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Marine Policy 30 (2006) 696–703
MARINE POLICY
www.elsevier.com/locate/marpol

Global scope and economics of illegal fishing

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Received 2 August 2005; accepted 3 November 2005

Abstract

We present a conceptual model for the analysis of the costs and benefit aspects of the risk inherent in illegal, unreported and unregulated (IUU) activity. We then develop and present a map of IUU incidences as reported in the Fisheries Centre's *Sea Around Us project* IUU global database. This map shows that IUU activities are quite widespread geographically. We next present an analysis of the cost and benefit aspects of risks of IUU fishing. A key result of the study is that for the cases analyzed as a group; the expected benefits from IUU fishing far exceed the expected cost of being apprehended. For an assumed 1 in 5 chance of being apprehended, our calculations show that reported fines for the vessels apprehended will have to be increased by 24 times for the expected cost to be at least as much as the expected benefits.

Keywords: Illegal; Unregulated; Unreported fishing; Cost benefit analysis; Risk of being apprehended

1. Introduction

Illegal fishing is conducted by vessels of countries that are party to a fisheries organization but which operate in violation of its rules, or operate in a country's waters without permission, or on the high seas without showing a flag or other markings [1]. Unreported catches are not reported to the relevant authorities by the fishing vessels or flag state, whether they are parties or not of the relevant fisheries organization. This category includes misreported and underreported catches [1]. Unregulated fishing is normally conducted by vessels flying the flag of countries that are not parties of or participants in relevant fisheries organizations and therefore considers themselves not bound by their rules [1].

Illegal, unregulated, unreported (IUU) fishing occurs not only in the high seas, but also within exclusive economic zones (EEZ) that are not 'properly regulated'. IUU fishing leads to the non-achievement of management goals and sustainability of fisheries [2,3]. When stock assessments are performed on fisheries, reported catch and effort data are used. However, the underreporting of illegal catches results in the absence of a significant part of the annual catch that is not included in the assessment and results in distorted estimates of sustainable catches [4,5]. The depletion of many stocks, for example, of Patagonian toothfish (*Dissostichus eleginoides*) has occurred partly because of the inaccuracy of the catch data. Significant decreases in some fish stocks have become an increasing concern especially because further restrictions on legal fishing can also exacerbate illegal fishing.

The issue of IUU fishing has therefore been receiving increasing attention among scholars, fisheries managers, governmental, intergovernmental and non-governmental organizations and the fishing industry itself (e.g. CALTO). In response, the FAO has begun the implementation of an International Plan of Action (IPOA) where all states and regional fisheries organizations are introducing effective and transparent actions to prevent, deter and eliminate IUU fishing and related activities [6]. A good understanding of the economics of IUU fishing is important in order to design appropriate measures. What are the cost and benefit aspects of the risks inherent in IUU activity? This paper explores this question. It discusses the possible drivers of risk and the costs associated with fraud,

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doi:10.1016/j.marpol.2005.11.001

avoidance and apprehension in relation to IUU fishing activities. A model is presented to help establish how IUU fishing vessel owners take such costs and benefits (monetary and social) into account when deciding on whether to engage in IUU fishing or not.

The rest of this paper is organized as follows. Section 2 conceptualizes a model for fishers' decisions on IUU fishing. The literature is briefly reviewed followed by a presentation of the key drivers of IUU fishing from the point of view of the violator. The formal model is detailed in Appendix 1. This is followed in Section 3 with the presentation of a global picture of IUU incidence. We present the cost benefit analysis in Section 4, and conclude the paper in Section 5.

2. Conceptualizing a model for fishers' decisions on IUU fishing

Since the first formal economic model developed by Becker [7] on the subject of criminal activity, several reasons have been advanced in the economic literature explaining why people engage in such an activity. Becker [7] and the papers immediately following him argued that criminals behave essentially like other individuals in that they attempt to maximize utility subject to a budget constraint. The economic argument was very strong in this explanation of illegal activity, embodied in what has come to be known as deterrence models [8,9]. These models argue that an individual commits a crime if the expected benefits or utility from doing so exceeds the benefits from engaging in legal activity. The models focus on the probability and severity of sanctions as the key determinants of compliance. Additional motivations have come to be recognized in the recent literature, namely, that moral and social considerations play a crucial role in determining whether an individual engages in illegal activity or not [10,11]. With regards to IUU fishing there is evidence to support the hypothesis that moral and social considerations, as well as economics play a role in the degree of IUU fishing that an individual decides to engage in [9,12].

Following Becker [7], Kuperan and Sutinen [9], Sutinen and Kuperan [10], and Charles et al. [8], we assume more explicitly that the following direct drivers and motivators play a role in fishers' decision-making on whether to IUU or not to IUU:

(1) benefits that can be realized by engaging in the illegal activity;
(2) the probability that the illegal activity is detected or the detection likelihood driver. This depends mainly on the level of enforcement or the set of regulations in place;
(3) the penalty the fisher faces if caught;
(4) the cost to the fisher in engaging in avoidance activities. This depends on the set of regulations in place and the size of the budget allocated by the fisher to this activity;
(5) the degree of the fishers' moral and social standing in society and how it is likely to be affected by engaging in IUU fishing.[1]

2.1. Benefits from IUU fishing as a driver

For many fishers, the potential to benefit from IUU fishing motivates them to engage in the illegal activity. To some extent the higher the economic return in a 'legal' fishery the lower is the tendency to engage in IUU fishing. In other words, if a fisher is doing well financially, i.e., making a sizeable profit from fishing 'legally' then the probability of cheating is low, alternatively if the fisher is losing money, and there is the potential to derive benefits from 'illegal' fishing then the probability of cheating increases. There is also the factor of greed, i.e., the fisher may be making a profit but still engages in IUU fishing because of the desire to increase profits. The following factors are important in determining the potential benefit to the fisher if they cheat:

- catches—the more catch that can be realized by engaging in IUU fishing the higher the probability that a fisher will engage in IUU fishing, *ceteris paribus*;
- catch per unit effort or the time it takes to catch the fish is also a consideration since the more time spent searching for fish to and from the fishing grounds, the more the cost and the probability of getting caught increases;
- price—this is related to catch and if prices are too low then in most cases there will not be a financial incentive to cheat. This logic breaks down when food security is a driving factor. However, for the purposes of this study food security is not the focus;
- cost of fishing, which includes consideration of the cost of labor, capital, fuel, license and royalty payments, etc.

2.2. The expected penalty drivers

Detection likelihood driver: The higher the probability of getting caught the lower the incentive to cheat, *ceteris paribus*, and hence, the higher the risk that the violator will be caught. The major factors that contribute to this driver are, (i) the effectiveness and efficiency of the enforcement system; (ii) social acceptance of cheating in society; (iii) awareness of the regulations; and (iv) the level of non-governmental or private organizations involvement in detecting infringements.

The avoidance driver: A rational fisher engaging in IUU fishing in a situation where there is some degree of enforcement will take measures (such as engaging in

[1] It is worth noting that we are here not dealing with small-scale fisheries, where community cohesiveness allows for social control (see for example [27]).

transhipment of catch) to reduce the chances of being detected, this is denoted as avoidance activity.

The penalty driver: The severity of the penalty when someone is caught is also an important driver in the decision of a fisher to cheat. The more severe the penalty the lower the likelihood is of cheating, *ceteris paribus*. This driver is related to the detection likelihood driver in that if there is no enforcement then the severity of the penalty is meaningless. For example, in Florida where a net ban was instituted the county with the highest level of NON-compliance was also the county that either dismissed the most cases or imposed the minimal economic penalty to net fishers [13]. The types of penalties that are applied include: (i) the amount of the fine; (ii) confiscation of the boat; (iii) confiscation of the catch; (iv) exclusion from the fishery; and (v) history of prosecutions/application of the penalty. For example, in Senegal the fines are doubled for foreign fishing vessels that repeatedly operate outside of the fishing access arrangements.[2] In the state of Victoria in Australia, first time offenders are served with a Penalty Infringement Notice (PIN), however, the penalty for repeat offenders can include seizure of the catch and vessel, imprisonment and other penalties [14].

2.3. Moral and social drivers

Many have observed that the deterrence model alone does not adequately explain why people engage or choose not to engage in illegal activities such as IUU fishing; rather moral and social factors also play a crucial role [10,11]. It has been observed that a given population of fishers, for example, can be classified into (i) chronic violators, (ii) moderate violators and (iii) non-violators [9]. Chronic and non-violators generally make up a small portion of a given population. The former have the tendency to undertake IUU activities no matter what, while non-violators will not engage in IUU fishing under any condition. Moderate violators, on the other hand, will only bypass regulations if the potential economic gain is high enough to cover the potential penalty they may face given the size of the penalty when caught, and the probability of being caught. Secondary influences that may affect the decision of moderate violators to IUU or not to IUU are the legitimacy of the regulation (and fishery management organization), and the norms of behaviour, including both the general behaviour of the fishers and the moral code of the individual fisher [10,11]. Gauvin [15] and Bean [16] have estimated that about 10% of fishers in the Massachusetts lobster and Rhode Island clam fisheries flagrantly violate major regulations. The other 90% of fishers normally comply with regulations. These estimates are not just relevant to these two fisheries: Feldman [17] presents a number of estimates for other fisheries that are similar to these numbers.

[2]See http://www.fao.org/docrep/V9982E/v9982e3n.htm.

2.4. A formal model

From the above conceptual framework, we developed a formal model of the economics of IUU in line with the literature (see Appendix 1). According to this model, the objective of the fisher is the maximization of the potential gains from engaging in IUU fishing moderated by moral and social considerations. If the fisher engages in IUU activities in a fishery in which there is close to no regulation, then the fisher faces close to zero probability of being caught implying that the expected penalty the fisher faces is also close to zero. In this situation there will be very little need, if any, to undertake avoidance activities. Moreover, the IUU fisher will choose the level of IUU activity such that the marginal revenue from the activity is greater or equal to the marginal cost of engaging in the activity, which in this study equates to the sum of the marginal cost of fishing and the marginal moral and social cost of engaging in IUU fishing. If the fisher undertakes IUU fishing when there is enforcement, then the fisher will choose the level of IUU fishing such that marginal revenue is equal to or greater than the sum of marginal cost of engaging in IUU fishing, and the potential marginal fine if caught.

3. Global scope of IUU incidence

Fig. 1 below summarizes IUU incidence in the world. This is a map developed from the SAUP database on global IUU fishing at the UBC Fisheries Centre. It contains data on discards and unregulated fishing activities that have been extracted from government fisheries department publications (such as annual reports and media releases) and databases, and data on illegal fishing activities that have been described in the media (e.g. Intrafish, FIS), fisheries management reports and peer-reviewed literature (see [3]). The data is spatially referenced by FAO area or sub-areas depending on the level of detail provided. The analysis (Fig. 1 and Table 1) presented here are therefore based on incidences that are published and therefore possibly biased to those cases where a large fine is handed down or the offence had a significant impact on the

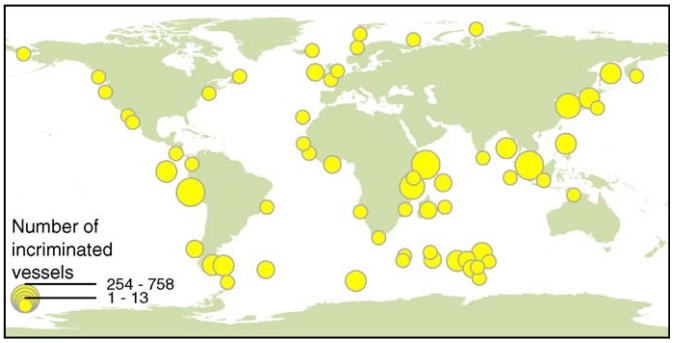

Fig. 1. Number of incriminated vessels for fishing illegally between 1980 and 2003. Source: Based on Sea Around Us IUU database; www.seaaroundus.org.

Table 1
Cost and benefit aspects of risks of IUU fishing when there is a 1 in 5 chance of being apprehended (i.e. $\theta = 0.2$)

Cases	Vessel/gear	Arresting country	Fishery	Catch (t)	Catch value (USDD)	Expected revenue[a] (USD)	Variable cost[b] (USD)	Fine[c] (USD)	Expected Penalty[d] (USD)	Total cost[e] (USD)	Total cost/ expected revenue[f]	New fine[g]
1	Longline	Australia	Patagonian toothfish	116	630 000	504 000	(0.70%) 439 091	435 000	87 000	526 091	1.04	0.75
2	Trawler	Unknown	Cod & haddock	24	1 138	916	(0.66%) 747	22	4	752	0.83	38
3	Boat/dive gear	Australia	Abalone	11 000	75 000	60 000	(0.70%) 52 500	26 250	5250	57 750	0.96	1.4
4	Longline	Chile	Patagonian toothfish	33	610	488	(0.45%) 273	420	84	357	0.73	2.55
5	Trawler	Unknown	Finfish	—	6 250	5 000	(0.70%) 4 375	2 250	450	4825	0.97	1.4
6	Trawler	Russia	Cod and haddock	48	1 138	910	(0.66%) 747	22	4	752	0.83	38
7	Trawler	Argentina	Fish include anchoveta	2 685	485 985	388 788	(0.62%) 300 399	24 138	4828	305 227	0.79	18
8	Pots	Japan	Crab	60	47 820	38 256	(0.62%) 29 648	7 414	1483	31 131	0.81	5.8
9	Longline		Patagonian toothfish	200	2 200 000	1 760 000	(0.70%) 1 533 333	100 000	20 000	1 553 333	0.88	11
10	Bottom trawler	Mexico	Shrimp	5	27 575	22 060	(0.56%) 15 337	5 455	1091	16 428	0.74	6.2
11	Pots	Russia	King crab meat	0.214	2 456	1 965	(0.66%) 1 621	34	7	1628	0.83	50
12	Bottom trawler	Russia	Alaska Pollock	6	11 022	8 818	(0.39%) 4 304	1 171	234	4539	0.51	19.4
13	Gillnet	Russia	Greenland halibut	132	119 328	95 462	(0.59%) 69 833	690	138	69 971	0.73	185
14	Longline	Canada	Sablefish	2.72	12 063.2	9 651	(0.70%) 8 408	15 385	3077	11 485	1.19	0.4
15	Longline	Mauritius	Patagonian toothfish	200	440 000	352 000	(0.70%) 306 667	2 400 000	480 000	786 667	2.23	0.38
16	Longline	Uruguay	Patagonian toothfish	201	2 122 560	1 689 600	(0.70%) 1 472 000	1 632 000	326 400	1 798 400	1.06	2.6

[a]Expected revenue = $\theta^*0 + (1 - \theta)^*$catch value. This captures the fact that when apprehended catch from IUU fishing is usually confiscated.
[b]Variable costs are the cost of operating the vessel as distinct from the fixed costs of acquiring the vessel.
[c]Reported fine imposed, assumed to be the total fine including the confiscation of catch/vessel, flag state's fine, where applicable.
[d]The product of the probability of detection (in this example 0.2) and the fine imposed.
[e]The sum of variable cost and the expected penalty.
[f]The ratio of the potential total cost of IUU to the potential value of engaging in IUU. A value of 1 and above implies engaging in IUU activity is not a profitable proposition.
[g]The number of times the reported fines need to be multiplied by in order to make the potential gain equal to the potential cost of engaging in IUU when $\theta = 0.2$. This gives an average multiple of about 24. Similar calculations for $\theta = 0.05$ and 0.1, shows that multiples of 173 and 74 are needed.

environment or fishers. It is worth noting that both the database and the map are 'living' research products as they are constantly being improved as more data is accumulated (see www.seaaroundus.org for updates).

Fig. 1 represents the spatial distribution of vessels incriminated in IUU activities. Most of these observed/reported IUU activities are in the EEZ of the country detecting the infringement. Our data indicates that fewer IUU activities are reported in the northern hemisphere. This may be a reflection of the resources expended on monitoring, control and surveillance. Nevertheless, the map does indicate that even with the limited information we currently have, IUU fishing is widespread spatially.

4. Cost and benefit aspects of risks inherent in IUU activity

Table 1 is a representation of the model presented in Appendix 1, except that the moral and social components are not included. This is because for the cases presented in the table, these drivers of IUU fishing are at best very weak. We have also implicitly assumed that the cost of any avoidance activity by a given vessel is included in the vessel's variable cost (see below), and the benefit of such action to the vessel is to reduce the effectiveness of monitoring, control and surveillance (MCS) activities (that is, reduce θ) for the vessel. The table lists a number of IUU fishing vessels that have been apprehended while illegally catching fish in different parts of the world. The first entry for instance, is a vessel apprehended by Australian authorities. The vessel, at the time it was apprehended, contained 116 tonnes of Patagonian toothfish with an estimated market value of USD 630 000. This vessel was fined USD 435 000. The 'catch' and 'fines' columns are completed with actual data. The numbers in italics in the 'value' column are calculated using the reported IUU catch and the global price of the fish in question. US prices (computed using data at http://www.st.nmfs.gov/commercial/landings/gc_runc.html) are used as proxies for global fish prices. This is reasonable given that recent studies have demonstrated that prices for many fish species tend to be co-integrated [18]. The variable cost of fishing as a percentage of landed value was calculated using information in Lery et al. [19].

Recall that θ denotes the probability of detection of IUU fishing—it is therefore crucial in the calculation of the cost and benefits of the risk inherent in IUU fishing. The current lack of data does not allow us to say what the value of θ is for the cases in Table 1, but it is probably safe to say that many of them will have probabilities of detection that are well below 0.2 or a 1 in 5 chance of being detected. More work to determine prevailing detection probabilities for IUU activities in different fisheries around the world will be very useful in the progression of the current analysis. This will also increase the utility of this work to fisheries managers in their effort to tackle the problem of IUU fishing.

Given the data situation, we explore the question, will the potential benefits of engaging in IUU be greater than the potential costs when $\theta = 0.2$, given the fines imposed, the value of the catches, and the variable cost of fishing (assuming fixed costs to be sunk)? In other words, will the ratio of potential total costs to expected revenue from IUU fishing be greater than or equal to 1? From Table 1, we can see that only four of the 16 cases proved to be uneconomical with a 1 in 5 chance of being detected. Similar calculations when $\theta = 0.05$ and 0.1 showed that the total potential cost exceeds the expected revenue only for Case 15.

Another interesting question explored is, what fines should have been imposed on each of the cases in Table 1 to make the costs aspects of risk at least equal to the benefits aspects for an MCS system when the probability of detection, $\theta = 0.2$. The calculations show that on average, for the cases studied, current penalty levels will have to be increased 24 times to ensure that IUU fishing is uneconomic. The equivalent numbers when $\theta = 0.05$, and 0.1 are 173 and 74, respectively.

From the results presented above one can make the following observations:

- given the current combination of fish price, IUU catch levels, variable fishing cost levels, and the level of fines imposed in vessels caught engaged in IUU fishing, the current fine levels will not serve as a deterrent for two-thirds or more of the cases reported in Table 1 when the probability of detection is equal or less than 0.2;
- for most of the cases, the probability of detection must be well above 0.2 for it to serve as a deterrent;
- the reported fines for the cases analysed will have to be increased many-fold even for fisheries that are monitored to ensure that there is a 1 in 5 chance of being detected, for the fines to serve as serious deterrents to IUU fishing.

5. Discussion and conclusion

Often the economic gains from IUU fishing are significant enough to motivate fishers to engage in IUU. In some cases, for example, the high valued Atlantic tuna fishery, where high prices have lead to an increased amount of IUU fishing, ICCAT has estimated that Flag of Convenience (FOC) vessels take 10% of all tuna catches by IUU fishing, which is unaccounted for in stock assessments. Another well known case is the Patagonian toothfish fishery, which has been fished down quite severely because of IUU fishing, to the extent that it is now considered endangered [20]. In this case, the incentive is very high as Patagonian toothfish sells on the illegal market for approximately USD 24 per kilo [21]. As the demand for fish in the market increases and effort limits are being imposed, there are more incentives to fish illegally [22]. As

the restrictions on legal fishing become greater, with quotas set, gear regulations enforced, and stock sizes managed, there is an increase in the motivation to participate in IUU fishing. Therefore more attention needs to be accorded this problem, otherwise current mismanagement of the world's fishery resources because of inaccurate stock assessment will only intensify.

It is also important to take into account the fact that there are many ways in which fishers can bypass regulations to engage in illegal fishing. Fishers can easily underreport catches and discard many low-value fish. They can also engage in transhipment at sea which is difficult to detect [23]. There are some cases where vessels report catches of one species for another in order to avoid quota non-compliance [23]. Some IUU fishing occurs in the high seas, which, due to its large area, is very difficult to monitor and survey [24]. Most of the illegal fishing (breaches against national fisheries statutes) is detected in the EEZ of countries, especially where there is an aggressive surveillance and enforcement program. However, this does not necessarily reflect the total IUU situation for two reasons.

First, on the high seas regional fisheries bodies have passed relatively few fishing regulations to control who has access to the resources. The North Atlantic and the waters managed by ICCAT are the exceptions where there are quotas and joint regional enforcement or national enforcement initiatives to encourage compliance among member states. However, if a non-member country fishes in the high seas contrary to the regulations as seen in non-ICCAT countries fishing for tuna in the Atlantic, the mechanisms are limited in applying penalties to offenders.

Second, regulations regarding by-catch and other non-target species caught on the high seas are generally not covered in regional fishing regulations or in required trip reporting and therefore not well captured in many databases.

In the face of these big challenges, monitoring, control and surveillance activities are still very limited in scope in many fishing areas. From 1979 to 1993, the estimated observer and aerial surveillance coverage of the high seas was 5% which is not enough to catch all illegal practices. Also, vessels that have been caught, operators cover the fine as operational expenses, and simply purchase another vessel and start all over again [25]. Since the profits from each vessel usually exceed the price of the vessel, abandoning that vessel once apprehension occurs is not a major problem for most operators [25]. Many vessels use fake operating companies to avoid having to pay fines when caught. The true identity of the vessel is never detected and the company name changes many times [26]. Surveillance and enforcement of the high seas will be very expensive, making monitoring systems difficult to implement on a regular basis, especially, in developing countries [25].

Finally, we can see a number of ways in which this contribution can be extended to make it even more relevant to policy makers and managers. First, the map presented here needs more data to provide better spatial resolution on the extent of the problem. This means more effort at building the SAUP IUU database is necessary. Second, the improved database can then be used to improve and extend the model calculations presented in Table 1. To further enhance the results presented in Table 1, more effort at estimating the value of θ (i.e., the chance of being apprehended engaging in IUU fishing) for different fisheries is warranted.

Acknowledgements

We thank our colleagues, especially, Louisa Wood, Robyn Forrest and Jordan Beblow (for their contributions to the incidence Map), Reg Watson, Tony Pitcher, Daniela Kalikoski and Daniel Pauly for providing us with insights, information and data. We thank the *Sea Around Us project* (SAUP) and the Pew Charitable Trusts for making this work possible by initiating the IUU Global database. Finally, we thank the OECD for their financial support.

Appendix 1. The formal model

In this section, we formalize the discussion above into a model. Following on the earlier discussion, we assume that the decision to engage or not to engage in IUU fishing depends on the potential net benefits (NB) from illegal fishing moderated by moral and social considerations. Let NB be defined in a broad sense by the following function:

$$NB = f(h(A,e,x),\theta(e,A,R),F,m(e),s(e)),$$
$$NB_{\mathrm{h}}>0; \quad NB_{\theta}<0; \quad NB_{\mathrm{F}}<0; \quad NB_{\mathrm{m}}<0, \text{ and } NB_{\mathrm{s}}<0. \tag{1}$$

where h is the catch from IUU fishing by a given fisher; e stands for IUU fishing inputs; x is the biomass of fish available; A denotes the level of avoidance activity undertaken by the fisher; the variable R is the set of regulations in place; θ is the probability of detection; F is the penalty a violator faces when caught; m denotes the individual's moral standing, which is assumed to be inversely related to the IUU fishing inputs; and s represents the fishers social standing in society. This variable also depends inversely on the degree of IUU fishing undertaken by the fisher.

To be more specific, Eq. (1) is rewritten as

$$NB = [ph(A,e,x) - T(e,A)] - \theta(e,A,R,)F - m(e) - s(e), \tag{2}$$

where p is the unit price of fish caught; $h_x>0, h_e>0$; $h_A<0$; $T(e,A)$ denotes the total cost of IUU fishing; $\theta_e>0; \theta_A<0; \theta_R>0$. The first and second terms in Eq. (2) denote the total revenue and total cost of IUU fishing, respectively; $0\leqslant\theta\leqslant1$ is the probability of the fisher being caught and convicted if found engaging in IUU fishing. When there is only partially successful regulation and enforcement, the value of θ lies between 0 and 1. F denotes the penalty the violator faces if caught, and to obtain the

total expected penalty to be paid by violators, the probability of detection is multiplied by F.

The optimality conditions [no. 3.2]

The objective of the fisher is assumed to be the maximization of the potential gains from engaging in IUU fishing moderated by moral and social considerations, that is, the maximization of Eq. (2).

If the fisher chooses not to IUU then NB as described in Eq. (2) is zero. And that is the end of the story.

If, on the other hand, the fisher chooses to IUU in a situation where there is close to no regulation, then the fisher faces close to zero probability of being caught, that is, $\theta \approx 0$, implying that θF is also close to zero. In this situation there will be little if any need for undertaking avoidance activities, A, hence $T(e,A)$ is reduced to $T(e)$ and $h(A,e,x)$ reduces to $h(e,x)$. The first-order condition under no enforcement is therefore simply:

$$ph_e = T_e + m_e + s_e. \tag{3}$$

That is, at the optimum solution, the IUU fisher will choose the level of IUU activity as represented by the decision variable, e, such that the marginal revenue from the activity exactly matches the marginal cost of engaging in the activity, which here means the sum of the marginal cost of fishing and the marginal moral and social cost of engaging in IUU fishing. Eq. (3) states that it is not enough for the fisher contemplating whether to IUU or not to IUU to seek to make the marginal cost of IUU fishing equal to the marginal revenue—the marginal revenue has to be more than the marginal cost to cover the loss of moral and social standing that the fisher suffers as a result of engaging in IUU fishing. In fact, it is possible that for a given fisher, the loss in moral and social standing is high enough to make engaging in IUU fishing not worth it under all possible marginal revenue scenarios. From Eq. (3) one can conclude that for non-violators, m_e and s_e are high enough for them to outweigh the marginal revenue from IUU fishing under all possible scenarios.

If the fisher undertakes IUU fishing when there is enforcement, that is, when $\theta > 0, F > 0$ and by implication $A > 0$, the optimality conditions become:

$$ph_e = \theta_e F + T_e m_e + s_e \tag{4}$$

and

$$-\theta_A F = T_A - ph_A. \tag{5}$$

Eq. (4) says that in the optimum, the fisher will choose the level of IUU fishing such that marginal revenue is equal to the sum of marginal cost of engaging in IUU fishing, and the potential marginal fine if caught. Eq. (5) stipulates that the marginal gain to the fisher from engaging in avoidance activity must be equal to the marginal cost of avoidance plus the marginal loss in revenues from catch due to avoidance activity. In other words, the fisher weighs the risk of being caught and penalized ($\theta_e F$), the risk of losing moral (m_e) and social (s_e) standing in society, against the expected gain (ph_e) from engaging in the activity. Note that in the case of Eq. (3) the risk of being caught and penalized is not present.

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