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Chapter 40

Collecting and shipping live coral: Techniques, tips and headaches

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ABSTRACT
With the advent of modern air travel and an increase in flight connections to remote tropical locations, the transport of live coral across the world is now a commonplace event. However, there are still hurdles to overcome and not every type of coral responds equally to the stress of shipping. This paper will cover some of the most common methods used today to transport live coral fragments, both hard and soft, via boat, truck or air. Topics will include collection and handling concerns, pre-shipment preparation, packing techniques and acclimation. In addition, the importance of proper collecting protocols and acquiring the necessary permits also are discussed.

INTRODUCTION

With the advent of modern airfare, the shipping of live coral around the world, for trips up to 36 hours or more, is now possible. In addition, the explosive growth of courier services has allowed for overnight delivery of live coral within countries, and has resulted in an dramatic increase in online vendors of livestock, including corals. However, there remain still several hurdles and obstacles to successfully shipping corals, some of which are based on biology and some on human factors.

The main purpose of transporting corals is to obtain specimens for exhibition and public education in public aquariums, for research on various aspects of their biology in a controlled setting, to establish the species in an aquaculture facility, for reef restoration work and for the international marine reef aquarium hobby.

SHIPPING MEANS

Air

When one thinks of shipping corals one inevitably thinks of shipping by air. The use of modern jet airplanes has allowed for the collection and shipping of corals from anywhere in the world, to almost anywhere in the world. Typically the corals are packed in a holding facility in such a manner as to withstand several hours of transit time, which varies depending on the distance traveled. In the live coral trade, this rarely exceeds 30 hours since most corals are first shipped to a wholesale facility where they are either removed for resale and distribution within the country, or simply transshipped to their next destination, sometimes with a water change performed. For many public aquaria, corals are obtained from such wholesale facilities, from other public aquaria or from local aquarium hobbyists. However, a select few also conduct their own collection trips.

The use of airlines to carry live corals is of course not without its problems. Most airlines have a priority list by which they determine which items get placed on the flight first and which might get bumped to another flight. Fortunately, live corals, since they are live animals, are usually higher up the list than other items but not always, and missed flights or connections are not unusual. It is for this reason that corals should also be packed with the assumption that they will take longer to arrive at their destination than anticipated. Wide shifts in temperature should also be expected. Air cargo terminals are rarely heated or cooled to any great degree, air cargo compartments in planes tend to be on the cold side even though they are pressurized and the temperature may be regulated, the

time the transport container sits on the tarmac can also hold some peril for corals by either baking them in the hot sun, or by leaving them in the freezing predawn or evening air. A small temperature datalogger is a great investment if corals are regularly shipped on the same routes since it will log the temperature in the container from the moment it is activated to the moment the data is downloaded on the receiving end (e.g. www1). These data can yield some very surprising results as to how much the temperature can vary. Combined with the time, one can easily see when the temperature changes occurred and by how much, and at what point during the trip. When you see how much the temperature can change, it is really amazing that these corals survive at all.
For this reason, proper use of insulating packing materials and the judicious use of heat or cold packs is advised (see Controlling Temperature). Some airlines also have temperature controlled containers that can hold several boxes of live animals but with a rental cost of $ 3000 to $ 5000 US this makes it cost prohibitive for all but the most critical of shipments (Brittsan, pers. com.).

Since most corals come from exotic destinations, direct flights are not possible and one or more connections are required. In these cases, reliable freight forwarding companies are essential for making punctual connections.
When collecting and shipping corals oneself, cargo bookings must be made several days or even weeks in advance. The most reliable method for shipping collected corals is to develop a working relationship with the local collecting station. When this is the case, the staff can often use their shipping connections and cargo space allotments to ship boxes of corals; this makes things MUCH simpler.

Boat, car or truck
When corals are collected by aquarium staff directly, additional categories of shipping may need to be considered, namely boat/truck/car. In this case, the individual corals need to be protected from damage caused by being jostled about. In some cases, corals need to be placed in separate containers for the drive back to shore as they may be excessive mucus producers or potent stingers and leaving them in the same container with other corals may cause problems, especially if the return trip is several hours. The other problem is heat. Keep holding containers out of direct sun and preferably immersed in a larger container of seawater or live bait well that gets a constant turnover of fresh seawater as the boat is moving.

In some cases, the collecting trip may take the entire day and the corals need to be protected during that entire period. The best way to keep corals in good condition during such trips is frequent water changes on the order of once or twice an hour or keep them in a live bait well that gets a constant supply of fresh, cool seawater. When using trucks or cars, hard bodied coolers are best along with the use of cooling packs, if available.

Individual corals may need to be gently packed with plastic strips to help cushion them from impacts. Small specimens collected on pieces of small rock can be floated in containers using Styrofoam peanuts and elastic bands; larger specimens can be affixed to PVC frames that hold them in position on the bottom of the container. The use of temperature-controlled food and beverage coolers is also a possibility provided there is electricity available (see Controlling temperature).

When at sea for extended periods of time, small holding tanks can be set up with running seawater or daily water changes to hold collected corals. A small powerhead or bubbler should also be used to provide additional water motion. It is best if the fragments are mounted on eggcrate trays using plugs or whatever mounting method has been developed institutionally. Mounting the corals in this way prevents them from rolling about in the holding containers. Floating specimens as previously mentioned is also an option (see wet shipping). When floating corals, it should be ensured that the coral colony does not extend out past the float or else it will collide with or rub up against the walls of the container causing damage that can lead to a secondary bacterial infection and tissue loss.

CORAL COLLECTION AND HANDLING

Although most public aquaria obtain their corals from suppliers, hobbyists or other public aquariums, there are several aquaria that are fortunate to be able to collect their own corals.

There are a variety of techniques that can be used to collect corals, depending on the type of coral and its growth form. When collecting coral from a reef, every precaution should be employed to do so ethically and with as little damage to the reef and mother colony as possible.

PERMITS

Before any discussion of coral collecting can take place there must first be consideration given to the legalities of collection. Most countries today have strict laws governing the collection and/or importation of live coral. In addition to the Convention on the International Trade in Endangered Species (CITES), there are national regulations in place in each country or region (e.g. the EU). Another paper in this chapter deals in more detail with the permitting issues so this paper will not delve too deeply into this topic. Suffice it to say, each institution planning a shipment must do their homework as to what permits and regulations are in place in the country where the collection will take place, and the country where the corals will be imported. In some countries, sufficient time must be allotted to obtaining the necessary permits to collect coral and a period of a year or more is not unheard of. One method to alleviate the collection permit issue is to work with a local collecting company if one is available as previously mentioned. Depending on the nature of their collection permit it is sometimes possible to collect under their permit and quota system.

COLLECTION: PLATING AND BRANCHING STONY CORALS

With few exceptions, the vast majority of stony corals do best when collected as fragments; collecting large, whole colonies is rarely successful, as they tend to die off very quickly. However, colonies the size of a closed fist or smaller can sometimes be successfully collected and transported. By far the best technique to use is to search around the base of large stands of branching or plating corals e.g. *Acropora* spp. and *Montipora* spp. There it is easy to find hundreds of ready-made fragments, most of which will have ends that are already free of tissue and can be easily mounted for holding and transport. Using fallen fragments has no impact on the mother colony and most of those fragments would eventually become covered by sand in all likelihood anyway.

Breaking off small pieces from a mother colony is the other option. The method can be to either break off pieces from the edge of the colony or from center. Typically, the outer edge of a colony is the youngest and fastest growing region and fragments from here will exhibit the same traits. Since they are the youngest, chances are their polyps are not yet sexually mature so you are not removing any potential spawning portions of the colony. A small pair of needle nose pliers or wire cutters can be used to remove a fragment and it can then be placed in a small plastic bag. The bag can then be placed into a small hard-walled container with a lid such as a Tupperware™ container. In this manner several fragments from different species can be placed into one container without risk of damage. The container(s) is then placed in a mesh bag that can be carried with the diver for the remainder of the dive.

COLLECTION: MASSIVE STONY CORALS

Several species of coral are classified as “massive” species in that they do not form branching colonies. This means that for the most part, the entire colony is collected. For this reason, only small colonies that can be easily removed and transported should be collected. For larger colonies, taking cores (plugs) is an option and is used by coral reef scientists. These cores can survive and grow, however, compromising the mother colony in this manner may have long term consequences as it exposes the interior of the coral to colonization by boring organisms such as worms, shrimp and sponges, that over the long term, may compromise the integrity of the colony; to the knowledge of the author this possibility has not been explored.

Using a hammer and chisel, or a geological hammer, it is a simple matter to knock off small massive colonies from their rock attachment. Dirk Petersen of the Rotterdam Zoo commented on this collection method while collecting Caribbean corals in Curacao, Netherlands Antilles as follows: “It works very well for *Diploria* – in almost all cases,

colonies break off the substrate at their base without damaging any live tissue. *Montastraea annularis* is a bit more difficult and you have to take quite a large portion of dead skeleton with the colony in order to avoid damaging the tissue. *Acropora palmata*, and I suspect any other coral with a very dense skeleton, always bears the risk of breaking the colony where you don't want it (i.e. through the live tissue). However, if you take whole colonies and put the chisel between the coral skeleton and reef substrate, in almost all cases, you will not damage the colony. Depending on the surrounding substratum, maybe a stone-saw could be used to determine as precisely as possible how the coral should be detached from the reef substratum. A hammer and chisel worked fine for us for all encrusting and massive species such as *Favia fragum*, *Agaricia humilis*, *Diploria strigosa*, *Montastraea annularis*, and *Acropora palmata*." (Petersen, pers. com.).

When transporting massive corals underwater, it best to avoid excess banging or tumbling of the corals. The use of plastic strips to wrap the coral and plastic bags to hold the coral work well. Care should be taken to cushion the pieces inside the transport chamber, so that adjacent pieces do not impact each other. Again the use of rigid containers works well for transporting several corals while on a dive and even during the boat trip back to shore.

Free-living corals such as *Fungia*, *Heliofungia*, *Herpolitha* and *Polyphyllia*, are especially easy to collect since they only need to be picked up, wrapped in a plastic bag and placed in the collecting container.

COLLECTION: SOFT CORALS, GORGONIANS AND ZOANTHIDS

Soft corals can be collected in a number of ways depending on the size of the colony and the type of soft coral. Simply taking cuttings from the upper part of the colony using a razor or scalpel can be used on leathery corals such as *Sarcophyton* and *Lobophytum*. This method is best used when the colonies are too large to transport easily. For smaller colonies, chiseling off a section of the substratum the coral is attached to works best. The author has even collected several soft corals by gently tugging at the base; if the substratum is not very consolidated it breaks apart easily and the result is a small colony of soft coral attached to a piece of rubble.

For encrusting genera such as *Protopalythoa*, *Zoanthus*, *Briareum*, *Xenia* and *Clavularia*, the substratum they are attached to often consists of loose coral rubble or dead coral branches. Efforts should be made to look for dead coral branches or loose pieces of rock when collecting soft corals, since these can be easily removed with the soft coral left completely intact. The tearing of soft corals from their attachment points should be avoided, since this torn tissue will release spicules and most likely toxic substances into the water that can affect other corals in the transport container. Torn surfaces are also more prone to bacterial infection. For this reason it is also best not to transport soft and hard corals together in the same container.

Chiseling off gorgonians at their attachment point along with a piece of the substratum is the best method for collecting most of the photosynthetic and non-photosynthetic species. For the photosynthetic species gorgonians can also be pulled off of the substratum by hand, when done properly this is very quick and does little damage to the coral. The gorgonian should be grasped at the base of the stem where it meets the substratum and then in one quick snapping motion, jerked backwards at an angle parallel to the substratum. If an attempt is made to pull straight upwards, it is akin to trying to pull a suction cup off of a flat surface. It can't be done and the collectors hand will end up sliding upwards along the full length of the gorgonian striping off the tissue from the underlying skeleton in the process.

SHIPPING CORALS

Along with the increase in demand for live coral, has come an increase in our knowledge for shipping them. Today corals are shipped between aquariums on a regular basis and new and innovative ways are constantly being developed to ensure increased shipping survival rates. The procedures described in this section are based on the experience of the author and that of others in the public aquarium field, as well as those in the coral aquaculture field and of reef aquarium hobbyists. It is by no means the definitive word on the subject and should be treated more as an opening discussion of the methods practiced.

The process of shipping corals involves a series of steps: specimen preparation prior to shipping, packing, transport, and unpacking and acclimation upon arrival.

SPECIMEN PREPARATION

Prior to shipping, corals are often "conditioned" for their journey. The primary process of "conditioning" involves stressing the coral so that it will begin to release mucus before it is packed, this reduces the risk of a bacterial bloom in the shipping bag, and a corresponding drop in pH and oxygen levels due to bacterial respiration. The amount of "conditioning" required depends on the type of coral and the anticipated shipping time; the longer the transit time the more important this process is.

Some corals produce copious amounts of mucus while others produce very little. Even within a genus there can be significant differences in mucus production between species. For example within the genus *Acropora*, there are some species that produce small amounts of mucus (e.g. *Acropora micropthalma*) while others seem to have a never-ending supply (*Acropora acuminata* and the infamous North American hobby species commonly called the 'Bali green slimer' for obvious reasons).

There are various ways that corals can be stressed. When the Waikiki Aquarium ships stony corals, these are usually fragments that are clipped and then placed in a separate container prior to packing. Clipping stresses the coral and it begins to release mucus. The fragments are then removed from the tank and rinsed by moving them rapidly within a bucket of clean seawater until the amount of mucus released is visibly reduced. Soft corals also vary in the amount of mucus produced e.g. *Clavularia* sp. produce very little mucus and do not need to be rinsed prior to packing (Fellenius, pers. com.; Delbeek, pers. observation) while *Xenia* species are prodigious mucus producers (Delbeek, pers. observation; Calfo, 2001). For *Xenia*, the colonies should first be attached to a piece of Styrofoam using rubber bands over the base rock, and then floated in seawater for at least 20 minutes prior to packing. The colonies should also be agitated several times while they are floating, to rid them of excess mucus, or placed in an area of good water flow.

At Reef Solutions Vanuatu, a coral farm in Port Villa, Vanuatu, corals are stressed by first exposing them to air. For stony corals such as *Acropora* sp. the corals are exposed to air for 5 minutes, out of direct sunlight, and then rinsed under running seawater for 15 seconds before being placed in holding tanks to await packing. This usually occurs within 30-45 minutes; ideally the time should be as short as possible. For soft corals that produce copious amounts of mucous, the same process is followed but repeated at least twice before being packed (Fellenius, pers. com.).

For corals with large, fleshy polyps (e.g. *Euphyllia, Lobophyllia, Goniopora*), care must be taken when stressing them. Corals with large, fleshy polyps should first be agitated so that they retract their polyps as much as possible before they are removed from the water. Otherwise exposing them to air can result in the tissue being stretched against the skeleton increasing the risk of tearing the tissue, secondary infection and ultimately tissue necrosis.

PACKING CORALS

There are several methods that can be applied to packing and shipping corals. The methods and techniques vary depending on the type of coral (soft vs. hard), size of coral (branches vs. whole colonies), growth form (massive vs. branching vs. encrusting vs. plate-forming), and length of transit time. Due to this variability, it is not possible to describe each in this short paper. The reader is encouraged to consult Borneman (2001), Bronikowski (1982, 1993a, 1993b), Calfo (2001), Carlson (1987; 1999), Delbeek and Sprung (1994), Petersen *et al*. (2004), and Sprung and Delbeek (1997) for further information.

Packing methods can be categorized into two main categories; wet shipping and dry shipping. The primary difference between the two is the amount of water placed in the shipping bag. In wet shipping, corals are shipped completely submerged in water, with some space left at the top of the bag for oxygen. When shipping corals "dry", the corals are exposed to the air within the shipping bag but are kept moist through the use of moist wrapping materials and a small amount of water at the bottom of the shipping bag. A variety of corals can be shipped

using the dry method, the main advantage of which is the significant shipping cost savings due to decreased weight. However, some airlines charge by space and not weight for large shipments, and some special air cargo services (e.g. Delta Dash service) charge a flat rate regardless of weight, so it is always best to first check how the shipping costs will be arrived at when deciding which packing method is to be used.

Wet packing

When packing corals for shipping submerged in water, there are several methods that can be used. Generally speaking, the shipping bags are first filled with clean, new seawater that has not held corals previously (if possible) to about the halfway mark of the bag. The rest of the space is filled with oxygen. When packing corals for more than 20 hours transit time, it is best to increase the amount of water to 70 % of capacity and decrease the amount of oxygen to decrease the chances of oxygen "toxicity" (Fellenius, pers. com.).

One of the exceptions to this procedure occurs with gorgonians. Some species of gorgonian do not tolerate exposure to air for any length of time and should be shipped totally submerged with no air space. These tend to be species with thin tissues that do not have a very flexible skeleton e.g. *Calcigorgia, Muriceopsis* and *Pseupopterogorgia* to name just a few. Other species with thicker tissue e.g. *Plexaurella*, *Briareum*, *Erythropodium*, *Diodogorgia*, and *Pterogorgia* can withstand exposure to air and can even be packed using the dry method (see below) (Sprung, pers. com.).

How corals are supported in the shipping bag is another area where a variety of methods have been used. The Waikiki Aquarium has shipped over 5000 fragments of branching stony coral in the genera *Acropora*, *Seriatopora*, *Anacropora*, *Seriatopora* and *Hydnophora*, as well as plating species such as *Montipora* and *Echinophyllia*. For the majority of these each fragment has been wrapped using plastic strips, 2.5 cm wide and 25 cm long cut from shipping bags. The plastic strips are first soaked in clean seawater before being used to wrap the coral. The wrapped fragment is then placed into the shipping bag, which also contains a few plastic strips for cushioning. The bags are filled 30-50% with water depending on the size of the fragment and the distance being shipped, oxygen is then injected till the bag is almost full and then tied off using rubber bands. The bag is then placed inside of a second bag lined with newspaper and this is then tied off a second time with rubber bands. This method can also be used for stony corals with large fleshy polyps (LPS) such as *Favia*, *Favites*, *Lobophyllia*, *Trachyphyllia*, etc. These corals must first be agitated to encourage the polyps to withdraw completely before wrapping them with plastic strips.

Many of the corals shipped from coral farms and public aquariums, are mounted onto bases and massive coral species with large polyps (e.g. *Euphyllia*) and many soft corals (e.g. *Xenia*) ship much better when they are placed in the shipping bag so that they cannot touch the bottom or sides of the bag during transit. By using floats made of Styrofoam the plugs or bases of the corals can be fastened to them using rubber bands so that the coral floats upside down. One must ensure that the float is large enough to prevent it from moving around too much in the bag and that the coral branches do not extend beyond the float edges or they will rub against the side of the bag. This method, sometimes referred to as inverted submersion (Calfo, 2001), works for just about any coral including large LPS corals, small polyped stony (SPS) corals, and soft corals provided they can be attached without damaging any tissue. For highly branching species like table *Acropora*, the inverted submersion method is preferred over dry packing (Fellenius, pers. com.).

Rings of PVC pipe large enough to hold the coral can also be used. The coral is fastened within it using rubber bands so that the coral sits firmly in the center of the ring and cannot touch the sides.

For large massive colonies such as *Montastrea*, *Porites* and *Diploria*, Petersen *et al.* (2003) described a technique involving the use of Portland cement to attach attachment points underneath the skeleton. These attachment points are then used in conjunction with plastic cable ties to fasten the corals to a support frame of PVC pipe fittings and polypropylene tubing. After curing in the ocean, the coral and frame are then placed on the bottom of a large plastic bag so that the coral is completely submerged; oxygen is then added to fill the bag. Using this technique Petersen *et al*. (2003) reported 100 % survivability after a

total transit time of 37 hours.

Important note: Whenever using any type of cement on corals to be shipped, it is critical to do so several days before the actual shipment. As cement cures underwater, it raises pH. Therefore, shipping corals that contain uncured cement bases will raise the pH of the shipping water too high and will kill the coral, therefore it should be ensured that the cement is totally cured before packing.

Important note: When filling bags with compressed gas, they should never be filled completely. During air flight, air pressure drops, and a bag that has been completely filled with oxygen will expand to the point where it may burst a seam or cause the staples or rubber bands sealing the bag to tear the bag or give way; they should only be filled with enough oxygen to give the bag shape.

Dry shipping

To the best of the authors knowledge, the first publication of the methodology for dry shipping corals was by Bronikowski (1982), later developed and popularized by Dr. Bruce Carlson (Carlson, 1987) and detailed with photos by Delbeek and Sprung (1994). This form of dry shipping used a rigid plastic container of about 1.5 L capacity commonly known as Tupperware™ containers. Small fragments of branching coral (primarily *Acropora* sp.) are then wrapped in plastics strips as mentioned previously, and placed into the container. The plastic strips should be soaked in clean seawater before use. Layers of fragments are alternated with layers of plastic strips until the container is full. The container is then filled and drained with seawater several times and then left with only a small amount of water in the container. A small amount of oxygen is then injected and the container lid sealed on with tape. Using this method, transportation times of 24 hours or more could be attained with little to no mortality. The limitation of this technique is that only small sections can be packed, and highly branching species fare much more poorly than single branches.

Soft corals such as *Xenia* sp., *Sarcophyton* sp. and *Lobophytum* sp., *Clavularia* sp., *Briareum* sp. and *Sinularia* sp. can also be shipped using this technique but proper specimen preparation as outlined previously is critical. *Xenia* in particular requires careful handling due to the amount of mucus it can produce; it should be protected against temperature fluctuations and be rinsed well upon arrival. Dry shipping of *Xenia* should be limited to trips of less than twelve hours (Calfo, 2001).

Another method of dry shipping varies only in the material used for wrapping. In this case strips of “bubble wrap” are used to wrap the coral fragments. Karl Fellenius of Reef Solutions Vanuatu related the following procedure:

1) Cut 30 cm strips of bubble wrap that are 4 bubbles wide and then soak in seawater before using;

2) Place one strip as a cushion for the coral base at the bottom of a small bag. For larger bags stuff two strips on the bottom;

3) Select the pieces by checking how ‘compact’ they are. *Acropora gemmifera* and *A. digitifera* dry pack well. Avoid thin branching species such as *A. echinata*, and *A. nana*, also avoid dry-packing tabulate species e.g. *A. selago*;

4) After soaking strips of bubble wrap in seawater gently, and loosely, wrap around the coral branches with the bubbles facing inwards. Make sure no coral is exposed, not even the encrusting coral on the rock base (which is always present, if aquacultured). One layer is technically enough, although a bit more in spots is preferred to make up for movement. Any exposed coral will get burned by the oxygen, so take care;

5) Usually two or three strips wrapped in addition to one underneath the base is required for a small fragment. Place this wrapped fragment on the bottom of the bag with the base sitting on the bottom of the bag. It should be reasonably snug by this point. To make it ‘snugger’ stuff two or three more strips in the sides;

6) Fill with seawater about 10 cm while holding the coral in place from the outside of the bag. Drain and repeat three times. This ensures that the bag is thoroughly soaked on the inside. After the third time, do not drain all the pack water. Retain just enough so that the rock base is covered with water, and

1) possibly 5 mm or so of the encrusting coral base and beginning of the stem;
2) Fill with oxygen and close without delay to ensure that maximum moisture stays inside and;

3) Pack so that each dry pack bag touches at least 2 wet pack bags.

Zoanthids can also be easily shipped wrapped in moist cloth or unbleached paper towels and packed with a small amount of oxygen. When using the dry shipping method, it is sometimes best to use a mixture of oxygen and air to avoid "burning" exposed tissue with pure oxygen.

Stéphan Henard of Nausicaä, Boulogne, France related three methods they have used to ship corals "dry" (Henard, pers. com.). In the first method, corals are simply laid on a piece of moistened padding material on the bottom of Styrofoam container and then covered with a second piece of moistened padding and then the box is sealed. This is an easy method but can only be used for transports of less than 5 hours and works well for both plating and branching stony corals. In the second method, coral fragments are placed either within a small plastic jar or bag, moistened and sealed, and then insulated and placed into a shipping container. The corals can travel for up to 12 hours using this method. In the third method, coral cuttings are placed on the bottom of a Styrofoam box, and the water added to a depth of about 5 mm and then covered with a plastic sheet before closing the box. Corals can also travel up to 12 hours using this method (Henard, pers. com.).

PROS AND CONS

When rating shipping techniques, the most common gauge of success is survivability. More often than not this is interpreted as survivability upon arrival; especially when talking about fish shipments. However, with both corals and fish, long-term survival is as, if not more, important and should be closely monitored. Loss of tissue and necrosis of sections of coral several weeks later can provide clues as to which part of the collection and handling process may have affected the coral e.g. if necrotic tissue develops along the edges of a colony, chances are it was rubbing against the side of the shipping container.

Wet shipping gives excellent results when used properly but does cost more than dry shipping due to the extra weight. Unless properly wrapped and moistened, dry shipped corals can undergo desiccation and death. For shipping large, tightly branching species, wet shipping is the best option; dry shipping just doesn't work as well.

CONTROLLING TEMPERATURE

Wet shipping tends to buffer water temperature variations; dry shipping is very susceptible to changes in ambient temperature. There are several methods that can be used to help alleviate temperature swings. As mentioned previously, the use of temperature sensors in the shipping box provides for an exact record of the temperature changes that a shipment undergoes. If it is suspected that high temperatures may be a problem (e.g. shipping during summer months, long layover times in hot climates or in direct sun) the use of gel cooling packs becomes essential. Frozen bags of freshwater can also be used but run the risk of leaks and take up more space.

When shipping corals where cold temperatures may be a problem (e.g. shipping in cold months, cold air cargo holds) the use of heat packs is recommended. Whether using cold or heat packs it is best to attach these to the lid of the shipping container so that they do not touch any of the shipping bags. Wrapping the packs in a thin layer of newspaper also helps "take the edge off".

Another method is to mix wet packed and dry packed corals in the same box. By placing surrounding dry packed corals with wet packed ones, the insulating effect of the water filled bags can be utilized (Fellenius, pers. com.).
When shipping smaller quantities of corals, hard walled portable coolers work well and offer excellent insulation value, but add weight. However, if the corals are of high value and small quantity the trade-off is acceptable. Coolers offer the best protect from damage as well. There are also portable coolers available with built in heating/cooling mechanisms based on the Peltier effect (e.g. www2). Often used for warming or cooling foods, these containers would work well for corals as well. The drawback is that they need a power source to operate (A/C or D/C) and it is not known if airlines

would allow these in a cargo hold. However, these would work very well for fieldwork and transport by boat or truck/car where they could be run off of the engine battery. For shipments that consist of a large quantity of very valuable corals or other marine life, several airlines offer temperature controlled shipping containers but as mentioned previously, with rates starting at $ 3000 US, these may not practical (Brittsan, pers. com.).

Since the production of CO_2 and organic acids can drastically drop the pH of shipping water, it can be helpful to buffer the shipping water by raising the alkalinity slightly using a commercial buffer.

PACKING MATERIALS

Once the corals have been packed in their shipping bags, they are then placed into shipping boxes. These usually consist of a Styrofoam box with lid. A bag liner or two should be used to line the inside of the Styrofoam box (with the bagged corals placed inside this bag) to help contain leaks, with another bag liner placed around the outside of the Styrofoam box. The wrapped Styrofoam box is then placed within a cardboard box and sealed with tape. Using liners is highly recommended as leaking boxes of saltwater are a major irritant to airlines and could affect the shipping institutions ability to use that carrier in the future. Finally, if available, and provided there is space, placing packing “peanuts” around and on top of the bags of coral will also help to maintain water temperature. As mentioned previously, the use of insulated coolers is another option for shipping.

The outside of the shipping box should mention the destination and shipper. Box labels indicating the proper orientation the box should be placed in and indicating the contents (e.g. LIVE CORALS) are also helpful. The box containing the export and import permits (if needed) should be identified and they should be sealed inside a plastic bag and placed on the top of the Styrofoam box to reduce the risk of water damage; a copy of these should be made and carried with any member of staff accompanying the shipment. In some countries/states there may be more than one agency that needs to inspect incoming shipments. In the US, the US Fish and Wildlife Service inspects all incoming plant and animal shipments, especially CITES organisms such as corals, and will require their own set of permits and completed forms. This should be kept in a separate labeled envelope so that the inspectors can quickly find the documents they need. Other agencies may also need to inspect the shipment and may require their own set of paperwork; these should be in a labeled envelope as well e.g. State of Hawaii, Department of Agriculture. Any effort to make the job of the inspectors easier will be appreciated, and will help in having the shipment cleared and processed quickly and efficiently.

Finally, any import from a foreign country will require the intervention of a customs agent. Unless a broker is being used to handle the shipment, the shipment will need to be cleared by a customs agent before it will be released by the airline.

ACCLIMATIZATION

When corals arrive at their destination they should be unpacked and handled with care. Some species are extremely sensitive to direct handling so the use of surgical gloves is recommended; avoid touching the tissue of these corals as much as possible as well e.g. *Xenia*, yellow leather (*Sarcophyton elegans*) (Calfo, 2001).

The water chemistry in the shipping bags should be checked for pH, alkalinity and temperature and if possible the receiving system water should be close to the values of the shipping water. Using a slow drip to acclimate is wise to prevent shocking the corals. However, the author admits to placing corals directly into the holding systems after adjusting for only temperature. In some cases, when a coral is severely stressed, this is usually better than trying to acclimate the coral first. If a coral arrives in poor condition with sections showing signs of decay, it is usually best to fragment the healthy portions and discard the rest.

When corals are first placed into a holding system, provide good water flow, especially for those species that produce a lot of mucus. In some cases, where excessive mucus is in the shipping bag, it is best to rinse the coral in a container of clean tank water before placing it into a system. Good water flow will help the coral rid itself of metabolites as well as excess

mucus, and will bring oxygen rich water to the coral tissue.

Before placing wild collected or aquacultured corals from in situ coral farms into a system inspect them closely for the presence of parasites e.g. snails, flatworms, nudibranches. In some cases, the use of a cleansing dip may also be beneficial. There are several such "dips" commercially available consisting of iodine compounds or plant extracts. These help to reduce the bacterial population on a coral and reduce the risk of secondary infections. In some cases, an antibiotic bath may also be required for corals that do not respond to the above steps. It has been implied that survivability problems with *Catalaphyllia* imports into the US over the last few years, could be addressed by the use of antibiotics (Sprung, pers. com.).

Careful attention should also be paid to light intensity. After a prolonged confinement in a dark container, exposing newly arrived corals to the intense lighting of the holding system may cause light shock and bleaching; gradually acclimate newly arrived corals to the lighting system over the course of several days or weeks. This is entirely dependant on the length of time the corals have been deprived of light, but it is always best to slowly introduce corals to full light intensity levels.

Finally, as with any import of wild caught animals, the use of a quarantine system is highly recommended. In fact, regardless of the source of corals, a quarantine system is recommended. The incidence of coral pests that have been spread across the United States by passing fragments from hobbyist to hobbyist has been well documented and more than one public aquarium has found their entire coral collection compromised by the introduction of a pest or pathogen from a single piece of "donated" coral. Red *Acropora* "bugs"; *Acropora* flatworms; Majano anemones; *Xenia*, *Porites* and *Montipora* eating nudibranches; *Rappa rappa*, *Heliacus* sp. and pyramidellid snails. The list is long and will only continue to grow; protect your coral collection and always quarantine new arrivals.

SUMMARY

With the advent of modern air travel and a greater understanding of the parameters required to insure the successful transport of live coral, the success rate of coral shipments has steadily climbed over the last 15 years to the point where mortality percentages are now measured in single digits. Public aquariums can add to this storehouse of knowledge by sharing their coral shipping experience with other institutions, the hobbyist community and exporters. In addition to the international trade in live coral, public aquariums and marine scientists are pioneering the transport of coral planulae and newly settled polyps.
The day will soon come when coral exhibits will be "inoculated" with coral planulae and fragments produced by aquaculture facilities, and our exhibits will literally become growing and developing coral reefs.

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INTERNET RESOURCES

www1. www.onsetcomp.com

www2. http://www.lentek.com/Files/Catalogs/CoolerWarmersTrifold.pdf