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A method to safely move mounted skeletons

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Abstract

Mounted skeletons in museums need to be moved occasionally for a variety of reasons. Sometimes within the museum site, but sometimes extensive road travel is required. In all instances it is best to at least partly disassemble the skeleton but all bones should be cleaned, labelled and photographed first in situ and extensive notes should be made as the skeleton is taken apart to aid re-assembly at a later date. However, dismantling should also be kept to the minimum possible to prevent unnecessary over-handling and damage being done to the bones in the process of taking them apart and reassembling them later. For instance as a minimum the skull, mandible, cervical vertebrae, tail and limbs would normally be removed but the skull and mandible might still be kept wired together and the bones of each limb may stay completely on its supporting mount, depending on how the specimen is mounted. Some bones will have been secured to the metalwork with irreversible methods in the past that may preclude some disassembly anyway. A good method for moving the complete ribcage (ribs, sternae and associated vertebrae plus the pelvic bones) is to build a wooden frame around the whole skeleton at the start and suspend the ribcage from a central beam using cotton tape, securing it to the uprights of the frame as well. This allows supporting limbs to be removed. Specimens should be transported on foam to absorb some vibrations, and the wooden frame can usually be secured to the side of the van. However, with road transport as much attention should be paid to the route taken and how the vehicle is driven as to how the specimen is packed.

Keywords: Skeleton; Bone; Conservation; Packing; Transport

Introduction

An articulated skeleton in a museum may need to be moved to another location for a variety of reasons: it can be sent out on loan; it may require conservation treatment by an external specialist; the pose may need to be adjusted by a mount-maker to suit a new exhibition; or a redevelopment project may mean that all specimens have to be moved off site or at least elsewhere on site.

Whatever the reason for removing a skeleton from display or storage, and whether the specimen only has to move a few hundred yards or needs to be transported hundreds of miles, it will be subjected to a series of processes that could inflict harm: partly or completely dismantling the specimen; packing the specimen; moving the specimen; and all the manhandling involved in moving a specimen across a museum site or getting a specimen to a vehicle and into the vehicle, then getting it out again. At every stage mistakes can be made that can potentially have long term consequences.

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There are descriptions in conservation literature of how to pack fluid-preserved specimens, taxidermy specimens and some other natural history objects (e.g. Carter & Walker, 1999). Apart from one good description of how to move a mounted fossil Miocene skeleton (Brown and Seevers, 1990) there is very little guidance published as to how a fully mounted or partially mounted medium-sized or large modern or historical skeleton could or should be moved and transported. This article attempts to address this by giving examples of how some skeletons have been packed and moved either in to temporary storage or been transported by road.

Dismantling skeletons

The process of even just partly dismantling a specimen is when harm might first be inflicted, both immediately and in the long term. If handled incorrectly bones can easily be broken during the dismantling process. If individual bones are not adequately labelled or not enough photographs are taken before dismantling mistakes might be made when remounting the bones at a later date. Sadly there are very rarely any records in museums detailing exactly – or even vaguely - how a skeleton was mounted in the past to provide a guide as to how it should be taken apart. You are faced with a complex and sometimes very fragile three-dimensional puzzle and you have to figure out how the skeleton comes apart and in what order. Therefore the specimen should first be dusted with a soft brush and vacuum cleaner with the nozzle covered in gauze (Fig 1) so that the clean skeleton can then be carefully studied and photographed from all angles before the dismantling process starts. This means that the details in the photographs will be clearer and also you will not be breathing in the dust during the dismantling process.

It is best practice to label the bones with clear legible handwriting on tie-on labels whilst the bones are still mounted, to avoid any confusion (rather than labelling them after their removal). Information on the label should include the specimen's unique number as well as what the element is e.g. '*Pongo pygmaeus* GMZ409: rib 15, right'. It is also worth taking photographs of the bones and their labels whilst the bones are still in situ on the specimen. To make the remounting process even easier at a later date, detailed notes should be made about how the specimen is mounted, with further photographs taken of details of the metalwork, and also diagrams should be drawn to explain the notes and photos. This is necessary even if you expect to be remounting the skeleton yourself in a matter of weeks: plans change, projects get shelved and people move jobs.

The metalwork that bones fit on to should also be labelled adequately. If parts of the supporting armature have to be removed they should certainly be labelled (again not just what part they are but what animal the armature belongs to), then photos should be taken of the mountwork with the labels legible (as they can become detached). It may also be worth recording the exact positon of the armature being removed e.g. how far away one end is from a nearby bone, and maybe even take photos of the tape measure in use, showing the items being measured and what the measurement is.

Depending on why you are dismounting a skeleton, it may well be best not to dismantle all the bones of the specimen and remove them from the metal mount unless you really have to. Whole limbs removed from skeletons might be easily and suitably packed as they are, without the need for individual bones to be removed (Fig 2). The less you dismantle the skeleton from mountwork and the less handling of the bones the better. Minimal handling of the bones leads to less physical damage being inflicted and removing fewer bones will certainly reduce the scope for bones being muddled up. This is usually the case with ribcages and associated vertebrae if all the ribs are wired together and wired to the vertebrae and to the sternum. It would not

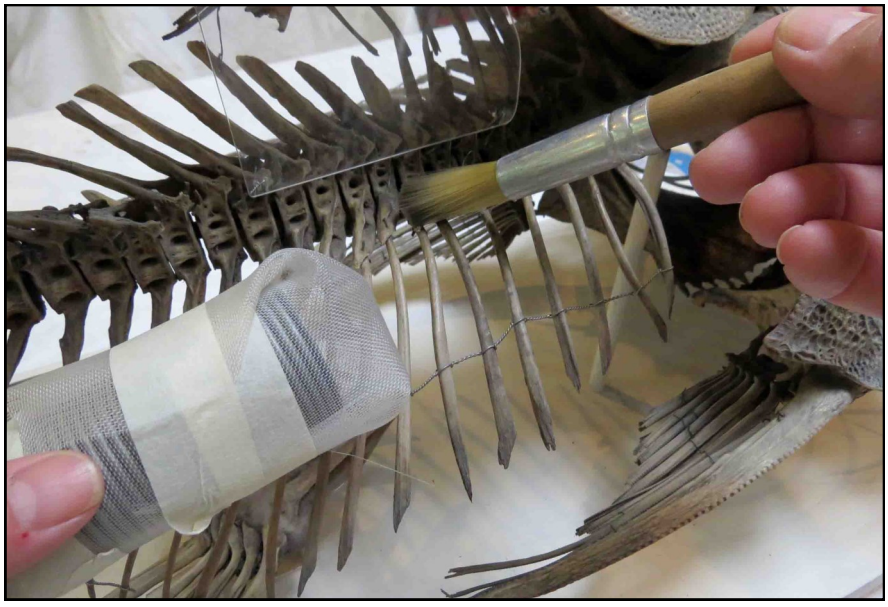

Fig. 1. Gauze taped over the end of the vacuum cleaner's nozzle whilst cleaning a skeleton with a soft brush. This prevents any small pieces entering the vacuum cleaner if they become detached.

only be very easy to damage the long thin ribs during the lengthy unwiring process but also when handling them and when wiring them up again later. There is a very successful alternative to all that unwiring and wiring up again, which is described below.

Be aware from the outset that in the past some people did not really think in the long term. Many specimens were mounted in a way that clearly would not allow for easy dismantling later on. They must have assumed these displays were never going to be changed and that curators would be happy with these exact poses for many years to come. An articulated skeleton may have had bones broken and then glued together again around the metalwork with non-reversible resins. Some bones may have simply been glued to the metal mount – again with irreversible resins – such as vertebrae adhered to a horizontal vertebral pole to stop them slipping and rotating. Unpainted metalwork may have rusted badly and in the process become firmly attached to bones. In these cases the metalwork cannot be removed and re-shaped and this may thwart your plans to completely dismantle a specimen or change the pose.

Some bones may be held in place with blank-headed coach bolts which makes undoing them much more difficult as you cannot hold one end still with a screwdriver or spanner whilst undoing the nut on the other end. And/or this nut and bolt may be rusted together and/or have their thread bunged up with several applications of paint. Rust is relatively easy to deal with by applying a lubricant such as WD40. Spray a little WD40 into a jar and then apply it exactly where it is needed with a cotton bud or a small brush, wiping away any excess so that it does not drip onto bones or onto the plinth. It is best to apply it a day or so before you need to undo the nuts so it can sink in, and it may need to be applied a couple of times. Paint in the thread of a bolt might be removed with a combination of scalpels and wire brushes but otherwise you can try very carefully applying a paint-stripper product. If it can be done safely you may need to resort to a boltcutter if no bones will be damaged in the process. There may not be room for this and a hacksaw might be necessary but bear in mind that the sawing action can make the skeleton sway a considerable amount so this should be done once as many bones as possible have been removed and it is useful to have someone else hold the mount steady. Ideally hacksaws and boltcutters would not be needed as it is best to re-use all the old mountwork as long as it is still fit for the job, down to the nuts, bolts and washers as they are part of the historical mount.

The good thing is that if you have to dismantle many articulated skeletons in a museum, once you have done the first one or two you often find the others are mounted in exactly the same way so the process becomes easier and quicker.

Fig. 2. The forelimbs of a finback whale at Cambridge University Museum of Zoology, being packed complete without further dismantling after some metal brackets had been removed, cleaned, repainted and replaced. Each limb was stored on several layers of acid-free tissue paper on bubblewrap rolls shaped to provide a snug fit for the bones. This was all on a thick layer of Plastazote foam inside a wooden crate which was easily carried by two people.

Packing bones removed from skeletons

When packing bones that have been removed from a skeleton it is best not to completely wrap them. Bones can be damaged when rolling them out of packing materials, even tissue paper, because their fragility cannot be appreciated until they are unwrapped and the physical unwrapping leads to overhandling. An alternative is to place the bone or articulated bones the safest way round onto a few sheets of acid-free tissue paper lying on a suitable amount of bubblewrap. Pick up the specimen and its bubblewrap and tissue all in one go and place into the packing box or crate, which may already be lined with more bubblewrap or Plastazote foam. Next, arrange the packing material so that the bone/bones is/are fitting snugly in the crate and only touching the tissue. Add more bubblewrap or acid-free tissue underneath and around the specimen as required and add more bones suitably packed until the specimens are sitting well protected in the crate and will not move in any direction. You will easily be able to see exactly what bones are in the box or crate, and hopefully also be able to read their labels (Fig 3). If you want the specimens covered, you can add layers of acid-free tissue, then bubblewrap and/or fluted polypropylene

Fig. 3. On the left is a hippo skull upside down (the safest way to store it) in a wooden crate. On the right are four feet of a diprotodon skeleton packed in a large, sturdy, stackable polypropylene Eurocrate. In both cases the bones sit on several sheets of acid-free tissue under which bubblewrap has been arranged to provide comfortable snug nests in which the bones are held securely. The bones have not been overwrapped, meaning they will already be visible before the unpacking process starts. Lids can be placed on top to keep off dust and prevent accidents.

display board (commonly known by the trade name 'Correx'). Some bones will be too big for standard crates and boxes and should not be handled and moved on their own but should be moved and stored on suitably sturdy bespoke pallets or in bespoke wooden crates lined with appropriate conservation packing materials (Fig 4). This cuts down on over handling and consequent accidental damage during loading, unloading, transport and storage.

If a skeleton is being partly dismantled and stored it is best to keep all the bones together if possible and to cover the specimen to protect it and keep off dust. This is easily done with simple tools and a combination of wooden batons, plywood, screws, cotton tape, Plastazote foam and either Correx (Fig 5) or more plywood. If you are in the midst of a large decant project and you do not know where the specimen is going to be stored, always pack it securely enough that it can safely undergo road transport if need be. Photographs of the specimen can be attached to the outside of the box so that staff moving it are aware of exactly what is inside. However, in the case of ivory, rhino horn or other high value items you may not want to draw attention to the contents.

Preparing skeletons for road transport

Something as small as a python skeleton might still be easily transported in off-the shelf storage media such as a large Euro crate if it is suitably lined with

Fig. 4. This Asian elephant skull is ready for transport. It sits on a bespoke pallet made with batons and plywood, lined with Plastazote foam and with two 'handles' (the batons) sticking out at either end to make it easy for two or four people to carry it. The top of the skull is covered in acid-free tissue so that the cotton tape does not damage the skull. The cotton tape is applied in many directions, and was staple-gunned to the pallet, to help prevent the skull from rolling off the pallet during transport. Also, either side of the skull blocks of Plastazote foam are glued to the foam the skull is sitting on to help hold it in place securely.

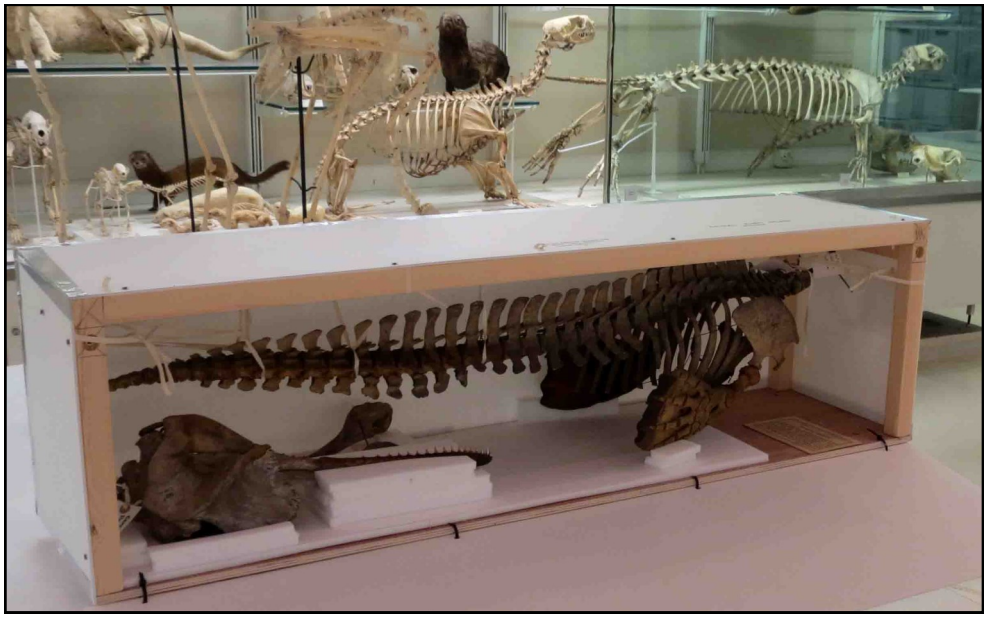

Fig. 5. This Ganges river dolphin was partially dismantled (the skull and mandible removed) and packed for temporary storage whilst the Cambridge University Museum of Zoology underwent redevelopment. Note: the skeleton is hanging from the central horizontal beam of a frame made of wooden batons; the protective sides are made of fluted polypropylene display board ('Correx'); the front side is hinged with polypropylene cable ties so the specimen can be accessed (this side is tied back in place, upright, with cotton tape); the skull and mandible lay on a Plastazote-lined plywood base and have Plastazote foam glued in place around them so they cannot move; and the forelimbs are also held in place with blocks of Plastazote foam glued to the base. If this specimen required transport by road, the forelimbs would have also been removed.

Plastazote foam and well packed with lots of small pieces of Plastazote foam and acid-free tissue underneath and around the bones so that the specimen does not 'bounce' and damage the spine. Most larger skeletons will require specific bespoke solutions to be transported and these can probably simply be different versions of the same basic arrangement: a sturdy well-made wooden baton frame with central lengthways beam to which the skeleton can be attached and from which the vertebrae can hang.

After carefully removing the skull, tail and possibly the cervical vertebrae (suitably cleaning, labelling and photographing them first) to reduce the chances of them being damaged, a wooden frame just a bit larger than the remaining skeleton should be made out of batons (square timber in cross section, about 2" x 2" or approx. 4cm by 4cm in size). Four lengths of batons are required, plus four uprights and four widths (Figs 6, 7 & 8). It is best to use small metal right-angle brackets (just visible in Fig 6) to secure these batons to one another at the corners, and have some extra wooden bracing externally at the corners (Fig 6). One more length of baton should be placed along the midline on top of the two upper widths, secured in place with more right-angled brackets.

Tie several loops of cotton tape so that they go under the vertebrae and over the central beam so that they are snug but not overtight, and well spaced from one end to the other. These will take the weight of the specimen once the legs are removed, so use plenty of cotton tape loops to spread the weight. Once this is done the legs, pelvis and their supporting metalwork can be dismantled and suitably packed away, leaving the ribcage, sternum and associated vertebrae hanging within the wooden frame. If the pelvis cannot be removed, make sure this is strung up in place with the cotton tape as well before the rear legs are removed.

Obviously you do not want this ribcage to be swinging from side to side when on a trolley or in the back of a vehicle, so use more cotton tape to tie it to the four uprights, in every direction, and you can also tie it to the lower lengths of wood. The tape should not be slack, nor overtight. This should stop most side to side and back and forth movement. For additional security, you can add more batons or planks to the side of the frame at the widest point of the ribcage and pack further with Plastazote foam and tissue paper etc, or you can use a sheet of Tyvek to sling underneath and around the ribcage, securing this to the upper beams either side with a staplegun (Figs 6 and 7). This will hold the rib cage very securely, provide some support and catch any pieces that fall off (which would be a very rare occurrence). The cotton tape usefully absorbs some of the vibrations during road transport.

If you make a rigid plywood base for the frame, this could be lined with Plastazote foam and the limbs, skull, mandible, tail and cervical vertebrae etc. could all be stored and transported on this below

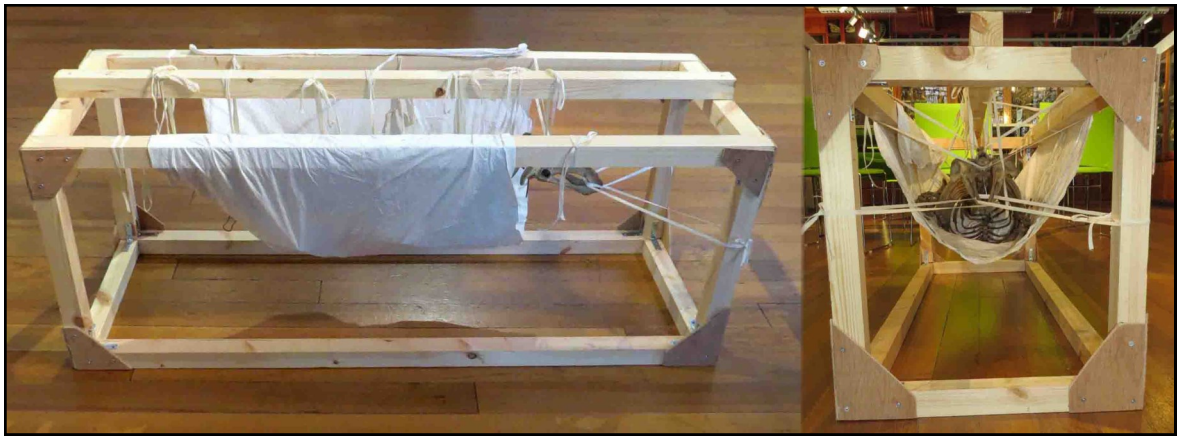

Fig. 6. A seal skeleton ready for transport in its wooden frame after its skull, mandible and rear limbs have been removed. It is suspended from the central beam with cotton tape running underneath several vertebrae and cotton tape is also used to tie the skeleton to the upright batons in the corners to stop it from moving backwards and forwards and side to side when in transit. The ribcage is also held securely in place with Tyvek staple-gunned to the frame. The image on the right shows the additional external wooden bracing in the corners.

the ribcage. You can add plywood sides for extra security, depending on requirements.

When using a hired van for larger specimens, one advantage is that they are usually boarded-out with plywood already. This means that simple shelf brackets can be used (Fig 8) to hold your specimen in place securely, screwing the wooden frame to one side of the van so that it cannot move backwards, forwards or sideways and will not sway within the van. If necessary, a large beam can be secured across the van widthways in the same way to help hold larger specimens (Fig 8). The framework should always be positioned on a large piece (s) of soft foam, to absorb as much vibration from the road as possible. Even the largest set of giant deer antlers can be transported this way, held comfortably in position in a giant web of cotton tape. Unless you are certain that the specimen will only be moved across perfectly smooth floors to and from a waiting vehicle it is best not to put wheels under this frame (which would put it at risk from unwanted vibration from a rough floor) but instead have enough people to carry it safely to and from the vehicle at either end of the journey. To make this easier, cut two planks or batons of wood slightly longer than the wooden frame and securely screw these to the frame at a height that will make it comfortable to lift and carry the specimen (Fig 8), especially bearing in mind the height of any doorways *en route*. Covering the whole specimen and its travelling frame with Tyvek would be useful if there is no loading bay and rain is expected, but it also catches the wind like a sail. If a tall or large specimen is being moved by hand this can make it very awkward. It is also very useful to be able to see how the bones are moving when carrying the skeleton to and from a vehicle, so that people can be slowed down or asked to move differently if bones are swinging or vibrating too much. Therefore too much Tyvek covering the specimen can be a bad thing. However, Tyvek is so easily added to the frame with a staplegun that the decision can literally be left until the last minute.

Driving with skeletons on board

Obviously, if you have a partially mounted skeleton or fragile giant deer antlers in the back of your vehicle you will need to drive very carefully e.g. avoiding potholes and raised ironwork in the road, taking corners and roundabouts gently and slowly and not braking sharply. However, it is also worth thinking about what route you should take to get to your destination. If you happen to know the roads it is

Fig. 7. A quagga skeleton with its plinth and upright metal supports held securely within a wooden frame ready for transport after the skull, mandible, tail and limbs have been removed. An extra central plank holds the upright metalwork securely in place whilst the pelvis, vertebrae and rib cage are all held securely in place with cotton tape tying them to the central beam and corner uprights. Tyvek staple-gunned to the horizontal beams provides additional security for the ribs.

Fig. 8. The ribcage of an adult rhino skeleton in the back of a van, ready for transport. Note the whole specimen and its frame is sitting on foam mattresses and the frame is secured to the sides of the van (the white shelf bracket at top left is clearly visible, the one at top right is screwed in behind the beam). Also, planks have been screwed to the side of the frame low down to act as handles so that the specimen is carried at a more comfortable height to and from the vehicle.

worth avoiding those that have particularly bad surfaces or that involve a lot of traffic lights and roundabouts and all the associated stopping and starting and going round bends. In this respect taking a longer route via a motorway would usually be preferable rather than shorter routes along 'A roads' and through town centres. There are exceptions, however: as an example, the raised section of the M6 motorway through Birmingham is built in sections and there is a sharp jolt experienced as a vehicle travels over the join in the road surface. Over just a few miles this adds up to hundreds of unnecessary jolts when the much newer and smoother M6 toll road could be used instead. Some of the worst roads are those of the inner cities such as central London, full of poorly patched trenches making an extremely uneven road surface in some areas. These roads have to be travelled with extra caution and at a greatly reduced speed to minimise swaying and bouncing of the bones in the back of the vehicle, particularly in vans where the swaying motion experienced is greater than that of cars as the vans are higher off the road and the uneven nature of the road surface gets exaggerated. Whatever the destination and the route taken, always make sure well in advance that the specimen and the driver – whether a member of staff or an external contractor - are insured for this sort of journey.

Not moving skeletons

Sometimes it is simply less risky, although at first maybe counterintuitive, not to move a specimen. For instance although the Zoology Museum at the University of Cambridge was going to be refurbished between 2014 and 2016 and would be a building site for a couple of years and the whale skeletons hanging from the ceiling would be at risk directly from builders and also the dust they generate, it would also have been quite a risk to try to dismantle the skeletons and take them down. They were hanging 12m above the gallery floor, weighed a lot and were very fragile. The relative risks had to be weighed against one another. The compromise was to remove the skulls, mandibles and limbs from the whales as these extremities would be the most vulnerable to damage as well as being the most useful taxonomically. This was easier said than done: the bones were cleaned, labelled, photographed and removed when standing on a platform swaying about ten metres above the gallery floor (Fig 9) and the space around the skeletons was limited by the size of the scaffolding platform. All the skulls, mandibles and limbs were packed for storage with the exception of the largest and heaviest skull which was deemed too unsafe to be removed under these conditions, especially considering it would have to carried all the way down the scaffolding tower as well. So this skull was left in place. It and all the other bones left at height (mostly just vertebrae and ribcages) were wrapped with acid-free tissue, then bubble wrap and Tyvek to protect them as best as possible from the building work.

Similarly, back down on the gallery floor the largest skeletons (including the African elephant and giraffe) were partially dismantled with their skulls, mandibles, tails and legs removed but their rib cages left intact. These remained on their metal frames on plinths which were totally enclosed within very sturdy wooden crates on wheels. These were covered in plastic sheets to protect them from water and taped-up to protect them from the inevitable ingress of dust and were left on site with instructions that they were only to be moved by museum staff. This saved a huge number of person-hours undertaking further dismantling work, reduced the chances of damage from all the extra unwiring of ribs etc and then the subsequent wiring back up again later on, plus reduced the chances of the plinths and the metalwork being damaged, muddled or lost when being taken to temporary storage and being returned and remounted.

Fig. 9. The author at the top of a 10m high scaffolding tower wrapping a large whale's ribcage and vertebrae (that hang from the ceiling) with acid-free tissue, bubblewrap and Tyvek after removing the more vulnerable bones. In the foreground is another whale already wrapped for the duration of the redevelopment project at Cambridge University's Zoology Museum (photograph courtesy of Matt Lowe, UCMZ).

Health and Safety

The immediate and long-term safety of specimens is always a central concern to professionals working in museums but this must never be at the expense of those working on or around the specimen. Mechanical handling equipment should be used where possible rather than undertaking manual handing, and training should be given in manual handling when it is required. Risk assessments should always be undertaken, especially when working at height even when just using a stepladder. Personal protective equipment appropriate to the task in hand must always be worn. If scaffolding towers of any height are to be used please be aware that they can only be legally assembled by staff or contractors licensed to do so. For the redevelopment project at Cambridge University Museum of Zoology several people including the author attended a PASMA scaffolding course run by HSS Hire. PASMA stands for Prefabricated Access Suppliers and Manufacturers Association. The standard 'Tower For Users' PASMA training course takes one day and attendees have to pass an examination to be awarded a licence valid for 5 years. This course teaches not only how build and operate a scaffolding tower, but very usefully how to identify when hire companies have sent defective or simply wrong parts which became apparent is a worryingly common occurrence.

Conclusions

If you need to move a skeleton more than a short distance (e.g. within a storeroom or gallery) it is best to at least partly dismantle it first to reduce the chances of an accident and reduces the seriousness of potential accidents. However, do not expect any dismantling of a skeleton to be straightforward. It is unlikely that there will be a record of how the skeleton was originally mounted and some bones may have been glued to the mount with irreversible resins so that the metalwork cannot be removed. If your intention is to get the metal mount adjusted this inability to remove some of the bones from the metalwork so it can be re-shaped will compromise your intended project. If at all possible, do not move the skeleton but remove the most vulnerable pieces. If it has to be moved, move it the shortest distance possible as long as it is left in a safe place, well protected. If a specimen is really large but would be vulnerable if moved yet a decant project is underway, consider leaving the specimen on site in a sturdy builder-proof crate, well labelled.

However, it is normally relatively easy to partially dismantle a skeleton enough to prepare it to be moved safely, even by road. The likelihood of having problems with remounting the specimen at a later date can be reduced if the bones are labelled before their removal from the skeleton and if extensive notes and numerous photographs are taken before and during the dismantling process to record in detail exactly how the skeleton is mounted and how it should be put back together. If articulated sections of the skeleton – such as a complete limb, or the vertebrae of the tail - can be removed as single units without risking damage to the bones, this is preferably to removing all of the individual bones one by one and over handling them and removing all the their connecting metalwork.

In particular, rib cages and their associated vertebrae and sternae that have been wired together would be quite vulnerable to damage if they were unwired to be totally dismantled and then were wired-up again at a later stage. Unless they have been wired together badly and the opportunity should be taken to redo the job, it would be best to leave them wired together as they are. The whole ribcage can be safely transported suspended by numerous lengths of cotton tape within a wooden baton cage, maybe with Tyvek holding it snugly from below and from the sides as well, but always placed on a foam mattress and secured to the inside of a van. A wide variety of specimens, even very large sets of giant deer antlers, have been moved safely this way without any breakage being incurred.

It is easy to forget that projects such as those described above appear very unusual, surreal or even exotic to members of the public. They are highly visual and can easily be exploited for publicity via 'social media' and more traditional means such as newspapers and local TV and radio news. Videos of time lapse photography and/or blog posts and twitter feeds of the process as it happens in real time are gold dust to public engagement, especially when a museum is closed to the public but needs to remain engaged with its audience. Using such methods will show what is going on behind the scenes and will help to explain why a project takes so long. They can also enhance the recorded history of a specimen and could even be useful when it comes to re-articulation.

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