WORKSHOP REPORT

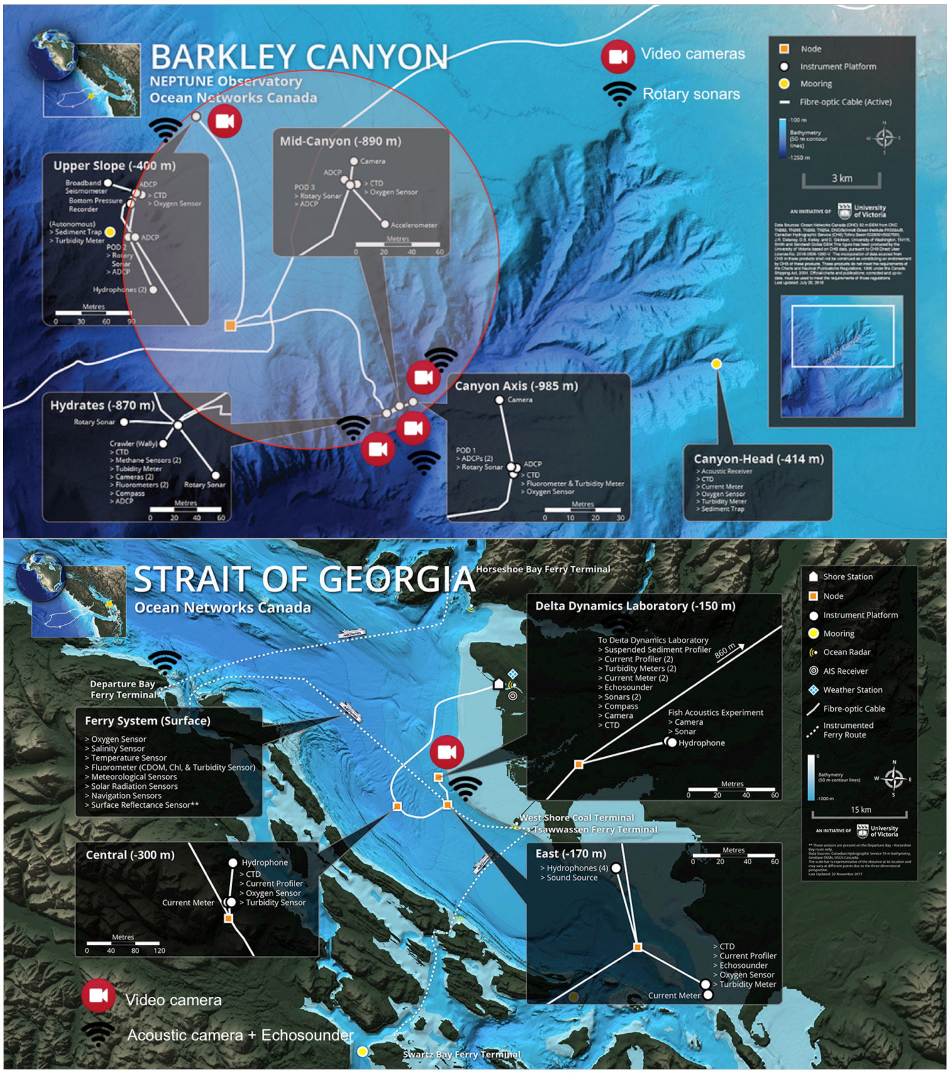
"Marine cabled observatories: moving towards applied monitoring for fisheries management, ecosystem functioning and biodiversity"

ONC Research Theme: 'Life in the environments of the NE Pacific and Salish Sea'

October 4-5, Institute of Marine Sciences, ICM-CSIC, Barcelona, Spain

Organizers:

Dr. Jacopo Aguzzi (ICM-CSIC; Science Theme Leader for ONC)
Dr. Fabio De Leo (Senior Staff Scientist ONC, Dept. Biology, UVic)



January, 2019

Report summary:

1. Attendance, venue workshop session structure

All the participants have perceived the workshop covering ONC's 'Life in the environments of the NE Pacific and Salish Sea' research theme as highly successful. A total of 20 researchers attended the workshop in person and 1, Laurenz Thomsen, from Jacobs University, Bremen, participated remotely (Appendix 1). The first day of the workshop opened with four 20 min introductory presentations to set the stage providing an overview of Ocean Networks Canada's installed monitoring infrastructure (Aguzzi and De Leo), and showcasing ongoing research projects in Barkley Canyon (L. Thomsen) and in the Strait of Georgia (X. Mouy) (see Appendix II for entire workshop program).

Continuing in the first day, the following three sessions contained shorter (10-12 min) presentations with examples of study cases from other long-term ocean observing infrastructures (S. Marini, C. Costa, E. Fanelli), examples of applied monitoring of commercially exploited species (F. Althaus, J. Drazen, F. Juanes, R. Rountree), a presentation on analytic approaches to the study of fish rhythmic behaviours (D. Withmore), and two presentations of potentially complementary monitoring approaches (S. Martini – bioluminescence; S. Stefanni – eDNA). In the morning session of the second day, two presentations focused on past experiences in computer vision applied to marine observatory video data (A. Albu, R. Fisher). These shorter presentations served the purpose of participants becoming acquainted with each other's fields of expertise before moving into the following discussion sessions.

Following the formal presentation sessions, three brainstorming sessions both in the first and second day of the workshop, discussed essentially three overarching questions:

(1) What does an ideal observatory for monitoring commercially important species look like? What is the minimal necessary infrastructure and ideal configuration?

(2) How can observatory data complement or 'ground-truth fishery-dependent observations?

(3) What existing data on ONC's data archives can be used in support of 'proof-of-concept' papers that demonstrate the potential for the long-term monitoring of commercially important species in Canada's NE Pacific?

The workshop venue at ICM-CSIC was very accommodating, with a room facing the shore of Barceloneta, where all participants fit comfortably (Fig.1). ICM staff, J.A. García, provided IT assistance for participants to upload presentations and with the connection with ICM's guest Wi-Fi network, which provided Internet access throughout the 2-day meeting without any complaints about performance. Coffee breaks also provided by ICM-CSIC featured self-service Italian espresso machines and assorted pastries.

Figure 1. Photos of participants during the ONC Theme Leader Workshop, Oct 4-5, Barcelona.

The majority of workshop attendees took advantage of the room block reservations at discounted rates at the Campus Del Mar Residence Hall, just a block away from ICM. A few other attendants booked hotel rooms or AirBnB apartments in nearby neighborhoods. Thus, commuting from and to the workshop venue was straightforward and convenient. Most participants actively socialized and continued workshop discussions during lunch breaks and dinners.

Following up after the workshop, the participant's travel reimbursements (airfare, ground transport, lunch and dinner meals) ran for the most part smoothly, with all participants being reimbursed in average in 1.5-month period. A few reimbursements are still pending, and ONC administrative assistants Jean Dickson and Kelly Yu are still providing assistance. The total final cost to run the workshop was **Cad$ 21,205.00**.

2. Main workshop discussion points by session

2.1 – Target commercial species to be monitored in the NE Pacific.

- The presentation by F. Juanes provided an overview of all relevant commercial fisheries in coastal BC and offshore NE Pacific that can practically be monitored by both the VENUS and NEPTUNE observatories.
- Much of the information about target commercial species came from previously published papers using Barkley Canyon's seafloor video cameras and from preliminary results from Xavier Mouy's PhD research using the VENUS Fish Acoustics Experiment at the Delta node.
- For Barkley Canyon, *Anoplopoma fimbria* (sablefish) is of moderate commercial importance while another two abundant species are of low commercial importance: *Chionoecetes tanneri* (tanner crabs), and *Eptatretus dani* (Pacific hagfish).
- Tanner crabs are still not commercially harvested in BC, but are important for shelf and slope fisheries off Washington, Oregon and Alaska.
- Sablefish is a migratory, iteroparous (multiple reproductive cycles during life) and broadcast spawner species, which occurs from Baja California all the way to Alaska at depths ranging from 300 to 2700 m.
- The majority of empirical evidence suggests sufficient movement and exchange of Sablefish to form a single biological population throughout their known range in the northeast Pacific Ocean (DFO, 2013).
- High mobility of Sablefish at almost all life history stages along with tag release- recovery suggests there is little impediment to spatial exchange and genetic analyses show only relatively minor support for genetic differentiation at very large spatial scales (e.g., Baja California versus Aleutian Islands. DFO, 2013).
- Based on associations with latitude and bathymetry, Sablefish are the most widely distributed commercial groundfish in the north Pacific (Moser et al. 1994).

- Tagging and recapture studies show that adult sablefish inhabiting the margin close to Barkley Canyon migrate to and from a complex of seamounts at Cascadia Basin (Heck, Eickerberg/Warwick, Cobb, Brown Seamounts).
- In British Columbia in 2016 a total of 1900 tones was reported as the total catch of sablefish, a value of $27 million, or 18% of the total Groundfish fishery.
- The fishery is mostly a trap fishery, although a small percentage of the catch comes from trawling and longline.
- The current BC sablefish fishery has comparable landings to the combined WA, OR, CA catch landings, while the US fishery off Alaska has nearly double in landings (Haist et al 2004).
- There are 9 main fishery target areas off BC's coast. Barkley Canyon is one of the target areas.
- Sablefish populations show strong age/length x depth trends, with larger and older individuals living at greater depths (Head et al 2014).
- There seems to be a uniform distribution of CPUE across 16 degrees of latitude (i.e. 32-48).
- Thus, sablefish qualifies as a good species for monitoring, given: 1) its wide geographical distribution, 2) strong size/age vs depth trends, 3) known seasonal abundance peaks; 4) recent decreases in catches.
- Very little is known about sablefish habitat preferences, diel population movements, vocalizations in the natural environment, behavioural responses to oceanographic and meteorological forcing and also to monitoring methods such as video recordings using artificial lighting. This gap in our knowledge stresses the importance for an integrated and multidisciplinary monitoring strategy.
- Sablefish sound production remains ambiguous as recordings from Barkley Canyon Axis (900 m) have never been replicated (Sirovic et al., 2012; Wall et al 2014)
- However, the species from the Anoplomatidae family are known to be soniferous and recent recordings in captivity demonstrate that (Riera unpublished observations). This information highlights the potential for its monitoring using passive acoustics in addition to traditional visual methods.
- For the coastal species, at least 7 families of fish with commercial importance were identified by the Fish Acoustics experiment in the Strait of Georgia (X. Mouy's presentation): Chimaeridae, Rajidae, Squalidae, Paralichthyidae, Gadidae, Scorpaenidae, Hexagrammidae. From those, Gadidae (Park et al.,

1994) and Scorpaenidae (Sirovic et al., 2009) are known soniferous fish families.

2.2 – Ongoing research in Barkley Canyon and Strait of Georgia

- L. Thomsen presented on recent published results (Thomsen et al 2017) demonstrating the monitoring capacity for ecosystem function and pelagic-benthic coupling in Barkley Canyon.
- Main recent discoveries from that published study include: winter phytoplankton production pulses are rapidly transported down canyon by internal tides and arrive in Barkley Canyon's seafloor between 12-72 hours;
- Winter phytoplankton pulses can be as important in POC transfer to depth as the pulses associated with spring and summer blooms.
- For their importance, and regular occurrence during NE Pacific winters, these short-lived pulses of fresh chlorophyll need to be considered as important components of fluxes in studies addressing deep-sea ecosystem functioning and productivity (and considered in global biogeochemical models as we have nearly 10,000 submarine canyons worldwide).
- The study also describes the effect of arrival of those POC pulses in the canyon's seafloor and the quantitative and qualitative response by the benthic communities.
- Sablefish and tanner crabs seem to enhance their activity following these pulses.
- X. Mouy presented preliminary results of the 'Fish Acoustics Experiment', deployed in the Strait of Georgia using the VENUS observatory.
- From two deployments of a monitoring platform combining video, acoustic imaging (ARIS sonar) and a hydrophone, Xavier discusses the advantages and disadvantages of using regular video and acoustic imaging for automatically detecting and counting fish.
- The subset dataset is of 1 month of data (5 Nov – 2 Dec 2017) from a combined 1 year and 7 months of available data from 2 deployments (May 2017-Oct 2018).
- Data processing included an automatic detection and classification algorithm (based on video data), trained by 24 hrs of manually analyzed video data (eliminating false negatives). A similar detection algorithm using the ARIS sonar also undergoes a series of manual annotations.
- While ARIS (acoustic camera) is a much more efficient in detecting fish (particularly at a longer range), under various environmental conditions,

including during high turbidity events, the video camera allows for a better taxonomical classification of individuals.

- The identification of fish sounds and assignment of specific taxa is still preliminary. A further investigation is being conducted in a larger time-series dataset.
- The overall soundscape has a variety of noise sources, but more predominantly of vessel traffic.
- With this experiment and associated datasets we still have the opportunity to explore three main questions: 1, the role of all measured environmental variables in the seasonal distribution of fish and invertebrate species; 2, the role of light attraction and avoidance in the estimation of fish abundances using the video; 3, the role of diel-vertical migration across seasons as sources of prey in determining fish abundance and community structure. 4, the role of the soundscape in influencing fish abundances (determined from the Echosounder data). Those are all highlighted in the selected possible 'proof-of-concept' papers.

2.3 – Experience from other observatory networks

2.3.1 - Ecosystem-based management (E. Fanelli)

- Ecosystem-based management in the context of marine observatories: towards the identification of food-web indicators.
- Observatories have the capacity to generate key data that helps in the definition and monitoring of trophic guilds (size distributions, relative abundance among different guilds, biomass/secondary productivity, diversity of guilds).
- Observatories also enhance our ability to improve the understanding of food-web interactions using imaging (e.g., recent work published based on 27 years of ROV footage in Monterey Canyon; Choy et al., 2017).
- Desire of inputting observational data into modeling approaches predicting responses from perturbations, including climate change, oil spills, etc.
- These capabilities can feed directly into ecosystem and species management plans, and also to support marine policy.
- Also, fixed observatories can and should be integrated with mobile surveying platforms, vessel-based periodic sampling, and with recent approaches of ecosystem 'omics' (genes>mRNA>proteins>metabolites).
- New observatories in Italy, such as the NEREA-FIX (under construction) are examples of infrastructure geared towards ecosystem-based monitoring. Good

synergistic interactions between NEREA-FIX and ONC (VENUS and NEPTUNE observatories) should be pursued in the near future.

2.3.2 - Automated image acquisition and processing

- S. Marini presents on two standalone autonomous programmable devices for image acquisition and processing, where data (text and images) are transferable remotely (**GUARD1 and DeepEye);**
- DeepEye can be deployed autonomously for nearly 27 months, with a high acquisition frequency of 1 image per 5 minutes.
- **DeepEye's internal image processing** method is based on supervised machine learning approach using Phython, OpenCV and PyEvolve. It employs a training and validation phase based on image examples, and an application phase, where the detection/classification algorithm is run automatically inside the device.
- Examples of the efficiency in automatic image detection and classification by this device is summarized in Marini et al. (2018), were time series of manual and automated detection/classification of fish show very good matching both in the Adriatic Sea and at the OBSEA observatory.
- Several data transmission protocols have already been tested for those two systems.
- A few take home messages regarding automated detection and classification algorithms were provided. First, the different conditions of image acquisition prevent a single algorithm to be usable in many imagery datasets that were acquired with different research objectives in mind, and also under very distinct environmental conditions (e.g. illumination, suspended particle load, hard-substrate vs water column backgrounds, etc.). Secondly, algorithms should be improved incrementally (i.e. by adding new computer vision tasks increasing in complexity). Thirdly, detection and classification algorithms should be compared in standard test image datasets.

2.3.3 - A chronobiology approach for monitoring commercial species

- All animals and plants have evolved under rhythmic light-dark (day-night) conditions. Except perhaps cave animals and abyssal and hadal organisms, which may still display rhythmic behaviours following cyclic patterns of internal tides and inertial currents.

- Terrestrial and marine vertebrates have internal clocks in their suprachiasmatic nucleus (inside brain – higher vertebrates), eyes or pineal glands (lower vert.).
- In Zebrafishes, directly light responsive circadian clocks are present in all tissues (retina, pineal gland, brain, kidney, fins, gills, heart, liver, spleen, etc). Plus, skin, blood, etc.
- Internal clocks are responsible for the rhythmic control of a myriad of organismal functions such as growth, metabolism, cell physiology, production of sexual hormones, and behavior.
- In Zebrafish, 4 new classes of opsin genes code for at least 32 non-visual photopigments. Thus, light impacted cellular processes can control DNA repair processes.
- **Tissue samples collected from our target species** (*Anoplopoma fimbria*) at different times of the day and the tidal cycle could help to better understand its biological clock and entrainment of physiological and behavioral rhythms. Such a molecular sampling, once accompanied with time-lapse optoacoustic data form observatories can help determining day-night rhythmic activity resulting in **vertical or horizontal migrations, as well as the occurrence of any temporal adaptation related to fisheries' pressure**.
- In addition to target species tissue sampling, the environmental monitoring should include the measuring of variables related to light intensity and wavelengths (e.g., *in situ* **PAR sensors or other technologies?**) as controlling highly motile sablefish behavior across a photic to disphotic depth range.
- At the same time, in order to study the indirect day-night temporal synchronization of deep-sea fauna upon rhythmic benthopelagic vertical migrations, the installation of Photomultipliers (PMTs) at Barkley Node would aid the detection of bioluminescence to potentially identify predator prey interactions following the diel vertical migrations of plankton and micronekton (see Aguzzi et al., 2017).

2.3.4 - Applied monitoring of commercially important species

- Two examples of applied monitoring of commercially important fish species where provided by Jeff Drazen and Franziska Althaus.
- In Hawaii, 7 species of the known 'deep-7', made up of 6 snapper and 1 grouper, have been monitored for several years using **Baited Underwater Remote Videos (BRUVs)**. Concerns about the over-exploitation resulted in the creation of MPAs ('Bottomfish restricted fishing areas', BRFAs) to protect the

key habitats of these slope dwelling fish (depths ranging from 50-400 m), and with largest aggregations occurring in high-relief terrain/structures).

- The complex of deep-water species has intermediate life history traits (i.e., mature in 4-7 yrs, longevity of 20-40+ years).
- The BRUV system ('BotCam') deployments were used to evaluate the efficiency of the BRFAs, i.e., did the fish increase in size, abundance, species richness, maturity inside vs outside the BRFAs? Any evidence of adult spillover?
- The methodology employs MaxN as the main metric of fish abundance, which means the maximum number of fish visible (by species) in a single frame, and an index of relative abundance. Also important, **are the accurate measurements of length, which is only possible to be measured accurately using a stereo video system**.
- The BotCam system is comprised of an **ultralow-light video camera**, coupled with a CTD, a battery pack, acoustic release and a **bait canister**. The deployments follow a random sampling design stratified by habitat type (soft/hard and high/low relief).
- The 2,328 BotCam deployments reveal that the BRFAs help to enhance fish length for most studied species. To the contrary, fish length outside the BRFAs is significantly reduced over 4 years of the study. There are also evidences of some level of spillover effects mostly where hard bottom habitats occur.
- In this approach obviously, the information/data collected allows for a much broader spatial resolution, and also includes the temporal, although not at high frequency, resolution. Not like what can be obtain with a 3-4 fixed point cabled (or even autonomous) observatory.
- This presentation also highlighted some high-level comparisons between other types of fish monitoring, such as surveys by AUV (that fish normally avoid), acoustics (which produce complex output with presence of too many non-target species).
- The BRUV/BotCam system advantages are: 1) easy to deploy from multiple small vessels; 2) highly accurate and precise identification and length measurements; 3) "Catch" metrics are similar to line fishing in length frequency but record higher numbers (which may represent all fishes, including those that are not biting the hook).
- The disadvantages are: 1) ambient light limited depths to 300 m (some species live down to 400 m); 2) sampling volume difficult to determine relative abundance – same issue with line fishing; 3) data processing time consuming.

- The overall response to the project's results was highly positive, as NOAA has now adopted the use of BotCam systems to perform stock assessment surveys.
- Some take home messages include: **observatories** provide the necessary **high-resolution of environmental data** needed for **ecosystem-based management**; baited camera systems can easily be deployed around or connected to cabled observatory nodes for a better **local population estimates**, especially in topographically complex areas. Even better if combined with bioacoustics data (e.g., ASZFP echosounders), which could help identify area of attraction of fish following prey fields. Caveat: robust stock assessment requires large spatial footprint for **regional population** estimates.
- In a similar approach but with differ target species a study in Australia also demonstrated the efficiency of traditional BRUVs in monitoring both shallow and deep-water (up to 1,200 m) species.
- Traditional BRUVS generally rely on large spatial coverage (many units in the water).
- A few studies have recommended the repeated deployment of BRUVs at specific locations for long-term monitoring of species (Newmann et al., 2012; Hill et al., 2018).
- DeepBRUVs was developed for long-term deep deployments. This system differed in that it has its own light LED source for the deep deployments. It also has a bait release system that is positioned at 1.5 m in the field of view of the camera. Recording time is ~24 hours, but the system can be programmed to set recording intervals over a longer time period (months). The bait mechanism can be programmed to release a plume at set intervals coinciding with recording periods during the deployment duration. The system is also coupled with an ADCP to investigate bait-plume dispersal, a CTD and an acoustic tag receiver.
- DeepBRUV Proof of concept survey in Cape Barren and Bass Strait maps the distribution of teleost and condrichthyan fishes. It compares MaxN with total abundance (MaxInd).
- From this study, new methodological recommendations emerge: control bait recipe for evaluating fish attraction efficiency, add multispectral LEDs, hydrophones and fish tag receivers.

2.4 – Other examples of computer vision as tools for enhanced monitoring

- A. Albu presented on three examples of computer vision with imagery datasets from ONC. The applications ranged from image quality control and enhancement; seafloor habitat mapping (feature class classification), and estimation of fish abundance.

- Challenges are considerable evident due to the variability of image acquisition methods and the resulting video quality. Thus, a **great level of interdisciplinarity** is required when **designing methods in computer vision**.
- B. Fisher presented on the successful results of the EU funded project, Fish4Knowledge, which consisted in the automatic detection and classification of multiple species of coastal reef fishes in an incredibly large video library (10 cameras, 3 years of data recorded 365 days/year, 12 hr per day).
- 1.4 x 10^9 fish detected from 1.5 x 100 frames with a total of 90,000 hours of 320x240 (5 fps) video.
- In this example the challenges of dealing with various types of images, in particular different backgrounds (algae, reef, moving plants, changes in lighting) are also evident.
- Even though for the 15 most abundant species, detection and correct classification were extremely efficient, with a 97% accuracy when averaged over all fish species.
- 850,000 detections, 81,000 fish trajectories also resulting in fish identification
- Some seasonal patterns of fish abundance were clearly detected. Also fish abundance declines following typhoon events, and recovery quickly after.
- Some species show clear diel occurrence patterns, other do not respond (but videos were recorded only during 12-hr of day-light). Some species are more active at dusk and dawn.
- Bias issues related to the multiple detection of same individuals (or ‘residents’) are discussed particularly for Clownfish. Could we use identifiable body features to identify/detect single individuals?
- Some other interesting patterns were investigated such as the correlation between fish swimming pattern /speed and water temperature.
- One take home message from this large study is that is very hard to develop a generalized tool for fish detection that will suit multiple marine ecologists using various imaging devices and in a variety of very distinct environments.

3 – Research questions for short- and long-term goals.

Description of the soundscape surrounding OCN installations

1. **Catalog fish and invertebrate sounds** associated with each ONC instillation.
2. Classify unknown sounds into sound types and determine spatial/temporal distributions of the most common types.
3. Compare inshore and offshore biological components of the soundscape. Are fish sounds in shallow waters more diverse than deep water?
4. Identification of unknown biological sounds observed at OCN nodes, **what species are soniferous**?
5. Which are the soniferous fish species in the Cascadia Margin upper slope? And in the Strait of Georgia off Vancouver?

Impact of soundscape on fish communities

1. What is the **impact of ambient noise** on fish behaviour and abundance?
2. What is the impact of the observatory infrastructure in the ambient noise levels? Most importantly, does the observatories' sounds result in masking of biological sounds, or impact fish behavior?
3. What is the potential for anthropogenic (e.g., ships) to mask biological sounds?

Circadian clocks controlling species behaviour and activity

1. How **species biological clocks** affect abundance counts?
2. Which species we know the internal clocks well and which ones we don't?
3. Does sablefish perform significant **daily horizontal and vertical migrations** that are triggered by internal clocks? What are the main controls, circadian periods or tides?
4. Which **molecular biomarkers** can be used (from tissue samples)?
5. How would we go about to collect **species tissue samples**? Only during ONC's yearly maintenance expeditions or also using some self-triggered bait-traps?

Environmental controls on fish communities (behaviour, abundance, diversity)

1. What are the **main environmental drivers** controlling the seasonal and interannual variability in fish assemblages, in particular the commercially important species?
2. We have now **nearly a decade of video data from Barkley Canyon** and Slope. How have sea-surface temperature warming and events such as the NE Pacific **'Warm Blob', El niño and La niña** affected the abundance of

sablefish and other species? Can we compare, side by side, the observatory time-series with fisheries data available for the NE Pacific region, to see if those are somehow correlated?

Role of artificial lighting used by *in situ* monitoring infrastructure

1. What role artificial lighting plays on species-specific fish behaviour including attraction and avoidance?
2. Does it have a significant biasing effect on fish counts by species?
3. What are the effects of a 'predictable' lights-on schedule? Do species learn that schedule? We can easily **define experiments controlling (randomizing) the duration and intervals of lights on video recording**.

Observatory vs Fishery-dependent assessments, how to reconcile both

1. How extracting species abundance data at a single or few monitoring fixed-stations may be relevant to fisheries?
2. Can we at least provide with confidence measures of 'local' population structure and densities?
3. What should be a **minimal spatial scale** resolution for nested, multi-depth observatory in order to generate meaningful monitoring data for target species? In other words, how many nodes and how far apart?
4. What **types of fish behaviour would be relevant** to monitor and which could provide key data to support fisheries management?
5. Would baited-video systems (BRUVs) be reliable for consistent deployments connected to the cabled monitoring locations?
6. Are **baited video systems** more or less efficient for monitoring fish diversity over time (for the ONC fixed-point observing network reality)?

Ecosystem function (feeding guilds and other functional traits)

1. Can we use ONC's large archived video library to **reconstruct the local food-web structure** (feeding guilds)? How this structure changes in response to climate-driven variability?
2. Likewise, which are other **species functional traits that can be monitored** over time that are of relevance for ecosystem-based fishery management (e.g. modes of displacement, as for swimmers, walkers, crawlers, and for benthopelagic, nektobenthic, endobenthic habits)?
3. If we are able to precisely define **size-class structure of sablefish**, and identify its horizontal and vertical movements, can we estimate its role for energy transference in the bentho-pelagic coupling?

Complementary monitoring strategies

1. How **e-DNA techniques** can help with the monitoring of the target commercial species? Sablefish and rockfish species in particular?
2. What **automated or semi-automated environmental sampling** could be performed near the cable observatory nodes?
3. How would **sediment samples** collected on a yearly basis by ONC be processed for e-DNA analysis? What would be the pipeline and which additional resources needed?
4. Can a relatively deep (~50 cm) sediment push core provide a much longer temporal proxy of sablefish population abundance in and around Barkley Canyon? How many locations of a deep sediment record would need to be analyzed?
5. Depending on our capability to install **ultra-lowlight cameras** as well as **Photomultipliers** in Barkley Canyon, how **bioluminescence signals** would be correlated to fish abundance? How it varies seasonally and interannually?

Computer Vision and automatic detection and classification of species

1. How reliable are the **existing video automatic detection and classification algorithms** to identify sablefish and other target species?
2. Should we try other algorithms and **investigate performance comparisons**?
3. Can we identify individual fish specimens using these various algorithms? (**Individual recognition** could provide key information about species site fidelity/residence and also about the effects of attraction to the physical structures of the observatory).
4. Can we measure trajectories of arrival into FOVs and time of residence?
5. How can ***in situ* video image detection classification devices** such as Deep-Eye improve our capacity to monitor commercially important species?
6. Would it be possible to integrate one of those systems into a cabled observatory? What is the level of hardware adaptation needed?

4. Short-term deliverables (1-2 years)

During the workshop were presented and discussed 'ready-to-use' datasets that were assembled prior to the workshop. These datasets were prepared by F. De Leo and X. Mouy, with help from junior staff scientist Lu Guan. These two datasets consist of:

A – VENUS observatory (Strait of Georgia/Delta Node – Fish Acoustics Experiment)

- 1 month of data (Nov 04-Dec 05)
- Video from SubC Dragonfish camera
- Acoustic images from ARIS dual frequency sonar (acoustic camera)
- ASZP 75 KHz Echosounder data
- Manual annotations of fish and invertebrate occurrence and abundance
- All ancillary oceanographic data (CTD, ADCP, turbidity, dissolved oxygen, etc.).

B – NEPTUNE observatory (Barkley Canyon Axis/MidEast/Upper Slope)

- Imagenex Rotary Sonar datasets from Thomsen et al. (2017) (4 subsets of 15-20 days between Dec 2010-May 2011)
- SubC Dragonfish H1080p video camera data (subsets from 9 year time-series)
- All ancillary oceanographic data (CTD, ADCP, turbidity, dissolved oxygen, etc.)

These datasets are now aimed to support tentatively nine publications which we are seeking as a **'proof-of-concept'**, that both VENUS and NEPTUNE observatories are capable of delivering essential ecological information that would be complementary to fishery-dependent monitoring data on commercially exploited species in the NE Pacific and Strait of Georgia.

The list of outlined publications is not limited exclusively to the datasets above. For example, a longer-time series for the Strait of Georgia would be required if seasonal patterns are to be investigated as well. Other sources of data include historical remotely operated vehicle video surveys and also passive acoustics data from a Naxys Hydrophone (deployed in 2009-2011).

Detailed information of main research objectives, data streams required, and tentative timelines are provided for each outlined publication.

1. Automated video-classification of fishes in the Strait of Georgia

Task leaders: S. Marini, C. Costa, A. Albu?, B. Fisher?, Rountree, R. X. Mouy, F. De Leo, J. Aguzzi

Topics/Questions/hypothesis:

- Test different computer vision algorithms to automatically detect and classify fish species
- Automated identification and classification of various behaviours, e.g. swimming pattern and speed, trajectories, etc.

	Description	**Status**
Dataset:	(1) 30-days of video (5 min. clips recorded @ 2 hrs intervals). (2) Sub-sample of manually annotated video data	(1) Readily available. (2) From Xavier's analyses (Fabio and Lu have the manual annotations)
Resources and effort needed:	- **Xavier** to provide results from his own video automation detection algorithm (in particular to help narrow down the analysis to video clips with the best visibility conditions and relevant biological information). - **Corrado** has new machine learning algorithms that could be used here. However only available after June.	**Comments:**
Timeline:	- Data inspection and preliminary assessment - Detection, classification algorithms developed - Interpretation of results and Manuscript writing - Manuscript submission	**March-April 2019** ?? ?? ??

2. Automated video identification and classification of fish and invertebrate behaviour events as tool to enhance ecological studies based on ocean observatory data

Task leaders: R. Rountree, S. Marini, Costa. C., A. Albu?, X. Mouy, F. De Leo, J. Aguzzi

Topics/Questions/hypothesis:

- Automated identification and classification of various behaviours, e.g. swimming pattern and speed, trajectories, etc.

	Description	**Status**
Dataset:	(1) 30-days of video (5 min. clips recorded @ 2 hrs intervals). (2) Sub-sample of manually annotated video data	(1) Readily available. (2) From Xavier's analyses (Fabio and Lu have the manual annotations)
Resources and effort needed:	- **Rodney** to provide computer scientists involved with the types of behaviour to be automatically tracked (already discussed with Fabio and Lu Guan and part of ongoing efforts in paper #9, with datasets from Barkley Canyon). - **Rodney** to provide **Marini, Albu and Fisher** with types of behaviour to be automatically tracked (already discussed with Fabio and Lu Guan).	**Comments:**
Timeline:	- Project scoping, data inspection - Detection, classification algorithms developed - Interpretation of results and Manuscript writing - Manuscript submission	**March-April 2019** ?? ?? ??

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3. Activity rhythms of fishes and their environmental controls

Task leaders: J. Aguzzi, D. Withmore?, C. Costa, F. De Leo, I. Steindal?, X. Mouy, F. Juanes, S. Marini, E. Fanelli

Topics/Questions/hypotheses:

- Are local species rhythms mostly regulated by diurnal, tidal and/or seasonal* rhythms?

- What environmental variables may be the best predictors of those rhythms (temperature, oxygen, turbidity, current velocities, river-runoff, prey availability (from ASZP echo sounder)?

*If we decide to include the ‘seasonal’ time-scale, we have to add additional datasets to include multiple seasons, and in particular covering pre- and post-spring river runoff (freshet) from the Fraser Delta. Ideal time periods for seasonal analyses would be:

(1) low winter discharge (1 month of data - November 2017 - already packaged)
(2) early freshet (April 2017 and 2018[+])
(3) peak freshet (June 15-July 16 2017 and 2018[+])
(4) end of freshet period (September 2017 and 2018[+])

[+] There nearly two years of data available, which would be even more interesting to draw between year variability.

Datasets:	**Description**	**Status**
** Any ARIS species automated counts should credit Xavier’s PhD chapter/paper.	(1) Species counts - video (2) Species counts – ARIS** (3) Pressure, temp., diss. Oxygen, turbidity, chl-a, current velocity and direction (4) River discharge data (available from DFO) (5) Echosounder (7) Primary productivity/MODIS satellite	(1,2) Xavier (3) Fabio/Lu Guan (4) ??? (5) Fabio/Lu Guan (6) Fabio/Lu Guan (7) ??
Resources and effort needed:	**Aguzzi -** **De Leo -** **Mouy -** **Whitmore -**	
Timeline	- Data inspection and prelim. assessment	**Mar-April 2019**
	- Time-series analysis (periodogram and waveform computing) -Multivariate statistic and modelling (e.g. CCA, PLS)	**??**
	- Interpretation of results and Manuscript writing	**??**
	- Manuscript submission	**??**

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4. Effects of light attraction and avoidance by fish and invertebrates

Task leaders: F. De Leo, J. Aguzzi, X. Mouy R. Roundtree, J. Drazen?, F. Althaus? S. Marini, F. Juanes

Topics/Questions/hypothesis:

- Are fish and invertebrate species attracted by or avoid the artificial lighting?
- How attraction and avoidance influence abundance estimations?
- Are there any other specific behaviours associated with light attraction and avoidance.
- Results will be helpful when setting up a future experiment to monitor commercially exploited species.

Datasets:	**Description**	**Status**
	- ARIS sonar **- HD Video**	Data already available
Resources and effort needed:	- Perform fish counts during initial 5 minutes of sonar recording - Fish counts during the following 5 minutes when artificial LED lights are turned on - Repeat this counting routine at LED light off with ARIS	*Fish counts (ideally automated)
Timeline	- Assessing data availability (i.e., simultaneously good video and acoustic images) - Determine methods to compare fish occurrence, abundance and behaviour during lights on and off.	**June-July 2019**
	- Data analysis	**July-Dec 2019**
	- Manuscript write up	**Early 2020**

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5. Effects of ambient noise on fish density and distribution		
Task leaders: Lu Guan, X. Mouy, F. De Leo, F. Juanes, J. Drazen?, Aguzzi J. Rountree, K. Kanes?		
Topics/Questions/hypothesis:		
- How the seasonal variability in the soundscape (e.g., vessel traffic) affects water column fish abundance and biomass (AZFP). Can we identity any effects on predator (mammals) and prey (fish) interactions?		
Datasets:	**Description**	**Status**
Resources and effort needed:	**TBD**	
Timeline	Scoping the project	**June-July 2019**
		??
		??

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6. Automated detection and classification of fish invertebrates from Barkley Canyon using a rotary imaging sonar		
Task leaders: S. Marini, C. Costa, A. Albu?, B. Fisher?, F. De Leo, J. Aguzzi		
Topics/Questions/hypothesis:		
- Assess feasibility of automatically detect and classify the most abundant species in Barkley Canyon Axis and MidEast locations using the rotary sonar data. - Assess ability to identify taxa by shape, size, and patterns in backscatter intensity signal. - Sablefish, tanner carbs, hagfish, gastropods, squat lobsters, are the more abundant species in these two locations. - Only qualitative analysis was performed on data from these rotary sonars (Thomsen et al 2017 – see Supplementary Material).		
Datasets:	**Description**	**Status**
	(1) Rotary sonar data (Nov 2010; Feb, April, May 2011; (2) Additional datasets may be required the above periods do not have high-quality video imagery for calibration.	(1) Data product available = png files) (2) Raw matlab files need to be made available
Resources and effort needed:	**Marini, Costa**	
Timeline	- Evaluating datasets to be used and nature of video and acoustic signals - Create a subset of annotated images (video and rotatory sonar)	**March-April 2019**
	- Scoping types of image analysis	**??**
	- Data analysis	**??**
	- Manuscript write up	**??**

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7. Defining benthic functional traits based on video and acoustic imaging in Barkley Canyon, NE Pacific		
Task leaders: E. Fanelli, S. Martini?, F. De Leo, J. Aguzzi, F. Althaus?		
Topics/Questions/hypothesis:		
- Given paper #5 makes good progress, a second step would be to use automatic video and acoustic image annotations to address food-web interactions and other behaviour to assign functional traits to the benthic community and investigate seasonal variations in those traits. - Investigate how functional traits are related to ecosystem functioning over a range of time scales.		
Datasets:	**Description**	**Status**
	(1) Rotary sonar data (Jan 2018-Jan 2019) (2) Video data (Jan 2018-Jan 2019)* *best-quality video to date collected by the observatory (4K	**Need to compile and share. Data available through Oceans 2.0 portal and ONC web API.**
Resources and effort needed:	**TBD**	
Timeline	**TBD**	**??**
		??
		??

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8. Role of seafloor heterogeneity in determining benthic megafauna community structure from a 7-year time-series of ROV video surveys in Barkley Canyon		
Task leaders: F. De Leo, M. Francescangeli, J. Aguzzi, E. Fanelli		
Topics/Questions/hypothesis:		
Comparison and cross-calibration of ROV video surveys performed since 2012 in Barkley Canyon, identifying effects of varying spatial scales (10s to 100s of meters) on megafauna abundance and diversity obtained from the fixed seafloor cameras connected to Barkley observatory node.		
Datasets:	**Description**	**Status**
-	- 2012-2018 ROV video transects -Data from the published literature (Chauvet et al., 2018; Juniper et al, 2014; Doya et al., 2014)	ongoing analysis by M. Francescangeli under supervision of F. De Leo
Resources and effort needed:		
Timeline	Video annotation	**Sept 2018-Feb 2019**
	Community and biodiversity analysis	**Feb 2019-July 2019**
	Manuscript write-up	**July-Dec 2019**
	Manuscript submission	**Early 2020**

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9. Sablefish vocalizations in Barkley Canyon

Task leaders: A. Riera, R. Rountree, F. De Leo, Lu Guan, F. Juanes, Xavier Mouy?

Topics/Questions/hypothesis:

- Using hydrophone and video data collected in Barkley Canyon in 2009-2011 to confirm the vocalizations by sablefish
- Annotate behavioural features during moments of sound emission, to produce functional justification of sound.

Datasets:	**Description**	**Status**
	- 85 video segments being annotated - Manually annotated acoustic files (Naxys hydrophone) - Running automatic detectors on the acoustic data	Amalis Riera (did not attend the workshop) but has been working with ONC in this project for several months.
Resources and effort needed:	Manual Video annotations Manual annotation of acoustic files Development of an algorithm to perform acoustic fish detections	
Timeline	Manual video annotation (85 clips)	**Dec-2018-March2019 (nearly finished)**
	Manual annotation of acoustic files (Amalis) - ongoing	**Ongoing ??**
	Development of an automatic detector for the hydrophone data	**??**
	Data analysis	**??**
	Manucript write up	**??**

5. Medium to long-term deliverables (3-5 years)

Question 1: What does an ideal observatory for monitoring commercially important species look like? What is the minimal necessary infrastructure and ideal configuration?

- ONC's monitoring infrastructure and multiple data streams may be particularly helpful in identifying key **species-specific behaviors of individuals and groups of individuals** of the target species to be monitored. Examples of such types of behaviors are: movement patterns related to migration trajectories, first arrival times and time of residence, which are good metrics for estimating population densities; trophic interactions determined by predator-prey 'events' classification.
- Monitoring of **species-specific behaviors in remote habitats** such as deep-sea ecosystems is still very limited, and breakthrough unexpected and new behaviors (potential of high scientific impact) will likely be observed. Workshop participants reinforced that the ability to perform **long-term monitoring of species behaviors** is an asset that will be very well received by the fisheries' stakeholder communities and industries, which are often scared and isolated from science-based organizations;
- Due to the increasing recognition of the importance of utilizing the background soundscape and the vocalization signals by target species, **the use of hydrophones was recommended in all locations in which ecologically and commercially important species are to be monitored** (e.g., Barkley Canyon; Folger Pinnacle; Clayoquot Slope; Strait of Georgia).
- There is sufficient data existing in the system to begin to make comparisons among shallow and deep-water sites which would help us understand some fundamentals of marine soundscapes. However, a critical problem is the identification of dedicated funding and significant personnel to conduct these post-processing studies as outlined in the suggested goals section. Although a major goal of the program is to develop autodetection and classification methodologies, this work is in its infancy and suffers from a lack of comprehensive catalogues of fish sounds and quantitative descriptions of their acoustic characteristics. We expect that manual processing will continue to be important for some time to come. This field has lagged behind others due to a lack of funding sources and recognition of its importance.
- **Hydrophones are extremely good tools** in particular to detect: 1) presence x absence of target species; 2) compare the fine scale variability in the sound field between locations (e.g., a noise soundscape x control/reference location); 3)

- In our new monitoring experiment designs, the **use of stereo-video** and **baited cameras** will allow the stimulation of interactions among individuals of the same species and of different species. The interactions (many antagonistic) can improve our ability to observe behaviour that is associated with sound production.

2.5.1 - Minimal monitoring infrastructure:

- The currently deployed **'Fish Acoustics Experiment'** at the VENUS-Delta node was perceived as an optimal/ideal-monitoring tool in that it records data of video and passive acoustics. This experiment is based **on video, acoustic imaging and passive acoustics**. Additionally, the community recognizes the importance of **Acoustic Zooplankton/Fish Profilers** (AZFP) to monitor the diel and seasonally variable prey fields near and above the seafloor. An AZFP is also installed at Delta node (specified in proof-of concept papers #2 and #4).
- **Stereo-video cameras are the only** type of imaging system (see proposed new experiments in the last session) capable of sizing commercial species for determining age groups. (refer to examples above by J. Drazen and F. Althaus).
- The video and acoustic cameras should de deployed in a configuration allowing for the monitoring of effects of '**platform residence**' by species (e.g., currently Barkley Canyon MidEast Camera has the Barkley IP nearby and PnT function allow monitoring of that far range field of view). When species are attracted to physical structures, it becomes easier to identify the sources of vocalization by individuals, and also, using computer vision tools, to identify single individuals (natural tagging – see below).
- For accomplishing the above, a **Pan-Tilt unit** is essential.
- Baited camera systems, were also discussed, in that attracting more fish to be observed, would greatly enhance the probability of detecting soniferous fish signals and matching with the video. An **adapted sediment trap carrousel** has been suggested as an easy to use, off-the-shelf 'bait release system' (Lavaleye et al., 2017).
- **An instrument to detect variations in the ambient light spectrum** (multiple wavelengths) is required to understand the biological clock cues the species are experiencing at various depths. Photosynthetically Active Radiation (PAR) sensors are limited in the detection of the spectral band (400-700 nm). Alternatively, at 600 m of depth, low frequency wavelengths are still represented.

- A device such as the Deep-Eye camera module, with in situ image processing capability, would be ideal for a high throughput video analysis. A parallel discussion needs to be developed evaluating if a similar system can be connected to the cabled observatory.
- For any video monitoring experiment **targeting Folger Pinnacle**, a good **device or methodology to deal with high biofouling rates during summer** months should be discussed.

2.5.2 - Complementary/highly desired monitoring infrastructure:

- Other types of **bait/lure devices** were discussed. For example fish lures that would mimic bioluminescent prey, and that could: 1, attract fishes into the field of view; 2, trigger fish sound production associated with feeding/frenzy behaviour.
- **Multiple individual tagging techniques** were discussed. Tagging multiple individuals would also be beneficial for determining 'residence' times. In addition, **tag recognition/reading capability on observatories would enhance traditional fisheries tagging studies** for determining fish population size, by providing **'recapture' data without stressing the animals** by physically recapturing them.
- **Tagging using dies or ingestible tags** was proposed by J. Drazen who pointed to previous research, which successfully employed ingestible tags for studying deep-sea fish behaviour and estimating population densities (from lander deployments).
- When possible, the installation of **multiple camera systems** in a single location would help identify species movement patterns from various directions simultaneously, enhancing the probability of capturing (and ground-trothing) soniferous behaviour.
- Explore **complementarity of already existing observation systems and data** (e.g., Line-P, La Perouse, MODIS, River-discharge data from Env. Canada, etc).
- **Sampling fish and invertebrate tissues as well as sediments and seawater** during our yearly maintenance cruises could add important value to the monitoring goals of commercial species. For example, samples for **environmental DNA (e-DNA)** from sediments and seawater, and fish tissues that entrain circadian-clock biomolecules were proposed as complementary species monitoring methods (by Sergio Stefani and David Whitmore).
- Good examples of e-DNA for censusing of marine fishes (e.g., Thomsen et al., 2012; Kelly et al., 2014) were provided in S. Steffani's presentation. These

new **molecular techniques** have been increasingly utilized as biodiversity monitoring and conservation tools (Thomsen et al., 2015).

- Recent studies also suggest that **fish DNA is more concentrated in sediments** than in surface waters (Turner et al., 2015). Thus, an experiment using time-series sediment samples from various sites in Barkley Canyon could provide good comparative metric of sablefish abundance near the target monitoring locations.
- Sergio introduces a streamlined approach (**Loop-Mediated Isothermal Amplification, LAMP**) to quickly and cheaply detect target nucleic acid without sophisticated equipment. Such techniques could be coupled in the near future with in-situ environmental samplers.
- Other biogeochemical more conventional approaches suggested include the use of stable isotopes, lipid biomarkers, and fish otolith microchemistry (S. Steffani).
- Extraction of **internal clock biomolecules** from fish tissue samples (D. Whitmore).
- The addition of **multispectral LED lights** would allow for a series of behavioral experiments testing species-specific attraction and avoidance to artificial lighting. This type of information is key to understand potential biases in species counts relying on video and artificial illumination.
- **The ability of detecting bioluminescent organisms** was also discussed during the workshop as a promising tool to monitor ecosystem function and change, as well as to support the monitoring of commercially important species. Today we know that 75% of pelagic and 25% of benthic species have bioluminescent capability (reviewed in Martini and Haddock, 2017). In particular, many key prey species are bioluminescent. Thus, the use of **low-light video imaging technology** has been proposed for future ONC monitoring infrastructure and experiments.
- S. Martini discussed some ideas of studying the relationship between species functional traits and changes in ocean optical properties.
- She showed some examples from ANTARES–KM3Net and NEMO observatories in the Mediterranean, where clear seasonal trends in bioluminescence can be used as proxies of environmental change, including seasonal productivity, and oceanographic forcing.
- This is a very promising field of research in particular if we can design some experiments to compare ANTARES, NEMO, MARS and ONC (future: STRAW) bioluminescence data.

- Here we need to streamline experimental studies that would help to connect bioluminescence with fish biomass and abundance.
- Deploy off the shelf and cheap camera systems attached to eel and crab traps and check about time of capturing with ONC time-lapse data.

2.5.3 - Experiment monitoring configurations and technical considerations:

- Co-location is fundamental (video, acoustic imaging, passive acoustics, multispectral LEDs, fish attractors such as bait and physical structures).
- Open the possibility for autonomous platform deployments in between nodes separated by 10s of kilometers.
- Tentative designs of an 'ideal' monitoring platforms are depicted in Figures 2-4 below.
- Figure 2 shows the two locations on ONC NEPTUNE observatory, where these experiments should be targeted due to the occurrence of commercially exploited species. It also highlights the main desired research capabilities.
- Figure 3 shows in more detail an experiment design for monitoring fish species at Folger Pinnacle, a rockfish conservation area.
- Figure 4 shows two iterations of an **expanded 'Fish Acoustics Experiment'** at Barkley Node (located in the slope adjacent to Barkley Canyon). As per suggestion of Xavier Mouy, an array of **3 to 4 hydrophones would be highly desirable to obtain directionality of acoustic signals**.

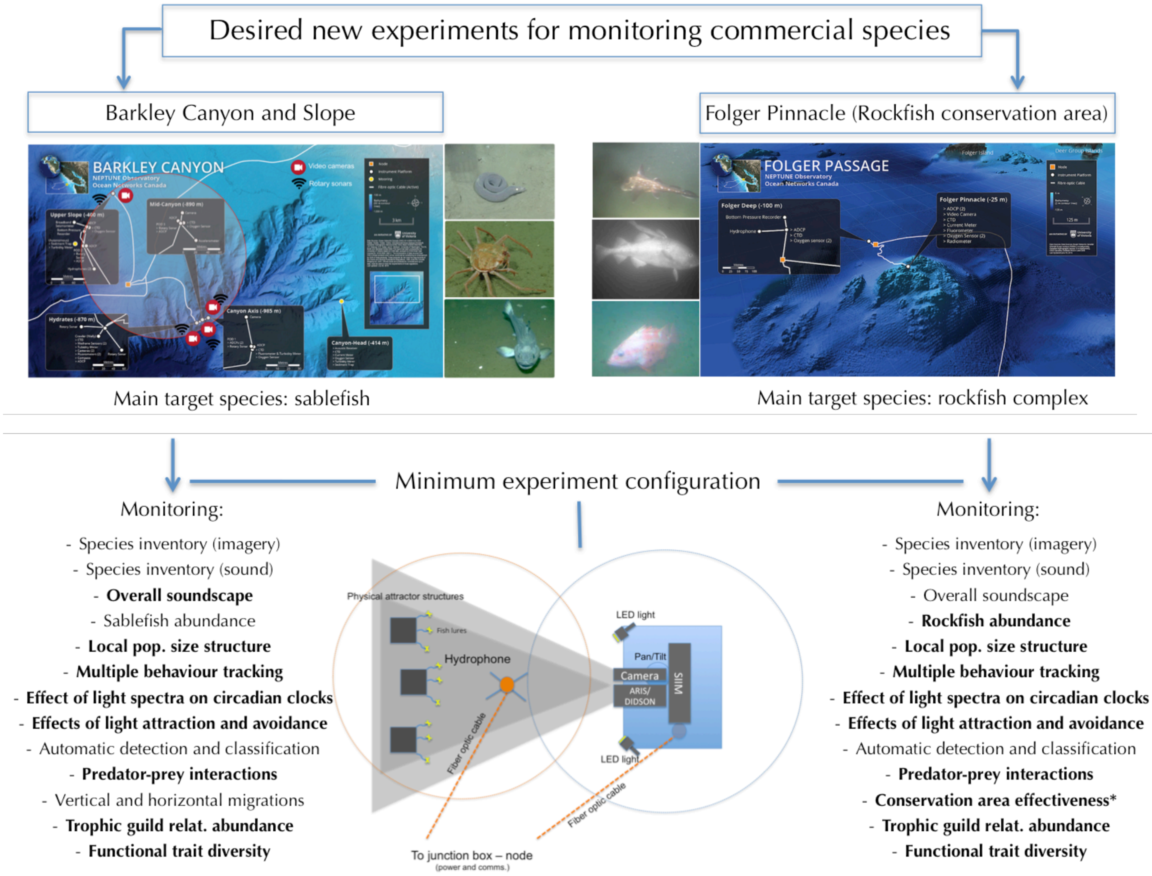


Figure 2: Conceptual framework and design of minimal infrastructure for experimental monitoring of ecologically and commercially important species in Barkley Node (600 m) and Folger Pinnacle (25 m). Key monitoring variables.

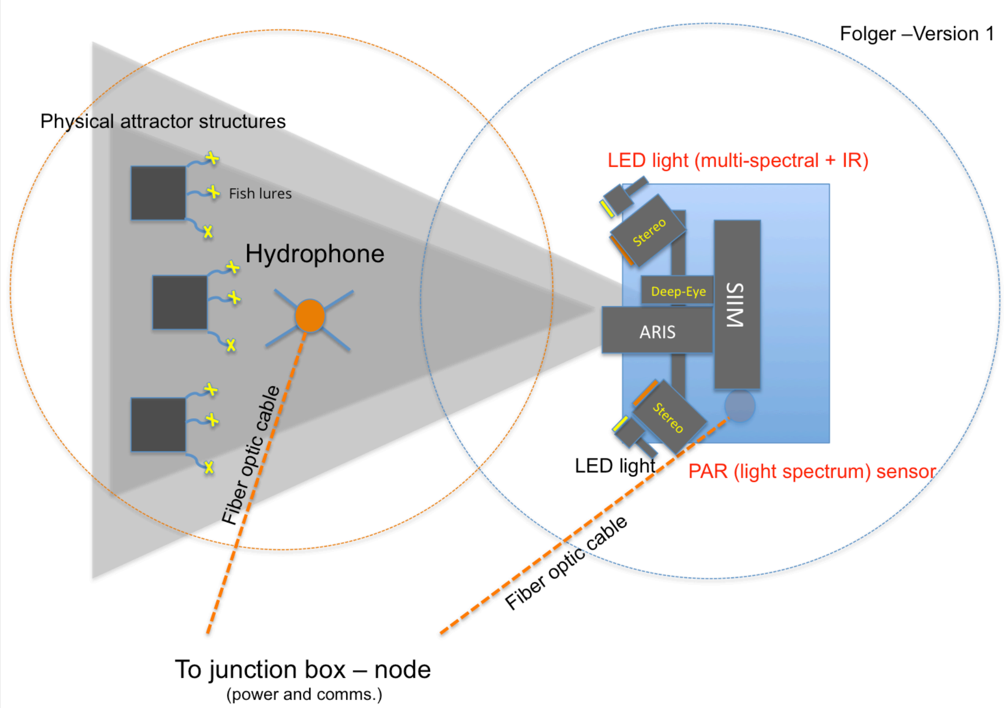
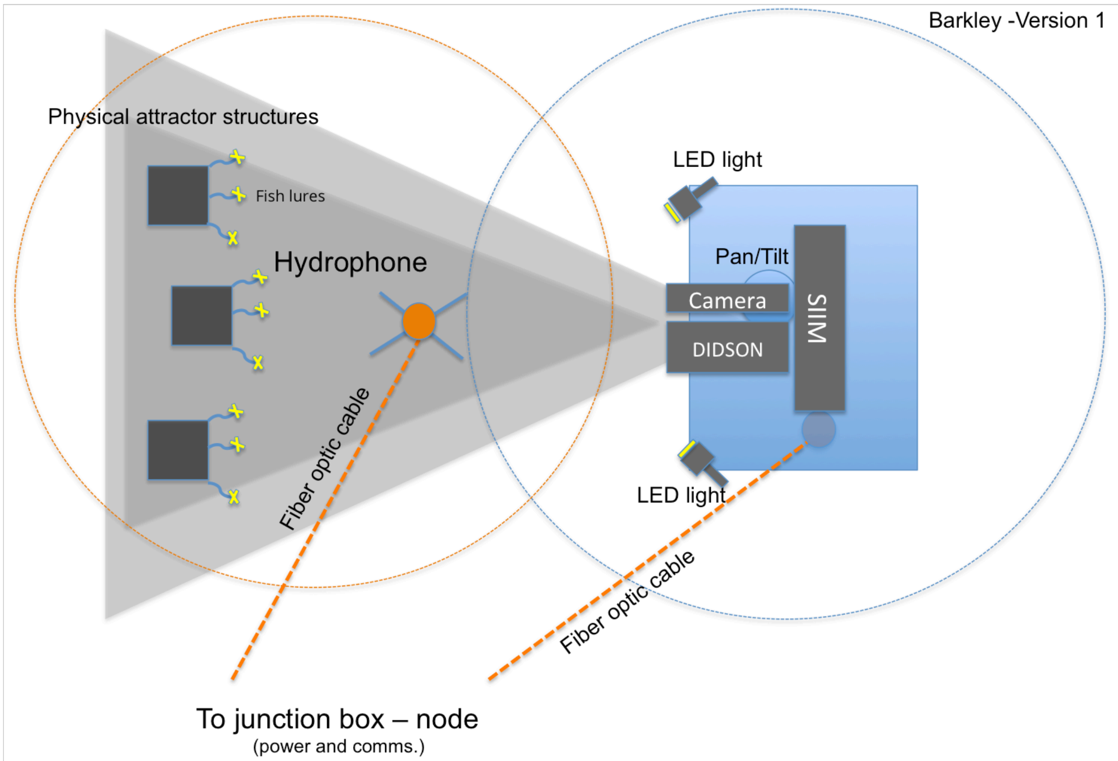


Figure 3. Iteration of a proposed 'Fish Acoustics Experiment' to monitor ecologically and commercially important species in Folger Pinnacle, overlapping with the Rockfish Conservation Area.



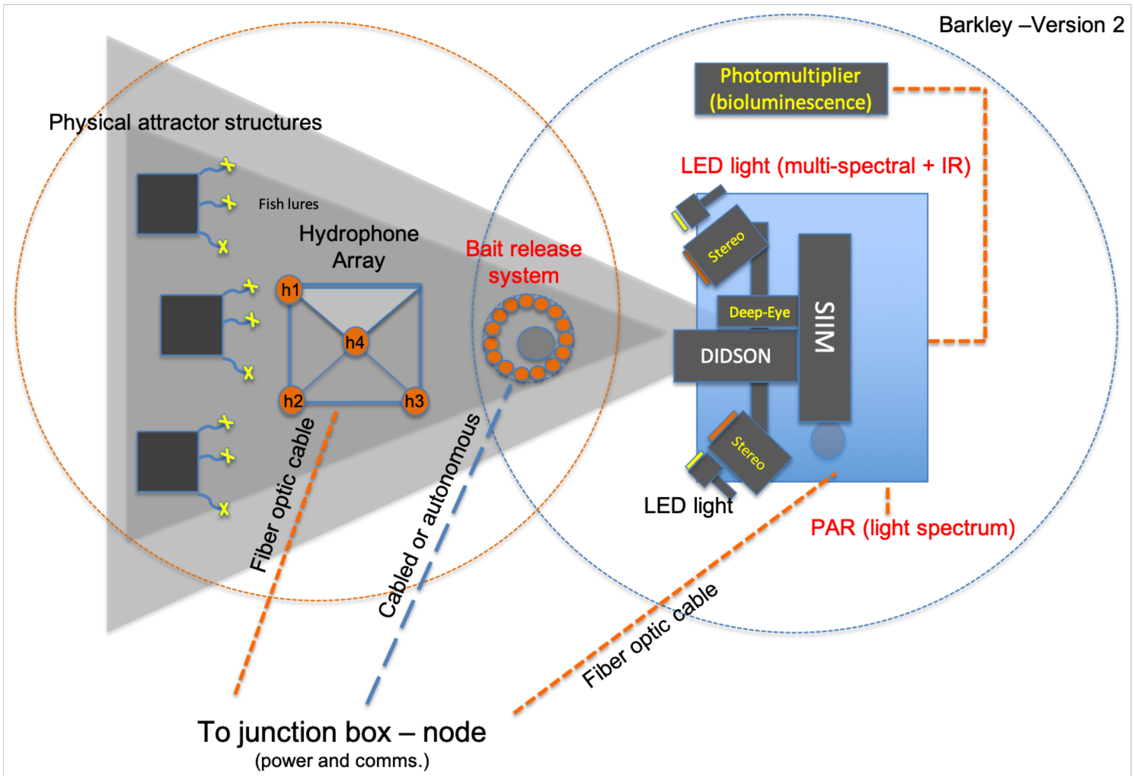


Figure 4: Two iterations of a new proposed 'Fish Acoustics Experiment' for deployment at Barkley Node (600 m depth). The **first iteration** relies heavily on instruments and other hardware already available at ONC and from Francis Juanes (DIDSON sonar), with not substantial additional costs for deployment. Exceptions may be a new platform design (to fit the larger DIDSON) and a new SIIM control module. The **second iteration** includes many more additional hardware proposed during the workshop (i.e., **Stereo-video, ultralow-light camera, multispectral LEDs, Photomultipliers, bait release system, PAR or other light wavelength spectrum sensor, and a hydrophone array with 3-4 hydrophones**). A thorough evaluation of feasibility needs to be conducted by ONC Marine Operations in conjunction with an ONC Science Project lead (timeline 3-5 years).

Question 2: How can observatory data complement or 'ground-truth fishery-dependent observations?

- The answer to this question is not very straightforward after rounds of discussions.
- Any proposition to study and monitor sablefish using ONC's observatory assets in Barkley Canyon should aim to generate data that is **complimentary** (and highly beneficial) to stock assessment data managers, and not seek to replace any existing fishery-dependent methodological tools. The fisheries community is particularly defensive when it comes to implementing any changes to their ongoing practices. After good proof-of-concept monitoring tools (e.g., published papers) and protocols are in place, a channel of communication needs to be established. The **Canadian Sablefish Association** (http://canadiansablefish.com/) seems a natural first candidate for establishing communication with our research community.
- A note along this topic was the lack of interest by DFO fisheries experts to participate during the workshop. Two experts on sablefish fisheries' statistics were invited to the meeting, Allen Kronlund and Adam Keizer. The former did not respond, the latter declined the invitation.
- Add **spatial resolution** to the fixed-point monitoring infrastructure by deploying multiple **autonomous and integrated platforms** (i.e., video, acoustic imaging, passive acoustics, fish tag receivers) in locations between the already existing nodes in Barkley Upper Slope and Barkley Axis and MidEast locations (see figure 2). Perhaps the **entire new experiment could be set up as an autonomous platform**, which could be deployed in multiple locations (canyon and non-canyon; N and S canyon walls, and at multiple depths). Enhancing the spatial resolution could be beneficial for better understanding aspects of local sablefish population movement, habitat preferences, and expression of circadian clocks.
- As stated in the answers for the previous question, the **Barkley Node, at ~600 m,** was identified as an optimal site for deploying an enhanced 'Fish Acoustics Experiment'. The location not only shows **higher fish diversity** than Barkley Canyon Axis and MidEast locations (870 and 970 m, respectively), due to a shallower depth which also represents a relief from the core of the Oxygen Minimum Zone (OMZ), near 900 m (De Leo et al., 2017).
- Additionally, sablefish are also abundant in the area, and it seems like the node location, at ~600 m, is much more protected from potential **undesired 'fish trawling events'** (top-right inset on Figure 5). Figure 5 displays AIS data from 2016, highlighting fishing activity near and at Barkley Canyons' Head.

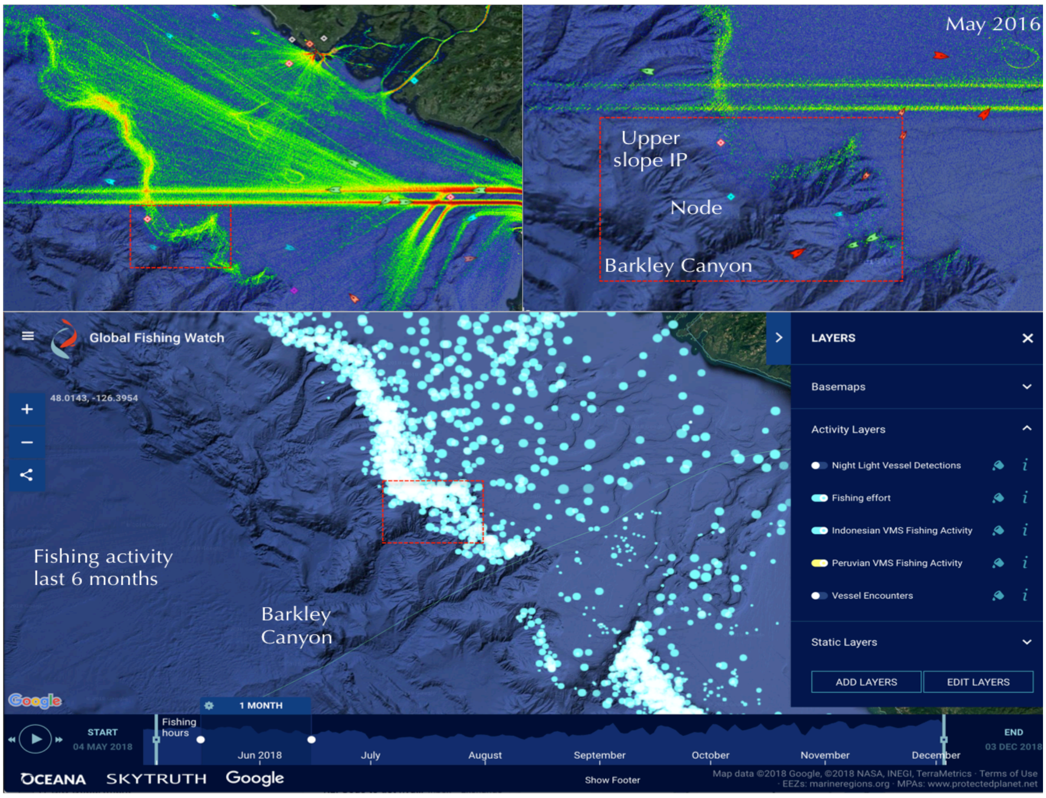


Figure 5 – Publicly accessible AIS data showing ship traffic associated with fishing events at the Cascadia Margin, with focus on Barkley Canyon's upper bathymetric boundaries.

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Appendix I – Workshop Participants

Participant	Institution/Country	Contribution/Expertise
Organizers		
Jacopo Aguzzi*	ICM-CSIC, Barcelona (Spain)	Chronobiology and environmental monitoring
Fabio De Leo	ONC, UVic, Victoria (Canada)	Benthic ecology, deep-sea biodiversity and ecosystem function, cabled observatories
Kim Juniper	ONC, UVic, Victoria (Canada)	ONC Chief Scientist, marine ecology and hydrothermal vent microbiology
International		
Simone Marini*	CNR-ISMAR, La Spezia (Italy)	Automated video-imaging applications form OBSEA experience applied to ONC acoustic and video products
Corrado Costa*	CREA.GOV, Rome (Italy)	Cause (environment)-effect (community) responses analyses
Emanuela Fanelli*	Marchs Polytechnic, Ancona (Italy)	Ecosystem-based management: extents of trophic food web
Francis Juanes*	SEOS, UVic, Victoria (Canada)	Fish ecology and behaviour using passive acoustics and imaging
Xavier Mouy*	SEOS, Uvic, JASCO, Victoria (Canada)	Passive acoustics, fish behaviour
Rodney Rountree*	Marine Ecology and Technology Applications, MA (USA)	Acoustic tracking of commercially exploited species
David Withmore	UCL, London (UK)	Fish behaviour: a bio-chronological perspective
Inga Steindal	UCL, London (UK)	Fish behaviour: a bio-chronological perspective
Sergio Stefanni	ADS, Naples (Italy)	e-DNA as tool for monitoring of biodiversity and ecosystem function
Severine Martini	MBARI/CNRS Marseille (France)	Bioluminescence as proxy of ecosystem function; time-series analysis
Jeff Drazen	UH Manoa, Hawaii, (USA)	Deep-sea fish ecophysiology and behaviour
Franziska Althaus	CSIRO, Hobart, Tasmania (Australia)	Use of stereo cameras to monitor shallow and deep-sea assemblages
Robert B. Fisher	University of Edinburgh (Scotland)	Computer Vision, Image processing, 3D vision
Alexandra Albu*	UVic, Canada	Computer vision
Based in Barcelona		
Joaquin del Rio	SARTI-Polytechnic University of Cataluña-UPC, Barcelona (Spain)	Cabled observatory mechatronic (Manager OBSEA platform)
Joan B. Company*	ICM-CSIC, Barcelona (Spain)	Stock assessment and management policies in deep-sea fisheries
Joan Navarro	ICM-CSIC, Barcelona (Spain)	Behavioural ecology and animal tracking technology
Jose A. Garcia	ICM-CSIC, Barcelona (Spain)	Automated video imaging and fishery data banking
Attended remotely		
Laurenz Thomsen*	Jacobs Univ. Bremen (Germany)	POC flux and bentho-pelagic coupling
*Already ONC users/partners (including in publications using ONC data)		

Appendix II – Workshop Program

Oct. 04 (Thursday) – Workshop scope, existing study cases (10 to 15-min presentations) and initial brainstorming

1. Presenting the scope for moving forward

09:00 – Participants arrive at ICM-CISC
09:10 – Welcome from IMC Director, **J.L. Pelegí Llopart**.
09:20 – **Aguzzi/De Leo/Juniper** - Introductory remarks and expected workshop outcomes.
09:30 – Participant introductions.

09:40 - **Jacopo Aguzzi (ICM-CSIC)**

The strategic scenario for networks of cabled observatories: outlining a path forward using already existing ocean monitoring infrastructure.

09:55 - **Fabio De Leo (ONC-UVic)**

From coastal temperate, high-arctic and deep-sea habitats: seafloor imagery and environmental monitoring using cabled observatories to track ecosystem function, biodiversity and bentho-pelagic coupling.

2. Study cases: Ocean Networks Canada

10:10 - **Laurenz Thomsen** (Jacobs Univ. Bremen, Germany – remotely via Skype)

The integration surface ocean climatology with benthic boundary layer dynamics: use of Internet Operated Vehicle platforms.

10:25 - **Xavier Mouy** (SEOS, Uvic)

Video and acoustic monitoring of coastal fish and invertebrate species in the Strait of Georgia using the VENUS cabled observatory.

10:40 - Coffee break

3. Short study cases: OBSEA, ENSO, MARS, ACO and other observatory networks (short 10 min presentations)

11:00 - **Simone Marini** (CNR-ISMAR, La Spezia Italy)

Artificial video-intelligence: Automated video-imaging applications from Argo floats and OBSEA experience applied to ONC video data products.

11:10 - **Corrado Costa** (CREA.GOV, Rome, Italy)

Cause x effect (i.e., environment x community) response analyses: multivariate and modelling tools.

11:20 - **Emanuela Fanelli** (ENEA, La Spezia, Italy)

Ecological approach to ecosystem-based management: biodiversity, biomass and food-web analyses and their limitations.

11:30 - **David Withmore/Inga Steindal** (UCL, London, UK)

The chronobiological perspective: analytic approaches to the study of fish rhythmic behavior.

11:40 – Time for questions

4. A perspective from applied resource and ecosystem management (15 min)

11:50 – **Franziska Althaus** (CSIRO, Australia)

Baited Remote Underwater Videos (BRUVs) as a non-extractive fishery-independent tool for monitoring fish populations.

12:05 - **Jeff Drazen** (UH Manoa/ACO-Aloha Cabled Observatory)

Commercial bottom fish fisheries assessed using BRUVs in the Hawaiian Islands, and the use of Aloha Cabled Observatory to study the ecology and behaviour of deep-sea fishes.

12:20 – **Francis Juanes** (SEOS/Dept. Biology, Uvic)

Ecology of NE Pacific fish and invertebrate species targeted by commercial fisheries.

12:35 – **Rodney Rountree** (Marine Ecology and Technology Applications MA, USA)

Fish behaviour, population dynamics and soundscape characterization using active and passive acoustics.

12:50 - Lunch break

5. New insights from complimentary approaches to ocean monitoring (15 min)

14:00 - **Severine Martini** (MBARI/CNRS Marseille France)

Use of bioluminescence as an indicator of biomass, biodiversity and ecosystem function.

14:15 - **Sergio Stefanni** (ADS, Naples, Italy)

Filling the blank spaces: species traceability using e-DNA as complementary approach to imaging for the study of marine biodiversity.

6. Initial brainstorming session: synergies among participant's expertise.

14:30 – Drawing board discussion (all participants):

(1) What does an ideal observatory for monitoring commercially important species look like? What is the minimal necessary infrastructure and ideal configuration?

(2) How can observatory data complement or 'ground-truth' fishery-dependent observations?

15:20 - **Fabio De Leo, Xavier Mouy**: ready-to-use datasets* from Ocean Networks Canada to test multiple hypotheses:

VENUS - Strait of Georgia* (Video and acoustic imaging, passive and active acoustics)

NEPTUNE - Barkley Canyon (Video and acoustic imaging, active acoustics)

* Datasets from a recently deployed '*Fish Acoustics Experiment*', using video, SoundMetrics ARIS dual frequency sonar, and an IcListen Hydrophone.

15:50 - Coffee break

16:10 – Brainstorm continued over central workshop questions (target species' biology, sources of environmental variability and 'signals'; constraints of fixed-point monitoring sites, etc.).

17:30 – End of 1st day discussions

Oct. 05 (Friday) – Proof-of-concept papers (testing of hypotheses based on existing datasets) and proposing new monitoring strategies.

7. Video imagery and oceanographic data analyses for environmental monitoring in the NE Pacific & automated detection and classification (15 min)

9:00 – **Fabio De Leo/Jacopo Aguzzi** - Video imagery archive in Barkley Canyon (2009-2018) from all four monitoring locations (Upper Slope, Barkley Axis, Wall and Hydrates mound): Designing a spatially coherent strategy to monitor sablefish, rockfish and tanner crabs.

9:15 – **Alexandra Albu** – Computer vision for underwater environmental monitoring.

9:30 – **Bob Fisher -** Collecting, Cleaning and Analyzing a Large Fish Dataset.

9:45 – **Jacopo Aguzzi** – Time-series analysis of available environmental data in support to fisheries management of target species (approaches from recently published papers).

10:00 – **Costa/Drazen/Althaus/Company** – Fishery dependent time-series data (survey and landing statistics): what are the best statistical approaches for effectively comparing with observatory-derived video/acoustic abundance data?

10:20 – Open discussion

10:40 - Coffee break

11:00 – Outline of proof-of-concept papers, assigning task leaders and timelines.

12:30 - Lunch break

8. Final focused discussions: a path forward

13:40 – Final discussion session continued to discuss short-term goals (proof-of-concept papers_ and medium to long-term goals, such as the design of a new experiment aiming at monitoring sablefish in Barkley Canyon.

15:30 - Coffee break

16:40 – **Fanelli/Company/del Rio/Aguzzi/Juniper**: how to frame a new proposed experiment within EU's MSFD and GES strategies and into new Horizon 2020 calls.

17:30 – Workshop closure.

Appendix III – Relevant Presentations