24 October 2000

# Colony Site Management Techniques

Steve Kress
National Audubon Society, Ithaca, NY

## Habitat creation by dredging

Dredging operations that deepen shipping channels and beach nourishment projects can help to create tern nesting habitat. Habitat areas created from dredge spoils are initially vegetation free and are readily used by terns and other colonial waterbirds (Soots and Parnell 1975; Portnoy 1977). Such habitats are especially important in the mid-Atlantic states. For example, about 80% of all coastal colonial waterbirds nested on dredge spoil islands in North Carolina in 1983 (Parnell et al. 1986).

Most dredging operations are under control of the Army Corps of Engineers which can deposit material in locations that favor tern nesting. Terns may readily colonize islands that are the proper size, shape, substrate, topography and location. These islands can mimic the bare sand, sand and shell, and sparsely vegetated habitats preferred by terns. Human-created dredged sand islands may even offer advantages over natural islands. Usually they are higher in elevation and thus less susceptible to flooding. They usually lack mammalian predators and inaccessibility often limits human disturbance.

However, man-made islands are often built where no island previously existed, thus this new feature in the system will be subject to greater erosion. In contrast, if the natural forces favored deposition of an island in a particular location, then an island would form on its own. For this reason, human-created islands must be renourished (another deposition of dredged sand) periodically to maintain the habitat and size of the site. Parnell and Shields 1997 observed that North Carolina dredge habitats were suitable for tern nesting for about 4-7 years, but this varies between regions. In contrast, East Sand Island in the Columbia River (Oregon) requires annual vegetation management. This is expensive and labor intensive, requiring the use of heavy equipment and good, clean sand where the option of renourishment is possible.

One possible disadvantage of artificially created islands is that dredged-material islands can be viewed as mitigation that might accelerate development or other destructive practices on good, naturally-occurring, stable nesting sites. Waterbird populations that depend solely on a system of artificially created islands are vulnerable if future dredging patterns prevent replacement of eroded or over-vegetated sites.

While islands created from dredged sand can be very good for terns, naturally-occurring islands and barrier beaches remain essential and every effort should be made to protect these sites. The following characteristics for dredge created islands were recommended by Walker Golder, Manager of National Audubon Society's North Carolina Coastal Sanctuaries.

24 October 2000

Characteristics for creating dredge islands favorable for tern nesting:

1. Size and shape:
Islands less than 15 acres are best; the ideal size is about 7-10 acres, although larger islands may also be used, especially points at the ends of islands. Topography less than 10' in elevation is also preferred. Islands that are encircled with a dike are usually not used by terns. In contrast, dredge islands with no dike are almost always immediately colonized by terns. It appears that terns do not like to roost or incubate nests where their view of the water is obscured by a berm. Deposition of dredged material on an undiked site results in an island with one or more domes and gentle slopes to the water. Shape is not as critical, but there is some evidence that kidney-shaped islands may be less subject to erosion than oval or elongate islands.

2. Method of deposition:
The primary method of deposition on undiked sites is "control of effluent" whereby the contractor directs the flow of the sand/water slurry in the desired direction and away from sensitive areas. This can precisely add sand to an existing site without impacting adjoining nesting habitats that may be important to other species such as wading birds. In some cases, large sand bags are used to contain the material. The sand bags are relatively low in elevation--usually <3' tall--resulting in a site that is more similar to an undiked island than a diked island. Cooperation and close communication with the dredging contractor is very important.

3.Material
Particle size is one of the most important factors to consider. Good coarse, clean sand or sand with shell or small stones (sometimes called “beach quality sand”) is essential. Fine sand, silt, clay, mud, etc. are not suitable as water will collect after rains, flooding nests and drowning chicks.

4. Location
Terns prefer islands that are remote and surrounded on all sides by expansive water. This isolated position from the mainland or the nearest barrier island prevents easy access by predators such as raccoons, skunk, coyote, fox and mink. This distance will vary depending on local conditions, currents, etc. Islands close to the mainland are more likely to be visited by avian predators. Islands that are further from the mainland or a public access point, have fewer problems with human disturbances. If the island is easy to access by boat, canoe, kayak, surfboard, or other means, then the people will likely visit and some will bring dogs.

5. Timing
Deposit dredged sand outside of the tern nesting season- allowing for sensitive times for other nesting waterbirds and fisheries. Usually the ideal for creation or renourishment projects is October to March.

6. Cooperation

In the United States, the US Army Corps of Engineers is responsible for most dredging. Other agencies involved include Ports Authorities and Depts. of Transportation, but this varies between states. Successful cooperation between wildlife groups and the Corps of Engineers includes active participation in dredging coordination meetings and providing the Corps with positive praise and public recognition . By showing the Corps exactly how they can help wildlife by placing the sand at specific locations, dredging operations can benefit birds while keeping dredge material away from sites where it is potentially harmful to birds and other wildlife.

Erosion Control

Dredged material can also be used to reduce the effects of erosion at colonies where habitat loss and flooding occur. This method has been proposed to reduce the loss of nesting habitat at Bird Island, MA and Warner Island, NY where severe erosion problems are reducing available habitat for Roseate Terns. Nesting habitat could be improved by deposition of sand from approved dredging operations such as the Cape Cod Canal (USFWS 1998). Placement of rip rap at Falkner Island, CT is helping to reduce erosion and will likely serve as future nesting places for Roseate Terns, just as most Roseate Terns at Great Gull Island use rip rap for nesting (USFWS 1998).

Vegetation Management

Nesting habitat requirements vary greatly among tern species (see Biology-Chapter II), but in general the species included in this plan require low or sparse vegetation (Severinghaus 1982). Patches of vegetation arising from bare rock or sand provide protection from predators and offer shade, but plant succession on beaches and the edges of islands usually lead to inferior habitat such as rank herbaceous growth or shrub communities. The rate of this succession appears to be related to guano splattered on the vegetation that stimulates rapid growth. Most tern species avoid dense vegetation-likely because it obscures visual contact and recognition between chicks and parents, making delivery of fish more difficult. Dense vegetation also prevents chicks from drying out after heavy rain or dew.

When vegetation succession changes degrade nesting habitat, Common Terns, Least Terns, Gull-billed Terns and Black Skimmers may move to new habitat created by sand deposition and erosion from storms. Likewise, Common and Forester's Terns may nest on vegetation that accumulates along the high tide line or on accumulated vegetation in salt marshes. In contrast, Roseate Terns often nest under driftwood. Arctic Terns usually nest on bare rock shelves, but they may also nest on sand beaches where they are vulnerable to extreme tides.

In general, terns are not always able to exploit newly created habitat because of predators and the potential for disturbance. Fortunately, terns usually continue to nest at the same site as long as the quality of the nesting habitat remains acceptable and they are relatively undisturbed by predators. Optimal nesting habitat can remain intact for long periods especially where terns nest on rocky islands with slow-growing, tundra-like vegetation or where erosion regularly reshapes beaches. Arctic Terns are among the most stable and have nested at some Maine Islands such as Machias Seal and Matinicus Rock

for more than 100 years (Palmer 1949). Here they nest on rock outcrops or on tussocks of fine grasses such as red fescue (*Festuca rubra*) that form low-growing mats. In contrast, introduced pasture grasses (e.g. timothy *Pheum pratense* and witch-grass *Agropyron repens*) can replacing the short-grass communities. Introduced pasture grasses were planted widely on coastal New England islands where residents grazed sheep and cattle (Conkling 1999). Where vegetation succession decreases tern habitat, managers can work to create or restore habitat using the following techniques.

Vegetation Removal

Where vegetation is well established, heavy equipment such as bulldozers may be necessary to remove dense growth. Such equipment was used at Great Gull Island for clearing vegetation (H. Hayes pers. comm.), but this approach is impractical at most island sites. Lighter equipment such as a disc harrow pulled by a small tractor was used for many years on Tern Island, Massachusetts for thinning vegetation from sandy soils. Each year at Great Gull Island, managers use a tractor-pulled disc harrow to turn over the top 6" of soil and then hand rake weeds from about 3 ha of tern nesting habitat (H. Hayes pers. comm.) This technique may have limited value to situations where tractors can be landed and where there is abundant volunteer help for raking or other intensive manipulations of the vegetation.

Managers can also actively remove vegetation by hand pulling. This is done annually at Bird Island, MA where dead stalks from robust annuals are removed each spring (Blodget and Melvin 1996). Maintenance is necessary at the beginning of each field season because of the nutrient rich soils (fertilized by the birds) and the annual natureof many beach weedy plants and the aggressive potential for root growth by perennials. For these reasons, pre-season habitat improvement projects may not even last through the nesting season.

Terns may initially nest in vegetation-cleared sites, but may not be able to rear chicks as disturbance of soil (associated with hand-pulling) can release an abundant reservoir of dormant seeds, such as ragweed (*Ambrosia artemisiifolia*). The growth of these plants is so rapid (especially in the presence of high nitrogen bird guano) that annual growth can disrupt terns attempting to nest in the newly reclaimed site. On coastal Maine islands, for example, ragweed germinates by late June, after most nests are laid in the cleared areas, but it can grow to 1.5 m high by mid July when terns are approaching fledging age. Annual hand pulling of weeds is extremely labor-intensive and mechanical tilling is impractical where abundant rocks emerge from the soil.

To further discourage vegetation succession, herbicides (Worsham et al.1974) and halite (Kress 1994) were used to retard vegetation succession, but these also require annual application and little is known about the long term effects of repeated applications on wildlife. There are also seasonal limitations to the use of herbicides. Glyphosate ("round-up") is only effective after vegetation is well into its growth cycle and then it takes about two weeks to kill the vegetation. By the time the vegetation has grown enough for application, it is usually too late for terns to colonize the prepared area.

Repeated applications are necessary to treat all of the plants released from dormant seed banks and for seeds blown in from adjacent non-treated areas.

Weed Barriers

Landscape fabrics offer several benefits over hand pulling and chemical treatment of weeds. The fabric can be attached to the ground just prior to the return dates of the terns and while the weeds are still dormant and flattened from winter. The fabric is secured from blowing in the wind with rocks or pins. To provide a more natural substrate for scrapes and nests, wood chips or thatch (collected on the island) can be used to cover the fabric.

The effectiveness of landscape fabric for creating tern habitat was demonstrated at Eastern Egg Rock, a 2.9 ha, treeless island located off mid-coast Maine. Here, two 15x4 m plots were covered by landscape fabric and secured to the soil surface with flat rocks in mid May 1990. Holes were cut into the fabric to allow large rocks and vegetation to protrude and 10 cm of wood chips were placed on each plot. Forty-five pairs of Common Terns nested on the plot just six weeks after placement of the fabric. Although, most of the wood chips decomposed or blew away after a single season, the landscape fabric was still present six years later and 65 pairs of terns were nesting in the plots on nests built from dried plant stems among accumulated thatch (Kress 1997).

Burying Vegetation by Adding a Layer of Sandy Soil

Similar to the effects of beach nourishment, managers can create new habitat by dumping sandy soil over areas of vegetation to encourage nesting by terns and Piping Plovers. On Duxbury Beach, MA, the beach managers dump sandy soil on American beachgrass, *Ammophila breviligulata*) to reduce the density of this vegetation. The goal is to annually create a 1-foot (or more) thick veneer of sandy soil during the non-breeding season over selected areas. These experimental habitat plots have been highly successful in attracting Piping Plovers and Least Terns. Piping Plovers will nest on areas as small as 15 meters in diameter and Least Terns prefer areas greater than 30 meters. Without annual treatment, the new habitat usually remains suitable for at least three years before vegetation becomes too dense for the terns and plovers (S.Hecker pers. comm.).

Prescribed Burns

Fire is a promising tool for improving tern habitat. Fire is widely used for managing upland birds that require meadow habitats. Quail, prairie chickens, pheasant and woodcock habitats are often improved by controlled burns (Cushwa and Martin 1969).

Controlled burns also have promising potential for managing seabird nesting habitat, but seasonal constraints often restrict the usefulness of the technique. Early spring burns must occur after the snow has melted, following at least three days of 10 degree C. temperature with light winds (Brown and Davis 1973). But the burns also have to occur before commencement of the seabird nesting season. Where terns share islands with puffins and eiders, spring burns may not be suitable, since these species begin nesting during the first week of April when snow and frozen soil may remain. Even with

ideal thawing and temperature, spring burns will likely not clear most of the accumulated plant stems, which form a dense, wet mat during at this season.

Fall burns may also be constrained by the presence of seabirds. This is especially true in areas where Leach's Storm-Petrel nest as these burrowing birds often tend their chicks until late October. On islands where storm-petrels are not nesting, a controlled burn (with proper drying and ambient temperature)following the first few heavy frosts in early Novembers offers the best opportunity for removing accumulated thatch. Wind erosion would further enhance the habitat for terns by blowing off ash and exposed peat. Prescribed burns have great potential for improving or creating tern habitat, but the precise conditions and timing necessary for conducting an effective burn remain unknown. Likewise, the effects on rare island vegetation are also little known as fire is not a common natural occurrence on coastal islands.

There are few examples of the use of fire to improve tern habitat. Although burn conditions were satisfactory, a prescribed burn at Eastern Egg Rock in mid March 1993 had little effect on vegetation composition and height between burned and control plots and there was no apparent new use of burned areas. This "cool" burn in late march removed only standing dead plant stems and was ineffective at removing wet, accumulated thatch or living raspberry and elderberry. In this case, there was no apparent difference in burned vs. control areas and terns did not colonize the burned section of the island. Fire was also used at Petit Manan Island (near Milbridge, Maine) to improve tern habitat. In mid March, 2000 a controlled fire burned much of the accumulated plant stems from a section of the island. Arctic Terns colonized the area, but were displaced by Laughing Gulls which used the same area for loafing (L.Welch pers. comm.).

Mammal Grazing (mice, sheep and goats)

Meadow voles (*Microtus pennsylvanicus*) were introduced in 1981 to Great Gull Island, NY where an endemic species (*Microtus nesophilus*) previously occurred (Hays 1984). Nearly 20 years after the introduction, 10,000 pairs of Common Terns nest on the island. Meadow sections of the island originally covered with grass and cleared by the voles are now covered with a variety of weeds which are disc-harrowed and raked each spring (Hays pers. comm.).

Cattle, sheep and goats have been used for nearly 400 years to directly or indirectly control vegetation on Maine islands. In the 1830's Maine was one of the largest sheep grazing states in the Northeast (Fallon 1991) and their widespread use had a broad impact on many tern nesting islands. While grazing animals kept vegetation cropped close to the ground, there are long-lasting effects from the grazing era. Pasture grasses such as Common Timothy *(Phleum pratense)* and witch-grass (*Agropyron repens*) were sometimes planted near residences and many weed seeds were likely introduced to islands during this period. These pasture grasses now dominate vegetation on many former grazing islands. Without grazing pressure, the grasses and associated weeds preclude terns from nesting over much of what was once suitable habitat.

Grazing by sheep and goats has potential for reducing vegetation height and exposing rock outcrops. In Iceland and Scotland, Arctic Terns often share habitat with sheep, maintaining low-cropped habitats (Furness 1989). However, sheep are known to occasionally predate tern chicks by eating legs and wings, presumably to supplement calcium deficient diets (Furness 1988). In addition, little is known about the effects of trampling and disturbance.

To study the effects of sheep and goats on introduced pasture grass communities before and after the tern nesting season, Williamson and Schubel (1995) placed three adult 'Cheviot' breed sheep in an electric fenced enclosure and two Cashmere fully grown weathers in a similar enclosure on Seal Island NWR (Maine) for 8 weeks of fall grazing in September and October and 8 weeks of summer grazing from mid June to mid August. The study compared the effects of sheep grazing on height and composition of introduced pasture grasses to grazing effects by goats. Both sheep and goats reduced the pasture grasses to close-cropped habitat. Sheep spent more time grazing than goats and were more effective at reducing the percent vegetation cover. Habitats grazed by sheep exposed bare rock and soil by 20%, while goats only increased vegetation cover by 4%. The benefits of grazing in this study were short-lived. Grazing in the fall had no obvious effect on vegetation during the following spring and both spring and fall grazing had no lasting effect on vegetation in the year following grazing.

Continued grazing over many years through the growing season promotes a change from taller pastures to communities composed of lower-growing plants. However, this approach places grazing animals on tern habitat during the nesting season, exposing nests to trampling, chick predation and disturbance. The direct threat to trampling would likely be reduced by aggressive nature of parent terns, but frequent disruptions could make terns more vulnerable to opportunistic predators such as gulls who might take tern eggs as parent terns attempt to drive off grazing animals. The usefulness of large grazing animals for tern management remains in question. Further research is necessary to explore the long-term effect of grazing on tern nesting habitat during the non-nesting season.

Nest Boxes and Shelters

Roseate Terns will nest on the open sand beach, but prefer to nest under driftwood, in rock crevices or dense vegetation. At Great Gull Island, NY Roseate Terns nest in a 12' long earthen terrace within a series of individual shelters separated by wooden partitions set at 6-8" intervals (Hays pers. comm.).

At Falkner Island, CT, Spendelow (1988) propped up rock slabs, driftwood and boards and set out half-buried automobile tires. He compared nesting success in modified sites vs natural sites and found that 80 % of pairs nesting in modified sites produced at least one chick, compared to 64% in natural sites. Where rock slabs and driftwood are unavailable, artificial nest boxes provide suitable nest sites. A plywood nest box design used successfully at Falkner Island provides a dark crevice and sloping roof (Fig. V-1).

Common, Arctic, Roseate and Least Tern chicks readily use artificial nest shelters which can help to reduce predation, especially where there is little natural vegetation or other shelter (Blodget and Melvin 1996). Several designs have been used, some patterned for economy from 4' x8' sheets of exterior grade plywood. Construction of artificial nest boxes and shelters are excellent projects for volunteers. For example, students from the industrial arts class at Kennebunk High School (Maine), constructed wooden Roseate Tern nest boxes and tern chick shelters that have been used for more than a decade at Stratton Island. These nest boxes played an important role in the restoration of this mixed Common, Roseate, Arctic Tern colony. Chick shelters are simply wooden boxes approximately 10" long, 6" wide and 4" tall, with a long side and bottom open (Fig. V- 2). Use exterior grade plywood and galvanized nails.

Relocation of eggs and chicks

Eggs that are threatened by high tides should not be moved to higher ground. If eggs are lost, parents will likely renest. Likewise, chicks which are found away from their nests, should not be moved since it is often normal for chicks to wander some distance- perhaps led to more secure cover at distant locations by their parents. Chick shelters may help to reduce wandering.

Fencing

To protect beach-nesting Least, Common and Roseate Terns from red fox predation, erect five-foot-high welded wire fencing (2x4" mesh size) with 1-2' of fencing laid flat on the sand on the outside perimeter. A strand of electric wire, powered by a solar panel/12v battery system helps to deter climbing predators such as raccoon and opossum (S. Hecker pers. comm). The costs of this system are considerable, so in Massachusetts it is used only to protect colonies of 200 or more pairs. Electric fencing alone is seldom effective as determined predators usually breach the barrier by digging or braving the shocks. Also, electric wires placed tooclose to the ground may become covered by drifting sand, resulting in short-circuiting the system.

In Maine (where Least Terns are state-threatened) electric fencing powered by photovoltaic cells is used in conjunction with decoys to lure Least Terns to protected areas. This technique alone is especially successful when it is combined with the presence of nest wardens that stay at the site day and night (M. McCullough pers.comm.).

Where terns nest on mainland beaches or on islands frequently visited by people, 'symbolic fencing' can help to reduce accidental human disturbance (Blodget and Melvin 1996). Simple post and string fencing can serve to keep the public from approaching too close to tern nesting areas. This reduces risk from accidental destruction of nests and eggs and disturbance of incubating adults and chicks. Fenced areas therefore serve as refuges where parent terns can safely rear chicks on otherwise crowded beaches. Such refuges are especially important for Least Terns which typically nest on open sand beaches where they are at risk to bathers and off-road vehicles (ORV's). Determining posting distances to Least Tern colonies is important so as not to exclude human use from excessive amounts of beach. Birders, swimmers, hikers and fishers which are using the

beach (but not disturbing the terns) may actually deter diurnal visits from wary red fox, thus incidentally increasing tern productivity (S.Hecker pers. comm.).

To create symbolic fencing, stretch strong twine or nylon twist line between posts set at 75-100' intervals with colorful surveyor flagging (or signs) at 15' intervals. Avoid using wire or monofilament line as these are difficult for birds and people to see. Pound or bury 5- 6' wooden posts into sand; for cobble beaches, use ¾" rebar or create posts from pvc conduit or wooden posts set into plastic buckets filled with cement. Attach the line to posts about 4' above the ground. The line should be taught between sturdy erect posts to give the message that the fence is well tended and serves an important purpose. Place warning signs at conspicuous locations at 50' intervals. The signs should reference enforceable laws, have a minimum of words and ideally display an illustration of nesting terns that features the vulnerable chicks and eggs. In addition to warning signs on the beaches, also place more detailed educational signs at key locations such as beach entrances, visitor centers, bath houses, etc. These can help to inform visitors about closed beaches before they encounter the warning signs surrounding beach colonies. All posts and signs should have nails tapped into the top edge to prevent or reduce perching by avian predators. For posts greater than a 3-inch diameter, use more than one nail/post or sign.

Create a buffer zone of at least 50 yards from the nearest tern nests and expand the zone further if this is inadequate to prevent terns from flushing. When appropriate, also use fencing to protect staging areas where birds congregate prior to migration and 'nursery areas' where recent fledglings congregate while awaiting meals.

When installing fencing on a beach colony where vehicles pass, be certain to leave an adequate corridor for the vehicles to pass between the fencing and the water. This should be monitored frequently to make certain that the fencing remains in tact. Beaches should be closed to vehicle traffic if there is not room for an adequate corridor. Place tern fencing soon after the first eggs are laid (usually mid-May) and it should be removed after chicks are flying (usually by end of July). These dates will vary depending on latitude as terns nest earlier in the southern part of the region. Where terns use the same location year after year, welded wire fencing may be left in place over the winter, but where colonies shift, fencing of any type should be removed after the nesting season and stored at a secure location off the beach to prevent vandalism and loss.

Dog-walkers and other beach disturbances

Most towns have local ordinances that prohibits dogs from beaches or requires that they stay on a leash. Some dog owners, unaware of the disturbance that their dog can create, ignore these rules and let their dogs run free at beaches. Tern wardens should work to reduce this disturbance by approaching dog owners, explaining that the beach nesting birds have few places to raise their young and that unleashed dogs can kill chicks and eat eggs. Many dog owners will understand, but some will ignore approaches from wardens or become argumentative. Be persistent without becoming confrontational. The presence of beach wardens may prove ample for encouraging some dog-walkers to find an alternative location for exercising their pets. If possible, wear an "official" uniform

with a shoulder patch or hat that suggests authority- and be prepared to offer information about biology and conservation of terns, plovers and other shorebirds. Also be prepared to field questions from the public about bathroom locations, fishing hotspots, and opportunities to join volunteer coastal bird protection groups!

The Presence of Nesting Area Staff and Volunteers May Reduce Predation

The Massachusetts Audubon Society's Coastal Waterbird Program strives to establish a daily, dawn to dusk presence of staff or volunteer wardens at priority nesting areas. At sites where either there are Coastal Waterbird Wardens present at the nesting site or high levels pedestrian activity just outside the disturbance buffer zone, predation appears to be significantly lower. Data particularly supports this idea concerning Piping Plovers (S. Hecker, pers. comm.).

## PREDATOR MANAGEMENT

With the exception of Least Terns which usually nest on mainland beaches, most terns in this region prefer to nest on remote islands where there are few predators. When these are unavailable, they often select compromised locations on mainland points, marshes and islands close to the mainland where risk from predators greatly increases.

Although local conditions can greatly influence nesting site choice, terns usually prefer islands that are at least two miles from the mainland. Remote islands are safest from predators, but foraging habitat located more than a few miles from estuaries usually has less food- resulting in lower clutch size and productivity. For Common and Roseate Terns, the ideal balance between predator risk and access to ample food occurs somewhere between two and eight miles from the mainland. Arctic Terns prefer more offshore sites where usually only Herring and Great Black-backed Gulls are Common predators. Black Skimmers and Gull-billed and Forester's Terns usually nest on islands in or near estuaries, while Least Terns almost always nest on mainland beaches where both the effects of predation and human disturbance are often severe.

In this review of predator control methods, we emphasize that whenever possible, non-lethal controls should be the methods of choice, but we also recognize that it is sometimes necessary to kill individual predators of abundant species where significant benefits at the colony or population level are at stake. There is increasing evidence that timing of control (e.g. harassment early in the nesting season) and use of non-lethal methods (e.g. trapping and translocation of individual predators) can temporarily reduce the impact of predators. Where these efforts fail, lethal controls may prove necessary. Usually, specialist predators account for most predation in tern colonies, so every effort should be made to cull individuals using the most humane methods available.

Removal of predators is especially important where rare species are concentrated, as part of restoration efforts to create new colonies and at larger colonies where predation becomes severe. The methods used for predator removal vary greatly from one species to

the next. The most humane approaches (e.g. fencing, harassment and placement of field camps during establishment periods) should be used whenever possible.

Island nesting terns must contend primarily with avian predators. In our region, Herring and Great Black-backed Gulls are the principle predators and nest site competitors, hence considerable discussion follows on approaches to gull management. Although large gulls also impact mainland-nesting Least Terns, mammals such as red fox and raccoons are the principle concerns. Occasionally, Great-horned Owls, and Black-crowned Night-herons can have devastating effects, but use lethal controls (which require federal and state/provincial permits) only as a last resort.

Gulls

Although accurate population estimates are unavailable, its likely that prior to European colonization of the northeast, Herring and Great Black-backed Gull populations were much lower than today. Small numbers of gulls likely nested compatibly with terns and where pressure from predators became too severe, or habitats became unsuitable, the terns were able to relocate to alternate nesting places. This pattern was disrupted as human coastal populations increased, providing abundant amounts of municipal and fisheries waste readily consumed by coastal Herring and Great Black-backed Gulls. Since most gulls do not migrate out of the northeast region, they can benefit from refuge and fisheries waste associated with large metropolitan areas such as Boston and New York and then migrate back to coastal nesting islands.. Here they further supplement their diet with waste from fisheries and lobstering.

Gulls nest earlier than terns and act as both nest site competitors and predators. Usually, their role as potential predators is likely more important than actual losses from direct predation of eggs, chicks and young. This is a key distinction when considering various alternatives for gull control, as techniques such as oiling and poking eggs which result in protracted incubation will keep gulls on nesting habitat where they deter terns from nesting. The presence of a single nesting gull may prevent terns from using a nesting island, or a significant amount of otherwise suitable nesting habitat.

In small numbers, Laughing Gulls usually nest compatibly with terns, but where populations increase, they compete for nesting habitat and some individuals take tern eggs and chicks. They can also steal food from parent terns. Sometimes groups of five or more will pursue a tern with a fish, eventually stealing the prize in mid air. Laughing Gulls in our region prefer to nest in dense vegetation and they readily use bare patches of rock or low vegetation for loafing areas. As Laughing Gull colonies increase, they may displace terns from the center of nesting islands- forcing them to nest closer to the shoreline where they become increasingly vulnerable to predation from Herring and Great Black-backed Gulls.

On large islands (20 hectares or more), there is usually ample space for both gull and tern nesting colonies. In such situations, an island may be divided into two or three of the following zones:

**'no gull zone'** (maximize gull control effort- gulls are not permitted to breed and predatory gulls are shot);
**'no gull breeding zone'** (where embryos are killed, but gulls are permitted to remain on territory- usually adjacent to a 'no gull zone')
**'gull breeding zone'** (where gulls are protected and permitted to nest in a safe zone- farthest from the tern nesting zone).

Efforts to control gull populations at a regional level through use of the labor intense management techniques such as egg-oiling are unlikely to succeed over the long term. Practical considerations of long term funding, training of workers and logistic effort necessary to implement regional gull control are enormous- especially considering the long life spans of most gulls (20 years or more). In contrast, effective local management at key tern nesting islands is possible and effective. However, this approach requires extraordinary institutional commitment to annual management into the foreseeable future.

Over the long term, more effective waste control- especially of municipal and fishing wastes- is the ultimate approach to gull management, but this will likely only be possible when there are ample economic reasons for municipal composting and recycling of organic waste.

Preferred options for gull control should side on non-lethal techniques whenever possible- such as harassment during the nest establishment period. For tern restoration programs, the amount of effort directed at gull control is inevitably highest during the first few years before terns build a strong tradition for nesting at a new site. However, sustained gull control including deterrents, egg/nest destruction and lethal removal of specialist predators should remain integral parts of most tern restoration and management programs.

Resident human presence combined with non-lethal harassment and destruction of nests and eggs

This is the primary technique for displacing relatively small gull colonies of about 300 pairs which occupy islands of 2 ha or less. The technique is also useful for preventing gulls from reclaiming former breeding grounds up to 20 ha where lethal control has previously lowered numbers.

The technique requires a team of resident stewards camping in a conspicuous location adjacent to or in the middle of tern habitat. For new restoration projects at well-established gull colonies, set up the field camp by about the third week of April- before egg-laying begins. After several years, the season may be pushed back to mid May, but more egg-breaking may be necessary. Daily visits by mainland-based stewards to large, well-established colonies (e.g. Bird and Ram Islands in Buzzard's Bay, MA) are sufficient to deter gull nesting, but depending on proximity to the mainland, landing conditions and other logistic constraints, daily visits can become more difficult to reliably maintain than staffing resident camps. Also, control of nocturnal predators such as Great-

Horned Owls and Black-crowned Night-herons is more difficult for mainland-based tern stewards.

The use of resident camps and harassment of gulls early in the nesting season is especially appropriate on small islands without early nesting seabirds such as eiders and alcids. The successful tern restoration at Seavy Island, New Hampshire is a model for the use of this non-lethal approach. The restoration included the following techniques:

- Establishment of a resident camp by April 21.
- Use of active dogs running through colony for about a week.
- Daily use of pistol-launched pyrotechnics ("screamers and bangers") until terns arrive.
- Destroying early gull nests by removing eggs and placing large rocks in nests.
- Daily walk around the island 30 minutes before sunrise and 30 minutes before sunset.

These techniques, combined with the use of tern decoys and sound recordings, led to six pairs of terns recolonizing 1.5 ha Seavy Island during the first nesting season (after more than a 50 year absence from the Isles of Shoals). The Common Tern colony has increased in size each year to 446 pairs in 2000. The number of nesting pairs of gulls declined during this period from 302 pairs in 1997 to just 6 pairs in 2000. Likewise, dogs were no longer deemed necessary to disturb gulls and few pyrotechnic shells were used in 2000 (D. Deluca pers. comm.).

Similar techniques recently helped to increase tern numbers at 19 ha Country Island, Nova Scotia. Managers noticed a decline in the numbers of Common, Arctic and Roseate Terns from 505 pairs in 1996 to 221 pairs in 1997. To reverse this trend, a resident camp was established on the island in late April and managers used hand-held pyrotechnics and nest destruction to lower the gull population from about 110 pairs in 1997 to just 3 pairs in 2000. The terns responded immediately and by 2000 the colony had increased to 957 pairs. In this study, the colony of at least 50 pairs of Common Eiders declined to just 16 pairs as a result of the pyrotechnics and disturbance, but increased to about 80 pairs by summer 2000 after managers avoided using harassment techniques in eider-nesting habitat (A. Boyne pers. comm.). Tern restoration projects using similar non-lethal techniques are also presently underway at Penekese and Muskeget Islands, MA (B. Blodget pers. comm.).

Overhead Barriers

A grid of parallel overhead barrier lines 3-feet apart strung from the top of 4-foot-high welded-wire perimeter fence prevented predation by Great Horned Owls and Black-crowned Night-herons on Least Terns at Cape Cod. Orange, nylon baling twine (1/8-inch thick) was used to reduce stretching and increased visual affect. The terns were able to settle easily through the grid which deterred the owls and night-herons, but predatory Herring and Great Black-backed Gulls learned to fold their wings and drop into the habitat (S. Hecker pers. comm.).

Egg and Nest destruction- Removal of gull eggs and chicks early in the nesting season (in the absence of resident human presence) has little effect on discouraging gull nesting. Gulls are 'indeterminant' layers and as such can readily replace their clutch early in the nesting cycle. For example, at Stratton Island, Maine Herring Gull eggs were removed from 17 nests in early May when most had newly completed nests with clutches varying from 0-2 eggs. The nests were visited on subsequent days and eggs were removed without disturbing the nest bowls. All of the birds continued to lay eggs even though they repeatedly found their nests. In this study, some gulls relayed as many as 10 eggs over a period of 16 days with an average of six eggs for the 17 pairs.

Embryo destruction

Where islands (or mainland spits) are large enough to accommodate both tern and gull nesting habitats, gulls can nest adjacent to tern colonies, but it is best to prevent these gulls from successfully nesting. The rationale for this is that some of the gulls nesting adjacent to a tern colony might raid the tern colony, taking tern eggs and chicks to feed their young. This control may also reduce the growth of a gull colony from young showing philopatric tendency.

An additional benefit of this approach is that when gulls remain on their nests, they deter additional gulls from setting up territories and the presence of gulls discourages terns from attempting to nest away from the 'tern breeding zone' where they are most likely receive the benefits of large colony size and resident tern stewards. Several techniques are used to destroy embryos while leaving the egg in tact:

**Poking**- a nail is attached to a stick and used to poke eggs.

**Oiling**- vegetable oil is painted on the egg shell which interfers with gas transfer through the shell membrane. Vegetable oil is preferable to motor oil (which could effect the parent gull's waterproofing) or formaldehyde (a carcinogen).

**Addling**- vigorously shaking the egg and replacing it in the nest.

**Dummy Eggs**- artificial eggs placed in the nest and eggs destroyed

Lethal Control

Lethal control using avicides should be used only where non-lethal approaches (such as harassment) are inappropriate. For example, human presence and harassment (from dogs, and pyrotechnics) may be inappropriate where sensitive species such as waterfowl, cormorants, alcids, egrets and herons nest in association with gulls. Common Eiders are especially vulnerable to disturbance, since they begin nesting in mid April and are often sitting on full clutches when gulls are settling into nest-building during late April and May.

While lethal control by avicides or shooting may be necessary- especially in the early phases of restoration, the use of avicides alone will likely prove inadequate for restoration of terns to former nesting habitat. For example, at Monomoy Island, the

avicide DRC1339 reduced gull numbers but proved inadequate for displacing all gulls from suitable habitat (USFWS 1996). Likewise, following application of DRC1339 at Eastern Egg Rock, some gulls became suspicious of poisoned bait, even when fish were substituted for avicide-treated bread sandwiches (Kress 1983). When avicides are used in combination with resident field camps, they serve to reduce the gull population, but human presence combined with egg and nest removal is necessary to discourage nesting by remaining pairs (Kress 1997; Koch 2000).

Most tern restoration programs have used lethal control of adults to reduce breeding gull populations and there are many dramatic successes. For example, tern restoration at Jenny Island, Maine relied on the lethal control of 35 Herring and Great Black-backed Gulls using shooting and the avicide DRC 1339 (also known as starlicide). This resulted in the immediate increase of Common Terns from 57 pairs in 1991 to 1,050 pairs in 2000 with as many as 16 pairs of Roseate Terns nesting in recent years. Similar results were achieved at other Maine and Massachusetts colonies (Kress 1983; Kress 1997; Koch 2000). In these successes, lethal control was only one technique among several and would certainly not succeed alone. The presence of resident island stewards, combined with annual destruction of nests and eggs and shooting specialist predators were also fundamental features of these restoration plans.

The avicide DRC1339 is federally registered for killing gulls. It can be applied only by licensed agents of the USDA or USFWS . The chemical is typically mixed with margarine, applied to bread and then placed in gull nests. Laboratory tests have shown that DRC1339 breaks into non-toxic components within 24 hours and that secondary scavengers are safe from poisoning (Schemnitz 1980). The poison causes renal failure, but this may take two or more days to occur, giving the birds sufficient time to fly from nesting islands to adjacent mainland property where they often seek fresh water.

Owls

Great Horned Owls and Short-eared Owls can visit tern colonies at night, feeding on adult terns and chicks. Such visits may lead to nocturnal abandonment of nests which results in longer incubation rates that contribute to weaker chicks at hatching (Morris and Wiggins 1986).

Modified soft-catch leg-hold traps- Owls can usually be trapped on treeless islands using modified leg-hold traps set atop 6' tall poles. Owls often land on such poles because they are the highest location on the island. From this high perch, they search for prey or they may land on the perch after making a kill to consume their prey. Soft catch traps for Great Horned Owls are modified coyote-size leg-hold traps (#3) in which the standard spring is replaced by a less powerful spring from a size #1.5 trap. The jaws are cushioned by a sheet of foam rubber secured to the jaws with duct tape. The trap sits atop the pole with a trigger tension of 300g. This is ample to support the weight of a pair of copulating terns, but sensitive enough for an owl to trigger it on landing. To increase the chances of the owl landing on the pole, attach rolled chicken wire to other tall

structure such as observation blinds to discourage owls from using these as convenient perches.

The trap is secured to a pole with approximately a 3" diameter. The trap is secured by a nylon line or light weight chain securely attached midway up the pole. This attachment position permits the owl to land on the ground when captured. This minimizes the possibility of the bird pulling free from the pole as well as giving the owl a chance to hide in nearby vegetation until it is removed by the trapper. When removing an owl from the trap, be sure to wear heavy leather welding gloves, primate handling gloves or similar weight protection that extend well up the arm. Owls rarely use their beaks for self-defense, but the feet are extremely powerful. These should be restrained as soon as possible and given greatest respect. To calm a captured owl, have someone put a dark bag over the owl's head, band it using lock on USFWS leg bands and place it in a cardboard box only slightly larger than the owl to prevent it from struggling in the box.

In Maine, 10 Great Horned Owls were moved from Pond and Jenny Islands in recent years. All but one were released at least 50 miles away and none of these are known to have returned. In contrast, one owl released at a coastal location just 30 miles from its capture site on Pond Island was retrapped at the island two years later.

Other traps- Raptor biologists use a variety of traps to capture owls for banding and these can be used in conjunction with or instead of the padded leg-hold trap. These could be especially useful in Massachusetts which does not permit the use of leg-hold traps.

1**. Bal chatri**- A hardware cloth box with the dimensions of approximately 6"tall, 6" wide and 12" long covered with heavy guage monofilament nooses tied to the top and sides of the trap. Live bait such as a feral pigeon or white rat attracts attention of the owl. Be sure to secure the trap to the ground with bricks or a cement block.

2. **Baited fowling net**- Hang a heavy gauge black fowling mist net- the size suitable for capturing waterfowl between two securely guyed poles. Use live bait such as a feral pigeon or laboratory rat, secured in a hardware cloth cage constructed from ½" hardware cloth- or use a pre-recorded distress call from a rabbit (available from hunting outlets such as Cabelas). The distress call can be played from a battery- powered boom box or from a special weatherized playback system developed for attracting predators (also available from Cabelas).

Black-crowned Night-heron

Tern managers should watch for missing tern chicks as evidence of a predatory Black-crowned Night-heron. While Great Horned Owls can also take chicks, they usually also give away their presence by killing adults. Likewise, occasionally Great Black-backed Gulls can raid tern nests at night, but night-herons are the most common specialist on newly-hatched chicks. While most night-herons do not eat birds, occasionally an individual will begin frequenting a tern colony and return year after year for newly hatched tern chicks or pipping eggs. Nocturnal observations at two Maine tern

colonies found that Black-crowned Night-herons will enter a tern colony any time from dusk to dawn, but were most frequent from dusk until midnight.

When tern colonies encounter this behavior, adults may start abandoning their nests- leaving them at about 2000 hours, returning at first light which is about 0400. Observations with night-viewing binoculars and heat sensing monitors, show that not all terns leave at night- especially as the eggs approach hatching. At this time, predatory herons may approach incubating or brooding terns, nudge them from their nest and consume chicks or pipping eggs. Its likely that the white plumage of incubating parents reveals the location of chicks. Abandonment at night may therefore offer chicks better camouflage, but this may provide chicks little benefit since young birds call more when they are chilled and this reveals their location to predators. Night-heron induced nocturnal abandonment can also increases tern chick losses due to exposure to cold temperatures and chilling rain. Once an individual night-heron begins specializing on tern chicks, it may return year after year.

Blinking strobe lights, large mesh nets stretched over tern nests (intended to let terns in but keep out herons) and automatic bow-nets triggered by an infra-red trigger were unsuccessful at Stratton Island, Maine to protect Common Terns. Aversive taste conditioning using the emetic carbachol reduced the extent of predation, but the specialist heron continued to kill chicks without eating them and even attempted to rinse chicks in a tide pool (Kress 1994).

After considerable effort, specialist Black-crowned Night-herons were removed by shooting with shotguns and .22c rifles equipped with night-vision scopes at Stratton Island, Maine (Kress 1994); Monomoy NWR (Koch 2000) and Great Gull Island, NY (H. Hayes pers. com.). After removal of a single night-heron from Stratton Island (where Common, Arctic and Roseate Terns failed to raise young for three consecutive years), the colony suddenly responded by an increase in nocturnal nest attendance, high productivity and increasing populations of all three tern species (J.Dodge pers. comm. 1999).

Hawks

Terns usually mob hawks such as buteos, accipiters and ospreys and can usually drive them far from nesting islands. They are less likely to effectively defend against falcons. Peregrines, Merlins, American Kestrels and occasionally Gyrfalcon can show up at any time during the nesting season, but most usually move on after a few days. While present, they can be extremely disruptive. For example, a single American Kestrel killed at least 200 Least Terns in a 10 day period (J.Atwood pers. comm.).

Northern Harriers are also occasional tern predators. Harriers forage over grassy islands during migration in late August and September, but most terns have already migrated by this time. Harriers sometimes nest at Monomoy Island, MA and occasionally wander into the tern colony, taking Common Tern fledglings- but they are usually driven from the colony by the terns without capturing a meal (S.Ware pers.comm.).

To trap hawks, tern managers must obtain federal and state/provincial depredation permits. Trapping is difficult in tern colonies because of the abundance of live prey, but traps (bal-cha-tri and bow traps) set with live pigeons as bait near roosting locations may prove successful.

Corvids

Northern Ravens and Common Crows can sometime affect tern productivity. Remote islands may provide habitat for ravens which may include seabirds in their diet. For example, remains of Black Guillemots, *Cepphus grylle* were found in a raven nest on Seal Island NWR, ME, but terns were absent among remains discarded at the nest. Even though the nest is located within .5 km of the tern colony, the ravens were rarely seen near the colony, preferring to live in more remote parts of the island. Predation at Seal Island may be uncommon in part because the ravens nest so early that they have already fledged their young by the time the terns commence nesting. Also, the proximity of the research camp near the raven nest may encourage the birds to forage elsewhere.

Common Crows are most likely to become a predation problem for tern colonies located on or within a few kilometers of the mainland. A pair of crows nested for several years in the interior of Stratton Island near a multi-species heron colony, but these crows were never seen near the tern colony. In contrast one pair each of crows and ravens nested on Country Island , NS and became chronic egg predators on Common, Arctic and Roseate Terns until nests were removed (A. Boyne, pers. comm.). These differences point to variation in behavior among individual crows and ravens.

Predatory mammals

Mammals are threats primarily to mainland nesting colonies, but mink are the principal exception to this rule. Mink can occasionally swim up to two miles between islands and therefore can reach islands further offshore than any other terrestrial mammal. The best evidence for the presence of mink in a seabird colony is a cache of recently killed prey. The prey are usually bitten on the back of the neck, but evidence of the bite may be difficult to detect. Frequently, however, careful examination show some blood at the base of the skull or accumulated in the down under the contour feathers.

Terns will often hover over mink during the daytime, helping managers to locate mink that are on the prow. Mink are noted for their bold behavior and are often not shy around people. In this way, a mink that avoided a variety of traps was shot at Eastern Egg Rock with a shotgun (S. Schubel pers. comm.). A mink which frequented Jenny Island, Maine in summer 2000 killed 49 adult Common Terns. When the adults began to abandon at night, the mink apparently left the island for about two weeks, but returned and resumed killing chicks.

Mink are usually trapped using lethal traps called "Conibears" baited with fish or attractive scents. While these are humane traps in that they kill the animal immediately, when placed on islands, they can also kill terns which wander into the traps by mistake while walking through runs in dense vegetation. For this reason, "Hav-a-hart " traps preferred for capturing mink, but success depends on careful placement in runs or likely

places (such as under driftwood piles). Tern colonies are difficult places to trap mink because the colony offers such an enormous choice of alternate prey.

Red Fox are the most frequent problem for mainland colonies- especially Least Terns, but oppossum, raccoons and skunks will also raid beach nesting colonies (S. Hecker pers. comm.) Fox are best excluded by fencing (see earlier discussion) and by placing tern wardens near large colonies. Coyote can also visit tern colonies on or within a mile of the mainland where they eat tern chicks and eggs. Coyotes can be lured into shooting range using calls and a decoy dog (Kerr breed) (Koch 2000).

To monitor for nocturnal predators, use night vision goggles (AN/PVS-7B Night Vision Goggles, Generation III, Night Vision Equipment Co., Inc., Emmaus, PA). To shoot coyote (and other nocturnal predators), use a .22 c rifle equipped with a night-vision scope (Aries MK6300s, 2nd Ge., AMT, San Francisco, CA or M963 AN/PVS-7B Gen.III, Night Vision Equipment Co., Inc. Emmaus, PA).

Ants

Ant predation has been reported from several Common and Roseate Tern colonies in the Northeast (Jones 1906, Austin 1929, Spendelow 1982, Safina, et al. 1994, LaBarr unpublished data). Ants are more likely to appear after hatching, although ants were noted in pipped eggs as well as on recently hatched chicks (Safina et al 1994). In some years ant predation accounted for as high as 64% of the hatched nest failures in Common Terns (LaBarr unpublished data) and 33% of Roseate Tern chick mortality (Spendelow 1982). Safina et al (1994) noted heavier ant mortality in Roseate Terns than Common terns at the same site. The authors speculate that the Roseates affinity for vegetation made them more vulnerable than the Common Terns to ant predation at this site. Sibley and Spendelow (1976) noted higher mortality of Common Terns than Roseates at the same site; differences may be due to habitat preferences of different ant species.

In Vermont in 1988, ant predation was responsible for greater than 50% of chick mortality in a small island nesting population of Common Terns. Since 1989, ants have been managed at this site. Initial efforts focused on a sugar based bait placed in circular ant traps adjacent to nest sites. In 1991, the bait system was replaced by a "barrier" system – circular pieces of landscape fabric were placed in the nest cup under the eggs, to prevent ants from emerging directly into the nest. In 1992, the barrier system was supplemented with both sugar based and protein based ant traps. Protein based bait proved extremely effective and more attractive to ants. From 1993 to 2000, the protein bait system was employed in conjunction with the nest barrier system. Between 1988 and 1999, chick mortality due to ants dropped from 64% to 0.0%, in 2000, 3.0% of nest failed due to ants but this was likely due to fewer traps used early in the season.

Drax ant bait gel is available on line at the following location http://www.pest-control-supplies.com/antdrax.htm. Each syringe costs 12.95 and comes with both the sugar and protein based baits, each in a separate tube. Two tubes were enough for a small island using 20 traps for a field season (LaBarr pers. comm).

**Social Attraction**

Terns, like most colonial seabirds, are reluctant to colonize new nesting sites- even when habitat characteristics are suitable. Orians (1966) suggested that birds evaluate suitability of habitat by the presence of conspecifics. The presence of conspecifics at suitable nesting habitat is one of the best ways for colonial birds to quickly assess that a site lacks predators and is near appropriate food. When birds of the same species find themselves together, the social displays (including vocalizations) of a few birds can facilitate similar displays in others of the same or related species. In this way, social displays become contagious among roosting birds- especially when they are stimulated with recorded sound early in the nesting season.

Decoys and recorded sound were first used to encourage Common, Arctic and Roseate Terns to recolonize an historic nesting site by Kress (1983). In this study, Kress placed 48 decoys and a sound system on Eastern Egg Rock in Muscongus Bay in June 1978. Arctic and Common Terns immediately began landing near the decoys, but did not nest until 1980 when the sound system operated non-stop. The first Roseate Terns nested the following year. By 2000, this colony has increased to the largest Common and Roseate Tern colony in Maine with 1,143 and 165 pairs respectively. Since this first project, the technique- known as social attraction- has been used widely in the northeast and elsewhere for starting colonies of Common, Arctic and Roseate Terns and Least Terns.

Typically, three dimensional tern decoys are placed in suitable tern habitat after displacement of Herring and Great Black-backed Gulls. Several commercial decoy sources are available and many decoy carving clubs will readily donate models for restoration projects.

The more decoys the better- new projects usually have at least 100 decoys that are placed near each other in a life-like arrangement. Care should be taken to keep the decoys from rolling onto their sides. Hollow decoys (such as polyethelene) usually have a large hole in the underside to fill the model with sand and then sealed with duck tape; solid wood or plastic models can be held in place by drilling a hole in the belly, then extend a dowel rod into soil or sand.

Tern colony sounds are a critical part of the social attraction technique, as prospecting terns soon depart quiet decoy groupings. Typical sound systems consist of a portable 6V CD player, 50W amplifier, a universal high current DC power adapter and two weatherproof patio speakers- all of which are available from Radio Shack. The universal power adapter steps the 12 v from the battery down to the necessary 6 v to operate the CD player. The speakers are usually placed about six meters apart and secured on posts

so that they are about .5 meters above the ground. Wire the two 12 v deep cycle or 'gel-cell' batteries in parallel (+ to + and - to -). These are recharged by two parallel-wired 60W photovoltaic panels. The batteries are kept from over-charging by a voltage regulator placed between the panels and batteries. The CD player, amplifier, power adapter and voltage regulator should be housed in a waterproof box. Gel cell batteries (the preferred variety for this application) can be housed with the other sound equipment, but deep-cycle batteries (which are shorter-lived and less-expensive) should be housed in separate battery cases. See Fig. V-3 for a wiring schematic.