The State of Recreational Fishing in Victoria

A review of ecological sustainability and management options by John Ford and Patrick Gilmour

Victorian National Parks Association

The Victorian National Parks Association (VNPA) is Victoria's leading nature conservation organisation. VNPA is an independent, non-profit, membership-based group, which exists to protect Victoria's unique natural environment and biodiversity through the establishment and effective management of national parks, including marine national parks, conservation reserves and other measures. We will achieve our vision by facilitating strategic campaigns and education programs, developing policies, through hands-on conservation work, and by running bushwalking and outdoor activity programs which promote the care and enjoyment of Victoria's natural heritage.

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Disclaimer

The VNPA has commissioned this report as part of its work to generate public discussion on the need for reform of Victoria's marine and coastal planning, protection and management frameworks. However, any opinions expressed in this report are those of the authors and do not necessarily reflect the policies or opinions of the VNPA.

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EXECUTIVE SUMMARY

Overview

Recreational fishing is a widespread and popular activity in Australia and around the world. In 1999–2000, 3.36 million Australians over the age of five went fishing, and almost one quarter of all households were estimated to have at least one recreational fisher. Recent figures by peak bodies claim that over 5 million Australians are recreational fishers. Recognising the potential for this to affect the marine environment, the Victorian National Parks Association commissioned this literature review to:

- document the potential and actual ecological impacts of recreational fishing on the Australian marine environment, with particular emphasis on Victorian coastal waters
- document the current frameworks for managing recreational fishing in Victoria as compared to other Australian states, along with the identification of key knowledge gaps
- identify and evaluate alternative management arrangements for Victorian recreational fisheries.

Current management and challenges for recreational fishing

Recreational fishing has been perceived to have low ecological impact due to its dispersed effort and generally simple equipment. Combined with the inherent difficulty of managing the large number of diverse and disparate individuals comprising a recreational fishery, this has meant that its monitoring and management have fallen well behind those of commercial fisheries.

Over the past two decades, recreational fishing has grown significantly in the level of participation and its geographical extent, while technological advances have made finding and catching fish easier. However, government fishery agencies experienced in managing commercial fisheries have found unique challenges in recreational sector management, and have encountered substantial difficulties in applying their traditional monitoring, evaluation and enforcement methods. There are fundamental underlying differences between commercial and recreational fishers that management must understand and accommodate, including the basic motivation to fish and the expectations from the fishery.

In a global context, Australia has a strong history of responsive recreational fishing monitoring and management, although the field is new and many challenges must still be addressed. Although Australia is developing a better understanding of the numbers of recreational participants and their direct impacts on fish stocks, broader ecological and trophic effects are not well understood. Further, advances in monitoring initiatives have not generally developed into robust management frameworks. Australian recreational fishing managers must continue to develop and improve methods, and learn from experiences around the world, including both successes and failures.

Victoria evaluates the size and impact of recreational fishing using three main survey methods. The first is a statewide phone survey, which aims to estimate the participation rates and total recreational catch. Fisheries Victoria has proposed a regular (five-yearly) and ongoing recreational fishing survey, but no full-scale surveys have been conducted since 2001. The second method is boat-ramp surveys of fishers and the number of boat trailers. Both these methods collect data about catch and effort by utilising stratified random samples of recreational anglers. Thirdly, an angler diary program collects important data on catch rates and the abundance of undersized or discarded fish. This program is one of the most cost-effective tools in monitoring recreational catch and effort, as well as in following trends in important fish stocks.

Fisheries Victoria employs an integrated stock assessment approach in its fisheries management, making use of multiple indicators of stock health from the state's recreational and commercial fisheries, along with independent fisheries surveys. The general approach is based on the ecosystem risk assessment model. However, there is no policy framework currently in Victoria to follow up important risks uncovered in the fishery risk-analysis process or to apply management controls or regulations to reduce that risk. Such action is decided on an *ad-hoc* basis using expert knowledge, consultation and, where appropriate, regulatory trials or modelling. Some ecological effects, such as trophic impacts, are very poorly understood or not incorporated into risk-management frameworks. As such, they may limit the effectiveness of risk-based management systems in addressing the ecosystem-level set of ecological functions of target species. The lack of ecosystem monitoring is a key knowledge gap in Victoria's fisheries management identified in this report.

Recreational fisheries are generally data poor and difficult to manage under traditional systems. Further investigation is therefore warranted into the best use of data obtained through angler diary programs and boat-ramp surveys in assessing

health and management controls in these fisheries. In comparison with other states of Australia, Victoria fares reasonably well in recreational fishing monitoring initiatives. The angler diary and boat ramp survey programs are particularly noteworthy.

Victoria has many fisheries in which productivity is limited by the environment, such as climate or available habitat. As such, identifying, managing and conserving important fish habitats are important next steps. A general increase in research support, development of harvest strategies, more focus on ecosystem impacts of recreational fishing, and the development of programs to identify and protect fish habitat, are this report's key recommendations for developing comprehensive and effective recreational fishing stock assessment and management.

Ecological impacts of recreational fishing

The ecological impacts of fishing can be broken down into three categories:

- direct impact on fish stocks
- direct impacts on non-target species (e.g. discards, birds and mammals)
- general ecosystem effects.

In general, our understanding of the direct impacts is far greater than that of ecosystem effects. In many cases there is a lack of monitoring systems to detect ecological impacts, or simply insufficient understanding of the natural fluctuations of ecosystems to be certain of the impacts. It is clear, however, that the magnitude and nature of recreational fishing pressure suggest that it can and does impact on marine ecosystems.

Both the international literature and Australian-specific case studies show that for some species the catch from recreational fisheries can be equivalent to, or exceed, that of comparable commercial fisheries. In 1999–2000, for example, the recreational catch of snapper *Pagrus auratus* in Victoria was estimated to be 332 tonnes (t), more than seven times the commercial catch of 47 t. During the same period, the recreational catch of both King George whiting *Sillaginodes punctata* (215 t recreational and 213 t commercial) and black bream *Acanthopagrus butcheri* (203 t recreational and 196 t commercial) also exceeded commercial catches. Although this trend appears to have continued in recent years, the data also highlights that most recreational catch data is many years, if not decades, out of date.

The impacts of recreational fishing on populations of target species also depend on how fishing occurs. Important factors include rates and survival of discards, the concentration of effort in accessible locations and the maintenance of fishing pressure, even at low catch rates and abundances. A comprehensive nation-wide survey in 2000 estimated that almost half (44%) of all fish caught in Australia by recreational anglers is returned to the water. The survival of these fish appears to be highly dependent on the particular species, the fishing location, and fishing and handling techniques. For example, experiments in Port Phillip Bay show the survival of snapper ranged from as high as 97% for fish hooked in the mouth to just 42% in 'deep-hooked' fish.

There is also a broader set of ecological impacts from recreational fishing. These include the entanglement of wildlife in fishing gear, translocation of marine pests, habitat impacts from vessels or trampling, and changes to community composition through trophic interactions. Importantly, these impacts are rarely assessed in detail.

Port Phillip Bay, Victoria, presents an interesting and important case of both the popularity and the potential impacts of recreational fishing. With the State capital of Melbourne on its shores, recreational fishing in this area attracts high levels of shore- and boat-based angling. Popular recreational and commercial species include snapper and King George whiting. For both species, the recreational catch is substantially higher than the commercial catch: 97 t recreational and 85 t commercial for whiting, and 208 t recreational and 54 t commercial for snapper (data from 2000-2001). Although currently the abundance of both species appears stable, the future ecologically sustainable management of these species clearly relies on sufficient attention being directed towards management of the recreational sector. Given that the most recent estimate of recreational catch was from more than ten years ago, out-of-date data is a key area of risk for future recreational fishing management.

Like commercial fishing, recreational fishing impacts on the marine environment. However, these impacts vary substantially between species and areas, and their significance in specific regions is generally poorly understood. Location-specific ecological risk assessments and consideration of the entire coastal-waters system are needed, and should also factor in the impacts from land-based activities. Such assessments, integrated within a broader coastal-waters management framework, would better inform the nature of management responses required, whether they are monitoring programs, education campaigns,

compliance activities or the creation of marine protected areas.

Fisheries Victoria's key responsibility is to manage fisheries in an ecologically sustainable manner, which includes the management of bycatch and byproduct species, and the aquatic habitats on which fisheries depend. Responsibility for monitoring indirect impacts of fishing on habitats and other species, such as wildlife entanglements or damage to seagrass, falls to the Department of Sustainability and Environment (DSE) and, in some cases, is shared with the Environmental Protection Authority (EPA). Many impacts are monitored in an *ad-hoc* manner as issues arise, and there is a need for a better-defined and more collaborative system of identifying and addressing impacts that are of high or moderate risk, e.g. bird and mammal entanglements with lost fishing gear.

Alternative management arrangements for the future

Victoria is well placed to build on its current recreational fishing monitoring programs through increasing the understanding of the ecological impacts of fishing, and implementing management controls that ensure ecological sustainability. Four main areas of improvement are highlighted in this report:

- assessing and addressing the ecological risk of the fishery
- ensuring that key habitats and levels of fishery productivity are protected from external threatening processes
- developing management strategies that are fair and precautionary, and encourage stewardship among recreational fishers
- integration of recreational fishing management within the responsibilities of representative and regional marine and coastal planning and management bodies.

An important step in effective recreational fishing management is the involvement of the fishers themselves in determining goals and strategies. Such involvement occurs to differing degrees in all states of Australia, where peak fishing groups are often represented on advisory panels. The flow of information through peak bodies could be enhanced, with the aim of increasing stewardship from the recreational fishing community. This should involve a greater focus on the regional level of involvement, where local knowledge is represented in groups specific to certain fisheries or localities. However, recreational fishers must be integrated alongside other stakeholders in regional marine and coastal planning and management bodies to ensure balanced and effective management of the marine and coastal environment.

The allocation of shared fisheries resources among commercial, recreational, Indigenous, tourism and other sectors, and ecological components, is a difficult challenge for managers. There are calls in Australia and overseas for the establishment of 'secure property rights' for recreational fishers, which it is claimed will ensure a proportion of the resource similar to the total allowable catch (TAC) and quota systems in commercial fisheries. Such a system has many complications when applied to recreational fisheries, due to the dynamic and dispersed nature of recreational fisheries, and the lack of control over the number of fishers. Allocation of rights or quotas to groups or individuals within the recreational sector and subsequent enforcement of catch limits would present a very large logistical and bureaucratic challenge for any management agency. It would also be inconsistent with an integrated and ecosystem-based framework for multi-user marine and coastal planning, protection and management.

In reviewing a range of recreational fishing management case studies from around the world, it becomes clear that each fishery has unique challenges and potential solutions. In some cases, an allocation of catch has been successful, as with Gulf of Mexico red snapper and the Shark Bay pink snapper. On the other hand, similar initiatives have been unsuccessful in places such as New Zealand. Controls such as harvest tags have promise for small, well-defined fisheries where a TAC is set. For most of Victoria's recreational fisheries, however, management should shift away from controlling biomass and TAC towards maintaining ecosystem health, natural population structures and distribution, and spawning potential within fish stocks.

RECOMMENDATIONS

Overview

The increasing popularity of recreational fishing, combined with improved technology and ease of access, means that more people are catching more fish in more places. Meanwhile, commercial fishing is either stable or in decline. The focus for management improvement must be on the recreational sector, and explore new and innovative methods outside traditional commercial fisheries management. The platform has been built for successful recreational fishing management in Victoria. However, more work is required, especially around assessing and monitoring ecological impacts, identifying and conserving key habitat, and engaging recreational fishers in a broader marine and coastal planning and management framework. In the current absence of data on the ecological impacts of recreational fishing, a precautionary approach to any management decisions must be taken.

Presented here are a number of recommendations for the management of recreational fishing in Victoria. Each recommendation addresses a deficiency, knowledge gap or area for improvement identified in this report.

Licensing and monitoring of recreational fishing

Recommendation 1: Large-scale quantitative surveys of recreational fishing participation and total catch should be adopted every three to five years following the methods of Ryan et al. (2009) and Appleford and Hurst (2010).

Recommendation 2: The Recreational Fishing Licence (RFL) database should be expanded to provide compulsory but free licences for the groups currently excluded, thus making details available for quantitative surveys. RFLs could be endorsed for Victorian coastal regions, as in Western Australia, to gain a better understanding of the spatial distribution of fishing effort. This could be as simple as the west/central/east split currently in place for abalone management, or as regions that represent the jurisdictions of future marine and coastal planning and management bodies.

Recommendation 3: Onsite surveys at all major boat ramps in Victoria should be continued, with a focus on collecting random samples of recreational fishing effort and catch for key species.

Recommendation 4: The angler diary program should be expanded to include more diarists, particularly research anglers targeting juveniles of key species, and focusing on the major recreational estuaries of Port Phillip Bay, Corner Inlet, Western Port Bay and the Gippsland Lakes. To encourage participation, angler diarists could be issued with free or reduced-cost RFLs.

Stock assessments

Recommendation 5: Alternative stock assessment methods for smaller recreational fisheries should be investigated and then applied, if appropriate, to make the best use of the data currently collected by the angler diary and boat-ramp surveys.

Recommendation 6: Fisheries-independent monitoring options should be investigated for key recreational species, such as sand flathead, rock flathead, garfish and calamari.

Recommendation 7: Current recruitment monitoring for King George whiting and snapper should be extended into Western Port Bay, an area experiencing significant growth in recreational fishing pressure.

Recommendation 8: The Port Phillip Bay annual trawl surveys should be re-established. They provide critical data on sand flathead stocks, non-target and rare species, and invasive species e.g. northern pacific seastar.

Recommendation 9: The incidence and consequence of discarding target species of declining abundance (e.g. sand flathead, dusky flathead), and non-target species of naturally low abundance (e.g. rare rays or sharks), should be investigated. This could be part of a review of the survival rates of key species caught using different gear types, with the intention of considering gear restrictions as management solutions for ecologically sustainable harvest strategies. Education programs should continue to teach best practice in maximising the survival of discarded fish.

Recommendation 10: TAC allocation to fisheries should not be used where data is not available to make robust biomass or fishing mortality estimates. Furthermore, TACs should only be used where catch limits can be effectively monitored and enforced in both the recreational and commercial sectors.

Stock enhancement, invasive pests and fishing gear

Recommendation 11: Stock enhancement proposals should be subjected to a public environment impact assessment process supported by an independent and thorough risk assessment.

Recommendation 12: The live transport of invasive noxious pests (e.g. European green shore crabs) as bait should be prohibited and

the national code of practice for recreational fishing (Recreational Fishing Advisory Committee 2011) amended to reflect this.

Recommendation 13: The use of biodegradable hooks and fishing lines should be introduced gradually over the next five years, at which time they could become mandatory.

Institutional

Recommendation 14: Regional recreational fishing groups should be important players in a broader marine and coastal planning and management framework. The establishment of empowered regional marine and coastal bodies with expertise and broad representation is one such option. Such bodies would value local knowledge and ensure legitimate and serious engagement of recreational fishers in management.

Recommendation 15: In Victoria's bays and inlets, the focus of the regional marine and coastal bodies should move towards broader ecosystem health and the improvement of natural environmental productivity. Many fisheries are currently limited by the extent of habitat and water quality, and seriously impacted by land-based activities. The adoption of improvement plans that encompass the whole catchment would be an important step for regional marine and coastal bodies to take towards achieving goals of improved ecosystem health and increased natural productivity in fisheries.

Recommendation 16: A 'key fishery habitat' identification and conservation program that is similar to those in other states of Australia should be established. Such declared habitats would become part of the integrated and ecosystem-based marine and coastal planning, protection and management framework and be protected from development and degradation.

Recommendation 17: Fisheries Victoria should develop a policy framework to follow up important risks uncovered in the fishery environmental risk assessment process and to apply management controls or regulations to reduce that risk.

Recommendation 18: Location-specific ecological risk assessments of recreational fisheries (e.g. bait collection of intertidal gastropods) should be used and should take a precautionary approach to unknown impacts such as trophic effects. Such assessments would better inform the nature of management responses required, whether monitoring programs, education campaigns, compliance activities or legislative changes.

Recommendation 19: Programs to monitor the community ecology of important benthic and pelagic ecosystems should be established to provide important benchmark data for monitoring the ecosystem impacts of fishing. There is currently no ongoing independent monitoring of marine communities in Victoria that could set historical and contemporary ecological baselines for monitoring ecosystem changes related to recreational fishing and other pressures. Such data could be used in ecosystem models to predict future changes under different scenarios, including changes in recreational fishing pressure.

Fishery-specific management

Recommendation 20: To improve the management of the snapper recreational fishery in Port Phillip Bay:

- mandatory fin-clipping of recreationally caught fish should be introduced to decrease the incidence of illegal sale
- the use of fish-wells should be encouraged to reduce the effects of high-grading
- responsible environmental standards for fishing competitions should be established and enforced
- a closed spawning season for snapper should be considered when the fishery is in decline, to protect spawning stock.

Recommendation 21: To improve the management of the black bream recreational fishery in the Gippsland Lakes:

- an ecosystem-wide management approach should be adopted, including the management of land-based impacts and the conservation of seagrass habitat
- spawning season closures should be considered in some of the rivers that enter the Gippsland Lakes.

Recommendation 22: To improve the management of the King George whiting recreational fishery in Port Phillip Bay, and to ensure healthy and naturally productive fish stocks, the conservation and enhancement of seagrass habitat should be the focus of management.

Recommendation 23: To improve the management of the rock lobster and abalone recreational fisheries in Victoria, the introduction of TAC output measures and fish harvest tags should be considered for the management of the recreational component of the two fisheries.

Recommendation 24: Should the southern bluefin tuna recreational fishery continue and a TAC is assigned to it in Victoria, the use of fish harvest tags should be investigated to regulate the catch.

INTRODUCTION

The context of this report

Recreational fishing is one of Australia's largest participatory pastimes (Recreational Fishing Advisory Committee 2011), engaging millions of Australians from many places and backgrounds. Almost every water body has an angler somewhere trying their luck, from yabby traps in backyard dams to trolling for big game off the continental shelf. So many people, so many places, so many methods, so many species—this is the challenge that fisheries and environment agencies face when attempting to evaluate the extent and impact of recreational fishing.

Our understanding of the ecological impacts of commercial fishing has steadily increased over the past century, along with mechanisms for managing these impacts (Caddy 1999). However, much less attention has been given to the ecological impacts of recreational fishing. This is a significant gap, given that the size of the catch from modern recreational fisheries may be similar to, and sometimes exceed that, of comparable commercial fisheries (e.g. Coleman et al. 2004, Cooke and Cowx 2004).

For decades, the general consensus has been that the impact of recreational fishing is intrinsically much smaller than that of commercial fishing (Cooke and Cowx 2006), thus it required little investigation or monitoring. But with increasing participation rates and improvements in catching efficiency, it is now argued by some that recreational fishing could cause an 'invisible' collapse of fish stocks (McPhee 2002; Post et al. 2002). The very perception that recreational fishing is a low-impact activity could be the main challenge that must now be faced when monitoring and managing the impacts (Cooke and Cowx 2006).

There is a clear need for further investigation into the ecological impact of recreational fishing in Australian waters. This report focuses on Victoria, but brings together Australian and international data and case studies to identify potential future directions in the evaluation and management of recreational fishing.

The purpose of this report

This report has been commissioned by the Victorian National Parks Association to review the ecological impacts of marine and coastal recreational fishing, and to discuss arrangements for its monitoring and management that are relevant to Victoria. It updates a 2001 literature review by Dr Mark Norman (Norman 2001), and focuses primarily on Australian and, in particular, Victorian coastal recreational fisheries. In line with the scope provided by the Victorian National Parks Association, the aims are to:

- update the Norman review by compiling published and unpublished Australian literature relating to the ecological impacts of recreational fishing
- document the magnitude, diversity and impacts of the recreational fish catch in Victorian coastal waters compared to commercial fisheries—with at least one case study of a region/area
- outline the current Victorian government framework for monitoring and managing recreational fishing
- identify key knowledge gaps in Victoria in the understanding, monitoring and management of the ecological impacts of recreational fishing
- outline alternative methods of monitoring and managing recreational fishing, using case studies from around the world
- provide recommendations for future monitoring and management of recreational fishing in Victoria.

The scope of this report

Section 1 outlines the current Victorian government framework for monitoring and managing recreational fishing. This includes evaluation of the extent of recreational fishing, fisheries stock assessment, and the management and regulatory arrangements applied to ensure ecological sustainability. Knowledge gaps in the monitoring and stock assessment system are also identified.

Section 2 details the documented and potential impacts of recreational fishing in Victorian marine and coastal waters. It begins by outlining a framework for categorising ecological impacts in fisheries. This is then used to identify potential impacts from recreational fishing, as documented in Victorian, Australian and international examples. The review then examines Victorian recreational fisheries by outlining the magnitude, diversity and potential impacts of the recreational fish catch in Port Phillip Bay as compared with the commercial fisheries in the same area.

Section 3 discusses the implementation of selected

regulatory and management initiatives and evaluates their success in promoting the ecological sustainability of fisheries. It begins by identifying the key challenges for the management of recreational fishing in Victoria. The Victorian system is then compared with management systems for recreational fishing that have been adopted in other Australian states and territories, with attention given to arrangements that could improve management in Victoria. Alternative approaches to recreational fishing management are then investigated, using case studies from around the world. Section 3 concludes with brief comment on the *Future fisheries strategy: proposals for reform*, some broad recommendations on improving institutional arrangements, fish habitat identification and conservation, risk assessment and ecosystem baseline monitoring, and recommendations on how to deal with management issues in five Victorian recreational fisheries.

Note that this review covers the impact and management of recreational fishing in marine, coastal and estuarine environments, and does not cover freshwater recreational fisheries.

CURRENT MANAGEMENT OF RECREATIONAL FISHING IN VICTORIA

An overview of recreational fishing in Victorian coastal waters

SECTION 1

Levels of participation and effort

A range of surveys of recreational fishing effort has been conducted in Victoria over the past two decades (reviewed by Ryan et al. 2009). However, the National Recreational and Indigenous Fishing Survey (Henry and Lyle 2003), conducted in 2000, remains the most comprehensive source of data on recreational fishing patterns across Victoria. According to the survey, almost 13% of the Victorian population went fishing between May 1999 and May 2000 (Table 1). Participation was much higher for males, but was spread across age groups.

In a 2009 survey (Ernst and Young 2009) of Victorian recreational fishers, participation was estimated to be 721 000. The methods used for this survey are unclear, particularly with respect to how the total numbers of fishers were extrapolated from the sample. However, the results do support other evidence that recreational fishing pressure in certain Victorian fisheries e.g. snapper in Port Phillip Bay and Western Port Bay (Coutin et al. 2006, Ryan et al. 2009), has increased over the past ten years.

Recreational fishers must purchase a recreational fishing licence (RFL), or be eligible for an exemption, to fish in any Victorian waters. These licences are effectively unlimited, with 268 484 sold in 2010–2011 (Department of Primary Industries 2011). Note that this figure does not account for fishers with licences valid for more than one year i.e. those who purchased a three-year licence one or two years previously. Nor does the figure account for fishers who are exempt from having an RFL e.g. Seniors Card holders, those under 18, etc. Thirty-five per cent of respondents to the Ernst and Young

Table 1. Number and proportion of people in Victoria who went recreationally fishing between May 1999 and May 2000, by age and gender

Age group	Males	Percentage of population	Females	Percentage of population	Total	Percentage of population
5-14	76 237	23.3%	41 475	13.3%	117 712	18.5%
15-29	89 322	17.3%	37 764	7.5%	127 086	12.5%
30-44	120 161	22.8%	39 642	7.3%	159 804	14.9%
45-59	81 090	19.1%	23 761	5.5%	104 851	12.3%
60-74	30 412	12.3%	4 722	1.8%	35 134	6.9%
75+	4 213	4.5%	1 004	0.7%	5 217	2.3%
Total	**401 435**	**18.8%**	**148 368**	**6.8%**	**549 803**	**12.7%**

Data from Henry and Lyle (2003).

(2009) survey fell into these two categories. Moreover, the study did not survey fishers under the age of 18. If these estimates are expanded out from the number of licences in 2010–2011, and the proportion of fishers under 18 from Henry and Lyle (2003) is factored in, then the result is an estimate of 571 186 recreational fishers in Victoria—a four-per-cent increase on the 2000 survey.

Table 2. Annual Victorian recreational fishing effort (hours) by gear type

Method	Annual fishing effort (hours)	Percentage of total effort
Line	10 646 345	94.0
Pots and traps	441 674	3.9
Nets	14 005	1.0
Spearfishing	21 445	0.2
Hand collection (including diving)	70 055	0.6
Pump, rake, spade	26 353	0.2
Other	40 919	0.4
Total	**11 319 878**	**100.3**

Data from Henry and Lyle (2003). Note that rounding errors mean the summed individual efforts do not equal 100%.

Recreational fishing methods and equipment

Recreational fishers are permitted to use a range of methods and equipment in Victorian coastal waters, as set out by the Victorian government in the *Fisheries Act 1995* and *Fisheries Regulations 2009*. These include:

- lines (four lines with no more than two hooks)
- bait traps
- hoop nets (two, in a limited season)
- hand-held spears and spear guns
- baited lines with no hooks (up to ten)
- dip or landing nets
- bait nets (a 6 m haul net)
- bait pumps.

Animals such as crayfish, abalone, mussels and the like can be collected by hand.

A range of equipment is explicitly prohibited:

- set nets
- mesh nets
- cast nets
- snares
- mussel rakes
- explosives
- firearms
- bow and arrow.

There are also species-specific size limits, bag limits, possession limits and seasonal and spatial closures. Despite the diversity of permitted equipment, 94% of recreational fishing effort is associated with line fishing (Table 2; Henry and Lyle 2003).

Powerboats are a key feature of recreational fishing in Victorian coastal waters. Henry and Lyle (2003) indicate that almost 40% of Victorian fishing effort was boat-based and, in 2009, 70% of all recreational boating trips were for the purpose of fishing (Cassell and Ashby 2010).

Key fish species caught by recreational fishers

Key species caught in Victorian coastal and estuarine waters are listed in Table 3, alongside Victorian commercial catches for the same species. The five species/groups of

Table 3. Estimated number and weight of key species caught by recreational fishers in Victorian marine and estuarine waters in 1999–2000 as compared to Victorian commercial catches

Species/group	Scientific name/taxon	Estimated recreational catch (number)	Estimated recreational catch (t)	Commercial catch (t)	Approx. % of commercial catch
Flathead	*Platycephalidae*	3 316 071	597	151[a]	395%
Snapper	*Pagrus auratus*	474 879	332	47	706%
Australian salmon	*Arripis spp.*	541 852	271	803	34%
King George whiting	*Sillaginodes punctata*	975 349	215	213	101%
Black bream	*Acanthopagrus butcheri*	506 704	203	196	104%
Rock lobster	*Jasus edwardsii* and *J. verreauxi*	51 228	61	543	11%
Mullet	*Mugilidae*	301 848	60	>51[a]	<115%
Leatherjacket	Monacanthidae	166 378	50	17[a]	294%
Trevally	Carangidae	107 241	38	42[a]	90%
Garfish	Hemiramphidae	255 199	26	>118	<22%
Tailor	*Pomatomus saltatrix*	57 428	14	13[a]	108%
Morwong	Cheilodactylidae	33 273	4	>4[a]	<100%
Abalone	*Haliotis spp.*	10 355	3	1 418	<1%
Australian herring	*Arripis georgianus*	11 354	1	1	100%
Whiting	Sillaginidae	4 997	1	8	13%
Pipi	*Donax deltoides*	638 401			
Mussels	Mytilidae	615 798			
Pike	Sphyraenidae and Dinolestidae	257 795			
Squid/cuttlefish	Spirulidae and Teuthoidea	199 202			
Wrasse	Labridae	120 689			
Barracouta	*Thyrsites atun*	108 895			
Sharks/rays	several families	89 423			
Scallops	Pectinidae	83 290			
Prawns	Penaeidea	69 721			
Flounders and soles	Bothidae and Pleuronectidae	37 572			
Luderick	*Girella tricuspidata*	33 273			
Sweep	*Scorpis aequipinnus* and *S. georgianus*	26 324			
Red mullet/goat fish	Mullidae	25 051			
Blue mackerel	*Scomber australasicus*	7 057			

Recreational data is taken from Henry and Lyle (2003). Note that weights are only presented for select species presented in Henry and Lyle (2003). Commercial catch data for 1999–2000 from ABARE (2001). [a]Where commercial catch data from 2000-2001 was unavailable, it was supplemented by 2006–2007 data from the Department of Primary Industries commercial fish production report – http://www.new.dpi.vic.gov.au/fisheries/commercial-fishing/commercial-fish-production-2011/. Where indicated by '>', a component of the commercial catch is unreported due to Department of Primary Industries privacy policies.

primary importance to recreational fishers were snapper, Australian salmon, King George whiting, black bream and flathead (Table 3; Henry and Lyle 2003).

The only Victoria-specific recreational fishing survey was carried out in 2006 (Ryan et al. 2009), which focused on the snapper catch in Port Phillip Bay and Western Port Bay. Approximately 40% of Victorian licence holders (total 55 582) caught snapper, with a total catch of 612 202 (±79 586) fish. No estimates are given for the weight of the catch, but if the same average fish weight (0.7 kg) is applied, as in Henry and Lyle (2003), the total Victorian snapper catch would have been 429 t (±56 t). The Port Phillip Bay estimate was 244 542 fish (171 t), while for Western Port Bay it was 152 168 fish (107 t). These estimates do not include licence-exempt fishers; boat-ramp surveys reveal that 14% of snapper was taken by anglers without an RFL. In this survey, 78% of fishers identified as being 'avid' i.e. >15 days per year.

Current management of recreational fishing in Victoria

Legislative framework for Victorian fisheries

Fisheries Victoria administers three pieces of legislation on behalf of the fisheries minister: the *Fisheries Act 1995, Fisheries Regulations 2009* and *Fisheries (Fees, Royalties and Levies) Regulations 2008*. The management and regulation of recreational fishing is the responsibility of Fisheries Victoria under these three pieces of legislation.

The *Fisheries Act 1995* provides a legislative framework for the facilitation, promotion, management and regulation of commercial, recreational and traditional fisheries, and aquaculture operations. Importantly, in the context of recreational fishing, Fisheries Victoria is to manage fisheries resources 'in an efficient, effective and ecologically sustainable manner', 'to protect and conserve fisheries resources, habitats and ecosystems' and 'promote... quality recreational fishing opportunities' (*Fisheries Act 1995*, Part 1.3). The *Fisheries Act 1995* also outlines offences related to recreational fishing, the granting and revoking of recreational fishing licences, the recreational licence trust and powers to prohibit persons from fishing.

Fisheries Regulations 2009 outlines the specific control measures and regulations put in place to manage fisheries sustainably. It contains all details of the recreational and commercial regulations in specific fisheries and areas of Victoria, including gear types, catch limits, size limits, area or temporal closures, and specific licence conditions and boat restrictions. These regulations are the applied outcomes of management decisions made under the *Fisheries Act 1995*.

Fisheries (Fees, Royalties and Levies) Regulations 2008 states the fees involved in holding a commercial or recreational fishing licence. In relation to recreational fishing, the legislation defines the cost of RFLs and boat registrations.

The *Fisheries Victoria positioning statement* (Department of Primary Industries 2011a) proposes three main strategic directions: securing, sharing and growing the fisheries resources of the state. The key management-based initiatives proposed to achieve sustainable fisheries within these strategic directions include:

- adopting a risk-based approach to the management of Victoria's fisheries by developing structured management arrangements for fisheries, including management plans
- enforcing measures that protect the resource, e.g. preventing overfishing and limiting illegal, unlicensed and unregulated fishing
- targeting research to improve the ability to minimise impacts of resource use
- informing and influencing agencies with control and management responsibilities that impact on the health of aquatic ecosystems.

Victorian framework for fisheries management

Fisheries Victoria works under a risk-based fisheries management system, which employs an adaptive and proactive approach that uses input controls to achieve its aim of sustainable fish stocks. The *Fisheries Victoria positioning statement* (Department of Primary Industries 2011a) proposes an approach that 'manages for maximum sustainable yield and viable industries' and is 'more adaptive and proactive'.

The general approach is based on the ecosystem risk assessment (ERA) model developed for the Commonwealth Government (Department of the Environment and Water Resources 2007), the successor to the ecologically sustainable development (ESD) risk-assessment approach developed by the National ESD Reference Group in the early 2000s (Fletcher 2005a).

The current approach is often labelled 'ecosystem-based fisheries management', but the definition of this concept is reasonably loose, and ecosystem-based management should integrate the management of all sectors that use marine resources, not just fisheries.

The most recent incarnation of the ERA ecosystem-based management in Australia is termed 'Ecological risk assessment for the risks of fishing' and has been applied to a number of Commonwealth fisheries (Hobday et al. 2011). Such methods require comprehensive information about the fishery and its ecosystem impacts, along with significant scientific research support to make informed decisions about risk in the fishery. Few Victorian fisheries have the depth and breadth of data required to make such an assessment, the exceptions being abalone and rock lobster. Victorian fisheries generally have low values of production and thus have low investment in scientific research.

Fisheries Victoria has a modified process for assessing the status of a fishery that uses an ERA system. There is, however, no formally documented policy or decision-making framework guiding the making or amendment of regulations for commercial or recreational fisheries. The development of fisheries management plans, which include goals and management targets, has been an aspiration of Fisheries Victoria for some time, but few effective plans are currently in operation. Plans exist for some of the smaller bays and inlets, but not for the largest recreational fishing areas of Western Port Bay and Port Phillip Bay.

The *Future fisheries strategy: proposals for reform* (Department of Primary Industries 2011b) outlines the need to develop harvest strategies for each fishery, in effect creating a framework of objectives, indicators and trigger points for management initiatives that include regulation. The strategy aims to provide a more transparent and evidence-based system of management. The basis for fisheries management reform outlined in the *Future fisheries strategy: proposals for reform* is reproduced in Figure 1.

Figure 1. Framework for management in *Future fisheries strategy: proposals for reform*

FRAMEWORK FOR MANAGING A FISHERY			
1. Set total sustainable catch:	All sectors		
2. Allocate % shares	Commercial	Recreational	Aboriginal
3. Access entitlements	Limited access (commercial entitlements)	Open access (licensing applies)	Traditional owners
4. Harvest strategy	Harvest managed within specific limits and targets, with performance indicators, and clear decision rules.	Harvest managed within general limits and targets, with clear decision rules.	Strategy design dependent on scale of fishery and nature of access.
5. Management tools	Output or input controls	Input controls (e.g. size, bag limits)	Input controls
Management planning, involving stakeholders and underpinned by cost recovery			

Reproduced from Department of Primary Industries (2011b).

The finalisation of the *Future fisheries strategy* is currently on hold, possibly pending major revision. The reaction from stakeholders was largely negative in their submissions to Fisheries Victoria during the public consultation period in early 2012. It is unclear which, if any, of the management changes outlined in the draft strategy will be implemented. However, it is hoped that the recommendations made in this VNPA-commissioned report can influence the revision of the strategy and future directions for the management of recreational fishing in Victoria.

Estimating recreational fishing activity in Victoria

Monitoring recreational fishing

It is only in the past two decades that Australian state governments have overcome the perceived difficulty in establishing monitoring programs, and begun to consider recreational fisheries as equal to, if not more important than, commercial fisheries. However, traditional techniques used to monitor commercial fisheries, such as compulsory logbooks, are not easily transferable to recreational fisheries. Large-scale surveys are the most successful monitoring tool, but they are expensive and provide only a snapshot of data for management.

The monitoring requirements for recreational fishing can be broken down into three important questions:

- How many people are fishing and how much do they catch?
- What is the status of fishing stocks affected by recreational fishing?
- What are the environmental impacts of recreational fishing activities outside the direct catch of fish?

Management agencies around the world are still developing effective and responsive recreational fishing impact monitoring programs. There is no tried and tested 'ideal' framework for how to monitor and manage recreational fisheries. In most cases, information about fish stocks still relies heavily on commercial catch and effort data and not on data from recreational fishers. Fisheries scientists are still developing useful indicators for recreational fishing impact on stocks; there will be continuing advances in this area in the coming decades. Unfortunately, the lack of successful monitoring programs has meant that the management of recreational fisheries has lagged even further behind. As a result, the resources allocated to monitoring far outweigh those given to management.

An overview of Victoria's monitoring of recreational fishing activity and impact is presented in Table 4. Victoria has a number of recreational fishing monitoring programs that are cutting-edge—the fishing diary program is an example—but in other areas it falls behind other Australian states (see section 3). With further development of fledgling programs, and the adoption of other proven and relevant strategies, Victoria could become a world leader in the development and implementation of recreational fishing monitoring programs. However, the conversion of these programs into effective management tools will be the toughest challenge for managers in Victoria.

Participation rates and total catches

Estimates of Victorian participation rates are determined primarily by tallying the sales of recreational fishing licences (RFLs), but there are two major problems with this approach. Licences are not required for children or pensioners, and licence numbers do not give an indication of the variability in individual fishing effort, which can vary considerably (Ryan et al. 2009). There is currently no routine and ongoing process to evaluate the recreational fishing pressure or effort beyond estimating participation rates by way of licence sales. However, the development of such a process is flagged as an important priority for future management, and a framework for regular surveys (probably every five years) is currently under development by Fisheries Victoria.

There have been numerous sporadic and spatially limited studies of recreational fishing effort and catch in Victoria, including aerial surveys, bus-route surveys and creel surveys (reviewed in Ryan et al. 2009). However, the current estimates for recreational fishing effort and associated catch in Victoria are primarily derived from two larger surveys conducted during the

Table 4. Recreational fishing assessment indicators and monitoring programs in Victoria				
	Indicator	**Data available?**	**Last survey year**	**Future frequency**
Recreational fishing monitoring	Participation rate	Yes	2006-2007	Unknown, possibly every 5 years
	Frequency of fishing	Yes	2005-2007	Unknown, possibly every 5 years
	Spatial distribution of effort	No	-	Unknown
	Total catch	Yes	2000-2001	Unknown, possibly every 5 years
Stock assessment information	Commercial catch rates	Yes	Ongoing	Ongoing yearly
	Recreational catch rates	Some fisheries through diary program	Ongoing but spatially limited	Diary program ongoing, ramp surveys ceasing soon
	Fisheries independent monitoring	Some fisheries	Ongoing for some fisheries	Ongoing for largest fisheries: abalone, rock lobster, snapper
Ecological impact of recreational fisheries	Risk assessments	No	-	None planned
	Monitoring of impacts	No	-	None planned

2000s. The first was an Australia-wide study, which estimated participation rates and the catches of many species across all states in 2000–2001. The second was a Victoria-specific study that focused on the Victorian western snapper catch in 2006–2007.

The National Recreational and Indigenous Fishing Survey 2000–2001

Henry and Lyle (Henry and Lyle 2003) conducted the first comprehensive national fishing survey in 2003. The survey sought to estimate recreational and Indigenous participation rates and fishing effort, profile demographics of those involved, and estimate species-specific catch in all Australian states and territories. The study was the result of a long development and research process that attempted to identify the most accurate and cost-effective survey methods.

The recreational component of the survey was the National Recreational Fishing Survey (NRFS) and was conducted using a three-stage process of random phone surveys, targeted diary surveys and attitudinal surveys of participants.

The random phone surveys targeted 43 945 households across Australia, including 9 055 in Victoria, and followed a structured interview process. The following information was gathered on household members:

- demographics
- level of recreational fishing participation in the past 12 months
- forecast participation in the next 12 months
- licence ownership
- club memberships
- boat ownership.

All those who intended to fish in the next 12 months were invited to participate in the angler diary survey, which attracted 8 449 households (17 092 fishers), including 1 228 from Victoria (2 232 fishers). Participants were contacted at least once a month by telephone during the period May 2000 to April 2001 and asked questions on fishing activity, including start and finish times, locations, catch and release, expenditure and distances travelled. Lastly, attitudinal surveys were conducted with diarists to determine motivations and attitudes to fishing. For data calibration, some follow-up phone surveys and onsite creel surveys were also used.

In the decade since the NRFS, recreational fishing in Victoria may have changed considerably, with evidence pointing to increased participation and effort, as well as a change in species catch (e.g. decline in flathead, increase in snapper). Nonetheless, the study provides valuable information on the national picture that is unlikely to be repeated (Appleford and Hurst 2010).

Victorian RFL snapper survey 2006-2007

This study, produced by Ryan et al. (2009), was principally designed to identify and trial the most effective and cost-efficient methods of determining recreational fishing catch and effort in Victoria. The NRFS was considered too costly and did not provide sufficient data on small spatial scales (Ryan et al. 2009). The study surveyed participation in the marine bay and inlet recreational fishery, and reported specifically on data

related to the catch of snapper in central and western Victoria.

The preferred survey design was very similar to those of Henry and Lyle (2003), the key difference being the targeted involvement of fishers from the database of RFL holders instead of random calls to residential phone numbers. Those willing to be involved (>90% participation) completed phone diary surveys very similar to those in the NRFS, and the survey was conducted for 12 months from July 2006 to June 2007. This was then followed up by attitudinal surveys and boat-ramp creel surveys.

The study concluded that using the RFL database to target angler-diary surveys is a cost-effective tool for estimating recreational catch and effort. Improvements are suggested, such as improvement in the database itself, the issuing of licences to all fishers, and a more targeted and detailed understanding of avid fishers and their practices. It is likely that this type of survey will form the basis of the ongoing monitoring program being currently developed by Fisheries Victoria.

Development of a regular recreational fishing survey in Victoria

Fisheries Victoria has proposed a regular and ongoing recreational fishing survey in its *Future fisheries strategy: proposals for reform* released for comment in late 2011. Although no details of this plan exist, it is likely to follow the strategies of Ryan et al. (2009) and Appleford and Hurst (2010), relying on phone surveys of RFL holders conducted every five years. This falls in line with Goal 4 of the national strategy on recreational fishing (Recreational Fisheries Advisory Committee 2011), and mirrors the surveys in other Australian states such as South Australia (Jones 2009), Tasmania (Lyle et al. 2009) and the Northern Territory. In a global context, the likely scale of the surveys is at the forefront of recreational fishing monitoring initiatives, with few examples of similarly ambitious initiatives anywhere else in the world.

Knowledge gaps

Estimating participation rates, the frequency of angling, spatial distribution of effort and the total catch of target and non-target species are the basic pieces of information required to monitor and manage recreational fishing (Cowx and Arlinghaus 2008; Arlinghaus 2010; Lester et al. 2011). Victoria does not have an ongoing program that collects such data; management decisions can only be made using old or incomplete data. The most recent survey (Ryan et al. 2009) is now over five years old and did not cover all recreational species caught in all locations in Victoria. The lack of such a regular comprehensive survey of recreational fishing is currently the major knowledge gap in recreational fishing management in Victoria.

Appleford and Hurst (2010) propose the need for a nationally consistent method of assessing the impacts and importance of recreational fishing. They build on the experience of Australian states and territories and outline a comprehensive and cost-effective strategy that will be likely to form the framework for any future strategy in Victoria. The phone diary technique is further refined in Lyle et al. (2010) and provides a nation-wide standard for survey methods.

The strategy design involves large-scale quantitative assessments similar to those of Ryan et al. (2009) every five years, with less intensive indicator data collection collected every year (Appleford and Hurst 2010). Quantitative surveys would focus on collecting total catch and catch structure (length and weight), and the spatial and temporal fishing effort. Although details on the specific methods are sparse, in Victoria this is likely to involve targeting RFL holders through phone surveys similar to Ryan et al. (2009). Ongoing fishery indicator programs would collect less intensive data on catch rates and catch structure, and would probably involve the continuation of both the angler diary program and onsite boat-ramp surveys.

Recommendations

Recommendation 1: Large-scale quantitative surveys of recreational fishing participation and total catch should be adopted every three to five years and follow the methods of Ryan et al. (2009) and Appleford and Hurst (2010).

Recommendation 2: The Recreational Fishing Licence (RFL) database should be expanded to provide compulsory but free licenses for the groups currently excluded, thus making details available for quantitative surveys. RFLs could be endorsed for Victorian coastal regions, as in Western Australia, to gain a better understanding of the spatial distribution of fishing effort. This could be as simple as the west/central/east split that is currently in place for abalone management, or as regions that represent the jurisdictions of future marine and coastal planning and management bodies.

Recommendation 3: Onsite surveys

at all major boat ramps in Victoria should be continued, with a focus on collecting random samples of recreational fishing effort and catch for key species.

Recommendation 4: The angler diary program should be expanded to include more diarists, particularly research anglers targeting juveniles of key species, and focusing on the major recreational estuaries of Port Phillip Bay, Corner Inlet, Western Port Bay and the Gippsland Lakes. To encourage participation, angler diarists could be issued with free or reduced-cost RFLs.

Assessing the size, nature and health of fish stocks in Victoria

Overview

Fisheries Victoria assesses the health of a key fishery based on a variety of data collected from research scientists, and commercial and recreational fishers. Each species is assessed under an ecological risk assessment (ERA) framework with the cumulative impacts of commercial and recreational fishing taken into account. Thus there are no separate assessments for the commercial and recreational fishery. Full assessment is based on a risk-based scorecard system that evaluates the following factors:

- ecosystem limitations on the fishery
- sustainability of fishing operations
- need for stock recovery plans
- impact of the fishery on the ecosystem
- level of compliance in the fishery.

Based on the outcomes of the evaluations, fisheries are assessed as underexploited, fully exploited, overexploited or environmentally limited (Table 5).

In total, 14 key marine and freshwater commercial fisheries representing at least 13 species have been fully assessed in Victoria (Department of Primary Industries 2010b), and many of the smaller commercial fisheries have stock assessment reports published or in preparation. The current status of commercial marine and estuarine fisheries in Victoria is presented in Table 6, however, the full fishery scorecard can be found in Department of Primary Industries (2010). The key stocks are assessed every three to five years. Note, however, that risk assessments are applicable only to the commercial fishery and not to the recreational fishery.

The ERA system adopted by Fisheries Victoria is much simpler than that adopted by the Commonwealth, and even more so compared to the original ESD-based framework. It directly reflects the amount of scientific data available to make confident decisions about stock status and ecosystem impacts.

Currently there is no policy framework in Victoria to follow up important risks uncovered in the fishery ERA process described above, or to apply management controls or regulations to reduce that risk. Such action is decided on an *ad-hoc* basis using expert knowledge, consultation and, where appropriate, regulatory trials or quantitative modelling.

Table 5. Victorian fisheries assessment categories

Underexploited	There are sustainable levels of fishing and satisfactory abundance of fishery stocks. The fishery could potentially tolerate additional harvest pressure.
Fully exploited	There are sustainable levels of fishing and satisfactory abundance of fishery stocks (minor issues may be affecting fishery stocks abundance, and/or the sustainability of fishing).
Over exploited	Stock abundance is not satisfactory, and/or overfishing is occurring.
Environmentally limited	Significant non-fishing (ecosystem) issues have been identified that are influencing productivity in the fishery. These issues are considered to be driving stock status.

Reproduced from Department of Primary Industries (2010).

Recreational catch and effort information for stock assessment

There are currently three ongoing Victorian projects designed to gather more specific effort, size and age data from recreational fishers for use in stock assessment: onsite boat-ramp surveys, angler diarists (general and research), and angler attitude surveys. Some have been ongoing since the 1990s and are likely to be incorporated into the broader program now under development.

Onsite recreational fishing surveys

These surveys have been ongoing since 1995 and involve interviews of recreational fishers at boat ramps in the Gippsland Lakes, Western Port Bay and Port Phillip Bay (Conron and Bridge 2004; Conron et al. 2012).

Representatives of Fisheries Victoria interview fishers at boat ramps as they return from their fishing trips. Data collected includes fishing effort and numbers of fishers, catch composition, fish length (through measurements on site), fish targeted, gear used and some fisher details. Boat-trailer surveys, which involved a simple count of empty boat trailers at each ramp, were also conducted.

The strength of onsite recreation surveys is in their ability to collect scientifically rigorous data from random samples of recreational anglers. Unlike other programs, fishers are surveyed randomly at boat ramps, with the data on fish size and age collected by trained employees. This increases both the reliability of the data in representing the diversity of fishers in Victoria, and the accuracy of fish measurements used for stock assessment. In general, this data is not used directly for stock assessment but as a supporting or complementary tool to commercial data. Continuing the frequent onsite surveys is therefore very important in maintaining an understanding of the catch and effort of recreational fishers. This is particularly important for regionally specific fisheries such as snapper in Port Phillip Bay, as well as for places where commercial fishing is absent and cannot provide important length and age data for fisheries stock assessment, such as for the southern bluefin tuna in south-western Victoria, or dusky flathead in Lake Tyers.

Table 6. Victorian fisheries assessments 2010

Fishery	Recreational component	Ecological risk assessment	Stock assessment	Stock status
Rock lobster (Eastern)	Moderate	Yes	Yes	Fully exploited
Rock lobster (Western)	Minor	Yes	Yes	Fully exploited
Giant crab	Negligible	Yes	Yes	Fully exploited
Abalone (Eastern)	Minor	Yes	Yes	Fully exploited
Abalone (Central)	Minor	Yes	Yes	Fully exploited
Abalone (Western)	Minor	Yes	Yes	Fully exploited
Scallop	Minor	Yes	Yes	Fully exploited
Snapper	Large	Yes	Yes	Environmentally limited
Black bream	Large	Yes	Yes	Environmentally limited
King George whiting	Large	Yes	Yes	Environmentally limited
Sea urchin	Minor	Yes	No	Underexploited
Calamari	Large	No	Yes	(Environmentally limited)
Garfish	Large	No	Yes	(Fully exploited)
Rock flathead	Minor	No	Yes	(Environmentally limited)
Sand flathead	Large	No	Yes	(Environmentally limited)
Dusky flathead	Large	No	No	Unknown
Australian salmon	Moderate	No	No	Unknown

Adapted from Department of Primary Industries (2010). Species with stock status in parentheses are unofficial but deduced from stock assessment reports.

Port Phillip Bay onsite surveys

In Port Phillip Bay, surveys were commenced in 2002 at 17 boat ramps in the peak fishing period of November-April. The surveys covered approximately six weekend days per month, or 36 survey days per year. Due to the high variability in angling success among recreational fishers in pilot surveys (Conron et al. 2012), data for key target species was collected only from 'avid' fishers (>5 fishing trips in the past year) who were specifically targeting that species. The use of avid fishers biases the catch rates and the resulting data should only be used as relative measures or as indicators for stock fluctuations through time.

The Port Phillip Bay onsite survey program was intensified (i.e. more surveys at more locations) under a framework created by the Port of Melbourne Corporation Fish Stock and Recruitment Program Subprogram 3 (Port of Melbourne Corporation 2010). These intensive surveys ran for four years (2008–2011) to monitor impacts of the Corporation's channel dredging operations. The aim of the program was to 'detect changes in the abundance and recruitment of key recreational fishing species outside of expected variability' (PoMC 2010 p.3). A statistical power analysis of data from 2002–2007 revealed that a significant increase in the intensity of the surveys was required to detect a 50-per-cent change in catch rates for key species. Smaller changes to fish stocks would therefore not be detectable with this method, although the natural variability of stocks at this level would be likely to make such detection levels meaningless. Survey days were subsequently increased from approximately 36 to 130 days per year.

The intensive onsite surveys were split into four-month blocks: January to April, May to August and September to December. Port Phillip Bay was divided into three regions: Melbourne, Mornington

and Bellarine. Data was specifically collected for seven species comprising snapper, King George whiting, flathead, calamari, garfish, Australian salmon and black bream, with that for other species collected opportunistically. Fishing effort and catch in the three regions were compared to the baseline period of 2002–2007 in the summer months, but to 2008–2010 data for the winter months (winter surveys started in 2008). Data from each survey period was collated and then published in reports on the website of the Victorian Government Office of Environmental Monitoring (www.oem.vic.gov.au). Data on the frequency and number of surveys, and fish counted and measured, is compiled in Table 7. Over the four years 2008–2011, Fisheries Victoria conducted surveys on a total of 593 survey days in Port Phillip Bay, interviewing 7 543 fishers, counting 31 532 fish and measuring 13 561. The final results, published in May 2012 (Bruce et al. 2012), detected a long-term decline in sand flathead, but stable levels of all other stocks.

The future is uncertain if they were to cease, the ability to accurately detect changes in catch rates and size composition will be significantly reduced.

Victorian angler fishing diary program

The angler diary program was initiated across smaller Victorian estuaries as a component of fishery management plans set up in the late 1990s and 2000s. Fishery management plans aim to conserve key target fish species and ensure ecologically sustainable fishing (Conron et al. 2012). The angler diary program was identified as one of the most cost-effective tools in monitoring recreational catch and effort, as well as following trends in important fish stocks. As most of these estuaries no longer support commercial fishing, the diary program replaced data about fish stocks traditionally gathered from commercial catch and effort.

Angler diarists are classified as either 'general anglers' or 'research anglers' and compile different types of information used to assess the health of fish stocks.

General anglers record information about their regular fishing trips including effort, catch, locations, gear types and targeting preference. They give information on catch rates and targeting preferences of legal-sized fish using standard gear. As angler diarists are avid fishers and consistently target specific species in specific locations, they can provide good time-series data on catch rates and size composition of retained fish. These can be compared on a relative scale to examine changes through time. However, the high turnover of participants may introduce a drift in catch rates over time, related to the experience and skill of the given participants.

Research anglers are required to target specific species in specific locations with specific gear; all catch is measured and some fish are aged. Research anglers can standardise their effort in terms of where and when they fish, time spent, gear type and bait, all of which are randomly sampled in the onsite surveys. The key stock assessment information gained from research anglers is the relative abundance of juvenile fish below the legal size limit. Using targeted gear types and standard times and locations, catch rates of juvenile fish give an indication of the strength of year classes yet to enter the fishery. Predictions can then be made as to how the stock will perform in following years. This method is the only predictive tool available in smaller estuaries where fisheries-independent indicators of recruitment are lacking.

The program was established in 1998 to study dusky flathead catch in Mallacoota Inlet and the Hopkins River, and has since expanded into Lake Tyers, Anderson Inlet, Glenelg River, Barwon River, West Gippsland, Curdies River and a number of freshwater riverine systems (Conron et al. 2012). The key target species are dusky flathead, black bream, mulloway and estuary perch, although catch of all species is recorded. In 2010–11, there were 75 angler diarists active in the seven small estuaries with a total of 764 fishing trips and a catch of 4 838 fish. Fish caught included other estuarine species as well as estuary perch, black bream and mulloway.

A small number of fishers were originally active in Port Phillip Bay in the 2000s, but this was expanded to around 40 under the Port of Melbourne Fish Stock and Recruitment Program (PoMC 2010), which ran from January 2008 until December 2011. Diarists collected information on snapper, King George whiting and flathead in seven regions in Port Phillip Bay, and on black bream in the Yarra and Maribyrnong rivers. In the four years from 2008 to 2011, a total of 1 785 angler-diarist fishing trips were made in Port Phillip Bay, and a total of 14 896 fish counted and measured (Table 7). The collected data was assessed to determine any significant changes in catch rates and age-size composition attributable to channel dredging by comparing results to the pre-dredging years (starting 2008). Although the program detected a decline in sand flathead over the period, this followed a long-term decline which started well before the dredging period began (PoMC 2010). This project has now ended, but Fisheries Victoria has two years of funding to continue the program, albeit with a reduced capacity.

Table 7. Port Phillip Bay recreational fishing monitoring program 2008–2011 with details of frequency, intensity and fish caught and measured

		Onsite survey program				Angler diary program						
Year	Period	Survey days	Interviews	Fish caught	Fish measured	Angler diarists	Trips	Fish caught	SP	KGW	FH	BB
2011	3	50	712	2 271	1 259	34	247	1 475	820	195	377	83
	2	30	291	1 052	339	3	17	13	0	0	0	13
	1	50	585	4 092	1 309	27	236	2 796	1 106	805	609	195
2010	3	45	550	3 542	1 086	32	241	1 529	749	61	648	71
	2	32	304	1 283	516	5	41	81	0	0	0	81
	1	62	819	3 631	1 821	32	273	3 038	1 422	578	728	310
2009	3	49	714	2 125	1 137	44	336	1 628	672	74	776	106
	2	46	370	1 202	656	5	48	77	0	0	0	77
	1	77	954	4 336	2 277	32	235	2 402	1 053	494	655	200
2008	3	56	833	2 937	1 504	28	170	1 035	383	0	480	172
	2	36	327	1 015	393	2	23	0	0	0	0	0
	1	60	1 084	4 046	1 264	20	165	2 297	686	1 205	375	31
Total		**593**	**7 543**	**31 532**	**13 561**		**1 785**	**14 896**	**6 071**	**3 217**	**4 271**	**1 256**

The three periods relate to 1: January to April; 2: May to August; and 3: September to December. SP = Snapper caught, KGW = King George whiting caught, FH = flathead caught, and BB = black bream caught. Data compiled from Port of Melbourne Corporation Milestone Reports (Bruce et al. 2012).

The strength of the angler diary surveys are their cost effectiveness, enhanced community involvement and the potential to standardise fishing effort, location and targeting. Reliable data on catch of undersized and returned fish, which provides important information on recruitment to the fishery, cannot be obtained in other ways. However, angler diarists represent only a tiny fraction of all recreational fishers, and expansion of this program both in terms of numbers and spatial coverage is recommended.

Angler satisfaction surveys

Although much less reliable in assessing fish stocks than onsite and diary surveys, angler satisfaction surveys provide qualitative information on the angler fishing experience. Satisfaction can be influenced by many factors external to the actual frequency, number or quality of fish caught by anglers (Spencer 1993). When these factors are properly accounted for, angler satisfaction can potentially be an indicator of large-scale changes, particularly for changes in the size distribution of target species (Petering et al. 1995; Arterburn et al. 2002).

Satisfaction surveys were conducted in Mallacoota Inlet, Lake Tyers and Gippsland Lakes in 2007 (Conron et al. 2010). Their primary purpose was to investigate the current level of fishing satisfaction, and how this compared to fishing prior to 2003, the year when commercial fishing was removed from Mallacoota Inlet and Lake Tyers. Gippsland Lakes, where commercial fishing still occurs, was used as a control. Fishers were asked about general satisfaction with black bream and dusky flathead catches, whether there were more or less fish than pre-2003, and whether the fish were larger or smaller.

From a scientific or stock assessment perspective, there is little that can be used from much of the analysis. However, the key conclusions were that fishers in the Gippsland Lakes were generally less satisfied, dusky flathead were bigger and more numerous in Lake Tyers compared to 2003, and black bream were smaller and less abundant in the Gippsland Lakes than in 2003. Taking into account the influence of attitudes towards commercial fishing—recreational fishers are less likely to be satisfied where commercial activity occurs—it is difficult to tell whether the differences actually reflect changes in the abundance and size of target species. However, the perceived reduction of black bream size and abundance in the Gippsland Lakes follows a decline in black bream stocks attributed to environmental factors during this period (Williams et al. 2012).

Although satisfaction surveys can provide important social data, other methods, such as onsite surveys, angler diary programs and the analysis of commercial catch and effort data could give more reliable insights into changes in fish stocks.

Comparison of survey methods

The three survey methods all offer different information for stock assessment (Table 8). Onsite surveys supply a representative sample of what recreational fishers are catching, and where and when. This informs fisheries managers about the extent of the impacts of recreational fishing. Angler diary surveys give more robust time-series about the catchability of fish, and the relative abundance of different size and age classes. This data can be used to make assumptions about the stock itself, whether it is increasing or decreasing, and whether its size and age composition is changing. The angler satisfaction surveys supply much less rigorous information for stock assessment. They may, however, be more useful in obtaining attitudinal data, which could help evaluate the effectiveness of management controls and regulations.

In summary, onsite surveys and general and research angler diary programs provide unique information on recreational fisheries, all of which is important for stock assessment and subsequent harvest strategies. Onsite surveys also supply representative information on what fishers are catching, general diarists supply time series of catch rates, and research anglers provide information on recruitment to the fishery.

Knowledge gaps

The catch and effort information currently provided by the onsite surveys and angler diary program is a strong platform from which to make management decisions. However, the scale of both programs is very small compared to the total number of recreational fishers and fishing trips in Victoria. As a result, the variability in data within each region is high. For example, over 50 000 fishers were estimated to have caught snapper in Port Phillip Bay in the Ryan et al. (2009) survey. However, an average of only 30 angler diarists were active in Port Phillip Bay over the summer months between 2008 and 2011 (Bruce et al. 2012). Further, only four angler diarists on average were active in the winter months targeting black bream in Port Phillip Bay.

The angler diary program has great potential to supply cost-effective and plentiful data on recreational catch. Increasing its scope is one of this report's key recommendations for filling knowledge gaps about fish stocks. In particular, the small number of research anglers provides critical information on juveniles entering the fishery. The program is also important for those estuaries where commercial fishing is absent or limited because it provides the only information on changing catch rates and stock composition.

Fishery – independent monitoring for stock assessment

Data collected by recreational or commercial fishers will never give a complete picture of the stock as a whole because fishing practices are targeted at fish above the legal limit. Data will only be representative of this 'legal' component of the stock and fail to give managers reliable indicators of the non-targeted portion of the fish population. These are often the larval or juvenile stages, but in some cases may be the breeding stock if the fishery is focused on juveniles of the species. Often a fishery-independent form of monitoring is needed to fill knowledge gaps about the stock as a whole.

The key Victorian commercial fisheries have established programs of fisheries-independent monitoring in the form of pre-recruit or juvenile monitoring. These programs are detailed in Table 9. The relative abundance of new recruits is used to predict the strength of year classes entering the fishery, and hence the total stock available to be fished in the future. There is a lack of fisheries-independent data for species of lesser value, or key species targeted in smaller estuaries or remote areas of the coastline.

Until 2011, an annual trawl survey was conducted in Port Phillip Bay to monitor fluctuations in the abundance and biomass of benthic species. Twenty-two sites in four depth-stratified regions of Port Phillip were sampled in March, with the data analysis focused on the 20 most abundant species (PoMC 2010). The project was incorporated into the Port of Melbourne Corporation Channel Deepening monitoring program in 2008. Funding ceased in 2011 and the program has since been suspended, despite it being the only continuous time series of data on the benthic species in Port Phillip Bay. The trawl is the only fisheries-independent source of data for commercial species such as sand flathead, bycatch species such as stingarees, and exotic pests such as the northern pacific seastar.

Knowledge gaps

Fisheries-independent data sources, particularly those that monitor recruitment, are critical to making robust forecasts about future stock fluctuations. Fisheries Victoria oversees fisheries-independent programs to monitor the five key recreational and commercial species (Table 9). However, these

Table 8. Comparison of survey methods employed by Fisheries Victoria to evaluate recreational fish stock status

Survey type	Stock assessment information	Other information
Onsite boat-ramp surveys	Catch rates from fishers of differing ability and avidity Estimates of total catch (with participation rates) Size/age distribution of retained catch	Random sampling of fishers Demographics of the fishery Targeting preferences
General angler diarists	Times series of catch rates of avid anglers Size distribution of retained (legal) fish	Discard rates
Research angler diarists	Standardised information on juvenile fish entering the fishery Size and age data on entire population	Some fisheries through diary program
Angler satisfaction surveys	Fisheries-independent monitoring	Angler perceptions of stock abundance and catchability Monitor perceived environmental changes alongside the fishery

do not occur in all locations, and some important species are not monitored. Important recreational fish stocks such as sand flathead, rock flathead, calamari and garfish are not the subject of fisheries-independent data collection. With the cessation of the annual Port Phillip Bay trawl survey in 2011, fisheries-independent data on flatheads, and many non-target species such as rays, is no longer available for stock assessment and environmental risk analysis.

Recommendations for stock assessment

Recommendation 5: Alternative stock assessment methods for smaller recreational fisheries should be investigated and then applied, if appropriate, to make the best use of the data currently collected by the angler diary and boat-ramp surveys.

Recommendation 6: Fisheries-independent monitoring options should be investigated for key recreational species, such as sand flathead, rock flathead, garfish and calamari.

Recommendation 7: Current recruit monitoring for King George whiting and snapper should be extended into Western Port Bay, an area experiencing a significant growth in recreational fishing pressure.

Recommendation 8: The Port Phillip Bay annual trawl surveys should be re-established. They provide critical data on sand flathead stocks, non-target and rare species, and invasive species e.g. northern pacific seastar.

Recommendation 9: The incidence and consequence of discarding target species of declining abundance (e.g. sand flathead, dusky flathead), and non-target species of naturally low abundance (e.g. rare rays or sharks), should be investigated. This could be part of a review of the survival rates of key species caught using different gear types, with the intention of considering gear restrictions as management solutions for ecologically sustainable harvest strategies. Education programs should continue to teach best practice in maximising the survival of discarded fish.

Recommendation 10: TAC allocation to fisheries should not be used where data is unavailable for making robust biomass or fishing mortality estimates. Furthermore, TAC should be only introduced where catch limits can be effectively monitored and enforced in both the recreational and the commercial sectors.

Table 9. Ongoing fisheries-independent surveys used for stock assessment in Victoria

Species	Location	Program
Snapper	Port Phillip Bay	Trawl surveys run in March to April each year to estimate the abundance of juvenile fish approximately two to four months old (Department of Primary Industries 2010a).
King George whiting	Port Phillip Bay	Surveys of larval King George whiting in seagrass beds have been conducted in spring each year since 1996 (Department of Primary Industries 2010a).
Black bream	Gippsland Lakes	A program of using seine nets to target pre-recruit black bream operated between 1996 and 2006 (Kemp et al. 2011). The program has recently been overhauled and recommenced in 2010. There is no published information on the methods of this survey.
Abalone	Victorian coastline	Both adult and juvenile abalone are surveyed by scientific divers at 200 locations along the Victorian coastline every year to provide estimates of total stock on each reef (Department of Primary Industries 2010a)
Rock lobster	Victorian coastline	The larval stage (puerulus) of rock lobster is monitored at various locations in Victoria (Department of Primary Industries 2010a), however published information on the program is lacking.

ECOLOGICAL IMPACTS OF RECREATIONAL FISHING

SECTION 2

A framework for identifying potential ecological impacts of recreational fishing

Impact categories and ecosystem considerations

The potential ecological impacts from fisheries are diverse and often poorly understood. Fletcher et al. (2002) developed a framework for identifying these impacts in a consistent and transparent manner. While the framework can be extended to assess specific risks and develop monitoring and reporting programs, it is used here as a way of identifying and organising the potential ecological impacts from recreational fishing.

The potential impacts of recreational fishing are organised into three categories:

- targeted/retained species (Figure 2)—the direct impacts on fish species retained by fishers
- direct interactions with other species (Figure 3)
- general ecosystem effects (Figure 4).

With respect to the *direct interactions with other species* category of impacts, Fletcher et al. (2002 p. 35) note these species are those that 'no-one in the fishery wants to catch at any time, irrespective of their size or life history stage'. The *interaction, but no capture* sub-category refers to situations where 'some species may be directly affected by fishing activities without actually being landed on the boat or caught by the fishing gear—i.e. accidental collisions between fishing boats and dugongs'. (Fletcher et al. 2002 p. 36)

The considerations under *general ecosystem effects* are associated with the indirect, more diffuse interactions a fishery may have with the broader ecosystem and environment (Fletcher et al. 2002).

These categories are now examined in relation to recreational fishing and the following two questions:

- What are the potential impacts based on the magnitude (e.g. number/ quantity/ pressure) and nature (e.g. location/efficiency/timing/equipment) of recreational fishing?
- What evidence is there of such impacts?

Figure 2. Subcategories for considering the potential impacts of recreational fishing on target and other retained (byproduct/bycatch) species (including undersized catch)

Adapted from Fletcher et al. (2002).

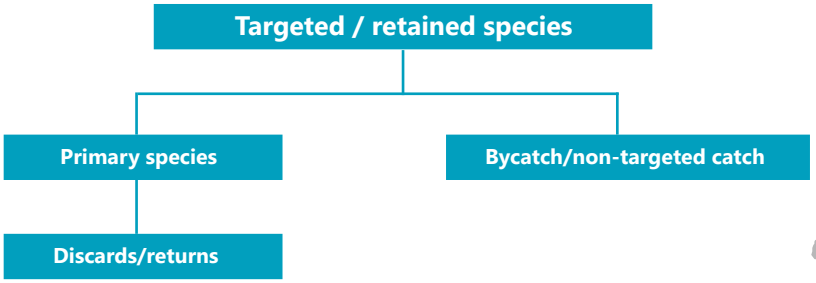


Figure 3. Subcategories for considering the potential impacts of recreational fishing on species not retained or interacted with by fishers during fishing

Adapted from Fletcher et al. (2002). Note that species of undersized target fish, or retained bycatch, are dealt with under the 'targeted/retained species' category.

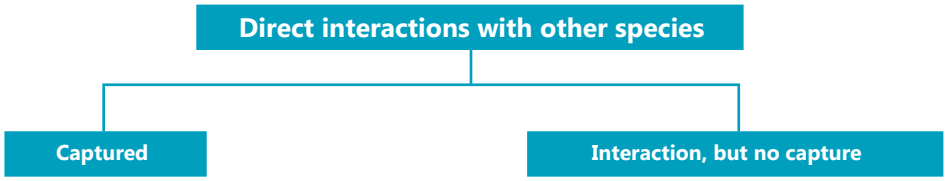
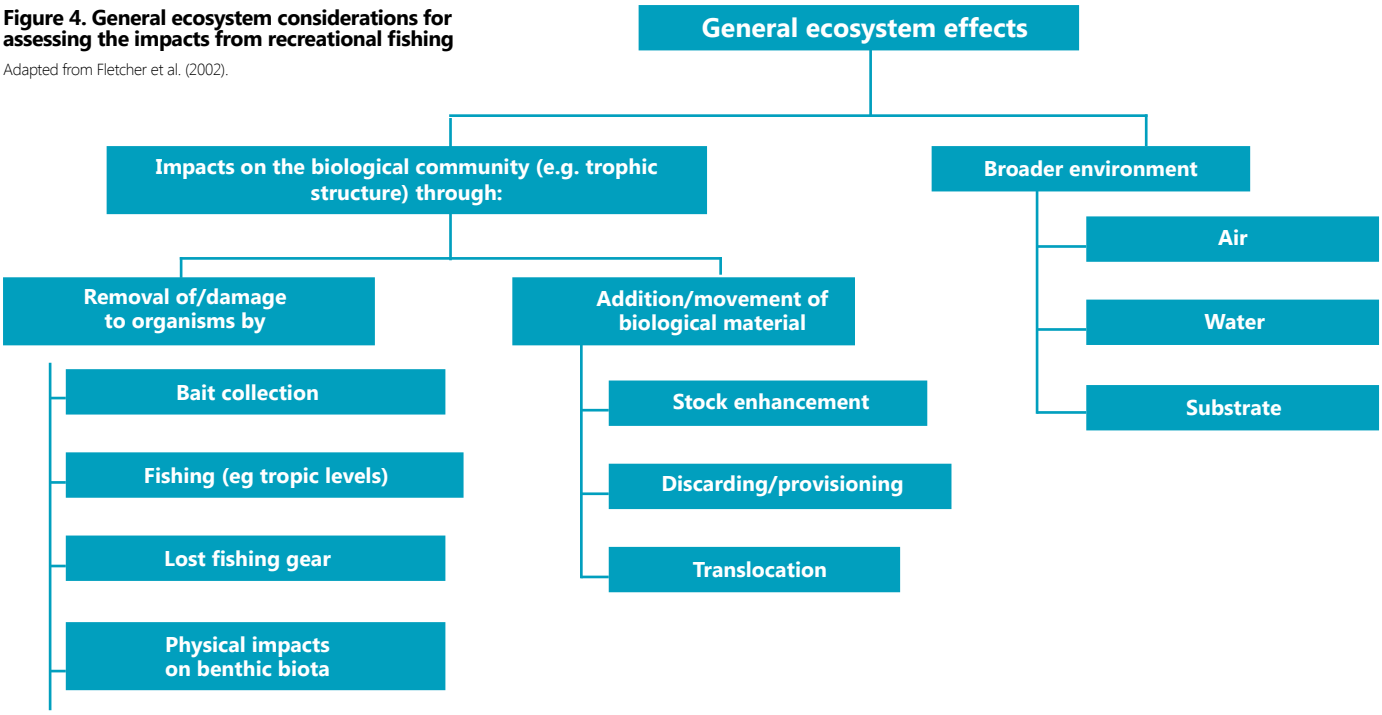


Figure 4. General ecosystem considerations for assessing the impacts from recreational fishing

Adapted from Fletcher et al. (2002).



Identifying the ecological impacts of recreational fishing in Victoria

A summary of ecological impacts

This subsection discusses the potential impacts of recreational fishing in Victoria, and gives evidence for these impacts from local and international sources. The ESD framework described above is used to identify possible threats from recreational fishing and their direct and indirect impacts on the environment. These threats are summarised in Table 10, including recreational fishing monitoring programs and the management agency responsibilities in Victoria.

Targeted/retained species

Primary species

Although recreational anglers catch and retain a wide variety of species, a few key species are particularly favoured and often targeted exclusively. In many situations the recreational catch of such species is comparable to or exceeds the commercial catch (e.g. Coleman et al. 2004). This is shown in Table 3 for key recreational fisheries in Victoria, and selected Australian fisheries in Table 11. Note that this is not necessarily representative of the relative contribution of recreational fisheries to the catch from Australian fisheries as a whole. Nevertheless, the data in Tables 3 and 11 indicates that in a range of popular recreational fisheries across different species and areas, the recreational catch is considerable.

There is a range of potential impacts that fishing pressure can have on populations of harvested species, including changes to rates of growth, size at maturity or sex distribution (Lewin et al. 2006, Matsumura et al. 2011). The most significant impact, however, is recruitment overfishing.

Table 10. Summary of ecological threats from recreational fishing in Victoria

Threat	Direct impacts	Indirect impacts	Agency responsible	Monitoring programs
Retention of target species	Population depletions	Trophic and ecosystem changes	Fisheries Victoria	Boat ramp and phone surveys, commercial fishing data trends, some independent monitoring of stocks
Discards and bycatch	Death or injury of discards	Population depletions	Fisheries Victoria	Boat ramp and phone surveys
Boat strikes	Death or injury of marine mammals or birds	Population depletions	Department Sustainability and Environment	None, public reporting only
Bait collection	Population depletions	Trophic and ecological changes	Fisheries Victoria	None, some monitoring from recreational fishing surveys
Trophic effects of catch	Change abundance of organisms higher or lowers on the food chain	Wider ecosystem shifts	Department of Sustainability and Environment	None
Lost fishing gear	Entanglements with wildlife	Population depletions	Department of Sustainability and Environment, Environment Protection Authority	None
Physical impacts on biota	Direct loss of seagrass and benthic habitat	Changes to ecosystems and fisheries productivity	Department of Sustainability and Environment	None
Stock enhancement	Reduce genetic diversity, translocation of disease	Change community and ecosystem interactions	Fisheries Victoria	None as currently no stock enhancement programs in marine waters
Discards of bait	Localised eutrophication	Potential benefits for introduced species	None	None
Translocation	Reduce genetic diversity, translocation of disease	Change community and ecosystem interactions	Fisheries Victoria	Official permit required
Air/water/beach pollution	Oil/fuel leaks, carbon emissions, garbage, loss of lead sinkers, 4WD beach erosion;	Population and ecosystem impacts	Environment Protection Authority, Department of Sustainability and Environment	None
Artificial Reefs	Altered seabed habitat	Aggregation of targeted species	Department of Sustainability and Environment, Fisheries Victoria	Surveys of benthic and pelagic fish community specific to each reef array

This occurs when fishing pressure is sufficiently high to deplete the abundance of breeding individuals to a point where they are no longer able to produce enough new recruits to replenish the fishery. Fishing pressure at this level is unsustainable and will lead to the collapse of stocks (Walters and Martell 2004). Growth overfishing, on the other hand, occurs when fish are harvested at a size that is smaller than would produce the maximum weight per individual, meaning that the fishery is not reaching its 'potential' yield. If the average size of catch is increased in such cases, a greater weight of catch can be taken with less fishing pressure—a characteristic particularly important in commercial fisheries (Hilborn 2007, 2009).

The magnitude of the recreational catch in some areas, such as those listed in Table 11, suggests there is at least the potential for overfishing to occur in these fisheries. However, the magnitude of catch should not be considered in isolation—the nature of recreational fishing pressure is also important.

Recreational fishing pressure tends to be highly localised (e.g. West and Gordon 1994, Lynch 2006) and is often correlated with population centres and access points such as piers and boat ramps (Stuart-Smith et al. 2008). Ryan et al. (2009), for example, suggest that 88% of the recreational catch from all Victorian bays and inlets came from Port Phillip Bay. This concentrated pressure can exacerbate threats to the reproductive viability of local populations.

Gorfine (2004) notes this threat for abalone stocks on accessible nearshore reefs in Victoria. He suggests that concentrated effort in these areas can decrease the abundance and, importantly,

Table 11. Magnitude of recreational and commercial catch in select Australian fisheries

Location	Species	Recreational catch (t)	Commercial catch (t)	Reference
South-west Western Australia	Blue swimmer crab *Portunus pelagicus*	395	505	(Sumner et al. 2000)
Shark Bay, Western Australia	Snapper *P. auratus*	9	1	(Mitchell et al. 2008)
Richmond and Clarence rivers, New South Wales	Bream, flathead and whiting	70	54	(West and Gordon 1994)
Victoria	Elephant fish *Callorhinchus milii*	45	69	(Braccini et al. 2008)
Perth, Western Australia	Roe's abalone *Haliotis roei*	40	36	(Department of Fisheries 2010)
Western Australia	Tailor *P. saltatrix*	651	56	(Young et al. 1999, (Fisheries Western Australia 2000)
Illawarra, Tuggerah, Wallis and Coila lakes, New South Wales	Penaeid prawns	96	343	(Reid and Montgomery 2005)
Stockton Beach, New South Wales	Pipi, *Donax deltoids*	47	191	(Murray-Jones and Steffe 2000)

See also Table 3 for popular Victorian species.

the density of mature abalone. If densities become too low, reduced sperm and egg concentrations at the time of spawning may impinge on reproductive success (Allee 1949, Babcock and Keesing 1999). This is particularly important in species such as abalone, because their relatively limited larval dispersal can hinder replenishment by more distant stocks (Prince 2005).

Another example is given by Griffiths et al. (2010 p. 79), who note that while the overall catch of longtail tuna *Thunnus tonggol* is likely to be sustainable, they 'may be particularly vulnerable to overexploitation by sport fishers owing to their restricted coastal distribution and their slow growth'.

Stuart-Smith and Barrett (2008) also noted that accessibility and concentration of effort were factors affecting the abundance of a range of fished species in Tasmania. In particular, their results indicate 'that the recreational fishery for rock lobster on the Tasmanian east coast likely affects the relative abundance of legal-sized lobsters in the depth range of our surveys (5–10 m) and that impacts are greatest at sites closer to boat ramps' (Stuart-Smith et al. 2008 p. 124). The distribution of catch effort is the important factor here. While Lyle and Morton estimate that the recreational catch of rock lobster was only eight per cent of the commercial catch in 2004 (119 t versus 1 523 t—Lyle and Morton 2006), they note (p. 26) that 'if only shallow-water catches were considered, then the state-wide recreational catch was just under one quarter of size of the commercial take in 2004–2005 and almost equivalent to the commercial catch off the south-east coast'.

Related to the issue of concentrated effort is the problem of serial depletion. As noted above, fishing pressure tends to be concentrated in popular locations—such as areas closer to boat ramps—or on popular species. If stocks or preferred species become depleted in these areas, fishing effort shifts to the next most popular area or species. This puts pressure on those stocks and potentially leads to their depletion. Importantly, this can occur without any concomitant

increase in overall fishing effort or catch. It is particularly problematic for species that have relatively closed populations at small spatial scales, because localised depletions may not recover (Prince 2005). Tracey and Lyle (2011) observed this phenomenon among three scallop species in a Tasmanian recreational scallop fishery. They suggest that once stocks of the preferred species *Pecten fumatus* had been depleted, divers began targeting their next preferred species *Equichlamys bifrons*, depleting the abundance of that species as well.

A compounding issue is that localised recreational fishing pressure can persist even when catch rates are low (Gorfine 2004). Commercial fishers are driven largely by financial imperatives and will either stop fishing or move to other stocks once catch rates become unprofitable (Salas and Gaertner 2004). This can provide some safeguard against overfishing (Grafton et al. 2007). This threshold is much lower for recreational fishers, who primarily fish 'to be outdoors', 'to relax' and 'to be with friends/family' (e.g. Henry and Lyle 2003, Ernst and Young 2009). The problem is that the maintenance of even low levels of fishing pressure on depressed stocks can prevent recovery through the above-mentioned issue of reduced fertilisation success at low densities (Allee 1949, Babcock and Keesing 1999).

Discards/returns

There is a range of reasons why fishers return a caught fish to the water. It may be undersized, in excess of the fisher's bag limit, or otherwise illegal to retain (e.g. female lobsters with eggs). Alternatively, fishers may simply be fishing for sport and to 'catch and release' (Abbott et al. 2009).

The rate of return and the post-release survival of returned catch have significant implications for the sustainability of those species (Coggins Jr et al. 2007).

Rates of return can vary enormously across recreational fisheries. From their comprehensive national survey of recreational fishers, Henry and Lyle (2003) estimated a 44% discard rate across finfish species. On the other hand, they estimated a discard rate of only nine per cent for harvested molluscs. Popular species/groups had a range of discard rates: bream 63%; flathead 45%; King George whiting 26%; pink snapper 66%; and tailor 38% (Henry and Lyle 2003 p. 175).

The survival of returned fish is variable and highly dependent on the species, tackle, location, environmental conditions, the fishing method used and the quality of the handling (e.g. Grixti et al. 2007, Grixti et al. 2010b). Most estimates range between zero and 95% (Munoeke and Childress 1994). Grixti et al. (2010a) demonstrated this high level of variability in a study of pink snapper *P. auratus* in Port Phillip Bay. They estimated the survival of fish hooked in the mouth to be 97%, while the survival of 'deep hooked' fish was 48%, falling to only 42% if the hook was removed.

Even at very high rates of survival, the impacts of post-release mortality on fish stocks may be significant. Modelling by Henderson (2009) shows that even with 75% survival of released blue cod *Parapercis colias* in New Zealand, the mortality of released individuals can still have significant impacts on the viability (and in this case, the recovery) of fished populations. Similarly, a study of murray cod *Maccullochella peelii peelii* in Victoria (Douglas et al. 2010), indicates that even with experimental survival rates of 98%, the high return rate of this species (approx. 93%) means 'discard deaths could be at least as important to consider in stock assessments as death due to directed harvest' (p. 21).

In addition to the potential issues of fish returned to the water, McPhee et al. (2002) also highlight the problem of fishers retaining undersized fish. West and Gordon (West and Gordon 1994), for example, reported that 78% of retained mulloway and 56% of retained sand whiting in the Clarence River, New South Wales, were undersized. Fortunately, as non-compliance is likely to be a combined function of education, attitudes and enforcement activities, there is a range of mechanisms through which it can be addressed. Moreover, compliance reports from various State fishery authorities (e.g. less than 10% of Victorian recreational fishers intercepted in 2011 were non-compliant—Department of Primary Industries 2011), suggest that the low level of compliance in West and Gordon (1994) may be atypical.

Evidence of impacts on targeted species

In summary, recreational fishing has the potential to impact on retained or targeted species because of the:

- magnitude of the recreational catch in some fisheries/areas
- tendency for localised effort
- potential for fishing pressure to persist, even at low stock levels
- variable levels of survival of fish returned to the water.

These issues, in combination, suggest that the magnitude and nature of recreational

catch have the potential, in some circumstances, to impact populations of retained species. Examples of the impact of recreational fishing on target species have been documented in a range of systems:

- the collapse of four inland fisheries in Canada (Post et al. 2002)
- differences in the biomass of key species between protected (no fishing) and unprotected areas of Ningaloo Marine Park, Western Australia (Westera et al. 2003)
- significantly higher density, abundance and biomass of target species in inshore marine national park ('green') zones compared to inshore recreationally fished areas in the Great Barrier Reef Marine Park (Evans and Russ 2004, Williamson et al. 2004)
- Braccinni et al. (2008 p. 25) suggest that for elephant fish in Victoria, there is a 'high risk of the current harvest levels being not sustainable' when the recreational (45 t) and commercial (69 t) catch are considered together
- depletion of scallop stocks by recreational divers in Tasmania (Tracey and Lyle 2011)
- the size of three intertidal gastropods, and the abundance of one, were significantly greater on Port Phillip Bay intertidal reefs that had *de facto* protection from recreational harvesting (Keough et al. 1993)
- the overexploitation of marron *Cherax cainii* in one of two stocks recreationally harvested in Western Australian stocks (Stephen et al. 2011)
- the collapse of regional stocks of two species of bass in California, United States, in response to the targeting of spawning aggregations by recreational fishers (Erisman et al. 2011).

Direct interactions with other species

Bycatch/non-targeted catch

In commercial fisheries, bycatch or byproduct usually relates to marketable non-target species that are caught in the process of catching a more desirable 'target' species. Recreational fisheries operate similarly, with anglers typically catching a wide range of species (e.g. see Appendix 5.12 in Henry and Lyle 2003) during the process of catching a few favoured species. While the potential impacts on these less-favoured species are the same as outlined above, the risk of such impacts is likely to be less, simply for the fact that the magnitude of catch is reduced. Unwanted catch may include relatively common species, such as toadfish (Tetraodotidae). Nevertheless, fishing pressure could be an issue for low-productivity, low-abundance species that would be vulnerable to even low levels of catch (McPhee et al. 2002). While there is a wide range of species for which these details are simply not known, while others have been listed in formal protected-species legislation.

Examples include the endangered grey nurse shark *Charcarius taurus*. Otway et al. (2003) note that, based on dive surveys between 1991 and 2001, the number of grey nurse sharks with remnants of fishing gear (i.e. hooks and broken line) embedded in them increased from two per cent to 12%. Combined with extremely high estimates of juvenile mortality, Otway et al. go on to note that 'the accidental hooking of grey nurse sharks is potentially an important process that may threaten the recovery of the species' (p. 42).

Quantifying the threat to the grey nurse shark and other species incidentally caught by recreational angling is extremely difficult. Understanding the number of interactions alone is complex, as recreational fishers are not obliged to report interactions. Also, because of their rarity, these interactions are not likely to be accurately sampled in population-level surveys (e.g. Henry and Lyle 2003). More highly targeted surveys of keen, high-effort anglers, such as those discussed by Ryan et al. (2009), may offer more useful data, though the challenge of understanding the population-level implications of such interactions remains. In the light of the above, protection of known aggregation sites, breeding grounds or other critical habitat from fishing may be an important precautionary management step (Otway et al. 2003).

Interaction, but no capture

Impacts under this category refer to direct interactions between fishers and animals that are not related to the animal being caught. For recreational fisheries, the primary potential impact is collision between marine animals and boats (McPhee et al. 2002).

Boat use is intimately linked with recreational fishing. Hardiman and Burgin (2010) noted that between 1999 and 2009, the number of registered recreational boats in Australia increased from 589 346 to 803 788. In Victoria, with approximately 180 000 registered recreational vessels, 70% of trips in 2009 were for fishing, spending an estimated 3 748 800 hours on the water (Cassell and Ashby 2010).

Large, relatively slow-moving animals such as turtles, dugongs and sunfish are likely to be particularly vulnerable to vessel strikes. Records of turtle mortalities in Queensland, for example, indicate that vessel strikes

accounted for 42% of the 140 deaths attributable to humans in 2003 (Greenland and Limpus 2003). As these records are based solely on strandings, they are likely to underestimate the true level of mortality from such interactions. While the population-level consequences of this mortality are difficult to assess, the growth in the recreational powerboat sector, particularly for fishing, suggests the need for more careful assessment, particularly in areas where vulnerable species may be present.

Entanglement with active fishing gear is a related threat and has been linked to a two-per-cent reduction in bottlenose dolphin *Tursiops truncatus* in Sarasota Bay, Florida (Powell and Wells 2011). Entanglement in active fishing gear has also been documented for seabirds, unattended lines being implicated in the majority of entanglements recorded by Ferris and Ferris (2004).

General ecosystem effects

As noted by Fletcher et al. (2002 p. 38), the general ecosystem effects of fishing 'cover the indirect and more diffuse interactions of a fishery with the broader ecosystem and environment. Consequently, there will generally be a greater degree of uncertainty about what is, or is not, likely to be an issue for a fishery'.

Bait collection

The potential ecological impacts on species collected as bait for fishing are the same as for species targeted for consumption or sport, which were discussed above. While there have been relatively few studies of recreationally harvested bait species in Australia, there are clear examples that show such harvesting can have impacts.

In experiments on the Californian coast, Smith and Murray (2005) demonstrated that even low levels of harvesting of the mussel *Mytilus californianus* can have significant impacts on the cover, density, biomass and size of mussels over time. Experiments by Fairweather (1991) on the New South Wales coastline suggest similar implications for populations of the ascidian *Pyura stolonifera*, a popular bait species across south-eastern Australia. Skilleter et al. (2005) also concluded that there are significant but local impacts from the harvesting of ghost shrimp *Trypaea australiensis* in a Queensland embayment. They noted that these impacts extended to several other benthic taxa (including crabs, polychaetes and bivalves), which became patchier as a result of sediment disturbance (Skilleter et al. 2005).

Recognising the particular vulnerability of the intertidal region to the impacts of bait and food collection, Victorian recreational fishers are heavily restricted in what they can collect from the intertidal shoreline in Port Phillip Bay and, to a lesser extent, along the broader Victorian coastline.

Trophic effects of fishing

It is well recognised that the fishing pressure put on a single species can have a range of complex flow-on impacts on the broader ecosystem (e.g. Hughes 1994, Pinnegar et al. 2000, Frank et al. 2005). These interactions between trophic (nutrition) levels can include increases in the abundance of competitors, decreased abundance of predators, altered benthic habitat or reduced mean trophic levels (Pauly et al. 1998, Mangel and Levin 2005). Little work has been done specifically on recreational fisheries but, in cases where catches are comparable to, or exceed, those of commercial fisheries, similar impacts may be expected. For example, in the Ningaloo Marine Park in Western Australia, Westera et al. (2003) reported significant differences in marine assemblages between recreationally fished and protected areas, suggesting some level of trophic disruption through fishing. The problem is that while there is clearly the potential for commercial and recreational sectors to impact on trophic interactions, there is a distinct lack of information for most Australian fisheries, representing a key gap in management.

Lost fishing gear

Entanglements of birds, turtles, fish and marine mammals in discarded fishing hooks, lines, pots and ropes are widely observed. As suggested by McPhee (2002) and Laist (1987), such waste is perhaps the most significant pollution problem from recreational fisheries.

Wells (1998) notes, for example, that the mortality of bottlenose dolphins in discarded fishing line in Florida could be greater than that caused by commercial net fishing. In Queensland in 2003, there were 22 turtles recorded as having been killed by ingestion of fishing tackle or entanglement in recreational crab pots and lines (Greenland and Limpus 2003). While the population-level consequences of such waste-related mortality are unclear, there is certainly an animal welfare issue that should be highlighted. With respect to birds, for example, Ferris and Ferris (2004) report that of 537 pelicans *Pelecanus conspicillatus* rescued in the Richmond River, New South Wales over nine years (1993–2002),

94% were entangled in fishing line and hooks. Importantly, Ferris and Ferris (2004) noted that many of these entanglements were associated with active but unattended fishing lines.

Physical impacts on benthic biota

The potential physical impacts on benthic biota by commercial fishing equipment, such as trawls, are widely appreciated (Beddington et al. 2007). But there is also the potential for impacts from the recreational sector. In particular, fragile habitats such as seagrass beds and coral reefs may be damaged by anchors (Frisch et al. 2008) or, in shallow waters, from propellers (Norman 2001).

Again, quantification of these impacts is difficult, but likely to be proportionate to the growth in recreational vessel ownership observed in Australia over the past ten years (Burgin and Hardiman 2011). In addition, Kearney (2002 p. 208) notes that such impacts should also be considered in light of the already heavy pressures on coastal marine habitats: 'the large number of boats involved and the growing weight of evidence on total environmental degradation suggests that education, and perhaps a code of practice similar to that for commercial fishers, could be advantageous'.

The impacts of trampling on intertidal biota, such as the seaweed, Neptune's necklace *Hormosira banksii*, have been well documented on south-east Australia's rocky intertidal platforms (e.g. Keough and Quinn 1998). However, although recreational fishers may contribute to such impacts, their impacts are likely to be no more severe than those of a range of other users of these highly frequented environments.

Stock enhancement

Unlike freshwater systems in Australia, marine recreational fisheries are generally not supplemented by stock additions (McPhee et al. 2002). There are substantial risks associated with stock enhancements, including impacts on genetic diversity, trophic interactions and the translocation of disease (Cowx 1994, Pearsons and Hopley 1999). Despite these threats, restocking of popular recreational species has been considered in some cases. For example, Dibden et al. (2000) report on a stocking experiment with black bream *A. butcheri* in the Swan River, Western Australia. In New South Wales there has been extensive stocking of both mulloway and prawns in coastal estuaries (Cardno Ecology Lab 2011). In Victoria, Taylor (2010) assessed 20 estuary-species combinations, identifying seven potential cases for re-stocking. However, he noted that substantially more research needed to be done to assess the feasibility of these cases, along with thorough environmental impact and risk assessments.

Bait discarding

Authors such as Lewin et al. (2006) identify provisioning (of bait) as a mechanism that can potentially lead to eutrophication of aquatic systems. Other authors suggest that highly localised provisioning, such as the cleaning of fish at piers and boat ramps, may benefit pest species (Kinloch et al. 2003). There have not been any direct studies of these potential impacts in Australian waters. Bait discards increase nutrients to the benthic environment, as bait generally sinks to the sea floor and is consumed by benthic organisms. The effect of this boost to benthic productivity is unknown in Victoria. Nevertheless, concentration of bait discards in seasonal fisheries, such as the snapper spawning aggregation in the Carrum Bight (unofficially estimated at many tonnes per week of discarded bait, mainly pilchards used as berley), may have significant consequences for the population dynamics of exotic species such as the northern pacific seastar and *Sabella* fanworms, and warrants a risk analysis.

Translocation

Hardiman and Burgin (2010) suggest one of the greatest potential threats posed by recreational vessels, such as those used by recreational fishers, is to translocate aquatic pests. Although Kinloch et al. (2003) ranked recreational motorboats relatively low as a potential vector of marine pests in Australia, Dommisse and Hough (2004) noted that both recreational and commercial fishing gear can entrain the northern pacific seastar *Asterias amurensis*, noting it has the potential to be a major vector for translocation (p. 32). Further, Hayes et al. (2007) suggest that the spread of Japanese kelp *Undaria pinnatifida* around the south-east coast of Tasmania 'is in part attributed to the movement of the vessels of recreational and commercial fishers and divers' (p. 1).

Air/water pollution

The broader impacts of recreational fishing on air and water quality relate mainly to the impacts associated with motorboats. As noted previously, a large proportion of the more than 800 000 registered recreational vessels in Australia (Burgin and Hardiman 2011) are used primarily for fishing (e.g. 70% in Victoria—Cassell and Ashby 2010). Each of these vessels is a potential source

of pollution (Hardiman and Burgin 2010).

In 2001, Norman (2001 p. 9) suggested that 'most' recreational vessels used two-stroke engines that deposited up to 25% of their hydrocarbon intake directly into the environment. Ten years later, Burgin and Hardiman (2011 p. 689) indicated that cleaner and more efficient four-stroke engines have helped most recreational vessels (70–80%) 'ameliorate the worst of the pollution from engine chemicals'. Nevertheless, they caution that little is known about the accumulation of engine chemicals in sediments. While Burgin and Hardiman (2011) also discuss potential impacts from sources such as anti-fouling paints, this is likely to be a less substantial issue for recreational fishing vessels, the majority of which are trailer-based (Kinloch et al. 2003).

Other possible sources of water pollution from recreational fishing include general waste from fishing activity e.g. bait bags (Ferris and Ferris 2004), lead sinkers and other refuse. This waste poses a threat to wildlife through entanglement or ingestion. Scheuhammer et al. (2003), for example, report over 400 cases of lead poisoning in birds and turtles in North America, all linked to the ingestion of lead sinkers. The magnitude of such waste is likely to be a function of fishing pressure, fisher behaviour, fishing technique and gear type, indicating a range of avenues for improved management of this issue.

The scale of recreational boating activity associated with fishing also highlights the potential for significant greenhouse gas emissions from this sector. According to the Australian government's National Greenhouse Gas Inventory for 2010, the recreational boating sector emitted 1 109 780 t of CO2 (and equivalent gases—AGEIS 2010). This compares to the 2 920 630 t emitted by all domestic marine transport and the 6 160 150 t emitted through domestic air transport (AGEIS 2010). It is likely that while recreational boat use has grown in Australia over the past ten years, emissions may have been partly offset by the improved fuel efficiency of engines (Burgin and Hardiman 2011).

With respect to substrate, the main threat posed by recreational fishing is the use of four-wheel-drive vehicles on sandy beaches, either for launching boats or for shore-based fishing (Hardiman and Burgin 2010). Although Schlacher and Thompson (2008) show that vehicle tracks can cover up to 90% of some shorelines, the implications for coastal erosion have not been studied. Dune habitat—the access point to many beaches—is likely to be particularly vulnerable to such impacts, with nesting shorebirds at particular risk. It is also unclear what proportion of four-wheel-drive activity is attributable to recreational fishing as opposed to other forms of coastal recreational activity.

Monitoring the ecological impacts of recreational fishing in Victoria

Overview

The key responsibility of Fisheries Victoria is to manage fisheries in an ecologically sustainable manner (*Fisheries Act 1995*), which includes the management of bycatch and byproduct species, and the aquatic habitats on which fisheries depend. Responsibility for monitoring the indirect impacts of fishing on habitats and other species is shared between the Environment Protection Authority (EPA) and the Department of Sustainability and Environment (DSE), although who has lead responsibility is often unclear. Many impacts will be monitored in an *ad-hoc* manner, as issues are perceived to arise.

Current Victorian monitoring of identified recreational fishing impacts

Discards and bycatch

Fisheries Victoria uses onsite boat-ramp surveys and the angler diary program to assess rates of discards from recreational fishers. Large-scale surveys such as Henry and Lyle (2003) estimated rates of discards, and this is likely to be continued under the future angler survey program under development (M. MacDonald, pers. comm.). Fisheries Victoria has also conducted a number of studies quantifying the consequences of recreational fishing discards on key species: black bream (Grixti 2007, 2008); snapper (Grixti 2010a; 2010b); and King George whiting (Grixti 2010b). Used together with accurate measures of discard rates from angler diaries and onsite surveys, the total discard mortality can be taken into account in stock assessments. Such studies are also used to guide education aimed at lowering the rates of discard mortality. The next logical step is to review the survival rates of key species caught using different gear types, with the intention of considering gear restrictions as management solutions for ecologically sustainable harvest strategies (Cooke and Schramm 2007). Grixti (2010b) detailed the mortality of fish caught by circle hooks or longshank hooks, and similar programs should be initiated to measure the mortality of discarded fish from other gear types across all key species.

Boat strikes

Injuries or death of animals by boatstrike are considered uncommon in Victoria, and thus authorities rely on citizen reporting of incidents. Responding to injured animals is the responsibility of DSE under the *Wildlife Act 1975, Flora and Fauna Guarantee Act 1988* and the *Prevention of Cruelty to Animals Act 1986*. Due to the few documented occurrences of boat strikes in Victoria (Department of Sustainability and Environment 2011), an intensive monitoring program is unlikely to yield useful data for management. The current system of public reporting is likely to be adequate, although it is necessary to improve education of boat users around the regulations of boat-mammal interactions and best boating practice to avoid collisions.

Bait collection

As bait collection is in effect a recreational fishing activity involving the take of a marine organism under the *Fisheries Act 1995*, stocks require review by Fisheries Victoria in the same manner as other species. This is demonstrated by the recent investigation into pipi harvest at Venus Bay (Department of Primary Industries 2009). A risk analysis of the major bait populations in Victoria is warranted, in particular those of recognised vulnerability such as intertidal gastropods.

Trophic effects

The trophic effects of fish removal is generally not considered to be an issue of high risk or impact by Fisheries Victoria (DPI 2008), thus no direct monitoring of ecosystem effects of fishing is ongoing in Victoria. Despite the lack of published risk assessments, however, this should still be considered a potential threat to marine ecosystems in Victoria.

Lost fishing gear

The loss of fishing gear is considered a littering offence, with its monitoring and regulation the responsibility of the EPA under the *Environment Protection Act 1970*. Responding to the entanglements of birds and marine mammals in lost fishing gear is the responsibility of DSE under the *Wildlife Act 1975, Flora and Fauna Guarantee Act 1988* and the *Prevention of Cruelty to Animals Act 1986*. Entanglements with whales and dolphins are listed emergencies under the *Emergency Management Act 1986*. Citizens are encouraged to report littering and entanglements to the appropriate authorities.

Physical impacts on aquatic habitat

Although both Fisheries Victoria and DSE have responsibility to manage aquatic habitats, no routine monitoring occurs that could successfully detect the extent of physical impacts by recreational fishers.

Stock enhancement

There is currently no stock enhancement of marine fisheries in Victoria, although there are extensive freshwater stocking programs. A report into the potential of marine stock enhancement in Victoria (Taylor 2010) identified only a small number of opportunities for stocking of Victorian estuaries, although plans are currently underway to stock eastern king prawns in Lake Tyers (Fisheries Victoria). Stock enhancement has the potential to significantly disrupt natural systems, so severe caution must be applied and thorough independent risk assessment and post-monitoring programs are essential.

Discarding bait

The discarding of bait is not generally considered an offence, and any impacts of eutrophication are thought to be very localised. The potential for spread of disease or exotic species by discarded bait is not monitored, although the sale and transport of some baits are restricted due to this concern.

Translocation

Although highlighted as a factor in the spread of exotic or unwanted species, marine pest translocation by recreational fishers is not monitored in Victoria. Concern over the spread of the abalone ganglioneuritis virus in the late 2000s resulted in a strengthening of education initiatives and the regulations governing translocation of marine plants and animals. More recently, Fisheries Victoria initiated a ban on the use of live European green shore crabs as bait to stop their spread; however, a major flaw still allows the live transport of the species. The national code of practice for recreational fishing (Recreational Fishing Advisory Committee 2011) does not directly dissuade translocation and should be updated to reflect the dangers associated with this practice.

Air/water pollution

The EPA is responsible for the control of air and water pollution stemming from recreational fishing operations under a range of legislation related to the *Environment Protection Act 1970*. Citizens are encouraged to report any such offences. Currently, there are no requirements to monitor the fuel consumption or carbon emissions of recreational fishing operations, although recreational boat use is accounted for nationally under the Australian Greenhouse Gas Inventory (AGEIS 2010).

Recommendations

Recommendation 11: Stock enhancement proposals should be subjected to a public environment impact assessment process supported by an independent and thorough risk assessment.

Recommendation 12: The live transport of invasive noxious pests (e.g. European green shore crabs) as bait should be prohibited and the national code of practice for recreational fishing (Recreational Fishing Advisory Committee 2011) amended to reflect this.

Recommendation 13: The use of biodegradable hooks and fishing lines should be introduced gradually over the next five years, at which time they could become mandatory.

The impact of recreational fishing in Port Phillip Bay, Victoria

The importance of Port Phillip Bay for fishing

This section documents the magnitude, diversity and impacts of the recreational fish catch in Port Phillip Bay, Victoria, as compared to co-occurring commercial fisheries.

The Department of Primary Industries (2010) notes that 'Port Phillip Bay is the most important embayment in Victoria for recreational fishing, with 55% of fishers who hold a recreational fishing licence nominating the bay as their most frequented fishing destination' (p. 8). Ernst and Young's 2009 survey of recreational fishers in Victoria indicated that 57% of the recreational fishing licences in Victoria were purchased in the Melbourne–Port Phillip Bay region. Using results from the National Recreational and Indigenous Fishing Survey (Henry and Lyle 2003), Ryan et al. (2009) noted that 88% of the total recreational catch from Victorian bays and inlets, and 47% of the state-wide retained recreational catch, was taken from Port Phillip Bay in 2000–2001. Port Phillip Bay, on the doorstep of Melbourne, is thus clearly one of the most important regions for recreational fishing in Victoria.

Although recreational fishers are permitted to use a diverse range of equipment and methods in Port Phillip Bay, around 97% line fish (Henry and Lyle 2003, Ernst and Young 2009). While Henry and Lyle (2003) estimated that close to 40% of Victorian fishing effort was boat-based in 2001, Ryan et al. (2009) indicate that these fishers took 95% of the total recreational catch from Port Phillip Bay.

The multi-species, multi-gear commercial fishery in Port Phillip Bay provides 48% of the commercial catch from Victorian bays and inlets (Department of Primary Industries 2010b). The fishery is limited through 40 transferable access licences. Licence holders are eligible to use a range of gear types including mesh nets, haul seines, long-lines, handlines, traps and jigs, though mesh nets and haul seines account for the majority of the catch. With the exception of species such as rock lobster *J. edwardsii* and abalone *Haliotis* spp., licence-holders may harvest most species of commercial value (Table 12). Minimum lengths apply to many species, but few have catch limits. King George whiting is the most valuable species in the fishery.

Table 12. Total 2009–2010 catch composition of the primary commercial species from Port Phillip Bay, sorted by market value

Species	Wholesale market value ($'000)	Commercial catch (t)	Proportion of total commercial catch (%)
King George whiting	1 414	86	13
Snapper	630	83	12
Calamari, southern	445	34	5
Other (mainly sardines)	397	312	46
Flathead, rock	206	31	5
Garfish, southern	127	18	3
Anchovy, Australian	109	44	6
Flathead, bluespotted	60	14	2
Flounder, greenback	38	4	1
Mullet, yelloweye	35	18	3
Gummy shark	33	3	0
Australian salmon	22	32	5
Flathead, southern sand	8	2	0
Total	**3 524**	**681**	**100**

Value is estimated from Melbourne Fish Market auction prices. Data sourced from Department of Primary Industries commercial fish production report – http://www.new.dpi.vic.gov.au/fisheries/commercial-fishing/commercial-fish-production-2010/.

Commercial and recreational catches in Port Phillip Bay

The species targeted by recreational fishers closely match those sought by the commercial sector and include snapper, King George whiting, flathead (mostly sand flathead), calamari, garfish, Australian salmon and gummy shark (Department of Primary Industries 2010b). These preferences are supported by data from the National Recreational and Indigenous Fishing Survey. The data from Henry and Lyle, however, also indicates that although there are a few select, targeted species, a broad range of species are caught and retained in Victorian waters, with more than 62 species in Port Phillip Bay alone (Coutin and Conron 2006).

Table 13 compares the commercial and estimated recreational catches of snapper and King George whiting for Port Phillip Bay. Two issues are immediately apparent, the recreational catch of key species is greater than the commercial catch, and there is little data available on the recreational catch. It is also important to note that the estimates of recreational catches are based on data from 2001 (Henry and Lyle 2003). They are, therefore, likely to be underestimates, given there is anecdotal evidence that recreational catches, particularly of snapper, have increased substantially since then (Department of Primary Industries 2008).

Norman (2001) also compiles several reports showing the substantial magnitude of recreational as compared to commercial catch in Port Phillip Bay. For example, the recreational catch of sand flathead greatly exceeded commercial catches during the period 1990–1994 (240 t versus 8 t). At the same time, the overall recreational finfish catch (excluding anchovies and pilchards) was 469 t, while the commercial catch was 482 t (Coutin et al. 1995 cited by Norman 2001). The problem is that these data are now close to 20 years old. Nevertheless, they demonstrate the general pattern of substantial recreational catches.

Table 13. Magnitude of recreational and commercial catch of select species in Port Phillip Bay

Species	Recreational catch 2000-2001 (t)	Commercial catch 2000-2001 (t)	Commercial catch 2010-2011 (t)	Reference
King George whiting, *S. punctata*	97	85	108	(DPI 2008)
Snapper, *P. auratus*	>208	54	112	(DPI 2008)

Note that estimates of recreational catch are sourced from the Department of Primary Industries (2008), which used the 2000–2001 data from Henry and Lyle (2003). Commercial data are shown for both the period during which the recreational data were collected (2000–2001) and for the most recent available period (2010–2011).

The above data should also be considered in relation to the potential discard mortality from the two sectors. Studies of commercial (Knuckey et al. 2002) and recreational (e.g. Grixti et al. 2010a, Grixti et al. 2010b) fishing practices in Port Phillip Bay point to moderate to high levels of post-release survival of target species (approx. 80–90%). However, even with high levels of survival, the large number of individuals released from both sectors (Knuckey et al. 2002, Grixti et al. 2010a) could contribute to an important source of mortality that needs to be accounted for in stock assessments (*sensu* Douglas et al. 2010). Poor handling practices, a particular risk with inexperienced recreational anglers, may substantially reduce post-release survival (e.g. Grixti et al. 2008).

While the magnitude of the recreational catch of finfish in Port Phillip Bay is substantial and, in many cases, greater than commercial harvests, the impacts of this catch on stocks are less clear. The Department of Primary Industries (2008) regards both snapper and King George whiting to be 'environmentally limited'; their abundance is considered to be largely driven by extraneous environmental variables rather than fishing pressure. Conversely, authors such as Hobday et al. (1999) attribute the decline between 1970 and 1991 of a range of species in fishery-independent surveys to the effects of recreational and commercial fishing. Ecosystem modelling of Port Phillip Bay fisheries e.g. Fulton and Smith (2004) suggests both perspectives are correct to some extent. In view of this, fishing pressure—both commercial and recreational—should not be ignored as a key driver in this system.

Port Phillip Bay is also a key example of how recreational harvesting can deplete intertidal communities. As mentioned previously, surveys by Keough et al. (1993) show that the size and abundance of a selection of harvested intertidal gastropods was significantly higher at sites with de facto protection from collection (i.e. military land). This highlights how recreational fishing pressure can have measurable impacts on marine communities and the value of areas with effective protection from harvesting.

Other ecological impacts in Port Phillip Bay

Aside from the above-mentioned impacts on recreationally targeted species in Port Phillip Bay, there may be a range of other ecological impacts associated with fishing practices in this area. Although often cited as a potential impact, trophic effects are unclear. For example, while Hobday et al. (1999) link an increase in stingaree (*Urolophus* spp.) abundance to the fishing down of competitors, the evidence is ambiguous. Nevertheless, the magnitude of the recreational catch as compared to the commercial catch in Port Phillip Bay indicates that if there are impacts from fishing, they are likely to be as much attributable to the recreational sector as to the commercial.

The prevalence of boat-based fishing in Port Phillip Bay, as noted previously in this review, has the potential for a range of impacts. Unlike more northerly Australian waters, collisions with marine animals such as turtles or dugongs are highly unlikely because of their low abundance or complete absence in southern waters. There is some risk of impacts from the concentration of engine pollutants or anchor or propellor damage to seagrass beds. The greater number of recreational vessels makes this sector a more substantial threat in this regard. However, while this threat has not been quantified, Kearney concludes that such impacts are likely to be of minor significance (Kearney 2002). Similarly, while commercial seine nets are generally perceived to be a threat to seagrass habitat (Kearney 2002), work by Knuckey et al. (2002) indicates that these impacts are also likely to be minimal.

The translocation of marine pests may be a particularly significant threat in Port Phillip Bay because of the numerous exotic species that have established populations in the bay (Hobday et al. 1999). For example, recreational and commercial vessels and gear may be potential vectors for transporting Japanese kelp *U. pinnatifida* or the northern pacific seastar *A. amurensis* to ports outside Port Phillip. The number of vessels and their relative exposure (time in the water) are factors contributing to their combined risk (Kinloch et al. 2003). It should also be noted that Victorian legislation allows recreational fishers to transport live European shore crabs *Carcinus maenas* across the state. While such crabs must not be used as live bait, there remains some risk of accidental translocation through escapees or the use of females carrying eggs. Within Port Phillip Bay, where the species is common, this is unlikely to be problematic. As with the other species noted above, the greatest risk is the translocation of these species to other areas along the coastline that are yet to be invaded.

As compared to the well-documented interactions between birds and fishing gear in New South Wales rivers (Ferris and Ferris 2004), animal entanglements in recreational fishing equipment appear to be a relatively poorly documented issue in Port Phillip Bay. Nevertheless, Harrigan (1991) and Norman (2000) both present cases of interactions between birds and fishing gear. Harrigan (1991), for example, notes several instances of little penguin *Eudyptula minor* mortality due to entanglement in discarded fishing tackle or lead poisoning from an ingested lead fishing sinker. Unpublished data collected by Wildlife Victoria indicates that between May 2011 and May 2012, there were over 150 reported cases of wildlife being entangled in fishing line in the suburbs of Melbourne and Geelong, including 22 swans *Cygnus atratus* and 11 seals *Arctocephalus pusillus* (K. Masson, Wildlife Victoria, pers. comm.). As these cases were incidental observations, the broader level of entanglement in fishing gear and the associated ecological implications remain unclear.

ALTERNATIVE MANAGEMENT STRATEGIES FOR RECREATIONAL FISHING IN VICTORIA

SECTION 3

Challenges of managing recreational fisheries

The challenge facing governments in regulating recreational fishing is a challenge they are largely unable to handle, due to lack of resources, differing priorities and the small political reward. Governments experienced in managing commercial fisheries are finding unique challenges in the recreational sector and experiencing the failure of traditional monitoring, evaluation and enforcement methods (Radomski 2003; Abbott and Wilen 2009). Three main factors create challenges for effective recreational fisheries management: inadequate resources, low economic motivation, and lack of clear goals or performance indicators (Pereira and Hansen 2003).

Inadequate resources

With such large numbers of diverse participants spread over many different geographic locations, monitoring and enforcement are very costly. Agencies are generally equipped to manage commercial fisheries that often have mandatory logbooks, long-term data collection, and established systems of licensing and enforcement. Translating these arrangements directly across to recreational fisheries is often unsuccessful due to the sheer scale of individual participation relative to a commercial fishery. The financial costs of comprehensively monitoring these fisheries are likely to be high. There is also a lack of understanding of the dynamic behaviours of recreational fishers in response to changing stock size or fishing success.

Little economic motivation

There are few individual recreational fisheries considered by governments or management agencies to be economically or politically important enough for them to justify significant management and research expenditure (Periera and Hansen 2003). This has severely restricted the building of knowledge about the marine ecosystems, habitats and species that are the focus of recreational fishers. The limited public funding of fisheries management and research has led to management agencies seeking the recovery of management costs from commercial fishers. Such cost recovery has only recently been considered for recreational fisheries (e.g. *Future fisheries strategy: proposals for reform*), but it could become a feature of management resourcing in the future.

Lack of clear goals or performance indicators

Without specific management plans detailing goals and performance indicators, most management decisions will be reactive rather than proactive. Traditional indicators of the ecological sustainability of commercial fisheries are unlikely to be relevant to, or even obtainable from, recreational fisheries.

The development of appropriate indicators may therefore have to be specific to individual fisheries.

These are the fundamental challenges that fisheries managers must overcome before implementing broader, integrated and ecosystem-based strategies for fisheries management. The motivation to fish is fundamentally different in the recreational fishery compared with the commercial (Kearney 2002), and therefore a traditional focus on maximising optimal yield may have little relevance to recreational fishers (Ihde et al. 2010). There must be a shift away from the resource-based, rigid regulatory system adopted in commercial fisheries towards one that better accounts for the human dimension of recreational fishers (Pereira and Hansen 2003; Arlinghaus and Cowx 2008; Salmi et al. 2008). Echoing comments by fishery scientist, Peter Larkin, about commercial fisheries, Arlinghaus (2005) states simply that 'recreational fisheries management is today as much people [management] as fish stock management'. Understanding how fishers respond to management changes is crucial in choosing effective management practices. Levels of compliance, willingness to engage and level of resource stewardship are all important factors to consider when tailoring management practices to each recreational fishery.

Australia's first attempt at a national recreational fishing policy was prepared in 1994 by RecFish Australia, the peak recreational fishing body (RecFish Australia 1994). It included sixteen principles for responsible and sustainable fishing. The policy was recently updated and has become the National Recreational Fishing Strategy (Recreational Fishing Advisory Committee 2011), with 12 recreational fishing principles and clear goals on how to attain them. These principles are non-binding and created from the perspective of the recreational sector, but nevertheless create a very useful input on which to base further management and monitoring programs.

Regulatory and management tools used for recreational fishing in Victoria

Input and output controls

The primary tools that managers possess for controlling the impacts of recreational fishing are known as input controls, which regulate how, where and when fishers can catch their fish (Pope 2009). Input controls are prescriptive by nature and involve the setting of parameters within which fishers can operate. The most common examples are the setting of size and possession limits, but managers can also regulate gear types, closed seasons and area closures (Cooke and Cowx 2006). Input controls are, however, fundamentally designed to regulate the effects of recreational fishing on the stocks of the target species, and not general ecosystem impacts (Holland 2007).

Output controls are primarily focused on capping the total amount of fish harvested by implementing systems such as a Total Allowable Catch (TAC). Although Victoria manages the abalone and rock lobster commercial fisheries using TACs, the recreational component of the fisheries is managed under input controls. There are few examples of TAC controls on recreational fisheries in Australia or the rest of the world.

General framework for fisheries assessment

The general framework for fisheries assessment and management in Victoria is as follows:

- ecological risk assessment of fisheries activity (ERA process described in 'Victorian framework for fisheries management' in Section 1 above)
- identifying moderate to high risk impacts
- developing management controls (primarily input controls)
- evaluating success of management controls and adapting where necessary (adaptive management).

Recent examples of this process, leading to recreational regulatory changes in Victoria, were size-limit increases for black bream in 1997 and 2003, and changes to catch limits for snapper in 2007. Assessment of the Gippsland Lakes black bream fishery in the 1990s identified a significant decline in catch, which was related to persistent poor recruitment (Conron 2004). To reduce the mortality of juvenile fish, and thus increase the number of fish reaching maturity, the size limit was raised to 26 cm in 1997, and then to 28 cm in 2003. The black bream regulatory changes were brought about through the identification of a mechanism for stock decline—recruitment failures—and sought to address this issue by increasing the chance that juveniles could reach maturity (Conron 2004). In effect, the regulations were designed to control recreational and commercial fishing pressure to more sustainable levels.

Such decisions require a fundamental understanding of the biology of the fish (e.g. size at maturity), structure of the fish stock (e.g. proportion of juveniles entering the breeding population) and the structure of the catch (where is the fishing pressure?), all of which can only be gained through effective monitoring programs that quantify these aspects of the fishery. It is vital that any future harvest controls are developed with effective monitoring programs and a firm ecological understanding of other influences on the fishery.

Management changes can also be driven from concern for fish stocks from outside the management agency, as the recent changes to snapper input controls demonstrate. The western Victorian snapper stock was identified as being in decline during the 1990s and early 2000s (Hamer and Jenkins 2007), but it appeared to be recovering during the mid-2000s due to strong juvenile recruitment (Hamer

et al. 2011). However, there was a perception among the recreational fishing community that the current limits were too generous, and that an increase in recreational fishing pressure could put the stock at risk. In October 2007, the minimum legal length was increased from 27 cm to 28 cm, and the number of large fish (>40 cm) that could be taken was reduced to three.

Both these examples address an identified high risk of stock decline. There are no apparent examples in Victoria where management actions have addressed the high risk of ecosystem impacts of recreational fishing. This is probably due to the perception that recreational fishing has little ecological impact beyond the removal of target species.

Seasonal restrictions

Unlike many states in Australia, Victoria has few seasonal restrictions on recreational fishing. Most seasonal closures are implemented to protect fish during spawning periods (Cooke and Cowx 2006), such as snapper in South Australia and Western Australia, and calamari in Tasmania. Seasonal closures on the abalone fishery in Victoria are primarily for enforcement reasons, making all fishing for abalone without a commercial licence in closure periods illegal, and thus easier to enforce. Although the snapper fishery in Port Phillip Bay is focused on spawning aggregations over summer, analysis of the fishery dynamics suggests the stock is limited by larval survival, not by spawning biomass (Department of Primary Industries 2010a). As a result, Fisheries Victoria has not used spawning closures in the fishery's management.

Identification and protection of fish habitats

Although identification and protection of key aquatic habitat is one of the roles of Fisheries Victoria, there are no structured programs covering all estuaries and coastal environments. Fisheries management plans for the smaller estuaries (e.g. Andersons Inlet, Mallacoota Inlet, Corner Inlet and other minor estuaries) state the need for fish habitat studies, and a number of these have been published (Conron et al. 2010; Kent et al. 2010; Kent et al. 2010). The larger and more recreationally important embayments of Port Phillip and Western Port bays do not have explicit fish habitat studies, despite the reliance of many major fish stocks on habitats such as seagrass and rocky reef (rock flathead—Koopman et al. 2004; King George whiting—Department of Primary Industries 2010; calamari—Department of Primary Industries 2010; garfish—Morris et al. 2011). The identification of important fish habitat must then be translated into effective management to conserve and enhance this habitat, particularly if it is limiting natural productivity, marine life recovery and fisheries production. Although the Department of Primary Industries advocates for habitat management, there are currently no direct tools by which Fisheries Victoria can influence decisions impacting such habitat.

Management approaches to recreational fishing in other states of Australia

Overview

Similar management approaches for recreational fishing are adopted across all states and territories of Australia. The use of ecological risk assessment, ecosystem-based management and input control measures are widespread and considered the most acceptable practices available to fisheries agencies. Some states have more comprehensive stock assessment modelling which incorporates commercial and sometimes recreational fishing pressure, and can provide more prescriptive advice on the effectiveness of certain input control measures. Management goals, performance indicators and trigger points (in effect a harvest strategy system) have also been developed for some commercial fisheries in most states, but recreational fisheries are not always incorporated into these assessments. Although many states have output controls on commercial fisheries, usually in the form of a total allowable catch, there are few examples of output-control systems currently applying to recreational fisheries in Australia. Where output controls are in place, the monitoring and enforcement of those controls are not as comprehensive as those applied to the commercial fishery, as the recreational component of these fisheries tends to be very small.

All states promote the national code of practice for responsible recreational fishing developed by the National Recreational Fishing Council (Recreational Fishing Advisory Committee 2011). Education programs to increase awareness of the twelve principles of responsible fishing, and to educate about best practice in fish catch and release, are also a priority for all fishing agencies.

All states, apart from New South Wales, have initiated large-scale recreational fishing surveys since the Henry and Lyle study in 2001. Most states have a number of one-off and ongoing monitoring programs specific to certain fisheries or certain locations, and a full list of these up until 2008 is given in Sahlqvist (2008).

Although all states aim to measure the ecosystem impact of fisheries, the amount of scientific research into these impacts varies among the states. Tasmania stands out as the leading research state. South Australia and Western Australia have strong research links with outside institutions, but such links appear limited in the eastern states.

All states see healthy fish habitat as important to healthy fish stocks, but there are different levels of action and management. In general, more emphasis is placed upon identification, protection and rehabilitation of inland and estuarine waterways, and little on coastal marine habitats. Western Australia has identified and protected key fish habitats, although these currently resemble marine parks similar to those in New South Wales and recently established in South Australia. Queensland has declared fish habitats that do not restrict fishing but are designed to enable the fisheries agency to be involved in planning decisions affecting those habitats.

All states use protected areas as a key tool in providing small and large long-term protection for marine habitats and marine species, including those of recreational importance. These can be in the form of multi-zoned marine parks, such as in Queensland and New South Wales, or marine national parks as in Victoria. There are moves to configure networks of protected areas to improve viability and better accommodate migratory movements. Marine Protected Areas (MPAs) can play a dual role in the management of fished species by both removing the impact of fishing and maintaining productive ecosystems to support targeted species. While there is much energy spent in the debate over the effectiveness of removing fishing pressure in MPAs, more attention needs to be paid to

addressing other, often more diffuse impacts affecting the viability and productivity of the ecological systems that support fished species. MPAs can play a key role in this if funded and managed correctly.

In comparison to other states (see Table 14), Victoria performs reasonably well in recreational fishing monitoring initiatives. The angler diary and onsite boat-ramp survey programs are particularly noteworthy. A general increase in research support, development of harvest strategies, more focus on ecosystem impact of recreational fishing, and the development of programs to identify and protect fish habitat would see Victoria having the most comprehensive recreational fishing management system in Australia.

South Australia

Primary Industries and Regions SA (PIRSA) manages South Australian fisheries under the *Fisheries Management Act 2007*. PIRSA follows a method of assessment and management of recreational fishing very similar to that of Victoria, with major stocks assessed under ERA principles. However, their application is primarily for the commercial side of the fishery. Input controls are the primary form of regulation for the recreational fishery, although the recreational rock lobster fishery is managed under TAC output controls. The TAC in this case is not strictly enforced, but input restrictions will be placed on the recreational fishery if the TAC is exceeded.

Harvest strategies are in place for the key commercial species, based primarily on the status of the stock and not ecosystem impacts, with management controls primarily through changes in TAC allocation. Concerns over stock status have led to a recent lowering of bag limits for snapper. However, concerns over garfish stocks, which led to a commercial netting closure, have not affected controls on recreational fishing.

South Australia uses a number of fishing closures, such as a seasonal one for snapper between 1–30 November to protect spawning stocks, and a spatial one in an identified breeding area for giant cuttlefish near Whyalla.

Recreational fishing effort and catch were last monitored in 2007–2008 by large-scale phone surveys of participants willing to log their catch and effort (Jones 2009).

There are four key differences in the management approaches of South Australia and Victoria:

- South Australia has a more intensive assessment of stock status, including a greater focus on assessing fisheries biomass and developing harvest strategies
- no recreational fishing licence is required in South Australia
- Victoria has a more comprehensive recreational fishing monitoring program in the angler diary and onsite surveys
- South Australia has more seasonal and spatial closures for the purpose of preserving breeding populations and nursery areas.

Western Australia

Western Australian fisheries are managed by the Department of Fisheries under the *Fisheries Resource Management Act 1994*. Recreational fishing licences are required in Western Australia to fish from a boat or to collect specific species such as abalone and rock lobster. The licences are granted to fish across the whole state, but input controls such as catch and size limits vary among the regions of Western Australia. The state is split into four geographic regions, although some smaller subregions are also managed separately (e.g. Shark Bay snapper stocks). There are many spawning season and general temporal closures across the state, including a two-month closure for demersal species in the western zone, and a three-month closure of the snapper fishery in Shark Bay. There is also a total possession limit in Western Australia of two days' bag limit or 20 kg of fish fillets.

All major Western Australian recreational species are assessed using ERA principles developed by Fletcher (2005a) and after having been placed in one of four categories: high, medium and low risk, and protected (Department of Fisheries 2011). Input controls are set for the species according to this risk factor.

Western Australia has established six Fish Habitat Protection Areas (FHPAs), which are managed for the conservation and protection of fish, fish breeding areas or aquatic systems. Management may involve the closure to fishing. In essence, FHPAs are similar to marine sanctuaries but are specifically for the conservation of fish, rather than the general marine ecosystem. They differ from the Declared Fish Habitats identified in Queensland, not in function but in the management and regulations applied.

A recreational fishing survey was conducted in 2011, using telephone interview methods with fishers who had agreed to log their catch and effort (similar to surveys conducted in South Australia, Queensland and the Northern Territory). The survey results were scheduled for release in late 2012, however at time of publication the report had not been made publically available.

The key differences in recreational fishing management between Victoria and Western Australia are:

- Western Australia has a more comprehensive system of ERA for all major fisheries
- Western Australia has a program of fish habitat protection
- Western Australia has more seasonal fish breeding closures.

New South Wales

New South Wales Fisheries are managed by the Department of Primary industries under the *Fisheries Management Act 1994*. Major fisheries have environmental assessments and management plans following ESD principles. These are based primarily around the commercial industry and its regulation, although the recreational impact is considered in all assessments. Harvest strategies and performance indicators were created for some larger commercial fisheries with a TAC, such as rock lobster, but these do not directly apply to the recreational fishery.

Recreational fishing catch and effort have not been comprehensively surveyed since the Henry and Lyle survey in 2000–2001, although recreational fishers were surveyed at boat ramps in the greater Sydney region between 2007 and 2009. New South Wales has many spatial fishing closures related to the use of fishing gear, particularly the use of traps, prawn nets and bait collection.

In New South Wales some key habitats, such as for grey nurse sharks, have been protected using a threat abatement planning process that includes a range of temporary and permanent closures and gear restrictions. A recreational fishing licence is needed for both marine and freshwater angling; funds are collected in a trust to improve recreational fishing.

The key differences between New South Wales and Victoria are:

- Victoria has a more comprehensive recreational fishing monitoring program in the angler diary and onsite surveys
- New South Wales has not completed a comprehensive recreational catch and effort survey, unlike all other states
- New South Wales has identified and protected some key marine habitats to protect vulnerable fish species
- New South Wales has better documentation on the environmental impact of its fisheries (although primarily commercial).

Queensland

The Department of Employment, Economic Development and Innovation (DEEDI), under the *Fisheries Act 1994*, manages Queensland fisheries. There are three major strategic aims for the sustainable fisheries management of Queensland fisheries: protecting habitat; managing harvest and maximising value; and working together to develop an ecosystem-based fisheries management framework (DEEDI 2009). ERAs adapted from the Commonwealth's ESD framework have been completed for key fisheries, with plans for the development of a harvest strategy framework similar to that outlined in the Victorian *Future fisheries strategy: proposals for reform*.

Queensland has over 70 Declared Fish Habitats covering 880 000 ha. Although these do not restrict legal fishing operations, they are priority areas for habitat protection and ecosystem maintenance measures.

Queensland surveyed recreational catch and effort using a phone survey similar to that of South Australia, Tasmania and the Northern Territory, which differed from the Victorian survey through the random nature of the telephone surveys and by not targeting licence holders.

The key differences in recreational fishing management between Queensland and Victoria are:

- Queensland focuses on identifying and protecting key fish habitat
- Queensland has a more detailed assessment of individual fisheries and data more publicly available than Victoria
- Victoria has a more comprehensive program of monitoring for recreational fishing in its angler diary and onsite surveys.

Tasmania

The Department of Primary Industries, Parks, Water and Environment (DPIPWE), under the *Living Marine Resources Management Act 1995*, manages Tasmanian fisheries. Tasmania puts a significant amount of resources into understanding its fisheries through scientific research, and publishes stock assessment reports for all key fish stocks. The stock assessments do not explicitly grade each fishery, but calculate the risk of stock depletion below performance indicators in the absence of new management. These are calculated primarily on commercial catch data. There have been a number of studies into the health and importance of fish habitat in Tasmania (e.g. rocky reefs—Stuart-Smith et al. 2008 and ecosystem and

Table 14. Comparison of marine recreational fishing management tools in Australian states					
State	**Marine recreational fishing licence**	**Recreational fishing survey**	**Key fish habitat protection**	**Research angler diary program**	**Harvest strategies**
Victoria	Yes	2006–2007	No	Yes	No
South Australia	No	2007–2008	No	No	Some commercial fisheries
Western Australia	Yes, regional	2011	Yes	Yes	Some commercial fisheries
New South Wales	Yes	2000–2001	No	No	Some commercial fisheries
Queensland	No	2010–2011	Yes	No	No
Tasmania	Some species and gear types	2007–2008	Yes	No	Some commercial fisheries
Northern Territory	No	2009–2010	No	No	Some species

trophic effects of fishing (e.g. rock lobster—Guest et al. 2009).

Tasmania issues recreational fishing licences for many gear types considered 'commercial only' in other states. These include lobster pots, gill nets, seine nets and set bottom longlines. There are many restrictions on the gear specifications and the areas and seasons of usage, but no general recreational fishing licence is required for marine line fishing.

A recreational fishing survey was completed in Tasmania in 2007–2008 using telephone interview methods of fishers agreeing to log their catch and effort, similar to surveys conducted in South Australia, Queensland and the Northern Territory. These surveys are planned for every five years, the next commencing in 2013. Tasmania also conducts a number of small-scale surveys to fill knowledge gaps around specific gear types and boat usage.

Tasmania has closed seasons to protect spawning populations for banded morwong, striped trumpeter, rock lobster, scallops and calamari. A number of fish-tagging programs encourage anglers to log their tagged catches to help understand fish movements. Species tagged include rock lobster, sharks, trumpeter and banded morwong.

Key differences between Victorian and Tasmanian recreational fishing management:

- Tasmania has significantly more investment in scientific research into fisheries, particularly into ecosystem dependency and impacts
- Tasmania allows the licensed use of commercial-style gear for recreational fishing, but does not require a line-fishing licence
- Tasmania has many closed spawning seasons and areas
- Victoria has a more comprehensive program for the monitoring of recreational fishing with its angler diary and onsite surveys.

Northern Territory

Northern Territory fisheries are managed by the Department of Resources under the Northern Territory's *Fisheries Act 1988*. Stock status reports are published every year, and each fishery has set performance indicators against which they are measured. Categories are roughly based on ESD and ERA principles and include the status of the stock, bycatch levels, byproduct status, threatened and endangered species interactions, and general ecosystem impact. There are set trigger points for management actions, similar to the harvest strategy system planned in Victoria's *Future fisheries strategy: proposals for reform*. As with most states, data used in stock assessment is mainly derived from the commercial industry.

A recreational fishing survey was conducted in 2009–2010, using phone interviews of fishers willing to log their catch and effort. The results of the study are yet to be released.

The Northern Territory has fewer input-control regulations than any other state of Australia. There are catch limits for only five finfish species, and all other species are covered under a total fish limit per person of 30. Many species are exempt from this limit including prawns, calamari, baitfish, bream and crabs. Size limits are in place for barramundi and mudcrabs only.

Key differences between Victoria and Northern Territory recreational fishing management are:

- the Northern Territory has harvest control strategies for major fisheries
- the Northern Territory has fewer input controls on recreational fishing, although it has a total fish possession limit
- Victoria has a more comprehensive program for the monitoring of recreational fishing with its angler diary and onsite surveys.

Alternative approaches to the management of recreational fishing

Overview

Although Australia could arguably be considered a world leader in recreational fishing management, this must be taken in the context of a generally low level of comprehensive recreational fishing management strategies worldwide. Nevertheless, there are lessons to be learned from the many innovative alternative management examples from around the world.

The case studies described here are divided into three broad categories of 'tools' used to overcome difficulties in managing recreational fisheries. These are:

- establishing property rights and developing quota allocation systems
- increasing engagement of recreational fishers in management
- other innovative approaches.

Each case study may incorporate a combination of these approaches, but the focus is on the innovative approach of relevance for Victoria's fisheries management. The case studies have been chosen solely from peer-reviewed publications, although supporting government documents have been used for background. This limits the scope of management examples, but the technical basis of this report demands peer-reviewed information in order to properly evaluate management effectiveness.

Developing property rights and quota allocation for recreational fisheries

A key tool used by fisheries managers to constrain harvest and associated ecological impacts is to restrict access to a fishery. Such restriction is ubiquitous for commercial fishers in countries like Australia, with licences required for any commercial fishing activity. Access to the Victorian Bay and Inlet commercial fisheries, for example, has been restricted and progressively reduced over the past two decades, to the point where Port Phillip Bay has less than a quarter of the licences active 25 years ago. Each licence allows a fisher to access the resource in the manner of their licence conditions, which could be considered a temporary access right to that resource. For a more comprehensive overview of fishing rights, see Huppert (2005).

Such an approach of restricting entry can be problematic when managers attempt to apply it to recreational fisheries. Restricting access to a recreational fishery is often politically unfavourable, with strong angling community backlash the likely result. This response is based on a fundamental underlying difference between commercial and recreational fishers—the former are users/renters of a resource owned by the public, while the latter are part of the public. This leads to a presumption by some recreational fishers that they have a basic right to freely access the public resource. To them, restricting or capping entry into recreational fisheries is seen as a violation of the public's right to access a public resource, which many anglers contentiously consider some kind of birth right (Kearney 2002). However, other sectors of the public may have similar views regarding access rights for their activities, such as the recreational diving community, and these may not always be complementary or compatible.

Recreational fishing licences, even though a relatively new concept, do not convey property rights to the fisher. Rather, licences are used to generate revenue for fisheries enhancement and management, and to track fishing effort. Public access to fisheries is considered a non-specified common law right, which is restricted only by input regulations such as bag and

size limits, and areas closed to fishing, such as marine national parks. Defining clear property rights for recreational fishing is often discussed as one way of ensuring ongoing access for recreational fishers and a voice in their management (Kearney 2001). However, it would also incur greater responsibility for stewardship of the resource, provision of data for monitoring, and covering the financial costs of management. Convincing recreational fishers to contribute more both intellectually and materially would be another challenge for resource managers, as well as demands for property rights from other users of the marine environment. A property-rights approach would need to consider all the many stakeholders who have an interest in the marine and coastal environment, and any defined right to access a public resource would have to allow access by all members of the public, not just recreational fishers.

Defining and strengthening access rights for recreational fishers is a key objective of *Future fisheries strategy: proposals for reform* (Department of Primary Industries 2011b). How Fisheries Victoria intends to do this is unclear. However, examples are given below of the application of total allowable catches (TAC) and their feasibility for some Victorian fisheries is discussed.

Total allowable catches as an output control

Total allowable catches (TACs) are principally harvest-control measures that dictate the biomass of fish that may be harvested in a fishing season (Pope 2009). TACs have been implemented in many commercial fisheries across the world in the past 30 years, and have become a key feature of Australia's approach to the management of commercial fisheries. However, the application of TACs to the recreational fishing sector has proved to be very difficult (McMurran 2000; Borch 2010).

Total allowable catches can be administered in a number of ways. Historically, they have been set across commercial fishing fleets. Fishing boats then harvest fish until the total catch limit has been reached, at which point the fishery is shut. In many cases, this arrangement led to the well-known 'race to fish', where fishers would invest in increasingly powerful vessels and gear to catch a greater share of the total catch before the fishery is closed. More recently, TACs have been divided between individual fishers through the allocation of quotas, which represent defined shares of the total catch. In many cases, the quota is transferable and issued in perpetuity, allowing commercial fishers to sell it on. As such, the quota takes on many of the characteristics of a property right, often vesting the owners of such quota with a valuable asset.

Key challenges with the use of such systems thus relate to how a total catch is monitored and enforced and, in the case of quotas, how they are allocated—this includes both problems of allocating catch between sectors (i.e. commercial, recreational, Indigenous) and also how that catch is distributed and monitored within sectors. In the commercial sector, quotas can be allocated to fishers as equal shares or as a proportion of their historic catches (Pope 2009). These quotas can then be traded within the sector. If a TAC is set for a recreational fishery, however, it is difficult to allocate the TAC within that sector due to the dynamic and dispersed nature of recreational fisheries and the lack of control over the number of fishers. Allocating a quota of a species to each recreational fishing licence may be meaningless to some fishers who do not target that species. Furthermore, fishers vary considerably in their avidity and skill, and some will historically catch more than others. The main problem, however, lies in trying to enforce and restrict an individual's catch to their limit of the TAC. This may require the logging of all catch, or weigh-in stations at all access points for recreational fishers. Either way, this approach is generally considered unworkable for anything larger than a single lake or pond.

An alternative is allocating the recreational TAC to a subsection of the fishery, for example angling clubs or regional management bodies. Although this may be more manageable, similar problems arise on a smaller scale, and once again the right to the resource is being diverted away from the individual to an organisation. An example of such a system is proposed by Sutinen and Johnston (2003), and involves the complete devolution of management to regional groups that would manage their allocation of the TAC in the way they see fit. However, this approach would involve an effective privatisation of the fishery, with the organisation selling quota units to recreational fishers to maximise profit and ignoring the interests of other users of the marine resource. While this may define temporary ownership and create economic incentives for sustainable fishing, it does not consider the fundamental desire of individuals to access fish recreationally without paying for the privilege, nor the conflicts with other marine users.

Because of this general unsuitability of the commercial TAC and quota system in recreational fisheries, most management comes full circle and uses input-control methods to implement the output control of

the TAC. In order to do so, reliable data is required on participation and total recreational catch, and this must be updated regularly to detect any breaches to the TAC allocation for the sector. In the event of a breach, input controls such as reduced bag limits or increased size limits are the only tools available, along with spatial and temporal fishing closures.

Consideration is now given to places where managers have attempted to implement TACs in recreational fisheries.

New Zealand Quota Management System

New Zealand's Quota Management System was set up in 1986 to address overfishing and overcapitalisation in its inshore fisheries (Borch 2010). TACs were set for key species and applied to the commercial fishery in the form of individual quotas for licence holders, and a trading market was established. Recreational fishers were factored into the system in the 1990s, when part of the TAC was allocated to the recreational and Indigenous sectors. However, the rights of recreational fishers were loosely defined, and discretion on the size of the annual recreational allocation lay with the fisheries minister (McMurran 2000). There was considerable protest from recreational fishers due to fear of restrictions, which until that time had been reasonably lax (Borch 2010). There was a demand for increased participation, but a lack of willingness to cover management costs, including strong opposition to recreational fishing licences.

Despite a strong desire to regulate recreational fishers under the TAC system, a very passionate and disaffected recreational fishing community confronted New Zealand Fisheries. A joint working group developed three options to take to recreational fishers in 1998:

- continued TAC allocation set by the minister
- a proportional share of the TAC that remained constant over time
- a separate system of recreational controlled management (meaning that recreational fishers would have more financial responsibility for management).

Although only these three options were offered, a fourth was proposed by the peak recreational fishing bodies, which formed an action group named 'Option 4'. This fourth option was that recreational fishers should have priority over commercial fishers, and that no licence system should be introduced.

Due to the overwhelming angler support for Option 4, the plan to incorporate recreational fisheries into the Quota Management System was abandoned. A consultation period was established to develop an amateur fishing trust of recreational representatives to advise on fisheries management (Lock and Leslie 2007), and this appears to be ongoing. Recreational fishers in New Zealand currently do not require a fishing licence. The recreational fishery is managed on input controls, not in the Quota Management System. Put simply, the failure to apply TACs to New Zealand recreational fisheries was a case of the managing agency misunderstanding the fundamental motivation for recreational fishing ('to get away from it all'—Borch 2010) and misjudging the strength of opposition to a perceived rigid control structure.

It should be noted that recreational fishers are now broadly represented on many regional fishing management bodies in New Zealand, which have the legal right to make limited management decisions within their fishery (Yandle 2008). Although the overall engagement of recreational fishers in the TAC system was unsuccessful in New Zealand, there are numerous examples elsewhere of better cooperation and involvement of fishers in management (see below).

US Gulf of Mexico red snapper fishery

The red snapper fishery in the Gulf of Mexico was estimated to have declined by 90% between the 1970s and 1990s due to overfishing and bycatch of juveniles in shrimp trawl fisheries (Gillig et al. 2001). A TAC was first set on the fishery in 1990, which allocated 51% to the commercial fishery and 49% to the recreational fishery (Weninger and Waters 2003), and individual quota allocation was set for commercial fishers in 2007. The recreational catch is monitored using phone and boat ramp surveys (NOAA 2011). Previously catch and size limits were used to constrain harvest, but the catch limit (two per person) has now reached a level where it realistically cannot be reduced further. Instead, the recreational season is very restricted, usually lasting for less than 60 days, and the fishery is closed when it is thought that the TAC has been reached (NOAA 2011).

The red snapper is still classified as overfished, but no longer subject to overfishing (NOAA 2012). With the TAC increasing in recent years, it is expected that by 2032 the stock will no longer be overfished. Although this may appear to be a successful example of the application of a TAC to the recreational fishery, the restrictions placed upon the fishery to achieve their proportion of the TAC were severe, encountered significant opposition and, are

therefore unlikely to be accepted in many fisheries around the world. Examples such as this cause recreational fishers to fear the implementation of a TAC and the resulting battle over allocation between commercial and recreational sectors.

Pink snapper fishery in Shark Bay, Western Australia

The pink snapper fishery in Shark Bay, Western Australia, was the first finfish fishery in Australia to impose a TAC on both the commercial and the recreational sectors (Mitchell et al. 2008). In 2003 the fishery was split into three management areas and each was allocated a TAC, of which 75% was reserved for recreational fishers and 25% for commercial fishers. Actual take is compared to the TAC share, and this is monitored through logbooks for commercial fishers and onsite surveys for recreational fishers. There is also a spawning zone closure for three months in the eastern zone and for one-and-a-half months in the western zone.

The recreational quota is further enforced by the use of management tags (Mitchell et al. 2008). Recreational fishers have to pre-purchase the management tags, each of which allows them to catch and retain one fish. The tag is inserted through the mouth and out of the lower jaw of the fish, and cannot be reused. Using an average size per fish, management agencies calculate the number of tags that can be issued to fulfil the TAC. This in effect constrains total legal harvest to the TAC, as only a limited number of tags are available for purchase.

These measures have been highly successful in limiting pink snapper catch in all management areas of Shark Bay (Mitchell et al. 2008). This trend is continuing, with the TAC breached only once in one zone between 2003 and 2007 (Department of Fisheries 2010). It should be kept in mind that the total harvest of pink snapper in Shark Bay is relatively small (total TAC 35 t in 2007), with only 23 000 days of fisher effort in 2007 (Department of Fisheries 2010). Such an approach could be complicated if scaled up to a larger fishery with greater catch, higher levels of participation and many access points, but could possibly be applied to fisheries with limited entry points such as the smaller estuaries in eastern Victoria.

Increasing the involvement of recreational fishers in management

As discussed above, managing the impacts of a diverse and dispersed recreational fishing community requires some fundamental changes to traditional fisheries management. A key concept developed in response to these challenges over the past two decades is the devolution of management to the fishers themselves (Kearney 2002; Sutinen and Johnston 2003). In essence, devolution is the transfer of responsibility and cost recovery from the government to the users of the resource. This may involve deferring responsibility for ecologically sustainable harvests to regional fishing bodies, fishing clubs or individual fishers, to the point where regulations can be set by these groups. Yandle (2008) summarises examples of fisheries management devolution being achieved via two distinct routes: evolutionary and 'crisis-driven'. Evolutionary development occurs where long-standing practices and management bodies become interwoven with central government approaches. Crisis-driven development occurs when the resource is depleted, or there is conflict between user groups or between stakeholders and government. The two examples given below are cases of crisis-driven involvement of recreational fishers, although in both the representative bodies existed prior to the fishery's crisis.

Proponents of the devolution approach (e.g. Sutinen and Johnson 2003) give examples of success in commercial fisheries, but despite its popularity with many governments, devolution has few working examples in marine recreational fisheries. Devolution is often associated with setting TACs for the recreational sector and, as discussed above, these are difficult to provide to recreational fishers, and potentially undesirable (Yandle 2008). Also, the same characteristics of recreational fishing that brought about the idea of devolution—disparate fishers with individual behaviour, and who as a group are difficult to manage—are also the main downfall of this approach. Devolution requires a cohesive user group with a central body that is respected and can represent the diverse views of fishers. Clearly this runs against the fundamental nature of recreational fishing in most locations. However, where strong representation already exists, there can be an evolutionary development of devolved management.

Although devolving management may not be viable in many recreational fisheries, there are some working examples of successful engagement of recreational fishers in the management and cost recovery of the fishery. Fishers are more likely to abide by regulations if they feel they are necessary, even more so if the regulations are suggested by

the fishers themselves (Kuperan and Sutinen 1998). Frameworks of involvement have been developed and applied to some fisheries, such as the FishSmart system (Miller et al. 2010; Ihde et al. 2011). Below are some examples where the increased involvement of marine recreational fishers has improved management.

Rockfish in the Straits of Georgia, Canada

Rockfish are a reef fish species targeted evenly between recreational and commercial fishers in the Straits of Georgia (Granek et al. 2008). In the 1990s, recreational fishers raised concerns about an expanding commercial fishery depleting the stock. At the time, recreational fishers were licensed and represented by the Sport Fishing Advisory Body (SFAB), which had approximately 400 000 recreational fishers as members. SFAB became engaged in management decisions, proposing closed periods, closed areas and a reduction in bag limits to constrain catch to sustainable limits (Granek et al. 2008). Local SFAB committees identified conservation reef areas in their regions, and these were subsequently closed. In all, there was an 81-per-cent decline in harvest due to these controls and other fisheries closures.

This process forced the recreational bodies to become much more knowledgeable about the species, its habitat, and the need for controls to ensure the sustainability of the fishery (Granek et al. 2008). This level of investment and engagement came about due to the successful nature of the SFAB committee, which had regional subcommittees and represented all licensed anglers. The process of decision-making in SFAB needed to be inclusive and transparent to gain the trust of individual anglers, just as the engagement of SFAB by fisheries management needed to be serious and consultative for managers to gain the trust of SFAB. Such a system has merits, but it must be created from the ground up—fishers must be properly represented and feel they have a say for engagement to be taken seriously.

New Zealand Rock Lobster Fishery

The New Zealand Rock Lobster Fishery is shared between commercial, recreational and traditional sectors, and has been managed under a TAC system in nine regions since the 1990s (Breen and Kendrick 1997). As discussed previously, the quota allocations of the TAC are not formally adopted by the recreational and traditional sectors, although they are accounted for when regulating the fishery as a whole.

The Gisborne area of New Zealand experienced falling catches in the 1990s, and the local rock lobster fishery was classified as overfished (Breen and Kendrick 1997). Illegal fishing was also thought to be comparable to the commercial catch. Commercial, recreational and traditional fishers formed a group to discuss changes to management procedures. The government advisory body became less of a provider of management advice and more of a facilitator of cooperation and discussion among stakeholders (Yandle 2008). Although the agreement was not unanimous, a majority supported a number of management changes including a reduced TAC, reduced season length for all fishers, no take of females by commercial fishers during breeding season, and a reduction in size limits for male lobsters (Breen and Kendrick 1997). It also shifted the commercial season to winter, a season when there are fewer illegal fishers who could steal from commercial pots. As a consequence of these actions, catch rates have improved and the fishery is now recovering.

The key to the successful co-management of the Gisborne rock lobster fishery was the local approach, the strong incentive to improve fishing conditions, and the established framework for stakeholders to work together (Yandle 2008). However, the commercial sector was the prime driver of the changes. Recreational fishers were invited to be co-managers but were not proactive in their initial involvement. Though this is an example of constructive co-management and some devolution of responsibility, a recreationally dominant fishery cannot rely on a minority commercial sector to do the 'heavy lifting', as was the case in this example and others around New Zealand, such as scallops (Mincher 2008).

Innovative management controls for recreational fisheries

There is scope within the current management system to create a more sustainable recreational harvest through the use of innovative approaches. Three examples of alternative strategies are presented in this section: an input-control method, an output-control method, and a different approach to determining a 'healthy' fishery.

Input controls remain the most widely used tools to manage recreational fishing catches worldwide (Cooke and Cowx 2006). Traditional controls on minimum fish length and maximum daily

catch per person are familiar to most fishers, with more recent developments such as maximum fish length to conserve reproductive potential, and a total possession limit, becoming more prevalent. Without the ability to restrict entry into the fishery, setting catch and size limits still often fails in constraining the catch as a fishery grows (Radomski 2003). However, there is the possibility for input controls to constrain harvest in innovative ways, such as increasing survival of released fish by use of specific gear types like the example of hook type below.

Increasing the complexity of controls generally must be approached with caution, as the reaction of fishers to control measures is a crucial factor in the effectiveness of the measures (Arlinghaus 2005). The willingness to adopt controls determines the compliance rates (along with enforcement threat), and willingness is often related to whether the controls match fishers' perceptions of their need and potential effectiveness (Raakjær Nielsen and Mathiesen 2003). Too many controls can be confusing (Jentoft and Mikalsen 2004), and a reduction in complexities and a broadening of scale are recommended for greatest effectiveness (Lester et al. 2003). The need to understand fishers' responses to control measures is crucial to their success (Arlinghaus and Cowx 2008).

Use of different hook types to increase catch and release survival

Two hook-restriction regulations designed to reduce fishing mortality are covered here. The first involves a minimum hook size that targets larger fish to reduce 'catch and release' mortality of smaller individuals. The second examines the use of circle hooks to reduce post-release mortality brought about by hooking injuries. Each tool is useful where specific fisheries have management problems with high post-release mortality.

Although most recreational fisheries enforce size limits on key species to manage harvest, the consequence is the handling and subsequent release of all undersized fish caught. Where the survival rates of released fish are low (particularly fragile fish or fish caught from depth), catch and release may cause greater mortality than the retained catch (Cerdą et al. 2010). In such fisheries, there is a need for incentives and mechanisms to target only larger individuals that will be retained. Cerdą et al. (2010) evaluated the effects of hook size on recreational fishing success off Belearic Island in the Mediterranean. Larger hooks reduced total catch, but larger fish of more valuable species were caught, with very few undersized fish. This is similar to that found in Victoria for black bream (Grixti et al. 2007). Fishes with small mouths showed greater selectivity, hence such an approach is more likely to be effective with small-mouthed fish. Larger hooks also reduce 'deep hooking', which is responsible for most shallow-water discard mortality (Arlinghaus et al. 2007). A minimum hook size may therefore be useful in a situation of high post-release mortality of undersized fish, particularly those with small mouths. However, enforcement would be a major barrier. Such an approach is likely to require extensive education programs to highlight the benefits of using larger hooks.

Another situation where discard mortality is high is when deep hooking of fish occurs (Arlinghaus et al. 2007). Deep hooking refers to when a fish is hooked, not in the mouth or lip, but further into the fish in the oesophagus, gills or stomach (Alós et al. 2009). Numerous studies have found that a change in hook type, in particular the use of circle hooks, decreases the incidence of deep hooking in many species (Arlinghaus et al. 2007; Policansky 2008; Alós et al. 2009), including sand flathead in Tasmania (Lyle et al. 2007). However, in Victoria, this was not found to be the case for snapper and King George whiting (Grixti et al. 2010). Angling technique and the striking method of the fish are likely to play a significant role in whether circle hooks are effective in reducing deep hooking (Cooke and Suski 2004; Grixti et al. 2010). Circle hooks are thought to be more effective on species caught with a slack line and non-vigorous striking action.

Fish harvest tags

Fish harvest tags are an output control designed to directly limit the amount of legal catch. Generally, limited tags are issued for the number of fish comprising the determined sustainable harvest for the season, similar to the example of Shark Bay snapper described previously (Mitchell et al. 2008). The prerequisite for harvest-tag programs is an assessment of the fishery and a TAC allocation for the recreational fishery, with the number of tags being issued corresponding to the TAC. Recreational fishers can acquire tags through lottery rationing, auction of tags or a set allocation granted with each fishing licence (Johnston et al. 2007). Tags are physically attached to the fish when caught and cannot be reused. There are numerous examples of tag programs, including Shark Bay snapper, salmon and sea trout in Ireland, cod in Newfoundland, and game and freshwater species in many states of the US (Johnston et al. 2007). Often the programs

require reporting of the harvest, which feeds back into management decisions.

Fish harvest tags can bring four main benefits (Johnston et al. 2007):

- limiting harvest to tagged fish only
- equitably distributing harvest opportunity
- promoting effective monitoring and enforcement
- providing data for management.

The system can have additional benefits of raising funds for management, and it is also relatively easy to incorporate the commercial and for-hire recreational sector. The downside is the administrative costs and logistical challenges in large fisheries with many fishers and multiple entry points. Such a system is likely to be more successful for high-value target species, particularly game fishing, where there is a greater focus on catching fewer larger individuals, such as southern bluefin tuna in south-western Victoria.

Shifting management away from biomass targets and TAC allocation for recreational fisheries

The concept of managing fisheries as a biomass has been prevalent for decades, and has led to the development of maximum sustainable/economic yield and the determination of total allowable catches. Although this approach has been effective in managing commercial fisheries when models are properly informed (Hilborn 2007), there are questions about their applicability to recreational fisheries (Ihde et al. 2010). The motivations and desires of recreational fishers are often very different from those of commercial fishers. They can be generalised as a return on 'quality fishing' for recreational fishers, and maximum economic return for commercial fishers. The idea of maximum biomass harvest may not give recreational fishers the best quality fishing and may fail to fulfill their desired outcomes, such as catching bigger fish rather than more fish. Alternatives to the biomass target system can be tailored to the values of fishers in that particular fishery, with a fundamental basis of providing a sustainable stock.

Recreational fisheries are also generally data-poor, and total catch can be difficult to estimate, making subsequent estimates of biomass unreliable. The data obtained through angler diary programs and boat-ramp surveys, which is generally catch rates and size distributions, may be more suited to other approaches. A simple but widely used indicator of stock health is spawner per recruit (SPR, otherwise known as spawning potential ratio), which estimates the spawning or replenishment potential of a fish stock (de Mitcheson 2009). Robust knowledge is required about the species' biology and reproductive capacity, as well as the size distribution in the fishery. SPR has been criticised as being too ambiguous and over optimistic (Prince et al. 2011), but combination-indicator approaches have been developed. Combining SPR with catch rates gives a more robust estimate of stock health (Prince et al. 2011), and such concepts can be simply interpreted and communicated (Froese 2004). Such an approach of SPR and catch-rate analysis has significant potential for recreational fisheries management where data is collected on catch rates and size distribution in the fishery.

Another alternative but similar approach to recreational fishery stock assessment is a focus on age diversity to maintain spawning potential (Ihde et al. 2010). As with the SPR approach, good data is required about fish biology and current size distribution in the fishery. Although most fisheries experience high variability in recruitment regardless of spawning output (Secor 2007), there is nevertheless a need for a strong spawning potential to take advantage of the years of recruitment success. Maintaining a greater proportion of older fish in the population produces higher spawning capability in the fishery (Venturelli et al. 2009). Fisheries can therefore be managed for more old and large fish to maintain the potential spawning for years of suitable recruitment conditions. This approach may, however, work against what fishers value in the fishery. For example, if fishers value larger 'prize' fish, protection of these fish may cause dissatisfaction. Conversely, a management focus on maintaining more large fish may mean that more of these fish are available to be caught.

Both approaches are similar in maintaining spawning potential rather than biomass, and present opportunities for recreational fisheries managers. Traditional input controls of size and catch limits can be adapted to maintain a desired size distribution in the fishery (Froese 2004). Such an approach does not limit total catch but it provides a simpler tool for managers, particularly in fisheries that may fluctuate greatly due to environmental limitation.

Building a future strategy for recreational fishing in Victoria

Overview

Victorian fisheries management is currently in a state of review and on the cusp of potentially significant changes. *Future fisheries strategy: proposals for reform* (Department of Primary Industries 2011b) outlines a new direction, the most important areas of reform being:

- establishing clearer resource sharing arrangements and access entitlements
- creating harvest strategies to manage fisheries sustainably
- increasing stakeholder involvement in management.

These areas of reform correspond with the management issues discussed earlier in this section, including property rights and the devolution of management. Currently this strategy appears to be on hold, or under review, due to the overwhelmingly negative response from stakeholders during the consultation period. Although the *Future fisheries strategy: proposals for reform* will not be critiqued here, there is a brief discussion of the applicability of these three concepts to the current Victorian situation, and recommendations are presented for the future management of specific marine recreational fisheries in Victoria.

Output controls and property rights in Victoria

One option under the draft *Future fisheries strategy: proposals for reform* is to allocate a proportion of the TAC of various commercially harvested species to the recreational sector. There are three significant challenges to implementing this option in Victoria:

- the data and resources needed to reliably determine fishery biomass and set a TAC
- the difficulty of conferring this TAC equitably to the vast and diverse group of individual recreational fishers
- likely opposition from other stakeholders.

Fisheries Victoria currently appears to have the data and resources to set TACs for a limited number of fisheries, conceivably rock lobster, abalone and snapper, and possibly black bream and King George whiting. Transferring the TAC to individual fishers appears much more difficult, and it is likely that the TAC will be a management target only, and not a strictly enforced output control. For species where TACs are unlikely to be set, distinct property rights will be difficult to establish. Revisions to legislation may define equitable resource sharing, although management mechanisms would be limited. Such fisheries may require alternative forms of setting management targets, which could involve the SPR and size-distribution methods outlined in the previous subsection.

Increasing recreational involvement in management in Victoria

Devolution of management to recreational fishers is most likely to be successful where an established representative group or groups can engage with managers or a broader marine and coastal management body on behalf of the general fishing population. Fishers must see that these groups represent their values and interests, and that the process of decision-making, lobbying and engagement are transparent and accountable. Although Victoria has representative recreational fishing groups and numerous independent fishing clubs, there is no organised regional system of representative bodies as seen in such

examples as the Georgia Straits rockfish fishery. To be engaged, recreational fishers must first feel appropriately represented, but this will require further work in Victoria. Many fishers will not want to be engaged under any circumstances (remembering a key drive to fish is to 'get away from it all'), and these fishers' views must also be taken into account. Furthermore, caution is required to prevent increased involvement and responsibility of recreational fishers leading to increased conflict with the commercial sector and other stakeholders. Devolved management decisions must be made to ensure ecological sustainability and the equitable sharing of the resource among all resource users, and not to be tools for granting larger shares of the resource to selected stakeholders.

Recommendations

Recommendation 14: Regional recreational fishing groups should be important players in a broader marine and coastal planning and management framework. The establishment of empowered regional marine and coastal bodies with expertise and broad representation is one such option. Such bodies would value local knowledge and ensure legitimate and serious engagement of recreational fishers in management.

Recommendation 15: In Victoria's bays and inlets, the focus of the regional marine and coastal bodies should move toward broader ecosystem health and the improvement of natural environmental productivity. Many fisheries are currently limited by the extent of habitat and water quality, and seriously impacted by land-based activities. The adoption of improvement plans that encompass the whole catchment would be an important step for the regional marine and coastal bodies to take towards achieving goals of improved ecosystem health and increased natural productivity in fisheries.

Recommendation 16: A 'key fishery habitat' identification and conservation program should be established that is similar to those in other states of Australia. Such declared habitats would become part of the integrated and ecosystem-based marine and coastal planning, protection and management framework and be protected from development and degradation.

Recommendation 17: Fisheries Victoria should develop a policy framework to follow up important risks uncovered in the fishery ERA process and to apply management controls or regulations to reduce that risk.

Recommendation 18: Location-specific ecological risk assessments of recreational fisheries (e.g. bait collection of intertidal gastropods) should be used and should take a precautionary approach to unknown impacts such as trophic effects. Such assessments would better inform the nature of management responses required, whether monitoring programs, education campaigns, compliance activities or legislative changes.

Recommendation 19: Programs to monitor the community ecology of important benthic and pelagic ecosystems should be established to provide important benchmark data for monitoring the ecosystem impacts of fishing. There is currently no ongoing independent monitoring of marine communities in Victoria that could set historical and contemporary ecological baselines for monitoring ecosystem changes related to recreational fishing and other pressures. Such data could be used in ecosystem models to predict future changes under different scenarios, including changes in recreational fishing pressure.

Dealing with management issues in five Victorian recreational fisheries

Port Phillip Bay snapper

The Port Phillip Bay snapper fishery is currently Victoria's largest and most important recreational fishery. Fisher participation has increased over the past decade due to factors including a growing Melbourne population, an increase in disposable income to purchase recreational boats, increased infrastructure and access, and (perhaps most importantly) the increase in stock abundance and corresponding angler catch rates. This increase in stock abundance is attributed to a number of strong recruitment events (i.e. number of juveniles entering the fishery) in the early 2000s, and possibly a greater proportion of the coastal Victorian stock entering Port Phillip Bay (Department of Primary Industries 2010a). The current health of the stock must be considered in the light of four important factors:

- the Port Phillip Bay fishery is only part of the larger western Victorian coastal stock, which is not intensively fished outside the Bay
- the Port Phillip Bay fishery is based on the major spawning aggregation for this stock, with recruitment success based on environmental factors outside the direct control of managers
- catch history from the past century suggests a cyclical nature of stock abundance on an approximate 30 to 40 year cycle, with peaks in abundance in the 1920s, the 1970s and now, in the 2010s.

All these are significant challenges for managers attempting to determine a sustainable level of fishing for snapper, particularly as natural fluctuations in the biomass may outweigh the effects of fishing.

Regardless of the environmental limitations in the fishery, managers still need to ensure that a viable spawning population exists in Port Phillip Bay to take best advantage of the years when conditions are right for recruitment. Given that the main fishery is based around the spawning period of snapper, fishing still has the potential to affect the reproductive potential of the population and hence recruitment.

Although a number of the management options discussed above may appear to be applicable to the snapper fishery, the large and diverse nature of the snapper recreational fishery in Port Phillip Bay causes numerous complications. If a TAC could be set for snapper, fish tags could be an effective way of controlling catch. However, the logistical, administrative and compliance costs would probably be prohibitive. Instead, a focus on improving environmental conditions, protecting essential habitat and increasing natural fisheries productivity would probably be a more effective and acceptable strategy.

Closed spawning areas or closed seasons are the next possible strategy to protect snapper stocks, such as the spring closure on the Carrum Bight spawning aggregation. Such a move may not be warranted given the healthy state of snapper stocks. However, as stocks decline, spawning closures could be essential in protecting spawning biomass. This could be carried out in a scientific manner by closing the fishery in spring until at least 50% of the fish had spawned. Fish could be sampled by Fisheries Victoria each week during this period and dissected for gonad analysis.

There are two main problems with this approach. The first is the resistance from fishers, both commercial and recreational, as this period is their most productive. Secondly, closures can lead to effort being displaced to other parts of the Bay and increase fishing pressure on smaller spawning aggregations around the Bay. However, spawning closures remain the most obvious and potentially effective control for the Port Phillip Bay snapper stock. Current stock levels are healthy and such a move

would not be considered necessary, but as stocks decline (in response to environmental variability), such an approach may be needed.

There are smaller strategies that would help ensure the sustainability of the Port Phillip Bay snapper stock and tackle two major issues in the recreational fishery. One is the illegal sale of recreational catch to retailers and restaurants, and the other is the high-grading of the catch.

Illegal recreational catch could be addressed by costly schemes like fish tags, but more simply by requiring all recreationally caught snapper to have a specific fin removed to identify it as recreational and not commercial catch. Anyone caught in possession of a non-clipped fish without a commercial licence, and any retailer selling clipped fish, would be in breach of the regulations.

High-grading occurs when fishers have reached their catch (bag) limit but continue to fish. When a larger fish is caught, one of the smaller fish of the fisher's bag limit is thrown back. These have often already been killed when caught or are dying due to poor handling. Increasing education and adopting a code of conduct would be a positive move. However, encouraging or even mandating fish-holding chambers, known as fishwells, could be a solution. Fish kept in fishwells are more likely to be healthy when returned to the water.

Fishing competitions targeting snapper are very popular in Victorian Bay and Inlets, and have the potential to concentrate fishing effort, encourage catch-and-keep fishing, and contribute to stock depletions. Competitions scheduled during breeding seasons are of particular concern, as they intensively target the spawning biomass and reduce reproductive potential of the stock. Adoption of responsible environmental standards for fishing competitions should be made mandatory in Victoria, and consideration given to banning competitions during spawning season.

Gippsland Lakes black bream

The Gippsland Lakes black bream is another fishery that is strongly influenced by environmental conditions, with strong long-term fluctuations in abundance. Spawning occurs in aggregations and primarily in the rivers. However, spawning location can change to the lower estuary in years of high rainfall. Effective spawning closures may therefore be difficult to implement as the location changes, but short-term closures in the rivers in drier years may be easy to communicate and enforce. For example, a trial closure during the spawning season in the Mitchell River between the main traffic bridges could be used to examine the effectiveness of spawning closures.

Fish harvest tags would again be difficult to implement in the Gippsland Lakes black bream fishery due to the 'holiday' nature of many of the fishers who are not there specifically to target black bream. Instead, they are simply fishing for the experience of catching a fish. High-grading is a potential problem, although the small size of most boats on the Gippsland Lakes makes fishwells more difficult to install.

King George whiting in Port Phillip Bay

Management of the King George whiting fishery in Port Phillip Bay should be approached very differently from other fisheries. The stock is generally thought to be a 'sink', meaning that it does not replenish itself but relies on another population (South Australia and western Victoria) for recruitment. Larvae spawned in South Australia and western Victoria drift east and enter Port Phillip Bay, where they grow to three to four years of age and then leave for the open ocean. They are not thought to return to the west, and no spawning population has been definitively identified in central Victoria (although there is limited evidence for spawning populations off Cape Otway, and the Corner Inlet population may be reliant on spawning stocks off Wilsons Promontory). Therefore managers may not have to manage for a spawning biomass in Port Phillip Bay. This makes setting a TAC difficult and possibly unnecessary for King George whiting. Management controls should focus instead on increasing productivity through protecting or enhancing seagrass habitat.

Rock lobster and abalone

The rock lobster and abalone fisheries are the most likely to be successful in using TAC output measures to guide recreational fisheries management. TAC is already determined for the commercial fisheries, and there are monitoring programs to estimate biomass and recruitment. The recreational component is also a minor proportion of the total catch, making it easier (and less necessary) to regulate. The rock lobster fishery may be a candidate for fish harvest tags to control total recreational catch. They could also work for abalone, although difficulty in tag attachment would be a major barrier.

Southern bluefin tuna

Australia's commercial southern bluefin tuna fishery is worth hundreds of millions of dollars and subject to international agreement on annual TACs. However, the recreational catch of bluefin tuna in the southern states is not covered under this TAC, and federal authorities are currently working with the states to address this issue. If the states are allocated a portion of the international TAC, or an additional TAC determined by the federal government, the enforcement of this catch in Victoria could be effectively managed using fish harvest tags. Only a finite number of tags, representing the TAC allocation, would be sold to anglers, and this could be effectively enforced given the few access points in western Victoria.

Recommendations

Recommendation 20: To improve the management of the snapper recreational fishery in Port Phillip Bay:

- mandatory finclipping of recreationally caught fish should be introduced to decrease the incidence of illegal sale
- the use of fishwells should be encouraged to reduce the effects of high-grading
- responsible environmental standards for fishing competitions should be established and enforced
- a closed spawning season for snapper should be considered when the fishery is in decline, to protect spawning stock.

Recommendation 21: To improve the management of the black bream recreational fishery in the Gippsland Lakes:

- an ecosystem-wide management approach should be adopted, including the management of land-based impacts and the conservation of seagrass habitat
- spawning season closures should be considered in some of the rivers that enter the Gippsland Lakes.

Recommendation 22: To improve the management of the King George whiting recreational fishery in Port Phillip Bay, and to ensure healthy and naturally productive fish stocks, the conservation and enhancement of seagrass habitat should be the focus of management.

Recommendation 23: To improve the management of the rock lobster and abalone recreational fisheries in Victoria, the introduction of TAC output measures and fish harvest tags should be considered for the management of the recreational component of the two fisheries.

Recommendation 24: Should the southern bluefin tuna recreational fishery continue and a TAC is assigned to it in Victoria, the use of fish harvest tags should be investigated to regulate the catch.

CONCLUSION

The range of characteristics associated with the magnitude and nature of recreational fishing pressure suggests it can and does impact marine ecosystems. In some areas, recreational fishers catch far more of particular species than do co-occurring commercial fisheries. Discard rates can be high and survival rates are extremely variable—factors that have significant consequences for population sustainability. Pressure can be highly localised and, because recreational fishers are not concerned by economic profitability, they are able to maintain this pressure at catch rates that would be unviable for commercial operators.

As with commercial fisheries, there is also a range of potential impacts from recreational fishing on species and ecosystems beyond the targeted species. This includes interactions between boats and marine animals, gear entanglements, air and water pollution and trophic effects on ecosystems. Specific examples of these impacts are documented throughout this report.

The clear issue is that although recreational fishing can impact on target species and broader ecosystem components, these impacts are likely to be highly specific to an area or species. This raises the problem of how to source appropriate data on fishing pressure and impacts, for which there is a dearth of information. An ecological risk assessment process, such as Fletcher et al. (2001) or Hobday et al. (2011), which assessed the severity and likelihood of these ecological impacts based on quantitative data and expert-opinion, is the next logical step. Such assessments would better inform the nature of management responses required, whether monitoring programs, education campaigns, compliance activities or legislative reform. This is outside the scope of the current review, however, and is a challenge exacerbated by the typically limited data associated with recreational fisheries.

The potential impacts from recreational fishing should also be seen in the context of the other diverse drivers of and impacts on marine ecosystems. These include environmental fluctuations, habitat changes, runoff and land-based pollution. Fishing pressure should be viewed as an additional impact in a system that is complex and difficult to predict (Ludwig et al. 1993). While it may or may not directly lead to the collapse of an ecosystem, fishing can reduce the resilience of an ecosystem to other pressures (Holling 2000). This highlights the importance of areas that are protected from these localised, cumulative and potentially resilience-reducing activities (Beetson et al. 2012). In this way, marine protected areas—such as those in place in Victoria and throughout Australia—may be more resilient to the impacts from broad-scale processes, such as climate change, that are beyond the control of marine and coastal managers.

An ecosystem-based approach to fisheries management should also extend to broader marine and coastal planning and management. Victoria needs a robust and representative system of regional marine and coastal management bodies that have influence over catchment, coastal and marine environments. Recreational fishers would form an important representative group to advise these bodies, along with the other users of the marine and coastal environment. Such an integrated approach could work to improve marine ecosystem health, increase natural productivity for fisheries and ensure ecological sustainability in coastal fisheries.

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