Discussion Document #14: Options for incentive-based measures

The role of incentives in achieving management objectives, specifically for the NEFMC FEP

This document has been prepared by the Council's EBFM Plan Development Team to identify and discuss options for using incentive-based measures to support the stock complex catch advice framework. This document is intended to be incorporated as a section in the example Fishery Ecosystem Plan for Georges Bank.

Introduction

The development of an appropriate incentive program for a multi-species fishery requires a good understanding of management objectives. Since there are implicit tradeoffs between common goals and objectives of fisheries management, managers can focus these objectives to help design a system which maximizes the probability of achieving the desired outcomes. Once goals and objectives identifying desired management outcomes have been developed, the management system can be designed to reinforce fishing behavior which supports these goals and objectives.

All of this occurs in a system linked through biological interactions. For example, in single species management the goal to maximize yield can compete with the goal to provide stability in catch limits through time. Similarly, maintaining employment may be in conflict with improving economic efficiency. However, fish species do not exist in isolation and thus fishing that impacts the abundance of one stock can have impacts on interacting stocks, through competition, predation, etc. The primary production of the ecosystem limits the total sustainable catch from the system, and it is impossible to concurrently catch all species at their assigned single-species MSY levels (e.g. Sissenwine 1977). Articulating an ecosystem level cap for fisheries can allow informed discussions of the trade-offs between different species, gears, and fisheries. For example, catching a forage species at its single species maximum sustainable yield could result in a lower abundance of and catch limit for predator species dependent on that species for prey. Similarly, fishing with a gear that impacts habitat will decrease the productivity of species dependent on that habitat.

Fishery management objectives are a great way to clarify stakeholder priorities for a fishery and give managers the information needed to build an appropriate incentive program. Articulating goals and objectives in clear and measurable terms provides specific targets that can be used to determine if management is meeting its goals or needs to be adjusted. They also articulate priorities such that management decisions can be made in a more transparent manner. Given that these objectives, and decisions regarding ecosystem caps, functional group management, and other foundational issues have not been finalized, the following discussion attempts to clearly define incentive based management, and provides examples of what these management systems could look like, without being prescriptive. Once management goals and objectives have been established, incentive program specifics would then be developed and tailored to align with these management priorities.

Most fishery management issues ultimately boil down to whether individual fishermen's incentives align with the goals and objectives of management, and society more broadly. Although the specifics for why individual behavior and management goals misalign can vary, market failures have long been identified as the root cause of the problem (e.g. Gordon 1954; Scott 1955).

Problem Definition and eFEP Goal

Most fishery management issues stem from a mismatch between individual fishermen's incentives (an incentive being a perceived reward for an action) and the goals and objectives of management. The goal of the NEFMC Fisheries Ecosystem Plan is to create a management system that provides fishermen with greater flexibility to choose when to fish, how to fish, and what to fish for while still incentivizing behavior aimed at achieving management objectives.

In a single-stock/single-species fishery a market failure derives from the fact that the ex-vessel price of a fish fails to account for the value of that fish if it was left in the ocean. For example, a landed fish no longer provides increased biomass or potential increase in price[1] via growth, increased recruitment via reproduction, or other benefits via biological interactions (such as serving as prey for other species). In multi-species fisheries the problem becomes more complicated, as fishermen do not have complete control over what they catch but can influence catch composition through fishing behavior/decisions such as choice of location, gear configuration, etc. (Abbott et al. 2015, Somers et al. 2018). An additional issue is the influx of effort possible most notably under open access and limited entry fisheries, which can lead to suboptimal value generated from the fishery due to over-investment in fishing technology and fleet sizes larger than optimal, as two examples. See Smith (2012) for a more exhaustive list of ways in which fisherman incentives and management objectives can misalign. The design of an incentive-based system within a multi-stock, multi-species fishery must contend with the potential for incentives to discard fish with low quotas or fish with low economic value. The extent to which these perverse incentives manifest themselves depends specifically on the difference between the net value an individual fisherman expects to derive through compliance (including the cost of compliance) and the net value derived from non-compliance (including penalties if caught in non-compliance). Incentive-based management looks to tip the scale away from non-compliance and towards compliance.

Barring the ability to monitor every action a fisherman takes, most research suggests that the best way to ensure management goals and objectives are achieved is to allow fishermen to benefit directly from behavior which supports achieving those goals and objectives. These approaches are broadly captured under the term "incentive-based management". As an example, the special access programs historically employed by the NEFMC are incentive-based management measures, as fishermen could gain access to areas otherwise closed to fishing by adopting gear designed to decrease bycatch of overfished species. The fishermen benefited directly by adopting conservation measures for overfished species, as they were allowed access to highly productive fishing grounds that they were otherwise excluded from.

Although relatively simple in concept, designing a system in which fishermen's incentives are fully aligned with management objectives is complicated, with potential for the development of perverse incentives. Further, the benefits attributed to incentive-based management hinge on transparent science and decision-making, and a system in which fishermen trust that management can achieve the stock levels being managed to. There are a multitude of management approaches that can be considered incentive-based management (see Pascoe et al. 2010). This section highlights a few incentive-based options to be considered with the NEFMC FEP, along with advantages and concerns surrounding their implementation.

1 Some species command higher ex-vessel prices for bigger fish

Background

Fisheries management is full of examples where fishermen's incentives do not align with fisheries management goals, creating conflict and unsustainable management. Hilborn et al. (2005) reviewed example fisheries management systems to determine characteristics shared across successful and unsuccessful management institutions. They found that the key to successful management is appropriate governance institutions that "include a reward system so that the individual welfare of fishermen, managers, and scientists is maximized by actions that contribute to a societally desirable outcome." Hillborn et al. (2011) conclude that the probability of management success is maximized with the alignment of fishermen's incentives with management goals, restrictive access, transparent (e.g. simpler) governance structures, and management implemented at ecologically and socially relevant scales. Osterblom (et al. 2011) similarly provide a general description of biologically sustainable and unsustainable fisheries management programs (Figures 1-2). In the unsustainable program there is a negative feedback loop where inappropriate incentives lead to decreased compliance with regulations and misreporting, which erodes the quality of the stock assessment, translating into incorrect catch limits and decreased confidence in the science, which again decreases compliance, and so on in a continuous loop.

In contrast, a fisheries management program with the proper incentives can create a positive feedback loop (Figures 1-2) with increased long-term value generated from a fishery. Accurate reporting of catches creates improved data quality, which can lead to better stock assessments and lower precautionary buffers, and increased trust in and engagement with the management system (Österblom et al. 2011). NEFMC should aim for these conditions when developing the incentive-based management for the NEFMC FEP.

Incentive-based management options

Below we outline two management structures that could be used when creating a proper incentive-based program: quota based management and credit based management. Of note is that both quota and credit based management are tools that can be used in rebuilding overfished stocks, as discussed in Discussion Document 4 of this eFEP. We also provide brief descriptions of other management options that could be included as part of either of these larger management structures: bycatch reduction gear technologies, auctions to allocate quota, and shorter-term allocations of quota.

Both of the management structures outlined below could be employed at the single species level or at the stock complex level, as is under consideration in this eFEP. Stock complexes in this case would be defined as species that are caught together, play similar roles in the ecosystem with respect to the transfer of energy, and have similar life history characteristics (growth, longevity, and reproductive characteristics). The revised National Standard One Guidelines [50 CFR 600.310(d)(2)(i)] state: "…Stocks may be grouped into complexes for various reasons, including where stocks in a multispecies fishery cannot be targeted independent of one another; where there are insufficient data to measure a stock's status relative to SDC {Status Determination Criteria}; or when it is not feasible for fishermen to distinguish individual stocks among their catch..."). Of a total of 913 individual stocks of fish currently under management in U.S. Federal waters, 658 are now aggregated into various stock complexes for management purposes (Gamble et al., in review). Although the motivation for management at an aggregate level is often related to data limitations or difficulties in species/stock identification, the revised guidelines clearly recognize the need to consider the problems in managing mixed species fisheries where targeting capabilities and species-level control on fishing mortality rates are subject to inherent limitations. In the Northeast, seven skate species are currently managed as a stock complex because the landed product cannot be visually identified by species. Silver and offshore hake are also managed as a complex.

Gamble et al. (In review) simulated a range of management scenarios applied to stock complexes. These included status-quo or catch-based management; the use of indicator species within a stock complex; and management of the species complex in aggregate. In the indicator approach, management targets are derived for a selected species and these targets are applied to all species in the complex. Gamble et al. found that catch-based or status-quo management is the least likely to achieve sustainable stocks and good yield, while assessments based on an indicator species or on the aggregate complex show a great deal of promise as management tools.

Option 1 – Quota-Based Management: This approach would create individual entity (i.e., fisherman, sector, or community) based quota share fishery with stock-complex level catch limits for healthy stocks and species specific catch limits for overfished stocks. Quota shares (usually designated as a percent of the catch limit for a species/complex) are assigned to entities and used annually to calculate and allocate the privilege to catch a specific amount of fish (quota pounds for each stock or stock complex) at the start of a fishing year. Entities are allowed to sell, trade, or transfer quota shares or quota pounds in order to capitalize on differences in profitability or catch composition/selectivity across the fishery.

At their heart, quota-based incentive systems attempt to align fishermen's incentives with management objectives by providing an enforceable and long-term privilege to harvest a subcomponent of a species' biomass. These privileges can be provided either directly through quota allocated to an individual or community of fishermen, such as the current sector based management of NEFMC's Large-Mesh Multispecies fishery, or indirectly through territorial rights of fishing (e.g. Christy 1982). For the purpose of this discussion, we focus on quota allocation, including individual transferable quota (ITQ)/individual fishery quota (IFQ) and sector management, as a management alternative with respect to the eFEP and explore issues to consider while developing this type of approach. Arnason (2002) and Sanchirico et al. (2006) provide surveys of ITQ fishery management systems, including evidence for changes in fishery profitability (i.e. efficiency), changes in discarding, and increased resource stewardship. The allocation of quota at the entity level is meant to allow fishermen to benefit from the biological stewardship of the species fished, in that as a stock rebuilds the fishermen can expect their individual annual allocation to increase. This benefit from long-term stewardship of the resource can allow for a decrease in focus on short-term decision-making. The current sector system is an example of this management system.

When quota is allocated at the species level, the cost of quota increases as you get closer to the TAC, which means fishermen have an incentive to avoid the stock. If quota is allocated at the complex level, this incentive to avoid any specific stock in the complex is removed. This decoupling can be problematic if catch ratios, ex-vessel price ratios, or cost of harvest across species are not constant, which could lead to a race to fish (Squires et al. 1998, Costello & Deacon 2007).[2] These realities suggest care is needed in identifying species for aggregation, and that aggregation should consider the ex-vessel prices of species. Examples of quota managed at the stock-complex level include New Zealand flatfish and British Columbia perch and redeye (Squires et al 1998). Given that this option proposes managing healthy species at the complex-level, if needed, incentives to avoid vulnerable or high economic value species within the stock complex must be induced purely through means discussed in Discussion Document 4 of the eFEP. Decisions around the aggregation approach would impact the exact manner in which the incentives can be best aligned to meet management goals.

Trades across individual fishermen are meant to increase flexibility in fishing by reallocating quota across fishermen depending on their need, making all participants better off than if no trade was possible. Purchase or renting of quota shares or quota pounds is the most common manner by which flexibility is built into a quota-based system. Allocations can be mismatched when the catch composition does not

2 Even without the ability to target, the incentive to high-grade might still result in similar outcomes, wherein fishermen race to land the high-valued species.

match the quota pounds available to a given entity. This is common as catch composition can be highly variable and is influenced by changes in the environment, changes in the abundance of predators and prey, as well as changes in fishing behavior in response to updated management measures (including the distribution of low-quota stocks). Thus, historical fishing patterns might not represent current and future plans. Flexibility[3] can be built into these systems through: interspecies trading of quota share or quota pounds[A, B, C, D], ability to carryover or use quota from one year to the next[A, B,C,D, E, F], landing fees[B], the ability to balancing quota through rental or purchase after usage[A, B, C], or allowing certain fish to be landed with no quota usage[A] (Arnason 2014; Sanchirico et al 2006). However, there can be issues with relying solely on the market to provide the necessary flexibility. For example, fishermen sometimes hold quota to buffer against uncertainty associated with catch of highly variable species with low catch limits, keeping necessary quota unavailable in the market. In the West Coast Groundfish Fishery, risk pools have developed to reduce the risk associated with an unexpected catch of stocks with low catch limits (Holland 2010; Holland & Jannot 2012; Kauer et al. 2018). More broadly, information asymmetries and transaction costs in the market can lead to a small trading volume and high variability in trade price, even within a stock on a single day, and managers can play a role in providing information to fishermen that minimizes these costs and asymmetries. See, as an example, the discussion of auctions that follows.

We note that high-grading and other forms of unobserved discarding along with illegally landing of species (i.e. mislabeling or underreporting landings) can be a concern across fisheries regardless of whether the fishery is managed by quota (Pascoe 1997), and the propensity for these practices should be accounted for within a multispecies/multistock quota system. Quota systems can incentivize discards of species with low quota (and thus high prices for quota pounds on the quota market), and can also incentivize high grading, where less valuable catch is discarded to save the quota pounds for higher value catch. Although a tradeable quota market can theoretically increase incentives to avoid bycatch and minimize misreporting (Boyce 1996), in reality this incentive depends on the level of monitoring possible[4] and penalties for non-compliance (Salvanes & Squires 1995).[5] Arnason (2014) identifies increased enforcement effort, increased penalties for non-compliance, a lowered threshold for legally establishing that non-compliance has occurred, and increasing the stigma of non-compliance through social norms as four general best practices to address issues of discarding in catch share systems. Importantly, Aranson (2014) also suggests allocation at the market category/species size can greatly help in mitigating discarding incentives, particularly with respect to high-grading. These approaches would also help address issues of illegally landing species.

The allocation of quota at the stock-complex level reinforces the need for additional catch accounting measures beyond those currently in place. In addition to the policies identified in the preceding paragraph, a discard ban (also known as a landings obligation or full retention program) is an alternate way in which some jurisdictions attempt to address issues surrounding high-grading and discarding and at least theoretically increase the quality of fishery-dependent catch information (see Karp et al. 2019 for a recent review). However, a discard ban by itself does not align incentives with management objectives, and thus needs to be coupled with appropriate levels of monitoring and penalties for non-compliance to be successful (Batsleer et al. 2013; Condie et al. 2013;2014; Hatcher 2014). Additionally, bioeconomic modeling has suggested that allowing some trading of the quota for the most abundant stock for the quota

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3 Programs currently or historically using these processes are: A-Icelandic groundfish ITQ fishery, B-historical New Zealand Quota Management System, C-historical Nova Scotia mobile gear groundfish IFQ, D-British Columbia trawl individual vessel quota system, E- NEFMC Sector management system, F-Australia Southeast Trawl Fishery.

4 Of note is monitoring can be a function of both the fishery management body and of fishing cooperatives/communities, where self-enforcement develops from social norms.

5 Salvanes & Squires (1995) also suggest using the average firm as a yardstick with which to manage a multispecies fishery with imperfect monitoring.

of the least abundant stock (Wise et al. 2015), and that setting quota based of multispecies, as opposed to single species, MSY (García et al. 2017) can help alleviate some of the issues associated with landings obligations, particularly surrounding decreases in profitability that has been consistently identified in the literature (e.g. Batsleer et al. 2016; Condie et al. 2014; Bellido et al. 2017, García et al., 2017). Potential perverse incentives include developing markets for juveniles and other undersized fish (Bellido et al. 2017), and the death of individuals in which bycatch release mortality is actually low. The perceived benefits of a discard ban must thus be weighed carefully against the costs of such a policy.

Besides the increased flexibility through trading, quota systems can provide additional flexibility by removing outdated input controls that are no longer required. For example, some gear requirements were removed after the implementation of the West Coast trawl program (see Federal Register Final rule at 83 FR 62269). Incentive-based management can also be paired with area/seasonal closures. This might be done to protect specific life history stages or vulnerable stocks, similar to the in-season spawning rolling closures currently in use.

<u>Option 2 – Credit-Based Management</u>: This approach would establish an individual entity (i.e., fisherman, sector, or community) credit-based fishery with species-specific credit costs of harvest, to ensure conservation of vulnerable, overfished, and both high and low economic value species. Credits are assigned to entities and used annually to calculate and allocate the privilege to catch fish at the start of a fishing year. The allocated credits can then be used to purchase the right to catch harvested species, with a pound of each species differing in credit costs depending on their abundance and economic value. Entities are allowed to sell, trade, or transfer credits.

Similar to quota-based management, credit systems look to incentivize fishermen behavior to meet specific objectives and to open opportunities for stakeholder choice as an integral and desirable characteristic of the system. In contrast to a quota-based system, in which the catch privilege is assigned at the species/stock complex level, credits are a currency that can be used to land any of a defined mix of species. The number of credits needed to catch each species differs depending on the biological status and economic value of the stock. Once an individual's allocation of points are used up, they would be obliged to either procure credits from others, either through rental or buying of licenses, or stop fishing for the remainder of the fishing year, in a similar manner to the quota-based system. The rental market for credit could function similarly to the current multispecies quota market. Also similar to a quota market, potential barriers to market trading should be given serious consideration. This is particularly true given the novelty of assessing a fair market price for credits which can be used to catch any species, and the management system can be designed to minimize barriers and facilitate trading.

An early, and innovative, example of a fisheries credit system was proposed by the Northeast Seafood Coalition in 2006 as the basis of groundfish management in the Northeast. In this case, the credit comprised an allocation of total points to individual fishers to be spent at their discretion. Individual species in the multispecies groundfishery were assigned individual points such that incentives to conserve over-exploited species (which would 'cost' more points) would be implemented and harvesting of lightly exploited species would incentivized by assigning lower point costs. The system was designed to allow ongoing updates in point pricing in response to changing resource condition, markets, and other factors. Although never implemented, the approach was tested using experimental economics in a laboratory setting and found to be promising (Anderson 2010). Simulation testing of the approach was also carried out at the UMASS School of Marine Science and Technology (Truong et al. unpublished ms) and again found to be promising. The Marine Conservation Society and Client Earth independently made a similar proposal for fisheries management under the Common Fisheries Policy of the European Union (see https://ec.europa.eu/fisheries/sites/fisheries/files/docs/body/clientearth_mcs_en.pdf).

Inherently, credit systems provide some protection from mismatches in allocation, which can for example stem from differences between historical fishing patterns and current and future optimal targeting. Credit systems can also negate the individual incentive to hold back quota as a buffer against uncertainty associated with catch of highly variable species with low catch limits, which in quota managed fisheries has been addressed by catch pools or other mechanisms.

Credit systems can be designed to meet species conservation, habitat protection, and other types of objectives. For example, Kraak et al. (2012) suggest using spatio-temporally explicit credit costs of fishing to protect critical habitat or species at critical life stages. Thus, for the same stock, a pound of catch in areas and times with known concentrations of juveniles or spawning adults would cost more in terms of credit than a pound of catch from other areas. As in Option 1, close monitoring of discarding would be required. In addition, the majority of the remaining management concerns outlined for quota-based management applies equally to credit-based systems, and can be addressed with similar approaches. Credit costs can also vary according to gear used, to help mitigate bycatch issues or habitat impacts, as examples.

An important, and challenging, requirement lies in dynamically setting the point prices for each species of interest. There can be little question that errors in setting the point prices can lead to undesirable outcomes. For example, setting the point cost of a species too low can lead to overharvesting if the error is not detected in a timely way and corrected. This general issue is of course not confined to credit/point systems. A misspecification of an ITQ species allocation can lead to similar problems. However, unlike the ITQ system which relies on accurate TAC and catch monitoring to ensure broad species conservation goals are met, a credit system necessitates accurate TAC, catch monitoring, and credit cost differential between species in order to ensure a TAC is not exceeded.

Ultimately further research is needed in understanding how incentives under a credit system differ from incentives under a quota system. In particular, the existence of lags in the management system impacts the speed at which the differential cost of landings, in terms of credit, can be adjusted throughout the year. The impact of these lags on the ability to meet conservation objectives needs to be more fully understood. Similar to Anderson (2010), experimental economics should be employed to more fully explore the ramifications of lags and other inherent constraints in the credit system on incentives to high grade and discard, and how they may differ from quota-based systems.

<u>Other Options to be Considered within an Incentives Program</u>

Bycatch Reduction Gear Technologies

The development and adoption of fishing gear/fishing practices that minimize bycatch of vulnerable and overfished stocks, as well as other ecological impacts, can also be incentivized directly in a number of ways (Pascoe et al. 2010). Similar to the special access programs historically used in New England, access to areas with concentrations of vulnerable and overfished stocks could be made conditional on the rigorous demonstration of gear and/or fishing practices that decrease bycatch of the species of interest. The Separator and Ruhle Trawls developed to mitigate groundfish bycatch, and pingers developed to mitigate marine mammal bycatch, are two examples of gear modifications employed to decrease bycatch in New England. Beyond more selective gear development, these practices could include bycatch hotspot communication programs such as have been developed by UMass Dartmouth in the scallop fishery, for avoidance of yellowtail flounder, and herring/mackerel fisheries, for avoidance of river herring. The adoption of more selective gear/fishing practices could also be incentivized by reserving a portion of quota to be distributed to fishermen within the season who rigorously demonstrate lower bycatch levels through their fishing practices. Bycatch avoidance could also be incentivized by a greater than 1 lb quota charge for every 1 lb of fish caught in areas known to host high quantities of the species of conservation interest.

Auctions

There has been increasing interest across the U.S. in using auctions as a method to distribute access in fisheries management. Although we discuss auctions with respect to allocating quota, it is important to realize that auctions could also be used to distribute the points discussed in Option 2. Auctions can be used to distribute the initial allocation of quota share, or subsequent distribution of quota share either through redistribution of reclaimed inactive, revoked, or forfeited quota, or via a system where quota duration is limited (see the discussion on shorter-term allocation of privileges in this section). Auctions can also be used in combination with other allocation mechanisms. For example, 80% of quota could be allocated based on historical use, with 20% distributed via auctions.

One of the major limits in the use of auctions by the federal government is current MSA language which states that any revenues generated through a royalty program would be "available subject to annual appropriations."[6] Therefore, there is no guarantee that the collected royalties will be returned to that specific fishery, or even to NMFS or NOAA. However, auctions have been used to sell Research Set Aside (RSA) quota for the summer flounder, scup, black sea bass, and bluefish fisheries in the Mid-Atlantic region (Seagraves 2014). In addition, the NEFMC recently conducted an RSA program review (April 2019; https://s3.amazonaws.com/nefmc.org/8a_Final-RSA-Report_DRAFT_REVISED.pdf) which considered an auction mechanism to improve efficiency and performance of the RSA program.

Auctions can be designed to meet a number of management objectives, including providing a more transparent allocation mechanism, providing a mechanism for new entrants to enter the fishery, providing more accurate information to potential buyers regarding the economic value of the quota (which can reduce uncertainty and thereby the time and costs associated with searching for price information), collecting rent in return for the use of a public resource (as is done in the oil and gas industry), and decreasing the windfall for fishermen who receive initial quota. Drawbacks can include the cost of buying quota, which can have a disproportionate impact on small scale fishermen and potentially decreases funds available for technological innovation, and increasing management costs as a result of having to administer the auction. Auctions can be structured and designed in a myriad of ways and tailored to meet the specific management objectives of each fisheries management program. For example, they can be structured to facilitate new entrants[7], provide protections for communities or smaller vessel classes, and also promote economic efficiency. Auctions should be thought of as another tool in the toolbox to help the Councils and NMFS meet their management objectives.

Providing incentives via shorter-term allocations of privileges

Extending quota for shorter-term allocations could provide a mechanism for incentivizing certain fishing behaviors. Similar to the discussion of auctions, shorter-term allocations are discussed with respect to quota, but equally apply to credit-based systems. Most existing quota programs distribute initial allocations based on some form of historical catch. MSA clarifies that the duration of the allocation

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6 According to the Department of Commerce Office of General Council, the only auction authority contained in the Magnusson-Stevens Fishery Conservation and Management Act appears at Section 303a(d) which deals with auctioning off allocations under a limited access privilege program to collect royalties. According to Section 303a(d)(2), "revenues generated through such a royalty program are deposited in the Limited Access System Administration Fund established by section 305(h)(5)(B) and available subject to annual appropriations."

7 Auctions can be developed that restrict who can bid on what as well as providing bidding credits to groups such as small boat operators, community permit bank entities, new entrants, etc. Please note there are other management tools that can also accomplish this and auctions are just one tool in the toolbox.

cannot exceed 10 years, but most programs include automatic renewal of quota shares if they have not been revoked. There are example international programs that contain allocations that have a definitive end date. For example, Chile has a quota program where the quota is allocated for 10 years at a time (Cerda-D'Amico and Urvina-Veliz 2000), with the primary objective being transition towards economic efficiency and redistribution is through an auction. Providing a mechanism for periodic re-allocation of quota also has the potential to facilitate entry in the fishery and generates an opportunity to incentivize conservation behavior. The system could reward fishermen who have met a conservation goal (e.g., use gears that reduce bycatch, have 100% video monitoring, avoid protected resources or weak stocks, etc.) with a higher allocation of quota (or a lower auction cost for quota). For example, upon expiration of quota, any fishermen not meeting specific conservation goals (for example verifiably installing bycatch avoidance technology or video catch monitoring) would receive back 80% of their expired quota shares, and the rest would be equally distributed across the fishermen who met the conservation goals. Conversely, fishermen meeting conservation goals would receive back 100% of their original allocation, plus the redistributed share of non-compliant allocation. In this way, non-compliant fishermen historically dependent on the fishery could transition slowly from the fishery, with their allocation slowly reduced through time by choosing not to meet the conservation goals. Over time, this would result in an incremental movement of quota to fishermen with the more sustainable fishing practices.

Figures

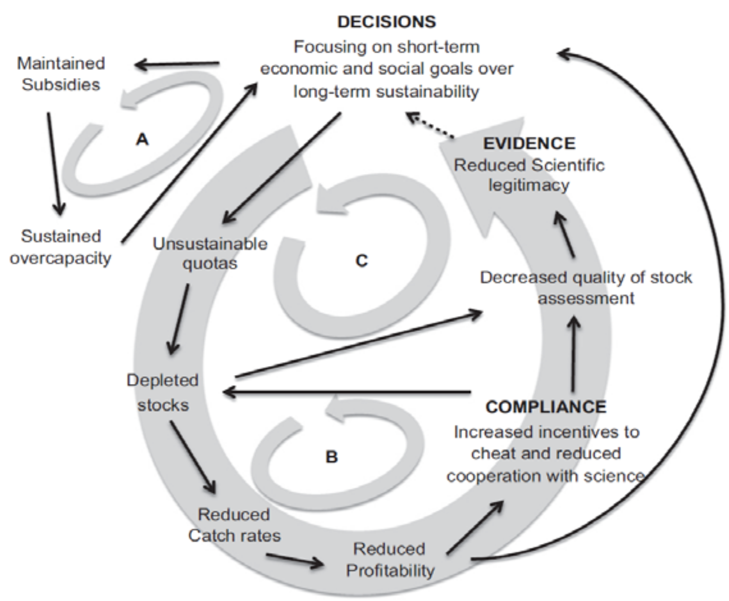

Fig. 1. Social–ecological feedbacks stabilizing an unfavourable European fisheries policy. In addition to the overall Evidence–Decision–Compliance feedback loop, there is also an (A) *decision-overcapacity feedback*, a (B) *stock status-compliance feedback* and a (C) *evidence-decision-stock status feedback*.

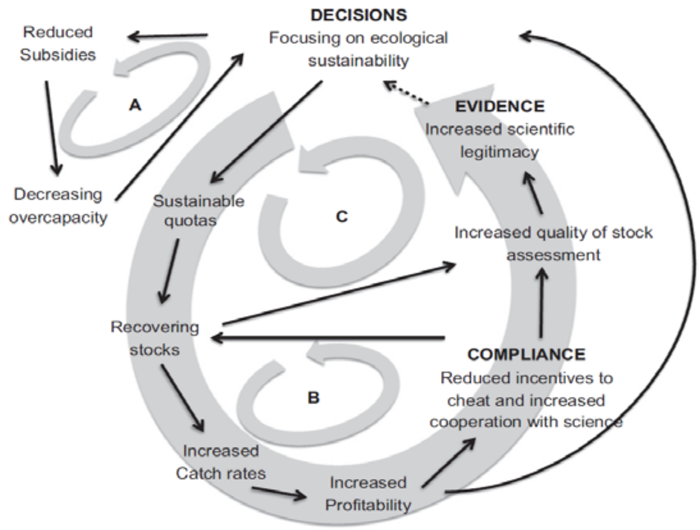

Fig. 2. Social–ecological feedbacks stabilizing a sustainable fisheries policy (see Fig. 1 for definitions of identified feedbacks).

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