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Review of Methods for Assessing the Status of the Harbor Porpoise Population in the Gulf of Maine and Bay of Fundy Region

Results of an At-Sea Workshop

by
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ABSTRACT

Approaches to determining the status of the harbor porpoise in the Gulf of Maine and the Bay of Fundy were reviewed during a workshop conducted aboard a research vessel in the Bay of Fundy from August 20-23, 1987. Participants alternated between reviewing information relative to the status of these animals and conducting experimental sighting surveys along short transects. The workshop resulted in a clearer understanding of what is known and what data sources exist. It also provided an important first step in developing a research program aimed at determining the status of the harbor porpoise population in this region.

INTRODUCTION

Recent research on the incidental take of marine mammals in the fisheries of the New England (Gilbert and Wynne 1985 in prep.) and the Bay of Fundy region (Gaskin 1977, 1984; Read 1987; Read and Gaskin 1988) suggest that substantial numbers of harbor porpoise (*Phocoena phocoena*) become entangled and drown in bottom-tending gillnets each year. The numbers killed have not been precisely estimated. Some interpretations of the available data suggest that the numbers killed could be in excess of 1 percent of the population in the Gulf of Maine region (Gilbert and Wynne, in prep.).

To review approaches to assessing the significance of these incidental mortalities, a workshop was conducted aboard the R/V *Gloria Michelle* from August 20-23, 1987. During the workshop, existing data on the biology and abundance of harbor porpoise in the Gulf of Maine and Bay of Fundy region were discussed, including levels of natural and incidental mortality, growth and reproductive rates, relative abundance indices, absolute abundance levels, behavior, and sighting survey methods.

The results of the workshop are reported here, emphasizing the general level of knowledge, and areas where additional information is needed. Priorities for different research tasks were not developed during the workshop. More specific results from the experimental sighting surveys conducted during the workshop are reported in Polacheck and Smith (1989), in which a method is described for testing assumptions of line transect theory in its application to cetaceans.

METHODS

Workshop participants were invited because of their expertise and experience with harbor porpoise, sighting surveys for cetaceans, and/or cetacean assessments. The workshop was conducted at sea to allow participants to compare this knowledge firsthand in order to rapidly determine suitable field procedures for surveying harbor porpoises. The western Bay of Fundy was selected because it is known to have high harbor porpoise density during summer and fall, and is also an area where incidental mortality due to fishing occurs.

The vessel offered a variety of sighting positions, ranging from the main deck forward of the wheelhouse (1.8 m above the water), to the top of the wheelhouse (4.2 m high), to the crow's nest (7.1 m high). Experimental transects were conducted under a variety of conditions in order to evaluate various factors which would affect the efficiency and reliability of line transect surveys. Teams of workshop participants surveyed from different sighting positions simultaneously to evaluate the effects of sighting conditions (e.g. observer height, use of binoculars) on reports could be more easily evaluated. Vessel speed during these transects was 9 nm/hr.

During the workshop, participants alternated between conducting experimental sighting surveys and discussing approaches to assessing the significance of incidental mortality levels. During poor sighting conditions, there were more formal discussions of these issues. Specific data collected during the workshop were analyzed where the sample sizes allowed.

RESULTS

INCIDENTAL TAKE LEVELS

The incidental takes of harbor porpoise in the coastal Gulf of Maine fixed-gear (groundfish gillnets and weirs) fisheries have been documented in recent years (Smith *et al.* 1983; Gaskin *et al.* 1985; Gilbert and Wynne 1985, in prep.; Read 1987; Read and Gaskin 1988). Smith *et al.* (1983) estimated that 70 animals per year were trapped in New Brunswick, Canada herring weirs between 1969 and 1982. Mortality of trapped porpoises was roughly 50 percent, and about one half of the entrapped animals were yearlings. During the period 1981-1983 individual fishermen reported (Gaskin *et al.* 1985) 0-15 takes per year in groundfish gillnets off Grand Manan, Nova Scotia . Gaskin *et al.* (1985) state that gillnets pose a greater threat to harbor porpoise than herring weirs, since animals entrapped in gillnets have always been reported to die.

Read (1987) and Read and Gaskin (1988) estimate 105 porpoises were killed in the Bay of Fundy in 1986 by Canadian gillnetters. In a three-year study of New England groundfish gillnet takes, the number of incidental kills reported to investigators by a small non-random sample of gillnetters were 30, 97, and 15 for the years 1984-1986 (Gilbert and Wynne, in prep.). This study indicates that the U.S. New England gillnet fishery has the capacity to exceed the annual quota of 180 animals allowed under provisions of a permit authorized under the Marine Mammal Protection Act (Gilbert and Wynne, in prep.).

POPULATION BIOLOGY

Workshop participants briefly reviewed the current knowledge on the population biology of harbor porpoises in this region. Data collected in Canada indicates a two year calving interval (A. Read, personal communication).[1] Most mature females are either lactating or pregnant. Females are rarely found that are both lactating and pregnant at the same time, which suggests a two-year calving cycle. The proportion of mature females that are both pregnant and lactating was reported to be approximately equal to the proportion which were in neither condition. These observations suggest a fecundity rate in the range of 0.5 animals per year.

Based on aging from tooth samples, the age of sexual maturity for females is around 3.5 years and the maximum age of sampled individuals appears to be around 12 to 13 years. Recent analyses in Canada suggest that there may have been a shift in the age structure towards younger animals. The fraction of the population that is juvenile appears to have increased and the overall size distribution of animals appears to have shifted to smaller sizes. The largest and oldest size classes (*i.e.* greater than 160 cm) observed in biological samples in earlier years are rarely observed today. Further analyses are needed to confirm the apparent shift and to assess its magnitude. A shift in the age distribution and a disappearance of the older age classes is expected in a population subjected to exploitation. The extent to which these shifts are occurring in the harbor porpoise popula-

[1] Andrew Read. 1988. University of Guelph; Guelph, Ontario.

tion is an indirect indication that the current incidental take may be significant.

While no formal analyses were available on the overall life table for harbor porpoises for this region, the reported two-year calving interval and the maximum age of 12 to 13 years indicates that harbor porpoises must have extremely high natural survival rates in order to maintain a viable population, and that the maximum possible net rate of increase is probably small. Such a combination of life history parameters would suggest that the population could not support a high level of exploitation and would be sensitive to relatively low kill rates. As such, the currently available information on the population biology of harbor porpoise suggests that it is critical to assess the impact of the current incidental take.

RELATIVE ABUNDANCE INDICES

The possibility of assessing the status of harbor porpoise using a relative abundance index from sighting data was discussed. A number of data sources exist that could possibly be used to develop a time series of relative abundance indices based surveys conducted by University of Guelph researchers on the Grand Manan Ferry, by the New England Aquarium (NEA) staff as part of their right whale research, and line transect surveys conducted by NEA in the early 1980s. The maximum length of any of these data series is seven years. However, participants agreed that none of these data sources are comprehensive enough in their spatial coverage to be used as a reliable index for assessing an overall trend in abundance.

Both development of a long-term time series of relative abundance indices and estimating absolute abundance at a point in time were compared as methods for assessing the significance of current take. At least ten years of time series data would be necessary to detect trends with reasonable statistical precision (Gerrodette 1987), given likely magnitudes for the coefficient of variation. Participants felt that the required number of years for a time series of relative abundance indices was too great to make it a viable approach for assessing the impact of the current takes, given their possible magnitude and the possible sensitivity of harbor porpoise to exploitation due to their life history characteristics.

ABSOLUTE ABUNDANCE ESTIMATES

Procedures for estimating absolute abundance of small cetaceans have been developed for several species based on line transect theory (Seber 1973, Burnham *et al.* 1980). The usual procedures involve sighting schools of cetaceans during aerial or shipboard surveys, recording location of the animals at the time of sighting relative to the trackline of the platform, and estimating the number of animals in a school. From these data, estimates of the average density can be calculated and used as a basis for estimating total abundance.

This approach has been used specifically for harbor porpoises and for several other species of dolphins (Smith 1975, 1981; Holt and Powers 1982; Leatherwood *et al.* 1978; Kasuya 1979; Barlow 1987a, 1987b, 1988; Barlow *et al.* 1988). Development and testing of specific field procedures has been necessary for each species and region. Platform constraints, species-specific behavior patterns, and geographic, oceanographic, and atmospheric features all affect sighting performance. Procedures must be adapted to these features in order to maximize survey efficiency and to avoid possible biases.

Previous harbor porpoise abundance estimates for the Gulf of Maine have been calculated using this approach (Winn 1982; Kraus *et al.* 1983). Since these studies, work on Pacific-coast harbor porpoise populations

(Barlow 1987a) has addressed some of the methodological aspects of applying line transect theory to this species. Similarly, there have been improvements in the statistical theory of line transect, and in our knowledge of the seasonal movement of these animals (Neave and Wright 1968; Kraus and Prescott 1984). These developments suggest that previous estimates of harbor porpoise abundance in the Gulf of Maine have several weaknesses. These include insufficient area coverage, and limited evaluation of the effects of different survey platforms, observers, and environmental factors (glare and cloud cover, for example) on sighting efficiency. Further analyses of the data from past studies using newer techniques may be useful.

SIGHTING SURVEY DESIGN CONSIDERATIONS

During the workshop participants compared sighting methods and aspects of survey design. These discussions are summarized here, with reference to specific results from the workshop transects where relevant.

Behavior

The number of porpoises that occur together, and hence constitute one sighting, varies seasonally in the western Bay of Fundy. Group size tends to increase toward the fall. Participants reported that in the summer, animals are typically seen as singles to triples, as was seen during the workshop. Mothers and calves are identifiable based on size of the calf until late summer. In late summer and fall, group sizes increase, with 5 to 15 animals commonly seen in a single group. Additional analyses of existing data are needed to more clearly define seasonal changes in group size.

Estimation of group size has been a problem for species occurring in large schools (Holt and Powers 1982, Holt 1984), and is a major source of uncertainty in abundance estimates. Estimation of group size is easier when groups are smaller. However, smaller groups of porpoises may be more difficult for observers to detect, and surveys conducted when group sizes are smaller may be less efficient.

Surveys conducted in portions of the region suggest that there are regular seasonal changes in density. Participants felt that there is a general pattern in which porpoise move north throughout the summer, becoming more concentrated in the Bay of Fundy until late September. Animals appear to disperse out of the Bay of Fundy in October and November, but where these animals spend the winter is not known. Incidental mortalities in the gillnet fishery in New Hampshire and southern Maine increase in late autumn. Sighting frequency increases in Cape Cod Bay to southern Maine in the spring. Participants were not able to examine several data sources during the workshop, but felt that this pattern could be better defined by synthesizing data from several sources. The seasonal movement pattern needs to be accounted for in design of a survey and may influence both the time period and area for a survey.

During the workshop, porpoise were observed to swim rapidly relative to the cruising speed of the R/V *Gloria Michelle* but did not appear to change either speed or direction in response to the survey vessel. The effect of target motion on estimates of abundance using line transect theory has been evaluated for some situations and thought to be of minor importance when animals move randomly and at speeds that are small relative to that of the sighting platform (Schweder 1968). However, because of the small sighting distances involved, the interaction between relative speed of harbor porpoise and the vessel needs to be evaluated. Such an evaluation should be done within the context of recent research on hazard rate theory (Hiby 1982, 1985; Basson and Butterworth 1984).

Animals sighted during the workshop

frequently remained visible at the surface for only a short period (one or two breath cycles). The short duration of the sighting cue in such situations has several implications. One is that detection is difficult even for animals on the track line of the vessel. A second is that some animals may not surface between the time they would be detectable and the time the vessel passes them. Visual observation and data collected from radio tagging experiments (Watson and Gaskin 1983) suggest maximum dive times need to be evaluated in relation to the speed at which surveys might be conducted. Third, the estimation of the angle and distance at which porpoise are sighted is more difficult when animals are visible at the surface for only a short time.

Sighting cues for harbor porpoise observed during the workshop were consistent with participants' previous experience, consisting of either the dorsal fin and the back of animals rolling to dive, or "rooster tails" or splashes. Sighting cues varied with sea state, with the fin or back being the most common in calm seas and splashes being more important in rougher seas. At higher sea states, animals appeared to rise higher from the water when breathing.

All participants noted that harbor porpoise were more difficult to detect than most cetaceans. This difficulty appears to be due to the size of the animal, the short duration of the cue, the small group sizes, and the lack of associated birds. The sighting process may depend more upon the previous experience and on observers' peripheral vision. Observer experience and training need to be considered in any survey design.

Differences in sightability with sea state noted during the workshop were consistent with reports from previous sighting studies both for harbor porpoise (Barlow 1987a) and other small cetaceans (Holt and Powers 1982, Smith 1981). Sea state will be an important variable in designing a survey. Several participants with experience in surveying harbor porpoise felt that surveys would not be possible at sea states greater than 2. Maximum sea state in which a survey could profitably be conducted would depend in part on the height of the sighting platform. It was noted that sea states above 2 and 3 are common in the Gulf of Maine/Bay of Fundy region and that time for bad weather must be allowed when designing a survey.

Participants described some geographic areas where extremely high density had frequently been encountered, and some areas surveyed during the workshop had very high rates of sightings (as many as eight schools per minute). Existing data should be examined to determine the extent and consistency of these areas. Survey procedures may need to be adjusted to allow for a large number of sightings in a short period of time. Additionally, survey designs that account for known areas of high density may be more efficient. The results from the workshop suggest that there may be a difference in the sighting function in areas of high density (Polacheck and Smith, in press). If this is the case, the possible effect on standard line transect methods needs to be considered since the probability of detection under such conditions is not independent of density.

Participants noted that porpoises may possibly congregate in some areas in relationship to tidal fluctuations, particularly in passages and eddies. Gaskin and Watson (1985) noted changes in the concentration and spatial distribution of harbor porpoises in relation to the tide cycle for harbor porpoises in Fish Harbor, New Brunswick. Randomization, or possibly stratification, may need to be considered in survey design to account for this effect.

Survey Platforms

A major consideration in designing a survey is choosing the survey platform(s). Participants discussed the relative merits of using a single platform versus multiple platforms. Given the geographic range, multiple platforms would allow the survey to be conducted in less time. However, because weather in this area is often unsuitable for surveys, it was felt that vessels would have to be available on stand-by for a relatively long period in order to insure that sufficient data are collected. In practical terms, there appears to be a trade-off between using a single, larger vessel for a more extended time and using multiple, smaller vessels that could be chartered as needed. If the latter option were selected, it would also be necessary to recruit observers who could be available on a flexible basis, complicating the logistical problems.

The use of multiple vessels raises the question of comparability of results. If the assumptions of line transect theory were met, the standardization among vessels would not be a problem as long as each vessel made enough sightings to estimate a sighting curve. In practice, some calibration tests among vessels would be desirable.

Vessel speed also needs to be considered. It is desirable to minimize the speed of the animals relative to the vessel, suggesting that vessels capable of higher speeds are preferable. However, the animals are often out of sight, below the water's surface for periods up to several minutes. In this regard, slower speeds are preferable. The trade-off between these two considerations is not clear. Further work, both within an analytical framework and in field tests, might clarify the relationship. However, practical consideration regarding the availability of vessels is a factor.

Workshop participants generally felt that the added height gained by searching from the mast improved their ability to detect porpoises and improved the efficiency of their searching. This was most strongly demonstrated during transects in which two teams of observers searched simultaneously and independently from the crow's nest and the wheelhouse. Observers in the crow's nest on low-density transects detected 25 percent more sightings. Results during high-density transects were confounded because there was no recorder in the crow's nest. Participants had similar conclusions about searching from the top of the wheelhouse compared to searching from the bow, although no direct quantitative comparisons were made. One disadvantage of searching at greater heights is that it may be more difficult to estimate the number of animals sighted. Participants felt that this was not a major problem within the height ranges tested, especially if binoculars were available for secondary use.

Survey vessel(s) should have accommodations for the full set of observers needed during a portion of the survey. This is important not only to reduce logistic problems but also to be able to randomize the location of transect with respect to interacting factors of tide, sun angle, closeness to shore, and diurnal weather patterns.

Survey Procedures

Based on the experience gained during the field trials, a minimum of three observers is necessary with one observer responsible for searching only a narrow angle of view directly on the track line. If binoculars are used for searching, extra observers may be needed in high-density areas in order to track individual sightings and prevent double-counting. Participants felt that dividing the sectors to be searched with some overlap between them was more efficient than having multiple observers scan the same areas. The optimal size of the sectors to be searched clearly depends on the number of observers searching at one time.

Based on comparative transects during the cruise, binoculars appear to improve the efficiency of the observers in terms of the number of animals actually sighted and the area of ocean searched. However, using binoculars caused serious problems when tracking individual sightings to prevent double-counting. During the first test transects with binoculars, an area of high porpoise density was encountered and reliable results could not be obtained when binoculars (at least with as high a magnification as those available) were used for primary searching. Participants felt that it would be worth testing binoculars of lower magnification (2 to 3x) as a possible compromise solution to the trade-off between improved efficiency and the problem of tracking individual sightings to prevent double-reporting.

The possibility of stratifying a survey according to the expected density of animals encountered and using two different search modes was discussed. In terms of obtaining an overall density estimate, such a stratification scheme should be defined prior to the survey and not based on the densities estimated at the time of survey. If areas of consistently lower densities can be defined, such a stratification scheme should be considered.

If searching is to be conducted using the unaided eye, participants felt that binoculars should be available to confirm possible sighing cues (such as splashes) and to help estimate the number of animals sighted.

To avoid effects of differences in observer ability, observers need to be rotated periodically. To minimize problems of observer fatigue, a rest station should be included in the rotation scheme (Holt 1984). The data that need to be collected are moderately complex. A separate data recorder for each team of observers using well-defined data forms and data recording instructions are required. Because the data must be recorded in real time, and because at times the rate of sighting is high, procedures must be efficient.

Participants felt that attempting to develop mechanical methods for measuring sighting angles and radial distances would be worthwhile. If searching is done with binoculars, consideration should be given to binoculars with built-in compasses and reticles (preferably with an artificial horizon) (Smith 1982). If searching is done with the unaided eye, participants suggested that some form of hand-held inclinometer be explored for estimating distances. For measuring angles, suggestions included locating a pelorus at each observer station, or using an instrument that would electronically record the angle when aimed in the direction of a sighting.

DISCUSSION AND CONCLUSIONS

Conducting the workshop aboard a research vessel allowed us to efficiently review and assemble the participants' knowledge about the status of harbor porpoise in the Gulf of Maine and the Bay of Fundy, and about sighting survey procedures for studying these animals. Further, this approach allowed participants to compare their field experiences and rapidly agree on suitable procedures. The resulting understanding of the general problem provided a useful basis for identifying research needs.

Participants agreed that the incidental mortality due to gill net fishing activities may be seriously affecting the harbor porpoise in this region. The levels may approach or exceed 1 percent of the total population, although estimates are very uncertain. There is some indication of a decrease in the frequency of older individuals, suggesting an increased mortality rate. Further, the intensity of gill net fishing effort in both Canadian and US waters appears to be increasing. Better information on the rates of incidental mortality, and on the amount of gill net fishing effort is needed.

Participants identified substantial amounts of information on the harbor porpoise that should be reviewed in greater depth than was possible during the workshop. Information on the biology, behavior, and distribution of these animals should be examined to try to estimate natural rates of population increase. Participants identified several sources of data on the abundance and distribution of these animals. Some of these may provide useful indices of relative abundance, at least at selected locations. More work is required, however, to obtain data to estimate absolute abundance reliably, as discussed earlier.

Participants noted that to determine the significance of the present levels of incidental mortality, two approaches could be taken. One is to monitor relative abundance over several years to determine if the population is increasing or decreasing. The other is to compare estimates of total incidental mortality and total absolute abundance, and natural rates of increase in order to calculate the likely net change in the population from year to year. Participants noted difficulties with both of these approaches. The first likely requires at least ten years of data collection to be statistically reliable. The second requires substantial improvements in line transect sighting survey methodology.

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LITERATURE CITED

Barlow, J. 1987a. Abundance estimation for harbor porpoise (*Phocoena phocoena*) based on ship surveys along the coasts of California, Oregon, and Washington. La Jolla, CA: NOAA/NMFS Southwest Fisheries Center. Admin. Rep. LJ-87-05. Available from: NMFS, Southwest Fisheries Center, Box 271, La Jolla, CA, 92038. 36p.

Barlow, J. 1987b. An assessment of the status of harbor porpoise populations in central California. La Jolla, CA: NOAA/NMFS Southwest Fisheries Center. Admin. Rep. LJ-87-06. Available from: NMFS, Southwest Fisheries Center, La Jolla, CA, 92038. 35p.

Barlow, J. 1988. Harbor porpoise, *Phocoena phocoena*, abundance estimation for California, Oregon, and Washington: I. Ship surveys. *Fish. Bull.* 86:3:417-432.

Barlow, J., C. Oliver, T.D. Jackson, and B.L. Taylor. 1988. Harbor porpoise, *Phocoena phocoena*, abundance estimation for California, Oregon and Washington: II. Aerial surveys. *Fish. Bull.* 86:3:433-444.

Basson, M. and D.S. Butterworth. 1984. An exploratory investigation of the use of a hazard-rate model to assess the target motion correction factor in sighting estimates of minke whale abundance. *Report of the International Whaling Commission* 34: 309-314.

Burnham, K.P., D.R. Anderson, and J.L. Laake. 1980. Estimation of density from line transect sampling of biological populations. Wildl. Monogr. 72: 1-202.

Gaskin, D.E. 1977. Harbor porpoise *Phocoena phocoena* (L.), in the Bay of Fundy 1969-1975. *Report of the International Whaling Commission* 27: 487- 492.

Gaskin, D.E. 1984. The harbor porpoise *Phocoena phocoena* (L.): Regional populations, status, and information on direct and indirect catches. *Report of the International Whaling Commission* 34: 569-586.

Gaskin, D.E., A.J. Read, P.F. Watts, and G.J.D. Watts. 1985. Population dispersal, size and interactions of harbor porpoise in the Bay of Fundy and Gulf of Maine. Ottawa: Department of Fisheries and Oceans. Can. Tech. Rep. Fish. Aquat. Sci. 1291.

Gaskin, D.E., G.J.D. Smith, A.P. Watson, W.Y. Yasui, and D.B. Yurick. 1984. Reproduction in the porpoises (Phocoenidae): implications for management. *Report of the International Whaling Commission* Special Issue 6: 135-148.

Gaskin, D.E. and A.P. Watson, 1985. The harbor porpoise, *Phocoena phocoena* in Fish Harbor, New Brunswick, Canada; occupancy, distribution, and movements. *Fish. Bull.* 83: 427-441.

Gerrodette, T. 1987. A power analysis for detecting trends. *Ecology* 68:1364-1372.

Gilbert, J.R. and K.M. Wynne. 1985. Harbor seal populations and fisheries interactions with marine mammals in New England, 1984. Report on NOAA/NMFS Contract No. NA-80-FAC-00029 and NA-84-EAC-00070. Available from: NMFS, Northeast Fisheries Center, Woods Hole, MA, 02543.

Gilbert, J.R. and K.M. Wynne, in prep. Marine mammal interactions with New England gillnet fisheries. Report on NOAA/NMFS Contract No. NA-84-ES-00070. Available from: NMFS, Northeast Fisheries Center, Woods Hole, MA, 02543.

Hiby, A.R. 1982. The effect of random whale movement on density estimates obtained from whale sighting surveys. *Report of the International Whaling Commission* 32: 791-793.

Hiby, A.R. 1985. An approach to estimating population density estimates of great whales from sighting surveys. *IMA J. of Math. Applied in Med. and Biol.* 2:201-220.

Holt, R.S. 1984. Testing the validity of line transect theory to estimate density of dolphin schools. La Jolla, CA: NMFS, Southwest Fisheries Center. Admin. Rep. LJ-84-31. Available from: Southwest Fisheries Center, P.O. Box 271, La Jolla, CA, 92038.

Holt, R.S. and J.E. Powers. 1982. Abundance estimation of dolphin stocks involved in the eastern tropical Pacific yellowfin tuna fishery determined from aerial and ship surveys to 1979. La Jolla, CA: NMFS, Southwest Fisheries Center. NOAA Tech. Memo. NMFS-F/SWFC-23. 95p.

Kasuya, T. 1979. The population of finless porpoise in the inland Sea of Japan. *Scientific Rep. of the Whales Res. Inst.* 31:1-44.

Kraus, S.D. and J.H. Prescott. 1984. Seasonal movements of harbor porpoise, (*Phocoena phocoena*), in the Gulf of Maine. Report on NOAA/NMFS Contract No. NA-82-FAC-0027. Available from: NMFS, Northeast Fisheries Center, Woods Hole, MA, 02543.

Kraus, S.D., J. Prescott, and J.R. Gilbert. 1983. Harbor porpoise, (*Phocoena phocoena*) in the U.S. coastal waters off the Gulf of Maine: A survey to determine seasonal distribution and abundance. Report on NOAA/NMFS Contract NA-82 -FAC-00027. Available from: NMFS, Northeast Fisheries Center, Woods Hole, MA, 02543.

Leatherwood, S., J.R. Gilbert, and D.G. Chapman. 1978. An evaluation of some techniques for aerial censuses of bottlenosed dolphins. *J. Wildl. Manage.* 42(2):239-250.

Neave, D.J. and B.S. Wright. 1968. Seasonal migration of the harbor porpoise (*Phocoena phocoena*) and other cetaceans in the Bay of Fundy. *J. Mammal.* 49: 259-264.

Polacheck, T. and T.D. Smith. 1989. A proposed methodology for field testing line transect theory for shipboard surveys of small cetaceans. *Report of the International Whaling Commission* 39:341-345.

Read, A.J. 1987. Incidental catch of harbor porpoises in Bay of Fundy groundfish gillnets. Abstracted in conference materials prepared for 7th Biennial Conference on the Biology of Marine Mammals, Miami, FL, Dec. 5-9, 1987. Contact Society of Marine Mammology, Lawrence, KS.

Read, A.J. and D.E. Gaskin. 1988. Incidental catch of harbor porpoises by gillnets. *J. Wildl. Manage.*

Seber, G.A.F. 1973. *The estimation of animal abundance and related parameters.* London: Griffin. 654pp.

Schweder, T. 1968. Transformation of point processes: applications to animal sighting and catch problems, with special emphasis on whales. Univ. of California, Berkeley. Dissertation. 183 p.

Smith, G.J.D., A.J. Read, and D.E. Gaskin. 1983. Incidental catch of harbor porpoise, *Phocoena phocoena* (L.), in herring weirs in Charlotte County, New Brunswick, Canada. *Fish. Bull.* 81:660-662.

Smith, T.D. 1975. Estimates of sizes of two populations of porpoises (Stenella) in the eastern tropical Pacific Ocean. La Jolla, CA: NMFS, Southwest Fisheries Center. Admin Rep. LJ-75-67. Available from: Southwest Fisheries Center, P.O. Box 271, La Jolla, CA, 92038. 56p.

Smith, T.D. 1981. Line transect techniques for estimating density of porpoise schools. *J. Wildl. Manage.* 45(3): 650-657.

Smith, T.D. 1982. Testing methods of estimating range and bearing to cetaceans aboard the R/V D.S. Jordan. La Jolla, CA: NMFS, Southwest Fisheries Center. NOAA Tech. Memo. NMFS-F/SWFC-20. 30p.

Watson, A.P. and D.E. Gaskin. 1983. Observations on the ventilation cycle of the harbor porpoise *Phocoena phocoena* (L.) in the coastal waters off the Bay of Fundy. *Can. J. of Zool.* 61:126-132.

Winn, H.E. 1982. A characterization of marine mammals and turtles in the Mid and North Atlantic areas of the U.S. outer continental shelf. In *Final report of the Cetacean and Turtle Assessment Program.* Washington, D.C.: USDOI, Bureau of Land Management. Report on Contract No. AA551-CT8-48.437p.