Swallowing the bait: is recreational fishing in Australia ecologically sustainable?

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Recreational fishing is a growing component of the total fishery harvest in many countries, but the impacts of this sector on aquatic resources are often ignored in the management of aquatic systems. Recreational fishing is open-access, and in many inshore regions, the recreational harvest exceeds the commercial harvest. The environmental impacts from recreational angling can be both ecologically significant and broad in scope and include: the removal of a considerable biomass of a wide variety of species; discarded by-catch; possible trophic cascades through the removal of higher order carnivores; impacts on habitat through bait harvesting; impacts of introduced and translocated species to support angling fisheries; direct impacts on sea-birds, marine mammals and reptiles; and angler generated pollution. Management, for several reasons, has largely ignored these environmental impacts from recreational fishing. Recreational fishing impacts are cumulative, whereas there is a tendency for consideration of impacts in isolation. Recreational fishing lobbyists have generally been successful in focusing public and political attention on other impacts such as commercial fishing, and recreational fishing has tended not to come under close scrutiny from conservation and environmental groups. Without changes to the monitoring and management of recreational fisheries that incorporate the broad ecological impacts from the activity, it may not be ecologically sustainable in the long term and Australia will not meet its international obligations of protecting aquatic biodiversity. The definition of property rights and appropriate measures to prevent or manage large scale marine restocking are two emerging issues that also need to be addressed.

Key words: Recreational fishing, ESD, Ecosystem impacts, By-catch, Introduced species, Fisheries management, Marine protected areas, Bait harvesting.

INTRODUCTION

TRADITIONAL fisheries management has generally focused on managing the impacts of commercial fishing on typically a small number of target species and has relied on stock assessments of them as the principal scientific tool to support management decisions. Owing to the general inadequacy of this approach, a clear regime shift is underway, whereby the broader impacts of fishing on aquatic ecosystems are identified and managed (for instance see Botsford *et al.* 1997; Sharp 1997; Hanna 1999). The need for this regime shift is reflected in policy. For instance, the ESD Fisheries Working Group (1992), and Australia's Oceans Policy (1998), both refer specifically to the need for an ecosystem-level approach to fisheries management to ensure sustainability into the future.

For many commercial fisheries, the regime shift has led to an increased examination of the impacts of fishing practices on non-target species and on associated habitats (e.g., Andrew and Pepperell 1992; Poiner and Harris 1996; Collie *et al.* 1997; Robins and Courtney 1999; Kaiser *et al.* 2000) resulting in the prevention of, or changes to, some fishing practices with reductions in or even elimination of identified impacts from these fisheries. For instance, the development and adoption of turtle exclusion devices (TEDs) and by-catch reduction devices have been effective in reducing impacts on by-catch (particularly marine turtles) in prawn trawl fisheries (e.g., Brewer *et al.* 1998; Broadhurst *et al.* 1999; Robins *et al.* 1999). In other commercial fisheries (e.g., inshore net fisheries), modifications to commercial fishing practices are being trialed with positive results, but are yet to be implemented (e.g., Gray *et al.* 2000; Kennelly and Gray 2000).

It has also been recognized that the previous focus on just commercial fishing and its impacts has been inadequate to provide protection of habitats and sustainability of fisheries resources. The ESD Fisheries Working Group (1992) and Australia's Oceans Policy (2000) both acknowledge that any implementation of the policies and principles of ESD should incorporate information on the recreational fishing sector and management of its ecological impacts, as well as information on land based sources of aquatic habitat loss and pollution. However, there is little evidence of any serious attempt to evaluate and control recreational fisheries and its ecological impacts.

Recreational fishing is a ubiquitous activity throughout most of the world that principally involves angling by hook and line, but may also include spearfishing and the use of various nets and traps. Recreational fishing as a rule is open access (i.e., there is no restriction on the number of anglers participating) and effort is generally considered to be increasing in most of these fisheries throughout the world (e.g., van der Elst 1989; Schramm Jr. and Edwards 1994; Anon. 2000). Growing pressure on fish stocks from recreational fishing strongly suggests that

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managing only the effects of commercial fishing may be insufficient to prevent fish stocks from being over-exploited (Lal *et al.* 1992). Peterson (1993) has suggested that because of the relative strengths of political lobby groups representing different fishing sectors, when there has been conflict over resource allocation the outcomes have tended to favour the recreational sector over the commercial sector. As such, recreational fishing is (or is becoming) the dominant (or only) source of fishing mortality and fishing related impacts in many areas, particularly freshwater and inshore marine areas adjacent to large population centres or tourist destinations. For instance, areas and species in Australia (O'Neill 2000), South Africa (Bennett 1988; Cockcroft and MacKenzie 1997) and the United States (Matlock 1982; Smith and Jepson 1993) have been or are in the process of being declared recreational only fisheries with no independent consideration of the ecological consequences.

In contrast to commercial fishing, recreational fishing is an activity that has, for the most part, escaped close scrutiny from the community and governments in relation to impacts on aquatic biodiversity. There is a public and political perception that recreational fishing is more environmentally benign than commercial fishing (Kearney 1999). When management of recreational fisheries has been undertaken, it has generally been in an *ad hoc* manner and based on anecdotal information (Smith and Pollard 1996). The question of whether recreational fishing is ecologically sustainable seems seldom to have been asked or seriously addressed. In this paper, we address this question and argue that the cumulative impacts from recreational angling on aquatic ecosystems are broader and frequently of a considerably greater magnitude than generally recognized. Specifically, we discuss the magnitude and diversity of the recreational catch, by-catch and the impacts on juvenile fish, the possibility of trophic impacts resulting from the removal of higher-order carnivores, bait gathering and its ecological impacts, angler pollution, interaction with marine reptiles, marine mammals and sea birds, and the impacts of species introduced or translocated for angling. We offer reasons as to why the ecological impacts of recreational fishing have largely escaped close scrutiny, both by environmental groups and the relevant management agencies. We contest that without changes to fisheries monitoring and management that incorporates the broad ecological impacts from recreational angling, this activity may not be ecologically sustainable in the long-term and Australia will not meet its international obligations of protecting aquatic biodiversity.

ANALYTICAL FRAMEWORK FOR EVALUATING RECREATIONAL FISHING IMPACTS

One of the consequences of the newly emerging paradigm for evaluating and managing fisheries is that the analytical frameworks are in their infancy. Although there have been many calls for an ecosystem approach to fisheries management, the legislative and policy tools in particular are fragmented among government agencies in Australia. For example, in some jurisdictions the responsibility for managing fisheries is spread across several agencies with some managing certain animals or habitats but not others. For instance in Queensland, the Department of Primary Industries manages fish and fish habitats, while the Environmental Protection Authority manages marine parks and marine biodiversity.

There are, however, several initiatives aimed at attempting to standardize fisheries evaluations and assess fisheries impacts at the ecosystem level. These frameworks tend to have three components in common: an assessment of the population status of target species; an assessment of the impact of the fishery on the wider environment; and an assessment of the effectiveness of management measures. For instance, these components are included in the framework adopted by the Australian federal environment agency, Environment Australia, for assessment of commercial fisheries for the purposes of issuing export permits, conducting strategic assessments and, potentially, conducting environmental impact assessments of commercial fisheries. The nations' fisheries agencies are also developing a system of evaluating fisheries using specific performance measures incorporating these three key components (e.g., Chesson and Clayton 1998). This system will complement the fact that most of the State's fisheries management legislation has been rewritten in the last ten years to enable an ecosystem approach to fisheries management to be implemented, at least for the commercial fisheries.

However, none of these approaches have been developed to evaluate or effectively incorporate assessment of recreational fisheries. The current reluctance to evaluate recreational fisheries according to modern fisheries management practices is disappointing because these frameworks provide useful tools to evaluate whether public resources are indeed being properly managed in the public interest. Although we are not conducting an assessment of specific recreational fisheries here, we have adopted the three-pronged (status of target species, impacts of fishing on the wider environment and effectiveness of management) approach as an analytical framework for discussing recreational fisheries.

MAGNITUDE, DIVERSITY AND IMPACT OF THE RECREATIONAL FISH HARVEST

While there is comparatively less known about the recreational harvest than the commercial harvest, it is generally considered to be substantially large. Kearney (1995) provides a preliminary estimate of the annual recreational harvest in Australia of approximately 50 000 tonnes. There is ample evidence to demonstrate that in many coastal areas, particularly those adjacent to large population centres and popular holiday destinations, the recreational harvest in Australia is substantial and exceeds the commercial harvest for some species and/or areas (Table 1). Despite the magnitude of the catch, there is currently no regular monitoring of catches by the recreational sector in any Australian State. In terms of the impact of the recreational catches on the stocks of harvested species, data on stock sizes are generally lacking. However, in the eastern Gulf of Shark Bay (Western Australia) where estimates of spawning biomass and the recreational harvest of Snapper *Pagrus auratus* are available, the recreational catch was estimated to have been the principal cause of the biomass of this stock being reduced to between 2 and 10% of virgin levels (Marshall and Moore 2000). Despite the magnitude of the recreational catch, angling lobby groups frequently and publicly dispute that recreational angling has a large impact on fish stocks. When faced with real or perceived declines in catch rates, recreational anglers tend to blame commercial fishing or impacts from pollution or coastal development (e.g., Sauer *et al.* 1997; Burger *et al.* 1999; O'Neill *et al.* 2000).

Although not quantified, the efficiency of recreational anglers is also considered to be improving through the widespread use of technological improvements such as: high quality echo sounders; global positioning systems (GPS); new types of low diameter high strength fishing lines; and chemically sharpened fish hooks (Anon. 2000). Additionally, there is greater information available to anglers through the media and the internet regarding "hot spots", the right seasons and the most efficient techniques for particular species. The prime offshore fishing locations were once well-guarded secrets and even if these spots were known it often took considerable skill to locate them by lining up various landmarks. Now such locations are easily located by GPS and these GPS co-ordinates are distributed on the internet and in the media. The effects of improved technology on the efficiency of commercial fishing operations and on fish stocks are well documented (e.g., Kirkley *et al.* 1995), but similar information is not currently available for the recreational sector. The increased usage of off-road vehicles is also considered to have increased the spatial extent of recreational fishing, and has led to increased conflict with existing but previously remote, shore-based commercial fisheries (Lamberth and Bennett 1992).

Assessing the tonnage of important fish species landed by recreational angling does not tell the complete story of the direct impacts from angling. Consideration also needs to be given to the fact that the angling harvest includes a very broad range of different species, of which, the basic biology, let alone the stock

Table 1. Comparative catches of species shared by recreational and commercial fishers in various Australian studies.

Location	Species	Annual recreational catch (t)	Annual commercial catch (t)	Reference
South-east Qld	Snapper (*Pagrus auratus*)	148*	50	Ferrell and Sumpton (1998)
Metropolitan Adelaide waters (SA)	King George Whiting (*Sillagonoides punctata*)	48.5	13.4	McGlennon (1992)
Fraser Island (Qld)	Tailor (*Pomatomus saltatrix*)	180	25–55	Pollock (1984)
Richmond and Clarence rivers (NSW)	Yellowfin Bream (*Acanthopagrus australis*), Dusky Flathead (*Platycephalus fuscus*) and Tailor	70*	54	West and Gordon (1994)
Pumicestone Passage (Qld)	Yellowfin Bream, Dusky Flathead and Sand Whiting (*Sillago ciliata*)	43.1	0	O'Neill *et al.* (2000)
Leschenault estuary (WA)	Blue Swimmer Crab (*Portunus pelagicus*)	45.7	2.8	Malseed *et al.* (2000)
Eastern Gulf of Shark Bay (WA)	Snapper	100	3	Anon. (2000)
Greater metropolitan Perth (WA)	Tailor	651	7	Young *et al.* (1999)
Port Phillip Bay (Vic)	Mixed inshore species (including Snapper and King George Whiting)	469	482	M. Norman, unpubl. data

*Only catches from daylight angling were recorded in these studies, hence, they are underestimates of the actual total catch.

status, is uncertain. Steffe *et al.* (1996) recorded that 210 different taxa were retained over a two-year period by boat anglers in New South Wales, ranging from the tiny pomacentrid *Parma microlepis* to the Great White Shark *Carcharodon carcharius*. Although scarce, the data that are available suggest the findings of Steffe *et al.* (1996) are not unique; Ferrell and Sumpton (1998) recorded that 194 taxa were retained by boat anglers in south-east Queensland. Sauer *et al.* (1997) identified that the boat based angling fishery off South Africa involved more than 120 species, and recreational fishing in Biscayne National Park (Florida) involved the capture of 170 species (Harper *et al.* 2000).

For several species recorded by Steffe *et al.* (1996), the recreational harvest in absolute terms was small (<1 tonne per year), yet even these small levels of mortality from recreational fishing may be enough to cause population decline in some of the harvested species. For instance, the populations of the various shark species (e.g., Draughtboard Shark *Cephaloscyllium laticeps* and Rusty Catshark *Parascyllium ferrugineum*) recorded in recreational catches by Steffe *et al.* (1996) may be susceptible to low levels of fishing mortality because of their life history characteristics which include low fecundity, slow growth rate, and late maturation (e.g., Brown 1999). Finfish species such as Bluefish *Girella cyanea*, which are believed to have small population sizes and restricted ranges, may also be significantly impacted by the low rates of recreational fishing mortality (Steffe *et al.* 1996). Species listed as protected under New South Wales legislation including the Eastern Blue Devil Fish *Paraplesiops bleekeri* and the Black Rock Cod *Epinephelus daemelii* were also recorded in anglers retained catches. One of the most notable and well-documented declines of a species linked to recreational fishing is the depletion of the now endangered Grey Nurse Shark *Carcharias taurus* caused principally by spearfishing along the New South Wales coast in the 1970s (Pollard *et al.* 1996).

IMPACTS OF RECREATIONAL FISHING ON AQUATIC ECOSYSTEMS

There is ample evidence that recreational fisheries discard large numbers of fish, retain substantial numbers of juvenile fish, interact with rare and threatened species and impact on aquatic habitats. These are the same issues that are currently being addressed in the management of commercial fisheries.

Discards from recreational fishing

There is substantial discarding associated with recreational angling. Discards include unwanted species such as toadfish (Family Tetradontidae) and undersized juveniles of species targeted by recreational and commercial fishers. While discard rates from commercial fishing are frequently quantified, this is not generally the case for recreational fishing, although some information is available. In a brief review of angling by-catch in Australia, McGlennon and Lyle (1999) concluded that angling discard rates are typically 30–40% of the total catch and need to be considered in any management regime for recreational fishing. Subsequently, Higgs (1999) found angling discard rates of 50% in Queensland. These Australian figures are comparable with the limited information from overseas. For example, Burke *et al.* (1994) suggested discard rates of 76% and 50 % in the Gulf of Mexico and Atlantic Coast recreational fisheries (United States of America) respectively.

Mortality of discarded fish from angling is highly dependent on the particular species being caught and a range of other factors such as water depth, and the type and size of tackle used, with rates of mortality varying from 0 to 95% of released fish (Muoneke and Childress 1994). McGlennon and Lyle (1999) concluded that the magnitude of angling discards in Australia could generate significant absolute mortality from even quite small mortality rates. Discards and associated mortality rates are not generally considered in the management of recreational fisheries and this contrasts with the management of commercial fisheries, where such factors are increasingly considered critical in assessing the ecological impacts of a particular commercial fishery.

Retention of juvenile fish by recreational fishers

Most recreational fishing pressure tends to be concentrated in inshore and estuarine areas that are considered important nursery environments for many fish species. Recreational fishers frequently retain a high percentage of juvenile fish. This is not a new problem (for instance see Roughley 1961), but it is noteworthy that it still persists and suggests that education and compliance initiatives targeting recreational fishers to date have largely failed. In the Clarence River (New South Wales), 78% of Mulloway *Argyrosomus hololepidotus* and 56% of Sand Whiting *Sillago ciliata* caught by anglers were juveniles below the minimum legal size (West and Gordon 1994). Likewise, more than 50% of tuskfish *Cherodon* spp., Grass Sweetlip *Lethrinus fraenatus*, Spangled Emperor *Lethrinus nebulosus*, Yellowtail Kingfish *Seriola lalandi*, Tailor *Pomatomus saltatrix* and Snapper retained by anglers in the inshore waters of Queensland were juveniles below the minimum legal size (Ferrell and Sumpton 1998). Such high retention rates of juvenile fish are not restricted to

Australia, having also been documented in recreational fisheries in the United States (e.g., Gigiliotti and Taylor 1990) and South Africa (e.g., Brouwer *et al.* 1997; Sauer *et al.* 1997). The impact on stocks by the harvesting of juvenile fish by recreational fishers is uncertain, but it should be the focus of future research.

INDIRECT IMPACTS OF THE RECREATIONAL HARVEST — TROPHIC CASCADES AND PREDATOR RELEASE?

Commercial and subsistence fishing can result in impacts to local or regional populations of other marine animals through trophic interactions or competitive release in a variety of habitats (e.g., Andrew and Choat 1982; McClanahan and Muthiga 1988; Russ and Alcala 1989; Roberts 1995; Jennings and Polunin 1996; McClanahan *et al.* 1999; Pinnegar *et al.* 2000). For instance, the removal of carnivorous fishes belonging to the Family Sparidae (which contains species commonly harvested by recreational anglers), may facilitate increased survivorship of benthic invertebrates (Andrew and Choat 1982; McClanahan and Muthiga 1988). If a particular prey species increases in abundance because of a reduction in the abundance of its predator from fishing, it may result in the competitive exclusion of weaker competitors (McClanahan and Muthiga 1988). The magnitude of the recreational harvest suggest similar impacts may occur as a result of this activity, although there is little direct experimental evidence to support or refute this. Since many popular recreational species such as Mulloway, Tailor and common Coral Trout *Plectropomus leopardus* are higher order carnivores and potential keystone predators (e.g., Goeden 1982), there is a high likelihood that such flow-on effects may have occurred.

The ecological impacts of recreational bait collection

The harvesting of a wide range of invertebrates (polychaetes, crustaceans, echiurans, ascidians and molluscs) from rocky and sedimentary intertidal areas for use as bait is a very common activity in Australia and overseas (e.g., Hailstone and Stephenson 1961; Suer 1984; Kingsford *et al.* 1991; Wynberg and Branch 1991; Skilleter *et al.* 2000). Significant environmental impacts have been identified as a result of these bait-harvesting activities. For instance, Wynberg and Branch (1994) in South Africa experimentally determined that disturbance from collecting thalassinid shrimps for bait on sandflats depressed the benthic macrofaunal populations of those sandflats, and that recovery of these populations was generally slow (>18 months). Harvesting of thalassinid shrimps in Australia has been associated with significant impacts on intertidal macrobenthos including crabs and polychaetes (Skilleter *et al.* 2000). The impact on benthic communities from harvesting invertebrates can flow on to affect the foraging success of migratory shorebirds of conservation significance (Shepherd and Boates 1999; Skilleter *et al.* 2000). While often overlooked in the context of fisheries management, the harvest of invertebrates for bait constitutes an important component of angling's ecological footprint (*sensu* Wackernagel and Rees 1996).

Recreational fishing and interactions with marine turtles, mammals and seabirds

Anglers may interact with marine turtles, mammals and seabirds causing injury and sometimes death through ingestion of baited hooks and fishing line, entanglement in crabpots and fishing line, and being struck by recreational fishing vessels (Laist 1997; Haines *et al.* 2001). Boat strike is the single biggest cause of marine turtle mortality in Queensland (Haines *et al.* 2001). This situation parallels that in Florida (United States of America), where boat strike is a significant source of Manatee *Trichechus manatus* mortality (e.g., O'Shea *et al.* 1985). Taylor (2000) notes that a variety of seabirds interact directly with anglers in New Zealand, but the impacts have not been quantified. Similarly, interaction between seabirds and gamefishers in New South Wales has been identified, but not quantified (Anon. 1999). Taylor (2000) also notes the potential for impacts on seabirds through recreational fishers accessing sensitive nesting habitats, however, this impact is not confined to anglers since access to these nesting habitats for a wide range of human uses can cause a similar effect (Carney and Sydeman 1999).

Pollution generated from recreational angling is a significant impact that is not commonly considered in the management of recreational fisheries. The most significant pollution problem from recreational fishing arises from discarded fishing line that can entangle a variety of animals including dolphins and several seabird species (Laist 1987, 1997). An initial census by the Australian Seabird Rescue Group in the Richmond River (New South Wales) revealed that of the 108 resident Australian Pelicans *Pelecanus conspicillatus*, 37 were suffering injuries from being entangled or hooked by fishing tackle. Subsequent studies in the region have shown that of all the human induced injuries to the Australian Pelican, 92% were from entanglement in fishing line (Australian Seabird Rescue Group, unpubl. data). Wells *et al.* (1998) concluded that, although often overlooked, the number of deaths or serious injuries to Bottlenose Dolphins *Tursiops truncatus* in Florida from recreational fishing, particularly entanglement in discarded

fishing line, could exceed that from the region's commercial net fisheries. While the rates of interaction of fishers with marine turtles, mammals, and seabirds in Australia are considered low, the high participation rates in recreational fishing appear to warrant quantifying these interactions and their impacts on these populations.

Fishery enhancement

Recreational fisheries are often enhanced, particularly in inland waters, through stocking with introduced or translocated species (e.g., McDowall 1989; Whittier and Kincaid 1999). Salmonids (among a range of other species) were introduced to temperate Australian and New Zealand freshwaters in the 1800s for the benefit of anglers to counter the lack of suitable native sportfish (Franklin 1996). Introduced salmonids impact on a variety of native fauna through predation and competition and are implicated in reducing the diversity of macro-invertebrate assemblages and population declines and/or the reduction and fragmentation of the ranges of several species endemic to Australia and/or New Zealand including River Blackfish *Gadopsis marmoratus*, many species of galaxiids, and the Tasmanian Mountain Shrimp *Anaspides tasmaniae* (Tilzey 1976; Fletcher 1986; McDowall 1989; Crowl *et al.* 1992; McIntosh 2000). Predation by introduced salmonids is also considered to have played a major role in the population decline of the critically endangered Spotted Tree Frog *Litoria spenceri* and possibly other frog species in southeastern Australia (Gillespie 2001). Although uncertainty exists, the introduction of salmonids was possibly a major contributing factor to the extinction of the New Zealand Grayling *Prototroctes oxyrhynchus* (Rutherford 1901; Allen 1949; McDowall 1989). The populations of at least two New Zealand bird species (the Crested Grebe *Podiceps cristatus* and the Blue Duck *Hymenolaimus malacorhynchus*) are impacted by salmonid introductions due to a reduction in prey availability (galaxiids and aquatic invertebrates) (King 1984; McDowall 1989). The introduction of salmonids is one of the causes of several galaxiids species being listed as threatened in Australia (Jackson and Wager 1993).

Despite these demonstrated ecological impacts, the stocking of freshwater habitats with salmonids and other species for angling is still strongly supported by recreational fishing groups and governments. For instance, in a vision statement regarding management of freshwater areas, the peak angling body in Victoria, Australia (VRFISH) states: "VRFish believes in active fisheries management, including breeding and stocking programmes for trout and native fish which should be encouraged and conducted in suitable waters" (VRFISH 2000). The stocking of introduced species is an example of the social benefits from angling taking precedent over the conservation of aquatic biodiversity and such thinking is not restricted to Australia (e.g., Courtney Jr. 1989; McDowall 1989; Pierce 1989). While social benefits, such as those derived from angling for an introduced species, are clearly a legitimate component of ecologically sustainable development, the environmental costs (which may be irreversible) of obtaining these social benefits need to be considered. This has not generally happened in the management of recreational fishing stocking programmes to date.

MANAGEMENT OF RECREATIONAL FISHERIES?

The management of most recreational fisheries, especially those operating in marine and estuarine areas, are characterized by very rudimentary controls. The fisheries are generally open access, area and time closures are rarely employed and size limits are commonly ignored. Quotas on the total recreational catch are impractical, but limits on the number of fish retained by an individual angler (bag limit) or boat (boat limit) are possible. However, with the exception of New South Wales and Western Australia, comprehensive systems of bag limits in marine waters that potentially limit angler catches are not in place in Australian states. Data on the effectiveness of bag limits are generally lacking, but the data that are available shows that they have not been effective at limiting angler catches because they are set too high. For instance, Ferrell and Sumpton (1998) found that of 4 400 boats surveyed in south-east Queensland, only four reached the bag limit of 30 Snapper per angler with the vast majority catching less than two per angler. For bag limits to be effective, they must be set at levels which actually limit the catch. Procedures exist for identifying bag limits which would result in a desired reduction of fishing mortality from anglers (Attwood and Bennett 1995a), but have not generally been used in the management of Australian recreational fisheries, although this should be a routine part of fisheries management.

Why have the ecological impacts of recreational angling not been addressed?

Why then have the impacts from recreational fishing generally not been considered or addressed in fisheries management? The answers are diverse and are rooted as much in the changing expectations of fisheries managers (with respect to environmental management) as they are in the increasingly politicised debates over resource allocation. There are four main points we wish to address.

First, angling lobbyists have generally been successful in shifting attention away from angling impacts and focusing public and political attention on other impacts, particularly commercial fishing, and to a lesser extent, coastal development and other land-use practices. For instance, the Queensland angling lobby group SUNFISH has a policy statement containing 30 points guiding their interactions with governments and industry. None of these points deal with impacts from anglers, but 13 deal with further restricting commercial fishing (Bateman 2000). Similarly in Victoria, the angling peak body (VRFISH) has a vision statement for the management of inshore marine areas which contains 15 points. Five of the points deal with further restrictions to commercial fishing, but only two with supporting management controls on recreational fishing (VRFISH 2000). In Florida, Smith and Jepson (1993) report that recreational fishing lobbyists formed "conservation groups" such as the Florida Conservation Association and the Gulf Coast Conservation Association that focused on the ecological impacts of activities such as commercial fishing, but not on recreational angling.

Second, the sheer number of participants makes recreational fishing a difficult problem to tackle politically. Kearney (2001) suggests that the knowledge that angling is dear to a large and very vocal group of voters, together with the belief that the ecological impacts from angling are insignificant, has led to governments not seriously regulating recreational fishing. Controls on recreational fishing, such as bag limits that are necessary to control catch are often unpopular, and as such, there may be a political tendency to delay or completely avoid their implementation. This appears to have been the case in Queensland, where recreational bag limits on important recreational and commercial species such as Tailor, Yellowfin Bream and Dusky Flathead *Platycephalus fuscus* have been in the "management pipeline" since 1993 (e.g., SGIRF 1993), but are yet to be implemented.

Third, there is a tendency for an impact to be looked at in isolation rather than assessing the cumulative result. It is highly likely that the impacts of a lone angler are less than that of a single commercial fisher. However, when the number of anglers relative to the number of commercial fishers is considered, the ecological impacts from angling can be substantial and, as discussed, may exceed that of commercial net fishing in some areas. This approach of considering only specific incidents is similar to that which occurs for coastal developments, where the impact of a particular development may be small but the cumulative impact of many of these small developments is substantial (e.g., Mercer 1995; Jennings *et al.* 1999).

Last, angling has also generally come under considerably less scrutiny from the conservation movement than other impacts on aquatic systems. We propose two (related) reasons why this may be the case. First, many grassroots members of conservation groups are anglers and would feel alienated (and perhaps unwilling to continue parting with subscriptions/donations), if one of their favoured activities was seriously questioned on environmental grounds. For similar reasons, Balon (2000) argues that animal-rights groups have tended to steer away from campaigning against the ethics of recreational fishing. Second, the cumulative nature of the impacts from recreational fishing do not lend themselves to a well focused "campaign" that has appeal to a wide range of people. The success of the campaigns to "save" the Wet Tropics (North Queensland) was attributed to an issue that appealed to a very large and wide variety of people, with environmental threats easy to define in the public psyche (e.g., loggers and the construction of the Cape Tribulation road) (see Doyle 2000). It would be more difficult to develop such a focused campaign for something as ubiquitous as recreational fishing, nor an issue that is considered a "family activity".

Recreational fishing and Marine Protected Areas

Attwood and Bennett (1995b) argue that no-take marine protected areas can circumvent the problem of non-compliance by anglers with management measures because infringements are clearly visible. The potential of marine protected areas to circumvent shortfalls in fisheries management and protect marine biodiversity are well documented although there is a clear tendency for Marine Protected Areas to be implemented in response to commercial fishing activities (for instance see Roberts and Polunin 1993; Roberts 1995), and not those associated with the recreational sector.

While anglers in South Africa have questioned the benefits of Marine Protected Areas (Attwood and Bennett 1995b), they generally agree with their existence and obey the regulations pertaining to these reserves more than other management tools (e.g., minimum legal sizes) (Sauer *et al.* 1997). On face value, a similar level of support for no-take Marine Protected Areas from anglers does not seem to currently exist in Australia. In Victoria, the announcement of no-take Marine Protected Areas by that State Government met with protest from anglers despite the area of no-take zones comprising approximately 6.2% of state waters. Victorian angling representatives claimed the proposed system of marine protected areas (based on comprehensiveness, adequacy and

representativeness) was unscientific, but supported closing fish breeding areas to fishing. Similar sentiments have also been echoed on various recreational fishing sites on the world-wide-web in regards to the development of a system of Marine Protected Areas in New South Wales. However, experience in Western Australia suggest that even a no-take Marine Protected Area designed to protect a known spawning aggregation of an important recreational species may not be strongly supported by anglers. Scientific information demonstrated that Snapper were clearly overfished in the eastern Gulf of Shark Bay and a Marine Protected Area was necessary to protect the spawning aggregations from angling (Marshall and Moore 2000). Anglers did not, however, agree with the scientific findings believing instead that they were inconsistent with their own anecdotal evidence (Marshall and Moore 2000). Marshall and Moore (2000) concluded that given the denial of the validity of the scientific evidence by anglers, fishing practices were unlikely to change significantly because of the establishment of a Marine Protected Area.

Why then the disparity between the apparent acceptance of no-take Marine Protected Areas by anglers in South Africa and the apparent opposition to their wider establishment in Australia? First, in South Africa the benefits of Marine Protected Areas for anglers have been demonstrated through research showing emigration of a popular South African angling species (Galjoen *Dichistius capensis*) from the De Hoop Marine Reserve to areas open to angling (Attwood and Bennett 1994). Importantly, South African scientists involved in Marine Protected Area research also spent considerable time communicating these positive benefits of Marine Protected Areas to anglers (and the whole community) in the popular press (Attwood *et al.* 1997). Second, it is unclear if there really is a disparity and whether the opposition voiced about the establishment of no-take Marine Protected Areas in Australia is truly representative of the majority of angler's views on the topic. For instance, opposition to the Shark Bay no-take Marine Protected Area from anglers occurred despite the peak recreational fishing body in Western Australia accepting the results of the research and the need for the Marine Protected Area. Likewise, VRFISH conditionally supported no-take Marine Protected Areas in Victoria. However, another body representing anglers in that state (the Australian Recreational Fishing Alliance) strongly opposed their establishment (Australian Recreational Fishing Alliance 2000). In a study on the perception of recreational fishers and elected officials in the United States, Burger *et al.* (1999) concluded that officials were hearing and acting on information from some of the more vocal fishers despite this information being inconsistent with the views of most others.

These examples highlight several important points. First, the basic message of marine conservation may not be reaching the general public, in this case grassroots anglers. Conservation of marine biodiversity is perhaps still viewed by many anglers as a tool of environmental groups rather than a legitimate concept. Second, anglers may be unwilling to change fishing practices or give up access to a fishing area even when a negative ecological impact is demonstrated, believing that their individual impacts are minor. Third, angling organizations may provide a biased perspective to the views of the majority of anglers. This is not a direct criticism of angling bodies *per se* but a reflection of the heterogenous nature of anglers and angling (see Vigliano *et al.* 2000) and the fact that many such organizations are generally comprised of "serious" anglers who comprise a minority of anglers as a whole (Hilborn 1985).

Future management, monitoring and emerging issues

Ideally, management plans need to be in place for all recreational fisheries and these plans need to have objectives and performance measures consistent with the need to manage impacts on the ecosystem, not just target species. Coupled with this is a need to not only monitor and assess catch and effort in commercial fisheries, but also do the same for recreational fisheries. As recreational fishing increasingly becomes the dominant or the only harvester of marine resources in some areas, catch and effort data from inshore commercial fisheries could become less relevant in monitoring and interpreting trends in the populations of harvested species. Research is also needed to assess the impacts of "technology creep" on catch per unit effort in recreational fisheries in order to better link trends in catch per unit effort to stock size.

The management of recreational fisheries has generally been hindered by a lack of information. However, there is increasing information showing that the impacts from recreational fishing are considerable. What is needed in all jurisdictions is detailed time-series data of recreational catch and effort and the broader ecological impacts. A national survey of recreational fishing is currently being undertaken, but it may well be a one-off. Australia's Oceans Policy (1998) contains no commitment for on-going monitoring of recreational fishing. Lack of on-going monitoring contributes to the lack of any performance indicators or reference points for

recreational fisheries. Lack of funding for on-going monitoring is a significant problem. However, New South Wales and Victoria have recently introduced angling licences in marine areas, and this is a significant potential source of funding for the monitoring of recreational fishing in these two states.

However, on-going monitoring itself is not the single answer to improving recreational fisheries management and ensuring the practice is ecologically sustainable. There must be the political will to use information obtained from monitoring programmes in a timely fashion to enact regulations that control recreational fishing and ensure long-term resource sustainability. Given the history of recreational fisheries management we are not optimistic that this will occur, yet it must in order to safeguard Australia's aquatic biodiversity for future generations.

We believe that anglers and peak angling bodies can contribute to the sustainable use and conservation of natural resources, but this is not a universal view among fisheries scientists. Balon (2000) contests that the idea that recreational fishers and their organizations are instrumental in the conservation of natural resources is largely an unfounded myth. Reducing the spatial impact of recreational fishing through implementation of a comprehensive system of Marine Protected Areas is one approach to reducing the overall impact of recreational fishing. However, we should be mindful of experiences in terrestrial systems that demonstrate "on-reserve" conservation by itself is not sufficient, and needs to be complemented by appropriate off-reserve management (e.g., Lindenmayer and Recher 1998). Achieving successful off-resource management requires stakeholders such as anglers and their representative groups to take greater responsibilities for their actions and impacts.

Greater efforts from governments are needed to educate anglers on the overall impact of angling and the need for management of all recreational fishing activities. Peak angling bodies then need to take a greater responsibility in disseminating information on the ecological impacts of angling and a greater leadership role in reducing it. The continued high rates of retention of undersized fish by recreational fishers strongly suggest that angler education has not been effective and new approaches need to be utilized. Several States have systems of voluntary fisheries liaison officers who are experienced anglers advising other less experienced anglers on a range of issues including local fishing regulations (Anon. 2000). With appropriate training, there is scope for these officers to spread a broader message of biodiversity conservation to recreational fishers. Importantly, education programmes need appropriate performance measures and monitoring to ensure they are meeting objectives.

Property rights based management systems are an emerging issue for fisheries managers and the recreational fishing sector. The use of property rights based management systems such as individual transferable quotas (ITQs) are increasingly being used to manage commercial fisheries in many countries (e.g., Squires *et al.* 1995; Kearney 2001). It is generally assumed by recreational anglers that access to fisheries resources is a birthright. However, the collective rights to, or responsibilities for a share of these resources have not been defined (Kearney 2001). While Kearney (2001) outlined the advantages and disadvantages of property rights management systems for recreational fisheries, the next step should be using case studies of specific recreational fisheries to investigate the practicality of such systems. The calls by recreational fishers for better defined property rights is likely to increase and the principles underlying resource access, impacts and allocation needs to be addressed.

Unfortunately, given the community and governmental support, continued stocking of salmonids and other species in freshwater habitats will most likely occur leading to continued impacts on native fauna. Anglers also see the restocking of marine waters with angling species as a possible panacea to (real or perceived) declines in angler catches (e.g., VRFISH 2000). It is imperative that any future marine restocking proposals be subject to impact assessment that addresses the ecological impact of elevating the populations of one or two species on existing prey and competitor species, and biodiversity in general.

CONCLUSION

For Australia to meet its national and international obligations to protect marine biodiversity, the way we view and manage recreational fishing needs to change. A wide range of ecological impacts result from recreational fishing, but are generally ignored in the management of these fisheries. We need to change the widespread perception that recreational fishing is an activity not important enough to warrant management. Given the vast number and diversity of anglers, precipitating the change represents one of the biggest challenges to managers of aquatic resources.

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