A Guide to Composting Marine Animal Mortalities

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Photo: University of New England Marine Animal Compost Site – Biddeford, ME. Credit: Mark King.

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Executive Summary

Marine animal carcass disposal has become more problematic for response agencies over the years due to logistical or biological complications. Routine methods of disposal have significantly increased in price, and the demands for proper disposition of biological material, in order to maintain biosecurity, have increased as well. The University of New England's Marine Animal Rescue Center (UNE MARC) collaborated with Maine Department of Environmental Protection and the Maine Composting School to evaluate composting as a disposal option for marine animal carcasses.

NOAA Fisheries Marine Mammal Health and Stranding Response Program and the John H. Prescott Marine Mammal Rescue Assistance Grant Program (Prescott Grant) awarded a two-year grant to the UNE MARC in 2006 titled "Composting as a Disposal Option" (NOAA Award Number NA06NMF4390151). The goal of the project was to construct and operate a composting station onsite at UNE to test the safety and usefulness of composting as a disposal method for marine animal carcasses. The project resulted in a tested and refined facility that was used as a module for a safe and economical disposal option for UNE and other stranding response agencies. Objectives of the project were met, and exceeded, by constructing a compost facility that was used for several years, and routinely processed marine animal carcasses becoming the primary method of disposal for MARC, and aided in areas of research to document the breakdown of certain types of compounds, such as sodium pentobarbital. Over several years, the compost facility was evaluated and improved, and proved to be a viable disposal method for the University. A second Prescott Grant was awarded to UNE MARC to expand the compost facility (NOAA Award Number NA12NMF4390163). The following compost manual is a result of the years of consultation, collaboration, trials, and operation of the pilot marine animal compost site at UNE.

The authors thank staff and volunteers at the University of New England's Facilities Management and MARC programs who assisted with these projects and composting trials.

Introduction

Each year, thousands of marine animals become stranded upon shores of the United States. A large majority of these cases do not survive, creating challenges for agencies responsible for their disposal. Effective management of routine and catastrophic mortalities remains a constant challenge for marine animal rescue facilities and municipalities. Traditional disposal methods, such as rendering and burial, have been abandoned in recent years, primarily due to rising costs of rendering services and concerns of burials releasing nutrients, pathogens, or contaminants to groundwater. Composting offers a cost effective, environmentally sound disposal alternative that is also protective of public health. During composting, organic ingredients and soluble nutrients are consumed through microbial activity and transformed into complex organic compounds that are slow to breakdown, contain very low levels of biological activity and are resistant to leaching. However, in order for composting to be a viable alternative to disposal, receiving sites must be located close enough to the generating facility to minimize transportation costs, and generating facilities must have adequate storage capacity to allow enough material to build-up to justify the transportation costs. The purpose of this guide is to provide practical instruction on composting, a preferred method for managing marine animal carcasses.

Benefits of Composting

It is important to note that marine mammals and sea turtles in the United States are **federally protected** species. It is critical that all pertinent federal, state, and local regulations are adhered to prior to beginning any composting effort. Once you do begin composting, however, numerous benefits become readily apparent:

Lower Costs: Composting may cost less than $35 to $40 per ton, and is therefore a relatively inexpensive disposal method. In comparison, costs of disposing the same materials at either landfills, incinerators, or by rendering can exceed $75-$100 per ton. In addition, disposing of carcasses through composting provides the long-term benefits of returning nutrients to our soils, maintaining biosecurity, and avoiding the consumption of limited disposal capacity at landfills.

Environmental Benefits: Diverting marine animal carcasses to composting facilities reduces the potential for water and air pollution that may arise from landfills, and increases biosecurity by limiting movement of waste. Composting also aids in the breakdown of persistent contaminants (mercury) and chemical pollutants (euthanasia solution) by reaching bactericidal temperatures for the appropriate time course. The use of compost can improve soil quality, reduce water consumption in the landscape, and reduce non-point source pollution by reducing the need for chemical fertilizers.

Improved Public Relations and Education: Informing and educating citizens to the benefits of a properly managed and promoted compost program is a readily accessible demonstration of “waste to resources” that has tangible benefits for the community and positively engages its residents and businesses.

Create a Useful and Desirable Commodity: Composting turns unwanted organic discards into a valuable end product. This material when added to soil improves structure, water-holding capacity, and enhances aeration.

Mutually Beneficial Partnerships: Composting and associated public education assists in building mutually beneficial partnerships between public and municipal entities. Remembering that marine animal strandings are a "community" problem allows for better coordination of rescue/recovery efforts, while simultaneously promoting partnering of private and municipal resources to ensure a more effective approach to addressing mortality events. Municipalities often possess heavy equipment (i.e., front end loaders and dump trucks) that may facilitate removal of marine animal carcasses and soft tissue remains for composting.

Overall, composting has a proven track record of being an effective and efficient method of disposal throughout the United States. While there is always ongoing research to improve methods of composting and to expand the uses of compost, composting has been an integral part of U.S. waste management strategy for several decades. This practice has been promoted at state levels through a variety of grant programs that have funded master composting training, home composting education and equipment, pilot and demonstration projects, and community leaf and yard trimmings composting operations.

All across the United States, there is ready access to technical assistance for composting. In addition to knowledgeable staff located at state and local natural resources agencies, there are a myriad of educational opportunities available for those interested in initiating a compost operation. For example, Maine is home to two internationally known resources on composting: the **Maine Compost Team** and the **Maine Compost School**[1]. Both programs are cooperative efforts by the Maine Department of Environmental Protection, Maine Department of Agriculture, and the University of Maine Cooperative Extension. Other states may offer similar expertise within their state environmental agencies and cooperative extension programs. To access these resources, contact your individual state agencies, such as the Department of Agriculture, Department of Environmental Protection, or your state's equivalent (Appendix II).

Carcass Collection Methods

The collection system for marine animal carcasses is a critical component of the composting program. The system for retrieving and separating compostable materials at the source and transporting the desired materials to a collection area should be as convenient as possible. The primary objectives of the collection system are to:

- Maximize the collection rate of marine animal carcasses;
- Eliminate non-organic contaminants such as plastic wraps, rubber bands, glass, and metal; and
- Minimize labor and space requirements.

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[1] www.composting.org

Collection systems will vary according to the specific needs of each organization/facility, space limitations, and general layout of work areas. For example, necropsy labs can use recycling and waste carts or Brute® 55 gallon (208 liters) trash bins on wheels to store soft tissue and bone fragments resulting from the necropsy. These carts/bins can be stored in a freezer and easily transported to a site near the compost area. If composting in the field and/or at the site of a stranding, the base of the compost pile can be built next to the animal so that soft tissue, as it is cut from the animal, can be placed on the base of compost (Figure 1).

Figure 1: Field composting of a marine mammal carcass. **Left:** carcass *in situ* with base of compost (in background) ready to receive parts. **Center:** base filled with marine mammal parts from necropsy. **Right:** finished compost pile.
Photos: Mark King

Figure 2: A selection of available Toter containers. Source: www.Toter.com.

In any case, containers should be conveniently located at points of generation and clearly labeled. Place trash containers next to the composting container to help prevent contamination from trash and non-organic discards. Plastic garbage containers are well suited for holding soft tissue, and can easily be placed in areas where the animal residuals are generated. For each organization/facility the container size will vary depending on the amount and type of compostable material generated and the amount of storage space available (Figure 2). Animal soft tissue can be heavy – the average weight of a filled 55-gallon Brute® (208 liters) container is 160 to 180 kilograms (350-400 lbs.). Safe lifting and moving limits should be adhered to when choosing containers for collecting animal parts. Clearly marked containers, such as green for animal soft tissue, blue for other recyclables, and brown for trash, are helpful for proper preparation and consistency throughout the facility.

Training of personnel in preparation areas is essential to good composting. Some organizations prefer to use liners in collection containers or liners only for storage for animal remains after necropsy. Compostable bags are typically more expensive than disposable plastic bags but may be composted along with their contents, depending on the composting system utilized. Non-compostable bags, i.e., so-called contractor bags, while less expensive, require an extra step of emptying the bags' contents at the compost site and generates another waste product – the bag. Because de-bagging can be very labor intensive and exposes workers to possibly diseased or contaminated remains, using no bags or compostable bags is preferable.

Just as trash hauling needs to be prompt and reliable in order to avoid health and safety problems, so too does animal tissue hauling. Some organizations/facilities have found it easier and more economical to do the hauling themselves, using a pick-up truck with a lift gate. Others contract with private waste haulers to collect and deliver the materials to a permitted composting site. In either case, the goal is to optimize vehicle capacity and collection frequency. If the vehicle is too small, excessive transportation costs may result from frequent trips to the compost facility. Conversely, small loads in a large vehicle may not justify use of the larger equipment. The goal is to match carcass generation and collection frequency with the right-size vehicles. When conducted efficiently, problems are reduced and transportation costs are kept to the minimum.

Organizations may also be able to arrange a custom composting scenario where an existing compost facility composts marine animals in a segregated part of the facility. It may be relatively easy to arrange collection and transportation of marine animal remains from your institution to an approved nearby composting operation. On-site (or internally run) composting programs differ from off-site programs in their levels of complexity, capital investment, oversight, and permitting required. In addition, there are considerably more planning and equipment costs, however, in the long run on-site programs are easier to control.

The Compost Process

Figure 3: Whale composting site at Highmoor Farm, Monmouth, Maine.
Photo: Mark King

Composting is a biological process in which microorganisms consume organic materials (carbon and nitrogen compounds) and produce compost, the nutrient-rich, humus-like end product. Composting can occur with oxygen (aerobically) or without oxygen (anaerobically). In this guide, we focus on aerobic composting, meaning that the microorganisms active in this process require oxygen to live. We will emphasize techniques that encourage aerobic microbial activity and discourage anaerobic decomposition. Unlike anaerobic decomposition, aerobic decomposition is rapid, generates heat, and is not as likely to produce noxious odors.

An active compost pile is a community of living organisms. In order to survive and multiply within a compost pile, microbes must have suitable amounts of carbon, nitrogen, and moisture, as well as oxygen. The moisture serves as the medium in which the microorganisms live and feed, the carbon provides the energy/food source to fuel them, and nitrogen provides the building blocks for reproduction. Composting begins when the appropriate ratios of raw materials (also known as feedstocks) have been mixed together. The physical process of mixing the feedstocks usually provides enough oxygen to initiate composting.

Composting occurs in three phases:

1. **Start-up Phase (Mesophilic):** During this phase, organic compounds are decomposed by mesophilic microorganisms that prefer to operate at temperatures below 110 ^{o}F (40 ^{o}C). These organisms rapidly break down the soluble, readily degradable compounds. Their increased activity raises pile temperatures rapidly.

2. **Active Phase (Thermophilic):** During this phase, microorganisms consume a large amount of oxygen as they feed on the available

organic matter. Simultaneously, producing heat, water vapor, and carbon dioxide as they consume and reduce the original mass of the material. Pile temperatures during this phase may often exceed 131 ^{o}F (55 ^{o}C) for weeks at a time.

3. **Curing Phase:** This stage closely follows the active phase. During curing, the microorganisms still feed, but at a slower pace, thus giving off less heat, water vapor, and carbon dioxide. Left undisturbed, the microorganisms will continue to feed until all organic matter has been consumed. The final product is a nutrient-rich soil amendment that is high in organic content, possesses enhanced soil structure such as higher porosity, and has an enhanced water holding capacity.

Setting Up a Compost Operation

Prior to picking a compost site, it is important to visit multiple candidate sites to identify one that will fit your needs, while minimizing potential impacts to the environment and neighbors. The first step is to consider how large a footprint, or compost site, you will need to handle your projected volumes of feedstocks. At a minimum, you should choose sites that:

- Are located in remote areas away from neighbors.
- Have adequate wooded buffers (visual screens).
- Are not near wet areas—keep site high and dry.
- Have slopes between 2% and 4%.
- Contain moderately well-drained soils.
- Have depths to seasonal high water tables $\geq$ 36 inches.
- Have depths to bedrock $\geq$ 36 inches.
- Are $\geq$ 200 feet away from streams, ponds, lakes, or drainages.
- Have adequate year-round access.
- Allow for ample storage of compost and carbon sources.
- Have concrete or asphalt working surfaces that will remain rut-free.

In reviewing sites, it will be helpful to consider some operational realities that may also influence site selection:

1. Compost that is ready for curing, storing, and use can be moved off the compost site.

2. Distances between the facility and property lines, wetlands or other protected areas, residences, or business must be considered. These buffer zones help to minimize possible odor, noise, dust, and visual impacts.

3. Outdoor compost sites may often be located on moderate to well-drained, hard-packed soil with a gentle slope for good drainage.

4. A slope of about 2 % on the compost pad is desirable to prevent pooling of water. If existing conditions are flatter or steeper, then a compost pad will

need to be shaped to meet the 2% slope. The initial site preparation will usually require grading and may require surfacing with gravel or compacted sand to allow year-round use. Concrete and asphalt pads can also be used, usually at sites where soils are highly permeable or where ground water levels rise too close to the surface. A paved site offers some advantages in terms of access, equipment operation, and ground water protection as well as protecting feedstock/bulking agents and finished product from contamination from the underlying surface. These advantages must be weighed against added surfacing costs, as well as difficulties in managing runoff. Most outdoor animal carcass compost sites have paved surfaces, which are recommended due to the need for year-round access.

5. Compost windrows should run parallel to the slope, rather than across, to allow runoff water to move between the piles rather than through them.

6. As you are reviewing potential composting sites, include discussions with the local or state permitting entity (as appropriate and necessary) so that you don't consider or select inappropriate sites.

7. To assist in the design of the composting site, subdivide the compost area into designated handling areas, list facility design features, and develop a flow plan for materials in the process. This will show you how many times the same material will have to be handled and how long materials will occupy space in the different management areas.

The following section describes a typical site-layout plan (Figure 4):

1. **Receiving and Handling Area:** Allows for the coordinated delivery and handling of incoming feedstocks. Problem residuals may also be isolated here. This area provides operators a first chance to control odors through good residual management (i.e., receiving putrescible materials, such as manure, on a bed of sawdust or leaves to help absorb leachate) and immediate mixing of seafood processing residuals with carbonaceous amendment.

2. **Amendment Storage Area:** Allows delivery and stockpiling of carbonaceous amendment, and helps prevent contamination with other feedstock.

3. **Mixing Area:** Allows pre-determined, measured amounts of feedstocks to be accurately and thoroughly mixed, while also providing for odor and leachate control. A heterogeneous mixture of feedstocks greatly enhances initiation of the active compost phase.

4. **Composting Area:** Allows for active composting. It is generally the largest portion of the site and should be centrally located with easy access to the receiving/handling and mixing areas.

5. **Curing Area:** Allows for aging and final maturation of compost piles that have completed the active composting phase. Curing is essential to complete the compost process by allowing natural progression and die-off of microbial populations.

6. **Waste Bypass Area:** Provides a centralized area for collection and storage of non-compostable material for later disposal. Rejected loads of residuals may be staged here while waiting for pick-up. Common contaminants may include the following:

    - Road grit and sand
    - Litter, coffee cups, and lunch bags
    - Rocks, roots, and dirt
    - Large branches and waste wood
    - Plastic bags, plant containers, and flower pots
    - Flipper tags
    - Latex gloves and plastic bags

The best way to determine the size of the needed footprint is to develop a site-layout plan.

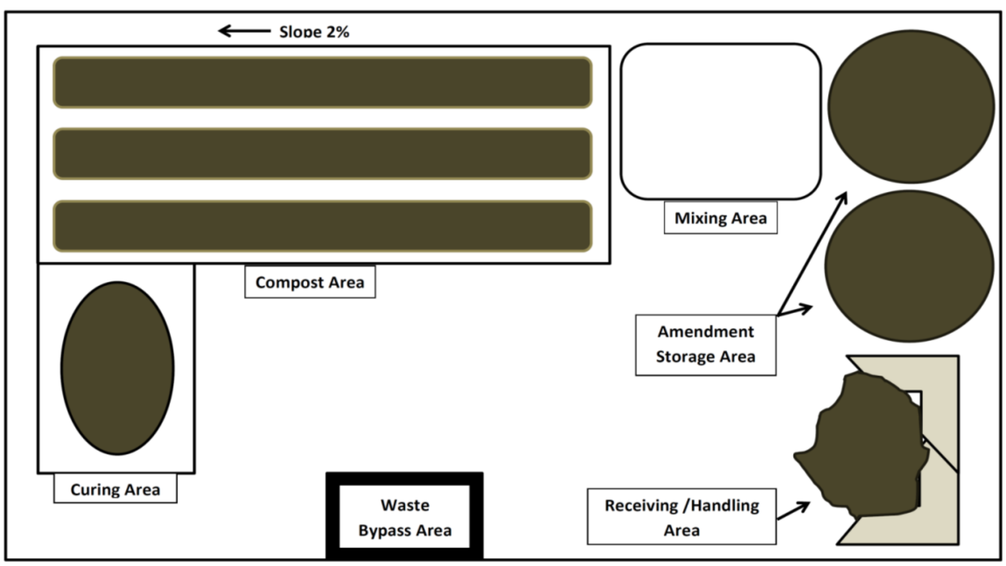

Figure 4: Illustration of the layout of a typical compost site developed by Mark King.

The Work Surface

One of the most critical parts of a compost operation is the work surface itself. A smooth, flat surface with a two to four percent (2-4%) grade serves as the ideal work surface, allowing surface precipitation to quickly move off the pad, thereby preventing trapping and pooling. The pad should also be designed to maximize site drainage. Every attempt should be made to divert surface run-on (clean water) away from the compost area, using upslope diversion ditches or berms. Stone-lined waterways and catch basins may be employed to intercept and channel surface water to prevent impact to surrounding watersheds. Likewise, runoff from the compost pad may be intercepted and treated by placing a vegetated "level lip spreader" on the down slope edge of the composting surface or collected and re-used to moisten piles. Finally, facility access roads should be designed and constructed with site drainage in mind. Run-on from surrounding slopes can be diverted from the compost site simply by constructing a perimeter road perpendicular to the surrounding slopes.

There are several options for the composition of the working surface or pad, such as asphalt, concrete, compact gravel or soil. Proponents of the asphalt pad claim that it provides an impervious barrier that prevents leachate from reaching groundwater. Asphalt and concrete pads are also very durable and can withstand years of use while requiring little maintenance. In contrast, soil and gravel pads are prone to leachate infiltration; and usually are prone to rutting and thus require annual resurfacing.

Figure 5: Sandy River Compost Site, Farmington, Maine. *Photo: Mark King*

Site Operations and Management

Once you have developed an adequate work surface you are now ready to begin composting. There are several steps that need to be accomplished to ensure success. These include: recipe development, mixing and pile formation, turning or not turning, and curing.

1. **Recipe Development**: The first step is to develop your recipe. This is usually done by balancing two key nutrients: carbon and nitrogen, into a ratio referred to as the C: N ratio, or carbon to nitrogen ratio. Typically, microbial organisms require more carbon than nitrogen. Carbon provides

the energy to fuel their metabolism, while nitrogen provides the raw materials to help organisms reproduce. However, if there is too much carbon, decomposition may slow down or even halt. The initial goal in creating a recipe is to achieve a **C: N** within the range of 20:1 to 30:1. Wood byproducts such as sawdust, wood shavings, and bedded horse manure, are high in carbon and tend to be ideal agents for carcass composting activities.

Moisture also plays a key role in composting. An ideal range is between 50%-65%. Too much water and piles will go anaerobic and become odorous; too little and compost activity ceases. In the case of marine animal composting, most of the moisture for composting is supplied by the soft tissue remains. As a general rule for most marine animal composting, a ratio of three to five parts of a carbon source/bulking agent by volume to one part of marine animal tissue will yield satisfactory results. If wet hen or cow manure is added to facilitate the mixture, at least two additional parts of bulking agent should be added for each part manure.

The final recipe may depend on the type and condition of marine animal tissue and variables like location of the facility and time of year. For example, at the University of New England (UNE) facility, the starting formula for mixing marine mammal remains and bulking materials was three to five parts of biologically active bulking materials by volume to one part marine mammal soft tissue. The bulking agent used at UNE consists of fresh, bedded horse manure composed of sawdust shavings, waste feed, urine, and feces. Standard protocol at UNE was to freeze soft tissue following each necropsy to eliminate decomposition and minimize offensive odors. However, prior to composting, the bins of tissue were thawed overnight so that the tissue was at least room temperature prior to addition to the compost pile. Frozen remains will eventually compost, but thawing does provide a more rapid onset of active composting.

In addition to proper C: N and moisture, there must be enough coarseness to the ingredients to promote natural diffusion of air throughout the final mixture (porosity). Bulk density refers to the weight (pounds) per cubic yard of material. In general, the higher the bulk density, the more resistant the material is to oxygen penetration and airflow. To ensure aerobic composting, the bulk density should be between 800 and 1,000 pounds/yd^3. Without proper aeration. anaerobic conditions occur and produce undesirable odors.

Rounding out the key criteria are pH and volatile solids. Maintaining an optimal pH of 6.5 to 7.5 will not only ensure a good compost performance, but will also help hold on to nutrients and prevent nuisance odors. Volatile solids refer to the organic fraction of the compost recipe that is available for composting. Recipes with at least 40% volatile solids usually perform well. The following list summarizes the target ranges for optimal composting:

A. Moisture 50 to 60%
B. Carbon to nitrogen ratio (C:N) 20:1 to 30:1
C. pH 6.5 to 7.5
D. Bulk density <1,000 lbs./cubic yard
E. Volatile solids >40% dry weight basis

2. **Mixing and Pile Formation**: Next to recipe development, proper mixing and pile formation is the single most important step determining success or failure of the compost operation. Obtaining a thorough, homogeneous mixture at the onset of the compost process will ensure intimate contact between the carbon, nitrogen, and moisture components of the pile, reducing the potential for the formation of dead spots, or inactive areas. In addition, proper mixing allows for even air distribution throughout the pile, helping to promote aerobic composting. Mixing can be accomplished by using front-end loaders, manure spreaders or other farm equipment, batch or continuous mixers, and windrow turners. Regardless of the method chosen, the objective is to obtain as thorough a mix as possible to help hasten the onset of the active composting phase.

   Once the material is thoroughly blended, it is time to build the compost pile. The objective here is to create a pile large enough to sustain the self-heating process that accompanies active, thermophilic (requiring high temperature) composting. As a general rule, piles should be constructed no higher than 6 feet high by 6 to 18 feet wide (2 meters high by 2-5 meters wide). In areas experiencing long winter seasons, pile height may need to be increased by up to 3 meters. The size and shape of the compost pile will ultimately be determined by the type of compost system that is chosen, and the volume of material being handled in a given season. In addition to adequate mass, the pile must also contain enough porosity (air spaces) to allow natural movement of air throughout the pile. Creating piles that are too high (in excess of 3 meters (10 feet)) creates the risk of compression of the inner core contents, due to the excessive weight of the overlying materials. This results in pore diffusion of air through the pile.

3. **Turning**: This is the physical process by which compost pile ingredients are blended and re-mixed throughout the active compost phase to help sustain high temperatures. The frequency of turning depends upon the individual needs of each compost pile. During the turning process, several things are accomplished at once: re-mixing of pile ingredients, further physical breakdown of resistant ingredients, and redistribution of air spaces within the pile to help promote passive air flow. In addition, the turning process can be used as a moisture management tool. Piles that are too wet can be turned more often to facilitate drying, whereas piles that are too dry may be turned immediately following precipitation events to help capture and retain moisture.

The easiest way to determine the need for pile turning is to take and record daily pile temperatures. To accomplish this, two temperature readings should be taken for each sampling site, with one at a depth of 1/3 meter and the other at a depth of 1 meter or in the pile core. These readings should be compared, and compost piles should be turned whenever the difference exceeds 20°F (10°C). As a rule of thumb, piles should also be turned whenever there is a significant drop in temperature that cannot be accounted for by an external cause (i.e., excessive rainfall), when active composting temperatures exceed 155°F (65°C), or when significant odor production suggests pile imbalances. Piles should not be turned so frequently that the compost process is interrupted and not allowed to reach the optimum temperature.

4. **Curing**: Once the compost mixture has completed the active compost phase, it must undergo a sustained period of curing. Curing is the single most important, but often neglected, phase of the compost process. During curing, microorganisms continue the process of organic matter degradation (concentrating on organic acids, large particles, resistant compounds and other particles remaining after the active compost phase), but at a much slower rate. Oxygen consumption, heat generation, carbon dioxide, and water vapor production are all decreased as the material matures.

Methods of Composting Applicable to Marine Animal Carcasses

A number of different methods and systems are available to assist in composting marine animal carcasses and other organic resources. The composting technology used by an institution depends on the amount of space available, the type and amount of animal carcasses available, and collection capabilities. In addition, economic feasibility, which can include initial capital investment, permit fees, labor, fuel, maintenance, repairs, upkeep, taxes, electrical, and distribution of end-product, is also an important consideration.

3. **Static Pile System:** This method involves mixing the compost ingredients together and constructing a pile from the blended material. Subsequent turnings are not typically accomplished until the material is fully composted.

Figure 6: Town of Skowhegan Leaf and Yard Compost Site, Skowhegan, Maine.
Photo: Mark King

Table 1. Advantages and disadvantages to using a static pile system as a composting method.

<table>
<tr><th>Advantages</th><th>Disadvantages</th></tr>
<tr><td>• The least labor/equipment intensive method. This is a low-tech approach that requires very little capital investment or accessory equipment. It has been widely used for manure and municipal sewage residual composting. This is similar to carcass composting because of the high nutrient content of the raw material.</td><td>• Composting in a static pile usually happens more slowly due to a steady reduction in the amount of oxygen available throughout the pile.</td></tr>
<tr><td>• The only equipment needed is a tractor with a bucket or a front-end loader.</td><td rowspan="4">• When this method is used with materials that contain a great deal of moisture and nitrogen, such as food scraps or animal carcasses, a lack of sufficient available oxygen may cause the process to become anaerobic and unpleasant odors may result. These piles must be constructed and monitored carefully.</td></tr>
<tr><td>• The pile may be turned up to 4 times a year but will usually compost without any further management.</td></tr>
<tr><td>• This can be a viable option for clean-up/disposal of marine animal carcasses on a beach.</td></tr>
<tr><td>• Build a compost pile above a high tide line, outside of the boundaries of environmentally fragile and protected areas (i.e. in a parking lot).</td></tr>
</table>

2. **Turned Windrow.** This is a preferred method for most carcass and seafood products composting. It may work equally well for municipal operations with sufficient space and resources and for emergency response during mass die-offs or disposal of large cetaceans. Typically, the material to be composted is layered in long piles (windrows) and mixed using a mechanical windrow turner. Windrows are then turned as needed with the same equipment. A front-end loader can be substituted to mix and turn the windrows though care must be taken to achieve good mixing. A front-end loader is less efficient and will require more time than a windrow turner, but is typically a more commonly found piece of heavy equipment.

Figure 7: Rainbow Valley Farm, Sidney, Maine.
Photo: Mark King

Table 2. Advantages and disadvantages to using a turned windrow pile system as a composting method.

Advantages	Disadvantages
• The windrow system is rapid and requires the least amount of time for the composting to occur. Large volumes of material can be turned in a short length of time.	• This method requires more management and space than static pile or aerated pile methods.
• Done properly, each subsequent turn further blends the compost ingredients, releases trapped carbon dioxide and water vapor, redistributes air spaces within the row, and also aides in physical breakdown of materials. This results in a very uniform product.	• Pile temperature must be carefully monitored so that the row can be turned at the appropriate time to maximize composting.

• Windrows would be convenient for a beachside municipality to dispose of marine animal carcasses that are found on beaches. This method requires the same equipment and roughly the same time as burial and has the advantage of quick reduction of carcasses.	• Windrow turning machines can be costly investments.
	• Unless carcasses are composted in the field, this method requires transporting carcasses from beach to facility.

3. **Turned Bin**. This method applies the turned windrow methodology to a series of three-sided bins, usually two or three connected in a row. During this process, the initial mixture consists of a base-layer of carbon amendment, usually 24 inches (60 cm) thick, followed by a 12-inch (30 cm) thick layer of marine animal soft tissue. A final layer of carbon amendment, typically 36 inches (90 cm) thick for odor control, is added to complete the pile construction. This initial mixture is allowed to sit for up to two weeks as a '"pre-conditioning period," before the compost is turned into the second bin.

   This "Pre-Conditioning" period helps reduce leachate and odor potential, while also allowing initiation of the compost process. Subsequent turnings timed at two-week intervals are accomplished until the material is deemed ready for curing. This is the preferred method for composting marine animals. This method has been thoroughly tested by UNE/MARC.

Figure 8: University of New England's three-bin compost facility. At UNE, this 30' x10' (roughly 10 meters by 3 meters) 'three bin compost facility' has kept up with the composting needs of the animal remains generated at UNE Marine Animal Rehabilitation Center for the past 5 years. In that time, approximately 38 piles of marine animal soft tissue have been composted (approx. 15 tons).
Photos: Keith Matassa and Mark King

Table 3. Advantages and disadvantages to using a turned-binned system as a composting method.

Advantages	Disadvantages
• The composting usually happens very quickly. Frequent turnings increase contact between carcasses and feedstock, replenishing oxygen and nutrients.	• More labor/equipment intensive method than the static pile. Piles need to be turned every two to three weeks, involving a front-end loader or turner of some sort.
• Higher temperatures are maintained for a longer period of time, facilitating the destruction of pathogens.	• Temperatures need to be monitored to determine progress of ongoing composting.
• The only equipment needed is a tractor with a bucket or a front-end loader.	• When this method is used with materials that are wetter and/or contain more nitrogen, such as food scraps, a lack of sufficient available oxygen may cause the process to go anaerobic and unpleasant odors may result. Care must be taken in selecting feed-stocks and properly constructing piles.

4. **Aerated Static Pile**: In this system, thoroughly blended compost mixtures are placed on a bed of coarse amendment underlain by a single or series of perforated pipes. The piping is then attached to a mechanical blower that forces air through the pile. Piles can be larger, generally 2-3 meters high and 3-5 meters wide. The width of the piles depends on the layout of the pipes; some piles are very wide with multiple pipes running through them. This method is more expensive than the previously mentioned methods because it requires additional equipment and relies on electricity to operate the blowers. However, this method can also accelerate the composting process if the mixture is optimized.

Figure 9: Former Bangor Sludge Compost Facility, Bangor, Maine.
Photo: Mark King

Table 4: Advantages and disadvantages to using aerated static pile system as a composting method.

Advantages	Disadvantages
• This is a low-tech approach that requires very little capital investment or accessory equipment. It has been widely used for manure and municipal sewage residual composting. This is similar to carcass composting because of the high nutrient content of the raw material.	• Once the pile is placed on the aerator system, it is difficult to turn; therefore, all materials must be thoroughly mixed at the outset of pile formation. Care must be taken to blend materials evenly.
	• Care must be taken in the layout of the aeration system to allow for the free exchange of air or else odors may occur. If the aeration system fails (either due to mechanical failure or due to clogging) the pile will become anaerobic.
	• There must be careful monitoring of airflow, temperature, and moisture content of these piles, as they are prone to excessive drying. This can result in a slowing down of composting activity.

Trouble-Shooting Composting

No matter how well you operate your facility you are invariably going to experience nuisance problems from time to time. Nuisance problems are the number one complaint about compost facilities. Engineering and technology to correct these problems can be expensive and ineffectual. The key to remember is that these are “people problems” and that prolonged nuisance conditions can lead to facility shutdown. Complaints should be met with an immediate response, including an explanation of the cause, if known. Good siting can help avoid potential nuisances by ensuring there are adequate buffers to neighboring residences. Valleys and gullies should be avoided whenever possible, as they can carry nuisance odors to neighboring residences. Access roads should be located away from residences, maximizing the use of existing visual screens (tree buffers). However, there is no substitute for proper site management. Most problems are often interrelated and, as a result, addressing one usually solves the others. The key to overcoming nuisance problems is to identify the root cause and to correct it. **The trick to remember is that most compost problems can be avoided simply by optimizing the compost recipe (50-60% moisture, 6.5-7.5 pH, 20:1 to 30:1 C: N, homogeneous mixture, and adequate “air spaces” within the piles) at the onset of composting.**

The following section describes the most common nuisance problems associated with limited marine animal compost facilities and methods that have been developed to correct them. A condensed Trouble Shooting table immediately follows this section.

Odors: Odors signify a breakdown in the compost process. Left uncorrected, odors can drift off site, impacting neighboring residences. Odor issues can be addressed by paying strict attention to process control. Incoming loads of marine animal residuals should be immediately mixed with carbon amendment as soon as they are received. This is the first chance to control odors. If this is not possible, materials should be received in waterproof, airtight containers until they can be processed. Initial compost recipes should be thoroughly mixed, and the following parameters should be optimized: C: N (25:1 to 30:1), porosity (adequate air space distribution) and percent moisture (45% to 60%). Finally, compost piles may also be covered with a 10 to 15 centimeter (25.4 to 38.1) layer of sawdust, peat, or finished compost to act as an odor scrubber.

Vectors: Vectors are organisms capable of transmitting diseases to humans. These organisms include birds (sea gulls and crows), mammals (rats and other rodents), and flies. They are attracted to odorous, decaying materials, especially pieces of marine organisms that have not been properly incorporated into compost piles. Vectors can be discouraged by maintaining a neat and clean operation. If there is a drop point at your facility for after-hours service, consider a bear-proof container like those used in the western states for containing edibles and trash; this will cut down on the odors that will attract unwanted vectors. Immediately adding fresh carcasses/residues to the compost pile will also reduce odors and vectors. Thoroughly cleaning empty storage vessels also reduces attractiveness to vectors and reduces the chance of diseases.

Leachate: Leachate results from poor moisture management during initial recipe formation and/or from prolonged exposure of compost windrows to heavy precipitation. As mentioned above, initial compost recipes should have a moisture content of 45 to

60%. Because leachate contains concentrated nutrients, it poses a significant threat to groundwater. In addition, if your piles are losing nutrients then your finished compost will be poorer in quality. There are several approaches to leachate management. The first is to prevent it. Leachate can be avoided by achieving proper mix ratios at the onset of composting. Additionally, composting under a roofed structure or by using water resistant covering materials can help minimize the effects of precipitation on leachate generation. Most Maine facilities try to capture the leachate by amending it with sawdust or other suitable materials and then re-incorporating it back into the compost piles. Other facilities collect the leachate into a storage tank and then reuse it on the piles when moisture adjustments are necessary. Finally, leachate may be discharged onto a level vegetated surface for treatment. The key to leachate control is to manage moisture in the initial recipe development.

Dust, Noise, and Traffic: These problems are often interrelated. Dust is created as a result of many compost facility operations including materials off-loading, mixing, compost turning, screening and traffic. Dust conditions can also be exacerbated by prevailing winds, carrying particles onto neighboring properties. On site, dust can be an irritant to facility workers, affecting the eyes and respiratory tract. Noise from compost equipment—such as front-end loaders, grinders, mixers, transport trucks, and compost turners—can annoy neighbors directly abutting your facility. Increased traffic results in noise, dust, excessive speeds, and bottlenecks. These issues can be addressed by developing daily operating hours, monitoring equipment noise, setting speed limits on access roads, and soliciting feedback from your neighbors. In addition, dust conditions can be minimized by moistening dry compost piles and enclosing screening, mixing, and turning operations. Noise can be lessened by planting a green sound barrier between the facility and the closest neighbors.

There are numerous issues posed by stranded marine animals beyond their sheer number, size, and bulk that make disposal activities problematic. Some of these concerns include:

Contaminants and Disease Many marine animals are middle to top-level predators, although, some large whales and sirenians are exceptions. Long-lived, higher order predators such as marine mammals tend to be more sensitive to bioaccumulation of persistent pollutants that occur in their diets. Some marine mammals have demonstrated high levels of lipophilic contaminants and high levels of heavy metals such as mercury, silver, and arsenic. Persistent concentrations of these metals can cause concern during disposal scenarios due to the documented human health impacts associated with their exposure. Because of the complexity of marine food webs, there can be enormous variation in contaminant loads. Some marine mammals appear to have normal or even reduced levels of the same contaminants (i.e.: females offloading contaminants to their young). So, although there are some common threads (inshore species tend to have higher contaminant levels than pelagic species), it is difficult, if not impossible, to predict contaminant loads in a particular marine mammal carcass. Zoonosis has been raised in connection with those working with live and handling dead marine animals. Those concerns prompted a report on the risks of working with living and/or dead marine mammals funded by the Marine Mammal Commission (MMC). In summary, the report by UC Davis Wildlife Health Center states that roughly 50% of those working with marine mammals for longer than five years reported some type of injury or illness (see full report at http://www.vetmed.ucdavis.edu/whc/mmz). The majority of these injuries, however, were due to bites from live animals or injuries from equipment. Although some chronic disease was reported, no fatalities were reported. Marine mammals, however, have been shown to carry a number of potential zoonotic pathogens.

Seasonality and Availability of Carbon Amendments: Many composting amendments have different availability throughout the year. Leaves, for example, are collected primarily in the fall and to a lesser degree during spring clean-up. When available, they may arrive in large quantities. Facilities must develop contingency plans to make allowances for this sudden influx. Seasonal feedstocks require additional storage as well as adequate space for immediate processing. Some facilities may wish to compost on a seasonal basis, operating only when the feedstocks are available. This method works well for small communities by saving a portion of space at the local transfer station to handle incoming leaves in the fall. One of the best feedstocks to use in composting of marine animals is horse bedding, which is typically a mixture of sawdust, feces, and urine and uneaten feed. Very little mixing or additions are needed prior to using this in the compost process. There is the added bonus that horse bedding is readily available in most locations. Unfortunately, most composters know how wonderful and available this commodity is and have already set up the infrastructure to have a steady source of this material. The key to being able to tap into a steady and reliable source is getting to know the area users, and buying the manure and bedding from them. A lot of the composters stockpile their feedstock and may deliver your needed quantity to the composting/storage area. For example in Maine, fresh horse bedding (delivered) costs about $10.00/cubic yard (approximately 1 cubic meter).

Unpredictability of Marine Animal Mortalities: Although marine animal strandings are generally unpredictable, there are seasonal and spatial distribution patterns that may help when planning the design and operation of a compost facility. In Maine, the most abundant species of marine mammal, harbor seals, are born in the middle of May on small coastal haul outs in the mid-coast and downeast. Newborn and young of the year mortality creates a seasonal increase during the spring and summer months. During the winter, many seals move offshore or head south to beaches around Cape Cod. Changes in mortality patterns can also occur due to mass standings of cetaceans. These strandings may involve entire social groups of dolphins or whales. Stranding of several dozen medium sized dolphins is not unheard of along the Maine, New Hampshire, and Massachusetts coasts. Increases in mortality can also occur due to disease or exposure to toxins - both natural and artificial. Unusual mortalities have caused great increases in mortality of seals, whales, and sea turtles in the Gulf of Maine and are increasing in numbers each year. It is therefore prudent to include disaster planning in the design and operational plan of a disposal facility, including provisions for containment, bio-security, and human safety.

Table 5. Composting Trouble-Shooting Table

Problem	Cause	Solution
Piles fail to heat	Pile too wet or too dry	Adjust moisture to 40 – 60%
	pH too low or too high	Adjust pH to 6.5 – 7.5
	Mix is not uniform	Breakdown and re-mix piles; grind ingredients to make compatible
	Particle size is too small	Add “bulking” source to pile to increase porosity
	C:N too high	Adjust C:N to 20:1 – 30:1
“Uneven” compost temperatures	Mix is not uniform; particle size mismatch	Breakdown and re-mix piles; grind ingredients to make compatible
Odor Production		
Ammonia	ph too high (>8.5)	Lower pH to 7.5
	Pile too dry	Raise pile moisture to 40%
	Too much nitrogen in recipe	Add carbon source until C:N is between 20:1 and 30:1
“Pungent-Rotting Smell”	ph too low (<5.5)	Raise pH up to 6.5
	Pile too moist	Dry pile down to 60% moisture
	Poor pile porosity	Re-mix pile to increase porosity and/or add more bulking agents
Failure to produce a stabilized finished product	Compost pile has not completed active compost phase	Re-mix pile, adjust recipe and allow to continue composting until active phase been completed
	Inadequate “curing” time	Allow pile to cure for additional time: up to 6 months if necessary

Glossary

This section defines many of the technical terms used in this manual. The following terms describe various aspects associated with the composting of marine animals.

Active Phase. Energetic phase of compost process in which busy organisms accelerate the breakdown of complex carbohydrates, proteins, and fats into more soluble compounds, producing high temperatures often in excess of 131 ^{o}F (55 ^{o}C).

Aerated Static Pile Composting. Forced aeration method of composting in which a compost pile is formed over a single or series of perforated pipes through which a mechanical blower actively moves air through the pile, providing oxygen to enhance the composting process.

Aerobic Decomposition. Decomposition that requires the presence of oxygen.

Amendment. An ingredient in the compost mixture that is added to improve the mixture. Amendments are often added to dry the pile, improve the carbon level, or add porosity to the pile.

Anaerobic Decomposition. Decomposition that occurs without oxygen. Anaerobic decomposition often produces nuisance odors.

Buffer. An area of vegetated land that is maintained between a compost operation and protected resource (Homes, water bodies, etc.) to help ensure air, soil, and water quality.

Bulk Density. The weight or mass of a material in relation to its volume. For example, in a compost mixture, the bulk density of a material is measured as pounds/cubic yard. The higher the bulk density, the more difficult for air to flow through a material.

Bulking Agent. An ingredient added to a compost pile to improve its overall physical structure and to increase the available pore spaces for oxygen flow throughout the pile.

Carbon. An essential element used by compost organisms as an energy source.

Carbon to Nitrogen Ratio (C:N Ratio). The ratio of weight of organic carbon to total nitrogen in a compost mix. Preferred range is 20:1 to 30:1.

Compost. A valuable soil amendment that has been produced through the careful decomposition of a mixture of organic materials.

Curing Phase. The final phase of the composting process in which organic compounds have been transformed to more stable compounds and decomposition continues at a reduced rate.

Feedstock. Raw ingredients added to a compost pile.

Humus. Dark, carbon-rich, stable material resulting from thorough decomposition of organic matter. Humus provides nutrients for soil life and plant growth.

Leachate. Liquid residue formed as it passes through a compost pile, extracting solutes or suspended solids, nutrients or any other materials.

Level Lip Spreader. Structures that are designed to uniformly distribute concentrated water flows over a larger (often vegetated) area, thereby reducing soil erosion.

Mesophilic. Operational temperature range preferred by Mesophilic Bacteria; usually between 50^{o}F (10^{o}C) and 105^{o}F (40^{o}C).

Microorganisms. Microscopic bacteria and other organisms responsible for bulk of decomposition activities during composting.

Nitrogen. An essential element used as a building block by compost microorganisms in cellular reproduction.

Percent Moisture. The percentage of a substance comprised of water. For ideal composting, the optimal range of moisture is: **50%-65%.**

pH. A measure of the concentration of hydrogen ions in a compound. For optimal composting, the ideal range of pH is **6.5-7.5.**

Porosity. A measure of the available pore spaces within a compost pile mixture.

Recipe. The optimal ratio or proportion of ingredients blended together to form a compost pile.

Run-off. Water that flows away from a compost operation. This material often contains soluble nutrients and is referred to as "leachate."

Run-on. Clean water flowing onto a site (usually in the form of precipitation). Compost facilities should be constructed in a manner that diverts this flow away from compost areas.

Slope. The slant of a piece of land or surface that encourages water to flow.

Static Pile Composting. A method of composting in which compost ingredients are blended together, formed into a pile and left to compost on its own.

Thermophilic. Operational temperature range preferred by Thermophilic Bacteria; usually between 131^{o}F (55^{o}C) and 160^{o}F (71^{o}C).

Turned Bin Composting. Method of composting in which compost ingredients are blended together and formed into a pile within the first of a series of three-sided bins. After a specified period of time, the pile is moved from the first bin to the second and so on. Using this method allows better mixing than the static pile method, while simultaneously enhancing pore space and oxygenation of the compost.

Turned Windrow Composting. A method of composting in which compost piles are formed into long rows (windrows) and, periodically, the entire pile is turned and mixed using a front-end loader or specialized mechanical device. Pile turnings may be based on time or temperature feedback.

Vector. Any organism capable of spreading diseases to humans. This group includes: birds, rodents, domestic animals, and insects.

Volatile Solids. A measure representing the amount of organic matter in a compost pile that is available for decomposition. Recipes with at least 40% volatile solids usually perform well.

Appendix I: About the Authors

Mark King
Mark is originally from Winthrop, Maine and has been with the Maine Department of Environmental Protection since 1991. Mark has a Bachelor's degree in biology from the University of Maine and a Master's degree in zoology from Southern Illinois University. Mark currently works as an Environmental Specialist in the Department's Sustainability Division, where he serves as the Department's compost contact. In 1993, Mark joined the Maine Compost Team where he developed an expertise in composting. In 1997, the Team established Maine's award-winning compost school (www.composting.org), where Mark serves as the director, as well as actively participating as a faculty member. To date, the school has graduated more than 800 students representing more than 40 countries. Mark provides ongoing technical assistance to new and existing compost facilities through compost facility design, operations assistance, and compost process trouble-shooting. Mark has worked with all levels of compost facility size and design, and all possible feedstocks from shrimp to whales. He has developed an expertise with medium and large-scale facilities. Currently, Mark is working on a project to promote statewide composting of pre- and post-consumer food residuals as an alternative to costly landfill disposal.

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Keith Matassa
Keith is originally from Connecticut, raised in Maine and has been working in the Marine Mammal Stranding field on both the east and west coasts since the early 1980s. Keith has a Bachelor's degree in marine biology from the University of New England and was the rehabilitation coordinator of UNE's Marine Animal Rehabilitation Center from 2001-2013. In 2013, he left to become the Executive Director of the Pacific Marine Mammal Center. While at UNE, Keith started composting marine mammals to find answers to challenges of disposing of marine mammals. Keith was also a steering committee member of the international carcass disposal symposiums.

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Mendy Garron

Mendy currently serves as the Regional Marine Mammal Stranding Response Coordinator and has been with the NOAA Fisheries Service, Greater Atlantic Regional Fisheries Office (GARFO) since 2003. Mendy has a Bachelor's degree in marine biology from the University of North Carolina, Wilmington, a Veterinary Technician degree from the Northshore Community College, and a Master's of Public Policy and Administration from Northwestern University. Historically, disposal of marine mammals has been a challenging issue for the Regional Stranding Response Program. Mendy has worked with network partners to forge new relationships and projects to identify new, environmentally conscious methods for marine mammal disposal, such as working with state agencies and other federal agencies.

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Appendix II: Coastal State and Territorial Contacts for Departments of Health, Agriculture, and Environmental Protection

State / Territory	Public Health	Agriculture	Environment Protection
Alabama	Department of Public Health http://www.adph.org	Department of Agriculture & Industries http://www.agi.alabama.gov/	Department of Environmental Management http://www.adem.state.al.us
Alaska	Division of Public Health http://dhss.alaska.gov/dph/Pages/default.aspx	Department of Natural Resources Division of Agriculture http://dnr.alaska.gov/ag/ag_es.htm	Department of Environmental Conservation http://dec.alaska.gov/
American Samoa	Department of Health http://www.samoagovt.ws/	Department of Agriculture http://www.samoagovt.ws/	Environmental Protection Agency: http://www.epa.as.gov/
California	Department of Health Services http://www.cdph.ca.gov	Department of Food & Agriculture http://www.cdfa.ca.gov	Environmental Protection Agency http://www.calepa.ca.gov/
Connecticut	Department of Public Health http://www.ct.gov/dph	Department of Agriculture http://www.ct.gov/doag	Department of Energy & Environmental Protection http://www.ct.gov/deep/site/default.asp
Delaware	Division of Public Health http://dhss.delaware.gov/dhss/dph/index.html	Department of Agriculture http://dda.delaware.gov/	Department of Natural Resources and Environmental Control http://www.dnrec.delaware.gov/
Florida	Department of Health http://www.doh.state.fl.us	Department of Agriculture & Consumer Services http://www.freshfromflorida.com	Department of Environmental Protection http://www.dep.state.fl.us/mainpage/default.htm
Georgia	Department of Human Resources http://health.state.ga.us	Department of Agriculture http://agr.georgia.gov	Environmental Protection Division https://epd.georgia.gov/
Guam	Department of Public Health & Social Services http://dphss.guam.gov	Department of Agriculture http://doag.guam.gov/	Environmental Protection Agency http://epa.guam.gov/
Hawaii	Department of Health http://hawaii.gov/health	Department of Agriculture http://hawaii.gov/hdoa	Office of Environmental Quality Control http://health.hawaii.gov/oeqc
Louisiana	Department of Health & Hospitals http://new.dhh.louisiana.gov	Department of Agriculture & Forestry http://www.ldaf.state.la.us	Department of Environmental Quality http://www.deq.louisiana.gov/portal/
Maine	Center for Disease Control and Prevention http://www.maine.gov/dhhs/mecdc/	Department of Agriculture, Conservation & Forestry http://www.maine.gov/dacf/	Department of Environmental Protection http://www.maine.gov/dep/
Maryland	Department of Health & Mental Hygiene http://dhmh.maryland.gov/Pages/Index.aspx	Department of Agriculture http://mda.maryland.gov/Pages/default.aspx	Department of the Environment http://www.mde.state.md.us/Pages/Home.aspx
Massachusetts	Department of Public Health http://www.mass.gov/eohhs/gov/departments/dph/	Department of Agricultural Resources http://www.mass.gov/eea/agencies/agr/	Department of Energy and Environmental Affairs http://www.mass.gov/eea/agencies/massdep/
Mississippi	Department of Health http://msdh.ms.gov/msdhsite/_static/30.html	Department of Agriculture & Commerce https://www.mdac.ms.gov/	Department of Environmental Quality https://www.deq.state.ms.us/
New Hampshire	Department of Health & Human Services http://www.dhhs.nh.gov/	Department of Agriculture, Markets & Food http://agriculture.nh.gov/	Department of Environmental Services http://des.nh.gov/
New Jersey	Department of Health http://www.nj.gov/health/	Department of Agriculture http://www.nj.gov/agriculture/	Department of Environmental Protection http://www.nj.gov/dep/
New York	Department of Health https://www.health.ny.gov/	Department of Agriculture & Markets http://www.agriculture.ny.gov/	Department of Environmental Protection http://www.nyc.gov/html/dep/html/home/home.shtm

State / Territory	Public Health	Agriculture	Environment Protection
North Carolina	Department of Health & Human Services http://www.ncdhhs.gov/	Department of Agriculture & Consumer Services http://www.ncagr.gov/	Department of Environmental Quality http://deq.nc.gov/
Northern Mariana Islands	Commonwealth Healthcare Corporation http://chcc.gov.mp/	Division of Agriculture http://www.cnmiforestry.com/division-of-agriculture	Bureau of Environmental and Coastal Quality http://www.deq.gov.mp/sec.asp?secID=18
Oregon	Department of Human Services http://www.oregon.gov/DHS/pages/index.aspx	Department of Agriculture http://www.oregon.gov/oda/Pages/default.aspx	Department of Environmental Quality http://www.oregon.gov/DEQ/pages/index.aspx
Pennsylvania	Department of Health http://www.health.pa.gov	Department of Agriculture http://www.agriculture.pa.gov	Department of Environmental Protection http://www.dep.pa.gov
Puerto Rico	Department of Health http://www.salud.gov.pr	Department of Agriculture http://www.agricultura.pr.gov/	Department of Natural Resources http://drna.pr.gov/
Rhode Island	Department of Health http://www.health.ri.gov/	Division of Agriculture http://www.dem.ri.gov/programs/bnatres/agricult/	Department of Environmental Management http://www.dem.ri.gov
South Carolina	Department of Health & Environmental Control http://www.scdhec.gov/	Department of Agriculture https://agriculture.sc.gov/	Department of Health and Environmental Control http://www.scdhec.gov/
Texas	Department of Health Services http://www.dshs.state.tx.us/	Department of Agriculture https://texasagriculture.gov/	Commission on Environmental Quality https://www.tceq.texas.gov/
Virgin Islands	Department of Health http://www.healthvi.org/	Department of Agriculture http://www.nasda.org/	Department of Planning and Natural Resources http://dpnr.vi.gov/
Virginia	Department of Health http://www.vdh.virginia.gov/	Department of Agriculture & Consumer Services http://www.vdacs.virginia.gov/	Department of Environmental Quality http://www.deq.state.va.us/
Washington	Department of Health http://www.doh.wa.gov/	Department of Agriculture http://agr.wa.gov/	Environmental Public Health http://www.doh.wa.gov/AboutUs/ProgramsandServices/EnvironmentalPublicHealth

Appendix III: NOAA Fisheries Service Marine Mammal Stranding Network

NOAA Fisheries Service Regional Office and Science Center Stranding Program Reporting Hotlines		
Greater Atlantic Regional Stranding and Entanglement Hotline		866-755-6622
Southeast Region Marine Mammal Stranding Hotline		877-433-8299
Alaska Marine Mammal Stranding Hotline		877-925-7773
West Coast Region Marine Mammal Stranding Network		866-767-6114
Pacific Islands Region Marine Mammal Stranding & Entanglement Hotline		888-256-9840
REGIONAL STRANDING NETWORK PARTNERS		
Greater Atlantic Regional Stranding Network (Maine through Virginia)		
Greater Atlantic Regional Fisheries Office	866-755-6622	Gloucester, MA
College of the Atlantic / Allied Whale	207-288-5644	Bar Harbor, ME
Marine Mammals of Maine	800-532-9551	Portland, ME
Seacoast Science Center	603-997-9448	Rye, NH
New England Aquarium	617-973-5247	Boston, MA
International Fund for Animal Welfare	508-743-9548	Yarmouth, MA
The National Marine Life Center	508-743-9888	Buzzards Bay, MA
Mystic Aquarium	860-572-5955	Mystic, CT
Riverhead Foundation for Marine Research and Preservation	631-369-9829	Riverhead, NY
Marine Mammal Stranding Center	609-266-0538	Brigantine, NJ
DE Department of Natural Resources and Environmental Control	302-739-9000	Dover, DE
Marine Education, Research and Rehabilitation Institute	302-228-5029	Nassau, DE
Maryland Department of Natural Resources	800-628-9944	Oxford, MD
National Aquarium	410-373-0083	Baltimore, MD
Smithsonian Institute, National Museum of Natural History	202-633-1260	Washington, DC
Virginia Aquarium and Marine Science Center	757-385-7575	Virginia Beach, VA
Southeast Region Marine Mammal Stranding Network (North Carolina through Texas)		
North Carolina		
North Carolina Division of Marine Fisheries	252-241-5119	Morehead City, NC
North Carolina Maritime Museum	252-504-2452	Beaufort, NC
University of North Carolina - Wilmington	910-254-5713	Wilmington, NC
Cape Hatteras National Seashore	252-473-2111	Manteo, NC
Duke University Marine Laboratory	252-504-7503	Beaufort, NC
North Carolina Aquarium at Fort Fisher	252-241-5119	Fort Fisher, NC
North Carolina State College of Veterinary Medicine	252-241-7367	Morehead City, NC
North Carolina Wildlife Resources Commission	252-241-7367	Corolla, NC
South Carolina		
Coastal Carolina University	800-922-5431	Conway, SC
NOS Charleston Laboratory	800-922-5431	Charleston, SC
Georgia		
Georgia Sea Turtle Stranding and Salvage Network	912-280-6892	Brunswick, GA
Georgia Department of Natural Resources	912-269-7587	Brunswick, GA
Florida		
Central Panhandle Aquatic Preserve Office	850-245-2094	Eastpoint, FL
Clearwater Marine Aquarium	727-441-1790	Clearwater, FL
Dolphin Conservation Field Station at Marineland	904-461-9941	St. Augustine, FL
Emerald Coast Wildlife Refuge	850-650-1880	Destin, FL
Florida Aquarium	813-273-4000	Tampa, FL

Florida Marine Mammal Stranding Network - Southwest Region	888-405-3922	Port Charlotte, FL
FWC, FMRI Marine Mammal Pathobiology Laboratory	888-405-3922	St. Petersburg, FL
FWC Northeast Field Laboratory	888-405-3922	Jacksonville, FL
FWC Tallahassee	888-405-3922	Tallahassee, FL
Gulf Islands National Seashore	850-934-2600	Gulf Breeze, FL
Gulf World Marine Park	850-234-5271	Panama City, FL
Harbor Branch Oceanographic Institute	772-242-2400	Fort Pierce, FL
Hubbs-SeaWorld Research Institute	407-370-1651	Orlando, FL
Marine Animal Rescue Society	888-405-3922	Miami, FL
Marine Mammal Conservancy, Inc	305-451-4774	Key Largo, FL
Mote Marine Laboratory	941-388-4441	Sarasota, FL
NMFS Southeast Fisheries Science Center Miami Laboratory	877-433-8299	Miami, FL
NMFS Southeast Fisheries Science Center Panama City Laboratory	877-433-8299	Panama City, FL
Northwest Florida Aquatic Preserves Office, FDEP	850-983-5359	Milton, FL
SeaWorld Orlando	888-405-3922	Orlando, FL
Volusia County Stranding Network	888-405-3922	DeLand, FL
Puerto Rico		
Mayaguez Zoo	787-538-4684	Mayaguez, PR
Puerto Rico Department of Natural and Environmental Resources	787-538-4684	Santurce, PR
U.S. Virgin Islands		
U.S. Virgin Islands Division of Fish & Wildlife	340-713-2422	Frederiksted, VI
Alabama		
Alabama Marine Mammal Stranding Hotline	877-842-5343	
Mississippi		
Institute for Marine Mammal Studies	888-767-3657	Gulfport, MS
Gulf Islands National Seashore	888-806-1674	Ocean Springs, MS
NMFS Southeast Fisheries Science Center Pascagoula Laboratory	877-433-8299	Pascagoula, MS
Louisiana		
Audubon Aquarium of the Americas	504-235-3005	New Orleans, LA
Louisiana Department of Wildlife and Fisheries	504-235-3005	Lake Charles, LA
Texas		
Texas Marine Mammal Stranding Network	800-962-6625	Galveston, TX
Aransas National Wildlife Refuge	361-286-3559	Austwell, TX
Texas State Aquarium	361-881-1200	Corpus Christi, TX
Alaska Region Marine Mammal Stranding Network		
NMFS Alaska Regional Office, Juneau	907-586-7235	Juneau, AK
NMFS Alaska Regional Office, Anchorage	907-271-5006	Anchorage, AK
Alaska Department of Fish and Game	907-459-7214	Fairbanks, AK
	907-766-2607	Haines, AK
	907-465-6167	Juneau, AK
	907-443-8191	Nome, AK
Alaska Sealife Center	888-774-7325	Seward, AK
The Alaska Sea Otter and Steller Sea Lion Commission	907-286-2377	Old Harbor, AK
The Alaska Whale Foundation	360-808-0579	Petersburg, AK
Bridge Veterinary Services, LLC	907-697-2664	Juneau, AK
Glacier Bay National Park and Preserve	907-697-2664	Glacier Bay, AK
North Gulf Oceanic Society	907-235-6590	Homer, AK
St. Paul Island, Tribal Government, Fur Seal Disentanglement Project	907-957-5022	St. Paul Island, AK

Southern Southeast Regional Aquaculture Association		Ketchikan, AK
Togiak National Wildlife Refuge	907-842-1063	Dillingham, AK
University of Alaska, Fairbanks	907-474-5998	Fairbanks, AK
	907-486-1517	Kodiak, AK
University of Alaska Southeast, Sitka Campus	907-747-7779	Sitka, AK
City and Borough of Yakutat	907-784-3329	Yakutat, AK
West Coast Region Marine Mammal Stranding Network (Washington, Oregon, and California)		
Washington		
NMFS West Coast Regional Office	206-526-6733	Seattle, WA
Whatcom Marine Mammal Stranding Network	360-966-8845	Bellingham, WA
San Juan Island Marine Mammal Stranding Network	800-562-8832	San Juan Islands, WA
Central Puget Sound Marine Mammal Stranding Network	866-ORCANET	Whidbey Island, WA
Seattle Marine Mammal Stranding Network	206-695-2277	Seattle, WA
Edmonds Seal Sitters	425-327-3336	West Seattle, WA
Seal Sitters Marine Mammal Stranding Network	206-905-7325	West Seattle, WA
MaST Center Stranding Team	206-724-2687	Des Moines, WA
Vashon Hydrophone Project	206-463-9041	Vashon-Maury Island, WA
Cascadia Research Collective	360-791-9555	Olympia, WA
Port Townsend Marine Science Center	360-385-5582	Port Townsend, WA
Dungeness National Wildlife Refuge	360-457-8451	Sequim, WA
Makah Tribe	360-640-0569	Neah Bay, WA
Olympic National Park	360-565-3115	Port Angeles, WA
Olympic Coast National Marine Sanctuary	360-457-6622	Port Angeles, WA
Washington Department of Fish and Wildlife	360-902-2515	Lakewood, WA
Oregon		
Cascadia Research Collective	360-791-9555	Olympia, WA
Portland State University / Seaside Aquarium	503-738-6211	Portland, OR
Oregon State University	541-270-6830	Newport, OR
California		
NMFS Regional Office	562-980-3230	Long Beach, CA
NMFS Fisheries Science Center	858-546-7162	La Jolla, CA
California Academy of Sciences	415-379-5381	San Francisco, CA
California Wildlife Center	818-222-2658	Calabasas, CA
Channel Islands Cetacean Research Unit (starting 6/1/14)	805-896-0858	Santa Barbara, CA
Channel Islands Marine Wildlife Institute	805-567-1506	Gaviota, CA
Humboldt State University	707-826-3650	Arcata, CA
Long Marine Laboratory, UCSC	831-212-1272	Santa Cruz, CA
Los Angeles County Museum of Natural History	323-585-5105	Los Angeles, CA
Marine Animal Rescue (response only)	800-399-4253	El Segundo, CA
Marine Mammal Care Center at Fort MacArthur (rehab only)	310-548-5677	San Pedro, CA
Moss Landing Marine Laboratories	831-771-4422	Moss Landing, CA
Northcoast Marine Mammal Center	707-951-4722	Cresent City, CA
Pacific Marine Mammal Center	949-494-3050	Laguna Beach, CA
Santa Barbara Marine Mammal Center (response only)	808-687-3255	Santa Barbara, CA
Santa Barbara Museum of Natural History (ending 5/31/14)	805-682-4711	Santa Barbara, CA
Sea World of California	800-541-7325	San Diego, CA
The Marine Mammal Center	415-289-7325	Sausalito, CA
Pacific Islands Region Marine Mammal Stranding Network		
Hawaii		
NMFS Pacific Islands Regional Office	808-944-2269	Honolulu, HI
NMFS Pacific Islands Fisheries Science Center	808-220-7802	Honolulu, HI

Hawaii State Division of Aquatic Resources	808-282-0155	Honolulu, HI
Maui Marine Mammal Response Program	808-292-2372	Kihei, HI
Hawaii Pacific University	808-384-4484	Honolulu, HI
Hawaiian Islands Humpback Whale National Marine Sanctuary	808-879-2818	Kihei, HI
University of Hawaii, Hilo	808-217-6812	Hilo, HI
Guam		
Guam Department of Agriculture	808-944-2269	Hagatana, GU
American Samoa		
American Samoa Department of Marine and Wildlife Resources	808-944-2269	Pago Pago, AS
Northern Mariana Islands		
Northern Mariana College	808-944-2269	Saipan, MP