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WHERE ARE ALL THE CORAL TROUT?

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Everyone wants to know where all the coral trout are. Recreational fishermen want to know so that they can catch enough for a feed and add the perfect touch to that day on the water, commercial fishermen want to know so they can make a good living and the Great Barrier Reef Marine Park Authority want to know so that they can manage the resources of the Great Barrier Reef (GBR) more effectively. We have spent hundreds of days at sea over the past few years trying to find out for the Marine Park Authority just how many coral trout there are on the GBR and where they live.

Marine scientists have been looking at methods for counting fishes underwater for some decades and the Marine Park Authority held a number of workshops in the late seventies and early eighties to develop techniques for counting coral trout. They also found that after training using wooden trout models a diver could make a good estimate of the length of any coral trout seen. We used a method that involved two divers searching for trout along 50 metre long by 20 metre wide survey transects so we could get an estimate of the number of coral trout living in a 1000 square metre area of reef. To cover as big a depth range as possible we ran the 50 metre fiberglass surveyors tape that defined each transect down the reef slope from the edge of the reef flat. On most reefs the transect ended in about 15 metres of water but on some shallow reefs the end of the tape was only at 8 or 10 metres depth and on the steep slopes of some outer reefs we reached depths between 20 and 30 metres.

Fish are not evenly distributed over a reef so we could not get a good estimate of trout numbers by searching only one transect. We surveyed ten separate transects on each reef scattered along about a kilometre length of reef edge. Because all reef animals find some bits of reef more to their liking than others, and coral trout are no exception, we did not find the same numbers of fish in all ten transects. Typically, if the *average* number of coral trout found in each transect was about five then the numbers we actually counted in the ten transects might range from only one or two fish up to a maximum of nine or ten.

But where on each reef was the best place to make our counts? Obviously we could not cover the entire reef with only ten transects twenty metres wide. We made surveys in a variety of habitats on a few reefs to see where most coral trout were found on a reef. There were very few coral trout on the reef flat or in shallow lagoon areas compared to the reef slopes. On the reef slopes we found that there were fewer coral trout on the exposed windward or front side of the reef, facing toward the predominant southeast wind, than on the more sheltered leeward or back reef. On average there were about 40% more coral trout on the back reef than on the front so we decided to confine our counts to the back reef slope habitat. This also has the advantage of being a safer place to work when strong southeasterly trade winds are blowing.

GBR Survey of Coral Trout

To cover the entire GBR region we had to make some other decisions. Clearly we could not count coral trout on all the 2,500 separate reefs the Marine Park Authority has listed. After consultations with the Marine Park Authority we chose reefs to survey at a wide range of positions from Triangle Reef at the top of Cape York, with a latitude of 10°30' south, to Lady Musgrave Island in the Capricorn-Bunker Group at a latitude of 24° south. The selected reefs also ranged across the shelf, from turbid coastal reefs where even seeing the coral trout was a problem, out to the reefs of the outer barrier rampart on the edge of the continental shelf where visibility in the deep blue, crystal clear water was often over 30 metres. We surveyed a total of 156 different reefs over a three year period, spending more than 200 days at sea. The sea time was spread over four major field trips on large charter boats, spending up to 50 days at a time at sea.

We got to experience the many moods of the GBR, from breathless, mirror calm days, when we wished life could go on like that forever, to those few hellish times when tropical lows or storm fronts pushed the winds over 50 knots. Several times we had to run to port for shelter as cyclones approached; T.C. Ursula drove us into harbour twice over a 14 day period, each time veering out to sea again once she had disrupted our survey routine and made us run for cover. At other times during the southeast trade wind season we had to put up with two weeks of continuous strong wind warnings, experiencing 20-30 knot winds as big highs pushed a strong ridge up the Queensland coast.

The survey diving was hard work, spending three hours underwater and swimming over three kilometres to complete each group of ten transect counts. Sharks often shared the count with us, especially on reefs toward the top of Cape York where we sometimes had up to fifteen grey reef sharks investigating what we were doing in their territory. Usually these were only a distraction but on a few memorable occasions, once on Yule Detached Reef on the far-northern outer barrier and once on Charity Reef off Cape Upstart we were forced to abandon our work: it was impossible to count coral trout and keep track of the large and aggressive sharks. On another occasion we decided not to proceed with the survey before we had even got in the water - a large crocodile slid off a sand cay and into our proposed dive site as we were ready to throw out the anchor. In the Swain Group of reefs at the southern end of the GBR we also had to contend with sea snakes. We found that if we kept still as they approached the snakes would ignore us, but keeping still took a bit of will power with a two metre sea snake investigating you.

Although there were a few frightening experiences we gained a unique insight into the true nature of the Great Barrier Reef, seeing it in all its variety, from pristine beautiful reefs to those that had just been devastated by crown-of-thorns starfish , from reefs with very little actual coral at all that were dominated by finger and whorl sponges, to those where a few huge coral colonies covered large portions of the reef. We saw animals beautiful and hideous, large and small. We saw whales and dugongs, dived with dolphins and touched giant manta rays as they glided around us. But most of all we saw the day to day life of the thousands of animals that make up a coral reef and learned that there is no such thing as a normal reef; they are all different.

We also learned a bit about coral trout. As most fishermen know there are actually several species of coral trout. All of them are fish eating predators and they are the most important reef-living predators on the GBR. They have a life cycle that sees all individuals start life as females and spend one or two years reproducing as a female before changing sex to become a male. All large coral trout are males. They are rapid growing fishes, becoming reproductively mature in their second year and reaching the 35 cm legal minimum catchable length in one to two years.

Different Coral Trout Species

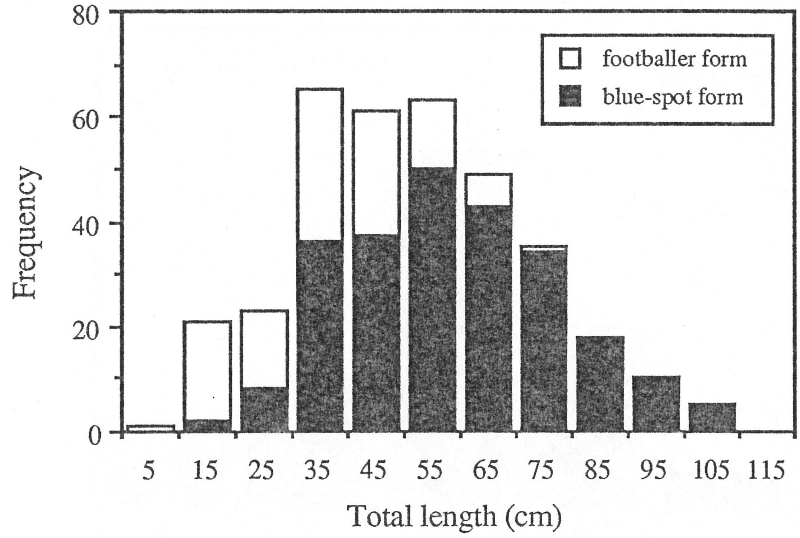
We started off counting six species. The common coral trout, known by the scientific name of *Plectropomus leopardus* and sometimes called the leopard trout, was the one most often seen. It ranges from white-grey to green-grey to red-brown, and is covered with small blue spots with a distinctive blue eyebrow. On turbid inshore and coastal reefs we encountered the bar-cheeked coral trout *Plectropomus maculatus*, a species that was usually orange brown in colour with larger, bright blue spots, and those spots on the side of the head elongated into bars. Occasionally we would see a footballer coral trout *Plectropomus laevis* (the scientific name *Plectropomus melanoleucas* is sometimes used for this species), sometimes known as the tiger trout, with its distinctive colour pattern. The five black saddle markings with outlines of blue dots on a blue-spotted white body and bright yellow fins make this species unmistakable. On outer barrier reefs the blue-spot coral trout was common. This species apparently had not been given a scientific name and was known as *Plectropomus* sp., meaning an unnamed species in the genus *Plectropomus*. The blue-spot reached a larger size than the other coral trout, we saw individuals up to 120 cm long, compared to the around 65 cm maximum of all the other species. Blue-spot coral trout are red-brown with darker brown saddles and a scattering of widely spaced large blue spots on the body. A rare species that we only saw a few times was the passionfruit coral trout *Plectropomus areolatus*. The colour pattern of this species incorporates numerous large blue spots set close together over the entire body; the other species do not have blue spots on the belly. We also counted coronation trout *Variola louti*, a bright red-blue fish with a strongly lunate tail.

On later surveys we left out the coronation trout as this was primarily a deep water species, besides not being in the same scientific group as the other species that were all in the genus *Plectropomus*.

We discovered part-way through the project that the footballer coral trout and the blue-spot coral trout were in fact dramatically different colour forms of the same species, with the scientific name *Plectropomus laevis*. At first we doubted that this could be true, but as we thought about it the pieces fell into place. We had never seen any young blue-spot trout, the smallest we had seen were about 20 cm long. The reason for this is that all blue-spot coral trout start life in the footballer colour pattern and later change colour to the blue-spot pattern; all individuals over about 65 cm long were in the blue-spot pattern.

Why does this species have two such different colour patterns? The reason for this became obvious when we saw some very small footballer coral trout and observed their behaviour. The footballer colour pattern with its black saddles, blue spots and yellow fins is almost identical to that of a small pufferfish, the black-saddled toby *Canthigaster valentini*. This pufferfish is highly toxic and is recognised and avoided by predatory fishes. There is a small leatherjacket that mimics the pufferfish colour pattern so that predators mistake it for a toxic pufferfish and do not eat it, and it appears that the small footballer coral trout are attempting the same mimicry, with some behavioural traits that enhance the similarity. Unlike juveniles of the other coral trout that swim with body undulations like the adults, juvenile footballers hold their body rigid, fold their tail to resemble the puffer, and swim with pectoral fin beats. They also hold the front half of the dorsal fin partially erect in a triangular shape to make the body outline more similar to that of the pufferfish. Many of the footballers change to the blue-spot colour pattern at around 20-25 cm TL when the mimicry is no longer effective or necessary but a number of individuals apparently do not bother to change colour until they are much larger, with occasional individuals reaching a length of 70 cm and still retaining the footballer colour pattern (figure 1). This is one of the many stories that make the study of coral reef animals so rewarding.

Figure 1. Length frequency distribution of the two colour forms of the footballer/blue-spot coral trout showing the differences in size.

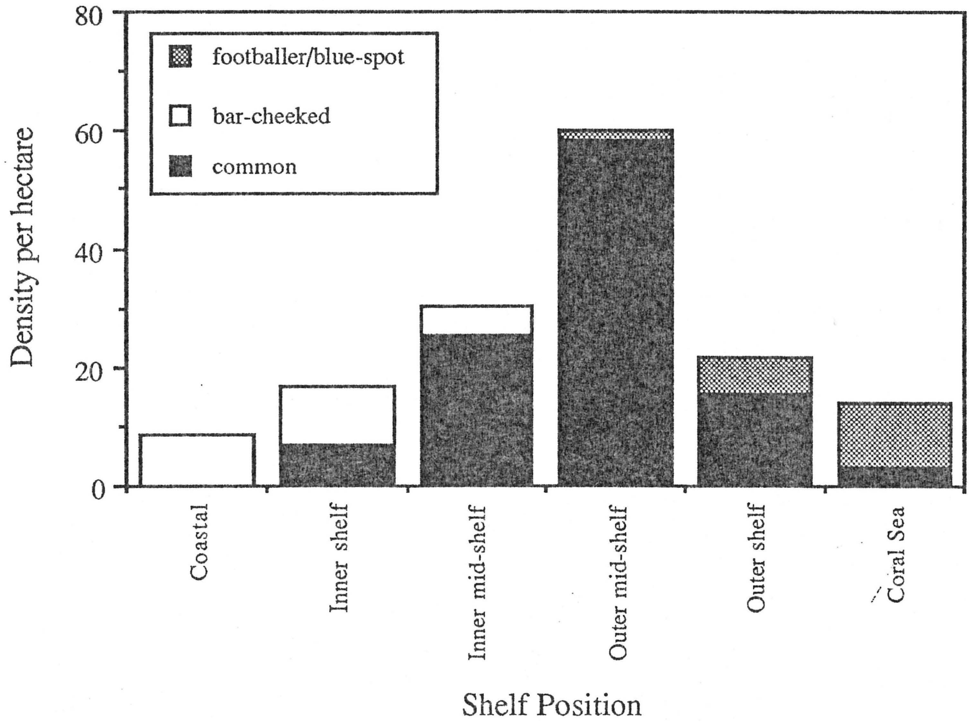


So we were dealing with three common species, the common coral trout, the bar-cheeked coral trout and the footballer/blue-spot coral trout, as well as the rare passionfruit coral trout. When the results from our surveys started to come in it rapidly became apparent that the major factor influencing where coral trout were found was the position of each reef on the gradient across the continental shelf. Anyone who has driven up the Queensland coast will realise that coastal and inshore reefs are usually very turbid. Underwater visibility is usually awful and if you can see five metres you are lucky. When the trade winds are blowing the waves stir up the silt and turn the water brown, reducing visibility to less than a metre. Animals that live on coastal reefs must be able to cope with this turbid water and with the seaweed forests that are often found in shallow water on these reefs.

Cross-Shelf Abundance

The bar-cheeked coral trout is able to thrive in these conditions, and is the only species of coral trout we found on the most turbid coastal reefs such as those around the Barnard Islands near Mourilyan Harbour. Average densities of bar-cheeked coral trout on these reefs was around eight per hectare (figure 2) (a hectare is 10,000 square metres, or a patch of reef 100 metres square). On inshore reefs where conditions are a bit better, such as around the Palm Islands north of Townsville, on Low Isles off Port Douglas and on the Cape Tribulation reefs, this species was also common (10 per hectare) but a few common coral trout were encountered as well (about 7 per hectare).

Figure 2. Changes in numbers of the different coral trout species across the continental shelf from turbid coastal reefs to the front of outer shelf reefs washed by the clear waters of the Coral Sea.



On mid-shelf reefs that are less than half way across the continental shelf water conditions are usually a lot better, with visibility around 10 metres, although in windy conditions this may drop to about 5 metres. In these conditions the common coral trout starts to come into its own, with average densities of over 25 per hectare, but the bar-cheeked coral trout is still found on the back reef slopes here (about 5 per hectare). As we get out into the clearer water around the reefs more than half-way across the shelf where visibility in usually between 15 and 20 metres, we get into the heart of coral trout country; the combined numbers of all species of coral trout are about twice as high here as anywhere else (figure 2). The common coral trout is the only common species on these reefs with average densities of almost 60 per hectare. So imagine, if you will, next time you are on one of these reefs - the majority of reefs on the GBR fall into this category - and the fish are not biting that there are around 60 coral trout within a stones throw of your boat. We also start to find a few footballer/blue-spot coral trout on these reefs but only about 1.5 per hectare.

When we start to get out wide, as the fishermen call it, out near the outer edge of the continental shelf where the water is a wonderful deep blue and underwater visibility approaches 30 metres, coral trout are less abundant. On the back of these outer shelf reefs the common coral trout is still the species most often encountered but only at densities of around 15 per hectare. The footballer/blue-spot coral trout becomes more abundant on these reefs (6.5 per hectare).

On the exposed front of these outer reefs, where the Coral Sea swell crashes unhindered, the reef slope is often very steep, falling quickly to depths of over 50 metres in visibility that often exceeds the same distance. Large blue-spot coral trout are dominant here, occurring at average densities of over 11 per hectare, and fish over 20 kilograms in weight are sometimes caught around these reefs. A few common coral trout are also seen on these steep front reefs but they do not seem to like these conditions and on reefs such as Raine Island they are not found at all.

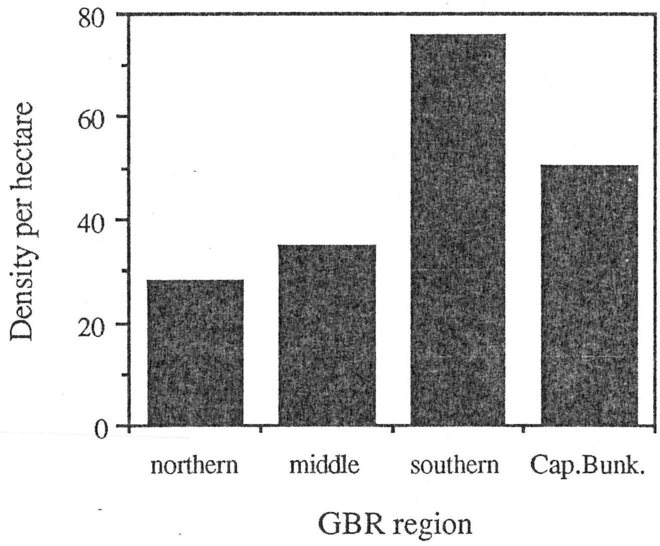
When the footballer/blue-spot coral trout is found on mid-shelf reefs about half the individuals seen are of the footballer colour pattern and half are blue-spots. On the clearer outer shelf reefs the majority of individuals are of the blue-spot colour pattern; over four times as many as there are footballers. Such a result would be possible if footballers were changing colour to the blue-spot form at a larger size on mid-shelf reefs, or if blue-spots had far less chance of survival on these reefs. If either of these mechanisms were operating then the average length of the two colour forms would be different on mid-shelf reefs compared to outer shelf reefs. If we calculate averages for these fishes on the two groups of reefs from our estimates of length for all coral trout counted we find that they were very similar: 40 cm versus 39 cm for the footballer form and 58 cm versus 59 cm for the blue-spot form, implying that these mechanisms are probably not the correct explanation for the different colour pattern ratios. A more likely explanation is that blue-spot coral trout prefer conditions on outer shelf reefs and migrate between reefs until they reach an outer shelf reef, moving tens of kilometres across the open bottom.

We can sum up by saying that in general the three common species of coral trout replace each other as we move across the continental shelf, with the bar-cheeked coral trout found on inner shelf reefs, the common coral trout on mid-shelf reefs and the footballer/blue-spot coral trout on outer shelf reefs.

North-South Abundance

There were also some dramatic effects on coral trout numbers caused by the vast latitudinal spread covered by the GBR. The GBR reef complex stretches a distance of over 1,800 kilometres, from 10°30' south to 24° south, with a winter water temperature difference between the north and south extremes of almost 5°C. There are changes in reef type along this huge distance and we might expect there to be changes in the reef animal communities as well. To the north of Cape Tribulation there is an almost continuous rampart of outer barrier reefs along the edge of the shelf and reefs in this northern region are different from those in the middle of the GBR, between Cape Tribulation and Cape Upstart, where the reefs are smaller and more widely spaced, without the protection provided by the outer barrier rampart. To the south, reefs become larger and closer together again, but they are a long way offshore, and subjected to much stronger currents than elsewhere on the GBR. Very few reefs in this southern region are close to the outer edge of the continental shelf. At the southern end of the GBR, and separate from the main body of reefs, is the Capricorn-Bunker Group of about 22 reefs, that includes Heron Island and Lady Musgrave Island.

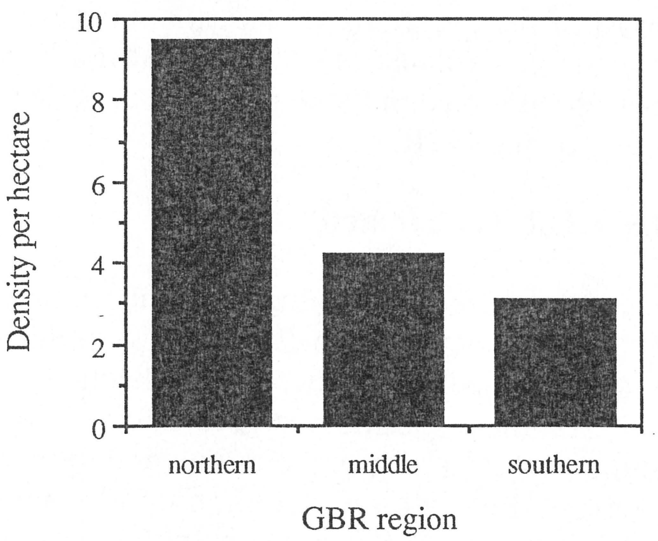
Figure 3. Numbers of the common coral trout on mid-shelf reefs in four major regions along the length of the GBR.



The density of some of the coral trout species changes markedly along the length of the GBR, although these changes are not as dramatic as those that occur across the continental shelf. On those mid-shelf reefs where it is most abundant the common coral trout has very similar average densities throughout the northern and middle regions of the GBR. In the northern region there are an average of 28 common coral trout per hectare on mid-shelf reefs, while in the middle region the average is 35 per hectare (figure 3). As we get into the reefs of the southern region there are far more common coral trout with average densities of 76 fish per hectare. On some reefs in the Swain Group at the south end of this region we counted more than 150 coral trout in a hectare of transects. Diving on these reefs we often found ourselves surrounded by curious coral trout, with 20 or 30 fish is view at once. In the Capricorn-Bunker Group of reefs there were also a lot of common coral trout, with average numbers of around 50 per hectare.

We are not sure why there should be such large numbers of coral trout on the southern region reefs. From all the information available the levels of commercial fishing are higher if anything in this region compared to areas further north and there is a lot a recreational fishing from charter boats. It is possible that there is more food available to coral trout on these southern reefs. During the summer months large schools of hardyhead bait fish are found around these reefs but do not occur further north and diet studies have shown that these are extensively preyed upon by coral trout. It may be that the reefs can support higher numbers of coral trout because of the seasonal availability of this abundant food supply. Interestingly there were no differences in the numbers of this species along the length of the GBR on outer shelf reefs where the bait fish schools do not occur. There is probably insufficient plankton to support these schools of small fish in the clear oceanic waters around reefs near the edge of the shelf.

Figure 4. Numbers of the footballer/blue-spot coral trout on outer shelf reefs in three major regions along the length of the GBR.



The footballer/blue-spot coral trout also shows marked latitudinal changes in density, but only on outer shelf reefs where this species is most abundant. For this coral trout there are higher numbers in the northern region, on the reefs of the outer barrier rampart, where there are an average of 9.5 fish per hectare, far more than the average of 3.6 per hectare on reefs further south (figure 4). In this case it is clearly some feature peculiar to these outer barrier reefs that these large coral trout prefer, but at this stage we have no real idea of what this could be. Numbers were even higher on the clear, steep fronts of these reefs with over 11 fish per hectare.

Coral Trout Length

Looking at the information of the length of the coral trout we counted reveals some interesting stories. For the common coral trout average lengths were higher on inner and outer shelf reefs where numbers were lower, than they were on mid-shelf reefs. There are a number of possible explanations for this but the most likely involves the movement of adults from mid-shelf reefs both out to outer shelf reefs and in to inshore reefs.

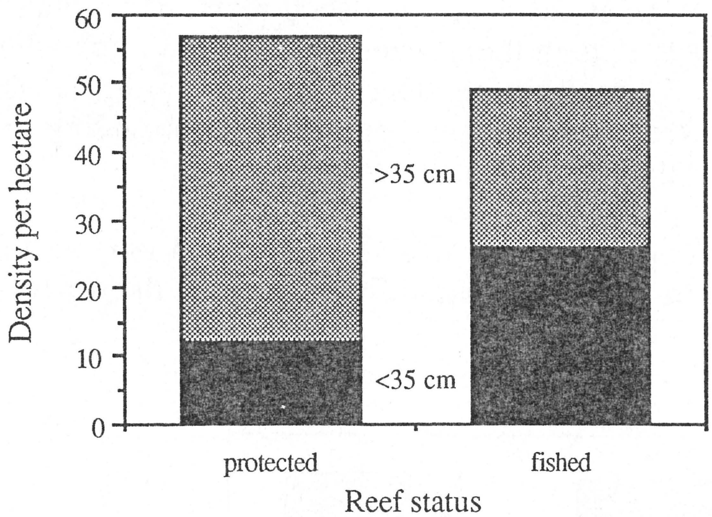
On mid-shelf reefs common coral trout lengths were similar along the entire GBR, averaging around 33 to 35 cm and with about half the coral trout over 35 cm long and available to fishermen. An exception was the reefs of the Capricorn-Bunker Group where the common coral trout was, on average, about 5 cm longer than elsewhere. If we looked at the maximum length the difference was even more dramatic. Maximum length for this species over most of the reef was between 65 and 70 cm long, and this was the same on reefs right across the shelf. In the Capricorn-Bunker reefs the largest common coral trout we saw were over 85 cm, and some individuals over 100 cm long have been recorded from these reefs. As with most of the questions we ask about coral trout, there are a number of possible explanations for this but the least unlikely is that the coral trout populations on these reefs are genetically different from those on the rest of the GBR.

Is the GBR Overfished?

We are often asked how fishing has affected coral trout numbers on the GBR. We were able to test this in the Capricorn-Bunker Group during this survey. On five of the reefs we visited fishing had not been permitted for from 2.5 to 4 years under the Marine Park zoning, while on six similar reefs in the same group fishing had continued as normal. Although there were, on average, slightly more common coral trout on the protected reefs than on the fished reefs (57 per hectare compared with 49 per hectare) statistical tests showed that these differences were not significant. This suggested that protection from fishing was not leading to a marked increase in the numbers of coral trout on the reefs.

If we divided the coral trout we recorded on these reefs into those that were over the 35 cm minimum takable length and hence available to fishermen, and those that were young fish below this length then the story becomes more interesting. There were almost twice as many coral trout over 35 cm long on the protected reefs compared with the fished reefs, but for the small fish the pattern was reversed, with twice as many on the fished reefs (figure 5). Why were there more small coral trout on the fished reefs? The most likely explanation is that the removal of large coral trout from a reef by fishermen improves the survival chances of small individuals, either by making more food available or because large coral trout eat small coral trout when they can.

Figure 5. Comparison of the number of fish over 35 cm long and those young fish below 35 cm on protected and fished reefs in the Capricorn-Bunker Group of reefs.

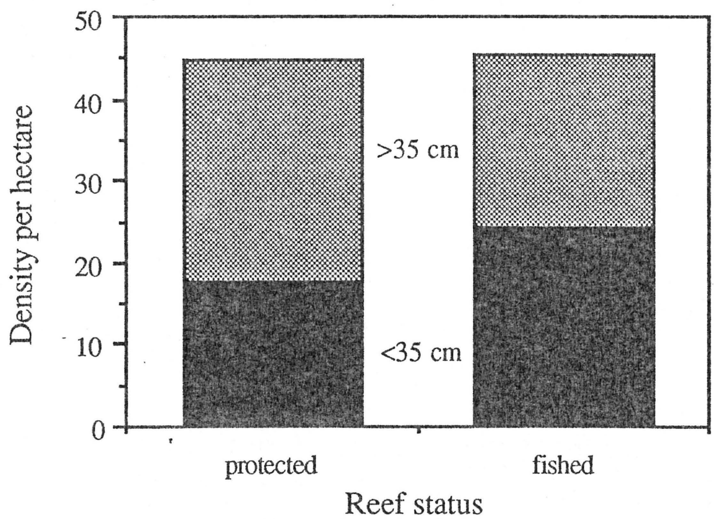


Protecting reefs from fishing did have an effect on the average length of coral trout. On these Capricorn-Bunker reefs the average length of the common coral trout was 36 cm on fished reefs and 45 cm on protected reefs. Taking adult fish away from fished reefs, and at the same time improving the survival of young fish, lead to a 9 cm reduction in average length.

During surveys for a more recent project to look at the effect of zoning protection in the Cairns Section of the Marine Park we collected more information on the effects of fishing protection on coral trout. The fifty reefs we surveyed had been zoned for seven years and more than a third of them had been protected from fishing of all types for this time. Of the mid-shelf reefs we visited, sixteen were still open to fishermen and ten had been protected. Overall average numbers of the common coral trout were almost identical on the two groups of reefs, with 46 per hectare on the fished reefs and 45 per hectare on the protected reefs. The story was the same on outer shelf reefs, where we counted coral trout on thirteen fished reefs and eight protected reefs. We found an average of 21 common coral trout per hectare on the fished reefs and 20 per hectare on the protected reefs. Seven years of protection had clearly not resulted in any increase in coral trout numbers.

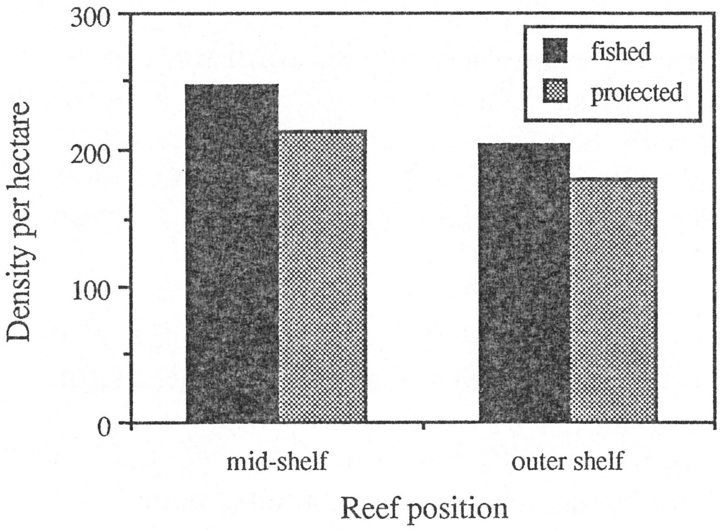
If we again split up the coral trout numbers into those that were over 35 cm long and available to fishermen and young fish less than 35 cm the picture was similar to what we found on Capricorn-Bunker reefs at the south end of the GBR. There were more adult coral trout on the protected reefs than on the fished reefs, but more young fish on the fished reefs (figure 6). During this survey we were able to count juvenile coral trout that were only 3-4 months of age separately from those more than a year old. The juvenile fish were between 8 and 18 cm long emphasising the rapid growth rate of coral trout. We found that there were twice as many juveniles on fished reefs, where there were almost 14 per hectare, than there were on protected reefs where average numbers were 7.4 per hectare. Once again, this suggests that if we take away some of the adults we get more juveniles surviving on a reef, compensating for the removal of the large fish.

Figure 6. Comparison of the number of fish over 35 cm long and those young fish below 35 cm on protected and fished reefs in the Cairns Section.



Given this juvenile compensation mechanism, that appears to increase the number of coral trout on fished reefs and compensate to some extent for those removed by fishermen, we might not expect to see much reduction in numbers. What happens to the numbers of some of the other groups of fish sought after by fishermen when a reef is protected? We counted all the fish species in the emperor and snapper (sea perch) families when we were surveying coral trout in the Cairns Section so we could also compare numbers of these groups between fished and protected reefs after seven years of protection. As with the coral trout, numbers of both these groups were very similar between fished and protected reefs, both on the mid-shelf and the outer shelf (figure 7).

Figure 7. Combined numbers of emperors and snappers on fished and protected mid-shelf and outer shelf reefs in the Cairns Section.



The preliminary information we have gathered on the effects of fishing on the GBR suggests that there is little or no increase in the numbers of fished species when a reef is protected from fishermen. Given that large numbers of juvenile coral trout settle out of the plankton each year (25% of the coral trout we counted in the Cairns Section mid-shelf reef surveys were juveniles less than a year old), and very few coral trout live for more than five years, we would expect a dramatic increase after seven years of protection if fishermen were severely depleting coral trout numbers.

How Many Coral Trout do Fishermen Catch?

So how many fish do fishermen remove from the reef? The annual combined catch of coral trout from both commercial and recreational fishermen over recent years has been about 2,000 tonnes. We can calculate from our surveys that the average length of coral trout over 35 cm long and available to fishermen is about 43 cm which equates to a weight of around one kilogram. If that is the case then the annual catch from the entire GBR is about two million fish. Looking at the maps of the region shows that there are about 1,200 major reefs on the GBR as well as about 1,400 small reef patches and island or coastal fringing reefs. Confining our discussion to the 1,200 major reefs we see that about 1,700 coral trout are taken from each reef per year. The average major reef has a length of reef edge of about 20 kilometres or about 200 hectares of reef slope, and about 1,000 hectares of reef flat and shallow lagoon. Combining these figures with our estimates of coral trout numbers we can see that there are about 20,000 coral trout on the average major reef and that about half of these, or 10,000 fish, are available to fishermen. This means that fishermen take only 8.5% of the total coral trout on a reef in any year, or 17% of the fish over 35 cm long. Obviously this fishing pressure is not spread evenly over all 1,200 reefs as we have assumed, but even if we say that only half of these reefs take most of the pressure then 34% of coral trout over 35 cm are being removed from these fished reefs each year. This figure equates remarkably well with the effects we observed in the Cairns Section, where there were 28% fewer coral trout over 35 cm long on fished reefs compared with reefs that had been protected for seven years.

As we mentioned above, almost 25% of the coral trout on any mid-shelf reef are juveniles, new fish coming onto the reef each year. If this is the normal state of affairs then the juveniles recruiting onto the reef would more than make up for the 17% taken from the reef each year by fishermen given the worst case scenario we have mentioned.

Catchability

So why don't we catch more fish? Why is it that some reefs appear to be fished out if fishing does not reduce fish numbers? The answer is that there may be plenty of fish on a reef but the fishermen can not catch them. Catchability is an important concept when considering the availability of the fish on a reef to the fishermen. Recent work has shown that there is no relation to the number of fish in an area of reef and the number that a group of skilled fishermen can catch. If an area has been heavily fished for some time the remaining fish are shy and hard to catch, even if there are large numbers of them. Conversely, in an area where the fish are naive and have not been fished for some years they are easy to catch. In another recent study, when scientists with appropriate permits visited protected reefs to sample fish for growth studies they caught three times as many fish as they did on nearby reefs that were open to normal fishing. This did not mean that there were three times as many fish on the protected reefs but that they were three times as catchable.

It is important to remember, however, that this does not mean that reefs can cope indefinitely with very high levels of fishing pressure, just that at the present level our evidence suggests that there is no cause for concern on the GBR. In other parts of the world sustained high fishing pressure exerted by large human populations on small reef areas has caused dramatic declines in the numbers of all of the larger reef fishes. We are fortunate to be in a position to be able to keep the GBR fish stocks in a healthy state with a sustainable yield of fine table fish.