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THE QUEENSLAND TROCHUS FISHERY AND MANAGEMENT-RELATED ASPECTS OF TROCHUS BIOLOGY

by

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The Queensland trochus fishery, and management-related aspects of trochus biology

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Willy Bour has presented a comprehensive review of the current state of knowledge of trochus, covering most of the aspects important to its biology and management. I will present information that complements Willy's without overlapping greatly.

I will address three topics here. Firstly, I will describe the Australian fishery as it now exists; it has some unusual features which have important consequences for management. Secondly, I will discuss the spatial structure of exploited populations - that is, the extent to which populations are related, and movement between populations. As part of this, patterns of recruitment to fished populations are discussed, and evidence is presented that larval recruitment may be, at least in some places, quite localized. Finally, the possibility of using trochus reared in a hatchery to replenish fished populations is considered. There are some clues obtained from the Australian situation which allow some predictions to be made of the likelihood of the success of this as a management tool.

1. The Queensland trochus fishery

The trochus fishery in Australia has had a history similar to that in other Pacific countries. It began in the first decade of this century, and continued, with considerable fluctuation in annual catch, until the collapse of the fishery in the 1950s, largely because of the advent of plastics. The fishery experienced a revival in the 1970s because of the increasing price of shell on the world market. In 1982 the price paid to the fisherman was about $1 200 (AUS) per tonne. It has increased steadily since then, and now is nearly $4 000 per tonne for top quality shell.

Trochus is fished using a mothership of about 13 to 20 m length, and shell is collected by divers operating from small dinghies with two or three men per dinghy. There are generally eight to 10 crew per vessel. Divers are

increasingly using hookah instead of free diving.

Shell is bagged in the dinghies and brought back to the mother ship where it is tumbled, live, in modified cement mixers lined with rubber sheeting to remove external encrustations, then cooked in gas-fired boilers for 10 to 15 minutes. When the shells are cool enough to handle, the meat is removed from the shells with a wire hook. Quite often, the visceral mass, containing the digestive gland and gonad, break off as the flesh is being extracted. These remnants are then removed by flushing the shells out with seawater passed through a coil of metal tubing attached to the deck hose. The shells are then left to dry before re-bagging and stowing in the hold of the mothership. This processing method results in high-quality shell, for which there is very high demand.

The cooked meat is usually thrown over the side of the vessel, although some may be eaten on board or taken home to the families of the crew. A device developed in north Queensland for removing the meat from the trochus while still alive has been patented in most trochus-producing countries of the Pacific, but so far no progress has been made toward developing its use. Early trials showed that the live animal could be removed from its shell in two or three seconds, but no extensive trials have been carried out to determine its cost effectiveness; nor has it been conclusively demonstrated that it clearly removes all of the retractor muscle from the shell. In early trials, the retractor muscle was severed, leaving a small piece attached to the shell columella to decay. It is not known whether this problem has been overcome. If not, there will be difficulty marketing the shell - or at least obtaining a high price for it - because of its bad smell. Until these problems are shown to have been overcome, more traditional methods must be used to remove the meat.

The present regulations for the trochus fishery in Queensland include:

- a lower size limit of 8 cm maximum shell diameter;
- an upper size limit of 12.5 cm maximum shell diameter;
- a total annual catch for the Great Barrier Reef (GBR) of 500 tonnes;
- individual annual quotas of 50 or 75 tonnes, depending on the area fished;
- a licensed diver is allocated a one-degree square area (95 km x 95 km) in which he has sole fishing rights.

The rationale for the various management options available are discussed by Nash (1985).

The last regulation listed above is rarely adopted in fishery management although, in some respects, this sole-access right has existed in some parts of the Pacific, where individual families or individual villages have fishing rights over a part of the reef, to the exclusion of others. The rationale behind sole access right to an area is that it immediately overcomes the attitude that inevitably arises when people compete for a common resource - the attitude that 'if I don't take it, the next man will'. It means that the diver can fish his reefs in a manner that will ensure the long-term sustainability of his trochus stocks. So far, this regulation is working well in practice.

One problem with this regulation, however, is that not all one-degree square areas of the GBR are equally productive. This is partly because reefs are more closely spaced in some areas than in others, and partly because trochus are more abundant on some reefs than on others. It is possible therefore that one diver may be granted access to an area containing many productive reefs, while another may end up with an area of few reefs, of which only a few contain trochus in commercial quantities. At present, the responsibility for the choice of area is the diver's: he may nominate the area he would like to fish. Provided there is no prior claim to his nominated area, he is likely to be awarded it. The likelihood of a diver being allocated an inferior area is therefore reduced.

It remains to be seen how effective this regulation is in the long term. If it proves to be promote a conservative fishing behaviour among divers, then its applicability to fisheries for other sedentary species must be considered. These might include other shellfish and perhaps some crustacean species.

2. Spatial structure of exploited populations and patterns of recruitment

As adults, trochus are sedentary animals, and their movements are limited to distances of no more than a few hundred metres in their lifetimes. It is likely that, in general, their movements would be measured more in metres or tens of metres than hundreds of metres. In a study of growth at four sites on two reefs, Nash (1985) found that most tagged trochus were recovered within 30 m of their site of release over a two year period. Moorhouse (1932) found trochus to move up to 50 m from the site at which they were tagged.

The greatest potential for movement and dispersal undoubtedly occurs

during the pelagic larval phase which, in the north-central GBR, has a duration of 3 to 4 days at 28-29°C. The distance that larvae could disperse from their parental population in this time will depend on hydrological conditions (water currents and movements) at the time of spawning. It will also be affected by larval behaviour: dispersal will be greater if larvae are positively phototrophic. Conversely, if they avoid light and stay near the bottom, the likelihood of settlement near the parental site will increase.

There are several pieces of evidence that suggest that in some cases, larval recruitment is to the parental reef. For example, McGowan (1958) stated that successful colonization of a reef by transplanted trochus sometimes depended on the position of their release on the reefs in relation to water currents: there was a greater chance of successful colonization if they were placed at the up-current end of the reef than at the down-current end. Other evidence of recruitment of larvae to the parental reefs is now presented, and the consequences of this to management are discussed.

Surveys of trochus populations on the reefs near Cairns in the north-central region of the GBR were undertaken in 1983 and 1984, in order to assess the abundance of the stocks (Nash 1985). This region had been fished commercially for about two years up until four years before the surveys were carried out. The fisherman moved to more southern reefs after two years because there were too few trochus remaining to maintain a fishery (K. Bradford, personal communication). In the surveys, it was found that the reefs which had been fished heavily in the past (most notably Thetford Reef) had not recovered at all. The only reefs where trochus were found in reasonable numbers were parts of Green Island reef, which has been a Marine National Park for many years, and Middle Cay Reef, which was deliberately not fished in order to have a ready availability of trade samples (K.Bradford, personal communication).

A re-analysis of the size composition of the Green Island and Middle Cay trochus populations presented by Nash (1985) indicates that the recruitment rates to these reefs are relatively constant. Thus, in the north-central region of the GBR, recruitment to reefs with few trochus is poor, and recruitment to reefs with reasonable numbers of trochus is constant and moderate. The simplest interpretation of this pattern of recruitment is that trochus populations are self-recruiting on the scale of individual reefs. The possibility cannot be ruled out, however, that trochus larvae are induced to settle by the presence of other trochus; absence of trochus would therefore result in absence of settlement, despite the fact that larvae may be present in the water over the reef. This possibility is

not likely, however, because evidence indicates that larvae are induced to settle when crustose coralline algae are presented, in the absence of adult or juvenile trochus (Heslinga 1981; personal observations).

Mechanisms by which self-recruitment of trochus populations may occur, despite the fact that there is a pelagic larval stage of 3-5 days (Heslinga 1981; Nash 1985) may be understood by a consideration of reproductive behaviour. There are no documented cases of trochus spawning in the sea, as far as I am aware. All published information of spawning is in tanks (Heslinga 1981; Heslinga and Hillmann 1981; Nash 1985). Although there is a danger that the artificial conditions in tanks may induce unnnatural behaviour, this danger is minimised if the trochus have been recently collected or are well fed, and there is an adequate supply of fresh seawater pumped directly from the sea. Observations of synchronous spawning in separate tanks by trochus collected from different reefs at different times (Nash, unpublished data) support this.

If it is accepted that spawning behaviour in tanks is not unnatural, we can make inferences and draw conclusions from these observations. A consistent observation is that trochus almost invariably move to high points to spawn. In tanks, this is usually up the walls of the tanks to the waterline, or may be to the top of another trochus sitting on the bottom, or a piece of alga-covered coral. There are two possible reasons for moving to high points on the reef: one is to ensure that eggs and sperm are dispersed as widely as possible. The other is that they move up the reef slope into the shallows on top of the reef to spawn. Based on observations by trochus fishermen of spawning and movement, it would seem that the latter is the more likely reason.

I will now describe two observations by trochus fishermen in relation to spawning. I believe that these are important observations, because they shed light on the spawning behaviour of trochus, and also indicate that methods used to estimate trochus stock size may greatly underestimate true abundance.

The first observation was at Bell Cay, an isolated reef toward the southern end of the Great Barrier reef. Its nearest neighbour is about 30 km distant. Trochus are extremely abundant on this reef. The fisherman anchored on the reef in mid-afternoon, ready to begin collecting trochus the next morning. That afternoon, as the tide was starting to rise, he went to the reef edge to see how abundant the trochus were. He observed that the reef top immediately adjacent the reef edge was covered in trochus. The dense population extended for more than two kilometers along the

reef edge. The fisherman estimated that there were 40 to 60 tonnes of trochus.

When the divers went to the same areas the next morning to commence collecting, there were very few trochus to be found - they were no longer on the reef top. Despite an extensive search using hookah to a depth of about 18 m, the trochus were not to be found, except in average numbers. Importantly, the diver noticed that all the trochus observed on the reef top the previous afternoon were encrusted with "mauve lime" - that is, mauve (purple) encrusting coralline algae. Such encrustations are only found subtidally, both on the substrate and on the trochus. Trochus which inhabit the high intertidal area have relatively clean shells.

It is reasonable to conclude that these trochus had moved from permanently subtidal areas into the shallows for a short period, then returned. Other observations would suggest that the reason for this movement was to spawn. One example of this is the observation by a fisherman of spawning on the reef top near the reef crest in the early evening as the tide was rising across the reef. As the water covered the trochus, they spawned. (The sea was calm at the time.) The fisherman observed the milky (that is, sperm-filled) water moving across the reef with the tide.

There is other anecdotal evidence which is also consistent with spawning occurring on the reef top in the early evening as the tide is rising, but the two observations cited here serve to illustrate it. The movement of trochus into the shallows to spawn, and the movement of water at the time of spawning, support the notion that eggs are retained on the reef where they are spawned. Egss are negatively buoyant, and will settle into the substrate unless re-suspended by turbulence. Whether or not the larvae will eventually recruit to the same reef will be determined very much by larval behaviour.

Although it is not intended to discuss stock abundance estimation methods or procedures here, it is important that very large numbers of trochus can effectively disappear overnight, as described above.If trochus periodically aggregate to spawn then disperse between spawning periods, comparison of trochus abundance between sites or at individual sites at different times, will be very prone to error.

The consequences of limited dispersal of larvae to management are great. Firstly, it means that reefs which are very heavily fished for a number of years will recover only slowly, since there will be few available

breeding animals. Secondly, management must be on a small scale to be effective. Setting an annual catch limit for a region may not be effective, because much of the effort may concentrate on a small area, causing localized overfishing. These overfished areas will recover only slowly; in the meantime, fishing effort may have been concentrated on another part of the fishery. Thus, serial depletion of the stocks may occur if limited larval dispersal is a widespread phenomenon.

Localized recruitment has some important consequences for the GBR trochus fishery. Since each licensed trochus fisherman has sole access to an area of the GBR, the effects of non-conservative fishing in terms of subsequent recruitment, will be felt by that fisherman, not another fisherman down-current, as would be the case if larval dispersal were extensive.

3. Stock enhancement with hatchery-reared juveniles

The regulation of fishing effort is essential for achieving sustainably high yields in a fishery, and history has shown that trochus are particularly prone to overfishing. Almost without exception, overfishing has occurred wherever trochus have been harvested commercially (Heslinga and Hillmann 1981; Bour and Hoffschir 1985; Nash 1985). Their vulnerability is attributable largely to their sedentary habit, and to the fact that they inhabit a well-defined area of coral reefs - the windward edge in shallow water generally no deeper than 5 to 8 m. Although trochus tend to retreat to crevices and overhangs in daylight hours, and are camouflaged by algal encrustations on their shells, a trochus diver can, with only a little practice, find them readily.

Thus, despite the fact that unfished trochus populations may be very dense, they may be very severely depleted in a short time. The need for careful control of fishing pressure is clear.

One management measure that may be taken is to artificially enhance the fished stocks with juveniles reared in a hatchery. As described below, high survival rates have been achieved through the larval stage, and the prospects of achieving satisfactory survival rates of juveniles to outplanting size (about 10 mm diameter) appear good. The feasibility of this technique as a management strategy would therefore depend on adequate survival rates after being placed on the reef. These factors are now described.

Compared to most species, trochus is an easy animal to rear because the eggs are lecithotrophic, so that the developing larvae feed on their yolk reserves instead of cultured unicellular microalgae grown under sterile conditions; the planktonic larval stage is brief (3 to 5 days) (Heslinga 1981; Nash 1985); and the newly-settled juveniles feed on the diatoms and algae which grow readily in tanks in the presence of sunlight. In addition, trochus from the Townsville region northwards spawn all year round with an approximate lunar periodicity (Nash 1985). (There is evidence that spawning by more southerly populations occurs only in the summer months (unpublished data).)

In a trial at the Orpheus Island Research Station, 70 km north of Townsville, in January 1987, a survival rate of larvae of nearly 100 percent was achieved between spawning and settlement four days later. If it can be shown that trochus seed can be grown in large numbers in tanks, then it would seem that stock enhancement by hatchery-reared juveniles is a feasible management option.

These results therefore are encouraging, but in the absence of information on the likely survival rates of the juvenile trochus once they are placed on the reef to grow to harvestable size, it would be premature to proceed with large-scale juvenile production.

In the only known transfer of hatchery-reared juvenile trochus to the reef (in Palau, Micronesia), almost total mortality was observed within a couple of days of outplanting; only remnants of crushed shells were to be found (G. Heslinga, personal communication).

Thus, unless it can be established that juvenile trochus will not suffer very high mortality when placed on the reef, stock enhancement would not be a feasible management option. An example of this is the abalone (*Haliotis*) fishery in Japan, where, despite the annual production of several million abalone seed in hatcheries, there has been no increase in the annual catch of adult abalone (Ino 1980). Although not established with certainty, it is likely that the cause is very high mortality soon after outplanting.

It would seem, therefore, that the prospects of stock enhancement of trochus populations with hatchery-reared juveniles are poor. Prospects are not as bleak as that, however, because there are several pieces of evidence which suggest that juvenile survival rates differ greatly between populations, with some being quite high.

Firstly, trochus fishermen distinguish between two types of reefs:

"swim reefs" and "dry picking" reefs. Swim reefs are those which are exposed for only a few days each month during low water spring (LWS) tides, whereas dry picking reefs are exposed much more frequently than this, because they are more elevated. Trochus are often collected by walking at low tide on these reefs - hence their name. This pattern of more trochus on dry picking reefs than on swim reefs is not coincidentally caused by transient fluctuations in abundance on reefs through time, since information supplied by old trochus fishermen shows that reefs that are good trochus reefs now were good trochus reefs in the 1950s. Some reefs, therefore, are intrinsically good trochus reefs and some are not.

Secondly, trochus are typically much more abundant on dry picking reefs than on swim reefs. In addition, and related to this, juveniles are seen in greater abundance on dry picking reefs. If these observations are tied in with the fact that juveniles inhabit the reef top immediately adjacent the seaward reef crest (i.e. the zone which becomes exposed at low water), it may be hypothesised that there is a causal relationship between juvenile survival rates and the frequency and duration of reef exposure: juveniles on swim reefs are underwater more often, and for longer periods, and therefore exposed to higher levels of predation by fish, than those on dry picking reefs. Juvenile trochus may avoid predation by hiding in holes and crevices and under rocks, but they must emerge to feed. At such times, they are exposed to predation.

If this hypothesis is correct (that patterns of trochus abundance are determined by higher predation rates of juveniles on dry picking reefs than on swim reefs), then the implication is that patterns of distribution and abundance of trochus are determined by post-settlement mortality rather than mortality in the planktonic larval stage. This is not to say that pre- settlement mortality is not occurring, but it suggests that it is not so high that it masks post-settlement factors.

If this hypothesis were correct, then survival rates of hatchery- reared juvenile trochus may be maximised by placing them on dry picking reefs at low tide at night (when most predators are not active). Whether the resulting survival rates to harvestable size would be high enough to make hatchery production economically feasible can only be determined by doing it.

This hypothesis could be tested in a suitably controlled and replicated experiment by placing small juvenile trochus in suitable habitat on both dry picking and swim reefs, and monitoring survival rates.

It cannot be ruled out that juvenile survival may be higher on dry picking reefs because the algal food is of higher quality or quantity than on swim reefs, rather than because of predation differences. This could be tested by comparing survival rates of caged and uncaged juveniles on the reeftop on swim reefs. Higher survival rates in cages would indicate that predation was the important factor.

Although caging would exclude other grazers (fish) as well as potential predators of juvenile trochus, this is not seen as a problem, since differences in predation rates of caged and uncaged juvenile trochus should be apparent within a few days - too soon for differences in algal abundance between caged and uncaged areas to occur, or to affect the survival rates of the trochus.

The possibility cannot be ruled out that high mortality rates of hatchery-reared juveniles when placed in the sea is because of behavioural differences between these and wild juveniles; the former may wander around in exposed areas when their wild counterparts are hiding in the coral. Cryptic behaviour may be learned, or may be cued to the tides; if the latter, it may take some time for juveniles released on the reef to synchronize their activity cycles with the tides. It would be necessary to test this possibility before any conclusions about relative mortalities on dry picking and swim reefs could be drawn.

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