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Principal-Agent Problems in Fisheries

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42.1. INTRODUCTION

A "principal-agent problem" arises whenever an individual or public agency or regulator (the principal) has another person, office, or firm (the agent) perform a service on its behalf and cannot fully observe the agent's actions, inducing information asymmetry. In economics, the traditional example is the potential conflict of interest between ownership and management, but any delegation of authority may give rise to this problem. The classic example in fisheries is the relationship between vessel owner and crew members. Principal-agent theory focuses on mechanisms to reduce the "problem" of asymmetric information, such as defining and selecting the "right" types of agents, implementing incentive contracts, including instituting forms of monitoring and various amounts of positive ("carrots") and negative sanctions ("sticks"). The underlying assumption is that the agent's interests may differ from those of the principal. Strategies to mitigate the problem produce a type of transaction cost, reflecting the fact that without cost, it is impossible for principal to be sure that agents will act in the principal's best interest. In other words, Pareto efficient allocation cannot be obtained.

There have been many areas of applications of the principal-agent paradigm in economics. In an employer-labor setting, an employer serves the role of principal, while workers act as agents. The classic example of the principal-agent relationship has a landlord monitoring the activities of a tenant farmer. In regulated industries, the regulator acts as principal, designing an incentive scheme or contract for the firms (agents) whose activities are being regulated. From the insurance sector, the policyholder might change behavior after becoming insured.

The applications of principal-agent theory to renewable ocean resources, including fisheries, have been diverse and in some instance superficial. To understand this, let us look at the area of regulation. The economics of regulation can be divided into two main approaches: public interest theory and interest group theory. In public interest theory, the regulations promote overall public interest, while interest group theory views the purpose of regulation as promoting narrow actions and interests of certain groups in the society. The general setup is that the government wants firms and/or households to adjust their behavior in such a way that certain things are prevented or some specific goals reached. In reality, it is very difficult for the government to control the actions taken by firms and/or households. Figure 42.1 shows a very simplistic interaction between different actors in the regulation of fisheries. The fisheries policy is formulated by the politicians and implemented by the ministry of fisheries. An important part of the ministry of fisheries is the section of control and enforcement because this section interacts with the courts to determine the final interpretation of the laws. So, it is not sure that the intentions of the politicians are put into practice. The fishing firms may consist of the owners, managers (e.g., the skipper), and a range of employees or crew members. The skipper and the crew members are actually doing the fishing, not necessarily the owner. Even though the figure is missing the consumer side, it is sufficient to show that the links between the politicians at the one hand and the skipper and crew on the other hand are imperfect. When the government (principal) cannot precisely control the fishermen (agent) has been termed a principal-agent problem. In the political economy literature, the situation in which a state agency (agent) pursues its own interest, which may differ from the interest of the government (principal), is called a principal-agent problem. Here the problem may be connected to the rent-seeking issue that arises when agents from the regulated industry try to influence the regulation in their favor (e.g., lobbying using resources to acquire subsidies). Both of these problems arise with conflicting objectives and strategies between agents and the regulators, and they both contribute to government failure (for an overview, see Edwards 1994).

The problem with this approach to regulation is that although it might emphasize that actors who are going to be regulated by the government cannot be expected to adjust passively to the regulation, it does not explicitly state the asymmetric information problem, which is a market failure (see Hanley et al. 1997). In fact, it is the opinion of the author that studies of the interplay between a principal and an agent or the regulator and the regulated should have some kind of asymmetric information problem attached before it can be called a principal-agent study. Otherwise, it is "just" a study where the regulator takes the reaction by the agent into account when the regulation is designed, which every sound regulation model has to do. In fact, several of the applications of the principal-agent model in fisheries do not include the information problem, and hence cannot be called principal-agent analyses (see section 42.3).[1] Jensen (2008) provides a recent review on uncertainty and asymmetric information in the fisheries regulation economics literature, where the purpose is to distinguish when uncertainty can be interpreted as asymmetric information.

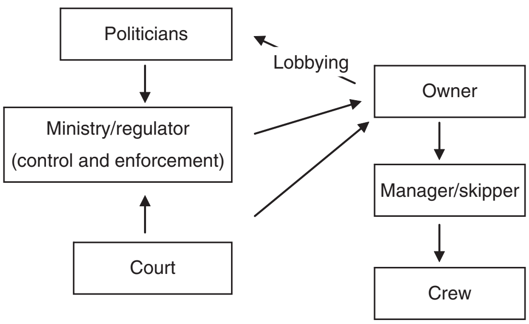

FIGURE 42.1 Interactions among the politicians, the government, and the fishing firms

This chapter presents principal-agent theory, with an emphasis on identifying the instances when it is suitable to apply the principal-agent approach and what are the gains in knowledge. It then surveys different applications of the principal-agent approach in fisheries.

42.2. PRINCIPAL-AGENT THEORY

Kwerel (1977) wrote:

> In a world of perfect information, optimal regulation of an isolated economic variable would be relatively straightforward. Unfortunately, we do not live in such a world. Regulatory authorities typically find that the information which they need during the planning phase is known only by those who are to be regulated. In this situation a serious incentive problem may arise. Unless a system can be designed which makes the objectives of the individual agents coincide with the regulator's objectives, self-interested agents will systematically deceive the regulatory authority when asked to reveal their information.

The economics of information and incentives has developed greatly in recent years. In the economic theory of contracts, agents are characterized by private information that determines their ultimate actions. The two key features of principal-agent problems are that (1) the principals know less than the agents about something important, and that (2) their interests conflict in some way (see Sappington 1991; two more recent introductions are Macho-Stadler and Pérez-Castillo 2001; Laffont and Martimort 2002).

There seem to be two sources of asymmetric information problems:

- Problems where agents can do some costly action to improve outcomes for the principal, but the principal cannot observe the action. These are known as moral hazard or hidden action problems. For example, this can involve effort in a production process or protection against risk.

- Problems where there are different types of agents, and principals cannot distinguish between them.[2] These are known as adverse selection or hidden information problems when the types are fixed and the question is which agents will participate. For example, this can include efficiency in terms of cost or willingness to pay for a given good.

While the type of the agent is unknown to the principal, the latter nevertheless is assumed to have prior information before the contract is negotiated, in terms of the statistical distribution of the type and other relevant characteristics of the agent. The challenge for the principal is to set up a contract scheme enforcing truthful revelation of the private information, thus allowing a second-best optimum to be attained for the economic variable of interest (production level, environmental externality, etc.). This is called the revelation principle.[3] In practice, contracts are largely used in domains such as insurance, public regulation, industrial relationships, agricultural production, and employment procedures. This suggests that asymmetric information can be present in many situations and must be taken into account in almost every regulatory and empirical analysis.

The timing of the interactions between principal and agent is shown in figure 42.2. A contract is offered to the agent, which the agent can either accept or refuse. If the agent refuses, the interaction stops. If the agent accepts, the contract is executed. The sequence of decisions is important because at each point in time the agent and principal have to make decisions based on the available information. Therefore, a correct classification of the asymmetric information situation is important (see Macho-Stadler and Pérez-Castillo 2001).

The advantage of the principal-agent approach is that the incentives at stake are highlighted. The focus is on the regulation problem, where the issue is to align the incentives of the private firms so the social objectives can be met. Put in another way, in fisheries, if the reactions of the fishermen are not taken into account when formulating the fishery policy of keeping, for example, the stock size within optimal size (e.g., assume that the fishermen passively adjust to quota settings), then the policy can lead to suboptimal and unexpected results. Another advantage of the principal-agent approach is that the information problems are explicitly taken into account when setting up the incentive scheme. The principal submits to the agents a menu of contracts that are conditioned on what both the principal and the agent can observe and on what can be verified in the legal system. In other words, asymmetric information is included explicitly, because the contract cannot be conditioned on what only the agents know.

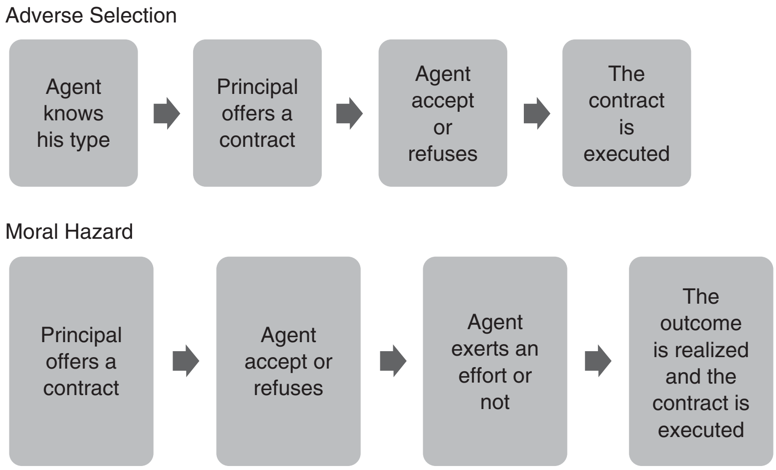

FIGURE 42.2 Timing of contract offers and interactions between the principal and the agent

42.3. APPLICATIONS OF PRINCIPAL-AGENT THEORY TO FISHERIES

The principal-agent model can be applied to different areas in fisheries such as share contracts, international fishing agreements, illegal landings and discards, safety, and invasive species.

42.3.1. Share Contracts

Share contracts are used as the main remuneration system in commercial fisheries all over the world. The fishermen or crew are paid not a fixed wage per hour but as a share of the revenue obtained by the catch of the vessel. These systems vary across countries, vessel types, and fisheries. In some systems, some of the common variable costs are deducted before the revenue is divided by the crew and the vessel owner, and in some systems the crew receives some minimum wage combined with a share of the revenue obtained.

Sutinen (1979) analyzed the social desirability of the share system and concluded that "the share system of remuneration is viewed as making a significant positive contribution to the development of a fishing industry." This result is driven by risk-averse vessel owners and competitive labor markets. Under the share system, the vessel owners can spread some of the risk to the crew, reducing the risk cost. Sutinen does not explicitly mention the moral hazard problem due to private information about the effort level of the crew, and he does not call the approach a principal-agent analysis. However, he writes that the share system "provides a work incentive that makes it less costly to extract the desired level of labour services from the crew." The analysis is done in a static framework.

In two studies, Hämäläinen et al. (1986,1990) analyzes the issue of share-fishing in a principal-agent and a dynamic fishery model. They use the term "Stackelberg game" as interchangeable with the principal-agent model because the principal (called leader in the Stackelberg game) defines the game and takes into account the reaction of the agent (called follower in the Stackelberg game). Because the principal defines the game, the reactions of the agents are passive in the sense that they, given the choice of the principal, optimize their behavior. In this model, the agents define their labor supply as a function of the share contract and the stock level. In both studies, Hämäläinen et al. use a dynamic fishery model in a principal-agent setup. Again, like other applications, there is no information problem in the model, because there is no asymmetric and private information. They argue that the reason for setting up the model in this way is that a contract based on labor time is not enforceable because of the high transactions cost in, for example, supervision of labor. The issue of risk sharing is not included in the model. In their 1986 paper, Hämäläinen et al. assume myopic behavior, because the owners and the fishermen are not coordinating their actions. In the case of a pure share contracts, they found, with myopic behavior under open access, that the share is equal to the elasticity of harvest with respect to labor input. They analyzed—given the share system—the possibilities to induce social optimal fishing and showed that a combination of licenses and taxation of harvest may lead to the optimal solution. In their 1990 paper, Hämäläinen et al. studied a fishery where cooperative vessel owners (the principal) hire unorganized fishermen (agents) to operate vessels. On each vessel, the fishermen's salary is a share of the value of the catch. The results show that harvest shares of myopic fishermen will be reduced when cartels are established. The results suggest that share-fishing is a self-adaptive and time-consistent remuneration system as it automatically incorporates differences in individual crews' labor supplies due to, among other things, fishermen's skills. They found that optimal regulation is accomplished by a constant subsidy on the price of fish.

Stanley (2007) studies relative payment contracts in a principal-agent framework between larva-gathering agents and their boat-owning employer principals who supply seed to shrimp farms. The effort level by the agents is not observable by the boat owners, and the output of the agents is related to the effort level and the unknown and stochastic environmental factors. A relative payment contract is designed such that the payment depends on the relative performance of the agents. That is to say, if the production of an agent is higher than the average production of all agents, the agent receives a bonus payment depending on production level and on whether the vessel owner is earning profit. The study incorporates the sources of production risk creating income shocks to gatherers. Two data sets from a Honduran coastal fishery case were used to test the hypotheses concerning contractual performance across environments. Which contract provides the highest mean income (and variation) depends upon the underlying production catch data. A simplified relative payments contract would perform better in reducing income risk in locations of stronger covariate shocks, but at the price of significantly lower mean earnings for gatherers. In areas of shocks, such as localized water pollution, piece-rate contracts (a given rate of the total production) would perform better. Objective risk exposure to gatherers was lower under relative payments, supporting the hypotheses.

42.3.2. International Fishing Agreements between a Coastal State and a Distant State

Clarke and Munro (1987) claim that their study is the first application of the principal-agent theory to fisheries management. They analyzed the situation where a coastal water state (the principal) contracts with the distant water state (agent) to do fishing in the water under the jurisdiction of the coastal water state.[4] The setup is that the coastal state allows the fleet from the distant state the return from fishing under the condition that the fleet pays a license fee, for example, through unit taxes on catches and effort. Since they assume complete information for both the principal and the agent, the setup is not a proper principal-agent problem because the principal knows exactly the same as the agent, that is, full information. Therefore, Clarke and Munro (1987) also reach first-best solutions in their analysis by implementing a tax scheme.

Jensen and Vestergaard (2002a) analyze the principal-agent problem under adverse selection, where the regulator does not know the cost of the fishermen; that is, the regulator does not know the type of the fishermen. They assume that there can be two types, low-cost and high-cost agents. The issue is that the low-cost agents have incentives to pretend to be high-cost, because the fishermen are compensated. The regulator might end up with paying too high compensation. In a steady-state equilibrium analysis, they found that the low-cost fisherman has to be paid an information rent in order to reach a second-best optimum. This optimum is characterized by two restrictions, namely, the participating and the incentive compatibility restrictions. The participating restriction says that the fishermen under the scheme shall be given a payoff corresponding to what they can get elsewhere—reservation utility. The incentive compatibility restriction says that the fishermen receive a higher payoff when telling the truth compared to when not telling the truth. That the low-cost agent receives an information rent is a general result, but what is new in a renewable resource setting is that the effort level by the low-cost agent changes under asymmetric and incomplete information compared to the situation with complete information. Because of the resource restriction, where the resource growth in steady state is equal to the total harvest of the agents, the low-cost agent is allowed a higher effort level under asymmetric information than under complete information. As a consequence, the high-cost agent is allowed a lower effort level. Finally, because of the total higher cost, the equilibrium stock level is higher under asymmetric information than under complete information. The study is the first to apply the standard adverse selection theoretical model to fisheries. The results are obtained under several simplifying assumptions, such as no discounting and no signaling. This area, signaling, could be an interesting future research area.

Jensen and Vestergaard (2001) analyze the fishery policy in the European Union under the assumption that the three actors involved—the EU Commission, the member states, and the fishermen—operate in a kind of double principal-agent framework with asymmetric information and hence incentives problems. It is assumed that the member states have information about the cost structure of the fleet, which the European Union does not have. In technical words, there is hidden information about an exogenous variable and hence adverse selection. Jensen and Vestergaard assume that the fishermen can either have low fishing cost or high fishing cost. In the study an economic incentive system, where the European Union taxes the member states based on effort, is formulated. The member states maximize—given short-run production and cost functions—profit minus the tax payment to the European Union. The European Union maximizes overall profits plus the tax revenue corrected for the marginal cost of public funds subject to three types of constraints: (1) the natural growth of the resource, which is equal to the total harvest; (2) the participating constraints; and (3) the incentives or self-selection constraints. The contract European Union offers to the member states is designed in such a way that they have nonnegative profit and also reveal their type, low cost or high cost. Setting the tax requires knowledge about the marginal profit of both types of fishermen, the marginal cost of public fund, the shadow value of the resource stock, and the probability of fishermen being either low cost or high cost.

42.3.3. Safety

The issue of safety in fisheries is analyzed by Bergland and Pedersen in 1997. The background is that it is necessary for the public authorities to engage in safety issues to secure a supply of communication and navigation systems used by all vessels, because these are public goods. In addition, to reduce accident risks, the supply of these public services will increase the production possibilities in the fishing industry. However, they found that moral hazard effects might occur because the supply of public services could induce the individual rational fishermen to behave in a way that increases risks because they may insert less of the safety-reducing and more of the safety-increasing private inputs as long as the total losses experienced when accidents happen are higher than the losses each of the fishermen are faced with. Their analysis has no information problem; the market failure in the model is the public good characteristic of safety. As moral hazard is defined in this survey, the adjustment of the fishermen to the provision the public good is not hidden.

42.3.4. Discards and Illegal Landings: Moral Hazard

Jensen and Vestergaard (2002b) treat output regulation in fisheries as a moral hazard problem, because the fishermen have private information about their catches. What the regulator normally can observe under reasonable cost is the landings. Observing catches is in many cases too costly.[5] With catches as private information, there is an incentive problem, because information about the real catches is important of several reasons. First, if the total real catch is higher than the level set by the regulator, this might represent an unsustainable harvest level, leading to direct long-term economic loss. Second, because the real catch is unknown, the assessment of the stock level will—all things equal—be more uncertain, and again, this can lead to situations where the assessed the stock level is different than the real stock size—a problem that the International Council for the Exploration of the Sea (ICES) has been dealing with for several years (see, e.g., ICES 2007). Third, all this leads to implementation of the comprehensive control and enforcement system to ensure that the total catches are held within the total allowable catches. In other words, the information about the variable—catches—is typically known only by the fishermen, who are to be regulated. Self-interested fishermen will systematically deceive the regulator, when asked to reveal their information about catches, unless a system can be designed that aligns the motives of the fishermen with the social objectives. Using results from the nonpoint pollution literature (Segerson 1998), an incentive scheme is formulated based on the state of the stock. The basic assumption is that in the case of many fishermen, asymmetric information and uncertainty the regulation of fisheries are a complex problem, where the assessment of each fisherman's real catches is prohibitively costly. This leads to defining the problem as moral hazard in groups. Solving this problem in the fishery case results in formulating the policy instrument as a function of the state of stock biomass. The tax rate (the policy instrument in this case) is equal to the expected marginal net social cost from exceeding the optimal catch divided by the fisherman's biological response. The tax structure eliminates "free-riding," because the fishermen pay on the basis of the full marginal costs that illegal landings generate (the difference in user costs). In this way, compliance with the total quota is ensured—the incentive for illegal landings is avoided.

Hansen et al. (2006) address the information problems in the mechanism proposed by Jensen and Vestergaard (2002b). Instead of grounding the tax rate on stock size and individual fishermen's cost function, Hansen et al. (2006) suggest a tax that depends on knowledge of the principal of the aggregate cost function and total catches of all fishermen. The tax is a function of the aggregate cost function and the fishermen's ex ante reports of planned catch. Hansen et al. show that this tax system will secure nearly optimal catches, least-cost production, and nearly optimal entry-exit incentives.

Jensen and Vestergaard (2007) analyze the issue of discards and illegal landings and moral hazard when there is uncertainty in stock size. The purpose of the study is to analyze incentive contracts as a solution to the stock externality problem, the problem of imperfect and private information about catches and the stock uncertainty problem. So, the incentive problem due to private information about catches, where landings or self-reported catches (e.g., in logbooks) are observable, is addressed in a realistic situation where there is uncertainty about the stock size. In other words, there are multiple market failures, and it is well known that with several market failures, multiple policy instruments must be used to secure a first-best optimum. The incentive contract offered to the risk-adverse fishermen consists of the two taxes: (1) a stock tax based on the difference between the target year-end stock size and the expected stock size at the end of the year multiplied by an unit stock tax rate that is a declining function of the self-reported catches; and (2) voluntary self-reported catches in logbooks are taxed using a tax-rate in terms of per unit of individual, voluntary self-reported of catches in the fishing period. Given stock uncertainty and risk aversion, the stock tax rate and the self-reported tax-rate both depend on the variance of the uncertain stock size and the risk-aversion function. Further, there is an interaction between the two tax rates. The reason is that tax rates have to be balanced against each other on the margin, because the stock tax rate is a declining function of self-reported catches. The uncertainty and risk aversion make it favorable for the fishermen to have a positive level of the self-reported tax rate. The use of a stock tax alone in a situation with uncertain fish stocks and risk-averse fishermen allows for a second-best optimum. In this situation, it is not possible to reach a full optimum. However, it is shown in the analysis, if in addition to the stock tax a tax on voluntary self-reported catches is imposed, a first-best optimum is reached.

42.3.5. Invasive Species

MacPherson et al. (2006) presents a dynamic principal-agent model of aquatic species invasions in which a manager, who is concerned about the spread of invasive species across lakes by boaters, sets management controls on a lake-by-lake basis, and boaters make a series of trip decisions during the course of the season based on the controls imposed by the manager. The results of a simulated invasion of Eurasian watermilfoil (*Myriophyllum spicatum*) highlight interesting aspects of the optimal management policies under two different management objectives: maximizing boater welfare and minimizing milfoil spread. As such, this study endogenizes resource user behavior in the management decisions related to a plant species invasion by allowing the lake manager, the principal, to anticipate boater reaction to management activity and the invasive species. There are two fundamental reasons to endogenize boater movements in a model of the spread of aquatic invasions by boaters: (1) to provide a better forecast of the rate and direction of spread of the invader and (2) to accurately estimate welfare effects. The welfare effect of closing a lake has a direct welfare effect because now access to the lake requires keeping a boat on the lake, but it also has an indirect welfare effect because it shifts the spread of the invasive, which may leave society worse off overall. In the analysis there are no asymmetric or private information problems. Therefore, the approach taken does not belong to the principal-agent approach under asymmetric information and incentive contracts, but the approach is connected to the more general principal-agent principle under the economics of regulation mentioned in the introduction.

42.4. CONCLUSION

This overview shows that applications of the principal-agent theory to fisheries have been diverse and not very systematic. The overview also demonstrates that the use of term "principal-agent model approach" has not been consistent in the fisheries literature. The traditional principal-agent approach considers asymmetric information as a market failure problem in the general relationship where the principal wants to induce the agent or agents to do certain things. Several applications have not included the information problem, which changes the research approach toward game theory. From a policy management point of view, regulating assuming full information will create an inefficient allocation of resources, and therefore the regulator has to create an incentive compatible regulation where the agents will reveal their private information. This has a cost, but the allocation is better than just going ahead with regulation assuming full information.

The state of the research so far indicates that more work needs to be done with respect to the information requirements for regulation and hence to be much more explicit about what a contract between the regulator and the fishermen may be based on. There is a lot of potential in this area, because regulation of fisheries in many countries is based on licenses that easily could be extended to include more items, for example, fishing behavior. Another area is signaling, where fishermen might be able to signal their type cost-free and in this way reduce the information problem. Further, the issue of designing a fishing contract between a coastal state and a distant state has not been fully explored.

Two other areas where the principal-agent approach could be applied to in fisheries are invasive species and marine reserves. Invasive species may in some marine areas threaten the marine environment and biodiversity. As a preventive measure, agents that are assumed to have a high risk of transferring species from one marine area to another area could be offered an incentive contract where they are compensated for reducing the risk of moving species to the foreign areas. With respect to marine reserves, the regulator might compensate the fishermen for their loss due to establishment of the reserve, but at the same time they might have less information about the cost and/or actions of the fishermen, raising the problem of setting up a proper incentive scheme (see for a very recent application, Quach 2008).

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Notes

1. One could speculate whether asymmetric information between different units in the government is market failure or government failure. It is not important for our purpose, because we want to look at cases where objectives and asymmetric information conflict.

2. In some literature, there is a distinction between whether the agent knows something a priori or will know something (see Mas-Colell et al. 1995). In fact, moral hazard issues and the situation when the agent is coming to know more than the principal is the original sense of the principal-agent problem. Adverse selection then refers to the case where information about some characteristics of commodities is not observable by all the participants. However, in recent years the way we use the term seems to be the most used.

3. The revelation principle says (in words) that whatever outcome you can achieve, you can achieve by giving the agent an incentive to tell the truth, and you do not lose anything by making the agent tell the truth.

4. In Macho-Stadler and Pérez-Castillo (2001, section 3B.2), the same moral hazard model between a coastal and distant state is formulated with asymmetric information based on Gallastegui et al. (1993). However, since the model is formulated on observed catches, it leads to paradoxical results, where higher catches than allowed are thrown back into the sea.

5. However, in some fisheries a 100 percent observer program is in place to ensure that the catches are reported correctly.

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