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Rescue and release of mass stranded cetaceans from beaches on Cape Cod, Massachusetts, USA; 1990–1999: a review of some response actions

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Abstract

Responses to aid mass stranded cetaceans are hampered by a lack of scientific guidance and shared experience. In this paper, we provide a qualitative and quantitative review of 17 selected mass stranding events that occurred on Cape Cod, Massachusetts, USA, and the responses taken to assist the animals. Three hundred and seventy-six animals were involved in the strandings. Most (n=299) were euthanized or otherwise died without rescue being attempted. We made concerted rescue efforts for 77 animal; 53 pilot whales (*Globicephala melas*), 16 white-sided dolphins (*Lagenorhynchus acutus*), and 8 common dolphins (*Delphinus delphis*). Rescue efforts did not include captive rehabilitation. Results from these attempts indicated that: 1) species involved could survive being transported to release sites up to 40 km away from the original site of stranding (90% survival, n=41), 2) previously stranded animals did not habitually restrand after release (82% not observed to restrand, n=73), and 3) rapidly obtained qualitative data could identify animals that did not restrand (91% not observed to restrand, n=24). Sixty of 77 animals, 78% survived transport and were released without restranding, or were released from the stranding site without restranding. We did not carry-out long-term studies to determine the ultimate survival or death of animals that were not observed to restrand. However, documentation of short-term survival is needed prior to undertaking expensive, long-term investigations. We also used the entire database to investigate the effect of season on stranding events. The number of stranding events did not vary by season, but group size was larger in the winter (G^2=54.6, df=2, P<0.01). There were also significant differences in the seasonal mortality rates of stranded animals. Mortality rates were: winter (0.96 ± 0.01, n=233), spring (0.79 ± 0.05, n=68), and fall (0.52 ± 0.06, n=71). Summer was excluded due to small sample size. Data suggest that rapid intervention by well-trained and equipped response personnel can increase the chance that animals will survive the stranding event, and that long-term studies of survivorship are advisable.

Key words: mass stranding, cetaceans, pilot whale, white-sided dolphin, common dolphin, rescue, euthanasia.

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Introduction

Human interventions to assist mass stranded cetaceans are a recent endeavor. Such efforts often are guided by emotion, or insufficient and conflicting scientific information. In terms of scientific information, some authors report pathologies in mass stranded animals and caution against rescue attempts that do not include long-term rehabilitation in aquaria (Walsh *et al.*, 1990; Walsh *et al.*, 1991; Bossart *et al.*, 1991; Duignan *et al.*, 1995). Others (e.g., Sergeant, 1982; Klinowska, 1985, 1986; Brabyn & McClean, 1992) offer non-pathologic causes, suggesting that mass stranded cetaceans might be healthy at the time of stranding. If so, the potentially lethal, somatic and psychosomatic, traumas induced by stranding might be reduced through quick response and proper care (see Geraci & Lounsbury, 1993; Turnbull & Cowan, 1998), making rescue and rapid release actions an important method of assistance. This lack of consensus can be traced to the rare, chaotic, and idiosyncratic nature of mass strandings that often conspire to inhibit scientific investigation. In addition, generalizable truths might not be attainable because mass strandings are likely complex, multi-causal events. As such, each of the above-cited authors (and others) might be correct in some situations, but wrong in others.

In this paper, we provide a qualitative and quantitative review of 17 selected mass stranding events that occurred on Cape Cod, Massachusetts, USA, and the results of responses taken to assist the animals. Specifically, we investigated the following questions:

(1) Can mass stranded pilot whales (*Globicephala melas*), white-sided dolphins (*Lagenorhynchus acutus*), or common dolphins (*Delphinus delphis)* survive transport to sites away from the original site of stranding?
(2) Will previously stranded pilot whales, white-sided dolphins, or common dolphins habitually restrand when rapidly returned to the sea without captive rehabilitation?
(3) Can rapidly obtained qualitative information be used to select pilot whales, white-sided dolphins, or common dolphins likely to survive the trauma of stranding, transport, and release without restranding?
(4) Are there seasonal differences in the number of stranding events, the numbers of animals stranded, and the survivorship of stranded animals?

Materials and Methods

In our experience, a mass stranding can occur over more than one day and be spread over many km of shoreline. We therefore, defined a mass stranding as an event that involved two or more animals, excluding a mother and her calf (Wilkinson, 1991), beached in a manner that was linked in time and space i.e., that in hindsight did not appear to be independent events. Strandings of multiple species were treated as separate events. To be included in the analyses, a stranding had to be responded to by a coalition of groups that included at least a combination of members from the New England Aquarium[1], the International Wildlife Coalition, and/or the Center for Coastal Studies, and to occur between January 1990 and June 1999. In addition, the dorsal fin of each released animal must have been marked with a uniquely numbered cattle-ear-type tag to allow the documentation of its handling and the identification of restranded animals or carcasses. In some cases, all individuals involved in a stranding were not used in the analysis. For example, we did not include animals taken to aquaria for long-term rehabilitation. We also did not include animals released by responders other than the above listed combination of groups, because techniques could have differed from those we describe.

[1]Legal authority to respond to strandings was held by the New England Aquarium in the form of a Letter of Authorization from the U.S. National Marine Fisheries Service.

Seventeen mass strandings involving 376 animals fit these criteria (Table 1). Numbers for each species were: pilot whales, seven events totaling 164 animals; white-sided dolphins, six events totaling 175 animals; and common dolphins, four events totaling 37 animals. Of the 376 animals, 299 were euthanized or died without human assistance. Concerted rescue efforts were made for 77 animals: 53 pilot whales, 16 white-sided dolphins, and 8 common dolphins.

Transport survival—Animals that were not returned to the sea at the point of stranding were transported prior to release. For short distances (i.e., a few hundred m), animals were transported using stretchers of the type described in Gage (1990). Stretchers typically were carried by members of the response team. In one case (9/30/91; distance ~ 600 m) stretchered pilot whales were slung from a front-end loading construction vehicle and in another case (12/12/92) stretchered pilot whales were picked-up and placed on a flatbed trailer using a construction crane. In most cases (Table 1), transport required movements in excess of a few hundred m, and animals were placed on a flatbed trailer cushioned with a specially designed, semi-inflated air bag (Vetter® Lifting Bag, Vetter® GmbH, Postfach 1260, Eifestrebe, 5352 Zuplich-Langendorf, Germany). The trailer was then towed using a four-wheel drive vehicle. Mortalities during transport were recorded. The percentage of animals that survived transport was examined by species and also by the total number of animals moved.

Release and restranding—We considered an animal to have been released when it was part of an organized attempt to return a group of animals to the sea. This did not include relatively haphazard attempts involving individual or small groups of animals pushed back to sea while the main group remained onshore, a practice that our early experience deemed unsuccessful and was discontinued. Animals were released from the point of stranding or after being relocated to more favorable areas of egress. We defined a restranding to occur when an animal returned to shore and died after release back to the sea. This excludes animals that temporarily grounded ($< \sim 5$ min) after release. An animal was considered not to have restranded if its carcass was not observed after release. The percentage of released animals that did not restrand was examined by species and by the total number of animals

Table 1. Results of attempts to aid cetaceans involved in selected mass strandings that occurred on Cape Cod, MA, USA from 1990–1999. All released animals were marked with a uniquely numbered cattle-ear type tag attached to the dorsal fin. NA = not applicable; Unk = unknown.

Species	Date	Stranding site (see Fig. 1)	Total number of animals	Mortality prior to transport	Mortality during transport	Mortality post release	Number not restranded	Release site (see Fig. 1)	Maximum time from grounding to rescue efforts	Minimum time from stranding to release	Observation post-Release	Marine mammal event number[1]
Pilot whale	12/11/90	A	53[2]	44	NA	4	5	a (Stranding site)	Unk	13 hr	NA	07149
Pilot whale	9/9/91	B	5	3	NA	0	2	b (Stranding site)	Unk	29.5 hr[3]	~7 days	07189
Pilot whale	9/10/91	C	27	4	NA	0	23	c (Stranding site)	Unk	5 hr	NA	07189[4]
Pilot whale	9/30/91	D	17	5	0	6[5]	6	d (Stranding site)	Unk	Repeated strandings over 4 days	11 days	07192
Pilot whale	10/8/91	E	12[6]	10	0	2	0	e[7]	Unk	24 hr	NA	07193
Pilot whale	12/24/91	F	31	31[8]	NA	NA	NA	NA	Unk	NA	NA	07209
White-sided dolphin	8/27/92	G	4[9]	2	0	0	2	g	Unk	5 hr	NA	09072
Pilot whale	12/12/92	H	19	14	3	0	2[10]	h	Unk	4 hr	NA	10239
White-sided dolphin	4/6/93	I	8	2	0	0	6	i	<15 min	4 hr	~14 days	10830
Common dolphin	12/20/93	J	4	1	0	0	3	j	<15 min	4.5 hr	NA	15675
Common dolphin	3/5/94	K	7	7	NA	NA	NA	NA	Unk	NA	NA	10163
White-sided dolphin	3/14/94	L	6	1	0	0	5	l	<15 min	3 hr	NA	15760
White-sided dolphin	12/31/94	M	28[11]	28	NA	NA	NA	NA	Unk	NA	NA	16895
Common dolphin	11/16/97	N	10	5	1	1[12]	3	n	Unk[13]	Unk	NA	15628
White-sided dolphin	1/31/98	O	82	82	NA	NA	NA	NA	NA	NA	NA	15639
Common dolphin	1/31/98	P	16	16	NA	NA	NA	NA	NA	NA	NA	15639
White-sided dolphin	3/19/99	Q	47	44	0	0	3 (1[14])	q	<15 min	7 hr	NA	16896
			Total 376	Total 299	Total 4	Total 13	Total 60					

[1]Marine Mammal Event Number is the identifier assigned to a stranding event by the Smithsonian National Museum of Natural History's Marine Mammal Events Program. This number can be used to obtain additional information (e.g., length and gender) on many of the animals involved in the stranding events reported in this paper.
[2]Number does not include two animals taken to the New England Aquarium, Boston, Massachusetts for rehabilitation.
[3]Animals were supported in ~1.5 m of water throughout the period.
[4]Marine Mammal Events Program grouped the 9/9/91 and 9/10/91 strandings under the same event number.
[5]Twelve animals restranded one day after the initial rescue. Six of those animals survived the second rescue effort.
[6]Number does not include four untagged animals released by Massachusetts Audubon Society.
[7]Transport by inflatable boat.
[8]Animals stranded Christmas Eve in sub-zero temperatures. No rescue was attempted and surviving animals were euthanized.
[9]Number does not include an unknown number of animals pushed back to sea by local residents.
[10]Animals stranded during winter storm, winds +50 knots, temperatures ~0°C.
[11]Temperatures with wind-chill were sub-zero. Many live animals had frozen body parts. The total does not include two animals, a mother and her calf, that were transported to NEA and released after rehabilitation.
[12]Animal was euthanized after continually returning to shore after release attempts.
[13]Five animals involved in the rescue attempt were never observed stranded. However, five animals were dead, but in the water upon our arrival and the area in which the event took place has <1 m of water at low tide. This suggests that the live animals also might have stranded.
[14]Animal tagged and released by the town of Eastham's Department of Natural Resources. We have not included this animal in the restranding analysis due to lack of our involvement.

released. Most animals were returned to the sea within three to ten hours of stranding (Table 1).

Efficacy of qualitative indices of body condition used as release criteria—For white-sided dolphins and common dolphins, we identified animals thought to be capable of survival by qualitatively examining a suite of 12 factors that might indicate somatic and psychosomatic condition. These indices evolved from our own experience with pilot whales and were augmented with information from Geraci & Lounsbury (1993). The suite included animal length, sex, body condition (e.g., emaciation, existence and severity of injuries or lesions), eye-blink reflex, flipper reflex, ventilation quality and pattern, mouth reflex, mouth lining and gum colour, capillary refill in the gum area, and the general 'attitude or gestalt' of the animal. Categories were scored subjectively by one or more biologists experienced with stranded cetaceans as either a plus or minus. A plus score was considered favorable for release and a minus was considered unfavorable. If almost all categories (e.g., >9) were favorable, the animal was considered suitable for release. The interplay of additional factors also was considered when deciding if rescue should be pursued (e.g., logistic support, environmental conditions, amount of time out-of-the-water, time of stranding relative to tidal cycle, or indications of previous stranding). Body condition often overruled other determinations. Animals that were emaciated or suffered from substantial wounds or lesions were not considered candidates for release.

We examined the efficacy of the qualitative methodology by calculating the percentage of animals chosen for release that did not restrand. Statistical testing of these data was not appropriate because we lacked a control group for comparison (e.g., animals not chosen as release candidates were euthanized and we lacked animals of the same species that were released without evaluation).

Seasonal influence on strandings—To investigate the influence of season on the number of stranding events, the number of individuals per event, and the survival of stranded animals, we grouped data into seasonal categories: spring (March–May), summer, (June–August), fall (September–November) and winter (December–February). The winter grouping consisted of the three months with the lowest average air temperature on Cape Cod. We examined the seasonality of stranding events by investigating their frequency by season. The ability of seasons to act as a predictor of group size was tested using a general linear model assuming Poisson distribution and a log link function (McCullagh & Nelder, 1989). To investigate the influence of season on the survival of stranded animals, we calculated mortality rates and associated 95% confidence limits (Sokal & Rohlf, 1981) for each season. Differences in seasonal mortality rates were considered significant if their confidence intervals did not overlap. We excluded the summer season from the latter two comparisons because of small sample size (n = 1).

Assumptions of the study
(1) *Health of animals prior to stranding* – If stranded animals are to be returned to the sea, there must be a reasonable expectation that they were not lethally compromised prior to stranding and that they would not pass dangerous pathologies along to other members of the population. There is little published quantitative data from past Cape Cod mass strandings to confirm or reject a pathological origin. Duignan *et al.* (1995) found a high percentage of stranded pilot whales they investigated were seropositive for morbillivirus, including one animal that was clinically ill. However, they were unable to implicate or rule-out the illness as a stranding factor, or make comparisons to the population at large. A probable exception was in one of the common dolphin events reported herein (11/16/97); 5 animals that died in the event had substantial pleural adhesions (MJM, unpublished data).

We speculate animals were healthy prior to stranding based on the following logic. First, of the many factors advanced to explain mass strandings (see reviews in Geraci, 1978; Walsh *et al.*, 1990; Brabyn, 1991; Geraci & Lounsbury, 1993), most (e.g., magnetic anomalies, navigational error, meteorological activity or topographical factors) do not require pathologic causation. Thus, there is support for the possibility that mass stranded cetaceans are healthy prior to stranding. Second, in our Cape Cod study area, support for a purely pathological cause seems particularly questionable. Mass strandings, especially for pilot whales and white-sided dolphins, habitually occur within a relatively small area, along the topographically complex coastline within and around Wellfleet Bay (McFee, 1990; G. E. unpublished data). Support for a pathologic explanation would require sick animals to seek-out that area or healthy animals to become immediately sick upon entering it. An alternative and more parsimonious explanation is that, prior to stranding, the animals were healthy, but the trap-like contour of Cape Cod Bay and the secondary trap configuration of Wellfleet Bay (see Fig. 1) caught the animals in a maze of sandbars and salt marshes. The large and rapid fluctuation in tides ($\sim$3–4 m every 6 hr) associated with the area could allow animals scant time to navigate the maze, with mistakes resulting in stranding.

This explanation is consistent with the findings of Brabyn & McLean (1992), who identified coastal

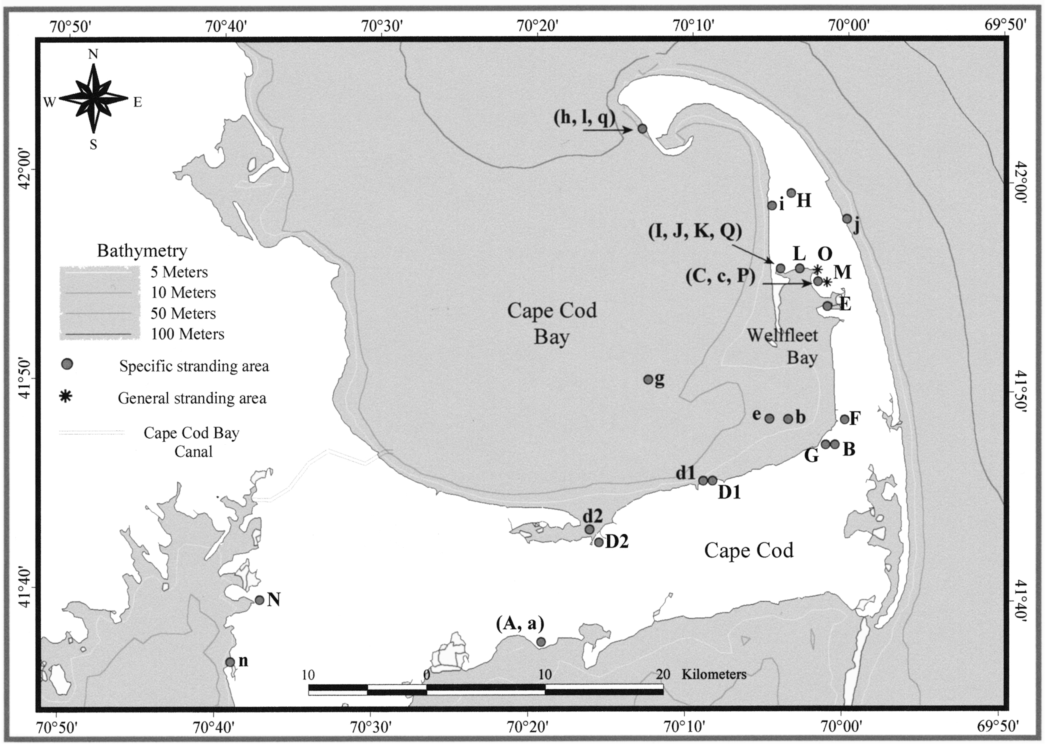

Figure 1. Cape Cod, Massachusetts, USA, showing stranding and release sites for mass stranded cetaceans. Letters correspond to specific stranding events listed in Table 1. Upper case letters designate the site of stranding. Lower case letters designate the site of release, if one occurred. Numerals accompanying letters indicate repeated strandings and releases that involved the same group of animals. The location of animals that stranded in a compact group is depicted as a specific location. Strandings in which animals were spread over multiple miles of beach are given a general location. Stranding sites that appear to be inland are located in unmapped tidal estuaries.

topography as an important factor for mass stranding sites in New Zealand. The potentially healthy nature of animals in our study area is supported by Walsh *et al.* (1990: 679) who stated '. . . on the northeast coast of Cape Cod Bay, Massachusetts, there is an area where mass strandings of pilot whales chronically occur. Blood sampling and histopathologic findings do not entirely incriminate illness as the major stranding factor. It is suspected that the local coastline, coupled with rapid tide changes, are the primary factors contributing to these strandings, although illness to possible leader animals has not been entirely ruled-out'. If mass stranded animals are found to suffer from major pathology or infectious disease, rescue efforts should be reconsidered and adjusted or terminated. However, if animals can be assumed to be healthy at the time of stranding, then rescue and release efforts are an acceptable way to aid them.

(2) *Recovery of carcasses* – We also assumed that restranded, tagged animals would be observed. This assumption is defensible for a number of reasons. First, Cape Cod beaches are heavily trafficked and people can be expected to observe and report carcasses. In 1999, two individually stranded cetaceans were tagged and released, and the tagged carcasses of both animals were later recovered; one in an extremely remote location. In addition, the tagged carcasses of 12 animals released after mass stranding also were recovered. While some stranded animals certainly escape notice, it is doubtful that animals would go unseen in the numbers that have been released. Second, Cape Cod Bay is a relatively enclosed embayment (Fig. 1) and prevailing winds and currents can be expected to force floating objects to shore. Therefore, it is likely that animals that died at sea, but within the Bay might also be recovered onshore. To make sure that tagged carcasses were not recovered at sites away from Cape Cod, we examined the stranding records provided to the National Marine Fisheries Service from all stranding response organizations working in an area from Virginia to Maine.

Table 2. Summary of survival and mortality during transport for 41 cetaceans that had previously mass stranded. Transport distances ranged from a few hundred m to over 40 km.

Species	Number transported	Number survived transport	Survival as a % of transport
White-sided dolphin	16	16	100
Common dolphin	8	7	88
Pilot whale	17	14	82
Total all species	41	37	90

Table 3. Results from the release of 73 previously mass stranded cetaceans. Thirty-seven animals were released after having survived transport and 36 were released at the stranding site. Animals were released within hours of having stranded and did not undergo extensive rehabilitation.

Species	Total number released	Number not observed to restrand	Not observed to restrand as % of total
White-sided dolphin	16	16	100
Common dolphin	7	6	86
Pilot whale	50	38	76
Total all species	73	60	82

Results

Transport survival—Forty-one animals were transported to locations away from the original point of stranding prior to release. Of these, 90% (37/41) survived transport (Table 2). All of the white-sided dolphins (n=16), 88% (7/8) of the common dolphins, and 82% (14/17) of the pilot whales survived transport.

Restranding—Seventy-three animals were returned to the sea; 37 after transport (see above) and 36 from the stranding site. Most were released within three to ten hrs of stranding (Table 1). Of these, 82% (60/73) were not observed to restrand (Table 3). No white-sided dolphins (n=16) were observed to restrand. Eighty-six percent (6/7) of the common dolphins and 76% (38/50) of the pilot whales were not observed to restrand. Examination of the National Marine Fisheries Service stranding database did not find additional tagged carcasses.

Overall success (transport and restranding combined)—Of the seventy-seven animals (41 transported and 36 released from the stranding site) for which rescue attempts were made, 78% (60/77) survived transport and were released without restranding, or were released from the stranding site without restranding (Table 4). All white-sided dolphins (n=16) survived transport and did not restrand. For common dolphins, 75% (6/8) survived transport and did not restrand. Seventy-two percent (38/53) of the pilot whales survived transport and were released without restranding, or were released from the stranding site without restranding.

Efficacy of qualitative indices of body condition used as release criteria—Qualitative triage-type techniques were used to identify 24 small cetaceans (16 white-sided dolphins and 8 common dolphins) as likely candidates for survival. Of these animals, 91% (22/24) survived transport, were released, and did not restrand. For white-sided dolphins, all of the identified animals survived transport and did not restrand. For common dolphins, one animal died during transport and one restranded.

Seasonal influence on strandings—We found no evidence of seasonal variation in the number of stranding events, but, excluding summer, group size varied significantly with season ($G^2=54.6$, 2df, $P<0.01$). Mean group sizes were 33.9 ($\pm$ 10.0), 17 ($\pm$ 10.0), 4, and 14.2 ($\pm$ 3.7) for winter (n=7), spring (n=4), summer (n=1), and fall (n=5), respectively. There were also significant differences

Table 4. Summary of the fate of 77 mass stranded cetaceans for which rescue was attempted (includes animals transported prior to release, n=41, and released at the stranding site, n=36).

Species	Total number attempted	Number not observed to restrand	Not observed to restrand as % of total
White-sided dolphin	16	16	100
Common dolphin	8	6	75
Pilot whale	53	38	72
Total All Species	77	60	78

in the seasonal mortality rates of stranded animals (Figure 2). Mortality rates were winter (0.96 ± 0.01, n=233), spring (0.79 ± 0.05, n=68), and fall (0.52 ± 0.06, n=71).

Discussion

These results support several potential options for response to cetacean mass strandings that occur on Cape Cod. First, with proper equipment and procedures, animals can be transported to release sites considerable distances from the original point of stranding without substantial mortality. This finding is of importance when structuring responses that maximize the success of animal releases. In situations where the stranding site consists of a maze-like coastal topography (as in the case of Wellfleet Bay and adjacent areas), knowledge that properly handled animals survive transport provides the option of returning animals to sea in an area of simpler egress. This removes the complication of animals already compromised by the stranding event needing to quickly navigate a difficult area.

The data also suggest that many pilot whales, white-sided dolphins, and common dolphins can be released without restranding. This finding is counter to claims that released cetaceans habitually restrand. However, our finding that released cetaceans did not inevitably restrand is not evidence that they ultimately survived, because the possibility of death at sea without carcass recovery cannot be ruled-out. This scenario was emphasized by Walsh *et al.* (1990) who used it to advise against the release of animals at the stranding site. Unfortunately, we have no data upon which to base a survival analysis. There has been little effort afforded to search for released animals, and most strandings occurred during times of the year or during weather conditions when few opportunistic vessels were on the water. Despite minimal effort devoted to resightings, observations indicated some animals survived at sea. For example, one group of white-sided dolphins was sighted by a whale watching vessel ~14 days after release and ~30 km from the release sight. A whale watching vessel observed pilot whales from the 9/10/91 stranding leaving Cape Cod Bay ~7 days after release. Pilot whales from the 9/30/91 stranding were observed in association with a group of ~30 pilot whales 11 days after stranding. Audio signals from a radio-tagged animal in that group suggested that it ultimately left Cape Cod Bay 14 days after stranding (C.A.M., unpublished data). Of the five[2] groups released during months when whale-watching vessels were in operation, three were resighted at sea after having moved away from the release site and towards the open ocean. There were no reports of the tagged animals behaving abnormally. However, it is difficult to assess animal condition visually in the field. Increased effort to relocate released animals at sea is needed.

Given the lack of sighting effort and the difficulty of seeing specific animals even when tagged, resightings have been substantial. We acknowledge that all resightings have been short-term and animals have been known to restrand after spending considerable

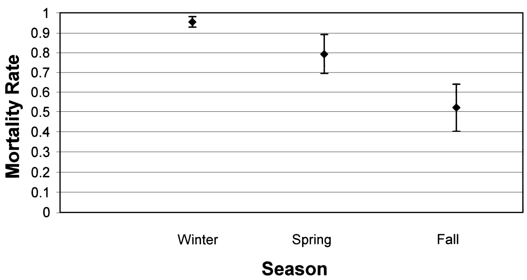

Figure 2. Mortality rate by seasons for cetaceans that mass stranded on Cape Cod, Massachusetts, USA, 1990–1999. Symbols represent mortality rates $\pm$ 2 SE. The summer season was omitted due to small sample size.

[2]Animals from the 9/09/91 and 9/10/91 stranding were released as a single group.

periods of time at sea (Fehring & Wells, 1976; Irvine *et al.*, 1979). We have no data on the long-term survival of the animals, and settlement of this question will require telemetry studies.

The data also suggest that rapid qualitative assessment can identify animals capable of being released without restranding. The existence of such indicators is important because the condition of stranded animals can be assumed to deteriorate over time (Geraci & Lounsbury, 1993), and assessment techniques that require lengthy periods of data collection and prolonged deliberation are at odds with the need to respond quickly. A disadvantage of such techniques is that their subjective nature relies heavily on the experience of the individuals making the determinations. This can make exportation of the techniques difficult without extensive hands-on training. While evidence suggests that the technique can identify animals that do not restrand, the euthanasia of animals judged to be unsuitable precluded further testing.

The findings that mortality rates were effected by season and that mortality was highest in the winter and lowest in the fall could have a number of explanations. First, winter is the season in which pilot whales and white-sided dolphins are least common in the region (Anonymous, 1982). If the winter season represents a period of reduced foraging opportunity or efficiency, nutritional stress might play a role in the mortalities. However, our qualitative observations of hundreds of live and necropsied mass stranded animals indicate that, unlike many single stranders, most were in good body condition at the time of stranding. If not a direct cause of mortality, nutritional stress might still be a factor by making animals more vulnerable to the effects of stranding induced trauma.

Another possibility is that stranded animals are vulnerable to the effects of hypothermia. The trend of decreasing mortality for the winter, spring, and fall seasons coincides with a trend of increasing air temperatures for those same periods. Average air temperatures[3] for Cape Cod are: winter, -0.9°C; spring, 7.4°C; and fall, 11.6°C. It is possible that being subjected to more moderate environmental conditions increased the chance of survival. For example, some winter stranded animals had frozen body parts that contributed to their death or decisions to euthanize them. The smaller group sizes that stranded during the spring and fall might also have played a role by being more conducive to rapid response efforts. It is also possible that rescue workers themselves are more effective during warmer weather with longer periods of daylight. In any event, rapid intervention to reduce the impact of trauma or exposure is likely to increase the probability of survival.

The value of rapid intervention is supported by our experience. For many of the events, we first became aware of the stranding after it had occurred and therefore, could not determine how long animals were beached (Table 1). However, successful rescue efforts generally began almost immediately after stranding and, once removed from the water, animals were transferred quickly to thick foam or air-inflated cushions. Turnbull & Cowan (1998) reported that individual stranders along the U.S. Gulf coast often showed signs of myocardial contraction band necrosis that was suspected of being induced by the act of stranding and contributing to the demise of the animals. If the act of stranding causes this condition in otherwise healthy mass stranders, some of our success might be due to quick action and techniques that minimized the onset and severity of cardiac lesions. In the future, we will seek to obtain time series data on cardiac function as a stranding event progresses and examine all mortalities for evidence of this condition. If the condition exists, medical interventions suggested in Turnbull & Cowan (1998) could further reduce its impact and increase survivorship. This pathology might also be a useful indicator of the effectiveness of intervention techniques.

While we have assumed that most animals that stranded in our study area were healthy, we cannot rule-out the possibility that a subset of animals might have varying degrees of pre-existing pathology. In all cases, one or more individuals died during the stranding event (Table 1). The differential survival among individuals might be attributable to pre-existing conditions that caused them to succumb to stranding induced trauma before healthier members of the group, and such conditions might also play a causative role in the stranding. Alternatively, individuals that died could have been out-of-the water for a longer period of time or have been otherwise more severely impacted than others in the group.

If mass strandings are multi-causal events as we suspect, the possibility of pathological causation might increase with increasing distance from the Wellfleet area. We might be particularly suspicious of the health of animals that stranded in areas of simple bottom topography and shoreline configuration, especially if strandings historically do not occur in that area.

It is clear that cetacean mass strandings remain enigmatic occurrences, and that considerable research is needed to determine causation(s). Additional research is also needed to provide guidance

[3]Average air temperatures are based on climatological data for Hyannis, Massachusetts for the period 1961 through 1990. Data obtained from Stormfax Climatological Data, Stormfax, Inc. Retrieved 25 June 2001 from http://www.stormfax.com/climohyn.htm.

for effective responses to mass stranded animals. In relation to response actions, future research should focus on tracking released animals to determine long-term survivorship, comparison of stranding 'histories' (e.g., length of time on beach, environmental conditions, types of rescue operations carried-out, health indicators, etc.) to understand differential survival among individuals and groups, the development of improved methods for making physiological assessments, the development and application of medical interventions, and even research into the most effective management regime for the rescue operations. This research might include the use of suction cup tags with a hydrophone to record heart and respiration rates and a system to record differences in cardiac electric potentials. Thermal and hematological data are also critical. Such research will continue to be challenged by the often conflicting needs of rescue and inquiry, and the multitude of confounding variables that conspire to make each event unique. Ideally, such investigations should cause only a negligible delay of rescue efforts.

Despite its limitations, this study represents the largest data set associated with mass strandings to date. Walsh *et al.* (1991) and Bossart *et al.* (1991) based their findings on the examination of ten individuals from a single stranding event, and Geraci *et al.* (1976), Fehring and Wells (1976) and Odell *et al.* (1980) each described single stranding events. Our findings, obtained from a different geographic area and based on a larger (although still limited) sample size covering a wider variety of species, provide an important addition to information. In particular, our findings indicated that conditions that accompany strandings on Cape Cod might be different from those in other areas, and might be counter to some of the generalities contained in Walsh *et al.* (1990), Walsh *et al.* (1991), and Bossart *et al.* (1991) that question the humane aspects of quickly releasing mass stranded animals back to the sea.

Until the diagnoses and prognoses of each stranding event can be predicted at the onset, the treatment of mass stranded cetaceans, and even the research that pertains to them, will continue to be controversial. These controversies often are rooted in philosophical positions that shape the scientific process, including the way hypotheses are constructed and results interpreted. For instance, an initial hypothesis that assumes live released animals to have died is no more valid than a hypothesis that assumes they lived. Similarly, assumptions that animals need to be euthanized to alleviate their pain and suffering are no more value-free than assumptions that they should be given the opportunity to survive. Such issues often lie at the heart of the stranding controversy and their consequences might not be trivial. Acceptance of the premise that animals cannot survive stranding might result in preparations and actions that aid in their death through euthanasia, neglect, or half-hearted/poorly designed rescue efforts. Acceptance of the premise that animals can survive stranding might lead to preparations and actions that favor their survival, but can cause unknown numbers of animals to suffer or drown, or diseases to be transmitted to a wider population.

In summary, the nature of mass strandings and the best way to assist mass stranded cetaceans remains unclear, and probably varies by species, location, and event. The data presented here suggest that, with the proper training and equipment, people can take actions that increase the possibility that mass stranded cetaceans will survive, at least in the short term. However, it would be a mistake to think that such success is easy, at least on Cape Cod. The large number of fatalities during the 1/31/98 and 3/19/99 strandings partially resulted from large numbers of animals overwhelming the available resources. Successful response to strandings of those magnitudes will require a common goal among response groups and greater resources at their disposal. Resolving the ultimate fate of released animals will require a commitment to extensive follow-up studies, such as the satellite tagging of released animals to examine long-term survivorship.

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