

## MEMORANDUM

To: Jones River Watershed Association, Kingston, Massachusetts

From: Charles "Stormy" Mayo, Ph.D., Senior Scientist, Director, Right Whale Habitat Studies, Senior Advisor, Whale Disentanglement Program, Center for Coastal Studies, Provincetown, Massachusetts

Date: April 12, 2012

Re: Response to questions regarding the effects of Pilgrim Nuclear Power Station operations on Northern Right Whales, Critical Habitat, and the Cape Cod Bay Ecosystem

This memorandum is to convey answers to the questions you have posed regarding the above-referenced topic. Note: Your questions and statements are underlined.

We understand North Atlantic Right Whales have a direct link to the food chain, and feed on zooplankton.

Yes, the close relationship between right whales and the zooplankton resource in Cape Cod Bay and, in fact, throughout the range of the species is well demonstrated. In Cape Cod Bay it's very clear that right whale distribution and occurrence is keyed directly to the plankton resources, principally composed of copepods, and that, of course, the health of the population depends on the quality and quantity of the food that the whales obtain in all of their few known critical feeding habitats areas of which one is Cape Cod Bay.

Is there zooplankton data that should be considered, and if so could you identify this data?

There are an abundance of zooplankton data available on the quality of the zooplankton resource on which the right whales depend and also on the cycles within the plankton community that so profoundly influence right whales' movements occurrence, distribution, and overall health. The most relevant data related to right whale feeding both in Cape Cod Bay and elsewhere throughout their range are those which we at Provincetown Center for Coastal Studies (PCCS) have collected over the last 28 years. However, in addition to our information, there are some useful sources of data collected in a number of habitats where right whale feeding is thought to predominate the behavior of the animals: Great South Channel, Jeffreys Ledge, and the Bay of Fundy. The collective information on foraging behavior describes an animal wholly dependent upon the quality of the zooplankton resource in the high latitude habitats identified by NOAA as critical to the future of the species. Indeed all of the information from the areas listed above and of course that collected in Cape Cod Bay, ought to be considered when assessing the impacts of human activities on the recovery of the right whales.

Do water and atmospheric temperature changes affect zooplankton in CCB?

Although we have not undertaken specific studies on the impact of temperature change on the zooplankton communities that support right whales, a general understanding of the impact of elevated temperature on plankton communities informs our emerging vision of the potentially wide spread impacts. Within a marine system such as Cape Cod Bay the organisms of the mid-water environment are known to respond in many ways to elevated temperature both directly through changes in reproductive success and cycling of larval and post-larval phases of their development, and indirectly through changes in their feeding success, both because of altered demands on their physiology and because of secondary impacts on the phytoplankton community. Although it is difficult to precisely answer your question there is little doubt that increased temperature will impact the zooplankton community, if for no other reason that the marine ecosystem is not endlessly plastic in its response to such system-wide changes in the basic interactions and physiology of its biotic components. Beyond these broad understandings, the answer to your question requires detailed investigations along with the digestion of information from specialists. Suffice it to say that temperature change **will** impact the quality and availability of the zooplankton resources in Cape Cod Bay including the critical habitat; what I cannot speak to without much more detailed study is the degree that elevated temperature will influence the acceptability to right whales of the Cape Cod Bay system. Finally, because we at the Center for Coastal Studies have joined many other institutions and state and federal agencies in pondering the impacts of climate change marine systems such as Cape Cod Bay, we have been concerned that a change in the quality of the bay ecosystem may have a profound impact on the overall health of the right whale population. For example, substantial information collected by our project and by a number of our colleagues points to the possibility that the low calving rates seen in the right whale population may have its roots in a degraded foraging environment in the few remaining critical habitats for the species; if that is the case, further degradation will likely further reduce the already-low calving rate in a small population already under extreme pressure from anthropogenic mortality.

#### How do temperature changes affect the thermocline in CCB?

The thermocline is defined by temperature change in the vertical profile, thus any changes in atmospheric temperature or from effluent addition to the bay will impact the thermal structure of the water column. Physical oceanographers would better answer this question, but generally my understanding is that increased water temperature during the period of stratification will likely lead to an increasingly deepened and stabilized thermocline in the system. In Cape Cod Bay it appears that the thermocline plays an important role in the processes leading to the concentration of zooplankton during the critical period of early spring feeding, processes that are therefore essential to right whales. Although it is not entirely clear how a deepened or more stable thermocline (or, for that matter, a change in timing of the development of the thermocline) will impact those processes, there is little doubt that modification of the near surface circulation, fine scale frontal processes, and associated concentrating mechanisms will likely change the processes that result in zooplankton patch formation, an essential quality of Cape Cod Bay making the Bay, including the critical habitat, acceptable to foraging right whales.

How will climate change change the temperature of Cape Cod Bay and how should this be assessed in order to determine whether PNPS operations will play a role in the changing temperature?

As with nearly all the complex ocean-atmosphere interactions, an understanding of the changes in the Cape Cod Bay thermal environment and of the impact of heated effluent discharges during a time of globally increasing temperatures is not easily evaluated. With that in mind, however, it is likely that the synergy between increased ocean temperature and the addition of heated effluent to the system will impact not only the success of the zooplankton (see above) but also circulation patterns and the thermal structure of the water column in ways that will ultimately impact the success of marine organisms such as the planktivores, including right whales. At the core of an effort to assess the impacts of the continued addition of heated water effluent on the ecosystem of Cape Cod Bay, it is critical that the synergy between continued thermal addition from the plant and elevation of temperature and alteration of circulation patterns due to climate change be considered. The plankton ecosystem on which most marine resources including right whales depend appears to be delicately balanced and subject to potential change, perhaps even small change, that will result in widespread impacts. It's essential that the quality of the resource on which right whales depend and the impact of the synergistic effects between continued discharges of heated effluent and climate change impacts be considered and monitored.

We understand over the last year the water temperature in CCB has been higher than normal. Could this be an example of things to come – if it predicts future temperatures, is this something that should be considered?

Indeed our preliminary information from the winter of 2011-2012 indicates that Cape Cod Bay water temperatures during the season of right whale residency have been elevated above the 15 year average by 2 - 2.5°C. During the winter of 2011-2012 there have also been substantial modifications in the quality of the zooplankton resource within Cape Cod Bay and a response of right whales to those changes, however it's not possible to ascribe a direct cause-and-effect related to elevated temperatures without further study. It is reasonable to assume that the future temperature regime in Cape Cod Bay, including the right whale critical habitat will mimic the conditions seen during this unusual year; therefore the winter of 2011-2012 may stand as a useful example of what changes we may anticipate in the next decade or so. Because much of our management of anthropogenic impacts within marine systems is somewhat experimental, it would be useful to examine the information collected during 2011-2012 as an example of what may happen in the future. It is equally important for the sake of right whale recovery and for the ecosystem of Cape Cod Bay that conditions within the system be monitored in order to track these extraordinary changes and to compare with those that are predicted.

We understand North Atlantic Right Whales feed on patches of copepods, the types of which vary by season. What information should be looked at to determine whether

## PNPS operations from 2012 to 2032 could affect the formation and distribution of these patches and layers of copepods?

In order to reasonably answer the questions regarding the impact of continued addition of heated water to Cape Cod Bay during a time of global warming, a coherent analysis of the substantial data collected in Cape Cod Bay by PCCS, combined with CTD profiles and information on the chemical and physical environment ought to be compared with data on right whale occurrence, distribution, and behavior. Such an analysis would provide a substantial baseline understanding of what has been. That baseline, which can be drawn from already existing databases, would provide the underpinning for an informed analysis of the synergy between continued heated effluent discharges from PNPS and increasing bay temperatures. With such baseline information and projections of oceanographic and meteorological change, and with an understanding of the energetic and nutritional demands of right whales, it will be possible to predict the impact of continued thermal addition. By coupling continued monitoring with such predictions it will also be possible to forecast impacts on right whales and, through monitoring, adjust the forecast or take actions if unintended consequences should arise.

## Are there specific quantities, densities, or locations of zooplankton that are critical for Right Whale feeding?

Our studies in Cape Cod Bay indicate that the value of the critical habitat to right whales is founded on a complex relationship between the physical environment and the zooplankton on which the whales depend. The interaction between the two is dependent in large part on the timing of the entry and exit of a variety of species of zooplankton forms, principally calanoid copepods. The cycles that govern the enrichment of Cape Cod Bay during the winter and early spring dictate the entry and exit of whales from the system. Primary among the different zooplankters are the three influential and energy rich taxa that form the primary food of right whales, *Calanus finmarchicus*, *Pseudocalanus* ssp., and *Centropages* ssp.; it is the interlocking cycling of the three taxa that cues the foraging behavior of the right whales. It is not, however, only a qualitative game; the density of these three taxa and the timing of their enrichment within the system is also critical to the success of the right whales. The monitoring work that we have done to date indicates that there is a year-by-year variability in the balance of the different taxonomic groups in the zooplankton and in the quantity of each group, and the right whales are exquisitely sensitive to those changes. Because the right whale is a grazer its distribution, habitat use patterns, and occurrence are tightly tied to the cyclical nature and enrichment of the zooplankton such that the very use of Cape Cod Bay as a critical feeding habitat for a large portion of the remaining right whales in the North Atlantic is dependent on the characteristics of the zooplankton (both quantitative and qualitative). We have shown in past work and hope to further amplify that right whales foraging is controlled by a surprisingly well defined threshold that releases feeding behavior, a density of food below which right whales will not feed and above which they will successfully make a living. So in summary, there are very specific densities of food that right whales demand, and when good quality food patches develop the whales are usually found in particular locations associated with very specific food resource and oceanographic conditions.

Does atmospheric and water temperature have an affect on specific quantities, densities, or locations of zooplankton that are critical for Right Whale feeding?

As I mentioned above, temperature change has a profound impact on the circulation patterns on which the zooplankton concentrating mechanisms that form the patches depend; as with the biology of the zooplankton, the relationship is a complex one, yet it's clear from our data that changes in circulation and stratification of the water column will have an impact on the concentrating mechanisms required to create acceptable patches of food that exceed the feeding threshold for the right whales. It is important to mention in this respect that Cape Cod Bay appears to be a unique habitat where relatively small-scale oceanographic processes and mid water biological conditions conspire to produce extraordinarily high concentrations of thin and exceptionally dense surface layers of the three taxa of calanoid copepods that, with such a combination of conditions, release surface feeding behavior by right whales; this rare combination of circumstances is the reason that Cape Cod Bay is considered a critical habitat for the remnant population of the North Atlantic right whale.

Atmospheric temperature change taken alone does not have a significant impact on the zooplankton; its impacts are important as they influence the water temperature, as in the impact of atmospheric temperature rise in the processes of climate change.

How does food supply relate to reproductive success?

There is substantial evidence from studies of a number of mammalian species that successful reproduction depends upon good nutritional support. The information from whales, because they are substantially more difficult to study than other mammals, has not been well developed, however information from our studies and from investigations at a number of institutions is pointing as expected to the similarity between the reproductive requirements of right whales and those of other species. From studies that we are presently expanding on, the results of which were presented a decade ago, there are strong indications that the reproductive rate of right whales of the western North Atlantic Ocean mirrors the zooplankton quality in Cape Cod Bay. The relationship demonstrated in those early studies, a relationship we are hoping to investigate in much more detail in the next year, suggests that not only the overall health of the population but the essential reproductive capacity of the species is ultimately dependent upon successful feeding in the Gulf of Maine and, particularly, Cape Cod Bay.

If there is a trend of more right whales using Cape Cod Bay, what should one consider to determine whether 20 more years of thermal, chlorine, and biocide discharges from PNPS is or is not likely to adversely affect the right whale?

Certainly if Cape Cod Bay were to continue to show its present increase in use by right whales it stands to reason that a greater demand will be placed upon the zooplankton resources of the bay. Exactly what impacts will arise from dynamic interaction between foraging rates, food resources, foraging strategies, and, ultimately, carrying capacity in response to the continued addition of chlorine, elevated temperature effluent, and biocides at a time of altered climate can only be approached with a baseline understanding of the interaction between right whales and the zooplankton and

phytoplankton community. Of particular importance in an effort to assess the synergy between these conditions must be an effort to develop an understanding of the role played by changes in large-scale climate patterns that may interact in a very new way with anthropogenic pollutants, including thermal energy. My concern lies particularly with the synergies among all of the variables, including climate change, leading to variations in circulation and impacts on zooplankton density, distribution, and composition.

**We understand the North Atlantic Right Whales exhibited unusual behavior in Cape Cod Bay this year. Are there theories about why this occurred?**

Without analysis of our present zooplankton samples, our understanding of the alterations in occurrence, distribution, and behavior of the right whales in Cape Cod Bay will remain conjectural. These zooplankton samples can readily be analyzed to establish the understanding of the alternations in occurrence, distribution and behavior of the right whales in Cape Cod Bay – these data are available. The best and most obvious theory that we work on is that there have been substantial changes in the timing and composition of the zooplankton enrichment during late 2011 and the winter of 2012. We do have some indications that changes have occurred in the composition of the zooplankton but associating changes in the zooplankton community with alterations in whale behavior awaits further analysis. One thing is quite clear, however, and that is that change has come to the Cape Cod Bay system and those are reflected in altered habitat use patterns; I suspect, but cannot prove, that if zooplankton composition is the cause of such change that the temperature regime of the winter of 2012 lies at the heart of the issue.

**Are acoustic impacts from PNPS something to be considered?**

I do not know what the acoustic signature of the plant and its pumps is, and I also do not know exactly how it is the right whales process acoustic information. Nevertheless it would be wise to consider an investigation of the acoustic impacts and to consult with specialists capable of assessing the potential impacts both in connection with the whale itself and the existing and proposed North Right Whale critical habitat. Certainly, because everything suggests that right whales are sensitively tuned to their acoustic environment it would be valuable to assess the potential impacts of noise pollution from the plant.

**In taking a holistic look at Cape Cod Bay, what information should be assessed to determine the contributions of PNPS to the temperature, salinity etc. changes.**

All of the information that has been referred to above is valuable material for assessing the characteristics of the Cape Cod Bay system over the past several decades, and forecasting both future trends and how PNPS operations might affect temperature, salinity, zooplankton productivity and patch formation, and multi-scale circulation patterns. I would emphasize however that the most useful strategy for such assessment would be in a comparison of predicted changes in the thermal and oceanographic environment in the future with the substantial volume of information already collected by PCCS in the critical habitat of right whales. It is virtually impossible to make any rational assessment of the impact of PNPS absent an understanding of the baseline

requirements of right whales and the baseline conditions that have heretofore supported them. Furthermore, it is crucial to make such assessments, probably including modeling, in light of estimated climate change. Finally, because all assessments that could be made on this important subject depend on a considerable amount of modeling and theory, it is also critical that the findings of such assessments be compared with ongoing monitoring of the Cape Cod Bay system and the right whales that depend upon it. So in summary it is essential to understand the biological and oceanographic characteristics of the bay vis-à-vis right whales, to consider those characteristics in light of synergies with the changing environment, and to monitor the environment to ensure that the assessments are correct.

**Should plankton monitoring be conducted in order to assess whether PNPS operations are likely to adversely effect North Atlantic Right Whales and their critical habitat?**

Yes. As has been outlined earlier in my comments, many aspects of the distribution, occurrence, behavior, and health of the right whales of the western North Atlantic are dependent upon both the food resource of the whales and oceanographic processes that concentrate the zooplankton into patches, processes which are not fully understood at this time. The phytoplankton of the Gulf of Maine is the primary source of food directly or indirectly for the productivity of the Bay, and so the characteristics of the primary producers should also be monitored. Monitoring is an essential part of the ongoing effort to conserve the right whale and the Cape Cod Bay habitat as we enter a period of significant change in marine habitats. The reason that monitoring is important is because it is not possible, even with the most detailed modeling and evaluation, to precisely forecast the synergistic effects of human caused impacts and their interaction with the complex system on which right whales depend. An effective monitoring program ought to be in place in order to clearly and unequivocally track changes in the zooplankton and phytoplankton communities and the impact on the marine resources, including right whales, of Cape Cod Bay. Absent such monitoring it will be impossible to confirm the forecasts provided by the review, modeling, and analysis or to mitigate any unforeseen impacts.

**Should there be a comparison of the amounts of plankton pre-and post PNPS operations?**

Indeed, an analysis of the zoo- and phytoplankton during both the pre-and post-effluent disposal would offer a useful baseline for the essential analysis and modeling. However, during a time when fundamental aspects of the Cape Cod Bay system are being impacted by both climate change and other human activities, the baseline information on plankton and on the relationship between zooplankton patches and right whales should be only one aspect of the whole evaluation. Equally important is the capacity to take present information and project it into the future scenario of elevated temperature due to climate change. Preliminarily such an analysis would require the use of existing databases, including any available pre-PNPS, and modeling by oceanographers, zooplankton specialists, and right whale investigators. Thus the most critical phase of such an analysis is the review of historic baseline data and the projection of potential impacts into the future, combined with an analysis of incoming monitoring data. The

point here is that the ecosystem is changing dramatically and it is crucial that we understand enough about the system to identify any potential tipping points that may impact the zooplankton community and, hence, right whales and other resources that depend on it. Such work will depend on a thoughtful combination of analyses of a variety of databases combined with an understanding of the requirements of right whales. The databases at PCCS are available and results from specific analyses have been published. PCCS works with a wide range of partners to make basic information on the right whales, zooplankton, and oceanography of the Cape Cod Bay system available to the public and the scientific community.

We understand there was plankton monitoring before PNPS began operating in 1972.

Yes, there have been several published papers predating the operation of the plant and the disposal of heated water, and those pieces of work should be investigated in detail. Although I have not recently reviewed the early work on the zooplankton and phytoplankton communities in the Bay, there are many potential sources of information from the Gulf of Maine and the general Cape Cod region that would give direction and understanding regarding pre-operation conditions. But in the foregoing answer I emphasized that, in a changing environment, the critical step is to deal with the synergy between heated effluent disposal and climate change. Simply, in this changing marine world little of the past is wholly informative of the near future.

Is there water quality data that should be considered?

Because water quality underlies all aspects of the health of Cape Cod Bay and impacts the variety of important and more cryptic resources in the system, clearly oceanographic changes that may be forecast when considering climate change interacting with heated effluent disposal may have substantial impact on the basic chemical and oceanographic structure of the Bay. Because of the essential interaction between water quality, oceanography, and the marine resources, along with monitoring the principal biotic components of the system, well integrated water quality data should be collected and compared with the available databases.

What information should be considered to determine whether PNPS operations could affect the current critical habitat, and the proposed critical habitat?

The foregoing answers cover the information that should be collected in order to determine potential impacts on the existing critical habitat or the proposed enlarged critical habitat. There is no question that a very significant portion of the remaining right whales of the North Atlantic Ocean use the region as a feeding, socializing, and nursery area. The information needed to determine if continued operation and disposal of heated effluent will have an effect on the critical characteristics of the greater Cape Cod ecosystem depends upon an understanding of the oceanography, mid water ecology, right whale habitat use and requirements, and the potential impacts of climate change on the biological health and multi scale circulation in the area.

Right Whale Critical Habitat is located in the central-eastern part of CCB. Does that mean



### the western portion of CCB is unimportant to right whales?

The Cape Cod Bay system is clearly a whole as embodied in the term "ecosystem". While we do not fully understand a number of the aspects of the system that support the rich plankton-right whale interaction, it is clear currents which enter the bay on the western side and sweep South then East, and eventually North toward the exit in the northeast quadrant is an essential feature of the productivity of the system. Whatever enters the gyre of Cape Cod Bay's currents along the West side has an almost inseparable impact on the marine biology and oceanography of the eastern side of the Bay. Thus, the only rational way of understanding the Cape Cod Bay ecosystem is to deal with the processes of the whole as they're interacting with the larger Gulf of Maine's oceanography. Underpinning the most advanced efforts to manage coastal systems is what is called "ecosystem-based management", similarly the only approach toward Cape Cod Bay and toward assuring its contribution to the success of right whales is to deal with the entire Bay system and with all of its inputs and outputs.

### Are right whales ever observed in the western portions of CCB?

Indeed right whales have been observed on a number of occasions in the western parts of the Bay. Those observations are made almost yearly by our air survey and vessel teams. These data are available. A number of observations have been made and are associated with information on behavior and zooplankton characteristics.