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Review

Approaches and methods used in analyzing compliance with fishery regulations

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This paper reviews existing literature on analytical framework and methodological approaches to study noncompliance with fishery regulations. The causes of the problem of illegal fishing and noncompliance with fishery regulations are analysed and reasons behind the failure of current management regimes to promote sustainable management and exploitation of fishery are investigated. Several deterrence models have been developed to study this problem in static and dynamic decision frameworks. The shortcomings of static model versus dynamic are specified and the static model found to be limited. Dynamic model on the other hand, consider allocation of resources overtime and hence account for the effect of discount future benefits and the repeated nature of the crime and detection. Extensions of both models are also discussed in details. Results from theoretical models are tested empirically using survey data. Different econometric models have been specified to conduct empirical deterrence analysis on determinants and extent of the decision to violate. Intensity of violation and frequency of violation as measures of violation rate are compared. Non-compliance determinants variables include socio-economic attributes, deterrence, and social and legitimacy factors. Empirical studies estimate both violation rate and extent of violation. Deep understanding of how fishers behave and their reaction to regulations is very crucial to tackle the problem and help policy makers to formulate policies accordingly.

Key words: compliance, dynamics, fishery, fisher's behavior, inconstant probability, management, static.

INTRODUCTION

Future viability and benefits from fisheries have been negatively affected by the practicing of illegal fishing and noncompliance with fishery regulations. This has become a global problem, presenting serious threats to fish stock rebuilding (MEA, 2005; Sumaila et al., 2006). Serious decline in inland water stocks has been reported in developing countries; the number of un-harvested inland fish stocks has been steadily decreasing; from 40% in 1990 to 23% in 2004 (MED, 2005). Despite the existence of fisheries management policies, fisheries in developing countries are encountering a serious threat of over-fishing (Allan et al., 2005). Particularly, African tropical fresh water lakes are believed to be fully exploited and even over-fished in many parts (MEA, 2005). This presents a big threat to the capacity of these fishery ecosystems to continue providing for the livelihood of many communities that are highly dependent on them. Many

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factors are believed to contribute to this problem; among them are difficulties in enforcing regulations and inefficient institutions to handle the problem.

The practice of illegal fishing leads to stock collapse and fishery closure. For instance the use of small mesh sizes removes small fish before they can finish their life span and hence limits the opportunity for reproduction (Clark, 1990). This calls for urgent action to reduce noncompliance with fishery regulations. Noncompliance with regulations also contributes to lack of accurate statistics about the status and potential role of fishery resources (World Fish Centre, 2003). It is believed that the actual catch from inland water is 2 to 3 times larger than what is reported in official statistics due to illegal fishing and noncompliance with regulation (FA0, 2003; Welcome et al., 2001). Failure to account for illegal fishing therefore gives incorrect estimates of the resource and misleads fishery policy formulation and management decisions based on this information (Atta-mills et al., 2004; Hatcher and Pascoe, 2006). Achieving compliance with fishery regulations is accordingly becoming an issue of serious concern to managers and policy makers worldwide.

Despite its major role in the failure of fishery management, illegal fishing has received little attention in the past (Sutinen and Hennessey, 1986; Anderson, 1989), particularly in the field of fishery economics and policy making studies (Charles et al., 1999). However, illegal fishing behaviour has gained considerable attention recently in both fields because of the increasing recognition of the damage and loss associated with this problem (Sumaila et al., 2006). Many studies have argued that fishery regulation failure is attributed to costly and weak enforcement and monitoring of compliance with laws and regulations, in addition to tolerance to corruption and cheating (Charles et al., 1999; MEA, 2005). The lack of effective enforcement and monitoring mechanisms also encourages corruption and creates a good environment for illegal fishing (Eggert and Lokina, 2010). Thus, fisheries' sustainability has been far more difficult to achieve although many efforts have been made to rebuild fish stocks. For instance, official limits on the size of fishing nets and harvests, as well as other management measures, have been used to help stock recovery and reduce over-fishing and consequently illegal fishing (FAO, 2003).

Many theoretical and empirical studies have been conducted to analyse reasons for noncompliance with fishery regulations by adapting different static, dynamic and policy oriented approaches. Different types of noncompliance with fishery regulations are cited in the literature such as: fishing in closed areas, catching with non-prescribed mesh size or fishing in a prohibited zone or any behaviour against the law (Furlong, 1991; Charles et al., 1999; Hatcher et al., 2000; Srinivasa, 2005; Sumaila et al., 2006; Akpalu, 2008a). Therefore good understanding of the motives for illegal fishing is necessary to help policy makers and managers design appropriate intervention measures that would improve effectiveness and efficiency of enforcement of regulations and ensures sustainability of the resource use. This can be achieved by reviewing the existing analytical frameworks and methodological approaches to study noncompliance with regulations worldwide. Next is a review of the approaches for analysis of determinants of noncompliance with fishery regulations under static and dynamic formulations, followed by empirical approaches to analyse factors influencing violation rate.

APPROACHES AND METHODS USED IN COMPLIANCE ANALYSIS

Noncompliance with fishery regulations has important implications for the welfare of fishing communities. The framework schema of Figure 1 is adapted from Sutinen and Kuperan (1999) and extended to include determinants of noncompliance with fishery regulations in dynamic approaches. The various components of the compliance modelling framework presented in Figure 1 are subsequently reviewed.

Static approach to study noncompliance with fishery regulations

Becker (1968) was the first who studded the behaviour of law breakers. He developed the first theoretical deterrence model to analyse the choice between legal and illegal options for a criminal to maximise his/her utility from illegal activities. Static deterrence models assume that a violator faces a single time period decision problem of maximising expected utility from illegal fishing, that is, the choice of either to follow fishery regulations or not. The model's implicit assumption is that a fisher has a fixed amount of time to be allocated to both legal and illegal fishing. The gain from violation is not guaranteed because of the probability of enforcement leading to detection and consequent punishment. This motivated the use of expected utility in deterrence models.

In the static context, the main determinants of the choice of an illegal option are the profit that an offender gains from the illegal practice and the low probability of detection combined with a small fine (punishment). Many studies have followed Becker's model of the economics of crime and punishment under static formulations (Furlong, 1991; Kuperan and Sutinen, 1998; Charles et al., 1999; Sutinen and Kuperan, 1999; Hatcher and Gordon, 2005; Sumaila et al., 2006).

The high profit that fishers gain by violating national laws is the main incentive for noncompliance (Charles et al., 1999; Hatcher and Gordon, 2005; Sumaila et al., 2006; King and Sutinen, 2010). Sumaila et al. (2006) estimated gains from illegal fishing to amount to about 24

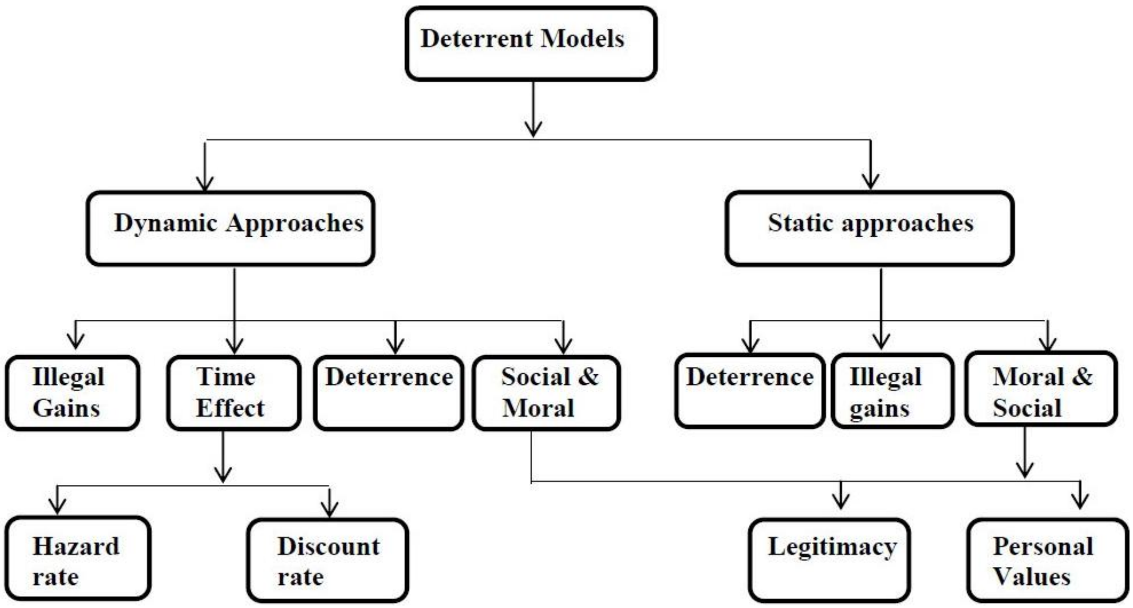

Figure 1. Approaches and factors considered in analyses of determinants of noncompliance with fishery regulations. Source: Modified/extended from Sutinen and Kuperan (1999).

times the fine paid as a punishment. King and Sutinen (2010) estimated it to be 5 times the penalty paid. The recommendation from the pure deterrence model is that detection should be made eminent and penalties should be high to offset gains from violation. On the other hand, Furlong (1991) conducted a self-reported survey among Canadian fishers and found that fishers are more sensitive to increases in likelihood of detection than increases in penalties.

Static model extensions and limitations

Some studies have argued that the policies suggested by the purely traditional deterrence model cannot be applied to real life and also do not give a complete explanation of compliant behaviour. One major extension of the static model is the attempt by Charles et al. (1999) and subsequently Sumaila et al. (2006) to consider effects of avoidance activities (any mechanism fisher use to avoid detection. for instance in Sudan fisher tie the illegal net to a big stone and let it think deep when regulator office shows, and try to recover it later, when feeling secure). Charles et al. (1999) applied a micro-economic static model to determine the level of enforcement a policy maker should allocate in presence of evasion activities for optimal management of a fishery. The study showed that fishers react to enforcement by focusing more on avoidance behaviour than reducing violation rate. This means that improvement of law enforcement in fisheries needs to be grounded in good understanding of avoidance behaviour.

Kuperan and Sutinen (1998) pointed out that profit from and cost of illegal behaviour, are not enough to describe fishers' decisions. Based on this last argument, some studies have extended the traditional deterrence model to account for moral, social and legitimate dimensions, known as normative factors that are believed to be important in determining violation among fishers (Kuperan, Sutinen, 1998; Hatcher et al., 2000; Akpalu, 2008a,b; Eggert and Lokina, 2010; Abusin and Hassan, 2014). These factors measure a fisher's behaviour and beliefs towards his peer violators and how that influences his values. It also measures a fisher's perception of the violation itself and his perception of regulations as effective or fair.

The influences of social and moral factors have been accounted for in theoretical and empirical applications to examine their impact on compliance. Results of empirical investigations revealed that such factors can have either positive or negative influences. Positive influence implies supporting or encouraging compliance and considering violation of regulations to be bad behaviour. On the other hand, negative influence result from the perception that violation is not a wrong attitude making noncompliance dominant and a normal part of their regular job. However, the normative effect was found to be smaller in comparison to the deterrence effect in a study by Hatcher and Gordon (2005).

One of the shortcomings of the static model is the assumption that two different agents have an equal set of constraints and the only factor that differentiates them is their affinity for taking risks. This distinction was argued to be immeasurable by Davis (1988), which makes the static model limited. The static model also does not account for the effect of discounting future benefits, that is, discount rates (Davis, 1988), which proved to be of significance especially among poor fishers (Akpalu, 2008a/2009). Static models by nature cannot measure the optimal rate of violation over time.

Dynamic compliance modelling approaches

Dynamic models have been developed to consider allocation of resources over time (that is, to study inter-temporal allocation decisions). In dynamic formulations, the fisher will be optimising his gains over time until he gets caught, because the crime is committed repeatedly. The two periods dynamic deterrence model (DDM) as developed by Davis (1988), postulates that violators seek to maximise expected discounted profit over both periods. In the first period, offenders gain from illegal activities until the time they get caught and pay a fine. Violators will then comply and engage only in legal activities thereafter, concluding the model' second period.

Justifications for using a dynamic model for illegal fishing analysis are motivated by many legitimate considerations, most important of which are the repeated nature of the crime (that is, violation occurs repeatedly), the change in the danger of getting caught over time (detection time evolves), and differences in fishers' time preference towards the future (discount rates). These factors imply a temporal objective of not analysing single period gains but rather maximising the sum of the stream of net benefits over time (at least over two periods). It also motivates inclusion of evasion efforts with the aim of prolonging the time before getting caught.

The difference in skippers' time preference is also a very important factor in deterrence analysis since it gives information about their patience (choice between consumption now or in the future). A study by Akpalu (2008a) found impatient (high discount rate) fishers have higher violation rates. It also provides information on skippers' poverty levels, given the fact that that poorer fishers are found to have higher discount rates.

Conclusions from the current dynamic model with constant probability of detection reveal that noncompliance is more likely to be deterred by increasing the probability of being caught than by raising the fine (Davis, 1988; Akpalu, 2008a; Leung 1991). The DDM adds the effect of the discount rate and modifies probability of detection from being subjective in the static model to a conditional probability that explains the fact that the profit from violation is conditional on the violator's survival.

Violation rates in DDM have been mainly specified only as "intensity of violation" (Akpalu, 2008a) whereas "frequency of violation" has been used only in static deterrence models (Furlong, 1991; Sutinen and Kuperan, 1999; Eggert and Lokina, 2010).

Dynamic compliance modelling extensions

As explained by Abusin et al. (2012). The DDM has been extended in three ways as follows:

Introduction of time as a random variable into the model to split the two periods

Although the DDM calculates profits from violation into two periods, namely, before and after getting caught, all previous literature using this model formulates the choice problem to be optimised over finite time horizon. The transition between the two periods is therefore not clear. Therefore the time of detection is introduced as a random variable that defines the end of the first period and the start of the second period, which then extends to infinity in period two. Splitting the two periods would then result in an easier distinction between the violation and compliance periods within the time horizon.

Frequency instead of intensity as measure of violation rate

Implementing frequency rather than intensity in the dynamic deterrence model due to four factors: First, intensity of violation may fit developed countries but is highly unlikely to work well in developing countries where property rights are less well defined and it is relatively easier for fishers to escape being caught. Second, by not employing frequency as a measure of violation rate, one misses the opportunity of capturing the direct link between violation rates and opportune time periods for illegal fishing (seasonality). This is due to the fact that, during productive months the quantities of small fish are high, which encourages illegal fishing compared to months of no breeding. Thirdly, the use of frequency also helps to classify fishers into categories of violators, a typology that will help policy makers and managers design policy measures and instruments suited for each group (Sutinen and Kuperan, 1999) for more details). Finally illegal catches are not sold on formal fishing markets, but are rather concealed and sold out of monitors' notice, outside formal channels.

Probability of detection depends on time

Standard DDM formulations have been limited by the case of probability of detection that does not depend on time assumptions (Akpalu, 2008a; Davis, 1988, Lueng, 1991). The model extended to allow for non-constancy (depend on time) of probability of detection by employing the Cox proportional hazard function, which defines probability of detection to be a function of the multiple of two terms, a constant individual characteristics function and a time-variant hazard function.

Empirical studies based on static and dynamic approaches

To design more effective deterrence mechanisms, more research is needed to gain better understanding of fishers' noncompliant behaviour. Illegal fishing, however, is difficult to observe, and information about it cannot be obtained from government and fisheries departments' statistics but is mostly based on surveys and interviews King and Sutinen (2010). Generally, there is little published research on empirical regulatory compliance. Some empirical studies of noncompliance with fishery regulations have been conducted in many parts of the world, generating results that differ across countries.

Measuring violation rate and extent of violation

Some studies analysed the extent of violation by looking at how frequently fishers violate (Furlong, 1991; Sutinen and Kuperan, 1999; Eggert and Lokina, 2010; King and Sutinen, 2010; Abusin and Hassan, 2014) and hence provide information on violators' degrees of violation. Studies that classified violators according to their violation rate believe that classification will help managers understand each group and hence formulate policy accordingly. Frequency of violation (as measure of violation rate) has been measured in different ways in studies conducted in different countries. Both studies of fishers in Lake Victoria (Tanzania) and Jebel Aulia reservoir (Sudan) measured violation of minimum mesh size regulations by the number of months when such illegal fishing was practiced within the year (Eggert, 2010; Abusin, 2014). In these studies, the surveyed fishers were asked about the type of net they own/use. Those who indicated that they own only legal net sizes were classified as non-violators and those who only owned illegal nets as chronic violators. Occasional violators are those fishers who owned both legal and illegal nets. Violation rates were measured by asking fishers about how frequently they have used an illegal size net in the past year in number of months (where zero stand for non-violator and 12 for chronic violator).

Furlong (1991) used proportion of violation (proportion of regulatory regimes violated) in a typical fishing trip in a specific season as a measure of frequency of violation. Hatcher and Gordon (2005) measured violation rate as the percentage of landings over quota in the previous year, whereas Kuperan and Sutinen (1998) measured violation rate by the number of days a fisher has fished in a prohibited zone.

In analysing factors affecting compliance with output restrictions (quotas) among fishers in the United Kingdom, Hatcher et al. (2000) measured violation rate by a fisher's decision to violate or comply. On the other hand, in a dynamic formulation Akpalu (2008a) measured the rate of violation of fishers in Ghana by looking at the intensity of violation, calculated as the value of juvenile fish in an illegal catch per day averaged over the past week's catch.

Hatcher et al. (2000), Kuperan and Sutinen (1998) and Akpalu (2008a) all investigated fishers' decision on whether to violate or comply using binary Probit models. Kuperan and Sutinen (1998); Akpalu (2008a) subsequently used the Tobit model. Their logic is to use a simultaneous probit-tobit method. The probit hypothesized, a "yes" violation occurs when the unobserved latent variable exceeds a threshold level of zero, and a "no" violation occurs otherwise. Then, violation group are explained by the Tobit model; violations are observed when an unobserved "propensity to violate, exceeds 0. When the propensity to violate is positive, actual violations equal the propensity to violate; when the propensity to violate is negative, a zero violation is observed. As some fishers do not violate for reasons other than their moral standing, like high cost of illegal nets.

The number of violators also differs across countries. For example, Eggert and Lokina (2010) found that about half of the surveyed fishers in Tanzania were violators. On the other hand, Furlong (1991) surveys reported about two thirds of fishers violate while Kuperan and Sutinen (1998) reported 75% violation rates among fishers in Malaysia. Generally, non-violators are found to be significant in numbers in many countries which support the positive influence of normative factors (Furlong, 1991; Kuperan and Sutinen, 1998; Sutinen and Kuperan, 1999; Eggert and Lokina, 2010; King and Sutinen, 2010).

Econometrics specification of violation to fishery regulations

Different econometric models have been employed to suit the different ways in which violation rates are measured. Eggert and Lokina (2010); Hatcher and Gordon (2005) and Abusin and Hassan (2014) used ordered Probit models to analyse determinants of violation with fishery regulation because of the ordered nature of the latent dependent variable. In these studies, the ordered likelihood function was used to predict changes in the probability of violation in response to changes in considered determining factors. Eggert and Lokina (2010), further measured the extent of violation within one fishers' typology (occasional violators) by truncating the data to exclude both no-violators and chronic violators. However, truncating creates data problems since it limits information and changes the sample. Abusin and Hassan (2014) measured extent of violation within violators only (occasional and chronic violators) by employing zero-truncated negative binomial model (ZTNB).

Furlong (1991), when conducted a survey of Canadian

Table 1. Different estimations of POD.

Estimation of POD	Econometric estimation	Relevant studies
exogenously determined	Y= X β+μ* POD is not included in X, it is estimated separately. But variables that determine POD (enforcement and avoidance activity) are included in X	Akpalu, 2008
Joint estimation	X include a variable say z that estimates POD jointly Z= probability of detection, the probability of an arrest given detection, the probability of being taken to court given arrest, and the probability of being found guilty given that the fisher is taken to court	Hatcher and Gordon (2005), Furlong (1991); Kuperan and Sutinen (1998); Hatcher et al. (2000)
As one variable	X includes a variable measuring POD.	Abusin and Hassan, (2014) Sutenin and Kuperan 1999

*Y is independent variable measuring violation, *X is a vector includes all determinants of violation, *μ is the error term, POD: probability of detection.

fishers, found some personal characteristics such as age, income from fishing and other employment are important in compliance analysis. This is confirmed by Sutinen and Gauvin (1989) who found, in their estimation of compliance in the lobster fishery of Massachusetts, that the effect of all three (that is, age, experience and fishing as source of income) on noncompliance to be statistically significant.

There has been a lot of debate in literature about the probability of detection and the way it enters the model and how to measure it. Probabilities of detection are either estimated separately or jointly in an econometric model as explained by Kuperan and Sutinen (1998). They considered probability of detection to be a salient issue of compliance and hence better understanding of how this variable behaves is very important. Probability of detection itself is the joint estimation of probabilities, which include probability of detection, the probability of an arrest given detection, the probability of being taken to court given arrest, and the probability of being found guilty given that the fisher is taken to court (Furlong, 1991; Kuperan and Sutinen, 1998; Sutinen and Kuperan, 1999; Hatcher et al., 2000; Akpalu, 2008; Eggert and Lokina, 2010). This implies that probability of detection by itself is a function of a number of factors. Kuperan and Sutinen (1998) suggested measuring the overall probability of detection variable in three different ways. They firstly proposed an exogenously determined probability of detection, which makes the overall probability of detection not included in the main violation model directly. Instead, exogenous determinants such as enforcement and avoidance activity enter the deterrence model.

The second way is to jointly estimate probability of detection as part of the violation model. For example, the overall probability of detection is treated as an explanatory variable and used in the main deterrence function. In a study by Furlong (1991), the probability of detection was jointly determined in the model and divided into four stages, probability of detection, prosecution, conviction and punishment in the function. The mentioned study encountered problems of both co-linearity and simultaneity due to the joint estimation of the overall probability of detection and violation function.

The third method entails an estimation of the probability of detection by one variable measuring the number of times the violator has been seen by the police landing an illegal catch or using unauthorised gear or by the perceptions of fishers about the chances of detection as increasing or decreasing. In a study by Hatcher and Gordon (2005), the probability of detection is measured by including the subjective probabilities as a regressor in the violation function. Table 1 explains the three possibilities of estimation by simple econometrics equation.

Almost all these studies (except Hatcher and Gordon, 2005) faced the problem of endogenity due to reasons explained in the preceding paragraphs (Sutinen and Gauvin, 1989; Furlong, 1991; Kuperan and Sutinen, 1998; Hatcher et al., 2000; Akpalu, 2008a; Eggert and Lokina, 2010). Hatcher and Gordon (2005) argued that the reason for not having endogenity is due to the fact that the violation rate and probabilities of detections were not estimated in the same time period (fishers were asked about their previous year's violations). This means correlation between violation and probability of detection is not contemporaneous, which made it still consistent based on the assumption that the perceived risk has not changed significantly within the time under consideration. Hence, the simultaneity problem falls away.

Kuperan and Sutinen (1998) argued that there is an inconsistency in the performance of variables measuring the probability of detection. This inconsistency stems from the fact that the probabilities are subjective and are difficult to analyse because of the lack of knowledge about the factors affecting their generation. Furthermore, the respondents may not understand the concept of probabilities.

Another problem related to compliance analysis is the strong correlation between variables measuring normative factors. The close link and interdependency between social, moral and legitimate factors usually create this type of problem (Hatcher et al., 2000; Akpalu, 2008a, b; Hatcher and Gordon, 2005; Abusin and Hassan, 2014).

Determinants non-compliance with fishery regulations

Some factors in the empirical model cannot be measured directly and hence proxies are used. For instance, probability of detection is measured by asking respondents about their perception of probability of detection, ranking on a five-point scale ranging from very high to very low (Hatcher et al., 2000). Akpalu (2008a) for example, measured the discount rate using experimental choice design. The skippers were asked to choose between two hypothetical fishery projects. Project A that supposed to increase skipper's income once by an amount at the end of the month in which the data were collected, and Project B which increased it once by twice the amount in six months' time. After the choice was made, the respondent was asked to indicate the value for Project B that would make him indifferent between the two projects. Depending on the fisher's choice, the discount rate was calculated as the amount quoted by the skipper over the amount that the project offered.

Enforcement is measured by asking fishers whether they perceive the current enforcement to be adequate and fair (Sutinen and Kuperan, 1999). The moral variables refer to the fisher's beliefs about violation given the fact that some people are impressionable and act according to others' standards (Tyran and Feld, 2002). Moral variables are also measured by the fisher's moral standing in the community, that is, when fishers are keen about their moral standing in the fishing community and how it might psychologically impact them (Sumaila et al., 2006). Moral aspects such as acceptance of bribes by police when violators are arrested have been found to be very significant in Tanzanian fisheries, where corruption and poverty make it difficult for fishers to comply with regulations (Eggert and Lokina, 2010).

The different measurement of the social and moral factors as explained above makes the effect of normative factors differ or may have both negative and positive effects on compliance with fishery regulations. The measure of the normative factors that one should choose in the model depends on the current fisheries environment in terms of the social relations within the fishing community under study and how fishers value violation and the way regulations are enforced, considering their fairness and effectiveness (Abusin and Hassan, 2014).

Empirical results from compliance studies are different. Some papers found that to deter violation, deterrent variables are the most important factors (Hatcher and Gordon, 2005) while others found both deterrence and non-monetary variables such as social and moral standards to be equally important (Kuperan and Sutinen, 1998; Hatcher et al., 2000; Akpalu, 2008; Eggert and Lokina, 2010; Abusin and Hassan, 2014). For instance, Eggert and Lokina (2010) tested for exclusion of either the deterrence or normative factors from the model and the results showed that both deterrence and normative factors are very important in explaining violation behaviour. It may also happen that the regulation officer could be socially excluded from the community in his or her efforts to enforce the regulations. This creates an incentive for a regulator to accept bribes in order to continue keeping social ties with his community and avoid shame-based sanction.

Empirical studies generally suffer from data accuracy and difficulties in obtaining quality and reliable information. This may refer to misreporting, not understanding concepts and giving misleading answers since reporting own violation is not an easy task. The concepts of probabilities and perceptions are new to fishers, who are most likely to have only primary education. In addition, some variables in compliance analysis cannot be measured directly; hence proxies are used, which may also have some effect on model parameters' estimates.

Management regimes associated with compliance with fishery regulation

There is a strong view in the empirical literature that for compliance to be applied in a proper way, a good management system should be designed and put into effect since the management regime has a direct influence on compliance (Hardin, 1968). Quite divergent view on which management system is most effective for better compliance with regulations exists in literature. For instance, many authors agree that the most suitable management system to ensure compliance is a properly implemented co-management system (Ostrom, 1990; Jentoft, 2000; Eggert and Ellegård, 2003; Hanna, 2003; Nilsen, 2003, Nielsen and Mathiesen, 2003). Jentoft (2000) attributed perfect compliance under this regime to the improvement of the legitimacy of fisheries management system such as sharing decisions, creating a feeling of fairness and justice and greater understanding of regulations. He further indicated, though, that if co-management is not handled carefully it may lead to loss of legitimacy. Nilsen (2003) ascribed the success of compliance to the fact that managers and decision makers lack knowledge about the factors that affect compliance and legitimacy within the fishers' communities. Legitimacy is defined as the perception of the fishers about regulations. He concluded that if there are large numbers of fishers involved in regulation formulation, legitimacy is more easily achieved. A survey of Swedish commercial fishers on regulation compliance (Eggert and Ellegård, 2003) found that the majority of Swedish fishers are in favour of co-management on a regional basis.

Hatcher et al. (2000), on the other hand, argued that co-management as a fishery management system is unlikely to result in high levels of compliance as long as output controls are concerned. They pointed out that it is not co-management *per se* but the flexibility in the management system that brings about efficient fishery management in many regulatory regimes. The management approaches that are currently applied in most developing countries are based on centralised government intervention and have proven inadequate to deal with the issue of compliance with fisheries regulations (Sterner, 2000).

CONCLUSION

Fisheries are experiencing serious over-harvesting stress and often consequent collapse of fish resource stocks due to many market and policy failure situations such as poor management and open access conditions. The stress is even worsened by the practice of illegal fishing and noncompliance with regulations, which has serious negative consequences on the resource. Accordingly, policy makers need to evaluate the extent of violation, understand and give more attention to fishers'behaviour and reasons for not complying with regulations in order to achieve an adequate level of compliance and save this important renewable source from collapse.

This paper review analytical framework and methodological approaches used in the literature. The static deterrence model assumes the fisher faces one-period binary decision of either to obey or violate specific regulations. This found to be limited since it ignores the dynamic nature of the detection time, the repeated nature of the crime and discounting the future benefits. It also ignores the fact that violators might get away from being detected and therefore wants to know how much money will accumulates through time from violation. This model extends to incorporate normative aspects to give a complete picture for compliance analysis.

On the other hand, the two periods dynamic deterrence model assumes that violators enjoy incremental profit in the first period from fishing illegally, get caught at random time, punished and forced to behave legally thereafter. The DDM modified to include frequency measures of violation and therefore inconstant probability of detection. Although the two periods DDM found to be the most advanced model, it suffers the limitation of not to account for recidivism which found to be very common especially among chronic violators.

Future research should not limit the applications of the modified DDM model to the fishery case but can be generalised to management and regulation of other natural resources such exploitation of common property forest, water and grazing lands and hunting of wildlife. Future research can also empirically measure inconstant probability of detection by regression analysis to test hypotheses on influences of identified determinants of probability of detection as demonstrated in medical and criminology fields applications of the Weibull proportional hazard regression model.

Empirically, determinants of noncompliance are found to be, mere deterrence factors and normative factors. Reviewing of such studies confirm the importance of both deterrence and normative factors to be accounted for when analysing compliance with fishery regulations. Introduction of such factors, advocates for co-management regime mechanism to manage the fishery.

Government intervention is crucial and important policy reforms to control the fishery from collapse. Some polices include investment in better education of fishermen, provision of alternative income and employment opportunities other than fishing especially during reproductive season, improvement of the credit market for ownership of legal net will be necessary for enhancing compliance with mesh size regulation. It is also necessary to promote community level organization and awareness campaigns among fishers about the dangers for future fish stocks of eroding small fish quantities through the use of illegal nets.

Conflict of Interest

The authors have not declared any conflict of interest.

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