 -- The next two pages list 129 sightings that include comments about whale reactions to human activities from a subset of 3817 sightings from 1957 to 1982 of 122 minke whales (B.acuto), 2259 finback whales (B.phy.), 833 right whales (Eub.), and 603 humpback whales (Meg.). The behaviors are listed in column 4 according to the description in the section on "Whale Reactions", categorized as positive (P), uninterested (U), or negative (N). These are compared in Table 1 (p 21).

TABLE 1

Species	No.	Date	Behav	Location	Ship/Air	Comments
B.acuto	1	17 Jul 60	N	Sandy Neck	s	caught in fish trap, released
B.acuto	2	17 Apr 76	P	Pkd Hill Bar Buoy	s	one stayed with boat for long period
B.acuto	1	24 Apr 76	P	1 km S Wood End	s	played around boat for 30 min
B.acuto	1	21 Aug 76	U	SW corner Stell.	s	around boat for 1.5 h (with finback)
B.acuto	1	30 Mar 77	U	3 km W PHB buoy	a	no reaction to fishing vessels
B.acuto	1	15 Apr 77	P	Race Rip	s	fled boat
B.acuto	1	26 Apr 77	P	1 km W Wood End	s	very uncooperative
B.acuto	1	17 May 77	U	25 km N Race Pt	s	elusive, didn't bother with boat
B.acuto	1	17 Apr 78	U	15 km W Great I	s	not interested
B.acuto	1	18 Apr 78	U	SW cor Stellwag	s	unconcerned, didn't come to boat
B.acuto	1	18 Apr 78	P	6 km N Race Pt	s	swam up to and around boat
B.acuto	1	26 Apr 78	U	12 km SW Race Pt	s	elusive, didn't bother with the boat
B.acuto	1	24 Apr 78	U	10 km W Great I	s	not interested
B.acuto	2	29 Apr 78	N	8 km W Great I	s	not interested
B.acuto	1	10 May 78	P	SW corner Stellw	s	circled boat underwater, belly up
B.acuto	1	15 May 80	U	4 km W Race Pt	s	not interested
B.acuto	1	19 May 78	U	4 km N Race Pt	s	ignored boat
B.acuto	2	26 Sep 81	U	SW cor Stellwag	s	not interested
B.phy	1	27 May 63	N	2 km N Brewster	s	partially beached, reacted to outboard
B.phy.	1	5 Jun 58	N	Off C.Porp.,ME	s	outran us offshore
B.phy.	2	5 Aug 58	U	39-25N,72-12W	s	blew repeatedly near vessel
B.phy.	2	5 Aug 58	N	39-47N,72-08W	s	did not round out near ship
B.phy.	1	28 Nov 59	N	30-44N,65-30W	s	he would have none of us.
B.phy.	1	17 Apr 60	U	32-13N,65-38W	s	closed the ship on a parallel course
B.phy.	1	12 Sep 61	N	42-17N,70-04W	s	spooked as we came by
B.phy.	1	13 Sep 61	N	42-18N, 70-05W	s	disappeared as soon as we stopped
B.phy.	1	14 Sep 61	N	42-20N,70-06W	s	came up to us as we drifted
B.phy.	1	27 Sep 61	N	42-17N,70-00W	s	shy
B.phy.	3	28 Sep 61	N	42-27N,70-05W	s	didn't stay; one fluked
B.phy.	2	29 Sep 61	U	42-11N,69-41W	s	got very close - pictures
B.phy.	1	30 Sep 61	N	42-11N,67-07W	s	moved off quickly
B.phy.	3	19 Jan 62	N	Cape Cod Bay	a	vessel passing, two blew underwater
B.phy.	1	2 May 74	N	8 km S Wood End	s	came close, no sounds, spooked
B.phy.	1	21 Aug 76	U	SW cor Stellwag	s	feeding nearby 1.5 hrs, unconcerned
B.phy.	4	28 Mar 77	N	5 km W Truro	a	three smaller whales plane-shy
B.phy.	12	11 Apr 77	U	4 km NE Race Pt	a	feeding; many fishing boats in area
B.phy.	1	20 Apr 77	U	2 km NW Race Pt	s	came very close
B.phy.	9	13 Apr 77	U	10 km W Race Pt	a	with fishermen, reacted to plane
B.phy.	1	15 Apr 77	N	2 km SW Long Pt	s	fled boat
B.phy.	1	16 Apr 77	U	off Race Point	s	very cooperative
B.phy.	1	27 Apr 77	U	7 km W Truro	s	ignored boat
B.phy.	1	29 Apr 77	U	8 km W Jeremy Pt	s	ignored boat, propable feeding
B.phy.	1	29 Apr 77	N	7 km W Great I	s	moving fast, apparently fleeing boat
B.phy.	1	29 Apr 77	U	10 km W Great I	s	ignored boat
B.phy.	3	4 May 77	U	8 km W Great I	s	uninterested
B.phy.	5	5 May 77	N	9 km NW Dennis	s	stopped feeding, moved away
B.phy.	1	6 May 77	N	8 km N Dennis	s	very elusive, moved away
B.phy.	2	7 May 77	U	9 km W Great I	s	uninterested but very elusive
B.phy.	1	11 May 77	U	7 km W Great I	s	ignored boat
B.phy.	4	11 May 77	U	8 km S Wood End	s	ignored boat
B.phy.	1	11 May 77	N	8 km N Dennis	s	very skittish
B.phy.	3	11 May 77	U	14 lm S Long Pt	s	ignored boat
B.phy.	2	14 May 77	U	6 km W Great I	s	ignored boat; many gulls
B.phy.	3	15 May 77	U	4 km W Great I	s	ignored boat
B.phy.	1	17 May 77	U	25 km N Race Pt	s	very near fishing boats, unconcerned
B.phy.	2	23 May 77	P	9 km N Race Pt.	s	one rolled belly up off bow of boat
B.phy.	4	31 May 77	U	20 km N Race Pt	s	one came very close as we steamed
B.phy.	12	21 Jun 77	U	S edge Stellewag	a	many feeding, fishermen not far
B.phy.	1	21 Apr 78	N	8 km S Long Pt	s	very elusive
B.phy.	1	3 May 78	U	0.5 km W Race Pt	s	elusive but continued activities
B.phy.	2	3 May 78	N	6 km N Race Pt	s	running ahead of us, side by side
B.phy.	2	2 May 79	U	8 km NW Bill Buoy	s	elusive, but generally uninterested
B.phy.	3	1 Jun 79	U	4 km SW Stellwag	s	unconcerned approaches with calf
B.phy.	1	21 Feb 80	U	4 km N PHB buoy	a	near fishing vessels
B.phy.	2	2 Apr 80	U	17 km NE Race Pt	a	draggers in area

TABLE 1 -- continued.

Species	No.	Date	Behav	Location	Ship/Air	Comments
B.phy.	2	6 May 80	U	8 km W Bill buoy	s	not interested
B.phy.	2	24 Apr 81	U	SW cor Stellwag	s	passed close, feeding on side
B.phy.	1	8 May 81	U	9 km NW PHB buoy	s	draggers in area
B.phy.	2	28 May 81	U	5 km S cor Stell	s	one came close, unconcerned
B.phy.	4	24 Apr 81	U	5 km W cor Stell	s	3 passed close to boat
B.phy.	1	3 Jun 82	N	9 km NE Race Pt	s	elusive; not showing fin
Eub.	5	11 Apr 60	U	3 mi off W End	a	ignored boats, sexual activity
Eub.	10	20 Apr 60	U	100 m Wood End	a	feeding, boats nearby
Eub.	2	27 Apr 61	U	off Race Point	s	nursing and feeding
Eub.	2	28 Apr 61	N	5 km NE CC Canal	s	social activity interrupted
Eub.	3	28 Apr 61	U	off Race Point	s	passed close carried away camera.
Eub.	3	26 Jan 62	N	500 m off Race Pt	s	spooked when plane landed
Eub.	2	29 Apr 65	N	4km E Highland Lt	a	scared by plane
Eub.	2	30 Apr 65	N	5 km W off Truro	s	maneuvers for tagging
Eub.	1	1 May 72	U	1 km off Race Pt	s	apparently feeding, came close
Eub.	2	17 May 73	N	1 km W Bill buoy	a	cow hid calf
Eub.	5	2 Mar 75	N	7 km W Truro	a	stopped activity
Eub.	1	26 Jun 75	N	E of Monomoy	s	very shy and on a passage
Eub.	1	24 Mar 76	N	7 km W Great I	a	not seen again, 30 min search
Eub.	2	6 Apr 76	N	8 km NW Barnstab	a	reacted to plane, small calf
Eub.	2	15 Apr 76	U	10 km NE PHB buoy	a	unconcerned, not protecting calf
Eub.	2	28 Mar 77	N	2 km SW Wood End	a	down 16 min intervals, spooked
Eub.	1	30 Mar 77	N	2 km N Sandy Neck	a	reacted, no feeding
Eub.	2	12 Apr 77	U	4 km W Race Pt	a	feeding, boats near
Eub.	2	2 May 79	U	2 km N Bill buoy	s	feeding, stayed with them 5 hrs
Eub.	2	17 Apr 80	U	7 km NW Race Pt	a	calf "playing with" L. acutus
Eub.	2	12 Jun 81	U	6 km W FishLedge	s	pair swam slowly away from us
Meg.	1	4 Apr 57	U	31-05N,62-05W	s	passed slowly as line was hauled
Meg.	2	30 Mar 60	U	32 km E Nantucket	s	uninterested, social activities
Meg.	5	12 Sep 61	U	42-17N,70-04W	s	good recordings nearby whales
Meg.	2	14 Apr 77	N	7 km NW Race Pt	a	first of season; bothered
Meg.	2	20 Apr 77	N	9 km NW Race Pt	s	skittish
Meg.	2	26 Apr 77	P	9 km W Great I	s	interest in cables
Meg.	1	27 Apr 77	N	2 km W Truro	s	startled close to boat
Meg.	1	1 May 77	N	12 km W Great I	s	very uncooperative
Meg.	2	5 May 77	P	16 km W Great I	s	circled boat; swam under cable
Meg.	2	7 May 77	P	15 km W Great I	s	played around boat for 25 min
Meg.	2	8 May 77	P	8 km N Dennis	s	played around boat for 30 min
Meg.	1	11 May 77	N	10 km N Dennis	s	moved away quickly
Meg.	1	12 May 77	N	2 km W Truro	s	very skittish
Meg.	1	17 May 77	N	6 km SW Truro	s	elusive, moved away
Meg.	1	21 Apr 78	N	4 km N Bill buoy	s	very elusive
Meg.	2	21 Apr 78	P	10 km N Race Pt	s	very cooperative
Meg.	1	22 Apr 78	P	SW cor Stellwag	s	very friendly; approached boat
Meg.	3	26 Apr 78	U	1.5 km N Race Pt	s	uninterested
Meg.	3	6 May 78	P	13 km N Race Pt	s	very playful
Meg.	3	19 May 78	P	13 km N Race Pt	s	we left & they chased us
Meg.	3	23 May 78	P	10 km N Race Pt	s	one approached boat
Meg.	1	25 Apr 79	U	33 km NE Race Pt	s	more interest other activities
Meg.	2	25 Apr 79	N	33 km NE Race Pt	s	moved away from boat
Meg.	1	23 May 79	U	SW cor Stellwag	s	swam close to boat once
Meg.	1	3 Jun 79	U	SW cor Stellwag	s	not interested in boat
Meg.	1	2 Apr 80	U	18 km NE Race Pt	a	draggers in area
Meg.	2	15 May 80	P	10 km NW Race Pt	s	with fisherman, waving flippers
Meg.	1	16 May 80	P	5 km NW Race Pt	s	lying almost touching the boat
Meg.	2	16 May 80	P	10 km NW Race Pt	s	with DIII and Cape Cod Princess
Meg.	2	16 May 80	P	7 km NW Race Pt	s	with Speedy VII and Tioga
Meg.	7	21 May 81	P	W of cor Stellag	s	went to DIII as it was audible
Meg.	1	28 May 81	U	SW cor Stellwag	s	not interested in us
Meg.	2	28 May 81	P	SW cor Stellwag	s	interested in the sonar fish
Meg.	2	11 Jun 81	P	SW cor Stellwag	s	interest in whale-watching boat
Meg.	2	27 May 82	P	4 km N PHB buoy	s	good sonar targets, chasing fish
Meg.	10	1 Jul 82	P	SW corn. Stell.	s	"trained whales"
Meg.	2	3 Sep 82	P	33 km N Race Pt	s	came close to boat

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