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Protection of Irish Marine Ecosystems and Fishing Communities under Uncertainty: A Review of Risk Management, Incentive Creation and a Portfolio Theory Approach

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Abstract

Marine ecosystems and wild fish populations can be severely negatively impacted by man's exploitation of the seas. Additionally, scientist predictions of MSY using single species methodologies can often lead to erroneous policy recommendations due to modelling uncertainty and the difficulty of observing marine species populations. While many marine scientists have responded by seeking more stringent modelling techniques that involve an ecosystem-based and precautionary approach, these calls often ignore the fact that fishing communities themselves can be negatively affected by policies designed to mitigate the impact of man on the marine environment. This term paper reviews the literature relating to these topics in an attempt to understand the various risks that fisheries and fishing communities are subject to, and reviews also the literature focused on dealing with those risks. Literature demonstrating the use of portfolio theory as a risk management tool is concentrated on, under the premise that such a methodology will be applied to Irish circumstances in future work.

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1. Introduction

The continuing overexploitation and depletion of fish stocks in Europe, not least off the Irish coast (Brander 1981; Curtis 2001; Hill et al. 1996), and the high potential for error in predicting MSY and TAC under a single species approach, have lead to proposals for ecosystem-based fisheries management (EBFM) by marine scientists (Botsford et al., 1997; Pew Oceans Commission, 2003; Pikitch et al., 2004). The idea is that previous failures to sufficiently reduce fishing capacity and effort arose out of a lack of understanding of ecosystems and that a better understanding will lead to more sustainable fishing practices. However, according to some, 'there are limitations, both theoretical and practical, to what science can accomplish' (Lauck et al., 1998) and therefore a Precautionary Approach has also been suggested (Garcia, 1994; Lauck et al., 1998; Hillborn et al., 2001; Charles, 2002; Ludwig, 2002; Weeks and Parker, 2002).

EBFM has been defined by the US National Research Council of 1998 as: "an approach that takes major ecosystem components and services - both structural and functional - into account in managing fisheries... It values habitat, embraces a multispecies perspective, and is committed to understanding ecosystem processes... Its goal is to rebuild and sustain populations, species, biological communities and marine ecosystems at high levels of productivity and biological diversity so as not to jeopardize a wide range of goods and services from marine ecosystems while providing food, revenues and recreation for humans".

The precautionary approach on the other hand, as defined by the FAO expert consultation on the Precautionary Approach to Fisheries Management:

a) Involves the application of prudent foresight. Taking account of the uncertainties in fisheries systems and the need to take action with incomplete knowledge, it requires, inter alia:

b) consideration of the needs of future generations and avoidance of changes that are not potentially reversible;

c) prior identification of undesirable outcomes and of measures that will avoid them or correct them promptly;

d) that any necessary corrective measures are initiated without delay, and that they should achieve their purpose promptly, on a timescale not exceeding two or three decades;

e) that where the likely impact of resource use is uncertain, priority should be given to conserving the productive capacity of the resource;

f) that harvesting and processing capacity should be commensurate with estimated sustainable levels of resource, and that increases in capacity should be further contained when resource productivity is highly uncertain;

g) all fishing activities must have prior management authorization and be subject to periodic review;

h) an established legal and institutional framework for fishery management, within which management plans that implement the above points are instituted for each fishery, and appropriate placement of the burden of proof by adhering to the requirements above.

There are a number of key things to be observed in relation to these two approaches. Undoubtedly, both the EBFM and Precautionary Approach are born out of the need to control for risk and uncertainty in the process of modelling marine bioeconomic activity. Additionally however, it is quite evident that both are primarily intended to protect the resource at almost *any* social and economic cost to fishery communities, ignoring fisher responses to such "stimuli". This is a very controversial point in the marine and social science literature (Hillborn, 1985; Salas and Gaertner, 2004; Hanna and Smith 1993; Robinson and Pascoe, 1997; Wilen et al. 2002). Given this circumstance, the specific types of fishery and modelling risks, the means through which the two approaches attempt to deal with them and the controversy associated with their exclusion of socio-economic concerns are discussed in next section. Ultimately it will be argued that such omissions end up handicapping measures to protect the resource instead of strengthening them. If socio-economic and political issues have been the stumbling blocks to the success of previous policy measures, it only calls for their increased consideration in future policy measures, rather than stricter adherence to scientific recommendations with no means of mitigating the corresponding social hardships.

Risk

Risk assessment and risk management have become increasingly prioritised in the fisheries science literature. Clark (2006) counts it surprising that ‘until quite recently uncertainty and risk have been all but neglected in formulating scientific advice for management’ (Clark, 2006). Lane and Stephenson (1998) claim that ‘the absence of this notion of “risk analysis” is a major weakness of current fisheries management systems’ (Lane and Stephenson 1998). From Clark (2006) biological modelling risks that effect scientist predictions have been identified as:

a) Process uncertainty: random temporal variation in recruitment and other population characteristics
b) Observation uncertainty during data collection
c) Estimation uncertainty relating to parameter values and assumptions for estimation procedures
d) Model uncertainty: including functional form and structural uncertainty

Fisheries risks are identified as:

a) Risks of overfishing, resulting in:
    i. Temporary loss of productivity
    ii. Fishery collapse thus long term productivity loss

b) Under fishing, for example specified TAC is much smaller than is necessary, resulting in:

   i. Reduced revenues for a fishing community
   ii. Complete collapse of fishing community if regulation is strict enough, e.g. marine protected reserve in perpetuity or abolishment of fishing for a set period

c) Risk of loss of ecosystem functioning, including degradation or destruction of habitat, change of ecosystem structure and loss of biodiversity

d) Market-price risk including fluctuations in dockside fish prices and changes in the price of production inputs, e.g. fuel.

Clearly, the first set of identified risks arises out of complex marine ecosystem dynamics and a lack of knowledge/data that results in predictive modelling errors. It is from here that proponents of EBFM take their cue and propose views such as the following: 'a holistic approach incorporating inter-specific interactions and physical environmental influences would contribute to greater sustainability by reducing the uncertainty in predictions' (Botsford et al., 1997). Contrary to this viewpoint those advocating the Precautionary Approach oppose the idea that further research into marine ecosystem modelling will reduce scientific uncertainty. They claim, 'the data requirements needed to validate any such model are vastly beyond our current capacity... full understanding and predictability of anything as complex (and, we should add, unobservable) as a marine ecosystem will forever remain a chimera' (Lauck et al, 1998).

Despite this difference the mindset of both camps of fisheries scientists are surprisingly similar. Both attribute previous failures to the uncertainty in observing the marine ecosystem and suggest more intensified resource-protection measures, be they based on precaution, or sensitivity to the marine ecosystem. This view contrasts starkly with the suggestion of Hillborn (1985) that 'the collapse of many fisheries can be best explained as the result of misunderstanding fisher behaviour, rather than a lack of knowledge of fishery resources' (Hillborn 1985). This viewpoint is supported by many other studies in the literature (Salas and Gaertner, 2004; Hanna and Smith 1993; Robinson and Pascoe, 1997; Wilen et al. 2002). All of these viewpoints have their merit. The purpose of this research project is to explore the avenues though which all of these concerns can be considered in unison through one risk management framework. More specifically, it is intended that techniques from financial portfolio will be adapted to achieve this. A portfolio theory approach to fisheries risk management is uniquely desirable due to the fact that it can incorporate:

1. A multi-species framework for fishery management decisions thereby satisfying one of the conditions of the EBFM approach to embrace a multi species perspective. Also, since a major intuition of portfolio theory is that asset diversification reduces the variability of portfolio returns, the methodology can also satisfy the condition of the EBFM approach to promote biodiversity. For fishers, a suite of target species as opposed to species specialisation can result in reduced revenue variability, an economic reward in itself. Of equal importance is that (under the certain institutional circumstances) this diversification holds another economic gain for the fisher; increased future revenue streams derived from forfeiting exploitation of the most valuable stocks in the current period;

2. Numerous requirements of the Precautionary Approach. For example, a portfolio of biomes/regions with different types of "returns". Certain biomes would focus mainly on the return to the fishing community and society through the production and harvest of fish. Other marine protected areas within the portfolio (in which no fishing was permitted) would be designed to manage the risk of fishery collapse, and provide returns to society derived

from biodiversity, consideration of the needs of future generations and priority being assigned to the productive capacity of the resource;

3. Socio-economic considerations. For stringent ecosystem and precautionary protective measures to succeed, the risks to the survival of fishing communities must be incorporated into the framework. Lower measures of TAC and MSY and large marine protected areas are likely to have a direct impact on fishing community revenues. Since the potential gains are the result of immediate losses on the part of the fishing community, and since their compliance with any directive are vital to its success, it is of great importance that they experience some of the future benefits. This is achievable under a portfolio theory approach by allowing fishing communities to develop their own portfolio of target species and treating them as 'risk bearing capital assets that can provide... benefits indefinitely' (Edwards et al., 2004). Legal harvesting rights for fishing communities and protective measures to ensure them are therefore an integral part of the methodology that will be developed.

In the literature, there are numerous examples of portfolio theory approaches to fisheries management issues and controlling for risks in that regard. This literature is reviewed in a further section. Firstly though, a brief discussion of the relevant policy, the CFP, is provided.

Policies and Incentives

In 1977 the EEC member states committed to the development of a common conservation policy to manage a scarce, shared resource. By 1983 the Common Fisheries Policy had been agreed to by all member states, with conservation treated as one of the primary objectives of the regulations (Holden, 1994). Twenty six years on, according to a recent publication by the Baltic Sea 2020 foundation, 'the Common Fisheries Policy has been poor as evidenced by':

1. A much higher rate of overfishing than the worldwide average;

2. Many fish stocks declining to historic low levels, including iconic stocks Baltic Sea cod;

3. Investments (*in some cases subsidized*) in more, larger, and more powerful fishing vessels than are needed to catch the available fish;

4. Widespread violations of fishery management regulations, including illegal catches;

5. Discarding of an unknown amount of fish;

6. Potentially negative impacts on habitat and biodiversity;

7. Deterioration in the quality of fishery dependent data used for scientific advice, often caused by illegal catches and discards;

8. Controversy over many fishery management actions, and a general loss of trust by stake-holders, Member States and the public in the CFP;

9. Poor economic performance by EU fishing fleets.

From the 1960s onwards, pollution, species depletions and coastal impacts called public attention to oceans and to the need for marine conservation (McCormick-Ray, 2004; Daw and Gray, 2004). Despite the increase in awareness of natural resource vulnerability that occurred in the late 20th Century, governmental and intergovernmental attempts to introduce measures to improve sustainability proved to be ineffective (Daw and Gray 2002). According to Daw and Gray (2002), instead of being "based on the best available understanding of the nature of these resources, as elucidated by scientific investigation... the translation of scientific discovery into practical policies is often slow and incomplete, as many other political, social and economic factors come into play" (Daw and Gray, 2004).

The inability of scientists (environmental, political, social or otherwise) to incorporate these "other" factors into policy considerations results in a failure to achieve many of the targets of management initiatives and failed outcomes such as those listed above. As a result of these failures the CFP underwent radical reform in 2002. This time the attempt to achieve sustainable development of fishing activities was *intended* to include environmental, economic and social considerations. However, according to many observers, that intention has not become a reality and the reformed CFP retains criticism for being 'too broad and un-prioritized such that... [it gives] ...little guidance for choosing between management options' (Baltic Sea 2020 Foundation).

Daw and Gray (2002) are largely concerned with the idea that "when scientific advice has been refracted through the political process, it may appear to shed little light on the final decisions' (Symes, 1999). Daw and Gray (2002) identify the stages of this process for the CFP:

1. Fisheries scientists from the International Council for Exploration of the Seas (ICES) from across member states carry out and report on their research;
2. The scientists and the ICES Advisory Committee on Fishery Management (AFCM) meet and agree upon the scientific advice to be submitted to European Commission;
3. A proposal is drawn up on the basis of the evidence/advice submitted;
4. Discussions follow between EU departments including the Scientific, Technical and Economic Committee on Fisheries (STECF) and the European Parliament Fisheries Committee;
5. The Council of Ministers consisting of national ministers from member states then receive any proposals;
6. Final decisions relating to policy and regulation of fisheries occurs at this final level.

Daw and Gray (2002) acknowledge the importance of socio-economic factors for successful outcomes of policy decisions but then focus on the political process as needlessly bureaucratic. This focus omits a consideration of the impact of socioeconomic factors on the political system itself. It is precisely the fact that the needs of fishing communities are ignored by the scientists who submit their recommendations that bureaucracy and political sway have this refracting affect. For example, it is envisaged that without a socio-economic component, such "refraction" would transpire for scientist recommendations based on EBFM or the Precautionary Approach. The author stresses this example because it is a more than ideal one for displaying the consistency with which economic incentives are not just ignored in policy decision making, but even in criticisms of how and why those decisions are made.

The logic is simple. It is 'obvious that economic forces are paramount - marine resources are exploited because of the demand for the product. If the revenue obtained from catching a fish of a certain population exceeds the cost of doing so, there will exist an economic incentive to exploit that population' (Clark, 2006). It is worth noting that this incentive exists *whether scientifically recommended or not*. Looked at from this light, the political distortions too can be seen as a derivative of the economic incentives that exist to *defy* scientific advice. There are examples of situations where 'fishermen have actually voted for a *smaller* TAC than recommended by scientists' (Clark 2006) and in every one of these circumstances there was an economic incentive at work (Grafton et al. 2006). On these occasions, some form of a protected right to harvest future stocks and yield larger future revenues acted as compensation for the short term losses of reducing effort. It is only in procuring harmony between scientific advice and fisher incentives that true fishery sustainability can be achieved. This is no less true for a portfolio theory approach. Making fishermen the future beneficiaries of their currently forfeited revenues is the key to achieving this.

Two caveats for the incentive based approach

i.

It is important to establish that addressing fisher incentives and attempting to formulate policies that relate to them *is not an alternative to controlling for environmental and scientific uncertainty*. It does not involve forfeiting an ecosystem approach or a Precautionary Approach to managing the resource. As per Grafton et al., (2006), 'the ecosystem approach is necessary, especially to account for fishery-ecosystem interactions, but by itself is not sufficient to address ... inappropriate incentives bearing on fisher motivation' (Grafton et al. 2006). Considering the observation of Clark (2006) that most fishery failures are '*fully predictable* on the basis of simple economic principles' (Clark, 2006) it is not surprising that Grafton et al., (2006) hone in on fisher behaviour and incentives as an economic tool through which to attempt sustainable fisheries practice. Specifically, 'a key to creating incentives for more sustainable behaviour is to provide fishers with more secure harvesting or territorial rights to fish' (Grafton et al., 2006). Rights based management ensures that in most cases 'those who have the greatest impact on fisheries have an increased interest in their long run conservation and directly bear the cost of overexploitation' (Grafton et al., 2006). Despite the potential advantages in this regard, it must be remembered that incentives are to be used as a means of protecting the resource, and other measures, such as EBFM and the Precautionary Approach remain important for this purpose.

ii.

It is also worth noting that the incentive based approach *does not require that fishers are given exclusive property rights*. This is important because, as just one example, Clark (1973) shows that it may be economically rational to mine a fishery, amongst other actions that damage the resource. The message then is that care must be taken and each management scenario must be considered carefully. Throughout the literature, there are numerous studies that propose specific rights based management fishery regimes such as Hillborn et al. (2003), Baland and Plateau (1996), Christy (1999), Clark (1973) and Hannesson (2004) to name but a few, but no "general rule" for deciding how to implement the approach is assumed. The core function of harvest or property rights institutions is to achieve sustainability of the resource to benefit society and fishing communities by using incentives as a management tool, not to hand exclusive rights to society's natural resources over to a small percentage of the population.

2. Literature Review: Some applications of Portfolio Theory to Fisheries Management

'Genes, species and ecosystems are often considered to be assets. The need to ensure a sufficient diversity of this asset is being increasingly recognised today. Asset managers in banks and insurance companies face a similar challenge. They are asked to manage the assets of their investors by constructing efficient portfolios. They deliberately make use of a phenomenon observed in the formation of portfolios: returns are additive, while risks diversify. This phenomenon and its implications are at the heart of portfolio theory'

(Figge, 2004)

Baldursson and Magnusson (1997) claim that 'portfolio theory becomes applicable... [for a single species] ...by treating different *age groups* of fish as different assets' (Baldurrsson and Magnusson 1997). Their study appears to be the first example of an explicitly portfolio theory based approach to a fisheries management scenario (Icelandic cod). Their primary focus is a reassessment of the standard results of the Beverton Holt model of fish-stock dynamics given the introduction of risk aversion in fishers' preferences and stochasticity in recruitment. Typically, the Beverton Holt model assumes density dependency, i.e., that stock recruitment is a function of an already existing parent stock (Baldurrson and Magnusson, 1997; Clark 1990). Later research from marine ecology suggests that the power of unpredictable environmental factors in influencing recruitment can potentrially drown out the relevance of stock density for recruitment predictions (Roughgarden, 1998; Roughgarden et al, 1998). Baldurrsson and Magnusson (1997) wanted to introduce stochasticity into the modelling of recruitment in order to capture this newly philosophised prediction uncertainty. Portfolio theory was thus ideally placed because as a framework it allowed them to treat the discrete time recruitment process as a series of independent, identically distributed random variables, as opposed to a function of stock density.

Additionally, using the portfolio theory framework allowed them to capture the risk aversion of fishermen in the model. In a single stroke, recruitment could be assigned an expected value, variance and standard deviation as emerged from a random process, and fishers could behave optimally (given their level of risk aversion) to maximise catch and minimise catch variability. 'A basic result of the standard, deterministic approach is that when the growth rate of the fish falls below the mortality rate, the cohort should be harvested immediately (Baldurrson and Magnusson, 1997). The portfolio approach however showed that instead of jumping from cohort to cohort to maximize profit, a smooth pattern of fisher behaviour emerged, 'where many cohorts are combined in a "portfolio" to obtain a desired combination of expectation and variance of profit' (Baldurrsson and Magnusson 1997). Thus it was shown that less variable revenues acted as a counter-incentive to pure catch-maximization and reduced short sighted, profiteering behaviour; 'a consideration of risk implied a reduction in effort... 20% in terms of the fishing mortality coefficient (Baldurrsson and Magnusson, 1997). Such an application of the portfolio methodology usefully reveals, (i) the importance of correctly deciding the structure of the model being used to describe the biological/environmental factors at play (getting this wrong is one of the primary modelling risks listed earlier by Clark (2006)) and (ii) the importance of considering the behavioural dynamics of fishers in assessing potential policies, and the likely impacts for the fishery (stock-wise and behaviourally) of potential and existent legislation.

Sanchirico et.al (2008) take the portfolio methodology a step further, employing portfolio theory as a potential alternative to the single species approach for determining MSY in a fisheries management regime. Within ecological science the implications of modelling species in isolation rather than as part of an ecosystem are well documented (Pimm, 1991; Begon et al., 1996; Milner-Guilland and Mace, 1998; Flemming et al., 2003). For example, Arnason (1998) posits, 'in virtually all fisheries, single species analysis is liable to lead to serious mistakes in the interpretation of the observed data, not to mention policy recommendations and predictions'. The belief is that the dependence of stock recruitment on wider ecosystem factors has lead to erroneous MSY/TAC recommendations when modelling under the single species perspective. As per comments at the outset of this paper, this controversy has lead to calls from marine scientists for a more ecosystem based form of fisheries management (Botsford et al., 1997; Pew Oceans Commission, 2003; Pikitch et al., 2004), and a Precautionary Approach in determining MSY given the difficulty of understanding and modelling marine ecosystems (Garcia, 1994; Lauck et al., 1998; Hillborn et al., 2001; Charles, 2002; Ludwig, 2002; Weeks and Parker, 2002).

According to Sanchirico et al (2008), 'portfolio theory provides a foundation for considering all of these features... [and] ...is a complement to... innovations in conventional deterministic and stochastic bioeconomic modelling' (Sanchirico et al., 2008). Sanchirico et al (2008) hone in on the fact that 'species interdependencies mean that risks from harvesting each species are correlated –whether positively or negatively related– and because of this correlation, there are potential benefits from considering multiple fish stocks jointly' (Sanchirico et al., 2008). The paper examines changes over time in historical catches in the Northwest Atlantic since 1950. Data used is a panel-type UNFAO data set of ten species for the Northwest Atlantic. Changes in catch levels over time 'reflect both changes in mean returns and variability in returns... [and they compute] co-variances in each year by averaging over the historical record of fisheries data' (Sanchirico et al., 2008). This information along with numerical optimization techniques allows them to construct efficient mean-variance return frontiers in order to compare the actual patterns of exploitation in the Northwest Atlantic to the "efficient sustainability frontiers" as they are termed. The efficient sustainability frontiers are similar to the efficient frontier of Markowitz (1952), but have different constraints (that tie in with ecosystem considerations) to incorporate definitions of sustainability. This study therefore displays well the potential for a portfolio approach to fisheries management to adhere to EBFM and Precautionary Approach criterion; a multi-species framework through the historical inter-species correlation matrix and increased precautionary measures through adaptation of the framework to include sustainability constraints.

Lauck, (1996) and Lauck et al. (1998), are concerned with fishery related risks to marine ecosystem functioning and like Sanchirico et al (2008) they stress the need to take a Precautionary Approach in decisions that affect them. However, these studies focus on the use of large-scale marine protected areas/reserves to *hedge* against 'inevitable management limitations' in the face of 'persistent, irreducible, scientific uncertainty pertaining to marine ecosystems' (Lauck et al, 1998). They attribute the decline and collapse of many fisheries to a failure to recognize the full implications of uncertainty in the design and implementation of fisheries management strategies.

Given this conclusion, they draw upon the example of “bet-hedging” and portfolio diversification as viable methods of controlling for risk and uncertainty and propose marine reserves be that hedge. These studies place much weight on the trophic, environmental and modelling risks identified by Clark (2006) listed earlier in this paper. This example of portfolio diversification is therefore established as an alternative to sustainability criterion and more explicit ecosystem modelling techniques. According to the authors, ‘the uncertainties and biases associated with setting quotas and determining actual fishing mortality imply that the fishery would remain vulnerable’ (Lauck et al, 1998).

In contrast to such studies that propose protective measures to protect the resource alone, Hillborn et al. (2001) place a greater level of emphasis on risks to fishing communities themselves. They suggest that ‘applying the Precautionary Approach to protection of the resources may lead to unnecessary fishery closures causing irreversible damage to the fishing communities’ (Hillborn et al., 2001). Thus in this study, the potential for severely restrictive legislation constitutes a risk in itself. Hillborn et al. (2001) contend that because fisheries scientists are primarily concerned with the resource and not necessarily the individuals who make a living from it, their calculations ignore the impact of stringently protective measures on the fishing community and the precaution required in that regard. On that basis it is deduced that ‘the Precautionary Approach should explicitly include the protection of fishing communities... by explicitly implementing risk management and risk assessment to evaluate and implement management measures that will reduce the risk that fishing communities are exposed to’ (Hillborn et al., 2001). It is also often argued that protective measures designed for the communities themselves are a vital ingredient to protecting the resources they depend on. This is commented upon; ‘if the implementation of the Precautionary Approach continues to be a techno/scientific/bureaucratic-driven process and the well being of fishing communities is not taken into account explicitly, the process will fail’ (Hillborn et al, 2001).

The current “them and us” mentality that exists between fishers and policy makers in Ireland and the general failure of CFP legislative measures (Baltic Sea foundation 2020) would certainly support this assertion. Portfolio management techniques are advocated as a ‘logical choice given that the overall productivity of fishery systems is more stable than the individual species are’ (Hillborn et al, 2001). This draws attention to the negative impact which species specific fishery licensing and limited entry programmes can have for a fishing community. The costs of such licensing can force fishers to ‘become specialized in one or in a small number of fisheries, thereby preventing them from using traditional means of risk management through diversification’ (Hillborn et al, 2001). Legislative constraints on the mobility of fishing capital and labour prevent risk diversifying behaviour and changes in species targeting. This constrains fisher revenues and places extra strain on the already over exploited species in question. Recall Baldursson and Magnusson (1997) and the positive impact of risk diversification between cohorts for Icelandic cod stocks, a 20% decrease in the mortality coefficient. As another example, Sanchirico et al (2008) showed that portfolio diversification in the Chesapeake Bay fishery would yield a higher portfolio return with lower variance by concentrating *‘more harvest on benthic invertebrates and less on predator fish’* (Sanchirico et al 2008). Predator species that are higher up in the food chain tend to be the primary target for overexploitation (Worm et al., 2005). Granting fishing communities more diversified harvest rights could reduce this tendency, as opposed to single species licensing which only exacerbates the situation further. Hillborn et al. (2001) draw attention to the potential of community based management where the community maintain diverse fishing privileges either by tradition or legal right. The community’s ability to diversify their harvest and fish for a mixed portfolio of fish grants them some protection from stock-level or price-level fluctuations in a particular species.

In keeping with the institutional ideas of Hillborn et al. (2001), attention is now turned to the portfolio approach developed by Edwards et al. (2004) who also strongly support the concept of property/harvest rights institutions to make the portfolio approach productive. There remains a fundamental difference between the basic concepts of the two studies however. While, Hillborn et al. (2001) are primarily concerned with asset/harvest diversification (the classic function of portfolio theory) the approach of Edwards et al. (2004) ‘evaluates tradeoffs in fishery benefits that result from ecology (e.g., predation, competition) or unspecialized fishing technologies (e.g. mixed-species catches), and balances the expected aggregate benefits from manipulating stock levels against the risks associated with various natural, market and institutional uncertainties’ (Edwards et al., 2004).

To make such strategies (which could increase the biological yield and revenue of the fishery) worthwhile for fishers, rights based institutions are needed to ‘create long-run time horizons among harvesters, internalize spillovers caused by ecological and technological jointness and reduce uncertainty through research and adaptive management’ (Edwards et al., 2004). The connotations of such an approach are powerful. For example, the ability to manipulate stocks to increase long term revenues creates incentives for development of (and industry investment into) technology that differentiates between target species, reducing “spillovers” between species that may negatively impact on the portfolio. The concept of reducing uncertainty through research and adaptive management indicates the potential for scientific advice to be welcomed by fishers, not as a risk to their revenues, but as the potential for long term pay offs given the stock manipulations that correspond. As an example, Gulland (1982), in a study of North Sea fisheries observes that the fish meal industry expanded such that finfish landings doubled between 1950 and 1974. Despite this, dockside revenues remained static. Gulland (1982) hypothesised that this situation would have been different (yielded higher revenues) by ‘drawing down stocks of piscivores and other species which compete with high priced invertebrate feeders such as haddock and plaice, and by maintaining stocks of herring and mackerel (which feed on fish larvae but are themselves important prey) at low to moderate levels’ (Edwards et al., 2004). Edwards et al. (2004) highlight research in other areas by biologists and economists to support the potential upside of such strategies (Sumalia, 1997; Christensen; 1996; Mitchell, 1982; Hannesson, 1983).

It is important to observe that while such a management approach would create incentives to reduce scientific uncertainty, reducing scientific uncertainty is not the *basis* of this approach per se. Unlike Sanchirico et al., who attempted to use the portfolio approach as a step towards ecosystem-based fisheries management, Edwards et al. (2004) point out that ‘the cost of reducing scientific uncertainty about ecological interactions may limit the portfolio approach to intensive management of relatively few species’ (Edwards et al., 2004). In this respect, the approach can be seen as a way of increasing fisher willingness to direct attention away from the species with the highest market price, fish down stocks that compete with that species and invest in technology (if necessary) that allows them to differentiate in this way. Such a strategy could reduce exploitative pressure on the typically over-exploited stocks and actually result in ecosystem conditions that assisted its multiplication, through the fishing down of its competitor species (for which fishers would receive dockside revenues, albeit less than if harvesting the most valuable species).

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