

JRC Scientific and Technical Reports



FP6 CEDER Project Deliverable 3.2 “Benefits of a new reporting system”

CEDER Project Implementation plan; expected benefits for government, industry, and science, of deploying information systems based on VMS, electronic log-books, sales notes, frequent GPS positions, and fishery-specific information.

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1 Executive Summary: CEDER Project Implementation Plan

The policy implementation plan summarises the results achieved within CEDER. It details how CEDER project outputs can be applied at the fishery policy management level to ensure envisioned benefits from implementation of project findings can be achieved. Costs involved in that implementation are summarized in Deliverable 3.1.

1.1 Initial expected and obtained results related to policy

The primary objective of the CEDER project was to harness modern technologies in fisheries (VMS¹, electronic logbooks (E-logbooks)) to provide more accurate and timelier information on catches, effort, landings, discards and quota and TAC uptake for European fisheries, and to assess the benefits of this information for fisheries management. Specifically:

The production of a harmonized database for fisheries data from six different fisheries;

Partner OLRAC developed and tested a harmonised database framework (“SUMFISH”). This tool can harmonise a variety of different data sets, at any resolution².

The construction of relationships between these data and national catches, landings; and an assessment of the accuracy of such relationships; the production and testing of a near-real-time system that can monitor catch, effort, discards and landings of these fisheries;

Analyses showed that the development of relationships to estimate catch and landings could not be generic, as approaches depend upon the available data. Therefore a number of case-study specific approaches were developed. CEDER has built several prototypes and mathematical models that can be used to estimate catch, effort, discards, and/or landings:

- Correlation’s ReelCatch prototype is usable in a range of fisheries, where it constructs relationships between input data and landings (split by area, species, and month). It can calculate effort from 15 minute GPS data. Additionally, from E-logbooks it can infer catches, discards, and landings per metier. It does so by using current E-logbooks and the most recently available (sometimes last year’s) discard per metier figures. Note that an estimate on catches and discards may come with a significant coefficient of variance³. We found the estimations made will necessarily be less accurate than stock assessments. Accuracy must be traded in for timeliness.
- Sirius developed a prototype that monitors Greenland shrimp fishery effort, by-catches, and landings. It validates data entered from hail messages and paper logbooks by cross-checking it with VMS messages. It uses hail messages, data entered from paper logbooks, and sales note

¹ Vessel Monitoring System

² Resolution in a spatial or temporal sense.

³ The EU decided on the ERS directive during the lifetime of CEDER. The ERS aims for 100% coverage in E-logbook gathering for many fleets, and is legally binding. At one point in the future, raising may therefore become unnecessary. Indeed, various raising and/or bias removal methods are currently used (for instance by STECF and ICES), and are subject to research (ex. “Choosing the best sampling unit and auxiliary variable for discards estimations”). For such a general case as the above, a cost-efficient option is to implement a comparatively simple algorithm into a prototype, which can be fine-tuned with various approaches. This is the approach that CEDER chose.

data, in order to track quota utilization. It is currently helping authorities to assess the quota uptake for Greenland shrimp⁴.

- CEFAS has developed a UK-vessel specific model (NE and SW England beam and otter trawls, as well as dredges) to estimate effort from 2-hour VMS data⁵. Under CEDER, CEFAS developed a separate model to estimate catch and discards using Bayesian methods in the NE England roundfish fishery specifically. The model fits to the actual data quite closely. However, the catch model requires additional specific information (early information on year class strength from new surveys) to improve estimates. The two models can be simplistically linked to provide a preliminary estimate of spatial catch and discards.
- The FRI prototype (“CARFI”) estimates the effort and landed catch from 2-hour VMS messages, for the Icelandic Redfish fishery⁶. The Icelandic project partners were able to draw a linear relationship between effort (time spent fishing) and landings, at an aggregate level. The linearity of the relationship gets stronger at higher aggregation levels.
- IMARES have researched on spatial and temporal distribution of fishing effort⁷. Initial findings indicate that “a smaller spatial scale results in an increased perceived patchiness of the fishing intensity while a longer time period does the opposite. The implication of this is that in order to determine the fishing-induced mortality of a particular species the trawling frequency needs to be determined at those spatio-temporal scales that are appropriate considering the species’ spatial processes (e.g. dispersion) or temporal processes described by life-history characteristics.”
- The JRC proof-of-concept predicts landings and quota uptake using a time series approach. Usually, the predictions prove fairly accurate. However the model breaks down in case of sudden changes in trends. Therefore, predictions must be interpreted with caution.

The delivery of an outline design for introducing such a system into operation;

This is the subject of CEDER Deliverable 3.1, which focuses on summarizing future communication pathways, data security, costs of transmission, and develops suggestions for implementation.

Deliverable 3.1 studies the requirements for a new reporting system for regulatory and scientific data, which benefits from the technological advances of VMS and electronic logbooks. The study analyses the modifications to existing communication pathways between stakeholders, and estimates the cost of moving to the future system. It analyses the accuracy and timeliness of information received by each stakeholder as well as its confidentiality which applies to landing declarations, hail messages, VMS positions and E-logbooks.

The main constraints and limitations of the existing reporting system are summarized from the Court of Auditor’s “Special Report No 7/2007” report and several enhancements are proposed. These would result, for example, in a speeding up of the TAC assessment, more effective inspections or a more efficient fleet management. The current security issues inside each fishery are described and a discussion on data protection, confidentiality and freedom of information for the future system is given.

⁴ Research financed in part by CEDER has determined that Greenland Shrimp by-catch and discards are known quantities, making this a special case. Additionally, observer coverage is around 50%.

⁵ This particular effort model pre-dates CEDER.

⁶ This is a special fishery, in which a fairly homogeneous fleet fishes in an area with specific biological characteristics.

⁷ See Annex 1

Our recommendations on a standard of data format that includes:

- A set of rules that allow research projects to have access to suitable data
- A set of terms designed to introduce a common terminology in fisheries data
- A set of data formats, based on ERS regulations 1966/2006 and 1566/2007, with added periodic location information, as would be required for a system that integrates “effort while fishing”.

A diverse range of satellite communications technologies capable of supporting the future reporting system have been investigated and compared against their costs which are divided into daily, monthly, first year, and recurring annual charges.

An assessment of the benefits to industry, authorities and to the sustainability of stock and the fishery.

CEDER has examined the potential benefits to authorities, industry and stock sustainability (the latter through simulation), as well as the assessment of ecological impacts of fishing. A summary can be found in this PIP, under the heading “Anticipated benefits of a management strategy based on accurately estimated catches”, “Implications for the ecosystem approach to fisheries management and spatial planning”. Further details can be found in this Deliverable 3.2.

1.2 Potential for application of results within policy frameworks

A new effort measure, effort while fishing

A result with possible policy implications is that CEDER has proven the technological capability of providing accurate effort estimations for many fisheries, using higher-resolution GPS data⁸, owing to the Correlation System ReelCatch prototype. Results can be displayed in a visual and intuitive way. A more precise and automated effort estimation algorithm, “effort while fishing”, could provide useful crosschecks for effort-based management regimes and E-logbook contents and assist in the enforcement of real-time closures. Because it only counts fishing time, it would help in spreading fishing effort more evenly between different fishing grounds of the same area. More so, since this new measure implies inferring time frames during which the boat was fishing, this new measure of effort can be used for verifying the haul by haul information contained in the E-logbook. This would bolster statistical tests, which could subsequently attract attention of inspectors.

As mentioned in the Court of Auditor’s “Special Report No 7/2007”, faster transmission of information using E-logbook can allow improved enforcement. Inspectors would be able to use CEDER’s “effort while fishing” tool for cross-checking purposes, also when boarding vessels, fostering a culture of compliance. A cost-efficient option, for both the E-logbook and the fine-grained GPS data to be available, is to integrate regular positioning data into the E-logbook. Changes to current legislation would be required.

Weak correlation between effort and catches can be useful for inspectors

In a general case such as the one explored by the ReelCatch prototype, the correlation between “effort while fishing” and fishing trip catches, discards, and landings is not strong enough to infer the latter from the former. However this correlation has statistical properties with possible policy implications. For instance, it could be used in order to help an FMC, by drawing attention to skippers that notoriously under-report their catches. Such under-reporting with respect to the other skippers of a

⁸ Frequency of sampling influences detection of behaviour. For demersal fisheries, 15 minute GPS data is deemed sufficient.

same metier class will leave a statistical trace, which is not enough to convict a skipper, but can aid the inspectors in focusing their efforts. As such, days at sea have been used for similar purposes in the past, but “effort while fishing” is a more precise measure, which promises to eliminate some of the variance when comparing days at sea to landings.

A system that cross-checks logbook data versus VMS

The Greenlandic system developed by Sirius under CEDER has helped identify data quality issues that have subsequently been rectified. First, it compares VMS to data entered from paper logbooks. Second, it contains a matching algorithm to attribute logbooks to sales notes. When it encounters issues, a point-based scale ensures that Greenland’s fishery authorities notice the most severe issues first. Sirius’ system is at present used in Greenland to track quota utilization, given that a CEDER-financed study concluded that skippers accurately report by-catch and discards.

However, there are practical limitations in the estimation of discards by skippers in many fisheries. Monitoring of discards in even a basic quantitative way requires special effort by fishers because of the way many catches are processed fish by fish, or mechanically, then immediately thrown overboard. Many skippers do not have the opportunity to monitor discarding, given the need to concentrate on monitoring the movement of the vessel from the wheelhouse. Some progress is being made with self-sampling schemes for discards, supported by scientists on shore, but data will likely be less informative than those collected by trained scientists at sea.

Fishery-specific approaches that predict catches from VMS

A number of different approaches to predicting catches (landings and discards) using data from VMS were trialled. Results proved fishery-specific. In particular fisheries, some approaches were successfully implemented during the project, providing direct benefit for fisheries managers. In the Icelandic redfish fishery, an effort estimation system using VMS data provided a useful cross-check for effort-based management regimes.

Anticipated benefits of a management strategy based on accurately estimated catches (1)

Consider a scenario in which a suitably accurate and precise model for catches would be developed, possibly on a fishery-specific basis, and for which required data would be provided in a sufficiently timely manner. Under these conditions, modelling performed during the project suggests that implementation of a CEDER system could result in benefits for stock recovery, and sustainability in mixed fishery situations. However, it must be noted that benefits require fisheries management to be reactive, with rapid decision-making and enforcement capabilities, which would require changes to the Common Fisheries Policy.

Anticipated benefits of a management strategy based on accurately estimated catches (2)

Consider the same situation as set forth in (1), but this time targeted at single species (e.g. North Sea cod) recovery. Then modelling performed suggests that a better knowledge of the situation in the current year could lead to benefits for recovery of a single stock. However, these benefits from more up-to-date knowledge were overshadowed by the effect of a modelled 15% inter-annual constraint on TAC change. The constraint prevented the TAC being set at the level that assessments suggested were appropriate, leading to fluctuations in future stock status and failure to reach and sustain desired levels. Up-to-date knowledge was therefore not able to compensate for effects resulting from the TAC rule.

Implications for the ecosystem approach to fisheries management and spatial planning

Systems developed using VMS information have benefits for the ecosystem approach to fisheries management, considering the impact of fishing on the marine system and the spatial planning of marine activities. The benefits of VMS information will depend upon the frequency of information on vessel position, and our ability to estimate their activities at that time. Two-hourly information results in considerable uncertainty in the actual location and activities between points, but may be sufficient for algorithms to identify fishing/non-fishing activity for some fisheries and on a coarse basis. For ecosystem studies, real-time information is not necessarily required⁹ (real-time management of closed areas being an enforcement issue). One cost-efficient option for both the E-logbook and the fine-grained GPS data to be available, is to integrate regular positioning data into the E-logbook. Another option is to store and download data on return to port. In both cases, changes to current legislation would be required. More details on the IMARES and CEFAS studies regarding the ecosystem approach are available in the annex, and in “benefits to sustainability” of this deliverable (3.2).

Changes in information flow for fisheries, costs for transmission of E-logbooks, and available satellite communication systems,

As mentioned further above in the PIP, project deliverables 1.3 and 3.1 jointly contain information on present and anticipated future information flows for pervasive E-logbook reporting. Deliverable 1.3 lists possible satellite communication systems and their potential use for E-logbook transmission, together with the providers’ pricing plans. Deliverable 3.1 anticipates costs for vessels and fleets. The deliverables were aimed at a future CEDER system, but they can in part be applied to the roll-out of the ERS directive.

Lessons from rolling out the CEDER pilot, applicable to the ERS roll-out

CEDER’s pilot project was a smaller-scale pre-ERS attempt at rolling out e-logbook solutions. Results obtained suggest the following. First, any roll-out of the ERS must be backed by prior enactment of national laws implementing the ERS directive. One particular goal in that aspect should be to regulate any lack of support. Second, even though this is foreseen in the ERS, it is important to insist on the following point. Any e-logbook system installed should always be set up so as to transmit data in an automated fashion, precluding any routine manual data transmission, and one should be wary of any exceptions to the above rule. This is needed to exclude complications linked to pick-up of data at landing time, which otherwise are to be expected.

1.3 Concerning further research

No general model that predicts catches from VMS

Guiding future research policy, one of the observations of CEDER is that predicting catches from VMS is unlikely to be successful in a general case involving many fisheries. First, such a model would typically require 15 minute GPS data instead of 2-hourly VMS data in order to infer fishing effort with sufficient accuracy. More importantly, the estimation of catch from (estimated) fishing effort fails in the general case, with the data as presently routinely available. In addition to being simplistic (when compared to stock assessment models), such an approach may also lack up-to-date and accurate data, most notably on current fish age-length structure (particularly of recent recruitments to the population) and biomass. Other factors (e.g. nutrients abundance, water temperatures, weather, salinity, ocean currents, fish prices, and indeed fuel prices) which can fluctuate over time but many of which are hard to predict, can also influence catchability. Note that fishery-specific models are more successful because they can make simplifying assumptions for a particular fishery based upon available knowledge.

⁹ Gathering of such data is less time critical than for “effort while fishing”.

E-logbook and observer reports “are complementary”

In the opinion of CEDER participants, Logbook data are currently uncertain, and while E-logbooks allow some cross-checking with landings information to occur, they still have the potential to provide uncertain data. In effect, without monitoring and cross-checking, E-logbooks can provide incorrect information faster. CEDER participants with experience on board fishing vessels largely agree that as long as there is an economic incentive to inaccurately report landings, any logbook system can be used to submit such data. Legally speaking, it may be difficult to prove that a skipper has wilfully submitted inaccurate data; proof may be as difficult to construct as in the case of VMS fraud.

Still in the opinion of CEDER participants, in the face of uncertain E-logbook data, several sources need to provide complementary information on which to base models. These includes observers, trawl surveys, market data, and someday perhaps, on-board cameras or gear sensors. For each one of these approaches, the level of coverage and the sampling needs to be sufficient to provide reliable information on all vessels within a particular metier. It cannot be stressed enough that this is a fundamental issue when trying to predict catches and discards. While in particular fisheries it may be possible to construct discard models, in the general case reasonably accurate discard data can currently only be obtained via observers. Also, we are concerned that the E-logbook’s reported discard data may be less accurate than reported landings, if indeed discards will be widely reported in the E-logbooks. More so, some participants fear that the new discard policy may not mitigate the discard problem in many fisheries; this scepticism was particularly echoed by those with experience on board fishing vessels. Finally, future means of collecting discard data could include on-board video cameras and gear sensors in combination with logbooks, but currently it is unclear if and how such systems will be deployed. Hence CEDER participants conclude that observers are a necessary part of a future fisheries policy. While data would benefit from greater coverage of observers, we acknowledge that financial and practical constraints limit the potential to expand these activities.

Quota uptake monitoring using predictions and statistical process monitoring

JRC had some success in predicting quota uptake using a time series approach, but the time series models are sensitive to sudden changes in trends. Therefore, a complementary measure to time series analysis would be to track such changes in trends. Initial research into trend breakers revealed that some current approaches¹⁰ yield results, but cannot be used because they detect the breaks in trends too late. However, research using a simpler approach, linked to standard statistical process control, holds the promise to address this issue. This research is currently conducted under the Administrative Arrangement between JRC and DG MARE, in the part termed “TAC and Quota uptake”.

(End of Policy Implementation Plan.)

2 Introduction

Uncertainties in human activities contribute significantly to the overall uncertainty in the assessment of fish stocks and in the estimated impact of management advice. As implied by the Court of Auditor’s “Special Report No 7/2007”, the current widespread deployment of modern technologies such as the Vessel Monitoring System (VMS) and electronic logbooks to record and communicate fishing activities have the potential not only to improve the accuracy of such data but also increase its spatial precision and to reduce the time it takes to arrive at the desktops of fisheries stakeholders – ship

¹⁰ Specifically, “cumulative sum of residuals” (Brown, Durbin, Evans) and “empirical fluctuation processes” (Zeileis) were tested on some recent tuna data. Results indicated a break in trend, but only by September 2007.

owners, producer organizations, authorities, scientists, and fisheries managers. This opens up a new set of possibilities for a more responsive fisheries management system.

The CEDER project aimed to harness these technologies to provide more accurate and timelier information on catches, effort, landings, discards and quota and TAC uptake. In addition to the development of statistical algorithms and IT systems that form the practical use of the new technology, the project aimed to assess the benefits of near real-time reporting and better information on catch, effort and discarding for fisheries management stakeholders in Europe. The benefits were examined for three different fisheries components:

- for authorities (section 4)¹¹;
- for industry (section 5); and
- for sustainable fisheries management (section 6).

This report presents the findings of CEDER work package 3.2, “Implications”. It summarises the findings of the three ‘benefits’ work streams indicated above.

¹¹ E.g. the Court of Auditor’s Special Report notes “Member States should develop analytical, programming and follow-up tools for their inspection activities ...”

3 Summary of advantages

3.1 Introduction

The current widespread deployment of modern technologies such as the Vessel Monitoring System (VMS) and electronic logbooks to record and communicate fishing activities have the potential not only to improve the accuracy of such data, but also increase its spatial precision and to reduce the time it takes to arrive at the desktops of fisheries stakeholders. This opens up a new set of possibilities for a more responsive fisheries management system. The CEDER project aimed to harness these technologies to provide more accurate and timelier information on catches, effort, landings, discards and quota and TAC uptake. In addition to the development of statistical algorithms and IT systems that form the practical use of this new technology, within CEDER work package 3.2, “Implications”, the project aimed to assess the benefits of near real-time reporting and better information on catch, effort and discarding for fisheries management stakeholders in Europe. The benefits were examined for three different fisheries components:

- for authorities;
- for industry; and
- for sustainable fisheries management.

This deliverable, apart from the PIP, presents the findings of the three work streams indicated above.

Within the benefits for authorities section, the range of potential management frameworks within which the CEDER system(s) might operate is presented. The range of prototype systems developed within the CEDER project to allow near real-time estimates of effort, catch and TAC uptake are provided. The following tables summarise the potential benefits for authorities arising from the use of the CEDER prototype systems in relation to the variety of plausible management approaches either already operating or of potential application within EU fisheries. Through the fleets taking part in the Project trials and based upon data from Black Sea fisheries, CEDER has proven the technological capability of using accurate effort estimation based on analysis of vessel geospatial data. This capability can serve as a tool for better control over E-logbook reporting and minimizing errors in them (both intentional 'errors' and poor quality data).

3.2 Summary of benefits for authorities

<u>Measure</u>	<u>CEDER prototype / model</u>	<u>Limiting factor</u>	<u>Benefit for Authorities</u>
Effort-based management	Correlation Systems	Availability of high-frequency (15 minute) GPS data in near real time, accuracy of such data.	<p>“Effort while fishing” can be calculated with high accuracy.</p> <p>The effort estimation from GPS data has the following benefits:</p> <ol style="list-style-type: none"> 1. It provides visual and numeric aids for cross-checking e-logbook haul information versus time spent fishing, which could be used by inspectors in extreme cases, in order to foster a culture of compliance. 2. It enables automated control of effort in hours spent fishing. 3. It provides useful statistical crosschecks of effort versus landings for effort-based management regimes. 4. Because it only counts fishing time, it could assist in spreading fishing effort more evenly between different fishing grounds of the same area¹². If trials are conclusive, a second stage could then reduce bureaucratic overhead.
	Icelandic	VMS needs to be present and accurate. Fishery needs to be similar to Icelandic Redfish fishery.	Estimates effort from 2-hour VMS data. The effort estimation from VMS data has the following benefits for the Icelandic Redfish fishery in particular: A more precise and automated effort estimation algorithm provides useful cross-checks for effort-based management regimes.
	CEFAS effort model ¹³	VMS needs to be present and accurate. Currently applicable to NE and SW England beam and otter trawls, as well as dredges.	Estimates effort from 2-hour VMS data.

¹² For instance, when fishing for redfish near the Faroe Islands, German fishermen submit fishing trip plans, which in turn grant them the right to traverse the North Sea without having the days for that traversal taken off their effort-based regime. This could be crosschecked and enforced by a VMS-based effort estimation algorithm.

¹³ Was not developed under CEDER, but serves as a basis for the Catch model developed under CEDER.

<u>Measure</u>	<u>CEDER prototype / model</u>	<u>Limiting factor</u>	<u>Benefit for Authorities</u>
Closed areas	Correlation Systems	Availability of high-frequency (15 minute) GPS data in near real time, accuracy of such data.	Automated warning system that detects fishing behaviour in closed areas. Estimating when and where a boat is fishing allows inspections to be targeted, if indeed closed areas seem to be violated.
	Icelandic	VMS needs to be present and accurate. Fishery needs to be similar to Icelandic Redfish fishery.	Estimating when and where a boat is fishing will allow inspections to be targeted, if indeed closed areas seem to be violated.

<u>Measure</u>	<u>CEDER prototype / model</u>	<u>Limiting factor</u>	<u>Benefit for Authorities</u>
TAC / Global Quota	Correlation Systems	Availability of e-logbook data. Availability and validity of metier specific information regarding CPUE, species composition, and observer discards, as current as possible. Predictions must be interpreted with caution.	While the correlation between “effort while fishing” and fishing trip catches, discards, and landings is not strong enough to infer the latter from the former, it however can yield a first automated guess. The benefits depend on whether the TAC/GQ regime monitors “catches” or “landings”, and on whether discard monitoring is required. If catch and/or discard monitoring are sought, then the figures can be fed into a system of cross-checks.
	Icelandic	VMS needs to be present and accurate. Fishery needs to be similar to Icelandic Redfish fishery. Predictions must be interpreted with caution.	An estimation of catches is valuable, as it represents an additional variable to feed into an authority’s system of crosschecks.
	Greenland	Logbook data must exist, but does not have to be accurate. VMS data and sales notes have to be accurate.	1. Help with data quality issues: The system’s data mining facilities are able to identify data quality issues. The rules can be extended to suit a range of different conditions. Any quota based system can benefit from such more accurate and timelier catch information. 2. Track quota utilization using hail messages, data entered from paper logbooks, and sales note data.

<u>Measure</u>	<u>CEDER prototype / model</u>	<u>Limiting factor</u>	<u>Benefit for Authorities</u>
	CEFAS effort model coupled with catch model	VMS needs to be present and accurate. Applicable to NE and SW England beam trawls, otter trawls, and dredges. Information on year class strength from new surveys improves estimates. Predictions must be interpreted with caution.	The CEFAS effort model can be simplistically linked with the CEFAS catch model, to provide a preliminary estimate of catch and discards.
	JRC	Landing figures are accurate. They are available for at least 2 years. Some regularity must exist in the data set.	The JRC prototype addresses the problem of being able to anticipate quota overshooting. Stakeholders can be warned, in case it becomes apparent that a particular quota is being overshot. Usually, the predictions prove fairly accurate. However the model breaks down in case of sudden changes in trends. Therefore, predictions must be interpreted with caution.
	(CoA recommendation: Sales note versus logbook)	<i>Landings and sales notes are computerised. Fishermen do not engage in sophisticated cheating.</i>	<i>More accurate landings data, better control of aggregate landings, leading to better estimation of fishing stocks and more certitude concerning quota consumption. Better enforcement of TACs.</i>

<u>Measure</u>	<u>CEDER prototype / model</u>	<u>Limiting factor</u>	<u>Benefit for Authorities</u>
IQs	Correlation Systems	Availability of e-logbook data. Availability and validity of metier specific information regarding CPUE, species composition, and observer discards, as current as possible.	<p>While the correlation between "effort while fishing" and fishing trip landings is not strong enough to infer the latter from the former, it however has statistical properties that can help an FMC, by drawing attention to skippers that notoriously under-report their catches¹⁴.</p> <p>This algorithm could be used at an individual vessel level for enforcement and control purposes, as a cross-verification measure for IQ management schemes. Fishermen that cheat significantly will have artificially low logbook catches, landings, and/or discards when compared to their effort. Since such cross-verification at a ship level meets with the inherent variability of catches per boat and trip, it would be an indicator, not a piece of court evidence.</p>
	Icelandic	VMS needs to be present and accurate. Fishery needs to be similar to Icelandic Redfish fishery.	<p>This algorithm could be used at an individual vessel level for enforcement and control purposes, as a cross-verification measure for IQ management schemes. Fishermen that engage in cheating¹⁵ will have artificially low logbook catches when compared to their effort. However, such cross-verification at a ship level meets with the inherent variability of catches per boat and trip.</p>
	Greenland	<p>Logbook data must exist, but does not have to be accurate. VMS data has to be accurate.</p> <p>By-catch and discards have to be accurately estimated. Sales note has to be accurate.</p>	<p>Help with data quality issues: The system's data mining facilities are able to identify data quality issues. The rules can be extended to suit a range of different conditions. Any quota based system can benefit from such more accurate and timelier catch information.</p>

¹⁴ The majority of vessel owners are not interested in misreporting and unlawful activities.

¹⁵ The majority of vessel owners are not interested in misreporting and unlawful activities.

CEFAS effort model coupled with catch model	VMS needs to be present and accurate. Applicable to NE and SW England beam trawls, otter trawls, and dredges. Information on year class strength from new surveys improves estimates. Predictions must be interpreted with caution.	The CEFAS effort model can be simplistically linked with the CEFAS catch model, to provide a preliminary estimate of catch and discards. Since such cross-verification at a ship level meets with the inherent variability of catches per boat and trip, it would be an indicator, not a piece of court evidence.
(CoA: Sales note versus logbook)	Landings and sales notes are computerised. Fishermen do not engage in sophisticated cheating.	More accurate landings data, better control of individual landings, leading to enforcement of individual quota.

3.3 Summary of relationship to the Court of Auditors' report

The timely publication of the Court of Auditors' special report allowed the comparison of developments under CEDER with recommendations within that report. A number of areas for comment are noted, including those where CEDER systems would be effective. In turn, a number of additional data sources, which were not considered within the Court of Auditors' report but are used within CEDER systems, are highlighted. Of specific reference to the recommendation for comparison of landings and sales note values, this process needs to be automated, with the development of an appropriate data mining tool, along with appropriate enabling legislation. In turn, the process also importantly needs the support of fish distributors.

3.4 Summary of benefits for Industry

Within the section discussing the potential benefits for industry of systems and practices that collect data from several sources and in multiple formats, it is noted that information that Industry may deem as beneficial is not necessarily the same as those viewed as beneficial by Government agencies and scientists. Indeed, specific Industry benefits could be viewed as:

- 1 An increase of TAC based on the more accurate and timely assessment of the target species (and/or increasing understanding of why TACs might be lower than desired).
- 2 An increase in days at sea to capture target species.
- 3 The capability to fish to the maximum of the allocated quota through the reduction in time taken to assess landing data that, at year-end especially, can artificially limit quota uptake.
- 4 Catch Prediction – Catch Management
- 5 Traceability

Transparency within the whole fisheries management process is needed. There is also a need to collect and assess catch data from all means and sources available. The benefits of combining VMS and e-logbook systems is noted, but the faster receipt of incorrect information is not the aim – ultimately the aim is to improve reporting, and for that the co-operation of the fishing industry is required, and to

achieve this, the benefits detailed above need to be stressed. The provision of additional days at sea for improved species targeting is used as an example of the potential rewards that might be provided. In turn, faster receipt of information on quota uptake, perhaps with the use of video monitoring of catches, updated through sales notes, allows more accurate quota uptake when nearing the limit. This also reduces the chances of overfishing, fines, and the need to trade quota at unfavourable rates to cover overshoots. Improved information may also provide improved location targeting, and possibly a reduction in both the level of discarding and steaming required. Traceability opportunities through improved reporting and information, as required by the chain of custody process within the Marine Stewardship Council's accreditation process and required by retailers for purchase of fresher, higher quality fish, provide further incentives.

These are just a sample of benefits that may potentially accrue through the technological advances on offer. Just as importantly, however, the correct mindset and goodwill on the part of the Industry must be in place to report fully and truthfully on the fishing operation.

3.5 Summary of benefits for sustainability

The final section examines the potential implications and benefits of using CEDER systems to improve stock sustainability resulting from European fisheries management. This was performed through computer simulations that examined two separate aspects of the benefits for sustainability.

In the first, a heavily fished fish population that was subject to a recovery plan was simulated. In this situation the potential benefits in terms of fish stock health of using up-to-date catch data in the assessment and management was examined. Results showed that there was some advantage in using up-to-date data estimated from the CEDER framework. The performance of management was improved, with the target level of fishing being achieved in less time. However, when components of the recovery plan that restricted the amount by which TACs could be changed between years were also modelled, management performed poorly. The effect of this limit overshadowed any benefit from obtaining more up-to-date data: improved assessments did not help when constraints meant that the necessary action could not be fully implemented. This inter-annual TAC constraint was put in place to protect the industry from large changes in effort between years and offer stability, but the results of this simple simulation suggests it results in longer-term instability.

In the second, the potential benefits of within-year active management using up-to-date data from a CEDER system for a fish stock caught within a multispecies fishery were examined. In the normal case, when the total allowable catch of a given species is taken but other key species have quota remaining, that species may be discarded as fishing continues. The impact on stocks will therefore be greater than expected from logbook information. Under the assumption that managers and fishermen can agree within-year management approaches, situations where managers could close a fishery once the TAC of a specific species had been fully taken were modelled. These simulations were based on the southwest fishery for two species of anglerfish, which are caught as part of a mixed fishery. These two anglerfish species are managed under a single quota. In addition to the active/current management scenario, additional simulations examined the case where the CEDER system was inaccurate, and consistently over- or under-estimated catch levels; scenarios were run with levels of additional 'effort' to mimic continued fishing on other species, with any additional anglerfish catch being discarded. Results suggested that if a CEDER system can be developed that is sufficiently accurate and unbiased, there could be benefits for mixed fishery management. The required accuracy is a key issue - if methods overestimate catch levels, there will be a short- and medium-term negative impact on fisheries, but potential longer-term benefits as stocks recover faster as fisheries are closed earlier. If the system underestimates catches, the stock and hence catches can suffer in the medium to longer-term. Implementation of such a system requires timely management, of a type only likely to be encountered

where stocks are under individual or binding multinational control. Whether this style of management is feasible in EU waters is open to question.

The improvement of VMS information has further benefits. New fisheries management drivers include the ecosystem approach to fisheries management, a more holistic approach to considering the impact of fishing on the marine system and the spatial planning of marine activities. The benefits of VMS information will depend upon the frequency of information on vessel position, and our ability to estimate their activities at that time. Two-hourly information results in considerable uncertainty in the actual location and activities between points, but may be sufficient for algorithms to identify fishing/non-fishing activity. For ecosystem studies, real-time information is not necessarily required (real-time management of closed areas being an enforcement issue). Therefore for ecosystem studies information collected at a greater frequency (e.g. every 15 minutes) could be stored and downloaded on return to port, thereby eliminating the issue of extra costs involved in more frequent VMS transmissions.

The potential benefits resulting from a CEDER-style system accrue at many levels. However, they will only be achieved if the system is sufficiently accurate, and if the fishing industry can perceive benefits to them.

4 Benefits for authorities

This section of the report assesses the benefits to authorities of the CEDER prototypes, in terms of being able to simplify or cross-check various fisheries management techniques.

The rest of this section is organized as follows:

1. We will briefly list the various types of fisheries management techniques, with their comparative advantages and disadvantages. These lists are by no means exhaustive.
2. Each prototype system developed under the CEDER project will be briefly summarized and examined in light of the fisheries management techniques. We then explore which potential benefits each system provides.
3. We will examine the crosscheck of landings against sales notes, as proposed in the Court of Auditor's report, and briefly explore why this is a useful but not sufficient measure.
4. We present a summary matrix for all prototypes, by fisheries management approach, listing for each the benefits and conditions.

4.1 Types of fisheries management techniques

This subsection is deeply indebted to the course "A popular look at fisheries management", written by Amos Barkai and Mike Bergh of Olrac.

Fishing mortality can be controlled in a number of different ways, these being divided into two general classes of regulations; input controls and output controls. Input controls are really about controlling the means of fishing so that only the desired quantity of fish are caught or die as a result of fishing operations. Output controls count the number or tonnage of fish of a particular size, sex or species that some groups of boats are allowed to land, and once they have caught the allocation, they have to stop fishing.

It is wrong to consider different control measures in isolation from each other. In every situation, the best control measure is probably a combination of different input and output controls. In order to make them more enforceable, they should be chosen with parsimony. In addition, some control measures are useful only for some fisheries, so one needs to keep the specifics of each fishery in mind.

4.1.1 Input controls

4.1.1.1 Effort-based management

Effort may refer to days spent at sea, days spent fishing, or kW-days for a set of boats, for an individual ship-owner, or to the enforcement of a particular fishing season.

Advantage: Relatively simple to manage and control, where effort is measured in days at sea, for example. In theory, if the relationships between catch, resource biomass and fishing effort is well understood, it should be possible to limit the amount that will be landed by setting an upper limit on fishing effort. Effort based management at a ship owner level is a useful complement to individualized quotas. Effort-based management is an important measure in mixed-species fisheries, where it is often associated with global or individual quotas.

Disadvantage: Control by fishing effort will run into a problem if harvesting efficiencies increase, via gearing up of vessels ("technological creep"). Therefore control by fishing effort puts a heavy burden on the management agency, which has to continually update its estimate of the effort level required to achieve a desired catch.

4.1.1.2 Closed spawning seasons

Refers to closure of the fishing operations during the season within which a species reproduces.

Advantage: Relatively easy to enforce. Appropriate to reduce levels of juvenile discarding. In other words: During spawning, fish may concentrate in higher densities than at other times. At these times they are therefore very vulnerable to fishing pressure. If the target species is already relatively depleted before the spawning season, and fishing pressure keeps up while fish concentrate in higher densities for spawning, then this can precipitate a stock collapse. Another reason for this measure is to avoid bycatch of another key species (e.g. protected, endangered or threatened species), when fishing for a given but more abundant target species.

Disadvantage: This measure is often misunderstood. Although many biologists have argued for closing the spawning period to fishing to protect females, this appears to be based on a misconception of population dynamics, and there is actually very little if any scientific justification for this argument.

4.1.1.3 Closed areas

Refers to forbidding fishing in a given area, often only for a subset of species that can be fished in such an area. Reasons for instituting closed areas are diverse, not the least of which is maintain a pool of mature adults to generate recruitment for commercial fishing grounds.

Advantage: Sensible if the species in question is bound to a certain geographic area during some, or perhaps the whole of its life history (shellfish, crustaceans). A number of inshore fish species are limited to sensitive estuarine regions during critical phases of their early life. Easy to enforce, if both fishing in and transit through the zone are forbidden, through the use of VMS, patrol vessels, and radar surveillance.

Disadvantage: For highly mobile open ocean species such as anchovy, pilchard and hake this is not a sensible measure, as this would result in very large closed areas¹⁶. No-fishing/no-transit zones will meet with political difficulties during implementation. No-fishing zones authorizing transit can be difficult to enforce, and require rules such as a minimal speed to be upheld while inside the zone, because in most fisheries one cannot fish at high speeds.

4.1.1.4 Gear related measures

Refers to allowing only nets with certain characteristics (e.g. mesh sizes, escape panels), or favouring vessel owners who are willing to switch to such nets. Such measures are mostly used to alter the size and/or species structure of the catch. Currently, it is popular to reward fishers who follow recommendations on gear sizes emitted by authorities; this often takes the form of awarding more days at sea to the responsive fishermen.

Advantage: In trawl and purse seine fisheries, a limit on the smallest permissible net mesh size is used to alter the size structure and species mix in the catch. In turn, this makes the fishing effort more species-selective, perhaps transforming a mixed-species fishery into several more manageable fisheries. A second advantage is that most species' maximum sustainable yield can be increased by using the proper gear.

Disadvantage: If the mesh size advocated by calculations is too large, it might cause unacceptably large reductions in harvesting efficiency. This would make a mesh size regulation very difficult to enforce, and the incidence of non-compliance will be high. Some fishermen circumvent such measures by carrying both a legal and illegal net. This has been observed for instance in the case of drift nets.

¹⁶ Although could be useful if there were a closure during particular key periods of migration.

The carrying of additional illegal nets can be difficult to police. Also, fishermen have various ways of manipulating selectivity of legal gear (e.g. towing speed, warp layout), which can have the effect of partially circumventing gear related measures.

4.1.2 Output controls

4.1.2.1 Total Allowable Catches

A total allowable catch is a limit on the amount that can be removed from a single species, area, and group of boats in a given year. (Note: In the European Union's Common fisheries Policy, "total allowable catch" means total allowable landings. The Scientific, Technical and Economic Committee on Fisheries takes the difference between these two measures into account when giving TAC advice.)

Advantage: A proven method with relatively high efficiency, for single species fisheries where TACs also act as a restriction on effort. Can be combined with many other measures. Can be applied and controlled at an international level. Some enforcement aspects can be automated, such as comparing landings with logbooks and with sales notes.

Disadvantage: In a mixed species fishery, the enforcement of species specific TAC's can create problems. For example, because it is not possible to target exactly a certain species, it may be necessary to discard catches of some species at sea, to avoid exceeding the allowance for one species, while continuing to fish for another. Due to non-selective gear, smaller fish are caught together with larger fish. The smaller fish then have to be discarded. Usually these discarded fish are already dead. While regulations can be put in place to prohibit discarding (e.g. as in Norwegian waters), they remain difficult to enforce. Indeed, if TACs are used together with size restrictions but without input control measures such as gear restrictions or effort based management, they can lead to the mostly unreported discarding of a large number of undersized fish.

Enforcement problems include that fishermen will have a collective incentive to under-report their catches, and may resort to transshipments and/or black landings. There are various ways in which this measure can be manipulated: for instance landings are sometimes interpreted as catches, or the landing mass of processed fish (e.g. fillet) is taken as being equal to landing mass of whole fish.

4.1.2.2 Global Quota

A global quota is a limit on the amount of all species combined that can be removed from a multi-species fishery. It has mostly the same advantages and disadvantages as total allowable catches, except that it is suited for fisheries that will inherently fish a species mix (such as demersal fisheries).

However, it may lead to preferential discarding of less valuable species.

4.1.2.3 Individual Quotas (IQs)

This mostly refers to allocating a fraction of a TAC to an individual ship owner.

Advantage: By specifying the amount that each quota-holder can catch, removes the race-to-fish inherent in Total Allowable Catches. This eliminates wasteful investment in fishing gear and infrastructure designed to maintain a competitive edge in the harvesting process.

By making these quotas transferable and permanent (ITQs), transfer takes place under market forces, starting a process of concentration of capital, which should make the fishery more efficient and economical. In addition ITQs have management advantages, as transfer and definitions of ownership of quota can be enormously simplified.

At the “Sharing the Fish Conference 2006¹⁷”, it was mentioned that: “The argument for ITQs is well known and was clearly presented.... When quota rights can be assigned such that they are secure, transferable and permanent, they result in fisheries that are ecologically sustainable because quota holders gain the incentive to care for the resource that they now own. Ecological considerations, previously externalities, are now internalized under ITQ systems.”

Disadvantage: As with TAC's, the enforcement of individual quotas is expensive, and there is a clear incentive for non-compliance, especially when not combined with other measures, such as effort regimes. IQs have the perverse effect of inciting the fisherman to falsify logbook information, rendering them untrustworthy for stock assessments. This could also undermine the recent trend in fisheries industries to recognize the long-term beneficial role of government controls. Also, the allocation of quotas is a difficult task, since most allocation mechanisms (e.g. a quota board) are open to political manipulation.

At the “Sharing the Fish Conference 2006” it was also mentioned that “[M]embers of the small South African delegation to the conference noted, ITQs threaten the livelihood basis of small-scale fishers.... The inequity of ITQs was echoed by... Ray Hilborn, who affirmed the challenge to equity that ITQs represent even in countries of the North.”

Discussion: “ITQ systems have been the subject of much controversy.... An alternative to allocating fishing rights to individuals is to auction fishing rights with the government receiving the auction fee.... Auction systems have been strongly opposed by existing fishermen. [Hilborn¹⁸]

In addition, there is a philosophical issue of fairness with ITQs operating within an open pool resource.

4.1.2.4 Size restrictions

Refers to imposing a minimal size for retained catches.

Advantage: Minimum size limits have the intention of maximising yield, and in some cases, to protect a certain size class of the biomass. This class can be the juvenile, or the juvenile and some of the spawning biomass, depending on the characteristics of the species. In other words, can be consistent with biological targets.

Disadvantage: In fisheries where the gear catches fish smaller than the minimum size, these undersize fish have to be returned to the sea. This is sensible only if these fish have a good chance of surviving the events of being caught and returned (for instance physoclist fish rapidly brought to the surface from greater depths usually suffer a fatal barotrauma, while physostomes may not¹⁹).

Sometimes size restrictions only reflect an agreement by the industry in order to cover market demands, rather than a concern for the species' biomass.

4.1.2.5 Gender restrictions

Refers to imposing a proportion on the gender mix for retained catches.

Advantage: In certain fisheries it is possible to select fish by gender as they are brought on board. If they are alive, and their chance of survival upon being returned to the sea is high, then it is sometimes beneficial to control the sex ratio in the catch. This measure is relatively easy to enforce by spot checks.

Disadvantage: There are not many fisheries where this measure can be applied, due to the difficulties in identifying sex from external features, or due to returned fish not surviving the barotrauma of being brought to the surface from great depths.

¹⁷ http://www.icsf.net/icsf2006/uploads/publications/samudra/pdf/english/issue_43/art03.pdf

¹⁸ Hilborn et al, doi: 10.1146/annurev.energy.28.050302.105509

¹⁹ Means that the gas bladder is sealed (physoclist) or does have a pneumatic duct (physostomes). For example, cod have a sealed gas bladder, while herring and anchovy have a duct in their gas bladder.

4.1.2.6 Productive stages restrictions

Refers to returning females in some stage of gestation back to the sea, presumably in a sufficiently good shape to produce offspring. Common in crustacean fisheries in which the eggs carried by in-berry²⁰ females are easily visible, to establish regulations requiring fishers to return in-berry females to the water.

Advantage: Easy to control.

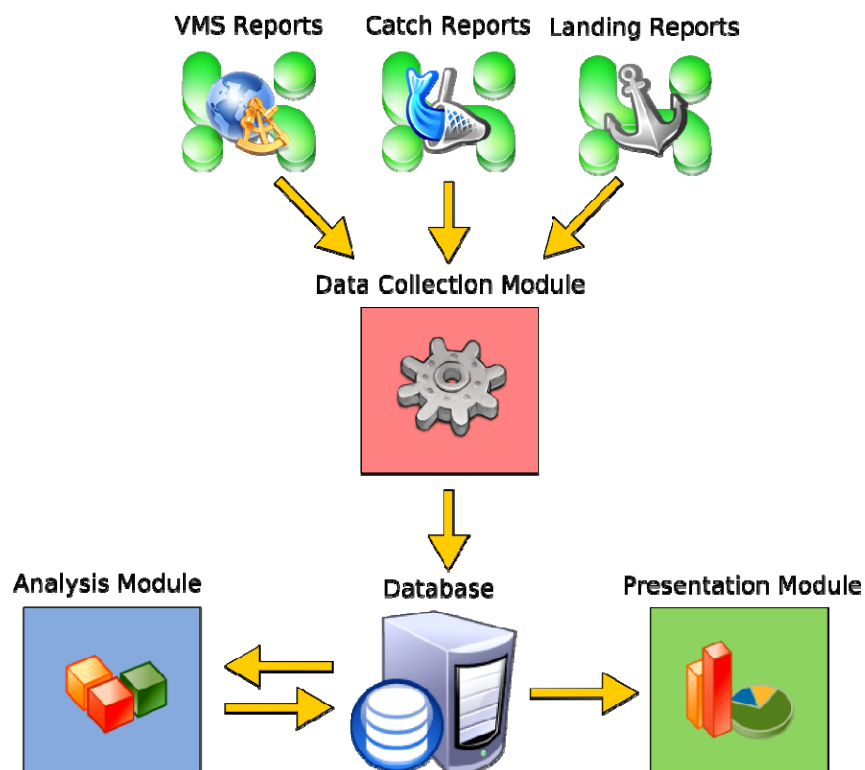
Disadvantage: Some field studies and simulation models have demonstrated the futility of this measure. Why should the death of a female going into berry soon, be significantly less important than the death of female that happened to be in-berry when it was captured? Also, there are not many fisheries where this measure can be applied.

4.2 Summary of prototype systems developed under CEDER

4.2.1 Icelandic Prototype System

4.2.1.1 System Summary

The Cedar Atlantic Redfish Fisheries Information system (CARFI) system is primarily aimed at the Atlantic Redfish fisheries, with the objective to demonstrate the feasibility of bringing real-time information on fisheries to stakeholders.



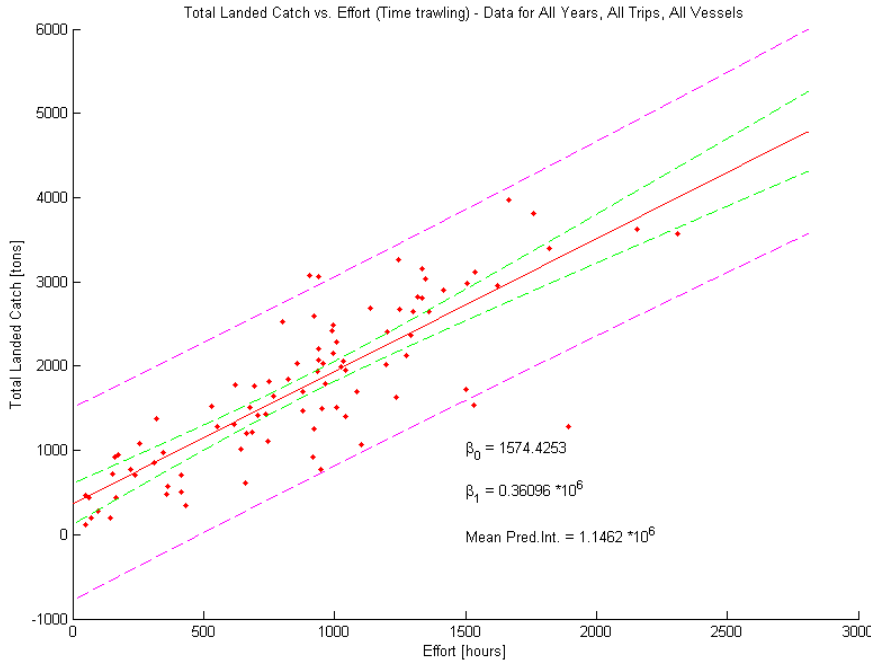
The CARFI system includes a module to estimate the effort and the catches from the VMS messages.

That effort estimate was then validated against the catch data. For each trip,

²⁰ "In berry": the condition of a female crustacean when she is carrying external eggs.

- the effort was estimated using the VMS messages,
- the landed catch was available,
- effort versus landings were plotted.

A linear relationship emerged.



4.2.1.2 Benefits

The Icelandic system makes it possible to estimate the landed catch from the 2-hour VMS messages, for the Icelandic Redfish fishery. The proportional model error between Estimated and Landed Catch is of the order of 4.41%, for a total of 2,500 hrs of trawling time.

Effort-based management	Estimates effort from 2-hour VMS data. The effort estimation from VMS data has the following benefits for the Icelandic Redfish fishery in particular: A more precise and automated effort estimation algorithm provides useful cross-checks for effort-based management regimes.
Closed areas	Estimating when and where a boat is fishing will allow inspections to be targeted, if indeed closed areas seem to be violated.
TAC / Global Quota	An estimation of catches is valuable, as it represents an additional variable to feed into an authority's system of crosschecks.
IQs	This algorithm could be used at an individual vessel level for

enforcement and control purposes, as a cross-verification measure for IQ management schemes. Fishermen that engage in cheating²¹ will have artificially low logbook catches when compared to their effort. However, such cross-verification at a ship level meets with the inherent variability of catches per boat and trip.

4.2.1.3 Conditions for realization of benefits

Limited applicability, designed for a particular fishery

The Icelandic Redfish fishery is a well-defined fishery, with

- Quota controlled and limited fleet size,
- Localised trawling, distinct fishing pattern,
- Strong correlation between effort and catches, due to the particularities of the Reykjanes ridge,
- Discard limited to infected and damaged fish (observer controlled),
- Observers controlling about 5% of trips.

The system that converts VMS tracks into effort is relatively simple. It uses the speed as a discriminator between the states of “fishing” and “cruising”. Such a system works well in that particular fishery, but breaks down in the general case.

The prototype developed by Correlation Systems has a more resilient effort from VMS estimation algorithm.

4.2.2 Greenland Prototype System

4.2.2.1 System Summary

The system gathers information in on a timely basis in the following way:

- The vessel transmits hail-messages on a weekly basis (vessels on shorter trips does not transmit hail-messages)
- Logbooks are sent to the authorities when the fishing trip has ended²². These logbooks always include discards.
- Sales-notes are sent to the authorities when the fish has been sold.

The database gets input from the following other sources:

- VMS (Vtrack)
- Observer reports
- Permits
- National quota register
- Vessel register

Data Mining and Alert Messages

²¹ The majority of vessel owners are not interested in misreporting and unlawful activities.

²² EU has decided (Council Regulation (EC) No 1966/2006) to implement an electronic logbook on all EU fishing vessels above 15 meters within the next 4 years, which will have the consequence that logbook information will be available no later than 24 hours after the fish has been caught.

In Greenland's fishery information system, the landings are calculated from the logbooks and the sales notes. Logbooks are cross-checked using the VMS, and this is at present where data mining is performed.

The prototype includes a user interface that permits to address quality problems in recorded fishery data. Each particular potential problem has a corresponding "alarm" with a particular weight in points. One part of the user interface includes a drill-down facility to get to the data entries that seem to have the most issues.

The following alarms are implemented, each with a weight in points: "speed as calculated from logbook is excessive", "end of haul too far from most recent VMS position", and "CPUE from logbook is too high". Currently, the error is dominated by typographical mistakes while transcribing the paper logbooks.

Greenland will introduce the e-logbooks after the EU e-logbook requirement comes into effect.

Quota uptake calculation

As soon as the hail message is entered in the system the reported catch will be deducted from the quota, when the fishing trip has ended and the logbook data has been entered in the database the logbook data will replace the catch data from the previous received hail messages. When the fish has been sold and the sales-note data has been entered in the database the sales-note data replaces the logbook data except for the discards, which is retained from the logbook.

4.2.2.2 Benefits

The prototype has at present been put into production in Greenland.

TAC / Global Quota / IQ	<ol style="list-style-type: none"> 1. Help with data quality issues: The system's data mining facilities are able to identify data quality issues. The rules can be extended to suit a range of different conditions. Any quota based system can benefit from such more accurate and timelier catch information. 2. Track quota utilization using hail messages, data entered from paper logbooks, and sales note data.
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4.2.2.3 Conditions for realization of benefits

Limited applicability for calculating discards in other fisheries

The Greenland shrimp fishery is a particular fishery in which:

- the coverage for observers on board of fishing vessels is at 50%.
- all fish by-catch is discarded, because all the catch that is not shrimp must be thrown over board, owing to strict hygiene measures,
- the total fish by-catch and shrimp discards are well known, and a CEDER co-financed study has confirmed the reported proportions.

In order for the system to be able to calculate catch data for a given fishery,

- Hail messages and/or e-logbook information needs to be forwarded as soon as possible,
- VMS data has to be accurate,
- By-catch and discards have to be accurately estimated. In case these are significant, they need to be made available in a database, so that they can then be taken into account by a future version of the prototype,
- Sales notes have to be authored in good faith, and be forwarded not more than a few days after the end of a reporting period.

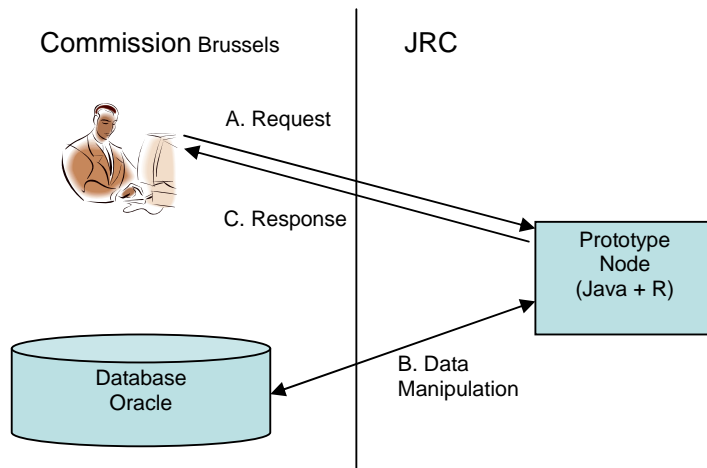
Considerations pertaining to system extension

The data mining facilities can cover a range of issues in incoming data. Because the data mining is based on a rule engine, the system would flexibly accommodate a certain set of additional rules. However, there is always the chance that someone may want to add rules that are outside of that set, or wish to add features that require the system to be overhauled.

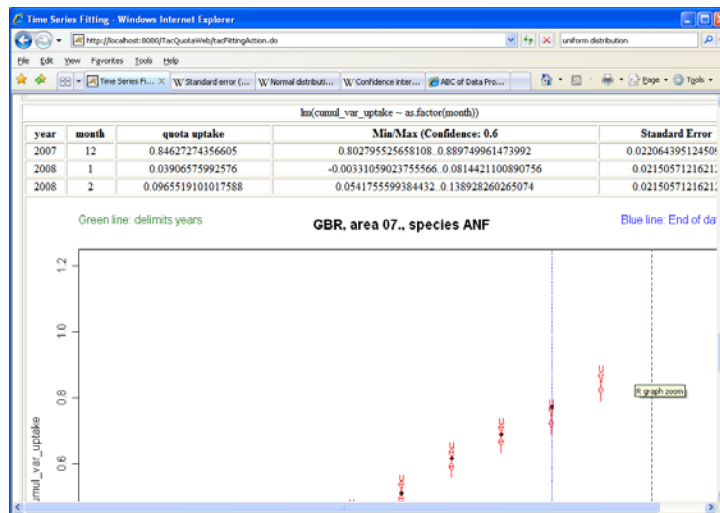
4.2.3 JRC Quota uptake prediction

4.2.3.1 System Summary

The JRC prototype predicts quota uptake using a time series approach. It is a web-based tool where a user can ask the question: “For a particular fishery X, given past behaviour, what will the quota uptake for the coming months look like?”



The system then attempts to give an answer based on past behaviour.



With reasonable effort, it is feasible to extend the system, in order to base the estimates on effort, market prices, meteorological factors, or indeed any other variable.

The accuracy of the answer is a function of:

- The regularity by which quota is consumed,
- The presence of regular (but not necessarily linear) trends,
- The quality of the data. (An absence of numbers and/or a presence of false data compromises the performance of predictions.)

4.2.3.2 Benefits

TAC / Global Quota	The JRC prototype addresses the problem of being able to anticipate quota overshooting. Stakeholders can be warned, in case it becomes apparent that a particular quota is being overshoot.
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4.2.3.3 Conditions for realization of benefits

Validity of data

In order to fully realize the benefit of such a system, one needs to ensure that landings figures are produced in good faith and reflect the actual landings. This may entail the implementation of a more accurate landings estimation tool. If such an implementation produces fundamentally different estimates, then this would either require waiting for at least 24 months²³, or alternatively require the revision of historical landings figures. Otherwise, the system will not have sufficient data to draw upon.

Statistical properties of data

²³ Consider an example. In September 2009, a new landings estimation tool is introduced, resulting in fundamentally different estimates. The first two years after its introduction would run up to September 2011. Indeed, 24 months would be the minimal data set needed to train a basic linear model, one in which the catch depends upon the month. This model would then yield an expected value and a standard deviance. This model can then be used from October 2011 onwards. Other more complicated models require additional training data.

The prediction algorithm makes use of a set of mathematical models, to predict quota uptake from itself, exploiting any seasonality and/or trend it can find. The algorithm performs forecasts with those models that performed the best forecasts in the past.

Such forecasting yields promising results if the time series has statistical properties that vary cyclically with time. For instance, this is the case for seasonal fisheries (with non-seasonal fisheries being a degenerate case, mathematically speaking). It would also be the case for seasonal fisheries with some form of trend, like a declining fishery.

These models however break down when the quota uptake exhibit an arbitrarily large variance. The models also have issues with abrupt changes in seasonality, where for example, a fishery would suddenly occur in the summer months rather than in the spring months, or if a fishery experiences a stock collapse.

4.2.4 Correlation System prototype

4.2.4.1 System Summary

The system is built around a relational database. The system's user interface is implemented as a web site, which enables the user to perform queries, view reports and manually insert data (such as VMS data, electronic logbooks, etc.) into the system's database. A scheduler process with low priority performs CPU-intensive analysis in the background.

The system supports 4 input data types:

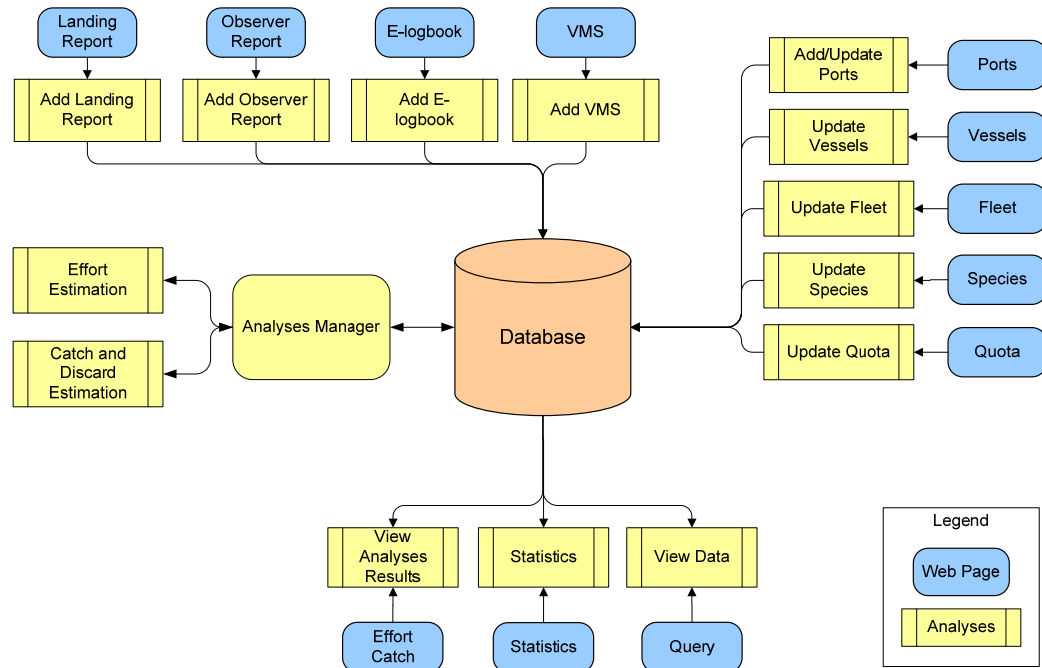
1. VMS data
2. E-logbooks
3. Observer Reports
4. Landing Reports

The data can be inserted into the system's database via the web site. The user can also update port details, vessel and fleet details and species details that are also maintained within the database.

The web site enables the user to perform analyses on stored data, such as:

- Effort estimation – the analysis is performed on VMS data of a single vessel, and determines for each record whether the vessel was fishing, cruising or in port. The records are collected into tracks, which are displayed on a map along with the effort estimation for each point.
- Catch and discard estimation – the analysis is performed on all data types stored in the database. The analysis estimates for a specified area, species and country the weight of catch and discard, and the catch/quota ratio. The output is displayed as a data table and on charts on the web pages.

The user can also perform statistical analyses on the results of effort estimation analysis.



The prototype has two algorithms to be mentioned in this context:

Effort estimation from VMS data

The effort estimation algorithm estimates practical fishing effort. It operates per-boat, as follows:

- For each VMS record of the boat, the boat’s activity is determined (fishing, cruising or at harbour) based on the vessel's geospatial parameters.
- Calculate the effort spent while fishing.

The effort algorithm represents an improvement about 30% in comparison to a “naïve” algorithm based on days at sea and average effort per day. Under most conditions, it is reasonably accurate in distinguishing fishing from cruising.

Note: Correlation System's prototype actually contains 2 estimation algorithms, based on VMS reporting rate: one targets 2-hour VMS data, and the other one targets 15-minute (or finer) VMS data. The latter algorithm yields superior results.

Catch and Discard Estimation Algorithm

The catch and discard algorithm estimates the weight of catch and discard, for the current month and year, in a specific country and area, and for a specific species. The estimation is based on a number of parameters: on landing reports from previous months and years, on logbooks, and observer reports, as well as on matching effort estimation of relevant vessels. This requires the availability of metier-specific information regarding CPUE, species composition, and typical discards, from at least 13 months prior to the month in question.

On a randomly chosen boat and month, the estimation yielded an error of 2.2% with respect to the reported figure.

4.2.4.2 Benefits

Effort-based	“Effort while fishing” can be calculated with better accuracy.
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management	<p>The effort estimation from VMS data has the following benefits: A more precise and automated effort estimation algorithm provides useful crosschecks for effort-based management regimes. For instance, when fishing for redfish near the Faroe Islands, German fishermen submit fishing trip plans, which in turn grant them the right to traverse the North Sea without having the days for that traversal taken off their effort-based regime. This could be crosschecked and enforced by a VMS-based effort estimation algorithm. If trials are conclusive, a second stage could then reduce bureaucratic overhead.</p> <p>Consider what happens if effort, in days at sea, is allocated to a particular ICES rectangle: fishermen will favour fishing grounds lying closer to their port. Basing effort regimes on time spent fishing, instead of days at sea, could lead to a better spatial distribution of fishing effort.</p>
Closed areas	By estimating when and where a boat is fishing, inspections can be targeted if indeed closed areas seem to be violated.
TAC / Global Quota	An accurate estimation of catches is valuable, as it represents an additional variable to feed into an authority's system of crosschecks.
IQs	This algorithm could be used at an individual vessel level for enforcement and control purposes, as a cross-verification measure for IQ management schemes. Fishermen that engage in cheating ²⁴ will have artificially low logbook catches when compared to their effort. Since such cross-verification at a ship level meets with the inherent variability of catches per boat and trip, it would be an indicator, not a piece of court evidence.

4.2.4.3 Conditions for realization of benefits

For Effort estimation from VMS data

Validity of data

VMS messages have to be accurate and complete, warranting investigation into VMS tampering²⁵ and transmission errors.

Fine-grained data

The prototype obtains superior results from position and speed data that is taken at least every 15 minutes. This data does not need to be available in real time, but could be downloaded at time of landing, or at the end of each month, whichever comes sooner.

Maturity

Further study in other fisheries, for effort estimation from VMS, would be beneficial. The prototype would then be able to perform better in those fisheries.

²⁴ The majority of vessel owners are not interested in misreporting and unlawful activities.

²⁵ In the MARUSE project (FP6, DG TREN), JRC worked on "Authentication in Fisheries Monitoring". Anti-tampering measures were one of the key aspects of that deliverable.

Validity of data

In order for the system to be able to calculate catch data for a given fishery,

- E-logbook, observer, and landings information needs to be truthful, and be forwarded as soon as possible.
- Other referenced information, such as ports, vessel, fleet, species, and quota details need to be kept up to date.
- Availability and validity of metier specific information regarding CPUE, species composition, and typical discards, from at least 13 months ago up to the previous month is needed.

Maturity

Further study is needed in order to evaluate the efficiency and typical errors of a catch and discard estimation algorithm. Other fisheries need to be involved, and further tuning of the algorithm would be beneficial.

4.3 On the Court of Auditor's report

The Court of Auditor's "Special Report No 7/2007" mentions various sources of data to input into a cross-verification process:

- VMS records
- Logbooks
- Landing declarations
- Sales notes

However, during the CEDER project, a number of additional data sources were explored:

- Observer reports and hail messages can be used by the Greenland prototype, but were not mentioned in the CoA report. The prototype of Correlation Systems can also use observer reports²⁶.
- The scientific trawling surveys, captain's diaries, fish age compositions, length/weight at age, fish market sampling data, and data on known area misreporting, also were not mentioned in the CoA report. However, these are used in various countries in order to perform stock assessments, and can be used as part of catch and discard estimation processes²⁷.
- Stock assessments would provide valuable information in a future system that addresses the shortcomings mentioned by the CoA report.

4.3.1 Data explored in the CoA report that was not explored in CEDER

CEDER did not explore the relationship between Sales Notes and Landing Declarations. We will briefly explore the reasons behind this.

²⁶ But not hail messages in its present state.

²⁷ E.g. the Cefas Bayesian approach to catch estimation for North Sea roundfish, which also relies on observer information

The report mentions the failure of some member states to routinely match the Landing Declarations against the Sales Notes. However:

- In the Netherlands, the inspection service does compare sales notes and landing reports. They decide which of these data sources they trust most and based on that decision the official catch is determined. In the TecTac and CAFE projects, IMARES developed a method to cross check landings declarations with logbooks, and landings declarations with VMS.
- For Scotland, England and Wales, the Fisheries Agencies confirmed that computerised crosschecks between landings and sales notes have been in place for a number of years.

CEDER explored relationships between VMS records, logbooks, and landings. We did not explore the aforementioned relationship because in the fisheries under investigation, such crosschecks are either implemented (Netherlands, United Kingdom) or were already in later stages of development (France). Of course, in countries where such crosschecks do not exist, they would be a useful complement to existing measures.

The report also notes (p. 20) that the United Kingdom sent corrected numbers for at least 6 stocks, for fishing that occurred in 2005, past the appropriate deadlines in 2006.

The United Kingdom matches the sales notes against the landings, yet it would seem that this alone is not a guarantee for timely delivery of aggregated information.

The reason behind the above discrepancy is that Scotland had launched a project called “Registration of Fish Sellers and Buyers”. This project estimated the availability of fish in various stores. The finding was that more fish was available in the stores than could have been explained through the sales notes. Scotland then estimated the amount of black landings, and corrected the TAC uptake figures for DG FISH.

Policing activity through the registered sellers and buyers²⁸, as well as through the fishing industry, led to the arrest of several skippers. Subsequently, illegal fishing activities declined to lower levels²⁹.

4.3.1.1.1.1 Opinion of CEDER on comparing landings versus sales notes

We believe that comparing landings versus sales notes will be a cost-effective measure that will be efficient to some extent, in order to cut down on the under-declaration of landings. However, this measure needs to be automated, as well as accompanied by a data-mining tool and appropriate legislation. Furthermore, this measure in itself is not enough, as the fish distributor market needs to be involved.

On why such checks would have some efficiency

There are ways to circumvent such a measure. Boats can perform black landings, transshipments, or combination of transshipments and black landings, where smaller undeclared transport vessels run extra catch to the shoreline. They could also land cargo in countries where controls are less strict. However, ensuring landings match sales notes where unreported landings are occurring is not straightforward, and may be difficult to organise on active fishing vessels.

The Scottish experience however has shown that there may be some persistent offenders, who if given the opportunity will engage in black landings on a very large scale. In order to curtail these individuals, the legislator needs to widen the stakeholder community, by enlisting and controlling the fish distributors.

²⁸ http://news.bbc.co.uk/2/hi/uk_news/scotland/3760320.stm

²⁹ <http://www.scotland.gov.uk/News/Releases/2006/11/28115222>

On what shape these checks could eventually take

Taken in its most basic form, the examination of the two sources of information can allow unreported landings to be identified. This approach should therefore be undertaken, at least to focus further investigations.

Curtailling non-declared landings would imply all of the following:

- Verifications of sales notes versus landings have to become an automated and routine process for a sufficiently large percentage of vessels. Either all vessels are controlled, or random spot checks are conducted;
- When vessels approach shorelines, effective control measures ensure that inspectors’ efforts are properly targeted. This would include both fishing and smaller cargo vessels;
- A legal background needs to exist, where Courts accept the comparison between declared landings and sales notes as evidence, and where a serious deterrent exists;
- The above has to be harmonised at a regional level, involving European Member States and their neighbours.

However, given the lessons learned during Scotland’s “Registration of Fish Sellers and Buyers” project, downstream controls seem to be a necessity in order to mitigate the risk of large-scale black landings.

The Scottish experience then seems to corroborate the DG FISH 28/02/2008 Inter-Service Consultation. In that document, FISH “proposes a new approach as regards inspection and control”, “effective cross checking systems of data from stakeholders; comprehensive traceability methods and processes”, whereas today “important areas such as auctions, markets and imports are neglected”.

We are looking forward to the adoption of a sufficient set of measures in the reformed Common Fisheries Policy.

4.3.2 Benefits of cross-checks between the sales notes and the declared landings

(Excludes downstream distributor checks)

TAC / Global Quota	<p>Cross-validation of sales notes and declared landings is valuable, as it represents an additional variable to feed into an authority’s system of crosschecks. This particular crosscheck can be used to determine quota uptakes at an aggregate level in a more reliable manner. We believe that this particular cross-validation would be cost effective.</p>
IQs	<p>This particular crosscheck can be used to determine individual quota uptake in a more reliable manner.</p> <p>This could be a part of a system where logbook, landings, and sales notes are used to co-validate each other, aiding in automating the task of deducting catches from individual quotas. Fishermen who want to defeat such a system would need to engage in organized cheating patterns.</p> <p>Yet, even such patterns could be revealed by complementary measures, such as using the VMS to calculate effort. Sting operations would then target vessels that have low CPUE while</p>

possessing technological sophistication.

4.3.3 Cross check between logbook data and VMS / GPS data

CEDER demonstrates the possibility to provide accurate estimates of effort activity based on high resolution location data. Such information can be obtained from VMS data, or directly from the GPS associated with E-logbook records.

By using this location information, it is possible to statistically estimate the effort that the vessel actually performed, for a number of purposes:

1. Geographic separation - Accurate separation of the catch data into different geographic regions for situations in which the vessel's logbook does not include such separation.
2. Verification of the accuracy and quality of data in the E-logbook (in terms of catch versus effort).
3. Fraud Detection - Indication of fraud or misleading data in the logbooks based on the comparison between accurate effort and catch.

With the fleets taking part in the project trials and with the Black Sea data, CEDER has proven the technological capability of using accurate effort estimation based on analysis of the vessel geospatial data. This capability can serve as a tool for better control over E-logbook reporting and minimizing errors in them (both intentional 'errors' and poor quality data).

5 Benefits for industry

5.1 Introduction

Systems have been developed within CEDER that are capable of harmonizing disparate data on fishing activities from a number of different fisheries. This section deals mainly with the possible benefits to industry of producing these systems and practices that collect data from several sources and in multiple formats, produce a meaningful result at the end of this process, and a tangible benefit to industry. It takes into account that what Industry may deem as beneficial may not be comparable to that considered beneficial by government agencies and scientists. Reconciling these differences will allow greater collaboration and co-operation between the different fishery actors.

When the facts are looked at the main advantages to Industry can be listed as follows:

- An increase of TAC based on the more accurate and timely assessment of the target species. (or a reliable justification of why the TAC is lower than wished).
- An increase in days at sea to capture the target species.
- The capability to fish to the maximum of the allocated quota through reduction in time taken to assess landing data that, at year end especially, causes major problems in completing quota uptake.
- Catch Prediction – Catch Management

- Traceability

Some of these goals may seem in direct contrast to the goals of government and the scientific bodies charged with the task of stock management and sustainability of stocks. However, by correct usage of the systems and data made available, we can transform the scenario of “poacher versus gamekeeper” to the benefit of all parties. Indeed, since most systems developed under CEDER require some knowledge of the levels of catches from particular fisheries in order to ‘train’ the models used, the importance of good information from the fishermen becomes clear.

A considerable issue within the fishing industry is stock assessment and in particular the TAC calculations based on the conclusions drawn from this exercise. Due to the prolific use of the complex quantitative models to assess fish stocks, the actual data being used for this purpose is months, and in some cases, years old. For instance, the time taken to collect and assess data (North Sea) in 2001 meant this data was only available for use in 2002 and this was then used to decide the TAC for 2003 (see section 6). The fishing vessels can report the discarding of large quantities of fish due to the fact that they have a quota limit that does not take into account the latest information, hence their experience is in direct conflict with the evidence of abundant stock being caught and consequently discarded. A careful balance needs to be maintained here, since discarding of juvenile fish may result from recent strong year classes that recruit to the fishery, but have not yet had the chance to spawn. However, the ability to collect, collate and decide on data which in “time” terms is relevant to that year will go a long way to reducing the criticism levelled at the ICES assessment process. This is examined further in section 6.

The introduction of systems that report in near real time and have the ability to assess stocks with more accuracy will help the estimation of true catch when calculating TACs. For instance the ICES estimate on haddock caught in Subarea IV (North Sea) was 60% above the official declared landing amount of 42,000 tonnes. This practice of estimating “real landings” as opposed to believing the official landing data loses credibility in the eyes of industry. As already mentioned, the physical evidence of the fishing vessels of more stock on the fishing grounds, the real lack of accurate data on stock assessment, and the resulting need to discard over-quota catch due to the lack of a realistic quota is not the best argument to win the hearts and minds of the fisherman. Until these issues can be discussed, the argument and gulf between the parties will continue.

5.2 Approach

How can we fix it?

There are several issues that can be addressed. The most important one is the need to collect and assess catch data (in a timely manner) from all means and sources available. These sources must be trustworthy and the process of drawing conclusions from this data must be (as much as is possible) transparent. The last issue is important - it provides little benefit to Industry if the data is collected and assessed behind closed doors with no explanation as to how and why certain decisions are made. This will involve a far closer partnership between Industry, Government and Science. For CEDER, it means that the approaches used to estimate effort and catch during the year must be clearly explained, and the industry must trust the approach.

The approach must include the cooperation of the fishing fleet, and for this incentives are likely required; to achieve fishing vessels collecting the vitally important data, there has to be something positive, a “reward”, for this activity. The casual observer may comment that it is the fishermen’s duty to collect and report data as decreed by law. This is correct but does not take into consideration the fact

that “misreporting” can occur, and just as importantly that discarding leads to legally unreported catch. This is discussed later in this section.

The vital element here is the truthful reporting of total catch and discarded catch. It has been reported recently in the UK fishing press that some prawn vessels are discarding up to as much as 60% of the total catch (independent observer reporting) because of the nature of the mixed fishery and lack of quota, and limit on the “by-catch”. If we multiply this practice by all the prawn vessels and each and every vessel does not report discarded catch, the size of the problem becomes evident. It is immense, and this is only one fishery out of the many. This illustrates the gravity of the problem and the need for accurate and comprehensive reporting on all elements of the catch, landed and un-landed.

The current technology available to monitor activities of the fishing fleet is VMS, a passive reporting tool with no crew intervention (and none desired). This system on its own is not suitable to provide the more detailed reporting requirements that CEDER has in mind. If we include the use of an E-logbook, this inclusion changes the situation dramatically. Combined together, these have beneficial attributes for monitoring. Both systems provide positional data and can be used to cross check and verify the accuracy of the provided data from each independent source. There have in the past been occasions when a vessel’s VMS has been manipulated to provide positional data many hundreds of miles away from the actual vessel location. The extra positional data provided by an independent E-logbook system will go some way to reducing this form of misreporting. The current projects, which include SAR technology from EO satellite systems, will also play a role in this area.

Rewards

It has been mentioned in the past that an E-logbook system will be very efficient in getting the lie quicker to shore. As it is the skipper and/or crew who are tasked with filling in the E-logbook and, as with the paper logbook, there is little information available on the accuracy of the information. Indeed, EU legislation can result in legally underestimation of catch levels within logbooks (see Court of Auditor’s report).

The combination of more accurate monitoring provided by the use of VMS and E-logbook will reduce the probability of misreporting through the enhanced ability to pinpoint more accurately any particular vessel that may be flagged as acting suspiciously, but the two combined will not eradicate this practice. This is where the usage of data from the reporting systems can and should be used to the benefit of Industry. The process requires understanding of the current needs of industry. It is not in our remit to include every issue, but to show that by using the current and proposed technology, certain goals are achievable.

Previous comments should not be misconstrued. The majority of vessel owners are not interested in misreporting and unlawful activities. For example, there is currently a SEAFISH scheme running in the UK where vessels are signed up to a voluntary conduct code that includes better stewardship of the fishery. The head count in this scheme currently exceeds 100 vessels and is growing daily.

As previously listed there are several areas of improvement that can be analysed and a possible solution introduced to help solve the problem.

Examples

5.2.1.1 A pro-active stance from Industry to increase the TAC

Under the current practice of TAC assessment, Industry feels justified in claiming that the allocated TACs are not based upon reliable scientific data. The practice of ICES on erring on the side of the “worst case scenario” argument when deciding TAC is well known (and consistent with the precautionary approach). It is also well known that every year, on the announcement of the TAC, Industry is up in arms. This is partly the fault of Industry itself. For generations it has been the practice and habit of industry to take a very non-cooperative stance in providing accurate data on catch composition and catch location. Recently there have been several widely publicised cases of “Black Fish” landings and misreported logbook submissions. Only through careful auditing and spot check controls has this practice been brought to light. No one particular country has had the monopoly on these practices. This has created the “poacher versus gamekeeper” mind set in official government bodies and industry alike. From the industry side, there is a difficulty reconciling increasing catch rates in the face of falling TACs. They also cannot be wholly blamed for reasoning that the practice of discarding perfectly good fish is wasteful – and then takes illegal steps to circumvent the problem.

To date the scientific argument on TACs has always carried the day. Industry has made noises but has done very little pro-active work to address this and to restore a balance in the argument. In short they lack a credible argument against the science. However the development of joint activities, such as the UK Fisheries Science Partnership, has increased co-operation, collaboration and trust between the industry and science. It has also increased the understanding of the industry in the activities and information that are used in scientific assessments.

To continue these advances, the task will be to position industry so that accurate recording of landed catch and discarded catch is carried out. The wide spread uptake and correct (truthful reporting) usage of E-logbooks will go a long way to readdressing the imbalance. By providing a complete and accurate story on the fishing activities of a fishing fleet, this very act is a huge step towards providing the much needed complete picture of all fishing activity on which the TAC is based upon. By doing so, industry can provide science with a far more accurate view of the current status of stock. They also increase the level of informed argument that they can produce.

If we assume that the provision of accurate and truthful logbook data leads eventually to a far more positive assessment of fish stock, we can also assume that by removing some of the uncertainty in stock status estimates, this will lead to an increase in TAC. However, if the argument goes in the opposite direction, and the data provides evidence that leads to TAC reduction, Industry can take some comfort in the fact that the data provided and the decisions leading from it are accurate, and that more conservative measures are justified.

By its very nature, the process described here will not have any “short term” benefit to Industry. However, the argument must be made that a long term view be adopted to break the cycle Industry and enforcement find themselves in today. The very positive effect these measures would have in the medium to long term should not be underestimated.

5.2.1.2 More days at sea

A scheme currently operating in Scottish Waters deals directly with the link between reducing discards, accurately reporting this reduction, and the resulting “reward” attached to this effort.

A case study is the North Sea is the Prawn fishery. Due to the nature of the mixed fishery in which prawn boats operate there is a substantial chance of catching unwanted cod, whiting and haddock, for which there is limited or no quota in this fishery. As already mentioned some prawn vessels have been observed catching as much as 60% or more unwanted cod which has to be discarded. This in turn leads

to extra effort to replace the unwanted catch (cod) with desired catch (prawns) which in turn leads to another round of discards due to the increased effort to make the trip viable. Eventually vessels may run out of days at sea and cannot continue to fish.

A scheme has been devised wherein through the usage of more selective gear and more selective choice of fishing ground, a notable reduction in by-catch is rewarded by extra days at sea. The maximum by-catch limit has been set a 5% of the total catch. The reported by-catch levels of 60% can therefore be reduced by providing the correct incentive.

The reason this case is being quoted is simple. The reward of extra days at sea is linked to the accurate recording and reporting of total catch and by-catch. At the moment this task is being carried out by designated observers. This is a man-hour intensive process and can only include a limited number of vessels at any one time due to limited man power and cost. This results in a very slow certification process to achieve the extra days at sea status.

However, we have today the capability to put on board a fishing vessel an E-logbook with the technology to record and report all the activities of the vessel. The E-logbook must be able to carry out the role of an independent observer; otherwise the data provided by the crew to achieve certification could be regarded as suspect. The system must have the means to provide independent verification on the data provided. However, technology provides the capability to record on video all aspects of the fishing operation. This would include the actual footage of the net coming on board to the footage of the catch being sorted, thus providing an “independent source” on the catch composition. See image below:



By using such E-logbook technology in partnership with more selective fishing practices, the fishing industry can shift from being reactive to proactive with all the added benefits of achieving more days at sea to increase the viability of the business, thus allowing more time to be more selective in choosing fishing grounds, achieve a major reduction in discards and the provision of more accurate data to government and science alike.

We have the quota but struggle to use it to its maximum (Industry Quote)

A large Scottish PO has noted the problem of end of year quota take up. During discussions it became apparent that the Government paper-based system of First Sales Notes and Landing Declaration was creating major problems. In the UK, the First Sales Note data can take up to one month to be processed and to be passed on to the relevant PO who then distributes the remaining quota amongst the PO

vessels. The time taken for the data on the sales notes to be converted into remaining quota was creating a serious time gap delay.

This delay is not an issue in the early months of the fishery, but in the closing two to three months up to date and timely data on the remaining quota is crucial and can lead to some quota not being taken.

Consultations with SEERAD confirmed the delays. The bottleneck was identified at the point where the calculation was made between submitted sales note, cross checking with submitted logbook data and the processing time required to come up with the remaining quota for that particular species (in this case haddock). Currently the UK system is a spreadsheet-based environment, which does not lend itself to speedy and accurate decision making.

A system was devised by OLRAC that could increase the flow of data by reducing the bottleneck at source. The system would be web-based and linked to the landing data provided by the E-logbook. The cross checking of landed data from the E-logbook and the comparison to the accurate weights of species recorded on the First Sales Note is an integral part of the system.

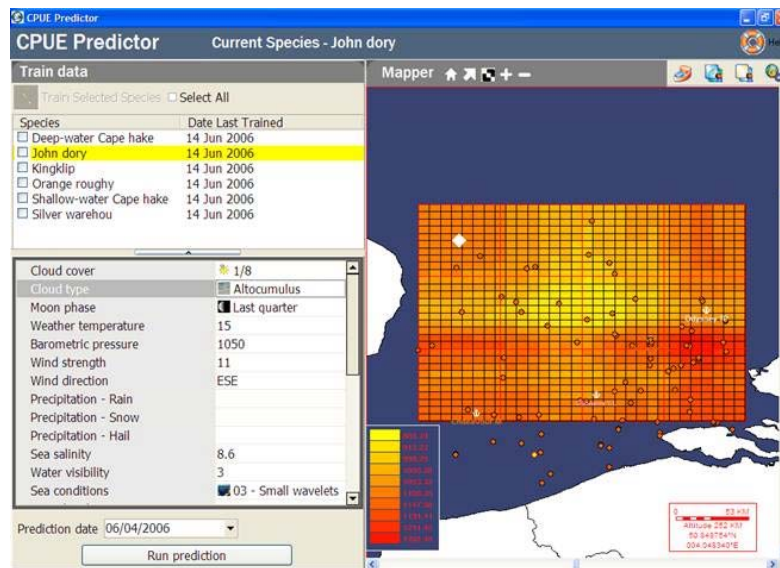
- The fishing vessel would submit the landing data through the web portal. This data would then be decrypted and uploaded to the web site.
- The First Sales Note would be completed by the vessel agent and the relevant recorded weights and species data uploaded to the web site. The agent would only ever be able to review and upload data from the vessels he deals with, and he would not have access to the submitted E-logbook data.
- The PO would be able to review all relevant data – E-logbook and First Sales Notes data. The PO could carry out a comparison exercise to establish quite accurately the remaining quota available based on the landing declaration from the E-logbook and First Sales Note data.
- The Government body would have access to E-logbook data and First Sales Note Data. They would then calculate the remaining available quota and upload this data on the website.
- The PO would then access the remaining official quota data and distribute this amongst the vessels in the PO.

Based on this technology data could be turned around in days as opposed to weeks. This would allow the PO to fish to its full quota potential, knowing that the data they are acting upon has been acquired in near-real time conditions. In addition, the burden of maintaining a paper based system by government, with all the man hour costs and possibility of error in recording data is dramatically reduced. Furthermore, the benefits to fishery management is enhanced by having the capability to see quota uptake in near real time, thus allowing management decisions on the fishery to be taken in near real time. This would vastly decrease the danger of over fishing and the subsequent fines imposed on POs for exceeding quota. An additional benefit with such a system would be the capability to identify lack of quota in near-real time.

There have been occasions when POs have been forced into a horse trading situation by suddenly discovering that due to vessels fulfilling their quota ahead of schedule (and not having the means to be forewarned adequately) there is little or no quota available for the remaining season. Under certain circumstances countries have been known to swap one species quota for another. Norway and Scotland are prime examples of this. It is often the case that the swaps are carried out in less than ideal conditions, due to the lack of forewarning of a depleted quota. By keeping a tight control of the quota and with the addition of near-real time data on the remaining quota, this would provide a more robust “early warning system” and would allow the negotiating parties more time to prepare their case.

5.2.1.3 Catch prediction – Catch management

Based on the assumption that a collective database is in operation, the task of predicting fish migration, juvenile hot spots, etc. will become vastly more efficient. This in addition to more reliable fish stock data will increase the efficiency of fishing fleets, and reduce steaming times. While this on its own could result in a greater impact on fish stocks, improved knowledge and targeting of areas, becoming more accurate in selecting fishing grounds and more selective in fishing techniques, discarding rates may reduce, benefiting data collection and stock status. Technology exists already in E-logbook systems to carry out calculations, based on historical catch data, to predict more productive fishing grounds. Not only does this have the capability to predict areas of good catch, it (just as importantly) has the capability to predict areas of “no go”.



5.2.1.4 Traceability

Traceability is an increasing issue in fisheries. Certification under the Marine Stewardship Councils' scheme requires a chain-of-custody audit to ensure that only fish caught from the certified fishery are sold with the Certification logo. Having a system that allows fish sold at market back to the vessel and haul in question allows the commercial benefits of certification to be gained.

By increasing the traceability of catches, by identifying the areas from which catches were taken, systems can also address the need to ensure acceptable food safety levels. Systems can be used to pinpoint every box in every haul, and to label this box with a unique barcode. As the start and end point of the haul can be accurately pinpointed by the GPS, the 40 kilos of cod in a particular box sold at auction can be traced back to a particular haul from a particular vessel, i.e. we can prove that box of cod was caught in that three mile haul which took place on that day at that time by that vessel.

This has potential benefits where environmental disasters occur. As an example, an oil spill in the North Sea has affected an area of 200 square miles. At that time there were 50 vessels fishing in or close to that area. In actual fact only 15 vessels were in the contaminated area. This leaves 35 vessels with a clean bill of health –but this needs to be proved. Under the current practice all 50 vessels would be suspect and the catch would be condemned. By having an e-logbook on board, recording the vessel position and haul activity every two minutes (shorter if deemed necessary) the “clean” vessels would have been able to show on the system the position of every haul, thus clearing the catch for sale.

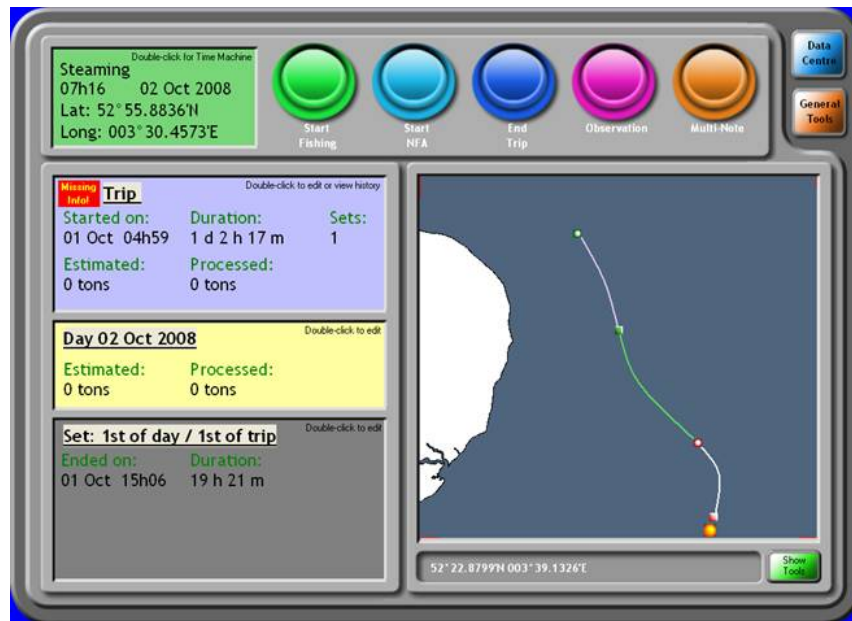


Image showing individual haul activity of vessel.

There are additional advantages. By being able to register on a haul for haul, day for day basis, the catch can be split and identified into “age of catch” segments. There are considerable market drivers asking for “fresh fish”. The fish is landed on a Friday, processed on a Saturday and in the supermarket on the Monday morning, and this can be proved through the traceability system. In addition, the supermarket benefits from better knowledge of shelf life - how long can the fish be safely merchandised? By knowing the exact day of the capture (plus other bonuses such as temperature stored on board vessel –input via logbook) the supermarket can, with a high level of certainty, sell that piece of fish within a certain “safe” time frame.

The price paid for that piece of fish is also determined by accurately knowing the date of capture. The younger the fish (date of capture), the fresher it is, therefore the higher price it will demand and the longer it can safely stay on the shelf and be exposed to a potential consumer. This data allows us all to make an informed decision on the product.

The information has a direct benefit to the vessel as well, even when certification is not involved. Being able to prove the date of capture, by passing this on to the buyer, who can then safely plan the shelf life, all means a better price for the catch. In certain cases, the last haul of the last day can be sold to a high end restaurant who is prepared to pay well over the average price for several day old fish, this done in the knowledge of certifiable freshness and traceability.

4.4 Summary

This section presents a range of the benefits that modern technology and the systems developed in the CEDER project and others can provide to Industry. The benefits do assume that vessels are equipped with an E-logbook that is user friendly and has an element of added value built in.

Just as importantly, the correct mindset and goodwill on the part of the Industry must be in place to report fully and truthfully on the fishing operation. This will only be present if certain political and regulatory changes are realised.

6 Benefits for sustainability

6.1 Introduction

Within Europe, advice on fisheries stock status and future fishing levels is provided by international bodies such as the General Fisheries Council for the Mediterranean (GFCM) and International Council for the Exploration of the Sea (ICES). Within the latter, the current framework for providing total allowable catch (TAC) advice for fish stocks within the ICES convention area is based on catch forecasts derived for multiples of current fishing mortality. Advice is based on “precautionary” reference points that trigger action intended to ensure that limit (or threshold) reference points, both fishing-mortality rate and biomass-based, are not exceeded. Within this framework, there is often an implicit harvest control rule (Kell *et al.*, 2005) and an increasing number of explicit pre-defined harvest control rules, which set the level of fishing mortality or catch in the subsequent year(s) in order to achieve longer-term goals.

Kell *et al.* (2005), in their examination of the implicit management procedures for a number of ICES roundfish stocks, noted that the types of stock projection used by ICES, which generally assume a 3 year average status quo in many parameters, including recruitment, do not incorporate important lags between assessing stock status and implementing management measures. For example, 2001 catch data are only available in 2002, when they are used in an assessment to set a TAC for 2003. The effect of TAC management in 2003 will be on the SSB at the start of 2004. However, any effect can only be detected first in 2005, when the 2004 data are available. This results in a 5-year lag between deciding upon management and detecting its effectiveness, although actually determining the effectiveness of any management action will require even more time because estimates from assessment methods such as Virtual Population Analysis (VPA) are more uncertain in the most recent period. If these lags are modelled, the results generated may be very different from those derived by ICES. In an extreme case, as seen for North Sea cod in that paper, traditional stochastic medium-term methodology does not identify a collapse in the stock as a result. The true uncertainty is likely larger, since important sources of uncertainty were not included in the simulations of Kell *et al.*, e.g. non-compliance with management and subsequent catches above the TAC, potential misreporting of the true catch³⁰, and more realistic biology.

The technological approaches and statistical algorithms developed within the CEDER project should allow a better indication of catch in the current year, rather than the existing delay where last year’s catch data must be used. The current year data can then be used within assessments to estimate the TAC in the following year, which has the potential to reduce a source of uncertainty within the ICES stock assessment process. Furthermore, management may be able to use the CEDER project outputs to monitor the rate of uptake of TACs within year, allowing finer control over the fishery.

Although stock assessment and management is generally on a single-species basis, species are caught by fishing vessels as part of a multispecies complex. Therefore it is quite possible that following the achievement of the TAC for one species, fishing may continue to occur to obtain the total TACs for other species within the catch, with additional catches of the first species being legally discarded. The amount of discarded fish is difficult to estimate, and while ICES Working Groups attempt to estimate this and other unreported catches, the lack of information adds uncertainty to stock assessment results.

All management is adaptive, in that it reacts to knowledge gained in previous years. A truly adaptive approach would use fisheries management policies as “experiments” from which managers and

³⁰ see the Court of Auditor’s “Special Report No 7/2007”

fishermen learn and use to adapt future fisheries policy (e.g. Walters, 1986). However, using the CEDER approach, rapid collection of information can allow a form of adaptive management to occur within a year, rather than between years. In theory, obtaining a better understanding of quota uptake within the year allows management intervention that limits catch rates (through effort control, more precise catch controls, fishery closure etc.) to ensure the TAC for vulnerable species is just achieved at the end of the fishing season. Within a multispecies fishery, the question is then against which TAC will the manager control the fishery? Within US fisheries management, the process is generally to close the fishery when the TAC of a key species (generally the target species) is reached. In this way bycatch species are generally not fully exploited, but the most valuable species is exploited to an agreed exploitable level without suffering additional unidentified discard mortality.

In this section, we report on the potential implications and benefits of using the CEDER system to improve the sustainability of European fisheries management. We present the results of computer simulations that examine two separate aspects of the benefits for sustainability, and discuss the implications for single- and multi-species management, as well as the ecosystem approach.

6.2 Methods

In order to plan the simulation work, a scientific group meeting was held during the July 2007 meeting in Iceland. The proposed simulation approach (methodology, scenarios etc.) was presented and discussed. Cefas staff subsequently performed the simulations reported here.

Management strategy evaluation (MSE; Kirkwood and Smith, 1996), a simulation tool that allows the consequences of different management strategies to be evaluated, was utilised. The simulations were carried out using the FLR programming framework (Kell *et al.*, 2007). The potential benefits of the CEDER system were examined for two different specific aspects of European fisheries:

- The inclusion of current year catch data in assessments (rather than being limited to last year's data as currently). This was examined for North Sea cod (*Gadus morhua*), where a recovery plan is in operation.
- The potential benefit of adaptive management based upon TACs in mixed fisheries. This is examined for a simulated fishery with aspects comparable to the anglerfish (*Lophius piscatorius* and *L. budegassa*) fishery in the southwest of the UK.

6.2.1 Real time catch data for a recovering stock – North Sea cod example

Most stock assessments are carried out using data from the previous year because data from the current year are not yet available. This means that assessments performed to inform managerial decisions are only able to use data that are at least one year old. The time lag between data availability and management advice may mean that the fishery is not being managed as effectively as it could be (see Kell *et al.*, 2005b). This may be of particular importance when the stock of interest is subject to a recovery plan. Using VMS data and the CEDER framework should allow more up to date catch data information to be available. This approach has the potential to reduce time lags between data availability and management advice. MSE was used to explore the impacts of using recent catch data in the assessment and management of a simplified version of the North Sea cod fishery and its recovery plan.

A simplified Harvest Control Rule (HCR) was designed to reduce the average fishing rate (F_{bar}) from the 2005 level of 1.2 to 0.4. This is achieved by setting an appropriate TAC, the level of which is decided in the previous year. For example, to achieve the target F_{bar} in 2008 requires an appropriate

TAC for 2008, and this TAC will be decided in 2007. However, under the standard management procedure the current year's catch data is not available, and only data up to the previous year is available. To overcome this gap in data caused by the lag in data collection a two year 'short term forecast' is required to determine the TAC (figure 11). The short term forecast has to make various assumptions including estimating the current and future recruitment levels and fishing rates. As these estimates are made without the most recent data, forecast results may be at best inaccurate and at worst misleading about the appropriate level of TAC.

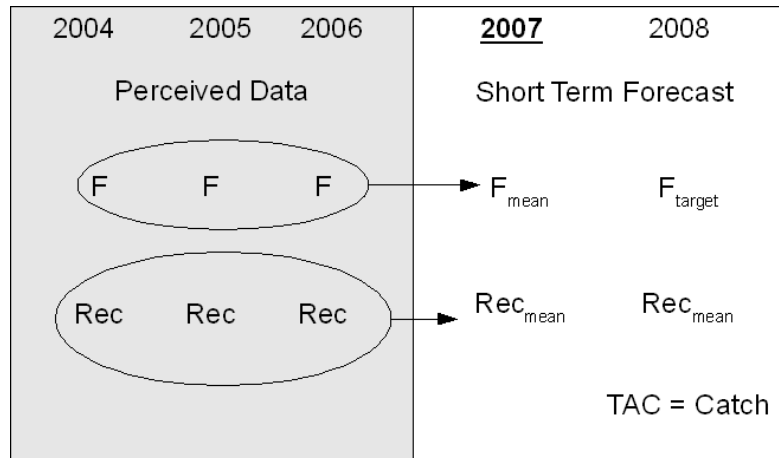


Figure 1. The standard management procedure with a 1 year time lag between data collection and assessment. Here 2007 is the current year. Data are only available to the managers up to 2006 (shaded grey). A short term forecast is therefore run for 2007 and 2008. The recruitment in the forecast years is the geometric mean of the previous three available years. The F in 2007 is the mean of the previous three years. The TAC in 2008 is set as the forecast total landings weight in 2008.

Through the CEDER system, catch data in the current year could be estimated. This means that in the HCR only a one year forecast would be required to set the TAC in the following year. As this forecast is for a shorter period of time and uses up to date data, it is likely to be more accurate and may allow more effective management than under the current process.

The HCR also imposes a restriction on the inter-annual change of TAC - to protect the fishing fleet from rapid changes in quota the TAC is not allowed to change by more than 15% per annum. If the desired change in TAC is greater than 15% then the TAC is set at the limit allowed by the constraint. This type of constraint is typical for the management plan for recovering stocks. The effect of this on management performance using CEDER estimates of catch was also investigated.

Within the stochastic simulations, the underlying population was taken from the results of the 2006 North Sea and Skagerrak Working Group results, providing stock numbers and harvest rates at age from 1963 to 2005 (ICES, 2006). A Ricker stock-recruitment relationship was fitted to the data and used to simulate recruitment in the biological operating model. To keep the simulations simple, only one fleet was simulated fishing on a single stock. Uncertainty was applied to the stock recruitment relationship - lognormal noise was applied multiplicatively to the recruitment estimate. Instead of performing a specific assessment, lognormal noise was applied to the underlying numbers-at-age to simulate differences between the perceived data and the actual data. This approach meant that the results of the simulation were free from any inherent bias resulting from the assessment method. This made it easier to identify any benefits of using recent catch data in stock management.

Due to simplifications used in the MSE (fleet structure and recovery plan) the results are not intended to be interpreted as actual projections of North Sea cod but as an investigation into the possible impacts of using current year catch data in the management of a fish stock under a recovery plan. Four scenarios were run; two for the standard management procedure with a 1 year lag between data

availability and management advice, and two for the ‘no lag’ management using the CEDER framework:

1. Lag = 1, no constraint on TAC change
2. Lag = 1, 15% constraint on TAC change
3. Lag = 0, no constraint on TAC change
4. Lag = 0, 15% constraint on TAC change

6.2.2 The advantages of active management – South West Anglerfish example

A further application of the CEDER framework is that it may allow fisheries to be ‘actively’ managed. The CEDER framework could provide very up to date landings data, allowing managers to make decisions and control the fishery in real time. This is in contrast to the standard management approach where data is seldom available in sufficient time for managers to make and act upon decisions during the year in light of TAC uptake. For example, in an actively managed fishery with TAC control, managers could theoretically determine when the landings of a species reached the quota, limiting overshoot. The fishery may then be closed when the quota has been reached. In a mixed fishery, this should reduce the level of discarding of a species that can occur when landings are not known until later on, and fishermen continue to fish for other under-quota species within the multispecies catch. In this situation, additional catches of those species whose quota has been reached would likely be discarded (potentially 13% of fish caught in the North-East Atlantic Zone; FAO 2005) Therefore the total fishing effort may be higher than anticipated as necessary to catch the TAC of a particular species.

Using MSE simulation, the potential impacts of actively managing a mixed fishery were explored. The simulations were based on a simplified version of the two anglerfish stocks in the South West UK mixed fishery that are managed by a single TAC. Under a ‘standard’ management regime, up to date information on the catches is not available throughout the year. However, the two anglerfish species are caught as part of a mixed fishery taking hake, megrim, sole, cod, plaice, and *Nephrops* (ICES, 2007). As a result, once the TAC of anglerfish is taken, additional catches while fishing for other (under-quota) species may be discarded, leading to a higher than desired fishing mortality. In turn, the two anglerfish species are considered as one for TAC purposes (two separate assessments providing single-species TAC recommendations which are summed into a total ‘anglerfish’ TAC). Even if the anglerfish TAC is taken precisely, there is therefore the potential for one or the other species to be overexploited.

The underlying biological status of the two anglerfish stocks was taken from the 2007 ICES WGHMM. Ricker stock-recruitment models were fitted to the original data and used to predict recruitment in the simulations. As the stock-recruitment process is strongly influenced by environmental conditions (ICES, 2007), uncertainty was added to the stock recruitment relationship for both species by randomly selecting each simulation year to be ‘good’ or ‘bad’ for recruitment: stock-recruitment residuals were added to or subtracted from the recruit estimates for each species under respective scenarios.

A single commercial fleet was simulated, while a survey fleet was also simulated to generate tuning indices for the XSA assessment performed for each stock, based upon perceived data. Uncertainty was applied to these tuning indices by multiplying them with lognormal noise with a standard deviation of 0.1 and a mean of 0.

To model the effect of a mixed fishery, the effort used to target the other species was represented by additional effort. A multiplier was therefore applied to fishing effort required by the fleet to catch the total anglerfish TAC. This multiplier leads to excess catch and consequently to discarding, as the

assumption was made that fishermen would not land in excess of the total TAC. These discards are not declared and were not considered in the stock assessment used to generate the perceived stock.

Within an active management process, we assumed that when the estimated total catch of anglerfish reached the TAC, the fishery was closed for the remainder of the year. This should mean that the fishery is perfectly managed for these species, and there will be no discarding. However, active management depends crucially on the accuracy of the real-time catch estimates from the CEDER system – it is expected that any system based upon model algorithms is unlikely to be absolutely accurate. In particular the effects of any bias in the catch estimates needs to be considered. If the real-time data overestimates the catch then the fishery may be closed too early, meaning the real landings are less than the TAC, potentially leading to a reduced income for the fishermen. If the real-time data underestimates the catch the fishery may be closed after the TAC has been reached, meaning that the real catch is greater than the TAC which then leads to discarding and higher than expected harvest rates. In specific scenarios we therefore applied a constant bias³¹ to the perceived catch numbers in the current year only, by multiplying the perceived catch numbers-at-age by a constant. This constant bias may be positive or negative, i.e. the perceived catch is either constantly greater or less than the actual catch. In the next year, the catch data for the previous year were assumed to be updated by the arrival of ‘traditional’ data from logbooks (which was assumed to be accurate).

We ran three standard management scenarios, based on the effort surplus. The effort surplus was 0%, 20% or 40% greater than that needed to catch the estimated anglerfish TAC. In turn, for active management where no effort surplus was assumed, three management scenarios were run based on the bias applied to the catch numbers-at-age within the active management system. That bias was 1 (no bias), 0.9, or 1.1, i.e. a 10 % over or underestimate of catch numbers.

6.3 Results

6.3.1 Real time catch data for a recovering stock – North Sea cod example

Results showed that although there was some advantage in using recent data from the CEDER framework, with management performance being improved, the impact on the dynamics of the fishery was overshadowed by application of the TAC constraint.

When using lagged data under the standard management process, without the TAC constraint the target of F_{bar} is reached in about 5 years. When up to date data were available the target was reached immediately (Figure 2). After the targets had been reached both scenarios showed similar dynamics although there was greater uncertainty when lagged data were used, represented by the larger range. There is no real difference in the level of landings between using lagged and non-lagged data (Figure 3) and hence little impact on fishers.

³¹ In reality, bias is likely to change over time, rather than being consistently biased one way or another. The results of this on estimation results will depend on their magnitude and distribution. The accuracy of catch estimates from a Ceder style system could be measured in the same way that surveys are (with catchability (Q) and variability). A catchability of >1 could result from underestimates of effort in Ceder.

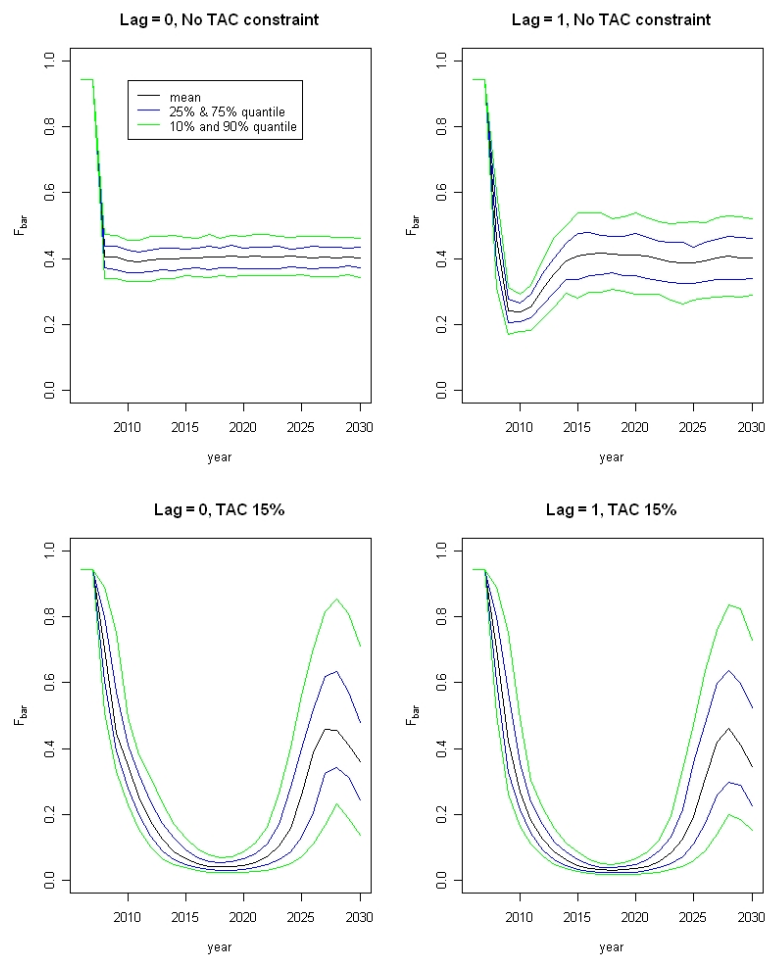


Figure 2. Range of F_{bar} from stochastic simulations when up date data are available ($Lag = 0$), only lagged data is available ($Lag = 1$), when managers are free to set the level of TAC, and when TAC is constrained to a maximum 15% change. Black is the median, blue lines the 25% and 75% quantile and green lines the 10% and 90% quantile.

When the TAC constraint was applied, the resultant dynamics were very different. The constraint prevented the TAC being set at the level that assessments suggested were appropriate. Consequently, the TAC was set either too low or too high, effectively chasing the level that would bring F to F_{bar} . This led to large fluctuations in F and to a system that did not settle down (Figure 2). The pattern of F was the same when using lagged or non-lagged data, indicating that fishery dynamics were driven by the constraint, rather than any lag between collecting and using the data. It is possible to see economic benefits from using up to date data by looking at the difference in landings between scenarios. For the first 20 years the landings are slightly higher when up to date data is available (Figure 3). However, by extending the time scale of the simulations past 2030 it can be seen that this is not always the case.

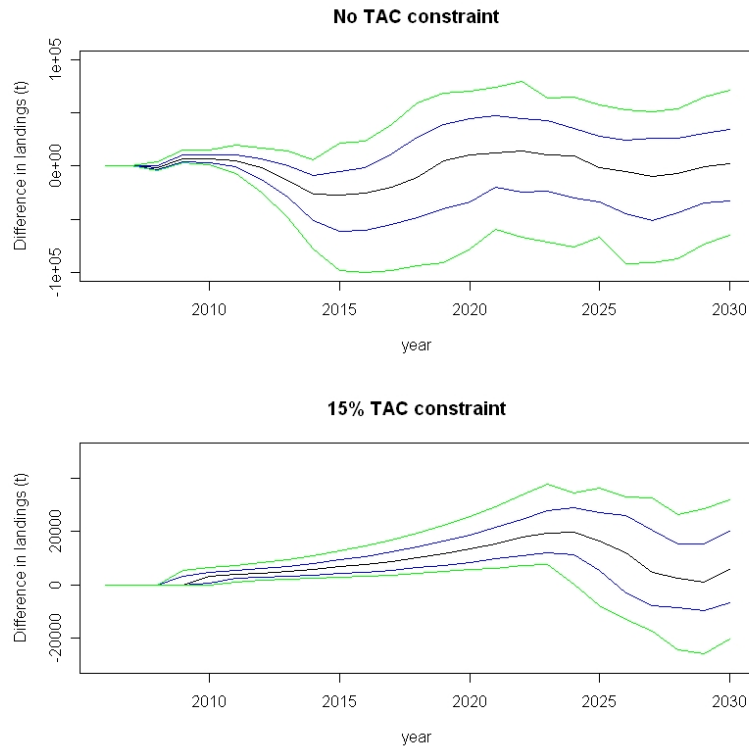


Figure 3. The landings when lag = 1 subtracted from the landings when the lag = 0, (hence showing the difference between landings when up to date data is available and when lagged data is available), for the scenarios with and without a TAC constraint. Black is the median, blue lines the 25% and 75% quantile and green lines the 10% and 90% quantile.

6.3.2 The advantages of active management – South West Anglerfish example

The simulation results suggest that an actively managed mixed fishery performs better than a fishery under standard management in terms of economic performance (measured as landings through time; Figure 4) and in terms of ecological performance (i.e. whether biomass is above the target and whether fishing rate is below the target; Figure 5). This clearly demonstrates the potential advantages of using a CEDER-style system to actively manage fisheries. However, the success of the active management is strongly influenced by the accuracy of the real-time data estimates, with a consistent under-estimation bias from the CEDER system resulting in a stock decline not dissimilar to the standard management (Figure 4).

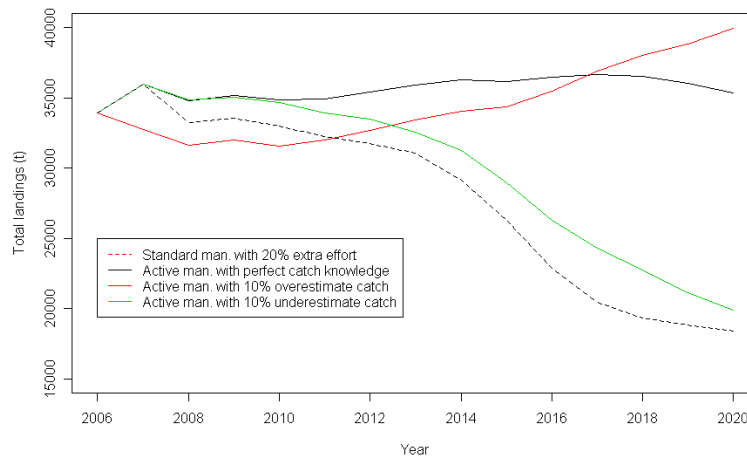


Figure 4. Total landings from both anglerfish stocks under alternative management scenarios. The standard management scenario with 20% extra effort (representing the additional effort in a mixed fishery) performs worst over time. The performance of the active management scenarios depends strongly on whether the catch is over or underestimated.

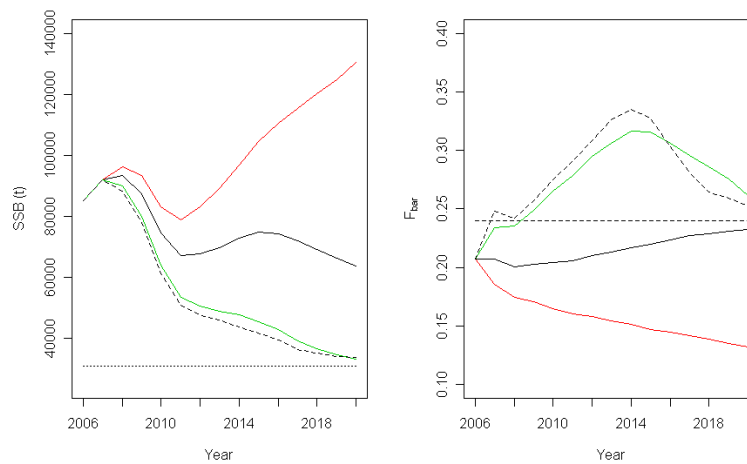


Figure 5. Spanning stock biomass (SSB) and fishing mortality rate (F) for the different management scenarios for one anglerfish species (see Figure 4 for legend). SSB is much lower and close to the limit (the black dotted line) and F has exceeded the limit under both the standard management scenario and the active management scenario when catch is underestimated.

6.4 Discussion

This section examined the potential benefits of the CEDER system for two contrasting issues of European fisheries management namely:

- Lags within fisheries management
- Issues of managing mixed fisheries

The results of the simulations have a number of implications for fisheries management.

6.4.1 Inclusion of current year catch

In the cod case study, while the CEDER system can offer some advantages for stocks under recovery plans, these were overshadowed by the imposition of an inter-annual limit on TAC change. This raises important issues regarding the management of not just fisheries systems, but all systems under management regimes. The feedback

between the operating model (the underlying fish population within the model) and the management procedure means that the TAC, SSB and fishing rate all interact. Here, we are trying to achieve a target F_{bar} but we are not able to manipulate it directly. Instead, we are trying to indirectly control F_{bar} by manipulating TAC levels. When there is a delay in the information the control is poorer (for example, the difference between a lag of one year and no lag when there is no constraint on the TAC). However, when we impose a 15% limit on TAC change, control becomes even more difficult. We are not able to directly control our desired measure (F_{bar}) and to make matters worse we have deliberately restricted our ability to control the thing that we are able to manipulate (TAC). The result can be not just ineffective control but actions that actually work against the intentions of the manager. It is interesting that the 15% constraint was applied by the EU to protect the industry from rapid change and bring stability. Instead it is the source of instability.

The assumption that the CEDER system will automatically result in improved data delivery to working groups is not strictly correct. The commercial catch data is but one component of the data used by the ICES working groups. Indeed, for North Sea cod, where the level of stocks is considered very low and commercial catch data are less certain, the use of commercial data in assessments has declined. The results of surveys performed within years, and the estimates of age composition derived from the collection, processing and reading of otoliths to generate age-length keys, is a drawn-out affair that will remain a limiting factor for the delivery of information to working groups.

Although not examined here, an effective CEDER-style system could be used within stock assessments as an additional tuning index (measure of stock abundance over time). This has the potential to further improve assessment performance, dependent upon the accuracy and precision of the CEDER estimates.

6.4.2 Management of multispecies catch

The results of the multispecies simulations suggest that if a CEDER system can be developed that is sufficiently accurate and unbiased, there could be benefits for mixed fishery management. The required accuracy is a key component. If the algorithms overestimate catch, there will a short- and medium-term negative impact on fisheries, but potential longer-term benefits as stocks recover faster than the situation where algorithms provide accurate catch estimates.

Implementation of a reactive management system requires timely action, of a type only likely to be encountered where stocks are under individual or binding multinational control (e.g. management of short-lived squid stocks in the South Atlantic). Whether this style of management is feasible in multinational EU waters is open to question. While Member States have primary responsibility for managing and monitoring quotas and avoiding quota overruns, potentially by closing fisheries, this is not straight forward in the generally multi-state fisheries within EU waters. While it is not the Commission's role to step in where this issue arises, regulations are in place for them to halt fishing if necessary (Regulation (EEC) No 2847/93, Article 21(3) & Regulation (EC) 2371/2002, Article 26(4)). As noted in the Court of Auditor's Special Report, however, due to the necessity of assembling sufficient evidence to provide assurance that a quota has been used up, the scope of this provision is confined to cases where there are a small number of ships and landings. In turn, to avoid legal risk, there must be a very high confidence level before action can be taken. Over-quota catches can also be deducted from the TAC for a country in subsequent years.

We did not explicitly model implementation error within the simulations, although evidence from examples of real-time management activities suggest that quite long lags can occur between the collection of data, agreement of assessment and the need for action, and subsequent closure of the fishery.

6.4.3 Other issues

A further concern is the issue of the accuracy and precision of estimates derived from any CEDER algorithm system. CEDER estimates will be less accurate and precise than logbook data. In turn, those algorithms must often be based upon catch data provided through logbooks, which in turn are open to uncertainty. As the Court of

Auditor's Special Report notes, the tolerance margin for quantity estimates declared in logbooks is set at 20%, but under-declarations can 'legally' be as high as 36% in the absence of landing inspections. Any CEDER system must operate in an environment with this level of uncertainty whether during the generation of algorithms or collection of near-real-time data. However, observer data can be used to derive the algorithms. While this has the potential to improve the situation, these data are of limited coverage both spatially and temporally. These issues need to be overcome before a CEDER system could effectively provide 'real-time' catch information. However, the results of the simulations have demonstrated what potential gains are possible.

6.4.4 Other sustainability benefits

The ability to ascertain fishing activity and behaviour in near real time has benefits beyond those of direct single- or multi-species fish stock sustainability. The systems also have potential benefits for the management of the wider marine complex. New fisheries management drivers include the ecosystem approach to fisheries management, a more holistic approach to considering the impact of fishing on the marine system and the spatial planning of marine activities (Eastwood *et al.*, 2007). The benefits of using near real-time information for ecosystem impacts should be considered in this context.

Many researchers have looked at the unexpected implications of a variety of fisheries management interventions on the environment. What appears to be a straight-forward management approach, for example limiting days at sea or closing particular areas, can result in effort displacement, if not accompanied by catch or effort controls (Rijnsdorp *et al.*, 2001). This can result in an undesirable increase in mortality on other species or life history stages of the target species outside the closed area (Horwood *et al.*, 1998). The closure of areas may lead to vessels dispersing more widely (Frank *et al.*, 2000), to search for profitable fishing sites, and to escape increased competition from vessels congregating along the boundaries of the closed area (Rijnsdorp *et al.*, 2000). Skippers may also postpone their fishing activities until later in the season, when their regular grounds reopen (Rijnsdorp *et al.*, 2001), leading to an increase in fishing intensity over a shorter time period. Trawling disturbance may affect the structure and diversity of benthic communities (Jennings and Kaiser, 1998), which is of concern when applying an ecosystem approach to fisheries management. Dispersal of effort into new areas has the potential to impact upon relatively pristine, previously minimally exploited, areas of seabed.

To use Vessel Monitoring System (VMS) information for analyses of the impacts of fishing, an estimate must be gained of whether fishing activity is actually occurring when the position report is given. Algorithms to estimate activity from current 2-hourly poling information have been developed by Mills *et al.* (2007), for example, as well as being developed and refined in the CEDER project. The application of fishing vessel effort estimation methods to spatial marine management issues has also been described elsewhere (e.g. Dinmore *et al.*, 2003; Mills *et al.*, 2007; this project).

The ability of scientists to identify potential ecosystem effects of fishing will be dependent upon the timescale and hence resolution of position information. Two-hourly poling by VMS results in considerable uncertainty in the actual location of activity between positions, but may be sufficient for algorithms to identify fishing/non-fishing activity. For ecosystem studies, real-time information is not necessarily required (real-time management of closed areas being an enforcement issue). Therefore for ecosystem studies information collected at a greater frequency (e.g. every 15 minutes) could be stored and downloaded on return to port, thereby eliminating the issue of the extra costs involved in more frequent VMS transmissions.

When implementing an ecosystem approach to fisheries management, the impact of a bottom trawl fishery on a habitat or the benthic community needs to be determined. This is often done by multiplying the frequency of the passing of trawls with a factor for the effect (i.e. % mortality) of the singular passing of the gear. As fishing intensity in an area is not homogeneously distributed it is necessary to determine the proportions of the area that are fished with different trawling frequencies as these sub-areas together make up the overall species' mortality. The work conducted as part of CEDER showed that the proportion of the area fished with a specific trawling frequency is determined

by the spatial and temporal scale used (see Appendix 1 (section 8)). A smaller spatial scale results in an increased perceived patchiness of the fishing intensity while a longer time period does the opposite. The implication of this is that in order to determine the fishing-induced mortality of a particular species the trawling frequency needs to be determined at those spatio-temporal scales that are appropriate considering the species' spatial processes (e.g. dispersion) or temporal processes described by life-history characteristics. Likewise, when establishing and reporting on the proportion of the surface area of a habitat that is trawled the spatio-temporal scale at which this was established should be provided.

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8 Appendix 1. Paper on spatial and temporal scale determining the impact of fishing

Spatial and temporal scale determine the impact of fishing

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Summary

The impact of a bottom trawl fishery on fish or benthos is often determined by multiplying the frequency of the passing of the trawl with a factor for the effect (i.e. % mortality) of the singular passing of the gear. As fishing intensity in an area is not homogeneously distributed it is necessary to determine the proportions of the area that are fished with different trawling frequencies as these sub-areas together make up the overall species' mortality. In this study we show that the proportion of the area fished with a specific trawling frequency is determined by the spatial and temporal scale used. A smaller spatial scale results in an increased perceived patchiness of the fishing intensity while a longer time period does the opposite. The implication of this is that in order to determine the fishing-induced mortality of a particular species the trawling frequency needs to be determined at those spatio-temporal scales that are appropriate considering the species' spatial processes (e.g. dispersion) or temporal processes described by life-history characteristics.

Introduction

Understanding patterns in terms of the processes that produce them is the essence of science, and is the key to the development of principles for management (Levin, 1992). Therefore, theoretical ecology relates processes that occur on different scales of space, time and organizational complexity. Fisheries research traditionally has been driven by the requirement to manage stocks of the harvested species. With the development of an Ecosystem Approach to Fisheries Management (EAFM) research has increasingly focused on the environmental effects of fishing on non-target fauna and marine habitats (Hall, 1999; Sinclair and Valdimarsson, 2003) and on ecosystem-based approaches to management that take account of these impacts (Murawski *et al.*, 2000; Brodziak and Link, 2002; Link *et al.*, 2002; Jennings, 2005). More than in traditional fisheries management this necessitates a reappraisal of the issue of scale in space and time.

The pressure state response (PSR) system (Garcia and Staples, 2000) that was adopted for an EAFM is in line with traditional fisheries management where we attempt to manage the state of a fish population, described by the spawning-stock biomass (SSB) by manipulating the pressure, described by fishing mortality (F) through a response that may involve management measures such as TAC, effort reductions or technical measures (Frid *et al.*, 2005; Piet *et al.*, 2006). This, however, requires that the relationship between Pressure, State and Response is understood (Jennings, 2005). Several studies have explored the relationship between Pressure and State and aimed to determine the impact of fishing by multiplying the frequency of the passing of the trawl with a factor for the effect (i.e. % mortality) of the singular passing of the gear, thereby recognizing that the first fishing event has proportionally more impact than subsequent ones (Collie *et al.*, 2000). However, the effects of multiple events are cumulative and the estimation of fishing impact is further complicated by the fact that in most biological systems mechanisms for recovery exist. Therefore the key issue is not the absolute frequency of an impacting activity but the frequency relative to the recovery time for that system. Thus, the impacts of fishing need to be considered in terms of intensity of impact, frequency of impact, and nature of the impacted system or component, in particular its ability to, and rate of recovery.

Spatial and temporal scales at which the impact on the system is determined must match those of ecological patterns and processes (Marceau, 1999). The above studies indicate that the choice of the appropriate scale depends on the ecosystem component, where studies on fish often use larger scales (Marchal *et al.*, 2006) while studies on benthos use smaller scales (km^2 or Nm^2 , e.g. Hiddink *et al.* 2006, Dinmore *et al.* 2003). For habitats like coral reefs a resolution of m^2 may be most appropriate (Andrews and Anderson, 2004; Fox and Caldwell, 2006).

When determining the fishing impact many studies emphasized the importance of the spatial component even though the spatial scale at which they studied the relationship, differed (Rijnsdorp *et al.*, 1998; Piet *et al.*, 2000; Dinmore *et al.*, 2003; Ragnarsson and Steingrimssson, 2003; Bellman *et al.*, 2005; Hiddink *et al.*, 2006; Marchal *et al.*, 2006).

Rijnsdorp *et al.* (1998) found that beam trawling was patchily distributed up to a spatial resolution of approximately $1 \times 1 \text{ Nm}$, random at higher resolutions and discussed the relevance of this when studying the impact on benthic organisms. Therefore several studies used this or similar resolutions when estimating the impact of trawling on the benthic fauna (e.g. Piet *et al.* 2000; Dinmore *et al.* 2003; Hiddink *et al.* 2006) while others (Marchal *et al.*, 2006) used a scale of ICES rectangles (approximately $30 \times 30 \text{ Nm}$) to describe the relationship between fishing mortality of commercial fish species and effort.

(Dinmore *et al.*, 2003) studied the micro-scale distribution of fishing at scales of 1×1 , 2×2 , 4×4 and $8 \times 8 \text{ Nm}$ and observed that the spatial scale may have a critical effect on any interpretation of fishing impacts but did not further analyze this. Piet *et al.* (2006) showed that estimates of fishing mortality based on a $1 \times 1 \text{ Nm}$ scale differed from those based on ICES rectangles (approximately $30 \times 30 \text{ Nm}$) but did not examine or attempt to describe the mechanism. Mills *et al.* (2006) shows that trawling effort can be reported as area impacted per unit time per unit area at a range of grid scales from 1 km to 100 km and decides that for VMS data with a two-hour interval trawling effort is accurately represented at a grid cell resolution of 3 km or less.

All these studies determine fishing impact based on yearly estimates of trawling intensity without considering different time scales. Eastwood *et al.* (2007) did consider this but indicate that they made no attempt to introduce a temporal component to their pressure assessment because of the complications of developing a common metric. Thus, there are several studies that have explored the relationship between effort and impact, often taking into account the spatial distribution of the fishery. However, none of them have fully addressed the issue of spatial or temporal scale, let alone the combination.

Therefore the aim of this paper is (1) to show how the spatial distribution of fishing effort in a specific area changes in relation to the total amount of effort exerted on that area and (2) to demonstrate the importance of the spatio-temporal scale when assessing the impact of a bottom trawl fishery by showing that the proportion of an area that is trawled with a certain frequency is also determined by the spatio-temporal scale chosen. We will argue that the models used to assess the fishing impact on a specific ecosystem component should use appropriate scales in both space and time. The choice of the appropriate scale may depend on spatial processes such as migration or dispersion or temporal processes described by life-history characteristics that are specific for that ecosystem component.

Material & methods

For this study we used what is probably the longest time-series of high-resolution spatial distribution data of fishing activity in European waters: the APR/VMS database of the Dutch beam trawl fleet in the South-eastern North Sea. This dataset commences in 1993 and continues until present. It was previously described by Rijnsdorp *et al.* (1998) and Piet *et al.* (2000, 2006). We combined this dataset

with the VIRIS database, which contains information on fishing activities of the entire Dutch fleet at a spatial resolution of ICES rectangles stored in individual fishers' EC-logbooks. This dataset is described in more detail in Piet et al. (2006).

In order to study the effects of the spatial and temporal scale we aggregated the fishing registrations into spatial and temporal units at different scales. For the spatial scale we used the ICES rectangle as the basic spatial unit as this is also the scale at which effort data are collected and divided it into increasingly smaller subunits (table 1). For the temporal scale we aggregated the registrations into units of quarterly, 1 year, 2 year, 5 year and 10 year periods (table 2).

Table 1. Codes used for the spatial scale. The surface area per spatial subunit was calculated for an assumed surface of the ICES rectangle of 30x30 Nm².

Code	Description	# subunits	Surface area
1	ICES rectangle	1	± 30x30 Nm ²
3	3x3	9	342.990 km ²
10	10x10	100	30.869 km ²
30	30x30	900	3.430 km ²
100	100x100	10000	0.309 km ²
300	300x300	90000	0.034 km ²
1000	1000x1000	1000000	0.003 km ²

Table 2. Codes used for the temporal scale.

Code	Description	# subunits
qtr	4 quarters per year, period 1994-2005	48
1	94, 95, 96, 97, 98, 99, 00, 01, 02, 03, 04, 05	12
2	94-95, 96-97, 98-99, 00-01, 02-03, 04-05	6
5	94-98, 99-03	2
10	94-03	1

The fishing impact on an ICES rectangle was described by the proportions of the surface area that were fished with a specific frequency (yr⁻¹). The trawling frequency per spatio-temporal unit was calculated from the registrations by calculating the equivalent area trawled according to Piet et al. (2006) and dividing this by the area of the spatial unit (see table 1). The following frequency classes were distinguished: 0, 0-0.1, 0.1-1, 1-10, 10-100, 100-1000, >1000.

Results

While the database based on individual fishers' EC-logbooks uses a spatial scale of ICES rectangles to express fishing intensity, the data that are currently being collected using VMS allow a much higher spatial resolution. The fishing intensity of the Dutch beam trawl fleet in the South-eastern North Sea shows distinct spatial patterns that determine how this fishery impacts the ecosystem. However, based on these data our perception may change considerably depending on the spatial scale used (Figure 1).

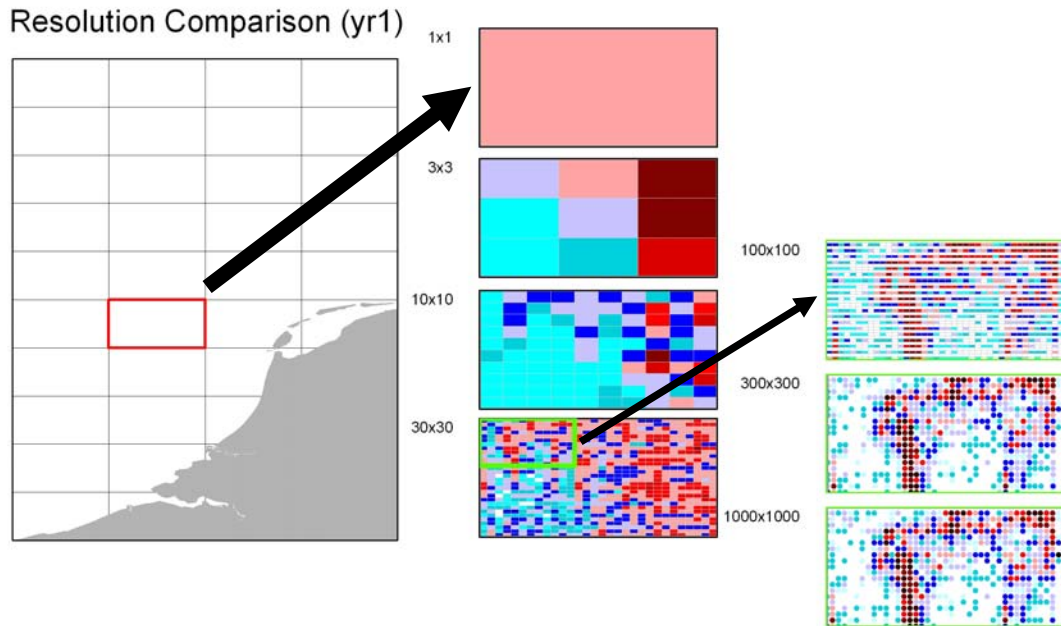


Figure 1. Spatial distribution of Dutch beam trawl fleet at different spatial scales. More information on these scales is in Table 1.

The spatially disaggregated information of fishing intensity is usually reported per year which may be appropriate at the crude spatial scale of ICES rectangles. However, when the spatial resolution is increased (Figure 1) the temporal scale at which the data are aggregated may become even more relevant when assessing the impact of a fishery.

An increase of temporal scale usually results in a more evenly distributed pattern of fishing activity. This is caused by the fact that the spatial distribution of the fishing activity gradually shifts from one year to the next. An analysis of the similarity in spatial distribution at different scales between years at different intervals shows how the similarity decreases at increasingly larger intervals and this decrease is stronger at higher spatial scales (Figure 2). At the spatial scale of an ICES rectangle there is a minimum overlap after some ten years of about 75%, at a spatial scale of 3x3 spatial units per rectangle this is about 40% while a higher scales this is only about 20%-30%.

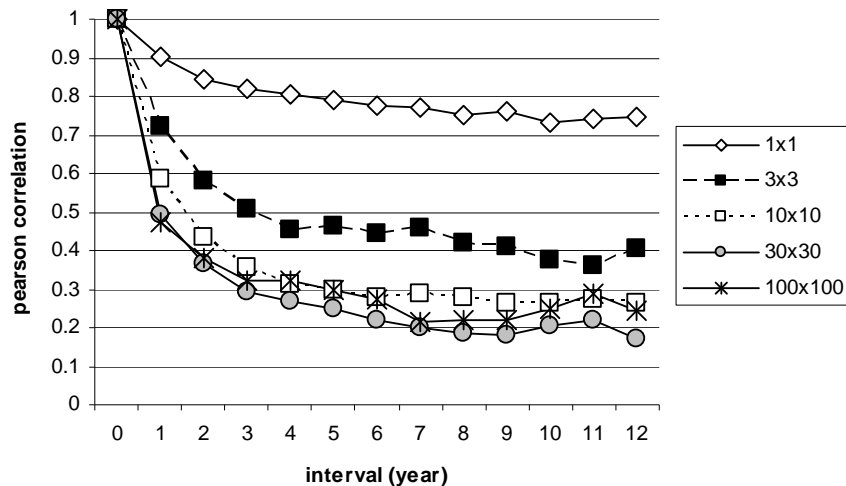


Figure 2. Similarity in spatial distribution at different scales between years with varying interval as expressed by the Pearson correlation coefficient (R^2)

The most accurate description of the impact of a fishery with known effort is provided using the proportions of the surface area that are fished with a specific frequency (yr^{-1}). Figure 3 shows how this is affected not only by the overall amount of fishing effort (expressed as number of days-at-sea) but also the spatial and temporal scale chosen.

In an average rectangle that is fished with an effort of between 50 and 100 days-at-sea per year the most commonly used high-resolution spatial scale of approximately 1 Nm^2 or 3.43 km^2 (30×30 spatial units per rectangle) and a temporal scale of year, would show that 34% of the rectangle is not fished, 8% less than 0.1 yr^{-1} , 31% between 0.1 to 1 yr^{-1} , 26% between 1 - 10 yr^{-1} , while 1% was fished with a frequency of 10 - 100 yr^{-1} . A smaller spatial scale such as 1000×1000 spatial units per rectangle would show that 86% of the rectangle is not fished, 5% between 10 to 100 yr^{-1} , while 9% was fished with a frequency of 100 - 1000 yr^{-1} . Even though the proportions may change, at the smallest spatial scale (1000×1000 spatial units per rectangle) all rectangles only consists of a large part that is not fished and a smaller part that is fished with a frequency of more than 10 yr^{-1} or even more than 100 yr^{-1} . In contrast a lower spatial resolution results in a more evenly distributed fishing pattern. Increasing the temporal scale of this rectangle (effort = 50-100 days-at-sea, 30×30 spatial units per rectangle) from the 1 year period that was previously described to a 10 year period would show that now only 4% of the rectangle is not fished, 8% less than 0.1 yr^{-1} , 38% between 0.1 to 1 yr^{-1} , 46% between 1 - 10 yr^{-1} , while 4% was fished with a frequency of 10 - 100 yr^{-1} . Thus, lowering the temporal resolution results in a more evenly distributed fishing pattern.

Fishing impact on a population is usually described by the annual mortality. Figure 4 shows how this is determined by the spatial and temporal scale chosen. Increasing the spatial scale affects mortality differently, depending on the amount of effort exerted on the rectangle. For high effort rectangles (500-1000 days-at-sea) mortality increases up to a scale of 30×30 spatial units per rectangle, after which it decreases until at a scale of 1000×1000 spatial units per rectangle the annual mortality becomes independent of the sensitivity of the species to the gear. Both species that differ in terms of their sensitivity (25% versus 75% mortality per trawling event) suffer a 17% annual mortality in the high effort rectangles and a 11% mortality in the low effort rectangles.

An increase of the temporal scale from 1 to 10 years (at a spatial scale 30×30 spatial units per rectangle) results in minor increase from 4% to 15% in annual mortality in case of a species that is not very sensitive to the gear (25% mortality after one trawling event) and in a low effort rectangle. In contrast it results in a markedly larger increase from 41% to 73% in annual mortality for a species that is sensitive to the gear (75% mortality after one trawling event) and in a high effort rectangle.

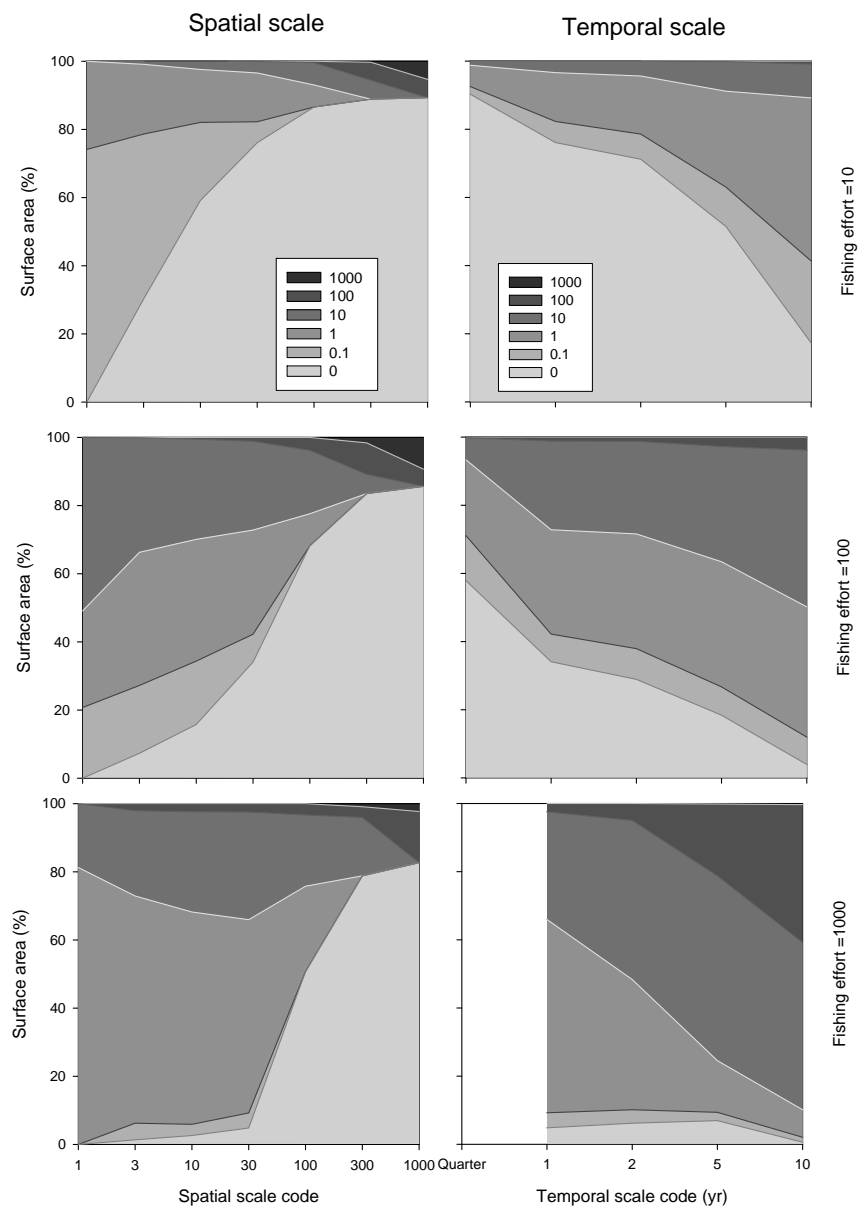


Figure 3. Proportion of the area trawled with a specific frequency (yr^{-1}) depending on the fishing effort (days-at-sea), the spatial and temporal scale. The spatial and temporal scale are described in respectively tables 1 and 2. At a temporal scale equal to quarter there were no ICES rectangles with the highest fishing effort.

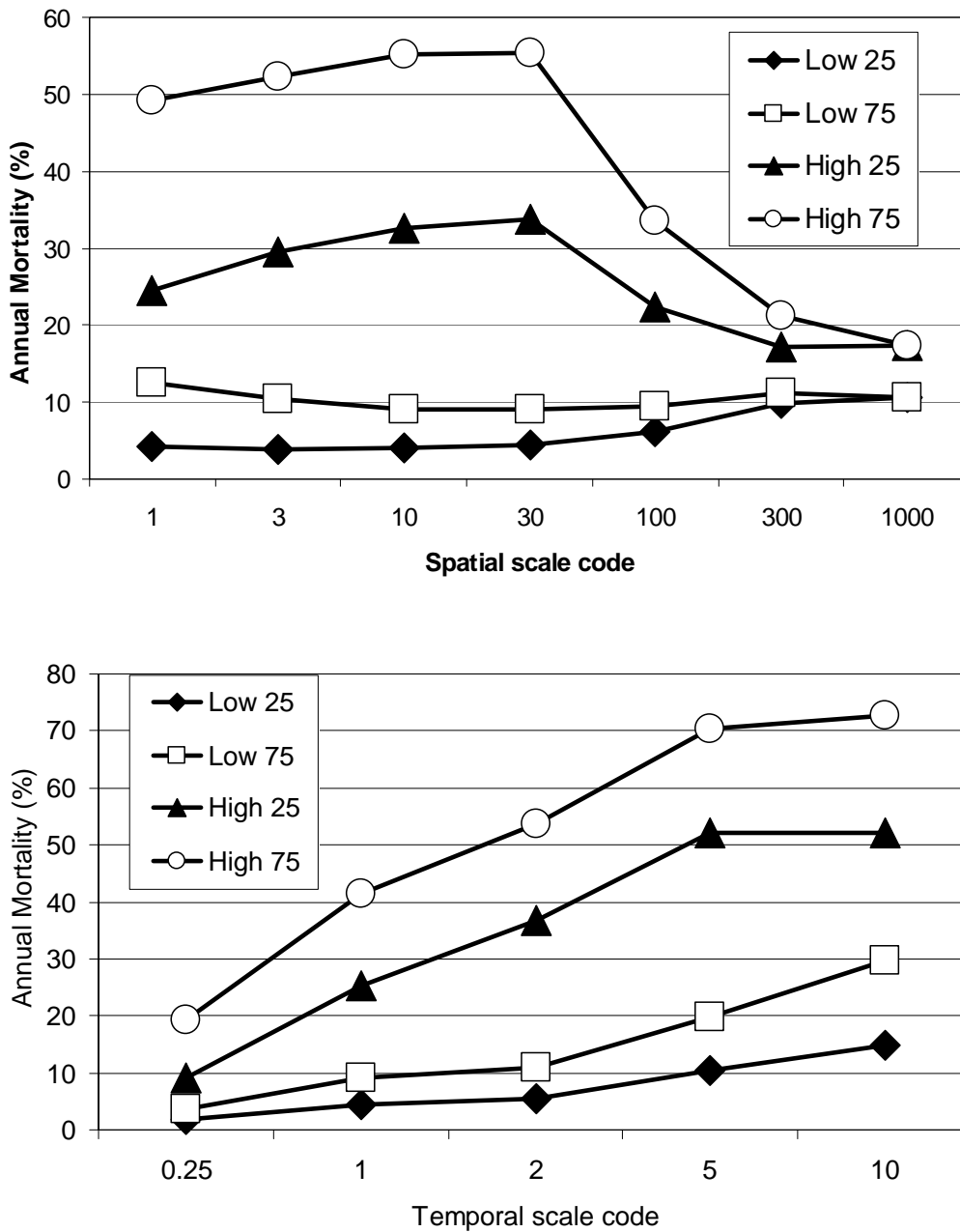


Figure 4. Spatial (upper graph) and temporal (lower graph) scale determine the annual mortality (%) in ICES rectangles with low (0-10 days-at-sea) and high (500-1000 days-at-sea) fishing effort and for species that differ in vulnerability expressed terms of the mortality caused by one trawling event.

Discussion

This study clearly shows that the overall amount of effort and the choice of spatial and temporal scale determines our perception of fishing impact both in terms of the spatial distribution of fishing effort as well as estimated fishing-induced mortality.

The results show that at the smallest spatial scale (1000x1000 spatial units per rectangle, surface area of approximately 56x56 m) the rectangle gets divided into a large area that is not trawled (and hence 0% mortality) and a smaller area that is trawled heavily with close to 100% annual mortality for all species that remain inside the spatial unit and are, even marginally, affected by the gear. For such sedentary species the vulnerability to the gear hardly makes any difference because in those spatial

units where fishing occurs the trawling intensity is so high that even very modest single-event mortalities of 5-10% or higher result in an overall annual mortality of close to 100% in that spatial unit. Thus for sedentary species that are vulnerable for the impact of a particular bottom trawl the overall annual mortality in an ICES rectangle (or larger) is almost entirely determined by the proportions of trawled versus un-trawled areas. For long-lived species the effect of temporal scale becomes important as the results show that larger temporal scales (aggregation over more years) result in a more even distribution thereby affecting the proportion of trawled versus un-trawled areas and hence the overall annual mortality.

The main problem with this analysis, however, is that it is based on VMS data that provide information of the location of a vessel at certain interval but negates the fact that the position registrations represent actual tracks. The amount of fishing effort is essentially condensed in these positions thereby incorrectly increasing the patchiness of the fishing activity and hence underestimating the estimated fishing impact. The main effect on the mortality estimate appears to be determined by the fact that the proportion of un-fished area suddenly increases (Figure 3). The apparent shift of this increase towards higher spatial scales when the total amount of effort increases suggests that the biased perception of the spatial distribution of the fishery at higher spatial scales may be avoided if enough VMS positions are recorded. This implies that for a correct estimate of fishing mortality at the appropriate spatio-temporal scale enough VMS positions need to be available. In practice this may be achieved by decreasing the interval between registrations. Currently this is approximately 2 hours and therefore a ten-minute interval would provide 12 times as many registrations. Alternatively the actual trawl track could be reconstructed. How many position registrations or additional information (e.g. direction) with each registration would be required for a sufficiently accurate track at the appropriate scale needs to be assessed. If the costs of transmitting this VMS-based information become limiting, the use of electronic logbooks could be considered. These can record all this information at low cost but only make this available on a trip-by-trip basis which is not a problem for the suggested use of this type of information.

If the number of registrations is limiting the use of appropriate spatio-temporal scales, than this reinforces the statement of (Hiddink *et al.*, 2006) that the constraints on compiling and accessing basic fishery data are an ongoing impediment to operationalizing an EAF in the North Sea and other EU waters.

A fundamental goal in ecology is to determine the dynamic processes underlying observed patterns. The single greatest difficulty confronting this important objective is that any pattern detected, and ultimately the understanding of the underlying dynamic processes, depends on the spatial scale at which we make our observations ([Wiens 1989](#), [Levin 1992](#), [2000](#), [Schneider 1994](#)). The challenge is to identify the appropriate scales of observation for ecological investigation ([Levin 1992](#)). The various ecosystem components that are considered when determining the fishing impact on the marine ecosystem, e.g. habitat with possible structural elements, benthic species or fish may all have different natural or “characteristic” scales that are optimal for describing the components functioning and dynamic. These scales need to be identified for each of these components in order to assess their state, understand how it is impacted by human activity and take appropriate measures to conserve it ([Rand 1994](#), [Bishop et al. 2002](#)).

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European Commission

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Title: FP6 CEDER Project Deliverable 3.2: "Benefits of a new reporting system"

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Abstract

Addressing the uncertainties in fishing activities, the CEDER project examines the use of observer reports, landings, e-logbooks, VMS and GPS tracks, and fishery-specific information. Such information was assessed in order to provide more accurate and timelier data on effort, catches, discards, and/or landings. This document contains CEDER's Project Implementation Plan for policy makers, as well as expected benefits for government, industry, and science. The CEDER consortium advocates the use of GPS data at 15 minute intervals for scientific purposes. Among these are improved spatial planning and a new fishing effort measure, the actual effort while fishing, which can be inferred from vessel behaviour. The correlation between catch and effort can be used as an indicator for inspectors, but one cannot reliably guess catches from effort. VMS and logbook data can be matched using rule-bases systems, leading to higher data quality and better use of quota. Furthermore, if fishing mortality were known in near real time, then the integration of current year fishing mortality into management plans would yield benefits for stock recovery. The full realisation of such benefits requires a re-appraisal of the 15% TAC revision rule. The CEDER consortium insists that any roll-out of the ERS e-logbook must be properly enforced, and that the e-logbook cannot by itself replace observer reports. Finally, estimating discards may be feasible in selected fisheries, but additional means such as gear sensors may be required in order to get more reliable data in the general case.

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