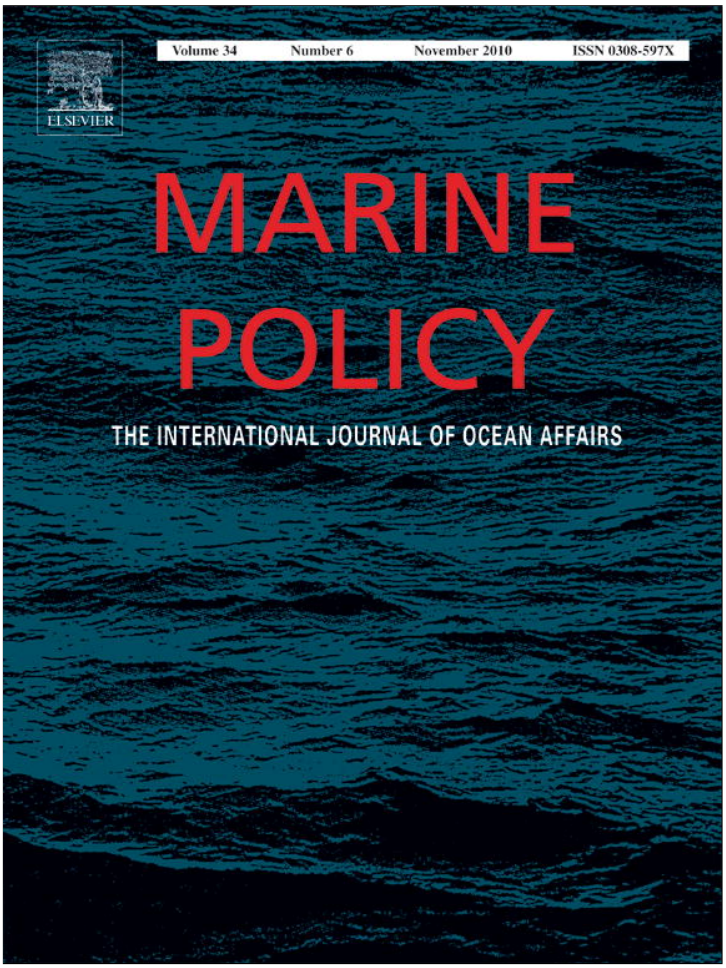

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An Ecosystem Based Fisheries Management framework: the efficient, regional-level planning tool for management agencies

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ABSTRACT

The value of applying a regional level, Ecosystem Based Fisheries Management (EBFM) framework, which is a step-wise, hierarchical, risk-based approach, was tested on the West Coast Bioregion of Western Australia. With structured stakeholder input, over 600 ecological, social, economic and governance issues were initially identified for the region. This complexity was reduced to a level useful for management by consolidating the individual risks into 60 regional-level risks, with a multi-criteria analysis used to integrate the ecological, social and economic risks into just 24 Departmental-level priorities, which ranged from very low to urgent. Given this success, EBFM-based priorities now form the basis for the Department's budget planning process, plus the framework is providing a critical link between fishery level issues and the broader processes undertaken by other marine based agencies. The EBFM framework is a significant step forward for the integrated management of natural resources by enabling all assets and issues relevant to stakeholders and government to be holistically considered at a regional level.

1. Introduction

Since the late 1990s, a large number of regional and international initiatives have sought to develop the mechanisms to apply ecosystem-based principles within the marine environment, but mostly focusing on the management of fisheries (e.g. [1–5]). For such an initiative to be useful, the most critical factor that has emerged is that they must focus on improving management decision-making processes, not just improving scientific understanding [6–9]. Given this recognition, there is now a developing convergence among the various ecosystem-based approaches that are being pursued [10].

Despite the significant progress made at the conceptual level [11,12], there are still few examples where ecosystem-based approaches have been fully adopted by management agencies across their entire spectrum of activities and processes [5,6]. In Australia, for the past decade, the management of individual fisheries has used an ecosystem-based approach [13,14], which was designed to meet the legislative changes and policy initiatives introduced at both the State and Commonwealth level [15,16]. In Western Australia, comprehensive assessments have been completed by the Department of Fisheries (also termed agency) for each major fishery using a risk-based framework [13,17] to examine the impacts on target species, by-catch species and habitats, plus any potential indirect impacts of these removals on the broader ecosystem. These assessments are independently reviewed by the federal environmental agency against a set of sustainable fisheries guidelines [18] with their ongoing performance reported annually [19].

The fishery level assessments do not, however, address the combined effects of all fisheries within the same area, nor do they cover cross-fishery allocation issues or agency prioritisation processes and most have yet to fully incorporate the assessment and integration of the social and economic aspects of fisheries [20]. To address these deficiencies, senior fisheries managers in Australia recognised the need to have a higher, regional level assessment and management planning system (Fig. 1). They termed this approach Ecosystem Based Fisheries Management (EBFM) because it would deal with the cumulative impacts on the environment (including fish stocks, habitats and ecosystems) from all the fisheries-related activities (commercial, recreational, etc.) operating at the regional, or ecosystem level [5,21]. These assessments would also document the overall social and economic outcomes generated by these activities and identify any impacts that might be generated by non-fishing activities (e.g. coastal pollution) managed by non-fishery agencies.

The advantages for fisheries agencies in taking a regional or ecosystem level approach include better consideration of the negative impacts from external sources on fisheries, which

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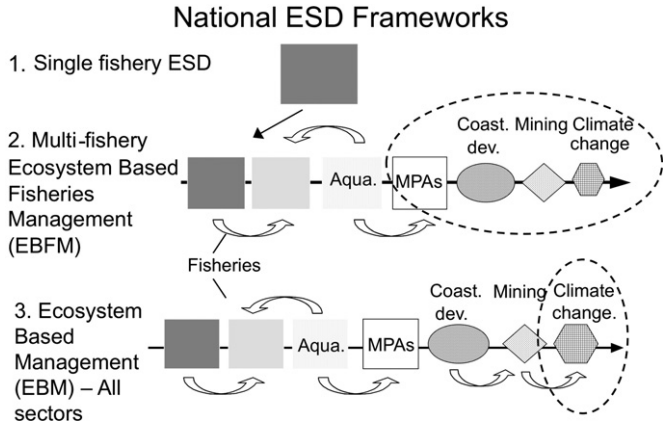

Fig. 1. Relationship between the three ecosystem based framework levels. The elements included in the dashed ovals represent the difference in external drivers between EBFM compared to EBM—modified from Fletcher [7]. Abbreviations have been used for aquaculture (Aqua.), marine protected areas (MPAs) and coastal development (Coast. Dev.).

typically affect all species within a region. Moreover, this is the level where most other government agencies operate, so taking a broader focus would better align fisheries management with regional marine planning processes. Adding an EBFM-level approach could therefore provide the critical linkage between the management of individual fishing activities with holistic planning needed for the management of all outcomes within a region, often termed Ecosystem Based Management (EBM, see Fig. 1).

Expanding the scope of management from a single-fishery to a broader, regional EBFM approach poses a number of logistical difficulties. The principal difficulty being that the process could quickly become extremely complex when trying to deal with all the potential ecological, social and economic issues of an entire region [22]. Initially, managers were understandably highly concerned that implementing EBFM would result in a dramatic increase in the number of management issues they would have to deal with, without increased resources. Numerous data deficiencies were also likely to be identified, which could raise unrealistic expectations among stakeholders about the need for significant additional resources to enable EBFM to be implemented. This meant that for the EBFM process to be useful, it had to adopt methods that reduced the complexity, knowledge requirements and expectations to a realistic and manageable level [6,7].

It was recognised that unless the various concerns could be dealt with effectively, EBFM was likely to suffer the fate of many initiatives with the only outcome being a large report left on a shelf that gained no ongoing management traction. The clear goals for this study were to examine whether applying an EBFM framework could generate significant improvements in fisheries agency planning processes and whether it could improve the linkage of fisheries issues with broader, whole-of-region level planning processes.

To test its effectiveness, the proposed EBFM framework was applied to the West Coast Bioregion (WCB), one of four marine bioregions defined by the Department of Fisheries in Western Australia [19]. As this was the first full-scale attempt in WA to apply the EBFM approach at a regional level, progress was regularly reviewed by a Departmental Committee with the final outcomes assessed by the Corporate Executive who would determine the ongoing benefits to the agency. The degree to which the EBFM initiative was deemed successful internally could be gauged by the level to which both the approach and the outputs were ultimately adopted into standard agency practices and processes. The level of external success could be gauged by the acceptance of other agencies for both the process and the outputs within their own planning schemes.

2. Methods

The EBFM framework is based on the National ESD framework developed for wild capture fisheries in Australia [13,14,17]. They are both step-wise, risk-based assessment processes, which use the International Standard Risk Management guidelines [23] as their foundation and they are fully consistent with the ecosystem approach to fisheries [24,25]. They both conduct workshops with stakeholders and generate reports that cover any impacts on the relevant ecological assets including the target species and other ecosystem elements, plus the potential social and economic issues (or expected outcomes) of interest to stakeholders, along with an examination of the current governance systems.

To deal with the increased scope of operating at a regional level and the associated potential difficulties and complexities that this generated, the EBFM framework required a number of specific modifications compared to the individual fishery framework. The regional scope of EBFM also resulted in the identification of some relevant issues or impacts that are the formal responsibility of other (non-fisheries) government agencies. This required a greater level of consultation and direct involvement by these non-fisheries agencies in the process for the overall outcomes to be useful.

While implementing the entire EBFM framework involves five steps (Fig. 2), only the first three steps will be covered in detail because only these are unique to the EBFM process.

2.1. Step 1—determine the scope of the assessment

The initial step was to generate outline descriptions of the ecological attributes and all the fisheries related activities that operate within the WCB region. These were compiled along with the current suite of spatial and other management arrangements that operate in the area. The first stakeholder workshop developed a shared understanding of the high-level community values and objectives relevant to the marine ecosystems within the WCB.

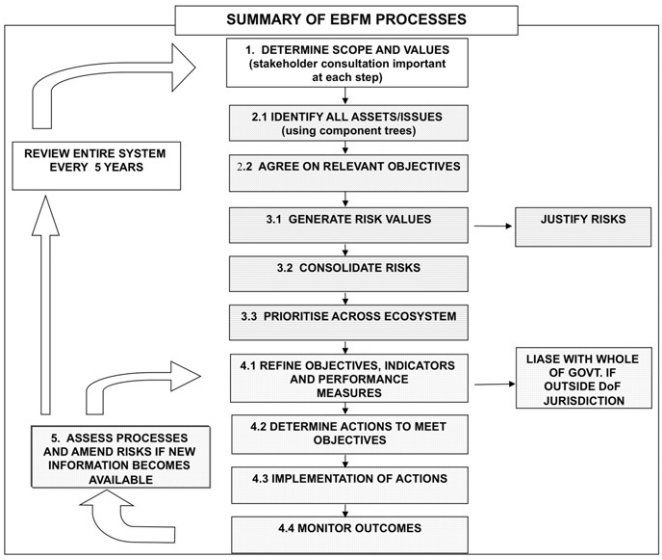

Fig. 2. Outline of the entire EBFM process which is based on the ISO 31000 risk management principles and guidelines and is modified from the single fishery process of Fletcher et al. [14]. DoF is an abbreviation of the Department of Fisheries. Only steps 1 to 3 are covered in detail here.

Together these provided a description of the key resources of the WCB and what the WA community wanted to achieve from the management of these resources.

The final part of this step was to document the various roles and responsibilities of the relevant agencies and stakeholders. This required formal consultation with many stakeholder groups and, importantly, obtaining agreements from other government agencies where overlaps in jurisdictional arrangements or government objectives had been identified.

2.2. Step 2—asset and issue identification

Using the agreed scope and values for the WCB (see Table 1), the next step was for the stakeholders to identify each of the ecological assets that needed to be managed. They also identified the associated social and economic issues that are generated from the activities that affect the ecological assets. The factors that affected the ability to achieve the desired management outcomes (institutional governance and external drivers; Fig. 3) were also examined and documented. For each of the identified assets and issues (i.e. the EBFM components), the stakeholders determined what specific objectives were to be achieved given any local, regional, national or global requirements based on their ecological concerns, economic realities or social attitudes.

Table 1
The high level values and objectives that were identified as being relevant to the West Coast Bioregion.

	Value	High level objective
1	Species sustainability	Keeping biomass levels above levels where recruitment could be affected
2	Ecosystem sustainability	Ensuring that any impacts on ecosystem structure and function are kept at acceptable levels
3	Economic outcomes	The economic benefits to the community are optimised
4	Social amenity	The social amenity (i.e. non-economic benefits) derived by the community is optimised
5	Social impacts	Social impacts and negative attitudes associated the management of these resources are minimised

To assist in the structured identification of the assets and issues into a hierarchy of related groups, a set of generic EBFM component trees were used. Through a series of workshops, stakeholders (including managers) specifically tailored each of the EBFM trees to the WCB by adding relevant assets and issues and deleting those considered irrelevant. The major addition in the EBFM trees compared to the individual fishery trees previously used by the Department, was the Ecosystem Structure and Biodiversity branch, which recognises that each of the individual ecological assets that are directly or indirectly impacted (e.g. habitats, target species, protected species) combine together to form ecosystems at the regional level.

2.3. Step 3—prioritising issues

To reduce the complexity generated from the identification of a large number of individual assets and issues across the entire WCB, a three-part prioritisation process was used. This determined which assets and issues needed direct management action from a whole-of-agency perspective, what level of action should be taken and at what scale this should be undertaken.

Individual risks: The risks associated with the objectives (see Table 1) for each individual asset or issue were examined separately using either formal qualitative risk assessment (consequence × likelihood) or more simple problem assessment processes, as detailed in Fletcher [17,26]. These methods enabled the analysis of risk (using a 5 year time horizon) for objectives related to species, habitat and community structure/ecosystem sustainability, plus social and economic outcomes to be completed. Internationally, risk has now been defined as "the uncertainty associated with achieving objectives" [23]; therefore, any uncertainties from a lack of specific data for an issue/objective were explicitly incorporated into the assessment, enabling the calculation of risk to be completed with whatever data were available at the time. All of the risk scoring considered the level of current activities or management controls already in place or planned.

Consolidating risks: The number of individual risk values generated across the entire EBFM framework for the WCB was too large (~600 assets and issues) to be of any practical use in

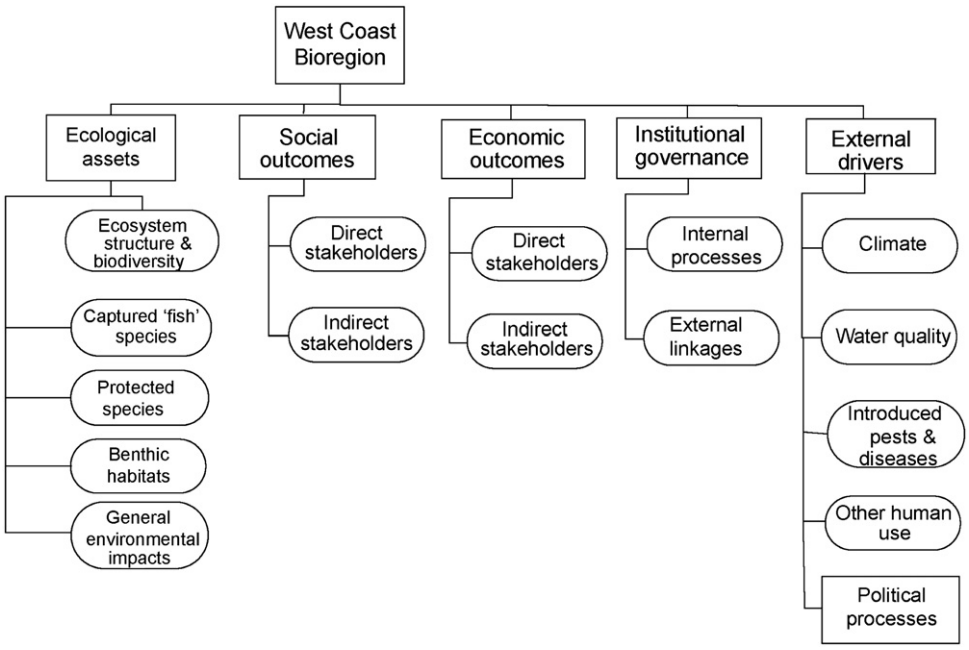

Fig. 3. EBFM component tree structure. Ovals represent components that separate into more detailed component trees.

whole-of-agency planning. Furthermore, many of the individual assets and issues were already the subject of specific management actions and planning processes at the individual fishery level. To ensure that the EBFM process complimented rather than duplicated the existing fishery-level activities, it was necessary to combine the individual asset and issue risks into regional or category-level risks.

The consolidation of risks extends an existing Departmental process whereby all captured species have been assigned to one of about eight 'species suites' in a region which are consistent with the key ecosystem sub-branches (e.g. nearshore, inshore, offshore). The same principles were applied to each of the other trees in the framework with the consolidated risks for each major branch of the component trees determined by the following:

- For ecological assets, specific indicator species or components were identified with the risk value assigned to the entire 'suite' of species or functional group using the highest risk value of any of the indicator species.
- For the non-ecological issues, the consolidated risk value was the average of the risk ratings for each of the components in the sub-branch and, where relevant, each sub-branch within a branch.

Thus, a hierarchical approach was used such that consolidation could be done at a number of different levels within each tree.

Agency/bioregional priority setting: The final, and arguably most important, part of the EBFM process was to generate a whole-of-agency priority score for each of the consolidated ecological assets within the bioregion which incorporated their associated social and economic risks and values. These overall priorities could then be used to guide the agency about the areas where it should invest its resources.

The integration of the various risk and value scores into Departmental priorities was achieved using a simple multi-criteria function and 'Agency Priority Formula':

$$\text{Agency Priority} = (\text{'Ecological/Stock' Risk-External Impact}) * ((\text{Economic Risk} * \text{GVP}) + (\text{Social Risk} * \text{Social amenity}))$$

The risk scores were obtained from the qualitative risk assessment process outlined above, with the criteria for assigning the economic value and social amenity scores to each issue provided in Table 2. In integrating the various risk and value scores, the formula recognises that the level of Departmental activity should be mostly related to the current ecological risk for the asset. It also recognises that if this stock or ecological risk is largely generated by human factors external to the management control of the fisheries (e.g. pollution), the overall scope for direct activity by the Department of Fisheries will be scaled accordingly.

In addition to the ecological risk, the formula recognises that the priority for undertaking activities will be affected by the value of the asset to the community. This value will be based on the direct economic benefit and/or from indirect benefits such as social amenity, importance to recreational fishers and the 'existence value' for non-users. The reason for independently assessing the risk and the value for the social and economic elements is that the individuals involved may clearly be facing a high risk of impact to their objectives, which can then be explicitly recognised, but if the overall value to the community is low, this will reduce the priority to expend significant agency resources. Thus, an asset will generate the highest scores and priority if its ecological sustainability risk is high, plus it is valuable economically and/or socially to the community.

3. Results

3.1. Scope—West Coast Bioregion

The marine environment of the WCB is predominantly a temperate oceanic zone that is heavily influenced by the Leeuwin Current, which transports warm tropical water southward along the continental shelf. The fish stocks of the region are typically temperate, in keeping with the coastal water temperatures that range from 18 to about 24 °C. The major habitats include extensive areas of sand plus rocky reefs (old coastlines) on which algae/kelp and sponge communities generally dominate. In addition, due to the Leeuwin Current's influence, coral communities are present in some locations (Abrolhos Is. and Rottnest Is.). Extensive areas of seagrass are present in sheltered nearshore and inshore waters.

The major commercial fishery in this region targets the western rock lobster (*Panulirus cygnus*) and is Australia's most valuable single-species fishery with a long-term average annual catch and value of 11,000 t and $300 million, respectively. Other significant invertebrate fisheries include scallops (*Amusium balloti*) and abalone (*Haliotis roeii*). Commercial fishers take a range of demersal scalefish species including dhufish (*Glaucosoma herbraicum*), snapper (*Pagrus auratus*) and various emperors (*Lethrinus* spp.), as well as various shark species using demersal line and net methods. Beach-based seining and gillnetting are used to capture a variety of nearshore species such as whiting (Sillaginidae) and Australian herring (Arripidae), with a small purse seine fishery targeting small pelagic fish (mostly Clupeidae).

The commercial fisheries in the WCB have all been under some form of restrictive management to limit access to a specific number of fishers and/or their effort/catch levels for some time. The commercial lobster fishery has had tight limits on pot and day usage, which are varied annually to ensure that the level of harvesting is appropriate. Similarly, a number of the larger demersal finfish fisheries (targeting scalefish or sharks) have time-gear access limits to regulate the total levels of capture of the key indicator species. Fisheries for abalone and deep sea crabs use quotas to limit commercial catch levels plus most commercial fisheries are subject to various time and spatial closures, as well

Table 2
Criteria used to assess the relative economic (gross value product) and social amenity value associated with each ecological asset in the West Coast Bioregion.

Score	Risk	Economic value	Social amenity
0	None	No commercial use	n/a—There is always some level of community interest in an asset.
1	Negligible	< $1 million	Minimal—there is no recreational fishing for the asset and no specific broader community interests
2	Low	$1–5 million	Some—the asset may be caught recreationally and/or there is some specific interest in the asset by the broader community
3	Moderate	$5–10 million	Important—this is an important asset locally and/or the use or existence of the asset is important to the broader community
4	High	$10–20 million	Major—the asset provides a major source the catch by recreational fishers for the entire region and/or the asset generates major interest for some of the general community.
5	Severe	> $20 million	Iconic—this is a primary asset targeted by recreational fishers across the region and/or it is an asset that is considered iconic by most in the general community

as other regulations such as size limits. The small trawl fisheries are heavily restricted spatially with over 50% of the continental shelf in this region permanently closed to trawling but the effective area not trawled is greater than 95% [27].

The WCB contains the largest population centres for Western Australia and is therefore the most heavily used bioregion for recreational fishing. The range of recreational fishing opportunities includes estuarine fishing, beach fishing and boat fishing either in embayments or open marine waters for demersal and pelagic/game species, often around islands and out to the edge of the continental shelf. Many of these resources are shared between the commercial and recreational sectors.

A cross-agency forum agreed that the primary-level marine ecosystems that would be used for all relevant WA Government based processes, including EBFM, were those defined in the Integrated Marine and Coastal Regionalisation of Australia (IMCRA) v3.3 [28]. Therefore, in the WCB, the main ecosystem divisions were the West Coast, Leeuwin-Naturaliste and Abrolhos Islands (Fig. 4).

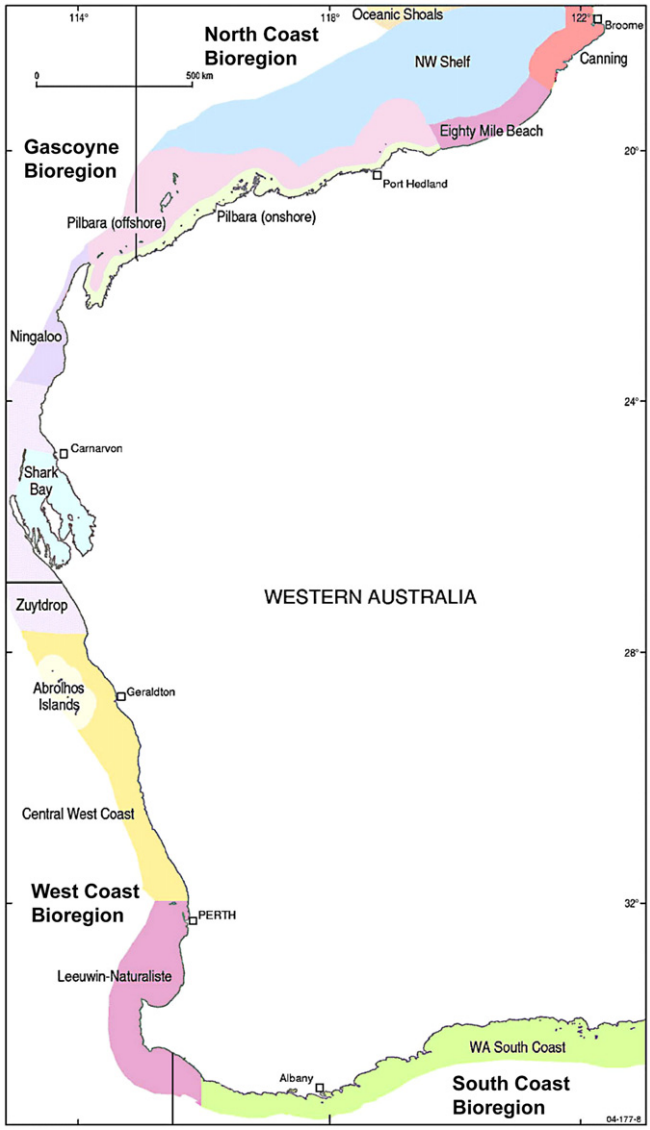

Fig. 4. Excerpt from IMCRA v 3.3 [28] showing the IMCRA bioregional boundaries (coloured regions) and the Department of Fisheries regional boundaries (black lines). The Central West Coast bioregion in this figure has been referred to as the West Coast bioregion in the article. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

The various legislative instruments and agency responsibilities associated with the management of the WCB were also considered to highlight any overlapping responsibilities and potential impacts for alternative management strategies. For instance, the Department of Fisheries is responsible for all activities involving 'fish' (i.e. all aquatic organisms except reptiles, birds, mammals, amphibians) and their habitats within State waters. This Department is also responsible for pearl oyster production and aquaculture. Overlapping with the Department of Fisheries are the Commonwealth Department of Environment, Water, Heritage and the Arts (DEWHA) and the State Department of Environment and Conservation (DEC). DEWHA is responsible for fisheries and protected species in Commonwealth (Australian waters excluding state waters which are generally close to shore) and DEC manages marine reserves, birds, reptiles and marine mammals in State waters. Overlaps between these departments are important as they determine that there are multiple management strategies operating simultaneously to manage various fish stocks that move between State and Commonwealth waters (DoF and DEWHA) or aquatic species that move between protected and fished areas (DoF and DEC). There are numerous other overlapping responsibilities with other agencies and Departments, such as the management of pests entering ports through shipping (DoF and Department of Transport) and the management of fish in estuaries (DoF and various river management agencies).

3.2. Assets, issues, outcomes and risks

Ecosystem: Using the three IMCRA ecosystems (Fig. 4) as the first tier in this tree, the stakeholders further divided these into functional levels that could potentially be measured and monitored for natural resource management purposes:

- Estuarine and embayments.
- Nearshore waters from the coastal shoreline to 20 m depth.
- Inshore demersal, which includes the benthic and lower layers of the water column from a depth of 20–250 m.
- Offshore demersal, which includes the deeper demersal waters from a depth of around 250 m to the Australian EEZ (exclusive economic zone).
- Pelagic, including the upper layers of the water column from the nearshore zone to the EEZ.

These functional ecosystems were further divided to reflect particular geographic elements of significance, including islands and specific rivers or estuarine systems, generating a set of 14 individual 'ecosystems' (Fig. 5). The current risk to each of these ecosystems was assessed and used as the basis for consolidation of risks back into the five regional level, ecosystem assets (Nos. 1–5 in Fig. 5). For these consolidated assets a relatively high risk was associated with the two estuarine and embayment systems within the WCB (e.g. [29,30]), with moderate to low risks associated with the three marine ecosystems.

Captured species: For practical purposes, the primary branches to structure this set of assets were finfish, crustaceans and molluscs. Each of these branches was then divided into suites of species based on the same functional groupings as outlined for the ecosystems (Fig. 6). Stakeholders identified over 80 separate species or stocks across 8 functional suites. Within each of these suites one or more indicator species had previously been identified for use in assessment and monitoring of the sustainability status for the entire suite (e.g. [31]).

Two of the suites of captured species had severe risk values (inshore demersal finfish and estuarine finfish), with the other six suites varying from low risk (pelagic finfish) up to high risk

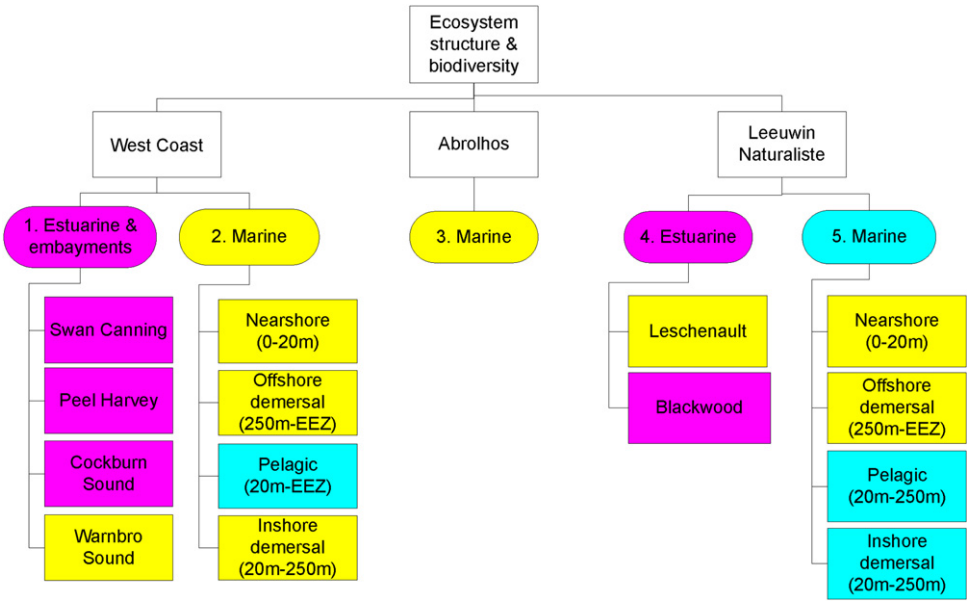

Fig. 5. West Coast Bioregion—ecosystem structure and biodiversity individual risks. Ovals represent the level at which sub-branch components were aggregated in the consolidated tree. Numbers indicate the categories that were used as the basis for the multi-criteria assessment (Table 3). Risk legend: SEVERE HIGH MODERATE LOW (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.).

(nearshore/estuarine crustaceans and nearshore finfish). The severe risk rating for the inshore demersal finfish suite resulted from sustainability issues that had been identified for a number of the indicator species, which had been generated by excess fishing [32]. For the estuarine finfish suite, however, the severe score was generated by the sustainability status of only one of the indicator species, which is largely the result of poor water quality and habitat degradation problems within estuaries [32].

Protected species: This component tree (Fig. 7a) was divided into protected fish and protected non-fish (e.g. little penguins and Australian sealions). Only the suite of protected non-fish species contained elements of sufficient risk to require ongoing management actions and monitoring. Given previous and current fisheries management actions in place, none of the protected fish species in this region were assessed to be at risk of further declines.

Habitats: The current fisheries management regimes determine that the benthic habitats of the WCB were, overall, generally at low risk (Fig. 7b) [27]. The exceptions were the non-fishing related impacts facing sand and seagrass habitats within some estuarine and embayment areas (e.g. harbour dredging, sedimentation from development, nutrient input). The activities generating these impacts are not managed by the Department of Fisheries and are the responsibility of another government Department.

Social and economic issues: The social and economic issues associated with the management of the ecological assets were found to have different (often competing) objectives and therefore these assessments were kept separate to enable a more focused discussion and less confusion when assessing the risk. Economic evaluations tend to focus on 'net economic benefits' to the commercial sector, which use prices and markets to describe benefits to a specific group or community. Compared with social evaluations, this allowed a relatively straightforward approach to the measurements and comparison of benefits across uses [33]. Furthermore, to better link the social and economic issues with fishery management priorities, the trees were divided into those issues associated with the direct stakeholders (often economic) and those of indirect stakeholders (often social).

The risk values for the diverse set of social and economic categories at the issue, sub-branch and branch levels varied substantially from low to severe (Figs. 8 and 9). Many of the high risks were caused from substantial changes currently being made to the management arrangements for the fisheries in this region (e.g. recreational fishing, inshore demersal finfish). Some, however, relate to actions being considered by other agencies (e.g. imposition of MPAs), or from the current and likely future status of stocks along with global market conditions and cost structures (e.g. inshore demersal crustaceans—rock lobster fishery).

Governance: The elements identified within the institutional governance tree cover all the legislative, administrative and bureaucratic processes that need to be completed to enable the assets and issues in the other trees to be dealt with effectively [14]. This tree outlines both the management processes undertaken within the Department of Fisheries plus the external linkages, including consultation with key stakeholders and conservation NGOs, interactions with other State and Commonwealth Departments, Universities and funding bodies (Fig. 10).

Many of the elements, and therefore the sub-branches and branches, were rated as being at high risk. This reflects the number of major reviews underway, including the stakeholder consultation processes and funding arrangements. In addition, the linkages with other state and federal agencies that independently conduct marine planning exercises also lead to difficulties. Moreover, the analysis of legislative responsibilities has indicated a number of areas with substantial duplication or ambiguity leading to inefficiency of processes, wastage of government funds and increased stakeholder uncertainty and frustration.

External drivers: Of the five major types of external drivers, two were identified for which direct fisheries agency activities were considered appropriate. The first is the impacts of climate and oceanographic conditions on ecological assets, and the second is the impacts of introduced pests and diseases. While the other external drivers are clearly anthropogenic and can impact directly on fisheries or ecosystems, they are the direct responsibility of other agencies or groups (Fig. 7c). Although not able to be controlled directly, these external issues still need to be taken into

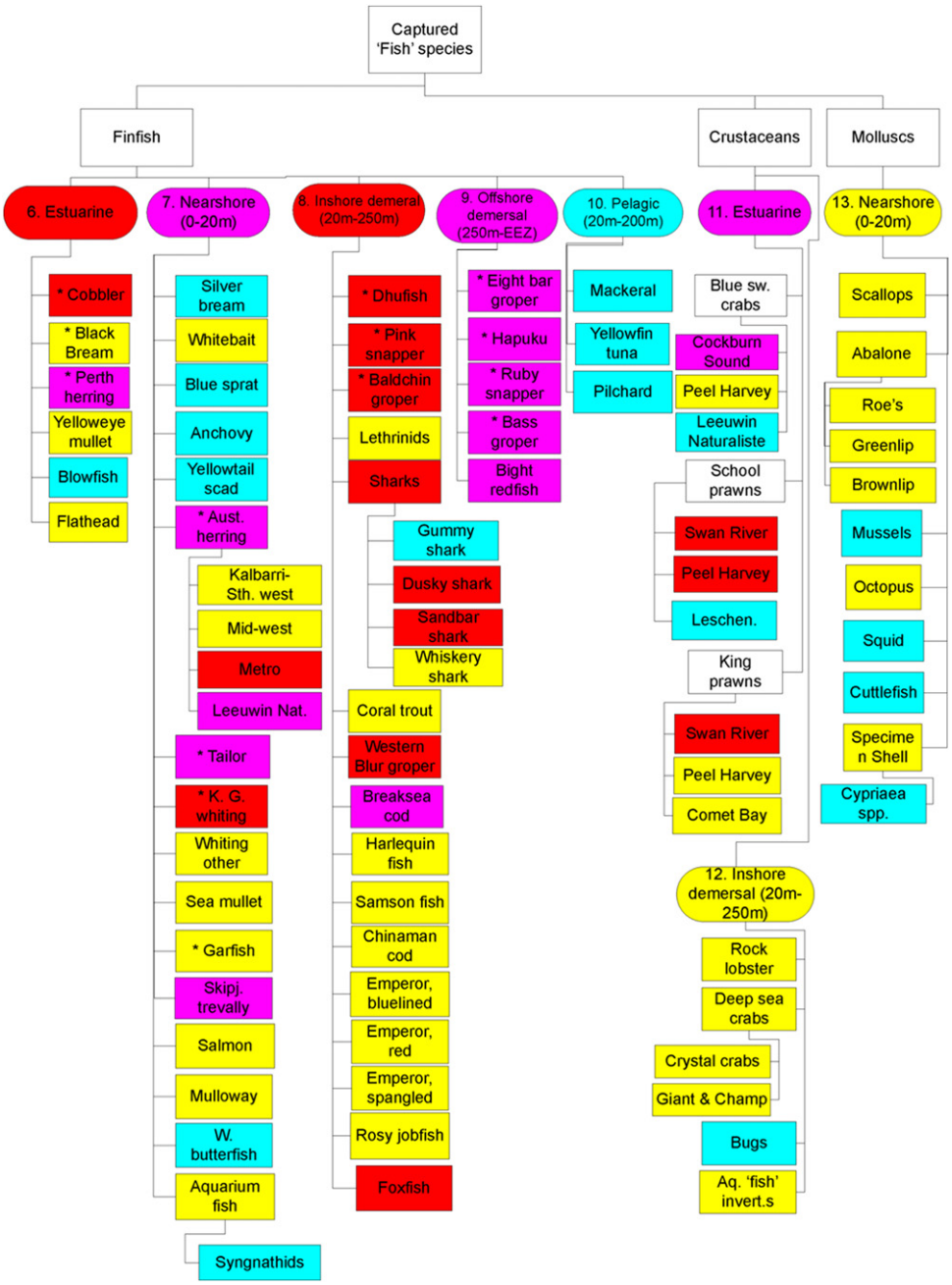

Fig. 6. West Coast Bioregion—captured species risks, consolidated risks are the ovals at the top of the branches. Numbers indicate the categories that were used as the basis for the multi-criteria assessment (Table 3) and indicator species are marked with an asterisk (*). Risk legend: SEVERE | HIGH | MODERATE | LOW. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

consideration, as they are likely to substantially affect the management outcomes and are often issues of concern to stakeholders. The strength or otherwise of the external drivers will also affect the level of management and priority of resource allocation for direct action by the Department of Fisheries.

3.3. EBFM based Departmental priorities

By combining the individual risks to a regional level, the consolidation process reduced the number of ecological assets and socio-economic issues to a combined total of 60. This was still considered too large to be of direct use within a whole-of-agency planning and priority setting process. Moreover, as many of the individual ecological, social and economic components were interrelated they needed to be integrated prior to undertaking any agency planning to ensure that a truly holistic approach to their management was taken.

The Department's primary objective is to manage the sustainability of the communities' ecological assets from which economic or social outcomes and benefits can be generated. Assigning Departmental (i.e. government) resources must first consider the direct risks to the stocks or environment and then the levels of economic and social outcomes derived from the 'use' of this asset by stakeholders. This concept resulted in the reduction of the set of assets to just 22 consolidated ecological assets plus two governance categories that the Department needed to consider in its prioritisation process for the WCB (see Table 3).

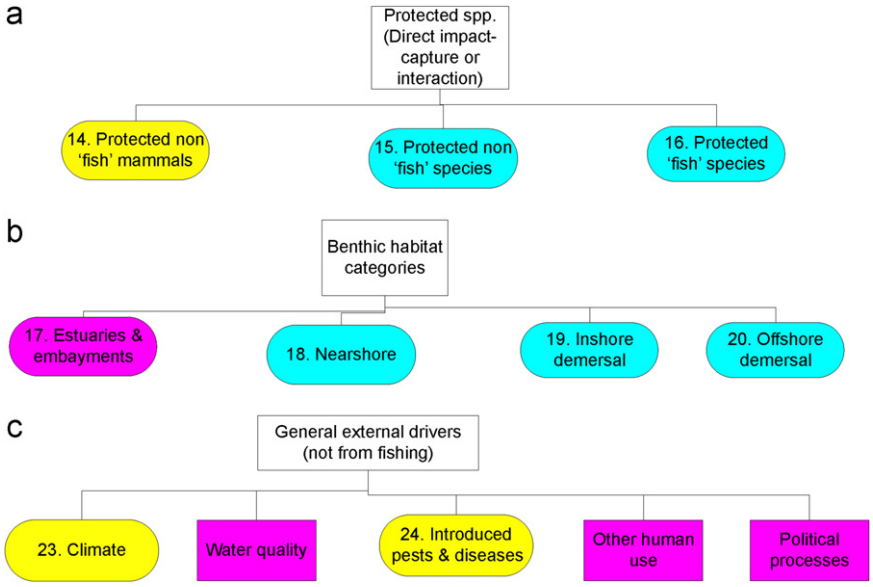

Fig. 7. West Coast Bioregion: (a) protected species risks, (b) benthic habitat categories and (c) general external driver risks. Consolidated risks are the ovals at the top of the branches. Numbers indicate the categories that were used as the basis for the multi-criteria assessment (Table 3). Risk legend: SEVERE HIGH MODERATE LOW. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

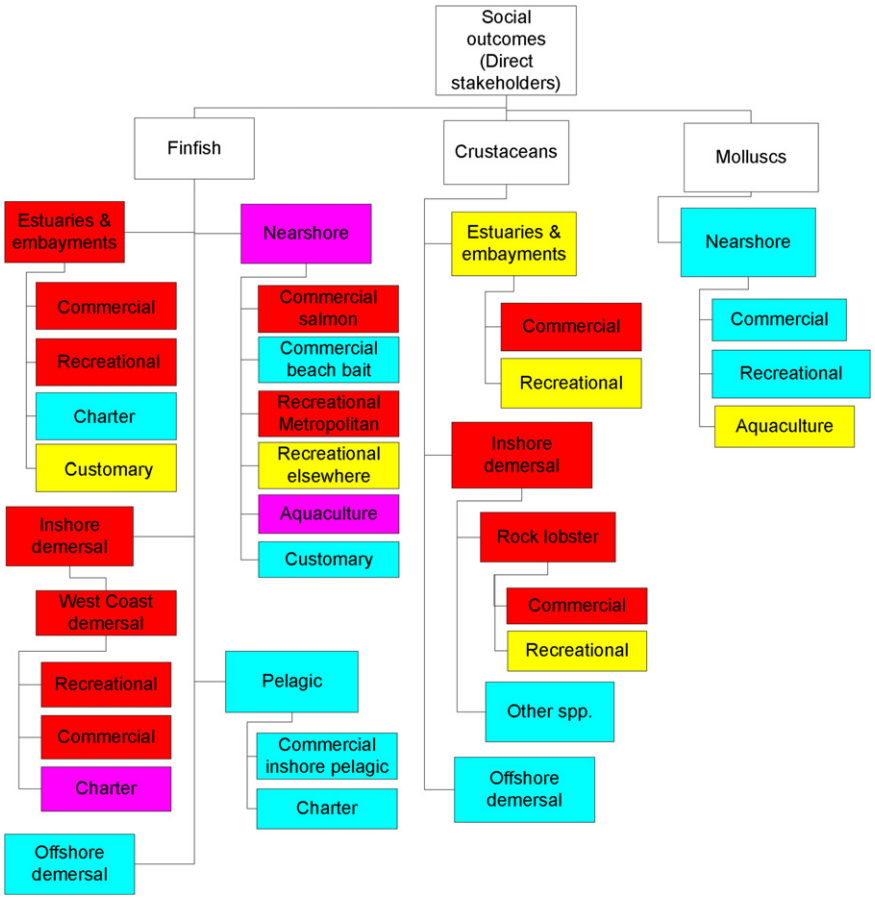

Fig. 8. West Coast Bioregion—social risks for direct stakeholders. The consolidated risks are not numbered because the social and economic risks are included within the multi-criteria analysis of the appropriate ecological asset (Table 3). Risk legend: SEVERE HIGH MODERATE LOW. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

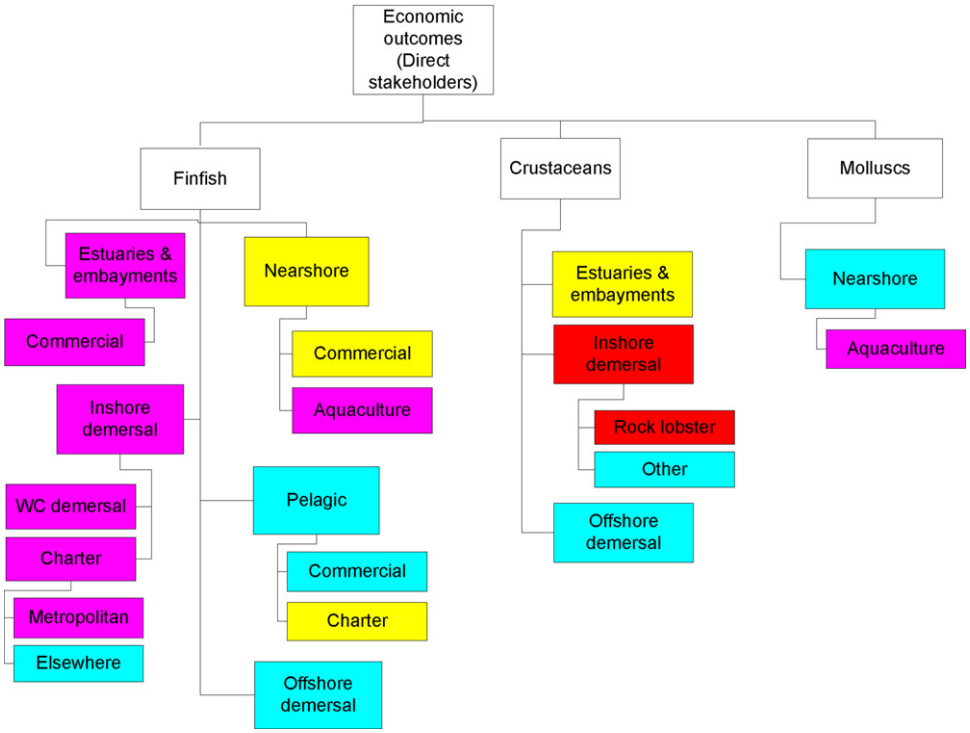

Fig. 9. West Coast Bioregion—economic risks. The consolidated risks are not numbered because the social and economic risks are included within the multi-criteria analysis of the appropriate ecological asset (Table 3). Risk legend: SEVERE HIGH MODERATE LOW. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

The simple multi-criteria system integrated the various ecological, economic and social scores into a single Departmental priority score that was used to compare priorities across the 24 regional level assets/categories (Table 3). The priority scores ranged from about 100 down to just 4, providing a relatively large degree of discrimination among assets: five had urgent priorities, two had high priorities and six each had medium, low and very low priorities.

The highest score was generated for captured species—shelf crustaceans (Asset #12), which is dominated by the rock lobster fishery, the largest and most valuable fishery in the State. The high score reflects that this fishery is currently facing a number of significant issues [19] including recent reductions in recruitment levels and major reductions in the allowable catch to ensure breeding stock levels are not impacted. In addition, the income levels for fishers are being affected by relatively low prices due to overseas market conditions and high exchange rates, which are exacerbating the impacts of increased costs associated with fuel and labour. This combination is generating significant social issues for the catching and processing sectors plus there are flow on impacts to the dependent communities and service groups. A substantial increase in new research is now underway to understand the cause(s) of the low recruitment, plus examine ways to make the fishery more profitable within the bounds of the lower acceptable catches [19]. A very high score was also generated for the Inshore Demersal Finfish suite (Asset #8). This suite is caught by three separate commercial fisheries as well as the charter boat industry and is also the primary target group for the boat-based recreational fishing sector [19]. Consequently, to ensure that all the EBFM objectives for this bioregional level asset are attained requires successful and coordinated management actions to be taken within a number of separate but interconnected fisheries. This includes a formal process to determine explicit levels of access to the resource among the various commercial and recreational sectors [19].

To deal with declining stock status of the indicator species, intensive management activities have been implemented over the past 3 years across all commercial and recreational fisheries to reduce their level of capture of the entire suite by at least 50% [31]. These actions have generated significant economic and social impacts for the commercial industry by closures to some zones and reductions in the total access levels allowed. Similarly, the recreational fishery has had strong measures imposed (including licences, closed seasons and reduced bag limits) to sufficiently reduce their catch, all of which has generated an intense level of public debate.

The priority for the West Coast Marine ecosystem (Asset #2) was medium. This outcome was based on an assessment of the community structure and trophic levels of all commercially caught fish species over the past 30 years which found no evidence of systematic changes, which would be evidence of an unacceptable impact on this ecosystem [34]. Given that the few components of this ecosystem that are considered to be at risk were already the subject of intense management, the only additional management activities required were the establishment of an ongoing monitoring scheme including sampling locations within and outside of areas closed to fishing.

One of the lowest priorities generated was for the pelagic finfish suite (Asset #10). This suite has had relatively minor levels of fishing for the past decade due to poor markets and difficulties in maintaining catches at economically viable rates. Consequently, the risks to the stocks are currently low to negligible and there are no additional risks for other trophic levels. There is minimal commercial value or risk and extremely limited capture of this suite by recreational fishers; hence, this has a very low priority for use of Departmental resources.

Most of the 24 categories had priority scores that were broadly consistent with both the ecological risks and the current levels of activity being undertaken by the Department. For the benthic habitats in estuaries (Asset #17), however, the severe risks did not

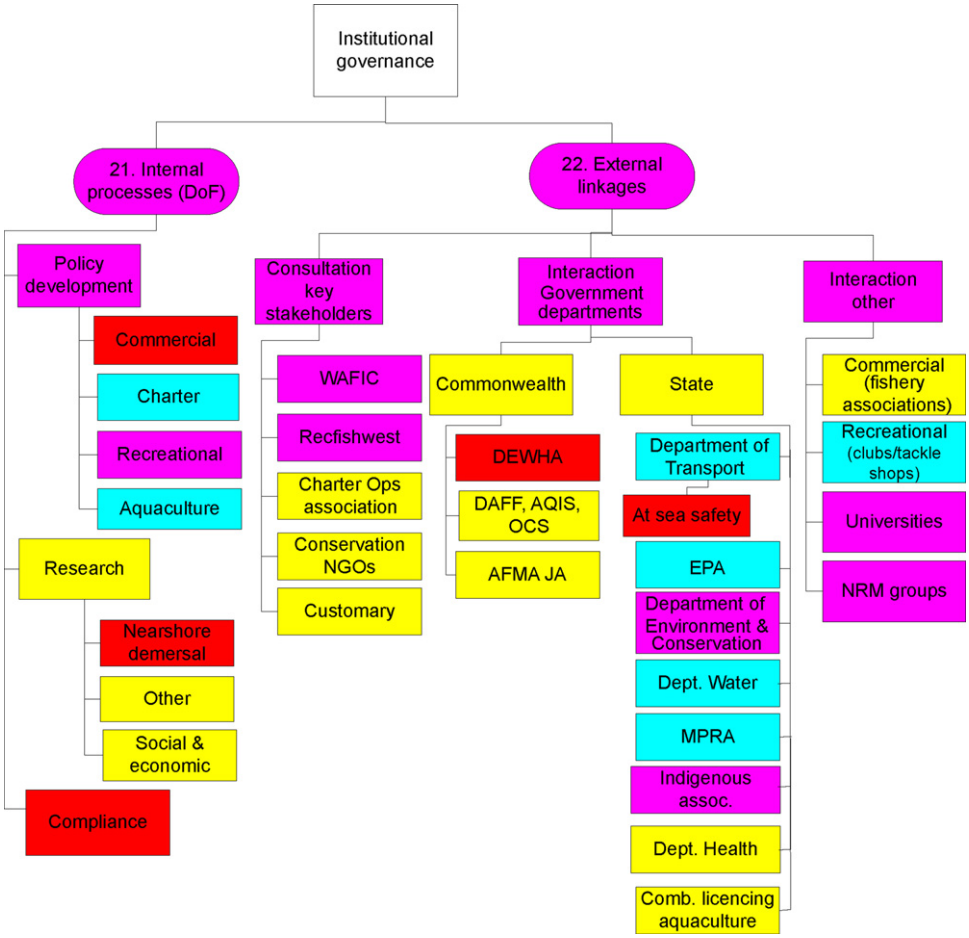

Fig. 10. West Coast Bioregion—governance risks, consolidated risks are the ovals at the top of the branches. Numbers indicate the categories that were used as the basis for the multi-criteria assessment (Table 3). Risk legend: SEVERE HIGH MODERATE LOW. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

result in a high Departmental priority because nearly all of these risks were generated by activities (e.g. harbour dredging, sedimentation) managed by other agencies. Similarly, the priority for finfish within estuaries (Asset #6) was not as high as would be expected from the risk level, because the majority of the risk to these stocks was generated by external factors such as coastal development, resulting in sedimentation/loss of habitat, agricultural run-off, etc. The Department has already banned the capture of the estuarine stocks most at risk and is working with the other agencies that are responsible for catchment management to try and influence improvements to water quality outcomes.

One area where there appears to be a mismatch between the priority score and the current level of Departmental activity is for introduced pests and diseases. This scored a medium to high priority but currently few resources are assigned to this issue. Having been identified, this situation is now being addressed through reprioritisations of existing resources and from submissions to government to cover this expanding risk area.

3.4. Integrating EBFM into Departmental planning and reporting

Following the completion of the EBFM assessment for the WCB, the value of this approach was formally reviewed by the Corporate Executive of the Department of Fisheries. After examining the outcomes from the case study and particularly the specific priority scores being generated by the EBFM process, it was agreed that the consolidated EBFM ecological assets and their associated agency priorities would become the primary categories for the Department's Risk Register, which provides the basis for the agency's budget planning process. The risk scores for each asset will be updated annually based on the outcomes of the previous year's activities and any resulting shifts in risk/value scores will be used for determining the budget priorities for the following year.

Measurement of the Department's performance in managing these regional level, ecological assets has already begun. A related set of research projects has been underway to develop the methods for cost effectively monitoring each of the ecosystem assets of moderate or higher priority [35]. The current status for each asset and a summary of activities are now included in one of the Department's annual reports to Parliament [19].

4. Discussion

Despite relatively few examples where ecosystem based systems have been fully adopted by management agencies, scientific endeavour within this field is growing rapidly. As was identified by Rice [8], the evolution of ecological science and the policies to make use of new information are often not well aligned. While ecological research continues to dominate the activities undertaken, there is a growing recognition of the equal, if not greater importance of the social and economic components and particularly the structure of the governance systems used for

Table 3
Outcome from the multi-criteria assessment for the evaluation of ecological assets in the West Coast Bioregion. The risk scores used are the outcomes of the consolidated risk assessments. Numbers refer to the component trees (Figs. 5–10). The criteria for scoring GVP and social amenity are also located in this table.

Asset/issue	Stock/Environ. risk	GVP	Economic risk	Social amenity	Social risk	Other human external impacts on stock/Environ. risk	Total score and overall current priority
12. WC Crustaceans—shelf (lobster)	3	5	5	3	3	0	**102 Urgent**
8. WC finfish—inshore Demersal	5	2	4	4	4	1	**96 Urgent**
7. WC finfish—nearshore	4	1	3	5	4	0	**92 Urgent**
22. WC governance—external linkages	2	5	4	5	4	0	**80 Urgent**
21. WC governance—internal processes	2	5	4	5	4	0	**80 Urgent**
3. WC ecosystem—Abrolhos	3	5	3	5	2	0	**75 High**
11. WC crustaceans—nearshore/estuarine	4	2	3	5	3	0.5	**73.5 High**
23. WC external–climate change	2	5	3	5	2	1	**50 Medium**
24. WC external–introduced pests and diseases	3	3	1	3	4	0	**45 Medium**
13. WC molluscs—nearshore	3	4	2	3	2	0	**42 Medium**
2. WC ecosystem—marine	3	5	2	5	2	1	**40 Medium**
6. WC finfish—estuarine	5	1	3	4	4	3	**38 Medium**
14. WC protected species – non fish – mammals	3	1	1	3	3	0	**30 Medium**
1. WC ecosystem—Estuarine	4	3	3	4	4	4	**25 Low**
9. WC finfish—offshore demersal	4	2	2	1	1	0	**20 Low**
19. WC benthic—inshore demersal	2	5	1	4	1	0	**18 Low**
17. WC benthic—estuaries	5	1	3	3	4	4	**15 Low**
4. LN ecosystem estuarine	4	3	2	3	3	3	**15 Low**
5. LN ecosystem marine	2	1	1	3	2	0	**14 Very Low**
15. WC protected species – non-fish – non-mammals	2	1	1	4	3	1	**13 Very Low**
18. WC benthic—nearshore	2	3	1	4	2	1	**11 Very Low**
20. WC benthic—offshore	2	1	1	2	1	0	**6 Very Low**
16. WC protected species—fish	1	1	0	3	2	0	**6 Very Low**
10. WC finfish—pelagic	2	1	1	1	1	0	**4 Very Low**

fisheries and ecosystem management [6,7,8,9]. The development of an EBFM framework which would enable practical, regional level management planning was undertaken to address a critical gap in governance that had been identified by senior managers.

While it was recognised by the Department that a broader ecosystem-based, EBFM approach was needed, initially there was a high degree of misunderstanding by many staff about precisely what this meant. This led to a high level of scepticism about whether EBFM would generate useful outcomes or just be a potential drain on resources leading to a loss of focus on core issues. These doubts continued until it could be demonstrated that the system could produce meaningful, whole-of-agency priorities not just endless lists of issues and gaps. Without these usable outputs, it is highly likely that the case study would have been just another research project that raised stakeholder expectations and consumed more than its fair share of resources.

The outputs generated by the framework not only had to be of practical value to managers, but also had to accommodate the expectations of the various stakeholder groups. This initially involved capturing all issues of concern (almost 600) for the WCB at the level of interest of the various stakeholder groups. By taking a hierarchical approach, while these were consolidated into regional level assets, the details were not lost because this is the level where specific actions are undertaken.

The structure of the priority matrix, whereby each of the ecological assets are integrated with their associated economic and social issues and risks, provides both conservation and fisher-based stakeholder groups with the holistic management system they have been seeking [36]. All of the ecological assets for a region, not just the targeted or directly affected species, are now assessed in a uniform manner and there are clear opportunities to indicate any differential levels of community importance associated with the use (or non-use) of these assets. This EBFM framework has, therefore, enabled the development of explicit but simple mechanisms to prioritise risks and proactively seek balances and trade-offs for use in the management "game" [6].

None of the individual methods used within this EBFM framework are novel or complicated; it was recognised that if the system was too complex or needed new data or models it was unlikely to be adopted. The novel combination of relatively simple steps has, nonetheless, proven particularly effective in generating regional level management outcomes without having to expend significant additional resources. Given the large scale of the region covered and the potentially limitless issues that could be identified, the approach taken to apply the EBFM principles was necessarily pragmatic. The decisions on the specific consolidated assets and categories sometimes had to involve compromises. Similarly, some of the risk and value scores could be refined if more resources were applied, but generally not by a degree that would materially change the overall priority for an asset.

The scoring system used in the multi-criteria system needed to be sufficiently clear, so that it could be applied in all circumstances and the formula developed had to be appropriate for the legislative responsibilities of the Department. Explicitly articulating how priorities should be determined was itself a useful exercise, because this was previously an implicit process. The recognition that the Department had been implicitly discounting risks generated by activities managed under other legislation was valuable in identifying the obvious lack of alignment with other agencies. Therefore, the EBFM process has not only been useful for setting internal priorities for direct actions but also for discussions with other agencies and government on the efficacy of current jurisdictional and management responsibilities. Clearly, the details of the priority formula used here would not be appropriate for a Department that had broader responsibilities, in which case there would be no need for 'discounting'.

Establishing a set of EBFM based priorities for the WCB has not only assisted the Department improve its planning processes, but it has revitalised the entire approach to identifying and managing risks

across the entire portfolio of the Department. It has further reinforced the formal adoption of risk management principles as the appropriate basis for natural resource management agencies [6,16]. Thus, following the successful completion of the EBFM process for the WCB (which effectively took 2 years), the same principles have now been applied to the other bioregions in Western Australia. With the clear format and detailed examples from the WCB to use as a guide, the time taken to undertake these assessments has been substantially shorter (a few months). Updating of these risks and values is now planned to occur on an annual basis as a formal part of the Department's planning cycle.

This case study reinforces the need for ecosystem-based approaches to be seen principally as a method to improve the system of management [6], and not to focus only on particular strategies. Thus, studies that conclude that some particular management strategy, e.g. decreasing fishing mortality (F) [37] or requiring MPAs [36], equates to the operational implementation of an ecosystem approach miss the real understanding of the benefits from taking an ecosystem-based approach. We contend that to be effective, the initial focus must be to prioritise all assets and present these results to stakeholders in a clear and relatively simple manner. Importantly for EBFM, touting a particular strategy '*a priori*' will tend to marginalise both stakeholders and fisheries managers before they really understand how the complete system would operate, thereby obscuring the end goal for holistic ecosystem management.

5. Conclusion

The purpose of this case study was to assess whether a regional framework could assist in providing better natural resource management planning at a regional level and meet the legislative responsibilities for managing fisheries and aquatic ecosystems in a more holistic manner. The EBFM framework that was developed was ultimately successful in meeting both of these objectives because a pragmatic, management-focused approach was taken.

The potential complexity of EBFM was dealt with by using a step-wise, risk-based approach to integrate the issues identified and information gathered into a form that could be used by a management agency. Similarly, the levels of knowledge needed for each of the issues only need to be appropriate to the risk and the level of precaution adopted by management. Implementing EBFM did not, therefore, automatically generate the need to collect more ecological, social or economic data or require the development of complex 'ecosystem' models [6].

The EBFM framework also had to accommodate the expectations of stakeholders in a realistic manner. This was achieved by using a hierarchical approach so every stakeholder group could input their issues but the process could consolidate these so they could be effectively used in management planning. Finally, being able to determine the relative priority for management of all assets in a region allows for a more efficient use of government resources because expenditure currently directed towards low-risk elements can (and should) be redirected towards higher risk elements.

The next phase in the development of this process is to identify the mechanisms to further engage other agencies involved in the management of activities within the marine environment and to determine how their processes link to the EBFM framework. Prior agreement on the determination of key ecosystems in the region should facilitate this process and discussions with other relevant agencies at state and national levels about how to link EBFM with EBM have already begun.

While Australia and a few other nations are seen to be achieving success at implementing EBFM, there is no doubt that much work remains to be done. The well-recognised problem of dealing effectively with the complexity of ecosystems within a management system will remain a problem if this ecosystem complexity remains the focus of EBFM. The EBFM framework presented here, including hierarchical asset/issue identification and a three-stage risk assessment and prioritisation process, represents a significant advance in the integrated system of management for natural resources within the marine environment.

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