EOF - F00132.

RESULTS OF THE BOULT REEF REPLENISHMENT AREA STUDY

FINAL REPORT
JULY 1989

Konrad Beinssen

A Report by the Department of Conservation, Parks and Wildlife.

EOF - F00132

SCOPE OF THIS REPORT

Between August and December 1986, a study of the response to fishing of the coral trout population at Boult Reef was carried out. During the study, additional information useful for management of the demersal reef fish stocks was acquired.

This report describes the results of the study. It is intended that the information be integrated later with other studies currently under way to give an understanding of the size of the demersal reef fishery in Capricornia. The information in this report will be further analysed and prepared for scientific publication.

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[This report outlines a 'feeding hypothesis' as one explanation of the results. Subsequent work in 1989 based at Heron Reef has shown this hypothesis to be incorrect and the report on that work shows why this is so. This report will not be published as is but may be used for management purposes.
GBRMPA 1990]

EXECUTIVE SUMMARY

Outline of general findings relevant to management

Point 1

The closure of Boult Reef as a replenishment area was successful in as much as fish stocks at opening were abundant and average size of fish very large. No evidence was found to suggest that fish stocks, if rested, do not respond in the ways which simple fisheries models predict ie by both number and average size of the 'rested' species increasing. Following re-opening, fish stocks were very rapidly reduced by fishing. After 14 days of fishing about 25% of the coral trout had been caught and after 18 months in the order of 25% remained.

Point 2

While the demersal reef fishery is a multi-species fishery, the catch is dominated by only a few species. At this stage, the fishery can best be managed by regulating in relation to individual species. The main species are coral trout, redthroat sweetlip, spangled emperor, red emperor and several of the large cod species. Complex multi-species considerations are not warranted at this stage.

Point 3

As a generalisation, reef demersal species do not move/migrate over large distances; most are relatively 'site attached'. Since the distribution of fishing effort is very uneven, accessable populations are vulnerable to being overfished. Both growth 'overfishing' and growth 'underfishing' are presently occuring in this fishery. Management action to distribute fishing effort more evenly is warranted.

Point 4

The level of fishing on the emergent reefs of Capricornia is very high and evidence suggests that growth overfishing of coral trout populations is occuring. An increase in the legal minimum size for coral trout in Capricornia to 450mm is warranted. Because the geographical area of the fishery is very large, it is considered practical to apply more than one minimum size.

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1. THE GREAT BARRIER REEF DEMERSAL REEF FISHERY IN PERSPECTIVE

Reliable information on the size and economic value of the demersal reef fishery within the outer boundaries if the Great Barrier Reef Marine Park is difficult to obtain.

Tilbury (1986) estimates that 160 commercial fishermen work the reef as a major part of their fishing activities, 30-40 unlicensed amateurs take 'substantial amounts' and a further large number (200) sell some catch. He estimates a total 'wharf' value of the catch from this sector to be $15 million.

Based upon information by Hundloe, PA Management Consultants (1984) estimated the total costs incurred by reef region recreational fishermen at $45 million in mid-1984 prices.

Other statistics, such as the increase in private motor boat registrations in Queensland, suggest that the demersal reef fishery is growing rapidly. For example, in the Bundaberg, Gladstone and Rockhampton Regions combined, there has been an overall growth of 20% in motor boat registrations between 1980 and 1985.

The high percentage of submissions relating to fishing in general, received during zoning public participation programs also highlights the importance of fishing in the Marine Park. For example, of the 287 first round representations received by GBRMPA for the zoning of the Southern Section, 44% related to commercial or recreational fishing.

These figures taken together, give an indication of the importance of the demersal reef fishery and more generally show that management of this fishery, encompassing efficient administration, research and enforcement, should be a high priority activity for resource management agencies operating in the GRB region.

2. THE EXPERIMENT AT BOULT REEF

2.1 BACKGROUND

Boult Reef is located near the southern end of the Great Barrier Reef at 23 46' S by 152 18' E, in the Mackay/Capricorn Section of the Great Barrier Reef Marine Park. The reef measures about 3.5 km by 2 km. The area of seabed outside the drying reef crest which supports demersal reef fish (ie where the resource is mostly located) is approximately 342 hectares.

Boult Reef was zoned as a 'replenishment area' in the first zoning plan prepared for the then Capricornia Section. It was closed to fishing and collecting on 1st July 1983 as an experiment to assess the effectiveness of periodic reef closures as a fisheries management tool. No information on the 'at closure' fish abundance is available although several diving surveys of coral trout abundance were conducted during the period of closure.

Boult Reef was re-opened to fishing on 1st December 1986 and the experiment described here was conducted around this date.

2.2 OBJECTIVES OF THE EXPERIMENT

The primary objective of the experiment was to measure the catchability (q), of a coral trout population. Sanders and Morgan (1976) show that catch per unit fishing effort is theoretically proportional to stock density, with the constant of proportionality being q, the catchability of the stock. Using their nomenclature;

$$c/X = qD = qN/A$$

In this case, c is the catch measured in number of fish, X is fishing effort measured in fishing hours and D is the density of fish measured in number per hectare, N is the total number of fish in the population and A is the area occupied by the stock.

An estimate of catchability is valuable because it can be used together with catch, fishing effort and fishing area statistics in the above equation, to estimate the total coral trout population and the fishing mortality it sustains, over wider areas of the fishery. Note that such calculations rely on several important assumptions which are explained by Sanders and Morgan (1976).

Secondary objectives were to describe the species composition of the catch taken from the reef, to measure the number and size distribution of trout and other important species taken from the reef and to describe the short term movements of fish around the reef. A final specific objective of the work was to educate the fishing community by involving it directly in the conduct of the experiment and providing feedback on the results.

2.3 EXPERIMENTAL DESIGN

A simple experimental design was employed. The strategy was to tag fish at Boult Reef prior to its opening and then to record the catch, effort and tag returns of all people who fished at the reef in the first two weeks following its re-opening. Additionally, underwater counts of coral trout were conducted immediately prior to opening and after two weeks of fishing, with a known fishing effort and catch in the intervening time.

Information to determine the initial population of coral trout (and other species) at the reef using three independent methods is thus available.

1. Total number of coral trout caught and tags returned can be used to give a Petersen estimate of the number of trout at the reef at opening.

2. Decreases in the number of trout caught per hour plotted against the accumulated catch, give a 'Leslie' estimate of the coral trout population at opening.

3. Pre and post fishing underwater counts of coral trout conducted by diving, give an estimate of the relative reduction in coral trout number caused by a measured amount of fishing and removal of a known number of fish.

The reduction in fish density (fish per hectare) over time, can then be correlated with catch per unit effort (fish per hour), giving an estimate of catchability.

Data to achieve the other objectives of the experiment were gathered incidentally.

2.4 METHODS

Tagging was conducted from a 5M open vessel with a team of four. Two commercial fishermen caught fish using standard handlining methods. In 95% of cases, fish were 'lip hooked' and survived the catching/tagging process well. One person tagged the fish while another recorded details.

Fish were placed on a 'bean bag' where they could be easily restrained in its folds for tagging and measuring. In most cases the fish were out of water for less than 30 seconds.

The tags used for this experiment were loop tags made of plastic filament which were surplus to an earlier reef fish tagging project. No problems in applying this tag type were encountered. All tags were applied with neosporin ointment to minimise risk of vibrio infection.

Care was taken to spread fishing intensity (fishing hours per unit area) evenly over all parts of the reef, to promote the process whereby tagged fish mix evenly throughout the total populations.

During tagging operations, detailed records of species, size, release condition, tag number(s), time caught, gear and bait type, location, fishing effort and weather were kept. This information was applied to a 'micro-ORACLE' data base which is now located in the Conservation, Parks and Wildlife Department's office in Rockhampton.

Catch and fishing effort The unit of effort chosen was 'fishing hour'. Since most fishers use only one hook per line and only one line at any one time, the fishing hour is equivalent to the hook hour or line hour. A negligible amount of spearfishing occurred during the first 14 days of fishing at the reef.

Details of catch and effort were recorded by individual fishermen, assisted by the survey team. Log books were distributed to and collected from all fishers at the reef each day, for the first fourteen days following re-opening. Use of these books and information about the experiment was explained to all fishers. An example of a log book is attached as Appendix 2. In May 1988, the reef was again fished by a commercial fisherman who volunteered to keep log book records of his activities; these records are compared with earlier statistics.

Additionally, notes were kept of vessels' fishing activities by the survey team so that anomalies in the log book information could be interpreted. In many cases it was possible for the team to board vessels, count and measure fish and help fill out log books. Note that during the experiment, virtually no fishing occurred at night. It should also be kept in mind that coral trout do not feed at night, so day-time fishing effort only is relevant to this species.

In an effort to ensure public co-operation, the experiment was widely publicised on the adjacent mainland in both the press and on radio during October/November 1986. Letters explaining the experiment were sent to all local fishing clubs, tackle shops etc and to commercial fishermen. Further, two substantial prizes were offered as incentives to fishermen, both to keep accurate log book records and to return tagged fish. A $5 reward was paid for each returned tag. All participants were promised feedback on the results of the experiment.

To assist fishermen to orientate themselves, a marker buoy was placed on each block boundary and a map was issued in each log book.

Underwater surveys The relative density of coral trout was estimated by counting fish underwater prior to the reef being opened and again after fourteen days of fishing. For logistic reasons, these counts were conducted in fishing block 4 only (Figure 1).

Block 4 was divided into six sub-blocks as shown in figure 1. The relative area of reef fish habitat of each of these blocks was measured from a large scale aerial photograph using a planimeter. In each block, a series of five minute counts of trout were conducted by a diver using hookah swimming over the reef with the boat following above. All counts were conducted by the same diver. Such counts were conducted both prior to the reef being opened to fishing and after 14 days of fishing.

Relative coral trout density was then estimated by applying the formula;

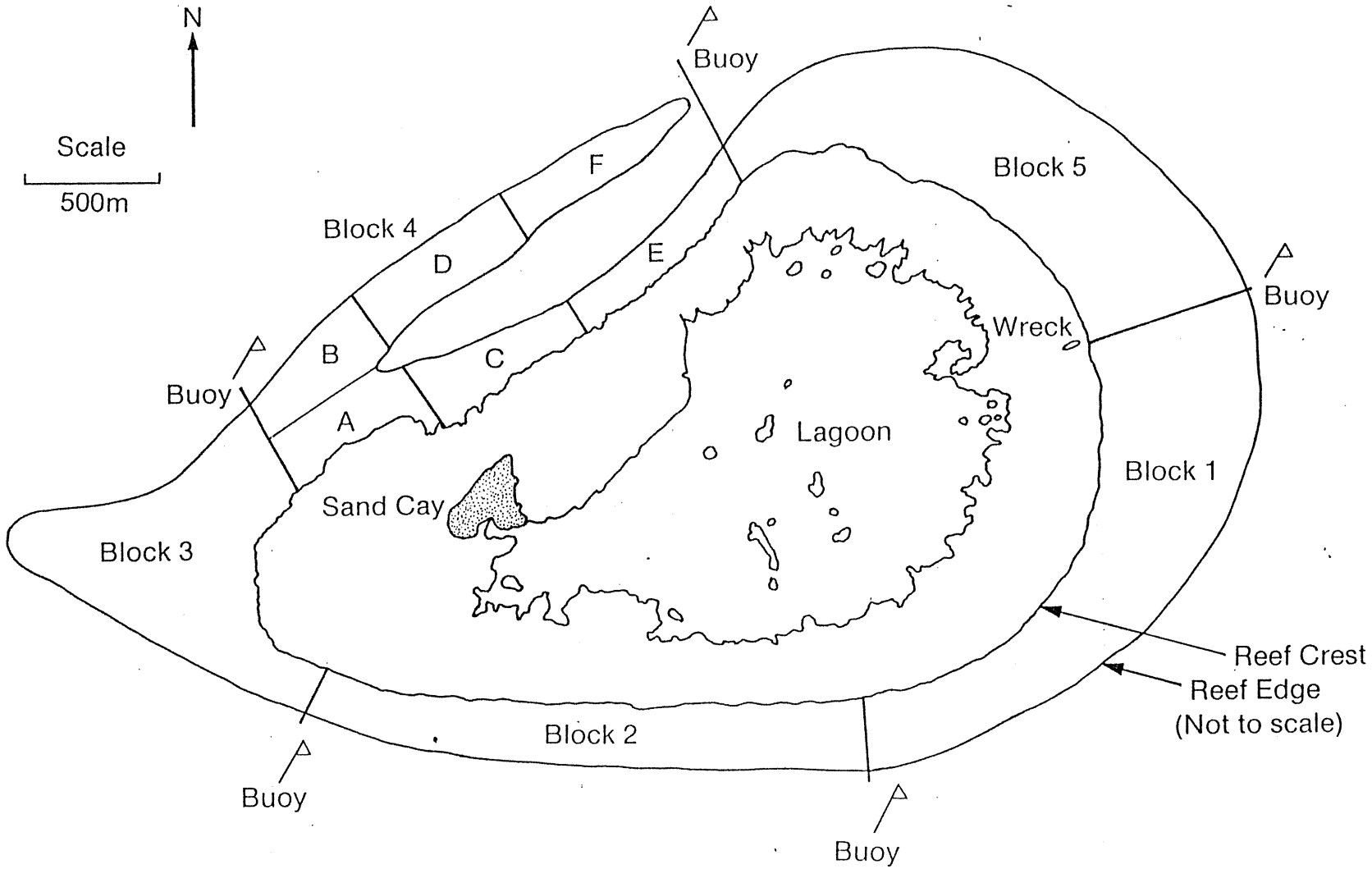
$$D = \frac{\sum_{i=1}^{6} \frac{xi \cdot ai}{ni}}{A}$$

Where D = relative density of trout
xi = total number of trout counted in the i th sub-block
ni = number of counts taken in the i th sub-block
ai = relative area of the i th sub-block
A = total relative area of the block

Reef area estimate The area of reef occupied by demersal reef fish resources at Boult Reef, ie the area of coral bottom lying between the drying crest of the reef and the outer reef edge at the coral/sand boundary, was measured.

A colour aerial photograph of the reef was enlarged and a scale applied by comparison with existing accurate maps. The reef crest boundary was traced from this photograph as was the outer reef edge where it was visible. Some additional vertical photographs of the reef were taken and echo sounder transects made to locate the reef edge boundary where this could not be seen on the enlarged photograph. A planimeter was used to measure the area.

Figure 1. Boult Reef showing fishing block boundaries.



2.5 RESULTS AND DISCUSSION

2.5.1 SPECIES COMPOSITION OF THE CATCH

The relative abundance of species caught during tagging operations, prior to the reef being reopened, is shown in table 1 and graphically in figure 2. It can be seen that four species account for 73% of the catch in number. It is estimated that coral trout, hussars, redthroat sweetlip and brown maori cod make up approximately 90% of the catch by weight. Management of these few species is thus of primary importance in Capricornia.

It should be remembered that the above species compositions are exclusively from catches taken beyond the reef crest and during daylight hours. Other species caught in Capricornia become more significant in other areas and at other times of day. For example, spangled emperor (Lethrinus nebulosus) are caught in lagoons at night and red emperor (Lutjanus sebae) are taken largely in areas of 'hard bottom' in deeper waters not necessarily associated with emergent reefs.

The possible effects on reef fish community structure of the removal of large numbers of large predator species has long been debated. Goeden (1986) points out that 'if the demersal reef fish community is based on stochastic processes, then it is possible that the role of 'keystone species' (such as coral trout) may be filled by less dominant populations.'

Evidence to suggest that fishing is causing changes in the community structure at heavily fished reefs may best be sought by comparing the species composition of the catch at one reef over time or at comparable reefs with different histories of fishing.

A sample of fish taken at Boult Reef 18 months after it was re-opened to fishing shows that coral trout and redthroat sweetlip had increased marginally (probabably not significantly) as a percentage of the catch and that the percentage of hussars in the catch had fallen (Table 2).

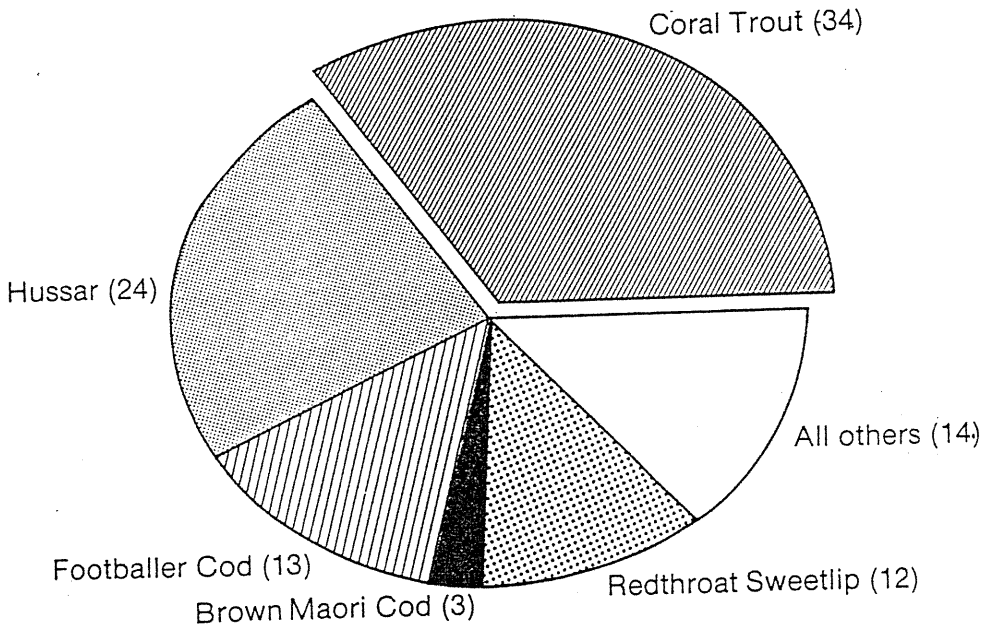
Simple fisheries models predict that if fishing pressure on a population is reduced, both density and average size of fish increases. No evidence was found to suggest that important commercial species do not respond in this predicted way ie do not replenish in the absence of fishing. For example, the processes predicted by Goeden (1986) ie competitive exclusion of depleted 'keystone' species by less catchable and less economically important species, did not appear to be occuring at Boult Reef.

TABLE 1 Species composition of catch taken during tagging operations

Common name		No.	%	Species name
leopard coral trout	*	604	34	Plectropomus leopardus
hussar	*	423	24	Lutjanus amabilis
footballer cod		239	14	Epinephelus fasciatus
redthroat sweetlip	*	211	12	Lethrinus chrysostomus
honeycomb cod		61	3	Epinephelus merra
mosses perch		51	3	Lutjanus russelli
brown maori cod	*	45	3	Epinephelus undulatostriatus
venus tusk		23	1	Choerodon venustus
coronation trout		21	1	Variola louti
purple speckled rock cod		13	1	Epinephalus flavocaeruleus
iodine bream		13	1	Gymnocranius bitorquatus
stripy bass		10	1	Lutjanus carponotatus
salmon mackerel		9	<1	Grammatorcynus bicarinatus
wrasse		8		Several species
trigger fish		5		Several species
stripy tuna		4		Katsuwonis pelamis
red bass		4		Lutjanus argentimaculatus
lowly trevalley		4		Caranx ignobilis
remora		3		Remora remora
yellow-tailed emperor		2		Lethrinus mahsena
variagated emperor		2		Lethrinus variegatus
small toothed cod		2		Epinephelus microdon
long tom		2		Ablennes hians
yellowtail kingfish		1		Seriola lalandi
yellow spotted cod		1		Epinephelus areolatus
speckle-finned cod		1		Epinephelus summana
reticulated emperor		1		Lethrinus reticulatus
queenfish		1		Scomberoides commersonianus
coral cod		1		Cephalopholis miniatus
chinaman fish		1		Symphorus nematophorus
black kingfish		1		Rachycentron canadus
barramundi cod		1		Cromileptes altivelis
barracuda		1		Agrioposphraena barracuda
total		1769		

* These four species made up 23% of the catch in number and an estimated 90% of the catch in weight.

Figure 2. Percentage frequencies of species caught at Boult Reef prior to opening.



(Note: 1769 Fish of 33 species were sampled)

TABLE 2 Species composition of the catch taken prior to the reef being opened to fishing and in May 1988.

SPECIES	% prior to opening	% in May 1988
coral trout	33.9	39.3
hussar	23.7	7.7
footballer cod	13.5	12.1
redthroat sweetlip	11.8	17.2
all other cod	7.0	4.7
coronation trout	1.2	4.4
all mackerel	0.5	1.5
red emperor	0.0	0.0
all others	8.4	13.0
Sample size	1769	338

2.5.2 CORAL TROUT MOVEMENT

An analysis of movement of tagged coral trout between fishing blocks at Boult Reef (figure 1) shows that 90% of recaptured trout were caught in the block in which released, 7% had crossed one boundary and 3% had crossed two boundaries. While these fish had been at liberty for up to 90 days only, it appears that in general, movement around the reef is very limited.

Further evidence of limited movement of coral trout is the fact that the red (strawberry coloured) fish are almost exclusively caught in deep water while green fish are taken in shallow water. Experienced fishermen believe that change between these colour types takes place only very slowly.

During the experiment, no tagged fish of any demersal species were returned from reefs other than that at which they were tagged and it is felt that such inter-reef migration is unlikely to be significant.

If coral trout are indeed relatively 'site attached', it leads to the conclusion that localised depletion at heavily fished sites is likely to occur. Management measures designed to spread effort and to protect reefs which are vulnerable due to their location, accessability from good anchorages etc, may be required.

More information on demersal reef fish movement/migration over longer periods is required.

2.5.3 AREA OF CORAL TROUT FISHING GROUNDS

The total area of Boult Reef occupied by the resource between the reef crest on the inner side and the reef edge (reef/sand boundary) on the outer side, is estimated to be 342 hectares.

A small percentage of the total resource is located inside the reef crest margin ie within the lagoon but this is excluded from the present study as little or no fishing occurred here.

2.5.4 TAG DESIGN FOR REEF DEMERSAL FISH

Early in the tagging program, coral trout were observed in the catch which showed obvious tag wounds behind the head. It was concluded that loop tags in this position are particularly vulnerable to shedding by being snagged on coral. Loop tags placed at the tail end of coral trout are far more durable but are also prone to be shed. Beinssen (1989) shows that over a period of up to a maximum of 90 days at large, 72% of coral trout initially double tagged at the head and tail end with loop tags, had lost one or both tags.

In addition, loop tags as used in this study remained mobile in the fish. The tagging wound was slow to heal and ulcers often formed.

Tags used in future studies of reef demersal species, in particular coral trout, should be of a design which does not snag and cannot move in the wound. It appears from some initial trials conducted in Capricornia that body cavity tags with external streamers are suitable. Dart tags may also be suitable.

2.5.5 STOCK ABUNDANCE ESTIMATES FOR CORAL TROUT

The 'recruited stock' is defined as the population of fish available to be caught; in this case the number of coral trout at Boult Reef above the legal minimum size. Three independent methods for estimating the recruited stock of coral trout at Boult Reef at the time of re-opening were employed.

* Petersen mark/recapture

Bailey's formula as described by Pauly (1984) was applied to obtain a population estimate. The potential sources of error have been classified by Gulland (1969) and are examined in Appendix 1.

Appendix 3 summarises the data required for the Petersen population estimate. A total of 2136 trout were captured at Boult Reef during the 14 day experiment. Of the 375 double tagged trout initially released at the reef, 83 were returned with at least one tag still attached and it is calculated (Seber 1982, Section 3.2.3) that a further 10 were returned unrecognized in the catch as both tags had been shed.

The population of recruited trout is thus estimated at 8813 with a standard error of +/- 873.

* Catch per unit effort analysis (Leslie method)

Pauly (1984) describes the method which relies on the formula

$$c/f = qNo - q\Sigma t$$

Where c = catch
f = effort
q = catchability coefficient
No = initial population size
t = cumulative catch to that period

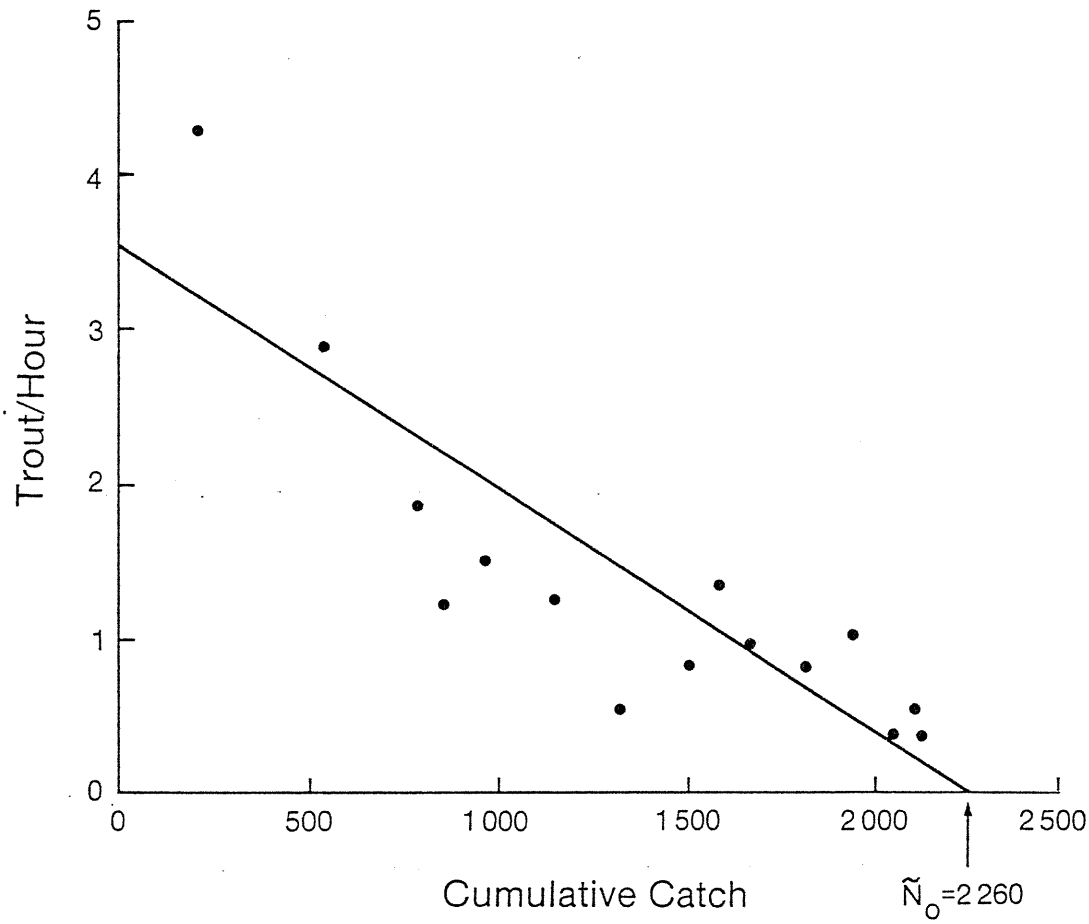
As can be seen, this method assumes a linear decline in the catch per unit effort with the decline in stock abundance caused by fishing (assume negligible natural mortality and recruitment over the 14 day period of the experiment).

TABLE 3 Catch/effort and 'Leslie Plot' information for coral trout taken at Boult Reef in the 14 days following re-opening.

i	n	f		y	x
DAY	number	effort hours	effort days	=n /f	cumulative catch
1	207	48.25	8	4.29	207
2	322	111.75	22	2.88	529
3	255	136.00	21	1.87	784
4	179	119.50	20	1.50	963
5	185	148.25	21	1.25	1148
6	154	286.25	50	0.54	1302
7	201	242.50	38	0.83	1503
8	85	63.50	12	1.34	1588
9	78	79.50	13	0.98	1666
10	162	198.25	33	0.82	1828
11	123	120.00	24	1.03	1951
12	102	267.00	25	0.38	2053
13	60	111.00	22	0.54	2113
14	23	62.00	9	0.37	2136
TOTAL	2136	1993.75	318		

Table 3 shows data used for the analysis. The data are plotted in figure 3, which indicates a recruited coral trout population of 2260 fish. This estimate is unduly low and would mean that virtually all coral trout at the reef had been caught since 2136 trout were known to have been taken. It is evident that the assumption that catch rate is proportional to recruited stock

Figure 3. 'Leslie Plot' for Coral Trout caught at Boult Reef during December 1-14, 1986.



abundance is not true. However, a surprisingly consistent fall in the catch per unit effort with cumulative catch is apparently caused by intensive fishing. Some possible mechanisms for this phenomenon are discussed later in this report.

* Underwater counts conducted before and after fishing

Table 4 sets out results of the underwater counts taken by diver before the reef was opened to fishing and again after 14 days of fishing.

Table 4 Underwater coral trout counts in block 4

Sub-block code	Relative area	Counts/5 min	
		Pre-fishing	Post-fisning
A	19	3,4,4,5 5,2,6,2 3,1,7,2	1,1,6,1 1,1,1,2
B	16	5,2,2,2 2,13,5,5	9,6,3,5
C	18	0,4,2,2 2,5,6,5 0,2,1,2	2,1,0,1 3,0,3,1
D	21	12,6,14,3 10,4,6,18	5,4,0,2
E	23	0,3,7,2 0,0,2,0	3,2,4,0 3,2,4,0
F	18	1,18,1,5	17,5,2,1

Using the formula given above, it is calculated that fishing caused a thirty percent fall in the average density of trout in block 4 at Boult Reef, from an average relative density of 4.63 prior to fishing to 3.24 after fishing.

Although a precise estimate of the number of trout caught in block 4 is not available because some fishermen pooled their catch taken from several blocks, it is known that block 4 received a greater fishing effort than the others. It is estimated that 850 of the 2136 trout taken came from block 4. This gives an initial trout population in the block of about 2850.

Many error sources exist in underwater count surveys of this nature. Nevertheless, the counts do confirm beyond doubt that after 2136 coral trout had been taken from the reef, significant numbers still remained. This lends support to the Petersen estimate of 8613 fish in the recruited stock at opening and indicates that the Leslie estimate of 2260 fish is in error.

2.5.6 CORAL TROUT CATCHABILITY

Figure 4 shows the Leslie plot of data obtained during the experiment combined with the independently obtained Peterser estimate of the initial trout population. A curve can be fitted which indicates that a progressive decrease in catchability occurs with removal of fish from the population.

The finding that catchability of intensively fished coral trout populations decreases with fishing, is supported by anecdotal evidence. Experienced coral trout fishermen report that if a population of trout is fished very intensively, remaining fish in the population will progressively go 'off the bite' or become 'hook-shy'. As a result many fishermen avoid fishing a particular reef for more than a day or so, in order not to 'turn the fish shy'. Fishermen report that if a population is spelled after a period of heavy fishing, it looses the hook-shy trait and catchability again increases.

It is interesting to note that on the third day of fishing at Boult Reef, most experienced fishermen recognised that the fish had 'gone off the bite'. At this time, some tried 'wogging' (trolling with a feathered lure) to induce fish to bite. However, this method did not improve catch rates.

The mechanism whereby fish become progressively less catchable remains unclear. It seems difficult to accept what some fishermen believe which is that fish learn to avoid baits by observing the fate of others. Other mechanisms may be postulated. Fish may simply become less inclined to take bait if there is a great deal of noise from vessels. Alternatively, fish remaining after a percentage of the population has been removed may not feed while social readjustments are taking place. An example of such a social readjustment would be the redefinition of territorial boundaries.

A further possibility is that only a percentage of the population is available to be caught at any one time. One such mechanism relates to the feeding biology of coral trout. Unlike some 'passive' capture methods, fishing using hook and line depends very much upon the feeding behaviour of the fish. Coral trout are predators and like many such species it is likely that they feed intermittently. It is postulated that at any time, only a percentage of the recruited population of coral trout are in 'feeding phase' and hence available to be caught by hook and line.

It is possible that virtually all trout in 'feeding phase' at Boult Reef were caught in the first two weeks of fishing. About 2260 fish (estimated by the Leslie plot) out of 8613 fish (estimated by the Petersen method) were in feeding phase during the experimental period. Of these, 2136 were caught thus leaving only 124 vulnerable fish after day 14. This accounts for the low catch rates towards the end of the experimental period.

The Leslie model thus applies to the 'recruited stock' in feeding phase ie there is a linear decline in the catch per unit effort with the abundance of stock in feeding phase.

If the above hypothesis holds, predictions about further fishing at Boult Reef (ie beyond the 14 days of the experiment) can be made. For example, if fishing intensity at the reef had remained high, an upper limit on catch rate could be predicted which is determined by the rate fish are naturally entering the feeding sub-population. Alternatively, if the population had been 'rested' for a period, a new equilibrium would have been established between feeding and non-feeding segments of the population. Ultimately about one quarter of the remaining population (about 1500 of the remaining 6000 fish) would again be in feeding phase. If fishing had then resumed, catchability would again have been high, as the vulnerable segment of the population was again removed. These scenarios are illustrated graphically in figure 4.

Thus, the rate which fish can be removed from the population is governed largely by the dynamics of the numbers of fish entering and exiting the feeding phase rather than solely by the absolute level of fishing effort being applied to the population. This mechanism could be readily modelled and tested experimentally.

If the mechanism described above is operating, it has very important management implications. It means that 'pulse fishing' is a very effective strategy for harvesting coral trout populations, since the catchability of the sub-population which is feeding is very high. As previously noted, many commercial fishermen already deliberately operate this way.

Table 5 sets out details of the catch per effort over the first 14 days of fishing at Boult Reef and the estimated decline in density of trout and these figures are plotted in figure 5.

Using fishing hours per hectare as the unit of fishing intensity, the value for catchability for the whole population is estimated at 0.15 (slope 'a' in figure 5). The most conservative value of 'q' would be in the order of 0.05 (slope 'b' in figure 5). However, the catchability of the feeding sub-population (assuming the above hypothesis is correct) is 0.6 (slope 'c' in figure 5).

Figure 4. Pathways towards 'fishout' taken under three theoretical fishing scenarios.

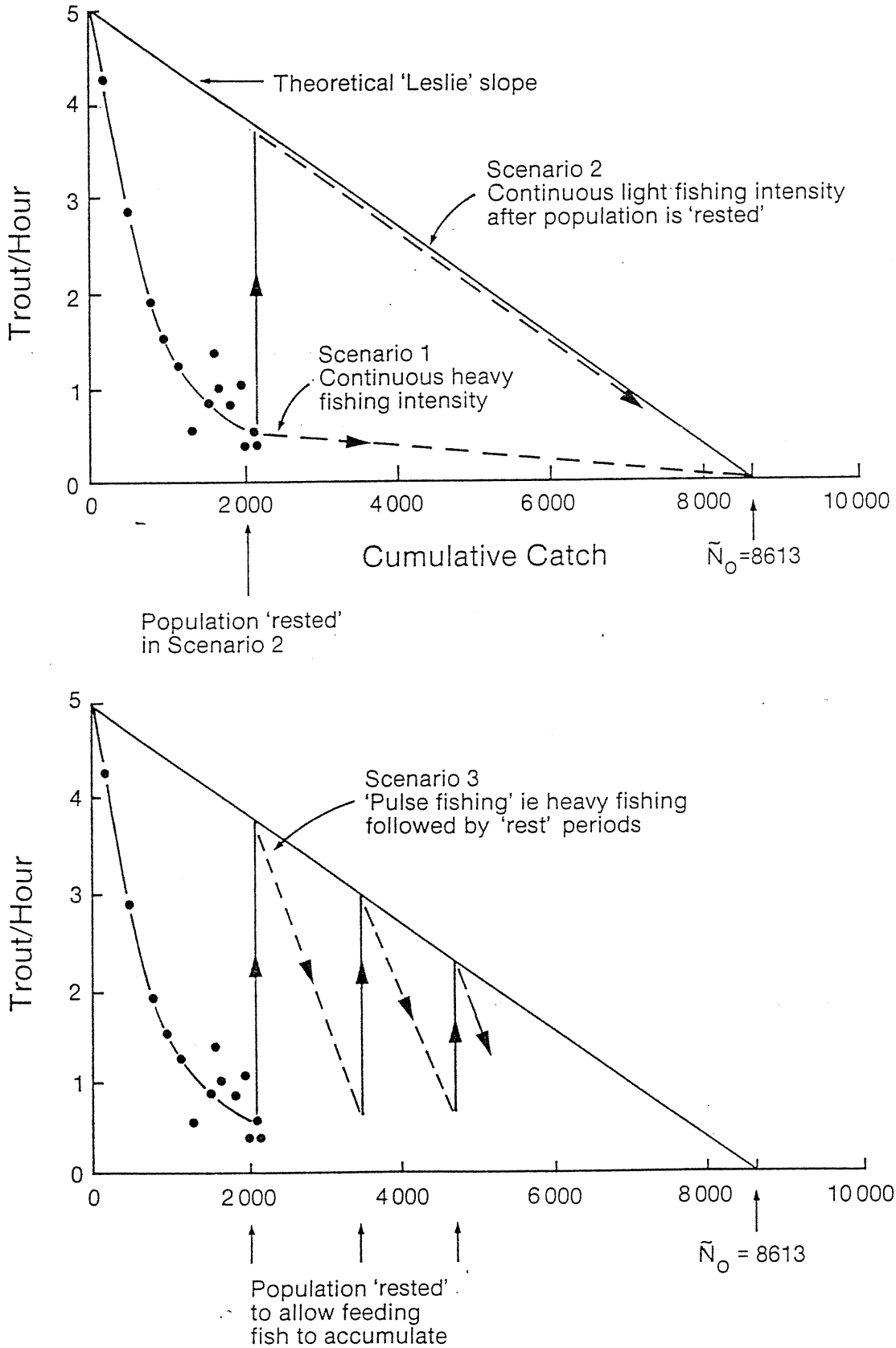
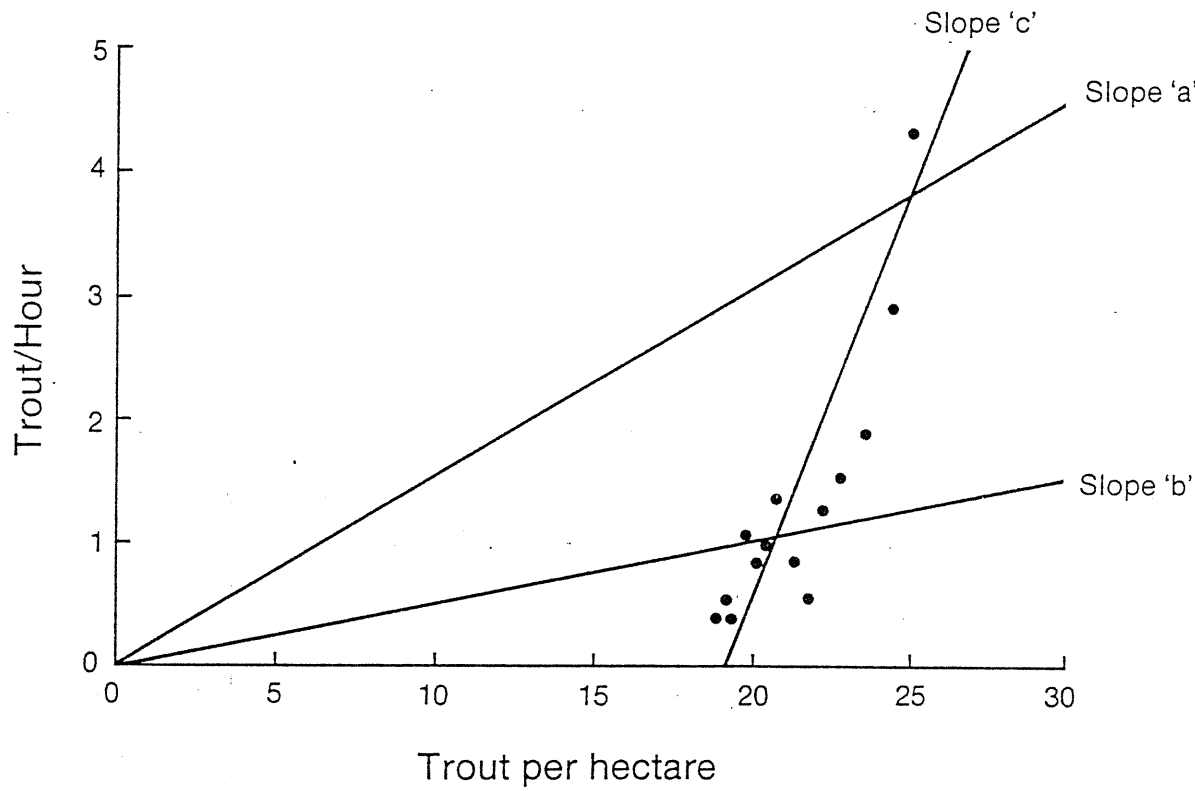


Figure 5. Catch rate by density of Coral Trout at Boult Reef (1-14 Dec. 1986).



2.5.7 SIZE DISTRIBUTION OF CORAL TROUT

Size frequency distributions for coral trout caught at Boult Reef and at nearby Fitzroy Reef between September and November 1986, are shown in figures 6a and 6b. These indicate that the average size of trout at Boult Reef was substantially greater than at nearby Fitzroy Reef, which had been continuously open to fishing.

Figure 6c shows the length frequency of coral trout caught at Boult Reef in May 1988, after the reef had been open for 18 months. The figure clearly shows a new cohort (estimated from Goeden (1978) to be 3.5 year old fish) growing into the fishable stock. In December 1988, these fish would have been aged two years and too small to be represented in the catch.

It is significant that the fishery in May 1988 was based substantially (about 40%) on a cohort of fish that was not represented in the catch 18 months earlier. It appears that only about 25% of the cohort of fish available at opening were left. From this fact and a knowledge of the growth rate of coral trout (Goeden 1978), it appears likely that substantial growth overfishing is occurring. More detailed analysis of available data is warranted.

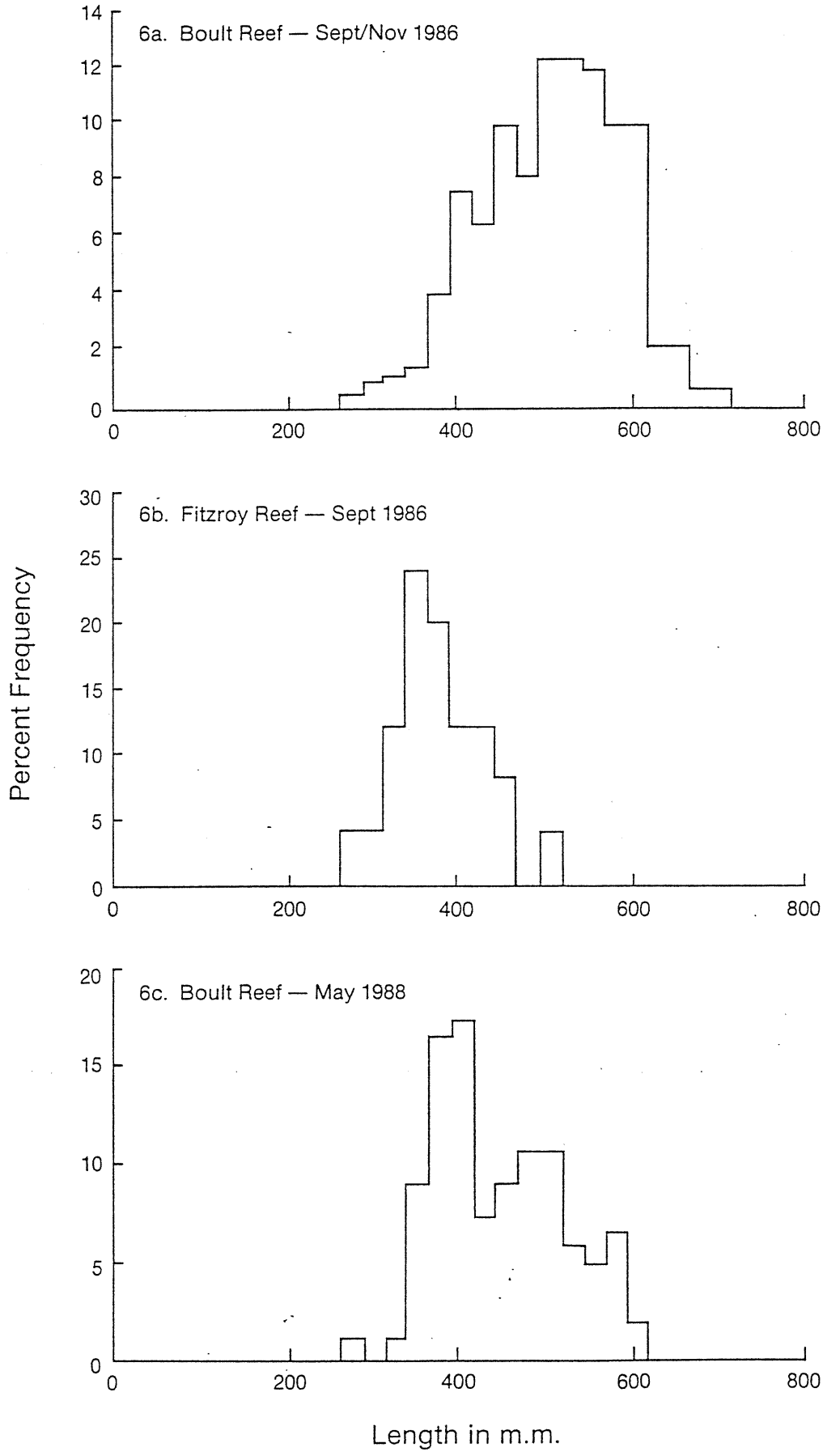
It is clear that the average size (and average density) of coral trout at Boult Reef at the time of its re-opening to fishing was substantially greater than at nearby Fitzroy Reef. The most likely cause for this is the 3.5 year closure of Boult Reef to fishing. It is concluded that the closure of Boult Reef to fishing did result in substantial replenishment of coral trout stocks. However, the population was very rapidly depleted following re-opening of the reef.

2.5.8 PUBLIC CONTACT ASPECTS OF THE EXPERIMENT

The experiment relied on the co-operation of the fishing public, particularly to keep log-book records and return tags. For this reason, considerable effort was made to publicise the work prior to the reef being opened. Prizes for returning tags and for record keeping were offered and a $5 reward was paid for each tag returned. Ultimately however, the fact that the monitoring team was continuously present at the reef to issue and receive log-books and tags and to explain the experiment to participants proved to be the most valuable incentive for people to co-operate. On-site supervision must be planned into any future work of this nature. Promise of feedback of results was also very important as an incentive for co-operation. The level of public co-operation was close to 100%.

The design of log books was felt to be too complicated since it involved recording catch and effort for each fishing block as well as a tally of catch and effort each three hours (see Appendix 2). Thus participants had to be aware of both time and fishing location in detail. For future work of this kind, the log books need to be simplified even though this would mean a loss of information.

Figure 6. Size frequencies of Coral Trout.



A major benefit coming from this work was the opportunity for extension contact with users which it provided. Extension took the form of media publicity before and after the experiment, face to face contact at the reef with many important users including commercial fishermen and charter vessel operators and publication in popular form of the results. Every participant was sent a summary of results soon after the completion of the experiment.

The project demonstrated to all levels of staff involved that a major side benefit of monitoring work is the user contact opportunities afforded. The conduct of high profile monitoring projects which involve the public directly (a stated GBRMPA objective) should be recognised by senior Q.NPWS and Authority staff as a legitimate public contact tool for day-to-day management staff.

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4.0 ACKNOWLEDGEMENTS

This experiment relied substantially on the co-operation of the fishing public who were asked to record catch and effort and return tagged fish. The co-operation of those people, professional and amateurs, who fished at Boult Reef during the first 14 days of December 1986 is greatfully acknowledged.

Professional fishermen who caught fish to be tagged prior to the reef being re-opened are acknowledged. Thanks are due to Alan Bartlen, Graeme Wassel, Tony Roberts and particularly Lance Hayward.

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P & O Resorts Pty Ltd and Charles Alvey and Son donated prizes for fishermen co-operating in the experiment. Those firms are greatfully acknowledged.

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APPENDIX 1

Discussion of potential sources of error in population estimates based on the Petersen capture/recapture technique

Gulland (1969) describes a number of error sources which may arise in tagging experiments. These errors are discussed below in relation to the experiment at Boult Reef.

* Death of fish immediately after tagging resulting from the tagging process

No direct evidence of this type of mortality was observed. Almost all coral trout tagged were returned to the water within 30 seconds and upon release swam off strongly. Tagged fish were observed by divers on many occasions and appeared to be behaving normally.

* Incomplete reporting of tags recaptured by fishermen

During the first 14 days following the re-opening of Boult Reef to fishing, a survey team was continuously present. The experiment was explained and a daily fishing log was issued to every person fishing at the reef. Completed log books and tags removed from fish were collected daily and in many cases the catch of individual vessels was sorted and measured by the survey team. To further encourage returns, $5 was paid for each tag returned ($10 for both tags from a double tagged fish) and a tag returned also provided one chance in a raffle for a substantial prize. The possibility of significant non-reporting of tags returned in the first 14 days of the experiment can thus be disregarded.

* Loss of tags from the fish

Evidence of tag loss was obtained during field operations early in the project. Some coral trout in the catch showed clear signs of having been tagged earlier.

Coral trout in particular, are often scarred above the head in the region where the loop tag is applied and it is now clear that their habit of swimming through coral makes a loop tag in this position particularly vulnerable to being snagged and lost.

When this became evident, all coral trout

subsequently caught were double tagged, with a second loop tag being applied to the tail end of the fish. Tail loop tags were much less vulnerable to being shed (see appendix 3). In all, 201 coral trout were released with one tag at the head end and 375 were released with a head and tail tag. Only three tags from fish in the former group were returned and this group has been excluded from the analysis.

Appendix 3 shows the return rates of various categories of tagged coral trout. Using these figures, a correction factor for those fish which had lost both tags and were therefor unrecognizable in the catch, can be calculated (Seber, 1982, Section 3.2.3). This factor is 1.12 and the total number of fish recaptured of those initially double tagged is therefore 93.

Over a period of up to a maximum of 90 days at large, 72% of coral trout initially double tagged had lost one or both tags (Beinssen 1989).

* Greater mortality of tagged fish as compared with untagged fish in the population

No direct evidence of increased mortality caused by the presence of a tag is available. Tagged fish observed by divers seemed to behave normally.

An observation on the use of loop tags was that since they tended to remain mobile in the fish, the tagging wound tended not to heal well and severe ulceration at the site was observed to occur in some cases.

* Emigration of tagged fish

During this experiment, no evidence for immigration or emigration of coral trout was revealed. Only limited movement of coral trout between blocks at the reef was recorded and no tagged fish were returned from nearby reefs. This error source can be disregarded.

* Tagged and untagged fish not equally vulnerable to fishing

It is likely that there are differences between individual fish in the population in relation to the taking of bait. It is therefor possible that the tagged sub-population is either more or less 'catchable' than the whole population on average. This is discussed in detail in Section 2.5.6 of this report.

For this experiment, fish were tagged over three separate weeks which were widely spaced in time. It is assumed that by the time the public began fishing at the reef, feeding and non-feeding fish were represented in the tagged sub-population in naturally occurring proportions.

* Tagged fish not uniformly mixed with the untagged population

Particular care was taken to distribute the tagged fish uniformly into the untagged populations by applying even fishing intensity (effort/unit area) around the reef and tagging all viable fish caught. Any movement of tagged fish would also assist the mixing process. Further, the fishing public selected fishing sites without a knowledge of the distribution of tagged fish. There is thus no reason to suppose that this form of bias exists in the data.

APPENDIX 2

Example of fishing log-book issued daily to participating fishers at Boult Reef

Date	: :	Time	:
Serial No.			

DAILY FISHING LOG
Boult Reef
Queensland National Parks and Wildlife Service.

Please take a few minutes to record your catch and fishing times. Record this information each time you move your boat to a new fishing block and at the following times each day.

6 a.m.
9 a.m.
12 noon
3 p.m.
6 p.m.
12 midnight

Please hand this completed log back at the end of each fishing day, before leaving Boult Reef.

To become eligible to win the prizes being offered, please fill out the space below.

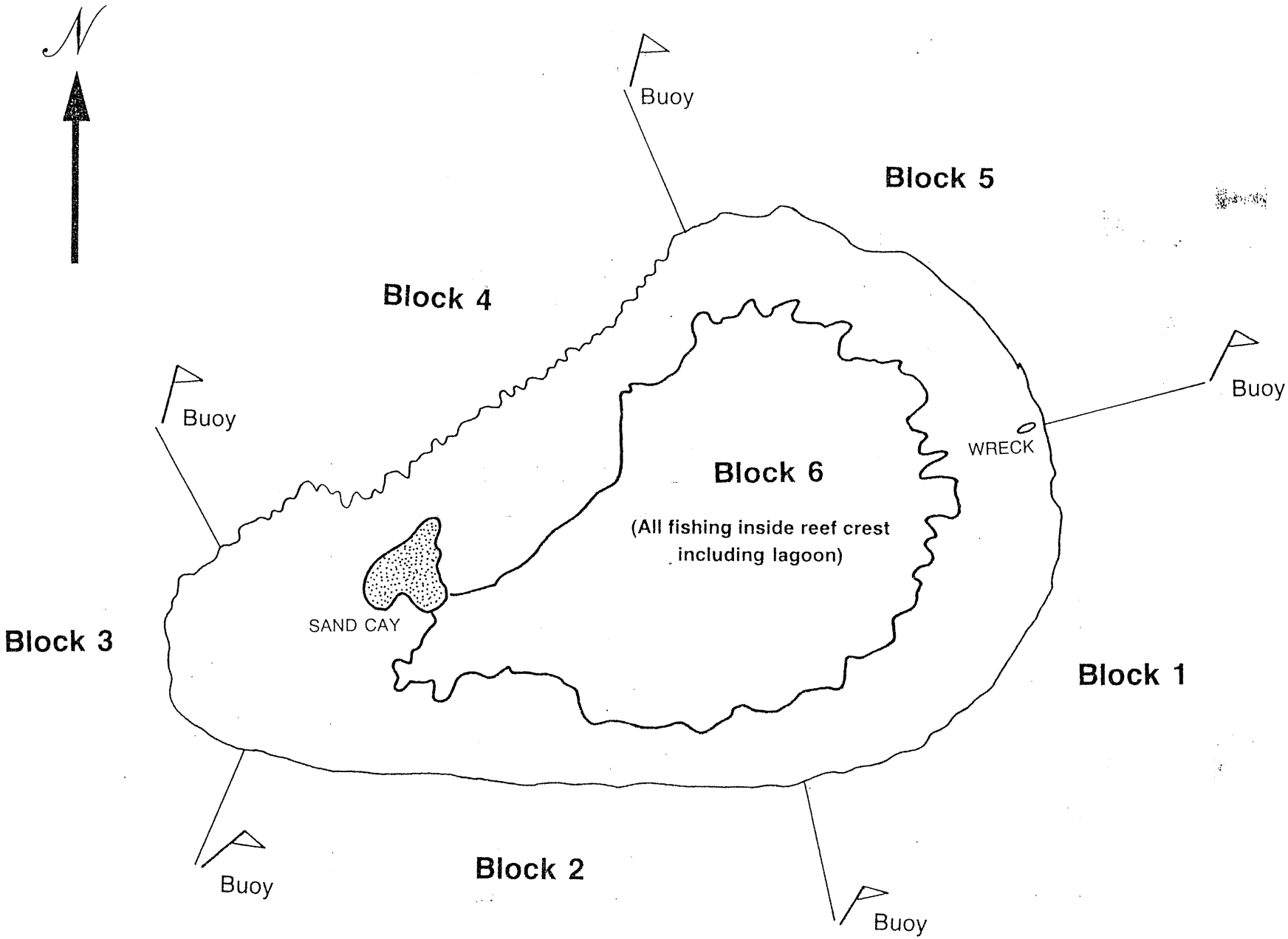
Name:.....

Address:.....

.....

Telephone Number:.....

Boult Reef Fishing Blocks



12 midnight to 6 a.m.

If you fished at Boult Reef between the above times, please fill out this page

A Please record your fishing locations, fishing time and catch.

FISHING BLOCK (see map)	EXACT TIME SPENT FISHING Hrs : Mins	NUMBER OF FISH CAUGHT AND KEPT									FISH THROWN BACK	
		Coral Trout	Coronation Trout	Lippers	Footballer Cod	All other Cod species	Hussars	Red Emperor	All Mackeral Species	All Others Combined	Coral Trout	All Others
1	:											
2	:											
3	:											
4	:											
5	:											
6	:											

B Please record the length in centimetres of each Coral Trout caught, from the tip of the snout to the fork in the tail. Use the tape measure provided.

C Please record any tagged fish caught (or fish with tag scars).

SERIAL TAG NUMBER	SPECIES	LENGTH	BLOCK	
				Please indicate on the map, exactly where each tagged fish was caught.

6 a.m. to 9 a.m.

If you fished at Boult Reef between the above times, please fill out this page

A Please record your fishing locations, fishing time and catch.

FISHING BLOCK (see map)	EXACT TIME SPENT FISHING Hrs : Mins	NUMBER OF FISH CAUGHT AND KEPT									FISH THROWN BACK	
		Coral Trout	Coronation Trout	Lippers	Footballer Cod	All other Cod species	Hussars	Red Emperor	All Mackeral Species	All Others Combined	Coral Trout	All Others
1	:											
2	:											
3	:											
4	:											
5	:											
6	:											

B Please record the length in centimetres of each Coral Trout caught, from the tip of the snout to the fork in the tail. Use the tape measure provided.

C Please record any tagged fish caught (or fish with tag scars).

SERIAL TAG NUMBER	SPECIES	LENGTH	BLOCK	
				Please indicate on the map, exactly where each tagged fish was caught.

9 a.m. to 12 noon

If you fished at Boult Reef between the above times, please fill out this page

A Please record your fishing locations, fishing time and catch.

FISHING BLOCK (see map)	EXACT TIME SPENT FISHING Hrs : Mins	NUMBER OF FISH CAUGHT AND KEPT									FISH THROWN BACK	
		Coral Trout	Coronation Trout	Lippers	Footballer Cod	All other Cod species	Hussars	Red Emperor	All Mackeral Species	All Others Combined	Coral Trout	All Others
1	:											
2	:											
3	:											
4	:											
5	:											
6	:											

B Please record the length in centimetres of each Coral Trout caught, from the tip of the snout to the fork in the tail. Use the tape measure provided.

C Please record any tagged fish caught (or fish with tag scars).

SERIAL TAG NUMBER	SPECIES	LENGTH	BLOCK	
				Please indicate on the map, exactly where each tagged fish was caught.

12 noon to 3 p.m.

If you fished at Boult Reef between the above times, please fill out this page

A Please record your fishing locations, fishing time and catch.

FISHING BLOCK (see map)	EXACT TIME SPENT FISHING Hrs : Mins	NUMBER OF FISH CAUGHT AND KEPT									FISH THROWN BACK	
		Coral Trout	Coronation Trout	Lippers	Footballer Cod	All other Cod species	Hussars	Red Emperor	All Mackeral Species	All Others Combined	Coral Trout	All Others
1	:											
2	:											
3	:											
4	:											
5	:											
6	:											

B Please record the length in centimetres of each Coral Trout caught, from the tip of the snout to the fork in the tail. Use the tape measure provided.

C Please record any tagged fish caught (or fish with tag scars).

SERIAL TAG NUMBER	SPECIES	LENGTH	BLOCK	
				Please indicate on the map, exactly where each tagged fish was caught.

3 p.m. to 6 p.m.

If you fished at Boult Reef between the above times, please fill out this page

A Please record your fishing locations, fishing time and catch.

FISHING BLOCK (see map)	EXACT TIME SPENT FISHING Hrs : Mins	NUMBER OF FISH CAUGHT AND KEPT									FISH THROWN BACK	
		Coral Trout	Coronation Trout	Lippers	Footballer Cod	All other Cod species	Hussars	Red Emperor	All Mackeral Species	All Others Combined	Coral Trout	All Others
1	:											
2	:											
3	:											
4	:											
5	:											
6	:											

B Please record the length in centimetres of each Coral Trout caught, from the tip of the snout to the fork in the tail. Use the tape measure provided.

C Please record any tagged fish caught (or fish with tag scars).

SERIAL TAG NUMBER	SPECIES	LENGTH	BLOCK	
				Please indicate on the map, exactly where each tagged fish was caught.

6 p.m. to 12 midnight

If you fished at Boult Reef between the above times, please fill out this page

A Please record your fishing locations, fishing time and catch.

FISHING BLOCK (see map)	EXACT TIME SPENT FISHING Hrs : Mins	NUMBER OF FISH CAUGHT AND KEPT									FISH THROWN BACK	
		Coral Trout	Coronation Trout	Lippers	Footballer Cod	All other Cod species	Hussars	Red Emperor	All Mackeral Species	All Others Combined	Coral Trout	All Others
1	:											
2	:											
3	:											
4	:											
5	:											
6	:											

B Please record the length in centimetres of each Coral Trout caught, from the tip of the snout to the fork in the tail. Use the tape measure provided.

C Please record any tagged fish caught (or fish with tag scars).

SERIAL TAG NUMBER	SPECIES	LENGTH	BLOCK	
				Please indicate on the map, exactly where each tagged fish was caught.

About you and your fishing gear.

1. Were you spearfishing, line fishing or both?

2. If line fishing, what bait(s) did you use?

Pilchards	%
Fresh Cut	%
Other	%
Wogs/lures	%
Hook size used mainly?	
Did you use mainly ganged hooks?	
Weight of line used mainly?	

3. Are you a member of a fishing club?

4. How experienced at reef fishing are you?

Never reef fished	
Reef fish once per year or less	
Reef fish 2 - 5 times per year	
Reef fish 6 or more times per year	

5. Are you licenced as a commercial fisherman?

6. Any Comments?.....

Please return this completed book to the Marine Park rangers or if this is not possible, post to:

Queensland National Parks and Wildlife Service
194 Quay Street,
Rockhampton, 4700.
Telephone: (079) 27 6511

Thank you for your Co-operation.

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APPENDIX 3

Release and recapture information for tagged coral trout at Boult Reef

A total of 604 coral trout were captured for tagging at Boult Reef, prior to its re-opening. Of these, 27 were inadvertently killed (4.5%) and one was released without being tagged.

A total of 201 trout were tagged with one tag only placed at the head end of the fish. It became clear during the second tagging trip from the number of fish with tagging marks being recaptured, that tags were being lost. It was therefore decided that most fish henceforth would be double tagged, at both the head and tail end.

Subsequently, only three single tagged fish were returned in the first fourteen days of fishing. It is clear that tags in this position are vulnerable to loss by being snagged on coral. Single tagged fish have thus been excluded from the analysis.

A total of 375 double tagged trout were released at the reef. Of these, the following numbers were re-captured in the first 14 days of fishing:

Fish returned with both tags	26
Fish returned with tail tag only	52
Fish returned with head tag only	5
Total fish returned	83

A correction factor for those fish which had lost both tags (and therefore unrecognizable in the catch) needs to be calculated as described by Seber (1982), Section 3.2.3. This is calculated at 1.12 and the total number of fish recaptured is thus calculated as 93 ie 10 tagged fish are estimated to have been returned unrecognised. A total of 2136 trout were caught in the first 14 days.

From the above information, a Petersen estimate of the total recruited population at opening is calculated at 8613 with a standard error of +/- 873.