Marine Policy 62 (2015) 169–177

Contents lists available at ScienceDirect

Marine Policy

journal homepage: www.elsevier.com/locate/marpol

Second-guessing uncertainty: Scenario planning for management of the Indian Ocean tuna purse seine fishery

Tim K. Davies [a,*], Chris C. Mees [b], E.J. Milner-Gulland [a]

[a] Imperial College London, Silwood Park Campus, Ascot, Berkshire SL5 7PY, UK
[b] MRAG Ltd, 18 Queen Street, London W1J 5PN, UK

ARTICLE INFO

Article history:
Received 12 July 2015
Received in revised form
19 August 2015
Accepted 11 September 2015

Keywords:
Scenario planning
Fisheries
Management
Uncertainty
Tropical tuna
Fleet dynamics

ABSTRACT

An important task of natural resource management is deciding amongst alternative policy options, including how interventions will affect the dynamics of resource exploitation. Yet predicting the behaviour of natural resource users in complex, changeable systems presents a significant challenge for managers. Scenario planning, which involves thinking creatively about how a socio-ecological system might develop under a set of possible futures, was used to explore uncertainties in the future of the Indian Ocean tuna purse seine fishery. This exercise stimulated thinking on how key social, economic and environmental conditions that influence fleet behaviour may change in the future, and how these changes might affect the dynamics of fishing effort. Three storylines were explored: an increase in marine protection, growing consumer preference for sustainable seafood, and depletion of tuna stocks. Comparing across several possible future scenarios, a number of critical aspects of fleet behaviour were identified that should be important considerations for fishery managers, but which are currently poorly understood. These included a switch in fishing practices, reallocation of effort in space, investment in new vessels and exit from the fishery. Recommendations for future management interventions in the Indian Ocean were offered, along with suggestions for research needed to reduce management uncertainty.

1. Introduction

An important task of fisheries management is deciding amongst alternative policy options. In doing this, policymakers must anticipate, typically using models, how key elements and dynamics of the system are likely to change in the future, and evaluate how the outcomes of management policies might be affected by this change. However, the future is loaded with uncertainty and surprise, and generating accurate, long-range biological, economic or political forecasts is a major challenge. In some regions, improved understanding of system dynamics and breakthroughs in computing power have led to the development of whole-of-system models (e.g. Atlantis, [22]), which has gone some way to improving the accuracy of forecasts. However, this depth of understanding and complexity of modelling is still beyond reach in most fishery systems, and in complex and uncertain systems the usefulness of modelled predictions of the future is limited [10].

In all fisheries systems, resource users are the key linkage between policymakers and the resource. The success of a management policy is more often than not contingent on the behaviour of fishers, and unexpected behaviours, resulting from a response to management or change in other drivers, can potentially generate unintended and undesirable outcomes (e.g. [5,25]). Despite the importance of fisher behaviour, this linkage between implementation and outcomes of management has often been downplayed or ignored in planning [23]. This is not helped by a lack of clarity on the role of fisher behaviour in management; whilst there has been considerable work directed at characterising fisher behaviour and understanding its drivers (see [40,44]), there has been little focus on the role of fishers in achieving (or undermining) management outcomes. Hence, fisher behaviour remains an important source of uncertainty in fisheries systems [23].

Scenario planning is a promising approach for aiding management decision making in complex, changeable systems. Rather than focussing on the accurate prediction of a single probable future, scenario planning involves thinking creatively about how the system might develop under a set of possible futures. In this way, policymakers can consider a range of plausible ways in which system dynamics might change, including surprise and catastrophe, and identify key uncertainties that might hinder the design and implementation of effective management policies. Scenario planning has been used extensively in business and politics

* Corresponding author. Tel.: +44 20 7594 2429
E-mail addresses: timkdavies@gmail.com (T.K. Davies), c.mees@mrag.co.uk (C.C. Mees), e.j.milner-gulland@imperial.ac.uk (E.J. Milner-Gulland).

http://dx.doi.org/10.1016/j.marpol.2015.09.019

to develop strategies for a range of possible futures [43]. More recently, scenarios have been used in the environmental sciences to improve decision making in complex ecosystems [3,46], to anticipate change in ecosystem services [36] and to explore strategies for sustainable development [39]. For instance, scenario planning was used in the Millennium Ecosystem Assessment for exploring the ways in which policy decisions may drive future ecosystem change, how ecosystem change may constrain future decision making, and ways in which ecological feedback may lead to surprise [32].

In this study, scenario planning was used to explore uncertainty in the future of the Indian Ocean tuna purse seine fishery, focussing attention on the behaviour of fishers. The aim was to stimulate thinking on how the key social, economic and environmental conditions that influence fisher behaviour, which are difficult to accurately forecast, may change in the future, and how these changes might affect the dynamics of fishing effort. A number of key aspects of fishing behaviour suggested in the scenarios as important considerations for policymakers were identified, and the current state of research on these behaviours was briefly reviewed to recommend avenues for future research.

2. Overview of scenario planning

There are many different approaches to scenario planning, which mainly differ in emphasis rather than method, depending on the goals of those who created them [37,4,43,45,46]. The scenario planning approach used here is adapted slightly from that described by Peterson et al. [36], who introduced the methodology of scenario planning to the discipline of conservation science. To the best of the authors' knowledge, there have been no scenario planning exercises published in the fisheries science literature, nor in the context of resource user behaviour. Peterson et al. describe scenario planning as consisting of six interacting stages, which, in order to incorporate a wide range of perspectives, are typically carried out in a workshop format by a diverse group of, for example, research scientists, managers, policymakers, and other stakeholders. In this case, the scenario planning exercise was the culmination of three years of detailed research on tuna purse seine fisher behaviour and was carried by the lead author (T. Davies) as a desk-based study.

2.1. Identification of the focal issue

Having a specific question in mind provides focus when examining possible futures, and therefore the identification of a clear focal issue is the first and arguably the most important stage in scenario planning. Here, the focal issue was uncertainty in dynamics of effort allocation in the Indian Ocean tuna purse seine fishery. These dynamics include two short term skipper-level behaviours; the allocation of effort in space and the allocation of effort between the two main fishing practices (fishing on free-swimming schools or floating objects), and two long term company-level behaviours; investment in fishing capacity and participation in the fishery.

2.2. Assessment of the system

This stage should determine what is known and unknown about the forces that influence the dynamics of the fishery system. The focal issue is used to organise an assessment of the actors, institutions and ecosystems that define the fishery and identify the key linkages between them. It is also important to identify engines of external change, whether they be social, economic or environmental, that drive system dynamics. Here, this assessment was based on an understanding of the system generated during the course of the research; from review of the academic and technical literature, interviews with skippers and other fishery experts, and primary research [12–14].

2.3. Identification of alternative futures

This stage involves the identification of alternative ways that the system could evolve in the future. How far into the future depends on the focal issue and the system; this study looked forward 15 years, as this was considered an appropriate length of time for both short term behaviours (e.g. patterns of effort allocation) and long term behaviours (e.g. investment in a fleet) to be influenced by the dynamics of the system. Although inherently uncertain, alternative futures should be plausible yet at the same time imaginatively push the boundaries of commonplace assumptions about the way in which the system will develop. These alternative futures should be based upon two or three uncertain or uncontrollable system drivers that have been determined in the previous assessment stage. For instance, uncertainties might arise from unknown behaviour of a group of actors, or from unknown dynamics in the natural or socio-economic components of the system.

2.4. Creating storylines

The next step is to translate alternative futures into descriptive storylines, based on the understanding of the various actors and drivers in the system accumulated during the assessment stage. Storylines should expand and challenge current thinking about the system, although they should be limited to three or four; a set of two storylines is usually too narrow, whereas more than four may complicate or confuse the scenario planning exercise [43,45]. In order to be plausible, storylines should link present events seamlessly with hypothetical future events, and the assumptions made and differences between the storylines must be easily visible. Consequently, storylines generally begin factual and become increasingly speculative at they progress. The storylines were constructed in three parts; first the changes in the fishery systems were set out, then what these changes mean in terms of fishing opportunities were outlined, and finally the storylines described the consequences for the behaviour of the fleet.

2.5. Cross-cutting behaviours

In this stage, the expected fisher behaviours under the different scenarios (a future and its associated storyline) were compared. This stage allowed opportunity for discussion on the sustainability of the fishery under alternative futures, and identification of which behaviours were common to more than one scenario and which were unique to one particular scenario. This final stage therefore served as the basis for recommendations concerning which of the fisher behaviours should be key considerations of policymakers when planning future management policies.

3. Assessment of the system

3.1. Operational, geographical and historical context

The tuna purse seine fishery exploits the surface schooling behaviour of three principal species; skipjack *Katsuwonus pelamis*, yellowfin *Thunnus albacares*, and bigeye tuna *Thunnus obesus*. In the open ocean tunas naturally aggregate in free-swimming schools (free schools) or associate with floating objects (associated schools), such as logs or branches [17]. Tuna fishers have learnt to exploit this association behaviour and deploy purpose-built fish aggregating devices (FADs) into the ocean to increase and expedite catches. A distinction is usually made between the two school types due to differences in the species composition of the catch, although skippers will generally target a mixture of free and associated schools during fishing trips [13]. Tuna schools are found using a variety of tactics and strategies, including satellite buoys and echo sounders attached to FADs, cooperation and information-sharing between skippers and the use of meteorological forecasts and environmental 'nowcasts' based on satellite remote sensing data from which promising tuna habitat is identified [8].

An industrial purse seine fishery for canning-grade tropical tunas began in the Indian Ocean in the early 1980s, when French and Spanish fishing firms moved vessels into the region from the tropical eastern Atlantic in search of new fishing grounds. There is still exchange of vessels between these two oceans, orchestrated at the level of the firm and based on perceived relative fishing opportunity in either ocean (Fonteneau, personal communication). Early operations were based in Port Victoria, Seychelles, which has remained the primary port of call for landing and transshipping catch, refuelling and resupplying and exchanging crew [38]. The European-owned distant water fishing fleet continues to dominate the fishery in the western Indian Ocean and have established a firm commercial foothold around Seychelles, Mauritius and Mayotte. Asian purse seine fleets are constrained mainly to the eastern Indian Ocean due to proximity to landing sites (e.g. Thailand) despite purse seine fishing generally being much poorer in that region due primarily to the deeper thermocline, which reduces the vulnerability of tunas to surface gears [12]. We did not attempt to anticipate the expansion of the Asian purse seine fleet into the western Indian Ocean in our scenarios as we had very little basis to justify our assumptions of how this would happen.

The size of the European-owned fleet has grown considerably since its beginnings in the 1980s, largely due to the intensive use of FADs [13]. Throughout the 1990s and early 2000s French and Spanish fishing companies invested in larger purse seine vessels, at an estimated cost of US$20 million per vessel, which offered numerous commercial advantages including the ability to make extended fishing trips with larger fish-wells [7]. However, because larger vessels are more sensitive to increasing operating costs (e.g. fuel price; [33]) it was necessary for fishing companies to adopt increasingly competitive fishing strategies to achieve the high annual catch thresholds necessary to remain profitable (e.g. circa 15–20,000 t; Fonteneau, personal communication). Consequently, purse seine firms have become increasing reliant on the use of FADs to achieve the very large catches needed to remain profitable [24,7].

The tuna caught by the Indian Ocean tuna purse seine fishery are destined mainly for the canning industry. Canned tuna is second only to prawn/shrimp as the largest internationally traded seafood product in terms of value and volume. Appetite for tuna is particularly strong in Europe, and the EU is one of the largest markets for canned tuna in the world, split between 5 principal consumers: Spain, Italy, the UK, France and Germany (FAO [18]). Premium-quality yellowfin tuna, canned in olive oil, is favoured by the southern European market, especially Italy and Spain, whereas lower-value skipjack tuna, canned in brine or vegetable oil, is preferred in the northern European market, especially the UK and Germany [7]. Both of these commodities are produced using tunas caught in the Indian Ocean purse seine fishery, which are landed in the Seychelles, Mauritius and Madagascar and processed in local canneries, or transshipped and sent to canneries in Europe, Asia and South America for processing [38].

The Indian Ocean tuna purse seine fishery is managed by the Indian Ocean Tuna Commission (IOTC), one of five regional fisheries management organisations (RFMOs) responsible for managing tuna stocks in international waters around the globe. Member states that comprise the IOTC include Indian Ocean coastal and island nations, as well as several Asian, European and other distant water fishing nations (DWFNs) with fishing interests in the region. The IOTC is ultimately responsible for setting catch limits, undertaking stock assessments and regulating fishing rights and has the power to take legally binding decisions that must be implemented by the various Contracting Parties. Scientific work underpins management decision making and is conducted by national scientists from the IOTC member states and reviewed at a Scientific Committee. On the basis of this scientific advice members at the IOTC annual session consider conservation and management measures (CMMs), and if a measure is agreed to by a two-thirds majority it becomes binding.

Since the early 2000s the primary management problem facing the IOTC, as with all tuna RFMOs, has been overcapacity in the fleet [2,29]. As a first step towards addressing overcapacity, in 2002 the IOTC attempted to limit access to the fishery by creating a Record of Authorised Vessels (RAV), a register of vessels of greater than 24 m length that were authorised to fish in the IOTC area of competence (Resolution 14/04; http://www.iotc.org/cmms; accessed 16th June 2015). This Resolution has been updated and superseded on a number of occasions to include restrictions on vessel numbers and diversified to include smaller classes of vessels, although the RAV has ultimately failed in its intended purpose to maintain stocks at target levels [2]. Alternative controls on fishing effort were implemented from 2010 in an attempt to control fishing effort, in the form of a temporary closed area situated in a productive region of the fishery, although this too appears to have had little success in reducing catches in the fishery [13]. More recently, discussions have been held in IOTC on adopting a rights-based management system, principally through the determination of total allowable catch (TAC) and quota allocation for stocks of yellowfin and bigeye tuna (Resolution 14/02; http://www.iotc.org/cmms; accessed 16th June 2015). This is an inevitably thorny issue, as it necessarily involves developing and agreeing on criteria for allocating catches between the member states of the IOTC, and it remains to be seen how and when this fundamentally different approach to management will be implemented.

3.2. Fleet behaviour and fishing strategies

The behaviour of the purse seine fleet is considered in terms of three aspects of effort allocation dynamics; the allocation of effort in space, the use of free school or floating object fishing practices, and participation in the fishery. These effort dynamics are driven by the behaviour of two fundamental decision making units; the firm and the skipper. Fishing firms generally make higher-level strategic decisions, for example to invest in new vessels, to modernise equipment, or move vessels into or out of the Indian Ocean fishery. Firms may also have a direct or indirect influence on the nature of its vessels' fishing operations, such as dictating catch thresholds or encouraging certain fishing practices. Skippers are responsible for everyday fishing decisions, and ultimately decide how, where and when to fish. Each skipper's decision making is influenced by the information available to them at any given time, their personal preferences and objectives, their skill and experience and the fishing resources available to them (e.g. crew, vessel size and speed, fish-finding technology etc.).

The tuna purse seine fishery sits within a much larger socio-ecological system (SES; Fig. 1), and the behaviour of the fleet is influenced by the dynamics of four main system components; the resource, the biophysical ocean, the IOTC and a variety of external influences (Table 1). External influences on behaviour include geopolitical decisions (e.g. fishing access agreements), socio-political

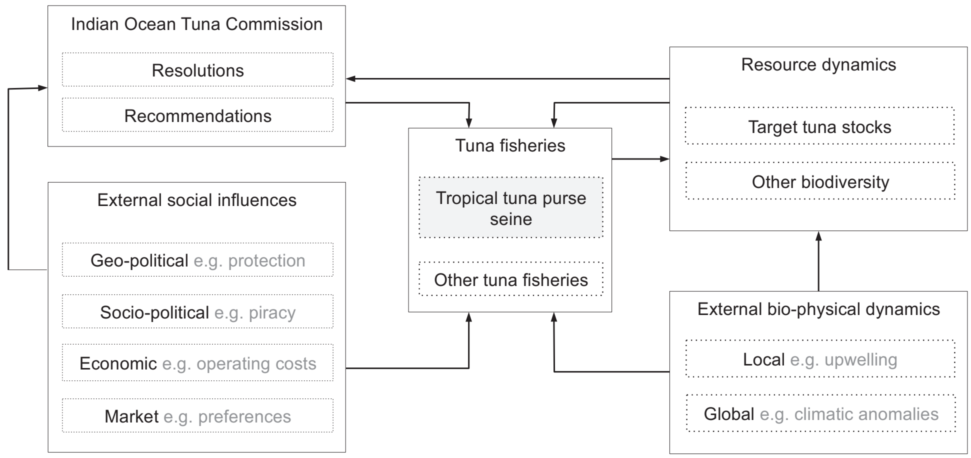

Fig. 1. Conceptual overview of the social-ecological system that contains the western Indian Ocean tuna purse seine fishery showing the main elements of the SES and the linkages between them.

consideration (e.g. piracy), economic forces (e.g. fuel costs, port fees etc.) and market pressures (e.g. consumer preferences). The dynamism of these system elements varies considerably, and each is characterised by different levels of uncertainty. For instance, IOTC decision making tends to be slow paced and management changes are gradual and often conservative [16,2], meaning that firms may be able to anticipate the management situation some way into the future. In contrast, external socio-political and socio-economic influences can change rapidly and unexpectedly, for example the designation of British Indian Ocean Territory (BIOT) as a marine reserve in 2010 (FCO Proclamation Number 1 of 2010) and the escalation of the piracy threat to fishing vessels in the late 2000s [9]. Although there are many linkages and feedback loops within this SES, the purse seine fishing industry ultimately has little or no control over most of the influences, beyond management action, that shape the dynamics of effort allocation.

4. Identification of alternative futures

In considering the future of tuna purse seine fishing in the western Indian Ocean, and on the basis of current understanding of the drivers of fleet behaviour outlined in the assessment of the fishery system, three main uncertainties stand out:

1. Will more nations designate ecosystem-scale marine protected areas (MPAs) similar to the BIOT marine reserve, and how will this change access arrangements and ultimately the characteristics of the fishery?
2. Will consumer preferences for sustainable seafood strengthen in regard to tuna products, and how will this impact the choice of fishing practices in the purse seine fishery?
3. Will management be ineffective, failing to prevent overfishing of tuna stocks, and how will change in the relative abundance of the main target species affect participation in the fishery and other aspects of effort allocation dynamics?

4.1. Increase in marine protection

MPAs in one form or another are becoming increasingly popular as tools for managing and conserving marine species and ecosystems. The Convention on Biological Diversity called for 10% of the world's ocean to be protected using some form of closed area by 2010, although the target deadline has since been pushed back to 2020. The World Parks Congress called for 20% of the oceans, including the high seas, to be protected within reserves by 2012, and the World Summit on Sustainable Development called for the creation of a global network of comprehensive, representative and effectively managed marine protected areas by 2012.

Recently, the Pew Ocean Legacy Program has proposed ecosystem-scale MPAs ('megareserves') in a handful of EEZs around the world [35]. The first of these to achieve formal protection in the western Indian Ocean was BIOT in 2010. The designation of BIOT was not linked to regional fisheries management policy, because the UK government, which administers BIOT, does not have a direct interest in tuna fisheries in the region. However, whilst no formal management plan has yet been developed, several objectives of the reserve can be inferred, including the provision of a scientific reference site and near shore and pelagic biodiversity

Table 1
Key influences on the decision making of tuna purse seine firms and skippers and examples of fishing behaviours in response to these influences.

Influence	Example of behavioural response	Reference
Resource dynamics	Firms may transfer vessels from the eastern Atlantic Ocean into the Indian Ocean on the basis of perceived relatively high abundance of one or more target species	Fonteneau, pers. comm.
Biophysical ocean dynamics	The depth of the thermocline can affect the surface-schooling behaviour of tunas and influence choice of fishing ground, and weather and waves can determine where a vessel can fish	Marsac, pers. comm.
Fisheries management	IOTC Conservation and Management Measures (e.g. area closures, prohibited species etc.) can constrain behaviour or encourage certain fishing practices	[12]
Piracy	Pirate activity is associated with personal and economic risk and the threat of piracy can be a disincentive to fish in certain areas	[9]
Fuel costs	Fuel costs are the single greatest variable cost in purse seine fishing and can determine how far a vessel will travel in a trip or to what extent a skipper is willing to search for free schooling tunas	[33]
Market conditions	Demand for a certain species or product (i.e. sustainably sourced) can determine ex-vessel fish price and in turn influence a skipper choice of target species or the design of fishing gears	[26,33]

conservation [42].

Although the Pew Ocean Legacy Program has not identified any other potential megareserve sites in the western Indian Ocean, it is still possible that other coastal and island nations will be motivated to rescind fishing access rights and protect part or all their EEZ in the form of marine reserves. For example, in 2014 the Seychelles government started exploring options for a 200,000 km^2 marine reserve in its EEZ as part of a debt-swap initiative with the UK, France and Belgium, facilitated by The Nature Conservancy (http://www.nature.org/ourinitiatives/regions/africa/wherewework/seychelles.xml; accessed 7th August 2015). Under this initiative, the Seychelles government will set up a trust fund to purchase, restructure and manage its debt. After 20 years, the endowment is expected to be fully capitalised at $45 million and will pay out $2.25 million per year to fund continued marine conservation activities, including implementation of the marine reserve.

Decisions such as these made by coastal states would necessarily carry considerable economic consequences, as the revenue and support-in-kind gained from EU Fishing Partnership Agreements (FPAs) or private agreements with tuna fishing firms is important to many Indian Ocean coastal and island nation governments. However, examples from other parts of the world suggest that this revenue could be compensated using alternative financial mechanisms, such as the endowment fund used by the Kiribati government to fund the Phoenix Island Protected Area (PIPA; http://www.phoenixislands.org/trust.php; accessed 1st December 2013).

4.2. Growing consumer preference for sustainable seafood

The principal market for purse seine-caught tuna is Europe [7]. Here consumer pressure for sustainably sourced fish is strong and seafood certification schemes, such as that of the Marine Stewardship Council (MSC), are popular [28]. In this environmentally-aware social climate, becoming associated with sustainable production has business advantages. To date one purse seine fishery in the Western and Central Pacific convention area has been awarded certification by the MSC, although this has been exclusively for free schools of skipjack tuna, and in the Indian Ocean at least one fishing company (Echebastar) has formally explored the possibility for MSC certification for free school catches (http://www.msc.org/track-a-fishery; accessed 12th June 2015).

There is growing discomfort with the practice of fishing for tuna around floating objects. This practice is associated with several potential negative ecosystem impacts, most notably catch of juvenile tunas and bycatch of non-target species, including vulnerable (and charismatic) species of sharks and turtle [1,6]. Furthermore, there is concern that the intensive use of FADs, if left unchecked, might exacerbate issues of overcapacity and ultimately lead to the unsustainable exploitation of tuna stocks [19,20]. There is currently little control on the use of FADs in the western Indian Ocean, although there has been increasing discussion within IOTC on managing their use more strictly [13,19].

The 'dolphin-safe tuna' campaign in the late 1980s set a precedent for consumer-driven change in the operation of tuna fisheries. This campaign, lead by a coalition of environmental organisations in the USA, was in protest at the bycatch of large numbers of dolphin in the nets of purse seiners in the eastern tropical Pacific Ocean, and was ultimately successful in improving the management policies of the Inter American Tropical Tuna Commission (IATTC) and changing US legal standards for catching tunas in dolphin-safe practices [47]. Whilst the issues of purse seine bycatch in the western Indian Ocean are arguably less controversial in the eyes of the public than in the case of the eastern Pacific, there is still strong pressure from organisations such as Greenpeace and WWF (through its Smart Fishing Initiative) to be cautious buying purse seine caught tuna, or even avoid altogether tuna caught using FADs. Some organisations are already lobbying or working with the purse seine industry to reduce the environmental impacts of FADs, mainly through technological innovation (see http://iss-foundation.org/resources/downloads; accessed 4th June 2015). However, should the industry aim to achieve sustainable seafood certification through schemes such as the MSC, fishing firms would be obliged to make far bolder changes to their operations in order to address a broader range of sustainability issues.

4.3. Depletion of tuna stocks

In the western Indian Ocean the three main target species of tropical tuna – yellowfin, skipjack and bigeye tuna – are currently considered to be exploited at sustainable levels ($F/F_{MSY} < 1$; [27]). Stocks of these species are differentially susceptible to overfishing due to variation in growth rate, the age of sexual maturity and duration of spawning. For example, yellowfin tuna, which is a large and relatively slow-growing species, lives a maximum of 10 years but reaches sexual maturity relatively late (2.8 years) and spawns for only half of the year. In comparison, smaller skipjack tuna, which live for 4–5 years, grow quickly, reach sexual maturity sooner (1.8 years) and spawn all year. Consequently, stocks of skipjack are generally considered to be able to withstand greater levels of exploitation than yellowfin and the biologically similar bigeye tuna [21].

Although tropical tuna stocks in the western Indian Ocean are currently in a healthy state, there are a number of drivers that could potentially lead to overfishing. In the case of skipjack, investment in larger vessels by fishing firms is likely to result in an increase in the use of FADs (Davies et al. FAD), and in turn fishing mortality of skipjack stocks. Signs of growth overfishing in the Atlantic Ocean in the late 1990s were attributed to the intensive use of FADs [20], and there is concern that unchecked expansion of FAD fishing in the eastern Pacific Ocean may ultimately lead to overexploitation of regional skipjack stocks [31]. Also, although skipjack are caught mainly in the purse seine fishery (38% of catch share in 2010), large quantities are also caught by vessels using gillnet (36%), pole-and-line (17%) and miscellaneous gears (9%; [27]), and growth in these fisheries would be expected to increase fishing pressure on skipjack stocks.

In the case of yellowfin and bigeye stocks, fishing mortality from gillnet and longline gears (28% and 15% of catches in 2010; [27]) is expected to increase as socio-political conditions in the Indian Ocean change. Increasing pirate activity in the northwest Indian Ocean during the mid 2000s displaced fishing activity, particularly the longline fleet, into other parts of the Indian Ocean [26,9], but attempts to control this threat (e.g. NATO counter-piracy operations, private security personnel etc.) has already allowed some of this fleet to return to the western Indian Ocean in 2013 (Seychelles Fishing Authority, pers. comm.). As the threat of piracy is reduced in future years, the presence of longline and gillnet vessels in the western Indian Ocean might be expected to increase further, leading to a significant increase in fishing pressure on stocks of yellowfin and bigeye tuna.

5. Constructing scenario storylines

5.1. Protected ocean

The designation of BIOT as a marine reserve in 2010 sets a precedent for marine conservation in the Indian Ocean. International marine conservation organisations have a strong voice in the region and campaigns to protect large areas of ocean within marine reserves gain momentum. In the late 2010s, with existing fishing fleets beginning to overexploit stocks, a number of East African coastal states opt to close their EEZs to industrial tuna fisheries rather than to develop their own national offshore fleets. This decision is motivated not only by the deterioration of tuna stocks, but also because the protection of very large areas of ocean serves as a big leap forward in achieving international biodiversity conservation targets for protected areas. The closure of national EEZs to industrial fishing necessarily involves withdrawal from EU fisheries partnership agreements or privately negotiated access arrangements, although in most cases the opportunity costs associated with prohibiting fishing access are offset using alternative financing mechanisms. In the early 2020s, with existing management measures largely failing and stocks of yellowfin and bigeye in a chronically depleted state, pressure mounts within IOTC for the implementation of a robust policy of spatial management. These proposals are seen as over-precautionary by some members and initial negotiations stagnate. However, coordinated awareness campaigns run by environmental organisations in Europe and Asia help to steer political opinion, and by the mid 2020s consensus is reached within the IOTC to close a large area of the high seas to the industrial fleets. This single area closure is situated in the northwest Indian Ocean and excludes fishing from a highly productive region associated mainly with fishing on FADs [13].

The implementation of marine reserves and fishery closures affects where the purse seine fleet can operate. The closure of several EEZs along the east African coast in the mid-2010s modifies the characteristics of the fishery by excluding the purse seine fleet from parts of the productive spring and summer fishing grounds. In each instance of an EEZ being closed to the fishery, the immediate response of the fleet is to reallocate effort into adjacent areas. This initial reallocation of effort is exploratory, as fishers, forced to break from tradition, investigate alternative grounds (see [15]). After a few years, the allocation of effort settles into a new pattern as skippers become familiar with the modified grounds of the fishery. The EEZ closures mainly affect the activities of the fleet in the west and southwest regions of the fishery, although the most productive summer grounds in the northwest Indian Ocean remain accessible. However, this changes following the implementation of an IOTC high seas area closure in the mid-2020s, which denies the fleet access to a significant part of the Somali Basin fishing grounds. The response of the fleet is again to reallocate effort into adjacent areas. The size and positioning of the IOTC closure forces the majority of effort to be allocated into relatively less productive grounds in the central western Indian Ocean, many of which have already been fished intensively in previous months. Subsequently, facing a shortfall in catches and increased competition with other vessels, skippers attempt to maintain catch rates by intensifying the deployment of FADs (see [11,13]), and, in some cases where fishing opportunities are perceived to be very poor, fishing firms reallocate vessels into the Atlantic Ocean, where there are fewer spatial restrictions in place.

5.2. Sustainable seafood

In the mid 2010s, consumers in Europe are increasingly favouring sustainably sourced tuna. Campaigns spearheaded by influential environmental groups communicate to the public the sustainability issues associated with the use of FADs in purse seine fisheries, focusing on issues of bycatch and overfishing. The campaigns also pressure major supermarket brands to promote or exclusively source tunas caught using sustainable methods. The initial response by the purse seine industry to these campaigns is two-pronged. Firstly, fishing companies endeavour to supply additional data to IOTC scientists on the use of FADs in order that uncertainties in their environmental impact can be better investigated. Secondly, at a global scale, the industry begins to develop more environmentally friendly FAD-fishing methods. Nevertheless, uncertainties about the ecological impact of FADs remain, and whilst technological innovation does reduce bycatch and ghost fishing by FADs, environmental groups continue to express serious concern over the contribution of FADs to overfishing.

FAD-caught tuna is unappealing to much of the European market, and free school-caught fish is regarded as the best choice. In the late 2010s, recognising the direction that the sustainable seafood movement is going, several of the smaller purse seine fishing firms invest in newer, more efficient vessels that can pursue free schooling tunas with lower operating costs. By the mid 2020s, although unable to achieve formal certification of sustainability, these companies are marketing themselves as using “clean, sustainable purse seine methods” and sell their products in the European market at a premium. In contrast, many of the larger Spanish-owned vessels, which are reliant on FADs to remain profitable, suffer as a result of the change in consumer preference. By the late 2010s, several of the largest vessels tie up in port, but, with no option to transfer operations into the Atlantic, which supplies the same European market, vessels owners are forced to sell these vessels. This divergence in strategies opens up a divide in the fishery, with part of the fleet targeting mainly free schools for the premium European market and the other targeting mainly FADs and selling to the budget and non-European components of the market. Moreover, these components of the fleet fish on different grounds, with the free school-oriented fleet fishing mainly in subequatorial waters where free schools are most abundant, and the FAD-oriented fleet focusing on the northwest and southwest grounds where floating objects exist at high densities [30].

5.3. Depleted ocean

In the mid 2010s, none of the three main target stocks is considered to be overexploited, partly as a result of the negative influence of piracy on purse seine and longline catches. On-going NATO counter-piracy operations, along with the protection provided to shipping by private security firms, are successful in reducing the pirate attack rate and many vessels feel more confident in fishing in the northwest Indian Ocean. Thus, as the threat of piracy lifts during the 2010s, longline and gillnet fleets report very high catch rates of yellowfin and bigeye. This bounty of catches prompts several nations to increase their participation in these fisheries, and the subsequent influx of additional fishing vessels into the northwest Indian Ocean rapidly exacerbates the already high fishing pressure. This increase in fishing capacity is largely unchecked due to clauses in the IOTC mechanism for regulating capacity, the RAV, that are designed to safeguard development potential of emerging fishing nations. By the mid-2020s the spawning stocks of yellowfin and bigeye are considered overexploited and catch rates fall in all fisheries, including purse seine, which in particular experiences a gradual decline in catch rates on free schooling yellowfin tuna.

In response to falling stock abundance in the late 2010s, most purse seine skippers increasingly use FADs to maintain overall catch rates. This increases the proportion of small and juvenile yellowfin and bigeye in the catch, and skippers must work harder to fill their fish wells. Moreover, as the use of FADs varies by region, this shift in fishing practice also results in a subtle adjustment in fishing grounds, with more effort allocated into western grounds where floating objects exist at higher densities. By the mid-2020s the localised deployment of more FADs in these grounds results in a decrease in the average size of sets and an increase in search costs, as vessels must move between a higher number of FADs to achieve sufficient catches (see [41]). This impacts on the profitability of fishing firms, especially those operating larger, less fuel efficient vessels, and some choose to tie up a number of vessels in their fleets temporarily until fishing conditions improve.

6. Cross-cutting behaviours

The three scenarios present imaginary but not implausible futures for the western Indian Ocean tuna purse seine fishery, and describe a number of ways in which the fleet may respond to change. It is not anticipated that any of these futures will emerge exactly as described in the storylines, although aspects of one or more futures may occur. The *protected ocean* scenario describes a mostly positive future for the Indian Ocean tuna stocks, with fishing pressure lifted from larges areas of ocean, but changes to the system are economically undesirable from the perspective of the fishing industry. Fishing opportunities are squeezed into a small area, increasing competition between vessels and prompting an increase in the use of FADs. The *sustainable seafood* scenario also describes a generally positive outlook for the resource, although the prognosis for the fishing industry is mixed. Some firms are able to tailor their operations to free school fishing, whereas other are less flexible and must continue to fish intensively using FADs in order to remain profitable. The *depleted resource* scenario is the only one that is negative for both the resource and the industry. Although overfishing of tuna stocks occurs mainly as a result of increased exploitation rates by other tuna fishing gears in the region, the consequences are keenly felt in the purse seine fishery, and skippers must increasingly use FADs in order to maintain profitable levels of catch.

Comparison of the scenarios reveals several commonalities in possible future behaviour of the fleet, as well as a number of behaviours specific to certain changes in the system (Table 2). A behaviour that was likely across all scenarios was a shift in fishing practice. In the *protected ocean* and *depleted ocean* scenarios, this was observed as an increase in the use of FADs, with skippers attempting to maintain catch rates using this highly effective fishing practice in the face of shrinking fishing opportunities. However, it should be noted that in the *protected ocean* scenario there was an increase in the deployment of FADs (in areas that remained accessible to fishing), whereas in the *depleted ocean* scenario there was a spatial shift by the fleet to fish in existing high density FAD areas. These may be regarded as proactive and reactive behaviours, respectively. In comparison, in the *sustainable seafood* scenario several companies changed their focus to specialise in fishing on free schools, and this shift in fishing practice was also associated with reallocation of effort into grounds most appropriate for the fishing practice. In all instances the overriding incentive to increase the use of one practice or the other was considered to be economic; skippers favoured the fishing practice that would achieve the greatest profits. However, it should be considered that some skippers are more inclined, either through specialisation, personal preference or some other factor, to fish on FADs than on free schools, and vice versa [34], meaning that shifts in fishing practice, if they do occur, may not be observed at the same rate for all fishing firms and individuals in the fishery.

Table 2
Cross-tabulation of fishing behaviours in the imagined future scenarios, showing commonalities or peculiarities in behaviours. The likelihood of the behaviour is represented by the + or −, where +++ indicates a very likely behavioural response.

Fishing behaviour	Scenario		
	Protected ocean	Sustainable seafood	Depleted ocean
Switch in fishing practice to/from FADs	++ (to)	+++ (from)	++ (to)
Reallocation of effort in space	+	++	++
Investment in new vessels	−	+	−
Exit from the fishery	+	+	+

Another common behaviour observed across the future scenarios was the reallocation of effort in space, although this varied in magnitude from subtle shifts in the areas fished in the *sustainable seafood* and *depleted ocean* scenarios, to complete displacement from former fishing grounds in the *protected ocean* scenario. As with shifts in fishing practice, these behaviours might be regarded as proactive (*sustainable seafood* and *depleted ocean*) and reactive (*protected ocean*), and consequently their drivers are likely to be very different. The subtle shifts in fishing grounds predicted in the *sustainable seafood* scenario were the result of decisions made by skippers to fish in areas with known FAD or free school opportunities, depending on their preferred fishing practice, and were therefore linked to overarching fishing strategies, for example the maximisation of profit, and driven by fishers' knowledge, past experiences and attitude to risk. In contrast, the displacement of effort imagined in the *protected ocean* scenario was a forced response by the fleet, with skippers left with little option but to move into suitable grounds in other parts of the ocean that remained accessible to fishing. This reactionary behaviour therefore may not be driven by heuristics, but instead by prevailing environmental conditions, fishers' intuition and the recent activity of others [12].

The *sustainable seafood* scenario was the only future in which new opportunities emerged, and consequently in which some fishing companies chose to invest in new vessels. In the other scenarios, both of which painted negative pictures of fishery production, catch rates suffered and investment in new vessels was consequently unlikely. Instead, exit from the fishery was a common behaviour in these scenarios, with the largest and least economical vessels the most likely to be tied up in port or sold. This temporary or permanent decommissioning of vessels by fishing firms was imagined in the scenarios as a last remaining option, with palliative behaviours such as an increase in the use of FADs failing to achieve profitable catch rates. An alternative plausible strategy by firms might be to withdraw vessels from the fleet at an earlier time in order to reduce costs and lessen competition with remaining vessels.

7. Possible IOTC interventions

In addition to identifying possible fleet behaviours, it is also useful to consider what, if anything, the IOTC might do to change the course of the imagined storylines. In the *protected ocean* scenario, the behaviour of the fleet is ultimately influenced by an external element of the fishery system, namely public opinion and government obligations in respect to the conservation of marine biodiversity (Fig. 1). The IOTC has little control over these societal influences, and consequently can probably do little to influence the *protected ocean* scenario should it emerge as imagined. In the *sustainable seafood* scenario, the main driver of behavioural change – consumer preference – is also an external social element of the fishery system. However, in this scenario, consumer backlash against unsustainable fishing is partly the result of poor management by the IOTC in respect to the use of FADs by the purse seine fleet. Hence, the course of the *sustainable seafood* storyline could to a certain extent be influenced by the implementation of timely and appropriate regulation on the use of FADs. The *depleted ocean* scenario describes a future of fishery overcapacity that cannot be effectively managed using existing controls, and hence pressure for behavioural change comes directly from the management of the fishery and the actions of the fleets. More so than the others the IOTC has the opportunity and influence to change the course of this scenario, for instance through the design and implementation of rights-based management approaches that specifically address the perverse incentives for overfishing a common resource [29].

8. Recommendations for future research

A skipper's choice of fishing strategy in the short term is a key behaviour that policymakers should aim better to understand, and some work has already been directed at this topic. This work has mostly focused on identifying the factors that determine whether a skipper is a FAD or free school fisher in the Indian Ocean purse seine fishery [24]. However, there has been no work directed at understanding the drivers of change from one fishing practice to another, and indeed the flexibility of fishers to do so, and the roles of the firm and the skipper in making these decisions. This should be a priority for research. Moreover, Moreno et al. [34], who highlight the variation in skills needed for FAD and free school fishing, suggest that research into this aspect of behaviour should consider not only economic drivers, but also the influence of culture and a skipper's knowledge, experience preference and habits on decision making.

The movement of fishers in space is another important behaviour for policymakers to consider. Davies [12] focussed on understanding the drivers of fleet-level behaviour, which is characterised by seasonal movement between regions of the western Indian Ocean. The role of the firm in the spatial behaviour of vessels was not examined, but should be considered in future work in order better to understand the top-down influence of firms on how and where skippers operate. Furthermore, future work should aim better to understand the link between the long term strategic decision making of firms (e.g. investment in vessels) and the short term spatial behaviour of its assets (e.g. skippers' specialisation on FADs or free schools). Similarly, investigation into the decision making of purse seine fishing firms would yield greater understanding of investment in new vessels and of entry and exit from the fishery.

9. Final remarks

Resource users are the key link between policymakers, as well as other social, economic and political elements of the system, and the resource. Unexpected behavioural responses to these system dynamics can potentially result in unwelcome or even disastrous management outcomes, and there is considerable benefit to fishery management planning in forecasting system dynamics and anticipating the behaviour of fishers. However, uncertainty is an inherent characteristic of the future and can frustrate the task of evaluating alternative management policy options. Although reducing uncertainty in the dynamics of natural and social systems has long been a focus of fisheries science, many aspects of the future remain unpredictable using models, either because of insufficient understanding of system dynamics or through uncontrollable, irreducible uncertainty.

In this study scenario planning, in the absence of reliable predictive models, was used to peer into the future and identify key uncertainties which may change fisher behaviour. These scenarios were not intended as predictions of the future, but instead they were used to identify uncertainties in fisher behaviour that may limit the ability of policymakers to evaluate how alternative management policy options will fare in the future. The findings presented here suggest that some fishing behaviours are likely under several possible scenarios. These behaviours, if enacted, would be expected to alter the dynamics of fishing effort and, in some cases, affect the sustainability of the fishery. It is therefore argued that these behaviours, which are only partially understood, should be a critical focus of research in order that robust management policies can be designed and evaluated.

This application of scenario planning in a fisheries management context is novel, but has been highly constructive in stimulating thinking on system drivers of fisher behaviour, and uncertainty in the future of these system dynamics. In particular, scenario planning has served to highlight that the behaviour of fishers is not a static element of a fishery system, and that it must be afforded greater importance in management planning. There are also ways that the planning exercise presented here could be adapted, for example by extending the timeframe over which system dynamics are considered to explore the effects of climate change on tuna stocks, fishery production and fisher behaviour. Indeed, the focus of scenario planning can be directed at almost any aspect of the system where model-based forecasting is unreliable or impossible. Furthermore, as scenario planning can be carried out as a relatively rapid and inexpensive exercise, it could be undertaken by policymakers on a regular basis (e.g. every few years) to help redefine priorities and consideration of future fisheries management policy.

Acknowledgements

We are grateful to the Economic and Social Research Council and the Natural Environment Research Council for funding this research (ES/I029273/1). Generous thanks are also given to J. Mumford and L. Dagorn for constructive feedback on an early draft of this manuscript. Thanks also go to helpful colleagues at MRAG, IRD, CSIRO, SFA, and a number of anonymous skippers who gave up their time to offer invaluable insight into the Indian Ocean tuna purse seine fishing.

References

[1] M.J. Amandè, J. Ariz, E. Chassot, A.D. De Molina, D. Gaertner, H. Murua, R. Pianet, J. Ruiz, P. Chavance, Bycatch of the European purse seine tuna fishery in the Atlantic Ocean for the 2003-2007 period, Aquat. Living Resour. 23 (2010) 353–362.
[2] M. Aranda, H. Murua, P. de Bruyn, Managing fishing capacity in tuna regional fisheries management organisations (RFMOs): development and state of the art, Mar. Policy 36 (2012) 985–992, http://dx.doi.org/10.1016/j.marpol.2012.01.006.
[3] E.L. Bohensky, B. Reyers, A.S. Van Jaarsveld, Future ecosystem services in a Southern African river basin: a scenario planning approach to uncertainty, Conserv. Biol. 20 (2006) 1051–1061.
[4] H. Bossel, Earth at a crossroads: paths to a sustainable future, Cambridge University Press, Cambridge, 1998.
[5] G. Briand, T. Heckelei, S.C. Matulich, R.C. Mittelhammer, Managing fishing power: the case of Alaska red king crab (*Paralithodes camtschaticus*), Can. J. Fish. Aquat. Sci. 61 (2004) 43–53.
[6] D. Bromhead, J. Foster, R. Attard, J. Findlay, J. Kalish, A review of the impact of fish aggregating devices (FADs) on tuna fisheries, Bureau of Rural Sciences, Canberra, Australia, 2003.
[7] L. Campling, The tuna commodity frontier: business strategies and environment in the industrial tuna fisheries of the western Indian Ocean, J. Agrar. Change 12 (2012) 252–278.
[8] E. Chassot, S. Bonhommeau, G. Reygondeau, K. Nieto, J.J. Polovina, M. Huret, N. K. Dulvy, H. Demarcq, Satellite remote sensing for an ecosystem approach to fisheries management, ICES J. Mar. Sci. 68 (2011) 651–666.
[9] E. Chassot, P. Dewals, L. Floch, V. Lucas, M. Morales-Vargas, D. Kaplan, Analysis of the effects of Somali piracy on the European tuna purse seine fisheries of the Indian Ocean, in: Proceedings of Indian Ocean Tuna Commission Doc, IOTC-2010-SC-09, 2010.
[10] J.S. Clark, S.R. Carpenter, M. Barber, S. Collins, A. Dobson, J.A. Foley, D.M. Lodge, M. Pascual, R. Pielke Jr, W. Pizer, Ecological forecasts: an emerging imperative,

Science 293 (2001) 657–660.
[11] L. Dagorn, K.N. Holland, V. Restrepo, G. Moreno, Is it good or bad to fish with FADs? What are the real impacts of the use of drifting FADs on pelagic marine ecosystems? Fish Fish. 14 (2012) 391–415, http://dx.doi.org/10.1111/j.1467-2979.2012.00478.x.
[12] T.K. Davies, Understanding fleet behaviour to reduce uncertainty in tuna fisheries management (Ph.D. thesis), Imperial College London, London, UK, 2014.
[13] T.K. Davies, C.C. Mees, E.J. Milner-Gulland, The past, present and future use of drifting fish aggregating devices (FADs) in the Indian Ocean, Mar. Policy 45 (2014) 163–170.
[14] T.K. Davies, C.C. Mees, E.J. Milner-Gulland, Modelling the spatial behaviour of a tropical tuna purse seine fleet, PloS One 9 (2014) e114037.
[15] T.K. Davies, C.C. Mees, E.J. Milner-Gulland, Examining the impact of spatial closures on the behaviour of a tropical tuna purse seine fleet, in: Proceedings of Indian Ocean Tuna Commission, IOTC-2014-WPTT16-17, 2014.
[16] P. de Bruyn, H. Murua, M. Aranda, The precautionary approach to fisheries management: how this is taken into account by tuna regional fisheries management organisations (RFMOs), Mar. Policy 38 (2013) 397–406, http://dx.doi.org/10.1016/j.marpol.2012.06.019.
[17] T. Dempster, M. Taquet, Fish aggregation device (FAD) research: gaps in current knowledge and future directions for ecological studies, Rev. Fish Biol. Fish. 14 (2004) 21–42.
[18] FAO Globefish. Market report: Tuna-July 2015 [WWW Document]. URL ⟨http://www.globefish.org/tuna-june-2015.html⟩, 2015 (accessed 08.07.15).
[19] A. Fonteneau, E. Chassot, N. Bodin, Global spatio-temporal patterns in tropical tuna purse seine fisheries on drifting fish aggregating devices (DFADs): taking a historical perspective to inform current challenges, Aquat. Living Resour. 26 (2013) 37–48, http://dx.doi.org/10.1051/alr/2013046.
[20] A. Fonteneau, P. Pallares, R. Pianet, A worldwide review of purse seine fisheries on FADs, in: J.Y. Le Gal, P. Cayré, M. Taquet (Eds.), Pêche Thonière et Dispositifs de Concentration de Poissons (Proceedings of the 1st Symposium on Tuna Fisheries and FADs, Martinique, October 1999), 28, Actes Colloques-IFREMER, 2000, pp. 15–35.
[21] J.-M.-M. Fromentin, A. Fonteneau, Fishing effects and life history traits: a case study comparing tropical versus temperate tunas, Fish. Res. 53 (2001) 133–150.
[22] E.A. Fulton, M. Fuller, A.D.M. Smith, A.E. Punt, Ecological Indicators of the Ecosystem Effects of Fishing: Final Report, CSIRO, Victoria, Australia, 2004.
[23] E.A. Fulton, A.D.M. Smith, D.C. Smith, I.E. van Putten, Human behaviour: the key source of uncertainty in fisheries management, Fish Fish. 12 (2011) 2–17.
[24] P. Guillotreau, F. Salladarré, P. Dewals, L. Dagorn, Fishing tuna around Fish Aggregating Devices (FADs) vs free swimming schools: skipper decision and other determining factors, Fish. Res. (2011) 234–242.
[25] J.G. Hiddink, T. Hutton, S. Jennings, M.J. Kaiser, Predicting the effects of area closures and fishing effort restrictions on the production, biomass, and species richness of benthic invertebrate communities, ICES J. Mar. Sci. 63 (2006) 822–830, http://dx.doi.org/10.1016/j.icesjms.2006.02.006.
[26] IOTC, Proceedings of the Fourteenth Session of the IOTC Working Party on Tropical Tunas Report, 2012.
[27] ISSF, Tuna Stock Status Update, 2013: Status of the World Fisheries for Tuna, International Seafood Sustainability Foundation, Washington, D.C., USA, 2013.
[28] S. Jaffry, H. Pickering, Y. Ghulam, D. Whitmarsh, P. Wattage, Consumer choices for quality and sustainability labelled seafood products in the UK, Food Policy 29 (2004) 215–228.
[29] J. Joseph, D. Squires, W. Bayliff, T. Groves, Addressing the problem of excess fishing capacity in tuna fisheries, in: R. Allen, J. Joseph, D. Squires (Eds.), Conservation and Management of Transnational Tuna Fisheries, Wiley-Blackwell, Oxford, 2010, pp. 11–38.
[30] A. Maufroy, E. Chassot, R. Joo, D.M. Kaplan, Large-Scale examination of spatio-temporal patterns of drifting fish aggregating devices (dFADs) from Tropical Tuna Fisheries of the Indian and Atlantic Oceans, PLoS ONE 10 (2015) e0128023, http://dx.doi.org/10.1371/journal.pone.0128023.
[31] M.N. Maunder, Updated indicators of stock status for skipjack tuna in the eastern Pacific Ocean, Inter-Am. Trop. Tuna Comm. Doc. Stock Assess. Rep., 02-08, 2011.
[32] MEA, Ecosystems and Human Well-being: Millennium Ecosystem Assessment, Island Press, Washington, DC, 2005.
[33] M.P. Miyake, P. Guillotreau, C.-H.-H. Sun, G. Ishimura, Recent Developments in the Tuna Industry: Stock, Fisheries, Management, Processing, Trade and Markets (No. No. 543) (2010), Rome, Italy.
[34] G. Moreno, L. Dagorn, G. Sancho, D. Itano, Fish behaviour from fishers' knowledge: the case study of tropical tuna around drifting fish aggregating devices (DFADs), Can. J. Fish. Aquat. Sci. 64 (2007) 1517–1528.
[35] J. Nelson, H. Bradner, The case for establishing ecosystem-scale marine reserves, Mar. Pollut. Bull. 60 (2010) 635–637.
[36] G.D. Peterson, G.S. Cumming, S.R. Carpenter, Scenario planning: a tool for conservation in an uncertain world, Conserv. Biol. 17 (2003) 358–366, http://dx.doi.org/10.1046/j.1523-1739.2003.01491.x.
[37] G. Ringland, P.P. Schwartz, Scenario Planning: Managing for the Future, John Wiley & Sons, New York, 1998.
[38] J. Robinson, P. Guillotreau, R. Jiménez-Toribio, F. Lantz, L. Nadzon, J. Dorizo, C. Gerry, F. Marsac, Impacts of climate variability on the tuna economy of Seychelles, Clim. Res. 43 (2010) 149–162, http://dx.doi.org/10.3354/cr00890.
[39] J. Rotmans, M. van Asselt, C. Anastasi, S. Greeuw, J. Mellors, S. Peters, D. Rothman, N. Rijkens, Visions for a sustainable Europe, Futures 32 (2000) 809–831.
[40] S. Salas, D. Gaertner, The behavioural dynamics of fishers: management implications, Fish Fish. 5 (2004) 153–167.
[41] G. Sempo, L. Dagorn, M. Robert, J.-L.-L. Deneubourg, Impact of increasing deployment of artificial floating objects on the spatial distribution of social fish species, J. Appl. Ecol. 50 (2013) 1081–1092.
[42] C.R.C. Sheppard, M. Ateweberhan, B.W.W. Bowen, P. Carr, C.A.A. Chen, C. Clubbe, M.T.T. Craig, R. Ebinghaus, J. Eble, N. Fitzsimmons, M.R.R. Gaither, C.-H.-H. Gan, M. Gollock, N. Guzman, N.A.J. Graham, A. Harris, R. Jones, S. Keshavmurthy, H. Koldewey, C.G.G. Lundin, J.A.A. Mortimer, D. Obura, M. Pfeiffer, A.R.G. Price, S. Purkis, P. Raines, J.W.W. Readman, B. Riegl, A. Rogers, M. Schleyer, M.R.D. Seaward, A.L.S. Sheppard, J. Tamelander, J.R. R. Turner, S. Visram, C. Vogler, S. Vogt, H. Wolschke, J.M.-C.-C. Yang, S.-Y.-Y. Yang, C. Yesson, Reefs and islands of the Chagos Archipelago, Indian Ocean: why it is the world's largest no-take marine protected area, Aquat. Conserv. Mar. Freshw. Ecosyst. 22 (2012) 232–261, http://dx.doi.org/10.1002/aqc.1248.
[43] K. Van der Heijden, Scenarios: The Art of Strategic Conversation, John Wiley & Sons, Inc., New York, 1996.
[44] I.E. van Putten, S. Kulmala, O. Thébaud, N. Dowling, K.G. Hamon, T. Hutton, S. Pascoe, Theories and behavioural drivers underlying fleet dynamics models, Fish Fish. 13 (2011) 216–235, http://dx.doi.org/10.1111/j.1467-2979.2011.00430.x.
[45] P. Wack, Scenarios: shooting the rapids, Harv. Bus. Rev. 63 (1985) 139–150.
[46] E. Wollenberg, D. Edmunds, L. Buck, Using scenarios to make decisions about the future: anticipatory learning for the adaptive co-management of community forests, Landsc. Urban Plan. 47 (2000) 65–77.
[47] B.G. Wright, Environmental NGOs and the dolphin-tuna case, Environ. Polit. 9 (2007) 82–103, http://dx.doi.org/10.1080/09644010008414552.