The impacts of spearfishing:

notes on the effects of recreational diving on shallow marine reefs in Australia.

Jon Nevill[1] first published in 1984[2], revised July 30, 2006.

> *"In the old days (1940's and 1950s) my friends and I used to be able to go to Rottnest (Perth's holiday island) and spear a boat load of dhuies (best fish around). These days there's nothing there - I don't understand it."*
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> 85 year old veteran Western Australian spear fisherman Maurie Glazier quoted by niece Jo Buckee[3].

1. Abstract:

On the basis of anecdotal information (as little other information is available) I argue in this paper that recreational diving (in particular spearfishing) has had devastating effects on the fish and crayfish (southern rock lobster[4]) populations of accessible shallow reef environments along much of the Australian coastline. Spearfishing in Australia is almost entirely recreational. The paper briefly reviews the global scientific literature on the subject, providing a backdrop against which local anecdotal information may be judged. My involvement, as a teenager, in overfishing Victorian reefs is described. Overfishing of a similar nature appears to have taken place in other Australian States where reefs are within ready access (by car or boat) from population centres of all sizes. Damage to shallow reef environments along Australia's sparsely populated coastline (eg: in northern Western Australia, north-western Queensland, the Northern Territory, western South Australia and western Tasmania[5]) seems likely to be concentrated at the more accessible or attractive[6] sites. These impacts are significant in a national context, yet appear to have been ignored or under-estimated by both spearfishers and the government agencies[7] charged with conserving and regulating marine environments[8]. This relaxed managerial approach runs counter to the voluntary *FAO Code of Conduct for Responsible Fisheries*, which Australian governments claim to support. Current government management of the sport of spearfishing fails internationally accepted precautionary benchmarks in all Australian States. Further controls over spearfishing by State Governments are recommended, covering nine specific issues.

Keywords: spear, spearfishing, effects, impacts, Australia, recreational diving, lobster.

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2. Introduction:

Before discussing spearfishing in detail, it is important to note that 'passive' recreational diving and snorkelling (while important in developing an informed public voice for marine conservation) can also result in damage to marine habitats. Ponder et al. provide a review which highlights the need for awareness instruction, particularly for novice divers, as well as management limits on the number of divers at popular sites (Ponder et al. 2002:381-382).

Commercial spearfishing is banned in all Australian States, and illegal commercial spearfishing has been rare for over two decades. Relatively little use of spearfishing is made within Australia's small artisanal fisheries. The bulk of spearfishing in Australia is recreational.

Spearfishing is one the few fishing techniques where each target is individually selected, so bycatch should be zero – a positive feature. It should also be acknowledged immediately that far more Australians go angling than go spearfishing (Henry and Lyle 2003[9]) and that recreational gill-netting is still permitted in Western Australia and Tasmania[10],[11]. The effects of these activities are widespread and significant[12]. However, while spearfishing has the

potential to be one of the most environmentally-sound fishing activities, it is a mistake to believe that the effects of the sport have not been important – and in many cases disastrous. Spearfishing activities are often concentrated at particular sites, and the activity is, in the right conditions, an extremely effective and efficient method of harvesting target fish – being far more time-efficient than angling in many situations.

Where reef species are heavily targeted, local populations of adult fish can be completely removed, and recruitment from deeper reefs may be low or non-existent. These locations are particularly vulnerable, and anecdotal evidence indicates local extinctions have occurred. A significant regional extinction is approaching[13] (the grey nurse shark: see below).

The Australian situation, where recreational spearfishing predominates, is different from the situation in many Pacific island States. Here substantial commercial and artisanal spear-fisheries operate under little effective control. According to Gillett & Moy (2006):

> The ten most important spearfishing difficulties [in Pacific island States] appear to be the contribution of spearfishing to inshore over-fishing, the use of scuba in spearfishing, night spearfishing, industrial spearfishing, negative interaction with line fishing, poaching and difficulties of surveillance, devastation of certain species, devastation of spawning aggregations, incompatibility of spearfishing with marine tourism, and increased [detrimental] algal growth due to the removal of herbivores.

Johannes (1978) discussing the demise of traditional fish conservation in oceania, refers to damage to fish populations by spearfishing, and cites examples of formal and informal bans on spearfishing in certain locations.

Judging by information presented by Gillett & Moy (2006) viewed in conjunction with local studies, heavy spearfishing pressures across the tropical Pacific have caused, and continue to cause severe declines and local extinctions of reef fish. Local extinctions, and possible regional extinctions of the giant humphead parrotfish (*Bolbometopon muricatum*) have been documented by Dulvy & Polunin (2004). Many less prominent fish than the humphead have, without doubt, suffered in a similar way. Dulvy & Polunin identify spearfishing as a primary threat to these reef fish.

Fisheries managers can ignore important anecdotal information which looks “unscientific”. Pauly (1995) refers to a ‘shifting baseline’ which has in part resulted from an apparent inability of fisheries science to use anecdotes to establish historical baselines[14]. Johannes et al. (2000) stressed the importance of considering fishers’ ecological knowledge. Saenz-Arroyo et al. (2005) after a detailed examination of historical evidence on the abundance of the Gulf Grouper in the Gulf of California, concluded:

> We should start rethinking our criteria for assessing marine species at risk, not just in the context of the shifting baseline, but also with respect to the type of information we require for these assessments. By only trusting the evidence that we are trained to use as ecologists or fisheries scientists we continue to run the risk of failing to adequately protect species that have been depleted without our noticing.

Discounting anecdotal information, even when no scientific[15] information is available, may be one of the reasons behind the failure of many fisheries management programs. This paper rests on fishers’ knowledge. It deals with the environmental impacts of recreational diving, focussing principally on spearfishing. Recreational harvesting of crayfish and abalone are also briefly discussed.

By way of background, it is important to note that, globally, the importance of recreational fishing has been consistently understated and under-reported (Cooke & Cowx 2004) and that recreational fishing can cause ecosystem degradation of similar scales and types compared with commercial fishing (Cooke & Cowx 2006). These authors provide examples

of declines caused by recreational fishing that "were largely unnoticed by fisheries managers, a characteristic that may be widespread in recreational fisheries." (2006:94). This comment certainly applies to the management of spearfishing in all Australian States.

Spearfishing on SCUBA (self-contained underwater breathing apparatus) while banned in Queensland, New South Wales, South Australia and Victoria, is still permitted in Western Australia, Tasmania and the Northern Territory. As far as I am aware, night spearfishing is still permitted in all Australian States. In my view this situation needs urgent review, and displays an absence of understanding (on the part of the agencies charged with regulating fishing activities) of the potential damage the sport can do to reef environments. Again, in my view, massive increases in marine no-take areas are needed to provide adequate protection for marine ecosystems, and spearfishing should not only be excluded from these areas, but from buffer zones around these areas as well.

3. International benchmarks:

The cavalier attitude to spearfishing common amongst Australia's fishery management authorities is underlined by a comparison of existing management frameworks with FAO[16] fishery guidelines. The voluntary *FAO Code of Conduct for Responsible Fisheries 1995*, echoing the *Rio Declaration 1992* (both endorsed by the Australian Government), requires all compliant States to apply the precautionary principle. The FAO precautionary principle guideline (the Lysekil Statement[17]) advocates (paragraph 7) that:

> (a) all fishing activities have environmental impacts, and it is not appropriate to assume that these are negligible until proved otherwise,

and that:

> (c) the precautionary approach to fisheries requires that all fishing activities be subject to prior review and authorization; that a management plan be in place that clearly specifies management objectives and how impacts of fishing are to be assessed, monitored and addressed; and that specified interim management measures should apply to all fishing activities until such time as a management plan is in place.

The failure of all Australian State fishery agencies to develop management plans for spearfishing, or to monitor effects and publish findings, places these agencies in clear contravention of the precautionary elements of the *Rio Declaration* and the *Code of Conduct* in this respect.

The Lysekil Statement contains a number of other recommendations which are relevant to the management of spearfishing:

Para.	Recommendation	State fishing agency response
6b	Prior identification of undesirable outcomes and of measures that will avoid them or correct them promptly.	Recommendation ignored.
6c	Any necessary corrective measures are initiated without delay.	Recommendation ignored.
6d	Where the likely impact of resource use is uncertain, priority should be given to conserving the productive capacity of the resource.	Recommendation ignored.
25	For all fisheries, plans should be developed or revised to incorporate precautionary elements.	Recommendation ignored.
28	To be precautionary, priority should be accorded to restoration of overfished stocks, avoidance of overfishing, and avoidance	Ignored – with the partial exception of

	of excessive harvesting capacity.	the GBRMPA[18].
41	Precautionary monitoring of fishing should seek to detect and observe a variety of ancillary impacts, eg: environmental changes, fish habitat degradation…	Ignored – with the partial exception of the GBRMPA.

To comply with the FAO Code of Conduct, a fishery must be precautionary. The Lysekil Statement presents accepted benchmarks which together define precautionary fishery management. No Australian State or Territory currently manages spearfishing in accordance with the precautionary approach.

4. Back in the old days ...

Humans have been spearing fish for thousands of years. However spearfishing as a popular sport is a post World War II phenomenon, underpinned by the technical innovations of SCUBA and neoprene wetsuits reaching the consumer marketplace. Spearfishing as a popular sport in Australia began in Queensland and New South Wales in the mid-1940s, and in my home State of Victoria (where water temperatures were lower) in the late-1940s. Neoprene wetsuits had, however, not yet reached the consumer market at this time, seriously limiting diver time in the cool waters of southern Australia.

When my father and I started spearfishing in 1959 (I was 13 years old) my first spear was a home-made affair, a length of bamboo with a steel barb at the tip and two straps of car inner-tube fixed to the rear. Mass-produced masks, snorkels and fins had been available for about fifteen years. Wetsuits had only recently appeared in shops selling sporting equipment, although these early suits had no linings, with the disadvantage that a lot of talcum powder was needed to don the suit, and the neoprene foam was easily damaged by contact with rocks. Within a year we had replaced our sling spears with home-made trigger-mechanism spearguns constructed from broom handles and rubber straps, with 5/16 inch stainless steel spears. Although mass-produced spearguns were available, they were expensive. The popularity of the sport at that time was increasing rapidly.

Our family lived in Hampton, a suburb of Melbourne, on the eastern shore of Port Phillip Bay. Our house was only five minutes walk from the Bay. In those days, snorkelling beside the Hampton breakwater, I could count on catching enough fish in 20 minutes to feed five people – generally 3 to 5 fish between 0.35 and 1.0 kg in weight. Leather jackets[19] and luderick[20] were abundant, as were several other species of reef dwelling fish. Large flathead[21] and flounder[22] could be easily caught on the sand near the reefs. Like most others spearing fish, we simply assumed that the fish we took would be replaced by fish moving in from deeper reefs. We were wrong.

There is no doubt in my mind that spearfishing in reef environments is hugely more effective as a harvesting mechanism compared to angling. Angling had taken place along the breakwater since it was built decades earlier. Although flathead were the primary angling target (fishing on the sand beside the artificial reef formed by the boulder breakwater) a few anglers targeted reef species, using floats to keep baits above the rocks. I participated in both angling and spearfishing at that location over several years.

Within five years of my first observation in 1959, the populations of reef fish along the breakwater were decimated. I undertook a visual census in 1964, and reconstructed 1959 population levels from memory[23] - see Appendix One. Within about ten years the species targeted by spearfishers were gone, for all intents and purposes. Even the marblefish[24], easy to catch but poor eating, were gone. Several fish species, by my observation, appear to have been entirely eliminated from this site. During this period there was no noticeable increase in recreational angling pressures, which remained almost non-existent in relation to reef fish. No commercial harvesting or recreational netting of reef fish took place at this site before, during or after the period in question. Because I lived with the breakwater almost on my doorstep, during my childhood I was there constantly, and I can remember no changes – pollution episodes or dramatic weather events[25], for example, which could account for the

decline I witnessed. There is no river or creek nearby which might have effected the site. I believe that spearfishing pressure was the single cause of the decline in fish populations in the 1960s[26]. A rapid increase in spearfishing pressures, starting during the late 1950s, coincided with a rapid decrease in fish numbers. Aquatic vegetation at the breakwater did change, but this change followed rather than preceded the decline in fish numbers. The existing marina inside the breakwater protects mainly recreational yachts and motor vessels, and was constructed to replace the original swing moorings around 1990. This could have resulted in an increase in local pollution by anti-fouling agents; however no site-specific water quality data is available. I estimate that the wetted-hull area after the marina was constructed increased by around a factor of 10[27]. It should be noted that this expansion post-dates the demise of the species in question.

With the rapid decline of shore-based reef spearfishing in Port Phillip Bay, I switched my attention to ocean locations. One of my favourite fishing sites was Flinders back-beach, near the entrance to Westernport Bay, a little over one hour's drive from my home in the suburbs of Melbourne. Flinders probably has the most extensive accessible shallow ocean reefs in Victoria. Other easily accessible ocean sites were the Inverloch, Eagles Nest and Cape Liptrap rocky shores, and shallow reefs near Tidal River at Wilson's Promontory.

Spearfishing became a popular weekend pastime at Victorian ocean locations at the close of the 1950s. In the early 1960s, the shallow (2-6 m) reef ledges at Flinders[28] were still so packed with fish that a spear shot into a ledge would often take two fish with the one shot. Large crayfish and abalone were abundant. At Eagles Nest, I can remember – along with two friends – filling a 50 kg flour-sack with crayfish in under one hour, snorkelling in water only 2-4 metres deep. By the time I started studying at university (1966) I had noticed a dramatic decline in both fish and crayfish in these shallow ocean reefs.

The crayfish populations in shallow water, although prolific in the early 1960s, were without doubt already well below pristine abundance. According to O'Hara (2000) the first European settlers on the Mornington Peninsula[29] in 1802 "reported catching up to 500 crayfish in a single evening from the shoreline of Point Nepean"[30]. It is clear that the abundance of crayfish in very shallow water, prior to the onset of fishing, was extremely high. Today adult crayfish have been (for all intents and purposes) entirely removed from these near-intertidal waters.

In Tasmania, when James Kelly called at Port Davey in 1815 he traded swans he had shot for crayfish; the local aborigines quickly collected over 1000 crayfish by hand from the water's edge. In 1905, James Rattenbury caught 480 crayfish from his ship the Rachel Thompson in six hours using only six 'cray rings' in Wineglass Bay (Gardner et al. 2005). I snorkelled the shallow reefs on each side of Wineglass Bay in 2003, without finding a single crayfish.

Others were also concerned at the rapid decline of Australia's shallow water fauna. In 1966 Pollard and Scott wrote:

> In many parts of the world, particularly along the coasts of Spain, Southern France, Italy, Jamaica and the Bahamas, spear fishermen have decimated populations of edible reef fishes. The same is now happening in parts of Australia. The inshore reefs for more than twenty miles each side of Sydney Harbour have been almost denuded of edible fish, and much of the remaining New South Wales coastline is also beginning to suffer (Pollard and Scott 1966:106 – see Appendix Two for further details).

Similar damage to reef environments from spearfishing was observed in the USA. According to Hale & De Sylva (1992): "In 1957, extensive spearfishing and coral dynamiting aroused conservationists, resulting in the establishment of the first aquatic preserve in the US – the John Pennekamp Coral Reef State Park, off Key Largo."

I wrote, with some alarm, to the Victorian Minister for Fisheries, suggesting that urgent controls needed to be implemented to reduce the impact of the sport. I suggested that spearfishing on SCUBA needed to be banned[31], and that licences should be introduced for spearguns, conditional on a display of knowledge concerning fishing regulations such as legal bag and size limits[32].

The Minister wrote back, politely replying that he was advised that there was no scientific evidence to justify my concerns. His response left me with the sense that no action would be taken by the Department to investigate the matter further. At that time Victoria had no fully protected marine reserves[33] other than a tiny circle of 100m radius at Pope's Eye near the entrance to Port Phillip Bay. The Pope's Eye reserve protects an artificial reef environment which has grown up around the foundations of a navigational marker.

As no scientific data appear to exist which would indicate natural abundance levels for reef fish, crayfish or abalone, historical anecdotes are important sources of information on 'natural' ecosystem levels. In the shallow reef ledges along Victoria's coastline in the late 1950s, my own experience suggests that it was common to see layers of abalone two-deep in places, as well as groups of six to twelve crayfish in the deeper ledges. Most of these shallow ledges are empty today. When commercial abalone fishing started in Australia in the 1960s, it was not uncommon for divers to harvest a full boat-load without moving their anchor. Local abalone clusters were estimated by divers at more than 100/m^2. These and similar anecdotes indicate a precipitous decline in both abalone and crayfish populations along Australia's eastern seaboard. Accurate declines are impossible to calculate, but it is not unreasonable to believe overall abundance levels for both these groups are now between 10% and 1% of their un-fished levels, and certainly lower still in many local areas where they are all but absent.

Anecdotes from temperate reef environments in other parts of the world support this view. According to Dayton et al. (1998) along the Californian coast:

> Both abalones (*Haliotis* spp.) and spiny lobsters (*Panulirus interruptus*) were extremely abundant before diving and effective trap fisheries. Divers of the 1950s reported green abalones stacked on top of each other in shallow water and describe the Point Loma kelp forest as ''paved with red abalones''. Abalones are now so scarce that all five species fished in southern California have been closed to both sport and commercial harvest, and there is good reason to believe that one, *H. sorenseni,* will become the first marine invertebrate known to become biologically extinct as a result of human fishing. Probably because the spiny lobster source population has yet to be rendered ecologically extinct in Mexico, the lobster fishery has persisted, but abundance and size distributions are clearly different from historical patterns. In 1888, 260 traps yielded 104,807 kg of lobsters. By 1975, 19,000 traps were required to harvest almost the same mass, 105,768 kg.

In the summers of 1982 and 1983 I was able to re-visit most of my old spearfishing locations. I wished to ascertain what changes had taken place at sites I was familiar with, as I was considering the preparation of a short article dealing with shallow reef environments[34]. In Port Phillip Bay, I found that several species appeared to have been entirely eliminated from accessible shallow reefs. Even tiny juveniles had disappeared. Abalone were still abundant[35], but they were small, and generally below the legal size limit – and were being harvested illegally at unprecedented levels. On weekends I saw families removing large plastic rubbish bins (around 70 L capacity) overflowing with undersize abalone. At that time there was a bag limit for recreational abalone of 10 per person per day as well as a size limit. Each bin would have held around 200 abalone, in my estimation. There were no bay-side information signs relating to fishing regulations in those days – multi-lingual signs were to appear a few years later. I never saw a fisheries enforcement officer, nor did I hear or see relevant information on radio, television or through newspapers.

Clearly, fishers like myself (as well as government experts) had under-estimated the ability of these reefs to recruit stock from deeper, less accessible habitats[36]. We had over-estimated

reproductive capabilities, and under-estimated fishing pressures. Are similar mistakes still being made today?

I was also surprised by a dramatic decline in large specimens of flathead and flounder – a matter I still fail to fully understand. They certainly were heavily harvested by both anglers and spearfishers, but there are huge areas of sandy habitat in the Bay. Commercial fishers did (and still do) target these fish, and I have not attempted to obtain further information on commercial harvesting pressures. Perhaps these bottom-dwelling fish are more territorial, or less mobile than I had imagined. These observations were made long before the very recent reports of major declines in fish populations of the Bay[37], thought to be the result of major ecosystem changes brought about by introduced invertebrate pest species.

As an aside, during the 1950s I had watched huge schools of whitebait (a schooling fish 70 – 100 mm in length) streaming past the end of the breakwater. These schools were so large they would take around a whole day to move past – a stunning sight of great areas of sea turned silver. I have never seen such schools again.

My survey of shallow reefs in 1982/83 revealed that the situation was a little better at ocean locations. Although crayfish had disappeared completely from the shallow ledges, vestiges of the former populations of reef dwelling fish remained – however the fish were generally much smaller and fewer compared with populations I had observed 10 years earlier. It was particularly sad to see the ledges at Flinders, which had been so thick with fish and crayfish, now virtually deserted.

5. The decline of two spearfishing target species in New South Wales.

Many reef-dwelling fishes have attributes which make their populations vulnerable to overharvesting – they are large, territorial, highly edible and have slow reproductive strategies[38]. Those that have restricted ranges are especially vulnerable. Apart from the three species discussed in this section, Pogonoski et al. (2002) implicated spearfishing in the decline of a number of other vulnerable species: the camouflage grouper (*Epinephelus polyphekadion*) – also targeted in the Pacific for the Asian life fish trade; the potato cod (*Epinephelus tukula*) – spearfishing is banned in Natal, South Africa; the western blue grouper (*Achoerodus gouldii*) – spearfishing is banned in South Australia; and the double-header (*Coris bulbi*) – restricted to Lord Howe Island and the NSW coast.

This section focuses on two species which were heavily targeted by spearfishers until they were protected by legislation – the black rockcod and the grey nurse shark. Unfortunately, populations have not recovered, and the eastern seaboard population of the grey nurse appears to be moving towards extinction. The resurgence of eastern blue groper[39] populations, however, provides a different story from the same general area: this animal too was heavily harvested by spearfishers prior to protection, and populations have recovered well in some areas[40].

The **black rockcod**, *Epinephelus daemelii,* has been a protected species in New South Wales (NSW) waters since 1983, and was listed as a 'vulnerable species' under the NSW *Fisheries Management Act 1994* in 1999. It is also listed under section 15 of the Commonwealth *Fisheries Management Act 1991*, making its take in fishing operations illegal unless covered by a scientific permit. The Australian Society for Fish Biology (ASFB) lists the species as potentially threatened (ASFB 2004).

Roughley (1916) reported specimens to 100 pound in weight, and that "at one time it was fairly plentiful in the vicinity of Port Jackson, but has become very scarce in recent years, owing to the havoc wrought by fishermen…" McCulloch (1922) reported that *E. daemelii* was "a valuable food fish" in NSW, indicating that the species was still reasonably common in the State at that time. Today, according to the ASFB, "abundance is low, and large males are considered to be rare." (ASFB 2004).

The overfishing reported by Roughley would not, presumably, have included spearfishing, as the sport did not achieve widespread popularity for another 40 years. However, the inquisitive and territorial nature of the animal, as well as its size, make it highly vulnerable to spearfishing (Leadbitter 1992). The total fishing ban in NSW was initiated after substantial anecdotal evidence of continued and major decline in population numbers; spearfishing was identified as a major threat (ASFB 2004).

The **grey nurse shark** *Carcharias taurus* was once relatively common along Australia's east and southeast coasts, with the largest adults reaching over 4 m in length. According to Roughley (1951:261) "the most prevalent shark at Port Stephens (NSW) was the whaler, followed by the grey nurse…". The shark, which is neither fast nor aggressive, became a spearfishing trophy target in the 1960s, with its territorial nature and its fondness for shallow reefs making it particularly vulnerable. At that time explosive spearheads were both readily available and unrestricted by government regulation, and were routinely used to kill the larger adults.

The grey nurse is now listed as an endangered species under the NSW *Fisheries Management Act 1994*, and listed as a threatened species under the Queensland *Nature Conservation Act 1992.* The east coast population of the shark is listed as critically endangered under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*. This shark was the first shark protected by legislation in the world when the NSW government initiated a fishing ban in 1984, following a dramatic decline in numbers credited to line and spearfishing (Fisheries NSW 2003). An overview of conservation issues is provided by Pollard et al. who identify spearfishing as a primary driver of decline (1996).

Rather than recovering, population numbers have continued to decline. Numbers are now so low (probably 300-400 adults) that serious concerns must be held for the survival of the east coast population (Otway et al. 2004). Limited habitat protection has been provided through marine protected areas, however these protected areas are comparatively small and not regularly policed, and illegal line and spearfishing continue[41]. Accidental kills are continuing to occur from beach shark meshing programs in NSW, which are designed to reduce the incidence of shark attacks on swimmers. The grey nurse has not been implicated in such attacks in Australia.

6. Fisher experience:

Ron and Valerie Taylor are amongst Australia's best known underwater photographers, and have had a long association with both fishing and conservation. They have dived extensively in all Australian States. According to Valerie[42]:

> We were both Australian Spearfishing Champions several times and Ron was world champion once. We however would know better than most the detrimental effects of spearfishing, specially competitions where an entire reef system is decimated, and from our 50 years of experience never ever returns to how it was or how nature intended it to be. I have seen a beautiful rich coral reef denuded of all the big fish in just 3 days. (off Maroochydore) during the Australian Spearfishing Championships.
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> The spearo who swims out and takes a selected fish or two to eat does less harm than a line fisherman, but a bunch of up to 60 or 70 good freedivers with guns shooting everything in sight can cause irreparable damage. We know, we used to do it. We used to believe that there were so many fish off the coast that no amount of harvesting could make a difference. It took us over a decade to really see the damage we in our ignorance were doing to life in our coastal waters.
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> As for wanting scientific evidence, in the 1960s there were no scientists monitoring what was happening off the coast. We know very well how quickly a species of reef fish can be wiped out in a large area. Ron and myself did all our spearfishing holding our breath.

> When good eating fish in the shallows became scarce, many spearos began using SCUBA to hunt commercially in deeper water, which was a disaster for our reef dwelling fish who all have a territory in which they live. Many species do not live below say 200 feet and were extremely vulnerable to SCUBA divers with guns.
>
> In 1970 Ron and myself along with the NSW politician Eric Willis had the practice of taking fish and crayfish using any form of self contained breathing apparatus banned in NSW. The uproar from the spearfishing clubs was enormous, but we were at the time Australia's two top spearfishing champions so there was little to argue about. We were out there and we knew first-hand what we were doing and we knew it was wrong. This made us very unpopular in spearfishing circles, although today many of the old timers now agree with us.

Valerie Taylor's experiences are, I believe, typical of accessible reef areas around Australia.

In South Australia, for example, an unpublished report by Shepherd (1967) suggested that excessive spearfishing was responsible for the denudation of inshore reefs along the South Australian coast.

Another unpublished report from South Australia (Ottaway et al. 1980) commented "Whether or not spearfishing could kill off all the larger fish of particular species on particular reefs has not been studied rigorously, but it is the personal opinion of three of us who did spearfish in South Australia some 15 years ago that it was happening then and it is still happening now on reefs further and further away from the main areas of population". The three giving this opinion, based on their personal observations, were John Ottaway, then a Queen's Fellow in Marine Science at Flinders University, Igor Oak, then the President of the South Australian Underwater Photographic Society, and R.B. Gardiner, then the Chairman of the SCUBA Divers Association of South Australia. These three highly experienced divers were among the first spearfishers and SCUBA-divers in South Australia.

According to John Ottaway more recently (personal communication, 2005):

> I have no doubt that the popularity of spearfishing in the 1960s, and no controls (when scuba gear became readily available) on spearfishing on scuba in the mid to late 1960s, was the major factor in the staggering decline in near-shore fish populations along the South Australian coastline, starting with the reef areas near Adelaide, and then radiating away from Adelaide as the nearer reefs became depleted.
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> There were many reefs along the Hallett Cove to Port Stanvac area where during the early 1960s I always saw many hundreds of fish, and commonly saw reef and pelagic specimens that would have been 5 kg plus and occasionally 10 kg plus. We left those big fish alone because the smaller fish were abundant, better eating, and we thought the big fish were probably important breeding stock. We also saw sharks reasonably often, ranging from 60 cm wobbegongs (frequently) to 4-5 metre white pointers (rarely).
>
> In 1978, I went back to that same area on several occasions to have a look around, and was shocked to find the whole area where I used to spearfish was now a 'wasteland' with not a single fish over a couple of hundred grams to be seen. Even the big schools of pelagics were absent.[43]

It seems surprising that government regulatory agencies could turn a blind eye to the major changes that spearfishing was creating in accessible coastal ecosystems – yet this happened consistently not just in Australia but around the world.

Describing the situation at Goat Island (once a popular spearfishing location, then newly declared as the Leigh Marine Reserve) in New Zealand, Russell – writing twenty years after the start of recreational spearfishing – wrote:

> Although reef areas support large numbers of fishes and high standing crops, they are very vulnerable to exploitation. Most reef fishes are non-migratory, many species spend their whole lives on the same small patch of reef, and they are thus more susceptible to fishing pressures than stocks of pelagic or wandering demersal species. The problem is especially severe for small isolated reefs, and there are numerous examples where reef fish populations have suffered marked local depletion through overfishing (e.g. Clutter 1971; Johannes 1975).
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> Certain methods of exploitation such as spearfishing may be particularly damaging. At Goat Island, the effects of spearfishing were evident in two areas (Areas D and E), both of which are within easy swimming distance of Goat Island Beach and are heavily spearfished during summer. Compared with less accessible reef areas (e.g., Area A) there was a notable scarcity of larger fishes such as *Cheilodactylus spectabilis* (red moki) and *Navodon convexirostris* (leatherjacket). These species are commonly taken by skindivers and, like most reef fishes, can be virtually eliminated from an area by indiscriminate spearfishing. The long-term effects of removal of these larger fishes from reef communities is difficult to assess, but possible consequences include reduced stocks, depressed age-size structure of the populations, and, by removal of the larger predators, alteration of the reef community as a whole. For some species (e.g. *Coris sandageri,* Sandager's wrasse) which occur only in small localised populations at Goat Island and other coastal areas of northern New Zealand, the threat of local extinction also is very real.
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> The establishment of marine national parks provides protection for fishes in some areas, but there remains the need for many species to be protected from spearfishing outside these areas. The recognition of marine fishes as native wildlife and according legal protection similar to other endangered wildlife might be a first step. Because the majority of reef fishes can be classified as residents and are therefore endangered by spearfishing, a large list of protected species is likely to be impracticable and from a management point of view, a declared list of fishable species is probably more feasible. As a basis it might include only transient species (Russell 1977).

More information on the Leigh Marine Reserve is contained in Appendix Three below.

Alan Curley started spearfishing the central coast of New South Wales in 1970, at least a decade after the sport gained popularity. At that time abalone were still common, with densities of 10-20 per m^2 in caves and 30-40 per m^2 in ledges around The Entrance. Abalone have all but disappeared from this area today, which Alan explains largely in terms of professional harvesting pressures. Fin-fish abundance today shows a precipitous decline since the early 1970s. According to Alan (pers. comm. 2/6/06):

> Toowoon Bay[44] (southern headland and deep hole) is a common spear and line fishing site even today. Thirty years ago the hole was full of pelagic fish, Silver Sweep, Silver Trevally, large Silver Drummer, Port Jackson sharks, Baitfish including Yellowtail and the occasional Kingfish and Snapper. Red Morwong and Rock Blackfish[45] were abundant together with Bream, Leatherjackets, Grouper and Luderick. I can remember lying on the bottom waiting for a 400 mm Grouper (a protected species) to clear the end of my gun to enable me to shoot a 400 mm Red Morwong, with a 900 mm Kingfish swimming in the background. Large Red Morwong lived in families of 4 to 8 per hole, and at least 2 individuals could be found within any 100m stretch of reef which had weed, boulders or ledges for cover.
>
> My daughter and I surveyed the same area in 2004-2005. The pelagic fish were non-existent and Red Morwong were rare despite the fact we were using SCUBA tanks and could search the reef thoroughly. There were also few large Rock Blackfish of any size and numbers of Luderick were well down. An estimate of around 50 Luderick per 100 meters of shallow reef would have been

> conservative for 30 years ago. The Groupers and Leatherjackets were almost non-existent. The reef is almost barren compared to when I speared there 30 years ago.

Such changes are dramatic but unfortunately typical. While angling and commercial fishing have undoubtedly played a part, the decline in the sedentary reef species, especially the Luderick which generally do not take a bait, are in my opinion principally due to spearfishing pressure.

7. Removal of larger fish – is it important?

Spearfishing is a selective sport, and spearfishers tend to harvest larger individuals within a species – partly driven by the 'trophy status' of the larger fish. In some cases the larger individuals are less timid and are easier to spear.

Birkeland and Dayton (2005) have reviewed the effects of removing larger individuals from populations. At least as far as long-lived reef fish are concerned, the available data indicate a variety of important effects:

- larger females are proportionately more fecund, yielding more eggs per gram of body weight;
- the larvae of larger females of some species have better survival rates;
- larger females spawn over an extended period, thus providing more resilience to changing environmental conditions;
- larger fishes can be more experienced and more successful in spawning;
- larger fishes of some species provide leadership in migrations to spawning aggregation sites;
- reduction of larger fishes may reduce genetic heterogeneity; "potentially leading to reduced adaptability, population productivity and persistence";
- for sequential hermaphrodites, where all the larger individuals may be of the same sex, significant removal of large fishes may prejudice spawning success of the metapopulation; and
- larger fishes can have different and important ecological effects; Birkeland & Dayton quote studies showing larger parrot-fish create important erosive effects which smaller individuals do not.

Birkeland & Dayton conclude that: "the selective removal of larger individuals probably contributes significantly to the impact of recreational fisheries, and to the difficulty that some populations experience in recovering from overfishing".

Birkeland & Dayton suggest that "spearfishermen could also be encouraged to take intermediate-sized fishes" rather than larger individuals. Speaking from my personal experience as a spearfisher, I believe such "encouragement" would undoubtedly fall on deaf ears – this approach is likely to be completely useless. In my view, the only way to protect larger individuals is through two strategies: either ban the spearing of the species in question, or create large networks of marine no-take areas.

It is sometimes suggested that the culture of recreational spearfishing in Australia has changed over the years, to embody more thoughtful and more environmentally-conscious ideas. A perusal of Australia's spearfishing magazines (see for example www.spearfishingdownunder.com.au) in July 2006 found no evidence to support this suggestion. In fact letters to the editor and editorials were dominated by "more and bigger catches are better" ideas, coupled with outright antagonism to any form of restriction on the so-called sport. The Underwater Federation of Australia's policy statement on spearfishing, published in July 2006, contains little evidence of any awareness of the ecological impacts which the activity can cause[46].

8. Site and specie risk factors:

There is not enough information in the available literature to make definitive statements about risk factors; however these are my suggestions for identifying species and sites at high risk:

Specie:
Obligate reef dweller; seeks shelter in caves and ledges; preferred habitat in shallow water (<20 m depth); territorial; edible flesh; edible size (over 20 cm fork length) or trophy target size; low reproductive rate; sequential hermaphrodite; forms breeding aggregations; active during the day.

Site:
Accessible (within an hour's travel by boat or car from a population centre); window of visibility (>5 m visibility for at least 20 days per year); easy to locate (presence of rocks above low water mark identifies reef location); isolated from adjacent reef habitat (by >1 km of different habitat (eg: sand, seagrass); relatively safe (regular currents < 0.3 m/sec); relatively comfortable (water temperature > 10 Celsius).

9. Spearfishing impacts – the literature:

Should I have been surprised by the destruction of fish populations at my favourite reefs? With hindsight, no. The pelagic environment is a dangerous place, there's really nowhere to hide. Pelagic fish need high-powered reproductive strategies. The reef environment is different, and it seems likely that much slower reproductive strategies might generally apply to sedentary reef-dwellers. The reef environment used to be a comparatively safe place…

Degrading reef environments[47] have not, of course, escaped the attention of the diving community – although many spearfishermen do not wish to acknowledge the decline or their part in it (Recfishwest 2003). Grovermann (1982) described changes to reef fauna in Western Australia and South Australia. Local groups lobbied to have particular sites declared speargun free (eg: Bail 1983), and competition spearfishing was the target of strident criticism from some divers (eg. Cahill 1979). Andrewartha (1972, 1981) drew attention to the dramatic decline of reef fish and crayfish around Wilsons Promontory in Victoria, as did McCallum (1982).

Although the effects of spearfishing have been so dramatic at those localities where fishing pressure has been focused, both fishing management agencies and marine scientists have generally ignored the issue. Only a handful of papers have appeared in the scientific literature over the last few years dealing with the effects of spearfishing on reef-dwelling fish. The usual research method involves a comparison of population density and size structure of spearfishing target species at similar protected and unprotected sites. Generally speaking, these investigations have all found the same thing: that spearfishing has a marked effect on target fish populations, reducing both the size of the population and the proportion of large animals[48]. Depending on the study site, the size of the effect varies from the significant to the severe (Bohnsack 1982, Bohnsack 1983, Oakley 1984, Harmelin et al. 1995, Chapman & Kramer 1999, Jouvenel & Pollard 2001). Other studies, while comparing abundance data inside and out of protected areas, do not attempt to discriminate between spearfishing and other forms of fishing (eg: Buxton & Smale 1989).

Jouvenel & Pollard (2001) examined abundance and size structure of populations of two highly sought after spearfishing target species in the north-western Mediterranean, inside and outside a protected area. Abundances were consistently higher inside the marine reserve: with *Dicentrarchus labrax* (European sea bass) averaging 3.92 individuals per 400 m transect compared with 0.69 outside, and *Sparus aurata* (guilt-head sea bream) averaging 0.68 inside and 0.05 outside the reserve. The average length of *D. labrax* inside the reserve was almost twice that outside the reserve. These results show a massive difference in biomass between fished and unfished areas.

Harmelin et al. (1995) in a similar study of fished and unfished areas, selected two target groups of fish – the first group of 16 species ('type A') were highly targeted by spearfishing, while the second group of two species ('type B') was highly targeted by angling. The unfished reserve was only 85 ha in size; nevertheless significant differences were found in the visual census surveys, which were carried out on 24 occasions over 3 years. Of the 16 spearfishing target species, eight were not detected in fished areas, supporting arguments that local extinction is possible. According to the authors: "the missing species are top carnivores, particularly threatened by spearfishing." Overall, abundance and biomass of both types (A and B) were significantly greater within the reserve, with average abundance in the reserve around twice that of the unprotected site. When only type A fishes were considered, "the mean number of individuals was 3-fold higher in the reserve than in the fished site" with this difference increasing to 10-fold when only large individuals were considered. Within the type A group, sargo bream populations (*Diplodus* spp.) were found to be particularly damaged by spearfishing, with abundance ratios inside/outside the reserve varying between about 4:1 to 30:1. That such large differences can be found within such a small reserve is a testament to the destructive power of spearfishing as a harvesting technique.

Dayton et al. (1998) discussing the disappearance of large fish from kelp forests in California, remark: "…for broomtail groupers [*Mycteroperca xenarcha,* large territorial fish], mortality caused by a few spearfishermen may easily explain their loss from the ecosystem". The authors continue: "… historical comparisons of spearfishing contest results with present populations suggests major changes in abundance and size distribution of species such as California sheephead, *Semicossyphus pulcher.*"

Oakley (1984) reports an investigation of the effect of spearfishing on grouper in the eastern Red Sea, through a short visual survey. Census sites of similar habitat were graded according to fishing pressure, and grouper abundance and size recorded. Large grouper were six times as abundant, and medium sized grouper (200-400 mm length) three times as abundant in the low pressure sites compared to the high pressure sites. Small grouper, however, were more than twice as abundant in the high pressure sites – an effect which Oakley attributed to reduced competition with larger animals. Oakley concluded that spearfishing pressure had a significant affect on grouper populations in this area. It would be interesting to revisit Oakley's census sites after twenty years. I suspect his 'low pressure' site average abundance figure of 6 large grouper per 250 m transect could not be repeated today.

Chapman and Kramer 1999 examined fish density and size within and outside the Barbados Marine Reserve – a small reserve protecting 2.2 km of coast to around 500 m offshore. The reserve was, at the time of the study, subject to illegal fishing. Given the small size of the reserve and the acknowledged enforcement difficulties, it would not be surprising to find little difference between sites inside and outside the protected area. Nevertheless, the authors found evidence of more large individuals (of species targeted by spearfishing) within the reserve, an effect which they attributed principally to spearfishing mortality.

Data from spearfishing competitions provides unreliable evidence on Catch per Unit Effort (CPUE) changes over time, for the reasons discussed elsewhere in this paper. Very few studies have tracked spearfisher CPUE over time in a reliable way. Harper et al. (2000) is one such study, which surveyed recreational fisheries in Biscayne Bay National Park (Florida) between 1976 and 1991.

Unfortunately the study start date is around 25 years after the commencement of spearfishing as a popular recreation – so the initial impact has undoubtedly been lost. Nevertheless the study produces some interesting information. Spearfishers, in comparison to anglers, accounted for about 10% of all fish caught, although anglers spent comparatively more time catching each fish – a not unexpected finding, and one which, in my view, is likely to apply over substantial areas of Australia's eastern seaboard. Species information is also informative. Nassau groupers, targeted by both spearfishers and anglers, showed a steeply

declining CPUE, from around 22 to 1 (number landed per 100 trips) over the 15 years of the study. Hogfish, targeted principally by spearfishers, declined more slowly, with CPUE dropping from 65 to 32. These findings suggest that spearfishing has had a major impact on this area, in combination with other pressures. It is also worth noting that reef fish in the Florida Keys are known to have undergone intense exploitation (overfishing) during the twentieth century (Ault et al. 1998).

In a marine protected area at Looe Key, Florida USA, all 15 species that were spearfishing targets increased in abundance after spearfishing was banned: snappers (*Lutjanus spp.)* by 93%, grunts (*Haemulon spp.)* by 439% (Clark et al. 1989). Looe Key Reef was the site of an earlier study (Bohnsack 1982) which found significant depletion of spearfishing target species in the period before the site was protected in 1981. So far I have not been able to obtain the full version of Bohnsack 1983, however the summary states: "In particular, the observed frequency of grey snapper (*Lutjanus griseus*) increased dramatically [following the spearfishing ban in 1981] although population levels remain well below those on the control reefs [fully protected since 1960]." Clearly spearfishing had a major impact on local populations of this target fish. The summary continues: "*Thalassoma bifasciatum*, the most abundant prey species, showed a drop in abundance correlated with increased predator populations. *T. bifasciatum* population levels at Looe Key Reef prior to sanctuary establishment had been double those on control reefs."

At a marine protected area in Banyuls-Cerbere, France (on the Mediterranean) six years after the implementation of a spearfishing ban, target reef fish abundance within the MPA increased to approximately twice that outside. Amongst target fishes, differences in abundance of 'small' individuals were marginal or non-significant, while for medium and large fishes the differences were highly significant. No difference in diversity or species richness was detected. (Bell 1983 quoted by Charton et al. 2000).

Sluka and Sullivan (1998) examined the effects of spearfishing on grouper populations in the Florida Keys. They surveyed two sets of similar habitats; all areas were open to line-fishing, but one set was closed to spearfishing in 1960 while the other remained open. They suggest that line fishing effort was roughly 10 times spearfishing effort, and they assume that line fishing effort was uniformly distributed across all areas. The Nassau grouper, resident at all locations, is a protected species, banned from take by both line and spear fishers.

The key findings of their report relate to abundance and size distribution. The abundance of the most commonly targeted groupers did not differ significantly between open and closed areas, although the abundance of the Nassau grouper was significantly reduced at sites open to spearfishing. The authors suggest that illegal spearfishing may be taking place for the Nassau, and may account for this effect. A significant difference between closed and open areas related to the presence of large fish, with generally smaller individuals present in the open areas. The authors conclude that: "the ban on spear fishing in the upper Florida Keys has significantly benefited the size distribution of groupers. However, it appears that a ban on spear fishing alone has not resulted in recovering population levels of grouper in this region." The authors recommend that, if grouper recovery is a management aim, all forms of fishing need to be excluded.

The difficulty with this study is the lack of information on line-fishing pressure. It seems highly likely that line-fishers will select areas where they know they are not competing with spear-fishers – yet the study assumes a constant high level of line-fishing pressure across both closed and open zones (closed and open to spear-fishers). If line-fishers are preferentially selecting closed areas, this is likely to compensate for the lack of spear-fishing pressure.

An Australian study by Lowry and Suthers (2004) provides limited information on the ability of a species to recolonise local depletion, indicating that, at two sites studied in NSW, red morwong (*Cheilodactylus fuscus*) successfully recolonised small reef areas depleted by high levels of experimental spearfishing. This paper is discussed in more detail below.

An electronic search of refereed scientific journals (August 2004) failed to locate any Australian publications dealing with the impacts of spearfishing, other than the papers by Lincoln-Smith et al. (1989) and Lowry and Suthers (2004).

Lowry and Suthers obtained population estimates at reef sites for red morwong, a common reef fish found along the NSW and southern Queensland coast. According to Lowry and Suthers: "Fish re-colonised the same location 2 to 4 months after a summer and a winter experiment removed >70% of the adults by intense spear fishing." This finding demonstrates that (at least for red morwong) recolonisation can occur fairly quickly where small sites undergo intense fishing pressure for a limited period of time. As the authors acknowledge, the study has several limitations. The two experimental sites were small – a total of 68 fish were removed from the two sites. Adjacent habitat was unaffected, supplying accessible areas to support recruitment. The authors did not conduct (or did not report) an observational study to determine 'background' levels of spearfishing pressure at the sites. The authors conclude that more information is needed to determine the effects of spearfishing on the species. They note: "spearfishing may have a significant impact on such a long-lived resident population. There is evidence that spearing is responsible for the localised depletion of cheilodactylid populations in New Zealand (Cole et al. 1990)".

Belinda Curley also studied red morwong in NSW: "One of the MPA's I studied was Gordons Bay near Sydney. The MPA covers 0.1 km^2 and fish have been protected from spearfishing since 1992. Line fishing is still permitted. I found that the abundance and size of red morwong (Cheilodactylus fuscus) was greater inside Gordons Bay when compared to three ecologically similar control areas. Given that red morwong are relatively sedentary and heavily spearfished in NSW this provides strong evidence that spearfishing does effect local populations of this species." (pers. comm. 10/5/06). I concur with Ms Curley's view, particularly given the small size of the reserve. To demonstrate an effect in such a small area requires very strong pressure on the animals concerned.

Papers such as Edgar & Barrett (1999) referring to the Tasmanian situation, do not attempt to separate spearfishing impacts from other harvesting activities – although confirming significant differences in fish populations across marine reserve boundaries. Not surprisingly, Edgar and Barrett note that small marine protected areas are relatively ineffective[49]. My personal observations of areas near their study site at Maria Island suggest that recreational gill-netting as well as spearfishing and crayfish collection pressures are significant immediately beyond the boundaries of the protected area. Between the declaration of the Maria Island protected area in 1992 and their 1997 survey, crayfish biomass increased by over an order of magnitude, and biomass of legal-size crayfish increased by over 20 times.

Catch per unit effort (CPUE) data in relation to the capture of reef fish is available from spearfishing competitions; however this data means little in itself, as the selection of competition site and prior access by spearfishers to this site are critical in establishing logical conclusions. The data, moreover, is prone to certain inaccuracies stemming from the way it is reported.

Competition data can be used in two ways: (a) if a site is under constant spearfishing pressure, competitions held, say, at 10-year intervals can provide surrogate measures of changes to the health of reef populations over time, or (b) if large competitions are held regularly at the same site, and spearfishing pressure between competitions is low, the impact of the competitions themselves can be measured.

Competition CPUE data are most useful if the first data come from fishing a virgin site (thus establishing a baseline) and where that site then becomes subject to significant and ongoing spearfishing pressure. In this case, the next time a competition is held at that site the CPUE data (provided other aspects like competition rules and weather remain more or less unchanged) can provide a measure of the effect of that regular pressure on the site. Here the competition itself is not the pressure measured, it is the yardstick - as it provides a surrogate measure of species density and the presence of large individual fish.

Papers by Johnson (1985a, 1985b) highlight difficulties in using competition CPUE data in an attempt to measure changes in fish populations. Spearfishing competitions in South Australia were documented in 1977/78 and again in 1983/84. Comparing data across these two events, catch rates decreased (effort increased) and the proportion of reef-dwelling fish caught decreased (compared with open-water species). However, no conclusions could be drawn as the competitions used different rules (eg: for ineligible and eligible species) and were held at differently defined sites, under different access conditions. It is also worth noting that the organisers "estimated" diver water time by guessing an overall figure averaged across all competitors – a technique prone to considerable inaccuracy.

The discussion of competition data by Lincoln-Smith et al. (1989) highlights other problems in using competition data: for example where rules allow only one or two fish per species to be weighed-in, discarded fish go unreported in both number and weight, and in fact unobserved by competition officials[50]. Competition catches are heavily influenced by competition rules, and may bear little relation to regular spearfisher catches in both species and weight per unit effort; thus comparisons between spearfisher impacts and angler impacts cannot be reliably based on competition data.

Problems with the use of competition statistics can be illustrated by examining the coral trout (*Plectropomus leopardus*) CPUE data from Smith and Nakaya (2003). Their Great Barrier Reef CPUE data (p.20) indicate that, over the 1980-2000 period, fish per diver hour CPUE declined by about 30% while the average weight of each fish caught declined by about 25%. While these figures suggest a steady decline in abundance commensurate with unsustainable fishing rates, they are moderate over the timescale, and perhaps do not support the sense of alarm which I am expressing. The actual situation, however, is that these figures disguise the fact that there has been a major decline in coral trout abundance due to fishing pressures on the Great Barrier Reef, particularly the heavily fished reefs of the inner South. The rigorous abundance surveys reported by Hughes (2004) "found a 4-5 fold depletion of the biomass of this targeted fish in fished areas [compared to adjacent no-take areas]." [51]

And what about fishing pressure? It's sometimes said that the spearfishing participation rate is low, and rocky reefs are often protected by weather, or difficulty of access. The NSW Fisheries Department, while dismissing claims of overfishing as "anecdotal", did not seek to even investigate the environmental impacts of spearfishing until 1997 (Minister for Fisheries NSW 1997). As far as I can ascertain, the studies promised by the Minister in 1997 have either not been undertaken, or not been published. Other State Fisheries agencies have generally followed the same lines in turning a blind eye to the impacts of spearfishing.

Fisher lobby groups tend to underplay the effects of spearfishing – arguing both lack of 'scientific evidence' and, paradoxically, recommending continued access to marine reserves by spearfishers (Recfishwest 2003). The Australian Underwater Federation (AUF) has produced a number of reports on spearfishing and its effects (Saenger and Lowe 1975, Hyde 1986). The AUF's paper by Smith & Nakaya (2003) presents data on spearfishing CPUE (catch per unit effort) out of the necessary spatial, temporal and pressure context, thus failing to establish any logical conclusion other than a general inference. No information is presented indicating that the competitions in question were held at the same or systematically comparable locations, at the same time of year, under the same rules, and under similar weather conditions.

In commenting on the bad press received by spearfishing competitions, Schmeissing 1997:58 pointed out that "on land the suggestion to kill native fauna for competition points would undoubtedly be met with public outcry". Schmeissing also noted that angling competitions had received better press coverage following the introduction of tag and release rules, but that tag and release would never be possible for spearfishing competitions.

Schmeissing's thesis (1997:59) noted that "catch records from the 1996 NSW State Spearfishing Titles indicate that 82% of species caught during the competition were sedentary reef species". His central recommendations at the close of his study included the removal of sedentary reef species from competition eligibility rules, after highlighting concerns that spearfishing pressures, both within competitions and more generally, were widely unsustainable.

10. Spearfishing: a sport out of control?

Have the impacts of spearfishing on accessible shallow reefs been underestimated? I believe they have been grossly underestimated – partly perhaps because fishery agency staff tend to focus on issues which they see as more important, particularly commercial fishery issues. Partly also because conservation lobby groups in Australia tend to be preoccupied with issues which they perceive to have wider public support – such as forest conservation or wilderness protection, for example.

A cursory examination of spearfishing pressures suggests that severe local impacts are predictable. As no reliable historical information on participation rates in the sport exists, it is necessary to make some assumptions[52],[53]. Given that the population of Victoria in the early 1980s was around four million, an assumption of a participation rate of point one percent actively engaged in spearfishing over the summer months would yield a spearfisher population of 4,000 people. During one Saturday morning in February 1982, I counted 8 spearfishers on the Hampton breakwater[54], and by my experience that would have been typical for a summers day at the weekend. The remaining 3,992 spearfishers were presumably somewhere else at the time (there are perhaps 100 similarly attractive spearfishing sites along the shore of the Bay and the nearby ocean coast). An assumption that the breakwater received 32 fishing visits per week, taking into account bad weather and a lower rate of participation during the week, seems realistic. My catch rate at that site in the early days was around 5 fish in half an hour, decreasing as the fish population dropped. So it's likely that spearfishing pressure on the virgin site *could* remove around 160 fish each week over the warmer half of the year, or around 4000 fish per year, conservatively. Effort to remove those fish would have been a minimum of around 800 hours. The breakwater site itself has only one open side, so the artificial reef in question forms a strip about 300 metres long by 6-12 metres wide (average 10). Visibility on the inside of the breakwater was, and remains, too poor to either spearfish or survey. If we assume a virgin resident population density of 2 edible fish per metre of length, that's 600 mature fish resident on the site (prior to the onset of spearfishing pressure). It's clear that the pressure imposed by recreational spearfishing is considerable - easily enough to remove all the breeding stock from the site over a period of three or four years – and, even taking recruitment from deeper reefs into account, that's exactly what happened.

In terms of access, as one site goes downhill, spearfishing pressure turns to less accessible sites. Easy access to small boats and SCUBA gear compound these pressures. Controls on spearfishing, where they exist, are seldom enforced – partly due to obvious difficulties related to enforcement effort.

In my estimation, most of Victoria's accessible shallow reefs were decimated between 1960 and 1985. They have not recovered. Without a knowledge of historical accounts, those entering the sport over the last twenty years can have no conception of the environment which existed forty years ago. This is the 'shifting baselines' effect referred to by Dayton (1998) where (due to pervasive environmental degradation) successive generations loose track of the meaning of a pristine environment.

11. Precautionary management of spearfishing:

After a detailed examination of the effects of fishing on the marine environment, the UK Blundell Report (RCEP 2004:Summary:10) stated:

> The precautionary approach needs to be applied comprehensively to fisheries management. Currently, the marine environment is regulated on the basis of a presumption in favour of fishing. Unless harm to ecosystems or habitats can be demonstrated by whatever organisation regulates fisheries, then it is usually acceptable for activities to continue. This approach has not prevented marine ecosystems from being severely damaged.
>
> **Therefore, we recommend that the presumption should be reversed; applicants for fishing rights (or aquaculture operations in the marine environment) should have to demonstrate that the effects of their activity will not harm the sea's long-term environmental sustainability.** This change would place the burden of justification on those seeking fishing rights and make both the industry and its regulator focus much more on the biological state of the marine environment. The new approach could operate through a system of licensing and marine planning. There will be areas that need to be entirely protected in order to fulfill the precautionary principle and achieve recovery of ecosystems.

This reversal of the burden of proof is being partially implemented in Commonwealth fisheries through the Australian Government's assessment program under the *Environment Protection and Biodiversity Conservation Act 1999* - with regard to some sections of the commercial fishing industry.

It is time to introduce the concept of precautionary management to recreational fishing, including spearfishing. Firstly, the steps outlined above (section 2) should be put in place as a matter of urgency. Secondly, a longer-term and more wide-ranging strategy is needed, and a national taskforce should be convened by the Australian government to plan the introduction of a precautionary approach over the coming decade. The taskforce would lay the policy foundation for an extensive community education and consultation program which would span the best part of ten years.

In my view, State governments, acting in unison, should announce that *all* waters will be closed to recreational fishing on a target date, with the exception of waters which are being fished under an agreed sustainable regime. Studies would need to be undertaken to demonstrate that particular local fishing regimes are in fact sustainable. Such studies should be funded in equal shares by recreational fishing organisations, the relevant State government, and the Commonwealth government. The target date, given the magnitude of the education and consultation task, should in my view be 2016.

12. Conclusions and recommendations:

While the above recommendations on introducing a precautionary approach would involve a massive shift in consciousness by both the fishing public and politicians (which could only take place over a period of several years) there are urgent short and medium term issues which need to be addressed immediately.

Australian agencies responsible for regulating marine harvesting activities have been lulled into a false sense of security in relation to spearfishing in particular. While participation rates related to harvesting by recreational divers and snorkellers are low (in the order of 1 in 1000), and bycatch from such harvesting activities is also close to zero, there is strong anecdotal evidence that the concentration of harvesting activities on shallow reef environments has caused major damage. Extensive local extinctions have almost certainly occurred, and entire reef ecosystems have been degraded. A significant regional extinction (the eastern grey nurse shark) is approaching, brought on in large part by historical spearfishing pressures.

Harvesting activities by recreational divers and snorkellers need much tighter control – as a matter of urgency. The current situation breaches the Food and Agriculture Organisation *Code of Conduct for Responsible Fisheries 1995* – particularly article 7.5 which requires the adoption of a precautionary approach to fisheries management. Australia has endorsed the FAO code, although it should be noted that compliance with the code is voluntary.

No national voluntary code of conduct exists to guide the sport of spearfishing. Such a code is needed and should be developed. While spearfishing is almost solely under the control of Australian States and Territories, national coordination is required. Initially, discussions need to be held between the Commonwealth Department of the Environment and Heritage National Oceans Office and the Australian Fisheries Management Authority with a view to devising a program to engage both fisheries agencies and stakeholders from the States. The next step would be to expand these discussions to include State fisheries and environment agencies, as well as environment and fishing stakeholders. The list of stakeholders should include the Australian Underwater Federation, large State spearfishing clubs, the Australian Marine Conservation Society, the Australian Society for Fish Biology, WWF Australia and the Australian Marine Science Association. The ultimate aim of the program would be to create, through a stakeholder-driven consensus process, a code of conduct which would (a) emphasize the vulnerability of reef ecosystems and their permanent residents, (b) encourage responsible fishing behaviours, and (c) initiate stakeholder-driven monitoring and reporting programs designed to track changes in reef ecosystems.

State fishery management agencies should develop management plans for spearfishing, in line with FAO recommendations (see above). Generally speaking, I believe nine key actions are urgently required to control spearfishing activities in Australia, and these issues need to be addressed within State fishery management frameworks:

1. There is an urgent need for a massive expansion of permanent marine no-take areas – principally to address biodiversity conservation and benchmarking concerns. Spearfishing activities should of course be banned in such areas. However, where buffer zones are established around such areas, spearfishing activities should be excluded from these zones as well, in order to increase the level of protection of ecosystems inside the no-take areas from harvesting edge effects. At the very least, in States where spearing on SCUBA and night spearfishing are still legal, these activities need to be totally excluded from buffer zones around no-take zones.
2. Temporary no-take areas, of substantial size, should be established specifically for the purposes of re-building fish stocks. The experimental use of such no-take areas should begin immediately, with closures of both 5 and 10 years. A selection of heavily-fished reefs should be immediately protected across Australia. The entire reef, plus lateral and longitudinal buffer zones, should be protected. Other significant habitats, such as seagrass areas, should also receive similar temporary protection for the same purpose.
3. The FAO Code advocates the use of 'interim' measures while a fishery management plan is being developed and finalised. One of the key areas where more knowledge is needed relates to the relative effect of angling compared with the potentially more effective (and more damaging) techniques of spearfishing and gill-netting. Quite apart from MPA programs, fishery agencies should institute partial closures of a variety of reef types (and locations) to netting and spearfishing in an experimental impact monitoring program. Such closures need to be for periods of at least a decade in order for reef populations to stabilise, and, for the same reason, they need to be substantial (> 10 km^2) in extent. Natural variations are high in marine systems.
4. Spearfishing on compressed air[55], and night spearfishing should be banned immediately in all Australian waters, including all of the Australian EEZ. These techniques increase the vulnerability of reef fish, or open water aggregations ,already under severe pressure. Spearfishing on SCUBA is currently banned in Queensland, New South Wales, Victoria and South Australia.
5. The sale of speared or damaged fish should be banned outright in all Australian jurisdictions. Such sales are currently banned in Queensland, New South Wales, Victoria and South Australia. Coherent fishery management requires a general regulation prohibiting the sale of fish by anyone not possessing a professional fishing licence, and this is the case on Australia's eastern seaboard. Due to the small chance of apprehension, high penalties should apply as a deterrent, even though in some cases the offence will appear trivial.

6. According to the FAO Lysekil Statement: “an open access fishery is not precautionary”[56]. The sport of spearfishing should be permitted conditional on the participant holding a current recreational fishing licence issued by a State government fisheries agency[57]. The costs of providing and administering the licence should be recouped via a licence fee. The licence should be provided after the fee has been paid, and the applicant has demonstrated knowledge both of relevant State statutory controls, as well as familiarity with the voluntary code of conduct (see below). Licences could be issued on an annual basis. Re-issue of a licence should be conditional on the applicant making annual internet-based catch reports at least one a year, even if catch has been zero.
7. There are obvious issues in enforcing compliance across fisheries generally. For this reason punishments for breaching regulations must have strong deterrent elements: punishments where the chance of apprehension is remote need to be severe. Breaches of regulations need to be categorised as minor or major. Those convicted of two major breaches should be banned from holding a fishing licence of any kind again. This should be a *requirement* of the relevant legislation.
8. Spearfishing competitions should be phased out over a 5-year period. Immediate bans should be placed, Australia-wide, on competitions which allow the catch of fish which are permanent or semi-permanent reef-dwellers.
9. A voluntary *national code of responsible conduct for spearfishing* should be developed by a joint State/Commonwealth working party, in consultation with spearfishing, fishing and marine conservation groups. Existing club codes are not widely circulated or used, and have not been prepared in consultation with government or conservation stakeholders[58]. State regulations should be introduced requiring that all sales of spearguns, and the issue of all spearfishing licences, should be accompanied by distribution of copies of the code of conduct.

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14. Appendix One: Hampton Breakwater visual census:

The visual census provides snapshots of populations over the period 1959 to 2006 (Table A1 below). I have no data on sea surface temperature variations or local pollution relating to the enclosed marina. The breakwater site, situated adjacent to suburban Melbourne, attracted many inexperienced spearfishers in the 1960s. This may account for the demise of species such as the marblefish, which have a weedy and somewhat unattractive taste, as well as the smaller species such as the wrasse, old wife, and sea sweep.

The survey data suggest that the species most heavily harvested by divers, such as the dusky morwong, leatherjackets and rock lobster, were quickly eliminated from the site. Moreover, even though spearfishing pressure appears to have remained low for many years at this site, populations of these animals have not recovered. The survey, however, reveals other changes which do not seem to have simple explanations. It should also be born in mind that marine ecosystems are dynamic by nature, subject to changes in water circulation or temperature resulting from changing weather/climate. For this reason, bearing in mind that the four survey data years are well separated in time, arguments on trends should be made with caution. Static equilibrium in relation to populations and energy flows may not hold.

The local marine ecosystem at the breakwater has undoubtedly undergone very significant change. Although sea lettuce has increased in abundance, kelp has undergone a recent decline of around three orders of magnitude, far out-shadowing the minor increases in abundance of other vegetation. In 1959 and 1964 almost no bare rock was visible under low tide line; today bare rock accounts for 20-30% of rock substrate. Mussels have declined in abundance, but this cannot be attributed to direct human harvesting, as the most accessible mussels – those in the intertidal zone – have remained the healthiest, with populations below low water mark virtually completely removed. In this regard the major increase in starfish populations should be noted – these animals feed on mussels.

Two once-common species which are not heavily harvested (to my knowledge) by either divers or anglers have declined almost to the point of local extinction: the small blenny and the local sea urchin. Some years ago I did observe harvesting of the sea urchin by a group of snorkellers, but my inquiries of regular visitors to the breakwater (in March 2006) suggest that little or no urchin harvesting is presently taking place. There are no signs of a recent disease outbreak within the formerly abundant urchin population – although such signs could be quickly eliminated by wave action in the now shallow water – a point which also requires discussion. In 1999-2000 the local ports authority, at the direction of the Victorian State Government, undertook a major beach renourishment project 2 to 4 km immediately north of the breakwater. The longshore drift at this location is southerly in winter, and it appears that a large amount of the sand that was brought to the beach has moved, and is now situated in the vicinity of the breakwater – accounting for the significant change in water depth observed at the 2006 survey[59].

The dramatic demise of the turban shell also appears to lack a simple explanation – I am not familiar with this animal's predators. I have seen newspaper reports of overfishing of turban shells in the Sydney area, and it is possible that populations of the shell at the breakwater have been heavily harvested in recent years. The small and poisonous toadfish is despised by anglers and spearfishermen, and has increased in numbers. The luderick, which is difficult to catch by angling, and nervous of divers at this site, has retained its presence over the years at the breakwater, although large fish are now missing from the local population.

Abalone, formerly under intense harvesting pressures, still retain a minor presence at the site, generally in shallow water (<2m) where harvesting is now prohibited by law. The stingaree is harvested by inexperienced spearfishers, and slow to reproduce, but nevertheless also retains a presence on site. Although not marked below as an obligate reef species, individuals do appear to return to the same rock shelters over extended periods. The eagle ray, once a regular visitor to the breakwater, has not been recorded in recent surveys. Unfortunately this impressive animal has been harvested by inexperienced spearfishers as a trophy target.

I have argued elsewhere in this paper that networks of marine protected areas need to be supplemented by temporary 'recovery areas' – significant portions of marine habitat closed for specific periods of time (in the order of a decade) to allow over-fished populations to recover, and to thus provide spill-over effects of both adults and eggs or larvae[60]. Such areas are needed every 10 to 25 km along the coastline[61], rotated each decade. The breakwater and nearby natural reefs at Picnic Point should be urgently considered for such a temporary closure[62], after issues of pollution from the nearby marina have been investigated.

Table A1.1 Hampton Breakwater visual census survey results 1959 - 2006

Average values from 6 transects in each survey year – rounded to integers; see notes.

		1959		1964		1982		2006	
COMMON NAME	GENUS & SPECIE	AVERAGE ABUNDANCE	MEDIAN LENGTH	AVERAGE ABUNDANCE	MEDIAN LENGTH	AVERAGE ABUNDANCE	MEDIAN LENGTH	AVERAGE ABUNDANCE	MEDIAN LENGTH
Green sea lettuce	*Ulva* spp.	0.1% cover		0.2% cover		2% cover		7% cover	
Kelp	*Ecklonia radiata*	40% cover		40% cover		35% cover		0.04% cover	
Sea velvet	*Codium fragile*	1% cover		1% cover		1% cover		2% cover	
Blue mussel *	*Mytilus edulis*	9% cover		9% cover		6% cover		2% cover	
Fairy mussel	*Electroma georgiana*	0		0		0		0.1% cover	
Triton shell *	*Triton* spp.	120	60 mm	120	60 mm	90	55 mm	90	55 mm
Turban shell *	*Turbo undulatus*	15,000	30 mm	15,000	30 mm	12,000	30 mm	10	30 mm
Sea urchin *	*Heliocidaris erythrogramma*	1200	55 mm	1200	55 mm	2000	50 mm	8	50 mm
Abalone *	*Haliotis rubra*	600	100 mm	300	90 mm	120	80 mm	100	70 mm
Variable seastar *	*Patiriella calcar*	900	60 mm	900	60 mm	12,000	60 mm	30,000	60 mm
Biscuit star	*Tosia australis*	0	-	0	-	0	-	0	-
Starfish	*Coscinasterias muricata*	0	-	0	-	0	-	30	300 mm
Rock lobster *	*Jasus edwardsii*	100	300 mm	0	-	0	-	0	-
Smooth toadfish	*Torquigener glaber*	10	100 mm	10	100 mm	20	100 mm	100	100 mm
Globefish	*Diodon nicthemerus*	2	180 mm	1	180 mm	3	180 mm	0	180 mm
Sparcely spotted stingaree	*Urolophus paucimaculatus*	12	400 mm	3	400 mm	4	400 mm	8	400 mm
Luderick *	*Girella tricuspidata*	200	220 mm	50	180 mm	100	200 mm	150	180 mm
Tasmanian blenny *	*Pictiblennius tasmanianus*	200	65 mm	200	55 mm	180	55 mm	2	55 mm
Snapper	*Chrysophrys auratus*	30	200 mm	0	-	0	-	30	200 mm
Sand flathead	*Platycephalus bassensis*	6	300 mm	3	280 mm	1	280 mm	1	280 mm
Greenback flounder	*Rhombosolea tapirina*	6	300 mm	1	300 mm	1	300 mm	0	-
Marblefish *	*Dactylosargus arctidens*	200	350 mm	60	300 mm	0	-	0	-

		1959		1964		1982		2006	
COMMON NAME	GENUS & SPECIE	AVERAGE ABUNDANCE	MEDIAN LENGTH	AVERAGE ABUNDANCE	MEDIAN LENGTH	AVERAGE ABUNDANCE	MEDIAN LENGTH	AVERAGE ABUNDANCE	MEDIAN LENGTH
Purple wrasse *	*Pseudolabrus fucicola*	100	280 mm	20	240 mm	0	-	0	-
Blue throat wr. *	*Pseudolabrus tetricus*	60	300 mm	6	250 mm	0		0	
Snook	*Sphyraene novaehollandiae*	20	500 mm	20	500 mm	0		0	
Rock ling *	*Genypterus tigerinus*	12	n/a	6	na	0		0	
Eagle ray	*Myliobatis australis*	2	1.4 m	0		0		0	
Dusky morwong	*Dactylophora nigricans*	6	500 mm	0		0		0	
Sea sweep *	*Scorpis aequipinnis*	30	250 mm	0		0		0	
Old wife *	*Enoplosus armatus*	10	200 mm	0		0		0	
Six spined leatherjacket *	*Meuschenia freycineti*	15	240 mm	0		0		0	
Yellow tailed l/j *	*Meuschenia flavolineata*	15	220 mm	0		0		0	
Brown striped l/j *	*Meuschenia australis*	10	250 mm	0		0		0	
Rough l/j *	*Scobinichthys granulatus*	10	250 mm	0		0		0	
Port Jackson shark	*Heterodontus portusjacksoni*	2	0.8 m	0		0		0	
Port Phillip pipefish	Vanacampus phillipi	0		0		0		0	
Northern Pacific seastar	*Asterias amurensis*	0		0		0		4	75 mm
European fan worm	*Sabella spallanzanii*	0		0		0		0	
Spearfishing pressure		32 person hrs/week		16 person hrs/week		2 person hrs/week		2 person hrs/week	
Sand depth end		6.5 m		6.5 m		6.5 m		3.5 m	
Sand depth start		1.8 m		1.8 m		1.8 m		1.5 m	

Table A1.2 Hampton Breakwater visual census survey results 2008 - 2014

		2008		2010		2012		2014	
COMMON NAME	GENUS & SPECIE	AVERAGE ABUNDANCE	MEDIAN LENGTH	AVERAGE ABUNDANCE	MEDIAN LENGTH	AVERAGE ABUNDANCE	MEDIAN LENGTH	AVERAGE ABUNDANCE	MEDIAN LENGTH
Green sea lettuce	*Ulva* spp.	8% cover							
Kelp	*Ecklonia radiata*	1% cover							
Sea velvet	*Codium fragile*	3 % cover							
Blue mussel *	*Mytilus edulis*	3% cover							
Fairy mussel	*Electroma georgiana*	0		0		0		0.1% cover	
Triton shell *	*Triton* spp.	80	55 mm						
Turban shell *	*Turbo undulatus*	0							
Sea urchin *	*Heliocidaris erythrogramma*	30	50 mm						
Abalone *	*Haliotis rubra*	90	70 mm						
Variable seastar *	*Patiriella calcar*	30,000	60 mm						
Biscuit star	*Tosia australis*	1	45 mm						
Starfish	*Coscinasterias muricata*	120	300 mm						
Rock lobster *	*Jasus edwardsii*	0							
Smooth toadfish	*Torquigener glaber*	200	90 mm						
Globefish	*Diodon nicthemerus*	2	180 mm						
Sparcely spotted stingaree	*Urolophus paucimaculatus*	3	400 mm						
Luderick *	*Girella tricuspidata*	50 300	120-220 50-119						
Tasmanian blenny *	*Pictiblennius tasmanianus*	5	55 mm						
Snapper	*Chrysophrys auratus*	60	180 mm						
Sand flathead	*Platycephalus bassensis*	0							
Greenback flounder	*Rhombosolea tapirina*	1 (blind)	270 mm						
Marblefish *	*Dactylosargus arctidens*	2	280 mm						

		2008		2010		2012		2014	
COMMON NAME	GENUS & SPECIE	AVERAGE ABUNDANCE	MEDIAN LENGTH	AVERAGE ABUNDANCE	MEDIAN LENGTH	AVERAGE ABUNDANCE	MEDIAN LENGTH	AVERAGE ABUNDANCE	MEDIAN LENGTH
Purple wrasse *	*Pseudolabrus fucicola*	0							
Blue throat wr. *	*Pseudolabrus tetricus*	0							
Snook	*Sphyraene novaehollandiae*	0							
Rock ling *	*Genypterus tigerinus*	0							
Eagle ray	*Myliobatis australis*	2	1 m						
Dusky morwong	*Dactylophora nigricans*	1 (juvenile)	90 mm						
Sea sweep *	*Scorpis aequipinnis*	0							
Old wife *	*Enoplosus armatus*	0							
Six spined leatherjacket *	*Meuschenia freycineti*	0							
Yellow tailed l/j *	*Meuschenia flavolineata*	0							
Brown striped l/j *	*Meuschenia australis*	0							
Rough l/j *	*Scobinichthys granulatus*	0							
Port Jackson shark	*Heterodontus portusjacksoni*	0							
Port Phillip pipefish	Vanacampus phillipi	2	100 mm						
Northern Pacific seastar	*Asterias amurensis*	30	80						
European fan worm	*Sabella spallanzanii*	5	75 mm						
Spearfishing pressure		2 person hrs/week							
Sand depth end		3.5 m							
Sand depth start		1.0 m							

NOTES: The 300 m breakwater wall is constructed of basalt boulders of typical dimensions in the vicinity of a metre, dumped on sand. “Depth” refers to the depth of the sand floor at mid-tide at the foot of the breakwater wall – which slopes at about 60 degrees to the vertical. Fish length was measured or estimated by comparison with a scaled note-board. Fish numbers were either counted (for specie populations less than about 50) or estimated by counting patches or schools and estimating the extent of patches or schools. Survey data dated 1959 was reconstructed in 1964 from memory and discussions with my father. Other survey data was obtained by visual census carried out by snorkelling two transects (one each way) along the breakwater per day on three consecutive days of visibility >5 m, in February 1964, February 1982, March 2006 and January 2008. Fishing pressure was estimated based on observation and interview. Tidal variation: springs 0.80 m, neaps 0.20 m. Biophysical region: Victorian embayments. Wave energy: low with occasional storm events of waves to ~3 m. Typical water temperatures: summer 20, winter 11 Celsius (Parks Victoria data for nearby Ricketts Point). Adjacent catchment: urban. Discharges: no creeks or major stormwater drains. Two stormwater drains of medium size are situated about 700 m northeast and south of the breakwater. No industry discharges to these drains. “*” indicates an obligate reef species. Approximate survey area ~3000 m^2 horizontal. The start of the breakwater connects with an area of shallow natural sandstone reef, thus forming a link with natural rocky habitat.

15. Appendix Two: Extract from Pollard and Scott 1966:

Spearfishing has undoubtedly had a marked effect upon populations of certain species. Spearfishing started in Sydney about twenty years ago, and today there are more than 1000 spear fishermen in New South Wales. The pastime is developing rapidly in all other Australian States. Gear has improved greatly, and today compressed air and carbon dioxide powered spearguns, underwater breathing apparatus, and rubber suits allow the spear-fisherman to tackle bigger fish at greater depths and in every sort of weather.

In many parts of the world, particularly along the coasts of Spain, Southern France, Italy, Jamaica and the Bahamas, spear fishermen have decimated populations of edible reef fishes. The same is now happening in parts of Australia. The inshore reefs for more than twenty miles each side of Sydney Harbour have been almost denuded of edible fish, and much of the remaining New South Wales coastline is also beginning to suffer.

The species commonly taken by spear-fishermen are blue groper, black bream, southern bream, strongfish, Queensland groper, kingfish, luderick, red morwong, mulloway, black drummer, silver drummer, flatheads and leatherjackets. The reef-living species among these are particularly vulnerable because of their sedentary habits and slow growth rates.

The populations of most of these fish have declined to some extent in different areas, but the blue groper of the NSW coast has suffered most. This large member of the parrot-fish family grows to over 100 lb. in weight, and is relatively easy to spear because it is so slow. The blue groper is much easier to spear than to land, however, because when speared it dives into the nearest cave or crevice and is very difficult to dislodge. In such cases, the spear often tears out and the fish is lost. These injured fish usually die. Blue groper have been slaughtered in NSW to such an extent that a bag limit of two per day has now been imposed.

In southern waters the strongfish or dusky morwong is suffering in a similar manner. The Port Noarlunga reef near Adelaide has been proclaimed a fish sanctuary in order to give this and other depleted species a chance to recover. In many countries the spearfishing of fish while using an aqualung is illegal. This regulation, if adopted in Australia, would help prevent the denudation of inshore reefs that has occurred along the northern Mediterranean.

In the past, when points were allotted on weight of fish caught, spearfishing competitions have denuded large areas of reef. In NSW points are now allotted according to both weight and the difficulty of capture of each species. Only one fish of each species may be take and these must be at least 25% above the minimum legal size.

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16. Appendix Three: the Leigh Marine Reserve, New Zealand

Source: Gell and Roberts 2003b.

The Leigh Marine Reserve encompasses 5km of coast, extending 800m seaward on the north-east coast of New Zealand. The reserve was gazetted in 1975 after a 10-year process of application and consultation. The initial motivation for its establishment was the concern of scientists from the Leigh Marine Laboratory of the University of Auckland over the level of exploitation of the shores and coastal waters, particularly from spearfishing. Its main aims were conservation of the marine environment and scientific research. The reserve became actively managed in 1977 and is enforced by marine rangers and by community enforcement via the Department of Conservation. Although not initially established for fisheries management, the fishing community have come to support the reserve, as have members of the wider community who have seen benefits through the increases in visitor numbers and associated revenue (Walls 1998).

In a survey after 10 years of management (Crouch and Hackman 1986, in Ballantine 1991) 78% of commercial fishers said they were in favour of more reserves, 78% said they would actively prevent poaching in the Leigh reserve and 40% said that their catches were higher because of the existence of the reserve. A second survey was conducted at Leigh in 1992

(after 15 years of active reserve management), focusing on three user groups – visitors, local residents and local businesses and this demonstrated almost total support.

Significantly, the survey confirmed the reserve had the support of commercial and recreational fishers, and that many fishers believed that fishing in the adjacent fishing grounds had improved. The role of fishers in enforcement of the reserve regulations was also found to be important in the day-to-day management (Cocklin et al. 1998).

Public participation and support is not currently a statutory requirement in the designation of marine reserves in New Zealand, but is now included in the application process (Department of Conservation 1994, in Cocklin et al. 1998). In the case of Leigh, Cocklin et al. (1998) identify a problem in defining the "local community" in that all consultation focused on one community. Another nearby community felt they too should have been involved. The importance of including visitors in consultation is also raised here.

The history of Leigh Marine Reserve shows that even when there has been long-term consultation, full agreement might not be reached at the outset. However, one encouraging characteristic of Leigh is that support has increased over time and now few people have objections. In a socio-economic study many local people believed that the community had benefited economically from the presence of the reserve, mainly through visitors buying food (Cocklin and Flood 1992, in Walls 1998). The indigenous people were not specifically included as a group in the initial consultation, although individual Maori people were involved. New reserves in New Zealand now specifically consult indigenous people under the Treaty of Waitangi (Walls 1998).

Effects on lobsters and the lobster fishery

In the Leigh Marine Reserve, Kelly (1999) found that experimental catch rates of lobsters showed strong seasonal variability. However, catch rates close to the reserve boundary were high compared with areas further away. Local lobster and fin fishers also choose to fish close to the boundary implying that the public perceive that the reserve has increased the abundance of fishery species (Kelly 1999).

Kelly et al. (2000) assessed recovery of the spiny lobster *Jasus edwardsii* in four marine reserves in north eastern New Zealand and compared this with similar non-reserve sites. They included Leigh Marine Reserve (protected for 21 years), Tawharanui Marine Park (protected for 14 years), Cathedral Cove Marine Reserve and Tuhua Marine Reserve (both protected for 3 years). They found higher lobster biomass inside the marine reserves than outside and they were also able to look at the extent of lobster recovery in relation to time since protection.

Lobster densities inside reserves increased by nearly 4% per year in shallow sites (less than 10m) and by 9.5% in sites deeper than 10m. Mean carapace length of lobsters increased by 1.14mm per year of protection, and lobster biomass was estimated to have expanded by 5.4% per year of protection in shallow sites and by 10.9% per year in deep sites. Estimated egg production increased by 4.8% (shallow) and 9.1% (deep) per year of protection.

In 1985/6 lobster fishers began setting their pots around the boundary of the Leigh reserve. Fishers reported very large catches with large male lobsters filling pots (Kelly et al. 1997, in Walls 1998). More recently, Kelly et al. (2002) looked at the value of the spillover fishery around the Leigh Marine Reserve. They compared catch per unit effort at the reserve boundary with a fishing site 0.3-2km from the reserve and another site 22-30km from the reserve. They found no significant difference in CPUE (in kg per trap haul) among the sites.

However, catches from the reserve boundary could only be made in the deeper offshore habitat as fishers could not use the inshore reefs favoured by lobsters at certain times. Catches from the reserve boundary contained fewer but larger lobsters, and were more variable than those from the other two sites. However, the amount of money made per trap haul was similar at each site because the occurrence of empty pots was offset by pots containing large numbers of lobsters. For instance, in 1995 nearly 21.6% of revenue earned by the study fishers came from just 4.4% of trap hauls. High variability in catches is not

something that is usually predicted for reserves and in this case is a consequence of the aggregation behaviour of lobsters near the reserve. Because of the seasonal nature of offshore aggregation, high catch rates were only possible during 7-8 months of the year and outside these months catches were likely to be low.

Jasus edwardsii supports one of New Zealand's most valuable inshore fisheries and is managed though a quota scheme that is perceived by fishers to work fairly well. The lobster fishing industry therefore opposes marine reserves, arguing that the quota system is a conservation tool and that marine reserves are not an effective management tool (S. Kelly pers. comm.). No detailed information was available on how the fishing community in general responded to the presence of reserves. However, the study fishers from whom Kelly et al. (2002) collected the CPUE data, responded to the loss of inshore reef sites and reduction of fishing area at the marine reserve by increasing the density of traps set around the reserve boundary. Evidence from New Zealand's reserves suggest that while they are presently small and acting principally as conservation tools, they could play a useful role in supporting other lobster fishery management measures.

Effects on commercial and recreational fish

Cole et al. (1990) studied densities of a variety of fish species in the Leigh Marine Reserve using underwater visual census in 1982 and found that only one species, the red moki (*Cheilodactylus spectabilis*) increased in abundance over the initial 6 years of management. Abundance of five other species, the snapper (*Pagrus auratus*), goatfish (*Upeneichthys lineatus*), spotty (*Notolabrus celidotus*), blue cod (*Parapercis colias)* and leatherjacket (*Parika scaber*) did not change significantly in these initial years. A subsequent survey in 1988 showed increasing abundance of snapper, blue cod, red moki and rock lobsters, but no trend in the abundance of sea urchin (*Evechinus chloroticus*).

Babcock et al. (1999) studied the most common demersal predatory fish, the snapper (*Pagrus auratus*), in the Leigh Marine Reserve and Tawharanui Marine Park and found that adults were 5.8 and 8.7 times more abundant inside the reserves than in adjacent fished areas. Individuals were also significantly larger with mean lengths of 316mm inside protected areas compared to 186mm in fished areas. Babcock et al. (1999) found significant differences in abundance of non-target species such as sea urchins (*Evechinus chloroticus*) which declined to less than a third of their former abundance in one of the marine reserves over 20 years of protection. They also found that kelp beds were more extensive in one of the reserves.

This suggests fishing pressure has changed not only the mean size and abundance of target species, but also the wider ecosystem. Snappers and lobster prey on urchins which in turn graze on kelp. In a study using tethering experiments, Shears and Babcock (2002) found that predation of sea urchins was 7 times higher inside the Leigh Marine Reserve and the Tawharanui Marine Park than in unprotected areas. Growing snapper and lobster populations in reserves have helped reduce urchin densities and facilitated an increase in algal cover. Urchin barrens covered 40% of available reef in unprotected areas but only 14% in reserves. Babcock et al. (1999) estimate that primary productivity from macroalgae like kelp has increased by 58% from what is was before the Leigh Marine Reserve was established. Benthic primary productivity was also found to be much lower outside the reserves than before intensive fishing began. Overall this study reveals some of the complex interactions that influence recovery of protected ecosystems from previously high levels of fishing.

Willis et al. (in review) studied density and size of snapper inside and outside three marine reserves in northern New Zealand: Leigh Marine Reserve, Hahai Marine Reserve and Tawharanui Marine Park. Snapper is the most important species for recreational fishing in upper North Island and one of the most important commercial fishery species (see Annala and Sullivan 1996, in Millar and Willis 1999). The abundance of snapper larger than the minimum legal size was 14 times greater in protected compared to fished areas, and egg production an estimated 18 times higher. In the Leigh Marine Reserve, legal-sized snapper were larger than legal-sized snapper in fished areas, but size differences were not

significant. Snapper abundance, like that of lobsters, was highly seasonal with higher densities in autumn than in spring.

Willis et al. (2001) explored movement of snapper in the Leigh Marine Reserve by tagging fish. They found that some show site fidelity to areas only a few metres wide and can occupy the same area for a number of years in the absence of fishing. Some snapper may move long distances but in the light of the large increases in their abundance inside the reserve it seems likely that some are permanently resident in the reserve (Willis et al. 2001). It is possible that some snappers can be mobile or site-attached and that reserves select for the site-attached snapper.

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17. Endnotes:

[1] Dr Jonathan Nevill is an environmental scientist and amateur spearfisherman (now fishing pelagic species only). Qualifications: Bachelor of Engineering, Bachelor of Arts, Master of Environmental Science (Monash University), Doctor of Philosophy (University of Tasmania). Email jonathan.nevill@gmail.com.

[2] See also newspaper article: "Marine park – spearfisherman says 'yes'. *The Leongatha Star*, 26 July 1983, p. 8.

[3] Jo Buckee, pers. comm. 8 September 2004.

[4] *Jasus edwardsii.*

[5] The relatively unrestrained recreational use of gill nets in Tasmania (see endnote below) has been responsible for major impacts on reef fish populations, making it difficult to untangle the various effects of gill net, line and spear fishing – all of which are probably significant in reducing reef fish populations in this State. Schaap & Green conducted limited visual surveys of matched lightly fished and heavily fished reefs, and found "…a consistent trend towards decreased diversity, species richness and number of individuals at the more heavily fished sites". Although the limited nature of the surveys made definitive conclusions difficult, the authors remarked: "the trend is consistent with the removal of vulnerable species by gill netting and other fishing activities such as spear fishing and line fishing" (1988:39). They concluded that there was "circumstantial evidence that fishing activities have had a major impact on reef fish communities in areas which have been subjected to relatively heavy fishing pressure" (1988:40).

[6] The coral patches of Shark Bay in Western Australia are not readily accessible sites, but they are attractive. Shark Bay is a full day drive north of Perth (although the regional cities of Geralton and Carnarvon are closer) and a small boat is required to access the patches. I spent three weeks in Shark Bay in 1984, researching a paper (Nevill and Lawrence 1985). Shark Bay is predominated by seagrass and sand habitats, with coral making up a tiny fraction (probably less than 0.01%) of the total area. My interviews with Denham locals indicated that all the coral patches had been heavily fished by commercial or semi-commercial spearfishers, as well as anglers, during the 1970s. By the early 1980s they were denuded of fish and all had suffered substantial anchor-damage to corals.

[7] Australia has a three-tiered government structure. The Australian Government (also called Federal or Commonwealth) is responsible for taxation, defence, economic regulation and international affairs, including Exclusive Economic Zone (EEZ) fisheries. Six States and two territories form the second layer, and are responsible for most health, education, law enforcement, social services, and resource management functions – including fisheries management (sole jurisdiction to the 3 nm boundary). Local governments form the third tier.

[8] Three recent publications of the Department of Fisheries Western Australia (2003a, 2003b and 2004) do not even contain the word "spearfishing".

[9] According to the 2001 recreational fishing survey: "Line fishing (including the use of bait, artificial lures and jigs as well as set-lines) accounted for 19.7 million fishing events, i.e. nearly 85% of the overall annual fishing effort. Fishing with pots and traps (7%), harvesting bait with pumps, rakes and spades (4%), fishing with nets (3%) and diving with spears or hand collecting (1%) followed in importance. Diving (using spears or underwater hand collection) contributed 266,000 events or just 1% of the overall effort. SCUBA/surface air and snorkel diving (hand collection) was the primary activity (55% of dive events) although spearfishing (36%) was also significant. Spearing fish from the surface accounted for the balance of the 'dive' effort (9%). Tasmania and Western Australia reported above average

levels of dive effort (3-4%) (Figure 5.19, Appendix 5.8). In Tasmania, Western Australia, Victoria and South Australia dive (hand) collection (mainly for rock lobster and abalone) using snorkel, scuba or surface air supply accounted for the bulk of the dive effort. Spearfishing was the main dive activity in New South Wales and Queensland but was also of significance in Western Australia. Dive effort accounted for about 582,000 hours nationally or less than 1% of the total. Event duration for dive activity ranged from an average of 2.7 hours for spearfishing to slightly less than 2 hours for hand dive collection". The survey figures for South Australia and Tasmania both recorded total annual fishing effort at under 2000 hours for each State, with a figure for the Northern Territory of under 300 hours total effort (Appendix 5.9, p.158). Australia's population in 2001 was just under 20 million. Population by State/Territory (2001): New South Wales 6,580k, Victoria 4,800k, Queensland 3,630k, Western Australia 1,900k, South Australia 1,510k, Tasmania 471k, Aust Capital Territory 319k, Northern Territory 198k.

[10] Baker et al. 2002:83-84.

[11] Brothers et al. 1996.

[12] According to Rees 1995: "Recreational fishing using gill nets is comparatively unregulated in Tasmania…". "[T]his practice has been recognised as decimating reef fish stocks and is banned or heavily controlled in all other States and Territories in Australia". "The Division of Sea Fisheries estimates net numbers at between 15,000 and 45,000, each up to 50 m long."

[13] Although spearfishing played a major role in the dramatic decline of the grey nurse shark, it seems unlikely to be a major current threat, even though illegal spearfishing of the shark is continuing at a low level. The key issue here is that the east coast population is now so small (2003 estimate: 400-500 adults), due mainly to historic fishing, that the animal may not be able to recover. Adult females usually produce 2 pups every second year. Many other sharks have similarly low reproductive capacities.

[14] According to Pauly (1995): "Essentially, this syndrome has arisen because each generation of fisheries scientists accepts as a baseline the stock size and species composition that occurred at the beginning of their careers, and uses this to evaluate changes. When the next generation starts its career, the stocks have further declined, but it is the stocks at that time that serve as a new baseline. The result is a gradual shift of the baseline, a gradual accommodation of the creeping disappearance of resource species, and inappropriate reference points for evaluating economic losses resulting from overfishing…" An exception to this general rule is the study by MacIntyre F, Estep KW and Noji TT (1995) NAGA (the ICLARM Quarterly) 18(3)7-8, which used anecdotes from Mowat F (1984) *Sea of slaughter*. Atlantic Monthly Press.

[15] 'Scientific' is usually interpreted in this context as meaning 'obtained and presented in an objective, verifiable and systematic manner'.

[16] Food and Agriculture Organisation of the United Nations, Rome.

[17] See reference list under "Technical Consultation… "

[18] In 2004 the Great Barrier Reef Marine Park Authority established no-take reserves over 33% of the Authoritiy's area, partly to allow recovery of natural ecosystems from fishing pressures – including spearfishing amongst other fishing pressures.

[19] *Aluteridae* family.

[20] *Girella tricuspidata.*

[21] *Platycephalus spp.*

[22] *Rhombosolea tapirina.*

[23] In my view, these figures are accurate to plus or minus 10%.

[24] *Dactylosargus arctidens.*

[25] An examination of Bureau of Meteorology records (www.bom.gov.au) shows no climate or weather abnormalities or changes which might account for a decline in fish populations.

[26] Although, with hindsight, I regret it, I was originally one of the most active participants in this sport at this site.

[27] The construction of the marina replacing the original swing moorings resulted in about a six-fold increase in stored boats, and these boats over the last decade have increased in size, reflecting the increasing affluence of the nearby suburbs.

[28] Flinders is a small township slightly over an hour's drive from the south side of suburban Melbourne.

[29] The Mornington Peninsula forms the eastern side of Port Phillip Bay.

[30] Pers. comm. T. O'Hara 15/8/05: "The 500 rock lobster abundance figure is from the short-lived Collins settlement at Sorrento in 1802. I have never seen the original, only heard it referred to verbally (by Tim Allen). Early sailors also noted the abundance of osyters in Western Port (abundant enough to be able to reach down and collect them by the handful from a rowboat".
[31] Spearfishing on SCUBA is now banned in Victoria, although still legal in the Northern Territory, Western Australia and Tasmania.
[32] Schmeissing (1997) reported that (in 1997) "there are no conditions or restrictions on the purchase of spearguns in NSW". His study recommended that the NSW government introduce regulations requiring retailers to include an information brochure (covering both government regulations as well as guidance on good spearfishing practice) with the sale of every speargun (Schmeissing 1997:65).
[33] Victorian marine waters extend 3 nautical miles from the shore. Today, over 5% of these waters are within protected areas meeting the IUCN protected area class I and II criteria.
[34] Later published as Nevill 1984.
[35] A quick check I made of these areas in January 2003 suggested that abalone abundance had declined by about two orders of magnitude in the preceding 20-year period.
[36] According to Valerie Taylor (pers. comm. 10/9/04: "Most rocky reefs off the coast of NSW that we fished (and we fished most of them) hit sand between 150 and 250 feet, some much shallower at say 30 to 80 feet so there appears to be little deep water reef habitat out of scuba range for the animals to trickle up from and repopulate the shallower water".
[37] A 40% drop in populations of some commercial species in the period 2000-2003. Reference to come. xx
[38] Groper, for example, have been identified as particularly vulnerable to spearfishing pressures (Oakley 1984, Morris et al. 2000).
[39] *Achoerodus viridis* – Eastern blue grouper. Spearfishing for EBG banned in NSW in 1969, and commercial fishing in NSW was banned following a continued population decline in 1980.
[40] According to Bruce Wallner (pers. comm. 22/9/04): "With respect to the [decline of the grey nurse shark] it would [be] good to compare the spectacular recovery of blue groper in recent decades since the application of spearing bans as another case study. Blue groper are an excellent example of the impact that spearing can have on reef populations, but why have they bounced back when others have not? It might well be that blue groper have been less available to other forms of fishing like recreational angling. That is anglers find them hard to catch – they are selective feeders both in terms of prey type and time of day and because they are powerful reef dwellers they more often break off the lines of the casual generalist angler. It might be that their niche is more plastic, or social structuring and sex-changing has allowed them to increase, or it just might be that stringent bag limits applied to the recreational anglers have actually worked. Whatever the reason, my point is that reef ecology is mostly pretty complex and the interactions between nature and human forms of mortality can be hard to predict."
[41] AUF website accessed 22 August 2004 www.auf-inc.com.au.
[42] Personal communication, 8 September 2004.
[43] John Ottaway, Assistant Director, Western Australia Department of the Environment, pers. comm. 10/2/2005.
[44] Toowoon Bay lies between Sydney and Newcastle, on Australia's heavily-populated east coast.
[45] *Girella tephraeops* -rock blackfish.
[46] Although extremely weak in the environmental area, the AUF policy statement does acknowledge that spearfishing in marine protected areas *on SCUBA* is not a good idea – hardly indicating progressive or thoughtful attititudes.
[47] In temperate environments such as those found across southern Australia, physical damage by recreational divers does not appear to be a major problem, although it is noteworthy that a study of a Spanish marine protected area in a temperate environment found significant local damage to colonial bryozoans, with slow recovery (Garrabou et al. 1998). In coral environments, anchor damage, trampling and fin damage to fragile coral structures are issues of concern (Hawkins & Roberts 1992, Harriott et al. 1997, Rouphael & Inglis 2001, Tratalos & Austin 2001).
[48] The large fish are comparatively more fecund than smaller individuals, and therefore more effective as individuals for maintaining populations (see review of this effect in Gell and Roberts 2003:449.

[49] A view now widely held: see for example Bellwood et al. (2003) who also present evidence suggesting that the overfishing of a spearfishing target species, the giant coral-eating parrot fish (*Bolbometopon muricatum*) is likely to have major effects on coral ecosystem structure and function. This large and mobile reef-dweller is unlikely to receive significant protection from small sanctuaries.

[50] According to Valerie Taylor (pers. comm. 10/9/04): “In our day during competition spearfishing we could weigh in 2 fish of each edible species (they are nearly all edible) over a certain weight. The heavier the fish the more points it is worth. In competitions we would spear the first fish of each species we saw then the second if it was larger, then a third if it was larger than the other 2 dumping the smallest and so it went. The number of dumped fish was usually quite extensive. I do not know if the rules have changed since then but the discarding of the smallest and replacing it with a larger specimen worth more points I am sure is still the practice. This would make it almost impossible to judge the number of fish killed in a spearfishing competition”.

[51] Coral trout (members of the genus *Plectropomus*) are the most heavily targetted finfish species on the GBR. Of the *Plectropomus* group, the common coral trout, *Plectropomus leopardus*, is the most heaviy fished. It is targetted (generally at different intensities at different places) by commercial line fishing, by recreational angling, and by recreational spearfishing. A detailed examination of fish size/abundance data supports the view that fishing can have a major impact on coral trout populations. In several areas coral trout are no longer 'abundant' when compared with levels in the early 1990s. Sweatman et al. 2003, for example, state in relation to Border Island: "Numbers of most fish taxa were relatively stable. Although numbers have fluctuated over the 9-year study period there has been little tendency for prolonged increases or decreases. One exception may be the commercially important coral trout (*Plectropomus leopardus*). Numbers have declined since 1994 and are currently stable but low. Evidence of fishing activity has been noted (presence of snagged lures and hooks) even though this reef has protected status."

Comparative (closed / open zone) data for southerly inner-reef areas in fact reveals a substantial difference between fished and unfished areas for coral trout. This difference is reduced for northerly and outer-reef areas, where both fishing pressures and compliance/enforcement are likely to be lower. Evans & Russ 2004 report: "The biomasses of *Plectropomus* spp. and *L.utjanus carponotatus* were significantly greater (3.9 and 2.6 times respectively) in the protected zones than fished zones at all three island groups [Palm, Whitsunday and Keppel]. Using before-reserve and after-reserve creation data, Williamson et al. 2004 report: "Density and biomass of coral trout increased significantly (by factors of 5.9 and 6.3 in the Palm Islands, and 4.0 and 6.2 in the Whitsunday Islands) in the reserve sites, but not the [control] fished sites..."

[52] Schmeissing 1997:56 made comparable assumption for NSW: 10,000 participants, on average fishing on 26 days per year, catching around 6 fish averaging about 1 kg each.

[53] These assumptions are not unrealistic compared to participation rates in the only available national study: Henry and Lyle 2003.

[54] Taken from notes prepared during the preparation of a small article for the *Environment Victoria* newsletter (Nevill 1984).

[55] Spearfishing on compressed air includes the use of SCUBA and air delivered by hose.

[56] Paragraph 47. See references under “Technical Consultation…”.

[57] The Victorian Government currently requires that spearfishers, like any other recreational fisher, hold a recreational fishing licence (RFL). This licence carries no reporting obligations, although the government does facilitate the submission of voluntary recreational fishing reports through the internet – see for example http://www.fishvictoria.com/pyoursay/reports/port_albert_sthgipp.php, accessed 20/3/06.

[58] Existing club codes are extremely weak concerning environmental matters. None warn against the possible ecological effects of night or SCUBA spearfishing (see Gillett & Moy 2006) and none carry information about the ecological dangers of targetting the biggest fish (see discussion above). The Australian Underwater Federation *Spearfishing Code of Conduct* for example, contains only one sentence in environmental issues: “Respect our marine life by never taking more game than for your immediate personal needs”. Recfishwest have a *Policy on Compressed Air Spearfishing* which, far from carrying warnings, attempts to justify the activity.

[59] At March 2006, the top 30-40 cm of the skeleton of the barge wreck at the end of the breakwater was visible. As a teenager (early 1960s) I used to dive and spearfish within the holds of the wreck.

[60] According to Evans & Russ 2004: “Adjacent fisheries may benefit from no-take marine reserves due to spillover (net export) of adult individuals (Russ and Alcala, 1996; McClanahan and Mangi, 2000; Roberts et al., 2001; Galal et al., 2002) and net export of propagules via larval dispersal (Stoner and Ray, 1996; Roberts, 1997; Gell and Roberts, 2002). See Evans & Russ for citations.

[61] For guidance on the spacing of marine reserves (permanent or temporary) based on arguments relating to propagule dispersal and adult movement, see Botsford et al. 2001, Halpern et al. 2006, Palumbi et al. 2003, and Shanks et al. 2003 – listed in Nevill J (2006) *Marine no-take areas – how large should networks of marine protected areas be?* Available online at http://www.onlyoneplanet.com/marineNotesOnNTA_targets.doc.

[62] Two issues would need particularly close attention, however, before a decision was made to close the breakwater area to fishing pressures. Firstly, the implications of sand transport from the nearby beach replenishment project would need examination, as the shift of such a massive amount of sand has not only smothered much of the former rock habitat, but has altered the wave environment at the site. Secondly, the sediments and water of the marina on the inside of the breakwater wall would need to be examined for pollution, particularly in regard to hull anti-fouling agents.