SPUMS ANNUAL SCIENTIFIC CONFERENCE 1987

which was caught on the bottom. He succeeded in doing this and was then observed to ascend rapidly. On reaching the surface complained of feeling nauseated. He was helped aboard the boat, his nausea was then worse but he attributed this to sea sickness. Within a further 2 or 3 minutes he collapsed on the dive boat. The description we have from his buddies was that he soon went unconscious. He was unable to speak. He was unable to open his eyes and one buddy described him as going rigid in the back. The buddies said that he was "unconscious" for perhaps 90 minutes. When he was brought to shore he was subsequently transferred by air ambulance to the Prince Henry Hospital Hyperbaric Unit in Sydney. I expected that he would have been transferred to Morwell as he came from Bairnsdale. He arrived in Sydney within approximately 4 hours of the diving accident, not pressurised, and when admitted to the hyperbaric unit he was fully conscious, it was noted that he was not speaking correctly and he used incorrect words. His mental processes seemed to be somewhat slow, his blood pressure was 180/120 initially but after resting for 20 minutes this fell to 150/80. A chest x-ray was done and this revealed no abnormality. He was immediately put into the hyperbaric chamber on oxygen.

In the meantime a full blood count and electrolytes were normal. The most interesting thing in the first blood test, which became available while he was still in the chamber, was the fact that his carboxyhaemoglobin was 20%. He was treated on the usual tables and by the following day his carboxyhaemoglobin had returned to normal. His CT scan showed a diffuse mild cerebral oedema but no other abnormality and an EEG showed some mild abnormalities on the left side with hyperventilation.

His treatment involved after the hyperbaric treatment, 2 days in bed and he was then mobilized. On the fourth day, after being examined by a neurologist, he was permitted to leave hospital.

I think it is worthwhile pointing out that carbon monoxide is toxic, it is odourless and it is tasteless. The greatest problem with it is its affinity to combine with haemoglobin, 200 times greater affinity than oxygen, to form carboxyhaemoglobin. Carboxyhaemoglobin displaces oxygen and hence if sufficient combination occurs hypoxia will result. The hypoxia produces symptoms. Probably some symptoms occur as a result of a direct toxic effect on the cell.

The interesting thing in the treatment of this patient was the fact that he, perhaps accidentally, received the correct treatment by having hyperbaric oxygen. The amount of oxygen in solution was increased so that the supply of oxygen to the cells and tissues was increased and the haemoglobin system was more or less bypassed. At the same time of course the oxygen encouraged the more rapid diffusion of carbon monoxide. As you know the correct treatment for most cases for carbon monoxide poisoning is hyperbaric oxygen.

In summary then, this was a sports diver who had two dives, one and somehow or other his hookah intake was contaminated with carbon monoxide from the compressor. Presumably he had some symptoms at the end of the first dive and they became much more pronounced on the second dive. I would have thought that if he had a carboxyhaemoglobin of 20% at least four to six hours after emerging from the sea, the level at the time when he came to the deck may well have been 50%. At 14%, divers may have headache, dizziness and some breathlessness on exertion. At 30% they usually become confused and supposedly at 60% they become unconscious. This patient maintains, during the 90 minutes that his buddies thought he was unconscious, that he was not unconscious but he admitted there was no way he could open his eyes and there was no way he could speak.

So the suspected cerebral arterial gas embolism due to pulmonary barotrauma after struggling with the anchor and a rapid ascent turned out to be a case of carbon monoxide poisoning.

Dr J McKee's address is PO Box 265, Bega NSW 2550, Australia.

CLAM MARICULTURE

David Davies

Introduction

For thousands of years, the seven species of Tridacnid bivalves or giant clam, prevalent in the Pacific, have played an important role in the diet, folklore and mythology of the Pacific Islanders. In some areas a traditional form of farming of the clams has occurred on the fringing reefs but, despite this, over harvesting has resulted in depletion of stocks and even in local extinction. During recent decades, massive commercial exploitation, mainly for the Asian market, has resulted in wide spread depletion of natural stocks in many areas and total extinction of the species in other areas.

Tridacnid harvesting for the Asian market is extremely wasteful as the fishermen have been taking only the adductor muscle. The shell, mantle and entrails are discarded despite the fact that all the flesh, apart from the kidney is quite edible. The Chinese tend to prefer the meat in the dried form whereas the Japanese prefer to use the raw form for sushi and sashimi.

Until stringent regulations were introduced and enforced by both the Australian and Taiwanese Governments, both

SPUMS ANNUAL SCIENTIFIC CONFERENCE 1987

the harvesting and importation into Taiwan was done illegally and consideration of the 1985 figures shows the reason. On the wharf in Taiwan a clam fisherman could command US$22.00 per kg, for frozen clam adductor muscle. Sun dried to about 30 percent of its live weight, this meat was being sold for US$120.00 a kg. It has been estimated that there is a market in the ASEAN region for about 3-4,000 tonnes of tridacnid meat per year.

Rates of meat production by young giant clams are similar to those produced by European Mussel Farms. However, because the clams can be raised without the high management costs, tridacnid mariculture is potentially more attractive than traditional ocean-based protein production system.

In order therefore to overcome this exploitation and devastation of the natural resources, programs have commenced in several centres throughout the Pacific Basin to try and breed the species back to some semblance of normal numbers.

The habitat of the giant clam is largely limited to the sunlit shallow waters of the coral reefs of the largely unpolluted Indo-Pacific islands. For many years it was considered not feasible to artificially grow these animals because of the limitations imposed by low concentrations of phytoplankton and essential inorganic nutrients. Trench and others in 1981 showed that a dinoflagellate living in enormous numbers in the blood sinuses of the siphon and mantle tissues supplied not only the major nutritional needs of the clams but were also responsible for the large size and the rapid rate of growth of the clams. Thus, for the reasons that the clams are sedentary, have very few predators, have a high growth rate, a high market value and much of their feeding is photosynthetic they become excellent candidates for domestic production.

Yamaguchi pointed out numerous similarities between tridacnids and trees and suggested that giant clams should be managed like intensive forestry.

Currently, research and development programs are underway in Palau, Fiji, Papua New Guinea, the Philippines, the Solomon Islands and Australia. The Australian centres are based on Orpheus Reef, run by Professor Lucas of the James Cook University, and a small commercial venture on Fitzroy Island, near Cairns. Figures from the Micronesian Mariculture centre on Palau, suggests that intensive farming of giant clams will produce as much, if not more meat than a comparable area of mussels.

Commercial production

Commercial production of large numbers of giant clams occurs in three separate phases, each of which has its own requirements.

<u>The Hatchery</u>

This is the land based section of the organisation. It needs to be sheltered, close to clean water, unpolluted by man or fresh water, and close to a fairly shallow reef suitable for planting out the seed clams. Usually the hatchery is set up with large tanks through which filtered seawater is pumped.

The broodstock clams are harvested from a nearby reef. Because the Great Barrier Reef is a Marine Park and the giant clams are protected species, it requires months of negotiation and a special licence to do this. Harvesting the mature clams too is quite a difficult manoeuvre as they are usually embedded in the reef and they are very heavy, requiring either several men or a mechanical lifting device such as a craypot hauler. These clams are then placed in the spawning tanks where they are covered with about 50 cms of filtered seawater.

Clam spawning takes place usually in the second and last quarters of the lunar month and occurs throughout the year. Prediction of spawning is made more accurate by needle biopsy of the gonad through the mantle tissue as not all clams spawn every month. As soon as spawning occurs, the tanks are flushed with filtered seawater, until all macroscopic evidence of semen disappears. About four hours later egg release commences and fertilisation takes place immediately with the residual sperm remaining in the mantle cavities of the brood stock. On completion of this phase the brood stock are replaced on the reef. The water level is raised to about one metre and the tanks are then left undisturbed for about seven days.

In the tank there is usually an algal bloom at about day 3 which coincides with the commencement of larval feeding. Metamorphosis of the larvae then occurs on day 5 and the resultant baby clams settle out onto the floor and sides of the tank. Once settlement occurs the tanks are gently flushed with filtered fresh seawater for about 8 hours per day. Despite this filtration, many varieties of other sea life find their way into the tanks. Most of these intruders need to be culled to prevent predation of the vulnerable young clams. However some other species such as the trochus are useful to keep the tanks clean of excess algae.

At about 5-6 months of age the young clams are scraped off the bottom and sides of the tanks and are transferred to special plastic trays, the bases of which are covered with basalt gravel. The clams at this time are about 12-17 mm in length so that about 1000 fit into each tray. The basalt gravel in the tray allows the byssal threads of the clams to fix but still enables them to be thinned without disturbing the clams or breaking the byssal threads. Over the next 4-5 months the clams grow to 30-40 mm in shell length at which stage they can be transferred to the waters of the lagoon.

SPUMS ANNUAL SCIENTIFIC CONFERENCE 1987

It is essential that all the materials used in the construction of the tanks and trays are inert. Early work resulted in losses of total populations of young clams until it was discovered that the clams were being poisoned by the chemicals leaching out of the plastic of the tanks.

The Nursery

In the sheltered, fairly shallow waters of the coral lagoon the young clams are maintained in trays on basalt chips until, over a period of 15 - 18 months, they grow to 100-120 mm in shell length. To reduce attack by predatory snails, crabs, octopus and fish, the trays are placed on concrete bricks about 30 cms above the sea floor and a polyethylene mesh lid is placed over the trays. As the clams grow, the trays become over-crowded so that, at regular intervals, the trays need to be lifted to the surface and the clams separated and thinned. This requires the services of a diver but as the water is shallow, decompression sickness is not a problem but gas embolism may be. Our experience is that most of the diving at this stage can be breathhold, thus overcoming all these worries.

There was initially concern that overgrowth of algae and weed on the mesh covers of the trays would exclude the sunlight thereby reducing the rate of growth of the clams but it has been found that this weed is a good source of food supply for parrotfish, surgeonfish and the like which tend to keep the weed growth under control. The screens are also cleaned when the clams are decanted into other trays so that the potential problem has not, in fact, been realised.

It has also been found that the trays with their protective cover act as an artificial reef and many little fish find refuge inside and under the trays. These fish, too, help to keep the trays and screens clear of excessive weed growth.

Planting Out

The nursery stage is deemed complete when the clams reach about 120 mm in shell length, usually at the age of about two years. They are then removed from the nursery trays and planted directly onto the reef. In their natural habitat clam densities vary between 10-100 clams per hectare. Obviously such sparsity is not compatible with efficient management. Since most of their nutrition comes from the photosynthetic activities of the zooxanthellae, densities much greater than this can be easily tolerated by the reef as the clams are ecologically innocuous. By the time the clams reach 120 mm in length they have very few predators and are easily able to fend for themselves. They are left on the reef for a further 2-3 years during which time they grow to the marketable size of 200-500 mm crown-rump length. At this stage the survival rate is about 90 percent.

Marketing

Clam meat

The Asian market currently takes about 3000 metric tonnes of clam adductor muscle meat each year. This is required both as fresh frozen meat and as sun dried meat.

Clam shells

Shells are a popular collectors item and small ones, 100-150 mm in length, retail for about $2-3.00 in the souvenir shops in Queensland. However larger shells up to 500 mm in length, can bring up to $100.00 each. Heslinga reported that in 1984 Taiwanese brokers were offering US$600.00 a tonne for 250 mm shells in quantities over 100 tonnes. These shells are used for crafted serving dishes, bowls, lamps and so on and, at this price, are more valuable than the meat itself.

Seed clams

There is a growing demand throughout the Pacific and Caribbean for seed clams in the 15-100 mm size range. These are used for stock enhancement, repopulation of denuded areas and experimental introductions by appropriate governments.

Aquarium specimens

In the US alone, the aquarium industry generates over US$1 billion annually and offers a potentially lucrative market. In Washington small specimens are fetching US$20.00 each and in Europe these same animals may bring up to US$50.00 each.

Whole live clams

Throughout the Pacific, small clams are usually eaten raw and have a clean, crisp, taste and texture. The rest of the clam meat is popular as subsistence food and all can be eaten except for the small kidney. This meat does tend to taste rather strongly of algae. The soft tissues can be readily used for soup or can be dried, chopped and used as high protein stock feed for pigs, marron, crayfish, prawns and barramundi.

Summary

Artificial culture of the giant clam along the lines of intensive forestry is now a commercially viable enterprise. There have been many problems in the past with the post larval stages of production but with greater understanding of the physiology and development of the clams and control of predation by other marine species, the way is now open for successful Australian production of this previously threatened species.

SPUMS ANNUAL SCIENTIFIC CONFERENCE 1987

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DIVER RESCUE, DECOMPRESSION SICKNESS AND ITS IN WATER TREATMENT USING OXYGEN

John Knight

To rescue a diver you first have to find him. It is difficult to see divers in the water from a small boat. It is difficult for divers to see each other in the water, because of water movement and waves coming between them. The New Zealanders have had problems in the past with lost divers (see page 163) and they have produced a very effective aid in the form of an inflatable plastic tube called the Safety Sausage.[1] (Figure 1) The Safety Sausage rolls up into a little bundle that fits easily in the pocket of a buoyancy compensator. When needed it is unrolled. The open end is put over the diver's regulator. One hand holds it tight round the regulator hose while the other presses the purge button. Suddenly there is a 2.4 m (8 foot) sausage of plastic, 10 cm (4 inches) in diameter, standing up out of the water clearly marking the diver's position. It is very much easier to see something sticking up out of the water than to see something on the water surface. It is quite easy to spot a mast against the horizon when one is looking for a boat. It is just as easy to spot a Safety Sausage against the horizon when looking for a diver. The Safety Sausage is wider than most small boats' masts, although not so high.

It is important that the Safety Sausage be held tightly round the regulator hose otherwise most of the air finds it easier to escape underwater rather than go up the tubing. It is a device that will sell for around $10.00 in Australian dive shops, so is a lot cheaper than a flare and unlike a flare can be used many times.

Having rescued the diver in an emergency, one has to treat any problems. One problem that is better avoided than treated is decompression sickness.

How to avoid decompression sickness (DCS)

It is usually recommended that one should always do no-stop dives. The next recommendation is always stay well within the decompression tables. What this means varies from speaker to speaker. It is important, in fact essential, when using tables that one knows the maximum depth reached. This means using a recently calibrated depth gauge. Depth gauges have been shown on many surveys to be inaccurate. There are two forms of inaccuracy. The safe one is where the gauge reads deep, because the diver thinks he or she is deeper than he is. The unsafe one is when the gauge reads shallow. This is a very unsafe form of inaccuracy as the diver thinks he is shallower than he or she actually is and dives deeper than the planned dive. There are some gauges that are inaccurate over part of their range only, so it is essential that one knows the inaccuracies of one's gauge, which means regular testing.

The next necessity with tables is to know the bottom time which requires a waterproof watch, or one of the many devices that automatically turn themselves on when a certain pressure is reached, and turn themselves off when they return to that pressure. These give a total dive time rather than a bottom time, defined as the period from the leaving the surface to starting the ascent, which is needed to work out most tables.

One should never ascend faster than 18 metres (60 feet) a minute and preferably much slower. It is quite clear that many cases of decompression sickness in Australia, and I suspect in other parts of the world, are associated with rapid ascents. I believe the correct ascent rate should be no faster than 10 metres a minute and preferably slower. One should always do a stop at 5 metres, or thereabouts, on every dive, so that there is time to let the lungs filter out any bubbles that have formed on the way from the bottom to 5 metres.

If one must do a decompression dive, one should decompress for the next deeper depth and the next longer time. A shot rope should be used because there is no other way that one can maintain depth accurately. Remember that currents and tides will swing the diver away from the vertical, so that the marked position on the shot rope will no longer be at that depth. One should always have extra air on the shot rope in case the decompressing diver runs out of air. After diving one should not fly or cross mountains for at least 12 hours and it is a lot better and safer to make it 24 hours.