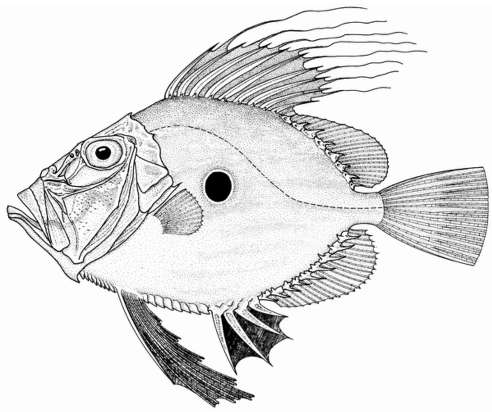
Fishface
Operational Trial

Draft Report for Discussion

July 2018



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Summary

Fishface aims to push hard at the cost boundaries for providing affordable, trustable, Fully Documented Fisheries, FDF, to smaller vessels in the developed and developing world. To do this it is based on low-cost consumer GPS-enabled HD video cameras, and readily available software.

This report summarises the results of the *Fishface* Operational Trial, the sea-going part of which took place in the winter 2017-18 off the Lizard, Cornwall, with land-based work over the following months.

It first describes the **Context**.

Then **In a Nutshell** deals with four main questions potential users may have: Does it work? [answer: it does] How much will it cost? [indicative cost of £32–£52 inc. VAT per boat/day depending on requirements; the capital equipment replacement cycle; operation to capacity; and similarity to the Operational Trial] Can the data be exported to other software, including Excel and R? [yes] Can the data be made as openly available as necessary, but still handle confidential information securely when required? [yes]

Chapter and Verse then provides background details.

Context

Fishface addresses the challenge of providing affordable FDF to small (under 10m) inshore day boats, in developed and developing countries, based on low-cost GPS enabled HD video cameras.

Globally, FDF is increasingly being used. FDF benefits fishers wishing to demonstrate catch, discards and bycatch profiles; to show compliance with regulations; to document catch location; to assist better, more locally relevant, stock assessments; to support the case for favourable treatment of the fisheries by managers and buyers; to show to potential buyers high food quality through good handling; and to better manage and analyse their own fishing records. FDF also benefits fish buyers; customers; fisheries managers and scientists; and the public who want information they can trust. Already fishing vessels that do not have FDF are finding their sustainability claims questioned, notably by fishers with FDF.

FDF for larger vessels typically uses bespoke equipment and costs several hundred pounds per day. For small fishing vessels, this the same order as the total gross value of the catch. So this is an existential threat should regulators take the view that FDF will become a requirement and that these boats, which only make up a small and regulatory-expensive part of landings, are expendable. This would be undesirable, because small boats (as well as making up most fishing employment) supply an economically valuable niche market, unavailable to larger multi-day boats—for locally caught ultra-fresh fish. This is a potential growth area for the local economy, often where employment prospects are limited. Local fishing, and sea food, is a very important element of the local scene that does have, or has, the potential to attract high-spending visitors who support the local economy, as well as generating high-value sales outwith the area.

It is therefore worthwhile, and critical for the local economy, of trying to find ways of cost effective FDF for smaller vessels. *Fishface* takes up that challenge, using affordable consumer GPS-enabled HD video 'action cameras', coupled with the latest high capacity 128GB high read write speed microSD cards. One aim is full HD video documentation from boat power up to power down. A second aim is to minimise crew time to inserting a card into, and plugging in, the camera in at the start of the trip, and then unplugging it at the end, and putting the used data card into a stamped addressed envelope. Specifically the fishers do not need to record any data. This is done later, by others, from the analysis of the video and GPS data. Optionally it may also be correlated with other information such as landing data or other scientific studies.

In a Nutshell

Potential uses need answers to four questions:

> (1) Does it work? (2) What does it cost? (3) Can the data be exported and used in other software, such as Excel and R? and (4) Can the data be made as openly available as necessary, but still handle confidential information securely when required?

The short answers are:

> (1) Yes. (2) An indicative cost of £36–£52 inc. VAT per boat day. If a MMO application is successful, this will be free to end users for the duration of the award. (3)Yes. (4)Yes.

Does it work?

The sea-going operational trial, funding jointly by [*Funding Fish*], an anonymous donor, and *modus vivendi*, ran mainly between December 2017 and February 2018, on FH214 *Lady Hamilton* to the east of the Lizard, Cornwall, with further land-based work over the following months. It was a success, coping with harsh winter weather conditions, producing some 186 hours of video. The main issue was low-tech: the boat-side connection of the camera cable to the vessel electrics, which was solved by progressively upgrading the connector to a higher marine grade and more robust specification. The land-side hardware and software performed as expected. The results, here shown in screenshots from Garmin's free marine GIS software [*Homeport*], (trialled as a means of keeping costs down, eg for developing countries) show the vessel trails in grey, with colour coded highlights for different types of gear recovery and fish extraction determined from inspection of vessel speed and the concurrent video (see below and Figure 1-3 captions for details).

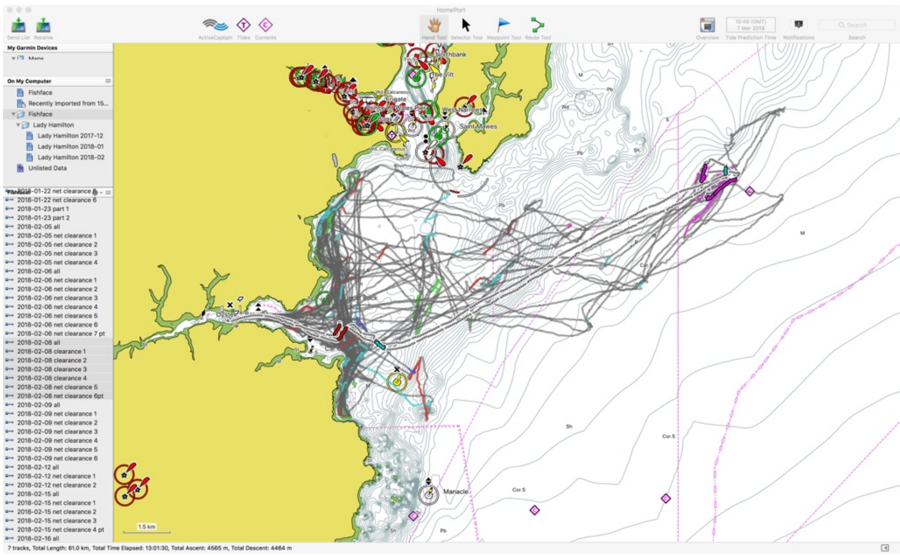


Figure 1. Overview of all data, one vessel December 2017-February 2018, displayed using Garmin's Homeport *GIS application. The underlying map, including depth contours and sea-bed type, has to be purchased, but the free* Homeport *app has full functionality albeit with a much lower resolution map.*

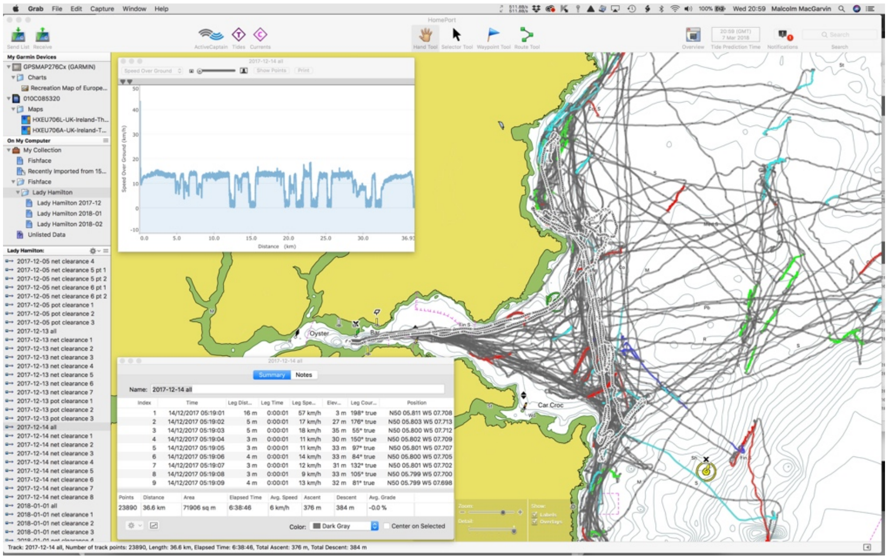


Figure 2. One fishing trip here highlighted on the underlying map, showing the log of vessel speed and position (bottom inset window) and speed plotted against time (top inset window). Changes in vessel speed clearly show three net setting events, and then eight net clearances (hauling the gear and clearing the catch) interspersed with further net setting.

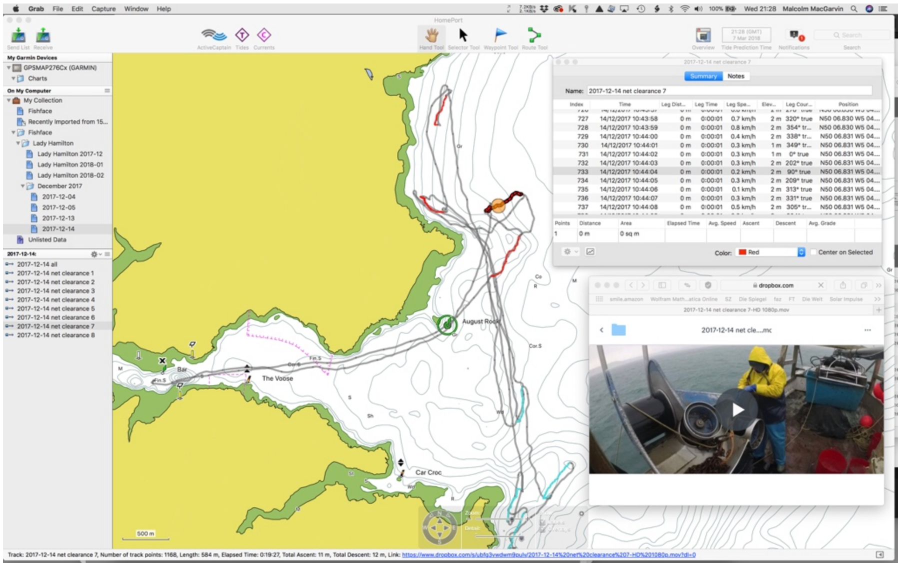


Figure 3. The same trip shown in isolation. Previously, skimming through the video in Final Cut Pro *has allowed the isolation of specific events, such as net clearing, cross checked against vessel speed in this GIS software. Within* Homeport *events have been colour coded, (defined by the (sub)type of fishing gear), a clickable link to the video in cloud storage added (see bottom right), and then the GPS log of the entire trip exported to cloud storage.*

For General Users

For end users, i.e. data consumers rather than creators, viewing the results in GIS software such as *Homeport*, including links to the associated videos prepared by analysts (see below), may be all that is required.

As set up in the *Fishface* operational trial, the end results are the tracks of individual trips, with eg gear setting or clearing (hauling) activity colour-coded for the type of gear being used. Clicking on the trail associated with a specific event reveals the GPS data log and associated notes, including clickable links to the video associated with that event stored online. A graphical visualisation of the GPS data is also available, allowing a plot of vessel speed during the trip, from which different activities (gear setting, gear retrieval, moving between locations) are all evident.

In common with most GIS software, *Homeport* can export the data to a non-proprietary .gpx format. *Homeport* also allows the inclusion of notes and hyperlinks within the .gpx file. The exported file could be of a single event (e.g. the hauling and clearing of one fleet of nets), or multiple events such as one day's fishing activity, or more. Exporting and importing open format .gpx files was found to be reliable up to a certain data file size (e.g. Dropbox link here for the entire vessel trip, gear clearance episodes and links to associated video on 14 December 2017). Beyond that, when transferring large amounts of data from one computer or user to another, it was more reliable to transfer a *Homeport* archive file, and then export .gpx files as required from within *Homeport* (Dropbox link here for the *Homeport Fishface* archive).

For the Analyst

The initial analysis involves marking up the video within video editing software to identify events of interest including gear hauling and clearing the gear of fish. It is helpful to be able to cross-check events with GPS data in GIS software such as *Homeport*. *Adobe Premier* and *Apple Final Cut Pro* were both examined; most work during the operational trial was with *Final Cut Pro*.

Each video sequence, from a single vessel, for an entire day, is viewed and uniquely labelled. The two main analytical steps are then, first, skimming the entire video to identify 'major' events, such as setting, hauling and clearing of sets of fishing gear, and discarding (where cross-referencing with the GPS data is useful). Then the second step, for 'finer-grained' events, is keywording: eg using the keyword 'mackerel' to cover all the frames from where an individual mackerel enters into view to when it exits a particular point (eg when it clears a hauler). Importantly, a keyword, eg 'mackerel', can be used multiple times, even for overlapping sequences (for example two or more mackerel on a hauler, partly overlapping in the time sequence). Multiple keywords can be associated with a sequence, for example '-mackerel', 'gill-net', '90mm mesh', 'discard', 'alive' and 'eaten by seabird' associated with a video sequence of a mackerel being removed from the boat by being discarded alive from specified fishing gear, and then eaten by a seabird. A tally of summary statistics of keywords for one or more video sequences (perhaps each boat/day) can then be viewed, e.g. to report the total mackerel caught, of mackerel discarded, and (by subtraction) the number retained. Because of the amount of data, subsampling may be sufficient (although no video is discarded). Note that custom data fields (perhaps 'gear type') can also be created and populated as required. 'Events' can then exported as video clips, and—as already described—the analysist would usually be working in conjunction with GIS software such as *Homeport*. Keywords are also always associated with a start and an endpoint of a video and can in principle also be exported as a video clip, but are more likely to be inspected and analysed within the video editing software.

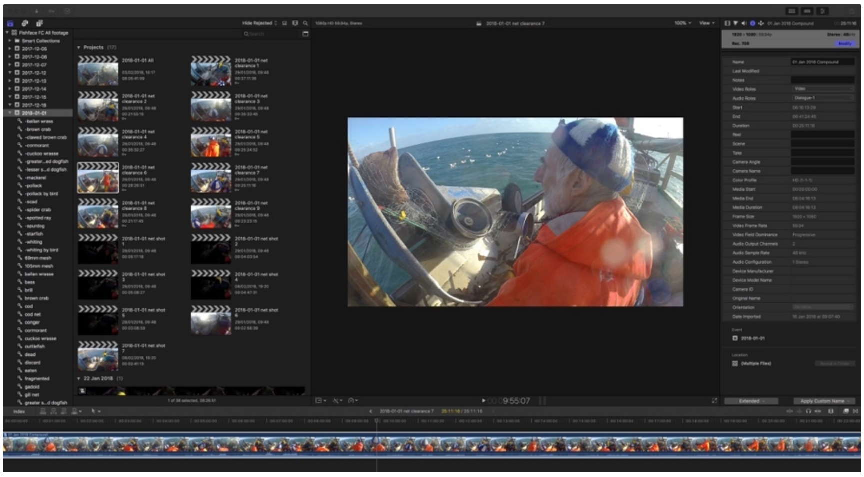


Figure 4. Video imported into Final Cut Pro with events—here gear clearing and gear setting—identified and ready for export, if required, to eg Dropbox as individual clips.

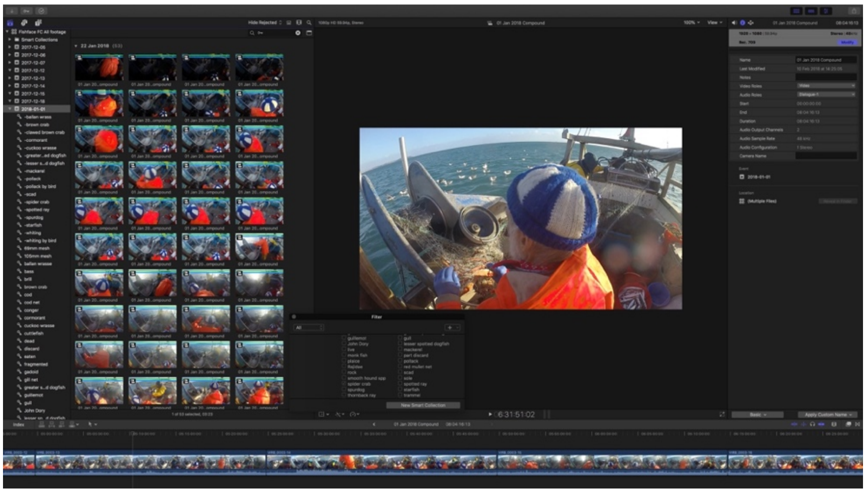


Figure 5. Keywords can be added, and number of occurrences summed for one or more keywords. These can be exported as individual clips.

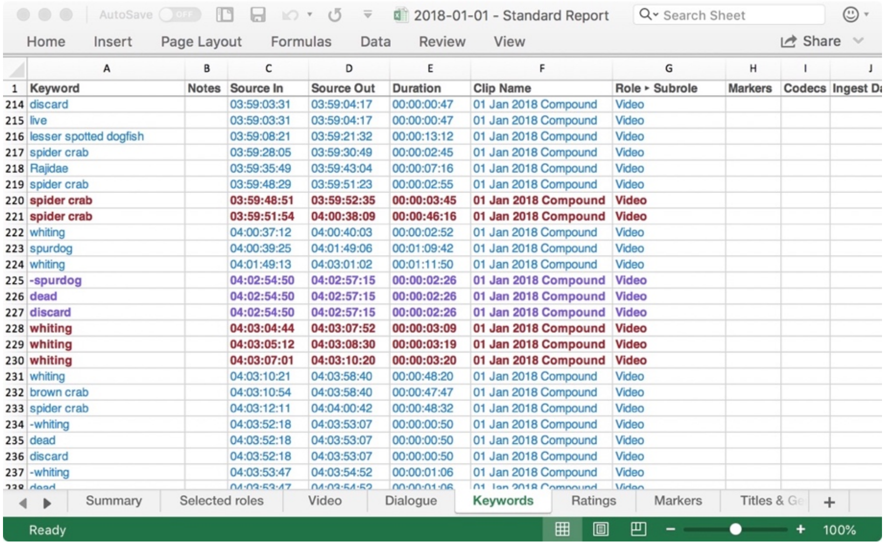
Keywords can be edited, merged, or multiple synonyms used. The result in the Operational Trial was (in addition to the original video and GPS data) the video database in *Final Cut Pro*; exports of 1080 HD video clips of the events; lower resolution video of the entire trip; plus .gpx file(s) with links to the relevant video(s) ready for viewing in GIS software (as per the General Users section above). These are placed online, or on a hard drive, either to end users or other analysts. It is not practical or affordable to store full resolution video of the entire trip online, but can readily be done on hard-drives.

Sharing and ownership of this data would be dependent on the nature of the agreement with the vessel owner, the funders, and the end users.

For Detailed Statistical Processing

Summary statistic of keywords from the video database can be manually entered into eg a spreadsheet. However a better route for detailed statistical analysis and data processing is by exporting metadata (such as start and end points of gear hauling, or start and end points of individual application of keywords) from the video database into other software.

Final Cut Pro (and Adobe *Premier*) allows the exporting and importing of .xml files containing this metadata. Third party software, such as *Producers Best Friend*, can then convert this to a format that can be read eg, by *Excel* (see Fig. 6) or the statistical package *R*, which are also where the GPS data is united with the keywords and other information from the video editing software database*. The common value allowing synchronisation of video and GPS data, is the time value, in seconds, from switching on the camera to switching it off.



	A	B	C	D	E	F	G	H	I	J
1	Keyword	Notes	Source In	Source Out	Duration	Clip Name	Role ▸ Subrole	Markers	Codecs	Ingest Da
214	discard		03:59:03:31	03:59:04:17	00:00:00:47	01 Jan 2018 Compound	Video			
215	live		03:59:03:31	03:59:04:17	00:00:00:47	01 Jan 2018 Compound	Video			
216	lesser spotted dogfish		03:59:08:21	03:59:21:32	00:00:13:12	01 Jan 2018 Compound	Video			
217	spider crab		03:59:28:05	03:59:30:49	00:00:02:45	01 Jan 2018 Compound	Video			
218	Rajidae		03:59:35:49	03:59:43:04	00:00:07:16	01 Jan 2018 Compound	Video			
219	spider crab		03:59:48:29	03:59:51:23	00:00:02:55	01 Jan 2018 Compound	Video			
220	spider crab		03:59:48:51	03:59:52:35	00:00:03:45	01 Jan 2018 Compound	Video			
221	spider crab		03:59:51:54	04:00:38:09	00:00:46:16	01 Jan 2018 Compound	Video			
222	whiting		04:00:37:12	04:00:40:03	00:00:02:52	01 Jan 2018 Compound	Video			
223	spurdog		04:00:39:25	04:01:49:06	00:01:09:42	01 Jan 2018 Compound	Video			
224	whiting		04:01:49:13	04:03:01:02	00:01:11:50	01 Jan 2018 Compound	Video			
225	-spurdog		04:02:54:50	04:02:57:15	00:00:02:26	01 Jan 2018 Compound	Video			
226	dead		04:02:54:50	04:02:57:15	00:00:02:26	01 Jan 2018 Compound	Video			
227	discard		04:02:54:50	04:02:57:15	00:00:02:26	01 Jan 2018 Compound	Video			
228	whiting		04:03:04:44	04:03:07:52	00:00:03:09	01 Jan 2018 Compound	Video			
229	whiting		04:03:05:12	04:03:08:30	00:00:03:19	01 Jan 2018 Compound	Video			
230	whiting		04:03:07:01	04:03:10:20	00:00:03:20	01 Jan 2018 Compound	Video			
231	whiting		04:03:10:21	04:03:58:40	00:00:48:20	01 Jan 2018 Compound	Video			
232	brown crab		04:03:10:54	04:03:58:40	00:00:47:47	01 Jan 2018 Compound	Video			
233	spider crab		04:03:12:11	04:04:00:42	00:00:48:32	01 Jan 2018 Compound	Video			
234	-whiting		04:03:52:18	04:03:53:07	00:00:00:50	01 Jan 2018 Compound	Video			
235	dead		04:03:52:18	04:03:53:07	00:00:00:50	01 Jan 2018 Compound	Video			
236	discard		04:03:52:18	04:03:53:07	00:00:00:50	01 Jan 2018 Compound	Video			
237	-whiting		04:03:53:47	04:03:54:52	00:00:01:06	01 Jan 2018 Compound	Video			

Figure 6. For more detailed or custom statistical analysis keywords and other data fields, including the contents of custom-created fields can be exported as a .xml file and opened in Excel or into Statistical programmes such as 'R'. Note the essential capability to use the same keywords for overlapping occurrences of individuals of the same species (dark red text) and of multiple keywords to the same sequence (purple text).

Software such as *Producers Best Friend* are orientated towards video post-production. There is potential for better tailoring this to scientific video analysis. However custom data fields can already be added to the video database and to the exported .xml file, and the expertise required to develop customised bridging code is likely to be readily apparent e.g by those familiar with developing custom statistical analysis within R, or for video post-production.

Automation

Particular fishing activities are often associated with particular speeds, changes in velocity or in direction, or other measurable parameters. Vessels travel out, between and back from fishing marks at relatively high speeds. Fishing gear is often set at intermediate speeds. Fishing gear may be hauled and cleared at low speed for many, but not all, fishing methods. This provides the potential to automatically identify fishing activities of interest and then either automatically extract video clips of those events, or create an .xml file that can be imported with the original video into editing software, when the items of interest will then appear as identified clips within the context of the entire video sequence.

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* Note that (unlike still photographs) there is currently no standard facility in video to embed GPS information within the video file metadata (as opposed to in a separate 'side-car' file) as the video is shot.

The operational trial included a demonstration of the principle of automated event identification (see Fig. 7). Even with a very simple algorithm for identifying changes in vessel activity from changes in speed, the results are very encouraging, as shown in the figure.

Autodetected events, GPS Time offset from start				Events detected by human; VIDEO time offset from start		
start time	end time	start offset	end offset	start offset	end offset	Event
05:40:44	05:46:13	00:21:43	00:27:12	00:23:06	00:26:29	net shot 1
05:52:27	05:59:04	00:33:26	00:40:03	00:29:36	00:34:01	net shot 2
				00:41:04	00:43:58	net shot 3
06:20:07	06:50:47	01:01:06	01:31:46	01:07:24	01:25:31	net clearance 1
07:00:11	07:46:33	01:41:10	02:27:32	01:40:12	02:17:19	net clearance 2
08:03:48	08:27:16	02:44:47	03:08:15	02:43:13	03:02:14	net clearance 3
				08:23:24	08:26:34	an event, likely net setting, need to check against video
08:32:58	09:05:13	03:13:57	03:46:12	03:10:38	03:34:55	net clearance 4
09:13:19	09:44:02	03:54:18	04:25:01	03:52:09	04:16:53	net clearance 5
09:50:04	10:07:37	04:31:03	04:48:36	04:27:30	04:42:10	net clearance 6
10:16:05	10:23:07	04:57:04	05:04:06	03:04:56	03:07:44	**net set 4 - success, autodetected, missed by human**
10:28:10	10:54:24	05:09:09	05:35:23	05:12:34	05:31:59	net clearance 7
11:01:36	11:29:52	05:42:35	06:10:51	05:39:20	06:03:55	net clearance 8
11:51:29	11:57:10	06:32:28	06:38:09			arrive back at mooring (no video clip)

Figure 7. Even a simple algorithm, detecting events from changes in vessel speed when compared against the actual events identified by human analysis. The main differences in timing is because the automated system detects changes in speed, whereas the human analysist consistently marks the recovery of the start and end of the nets, without including the hauling of the leading and trailing ropes. In this case the automated system detected an event – net shot (=set) 4, initially missed by the human analyst.

Note that the point of automation is not to produce to perfect edit of relevant video. It is to do a good enough job of reducing the amount of video that should be inspected, at least in the first instance, before being passed onto human or AI processing.

Open, Secure, Trustable: Providing An Unalterable Record

For fishers, buyers, consumers and managers alike it is important to know that the video record can be trusted—that the video really did come from the stated vessel, on a stated date, at a stated location; when certain things were caught, which were then either retained or discarded. There needs to be assurance and an agreed authentication system that an entire record really is the entire record; that a chain-of-custody exists that is exceedingly unlikely to be forged (because the cost of doing so exceeds the value of the catch). There also needs to be a way of making data and video openly available as and when required, but also to secure confidential information as necessary.

For some circumstances the GPS and video record alone, held by a trusted third party, are themselves enough to make misrepresentation unlikely. If a secure tamperproof copy of the entire GPS data log, and (even) a low resolution version of the entire video sequence from vessel power up to power down is available, this allows certainty that clips of specific events, or sub-sampling statistics, have not been doctored.

It is unlikely that fishers would attempt to alter the GPS record. And even with the technical know-how, the amount of effort required, and the speed at which it would have to be done before returning the data card would exceed any likely value of the catch. It would be possible for somebody knowledgeable at the central body holding to edit GPS records. However significant catch discrepancies in the summary statistics would be clear when compared against landing declarations; significant locational discrepancies would become evident from the video (this are inshore vessels with landmarks and distances readily evident); and mis-stating the vessel identity, or the catch, would also be plain.

Using a Mutually Distributed Ledger, aka Blockchain. However, this 'hands-on' after-the-event analysis may be overwhelmed where there is no basis for trust and large amonts of data are being handled. Alternative solutions are then be required and any such solution offered for FDF has to also show how it can be integrated with other developments, notably the growing emphasis and elaboration of chains of custody from fisher to the consumer. That said, *Fishface* addresses a weak point in current chains of custody, right at the start of the chain, regarding the evidential basis for the stated origin of the fish, and the circumstances under which it was caught. Meanwhile there is an ongoing global revolution enabling small businesses of all types to sell more directly and shorten supply chains. But how can regulatory and other demands for information be cost-effective at this scale, while also meeting other requirements and creating trust? Any system also needs to ensure that the data (what was caught, who caught it, where and how was it caught, who currently owns it, what price can I buy it?) can be disaggregated and available at the appropriate levels of granularity in space and time for partners, regulators, researchers and the public. This includes ensuring that data is not altered as it passes through the chain or at a later date.

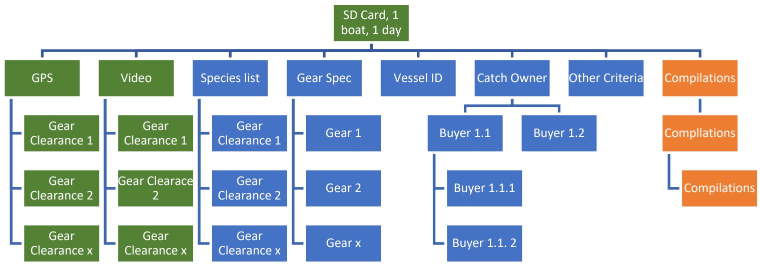


Figure 8. Mutually Distributed Ledger (aka blockchain) for Fishface. Boxes in green have been included in a proof of principle for the operational trial. Blue indicates some of the additional blockchains that could be added. Orange 'compilations' has been added as a reminder that additional blockchains, holding records with links to other records in one or more other blockchains can be included, including links to other compilations.

For various reasons, a 'mutually distributed ledger' (Fig. 8, see text below for an elaboration) is a strong candidate to address these issues. Because copies of this ledger are distributed between many independent holders it is disproportionately expensive to alter it. Essentially each ledger entry, at its simplest, is a text record of whatever you want to be included, with a backward reference to the parent entry. There is nothing particularly complex about them: they could be created, albeit not very practically, with paper and pen. Although mutually distributed ledgers, aka blockchains, are most widely known as a record of transfers of ownership of cryptocurrency coins, they have many other capabilities. Once entered a record is immutable and undeletable, even for correcting errors—amendments can only be made with child records referring back to the parent. Records may be entirely or partly encrypted. They may include computer code to automatically trigger or record certain events, and links to files held either as part of the ledger or elsewhere. They can also record who has subsequently viewed the ledger entry. Any change to one of the records changes the 'digital fingerprint' of the entire distributed leger and is immediately evident in comparison to the other copies. To ensure that there are sufficient copies of the ledger, they are often held by third parties who incorporate records from multiple users, and who may have no interest in the contents.

In the case of *Fishface*, in collaboration with City of London partners *Z/Yen*, and the *Distributed Futures* timestamping and file storage facility *MetroGnomo*, we have demonstrated the use of a mutually distributed ledger for those aspects marked in green in the figure above, for the video and GPS data gathered from *Lady Hamilton* on 14th December 2017. These can be accessed online by pasting the MetroID for the *Fishface* Operational Trial, 735b7770-237d-4aa1-803a-602e06a84ee7 into the top field and clicking 'search' (See Fig. 9).

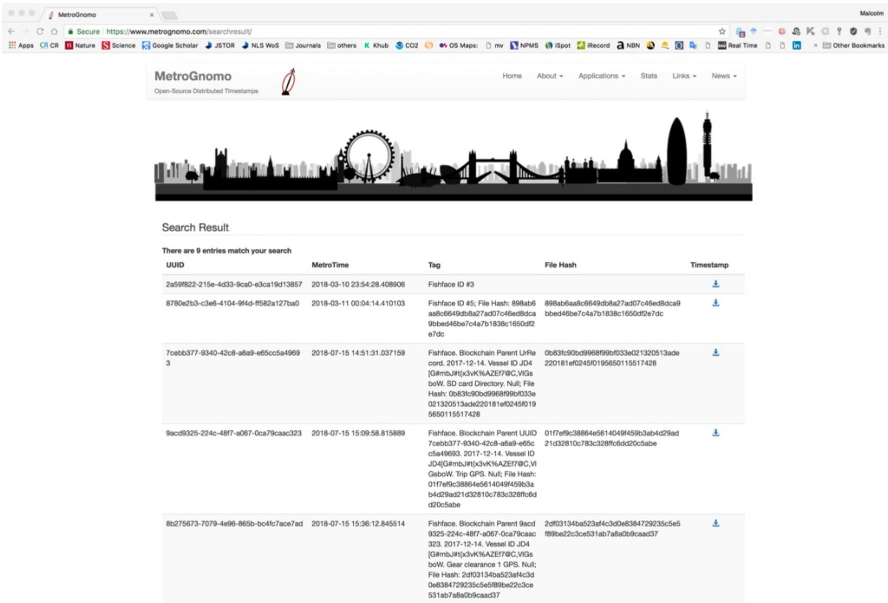


Figure 9.Screen shot of the MetroGnomo *Mutually Distributed Ledger showing* Fishface *entries. The entries here are in clear text, and can be viewed here by pasting in the* Fishface *MetroID. The associated files can be downloaded by pasting the relevant* MetroGnomo *File Hash here or by pasting the Dropbox link into a web browser.*

Ignoring the first item (dated March) the first record in the chain is the 'ur-record' of the directory of file names, sizes, creation and modification dates of the GPS and video files on the SD card as received from the vessel. It is time stamped when it enters the ledger. The second is a link to the exported .gpx file. Both are stored within the *MetroGnomo* facility, so there is a link (the 'File Hash') to each file. The .gpx files themselves contain a further link to the relevant video stored on Dropbox. There are further ledger entries to .gpx files, to gear clearances 1 and 5, including showing how an error is corrected (here for Gear Clearance 1) by adding a further record which links back to the erroneous parent. The files can be downloaded by pasting the File Hash into the appropriate field on the File Retrieval page. The original 1080 HD videos on the SD cards are too large to routinely store in the cloud. The video, reduced to 0180 standard format is around 1.75 GB—still too large to store on *MetroGnomo*. So instead the ledger entry contains a hyperlink to the video stored on Dropbox, and there is no *MetroGnomo* File Hash. This video is sufficient resolution to check that all gear clearances have been recorded, and whether other significant events have occurred. It can also be checked against the linked .gpx file earlier in the ledger to ensure that the video evidence concurs with vessel speed and heading data. Subsequent records include links to high definition video of each gear clearance, of which one example, for Gear Clearance 5, is included in this demonstration ledger.

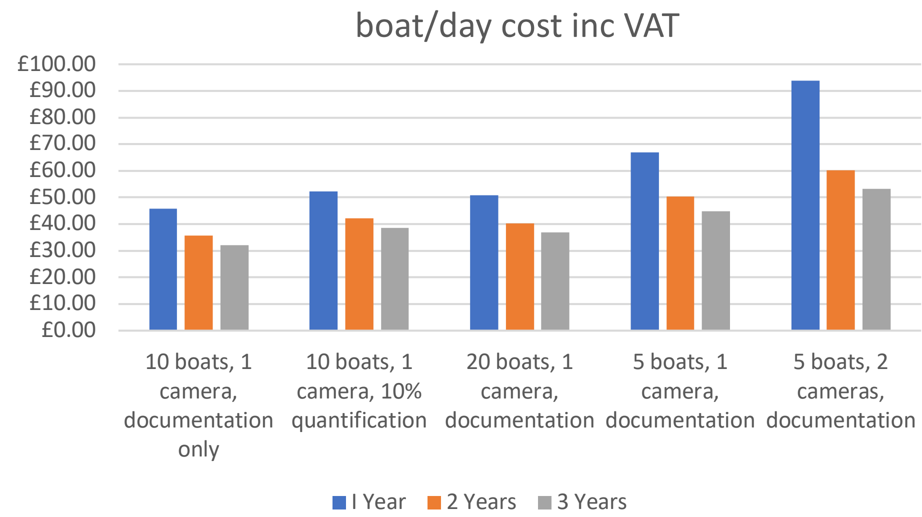
Note the long time delay between the event (14th December 2017) and the *MetroGnomo* timestamp (July 2018). In normal operation, anything other than a few days delay would raise questions where a third party (such as modus vivendi) is responsible for processing the microSD card once it arrives, by post, from the vessel. Note also that the first leger entry, a screen shot of the microSD card file directory, is not technically demanding and could be done by the skipper or boat owner. The link to this MetroGnomo blockchain entry can then be provided in the conventional fishing vessel log book, landing returns etc. for this day, so providing an unbreakable link to current methods of data collection. The second ledger entry would then likely be another screen shot of the file directory upon receipt by *modus vivendi* or any other *Fishface* data processor.

In the earlier Fig. 8 some of the additional information that could be incorporated in the ledger are shown in blue. In this schema they are shown as separate blockchains linking back from the one boat, one day, SD card: for species lists (and other biological data) associated with each gear clearance; the gear specification for each gear clearance (for example 90mm mesh gill net); and the vessel identity associated with the SD card data. It also shows a blockchain for ownership of the fish as they take their various routes through the supply chain. If this already exists, from that perspective the SD card record would be a spur to the original catch owner record.

In addition there could be compilation entries (shown in orange) that provide links to multiple ledger entries, such as GPS, video, species and gear specification, associated with any individual event. Or they could be compilation entries of aggregate data for a geographic area, and/or for an aggregate time period.

Costs

The per boat/day cost of the proposed next phase of *Fishface*, intended to have the capacity to cope with 10 vessels per day, for 1 to 3 years, depends on a number of variable and fixed costs. Put simply, if it up-scales the set-up in the Operational Trial (See Fig. 10 below, options 1 and 2), the indicative cost ranges between ca. £32-£52 inclusive of VAT per boat day, depending on whether the programme runs for 1-3 years using the same (expensive) hardware, and is run at full capacity. The range in costs also depends on whether *Fishface* focuses on documenting fisheries—securing, processing and storing from raw video and GPS data, plus identification and isolation of likely events such as gear clearances—for others such as fishers (eg for certification scheme assessments, documenting discard and/or bycatch levels, or responding to other regulatory requirements in the UK or abroad), fisheries scientists (stock assessments and/or wider impact assessments), or other users, or whether *Fishface* also includes analysis of around 10% of the relevant video as part of this budget. Initial users would likely get this free, or at very reduced cost (depending on their requirements), if an application to MMO and others, now being discussed with potential partners, is successful.



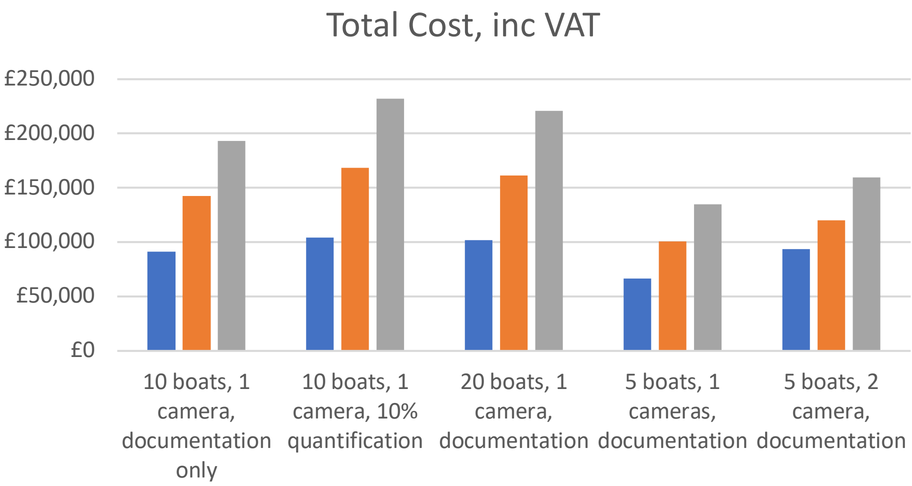


Figure 10. Cost per/boat day (top graphic) and total cost, taken from the grant proposal being developed in a funding application to MMO and other potential funders. The first option is for 10 unique vessels, documentation only. The second option assumes that ca 10% of the video including fish is also quantified. The third assumes that 20 unique vessels are included during the programme, with associated set-up costs for each vessel (although only 10 vessels can be surveyed at any time). The fourth assumes that the project only works at half the potential capacity, saving on running costs but with the same capital costs. The fifth assumes that two cameras are operated simultaneously per vessel, which would limit the total number of vessels to five. These are indicative and subject to discussion; many other permutations may be possible.

This is a small fraction of the cost of putting a human observer on board a boat, and of FDFs on larger vessels. Nevertheless, it still represents a significant portion of the likely gross value of the catch of an individual vessel. However, it could be cost effective where one or more sentinel vessels are representative of a wider fleet. For all potential users, having the costs covered is an additional incentive to discuss possibilities.

In more detail, the costs of *Fishface* are determined by how the capital costs can be shared across many users; how intensely the capital equipment is used; how many boats; how many cameras per boat (usually one) and the total length of the overall project, or capital equipment replacement cycle, across all users. The graphs in Figure 10 suggest the per boat/day and total indicative costs for processing video from up to ten boats on any day, assuming 10 vessels x 40 weeks x 5 days data in a year. Ten vessels is used as a basic unit of account, because processing the data generated by around ten boats fully utilises one computer and associated hardware and software over an 8 hour working day if there is also some analytical component. If *Fishface* is primarily capturing data for analysis by others, it may be possible to handle more than 10 vessels per day. Because potential users may not be able to reclaim VAT, the costs indicated are inclusive of VAT.

The base figure, on the left, is for documenting the same 10 boats for one entire year. The cost is ca £46 per boat day, some £91,500 in total. If the (expensive) capital equipment can be utilised for two years instead of one, the boat/day costs fall to £36, and the total cost is £142,000. For three years the boat day cost is £32, and the total cost is £193,000. (Note that there are some additional costs included here in years 2 and 3, notably external hard drives for archiving the previous year's video).

For some users, video documentation of the entire fishing trip, and clip extracts of fishing activity, available either online or delivered on an external disk, is sufficient, and/or they may go on to carry out their own analysis. Others may commission further analysis as part of *Fishface*. If in addition to documentation the fish in a ca. 10% sample of gear clearances is quantified as part of *Fishface*, the cost for ten boats rises to £52 per boat/day (£42 over two years, £37 over three). This may be sufficient for some users, and it also provides valuable 'bootstrapping' data to start the process of helping computers learn to count, measure and identify fish.

Some uses do not require monitoring vessels over an entire year, for example a seasonal fishery. This means that more than 10 vessels can be documented overall, even though dealing with only 10 vessels at one time. However there are set-up costs for each vessel, resulting in an increased overall cost. For example, if 20 vessels in total are monitored, for one year the overall per boat/day figure rises from £46 for 10 vessels to ca. £51 ((£40 over two years, £37 over three). The total cost for 20 vessels over one year is ca £102,000.

Similarly, if the capital equipment is not fully utilised, per boat day costs rise, although the total cost falls (because of lower data processing costs). For example, were the overall uptake over one year the equivalent of 5 boats with 1 camera x 40 weeks x 5 days, the cost is ca. £67 per boat/day. ((£50 over two years, £45 over three). The overall cost falls to £67,000.

The other possibility is that more than one camera is required per boat, for example where it is difficult to get an unobscured or comprehensive view with one camera, or where a stereoscopic view is required. Overall, this may not be a significant issue. However, the maximum capacity would then be 5 boats with 2 cameras x 40 x 5, which would mean a per boat/day cost of £94 (£60 over two years, £53 over three).

To sum up, the exact cost, and how many fishing operations are included, will depend on who signs up, with how many boats and for how long. It would be preferable to front load expenditure on equipment, as this facilitates planning and can then be used for two or possibly three years, with data analysis funded from additional smaller grant applications or from other financing sources.

Next Steps

This now goes to a series of discussions and workshops to explore various aspects and the potential of *Fishface*: for fisheries science; to improve inshore management; on data standards; on the use in developing countries; on the governance and ownership of the data; on its use by fish buyers and consumers; and on the development of projects that can make use of the information that *Fishface* can generate – specific scientific and management studies; citizen science production of training sets to help computers learn to count and identify fish; the best means and safeguards for incorporating this information into mutually distributed ledgers and chains of custody.

At the same time this information is informing an application to MMO (and potentially others) that would upscale *Fishface* to be able to handle the data provided by up to ten vessels per day.

Acknowledgements

This project would not have been possible without the help of Morwenna Bean, who co-ordinated the work in Cornwall, including preparing the camera for each days fishing, checking the camera condition, and returned the cards to *modus vivendi*; Chris Bean, skipper of *Lady Hamilton* for permission to use the vessel as an experimental platform; to Jake for setting up and monitoring the camera on the boat each day, and providing advice; Jennifer Stewart for advice and support throughout the project, and for commenting on the text; Brian Woodgate, electrical engineer, for bringing a life-time's experience to bear on the vessel electrics and connection of the VIRB camera; to Simon Hamner for work on the code to automate video clip selection and extraction; Prof Michael Manelli, *Z/Yen*, for long term support, encouragement, and sharing his interest in the risk/reward criteria of fisheries, and specifically regarding the potential and relevance of Mutually Distributed Ledgers and the availability of the *MetroGnomo* platform; to Dylan Bean of *Kernow Sashimi* for additional assistance; and to Callam Dingwall, *Shenval Blacksmiths*, for work on shaping the hard steel of marine specification Jubilee Clips.

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Chapter and Verse

This section provides details of the Operational Trial; issues that arose and how they were addressed; and an indication of the current capabilities and limitations for prospective users.

Purpose of Operational Trial

The purpose of the operational trial was

- to test equipment and methods at sea under realistic operational conditions, and to make modifications to resolve any issues that arise, and
- to test the land-side data handling path. This starts with taking data off camera cards, through video analysis, GPS analysis, the linking of video to GPS data; the demonstration of the feasibility to process and store large amounts of video data; the analysis, marking and extraction of events in the video, the demonstration of a means of transferring that analysis in a form suitable for spreadsheet and statistical applications, the demonstration the securing the data within a chain of custody via a mutually distributed ledger (blockchain).

Trial Particulars

Location

Falmouth Bay and environs, in Cornwall, operating out of the Helford Estuary.

Date

Initial tests December 2017. Run with sea-proofing modifications to cabling through January and February to establish equipment longevity and operational methodologies. Run through March to text final modifications.

The operational trial took place during the stormiest, coldest and darkest period of the year. The vessel has limited deck lighting and a 12v electrical system used to full capacity. Overall, these conditions provides a strong test of both the equipment and video quality in realistic operating conditions.

Boat

Lady Hamilton, FH214, an under-10m vessel skippered by Chris Bean, that has been operating in the area since the 1970s, and with which modus vivendi has documented fishing activities since 2004.

Fishing metiers

Lady Hamilton is primarily a netter using a variety of gill, trammel and tangle nets to pursue different fisheries, in different seasons, also carrying out some shellfish potting.

Equipment – hardware and software

Currently, Garmin *VIRB* HD video cameras are favoured over *Go-Pro* because of Garmin's early support of GPS; provision of hardware support for the wiring of cameras into a 12-24v DC power supply; because Garmin is a leading provider of mapping software that provides all essential features free (and provides open-format data export), and other extensions, such as marine charts, at a relatively modest cost compared to other providers; and because of Garmin's involvement in the production of marine plotters and fish-finders.

Figure 11.Garmin VIRB Ultra 30 *in its waterproof housing with the custom made entry point for the vessel 12v DC power supply, complete with Jubilee clip; undergoing a 12 hour water endurance test; and two images of the camera* in situ *on board* Lady Hamilton.

Fishface also requires the use of video editing software with comprehensive documentation features, for example keywording of video sequences that allows overlapping segments of video to be keyworded, for searches by keyword, to provide some capacity summary statistics of those keywords, and which allows the export of analytical data in a format that can be transferred to spreadsheets and statistical software. In the Operational Trial Apple *Final Cut* Pro was used, the operation of which be familiar to many people from the free cut-down version *iMovie*.

Analysis prior to the operational trial showed that the two bottlenecks that determine both the practicality and economics of the project for mass use were the speed that data could be read from microSD cards returned by vessel to storage, and the speed at which video data could be extracted and processed, particularly to produce a reduced size reference video file of the entire video (‘transcoding’) appropriate for cloud storage and remote access, e.g. from vessel power up to power down.

Apple was favoured because *Final Cut Pro*, one of two prime candidates for video analysis, is only available for Apple machines, and many years familiarity with the Apple ecosystem. At the time of funding, in late 2017, the highest specification Apple *MacBook Pro* was the only machine available that allowed 4 microSD cards with the highest available speeds to be simultaneously read at performance limits. The *MacBook Pro* also had comparable video transcoding speeds to the highest relevant specification late 2017 *iMac*.

Figure 12.View from the camera on board Lady Hamilton*. Still image from video, 2nd January 2018, taken 16m, 52 seconds and 3 frames into Gear Clearance 2.*

The speed provided by the highest specification microSD cards and computers more than compensated for their higher cost, due to the higher capacity that could be handled in any day, and so the reduced labour cost of supervising data transfers.

Results

Procurement

The only issue when equipping up for the project was the scarcity and increasing cost of the highest capacity, highest possible speed microSD UHS-II cards: 128 GB 270+ MB/s (megabyte per second) read speeds. These are quite exotic cards—mainstream premium cards have read speeds one-third of this, at around 100 MB/s. The ten cards needed had to be ordered in small numbers and in repeat orders from multiple suppliers as stocks became available.

The assumption is that in time availability will increase (and indeed higher capacity cards will become available) and price will fall as consumer Ultra-HD video cameras become more widespread.

At Sea equipment performance

No Major Issues

There were no major ‘show-stopping’ issues, such as finding the camera could not be powered from the vessel electrical system; that the camera itself was unreliable in service, or insoluble problem emerged maintaining the waterproof integrity of the case.

Resolution of Secondary Issues

Various subsidiary issues were identified, all of which were resolved, or were likely resolvable if required. These are summarised below.

Issue	Description	Remedy	Resolved?
Camera touchscreen uncontrollable	First camera failed out of the box	Replaced camera, no further problems.	
Battery recharging affects boat lights	The trial vessel has a lot of equipment working off 12v system. Connecting a camera with a (partially) discharged battery results in vessel deck lights dimming until battery is fully charged.	Ensure that camera battery is charged (this will normally be the case other than first use on a vessel) unless WiFi is left switched on overnight and the camera is disconnected from external power.	
Camera switches off	During operation, camera switches off before card is full and with a charged battery	Original connection boat-side of transformer replaced by electrician with a heavy duty waterproof connection	
Lexar SSD card failed	In pre-boat trials, all cards were noted to get extremely hot when reading, and especially when writing, at maximum speed, to the full capacity of 128GB to cards (nb writing at maximum speed to full capacity is not a normal operational parameter, where the card is written to over many hours). Lexar cards have a pigment ink on their top side (SanDisk cards have minimalist red typeface) and for one card this softened to the extent that the card was virtually frozen within the card reader when not immediately extracted. Some one month into the trial this card failed.	Card still under warranty. It was replaced with a sixth SanDisk card, as the read speeds of the SanDisk cards in normal operating conditions are notably higher (up to 288 MB/s vs 260 MB/s. Because of this speed difference, Lexar cards would not be used in future, even though the cost is slightly less.	
Connection wire broken	During operation the boat-side connection was broken	Evaluated by electrician and more robust connection made	
Fogging of image	Around 1.5 months into trial desiccants no longer removing	Apparently we have established the life-time of desiccants, even with	

	moisture that condensed inside the camera housing on lens window on sunny days	measures in place to regenerate absorptive capacity, so now know these should to be replaced eg after one month.	
Camera alignment disturbed	The vertical camera alignment can be disturbed by crew pressing against the camera when keeping a forward look-out over the cabin roof of the boat	Because the horizontal alignment has never been disturbed this likely means that the lock screw for vertical alignment has been inserted from the wrong side, so that the friction grip is less effective. Regardless, it can be remedied by adding a 'roof' to our custom back plate, projecting further forward than the camera lens. In practice, a crew member usually re-adjusted the vertical alignment, this has been left as a post-operational trial modification.	

Cautions and Current Limitations

Video recording at 1080 HD (ie 1080 vertical lines, High Definition) fills a 128GB card in 8 hours. This may usually be sufficient to record from powering up the vessel in port to powering down upon the return. If not, recording at 720 HD provides 14 hours video coverage. 256GB UHS-II cards are becoming available, although not formally supported by Garmin (or GoPro).

Go-Pr*o* do not support connection to an external power source, and Garmin do not support a connection though the waterproof housing. This means that a custom waterproof connection had to be developed. So far a maximum waterproof life of these seals of 6 weeks has been demonstrated before signs of failure, which means that, as a precaution, the housings should be recycled and serviced every 4 weeks. As experience is gained it may be possible to extend these periods. However it is currently simply addressed by making sure that a spare case is included with the equipment.

Land-based work: Method

The headline results:

Data Transfer

Claimed data read speeds of these highest possible specification cards, read speeds of 'up to' 275 MB/s (SanDisk) or 270 MB/s (Lexar) were typically exceeded by all the SanDisk cards, with read speeds up to 288 MB/s, but the Lexar cars rarely exceeded 255 MB/s. In practice this meant that up to 4 full 128 GB SanDisk cards could simultaneously be transferred to the computer in 7 minutes, and in 8 minutes for the Lexar cards. These differences mount up with a big project

Video editing and video database

The professional video editing software tested, *Apple Final Cut Pro* and *Adobe Premier*, provided instantaneous video skimming and other editing facilities at 4K (ie 2160 vertical lines) and below, as expected from the high specification of the MacBook Pro. Currently 1080 HD is the maximum practical size for video recorded on vessels, starting with the current storage capacity limitations on microSD cards.

Garmin *VIRB Edit* As anticipated from earlier work, the Garmin *VIRB Edit* software is too slow for sophisticated video tasks, because it can only utilise one processing core on a computer. This means that the high performance features of multi-core computers cannot be utilised, when loading, processing or exporting video. This is a pity because some of the metadata overlays are useful, for example in a first review of video.

Final Cut Pro. So far only *Final Cut* has been tested for detailed editing and mark-up facilities required for *Fishface* analysis. It is extremely easy to skim through video to mark up and extract clips, and also to turn keyworded sequences into clips, including partially or completely overlapping events (for example two fish of the same species (i.e. the same keyword) coming over the hauler (in and out of vision) at the same time. It also allows a text search for named clips, and for individual keywords or combinations, and provides totals for the number of occurrences. Used in conjunction with third party software the video database metadata (such as the start and end point of keyword mark-ups) can be exported in a format that can be read by spreadsheets and statistical software such as R. This makes working within *Final Cut* a viable option for analysing video data.

Third party software exists specifically designed to export video database metadata between *Final Cut* and Adobe *Premier (and vice-vers*a) which should mean that users are not captive to any one software vendor.

These clips can then be exported individually and added to a list for subsequent batch conversion to whatever resolutions are required.

Weaknesses and Limitations. An automated means creating a batch of clips for export (for example all clips of individual fish) is not available within *Final Cut*. This would be a problem if there was a requirement for exporting many keyworded video sequences (e.g overnight). However, if required, bespoke software to do this could be written relatively easily.

GIS Mapping

GPS data was exportable to open standards. In this operational trial free desktop Garmin software, *Homeport* was mainly used. Garmin *Basecamp* was fully functional but does not allow Garmin marine charts and their data to be used (such as contours and sea bed type); instead marine areas appear as simple blue. In either case, without additional purchases, only a crude coastline is shown, but the necessary functionality is retained (see below). There are no comprehensive open source maps of seabed depth or type for the UK. For the operational trial we used Garmin *Bluechart 2* maps to produce the charts shown indicated depth and seabed type. These effectively cost several hundred pounds, but are still cheaper than alternatives where there are no institutional licences.

GPS tracking at sea was good, with no significant latitudinal or longitudinal jitter. There was more jitter in the vertical plane. Documented changes in vessel speed allowed the unambiguous identification of shooting of nets, both by humans and automated processes (see below), as confirmed by the video, using seconds from the start of the record for both GPS and video.

Weaknesses and Limitations None evident.

Integration of Video and GPS Data in GIS software

As would be expected from a consumer orientated product, it was easy within *Homeport* or *Basecamp* to organise data; to produce end-user maps of fishing activity and zoom into detail of a single event of fishing trip, or see an overview of all fishing activity by all vessels within a defined period. *Basecamp* (the terrestrially orientated Garmin GIS offering) had the same functionality as *Homeport* with the exception that Garmin marine charts cannot be imported, which in effect means that depth contours and seabed types cannot be viewed.

Typically the video analyst would work closely with the GIS software, for example to check the video whether any significant events indicated from the GIS. Because the GPS trail and the video are measured in seconds from the same starting point of the vessel it is then easy to read off the start and end point of the video, mark up the same start and end points on the GPS track, and confirm that there has been no confusion by inspecting the plot of vessel speed. Once video files have been exported from the video editing software and placed in the cloud it is easy to include a clickable link to the video file of the event, or events, within either versions of the GIS software.

Weaknessess and Limitations When confronted with this large data set *Homeport* was fairly flaky, at least in the Mac OS versions, typically crashing perhaps a couple of times when being used intensely over several hours when overlaying multiple tracks over marine charts. No data was lost in these crashes. It is not clear that Garmin is particularly active in supporting this software, far less actively developing it. However there was one software update during the period of the trial.

The functional limitations are also fairly evident. Nevertheless it had the basic means to perform all the tasks required of it in the operational trial, is easy to master, and it is free. This makes it attractive where funding is limited. If greater functionality is required, it is easy to export the data to other GIS software for more elaborate analysis.

File Resolution, File Size , Data storage, Processing time requirements

The practicalities of *Fishface*, and indeed any Fully Documented Fishery involving video documentation, has very little to do with fishing and fisheries. Instead it hinges around technology: file sizes; the time taken to process these very large files as stored on the camera to something smaller without losing value; the means of making this accessible (time and cost of uploading and downloading to the cloud) ; and ultimately the cost of equipment and storage.

The 128 GB microSD cards currently used hold just over 8 hours of raw HD video and sound at 1080 (vertical pixels) resolution, and 14 hours HD video at 720 vertical pixels. 128 GB files are large by normal standards but are not unusual for video editing or a problem for partners receiving data on hard drives.

Data storage requirements quickly mount up. Storing one year's worth of video, as it comes off the camera, from ten vessels each producing 128 GB per day amounts to 256 TB, if a fishing year is on average 40 weeks x 5 days. However the camera's compression algorithm is not very efficient. When tested during the operational trial, file sizes could subsequently be reduced on the computer to 44% of that off the camera without obvious loss of quality using (older) mp4 transcoding, and with a further 50% reduction if transcoded instead with the more recent (but computationally more demanding) m4v format. In both cases, on both the late 2017 top end specification *MacBook Pro* and on the *iMac*, this took some 3 hours for an 8 hour video. It takes a similar time if the resolution was downsized, but at the lowest 280 (vertical lines) resolution tested, file size was reduced from 128 to around 2GB. In the next stage of *Fishface*, planned to use the 2018 high specification *iMac Pro*, one could expect to reduce the processing time to take 90 minutes or less which, allowing for some multitasking and overnight processing, makes it possible to handle incoming video from ten vessels every day without falling behind, although it does require the full use of the processing power of the latest high end computers. In the future, as you move beyond ten vessels, with access to 1Gbps+ internet, you would look to do this video transcoding in the cloud.

You also have the issue of accumulating video, year-on-year, should this be required (ie building up a database for computers to learn how to count and identify fish). Currently some cloud-based storage (e.g Dropbox Business) is unlimited for an affordable fixed cost. If in addition, or for purposes of back-up or convenience, local hard drive storage is required, large capacity fast read/write hard drives are becoming increasingly affordable. A 20 TB external hard drive for which independent reviewers obtained 335 MB/s read speed and 317 MB/s write speeds, currently costs £463 ex. VAT. Fourteen such 20TB drives (once formatting space is subtracted) would be required if this video is saved as it comes off the camera, currently costing £6,484 ex. VAT. The cost per vessel, especially if these vessels act as sentinels or representatives of a larger fleet could well be affordable. Courier exchange of drives to partners with the latest data is also cheap and reliable if internet transfers are impracticable.

If the requirement is to keep lower resolution video of each video from power up to power down of the vessel, and /or HD video only of those segments showing activities involving fish, the storage requirements are reduced to around one third.

If interactive cloud based processing is not required or possible, it is relatively cheap to store the final 'inert' video emerging from local (desktop) processing, for example in Dropbox, and then reference this via a link, as done in this Operational Trial via *Homeport*, and in the demonstration distributed ledger (blockchain). This will be adequate for many current uses and users.

But other uses would ideally be delivered with video stored in the cloud. This includes of the most exciting developments, for example where there are potentially many possible analysts, to whom video snippets can be selected automatically according to some protocol, extracted and delivered on the fly, and results incorporated and manipulated by cloud computation. This includes citizen science projects, including the creation of training sets of identified fish for computers to use to learn how to identify, count and measure fish. And cloud processing is essential for the high speed automated analysis of video that is likely to be part of any ultimate AI initiative.

Providing you have access to 1Gbps internet, it is not particularly expensive or problematic to upload video into the cloud at a rate that keeps pace with video being received from fishing vessels. Ideally one would simply upload HD video 'as is' from the camera cards into the cloud and then later extract video sequences on the fly, as required, at the resolution required. However, video storage in the cloud allowing this type of access is not cheap. (See *What does a $5 video camera cost?* Spoiler alert: potentially well over $1 million). Instead, a more affordable use of such facilities is to upload raw video into temporary storage from which a low resolution index file of the entire sequence is transcoded and saved (in the cloud) along with a narrower portfolio sequences of interest that are extracted and stored at higher resolution, before discarding the raw video and uploading the next.

For larger scale use, this has to be in the cloud because the processing power is far greater than massed ranks of desktop computers.