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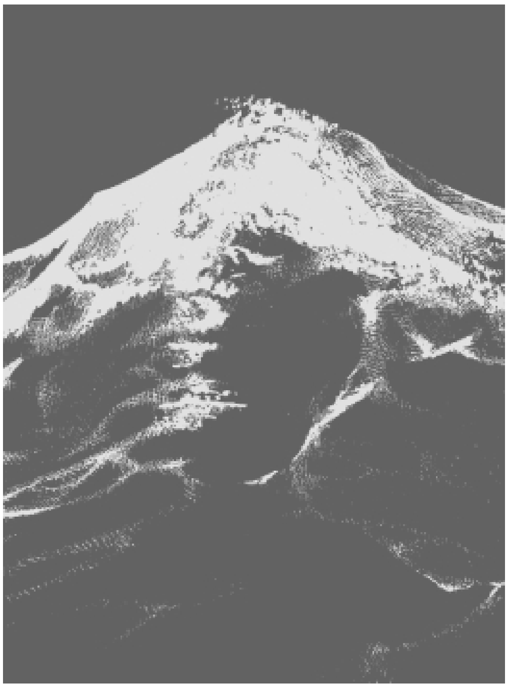

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A complex quota-managed fishery: science and management in Australia's South-east Fishery. Introduction and Overview

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Why a South-east Fishery Special Issue?

Fisheries science and management is under increasing scrutiny. There are widely held views that fisheries management has been unsuccessful and there is concern for the status of fish stocks worldwide (Mace 1997). There is also increasing community concern regarding the impact of fishing on the ecosystem, particularly by-catch and effects on threatened species. Concurrently there is a move towards participatory or co-management in which stakeholders, particularly industry, are involved directly in the management process (Jentoft 1989). Fishery science is also changing, from prescriptive to descriptive advice, and with increasing recognition of the limitations of single-species approaches and the need for a greater understanding of ecosystem interactions (Pajak 2000).

In Australia, the partnership approach of the Australian Fisheries Management Authority (AFMA) (Smith *et al.*1999) and management arrangements in most States, such as Victoria's Fisheries Co-management Council, have developed effective mechanisms for collaborative management. The public concern about the impacts of fishing on the ecosystem is reflected in recent changes by Environment Australia to regulations governing fisheries. The most significant change is the requirement to demonstrate ecological sustainability to gain certification for export of all commercial fish species. Australia's fisheries jurisdictions have also recently instituted a practical framework for adopting Ecologically Sustainable Development (ESD). Setting sustainable levels of fishing has, of course, been central to fisheries management and science for a long time, but the focus now is far broader than the target species. Within Australia, these major shifts in focus and their implementation have taken place in a relatively short time.

So why a Special Issue about the South-east Fishery (SEF)? Within the policy framework described above, the fishery provides a striking example of changes in management philosophy and process, and in scientific approach and emphasis. It is also extraordinarily complex. As this issue shows, it has evolved from a simple trawl fishery, operating in a relatively small area, targeting only a few species, to what could be facetiously called a multi-everything fishery. It is a multi-species, multi-fleet/gear fishery that operates across a broad geographical region around Australia's south-east coast including Tasmania, in depths from 30 m to 1200 m. It exploits many species with widely varying life histories and ecologies in numerous habitats. For primarily historical reasons, it has two sectors, each with its own industry association and management advisory committee (MAC). Research and monitoring are conducted by several federal and State agencies. Current management is primarily through ITQs on the major species, but some input controls including area management are also in place. The fishery is managed by a federal statutory authority – AFMA.

Papers in this issue cover a broad range of themes and issues including fishery history, resource assessment, biology, habitats, food webs, the perspectives of the industry, quota trading and management. This contrasts with a previous review of the fishery (Tilzey 1994), in which there is little or no mention of ecosystem issues and for which few quantitative assessments were available. The papers have been organized into four broad groupings, although several could fit into more than one: the fishery and its management; the South-east Fishery ecosystem; biology and life history parameters; and quantitative stock assessments.

Below, we briefly summarize some of the key aspects of these 'chapters' and then identify some issues for the future.

The fishery and its management

The history of the fishery is characterized by three broad overlapping phases (Table 1) although the most dramatic changes have occurred within the past 15 years. These phases encompass developments in the fishery, its management and the science and the processes under which the science is undertaken. The first phase covers the years up to the early 1970s when the fishery operated mostly on the continental shelf off New South Wales and north-eastern Victoria. The fishery was primarily an open-access fishery with no formal processes to coordinate research and monitoring. During the 1970s and 1980s, the fishery

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expanded spatially and into upper- and mid-slope waters. Limited entry was introduced and there was coordination of research. In addition, during the end of the period, arrangements to formally involve industry in research commenced. The most recent phase occurred during the 1990s, with the introduction of ITQs, the establishment of an inclusive assessment process and increased interest in fishery–ecosystem interactions.

Tilzey and Rowling (2001) provide a detailed review of the history of the fishery from a scientist's perspective. They refer to the three phases mentioned above as the steam trawl and Danish Seine era, the 'new development' era, and the modern, 'stock assessment' era. The years encompassing these are generally the same as in Table 1. Dealing with the 1980s onwards, Grieve and Richardson (2001), in an interesting comparison with Tilzey and Rowling, describe the recent history of the fishery from a manager's perspective. They discuss whether AFMA has met its fishery management objectives and develop simple indicators of change against which performance can be measured, particularly economic efficiency. Connor and Alden (2001) extend the economic discussion through an analysis of quota markets in the SEF. They conclude that the market is working relatively well and that there is little evidence of ownership concentration (a common criticism of ITQs). There has, however, been little reduction in fishing capacity.

The remaining three papers in this section deal with operational aspects of the fishery. Klaer (2001) presents the first rigorous examination of steam-trawler logbook data for the early years of the fishery (1918–57). This analysis provides an important 'baseline' on the fish assemblages exploited during that period, to which later information can be compared.

Jeremy Prince, who has been a scientific consultant to the trawl industry since 1992, has argued for a number of years that analysis of trends in commercial catch rates must take into account changes in fishing practices due to the introduction of quotas in the fishery. These changes include a shift from targeting individual species to diversifying catch composition in response to quota holdings and market value. Baelde (2001) demonstrates the importance of these changes through a synthesis of fishers' own descriptions of fishing gear and practices.

The development of the fishery in recent years is recorded by Larcombe *et al.* (2001), who describe the spatial distribution and intensity of the current trawl fishery; they find that although effort has increased in recent years, the area fished has actually stabilized and the fishing grounds make up only a small proportion of the total *management* area.

The South-east Fishery ecosystem

The number of papers under this broad heading demonstrates an increased scientific interest in fishery–ecosystem interactions in recent years. Many of the papers derive from a 5-year study of the south-eastern Australian continental shelf (Bax and Williams 2001). This is one of

Table 1. Broad evolutionary phases of the South-east Fishery

	Pre 1970	1970 s, 1980 s	1990 s	The Future
Fishery	Primarily steam trawls and Danish seines operating on continental shelf in eastern zone	Diesel trawlers – expansion to upper and mid slope and into southern and western zones. Development of the non-trawl fishery (gill-net, trap, line)	Some reduction in number of vessels but increase in bottom time	Increasing use of environmentally 'friendly' fishing methods. Better utilization of catch
Management	Mostly open access. Separate State regulation of mesh sizes and minimum legal lengths	Trawl fishery brought under federal jurisdiction and unitized in the mid 1980 s	Non trawl brought under federal management. Introduction of ITQs for 16 species. Development of fishery management plans.	Integration of trawl and non-trawl fisheries. Development of environmental management plan
Research and monitoring	*Ad hoc*	Major programmes initiated by States and Commonwealth agencies. Co-ordination through Demersal and Pelagic Fisheries Research Group (scientists only)	Integrated fishery-wide sampling (CAF[a] and ISMP[b]). Co-ordination through South-east Fishery Assessment Group (all stakeholders)	Increasing direct involvement of industry in research and monitoring
Fishery assessment	No formal stock assessment	Several quantitative stock assessments by scientists. Presentation by scientists to industry and managers	Many quantitative stock assessments and some agreed harvest strategies. Clearly defined stock assessment process with all stakeholders involved	Extension to include broad set of ESD[c] indicators and assessment of ecological impacts of fishing

a. CAF Central Ageing Facility
b. ISMP Integrated Scientific Monitoring Program
c. ESD Ecologically Sustainable Development

only a few integrated studies of the SEF ecosystem. The other major study was undertaken during the 1980s on the Tasmanian upper slope (Blaber and Bulman 1987; May and Blaber 1989). In addition, research on orange roughy in the early 1990s included aspects of the ecology of the mid slope and sea mounts where this species is found (Koslow *et al.* 1994; Koslow 1997; Koslow *et al.* 1997).

The first paper in this section is a review of the literature, integrated with fishers' own views of the SEF ecosystem. In this paper, Prince (2001) argues that the importance of oceanic primary production has been underestimated and that many of the important commercial species forage pelagically. Thus they are not as closely linked to benthic habitats as was previously assumed.

Bax *et al.* (2001) find that the source of primary production on the eastern Bass Strait shelf is oceanic, and that phytoplankton blooms do not contribute directly to sediment organic matter. The importance of eddies to production in the SEF ecosystem is demonstrated by Young *et al.* (2001).

The next two papers in this section deal directly with seabed habitat. Kloser *et al.* (2001) describe a method that uses multi-frequency acoustics with associated 'ground truthing' (benthic samples, sediments, photography and videorecording) to identify seabed structure. Using this information, Bax and Williams (2001) develop a hierarchical approach to mapping seabed habitat as one of the first steps to building a framework of knowledge upon which future spatial management can be based, particularly the management of fishing effort.

Williams and Bax (2001) analyse the spatial structure and composition of the fish communities of the eastern Bass Strait shelf, finding that communities are correlated with depth, latitude and seabed type. They produce a biophysical map by overlaying community patterns on seabed type in the area studied. They discuss their approach in the context of regional marine planning and ecosystem-based management.

Bulman *et al.* (2001) identify 10 trophic guilds through an analysis of >8000 stomach samples from 102 fish species caught on the south-eastern Australian shelf. Importantly, they find that although benthic prey items dominate diets, pelagic prey are important in a subset of commercially and ecologically important species including 12 quota species. They conclude that pelagic production contributes significantly to the SEF.

The final paper in this section describes the effects of fishing on sharks and rays off the New South Wales coast. Graham *et al.* (2001) find that the overall abundance of these species declined to 20% over a twenty-year period. Their results indicate that the biomasses of most species of sharks and rays on the NSW slope declined rapidly as the SEF developed and are now at low levels. They attribute this to the susceptibility of chondrichthyans to fishing pressure, and to the lack of direct management for these species in the SEF.

Overall, the papers in this section reflect a growing understanding of the SEF ecosystem emphasizing temporal variability, spatial complexity, and important links between benthic and pelagic production. This further reinforces the views of fishers, described in Prince (2001). This understanding has potentially important implications for assessment and management.

Biology and life-history parameters

Despite the longevity of the fishery, there is still much that is not known about the biology and life-history parameters of many of the key species, let alone by-product and by-catch species. Papers in this section cover a wide range of studies from genetic population structure to age and growth.

Knowledge of the stock structure of exploited species is a key requirement for effective management. Ward and Elliott (2001) review allozyme, mitochondrial DNA and micro-satellite data for 20 species in south-eastern Australia. For most fish species, there is little genetically detectable population structure. Gemfish is a striking exception. Most fish species show significant differences between Australia and New Zealand but the degree of this difference is generally small. Consequently, most quota species in the SEF are currently managed as one stock, apart from gemfish (two stocks) and orange roughy (which is managed as five stocks, although not on the basis of genetic evidence). However, genetic studies often provide ambiguous results on stock structure, and other information for some species suggests that sub-fishery spatial units may be more appropriate.

Knuckey and Sivakumaran (2001) describe the reproductive characteristics of blue warehou, extending their results in an eggs-per-recuit analysis**.** Jordan (2001*a*) presents the reproductive biology and early life history of sand flathead. Prince and Griffin (2001) describe the oceanographic factors that influence the timing and location of pre-spawning aggregations of eastern gemfish; this has led to an interesting exchange of views within these pages (Rowling 2001 and response)

The major spawning area for blue grenadier is off the west coast of Tasmania. However, Bruce *et al.* (2001*a*) provide the first evidence of larvae from mainland Australia. Their results indicate that there is a second but limited spawning area in south-eastern Australia. The implications of this for assessment of the fishery (Punt *et al.* 2001*b*) have yet to be considered.

The abundance and distribution of larval blue and spotted warehou are described by Bruce *et al.* (2001*b*). They suggest that there are separate spawning areas for blue warehou in eastern and western regions of the SEF. Similarly to Knuckey and Sivakumaran (2001), they find the timing of spawning varies between regions. For spotted warehou, the picture is less clear, with the data indicating a more continuous link between areas.

Age and growth are crucial inputs to stock assessment. In this issue, the results of two studies are presented. Morison and Rowling (2001) describe age, growth and mortality for redfish. Sex ratios, natural mortality and growth are found to vary between regions. However, because the difference in growth is not consistent between years, they argue that although there is some structuring within the population, the situation is more dynamic than spatially segregated stocks. Jordan (2001*b*) demonstrates that jackass morwong are far older than had been estimated by previous studies, but he reports similar levels of recruitment variability. From trawl surveys off southern and eastern Tasmania, Jordan (2001*c*) finds that jackass morwong abundance varies seasonally at all depths, and that there is distinct size structuring by depth, with juveniles occurring at shallower depths than mature fish. Oceanographic influences on the recruitment of post-larvae are also discussed.

Most of the papers in this section demonstrate the complexity of the SEF, particularly with regard to spatial structure of populations. This has important implications for assessment and management of stocks, which are yet to be fully explored.

Quantitative stock assessment

Surprisingly, few papers dealing with quantitative stock assessment were submitted for this issue. This does not reflect the level of activity in the fishery because assessment is one of the key inputs in the TAC setting process and considerable resources are directed at this area. The primary reason may be one of timing. Aspects of the assessment of two key species, orange roughy and eastern gemfish have been published previously (Smith 1993; Smith and Punt 1998; Punt and Smith 1999), and the assessments of a number of other species are not yet ready for formal publication. Nevertheless, this section provides a useful snapshot of current work.

First, Smith *et al.* (2001) describe the stock assessment process used in the SEF and compare it with that used in other countries. They argue that, although the approach has disadvantages as well as advantages, the latter clearly outweigh the former. Interestingly, Australia appears to be the only country in which fishery managers are active participants in the process.

A primary input to most stock assessment methods is the age composition of the catch. Several methods are available for computing these, but Punt and Smith (2001) demonstrate that assessment and risk analysis may be very sensitive to the method used, particularly for species that show variable growth rates. Another important consideration is selectivity. Cui *et al.* (2001) develop a method of estimating selectivity that allows for variability beyond sampling error. They find that population size-structure and selectivity depend on depth and habitat type, and they discuss the implications of this for future work.

Blue grenadier has become the most important species by size of catch in the SEF. Punt *et al.* (2001*b*) present the first quantitative assessment of this species in Australia. Over 20 years of research and monitoring are synthesized through an 'integrated analysis'. The paper describes how conflicting trends in fishery components are resolved, and the importance of discard data to recruitment estimation is stressed.

The final paper in the issue provides an update on the use of management strategy evaluation (MSE) in the SEF (Punt *et al.* 2001*a*). This approach, likened to use of a 'flight simulator', allows alternative harvest strategies, stock assessment methods, performance indicators and research projects to be compared in relation to achieving management objectives. In terms of stock assessment, it probably represents the way of the future. In the SEF, Punt *et al.* (2001*a*) argue that the lack of clear management objectives and the lack of quantitative assessments for some species are the main challenges to the use of this approach.

Overall, the papers in this section reflect a range of issues associated with stock assessment in the SEF, from a description of the process itself, through key inputs to particular assessments, to new methods for providing advice to decision makers. The papers do, however, reflect the current predominant focus on single species assessments in this multi-species fishery.

Issues for the future

As noted above, the SEF has seen major changes in its 100-year history, in area of operation, industry structure, management and research. As it enters the 21st century, these changes appear set to continue (Table 1). Some of the directions of this change are briefly discussed below, in relation to environmental, management, scientific and industry challenges.

Undoubtedly, the key external challenge to the SEF over the next five years will be in relation to environmental effects of fishing. Clearly, this issue is not limited to the SEF, but the complexity of this fishery will make this challenge all the more difficult to deal with.

Two specific pieces of federal environmental legislation are having an important influence on fisheries in Australia. The first of these is the *Wildlife Protection Act 1984* (WPA), and in particular the decision to remove automatic exemption of commercial fish species under the provisions of Schedule 4 of the Act. This means that fisheries will require approval from the Federal Minister for the Environment to export fish products. The criteria for environmental certification have been developed and are similar in structure to those applied by the Marine Stewardship Council. They require an assessment, not only of the status of the stocks and the sustainability of exploitation, but also of the impact of fishing on the wider ecosystem, including by-catch species, marine habitats and marine food chains. Although some aspects of the wider ecological impacts of fishing have started to be addressed under the ESD objective of the Commonwealth *Fisheries Management Act 1991*, assessment under the WPA is likely to hasten this process and to require more explicit measures to deal with potential adverse ecological impacts.

The second piece of federal environmental legislation that will affect the SEF is the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBCA). This Act brings together a number of facets of environmental legislation, including provisions for endangered species, and will apply to all federally managed fisheries. The EPBCA also requires environmental impacts of fisheries to be assessed, and will audit fishery management plans for compliance with the Act.

The SEF will require environmental certification under both the WPA and the EPBCA. Responses so far have included development of an industry code of conduct and a by-catch action plan. Research projects are underway to study effects of gear (Knuckey *et al.* in press), to improve utilization of by-catch, and to map habitat in the area of the SEF, and at least one no-take MPA has been declared, in an area of sea mounts south of Tasmania. However, little work has been undertaken to look at possible effects of fishing on food chains in the SEF.

Another Federal Government initiative that will affect the SEF is the development of Australia's Ocean Policy (Reichelt and McEwan 1999). A major initiative under the Policy is to develop large-scale Regional Marine Plans (RMPs) based (geographically) on eight identified marine bio-regions. The first RMP to be developed is in the south-eastern area of the EEZ, and is essentially coincident with the area of the SEF. There are still many uncertainties about the form that RMPs will take. What is clear is that they will be based around management of regional marine ecosystems and will deal with multiple uses of the marine environment and interaction between uses. These plans are also likely to incorporate consideration and development of the National Representative System of Marine Protected Areas (NRSMPA).

Several changes in management are already in train over the next five years (Grieve and Richardson 2001). Principal among these is the planned integration of federally managed fisheries in south-eastern Australia under a single management framework. This would bring together the existing trawl, non-trawl and shark fisheries under a single management plan. This will prove challenging for industry as well as for managers, in bringing within a single MAC framework sectors that have traditionally been antagonistic to one another. Aside from amalgamation, the management challenges facing the fishery will include the development of an effective response to the environmental challenge outlined above, developing an appropriate mixture of input and output controls, development of spatial management strategies, and development of agreed harvest strategies for target species (Punt *et al.* 2001*a*). Other key management issues will include the development of effective statutory fishing rights, and containing the costs of management in the face of increasing external demands.

The future scientific issues facing the fishery are reasonably well covered in this journal issue. They include further development and refinement of the Fishery Assessment Group process (Smith *et al.* 2001), development of a programme to obtain fishery-independent abundance data for single-species assessments, and increasing involvement of industry in research and monitoring. The greatest scientific challenge will come from developing a better understanding of the nature of the SEF ecosystem(s), and then developing cost-effective monitoring and assessment tools to manage the effects of fishing on this ecosystem. A starting point will be the identification of robust indicators for ecosystem status and change.

Coping with these challenges and changes over the next decade will require a continuation and strengthening of the partnership approach that has developed between industry, managers, scientists and (increasingly) conservation groups. The particular challenges facing the industry include developing a common identity and purpose across the range of currently disparate sectors, fishing methods and regions, increasing sophistication in dealing with technical scientific issues, and willingness to engage rapidly and effectively in the 'environmental challenge'.

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