FOGONATURE.COM: ONLINE AND ON-OCEAN CROWDSOURCING FOR ADAPTIVE FISHERIES MANAGEMENT

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2. Executive Summary

This project is a participatory citizen project in collaboration with research partners (fishermen and fisherwomen) from Fogo Island. The project deviates from other citizen science projects in that our community partners, and not the university researchers, have developed the research question. Thus, the project outlined here deviates somewhat from the original proposal (as well, we discovered there were large technical limitations to the work originally proposed, which could not be overcome within the scope of this project).

The project described here is in two parts, and both form the major components for an MSc(Env) thesis by Matt McWilliams (currently completing year 1 of his graduate program). The first part of the project is the participatory citizen science. Through meetings with fishermen and fisherwomen, we identified a research question about ocean tempeartures and developed a sampling methodology. Matt McWilliams lived on Fogo from May-September and assisted with deploying data loggers and downloading data. We presented

these data back in the community and solicited feedback and recommendations for future sampling.

The second part of the project is a digitization exercise of historical (1979-1992) fishing log books. This was completed at the request of community members, who felt it would be useful to compile the data in a format that could be analysed and shared rather than have them sitting on a shelf. Matt McWilliams digitized tabular data into a relational database and the hand-drawn maps as a GIS database.

The project is on-going, as Mr. McWilliams has a second year left in his degree. He will spend part of the summer on Fogo, facilitating additional data collection. He anticipates completing thesis work by December 2016.

3. Glossary and Acronyms

CS: Citizen Science

GIS: Geographical Information Systems

PAR: Participatory Action Research

PCS: Participatory Citizen Science

4. Introduction

4.1 Project Background

This research project is an interdisciplinary study attempting to combine several best practices from a variety of fields. The goal was to design a project that results in the effective and sustainable management of the Fogo Island fishing industry.

The project was motivated by research on and with citizen science and the potential it has to elicit meaningful change and engage communities with a local ecosystem. However, in researching different citizen science projects, it became apparent that the current way citizen science is conducted, does not fulfill the hope of creating meaningful change in a local community and ecosystem. The citizen science projects we reviewed in literature do many things very well, but usually only for the scientists, or else for fostering public appreciation for an issue. We felt that many citizen science projects do not effectively engage participants and provide tangible benefits to them (Franzoni and Sauermann 2013). With the increased frequency and intensity of changes happening to the environment, there is more demand for research at a pace that scientists simply cannot produce. The larger scientific community needs to incorporate citizen science to a much larger extent than it presently does in order to have a chance of sustainability (Catlin-Groves 2012). A more effective solution to the current model for citizen science is one where a research project is co-created by scientists and citizens (Stevens et al. 2014). This is necessary because all questions scientists pose need to be pertinent to local and global issues and contribute to solving them.

The project as described in this report did not match the proposed methods exactly. We conducted a survey of boat gears to try to develop some software/hardware that could be

used to seamlessly collect data from on-board instruments. We quickly realized that there was too much variation in the types of gear on different boats and in the makes/models that would make standardizing sampling through a technological add-on impossible in the time frame of this project.

4.2(a) Rationale for the Project

A very useful methodology to conduct research meant to address local problems and engage communities in the field of Sociology is Participatory Action Research (PAR). This methodology is most often used within education, health, and agriculture (Stringer 2007) however it can be applied to science research. The steps given differ slightly but most PAR guidelines contain the same basic principles; gather information about the local issues, formulate why these problems exist, act on those theories, and evaluate the outcomes (Stringer 2007, Kemmis and McTaggart 1999). These steps can easily be adapted to the scientific method. The only difference is that local community members are essential to this type of research as their expertise is required when designing research to solve local issues.

This research attempted to combine citizen science and PAR into a Participatory Citizen Science (PCS) project to successfully co-create a research project that addresses local problems. This project took place on Fogo Island in Newfoundland, Canada, and as such, we addressed problems that the participants in the fishing community identified for us (and hence why we had to deviate our methods from those in the original proposal). The participants for this particular study were a group of Fogo Island fishers that target a wide variety of species, use many different types of gear, boat sizes, and fishing grounds.

Fishers' knowledge and expertise has been used for many years by scientists and fishery managers without much success in regards to successfully managing harvested species, so why do we think it would it be different this time? Hind (2014) details how fishers' local knowledge and expertise has traditionally been used via interviews, surveys, and questionnaires developed and delivered by scientists or sociologists. A problem with interviews and other qualitative methods in regards to changing how fisheries are managed is that they are not easily translated into scientific evidence or empirical data that plays a large part in formulating fisheries management practices. This is why we feel PCS may be more appropriate when working with fishers and fisheries management. Our project demonstrated that it is possible to formulate an incredible amount of traditional/local knowledge into empirical data by directly involving the Fogo Island fishermen and fisherwomen in all parts of co-created PCS project.

Callon et al. (2009) argues that all types of people from citizen to scientist to politician must be involved in conversations to answer dynamic real world problems. This project is meant to address the problems of current fisheries management by bringing local experts together to answer exactly these types of questions. To effectively manage a complex natural system, issues with current management strategies must be identified. Once identified, research questions need to be designed to address these issues and inform potential changes in policy (Walters and Holling1990).

PCS is a relatively new field that has the potential to accomplish what Callon argues is needed to address complex and dynamic problems. There is a need for a sustainable fishing industry, but in order to have a sustainable fishing industry on Fogo Island, or anywhere for that matter, changes are needed in fisheries management and practice. One problem with

past fishing management strategies are that they utterly failed to predict the large, complex, and dynamic interactions of the ecosystem around Newfoundland.

In our initial discussions with members of the fishing community on Fogo, people mentioned participating in a past Department of Fisheries and Oceans (DFO) study detailing catch rates, fish grounds, and ecological resource location around Fogo Island. They were interested in seeing the data from this project being turned into something useful, or at least see something done with it as it was created from their hard work and knowledge. Because of this, and the nature of the data, creating a GIS database seemed like the best way to make this historic data useful to the fishermen and fisherwomen of Fogo Island. On a second visit we worked collaboratively to refine a research question and sampling methodology (detailed below). Matt McWilliams spent the summer (May-September) on Fogo Island facilitating data collection and we returned to Fogo in November to present the data and results.

In reaching out to the Fogo Island community, we received an old DFO fisheries database that was slowly degrading on a closet shelf. The participants had requested something be done with this data as it was important documentation of historical fishing grounds. These log books represent a valuable data source detailing catch rates and locations from the 1970s up to the 1992 cod moratorium which we did not anticipate in our original proposal. We quickly adapted our work plan to enable the graduate student, Matt McWilliams to digitized all the data in databases and a GIS map (detailed below).

4.2(b) Rationale for the GIS Historical Logbooks Database

In a large ecosystem like the North Atlantic Ocean, the amount data required to make informed decisions is impossible to acquire for scientists alone (deYoung et al. 2008). There

simply is not enough local expertise, resources, or funding within the scientific community to collect and analyze the substantial amount of data to make informed decisions about local ecosystems. GIS presents the potential to create the knowledge necessary to solve these problems. "GIS is not the only means of answering these questions, but it allows for increased speed and accuracy, thus allowing decision makers to evaluate various proposed management scenarios and make more informed decisions" (Stanbury and Starr 1999). The speed at which GIS can answer complex questions can give local communities a chance to deal with the increasingly volatile climate and argue for more adaptive management policies.

The incorporation of local knowledge into ocean ecosystems management has been a mandate of the Canadian government since the 1996 Oceans Act (DFO 1996). GIS promises a way to successfully bring local knowledge and scientific knowledge together. The segregation of data is not just limited to quantitative and qualitative forms, but also between scientific disciplines. GIS can bring together geologic, biologic, climatic, and temporal data (Stanbury and Starr 1999). As such, GIS is an incredibly powerful tool that can be used to effectively manage marine ecosystems.

As fisheries management is now focusing on ecosystems based management rather than species specific management, the importance of spatial information and maps has increased (Lanz et al. 2007). This type of management is accomplished by defining ecosystem boundaries. The Food and Agriculture Organization of the United Nations (FAO) has designated 18 global fishing zones (Lanz et al. 2007). These zones are quite large and do not appropriately account for local phenomena, habitats, and smaller fish species (Lanz et

al. 2007). Thus, there is great need for small scale ecosystem mapping, especially in regards to small-scale fisheries.

A problem with small-scale fisheries is a lack of available data to analyze and assess the state of local fisheries and ecosystems. The data at small scales is piecemeal and must be scraped together from an array of different sources. These are primarily from landings data, logbooks, and from interviews with local experts (Papaioannou 2012). With this assortment of data and GIS, several researchers have been able to effectively map SSFs and the local ecosystems in which they operate. They show the potential in small scale ecological databases is rather large.

A study conducted by Lanz et al. used landings data from one commercial fishing company to create a map to, "get a reliable vision of the fishing grounds location, especially in a small scale, and to analyze the variability of species composition in the resulting regions toward its sustainable management" (Lanz et al. 2007). With that database they were, "able to detect the spatial variability in the relative composition of species of small pelagic fishes among regions (Lanz et al. 2007). A different study from Alexander et al. used historical logbooks about the Gulf of Maine cod landings to both identify historical fishing grounds and extrapolate population density and size structure (Alexander et al. 2009). By using GIS to digitize historical logbooks, they were able to represent what a healthy ecosystem for cod looked like in the Gulf of Maine (Alexander et al. 2009). What this shows is that it is possible to create meaningful data from historical logbooks that can be effectively applied to current problems within local fisheries.

This GIS project is attempting to combine a wide array of knowledge and data across multiple spatial and temporal scales. The reason GIS was chosen is because GIS allows for

the synthesis of massive amounts of varied data (deYoung et al. 2008). The idea for creating this project originated with fishermen and fisherwomen from Fogo Island in the early consultations that formed part of our PCS project.

4.3 Objectives

Following discussions with our research partners in the fishing industry, we developed a two-part project with one goal (which matches the goal in the original proposal). The aim is to create a growing database of the Fogo Island environment by digitizing fishers' logbooks dating back to 1979. In addition to the historical data, we incorporated data collected from the 2015 fishing season through the Participatory Citizen Science research project. This project co-created scientific data from Fogo Island which the local community can use to advocate for adaptive, sustainable fisheries management. The specific PCS project was decided in a consensus meeting with local fishermen. The research question was motivated by a desire to monitor the changes in ocean temperature around Fogo Island for the 2015 fishing season in attempts to discover any effects changing temperature is having on local species. In addition, the GIS historical Fogo Island logbook database was designed to help the fishermen and fisherwomen of Fogo Island to document historical fishing areas. This project laid the historical framework for an ecological database of the Fogo Island ecosystem and the small-scale fisheries that operate in these waters from the 1970s to the present.

4.3(a) Research Methodology and Approach for the PCS Project

The first PCS meeting used a consensus modeled meeting to arrive at a hypothesis for our research. The methodology used for our March 28, 2015 consensus meeting was as follows:

Step 1, we began with an open discussion into what research questions participants want to ask.

Step 2 was to have fishermen and fisherwomen write their main questions or issues on cards. These cards were collectively ranked based on what is most important to the entire group. Once the cards have been sorted and prioritized we asked if there were any remaining concerns. Step 3 used the top-ranked cards to collectively create a research question and to modify that question until a desired level of agreement is reached. Step 4 was to assess the level of support for the research question. If there was not unanimous consent for the proposed research question, Step 2 through Step 4 would have been repeated with progressively more focused inputs until a 100% consensus was reached. Once we had our hypothesis we designed the data collection protocol and what data we needed to best answer the research question.

A final meeting was held in November 2015 after all the data has been collected. At the meeting, we gave a formal presentation of our results to the fishermen and fisherwomen involved in this project, gave them all their collected data as well as the graphs and charts we created. Then together, we discussed these results and with their input tried to pick out any trends and possible effects that temperature had on their catch rates throughout the summer.

4.4(b) Research Methodology and Approach for GIS Historical Logbooks Database

The primary data source for this project was from the Fogo Island Cooperative Fisheries Database. This consisted of two logbooks entitled, *Fogo Island Fisheries Database 01-05*, and *Fogo Island Fisheries Database 01-15*. These logbooks contain data regarding fishing

grounds, depth, gear used, boat size, crew size, daily and yearly cod landings, size of cod landings, flounder landing, lump roe landings, squid landings, capelin landings, and by catch (flounder bobtail, flounder black back, rock cod, skate wings, lump roe). Each of the logbooks contained one hand drawn map of the fishermen and fisherwomen's specific fishing grounds from the years the fishermen and fisherwomen participated in the study. *Fogo Island Fisheries Database 01-05* contains data from 1979-1992. *Fogo Island Fisheries Database 01-15* contains data from 1982-1995.

The base maps used in this database are digital charts obtained from Memorial University's Queen Elizabeth II Library Map Room and are as follows: 4530 Hamilton Sound, 4531 Carmanville to Bacalhao Island and Fogo, and 4560 Indian Bay to Wadham Islands. These detail the southern half of Fogo Island and its associated waters which are also the area detailed within *Fogo Island Fisheries Database 01-05* and *01-15*.

Multibeam bathymetry data was received from Canadian Hydrographic Service (CHS) for the area within CHS Chart #4820 Cape Freels to Exploits Islands. This data was received via an ftp site and is in .txt format. The data is bathymetry data with latitude, longitude, and depth at 25m resolution and 5m resolution. Singlebeam bathymetry data was also received for the same area but the resolution is not specified.

The foundation of the Fogo Island ecological database is historical ecosystem data from these fishing logbooks and current data collected by a variety of local fishermen and fisherwomen about ocean temperatures from the PCS project during the 2015 fishing season. This data was collected, digitized, and assembled into a Microsoft Access Database and a GIS Database.

4.5 Clearances

Ethics clearance was received from the Interdisciplinary Committee on Ethics in Human Research (ICEHR) for the PCS project for March 11, 2015 to March 31, 2016. (ICEHR # 20151835-SC)

5. Project Details and Results

5.1 The PCS Project Details and Results

The PCS project consisted of three major sections. The first part was the consensus meeting which took place on March 28, 2015. During this meeting the participants from Fogo Island first decided on a research question which was, "what affect does temperature have on different fisheries in terms of catch rates?" Other interests were effects on sea ice, capelin spawning, herring populations, and slub. This meeting was audio recorded and then transcribed for future analysis as needed. We also collaboratively designed the sampling methodology at this meeting. Fishermen and fisherwomen collected ocean temperature data during the 2015 fishing seaon by attaching *iBCod* temperature loggers at three points on the gear to sample water temperatures at the surface, in the middle of the water column, and at the seafloor. Temperature was taken every 240 minutes.

The second part of the PCS project was to collect the data. Graduate student Matt McWilliams lived on Fogo Island throughout the 2015 fishing season to assist with the deployment and retrieval of the instruments and shared the temperature data with the participants as soon as it was downloaded and plotted. Over the summer the temperature loggers were put onto crab gear, shrimp trawls, turbot nets, and cod pots. Best practices were developed for attaching these loggers to the gear so that they would not be destroyed

or lost during the fishing process. In addition to collecting temperature data, latitude and longitude, depth, and additional notes were taken with a log sheet which we collaboratively developed with the participants (Figure 1).

The third part of the PCS project involved assembling all the data into the Microsoft Access Database and the GIS historical logbooks database for the creation of maps and graphs for the second scheduled meeting. At the November 19, 2015 meetings we presented the participants all the data they collected and together, attempted to answer our research question (Figs. 2-4). The fishermen provided the catch rates and with the temperature data collected, tried to discern noticeable affects that temperature had. No significant impact of temperature on catch rates was discerned from this meeting; however, the participants believed that a larger impact on catch rates was due to changes in species location and populations. There was a noticeable increase in capelin and cod (quantity and size) this season. Additionally, the shrimp fishery moved further off shore and had the highest yields they had ever experienced.

The return of large numbers of capelin and cod was thought to drive the catch rates of shrimp more so than temperatures. However, one year of data is not enough to spot any potential trends. As temperature changes from previous years to the 2015 fishing season may be a driving factor for catch rates.

We also discussed the desire that the fishermen and fisherwomen had to continue the PCS. There are plans for another field season from May 2016 to September 2016 in which additional ocean temperatures will be collected. However, the specific methodology used in the 2015 fishing season may be adjusted to take temperatures at shorter intervals and on different fishing equipment.

5.2 The GIS Historical Logbooks Database

Digitizing the tabular data from *Fogo Island Fisheries Database 01-05, Fogo Island Fisheries Database 01-15,* and *Fogo Island Cooperative Fisheries Database Final Report 28 November 1996* involved manually inputting the data into Microsoft Access (Fig. 5). Access tables were created before integration into GIS because this created a separate database more accessible to the fishermen and fisherwomen of Fogo Island. Additionally, Access allowed for better organization and file management of the tabular data. The data from each year for logbook 01-05 and 01-15 was created as a separate Access database file. The yearly database files contain multiple tables for each type of fishing gear used during that particular year. The Final Report document was used to create an additional Access database file detailing fishing grounds and their associated IDs. Tables within this file were fishing grounds, trap berth locations, capelin grounds, and herring grounds. Relationships were built between the fishing grounds and their associated IDs. These tables were then imported into GIS. During the importing process the Access tables lost their relationships and the Access database structure (one file per year containing multiple tables).

Before the hand drawn fishing grounds of the paper maps from *Fogo Island Fisheries Database 01-05* and *Fogo Island Fisheries Database 01-15* were transferred into GIS, the three digital charts, 4530, 4532, and 4560 were edited and added to the database. These edited charts are currently serving as the base map layer of the database.

The fishing ground maps from *Fogo Island Fisheries Database 01-05* and 01-15 were re-created in GIS by constructing individual polygons within layer shape files. These layers are differentiated by species and gear type and grouped according to which logbook they derived. The polygons were transferred by using a similar chart for the base map as those

the hand drawn maps were on. Thus, by comparing similar features from the digital and paper charts, a degree of accuracy was achieved in digitizing the logbook maps in GIS (Fig. 6).

After the assorted data from the logbooks was incorporated into the geodatabase, relationships were built between the tabular data and the fishing ground shape files. In order to accomplish this for all the fishing grounds, the fishermen and fisherwomen's expertise is required, as identifying the locations of all the fishing grounds without local expertise and knowledge is impossible. For the few that were able to be identified, the tabular data that from particular fishing grounds ID was related to specific polygons (Fig. 7). This enables queries to be made from the spatial data related to the individual fishing grounds and yearly and daily landings for several different species.

6. Future Recommendations

While not currently being discussed by the group, this database could help influence where future Marine Protected Areas (MPAs) can and should be placed. Canada's Oceans Act of 1996 has adopted MPAs as a way to regulate fishing (DFO 2009). As such, a detailed ecological database of Fogo Island provides the fishermen and fisherwomen with a powerful tool and voice in managing their surrounding ocean ecosystem. However, many MPAs implemented have not had the success they intended. This is due to a number of factors, but two pertinent ones are a lack of local involvement in the planning process and a lack of information on local ecosystem dynamics (Yates and Shoeman 2013). With this data being provided by local fishermen and fisherwomen, communication could be created between the policymaker who needs this data and the local community members who own it. This

relationship is also important for community empowerment and for community driven policy change to occur.

The Fogo Island geodatabase belongs to all participants involved in the project and any decisions about how to use the database is up to them. This empowers the Fogo Island fishermen and fisherwomen and by having the rights to the database they some leverage with who can access it. Knowledge is power and the Fogo Island database will contain a significant amount of local scientific knowledge. In this case, knowledge is a type of currency and the payment for such knowledge is inclusion in the policy making process (Sedlacko et al. 2014). It is empowerment and inclusion through control over a desired commodity. We are currently working on ways to effectively share the data with all members of the community.

The feedback from the particpants when we presented the data suggested they would like to collect additional temperature data. We recommend a second field season and plan to collect additional data. Based on conversations with the fishermen and fisherwomen, we recommend adjusting the sampling to increase coverage in space and time. However, it will not be possible for the graduate student to be on Fogo all summer, so we recommend training a student on Fogo on how to deploy the loggers and download data on retrieval.

We are unable to develop broader recommendations on PCS until this project is completed and we can adequately reflect on the process. However, for those individuals or groups considering engaging in PCS, we make the following suggestions based on experiences thus far:

- Engage research participants at the very earliest stages possible. In this project, we held two meetings with the fishing community even before writing a grant proposal.

- Work with an interdisciplinary research team. Our team has expertise in citizen science, participatory research, folklore, GIS and statistics. We also consult with oceanography and fisheries experts as needed.
- Schedule at least 2-3 formal meetings per year. More than 3 can result in participant burn-out. Formal meetings can be complemented by informal meetings (in person or over the phone)
- Having a graduate student embedded in the community for an extended period of time was immensely valuable and should be a part of any PCS project.

7. Conclusions

As the Northwest Atlantic climate continues to change, so do the species patterns inhabiting this ecosystem. In order to understand some of these ecological changes, with a group of fishermen and women from Fogo Island, a local ecological database was constructed. The foundation of this Fogo Island database is 20 years of historical data from fishermen and fisherwomen's logbooks around the island. This information details historical fishing grounds, gives insight in to the abundance and structure of several primarily fished species, and maps habitat.

As the local environment changes, new strategies are necessary to protect the local ecosystem and way of life on Fogo Island. This project attempts to construct a local geodatabase of Fogo Island through PPGIS. PPGIS has been an effective way to involve and engage local communities in all aspects of solving local problems. It has been able to bring together local stakeholders, scientist, and policy makers to answer complex local problems. In the case of Fogo Island, can such a feat be achieved? Given the history of Fogo Island

and the resilience of its community, I believe that this geodatabase can help the Fogo Island community to positively affect the local ecosystem through their increased involvement in management decisions and policy making.

This project was a small, local geographic window into the fishing history of Fogo Island from an ecosystem perspective and a social one. This project was important because it improved the data available to local fish harvesters. The resolution and type of data will lead to a better understanding of the Fogo Island ecosystem. More scientific data, over a long period of time, at a specific location will provide a better understanding of environmental and species trends around Fogo Island. This in turn should lead to better informed management practices for a sustainable fishing industry. The amount of data on small scale inshore fisheries is relatively sparse and such data is valuable to the scientific community.

From a sociology perspective, there is a possibility to see what effects these previous studies had on fisheries management and local community, if any. It is also the chance to showcase the positives and negatives of Participatory Citizen Science since it is relatively new and lacks published research. This project can give individuals involved in the fishing industry on Fogo Island the means to argue scientifically, why and how oppressive and unsustainable management strategies need to be changed. Development of such projects that directly involve industry in the scientific process can give more value to arguments fishers' are making to change policy and move towards a sustainably managed fishery.

Furthermore, fishing is not just an important part of the economy and industry; it is deeply rooted in the culture, history, and identity of Newfoundlanders. These inshore fisheries are in real danger of disappearing as they face threats from the climate change and difficult policies. If these inshore fishing communities are to remain, significant change

needs to happen to make the industry viable before the local fishers move away to more profitable jobs. If this project is successful, it has the potential to create a sustainably managed fishery on Fogo Island and help to preserve an ecosystem, an industry, and a way of life. This project is also important because it will provide new and novel approaches to data collection to inform local fisheries management. Fishing on Fogo Island is still, and should continue to be, an economically and culturally important part of rural Newfoundland.

Another benefit is that fishermen and fisherwomen will be able to answer questions about changes happening in their local ecosystem. The specific question developed by this group was, what affect does temperature have on different fisheries in terms of catch rates? This database with current information on temperature and historical data on catch rates can create interesting analysis and provide insight into species interactions with changing ocean temperatures. This could provide positive correlations between ocean surface temperatures, depth, and seafloor temperature. In a previous study, Reynolds was able to show evidence of annual and seasonal patterns with relation to depth and habitat association for widow rockfish (Reynolds 2003). Any such correlations could improve catch rates by allowing for fishermen and fisherwomen to more accurately determine when and where to fish. In addition, correlations for the Fogo Island ecosystem could also benefit conservation efforts by identifying local habitats, spawning grounds, and critical areas to protect.

While this database and PCS project is creating a robust tool for answering complex questions about the Fogo Island ecosystem, the real test of its power is whether or not it is useful to the Fogo Island participants. The database was showcased to the fishermen and fisherwomen on Fogo Island at a meeting on March 28. In seeing the digitized charts they had clear ideas about what other data could be incorporated into this GIS database and how it

could be used to argue the extent of their historical fishing grounds. This was promising because it showed that there already exists a potential use to affect management within the current database. The ability to argue historical fishing grounds comes from GIS linking historical landings directly to fishing grounds. This identification can be supported through records and receipts held by the Fogo Island Cooperative and other fishermen and fisherwomen. These records can spatially and temporally prove the extent of these traditional Fogo Island fishing grounds.

Finally, this project details the past and present Fogo Island fishery and ecosystem. Potentially, it also shows the future of Fogo Island whereby the local fishers co-create scientific research that empowers the community and begins to builds a sustainably managed fishery.

8. References

Alexander, K.E., Leavenworth, W.B., Cournane, J., Cooper, A.B., Claesson, S., Brennan, S., Smith, G., Rains, L., Magness, K., Dunn, R., Law, T.K. Gee, R., Bolster, W.J., and Rosenberg, A.A. (2009) Gulf Of Maine Cod In 1861: Historical Analysis Of Fishery Logbooks, With Ecosystem Implications. *Fish and Fisheries*, 428-49.

Aporta, C. (2011). Shifting perspectives on shifting ice: Documenting and representing inuit use of the sea ice. Canadian Geographer / Le Géographe Canadien, 55(1), 6-19.

Barndt, M. (2002) A model for evaluating public participation GIS. In W. J. Craig, T. M. Harris and D. Weiner, (Eds). Community participation and geographic information systems (246-356). New York; London: Taylor & Francis.

Callon M., Lascoumes, P., and Barthe, Y. (2009) Acting in an Uncertain World: An Essay on Technical Democracy. MIT Press, Cambridge, Mass.

Catlin-Groves, C.L. (2012) The Citizen Science Landscape: From Volunteers to Citizen Sensors and Beyond. *International Journal of Zoology*, 1-14.

Cinderby, S., Snell, C., and Forrester, J. (2008). Participatory GIS and its application in governance: The example of air quality and the implications for noise pollution. Local Environment, 13(4), 309-320.

Conde, M. (2014) Activism mobilising science. *Ecological Economics*, 67-77.

Department of Fisheries and Oceans (2009) A Fishery Decision-Making Framework: Incorporating the Precautionary Approach. Ottawa: DFO Accessed on March 20, 2015 at http://www.dfo-mpo.gc.ca/fm-gp/peches-fisheries/fish-ren-peche/sff-cpd/precaution-back-fiche-eng.htm.

deYoung, B., Barange, M., Beaugrand, G., Harris, R., Perry, I.R., Scheffer, M., and Werner, F. (2008) Regime shifts in marine ecosystems: detection, prediction and management. Trends in Ecology and Evolution, 23(7), 402-409.

Franzoni, C. and Sauermann, H. (2014) Crowd science: The organization of scientific research in opencollaborative projects. *Research Policy*, 1-20.

Foster-Smith, J. and Evans, S.M. (2003) The value of marine ecological data collected by volunteers. *Biological Conservation*, 199-213.

Gendron, C. (2014) Beyond environmental and ecological economics: Proposal for an economic sociology of the environment. *Ecological Economics*, 240-253.

Hartter, J., Ryan, S. J., MacKenzie, C. A., Parker, J. N., & Strasser, C. A. (2013). Spatially explicit data: Stewardship and ethical challenges in science. PLoS Biology, 11(9), e1001634.

Hind, E.J. (2014) A review of the past, the present, and the future of fishers' knowledge research: a challenge to established fisheries science. *ICES Journal of Marine Science*

Kemmis, S. and McTaggart, R. (1999) *The Action Research Planner* (3rd Ed.). Geelong, Australia: Deakin University Press

Kidd, S.A. and Krall, M.J. (2005) Practicing Participatory Action Research. *Journal of Counseling Psychology*, 187-195.

Lanz, E., Nevárez-Martínez, M. O., López-Martínez, J., & Dworak, J. A. (2008). Spatial distribution and species composition of small pelagic fishes in the gulf of california. Revista De Biologia Tropical, 56(2), 575-590.

MacNab, P. (2002) There must be a catch : participatory GIS in a Newfoundland fishing community. In W. J. Craig, T. M. Harris and D. Weiner, (Eds). Community participation and geographic information systems (173-191). New York; London: Taylor & Francis.

Moody, R., & van Ast, J. A. (2012). Implementation of GIS-based applications in water governance. Water Resources Management, 26(2), 517-529.

Panek, J. (2015). How participatory mapping can drive community empowerment - a case study of koffiekraal, south africa. South African Geographical Journal, 97(1), 18-30.

Papaioannou, E. A., Vafeidis, A. T., Quaas, M. F., & Schmidt, J. O. (2012). The development and use of a spatial database for the determination and characterization of the state of the german baltic small-scale fishery sector. ICES Journal of Marine Science, 69(8), 1480-1490.

Ramasubramanian, L. (2010). Geographic information science and public participation. Berlin: Springer.

Reynolds, J. (2003). Quantifying habitat associations in marine fisheries: A generalization of the kolmogorov-smirnov statistic using commercial logbook records linked to archived environmental data. Canadian Journal of Fisheries and Aquatic Sciences, 60(4), 370-378.

Robinson, J. A. (2010). Syracuse community geography: Evaluating a new approach to public participation geographic information systems

Rosenberg, A.A., Bolster, W.J., Alexander, K.E., Leavenworth, W.B., Cooper, A.B., and Mckenzie, M.G. (2005) The History of Ocean Resources: Modeling Cod Biomass Using Historical Records. *Frontiers in Ecology and the Environment*, 84.

Rugg, R.D. (2003) A framework for the use of geographic information in participatory community planning and development. URISA Journal, 15(APA II), 75-80

Sedlacko, M., Martinuzzi, A., Ropke, I., Videira, N., & Antunes, P. (2014). Participatory systems mapping for sustainable consumption: Discussion of a method promoting systemic insights. Ecological Economics, 106, 33-43.

Sieber, R. (2006) Public Participation Geographic Information Systems: A Literature Review and Framework. Annals of the Association of American Geographers 96(3), 491-507.

Stanbury, K.B. and Starr, R.M. (1999) Applications of Geographic Information Systems(GIS) to habitat assessment and marine resource management. Eceanologica Acta, 22(6), 699-703.

Stevens, M., Vitos, M., Altenbuchner, J., Conquest, G., Lewis, J., and Haklay, M. (2014) Taking Participatory Citizen Science to Extremes. *IEEE Pervasive Computing*, 20-29.

Stringer, E.T. (2007) *Action Research* (3rd Ed.). Thousand Oaks, California: Sage Publications

Tobias, T. N., Union of British Columbia Indian Chiefs, & Ecotrust Canada. (2000). Chief kerry's moose: A guidebook to land use and occupancy mapping, research design and data collection. Vancouver: Union of British Columbia Indian Chiefs.

Walters, C.J. and Holling, C.S. (1990) Large-scale management experiments and learning by doing. *Ecology*, 2060-2068.

Weiner, D., Harris, T. M., Craig, W. J. (2002). Community participation and geographic information systems. In W. J. Craig, T. M. Harris and D. Weiner, (Eds). Community participation and geographic information systems (3-16). New York; London: Taylor & Francis.

Wintle D.A., Runge, M.C., and Bekessy. S.A. (2010) Allocating monitoring effort in the face of unknown unknowns. *Ecology Letters* 1325-1337.

Wood, D. (1992) The Power of Maps. New York: Guilford

Yates, K. L., & Schoeman, D. S. (2013). Spatial access priority mapping (SAPM) with fishers: A quantitative GIS method for participatory planning. e68424. PLoS ONE, 8(7)

9. Figures

NAME:		VESSEL:			Y/N	Y/N	Y/N	Y/N	Y/N	
	Latitude	Longitude	Depth for White logger @ seafloor	Depth for Grey logger @ middle	Ice	Capelin	Cod	Sea Lice	Slub	Notes
Time/Date In:										
Time/Date Out:										
Time/Date In:										
Time/Date Out:										
Time/Date In:										
Time/Date Out:										
Time/Date In:										
Time/Date Out:										

Figure 1. Sample data sheet (developed collaboratively with fishermen and fisherwomen) to accompany data loggers

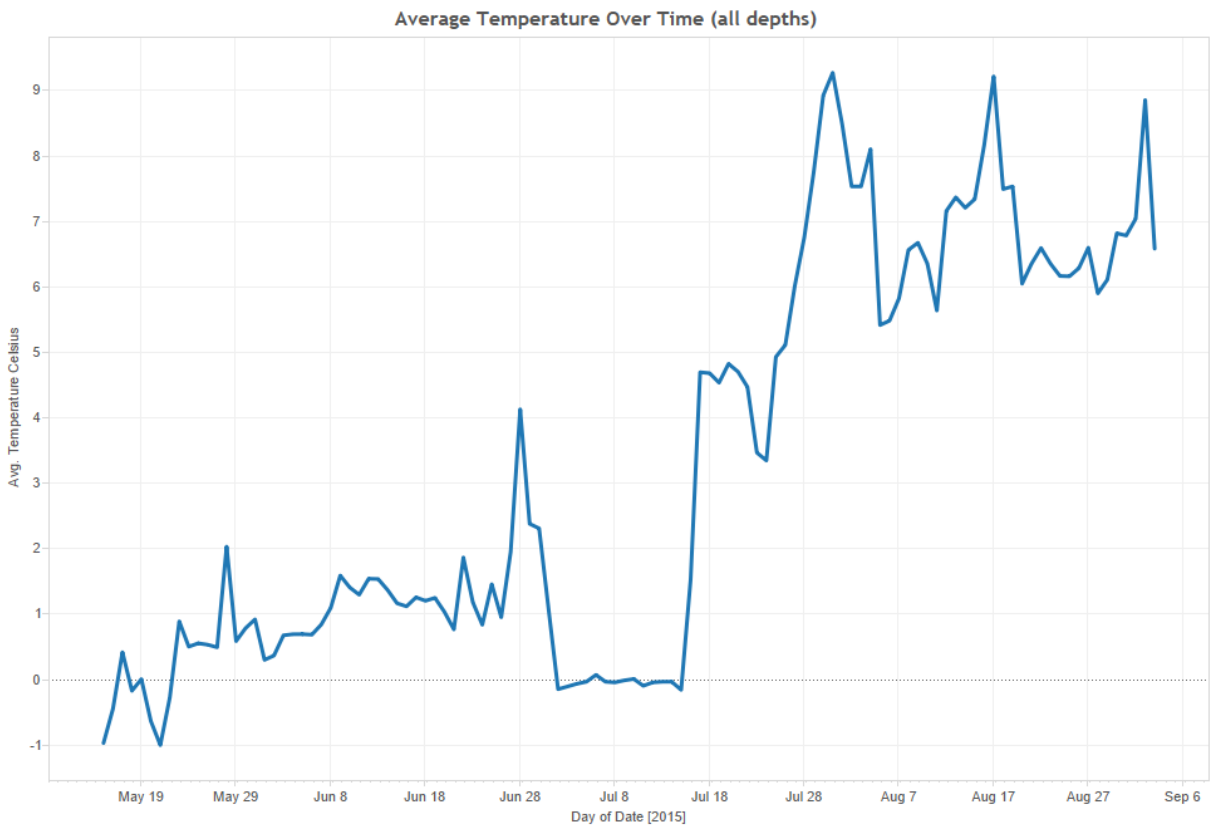


Figure 2. Average temperature in the ocean around Fogo Island over time

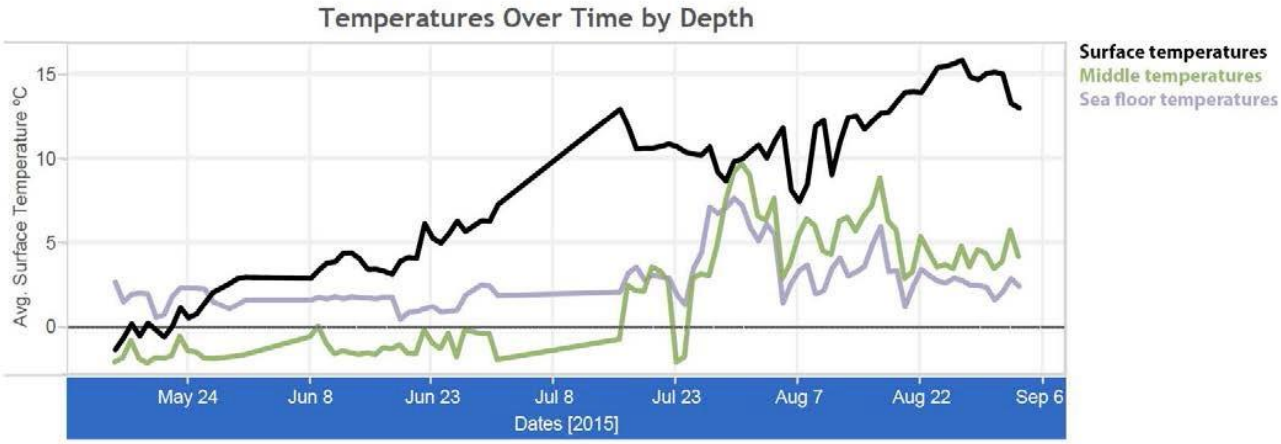


Figure 3. Temperatures over time by depth in the ocean around Fogo Island

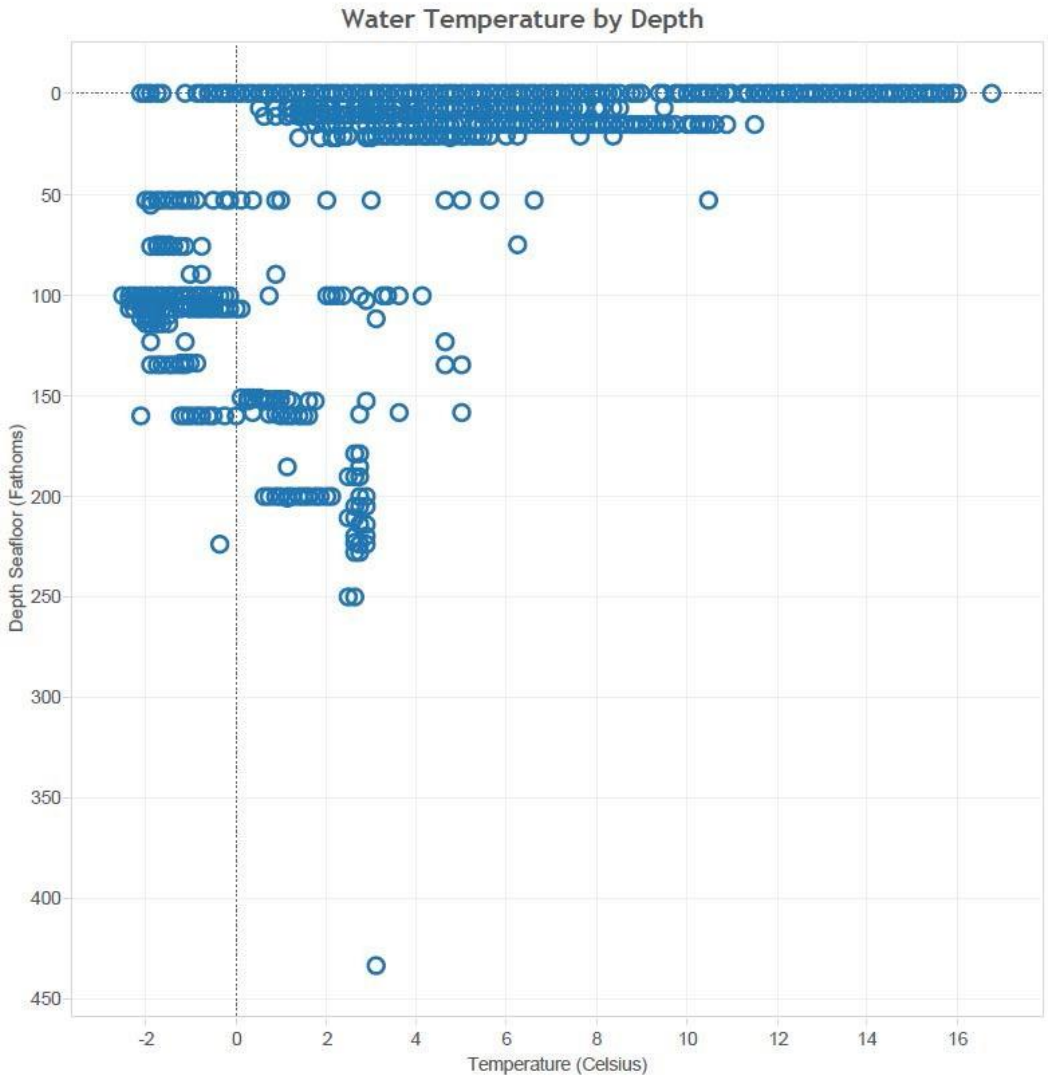
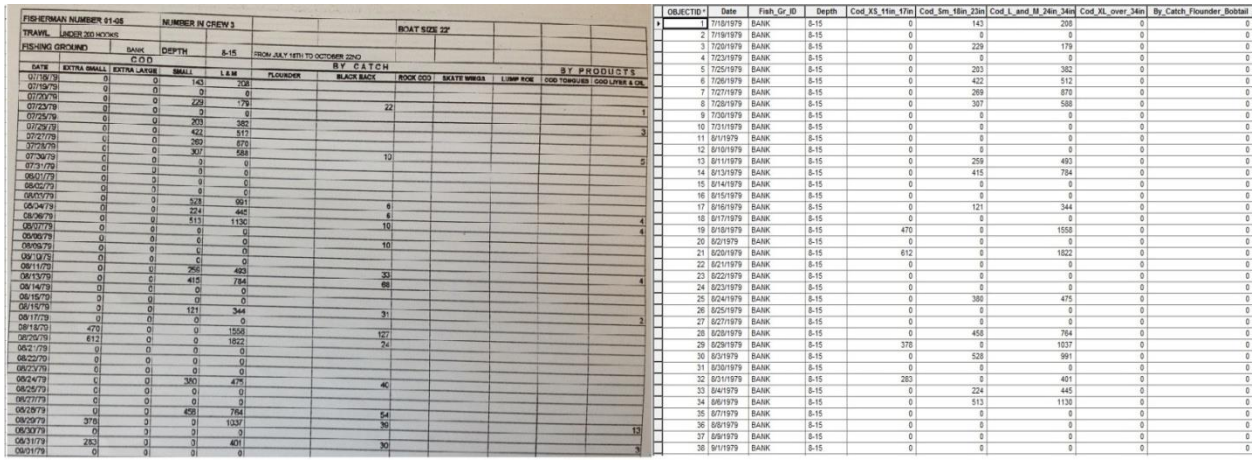


Figure 4. Water temperature by depth in the ocean around Fogo Island



FISHERMAN NUMBER 01-05 | NUMBER IN CREW 3 | BOAT SIZE 22'
TRAWL UNDER 200 HOOKS
FISHING GROUND BANK | DEPTH 8-15 | FROM JULY 16TH TO OCTOBER 22ND

	COD				BY CATCH					BY PRODUCTS	
DATE	EXTRA SMALL	EXTRA LARGE	SMALL	L & M	FLOUNDER	BLACK BACK	ROCK COD	SKATE WINGS	LUMP ROE	COD TONGUES	COD LIVER & OIL
07/19/79	0	0	143	208							
07/19/79	0	0	0	0							
07/20/79	0	0	229	179		22					1
07/23/79	0	0	0	0							
07/25/79	0	0	203	382							
07/26/79	0	0	422	512							3
07/27/79	0	0	269	870							
07/28/79	0	0	307	588							
07/30/79	0	0	0	0		10					5
07/31/79	0	0	0	0							
08/01/79	0	0	0	0							
08/02/79	0	0	0	0							
08/03/79	0	0	528	991							
08/04/79	0	0	224	445		6					
08/06/79	0	0	513	1130		6					
08/07/79	0	0	0	0		10					4
08/08/79	0	0	0	0							4
08/09/79	0	0	0	0		10					
08/10/79	0	0	0	0							
08/11/79	0	0	266	493							
08/13/79	0	0	415	784		33					4
08/14/79	0	0	0	0		68					
08/15/79	0	0	0	0							
08/15/79	0	0	121	344							
08/17/79	0	0	0	0		31					2
08/18/79	470	0	0	1558							
08/20/79	612	0	0	1822		127					
08/21/79	0	0	0	0		24					
08/22/79	0	0	0	0							
08/23/79	0	0	0	0							
08/24/79	0	0	380	475							
08/25/79	0	0	0	0		40					
08/27/79	0	0	0	0							
08/28/79	0	0	458	764							
08/29/79	378	0	0	1037		54					
08/30/79	0	0	0	0		36					13
08/31/79	283	0	0	401							
09/01/79	0	0	0	0		30					3

OBJECTID *	Date	Fish_Gr_ID	Depth	Cod_XS_11in_17in	Cod_Sm_18in_23in	Cod_L_and_M_24in_34in	Cod_XL_over_34in	By_Catch_Flounder_Bobtail
1	7/19/1979	BANK	8-15	0	143	208	0	0
2	7/19/1979	BANK	8-15	0	0	0	0	0
3	7/20/1979	BANK	8-15	0	229	179	0	0
4	7/23/1979	BANK	8-15	0	0	0	0	0
5	7/25/1979	BANK	8-15	0	203	382	0	0
6	7/26/1979	BANK	8-15	0	422	512	0	0
7	7/27/1979	BANK	8-15	0	269	870	0	0
8	7/28/1979	BANK	8-15	0	307	588	0	0
9	7/30/1979	BANK	8-15	0	0	0	0	0
10	7/31/1979	BANK	8-15	0	0	0	0	0
11	8/1/1979	BANK	8-15	0	0	0	0	0
12	8/10/1979	BANK	8-15	0	0	0	0	0
13	8/11/1979	BANK	8-15	0	259	493	0	0
14	8/13/1979	BANK	8-15	0	415	784	0	0
15	8/14/1979	BANK	8-15	0	0	0	0	0
16	8/15/1979	BANK	8-15	0	0	0	0	0
17	8/16/1979	BANK	8-15	0	121	344	0	0
18	8/17/1979	BANK	8-15	0	0	0	0	0
19	8/18/1979	BANK	8-15	470	0	1558	0	0
20	8/2/1979	BANK	8-15	0	0	0	0	0
21	8/20/1979	BANK	8-15	612	0	1822	0	0
22	8/21/1979	BANK	8-15	0	0	0	0	0
23	8/22/1979	BANK	8-15	0	0	0	0	0
24	8/23/1979	BANK	8-15	0	0	0	0	0
25	8/24/1979	BANK	8-15	0	380	475	0	0
26	8/25/1979	BANK	8-15	0	0	0	0	0
27	8/27/1979	BANK	8-15	0	0	0	0	0
28	8/28/1979	BANK	8-15	0	458	764	0	0
29	8/29/1979	BANK	8-15	378	0	1037	0	0
30	8/3/1979	BANK	8-15	0	528	991	0	0
31	8/30/1979	BANK	8-15	0	0	0	0	0
32	8/31/1979	BANK	8-15	283	0	401	0	0
33	8/4/1979	BANK	8-15	0	224	445	0	0
34	8/6/1979	BANK	8-15	0	513	1130	0	0
35	8/7/1979	BANK	8-15	0	0	0	0	0
36	8/8/1979	BANK	8-15	0	0	0	0	0
37	8/9/1979	BANK	8-15	0	0	0	0	0
38	9/1/1979	BANK	8-15	0	0	0	0	0

Figure 5. Historical logbook table on the left and converted table in the GIS database on the right *(from Fogo Island Fisheries Database 01-05)*

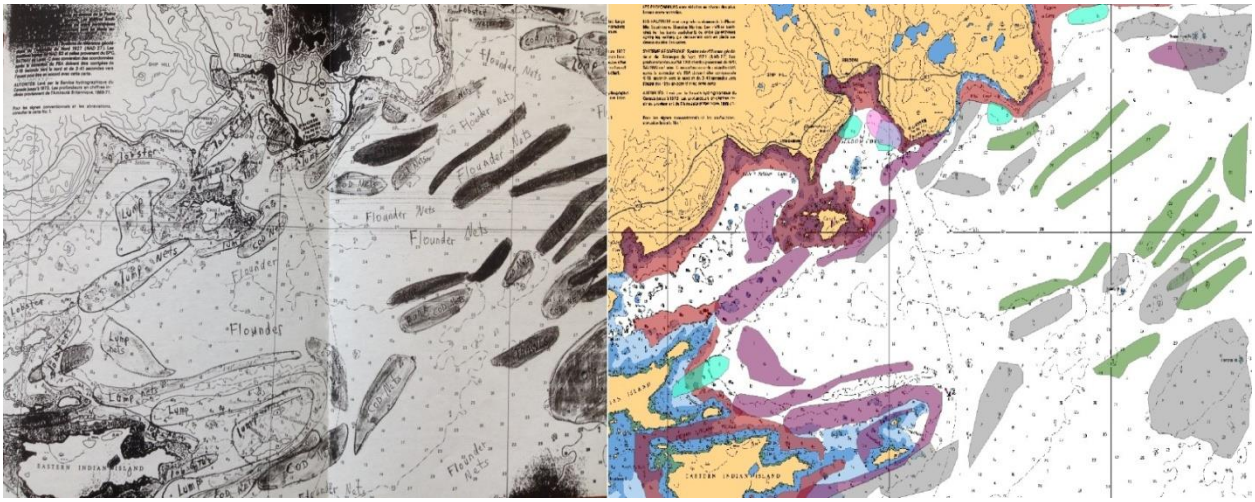


Figure 6. Historical chart from a logbook on the left and the digitized chart in the GIS database on the left *(from Fogo Island Fisheries Database 01-05)*

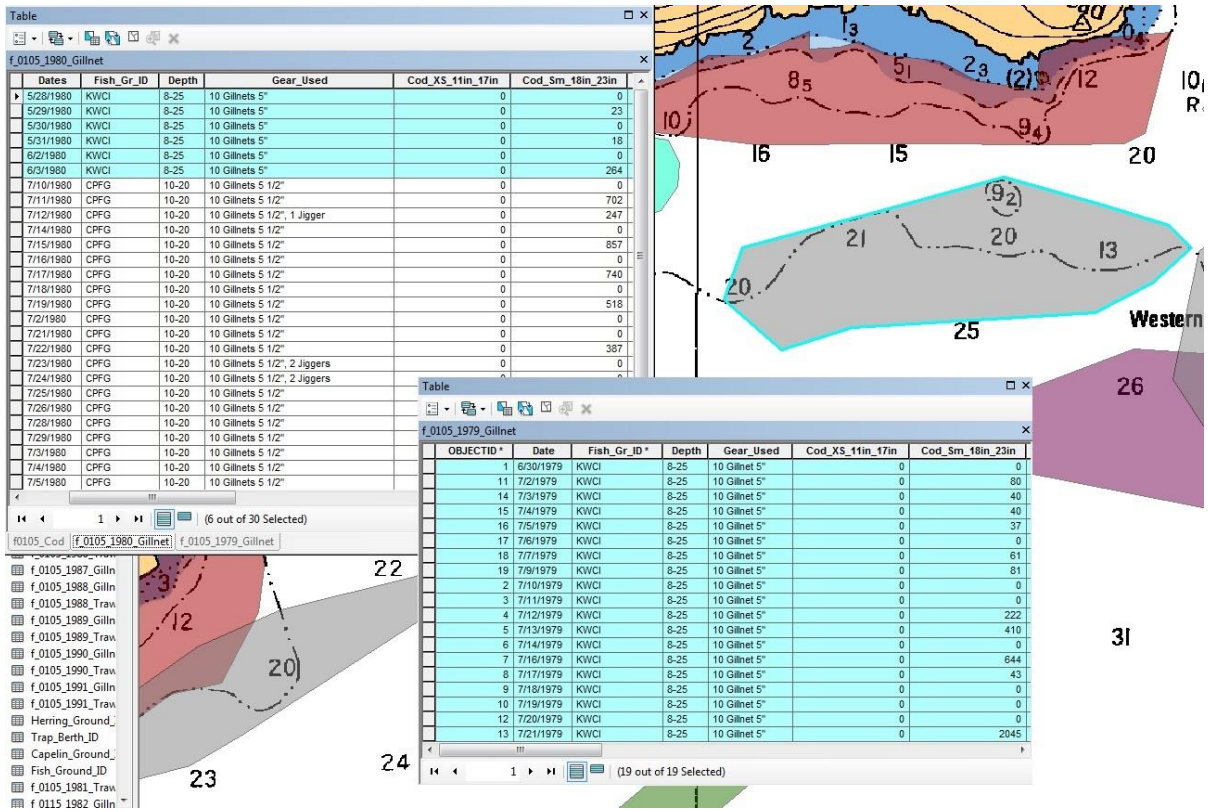


Figure 7. Screen shot showing tabular data from 1979 being related to the polygon identified as fishing grounds KWCI, Kippens Cove *(from Fogo Island Fisheries Database 01-05)*

10. Appendices

a. Copy of Informed Consent Form

b. Copy of email script invitation to first meeting

Matt McWilliams
38 Howley Avenue
St. John's, NL A1C 2T5
(513) 608 –6127
mm0254@mun.ca

Dr. Max Liboiron
239 Prince Phillip Drive
St. John's, NL A1C 5S7
(709) 846 –2167
mliboiron@mun.ca

Dr. Yolanda Wiersma
239 Prince Phillip Drive
St. John's, NL A1C 5S7
(709) 864 –3068
ywiersma@mun.ca

Informed Consent Form

You are invited to take part in a research project entitled *'FogoNature.com: Online and on-ocean crowdsourcing for adaptive fisheries management,'* conducted by Matt McWilliams for his Master's thesis in Environmental Science. He will be under the supervision of Dr. Yolanda Wiersma of the Department of Biology and Dr. Max Liboiron of the Department of Sociology at Memorial University.

This form is part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. It also describes your right to withdraw from the study. In order to decide whether you wish to participate in this research study, you should understand enough about its risks and benefits to be able to make an informed decision. This is the informed consent process. Take time to read this carefully and to understand the information given to you. Please contact the researcher, Matt McWilliams, if you have any questions about the study or for more information not included here before you consent.

It is entirely up to you to decide whether to take part in this research. If you choose not to take part in this research or if you decide to withdraw from the research once it has started, there will be no negative consequences for you, now or in the future.

Purpose of study:

The goal is to increase our understanding of the ways we can improve citizen science data quality through collaboration with local users of natural resources who collectively have a long-term and intimate understanding of their natural world. We want to work with local knowledge holders to generate data that is useful to them, but also useful to the scientific community. We will be engaging local fishers from Fogo Island in a Participatory Citizen Science (PCS) project to generate a testable hypothesis.

What you will do in this study:

We are asking for your professional opinions in the PCS research project where together, we will generate research questions about the Fogo Island ecosystem that will be useful to you and to the scientific community.

The estimated time for these meetings is 1 - 2 hours.

Withdrawal from the study:

You can withdraw from the study at any time you wish by stopping participation. There are no consequences for withdrawal. Any data collected by you up to that point will be used unless you ask us to remove it, at which point that data will be removed. If you wish to have any images, personal information, or data recorded during the meeting about you or provided by you deleted from our files, we will accommodate that as well. However, once images or data are incorporated into published or printed materials they will not be removed or altered.

Anonymity and Confidentiality

> Anonymity is impossible due to the nature of Participatory Action Research and consensus modeled meetings. Any personal information of the fishers' will be for the research team only and will be kept for a minimum of five years, as required by Memorial University's policy on Integrity in Scholarly Research, after which it will be deleted.

Possible benefits:

Being directly involved in the research question, design of the project, and how the data will be analyzed can allow for questions pertinent to the local industry, community, and environment to be answered. Your point of view, interests, and concerns will directly influence the type of research we do.

Possible harms:

There are no risks to you beyond what you would encounter in a normal day.

Recording of Data:

This meeting will be documented with audio recordings, written records, and photographs. The audio will not be transcribed. If there is not unanimous consent for audio recording, then it will not be used during the meeting.

Reporting of Results:

All data and analysis will be given to the participants once the study is complete. Hard copies of all products (maps, data tables, thesis, publications, etc.) arising from the final research will be left with the community (facilitated through the Shorefast Foundation). Participants will be able to access study results via our partner organization (the Shorefast Foundation).

You are welcome to ask questions at any time during your participation in this research. If you would like more information about this study, please contact: Matt McWilliams, Dr. Wiersma, or Dr. Liboiron whose contact information is listed above.

The proposal for this research has been reviewed by the Interdisciplinary Committee on Ethics in Human Research and found to be in compliance with Memorial University's ethics policy. If you have ethical concerns about the research, such as the way you have been treated or your rights as a participant, you may contact the Chairperson of the ICEHR at icehr@mun.ca or by telephone at 709-864-2861.

Consent:

Your signature on this form means that:

- You have read the information about the research.
- You have been able to ask questions about this study.
- You are satisfied with the answers to all your questions.
- You understand what the study is about and what you will be doing.
- You understand that you are free to withdraw from the study without having to give a reason and that doing so will not affect you now or in the future.
- You understand that any data collected from you up to the point of your withdrawal will be destroyed
- If you sign this form, you do not give up your legal rights and do not release the researchers from their professional responsibilities.

Your signature:

I have read what this study is about and understood the risks and benefits. I have had adequate time to think about this and had the opportunity to ask questions and my questions have been answered.

I agree to participate in the research project understanding the risks and contributions of my participation, that my participation is voluntary, and that I may end my participation.

I agree to be audio-recorded during the meeting	Yes	No
I agree to the being photographed during the meeting	Yes	No
I agree to the use of quotations	Yes	No
I allow my name to be identified in any publications resulting from this study	Yes	No

A copy of this Informed Consent Form has been given to me for my records.

_____ _____

Signature of participant Date

Researcher's Signature:

I have explained this study to the best of my ability. I invited questions and gave answers. I believe that the participant fully understands what is involved in being in the study, any potential risks of the study and that he or she has freely chosen to be in the study.

Signature of Principal Investigator	Date

Email statement to subjects (recruitment):

Dear [Name],

I am a graduate student at Memorial University and I would like professional opinions from fish harversters like you in a Participatory Citizen Science research project where together, we will generate a research project about the Fogo Island ecosystem that is useful to you and to the scientific community.

You are of particular interest because of your local expertise and experience as a professional fishermen or fisherwomen. Your participation in this meeting, where we will refine the research question with others, and will work out the details of how, when and where we sample will take 1-2 hours, conducted at the Fogo Island Academy from 3:30-5 p.m. on Saturday, March 28, 2015. At this meeting, we will also show you some of the early results of digitization of the logbook data.

Your participation would, of course, be entirely voluntary and you could decide to stop participating at any time. Selections of your remarks may be published on a public website, in blog posts, in white papers, in reports, or in an academic journal articles resulting from the study. You can choose to remain anonymous in these printed materials if you wish, but you will know the other participants at the meeting and be known to them. If you have concerns about this, please let me know.

Thank you for your time. Please let me know if you are interested in participating or if you have any questions.

Sincerely,

Matt McWilliams

38 Howley Avenue

St. John's NL, A1C 2T5

mm0254@mun.ca

The proposal for this research has been reviewed by the Interdisciplinary Committee on Ethics in Human Research and found to be in compliance with Memorial University's ethics policy. If you have ethical concerns about the research, such as the way you have been treated or your rights as a participant, you may contact the Chairperson of the ICEHR at icehr@mun.ca or by telephone at 709-864-2861.