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The impact of new monitoring technology on fisheries management

Can camera technology improve compliance in the discard ban?

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Abstract

Fisheries management has seen many changes over the years, from the introduction of the quota system to the ban on pulse fishery. More recently there has been the introduction of the discard ban. The discard ban is thought to be difficult to monitor, as current technologies are insufficient outside of the ports. Fishermen are also known to be upset about the ban and are unlikely to comply out of their own volition. For this reason many countries with similar policies have opted to make use of on-board camera monitoring, however new technologies are not always easily accepted. People's behaviour can be influenced by playing into various factors having to do with intrinsic motivation. Self-determination, trust in the system and reciprocity are some examples. It is believed that camera monitoring could have a positive effect on these factors, and if the government were to invest in the right developments it may result in voluntary compliance with the discard ban. Stakeholder participation is also thought to influence compliance, as social norms can be used to have individuals adhere to the rules, either through leading by example or retaliation. Camera technology gives the tools for such possibilities. It may even make a policy change possible, where the discard ban is changed into a new system where catches are fully registered at sea, instead of on land.

Foreword

The following paper is written as a thesis for the MSc Aquaculture and Marine Resource Management. This MSc encompasses different fields related to the marine environment such as aquaculture, marine ecology, and the management of the marine environment and its resources. This particular thesis is the last hurdle towards the specialisation in marine governance.

The following thesis focuses on gaining more understanding on one aspect of marine governance in the Netherlands, namely how one can make fishermen accept the new discard ban. To this end we explore the use of camera technology, one of the ways deemed most useful for the monitoring of the discard ban, and how it may affect intrinsic motivation to comply. The thesis was written under the supervision of Dr. P.A. Richter, Environmental Economics and Natural Resources, Wageningen University and Research (The Netherlands).

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1. Introduction

Since the beginning of mankind humans have fished (Sahrhage & Lundbeck, 2012). Of course this does not mean fishing is primitive. Fishing has changed over the millennia, from one man fishing only for his own consumption, to a huge industry feeding the entire world (Sahrhage & Lundbeck, 2012). This change in fishing made management necessary. At first, the main task of fishery management was the division of fishing territory amongst fishermen, but some communities such as the Maori in New Zealand had rules to prevent local overfishing as well (Meredith, 2009). In the Netherlands, concerns of overfishing arose during the time of the Dutch Republic. The North Sea was being overfished massively due to the invention of the beam trawl, which would lead to its ban in 1676 (Davidse, et al., 1975). In the late 19th century the first concerns of global overfishing came up, leading to the foundation of the International Council for the Exploration of the Sea (ICES) in 1902 (Engesaeter, 2002). Since then, overfishing has been one of the leading causes for new management in the last decades. Sadly, despite all the effort by the relevant institutes in those years, overfishing is still a problem in the present day. Moreover, new concerns have arisen, as seen by the campaign started by Hugh Fearnley-Whittingstall to stop food spillage due to discarding of edible fish (Blake, 2011). These two factors lead to the CFP being altered again in 2013 (Penas & Lado, 2016), resulting in the implementation of the discard ban. Since 2015, pelagic fisheries have been forced to land all quota species while other fisheries followed in the years after, as of 2019 the ban was enforced for all EU fisheries (European commission, 2016b; Veiga, et al., 2016).

With what has been previously said, one might think that prevention of overfishing is the government's only goal for their fishery policy. However, governments also try to use policy to stimulate innovation. Innovation is thought to change fishing behaviour and increase fishery selectivity, making the fishery industry more sustainable without limiting them with extra regulation (Hedlye, et al., 2015; Helmond, et al., 2016).
Fishermen in turn hope that by innovating, management changes in their favour. After all if they are more sustainable or easier to monitor, some regulation could be relaxed. This is seen in the fishermen participating in research testing electronic monitoring (Green, 2012). They hope to influence the discard ban in the favour of the fishermen, as they are currently not happy (Visned, 2018). Previously regulation has been relaxed for fishermen participating in pulse fishery research. However, although the Dutch government certainly gave them those favours, the EU decided to ban pulse fishing instead (European parliament, 2018; Rijnsdorp, et al., 2016). This might give some fishermen the impression that innovation does not always lead to more favourable regulation, and indeed previous research found that often innovations in gear efficiency do not contribute to changes in management. The reason being that it is difficult to determine the change in fishing power and properly adjust regulations to this new fishing situation (Standal, 2005). Nevertheless, innovation in monitoring technology may indeed change management. This was shown with the introduction of satellite tracking and the electronic logbook, which both have lead to changes in fishery management (European commission, 2016a). The implementation of these methods greatly reduced monitoring and surveillance effort, reducing the need for surveillance vessels.

Monitoring fish processing is still mostly done by boarding a vessel or trusting on logbooks, but this does not give a complete picture (Alverez & Indregard, 2003). This leaves opportunities for fishermen to help innovate monitoring technology. However, even when innovation is necessary to remain profitable under new regulations, it may be difficult for fishermen to accept new technology. Moreover, there is nothing that says that after participating in research the regulations will change or the government will make use of the new technology, as was the case with the recently banned pulse fishery (European parliament, 2018).
Government and fishermen both need to be convinced of the use, as otherwise it may not be supported or used by either, perhaps leading to the technology being less effective.

Reasons for why fishermen would not agree with a new technology are for instance privacy concerns (Sylvia, et al., 2016), as is the case with on-board cameras. Fishermen may also feel like they are mistrusted, widening the gap of understanding between government officials and fishermen, lowering compliance (Hatcher, et al., 2000). This mistrust would be counterproductive and may even cause more problems for fishery management compared to how things were before. What mistrust can lead to was seen during the introduction of catch quotas in 1975 when there were massive protests leading to confrontations between fishermen and the authorities (Ruigrok, et al., 2018).
There is also an economic factor that may cause fishermen to be opposed to new management or technology. For instance, the matter of who would pay for any new technology that makes monitoring and managing easier. If the fishermen do not see any economic benefit for themselves, they are likely to be opposed to it. Moreover, with new monitoring technology it is also likely to become more difficult to cheat the system, lowering profits for people that did so before. Making sure that new technology is economically attractive to fishermen is therefore important and involving them in the process of management can help in lowering resistance and non-compliance further (Hatcher, et al., 2000). Involving fishermen in the process or supporting positive developments that make their work easier may be seen as an act of kindness, making the fishermen reciprocal, meaning they want to do something in return (Fehr & Gächter, 2000). Compliance can also come from increased intrinsic motivation, which comes about through enhancing the feeling of self-determination or fairness of the system (Andries & Soest, 2012). Developing technology that enhances those feelings will result in more compliance.

As said, the implementation of the discard ban since 2015 puts pressure on fishermen to innovate and try to get either a better deal from fishery managers, or try to open new management possibilities for managers. The technology that may help fishermen reach this goal is the on-board camera technology or electronic monitoring. By helping the development of this technology governments may hope to play into the intrinsic motivation of the fishermen, resulting in voluntary compliance with the regulations in place (Andries & Soest, 2012). Meanwhile fishermen themselves may join development in the hope of changing the discard ban into a more favourable policy, such as a registration obligation (Visned, 2018). Others may only participate in the research for beneficial incentives (Helmond, et al., 2016).
On board camera monitoring is an exciting development, not just because of the alternative management opportunities, but also because of the opportunities it brings for fishermen. Camera technology could potentially lead to better sorting systems, better catch handling, and higher rates of survival in fish (Sintef, 2011). Developments in those direction are likely to make the fishery more efficient, and perhaps the fishermen more compliant.

1.1. Aim

The aim of this thesis is to look into the discard ban and how it may be made more effective and attractive with on-board camera technology and if such a technology can change the policy of the discard ban for the better. The study will focus on the situation in the Netherlands.
On-board monitoring technology with cameras is shown to be applicable to all fisheries, however for some it is more effective than for others (Hedley, et al., 2015). For instance, on-board camera technology used in demersal trawl fisheries is least effective at recognising fish species and sizes due to the mixed catch. The problem is that this type of fishery is also the most affected by the discard ban (Alverson, et al., 1994; Lindeboom & De Groot, 1998). Therefore it may be difficult for mixed fisheries to remain profitable, now that the discard ban has taken effect. Due to this fear of becoming unprofitable fishermen are opposed to the landing obligation and protest against it (Kraaij, 2018). This could potentially lead to uncooperative behaviour, making the discard ban difficult to enforce, especially without on-board cameras. Such a situation needs to be avoided by either changing the discard ban or making on-board cameras attractive to fishermen so that they may become more cooperative. Cooperation is important as otherwise fishermen will simply start illegal activities like they did back when the quota system was introduced (Ruigrok, 2018).
As of yet on-board cameras only cost the fishermen money and are seen as a breach of privacy (Hatcher, et al., 2000; Sylvia, et al., 2016). This may be changed by looking into opportunities of combining on-board cameras with other technologies, such as automatic sorting systems or ways to increase survival chance of caught fish so extra profit is created for fishermen. The effect these technologies may have on the intrinsic motivation of fishermen could be considerable and should be explored. Technologies could potentially increase stakeholder participation, increase self-determination or invoke reciprocal feelings, all of which could have a positive effect on compliance (Richter & Soest, 2012).
The technologies could also make management alternatives more promising, such as a registration obligation (Visned, 2018). The registration obligation would require fishermen to register all quota fish with video images as proof so that they could be subtracted from the quota. Afterwards, the fish could be thrown back into the sea to spare cargo space and to give the fish a chance at survival. This alternative for the discard ban could have potential, which makes it worth studying further.

1.2. Research questions:

- Can on-board camera technology be used to create voluntary compliance in fishermen towards the discard ban?
    - What insights can we gain from existing monitoring techniques?
    - Are automatic sorting or in-net cameras effective enough to make on-board camera monitoring attractive for fishermen?
    - Is a registration obligation a feasible alternative to the discard ban?

2. Theoretical Framework

Compliance can be defined as a person's behaviour that conforms to a contract's rules. Governments and private actors may adhere to a contract for many reasons having little to do with what the contract dictates. These reasons can be broadly categorized as arising from independent or interdependent self-interest (Mitchell, 1993). According to the compliance theory (Mitchell, 1993), independent self-interest means adhering to a contract out of fear for repercussions or because there are benefits, monetary or otherwise, to themselves. Interdependent self-interest is complying when a contract involves multiple actors that benefit from working together. The problem with contracts involving multiple actors however, is that some may not be willing to put in as much work as others if it has no effect on the received benefits. Something often the case with contracts involving common pool resources (Mitchell, 1993). The contract itself will becomes less effective due to these self-interested actors, which makes other actors unwilling to put in the right amount of effort as well, as they do not want to benefit the freeloaders. Eventually this leads to a situation where everyone knows that if everyone cooperated it would be beneficial for all, but everyone is too afraid that someone might not contribute, and thus nothing gets done. This is the commonly known prisoner's dilemma (Mitchell, 1993).
There are mechanisms that can facilitate compliance to contracts however. These range from giving financial aid, to developing technology to make compliance easier, or facilitating discussions between various parties to improve cooperation. There also remains the possibility to instead use deterrence methods, such as fines to enforce a contract (Mitchell, 1993). These mechanisms however do not give the complete picture of why people adhere to contracts. This is because the traditional self-interest model does not take into account voluntary compliance, as a result of reciprocity or intrinsic motivations.

Reciprocity is the response to friendly actions whereby people act more cooperative than traditionally predicted by the self-interest model. It also means that in response to hostile actions they can be much more uncooperative in return, even if it is detrimental to themselves (Fehr & Gächter, 2000).
Although still not all people show reciprocal behaviour, in fact, 20 to 30 percent of the people still behave according to self-interest theory alone. Reciprocal people can however force self-interested people to cooperate by retaliating if given the opportunity (Fehr & Gächter, 2000). This opens up more ways to create compliance to a contract.
Another example where reciprocity causes a higher return compared to what the self-interest model would imply is in incomplete contracts, such as wage contracts. In an experiment from Fehr, Gächter & Kirchsteiger (1997), employers would like their employees to put in an effort of 7 on a scale of 1 to 10, but always give the same wage in return. In a self-interest model, effort of the employee would always equal 1. If employees give more generous wages however, the reciprocal people were inclined to do more, raising their effort level to 4.4. This is still not enough, but it is more than the self-interested employee would provide (Fehr, Gächter & Kirchsteiger, 1997). Expanding the model with retaliation in mind, the effort level can be increased further. If the employer rewards or punishes their employees for their performance, the desired effort level as stated in the contract is reached in 74% of the cases, in 38% the level is even exceeded, something not seen without retaliation in mind. This evidence suggests that reciprocity can make a big difference in the enforcement of contracts (Fehr, Gächter & Kirchsteiger, 1997). Reciprocity is especially handy when dealing with groups of people, as it was found that group reciprocity also exists. This means that if one does a good or hostile action against one member of a group, the whole group will respond more favourably or hostile to this person or the group that person belongs to (Moreno-Okuno & Mosiño, 2017). This means that one only needs to convince a few people of their good intentions, to make sure the entire group adheres to the contract.

Besides reciprocity, compliance can also come from the intrinsic motivation of people. Intrinsic motivation can be defined as an actor doing something because it is morally right or gives the actor a sense of fulfilment (Andries & Soest, 2012). Interestingly the effect can be both helped or hampered by external intervention, in this way it is like reciprocity. It was found that incentives can be considered inadequate or restricting, causing the receiver to lower their effort level compared to when they were purely intrinsically motivated. This causes them to become purely externally motivated, this effect is known as "crowding out" (Andries & Soest, 2012). This means that it is very important for a government to assess the proportionality or supportiveness of a given incentive to stimulate intrinsic motivation or "good behaviour". Without proper incentives, the effort put in by the actor will be lowered due to crowding out. Nevertheless, with proper incentives the actor will put in more effort compared to before, either because he is now entirely externally motivated, or because his intrinsic motivation has been strengthened (Andries & Soest, 2012).

Ways to strengthen intrinsic motivation are varied, but it is thought that it is best done in a way that does not reduce the sense of self-determination, the policy is perceived as legitimate and fair, and it supports social norms in place. If one were to combine these points, it can be said that playing into direct stakeholder participation is the best way to intervene (Andries & Soest, 2012). This has to do with the fact that with stakeholder participation, good and bad behaviour becomes more visible for everyone. As a result, it may strengthen personal or social norms towards the wanted behaviour, because it gives individuals the opportunity to lead by example or gives opportunity to punish those that show bad behaviour. All in all it makes everyone more likely to stay in line with the group's norms and does so without further restrictive regulation from the government (Andries & Soest, 2012; Kinzig, et al., 2013).
Therefore if the government were to stimulate the development of technologies it could help increase interaction within a group of fishermen, potentially leading to increased compliance, something worth studying further.

3. Fisheries monitoring & management in the Netherlands

In this chapter an overview is given of the current situation in European and Dutch fishery management and some of its history, as well as some recent developments applicable for the Dutch fisheries.

3.1. Introduction of the fishing quota

Back in 1975 a fishing quota was first introduced in the Netherlands according to the new common fisheries policy at that time. It was introduced as concerns of overfishing had reached a tipping point. Fish stocks had been overfished for years and were collapsing, something had to be done. However, during this time the Dutch fleet had just made investments in new equipment, something other fisheries in Europe had not done due to their static nature (Davidse, et al., 1975). This created fear under the fishermen (Ruigrok, et al., 2018), there were especially doubts about their ability to compensate the lost sole catches with extra cod and whiting catches, as they had not been able to catch the amount that the new quota allowed for those species in years. Therefore it was expected the fisheries would be facing a difficult year with the introduction of the quota. However, it was expected to be a difficult year either way, due to inflation, rise in gas prices, overcapacity of the fleet, and the inability to increase catches despite increasing fishing effort. Some grievances were justified however, as there were indications that other countries did not take the national quota system seriously apart from the Netherlands, which would also mean a worse competitive position. Therefore it could be concluded that the time during the introduction of the fishing quota, the Dutch fishing fleet was in a heavy economic crisis (Davidse, et al., 1975).

At the time the Dutch agriculture and economic institute called for individual transferrable quotas (ITQs) as the best solution for the new national quota policy, as it would prevent a race for the fish where the "strongest" would fish away the entire quota. Moreover, it would also introduce a favourable situation for fishermen that wanted to quit fishing, as they could sell their ITQs for a last bit of cash to get a good pension (Rijneveld & De Wilde, 1974). At first the government did not opt to introduce transferrable quotas however, but after a few years it turned out that fishermen were unofficially transferring quotas anyway by simply transferring boats and people between companies as well as by splitting or merging enterprises. Therefore it was decided to introduce official ITQs and give fishermen the freedom to organise themselves in quota pools, although the development of the pools was not completed until 1992 (Smit, 2001). Besides this measure, the government also gave money to fishermen so they could quit, or avoid going bankrupt due to the introduction of quotas (Postuma, et al., 1980). With these regulations it was hoped the impact of the top down decision of introducing a quota system could be reduced. Nevertheless, it still came to conflict between fishermen and government officials in the years after the introduction of the quota system due to a failure in effective control and slow handing out of punishments. Most fishermen did not adhere to the rules and fished more than their individual quotas allowed causing early closure of the fishery and more angry fishermen. A low point in the clash between fishermen and government was the rise of a black market for fish (Postuma, et al., 1980; Ruigrok, et al., 2018: Smit, 2001). This black market also caused the fishermen to again invest in new ships, while the government had tried to decrease the fishing capacity in the years prior by buying out fishermen. With the adjustment in the CFP in 1983, the government decided to include extra measurements to limit fishing effort by limiting horse power and days-at-sea, as ITQs on their own had been unsuccessful in adjusting landings in line with allowed catches. Nevertheless around 1995 most fishermen considered the existence of ITQs positive and the program could be considered a success (Smit, 2001). Especially the development of the quota pool groups has contributed to the success of the program, as it

allowed the government to deal with much less people when handing out quotas. Now they only had to deal with eight groups, while otherwise they would have to approach each fisherman individually. Moreover, the groups monitored their fishermen themselves, as fishing more than the allowed quota would hurt everyone (Salz, 1996).
Although initially there were fears not everyone would join a group, by the end 95% of the fishermen did join up. This was mostly because of the threat of withdrawing licences if the industry could not prevent overfishing of quotas and because there was more freedom in the trade regulations within a group than outside one (Salz, 1996). In hindsight this kind of co-management had a larger influence on decreasing fishing effort than the extra measurements the government implemented in 1983 (Smit, 2001).

3.2. Current monitoring

Current fishery management in the Netherlands mostly comes from the EU. Management of fisheries depends heavily on many monitoring technologies. Within the Netherlands the following systems are used: the electronic recording and reporting system (ERS), vessel monitoring system (VMS), vessel detection system (VDS), and the automatic identification system (AIS). These systems are all mostly used for tracking and identifying fishing vessels at sea, however the ERS is also used to gather data on gear, catches, landings, sales and transhipments (European commission, 2016a). The ERS or e-logbook is compulsory for all fishing vessels, however vessels between 10-12 meters also need to keep a traditional paper logbook. The ERS system for vessels smaller than 12 meters is called the e-lite logbook but requires the same data to be filled in as with the ERS (RVO, 2018).
The data in the ERS and e-lite logbook needs to be transmitted to the *Nederlandse Voedsel- en Warenautoriteit* (NVWA) and *Rijksdienst voor Ondernemend Nederland* (RVO) respectively once every day, on request of inspection, or after the last fishing operation (European commission, 2011; NVWA, 2018; RVO, 2018). The ERS and e-lite logbook are however dependent on data put in by hand and not detected automatically, making it susceptible to fake inputs. This means that regular inspections at sea are still required to ensure that logbook data complies with catches found aboard. Nevertheless, the electronic logbook revolutionises the way data is collected and reported, as now catches can be linked to individual fishing operations and position at sea (Girard & Du Payrat, 2017).

The VMS, VDS, and AIS systems are detection and identification systems. VMS and VDS make use of satellite data, VDS is used to identify the position of multiple fishing vessels within a given area through satellite images. Meanwhile VMS identifies the position of an individual fishing vessel as well as the vessel's speed similar to the GPS one may use in a car. VMS can also be combined with the Global Packet Radio System (GPRS), which is an alternative of VMS making use of the GSM network instead of satellites. The benefit of the hybrid system is that fishermen can still use their mobile phone cheaply a little further out of the coast compared to without GPRS and only switch to satellite communication six to eight nautical miles from the coast (Girard & Du Payrat, 2017). AIS is a system that is used by all large vessels at sea, and gives the position and identity of a ship to other nearby vessels and potentially also the coast through direct signals (European commission, 2016a). The advantage of AIS to fishermen is that they can also know the position of other vessels in low visibility, avoiding collision (Girard & Du Payrat, 2017). VMS and AIS are compulsory systems for ships larger than 12 and 15 meter respectively. VDS is not compulsory, but a country's fishery control authority does need to have the technical capability to use it (European commission, 2016a). The data from VMS and VDS are sent to the NVWA in the case of the Dutch fisheries, whereas data from the AIS is send to Rijkswaterstaat.

VDS and VMS can be used together to cross reference the position of the vessels in order to ensure compliance. VMS sends out a signal to a satellite, and VDS can be used to get an image of the ship that send the signal (Alvarez & Indregard, 2003). Detection by the VMS can be circumvented with a metal bucket over the transmitter, however VDS cannot be avoided (Gad &

Lauritsen, 2009). AIS can also be used to crosscheck the VMS or VDS, as AIS works with radio waves. The captain can turn off both VMS and AIS, however, doing so often could be recognised as a pattern making it risky. Besides intentionally turning the system off, AIS may also suffer from radio interference making it less reliable (Girard & Du Payrat, 2017). This means that aircraft and ship patrols are still needed (Alvarez & Indegard, 2003), however they are spotted from far away and can only confirm caught species and discards by boarding the fishing vessel. Boarding can be dangerous and influences fishermen's behaviour, it is unlikely they continue any illegal activities with surveillance nearby (WWF, 2015). Once fish are landed they are weighed and auctioned, however before being sold the boxes of fish are crosschecked with the logbook data by the auction. After the auctioning the auction data is handed to the NVWA (visserijnieuws, 2018). All in all, current monitoring is extensive, but it is not all-knowing.

3.3. Changes in monitoring

Currently there are a few changes happening worldwide when it comes to better monitoring of fisheries. A first example of this is a result of the increasing importance of monitoring catches since the implementation of the landing obligation in 2015 by the EU (Veiga, et al., 2016). Effective management is difficult with current monitoring technologies, as none of those can be used to see on-board processing, therefore the EU remarks the possibility to make use of on board cameras (European Parliament and of the Council, 2013; WWF, 2015). Using cameras however would require a complete restructuring of the current governmental institutions involved in fisheries monitoring, as data needs to be collected and reviewed. This would likely require a substantial number of new employees doing very intensive labour. Reviewing of video material can be decreased to 20 minutes on average per haul in cod fisheries, but would still take hundreds of hours for the whole Dutch fleet (Bergsson, et al., 2017).
Nevertheless, cameras have been proven effective tools to recognise discarding and can be used to identify and measure the sizes of caught fish when relying on the human eye (Bergsson & Plet-Hansen, 2016). As of yet no EU country has implemented the use of on-board cameras beyond research projects, however in Australia and Canada they are already compulsory for certain hook and line fisheries (AFMA, 2015; Stanley, 2014).

Another technology that has been gaining popularity according to the OECD is the smart weighing system at sea. This weighing system can automatically weigh fish at sea and electronically tag fish boxes. The tag makes traceability from net to fork possible, while the weight data can be used to accurately fill in the electronic logbook, avoiding fines for wrongly estimating catches (Seafish, 2011). The data is also sent regularly to the shore in order to get accurate landing estimates, giving an additional reference for when the landings are checked before auctioning. Smart weighing systems at sea are however not yet compulsory in the EU and sometimes not even accepted as legal weight data by the authorities, as is the case in France. (Girard & Du Payrat, 2017).

Besides the above, the use of drones is also likely to increase in the near future as a replacement of the manned surveillance planes and ships. Some drones can stay out for much longer compared to manned surveillance vessels, however they do not have the capability to board. Drones can also be expensive, especially the ones that can actually go further than a few hundred meters, and international regulations are not yet in place making the use of drones difficult (Girard & Du Payrat, 2017). Nevertheless, tests with small drones are taking place, for instance in the Netherlands a test is being done where drones are used to check illegal nets and mesh sizes of standing wall nets near the coast (Koolhof, 2018).

With all the new monitoring methods, it has become more difficult to analyse the data effectively. The problem with gathering data at the moment is that a lot of systems use different formats, making the development of a unified database difficult. Nevertheless there are currently attempts to unify the data for easy exchange between parties. Examples are the

European FLUX program, and the worldwide programs Global Fishing Watch and The Eyes on the Seas Project. The European FLUX program attempts to i.a. unify the electronic logbook data with VMS data, the goal being to increase traceability for all (Ceccarelli, 2018). The global projects meanwhile attempt to unify all VMS and AIS data worldwide to get a world map of fishing activity to make illegal fishing more easily detectable (Girard & Du Payrat, 2017).

3.4. Current management

In the European Union the Common Fishery Policy (CFP) is leading for all fishing done by nations within the EU (European Commission, 2009). Many of the CFP's laws are there to help the EU fisheries manage the shared waters and have the fisheries reach maximum sustainable yield instead of overfishing. To this end it was decided that the EU has the authority to manage the various fish stocks in European waters and set and divide the total allowable catch (TAC) amongst countries. Moreover the EU gives out subsidies and sets rules to regulate fishing activity, fleet sizes, and access to waters. The EU is also responsible for international policy on working with non-EU fisheries and the setting of standards and requirements for clear product labels (European Commission, 2009). Every so often the CFP is also updated to account for new developments. In 2013 for instance new regulation was added for the European fisheries which banned the discarding of certain target species. This landing obligation has been slowly implemented in the Netherlands since 2015, and was fully implemented in 2019 (European Commission, 2016b).

Although it may seem that the CFP decides all fishery policies of the EU member states, this is not truly the case. The policy leaves a lot of room for countries to decide things for themselves, as to prevent regulations from becoming too centralised. Nations can decide, among other things, further gear restrictions, the division of given TAC amongst the country's fishermen, and may lobby for exceptions on EU wide regulation (European Commission, 2009).

Currently the most important topic in fisheries management is the landing obligation, as it is still relatively new (European Commission, 2016b). As said, the landing obligation bans discarding of quota species, which is an interesting change. Previously total allowable catch was measured in landed fish, while discarded fish were left uncounted. The new system actually counts both, meaning the system automatically changes to a catch quota system where the entire catch is counted against the TAC (Hatcher, 2014). Knowing the exact catches allows future quota assessments to be more accurate and works towards a correct calculation of the maximum sustainable yield, alleviating some fishing pressure.

There is some indication that the discard ban may not always lead to the reduction of fishing pressure however. It was found that under a total discard ban some species may benefit and have a stock increase, while others such as the saithe stock decreases as a result of changing strategies. In this case, cod are generally the target species for a fishery, and to avoid wasting cod, areas with undersized cod are avoided. However, the areas that are fished have a lot of undersized saithe, which was shown to result in a decrease of total stock (Simons, et al., 2014). Juvenile bycatch can be seen as problematic due to the fact that selling undersized fish for human consumption is not allowed. The reason for this is that one of the goals of the discard ban is to force fisheries to become more selective by more or less increasing costs of catching unwanted fish. However, the original goal of the discard ban was to prevent food spillage, something that seems to have a lower priority now considering undersized or over quota fish is not allowed to be consumed but still has to be landed (European commission, 2016b; Blake, 2011).

Although under the discard ban quota species are not allowed to be discarded, the policy does not alleviate the main reason for discarding, namely being over quota. Instead the discard ban is likely to cause choke species to form. Choke species are low quota species that will prevent fishermen from fishing after the quota is filled, something feared to happen after only a few weeks of fishing (Hatcher, 2014). Fishermen may feel that they cannot be profitable without discarding undersized or over quota fish, as those are not allowed to be sold at a profit but still take up cargo space. Moreover, they will be fined for catching over quota species and will not be allowed to fish further on other fish that still have quota left due to the chance of catching species with a depleted quota. This may make fishermen less likely to comply as the regulation would be seen as incompatible with fishing practice (Nielsen & Mathiesen, 2003). Of course, incompliance would mean fines if they are caught, however the economic benefits of discarding may be considered larger than adhering to the law if fines are not high enough and chance of capture is low (Wiium, 2001). To ensure more compliance, the EU therefore decided to allow discarding of species with a high survival rate up to a certain percentage, or if becoming more selective is not possible on the short term, as is the case with the Dutch mixed demersal fishery according to M.A. Wegen, Policy officer European Fisheries at the Dutch ministry of agriculture, nature and food quality (personal communication, 07-04-2019).

3.5. Changes in management

Fishery management is not static; it changes due to changing international relations or treaties, as well as due to environmental changes, new scientific insights and economic reasons. For instance, in 1976 fishing waters were extended to 200 nautical miles in accordance to new international rules. Meanwhile the CFP is revisited every few years for reform, it has for instance been adapted multiple times due to concerns of overfishing. This has resulted in a reduction of fleet size, while in 2013 the landing obligation and TAC according to the maximum sustainable yield principle were introduced (European Commission, 2009; European Parliament and of the Council, 2013).

Changes in management do not always work out the way it was hoped. If one looks into the changes made during the various alterations of the CFP over the years, one finds that it has been difficult to combat overfishing, as policy has changed multiple times on the matter. It is known that there are many factors involved in overfishing, but the main one is the insufficient enforcement of advised TAC. There are simply a lot of difficulties with monitoring at sea. Often the ICES advises much lower quotas compared to what politicians decide on, as they do not want to upset the fishermen when they suddenly should be fishing much less compared to the year before. This causes overfishing in the long term even if those quotas are enforced well, as they would still be above the maximum sustainable yield. Nevertheless, difficulties with enforcing quotas on fishermen, as well as the unknown exact amounts of discards also are a large contribution to overfishing in the EU (Villasante, et al., 2011).
Besides having difficulty implementing management plans as intended, fishery management has also shown to sometimes be slow at adapting new monitoring technologies in their plans. This can be seen in the implementation of the VMS, fishermen had already been using satellite positioning at sea since 1990 (Eigaard, 2009), however it took until 2005 for the EU to make VMS mandatory and use it for monitoring (European commission, 2006). Implementation of the VMS did radically change fisheries management once it became available, as it became much easier to close down areas for e.g. nature conservation (Cady, 1999). Moreover, it became possible to follow all fishing vessels and see potential fishing activity by looking at the speed at which the vessel is traveling, a slow speed could indicate fishing activity (Girard & Du Payrat, 2017).

A possible future management change may come with the implementation of the fully documented fisheries, the monitoring technique that makes use of on-board cameras. Camera monitoring may make it possible to change the catch or landing quotas to a quota system of individual fishes not linked to size or weight. Other options are to implement actual catch quotas where fish does not necessarily need to be landed (Visned, 2018).

3.6. Management and fishermen behaviour

In previous research it was found that fishermen behaviour is influenced significantly by technology and fishery policies. With the introduction of the VMS system, fishermen started to zigzag between two quota areas, as it was a way to circumvent regulations with minimal chances of detection. By zigzagging they could claim fish were caught in one area where the quota was not filled, while the fish actually came from the other area. Besides zigzagging, fishermen give each other the position of patrol vessels to lower detection chances further, as those could be easily spotted from a distance (Gad & Lauritsen, 2009).

Besides this kind of behaviour to circumvent detection, fishermen also behave differently when given certain benefits for participating in research or for using certain technologies. The government hands out these benefits, an example of this in the Netherlands was the benefits given in Helmond, et al. (2016)'s research. In Helmond, et al. (2016)'s research participating fishermen received an increased personal cod quota as a percentage of what they caught the year before, as well as more allowed days at sea increasing fishing flexibility. This benefit was given in return for installing on-board camera monitoring equipment and stopping the discarding of cod. It was found that these benefits had a big impact on fishermen behaviour, but also that there are differences between fishermen in how they make use of the benefits. Fishermen with small vessels took more advantage of the increased days at sea, whereas those with larger vessels changed their strategy and bought more personal cod quota so that the amount of extra allowed cod catches was much larger than initially thought by the researchers. The reason for why smaller vessels preferred the increased days at sea was that they could not focus on catching cod, as rich cod waters were too far away, thus the extra cod quota did not give them much benefit (Helmond, et al., 2016).
The difference between preferences is in line with Salas & Gaertner (2004)'s research, where it was noticed that small scale fisheries have very different needs and wants compared to large scale fisheries. But also between types of fishery the preferred benefits differ, although most do prefer direct payment or more days at sea (Mangi, et al., 2015).

Knowing this, policy makers may be able to come with more suitable benefits for each fisherman, allowing for a more effective introduction of new technology or new management. As without any concessions from the government, fishermen may feel attacked in their livelihood. Even with established cooperation however, if a fisherman wants to cheat the system he will likely still find a way. Moreover, handing out benefits may be good for fishermen, however they may cost the fishery manager more than they initially wanted, as was the case with the cod quotas in Van Helmond, et al. (2016)'s research. In Van Helmond, et al. (2016)'s research fishermen bought extra cod quota from others to increase the amount of extra tonnage they would be allowed to fish, because they would get a percentage over what they fished the year before. So, by increasing their catches they got allotted even more quota, meaning they were allowed to fish much more than the TAC would normally allow, which puts more stress on the population than originally accounted for.
A fishery manager needs to watch out that the policies in place do not result in unforeseen damages, especially because handing out benefits is one thing, but taking them away again may result in angry fishermen. For instance, up to 54% of global high seas fishing fleets would be unprofitable without subsidies, and they will likely not go bankrupt quietly if those subsidies were cancelled (Sala, et al., 2018). Therefore it could be said that relying on government benefits to incentivise fishermen to participate or comply is not always a good idea. It crowds out a fisheries' intrinsic motivation to comply (Richter & Soest, 2012). Other management tricks may better influence fishermen behaviour instead.

Co-management is one way to increase trust between the government and fishermen. In co-management the policy makers and fishery lobbyists try to come to an agreement on new policies and monitoring methods. It is a way to increase compliance as the fishermen may feel like they have chosen for the policies themselves through the involvement of the fishery lobby.

Engaging fishermen has been difficult in the past, due to the traditionally closed fishermen society, however in the last two decades this has seen a change within the Netherlands (De Vos & Mol, 2010). Since the 90s co-management is said to have lead to the decrease of black market fish and to more research participation by fishermen within the Netherlands (De Vos & van Tatenhove, 2011). It may be because participation is said to be a good way to change social norms and influence intrinsic motivation of participants (Richter & Soest, 2012; Kinzig, et al., 2013) However, due to the nature of the CFP it is sometimes difficult to co-manage everything, as the EU directly decides on some policies such as the discard ban. This decreases trust again, which is why in such a case good enforcement and monitoring is still necessary to ensure compliance to the regulations of the CFP. Within the EU this has not always been the case, which is why the EU is currently trying to level the playing field of the monitoring of fisheries between countries (European commission, 2018). Once fisheries between countries are more equal it may again lead to increased co-management, even between countries, as no unfair advantage between countries would exist.

Besides co-management another management option is to incentivise the use of monitoring technology so it becomes easier to enforce the rules. For the discard ban it has been said before that the on-board camera would be an almost necessary tool to be able to enforce the ban (European commission, 2018). Incentivising technology is not just handing out beneficial regulations, but also encouraging the development of the technology to become profitable for the fishermen. For instance, the systems used to determine the position of fishing vessels such as the VMS and AIS, also benefit the fishermen. These systems enable the fishermen to see their own position, but also to see the largest aggravation of other fishermen so that they can either avoid those areas, as they would already be fished, or to go to those areas because there may still be some fish left (European commission, 2016a). The systems increased their fishing power and could help detect illegal fishery as well, the AIS also prevents collisions in low visibility conditions.
Developing artificial intelligence to detect, measure and weigh fish could be a good way to incentivise fishermen to start using on-board cameras, as it could make automated sorting possible, decreasing costs there (Ibrahim & Sultana, 2006).

4. Monitoring technologies

In this chapter we will take a deeper look into the various monitoring technologies available such as, VMS, AIS and the e-logbook in the Netherlands and how it changed the fisheries. After that we will take a look at current use of on-board cameras in other countries, what these systems are capable of and what the current development of these systems is at this point in time.
Thereafter, we will look into what the possibilities are for combining camera systems with other technologies and the advantages of such systems for fisheries and managers in the Netherlands, and how it could benefit the situation for the discard ban. Lastly, the various technologies are put side by side to investigate the various effects they may have on the motivation and compliance of the Dutch fishery.

4.1. Tracking systems

In the Netherlands the vessel monitoring system (VMS) was first introduced in 2005 (European commission, 2006), while the automatic identification system (AIS) was introduced in 2002 (European parliament, 2002).
The introduction of the VMS brought some complaints, but it was nowhere near the disturbance created by the introduction of the quota system. The complaints mostly consisted of privacy concerns and the effect it could have on competition, but those concerns quickly subsided once it became clear the data was not shared with other fishermen and the signal frequency was at most hourly (Shepperson, et al., 2017).
Despite the hourly signal frequency, the VMS can be considered an incredibly beneficial technology for fisheries management. With the introduction, it became possible to accurately see each fisherman's position at sea, while it could also give the speed and direction of the vessel. With this information it became possible for managers to guess when fishing is taking place (Hintzen, et al., 2018), allowing fishing grounds to be mapped accurately (Jennings & Lee, 2011). As a result monitoring vessels had more accurate and predictable destinations, significantly decreasing the amount of time searching for vessels at sea.

Besides VMS, AIS is another important tracking system at sea. Other than the VMS, the AIS was introduced as a safety measure at first, however this changed when it was found to be useful for identifying fishing vessels as well. It is more temporally accurate compared to the VMS, as the signal frequency is much higher ranging from once every second while travelling to every 5 minutes when anchored (Malarky & Lowell, 2018). Nevertheless, there is a big disadvantage with AIS, namely the susceptibility to radio interference, and the fact that some fishermen turn their AIS off while fishing out of fear of competition. This leads to a lot of missing data (Shepperson, et al., 2017). Due to the missing data AIS cannot replace VMS, but does prove especially handy as a cross-reference for the position given by the VMS, in fact combining the two makes more accurate data than either can give on their own (Malarky & Lowell, 2018).

Using VMS and AIS for tracking the position of fishing vessels at sea has lead to a big advantage for fishery management, namely the closure of areas at sea for fishing (Cady, 1999). Closing down areas for fishing was not always met with positive reactions from fishermen however, as it would mean less catches and therefore a loss of income. In fact, it was calculated that closing the coastal area of the Netherlands, Frisian front, Dogger bank, Cleaver bank and the central oyster grounds, would result in a decrease of value between 10-15% of the total catches. However, this research did not account for shifting fishing grounds and diverting effort, meaning that in reality the closure of the areas would result in less decrease of value as fishermen would simply start fishing elsewhere (van Oostenbrugge, et al., 2004). Moreover, management reasoned that closing fishing grounds would be beneficial for fishermen in the long run, as a closed area would mean a safe haven for fish where they could multiply and grow before swimming into other areas where they could again be caught. This is called the "spill-over" effect (Halpern, et al.,

2009). However, for most marine protected areas this spill-over effect only works for sedentary fish, and not migratory fish (Breen, et al., 2015). Migratory fish do not stay in one area, and are therefore thought to not benefit as much from marine protected areas. Still, with effective management and either a very large protected area, or multiple smaller but connected protected areas, migratory fish could also benefit and increase in stock size (Breen, et al., 2015).
Such large protected areas would be difficult to monitor without accurate and frequent location updates from fishing vessels. The VMS is capable of being very accurate, as Hintzen, et al. (2018) shows that the spatial fishing effort can be mapped at an accuracy of 24x24 meters. Nevertheless, due to the infrequent location updates of the VMS, management still has difficulty preventing fishermen from using tricks to make it possible to fish inside marine protected areas, such as zigzagging on the border or simply turning off the AIS (Gad & Lauritsen, 2009; Malarky & Lowell, 2018). The zigzag strategy is however not the fault of the technology but a managerial choice to lower VMS transmission costs for fishermen, as Shepperson, et al (2017) points out.

4.2. The e-logbook

The e-logbook was introduced in 2010 as a replacement for the old paper logbook (Visserijnieuws, 2009). It was introduced to make the administration of the fishing trip more easy. No more missing pages during inspections, but also a clear overview for the fisherman of what needs to be filled in, even including an equation to calculate live weight of the catch (Visserijnieuws, 2009; vistikhetmaar, 2016). Simply put, the e-logbook has made administration much more streamlined and faster, especially because the data no longer needs to be sent to different institutes separately (Visserijnieuws, 2009). Nevertheless, oversights and cheating are still possible, as the data is still filled in by hand, unless one makes use of auto-weigh systems (Seafish, 2011).
Although there have been plenty of benefits, it is difficult to visualise the impact the e-logbook has had on the Dutch fisheries management. The biggest impact for management has been in saving time and money, up to 1.1 million euros in the year after introduction in fact. But the ones that benefitted the most after the e-logbook introduction are the fishermen; they saved over 4 million euros simply by saving time on paperwork. Besides this financial windfall, the fishermen increased their transparency by having clear data and better data gathering, which has made it easier to apply for, and keep sustainability labels (Visserijnieuws, 2009).
In Canada the e-logbook has made another impact in more recent years. Here the logbooks are used in combination with camera images in the halibut fishery, which works with a catch quota system (Stanley, et al., 2014). By taking a sample from the camera images and crosschecking it with the data from the logbook, it becomes possible to estimate the total catches (Emery, et al., 2018). This way the government saves money, as without the data from the logbook all camera images would need to be reviewed (Stanley, et al., 2014).

4.3. On-board camera systems

On-board camera systems, also known as electronic monitoring systems are systems capable of capturing images of fishing activities. The systems usually consist of multiple cameras that grand the observer a view of the deck, the nets, and the sorting of fish (see Figure 1). Due to the nature of most ships, cameras that are used to observe the sorting of fish are often in danger of getting dirty lenses. This problem is still difficult to solve and requires crew to often clean the lens, although water repellent coatings exists, problems may still occur (Bergsson, et al., 2017).
The camera systems are usually not filming continually, but are turned on when fishing takes place or the net is hauled in. Trawling is often done by an electronic system, which makes it possible to install a system that gives a signal to the cameras to turn on. This also gives the observer the possibility to time the fishing activity. Besides timing the fishing activity, the system can also be programmed to give the location of the vessel. By combining the location and time of the fishing activity the fishing trip can be visualised accurately for monitoring purposes. This automated system is only possible in fisheries that make use of electronic hauling, if the nets are cast and hauled in by hand, than the complete observation of the fishing activity cannot be automated easily (Bergsson, et al., 2017).

Figure 1. Example of camera angles on board a fishing vessel (Helmond, et al., 2014).

Research has shown that the best cameras for the job of analysing the catch are cameras with a square lens instead of a wide lens due to the distortion of the image when using wide lenses. Wide lenses do give a larger frame of view for overview shots (Bergsson, et al., 2017).
The recorded images from the camera systems are stored on a black box and/or send directly to the shore via satellite or 4G. Although the black box should not be accessible by unauthorised personnel there is still a risk of recordings going missing due to tempering with the system, by sending the data immediately to shore this is avoided. Sending data directly to the shore also has the advantage of making live viewing available for the monitoring personnel, moreover it makes live adjustments to camera settings possible which improves image quality (Bergsson, et al., 2017).

Camera systems in use today are mostly not automated yet. Although there have been developments, current use of cameras to regulate fisheries are mostly found to still make use of people to identify fish. This takes considerable time, but with training can still be fairly efficient. In research projects from the last few years, fish were still mostly identified by eye and not by a computer (Helmond, et al., 2014; Bergsson, et al., 2017). Current commercial projects also mostly use identification by eye, the FishFace project in Indonesia is a good example (TNC, 2015). This project makes use of a single camera to take pictures of the caught fish for identification of species and length, as fish are photographed on a special measuring board. The project focuses on the snapper fishery and is used to identify the 100 most common caught fish in this fishery. The species and length data is gathered from all participating fishing vessels and used to calculate population data and catch effort. This data is later made available to the fishermen, but also used by the nature conservancy to give advise on fishery management. The available data gives fishermen an overview of the amount of caught fish per species and which sizes have been caught. This way fishermen can profit from the camera monitoring, as now they have the knowledge to better adapt their fishing strategy to the situation their target species is in (Mous, et al., 2019).

In Alaska, Canada, and Australia it is already policy that some fisheries are fitted with electronic monitoring to ensure no discarding is taking place when it is not allowed, or to count the amount of discards when it is allowed (AFMA, 2015; Loefflad, et al., 2014; Stanley, et al., 2014). Because they have been using this as policy for some years, problems have been discovered with the use of camera systems instead of on-board observers. In the case of the individual catch-quota fisheries, observers do not report the catches fast enough due to the slow processing of video images, causing fishermen to go over quota (Loefflad, et al., 2014). In British Colombia (Canada) this is avoided thanks to observers only reviewing 10% of the camera images while taking logbook data as the primary source of calculating total catch (Stanley, et al., 2014).
Another problem that was observed is the use of blind spots by fishermen to illegally discard fish, as well as the fishermen turning off the camera to discard. Without proper discouragement, like high fines for turning off the camera, such behaviour is difficult to prevent (Loefflad, et al., 2014). In Canada, the observers take averages of previous month into account to spot cheating fishermen earlier. If camera images and logbook data are not in line, the full video has to be reviewed, which will have to be paid by the fisherman. This seems to be enough of a discouragement, as no offenders have been found in the most recent years before Stanley, et al. (2014)'s research.
The camera monitoring taking place in British Colombia seems to be such a successful endeavour, because it was thought up by the fishery sector themselves after a threat made by the Canadian department of fisheries and oceans (DFO). This threat consisted of an ultimatum, either the fisheries would start working together and come up with a plan to give the DFO full insight in total catches of the target species, or the fishery would be closed down until the DFO installed their own plan (Stanley, et al., 2014).

4.4. Automatic fish recognition

In recent years developments in automated image analysis have put the automated identification of fish back on the agenda. Currently multiple companies and researchers are trying to develop artificial intelligence systems that automatically identify certain fish species using machine vision (e.g. Anchorlab, 2018; TNC, 2015; Wallace, et al., 2015). Anchorlab is developing a system for the Australian government and testing a system that recognises angler fish in Danish demersal fisheries (Taylor, 2018; Anchorlab, 2018). Meanwhile, the FishFace project is piloting a camera system from REFIND technologies (Refind, 2018a) to accurately identify multiple similar fish species in Indonesia. And in Alaska the local fisheries science centre has a project developing a system relying on machine vision for the halibut fishery (Wallace, et al., 2015). In the Netherlands a project is said to start according to A.T.M. van Helmond, project leader of the Dutch catch monitoring program, where technology from plant sciences is used to recognise fish species (personal communication , 07-02-2019).

A general fish recognition system seems to be far off, however researchers have been able to identify fish with computer technology as far back as 1982 (Tayama, et al., 1982). The technologies in use back then were very different from today and worked with individual fish. Nevertheless Tayama, et al. (1982) were able to differentiate four fish species with 95% accuracy. In more recent years researchers have managed to develop systems that can recognise more fish, such as Miyazono & Saitoh (2018) who were able to develop a system that recognises 50 species with 91% accuracy after training. The images were however still taken in perfect conditions, with only one species of fish in the picture without anything else in the image (Miyazono & Saitoh, 2018). Other researchers did try to develop systems that could identify fish in less favourable conditions. For instance, Salman, et al. (2016) were able to develop a system that could recognise multiple fish species underwater on a reef with 90% accuracy.
Both researches made use of the same automatic image analysis software named convolution neural networks (CNN) (LeCun et al., 2004). Salman, et al. (2016) preferred CNN to others, as it is able to better recognise moving images, works under different lighting conditions and functions with distorted images. Other tested software was principal component analysis (PCA) (Turk and Pentland, 1991), linear discriminant analysis (LDA) (Mika, et al., 1999), and sparse

representation-based classification (SRC) (Wright, et al., 2009). These however are known to have difficulty distinguishing between similar fish species and varying backgrounds make detection harder (Salman, et al., 2016). Miyazono & Saitoh (2018) improved their system by helped their AI recognise fish by coding it to focus on four particular points (nose, dorsal fin, caudal fin, and anal fin) instead of the whole image. By giving direction to the system, it becomes better at learning how to recognise a new fish and it makes it quicker at distinguishing species later.
Besides recognising species, camera systems can also be used to count fish. In French, et al. (2014)'s research CNN was used to identify fish huddled together on a processing line. By making use of CNN in combination with the N^4-fields algorithm, a nearest neighbour search system capable of finding the natural edges of objects (Ganin & Lempitsky, 2014), it becomes possible to count fish with a 2% to 16% error depending on the conditions of the processing line. The worst accuracy is found in conditions where a lot of guts and fish were on top of each other, while the best accuracy was on a clean processing line with only a few fish (French, et al., 2015).
Once fish can be recognised on a processing line, more data can be gathered by adding new algorithms as well. This was already shown in 1991, when researchers made a system capable of identifying flatfish on a processing line and measuring them with a laser (Storbeck & Daan, 1991). From the measurements the computer was then able to calculate weight by using known volume to weight ratios for the identified fish species. The system was further developed in 2001, which made it possible to recognise cod and whiting as well (Storbeck & Daan, 2001). There was one flaw in the technology however, when a fish convulsed the length measurement was incorrect and needed to be performed again, something that slows down processing speed significantly (Storbeck & Daan, 1991).

The possibility of using automated image analysis for fish monitoring is no longer science fiction. In fact it is already close to a commercial level in the USA, Canada, Australia, and Indonesia (Wallace, et al., 2015; TNC, 2015).
As said, the FishFace project partnered with REFIND technologies to make machine vision possible for the determination of their fishes. However, this technology is its own machine and does not use the simple camera from before. It is a sort of photo booth for fish installed aboard the participating fishermen's vessel. Fish are put in by hand, making it not very automated, but results indicate that the system can be used to recognise up to 65 fish species at sea with good accuracy. Moreover, the system makes real time data collection possible, when the connection to the servers on land remains stable, but if the connection to the servers is lost, the data is stored on a black box instead (Refind, 2018b). As of yet, the photo booth is unable to measure the fish, but this is planned for the future according to Mous, P.J. from FishFace (personal communication, 24-01-2019), as well as integrating the system with on land processing plants, so the processing of fish can be automated further (TNC, 2015).

Meanwhile in Alaska the local marine research institute has been working on two systems for the monitoring of halibut. One that works a bit like conventional electronic monitoring systems, as cameras are placed in such a way that they have a view of the side of the ship from where the halibut are hauled aboard. This system is also able to measure the length of the caught fish.
The other system coincidentally looks a bit like the photo booth system from Refind, except it is connected to the processing line aboard the ship and is also able to measure the length of the halibut with 79% accuracy (Wallace, et al., 2015). Development of the first system has continued using the data gathered from the photo booth system as training images. The goal of the project is now to make the software open source as to help independent development of image recognition systems further (NOAA, 2018). This shows that we may expect an increase in the use of machine learning and image recognition in the near future.

The recent developments are promising, however it must be said that using machine vision to recognise fish or measure length and even weight, is nothing new. New systems should however be better at performing these tasks according to Salman, et al. (2016) and Wallace, et al. (2015), because the technology has improved when it comes to seeing contrasts between moving objects and background. The various techniques used in previous research is something to take into account by a government that wishes to invest in further development of automated recognition systems.

4.5. In-net camera systems

Besides automated image recognition, another advancement made in camera technology is the use of underwater cameras to look inside the net during fishing. By placing cameras inside the net it becomes possible for a fisherman to see what he is catching at that point in time. This makes fishing more flexible (vonin, 2014). For instance, when there seems to be few fish one can decide to quit early and try fishing elsewhere, or when there is too much fish, the net can be hauled in before it gets too heavy and fish get crushed under all the weight.
A.T.M van Helmond, does not see much future in the technology however, as to him it seems to mostly be beneficial for research and not for fisheries. It could however be a way to save marine mammals if integrated with a release mechanism (personal communication, 07-02-2019).

4.6. Automated sorting

Automated image recognition opens the door for new management, but also for other innovations, for instance automated sorting. Automated sorting already exists for vegetables for some time, but there are some pioneers that are trying it with fish as well. REFIND has a machine that is said to recognise and sort fish on land (Refind, 2018c). It is not too far fetched to say that it could potentially be of use aboard a freezer trawler as well, as they already have very complex on-board processing lines, where fish are sorted and packaged by hand (FAO, 2019).
As said in Storbeck & Daan (2001)'s research it was found that measuring length sometimes goes wrong, and needs to be done again. This makes it unviable for commercial sorting, as the system should preferably perform as quickly as a person would. According to White, et al. (2006), their system was able to process fish at a speed of 7200 fish/h, but the limiting factor was in fact the processing line. Fish could be recognised within 20-100 ms depending on the size of the fish, and with a new system it would theoretically be possible to sort up to 30000 fish/h of 10 cm or 3600 fish/h of 1 meter. The system could differentiate seven fish species with 98.8% accuracy, as well as measure length with 1.2 mm accuracy. Because of these results the system was installed aboard a Norwegian research vessel as well (White, et al., 2006).

4.7. Applying the theoretical framework

The above technologies are all interesting in their own good, however it is questionable if they are all suitable as monitoring tool for the discard ban. For that reason the technologies are put through the test seen in table 1 where we look into various factors and effects these technologies may have. With the knowledge gained from the various literature sources used in this chapter it becomes possible to assess technology on their best advantages, worst disadvantages, as well as on their effect on intrinsic motivation and stakeholder participation within the fishery. It is thought that some technologies may have positive or negative effects on trust, self-determination, or legitimacy of a policy. If a technology is reviewed to have an overall positive effect on these factors, it could indicate a positive effect on compliance as well.

Table 1. Various monitoring technologies and their effect on intrinsic motivation and stakeholder participation. Loosely based on fig. 5.2. found in Eikeset, et al. (2011)'s paper.

Technology	**Biggest advantage**	**Biggest disadvantage**	**Effect on intrinsic motivation**	**Effect on stakeholder participation**
Tracking systems	Position of catches can be determined	Easily fooled	May create feelings of mistrust due to being watched. But, it could also be used to map good harvest areas.	Fishermen may keep an eye on each other.
E-logbook	No more "lost" pages	False reporting	Less paperwork for the captain may make him reciprocal and more honest in his reporting.	Data is only shared with the authorities and therefore has little effect on other stakeholders.
On-board camera	Complete documentation of catch	Slow processing of images leads to fisheries going over their catch quota	May create feeling of mistrust similar to tracking systems, but may also give fishermen a tool to support their report in the logbook.	If image processing is handled by fisheries themselves, it can be used to make good and bad behaviour more visible.
Automated recognition	Fast processing of images	Still in development	It allows for more detailed information on the catch while it is still on-board, increasing the sense of self-determination for the captain.	The detailed catch data could be pooled together to give an overview of the stock, giving the industry more information to base their fishing strategy on. This way fishermen can coordinate their strategy better.
Automated sorting	Lowering labour costs	Large machinery may not fit on every boat	The system will save money, which might make the fishermen externally motivated instead of intrinsically. It could however also strengthen intrinsic motivation, as the technology makes the use of cameras more legitimate.	It would lead to a loss in jobs, however profits will increase. An internal conflict in the fishery may happen.
In-net camera	Gives opportunity to release unwanted catches	Not very effective without escape	It increases self-determination, as it gives the captain more options during fishing.	None, as the camera images are only used while fishing.

	like dolphins before it is too late.	hatches in the net.		Underwater images are useless for monitoring.

From table 1 it can be gathered that some technologies have less positive effects on compliance than others. For instance, the tracking systems are thought to create mistrust in fishermen due to their position being shared with the shore and sometimes other fishermen. Although in theory tracking devises could open up further cooperation between fishermen, such situations are not commonly found. This is likely because even with personal catch quota, fishermen still share a common pool resource of variably sized fish. If one fisherman finds a spot with large fish, he is unlikely to be willing to share the information (Shepperson, et al., 2017), as large fish tend to be worth more money. Nevertheless, tracking systems are mandatory and in use by fishermen today, however this does not necessarily make them useful for monitoring new policies like the discard ban. In fact, tracking systems have only a minor role in monitoring the discard ban and could even be put aside entirely. They could be useful for tracing catches and mapping areas where there is a lot of bycatch (Jennings & Lee, 2011), which would help prevent overfishing, one of the goals of the discard ban. However, tracking systems are not useful for determining the amount of catch and landings, and therefore useless for monitoring the discard ban.

Changing the e-logbook to work with the new regulations of the landing obligation could streamline the process of reporting undersized and “over quota” catches. This may motivate fishermen to comply, however due to the nature of the e-logbook, false reporting remains possible. If false reporting goes undetected, the motivation to comply could quickly go away as the legitimacy of the policy is put into question. Therefore it is questionable if e-logbooks alone are enough to make fishermen comply with the discard ban.

The e-logbook may make acceptance of the next technology more easier, namely the on-board camera. Here the e-logbook can shave of a lot of time spend on checking camera images (Stanley, et al., 2014). Comparing logbook data with subsamples from the cameras could make on-board cameras much more attractive. Besides e-logbooks, tracking systems could also be integrated with on-board cameras as both systems are in contact with the land via satellites. Cameras could potentially make separate VMS systems redundant, saving some money.
On the topic of on-board cameras, although they could have some negative effects on intrinsic motivation due to trust issues, they could also be used to increase group cohesion. When camera images are shared amongst fishermen in for instance a quota group, fishermen would find it easier to see if any are going over quota or discard quota species. By making bad behaviour visible to others, social convention could prevent such behaviour occurring (Fehr, Gächter & Kirchsteiger, 1997; Kinzig, et al., 2013). For that reason they could be the only truly effective way to make fishermen comply with the discard ban.

A downside of the on-board cameras is that the processing of images can be quite slow. Without automated recognition for instance, it makes it impossible to process images on-board. For that reason, investment in the development of automated recognition by the government could be highly appreciated by the fisheries. As said in table 1, by having fish automatically identified, the captain will immediately have more detailed information of his catches. He could know the sizes and exact amount of certain species he has caught, making it possible for him to adjust his strategy on the go, increasing his self-determination. It is likely to make him more intrinsically motivated to register his exact catches, which will help in managing the discard ban.
Groups of fishermen could also use automated recognition to pool the information of their catches together, paving the way to creating detailed maps of where which species and what sizes can be caught.
These positive effects alone could make the fishermen compliant, however automated recognition could make the captains reciprocal in another way as well. The technology makes it possible to automate the e-logbook, saving the captain even more time, while simultaneously making false reporting almost impossible, increasing fairness of the system.

As said, on-board camera technology can make a fishermen comply with the discard ban. Some fishermen may be thankful for the decrease in unfairness between fishermen and thus in return comply to the law, while others may only comply out of fear of retaliation (Fehr, Gächter & Kirchsteiger, 1997). However, as seen in table 1, automatic sorting technology could increase compliance even more. If the government were to stimulate the development of this technology, fishermen may become reciprocal due to the decrease in labour costs. After all, a ship would need less handlers when sorting is automated.
When having cameras on-board is beneficial to the fisherman owning the camera, the threshold of using those same cameras for monitoring the discard ban also becomes lower. An example of this is when the government started tracking fishermen at sea. The use of the technology in that way is not very attractive to the fishermen, yet they did accept it. This may have to do with the fact that GPS was already used by the fisheries themselves, and thus they did not have to change much. It could be said to be in line with the norms in place, therefore it is advised that the government invest in the development om automated image recognition and sorting of fish.

Lastly, in-net cameras were looked into. Although they could increase the self-determination of fishermen, due to giving them more knowledge of what is inside their nets during fishing activity, it is unlikely that this would increase compliance towards the discard ban. It could prevent unwanted bycatches, which is in line with the goal of the discard ban, but the cameras themselves cannot be used to monitor discarding.

5. Discussion

From the various sources that have been used in this research it has become a little clearer as to how on-board camera monitoring can change fishery management, but also how the technology may be used to change fishermen's behaviour towards the government regulations.
The various monitoring technologies used today, the VMS, AIS and e-logbook, could all benefit from the inclusion of camera technology. Fishing activity will simply be much more accurately documented, which will help fishery management in getting more insight on total catches and simultaneously save the fisheries money on time spend reporting their catches. This is also why it is such an important technology for the discard ban, as without it, it is almost impossible to know if fishermen are adhering to the ban. Something that may rightly be put into question, when one sees the parallels between the current situation and the situation during the introduction of the quota system back in the 70's. In hindsight it was no surprise that it became an incredibly unpopular decision with limited success at the start of its implementation. The fishermen were in an economic crisis, just like the ones today that were involved in the, now banned, pulse fishery. Moreover, there was hardly any enforcement, both within the Netherlands and abroad, lowering the bar for non-compliance further. The same may be feared for the discard ban, which is why it is important to show fishermen that the discard ban can be monitored.
It is also important to remember that it was only after the proper enforcement of ITQs and when fisheries started to regulate themselves, that ITQs became accepted (Smit, 2001). By learning from this past it becomes clear that in the current situation the discard ban is unlikely to be adhered to without proper involvement of the fisheries.

Proper monitoring and enforcement of the law is needed, as otherwise the fishermen that do adhere to the rules would suffer unfair competition from those that do not. This is where on-board cameras can play a vital role, as they seem the only viable option of detecting discards. Cameras themselves are however also unpopular, so fishery management would have to think of something else instead of making it a top down decision, as that is unlikely to be accepted. By including the fishery sector in the implementation of camera monitoring this may be avoided as seen in British Columbia (Stanley, et al., 2014), which is in line with the theory on intrinsic motivation to comply (Andries & Soest, 2012). By co-managing the camera systems, just like was done with the introduction of ITQs, monitoring becomes cheaper for the government, but it also gives the fishermen a better view of what is happening with their data. The fishermen could also remain owner of their own camera images, which means that they can use the images to innovate further. It allows for self-determination, which is also said to be good for compliance (Andries & Soest, 2012).
Currently, it seems that the Dutch fishery management is following this line of thought, as according to M.A. Wegen, the plan for the next Dutch pilot would make each fisherman the owner of their own images (personal communication, 07-04-2019). Eventually such a situation may change management further to better fit the real situation, just like when personal quota became transferable because fishermen were already treating them like they were (Smit, 2001). But it would be wise for the government to take steps ahead of time to stimulate the already existent quota groups to take up camera monitoring. This way, the groups can monitor themselves and demand compliance to the rules by all members through social contracts. If a group is given the tools and allowed to punish their own, it will make everyone more compliant (Fehr, Gächter & Kirchsteiger, 1997).

Literature has not only shown how on-board cameras may change current monitoring and fishermen behaviour towards the discard ban, but fishery management itself may change as well. Previous introduction of the VMS and AIS indicate that monitor technology can change policies. VMS and AIS made it possible to close areas at sea for instance.
Similarly, on-board cameras may also help tracking systems in this role. As VMS has a low

transmit frequency and AIS an unreliable transmission, on-board cameras could help deter fishermen from fishing inside closed areas. After all, cameras are connected to the land via satellite and could potentially transmit the location of fishing activity (Bergsson, et al., 2017). Although this would save money and make illegal activities more easily detectable, it seems unlikely that cameras would become more popular if they would share even more private data.

The introduction of the e-logbook has resulted in the least commotion compared to the other changes in management discussed here. The main reason for this is likely because it had big positives for the fishermen, namely a reduction in time spend on administration, easier access to sustainability labels, and a decrease in administration costs.
When camera monitoring becomes mandatory the e-logbook will likely be automated further, as data gathered during fishing could immediately be put into the logbook. This further automation may also be used to get fishermen to accept camera monitoring faster, as it would result in a further reduction of time spent on administration. Less time spend on paperwork would result in more time spend on fishing, something that fishermen may feel thankful for. At the very least it would increase self-determination, but admittedly seems unlikely to result in complete compliance with the discard ban on its own.

One problem this thesis faced was the fact that there is as of yet no real governmental policy in the Netherlands when it comes to the use of on-board cameras for monitoring discards at sea. It is only known that for now they will mostly focus on the catch and not general surveillance of what is happening on board, as that seems to be a step too far for most fishermen. Therefore there has been little research with Dutch fisheries and a lot of the literature had to come from grey source material, which may weaken some argumentation in the paper.
A reason for why the Dutch government has not thought much about the implementation of this new technology is that it is simply too novel. The only country within the EU that has put much thought in it yet is Denmark (Bergsson, et al., 2017), something other countries can take advantage of with the help of the EU. By looking at Denmark, the EU may be able to formulate guidelines for other countries when it comes to the implementation of electronic monitoring. This way the introduction of camera monitoring may even lead to big changes to the common fisheries policy in the EU and lead to closer ties between the fisheries of each country. This may be reinforced further if the camera data can be integrated to the FLUX project the EU is carrying out at the moment, which is about unifying all VMS and logbook data within the EU so that countries can exchange this data (Ceccarelli, 2018). If this can be achieved, fishermen can be assured that their colleagues abroad will be subjected to the same monitoring equipment, taking away some of the fears of unfair competition.
The Dutch government and fishery may be in favour of such a solution, as closer cooperation between countries could also prevent a situation as with the pulse fishery. Other countries were very much against the Dutch pulse fisheries, because they had doubts about the monitoring of this equipment and feared that it was killing all fish in the North Sea.
The Dutch government did say that it would lobby for a relaxation on the discard ban if high survivability of the caught species could be proven (M.A. Wegen, personal communication, 07-04-2019). Moreover they are willing to look into lobbying for a registration obligation, where fish are still allowed to be returned to sea, if properly registered in the total catch. Both management changes may need the use of camera images to work.
As of yet, it is doubtful if cameras are advanced enough for a role in registering catches and mortality. The technology that is needed to automate recognition of fish is not yet on a commercial level. It will take time before artificial intelligence is able to differentiate fish on a crowded processing line with many different species lying on top of each other. Which is problematic, as this is precisely the situation the cameras would encounter in the Dutch fisheries. Therefore stimulation of the development of such technologies will be important.

Besides the technical limitations for implementing a registration obligation, there is also a concern from the NGOs that it would stop fishermen from fishing more selectively. They argue that the discard ban forces fishermen to innovate on gear selectivity, but once discards are allowed to be dumped back into the sea, there would no longer be an incentive to do so. As of yet, it is too early to say anything about as no tests have been done with this in mind. Camera technology in combination with automated fish recognition could however alleviate some of the concerns, as they have the potential to increase fish survivability. However, because there has been little research, the opinion of NGOs and the effect it may have on the compliance of the fishermen has not been taken into account.

6. Conclusion

Is it possible to use on-board camera technology make fishermen voluntarily comply with the discard ban? With the research done in this study, it can be said that there certainly is a potential for various technologies to do so. If camera images are handled by the fishermen themselves, like the quota is in groups, than it will allow the fishermen to check each other. This way, the fishermen can force selfish actors to comply with the law and punish them if they do not. Furthermore, helping development of such systems could be seen as a doing the fishermen a favour, in which case non-selfish actors are more likely to adhere to any government policy.

Of course this does mean that on-board cameras themselves need to be accepted as well. But that may not be a problem. Having looked at the existing monitoring techniques, it is clear that they have many flaws. Camera images may however remove some, if not most, of these flaws. Cameras may be in connection with the shore at all times via satellites, this way they can take on the role of VMS and maybe even AIS saving costs on equipment. Camera images can also assist with the e-logbook, giving fishermen evidence of what they filled in. Vice versa, the e-logbook saves money on analysing camera images, as is seen in Canada. Integrating the two systems would therefore help fishermen in accepting camera technology, as it makes the analysis of camera images significantly cheaper.

Besides improving existing monitoring technologies, camera technology also opens up possibilities for new kinds of monitoring and cost saving methods. In this study we looked at three such technologies, namely automatic recognition of catches, automated sorting and in-net camera monitoring.

Automated recognition of catches makes it possible to fill in the e-logbook automatically, saving time and removing the possibility of false reporting, making the system more fair for all. It also makes it possible to accurately map species and sizes of the catch, giving fishermen more information with which they can decide their fishing strategy. Encouraging the development of such a technology would surely be appreciated, enhancing voluntary compliance of the fishermen.

Automatic sorting is also a very promising technology, although still not close enough to being commercially attractive. Especially for the Dutch demersal fishery it will be a while before the automated image recognition technology is far enough to actually recognise all fish species. In pelagic fisheries, such as the herring fishery, the technology is more likely to succeed. Also because the boats used in the pelagic fishery are usually larger compared to the boats used in the demersal fishery. If the technology is proven to be useful it is likely that fishermen themselves will start using cameras on their own volition, as the technology would lower the need for personnel, saving money. When cameras are already on a ship it would lower the bar for using the images as a way to monitor the discard ban.

In-net camera monitoring does not seem to be as useful. It is a way to monitor the catch live, however, according to the professionals it is uncertain if that saves enough money to make the investment worth it. Furthermore the images are unlikely to be useful for monitoring the discard ban.

Lastly, we asked if a registration obligation is a feasible alternative to the discard ban. Although it will be very costly for the government to hire people to check camera images, by doing the same as in Canada, namely only checking 10% of the camera images and cross checking it with the e-logbook, it may indeed be feasible. Considering the registration obligation removes many of the grievances the fishermen have with the discard ban, such as the landing of undersized fish, it is likely to improve their intrinsic motivation to comply. By having a registration obligation the fishermen would be able to fill their hull with saleable fish, instead of having to land undersized fish. Moreover it will remove the argument that with the discard ban you do not give the fish a chance at survival, as discarding would be allowed again.

If the government thinks the investment of cross checking e-logbook data and camera images is too high however, it may instead opt to invest in research towards automatic image recognition. After such technology becomes available, the registration obligation becomes easily feasible and perhaps even desirable.

All in all, it can be concluded that as long as the camera technology itself becomes accepted it is a useful tool to get fishermen to comply with the discard ban. Especially if the camera images are shared with the various quota groups in existence it is likely to result in social convention regulating compliance. After all, going over quota due to illegal discarding would hurt everyone in the group, therefore it is likely they will punish anyone not adhering to the ban.
It is also advised that the governments spends the coming years to invest heavily in the development of integrating camera images with the e-logbook and in the advancement of the technology towards an automated recognition system. This should result in a system that is more fair for the fishermen, as it would be harder to cheat, and a system that gives the fishermen more self-determination thanks to an increase in catch information.

If any of this is done by the government remains to be seen, considering research is still in its early stages within the Netherlands and the EU still has to make clearer policy on how they want the discard ban to be enforced. The next revision of the common fishery policy will be in 2022, perhaps then it will be time again to look into the questions and solutions given in this thesis.

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