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Ecosystem-based fisheries management requires broader performance indicators for the human dimension

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ABSTRACT

Ecosystem-based fisheries management (EBFM) is a globally mandated approach with the intention to jointly address ecological and human (social-cultural, economic and institutional) dimensions. Indicators to measure performance against objectives have been suggested, tested, and refined but with a strong bias towards ecological indicators. In this paper, current use and application of indicators related to the human dimension in EBFM research and ecosystem models are analysed. It is found that compared to ecological counterparts, few indicators related to the human dimension are commonly associated with EBFM, and they mainly report on economic objectives related to fisheries. Similarly, in the most common ecosystem models, economic indicators are the most frequently used related to the human dimension, both in terms of model outputs and inputs. The prospect is small that indicators mainly related to profitable fishing economy are able to report on meeting the broad range of EBFM objectives and to successfully evaluate progress in achieving EBFM goals. To fully conform with EBFM principles, it is necessary to recognise that ecological and human indicators are inter-dependent. Moreover, the end-to-end ecosystem models used in EBFM will need to be further developed to allow a fuller spectrum of social-cultural, institutional, and economic objectives to be reported against.

1. Introduction

Since the adoption of the FAO Code of Conduct for Responsible Fisheries [1], a challenge has been how to fully operationalize ecosystem-based fisheries management (EBFM) [2]. Many definitions of EBFM have developed over time, but a consensus regarding core principles is emerging (e.g. Refs. [3,4]). Amongst them are recommendations that management should be science-based; use relevant ecosystem connections and scales; handle uncertainty (precautionary and adaptive management); consider long-term socio-ecological wellbeing; have a collaborative and interdisciplinary decision-making process; and be effective in achieving objectives. These principles have essentially remained consistent with FAO guidelines [1,5] and are universally applicable.

While there is increasing clarity (or broad agreement) over EBFM principles, there is less consensus and clarity over the operational objectives and the actual implementation process. In this statement we distinguish between EBFM principles described above, and more place-based operational objectives (e.g. setting exploitation levels for commercial species) and implementation processes (e.g. tools that are used to operationalize EBFM), which have to be developed at a local level and be context-specific and scale sensitive. Management agencies today selectively adopt and develop their own objectives and implementation processes [6]; there is no single solution to how to operationalize EBFM (e.g. Refs. [7–9]). The question that remains is how current practice aligns with EBFM principles to achieve the intended goals and objectives, such as maintaining ecosystem structure and function for all human needs (and others as stated in Refs. [1,4,5,10]).

Management agencies aspiring to operationalize EBFM can be assisted by guiding documents and frameworks (e.g. Refs. [11,12]). Ecosystem models, for example, are one important tool set for EBFM, and are generally used to represent the past dynamics, status quo and predict change over time for a marine system (reviews for the various ecosystem models and their application are available in Refs. [13–16]), but can also be used to assess ecological status and management strategies. This requires a set of

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indicators and associated performance measures for judging performance against objectives (where the difference of an indicator's value from a reference point forms the performance measure), which is a universally important requirement for the implementation of EBFM. Although extensive work has been carried out on candidate EBFM indicators, only a few studies have tested their reliability in terms of acting as the basis for performance measures (i.e. their capacity to report against EBFM objectives) – and those that have been evaluated are mostly ecological (e.g. Refs. [17–19]). Development and testing of economic, social-cultural, and institutional (collectively referred to hereafter as human) indicators in this role have received less attention [20,21], urgently needed to inform and make explicit the trade-offs between ecological and socio-economic management objectives and minimizing the risk of providing misleading advices.

Accordingly, there is increasing recognition that the human objectives should be considered in conjunction with environmental objectives. For example, the Australian Fisheries Management Authority, which has elaborate tools for addressing the ecological dimension [22], now aspires to include and consider the human dimension and ensure that it is well represented in EBFM. This requires appropriate indicators. Therefore, the overall aim of this study is to identify which EBFM objectives of the human dimension are not being addressed by current indicators employed. To do this, 134 papers from the EBFM peer-reviewed literature were examined to determine which human indicators have been considered. The indicators were categorised by type, frequency of mentions, the EBFM objective they most related to, and the geographic region in which the indicator had been studied. Furthermore, an overview on how the human indicators found in literature are represented in the most commonly used ecosystem models is provided as trialling indicators in these virtual test beds has been a proven method of evaluation, at least for the ecological indicators (e.g. Refs. [17,23]). The results are intended to aid facilitation of EBFM implementation by identifying where greater effort is needed to improve our understanding and evaluation of feedback between ecological and human dimensions.

2. Material and methods

2.1. Literature review

A review on peer-reviewed EBFM literature was performed to identify which human (social-cultural, economic and institutional) indicators were mentioned. The choice to focus only on human indicators was made since there is already an abundance of research on ecological indicators (e.g. Refs. [17,23–25]). The Web of Science database was used to search for published papers. The search was restricted to the period between 1990 and 2017, with the starting date approximately representing the time at which EBFM principles were first discussed. Given that different terms for EBFM-approaches are used, a search and filtering path shown in Fig. 1 was followed to refine the search to the final set. This process returned 134 papers that were screened for human indicators and objectives (list of papers included are found in Appendix A).

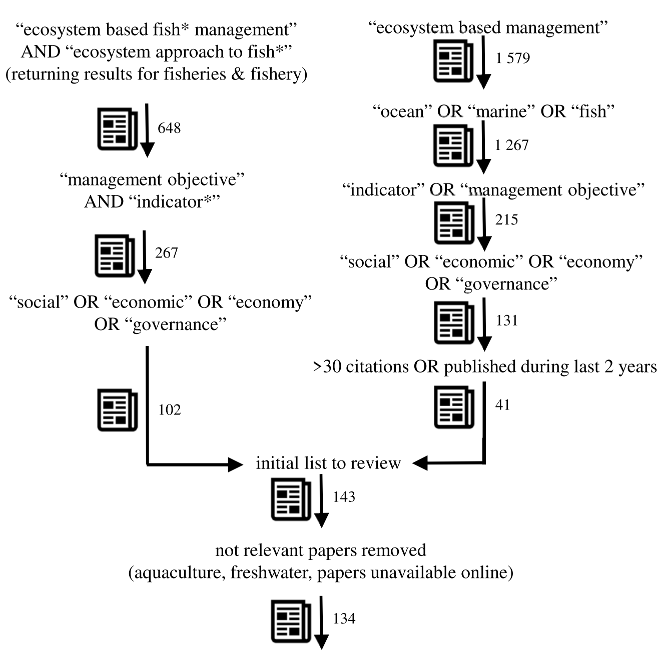

Fig. 1. Schematic of the Web of Science steps in the search.

2.2. Data processing

All human indicators found in each of the 134 identified papers were recorded in an excel spreadsheet, i.e. any mention of fisheries catch volume (catch/yield/landings/TAC), for example, was listed as one indicator, fishing profit (net profit, economic viability) as another, etc. (Appendix B). There were two papers that had to be considered differently: Breslow et al. [26] that had compiled a database of 2300 generic socio-ecological indicators to suggest a framework for addressing human wellbeing, and Biedenweg et al. [27] with 23 context-specific indicators on human wellbeing. Instead of listing 2300 + 23 separate human wellbeing indicators, these two papers were recorded as two mentions of the indicator human wellbeing. Geographical and regional uses of the indicator based on the origin of the research were also noted.

Next, the indicators were sorted into three human EBFM domains (economic, social-cultural and institutional). Including institutional as a separate domain is motivated from the repeated recognition that this component of EBFM deserves special attention (e.g. Refs. [5,28]). The sorting was based on what the indicators referred to: if referring to monetary values (=economic), related to management (=institutional) and the remaining (=social-cultural). This exercise was done to identify where the current emphasis lay in relation to the three overarching components of the human dimension.

To be able to identify what aspects were specifically given attention, we identified eight specific groups that the indicators belonged to (e.g. working conditions, culture & identity) and by which indicators were further categorised to. This exercise is not free from subjective elements, but there is arguably no completely objective procedure to categorizing indicators (as expert judgement is typically used to either categorise the indicators or to set the criteria used as the basis of the classification). Many frameworks for evaluating broad sustainability of fisheries have already been developed and proposed for different purposes (e.g. Refs. [12,29–31]). As an example, 'human wellbeing' was here reported on as one indicator ('wellbeing') when found – but just as easily, all the human indicators found could have been considered as different components of a human wellbeing framework [26,27]. This element of subjectivity is addressed by being transparent with the categorizations by making all material available as supporting information (Appendix B).

On the basis of the combined modelling experience of the co-authors, it was determined which of these human indicators could be calculated in the five of the most common ecosystem modelling approaches (Atlantis, Ecopath with Ecosim, size-spectrum, MICE, Osmose) – either dynamically within the model or based on their outputs. At a workshop, where co-authors who have developed and/or worked with each of the models were present, a consensus decision was made for each of the indicators on whether the indicator was Y = dynamically represented in the model; N = not possible; I = given as input; P = possible to add to the model but not in the standard existing model structure; O = available as an option in the model but not often used; C = only calculated from outputs, not used dynamically within the model. This task is seen as a valuable contribution for future work (similar efforts have previously greatly facilitated the evolution of work around the evaluation of ecological indicators).

Finally, to examine current human indicator coverage and potential short-comings related to human EBFM objectives, every indicator was mapped to an EBFM goal and objective based on what the indicator primarily referred to. Since the literature reviewed did not provide an adequate number of papers in which EBFM objectives were explicitly stated in conjunction with indicators, a bottom-up approach was chosen to derive a categorisation of EBFM goals and objectives. This was done by consolidating terms stated in key EBFM documents [1,4,5,10] into broad goals and more specific objectives labelled based on wording (Appendix C). This categorisation is also not free from subjective choices, but this is again addressed by being transparent in the categorisation (Appendix B).

The identification and categorisation of indicators thus involved several steps: 1) extracting and reading the literature; 2) recording and naming the indicators; 3) standardising the naming of the indicators; 4) mapping the indicators to the different human domains; 5) mapping the indicators to eight groups; 6) mapping the indicator to an EBFM objective; and 7) mapping the indicators to their role and function in different ecosystem models. Steps 1–3 was primarily undertaken by the first and second authors. Prior to completing steps 2–3 for all papers, a trial run was done on around 10 papers, where the two co-authors checked each other's naming to ensure a common understanding and naming convention was adhered to. Step 4 to 6 was also initially undertaken by the first two authors, but the other co-authors were involved in a later stage (through e.g. three project meetings, follow-up correspondence) to verify accuracy and ensure logic. Step 7 was done in a workshop situation with the relevant co-authors as described above. The preliminary results were also presented at a related project meeting attended by 12 people (fisheries researchers and managers from four different countries from around the world); comments and responses that were received were incorporated where appropriate.

3. Results

3.1. Indicator coverage of the human dimension

Of the 134 papers reviewed, less than half (57) explicitly mentioned human indicators for EBFM. In these 57 papers a total of 143 human indicators were mentioned. The different indicators were mentioned a total of 302 times.

Most of the indicators could be categorised as economic (52 indicators), followed by social-cultural (50 indicators), and institutional (41 indicators). Economic indicators also dominated in terms of frequency of mentions (55% of the total of 302 mentions), followed by the social-cultural (28%), and institutional (17%) indicators (Table 1). Most of the indicators were mentioned only once (93 indicators in total) or twice (28 indicators).

In terms of groups the indicators related to, it is perhaps not surprising to see a strong bias towards indicators that relate to the fishery and fleet (Table 1), since the analysis is on fisheries. However, there has been little effort beyond profitability.

3.2. Human indicators in relation to EBFM goals and objectives

Most human indicators measure achievements against the EBFM objective that we labelled 'profitable fishing economy'. This category accounted for 31% (93 instances) of the total number of indicator mentions (Table 2). The types of indicators that could be categorised as measuring the profitability of the fishing economy were related to, for instance, catch, fishing cost, and profitability (see also Table 1). The objective of a profitable fishing economy nests within the overall EBFM goal to 'ensure and maintain ecosystem structure and function for all human needs'. This goal is closely linked to the ecological indicators which may partly explain why so many indicators for this goal are

Table 1
Human indicators (percentage mentions out of total 302 indicators) found in EBFM literature sorted by groups and domains (more than one may apply).

Group	Description	Human domain			Sum of literature mentions (% of total 302)
		Economic	Social-cultural	Institutional	
Fishery & fleet	Relate to catch, profitability, fishing cost, vessel and fleet characteristics, and quota	44%	1%	1%	138 (46%)
Coastal community	Related to equity, social services, nutrition, sectoral contribution	1%	11%		38 (13%)
Governance context	Management effectiveness, conflicts, targeted regulations, internal communication, participatory processes	1%	1%	12%	42 (14%)
Marine sector	Includes indicators related to recreational fishing and tourism, sectoral contribution, post-harvest, regional multipliers	2%	6%		26 (9%)
Working conditions	Engagement in commercial harvesting, employment in fishing, job creation, job seasonality		6%		19 (6%)
Product & price	Related to product quality, value added, and supply chain characteristics	6%			18 (6%)
Culture & identity	Focus on aspects such as connectedness, subsistence, community coherence, and sense of control		3%		8 (3%)
Compliance and monitoring	Enforcement costs, enforcement capacity, level of compliance, number of patrols	1%		4%	13 (4%)

Table 2
Number of mentions of human indicators in EBFM literature mapped against consolidated EBFM goals and objectives (based on key EBFM documents; Appendix C). For full list of indicators see Appendix B.

EBFM goals	Objective	Example indicators	% of total indicator mentions
Ensure and maintain ecosystem structure and function for all human needs	Profitable fishing economy	Catch efficiency, profit, market price	31%
	Community wellbeing	Human wellbeing, regional multipliers	9%
	Equitable outcomes	Sectoral allocation, Gini coefficient, recreational fishing engagement	8%
	Food security	Catch, subsistence catch	8%
	Secure and just livelihood	Employment rate for fishers, Human Development Index	3%
Ensure prerequisites exists for adaptive and precautionary management	Compliance and monitoring	Level of compliance, monitoring costs	4%
	Science-based decision-making involving stakeholders	Research costs, staff expertise, participatory process	2%
Management should be effective in minimizing impacts	Institutional capacity, integration & flexibility	Stability of year-to-year management, fiscal capacity	9%
	Fleet capacity balances resource abundance	Exploitation rate, size of fleet	11%
	Minimize negative environmental impacts	Discards, habitat impacts	5%
Ensure responsible international supply chains	Safe, healthy, fair working conditions	Employment, seasonality of jobs, wage rates	7%
	Responsible and profitable trade	Export value, commercial processing reliance	3%

mentioned. In fact, they are mentioned three times more often than indicators for the goal that 'management should be effective in minimizing impacts' and seven (or more) times more often than the indicators for the goals focused on the delivery of precautionary management and responsible supply chains.

We found that EBFM research where human indicators are explicitly stated is dominated by efforts in North America (in particular the US), followed by Oceania (mainly Australia) and Europe; only one paper was from Asia (Korea) and four from Africa (South Africa). A considerable regional variation was also found in focus on objectives. European (n = 12) and South American (n = 5) research effort have almost exclusively focussed on indicators related to the fishing economy, whereas e.g. North American research (n = 15) have focussed equally on fishing economy and those related to wellbeing. Research in Oceania (n = 8) has had approximately the same emphasis on profitability and equity. In Africa, few studies have been done (n = 4) but with a more even spread and the broadest coverage of different EBFM objectives; no particular objective stands out compared to others. Across countries, North American studies dominate by far research on wellbeing and Oceania studies on equity.

3.3. Human indicators found in literature compared to models

The top mentioned indicators and the ability of different types of ecosystem models to incorporate or represent the different human indicators is illustrated in Table 3 (see Appendix B for full indicator list). The small number of indicators (14) that were referred to five or more times in the literature were mainly of economic nature. In each model, the behavioural modelling approach taken (and the available input data) determines which human indicators can be calculated and whether an indicator is calculated dynamically or *a posteriori* using model outputs.

The majority of models are capable of calculating a number of economic and social-cultural indicators *a posteriori*, in particular indicators of profitability and employment (see the indicators marked with a 'C' in Table 3 and Appendix B). Fewer human indicators are calculated dynamically, and these only inform on the economy of fisheries and fleets (marked with 'Y' in Table 3 and Appendix B). The representation of human behaviour in ecosystem models is often limited to fleet dynamics; fleets are modelled as economic entities that dynamically allocate fishing effort in space and time to maximise profit or utility. However, other behavioural modelling can also be

Table 3
Top human indicators mentioned five or more times in the reviewed literature and the ability of models to return these as output indicators (Y = dynamically represented in the model; N = not possible; I = given as input; P = possible to add to the model but not in the standard existing model structure; O = available as an option in the model but not often used; C = only calculated from outputs, not used dynamically within the model).

Group	EBFM domain	Indicator	Number of literature mentions	Model capacity to represent the indicator				
				Atlantis	EwE	MICE	Size-based[a]	OSMOSE
Fishery & Fleet	Economic	Catch volume	19	Y	Y	Y	Y	Y
		Revenue	15	C	C	C	C	C
		Profit	14	O/C	C	C	C	C
		Catch efficiency	10	Y	Y	Y	Y	Y
		Fishing effort	10	Y/I	I	Y/I	Y/I	I
		Exploitation rate	8	Y	Y	Y	Y	Y
Working conditions	Social-cultural	Employment	8	O/C	C	P/C	P/C	P/C
Fishery & Fleet	Economic	Capital costs	7	I	I	I	I	I
Product & price		Market price	6	O/I	I	I	I	I
Coastal communities	Social-cultural	Index of social welfare	6	C[2]	C[2]	C[2]	C[2]	C[2]
Fishery & Fleet	Economic	Discards	5	Y	Y	Y	Y	Y
		Net present value (NPV)	5	Y	C	C	Y/P	C
Coastal community	Social-cultural	Wellbeing	5	C	C	C	C	C
		Demography	5	O	N	P	N	N

[a] Size-based is a big model category (e.g. Mizer, BOATS, APECOSM) with different features. Here we focus on Mizer. [2]Possible to calculate but fisheries may only be a small part of the index so information content of the indicator may be low.

incorporated – such as network modelling for quota trade and information sharing (e.g. in Atlantis) – which then expands the range of indicators that a model can calculate dynamically. The sophistication of the representation varies between modelling platforms but generally there would seem to be potential to include more of the human indicators than they currently do (thus the large number of 'P's in Table 3 and Appendix B).

The less tangible social-cultural and cultural concepts are more complicated to model. Consequently, three of the four most mentioned social-cultural indicators (such as wellbeing) were not model output (Table 3). Indeed, the majority of the indicators found for the EBFM objectives 'institutional capacity, integration & flexibility', 'community wellbeing' and 'compliance and monitoring' are not easily modelled using the above-mentioned modelling approaches (marked by an 'N' in Appendix B).

4. Discussion

This paper has highlighted the limited research on indicators for assessing human dimension objectives that exist so far, largely defaulting to fisheries economics with little mention of many of the other aspects of EBFM. Since human and ecological indicators are not independent, i.e. quality of management and ecosystem goes hand in hand in fisheries [32,33], there is an urgent need to develop a broader suite of meaningful and pragmatic human dimension objectives and indicators. This is vital to handle all dimensions with equal rigor, operationalize a truly socio-ecological systems approach and conform with EBFM principles and beyond; developing the human dimension is urgently needed to achieve the targets set for the Sustainable Development Goals [34]. Such action will require the immersive engagement of disciplinary experts who have the depth of knowledge needed to do this well – including geographers, psychologists, anthropologists and many other disciplines not typically seen in fisheries science and management arenas. Moreover, it will involve the kinds of efforts attempted here, where potential indicators are paired with objectives to enable the assessment of management actions against all EBFM goals and objectives.

The narrow focus in research on human indicators so far also implies that the scientific basis for holistically understanding and incorporating the human dimension in EBFM today is very limited. Based on findings in this study, there are only 14 commonly-studied indicators representing the human dimension (i.e. mentioned more than five times in EBFM literature). The prospects that these indicators could successfully evaluate progress in achieving EBFM goals, such as to "Ensure and maintain ecosystem structure and function for *all* human needs" when predominantly profitable fishing economy is considered, are likely to be limited. Many of the human indicators mentioned more than five times are in fact already used in single species management (catch, effort, exploitation level, discard), thus showing little progress from existing practices.

A decade ago, many fisheries management agencies around the world failed in meeting many important EBFM principles [35,36]. However, during the past ten years or so, broad principles and goals have become more ingrained in fisheries management through international agreements, driven by ecological goals such as the protection of sensitive species and habitats. This has led to a wider acceptance of the need to shift from single-species management towards EBFM in different places around the world. As an example, governance of small-scale fisheries in South Africa has changed in recent years – from a largely resource-centred approach to one that is more people-centred [37]. Progressing the inclusion of the human dimension of EBFM however requires reference points and operational management objectives in order to develop and test indicators, as with the ecological counterparts [38].

Clearly linking indicators to objectives is critical to ensure indicators are useful within an adaptive management context [39]. Whereas there are methods available to set and prioritise locally relevant ecological objectives (e.g. Refs. [24,38]), there is less (but growing) practical experience in setting and implementing human objectives in operational fisheries management. At this point in EBFM science, one might ask:

- Is this task more difficult for human dimensions than for ecological ones?
- Are human objectives and indicators more context-specific/regional than ecological ones?
- What needs to be better understood and accounted for if decision-support is to allow managers to fully understand trade-offs and prioritise when balancing various objectives?
- From the relationship between ecological and human indicators, what may human indicators tell us about structure and function of ecosystems and vice versa?

This review has shown that the scientific basis for addressing the points above is today rather thin. It was also found that only a few of the here reviewed papers have made a clear link between objectives and indicators. The ecology of a fished ecosystem is complex, yet there's an abundance of ecological indicators; the human dimension is no less complex, but there is an overall paucity of indicators in comparison. In this study we found less than 150 human indicators, most only mentioned once or twice – compared to roughly 470 extant ecological indicators. Efforts to collate indicators of potential use for future EBFM research on the human dimension (such as the impressive work by Ref. [26]) have highlighted that there is a wide range of human indicators that are linked to ecological status. It is clear that much remains to be done in addressing this imbalance between human and ecological indicators in EBFM research. Increased effort on collecting data and developing indicators related to in particular social-cultural and institutional dimensions of EBFM is vital for EBFM to go forward. In this task, some understudied objectives, such as indicators belonging to 'Responsible and profitable trade' and 'Safe, healthy, fair working conditions', are more easily included due to their quantitative nature – whereas the objective 'Community wellbeing' may comprise of more qualitative indicators that are difficult to both manage and develop objectives and appropriate performance indicators for.

4.1. Perspectives for the future

This review found that many of the top mentioned human indicators are incorporated into different ecosystem models today, which is promising. Even if most modelling has been constrained to ecological considerations, including aspects of the human dimensions provides extra richness, allowing for recognition of unintended consequences, potential sources of performance failure and useful directions for the shape of EBFM (e.g. Ref. [40]). Much remains to be done in terms of modelling, however, and at this point in EBFM science, one might need to think about what role models will have in reporting on the human dimensions of EBFM. Some models (e.g. Atlantis) have options to include attitudinal aspects of decision making and indicators of social-cultural perspectives on ecosystem state [41], and others (MICE models) have been developed that explicitly model human aspects such as sense of place [42]. It is thus possible to include a broader suite of considerations of the human dimension in ecosystem models, even if so far, this has been done via defining richer scenarios rather than in achieving more dynamic model representations. Similarly to the way in which modelling has progressed in ecology, there is also the potential to use empirical statistical relationships to characterise the outcome of poorly understood processes, progressing to more mechanistic representations only as the understanding and need arises [43]. Perhaps models can be extended to incorporate more human indicators, but we also need to recognise the limitations of models in addressing EBFM needs.

Table 4
Examples of short-comings between current management and EBFM research needs that have been paid less attention to so far (i.e. excluding 'Profitable fishing economy').

Objectives	Current management	EBFM research needs
Community wellbeing	Fishing management bodies (e.g. Alaska) have begun to use indicators on fishing community wellbeing [46]	Ethnographic field research on self-governance and community wellbeing in fishing communities (e.g. Ref. [47]). Gender studies are also interested in the role of women in the construction of wellbeing in fishing communities and households [48].
Equitable outcomes	Quota allocations (sectors, gears)	Behavioural economists and psychologists are using experimental techniques to elicit how humans perceive the provision and allocation of public good [49,50].
Food security	Landings, TAC, MSY	EBFM implementation may benefit from acknowledging threats to production [51], equity of access [52], destination post-landing [53] and size-structure [54].
Secure and just livelihood	Relative stability in the EU Common Fisheries Policy, MEY objectives in Australian fisheries [55]	The FAO, International Institute for Sustainable Development and the IUCN, amongst others, have put significant effort into outlining what is needed to avoid conflict by improving resource status, livelihoods and (thereby) security [56].
Science-based decision-making involving stakeholders	Increased stakeholder participation around the world	Identifying best practice for stakeholder inclusion [57,58], understanding the psychology behind socio-political conflict [59].
Compliance and monitoring	Monitoring is integral part of general fisheries management	Identifying monitoring needs for holistic EBFM, e.g. supply chain data on processing yield may send contrasting signals from a seemingly well-managed fishery [54].
Institutional capacity, integration & flexibility	Often complex, in the EU with little flexibility ("relative stability" between years and countries) and integration (between conservation and fisheries)	Balancing integration with complexity and flexibility. While institutional dynamics is one of the most poorly quantified of the human dimensions there are a growing list of potentially relevant indicators, such as those from the World Bank Group [60]. Transparency has been shown as key to management success [61], but balancing transparency-confidentiality-ethics will likely be a challenge.
Fleet capacity balances resource abundance	Common objective in traditional fisheries management	Beyond target species- how to safeguard ecosystem structure and function [44], avoid shocks to production [51]?
Minimize negative environmental impacts	Focus on reducing discard, areas closed to fishing	Utilize systems analysis perspectives such as least environmental impacts with most societal benefits, i.e. pressure per tonne [62].
Responsible and profitable trade	Not within the remit of current fisheries management	Linkages between fisheries, wellbeing and supply chains may deserve more attention, such as effects on processing industry from management failure to preserve stock structure and productivity [54], how to safeguard benefits to vulnerable people [63], local effects from global markets [64] and the role of communities [45].
Safe, healthy, fair working conditions	Commercial fishing safety often tracked	Addressing the implications of climate change induced shifts in storm frequency and intensity on fisheries production and working conditions [65].

Traditional fisheries management is arguably well-founded in one topic of the human dimension: fisheries exploitation. Less attention has historically been given to both broader ecological considerations (e.g. maintaining ecosystem structure and function [44]); and broader objectives of the human dimension, such as community wellbeing [45] and institutional aspects [33] – this is where EBFM principles intend to improve practice. However, based on results in this study, fishing economy has been given disproportionate attention in EBFM research. The reason behind the imbalance in attention paid to the complex human dimension in EBFM is not evident. The current situation is probably a result of a combination of challenges related to both intrinsic differences between social and ecological/fisheries sciences and less research effort in this area. Future research efforts should thus ideally be channelled to understudied components of EBFM. Truly operationalizing EBFM objectives related to e.g. 'Food security' and 'Equitable outcomes' would benefit from improved practice from traditional single-species management. This task may be guided from findings in other research fields (some ideas are given in Table 4). There is a significant body of scientific work that could be drawn upon from other disciplines, such as social sustainability science (e.g. Ref. [66]). To ensure effective EBFM implementation, the joint consideration of human and ecological dimensions is arguably of the very essence – monitoring and understanding connections and feedbacks between the human and ecological system [67] – in contrast to single-species management where human objectives are some of the most heavily considered (e.g. fishing at maximum sustainable yield, consistent yield from year to year, etc.). While emphasis on the complex ecological dimension has been needed to be able to support the transition from single-species management, it is time to more effectively expand the concept of the human dimension beyond the fishing economy and provide science to support EBFM as wholly as intended.

Disclosure statement

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Appendix A. Supplementary data

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