

Husbandry Guidelines For Mourning Cuttlefish



Sepia plangon
(Cephalopoda: Sepiida: Sepiidae)

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DISCLAIMER

These guidelines have been compiled to the best of the authors' ability, however they should only be used as a guide. Please refer to your institution's SOP's as well as your institutions veterinary staff before proceeding with any changes to animals' husbandry.

OCCUPATIONAL HEALTH AND SAFETY RISKS

There are some OHS considerations when working with Mourning Cuttlefish:

Bites

Mourning Cuttlefish have a very sharp hooked beak. This can give a nasty bite. Having said this, it's very rare that a cuttlefish would bite, as they are skittish when being handled. If you do get bitten the first aid is the same as for a normal insect/animal bite.

You should:

- Wash with soap and water and apply an antiseptic
- Ensure that the patient's tetanus vaccination is up to date
- Apply an ice-pack to reduce local pain and swelling
- Pain relief may be required eg. Paracetamol or an antihistamine to reduce swelling, redness and itch
- The patient should seek medical advice if they develop any other symptoms or signs of infection

Electrocution

Due to the fact that aquarists will be working with water and electricity there must be caution not to receive an electric shock. Our bodies are around 70% water and therefore conduct electricity very well.

If there has been an electric shock you should:

- Stop electric supply; do not try to touch the casualty directly. First of all power off the electric supply directly or else break the contact of the victim with the help of non-conductive objects like wood or rubber.
- If the victim is in contact with downed power lines then do not try to rescue.
- Immediately call for emergency medical treatment.
- A casualty either conscious or unconscious needs to be hospitalized.

First Aid Procedure for casualty:

- Check airway and breathing of the casualty. This can be done with the help of ABC test that is airway, breathing and circulation. If any of this is missing immediately give mouth-to-mouth resuscitation to the casualty and/or CPR according to the need to keep their pulse and breathing normal.

- There will be electric burns on the body of the casualty. These burns can be third degree burns. They come in a pair as an entry wound that is smaller and an exit wound that is larger in size. Cover the wound with a sterile dressing pad.

Slips

Because there can often be water spills etc, there is a high chance of slipping. Be cautious to clean up these spills and utilize wet floor signs when necessary.

Back strain / Heavy lifting

Water is very heavy. Aquarists will often need to transport buckets of water or move transport containers full of water. This should be done using the correct lifting techniques to prevent back strain. Don't lift beyond your capabilities and use 2 people where possible.

Below is the correct technique for lifting:



Image 1

- Make sure to keep your back straight
- Bend at the knees to let your legs do the work

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1. Introduction

The Mourning Cuttlefish *Sepia plangon*, belongs to a group of animals known as cephalopods; this encompasses the cuttlefish, squid, octopus and nautilus. The cuttlefish are extremely intelligent animals that have captivated humans for many years. There are many myths and legends surrounding the sea and the amazing and mysterious creatures that live in it.

Humans have found many uses for the cuttlefish; in early times we used the ink from the cuttlefish to make the colour sepia. We use them as a food source, keep them as pets, we wonder at their ability to change colour and texture in the blink of an eye at our local aquarium and due to their intelligence the cuttlefish are often used in behavioural and medical research. Even after they have died we feed the cuttlefish bone to our pet birds!

Although these animals feature so much in our lives they are still extremely unknown and there is little husbandry advice available for them. The aim of compiling these husbandry guidelines is to try to bridge the gap of information surrounding the cuttlefish, in particular the Mourning cuttlefish. Hopefully this will allow for rewarding experiences as aquarists and enriched lives for these animals I have come to know and love.

1.1. Species Co-ordinator

Not currently applicable for invertebrates

1.2. Studbook Holder

Not currently applicable for invertebrates

2 Taxonomy

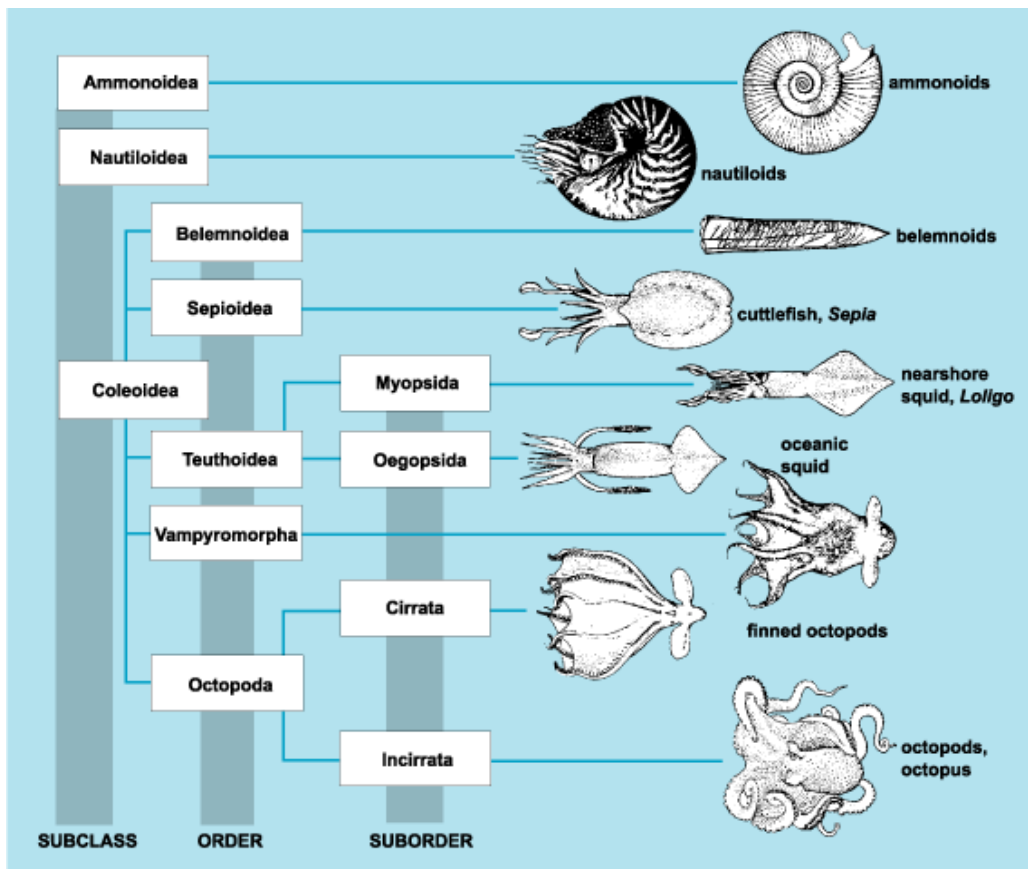


Image 2

2.1. Nomenclature

Kingdom: Animalia
 Phylum: Mollusca
 Class: Cephalopoda
 Order: Sepiida
 Family: Sepiidae
 Genus Species: *Sepia plangon*

2.2. Recent Synonyms

N/A

2.3. Other Common Names

Striking Cuttlefish

3 Natural History

The Mourning Cuttlefish belongs to a group of animals known as cephalopods; this encompasses the cuttlefish, squid, octopus and nautilus. 'The term "cephalopod" is formed from two Greek words meaning "head" and "foot" and refers to how cephalopods are anatomically constructed, with the arms coming directly off the head surrounding the mouth. The cuttlefish's body organs are contained in the mantle, a bag-like structure that comes off the head.' (Colin Dunlop & Nancy King, 2009)

Most people know very little about these animals, although they are quite abundant and humans have had an association with them for centuries. Many beach goers have come across the cuttlebone, this is the internal shell of cuttlefish. This can also be bought at pet stores and is sold to bird keepers, who offer them to their pets as a source of trace minerals and calcium as well as to keep their beaks sharp.

An interesting fact about the cuttlefishes ink is that it is where we got the brownish ink known as sepia. 'The brown sepia ink was popular in the early nineteenth century for artists drawings and was made by mixing shellac with dried cuttlefish ink.' (Colin Dunlop & Nancy King, 2009)

Cuttlefish are extremely intelligent invertebrates. They have large brains as well as a complex nervous system. This makes them popular aquarium exhibits as they can be interactive and will actually make eye contact with the viewing public.

Mourning cuttlefish are small – medium sized cuttlefish. They reach an average size of 13 – 15cm in length. They are solely marine with quite a wide distribution in Australian waters. They are found from Northern Australia and Papua New Guinea down the east coast to lower New South Wales. Usually found in shallow water down to 80m, they are often found in a male/female pair. Not always but mostly the male will be slightly larger.

Cuttlefish are carnivorous, and are active hunters. They feed on fish, crustaceans, shrimp as well as other molluscs and marine worms.

One of the Mourning Cuttlefishes most amazing features is its ability to change colour as well as the appearance of the texture of its skin. This is done through the use of chromatophores, reflecting cells as well as other structures. They use these patterns in many of their behaviours, such as feeding, avoiding predators ie camouflage, mating and communication. 'The beautiful play of colour and pattern in the skin of a cuttlefish appears almost magical.' (Roger T Hanlon & John B Messenger, 1996)

Different species of cephalopods including the Mourning Cuttlefish are used in medical research. This is because of the large eyes as well as their intelligence ie. Behavioural studies.

Diagnostic Features

Mourning Cuttlefish are sexually dimorphic. This means that the males and females look physically different. The males are often slightly larger. In the below images you can clearly see the difference between the males and females. In image 3 there are 3 individuals. The top 2 are males who are displaying a very typical male pattern. Below them is the smaller female. Image 4 shows the same male pattern and allows you to see a typical female pattern.



Image 3



Image 4

Female

The Mourning Cuttlefish is a small to medium sized cuttlefish. It grows to an average length of 9 – 15cm.

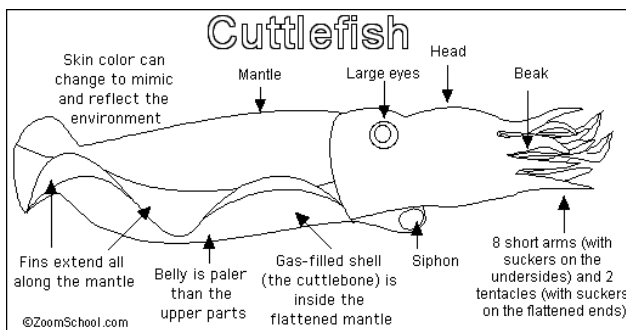


Image 5

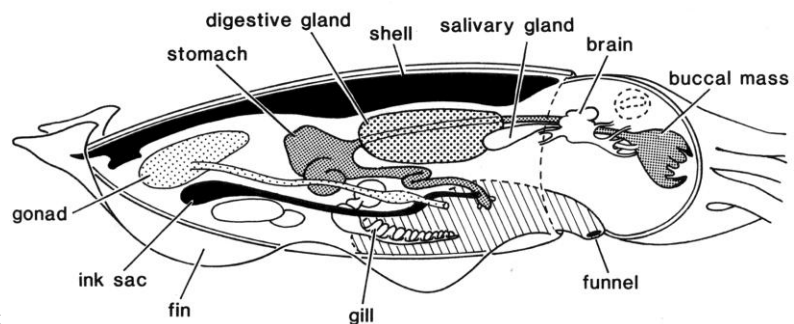


Image 6

There is not much information about weights for the Mourning cuttlefish however Martin Garwood has provided me with weights and lengths obtained through his research at Manly Oceanworld. There were 20 individuals used in the research. The animals were hung on scales in a net. There is a small window of variance due to the water on the net however this is negligible in the scheme of things. His findings were:

Cuttlefish	Gender	Weight (g)	Length (cm)
1	M	48	11
2	M	50	11
3	M	61	12
4	F	65	12
5	M	55	11
6	F	52	11
7	F	42	9
8	M	81	13
9	F	56	11
10	F	67	12
11	M	85	14
12	M	57	12
13	M	59	12
14	F	48	9
15	F	88	14
16	M	68	11
17	F	47	11
18	M	65	12
19	M	59	12
20	F	51	11

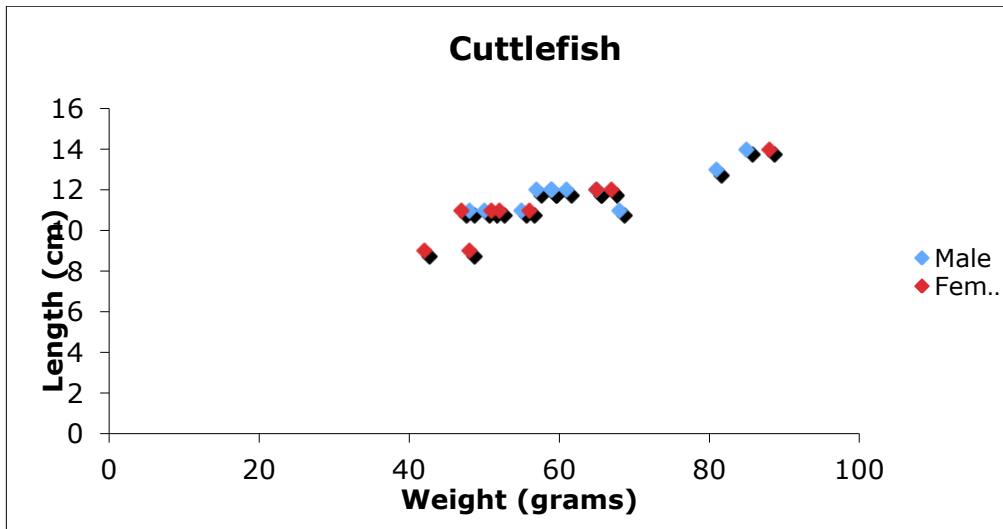


Image 7

Identifying cuttlefish in your collection from other cephalopods is quite easy. Generally the mantle is much shorter and wider than a squid. Octopuses have a much rounder shape to their mantle and their arms are structured very differently. The arms of a cuttlefish are designed to hold prey after catching it whereas the arms of an octopus are designed to find prey they cannot see hidden in-between rocks etc. Nautiluses have an external shell rather than the internal shell of the other cephalopods.

‘ Octopus and cuttlefish are known to have chemoreceptors in the lips and on the suckers. The sucker rims in particular contain large numbers of tapered, ciliated cells. In *Octopus* there are about 10,000 of these primary receptors on each sucker; since there are 200 suckers on each arm there are about 16 million of these cells in an adult animal. In *Sepia* there are only about 100 cells per sucker and far fewer suckers on the arms.’ (Robert T Hanlon & John B Messenger 1996) You can really see how the difference in the lifestyles of the two different cephalopods affects their biology!!

See below images of the different cephalopods to compare the different body shapes.

Cuttlefish



Image 8

Octopus



Image 9

Squid

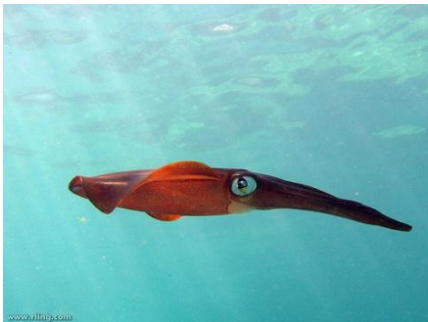


Image 10

Nautilus



Image 11

3.2 Distribution and Habitat

Mourning Cuttlefish are found in the South-western Pacific region, along the eastern coast of Australia.



Image 12

These animals are usually found on sandy bottoms in shallow water. The maximum depth they have been found is around 83m.

3.3 Conservation Status

The conservation status is N/A for this species. There is no formal status for these animals.

3.4 Longevity

Cephalopods as a group are short lived animals. Some live only 6 months while others may reach around 15 months. They grow quite quickly and usually have only one breeding event in their life, although in Captivity (Sydney Aquarium) they have been seen to double clutch (lay a second batch of eggs).

3.4.1. In the Wild

In the wild cuttlefish will live to about 15 months.

3.4.2. In Captivity

In Captivity these animals are usually wild caught. This means that you cannot know the exact age of the animal and therefore may only have it in the aquarium for a short time before it dies. To reduce the amount of animals taken from the wild Sydney

Aquarium is beginning an exciting new breeding program that it still in its early stages. This would hopefully result in having animals in captivity for their entire life expectancy.

In captivity as mentioned above you can sometimes extend the life of the females slightly. This can be done by continually offering food even after she has laid eggs. During this time in the wild she would not eat and her body condition would start to deteriorate. Death can sometimes follow quite quickly after as the animals become susceptible to predation in this weakened state.

3.5 Techniques Used to Determine Age in Adults

Determining age in cuttlefish seems to be extremely hard. Some studies have been done through necropsy to try to find a link between the growth lamellae on the cuttlebone and the age of the animal. Below are some of the findings from a study done by Gregory J Barord, Graduate student, University of New York. This study was done on *Sepia officinalis* and *Sepia pharaonis*.

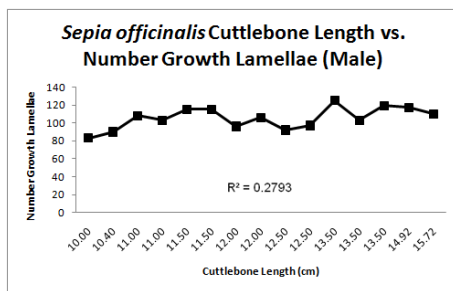


Image 13

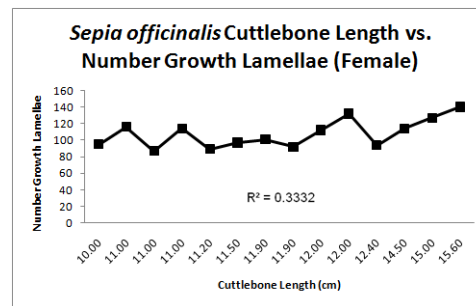


Image 14



This image shows the growth lamellae on the cuttlebone.

Image 15

From a behavioural point of view cuttlefish will start to pair up once they become sexually mature.

4 Housing Requirements

4.1. Exhibit/Enclosure Design

Important points to consider when designing a cuttlefish exhibit:

- Is there enough space for each pair to have their own territory? This will reduce fighting. Visual barriers will also help.
- Consider the keeper access. How will the tank be cleaned? Does the tank require enough room to dive in, or can it be easily cleaned from above?
- Security – When startled cuttlefish can jet out of the water. Make sure there are security measures in place to prevent them landing in another tank or on the floor.
- Cuttlefish require extremely high water quality. Ensuring sufficient filtration is provided is essential.

On consultation with the Australian Museum they suggested that the Mourning cuttlefish was ill suited to tanks that are glass on all sides. They found the cuttlefish were easily frightened when there were people on all sides and jetted around the tank allot. They switched species to the Reaper cuttlefish *Sepia mestus*, which they found to be much better suited to their set up. (Pers.Com Chris Hosking 2012)



Image 16



Image 17

These images show the tank set up at the Australian Museum. You can see that the majority of the tank is glass on all sides. The museum staff found that this design was not suitable for the Mourning cuttlefish.



Image 18



Image 19



Image 20

Images 18 -20 show the Mourning cuttlefish tanks at: Merimbula Aquarium, Sydney Aquarium and Manly Oceanworld respectively. These tanks are between 900L – 6,000L.

4.2. Holding Area/ Off Exhibit Design

The holding tanks or off display tanks are much smaller than the on display tanks. This is a benefit for a few different reasons. Usually there is less space to work in behind the scenes. Also any new arrivals that need quarantining may be a little nervous and the smaller tank along with a good hiding spot will help them to feel more secure. ‘A minimum off display tank size would be approximately 300 – 400L’ (Pers.Com Martin Garwood 2011)

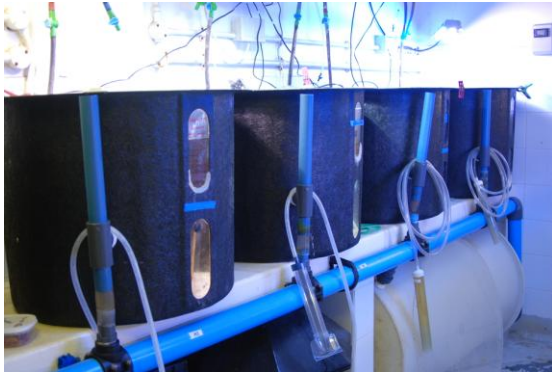


Image 21

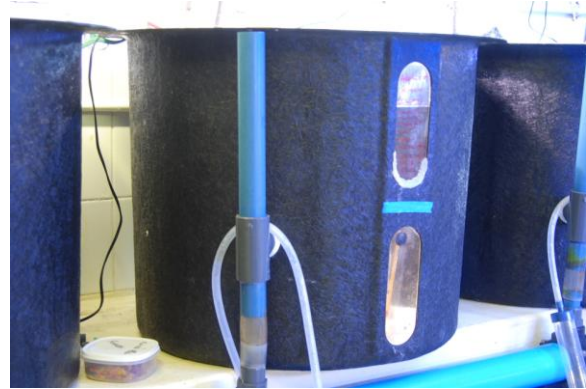


Image 22

These are the off display holding tanks for cuttlefish at Two Oceans Aquarium, Cape Town, South Africa. They are great because of the black walls which removes a lot of outside stimulus (scary people) however there are viewing windows to check on the animal with minimal interference.

4.3. Spatial Requirements

Due to the fact that Mourning cuttlefish are an invertebrate there are no State or Federal laws regarding keeping them in captivity. This is also one reason why they are often used in scientific research. There are no minimum enclosure sizes or rules regarding husbandry practices. It is up to each individual institution to decide what they believe is best for the animal.

When considering tank sizes, bigger is usually better. This is because ‘the larger the aquarium, the larger the body of water, and therefore the more stable the aquarium will be.’ (Colin Dunlop & Nancy King 2009)

At Sydney Aquarium Mourning cuttlefish are kept in tanks that hold approximately 2,000 L of water. This tank size seems to allow enough room to let the pairs of cuttlefish have their own space. At Manly Oceanworld they are kept in a tank that hold approximately 6,000L of water. (Marina Tsamoulos 2012)

4.4. Position of Enclosures

More often than not cuttlefish enclosures are indoors. If you have an outdoor enclosure then you must consider a few things. The amount of direct and indirect sunlight (algae can be a big problem with natural sunlight), can pollutants fall into the tank and when it rains how much water will enter the tank (this will change the pH and salinity of the water especially in a smaller tank where the parameters change quicker). Outdoor enclosures are not recommended.

If you are choosing the position of a new enclosure indoors then there is not much that will hindered you. You can create any space you like. At Sydney Aquarium, Manly

Oceanworld and Merimbula Aquarium the Mourning cuttlefish are in a rectangular tank set into the wall between other tanks. The cuttlefish can easily see people approaching. At Two Oceans Aquarium, Cape Town, South Africa, they display the Common Cuttlefish *Sepia vermiculata*. They had a problem with a tank positioned immediately around a corner. Each time a person walked around the bend they surprised the cuttlefish and they often inked (requiring a large water change) or they jetted into the glass or walls, which will cause butt burn. (Pers.Com Tersia Greenstone 4/6/11) This may be due to the position of the tank or a natural shy disposition of this particular species.



Image 23



Image 24

Two Oceans Aquarium, Cape Town, South Africa found that their cuttlefish *Sepia vermiculata* preferred to be in a smaller tank with a rock cave to hide in, rather than in a larger tank.

4.5. Weather (and other) Protection

Indoors will obviously need no further protection. An outdoors enclosure will require full protection from the elements.

4.6. Temperature and microclimate Requirements

Heating

Sepia plangon is endemic to the coastal waters of Eastern Australia. The temperature range around Sydney is approximately 12 – 20 Degrees Celsius. At Sydney Aquarium, Manly Oceanworld and Merimbula Aquarium they are lucky enough to have access to the natural seawater. This is pumped in from the harbor and filtered before going into the tank. This allows the tank to warm and cool naturally as it does in the wild. If your institution is not close to the water then it is best to keep the temperature at a set level, for example 18 Degrees Celsius. This can be achieved through the use of heaters and chillers. It is not very aesthetically pleasing to see the different heaters etc on display. This can be avoided by heating the filtered water in a reservoir before it is let into the tank. Off display this is not a problem. Also the tanks may be smaller and generic small home aquarium heaters may be used in these tanks.

Lighting

There is no specific lighting required for cuttlefish.

Filtration

There are different types of filters that can be used:

- Underground filters – These are mainly for biological filtration. Water is drawn through a filter media such as gravel at the bottom of the tank before being directed to the top again.
- Canister filters – Canister filters are better suited to small off exhibit tanks.
- Rapid sand filters – These are large powerful filters that are usually used on large tanks. Water is pumped through the sand to remove suspended particles from the water.
- Trickle filters – These are great for removing toxic nitrites. Water is pumped to a container above the tank and allowed to slowly trickle down through the filter media via gravity.
- Ozone – Ozone is bubbled through the water and binds organic matter and kills micro-organisms. Caution must be taken with this method, as it is harmful to be exposed to ozone.



Image25



Image 26

At Merimbula Aquarium they use gravity fed trickle filters. Ocean water is pumped into a reservoir then gravity fed in the filter buckets. These buckets are filled with filter media such as filter wool. After the water leaves the buckets the water flows into the tanks. (Pers.Com Michael McMaster 2012)

Open / Closed Systems

There are two different types of tank systems used in public aquariums, open and closed. Aquariums near the ocean are able to utilize the close proximity of the water to their advantage. They can cycle the water directly from the ocean into the facility and back again.

Closed systems are more like a home aquarist would have. These systems can be more difficult as the parameters of the water can change faster. Water is taken from the town water, aged and salt is added. This is better than shipping huge amounts of salt water to the aquarium. Closed systems require regular water changes and top ups.

Below is an example of a layout of a closed system. This is in use at the Australian Museum, Sydney, Australia.

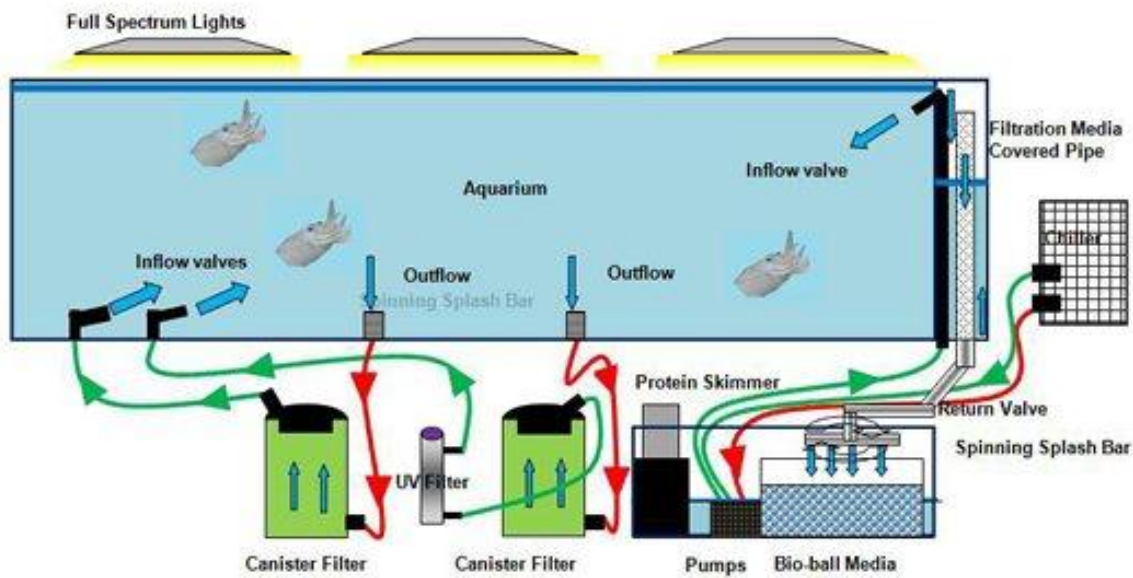


Image 27

Artificial Sea Water

If an aquarium does not have access to natural sea water you will need to make up artificial sea water. At the Australian Museum they make up artificial sea water for both top ups and water changes. They use Aquasonic Ocean Nature Sea Salt. This brand of artificial sea salt contains no nitrates and is safe for sensitive invertebrates. They have always found it to work well. The dose rate is 2kg per 60L @ 24C = 1.022 Specific Gravity.

To make up the sea water they fill up their makeup tank under their system with tap water, dose it with Prime to dechlorinate / deaminate overnight then add a rough

initial amount of salt, agitate and leave to mix and settle overnight then top up salt to meet their needs for new water. (Pers.Com Steve Vogel 2012)

Below is a step-by-step guide to making up the artificial sea water from the manufacturer:

MIXING AQUASONIC OCEAN NATURE

- 1) It is recommended that the tap water be filtered through AQUASONIC “ACTIVATED CARBON” into a plastic container that is especially kept for the purpose. For best results pH should be neutral.
- 2) Fill a little less than the desired quantity and add AQUASONIC “EXTRA POWER WATER PURIFIER”.
- 3) Now add the appropriate weight of “OCEAN NATURE” sea salt. 1kg mixes approximately 30L. NOTE: Never put the salt in and then add water as precipitation may occur. Always add the salt to almost the full volume of water.
- 4) **CIRCULATE THE WATER WHILE ADDING THE SALT.**
- 5) Small addition of tap water may be required to reach the desired specific gravity.
- 6) Aerate for 24 hours before use. The salt may be mixed well in advance without any deterioration in quality.

4.7. Substrate

There are two main substrates used in cuttlefish enclosures, coral gravel and sand. The substrate you choose should not have any sharp edges and it should not contain any pollutants or properties that will adversely affect water quality. There are advantages to both. Coral gravel is very easy to obtain and looks natural. Coral gravel is also good for aquarium enclosures as it acts as a buffer and will keep your pH from dropping over time. Sand is the most natural substrate if you are reproducing their natural environment. Mourning cuttlefish are often seen resting on the sandy bottom. It is also soft and therefore won't harm the cuttlefish's delicate skin. 'Gravel should be used to a depth of 2.5cm' (Colin Dunlop & Nancy King 2009)

4.8. Nest boxes and/or Bedding Material

After mating 'eggs are laid by the female individually within protective casings, and are attached to the underside of flat rocks in tight hard to get at spaces.' (PIRSA Fisheries) As long as your enclosure furnishing provides a space like this you should be fine. Take into consideration though if you wish to remove the eggs and incubate them in another enclosure. If they are laid in a very hard to reach place this may not be possible.

4.9. Enclosure Furnishings

It is important both from an aesthetic and behavioural point of view to provide the cuttlefish with different enclosure furnishings. You can use a mixture of live rock, normal rock, kelp, PVC pipe, flowerpots, shells, barnacles etc. As with the substrate you must ensure that nothing you add to the tank will pollute the water in any way. You may prefer to stick to natural furnishings on display and keep the PVC pipe etc for the off display enclosures. Providing shelter allows the cuttlefish somewhere to retreat and hide if they are feeling scared and providing these spaces will lower stress levels. Occasionally there will be small crustaceans on kelp that has been collected and this will also act as behavioural enrichment for the cuttlefish as they find and catch them.

Some plant species that can be utilized in the cuttlefish tank are:

- 12 Giant Kelp *Macrocystitis pyrifera*. This cannot be planted in the tank however is a good plant to collect and display in the tank in bunches.
- 12 Neptune's necklace *Hormosira banksia*. Also a good species for collection and display in bunches.
- 12 Sea grasses such as *Halophila australis* and *Zostera muelleri*.

5 General Husbandry

5.1. *Hygiene and Cleaning*



Image 28 - An aquarist using a gravel vacuum to clean the gravel in the cuttlefish enclosure.

It is extremely important to maintain a clean cephalopod tank. The lives of the cuttlefish rely on the aquarists keeping the tanks free from harmful build up of chemicals etc. ‘Manly Oceanworld uses an “open system” where sea water is pumped directly in, filtered, heated and channeled into the tank, before being sent back to the ocean as waste water. This creates a high turn over of water.’ (Pers.Com Martin Garwood 2011) In a closed system regular water changes and high filtration is required to maintain good water quality.

There are a number of pieces of equipment that will be used to keep the tank clean:

- Gravel vacuum – This is used to suck solid waste from the gravel and around the tank.
- Filters – In public aquariums a large portion of filtration is manual. It is preferred to avoid chemicals if possible. Mechanical filtration is the physical removal of waste from the water. These filters also provide an area for biological filtration to take place.

- Protein skimmers – ‘These filters act the same way the waves do in the ocean. They remove proteins and other organic material from the water.’ (Pers.Com Paul Baker 2011) These are also good at helping to reduce the likelihood of losing a cuttlefish when it inks.
- Aerators – ‘Octopuses and cuttlefish have a high demand for oxygen within the tank, requiring a steady supply of well oxygenated water.’ (Colin Dunlop & Nancy King)



Image 29 – This shows the equipment kept next to the cuttlefish display at the Australian Museum. There are gravel siphons, feeding tongs, nets, stepladder and chemical treatments for the water.

Within the substrate and filter media there will also be many beneficial bacteria. These play an important role in decreasing harmful chemicals in the tank. Care must be taken not to remove too many of these bacteria or this will decrease the effectiveness of the bacteria. Below is a chart to explain the nitrogen cycle:

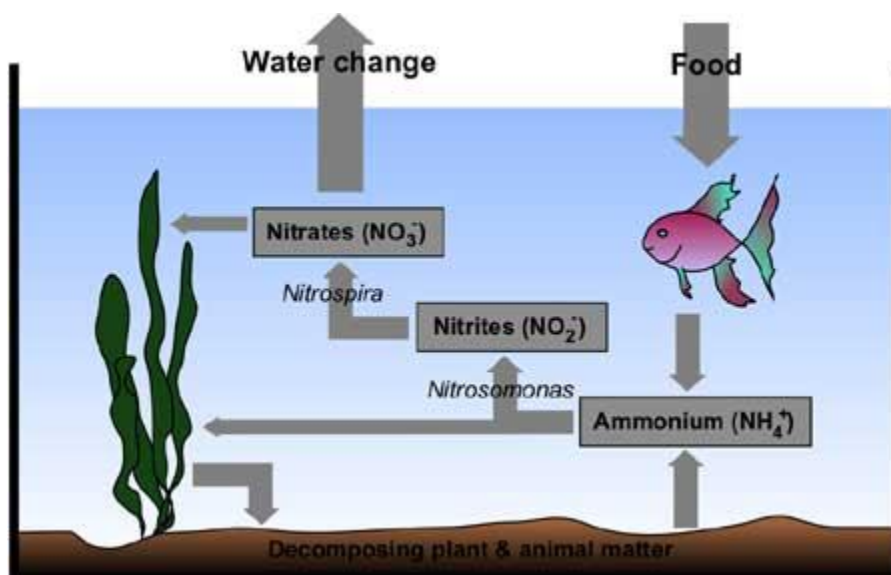


Image 30

Below is a recommended table of tasks to be completed to maintain your cuttlefish enclosure:

Tasks	Daily	Weekly
Visually check the appearance of the cuttlefish	<input type="checkbox"/>	
Temperature check	<input type="checkbox"/>	
Remove any uneaten food	<input type="checkbox"/>	
Check all equipment is in working order, eg. heaters, returns etc	<input type="checkbox"/>	
Check water parameters eg. pH, ammonia, salinity	<input type="checkbox"/>	
Remove algae from the glass	<input type="checkbox"/>	
Backwash filters		<input type="checkbox"/>
Check overflow for blockages	<input type="checkbox"/>	
Empty protein skimmer cup	<input type="checkbox"/>	
Gravel vacuum any solid waste and gravel		<input type="checkbox"/>
Water change (if using a closed system)		<input type="checkbox"/>

Below is a step-by-step guide on how to perform some of the above tasks:

Backwashing:

Each institution has a slightly different set up so backwashing will be a little different for each system however these are the basic rules.

1. Turn power to filter off.
2. Open waste pipe (remember it is always safer to open valves before closing others).
3. Close return pipe to prevent waste returning to the tank.

4. Switch setting on filter to backwash (the term backwashing refers to pumping the water backwards through the filter to help removed built up waste, this cleans the filter).
5. Turn power back on and run for a few mins, time depends on how often backwashing is done and the amount of water that can be used.
6. When ready turn power off.
7. Switch filter setting to rinse (this means the water will be pushed through the filter in the normal direction however the water will still be sent out the waste pipe rather than returning to the tank). This only needs to be done a short time to resettle things.
8. When ready turn power off.
9. Close waste pipe. Open return pipe.
10. Switch filter setting to filter.
11. Turn power on (This completes the backwashing process).

Gravel vacuuming:

This is the process of removing solid waste that has settled in the substrate.

1. Make sure you have all the necessary equipment. This will include, gravel vacuum and possibly a bucket if only doing a small vacuum or access to a waste outlet if possible.
2. Start by priming the lines. This means that you need to fill the vacuum hose with water. This can be done in a number of ways. You can place the vacuum head in the water and suck water into the hose. The vacuum head can be held in front of a return, which will force water into the hose or if you have a container of water big enough you can push all the hose under the water and move around till the air has naturally come out.
3. Once the hose is primed as soon as the end of the hose is placed lower than the vacuum head, water will begin to be sucked out. Make sure the hose is placed immediately in the bucket or waste outlet.
4. Begin by placing the vacuum head into the substrate. You will see the waste begin to be sucked out of the substrate. Remember to try to get to the bottom of the substrate and not just clean the top layer.
5. Move in a regulated pattern, for instance, left to right, front to back. It is a good idea to slightly overlap the section of gravel you are suctioning each time to ensure nothing is missed.
6. Initially when the vacuum goes into the substrate you will see the waste being sucked up. When the water runs clean then you know that section is done and you can move to the next point.
7. Sometimes depending on the width of the hose the water will run too fast and start to suck up the substrate. If you find this is the case it is easy to fix the problem by placing a valve in the hose. This way you can control the amount of water that can flow through the hose.
8. When finished simply remove the vacuum head from the water and let the remaining water run out of the hose.

Collecting water for testing:

Each test kit comes with different powders, tablets equipment etc to use for water testing. I won't go into any detail here about how to perform a water test as it's too individual to each test and brand. Please follow the brand's instructions carefully. Below are some considerations for collecting water.

1. Before collecting water, make sure the equipment you are going to use is clean.
2. You can never trust that things have been done correctly before you so before using equipment wash in distilled water. If using a syringe pull the plunger apart from the measured cylinder and rinse separately.
3. When ready take water sample from the main water body, or as close to it as possible.
4. It is usually a good idea to use the sample water to rinse any test tubes etc that you are going to use in the water tests before use. This helps to prevent getting a false reading from residue left from previous test.
5. After use pull the syringes etc apart and rinse thoroughly and set aside to dry before putting back together.

5.2. *Record Keeping*

Record keeping is extremely important. Keeping a daily record of what is happening in your enclosure or to your individual animals allows you to pick up on trends or patterns. It also provides you with a record to look back on if the animal might need medication or to see what actions preceded a successful breeding etc.

Examples of what should be recorded are:

- Water quality tests
- Water temperature
- Any births or deaths
- Cleaning conducted
- Animal movements
- Feeding
- Veterinary treatment
- New behaviours / Interactions with other animals

Please see the daily record sheet at the end of this document for an example of what your daily record sheet should look like.

5.3. *Methods of Identification*

Cuttlefish are not tagged or marked like some other animals. Also their body patterns are able to change in an instant so the traditional methods of identification are not very useful. It is down to the aquarist to know their animals. As mentioned before males are usually larger than females. The animals may have small marks or scars or missing arms that distinguishes them from other individuals. All these things should be recorded on the animal's daily record sheet to make sure animals are not mixed up.

5.4. *Routine Data Collection*

Data that is routinely collected would be Notable Events. Use the ISIS codes to record relevant information.

6 Feeding Requirements



Image 31 – Tentacle ejection during feeding.

Interesting Facts / Considerations Regarding Feeding in Cephalopods

Cephalopods such as the Mourning Cuttlefish have 3 main morphological adaptations: ‘the arms and tentacles, the mouth and buccal mass, and the gut.’ (Roger T Hanlon & John B Messenger 1996)

They have 2 long tentacles that can be extended well beyond the arms to seize prey and bring it back to the arms, which hold it during ingestion. Tentacle ejection is rapid: in *Sepia officinalis*, at 25 Degrees Celsius, the tentacles reach the prey in less than 15ms, which is faster than the strike of a praying mantis. The cuttlefish mouth is small, and the esophagus, which passes through the brain, is usually narrow. This means that prey is not swallowed whole but is broken up by the combined actions of the break and the radula and by the secretions of the salivary glands. (Roger T Hanlon & John B Messenger 1996) The passage of food can be dangerous for the cuttlefish due to the close location to the brain of the esophagus. In *Octopus vulgaris*, crustacean exoskeleton fragments, as well as harpoon-like setae from polychaete worms (stinging worms) have been found embedded in the brain. Cuttlefish secrete toxins in the salivary glands to help immobilize their prey while rendering it suitable for ingestion. In *Sepia officinalis*, prawns are bitten and paralyzed within 6 seconds of capture and crabs are paralyzed in about 10 seconds. (Roger T Hanlon & John B Messenger 1996)

The gut of cephalopods is well differentiated but short, as in most carnivores. They also have a spiral caecum, which permits opportunistic feeding. The rate of digestion in cephalopods is related to their habits. Due to the bottom dwelling nature of the Mourning Cuttlefish the rate of digestion can be between 16 – 20 hours. (Roger T Hanlon & John B Messenger 1996)

Cuttlefish can also use their funnel to aid feeding. Hunting cuttlefish can direct a jet of water in the gravel to make a half-buried prawn more visible. (Roger T Hanlon & John B Messenger 1996)

Cephalopods can sense prey by sight, by scent, by touch, via ‘distant touch’ such as the lateral line analogue, possibly by hearing and by any combination of these.

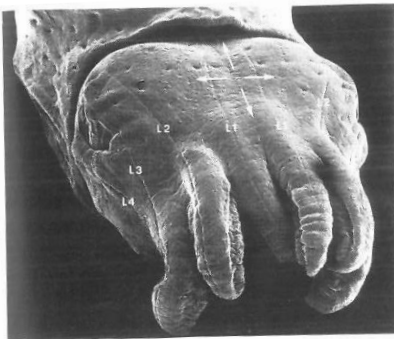


Image 32 - Lateral Lines shown on a Cuttlefish. The lateral line is a sense organ in aquatic organisms used to detect movement and vibration in the surrounding water.

‘Research has been done on the visual attack sequence of the cuttlefish on prawns. This is a 3-stage sequence involving attention, positioning and seizure. When a prawn approaches, the cuttlefish shows attention: there are changes in the body patterning, erection of the first and sometimes second pair of arms and movement of the eyes, head and body so that the eyes are directed towards it. During positioning the cuttlefish swims towards or away from its prey until it achieves its attacking distance, which is equivalent to about one mantle length. Finally during seizure the tentacles are ejected to strike at the prawn, which is seized and brought back to the arms and mouth. This kind of attack is reserved for prawns, small fish etc. If the prey is a crab then the first 2 stages are the same but the third stage is a jump with partially open arms. This is done from the back to avoid being nipped.’ (Roger T Hanlon & John B Messenger 1996)

In the laboratory *Sepia latimanus* often shows a luring display to small shrimps. The first arm pair is raised and swayed left and right while a dark spot is produced at the midpoint. Each second arm is twirled in a figure of eight. The shrimps usually stop and watch, then the cuttlefish ejects the tentacles, which have been hidden amidst the twirling arms...Very clever!

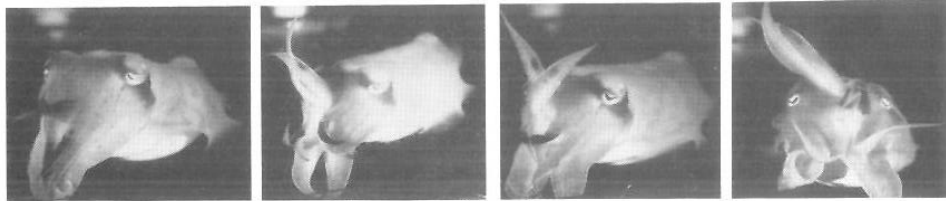


Image 33 – Luring display of *Sepia latimanus*.

6.1. Wild diet

Mourning Cuttlefish are carnivorous. In the wild they feed on a variety of different animals such as crabs, mysids, shrimps, prawns, whiting, bivalves, polychaetes as well as other cephalopods (cannibalism). They are generalized predators with preferences for certain prey but feed opportunistically according to circumstances.

The size of the prey will obviously change, as the individual grows, from small to larger. As the cuttlefish are such intelligent animals they are able to learn as they grow and develop better feeding strategies. ‘Adult cuttlefish will attack crabs from behind to avoid being nipped.’ (Roger T Hanlon & John B Messenger 1996)

The cuttlefish are voracious feeders and will feed every day, as their growth rate requires a large amount of food. ‘Cuttlefish can increase their body mass by approximately 25% each week if fed correctly.’ (Colin Dunlop & Nancy King 2009)

6.2. Captive Diet

At Sydney Aquarium the Mourning Cuttlefish *Sepia plangon* are fed either whole whitebait or prawns. These are fed out dead as it is easiest and the laws regarding feeding live vertebrates in NSW prevents us feeding fish out live. (Pers.Com Amy Wilkes)

At this point in time all the cuttlefish at Sydney Aquarium are collected from the wild and sometimes may be a little reluctant to take dead food. There are different methods to encourage feeding which are discussed below in food presentation.

As well as the above-mentioned food, occasionally live food such as small crabs or yabbies may be offered as a treat. Caution must be taken to make sure the nippers of

these animals cannot harm the cuttlefish and may need to be removed before being fed out. Some aquarists also like to remove prawn heads' as they are usually not eaten and will save cleaning later on.

The cuttlefish are fed once a day, usually in the morning. Enough food is presented into the tank to allow for each cuttlefish to grab one or two food items.

Food items offered:



Image 34 - A selection of food offered, prawns, whitebait and muscles.

6.3. Supplements

N/A – None used at this point in time.

6.4. Preparation and Presentation of Food

Food that will be fed out the following day is removed from the freezer and placed in the fridge the night before which allows it to thaw out slowly. This process at Sydney Aquarium is part of what is called 'break out'.

Food is dropped in from the surface of the tank. As the cuttlefish are housed with other fish species that can be quite aggressive feeders you must first place muscle/prawn/whitebait mince in to distract the fish. Once this is done the cuttlefish food should be spread around the tank to allow easy feeding / less competition and aggression between cuttlefish during feeding. Any food that is not consumed must be removed from the tank the same day before it starts to decompose and pollute the water.

When new individuals are introduced into the aquarium from the wild they may be reluctant to feed. The best method for encouraging feeding is to tie fishing line loosely around a piece of food and dangle it around in the water to mimic live food. (Pers.Com Amy Wilkes) You may also use feeding tongs but this method requires a small enough tank to be able to reach the animal easily such as in an off display tank or home aquarium. Home aquarists sometimes hand feed animals as they enjoy the interaction but

this is discouraged as it can result in a bite and is not necessary or benefiting the animal in any way.

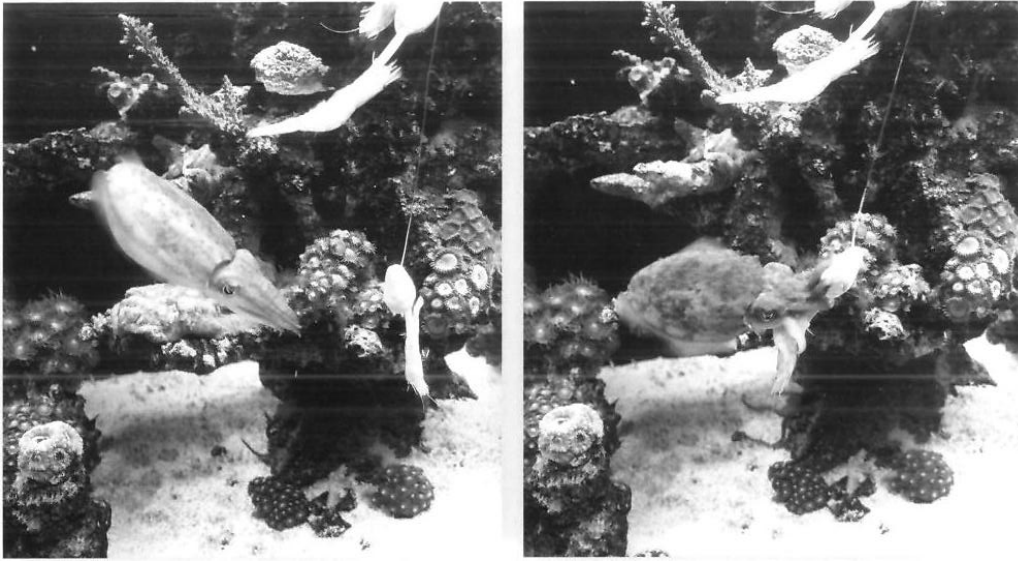


Image 35 – Encouraging a cuttlefish to eat using fishing line.



Image 36 – Feeding tongs used at the Australian Museum.

6.5. Dietary changes

Feed items will change through the stages of the cuttlefishes' life. When they are young they are usually fed on live food such as live mysid shrimp. As they progress into adults they are weaned onto dead food.

At the Institute of Neuroscience, University of Oregon 'all *Sepia* younger than 3 months require live food. Hatchlings to 3 week old are fed small amounts of adult brine shrimp four to five times a day. 3 to 5 week old cuttlefish eat a mixture of adult live brine shrimp, various species of feeder fish (approximately 2.5 cm long), and/or zebra fish hatchlings (one fish per cuttlefish each feeding). The diet of 5 week to 3 month old juveniles consists of goldfish, adult zebra fish and/or guppies (1±3 fish per cuttlefish each feeding). *Sepia* older than 3 months survive well on frozen shelled shrimps (1±2 shrimps per cuttlefish each feeding) (P.K. Loi and N.J. Tublitz 1998)

6.6. Feeding Regime

The cuttlefish are fed once a day at Sydney Aquarium as well as Manly Oceanworld. At Merimbula Aquarium they will feed alternate days or up to once a day, then when they are egg laying they will feed twice a day to support the general condition of the cuttlefish.

6.7. Plant propagation

Kelp bunches are collected from the wild to provide shelter in the tank. Occasionally there are small crustaceans on the kelp that the cuttlefish will enjoy hunting.

Giant Kelp *Macrocystis pyrifera* is a very fast growing and prolific species around the temperate waters of NSW and is easily collected.

7 Capture, Restraint, Handling and Transport

7.1. Timing of Capture and Handling

There is no preferred time of day to capture and/or handle the cuttlefish with regards to being more relaxed or less active at a certain time of day. It would however be preferable to do this early in the morning before public arrive. The cuttlefish may ink due to stress of the move and the tank will then need a significant water change.

7.2. Capture Equipment

Capture of cuttlefish should be done with very soft nets. The gauge of the net (how closely it is woven) should be very small to be able to provide support for when the animal is out of the water. 'The size of the net should be proportionate to the size of the animal as well as the size of the area you are working in.' (Pers.Com Amy Wilkes 2011)

7.3. Capture and Restraint Techniques

7.3.1. The best handling method for the safety of the animals as well as the handler

It is very important to minimize the stress on the animals during capture. If stressed cuttlefish can ink into the water. 'If they are in a small container the ink can coat their gills and cause asphyxiation.' (Pers.Com Amy Wilkes 2011)

What you may need:

- Buckets filled with clean salt water. The temperature of this water should be as close to the water the animal is coming from to minimise shock
- Multiple soft nets
- Oxygen tank / Air stone and tubing (for longer transport, not needed if just being moved from one tank to another within the institution)
- Temp probe

Steps to follow when capturing a cuttlefish:

- Before starting check water temperatures in both new and current tank and adjust as needed.
- Using the nets guide the cuttlefish towards the surface of the water.
- Gently bring one net underneath the cuttlefish. You can use your free hand and extra net as a safe guard to block the cuttlefish if it should jet out of the water.
- Preferably use a bucket to scoop the cuttlefish out of the water. (It is best if the animal never has to leave the water as it may get air trapped un the mantle cavity)

- Carry the bucket of water containing the cuttlefish to wherever you need to release it. No time should be wasted once the cuttlefish is in the bucket as it could be stressful and will eventually run out of air or could ink.
- When you reach your new tank/enclosure you can gently lift the bucket into the water.
- Slowly tip the bucket till it starts to take in some of the new water. Once the bucket is nearly fully submerged you can gently tilt and lift it out so that the cuttlefish is left in the new tank.

7.3.2. The best method for collecting in the field

Collecting Mourning cuttlefish in the wild follows similar principles to capture in captivity. It is important to have spare buckets on the dive boat with aerated water so that if the animal inks it can be transferred into a new bucket to avoid asphyxiation. Divers work in pairs (this is due to dive safety regulations recommending a buddy system). A diver will try to gently coax a cuttlefish or a pair of cuttlefish into a soft bag. Once captured divers should swim slowly up to the boat to ensure that the cuttlefish are not bumped around too much. It is important to swim slowly to allow the cuttlefish to adjust their buoyancy as bringing them up from deeper water to shallow quickly can cause barotrauma. Use a spare bucket to gently scoop the cuttlefish up and into the boat. Place an air stone in the bucket straight away. Once back at the institution follow release steps from section 7.3.1 to place the cuttlefish into their new home.



Image 37



Image 38

Merimbula aquarium uses weighted tubs for collects. The top can be screwed off in two places, a small inner lid and the larger main lid depending on the animal being transported. The collects are conducted directly off the Merimbula wharf, close to the aquarium therefore the buckets don't require air stones for transportation. (Pers.Com Michael McMaster 2012)

7.4 Weighing and Examination

When weighing a cuttlefish it must be done as quickly and efficiently as possible. Removing an animal such as this from the water is extremely stressful. The cuttlefish will not be able to breathe while they are out of the water and their body may be damaged without the support of the water. If you need to weigh an animal catch it using the above-mentioned steps. Once in a small bucket gently scoop the cuttlefish into a soft net. This net can be hung on hanging scales. After the cuttlefish is returned to the bucket or tank the weight of the net can be removed from the weight recorded to find out the actual weight of the animal.

An alternative method to this would be to weigh and tare a bucket of water then place the cuttlefish in it. This will give a weight reading without having to remove the cuttlefish from the water. (Pers.Com Marina Tsamoulos 2012)

7.5 Release

Release into the tank should be done as quickly as possible without harming the cuttlefish. It is always helpful to float the bags in the water to help acclimate the animals to the temperature of its new tank. You can also allow small amounts of water into the bag to acclimate the animal to differences in chemical makeup of the water. When doing this it is important to consider how stressed the animal is looking. Remember that the less time the animal is being moved around the better so you may need to find a happy medium between the two.

7.6 Transport Requirements

7.6.1 Box Design

Outer container:

The transport container should be made of water-resistant material such as fiberboard, insulating material, plastic, wood, expanded polystyrene or Styrofoam. The transport container should not have any sharp edges or stapled closings, which may puncture the inner plastic bag.

Inner container:

This should be a strong plastic bag. It is easiest to fasten the bags by twisting the top and folding the twisted part so that can be easily sealed with elastic bands. The inner bag must be filled with water to approximately 1/3 of its capacity. The remaining 2/3 of the container should be filled with oxygen. (IATA Live Animal Regulations)

This is an example of what the transport container should look like:

EXAMPLE:

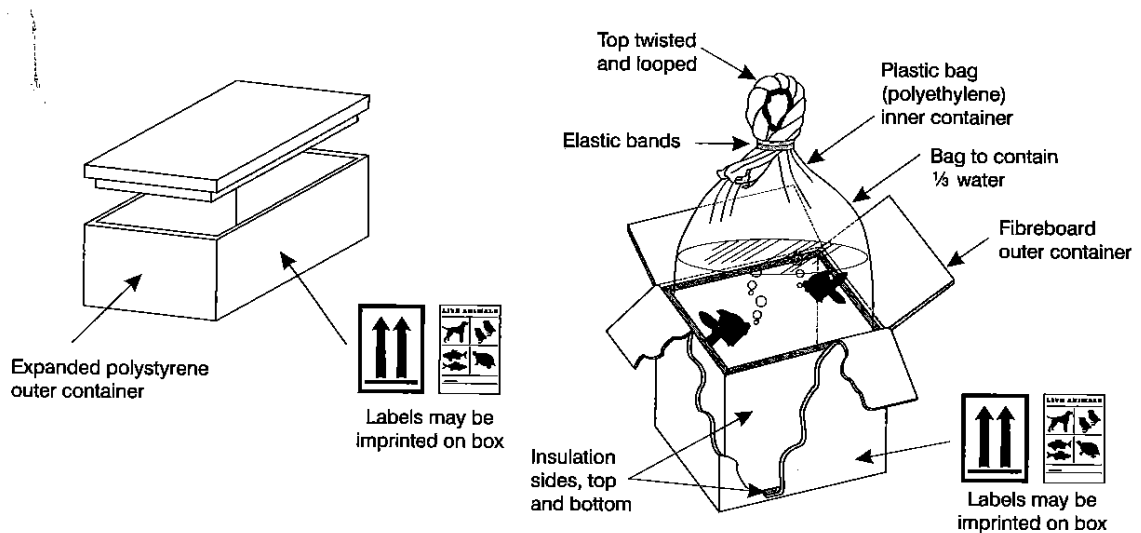


Image 39

7.6.2 Furnishings

There are no special furnishings required during transport.

7.6.3 Water and Food

The water should be well aerated. No food needs to be provided if it will be a short trip (less than 48 hours).

7.6.4 Animals per Box

There should always be one animal per bag. Stress of moving could cause animals to attack each other. There can however be multiple bags in the one box if space allows.

7.6.5 Timing of Transportation

The animals can be transported at any time of the day.

‘Important points to consider when transporting cuttlefish are:

- How long the trip will be? You need to minimise the amount of time the cuttlefish will spend in transit. Are you going to be traveling in peak hour traffic?
- If it's flying, try to arrive as close as possible to the flight departure time.
- Consider what time of year it is? For example transporting a cuttlefish in the middle of the day in the middle of summer, the bag water temperature is likely to increase. This will cause extra stress.

- If the cuttlefish is to be traveling for an extended period of time the cuttlefish will need to be routinely checked. If it inks it will soon suffocate without a water change.
- Overall, it is important to minimise the time spent in the bag!' (Pers.Com Marina Tsamoulos 2012)

7.6.6 Release from Box

Using a temperature probe you should check the temperatures of both the transport water and the tank the animal will be going into. You can also check the pH, DO (Dissolved Oxygen) and salinity. 'This is very important as the animal can become stressed if the water chemistry parameters are vastly different.' (Pers.Com Marina Tsamoulos 2012) It is always helpful to float the bags in the water to help acclimate the animals to the temperature of its new tank. You can also allow small amounts of water into the bag to acclimate the animal to differences in chemical makeup of the water. When doing this it is important to consider how stressed the animal is looking. Remember that the less time the animal is being moved around the better so you may need to find a happy medium between the two.

8 Health Requirements

Note: There is relatively very little information on the health and treatments of cephalopods. Most treatments have not been tested enough to have definite data on them. This section should only be used as a guide. Treatments should always be confirmed with your facilities veterinarian before implementation. It is always important to make the best effort to correctly diagnose a disease before treating as adding chemicals to the tank that are incorrect can sometimes further hinder recovery time for the animal.

8.1 Daily Health Checks

Each day distance observations are undertaken to assess the general health and wellbeing of the animals. This can easily be done during feeding and general maintenance procedures. Also as you are walking around the facility during other daily tasks it is good practice to keep an eye out for any changes that may occur during the day. Some things you should be looking for:

- All tentacles / arms appear to be moving freely.
- Feeding response is good.
- Eyes are clear.
- General appearance is good – colour looks good, no slime coating on skin, no patches of white marks etc (may be scar tissue where the chromatophores no longer work).
- Tissue damage.
- Changes in behaviour.

8.2 Detailed Physical Examination

It is very rare that you would physically restrain a cephalopod as you would with a terrestrial animal in a zoo / aquarium setting. These sort of procedures are normally undertaken in medical / behavioral research facilities.

If an animal did need to be anesthetized, magnesium chloride (MgCl_2) is a suitable anesthetic agent because it is easy to obtain, inexpensive, stable and nontoxic. (Gregory A. Lewbart) Made up as an isotonic solution by mixing 7.5% $\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$ (in distilled water) with an equal volume of sea water, this simple salt was found to be an effective anesthetic for cephalopods, especially *Sepia* who normally react to handling by violent inking. (Trevor Poole 1999)

Anesthesia by immersion is the only method used for cephalopods. Anesthesia by injection has not been attempted. Depth of anesthesia is controlled only by its concentration and the period of immersion. Signs of anesthesia are the progressive loss of activity and paling of the skin. Ventilatory movements slow down and stop, at which

point anesthesia is complete. Since fully anaesthetized animals have stopped breathing, they will begin to asphyxiate from that point on, even though the heart and circulation may be functioning. After 10 – 20 minutes (this estimate is from using an octopus) the animal must be returned to clean aerated seawater. Recovery can be assisted by flushing water through the mantle cavity. 2-5 minutes should be sufficient for full recovery. (Trevor Poole 1999)

Two other types of anesthetic compounds used are, urethane (ethyl carbamate) 3% in seawater used to be used, but is now usually replaced with ethanol (or industrial methylated ethanol, IMS) 2-2.5% in seawater at ambient temperature. (Trevor Poole 1999)

The use of anesthetics in cephalopods is at a relatively primitive stage. Little is known of the central effects of these compounds and the parameters of adjustment of anesthetic type or concentration to cephalopod species and body size. For many types of chronic physiological procedures or long surgical techniques continuous control over anesthetic level is clearly desirable, but as yet there have been no attempts to establish methods of continuous and controllable anesthesia. (Trevor Poole 1999)

8.3 Routine Treatments

At this point in time the best method to prevent disease in cephalopods is to maintain an extremely high level of water quality. There are no routine treatments. Providing good quality food at the correct quantity with a good variety of what's offered will also assist in maintaining a healthy animal.

8.4 Known Health Problems

In the wild, cephalopods can often survive major trauma. Healthy individuals that have been captured had several regenerating arms. In literature, numerous disease states have been reported in which cephalopods carry a wide variety of parasites and symbions, including viruses, bacteria, fungi, protozoans, nematodes, monogeneans, digeneans, cestodes, acanthocephalans, polychaetes, hirudineans, branchiuran crustaceans, copepods and isopods. (Gregory A. Lewbart) For example:

Fungus: Most fungal infections in cephalopods are secondary infections that occur as a result of trauma or something else compromising the immune system. The common fungus occurring in cephalopods is *Fusarium*.

Bacteria: The most common bacteria in cephalopods are *Vibrio*.

Viruses: Are even less described in cephalopods. (Greg 2007)

Some common pathogens encountered in cephalopods:

Category	Species affected
Bacteria	
<i>Vibro sp.</i>	Multiple Cephalopods
<i>Aeromonas hydrophila</i>	Multiple Cephalopods
<i>Citrobacter freundii</i>	Multiple Cephalopods
<i>Pseudomonas sp.</i>	Multiple Cephalopods
<i>Acinebacter anitratus</i>	Multiple Cephalopods
Viruses	
Virus particles: arm musculature	Octopus
Virus particles: stomach epithelium	Cuttlefish
Fungi	
<i>Fusarium sp.</i>	Nautilus
<i>Cladosporium sp.</i>	Octopus
Protozoans	
<i>Ichthyobodo sp.</i>	Octopus
<i>Aggregata sp.</i>	Multiple Cephalopods
<i>Microspora sp.</i>	Cuttlefish
<i>Chromidina sp.</i>	Multiple Cephalopods

In a study of 186 cuttlefish, the top ranked clinical disease syndromes were anorexia, mantle lesions, ocular lesions and lethargy. Septic conditions can lead to ocular opacities, but not all ocular opacities are related to infectious processes. The epidermal microvillous skin layer is one cell thick and contains many delicate mucous and columnar epithelial cells. The skin is easily damaged and, in captivity, cuttlefish can jet across the tank and damage the skin, eventually leading to septicemia and death. Mantle lesions are typically preceded by abnormal swimming behavior and commonly lead to secondary bacterial infections affecting multiple organ systems and leading to rapid death. If the force of the animals propulsion against the side of the tank is great, as in the case of the cuttlefish, the result may be cuttlebone fracture. If there is an air stone in the tank, they can hover in the stream of bubbles and eventually an air/gas pocket will form beneath the skin in the head region. This air pocket will break, causing an ulcer that will become septic and their death shortly afterward. The early treatment of lesions is useful, but not all lesions heal in a display tank. Cuttlefish with a fractured cuttlebone usually do not grow well and are best removed from the colony. (Gregory A. Lewbart)

Some possible treatments for bacterial infections are: Baytril or enrofloxacin. These can be administered intra-venous, orally or in a bath. The oral dosages are 10mg/kg and the bath dosage is 2.5mg/L for 5 hours. Be cautious with these dosages, as of 2006, are still only empirical values. Keep a close watch on the ventilation rate and overall behavior and if anything seems abnormal discontinue the treatment immediately. (Greg 2007)

‘Oral medication can be difficult due to the action of the beak as it feeds. The food will break up into the water as if feeds and some of the medication will be lost, possibly making it less effective. This is a problem when dose rates are very specific.’ (Pers.Com Marina Tsamoulos 2012)

Animals at the Institute of Neuroscience, University of Oregon ‘with bacterial lesions were treated daily for 10 days with 0.05 ml of chloramphenicol sodium succinate (100 mg=ml; Sigma) administered in their food. Animals were then carefully monitored for an additional 10 day period. This 20 day cycle was repeated if lesions were still visible after the observation period. In most cases the bacterial lesions disappeared after one or two 20 day cycles.’ (P.K. Loi and N.J. Tublitz 1998)



Image 40 – This shows a case of ‘face burn’. This condition is caused by constantly rubbing against the tank glass.

Finally, if you are able to keep a cuttlefish till the end of its natural lifespan, you may get to experience the animal going through senescence, which really means the process of getting old, but in cephalopods the process is gut wrenching. The onset of senescence is often marked by clouding of the eyes. Since eyesight is central to a cuttlefish’s hunting ability, such clouding can be disastrous (unlike octopus who rely heavily on other receptors such as in their arms for prey capture). The ability to track and capture prey is impeded, with the animals tentacles seeming to not function properly and an inability of the tentacular club to hold onto prey. Eventually, the animal can become lethargic, showing no interest in food or even moving. To make it even more painful, senescence can last for days or months. (Richard Ross)



Image 41 – This Mourning cuttlefish has reached senescence. In the final stage of its life the skin began to waste away (the white patches show where the skin had worn away). This particular individual also lost the ability to control its buoyancy.

Important Note: Never use fish medications without first checking what is in them as most fish medications contain copper. Copper will kill your cephalopod!!! There should never be copper in the tank.

8.5 Quarantine Requirements

Most animals that enter an aquarium will be housed in quarantine for a minimum period of time (around 30 days). The cephalopods however do not seem to require this time from a disease point of view however may need some time in quarantine or off exhibit to acclimate to living in captivity. These tanks should be made of perspex rather than glass to provide a softer surface if they jet into it.

There is little information at this point in time on quarantining cephalopods.

8.6 Euthanasia

The simplest and most effective way of killing a cephalopod is terminal anaesthesia. Whichever anaesthetic is used (see 8.2), respiratory movements stop within 5

– 10 minutes. If left in the anaesthetic the animal will quickly asphyxiate. Under anaesthesia the brain can be destroyed to ensure no recovery is possible. (Trevor Poole 1999) 'It is advisable to monitor the cuttlefish for a further 30 – 60 minutes following last observed respiration to ensure terminal anaesthesia.' (Pers.Com Marina Tsamoulos 2012)

8.7 Post Mortem results

(Needs further research)

9 Behaviour



Image 42 – 2 male Mourning cuttlefish *Sepia plangon*, in an agonistic display. The male in the middle is blocking the male to the back from reaching the female at the front.

9.1 General Behaviour

Although cuttlefish are invertebrates, they are much more like fish in their morphology, physiology and ecology as well as in their behavior. (Roger T Hanlon & John B. Messenger 1996) Cephalopods have the largest brain of any invertebrate.

Evolution and behaviour:

‘It has been argued that the evolution of the modern coleoids (cuttlefish, squids, octopus and their ancient relative, nautilus) has been influenced strongly by competition and predation pressures from fishes and marine reptiles from the Mesozoic onwards. In particular the adaptation of fish and reptiles in the near shore waters forced the shelled cephalopods into deeper offshore waters. One consequence of this was the loss of the chambered shell, because of the depth limits imposed by the hydrostatic pressure acting on the low-pressure gas spaces in the shell. Subsequently some of the new shell-less

coleoids returned to shallow waters to compete again with the teleosts (fish)'. (Roger T Hanlon & John B. Messenger 1996)

Sense organs:

‘The behaviour of an animal depends, among other things, on the kinds of information collected by its sense organs, on the nature of its effectors or motor apparatus and on the organization of the brain. (Roger T Hanlon & John B. Messenger 1996) Below is a brief outline of the organs that relate to behaviour:

- **Mechanoreceptors:**

Statocysts:

Statocysts are a paired organ situated in the cartilage below the brain. They provide information about gravity and acceleration. They are used to maintain correct orientation. They are also used to control countershading as well as being responsible for sensitivity to vibration. This sensitivity to vibration is often called infrasound. (Roger T Hanlon & John B. Messenger 1996)

Lateral line analogue:

Lateral lines found on the cuttlefishes head and arms are full of many thousands of hairs. These hairs pick up water movement or displacement. They are sensitive enough to pick up the movement of a 1m long fish at a distance of 30m. (Roger T Hanlon & John B. Messenger 1996)



Image 43 – Lateral lines shown on the face and arms of a cuttlefish.

- **Chemoreceptors:**

Cuttlefish are sensitive to chemical as well as tactile stimuli all over the body and are known to have chemoreceptors in the lips and on the suckers. (Roger T Hanlon & John B. Messenger 1996)

- **Photo receptors:**

Eyes:

Superficially the eye resembles the vertebrate eye. There is a large posterior chamber, lens, iris, retina, choroid, sclera and argentea. Despite the similarity to the vertebrate eye, the retina contains no rods or cones. In this sense it is more like the rhabdomeric type found in other molluscs and also in arthropods. (Roger T Hanlon & John B. Messenger 1996)

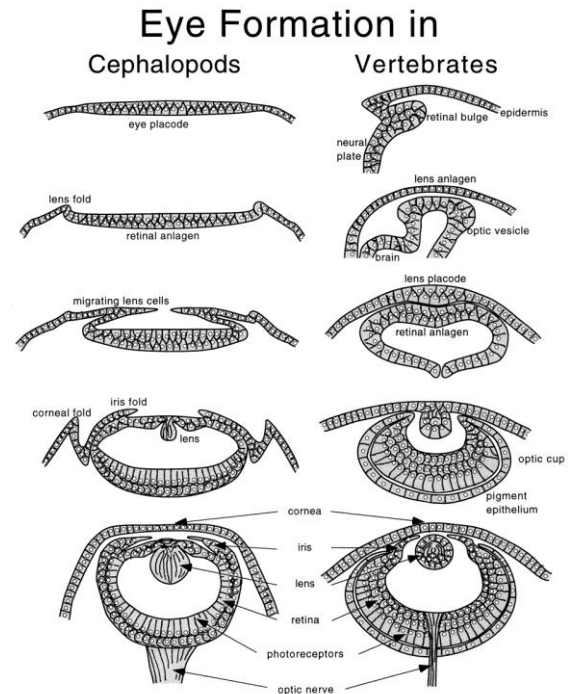


Image 44 – Eye formation.

Photosensitive vesicles:

Cuttlefish, like many other molluscs, possess photoreceptors other than the eyes. In cuttlefish there are photosensitive vesicles lying close to the olfactory lobe in the brain. Their function is not yet well understood. (Roger T Hanlon & John B. Messenger 1996)

- **Effectors** – The effectors are the body organs which effect an animals response to a stimulus. The most common effectors are muscles, however in cephalopods there are many more, such as, the chromatophores, reflecting cells, the photophores, the ink sac, the arm appendages and the buccal mass. (Roger T Hanlon & John B. Messenger 1996)

Muscles:

The muscles form 6 major structures: the fins, mantle, funnel, head and eye muscles, the arms and tentacles, and the skin muscles. (Roger T Hanlon & John B. Messenger 1996)

Chromatophores:

Chromatophores are part of the muscle system. Chromatophores contain pigment (black, brown, red, orange or yellow) and are surrounded by muscles. The muscles are linked to the nervous system and therefore can be contracted and relaxed at rapid speed. They allow patterns in the skin in a way that would be impossible in other animals. (Roger T Hanlon & John B. Messenger 1996)

Reflecting cells:

Reflecting cells may be found in the dermis, around the eyes and ink sac and sometimes in the photophores. They provide the blues and greens of the cephalopod body coloration. (Roger T Hanlon & John B. Messenger 1996)

Photophores:

These organs can produce a steady glow or give intermittent flashes. Not much is known yet on how these organs function. (Roger T Hanlon & John B. Messenger 1996)

Ink sac:

The ink sac comprises the ink gland and a reservoir with sphincters. (Roger T Hanlon & John B. Messenger 1996)

The buccal mass: beak, radula and the salivary system:

The buccal mass lies in front of the brain, in the center of the arms. The beak is chitinous and its musculature generally massive, which means it is a formidable weapon. (Roger T Hanlon & John B. Messenger 1996)

The brain:

Because cephalopods are advanced animals and have elaborate sense organs and effectors, their brains must routinely handle much more information than a limpet or snail. (Roger T Hanlon & John B. Messenger 1996)

9.2 Activity

Mourning cuttlefish are found around the temperate waters of the east Australian coastline. They are found at shallow depths up to around 80m deep. They are mostly found living in male / female pairs on sandy bottoms or near kelp beds. Their bodies have been specially designed to live in these types of environments. “One important structure is the internal cuttlebone. Rounded and shaped similar to a small, thickened shield, the cuttlebone is divided into many thin chitinous partitions, separating gas filled anterior chambers and fluid filled posterior chambers. Functionally similar to fish swim bladders,

the forward most gas-filled chambers are used to control buoyancy, aiding in easy hovering over the substrate. The smaller posterior chambers contain fluid that cuttlefish can manipulate, using strong mantle muscles to increase or decrease the internal volume. This specialized region of the shell enables the animals to angularly orient their bodies in the water column” (Kimberly Wright 2002)

Mourning cuttlefish are diurnal, meaning they are active during the day.

9.3 Social Behaviour

As mentioned before, Mourning cuttlefish live in loose social groups and are commonly found in male / female pairs. They are nowhere near as social as the schooling squid, however are more social than the solitary octopus.

9.4 Reproductive Behaviour

‘Cuttlefish use their diversity of locomotion to employ several characteristic reproductive behaviors. They actively participate in elaborate courtship displays, agonistic behaviors, mating rituals, and guarding tactics in order to reproduce.’ (Kimberly Wright 2002)

Mourning cuttlefish are both polygamous and polyandrous, which means the males will mate with multiple females and females will mate with multiple males. Generally they are found in pairs however a male without a mate will try to steal females off the others. ‘The reason behind the multiple matings may be to provide opportunity for sperm competition after copulation.’ (Jean Geary 1997) ‘Due to the short lifespan of the Mourning cuttlefish mating opportunities are limited and competition for fertilization success is obviously fierce.’ (Martin Garwood 2010) After mating and laying eggs both the male and female will die.

Mourning cuttlefish males utilize a deceptive dual gender body pattern in the presence of audience males. 'The deceptive males present a male specific (striped) pattern to the targeted female while presenting a female specific (mottle) pattern on the other half of its body facing the audience males. As the audience males perceive two females, the deceptive male can carry out an uninterrupted courtship.' (Martin Garwood 2010)



Image 45 - This amazing photo shows the male cuttlefish utilizing the dual gender display. The female is to the left of the shot viewing the male pattern, there is a male out of shot to the right who is viewing the female pattern.

9.5 Bathing

N/A

9.6 Behavioural Problems

In captivity the main behavioural problem is aggression caused by inadequate space or inappropriate ratio of females to males. If the cuttlefish fight they can not only injure themselves but also frighten others into the tank glass which will often cause 'butt burn', an infection which occurs through the skin breaking on contact when jetting into the glass. The best way to avoid this is to keep more females than males and to ensure an appropriate amount of space for each pair. Also ensuring there are enough visual barriers such as kelp and rock caves to help with creating small territories is very helpful. 'Also be mindful of sizes. Large individuals will outcompete smaller ones.' (Pers.Com Marina Tsamoulos 2012)



Image 46 – A male cuttlefish defending his female. There is a circular bite mark from his competitor at the top of his arms.

Bite



Bite

Image 47 – This male cuttlefish has a bite mark from a competitor on his side just below his head.



Image 48 – This picture depicts sever ulceration on the tip of the mantle. This is caused through jetting into the tank glass. Often a serious bacterial infection will follow, causing death.

9.7 Signs of Stress

Signs of stress in captive cuttlefish are:

- Anorexia
- Mantle lesions
- Mantle infections
- Missing limbs (through aggressive interactions)
- Irregular swimming patterns
- Irregular jetting
- Depression / Lethargy
- Agitation
- Aggression
- Hiding
- Inappropriate growth (runts)
- Lack of interest in food

9.8 Behavioural Enrichment

The best way to enrich a cuttlefish is to provide the best environment possible. Due to their loose social groupings it is better to house them in male / female pairs or in a small group, allowing enough space for each pair.

Due to the nature of their hunting technique and general lifestyle they do not play with a 'toy' in the way an octopus would. Instead of using their arms to explore rock crevices as an octopus would, they float mid water and catch their prey by ejecting their tentacles.

One of the most enriching husbandry methods is to feed live food such as appropriately sized crabs. The cuttlefish learn from a young age the specific angle they must attack to avoid being bitten by the crabs' claws.

9.9 Introductions and Removals

Once established in a territory, males can be aggressive towards others. Make sure there is enough space for both to hide if they want. Watch carefully to see how the animals react to one another. Male to male interaction will often involve sizing up to each other, displaying and forming the arms into a narrow point. This is aggressive behaviour and may result in physical contact. Male to female interaction will be much more peaceful. The male will try to solicit mating by touching the female with his arms. If she

is willing she will respond by facing the male head to head, opening her arms in a show of encouragement to mate. If she is not interested she will jet away from the male.

‘Inking is a characteristic behaviour shown by nearly all coleoid cephalopods. It can occur in two forms. First, the production of a well-defined ‘pseudomorph’, a blob of ink held together by mucus that hangs in the water while the emitter jets away. The pseudomorph is usually about the size of the cephalopod and probably serves to hold the visual attention of the predator while the cephalopod escapes. Second, cephalopods can produce a large cloud of ink like a ‘smoke screen’ behind which they can disappear. Cuttlefish can emit especially dense clouds of ink in aquaria.’ (Roger T Hanlon & John B Messenger 1996) If this happens it is important to monitor the tank to ensure the ink is removed quickly by the filtration system as the ink can coat the cuttlefish’s gills and cause asphyxiation. If the cuttlefish is in a closed system, water changes will be necessary.

When introducing a new animal to the tank, great effort must be made to ensure that the water parameters are as close as possible. It is also a good idea to acclimatize the new animal to the new tank by floating the bucket or bag that it was transported in in the tank to allow the temperature to slowly become exactly the same. Whilst this is being done small amounts of water periodically can be let into the bag to ensure the water content (salinity etc) is also exactly the same.

9.10 Intraspecific Compatibility

Mourning cuttlefish can be housed together, providing enough space and visual barriers are in place. They live in loose social groups in the wild and therefore are used to having conspecifics around.

9.11 Interspecific Compatibility

There are many different species that can be housed with the Mourning cuttlefish. Invertebrates such as crabs, snails and sea stars are good for cleaning up left over food, however small crabs may be on the menu for the cuttlefish so this needs to be taken into consideration. You can also house cuttlefish with some fish species, however a problem I have encountered at Sydney Aquarium is that fish can often become larger and more aggressive than the cuttlefish, and will steal all the food at feed times, scaring the cuttlefish away. ‘At Manly Oceanworld it has been found that bottom dwelling fish such as Flathead and Flounder work best as they don’t compete for food, as well as avoiding small fish that would pick at the cuttlefishes tentacles.’ (Pers.Com Marina Tsamoulos 2012)

9.12 Suitability to Captivity

Mourning cuttlefish are a great display animal. They are intelligent and interactive with the public, which makes them very popular displays. It is this intelligence as well as the need for extremely high water quality that can make them difficult to look after. Also their very short life span means that animals need to be replaced often. At the time of writing, aside from Merimbula Aquarium, Mourning cuttlefish are not bred for aquariums. They are wild caught. This is not an environmentally friendly practice as Mourning cuttlefish only reproduce once and therefore you are effectively removing any chance of the animal's genetics continuing in the wild. I believe that it is important for there to be a focus on the captive husbandry of cephalopods, including cuttlefish to increase the self sustainability of the species.

The Australian Museum found that Mourning cuttlefish are better suited to tanks or displays with solid back and sides, rather than glass on all sides. This allows them to feel more secure and startle less. (Pers.Com Chris Hosking 2012)

10 Breeding

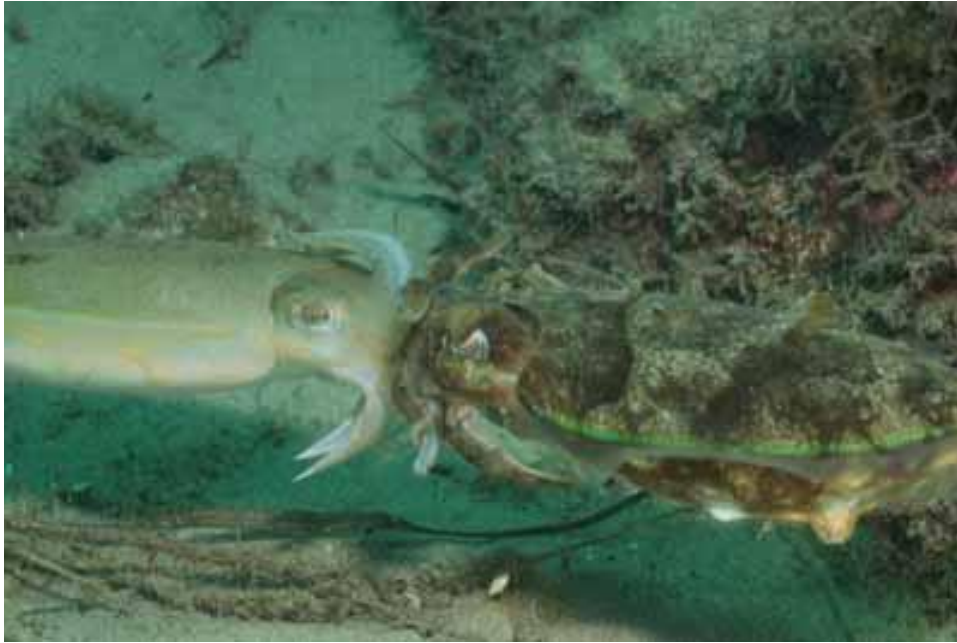


Image 49 – Mourning cuttlefish mating in the head to head position. They will mate in this position for a few seconds before releasing.

Sexual maturation of cephalopods is under control of hormones released from small bodies called optic glands located on the optic tract (connecting optic lobes to the brain). At the onset of sexual maturity, there is an apparent rapid process of gonad growth, yolk secretions and ripening of accessory glandular systems. After reproduction both males and females will die. The immediate causes of this apparently universal mortality are not clearly understood, but it is as if the sequence of physical changes brought about by the optic gland hormones cannot be reversed. (Trevor Poole 1999)

Mourning Cuttlefish mate in a head to head position common to many cephalopods. This mating will last for a few seconds and will be repeated multiple times. A male will try to guard the female however if a stronger male can steal her off him she may mate with them also. The new male may use his funnel to flush the original males spermatophores from the female before mating.

Males will display both to females as well as other males. These displays consist of the vibrant zebra stripe pattern as well as either spreading their bodies flat or long depending on what the situation requires. The male will try to encourage the female to mate by touching her around the head and arms with his arms. Once she agrees to mate they will mate in the head to head position. In this position the male uses a specially modified arm, the hectocotylus, to deposit the spermatophore from the Needhams sac into the females seminal receptacle, which is around the mouth. She will store this sperm until she is ready to lay her eggs at which time she will pass the eggs over the seminal receptacle to fertilize them before depositing them.

Below is a table showing general maturity stages in cephalopods:

TABLE 1. A general scale of maturity stages for male and female cephalopods. (AG = accessory glands, oviducal glands, NG = nidamental glands, SG = spermatophoric gland, SP = spermatophore, SOC = spermatophoric organ complex.)

Female			Male	
Maturity stage	Octopus and cuttlefish	Squid	Maturity stage	Octopus, cuttlefish and squid
0	Sex is not distinguishable. Gonad is a thin filament, attached to the main blood vessel of coelom.		0	The same as in female.
Juvenile			Juvenile	
I	AG Primordia. OG visible at both sides of coelom. Gonad is dull-grey filament. Oocytes are at phase II (Protoplasmic growth).		I	Primordium of SOC is visible on coelom membrane.
AG appearance and gonad development.			AG appearance and gonad development.	
II	Possible to distinguish parts of OG and NG. AG are usually dull white. Gonad has semi-transparent dull-white lamina. Oocytes are simple follicles.		II	Parts of SOC distinguishable. Gonad is dull-white. At the end of this stage the first spermatozoa appear in testis. SG is dull-white.
AG differentiation further gonad development.			AG differentiation, further gonad development	
III	Gonad is large, opaque and appear granular. Oocytes are at intercalary and protoplasmic growth phase. AG are completely formed and usually white.		III	Gonad is large, usually dull-white. Spermatozoa accumulate in testis ampullae. SG completely formed, usually white.
Gonad maturation, AG final formation.			Gonad maturation, AG final formation.	
IV	IV-1. First mature eggs appear in coelom.	No accumulation in coelom.	IV	Spermatozoa extrude into the coelom. Testis edges erode.
Mature gonad and eggs in coelom.	IV-2. Mature eggs accumulation in coelom (includes stage V).		Mature gonad and spermatozoa in coelom.	
V	Occurs at spawning.	V-1. First ripe eggs move to distal end of oviducts.	V	Spermatozoa move into the spermatiduct. No SP in the Needham sac.
Transport of mature eggs in gonoducts.		V-2. Eggs accumulate in oviducts, gonad still functional. V-3. Eggs accumulate with gonad eroding.	Transport of mature spermatozoa.	
VI	Occurs at spawning.	Occurs at spawning.	VI	VI-1. First SP appears in Needham sac. VI-2. SP accumulate with testis still functional. VI-3. SP accumulate with testis eroding.
Transport of eggs to the region of AG secretions.			Spermatozoa ready for fertilization.	
VII	Gonads spent.	Gonads spent.	VII	Gonad spent.
Gonads spent			Gonads spent.	

Image 50 - Atlantic Research Institute of Marine Fisheries and Oceanography

1. 10.1 Mating System

Males will guard females to try to prevent other males from mating with her, however if another male is able to steal her off the original male she may mate with him as well. The seminal receptacle is located just below the mouth and fertilization does not occur till the female removes the eggs from her body and passes them over the seminal receptacle before depositing them in a safe location such as under a rock ledge. This means that there is motivation for numerous males to mate with a female as his sperm may eventually fertilize the eggs.

10.2 Ease of Breeding

So far there is very little success with breeding Mourning Cuttlefish in aquariums within Australia. Merimbula Aquarium is the only institution that I have come across to have successfully incubated and raised Mourning cuttlefish. They put this down to using a minimal intrusion method of husbandry. The eggs are not removed from the tank and the water temperature is not altered at all from what is occurring in the wild. (Pers.Com Michael McMaster 2012)

Other institutions have incubated eggs that have either turned out to be unviable or the young die after hatching.

10.3 Reproductive Condition

10.3.1. Females

(Further research required)

10.3.2. Males

(Further research required)

10.4 Techniques Used to Control Breeding

Due to the fact that Mourning Cuttlefish have not been bred in captivity there is no reason for concern with regards to controlling breeding. If this were a concern then the best method would be to separate sexes. I suggest housing a group of females together rather than all males due to the fact that males will fight when housed together in an incorrect male to female ratio.

10.5 Occurrence of Hybrids

In captivity I have witnessed a male Reaper Cuttlefish *Sepia mestus* attempting to mate with a female Mourning Cuttlefish. The female seemed uninterested however matings could have occurred at other times. There are a few different points to consider with this; at this point there were no female Reaper Cuttlefish in the tank, possibly the male was choosing a female he normally would not due to the lack of a female of his own species. Both these species occur naturally in the same region and therefor there is a possibility of hybrids.

I am unable to find information to say whether or not hybrids do occur.

10.6 Timing of Breeding

Merimbula Aquarium found the Cuttlefish to begin laying around October / November. They laid eggs for around 6 weeks. The egg laying period was complete by the end of November. Eggs hatched during December / January. The eggs hatched over a period of 6 – 8 weeks. (Pers.Com Michael McMaster 2012)

The egg laying appears to be daily. Towards the end of the 6 weeks the quality of the eggs deteriorates. Eggs will occasionally be laid that are not formed properly. They may be smaller, appear less full or shriveled. (Pers.Com Michael McMaster 2012)

10.7 Age at First Breeding and Last Breeding

Mourning Cuttlefish will only reproduce once in their life. Once they have reproduced both males and females will die.

Males of most species of cephalopods mature early in life, around 3 – 6 months. They are capable of passing ripe spermatophores to females for roughly 2/3 of their life span. Females usually mature around 4 – 8 months and can also mate and store sperm for up to 2/3 of their life. (Roger T. Hanlon & John B Messenger 1996)

1. 10.8 Ability to Breed Every Year

Mourning cuttlefish reproduce once in their lifetime.

10.9 Ability to Breed More than Once Per Year

Mourning cuttlefish reproduce once in their lifetime.

10.10 Nesting, Hollow or Other Requirements

Cuttlefish will often lay their eggs in a secluded area of the tank. Objects should be placed in the tank that the female will feel are a suitable area to protect the eggs. Rock over hangs, hollows, tubes, pots or any number of shelter can be used. It is important to consider if the eggs are going to be left on display or removed as many objects are not easy to remove once there are eggs attached.

Merimbula Aquarium found the female was very selective in where the eggs were placed. They found that any area of the tank that was likely to form algae was not used. Mostly the eggs were laid in areas of shade. (Pers.Com Michael McMaster 2012)



Image 51 – Mourning Cuttlefish at Merimbula Aquarium.
They have chosen a rock overhang to lay their eggs.



Image 52



Image 53

These pictures of *Sepia marmorata* eggs were taken at the Australian Museum. The female chose very well hidden areas of the tank to lay the eggs. Even though the eggs were hidden in rock overhangs the museum reported egg loss from other tank mates such as snails and crabs eating the eggs.



Image 54



Image 55

These images show the off display tank with *Sepia mestus* eggs. The female chose to lay her eggs inside a brick.

As with adult cuttlefish, young and juvenile cuttlefish require a high level of water quality. When Richard Ross of the California Academy of Sciences bred *S. bandensis* his water parameters were; temp 26C, salinity 33-35 ppt, pH 8-8.4, calcium 380-400 ppm, alkalinity 7-9 dKH, ammonia 0, nitrate 0-10 ppm (NO₃), PO₄ 0.05 ppm or below.

10.11 Breeding Diet

As mentioned before you can easily get cuttlefish onto feeding on defrosted food, however many different articles suggest that it is healthier and I believe more enriching for the cuttlefish to be fed live food. Live mysid shrimp and small crabs are a good option. Also feeding the cuttlefish 2 times a day instead of one, or ensuring there is always a good supply of food (live food, as you cannot leave dead food in too long) in the tank will encourage reproduction through good general health.

During the laying period Merimbula Aquarium staff feed the cuttlefish twice a day to increase body condition and support health during this time of energy use. Outside of this period they are fed daily or every second day. (Pers.Com Michael McMaster 2012)

10.12 Incubation Period

Females generally lay their eggs a few weeks after mating.

Development time in the egg depends on the species, temperature, and ranges from less than 10 to over 100 days. (Trevor Poole) *S.bandensis* at the Steinhart Aquarium hatched in approximately one month. (Richard Ross 2010) Mourning cuttlefish eggs at Merimbula Aquarium also hatched after about one month. (Pers.Com Michael McMaster 2012) If the eggs were left with the adult cuttlefish the mother may show some care of the eggs such as blowing water around them to keep them aerated and keep them clean, however it is recommended that the eggs be removed to be incubated in a specifically designed tank.

‘The egg masses need gentle circulation of clean aerated water. Commonly used methods to achieve this include suspending the egg masses in water from threads across the tank, or in containers such as net bags or floating plastic strainers. Direct agitation from stirrers or aeration bubbles should be avoided, and low light levels should be maintained.’ (Trevor Poole) At the Steinhart Aquarium the eggs were kept in a pet pack / critter keeper style enclosure suspended in a larger tank. ‘Water was supplied to the critter keeper by a Maxi Jet 1200 power head in the sump of the system, with the flow rate controlled by a ball valve. The water gravity drained through the slotted lid into the weir box. There was enough flow to gently keep the eggs ‘swaying’.’ (Richard Ross 2010)

10.13 Clutch Size

At Merimbula Aquarium there were three females within the one tank. Two females were larger in size and one smaller. Between them there was over 100 eggs laid.

After about one month, the baby cuttlefish emerge from the eggs ready to meet the world. Sometimes a yolk sack is still attached, however this is generally considered to be an effect of a premature hatching. ‘Though tiny, they are perfect replicas of their parents and begin color

changing almost immediately (and even while still in the egg)’ (Richard Ross 2005) Mourning cuttlefish appear to hatch at night. (Pers.Com Michale McMaster 2012)



Image 56 - *S.bandensis* laying eggs while the male guards them. These eggs are quite different from the Mourning cuttlefish eggs as they are filled with ink. Mourning cuttlefish eggs are white in colour and oval in shape. As the cuttlefish matures the eggs becomes transparent and you can see the young inside the eggs.

Some estimates of other cephalopods suggest they can lay between 25 – 1000 eggs depending on the species.

Below are some amazing pictures of young cuttlefish inside their egg.



Image 57

Baby *S.bandensis* inside the egg.

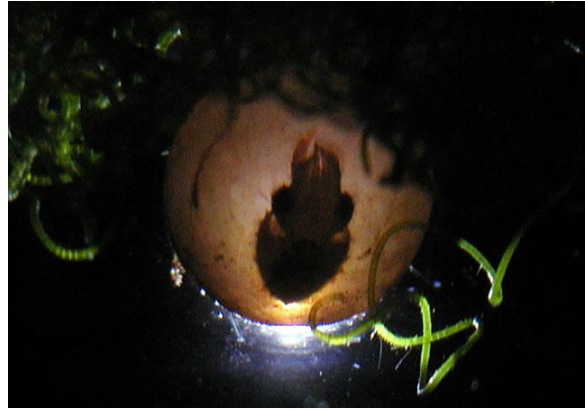


Image 58

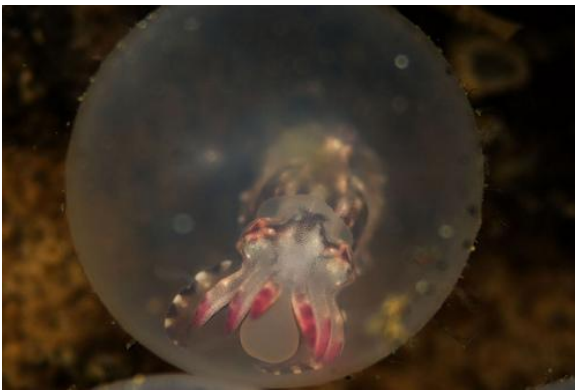


Image 59

Baby Flamboyant Cuttlefish *Metasepia pfefferi*



Image 60

10.14 Age at Weaning

It is recommended that the eggs are removed to a separate tank designed specially for incubation and hatching as well as holding the young. When the cuttlefish hatch in this specified tank it is ok to leave them in it till they are approximately 12 weeks or until you see sexually related aggression / competition between the young. At this point you will need to break up the young into smaller groups, preferably with many more females to males to reduce fighting.

10.15 Age of Removal from Parents

There is no parental care on the young. When they hatch they are miniature replicas of their parents. They are capable of hunting by themselves and colour change. This can sometimes be seen even before they hatch!

10.16 Growth and Development

Hatchlings grow very quickly and will eat a lot of food. Most hatchling cephalopods double their weight every week or so for the first few months. (Dr. James B. Wood)

Below is a graph showing the mean growth rate, feeding rates as well as food conversion for *Sepia officinalis*. This study was done between hatchling – 40 days old. This species of cuttlefish is larger than the Mourning cuttlefish however I believe it will still act as a good guide to how quickly a cephalopod can grow.

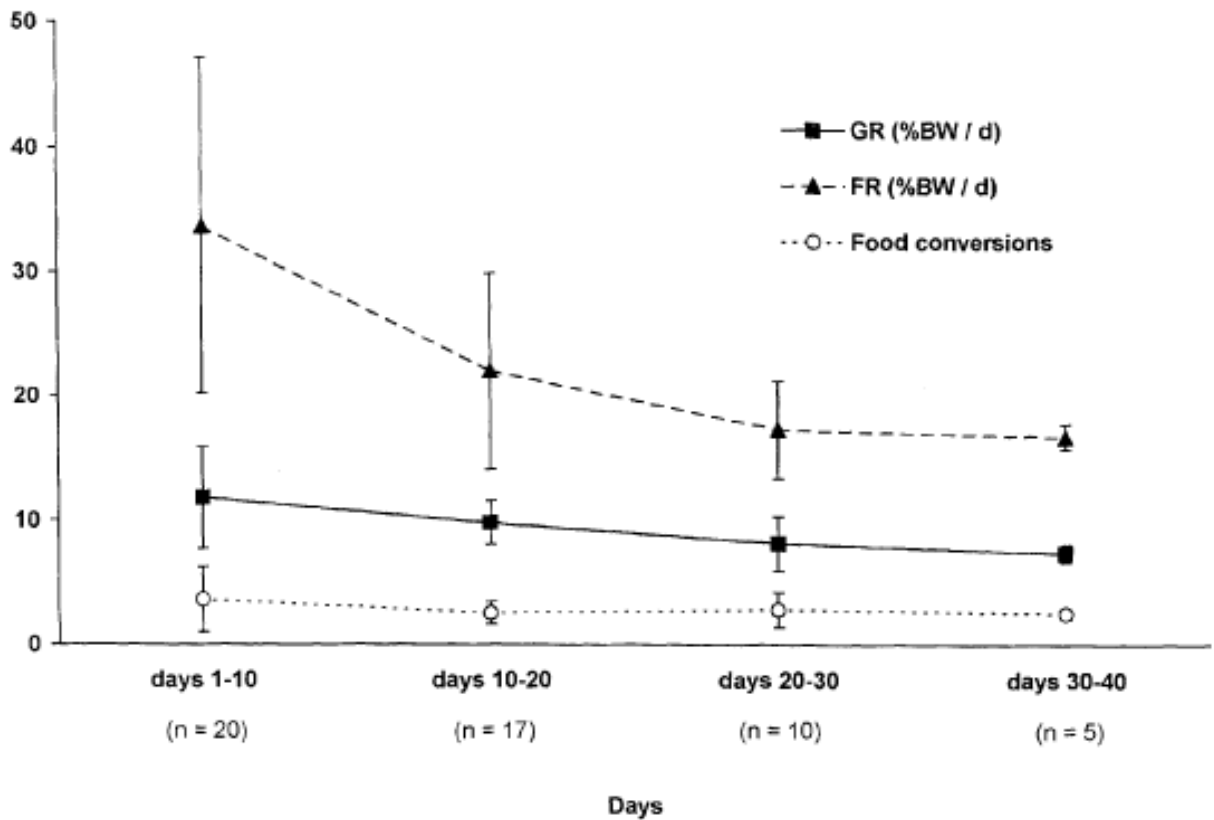


Image 61 – Mean growth and feeding rates as well as food conversions for *Sepia officinalis*, hatchling to 40 days old.

11 Artificial Rearing

11.1 Tank set up

There are three different options for tank set up. Different institutions have different preferences. One is to have a separate tank that the eggs are removed to, to incubate. Two is to set up a small incubation tank within the main display, and three is to leave the eggs to incubate on display wherever the female has chosen to lay them. Some aquariums believe that the female knows best where to place the eggs so why move them. The material for the small incubation tanks can be either Perspex or glass structures or fish breeder nets also work well. The breeder nets seem to be the preferred option for breeders internationally.

Removing the eggs from where they are laid to the incubation tank must be done with extreme care. The eggs can be easy to puncture. If it is possible to remove a rock cave that the eggs are laid in then it may be easiest to keep the eggs attached and move the whole structure. If this is not possible then you need to gently cut the eggs away from the rock etc taking care not to puncture the egg. Eggs should be removed from the tank by scooping them into a container full of tank water, rather than using a net. The net will not provide enough support to the eggs.



62



63

Images – *Sepia bandensis* in an incubation set up. Image 62 shows a perspex box within the main tank. Image 63 shows a net breeder set up within a tank.

The incubation tank whether set up within the main tank or set on its own needs to have a gentle flow of water to ensure enough oxygenated water is circulated around the eggs. The water will also need to be of very high quality. Ammonia, nitrate and nitrite should all be below 0.01. There should never be any copper or heavy metals in the cuttlefish tank as these are fatal to the cuttlefish. Care should be taken to ensure that any

tanks that are used for the incubation and growth have not been medicated with fish medication as these often contain copper.

11.2 Incubation Temperature

The temperature that you incubate the eggs will alter the rate at which they hatch. 'At the present time, all published information about the reaction of water temperature on the embryonic development of cephalopods, makes the assertion that this factor has a direct influence, by increasing the speed of growth-rate and development.' (Olivier Bouchaud 1991) If temperature is increased the eggs will hatch sooner but possibly be smaller hatchlings. If the temperature is decreased the hatchlings will hatch later but can be larger.

Mourning cuttlefish reproduce during the summer months. They have quite a range up and down the east coast of Australia therefore the temperatures at which the eggs are incubated will vary quite a bit. The temperature during summer in Sydney averages 22 Degrees Celsius. Merimbula is located about 6 hours drive south of Sydney. The water there during December / January is usually around 18 – 19 Degrees Celsius. Merimbula Aquarium does not alter the temperature of the water therefore the incubation temperature is around this. The water is pulled directly from the ocean, therefore any naturally occurring temperature fluctuations will also occur in the tank. (Pers.Com Michael McMaster 2012)

11.3 Diet and Feeding Routine

The Institute of Neuroscience, University of Oregon, uses the following diet for raising cuttlefish (*Sepia officinalis*): 'All Sepia younger than 3 months will require live food. Hatchlings to 3 week old cuttlefish are fed small amounts of adult brine shrimp four to five times a day. Three to 5 week old cuttlefish eat a mixture of adult live brine shrimp, various species of feeder fish (approximately 2.5 cm long), and/or zebrafish hatchlings (one fish/cuttlefish/each feeding). The diet of 5 week to 3 month old juveniles consists of goldfish, adult zebrafish and/or guppies (1±3 fish/cuttlefish/each feeding). Sepia older than 3 months survive well on frozen shelled shrimps (1±2 shrimps/cuttlefish/each feeding) bought from a local grocery store and thawed just prior to feeding. Except for hatchlings, animals are fed twice a day, once in the morning and again in the late afternoon. Periodically, the adult diet is supplemented with 0.05 ml/day of chloramphenicol sodium succinate (100 mg/ml; Sigma) injected into thawed shrimp immediately prior to feeding as a preventive measure against infection. This diet is similar to that given to cuttlefish reared in the large scale Galveston facility.' (P.K. Loi and N.J. Tublitz 1999)

It is important to note that some state regulations prohibit feeding live vertebrates. This is the case in NSW. The live fish provided in the above diet could be replaced with thawed fish such as whitebait.

Merimbula Aquarium fed a varied diet to their young cuttlefish. They fed live Mysid shrimp, Estuary shrimp and Rock pool shrimp. The Mysid shrimp were delivered to the aquarium and the estuary and rock pool shrimp were collected from the wild almost daily. The food was placed in the tank and the young hunted for themselves when they were hungry. The live food was monitored in the tank and topped up as required. They found the young cuttlefish to be more cryptic than the adults when it came to feeding. The young usually preferred to hunt during the night rather than in the day, as the adults do. (Pers.Com Michael McMaster 2012)

11.4 Data Recording

The below information should be recorded for each animal:

- Hatching date
- Feeding response
- How much is eaten
- What is fed
- Sex (this may be difficult till they begin to display gender specific colour patterning)
- Internal movements

11.5 Identification Methods

There are no safe methods such as banding or tagging for identifying the young cuttlefish. The cuttlefish's ability to rapidly change their body colour and patterning also limits the effectiveness of photo id.

11.6 Hygiene

It is important to provide a very hygienic environment for the young cuttlefish. Excrement and left over food should be removed once or twice a day to reduce bio-load on the aquarium.

When cleaning or performing maintenance on the tanks the equipment used should be kept specifically for these tanks. Having a set of equipment for each area reduces cross contamination from tank to tank.

11.7 Behavioural Considerations

Cuttlefish are very timid animals. They can be easily frightened. If this happens they will either ink or jet about in an effort to get away. If they ink there is a possibility of

asphyxiation. This happens because the ink will coat the cuttlefish's gills. If the cuttlefish ink an immediate water change must be done to clear the water.

When the cuttlefish jet backwards they can cause damage to their mantle. This can then lead to infection and death. The best way to prevent this is to provide places for the cuttlefish to hide from each other. Also limiting the number of cuttlefish in each tank will reduce stress around feeding time when the young cuttlefish can scare each other by grabbing the same bit of food. Limiting the amount of activity around the tank will also reduce stress.

As the cuttlefish become older they will start to form territories. To prevent fighting there should be enough room for each cuttlefish. Providing shelter and visual barriers is a good way to reduce fighting. When they are old enough to pair up, an appropriate male / female ratio should be kept. If there are not enough females for each male they will continually fight.



Image 64 – Male Mourning cuttlefish fighting.

11.8 Weaning

There is no point in time where a cuttlefish is weaned. They are self-sufficient hunters from the moment they hatch. There does however come a point where they can be transferred from live mysid shrimp onto dead thawed fish.

Cuttlefish are very movement orientated. They can be reluctant to eat dead food, as it doesn't stimulate a good feeding response. This can be overcome in a similar way wild caught adult cuttlefish are transferred onto dead food. A piece of food such as whitebait can be loosely tied to a strand of fishing line. This can be dangled and bounced in front of the cuttlefish as if it is a struggling fish. Once the cuttlefish are readily accepting this form of food presentation you can start dropping fish in from the surface.



65



66

Images show a cuttlefish grabbing whitebait off a weighted fishing line.

1. 12 Acknowledgements

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13 References

Publications

- Colin Dunlop & Nancy King 2009 – Cephalopods: Octopuses and Cuttlefishes for the Home Aquarium. T.F.H. Publications, Inc.
- Gregory A. Lewbart 2006 – Invertebrate Medicine, Blackwell Publishing
- Dr. James B. Wood – Cuttlefish Husbandry: Part IV - How do cuttlefish reproduce? The Cephalopod Page www.thecephalopodpage.org
- Jean Geary 1997 - Female choice of males in cuttlefish (Mollusca:Cephalopoda). Marine Biomedical Institute, University of Texas Medical Branch
- Kimberly Wright 2002 - Biomechanics and Behavioral Adaptations associated with Cuttlefish Locomotion
- P.K. Loi and N.J. Tublitz 1998 - Long term rearing of cuttlefish in a small scale facility. Aquarium Sciences and Conservation, 1999. Kluwer Academic Publishers. Printed in the Netherlands.
- Martin Garwood 2010 – In two minds: Cuttlefish dual gender deception. Department of Biological Sciences, Macquarie University
- Olivier Bouchaud 1991 - ENERGY CONSUMPTION OF THE CUTTLEFISH *SEPIA OFFICINALIS* L. (MOLLUSCA: CEPHALOPODA) DURING EMBRYONIC DEVELOPMENT, PRELIMINARY RESULTS. BULLETIN OF MARINE SCIENCE, 49(1-2): 333-340
- P.K. Loi and N.J. Tublitz 1999 - Long term rearing of cuttlefish in a small scale facility. Institute of Neuroscience, University of Oregon, Eugene, OR 97403 USA. Aquarium Sciences and Conservation, 2: 135-143, 1999. Kluwer Academic Publishers. Printed in the Netherlands.
- Richard Ross 2005 – Keeping and Breeding the Dwarf cuttlefish *Sepia bandensis*, The Cephalopod Page, www.thecephalopodpage.org
- Richard Ross 2010 – Drum and Croaker, A highly Irregular Journal for the Public Aquarist. Display, Husbandry and Breeding of Dwarf Cuttle, *Sepia bandensis*, at the California Academy of Sciences. Steinhart Aquarium, California Academy of Sciences, 55 Music Concourse Drive, Golden Gate Park, San Francisco CA, 94118 USA
- Roger T Hanlon & John Messenger 1996 - Cephalopod Behaviour, Cambridge University Press
- Trevor Poole 1999 – The UFAW Handbook on The Care and Management of Laboratory Animals, Seventh Edition, Volume 2, Amphibious & Aquatic Vertebrates & Advanced Invertebrates, Blackwell Science

Pers.Com

- Amy Wilkes 2011 – Senior Aquarist, Sydney Aquarium, Sydney, Australia
- Chris Hosking 2012 – Interpretive Officer, Australian Museum, Sydney, Australia
- Marina Tsamoulos 2012 – Senior Aquarist / Vet Nurse, Oceanworld, Manly
- Martin Garwood 2011 – Senior Aquarist, Sydney Aquarium, Sydney, Australia
- Michael McMaster 2012 – Curator, Merimbula Aquarium, Australia
- Paul Baker 2011 – Senior Aquarist, Sydney Aquarium, Sydney, Australia
- Steve Vogel 2012 – Information Coordinator, Australian Museum, Sydney, Australia
- Tersia Greenstone 4/6/11 – Aquarist level 2, Town Oceans Aquarium, Cape Town, South Africa

Websites

- PIRSA Fisheries – Government of South Australia,
http://www.pir.sa.gov.au/fisheries/recreational_fishing/target_species/cuttlefish

14 Bibliography

- Amazing Facts about Australian Marine Life, Steve Parish Publishing 2008
- An Introduction to Marine life, Museum Victoria, Robin Wilson, Mark Norman Anna Syme 2007
- Atlas of Invertebrate Anatomy, DT Anderson, University of New South Wales Press 1996
- Common Cuttlefish (*Sepia officinalis*) Mortality at the National Zoological Park: Implications for clinical management. Johanna Sherrill, D.V.M., M.S., Lucy H. Spelman, D.V.M., Dipl. A.C.Z.M., Carrie L. Reidel, B.S. and Richard J. Montali, D.V.M., Dipl. A.C.V.P., Dipl. A.C.Z.M. *Journal of Zoo and Wildlife Medicine* 31(4): 523–531, Copyright 2000 by American Association of Zoo Veterinarians, page 524
- First multi-generation culture of the tropical cuttlefish *Sepia pharaonis* Ehrenberg, 1831. J.W. MINTON, L.S. WALSH, P.G. LEE and J.W. FORSYTHE. *National Resource Center for Cephalopods (NRCC), Marine Biomedical Institute, University of Texas Medical Branch, Galveston.*
- Invertebrate Zoology 7th Edition. A Functional Evolutionary Approach. Ruppert. Fox. Barnes. Copyright 2004 Brooks / Cole, a division of Thomson Learning Inc.
- Telemetered Cephalopod Energetics: Swimming, Soaring, and Blimping. Ron O'Dor 2002. *Census of Marine Life, CORE, 1755 Massachusetts Ave., Washington, D.C. 20036*
- The Manual of Marine Invertebrates, Martyn Haywood, Sue Wells 1989

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- 1) Cover image – Dave Harasti
[http://www.scuba-equipment-usa.com/marine/FEB04/Mourning_Cuttlefish\(Sepia_plangon\)3.html](http://www.scuba-equipment-usa.com/marine/FEB04/Mourning_Cuttlefish(Sepia_plangon)3.html)
- 2) Unknown source
- 3) <http://egeology.blogfa.com/page/cephalopoda.aspx>
- 4) www.flickr.com/photos/rling/page50/
- 5) www.flickr.com/photos/haruspex/page52/
- 6) www.enchantedlearning.com/cgifs/Cuttlefish_bw.GIF
- 7) w3.shorecrest.org/.../cuttlefish_anatomy.jpg
- 8) Martin Garwood
- 9) www.pbs.org/wgbh/nova/camo/images/anat-main.jpg
- 10) www.biolib.cz/IMG/GAL/12061.jpg
- 11) www.flickr.com/photos/rling/2326888365/
- 12) www.manandmollusc.net/.../Images/nautilus.jpg
- 13) <http://www.divearound.com.au/fish/Mourning-Cuttlefish>
- 14) Gregory J Barord
- 15) Gregory J Barord
- 16) Gregory J Barord.
- 17) Kerrie McDonald
- 18) Kerrie McDonald
- 19) Kerrie McDonald
- 20) Kerrie McDonald
- 21) Kerrie McDonald
- 22) Kerrie McDonald
- 23) Kerrie McDonald
- 24) Kerrie McDonald
- 25) Kerrie McDonald
- 26) Kerrie McDonald
- 27) Kerrie McDonald
- 28) Chris Hosking, Australian Museum
- 29) Kerrie McDonald
- 30) Kerrie McDonald
- 31) <http://www.fishlore.com/NitrogenCycle.htm>
- 32) <http://www.tonmo.com/articles/basiccuttlefish.php>
- 33) Cephalopod Behaviour, Roger T Hanlon & John B Messenger, page 15, top of page.
- 34) Cephalopod Behaviour, Roger T Hanlon & John B Messenger, page 54, top of page.
- 35) Kerrie McDonald 2011
- 36) Cephalopods: Octopuses and cuttlefishes for the Home Aquarium, Colin Dunlop & Nancy King, page 121
- 37) Kerrie McDonald
- 38) Kerrie McDonald
- 39) Kerrie McDoanld
- 40) IATA Standards 36th Edition October 2009
- 41) Tonmo Website, Online Cephalopod Form – www.tonmo.com
- 42) Kerrie McDonald
- 43) Merimbula Aquarium
- 44) Cephalopod Behaviour, Roger T Hanlon & John B Messenger, page 15, top of page.
- 45) <http://www.pnas.org/content/94/6/2098.full>
- 46) Martin Garwood
- 47) Kerrie McDonald
- 48) Kerrie McDonald
- 49) Common Cuttlefish (*Sepia officinalis*) Mortality at the National Zoological Park: Implications for clinical management. Johanna

- Sherrill, D.V.M., M.S., Lucy H.
 Spelman, D.V.M., Dipl. A.C.Z.M.,
 Carrie L. Reidel, B.S. and Richard J.
 Montali, D.V.M., Dipl. A.C.V.P., Dipl.
 A.C.Z.M. *Journal of Zoo and Wildlife
 Medicine* 31(4): 523–531, Copyright
 2000 by American Association of
 Zoo Veterinarians, page 524
- 50) Nigel Marsh, Consummating
 Cuttles, an article from Asian Diver
 Magazine, No.94 Dec 2007/Jan
 2007
- 51) Reproductive System Structure,
 Development and Function in
 Cephalopods with a New General
 Scale for Maturity Stages. A. I.
 Arkhipkin Atlantic Research
 Institute of Marine Fisheries and
 Oceanography (AtlantNIRO) 5
 Dmitry Donskoy Street, Kaliningrad,
 236000, USSR
- 52) Anna McDonald 2011
- 53) Kerrie McDonald
- 54) Kerrie McDonald
- 55) Kerrie McDonald
- 56) Kerrie McDonald
- 57) Richard Ross
- 58) Mike Irving, The Cephalopod Page,
www.thecephalopodpage.org
- 59) Richard Ross, The Cephalopod Page,
www.thecephalopodpage.org
- 60) The Amazing Cephalopoda Class,
<http://cephalopodlove.tumblr.com>
- 61) The Amazing Cephalopoda Class,
<http://cephalopodlove.tumblr.com>
- 62) Growth of young cuttlefish, *Sepia
 officinalis* (Linnaeus 1758) at the
 upper end of the biological
 distribution temperature range. P
 M Domingues, T Kingston, A Sykes
 & J P Andrade, 2001
- 63) Daniel Pon
- 64) Daniel Pon
- 65) Lumir Kalbac 2012
- 66) Kerrie McDonald
- 67) Kerrie McDonald

16 Glossary

Asphyxiation - The condition of being deprived of oxygen (as by having breathing stopped).

Buccal mass - The buccal mass is the mouth area on a cuttlefish. It contains the beak, radula and the pharynx.

Chemoreceptors - A sensory nerve cell or sense organ, as of smell or taste, that responds to chemical stimuli.

Chitinous - A tough protective covering or structural support in certain organisms.

Esophagus - The esophagus is the tube that carries food, liquids and saliva from the mouth to the stomach.

Growth lamellae - lamella is a thin plate-like structure, often one amongst many lamellae very close to one another, with open space between. With regards to the cuttlefish these structures are the growth increments of the cuttlebone.

Radula - A band of chitinous teeth used to drill into and break up food.

Spermatophore - A capsule, packet, or mass enclosing sperm that is extruded by the male of various animals such as invertebrates and is transferred to the reproductive tract of the female.

17 Appendix

The following two pages are examples of daily record sheets.