Report of the CLIOTOP workshop on“Designing an Ocean Mid-trophic Automatic Acoustic Sampler (MAAS)”

January 15-18, 2007
IRD-CRH, Sète, France

By Olivier Maury (IRD) co chair of the CLIOTOP program
and
François Gerlotto (IRD) chairman of the workshop

A CLIOTOP workshop *“Designing an Ocean Mid-trophic Automatic Acoustic Sampler (MAAS)”* was organized at the Centre de Recherches Halieutiques (CRH) in Sète (France) on Monday through Thursday, January 15-18, 2007.

The general goal assigned to the meeting was to set up a project to develop a novel tool for large scale monitoring of mid-trophic level prey organisms, their horizontal and vertical size-resolved distribution and abundance in the pelagic environment.

Sixteen scientists from a wide range of origins attended the meeting and contributed, by their enthusiasm, to its success. In conclusion to the workshop, they decided to submit an official request to the CLIOTOP Steering Committee for the creation of a CLIOTOP-MAAS Working Group in charge of implementing the project.

Fig. 1.: Some of the meeting participants: standing from left to right Nereus (the fish), Stratis Georgakarakos (IMB, Greece), Olivier Maury (IRD, France), Lars Nonboe Endersen (SIMRAD, Norway), David Demer (NOAA, USA), Rudy Kloser (CSIRO, Australia), Erwan Josse (IRD, France), Laurent Dagorn (IRD, France), Christophe Corbières (Simrad, France) Nils Olav Handegard (IMR, Norway.). Squated: Patrick Lehodey (CLS, France), François Gerlotto (IRD, France), Hiroki Yasuma (HOKKAIDO UNIVERSITY, Japan), Meng Zhou (UMB, USA).

1. INTRODUCTION

Despite the wide spatio-temporal distribution and huge abundance of mid-trophic level organisms (meso-zooplanktonic and micro-nektonic organisms being preyed by top predators) and their major influence on top predator distribution and population dynamics, they are still one of the less known components of pelagic ecosystems. To address this critical lack of information, the CLIOTOP Steering Committee decided during its last meeting in april 2006 to promote the development and deployment of acoustic recorders to monitor those organisms:
"According to its Science Plan, the development of an automatic acoustic sampling tool (<u>phase 1</u>) and its large scale deployment (<u>phase 2</u>) for sampling prey organisms, are important crosscutting issues for CLIOTOP. Such a monitoring of preys is crucial to help to parameterize and to validate the models used to represent their spatial distribution and abundance. The Steering Committee considered that the development of such a tool is timely from a technological point of view and should be promoted. […] The proposal developed could be submitted to different donors for co-funding." (Extract of the report of the first CLIOTOP Steering Committee meeting, Hawaii, april 2006).

The purpose of this first workshop was to identify the requirements (both technical and organizational) needed to address the phase 1 of the project: the development of a prototype of a generic automated acoustic sampler of the open ocean mid-trophic organisms in the perspective of the future and more ambitious second phase which will be devoted to its large scale deployment on drifter networks in the three oceans.

After the presentation of the objectives of the MAAS project in the CLIOTOP framework and the state-of-the-art of existing acoustic technologies, the working group defined the objectives and potential technical limitations and discussed, in relation with manufacturers, the details of the technical specifications required for the development of the MAAS. Finally, the group outlined a project proposal addressing phase 1 and proposed the creation of a new CLIOTOP Working Group in charge of the MAAS development and implementation.

2. Presentations given by the participants

2.1. The MAAS in the CLIOTOP framework (O. Maury)

Acoustic observations are essential for getting information about the distribution of mid-trophic organisms, their dynamics, ecology and behavior. Those organisms constitute the bulk of the food of top predators and therefore they are essential to understand the ecology of top predators. In CLIOTOP, both WG3 (trophodynamics) and WG4 (synthesis and modeling) explicitly identified hydro-acoustic studies of mid-trophic organisms as a key tool for their investigations.

Two spatially-explicit basin-scale ecosystem models (APECOSM and SEAPODYM) are developed in the framework of the CLIOTOP modeling Working Group (WG4). Those models represent explicitly the trophic interactions between primary producers, mid-trophic level organisms and top predators. Presently, mid-trophic levels are represented using several functional groups primarily characterized by their vertical distribution and movements. Epipelagic mesozooplankton and micronekton are distinguished from meso-pelagic and bathy-pelagic migrant and non migrant groups. APECOSM also considers explicitly the size distribution of those groups and plans are made to structure them on a taxonomic basis (*i.e.* crustaceans, jellies, molluscs, and fish will be distinguished in each vertical group).

Data assimilation techniques are used to estimate the model parameters and to improve the parameterizations through quantitative comparisons of SEAPODYM and APECOSM outputs to fishery (catch, effort, size-frequencies) and tagging data. However, no synoptic observations of mid-trophic organisms exist nowadays so that the corresponding components of the models cannot be properly formulated, constrained and evaluated. To be useful to improve and validate those models, the acoustic observations provided by the MAAS should therefore ideally provide:

- The vertical distribution of the biomass and the depth and extent of the different biological layers including their daily vertical migrations.
- The absolute and relative abundance indexes per depth layer.
- Taxonomic groups or species identification per depth layer.
- The size distribution of biomass per depth layer.

2.2. Remote Echosounder Module (REM) by David Demer (NOAA/SWFSC, USA),

Remote Echosounder Modules (REMs) have been developed for studying zooplankton and fish and their associated biotic and abiotic environments (Figure 2a). The REMs are calibrated and deployed on a variety of platforms (ships, towed-bodies, buoys, and drifters). The REMs are low power (2A/12V), light-weight (<15 kg), low-cost, and currently remotely-monitored by 900 MHz ethernet radio modem.

Two REMs including Simrad EK60 120 kHz split-beam echosounders are currently deployed on the Monterrey Bay Aquarium Research Institutions (MBARI's) M0 and M1 buoys. In that application, raw data is telemetered nearly 20 n.mi. to a land-based PC, located at UCSC, for automated system control and data display and processing. Automated processing includes filtering of bad data, noise subtraction, and seamless multi-frequency scatterer size classification via SonarData Echoview. The processed data is automatically updated to a server and emailed to selected recipients. Email alerts are also automatically transmitted if there are interruptions in any aspect of the data collection, processing, archive, or dissemination process.

REM modules have been integrated into multi-frequency echosounder/ADCP buoys (Figure 2b), and deployed in the Southern Ocean to characterize prey (krill) availability to land-based predators (seals and penguins). The autonomous buoys measure currents, volume backscattering, water temperature, and buoy pitch, roll, and bearing. The buoys are equipped with a GPS receiver, radar reflector, strobe, radio-ethernet modem, and power management circuitry. Ongoing efforts are focussed on making the REM smaller, lighter, and cheaper; telemeter data via Iridium, cell-phone, or Argos; and process and log data internally for durations of up to two years.

Fig. 2: a) The Remote Echosounder Modules (REMs). b) REM modules have been integrated into multi-frequency echosounder/ADCP buoys

2.3. Stratis Georgakarakos (IMB, Greece),

- Development of software for structures identification and parameter extraction
- Three Dimensional visualisation and shape reconstruction.
- Data base management systems (ORACLE)
- GIS for spatial analysis and spatial query
- WEB based data access and analysis

2.4. Nils Olav Handegard (IMR, Norway.),

The Institute of Marine Research has developed several acoustic platforms for observing the marine ecosystem. Platforms relevant for the MAAS include stationary landers, vertically migrating drifting platforms, acoustic buoys, fixed bottom mounted platforms etc.

The large lander was deployed for one year on the Mid Atlantic ridge (MarEco project), and some preliminary results on the monthly diurnal variation were presented (Fig x). This is believed to be relevant for the MAAS project. Other relevant activities such as automated processing of data and compressing of echograms were mentioned.

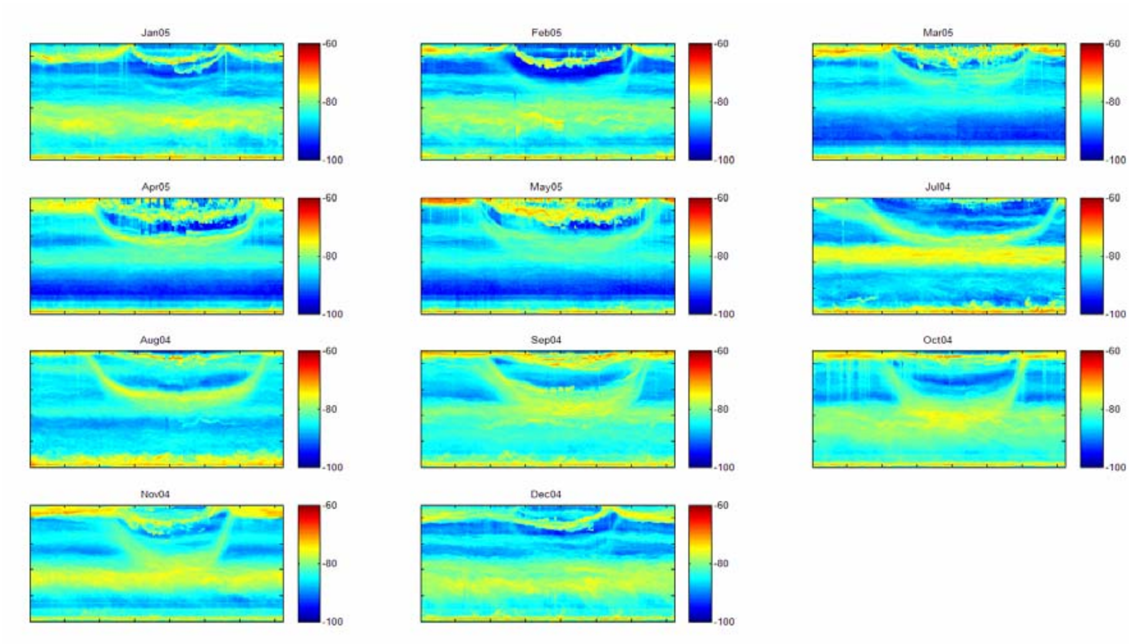

Fig 3. The monthly diurnal variation from the stationary lander located at the Mid Atlantic Ridge (MarEco project). These are examples of what we possibly can get from the proposed systems.

2.5. Erwan Josse (IRD, France),

The choice of frequencies is of prime importance. In addition to the problems related to the variable depth range according to the frequency used, the response of the small organisms (mainly the zooplanktonic ones) is not linear, and interpreting acoustic profiles of acoustic densities can lead to opposite conclusions according to the frequency used.

In the following example (Fig. 4), data from three FADIO cruises in the Indian Ocean: FADIO3 (blue) in October 2004, FADIO 4 (red) in February 2005 and FADIO 5 (green) in October 2005 are displayed. The observations were carried out at two frequencies: 38 Khz (continuous line) with a range of 600 m, and 70 Khz (dashed line) with a range of 500 m. The observations carried out during day and night were processed separately.

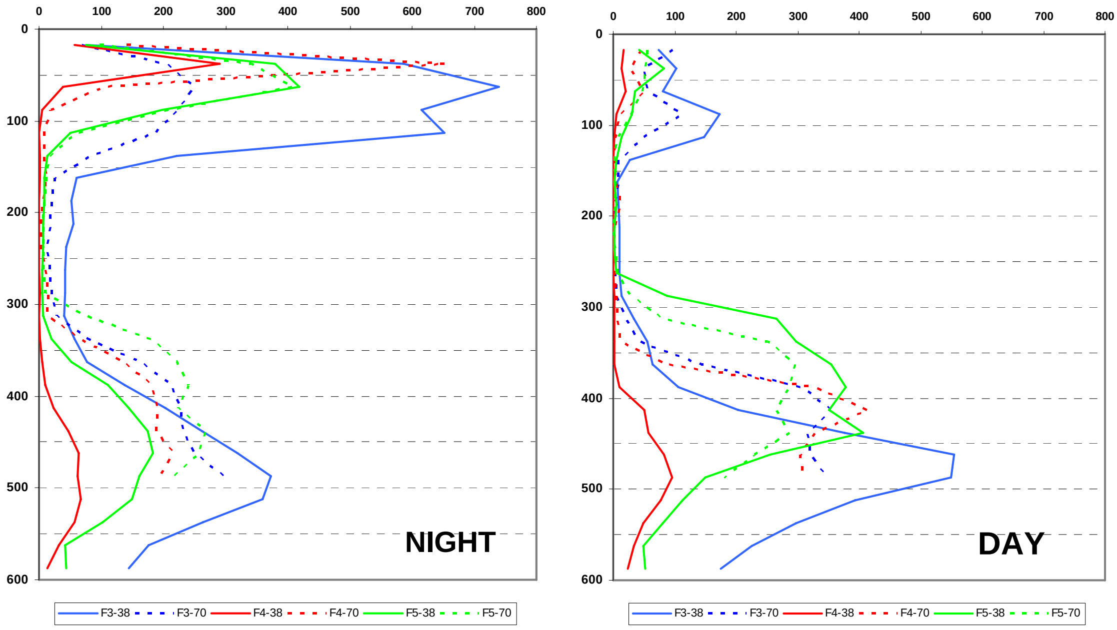

Fig. 4 : Sa ($m^2.m^{-2}$) for three cruises of the FADIO project (blue, red and green). Two frequencies were used: 38 Khz (continuous line) and 70 Khz (dashed line).

During night-time, for the surface layer (0 to 250 m), the two frequencies give a similar vision of the biotic environment only during the FADIO5 cruise (October 2005). For the two other cruises, the vision given by the two frequencies is identical in terms of structure (thickness) of the layers. However, in terms of acoustic energy, the conclusions are opposite: FADIO3 >> FADIO4 if we consider the 38 Khz only, which does not appear clearly if we use the 70 Khz.

During night-time, for the depth layer (> 250 m), the three cruises are at the same level in terms of energy with 70 kHz, while in terms of structure, the layers appear to be closer to the surface during FADIO5. With the 38 kHz, the three cruises are different, and we find the same classification FADIO3 >> FADIO5 >> FADIO4 observed with the same frequency for the surfacing

For the deep layer during the day, the previous observations remain valid if we consider only the FADIO 3 and 4 cruises. We also find, as during night-time, an energy level higher with 70 kHz than with 38 kHz during the FADIO4 cruise. During FADIO5 cruise, whatever the frequency considered, the deep layers appear denser, thicker and closer to the surface than during the two other campaigns.

2.6. Rudy Kloser, Jock Young and Chris Wilcox (CSIRO, Australia),

Acoustic sampling of mid-trophic meso-pelagic organisms – needs and realities

Shelf and basin scale methods of characterising mid-trophic meso-pelagic (~ 2 to 20 cm) communities would be a valuable input into the ecosystem based fisheries management (EBFM) approach and monitoring impacts of climate change. The mid-trophic communities are a linking group to top predators and recent coupled ocean-biogeochemical-populations models need information on this group to predict impacts of fishing and climate change. These ecosystem models require monitoring data on the distribution, size and abundance of these meso-pelagic mid-trophic functional groups at shelf and basin scale to be predictive.

Acoustic methods have demonstrated that they can provide information about the distribution and abundance of a range of organisms from plankton to fish at the shelf and basin scale for specific studies. In the Australian region, basin scale measurements have been obtained from fishing vessels on transit between Tasmania and New Zealand providing a unique insight into biota distribution and abundance. Dedicated research vessel voyages have characterised basin scale mid trophic biota with a combination of vessel and deeply deployed acoustic sensors in conjunction with net sampling. Frequency response modelling of acoustic scattering from biota has highlighted the role of resonance scattering for gas bladdered fishes at variable depths. These studies inform the limitations of the instruments, their finite sampling resolution, variable selectivity, finite species groups and size resolution resolving capability with potential variable temporal and spatial bias. Understanding these limitations will lead to the development of an integrated observation and model strategy where measurement resolution and bias is incorporated into model uncertainty. Our strategy is to continuously improving the observation and modelling methodology whilst obtaining some long term data series and carrying out specific process studies.

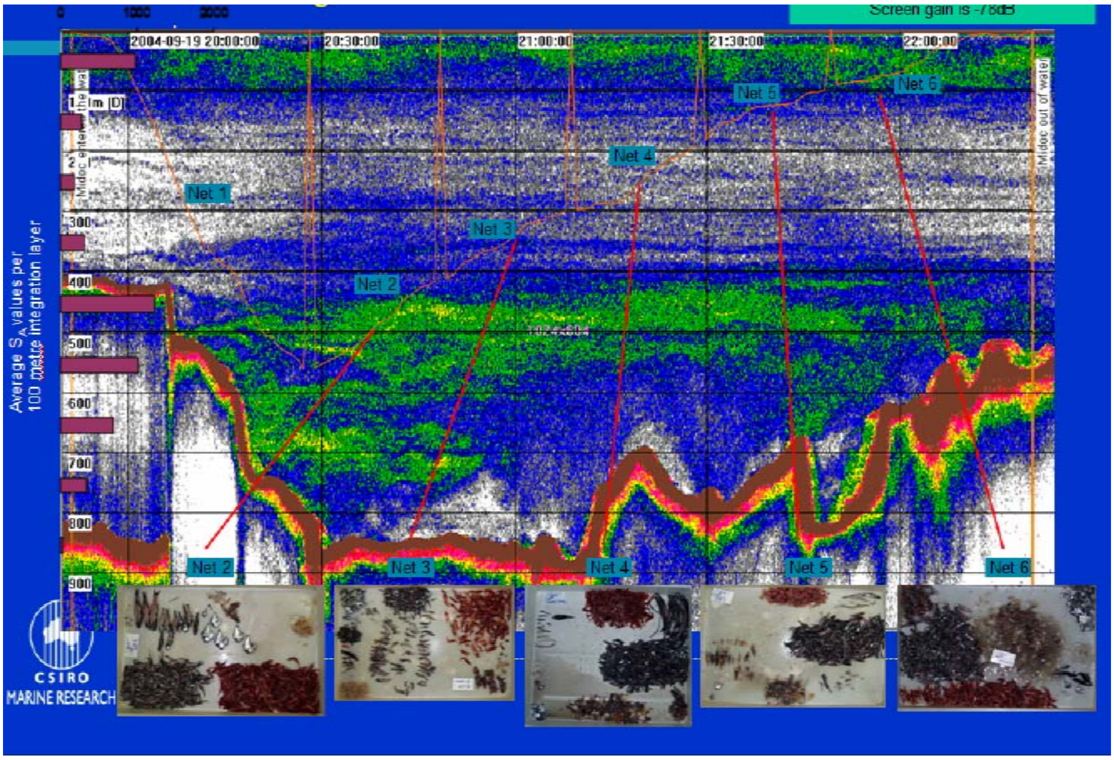

Fig. 5 : 38kHz echogram and summary echointegration with trawling depths and resulting catches overlaid. Britannia Seamount 19/09/2004.

2.7. Marie Hélène Radenac (IRD, France),

Backscatter strength data derived from Acoustic Doppler Current Profilers (ADCP) mounted on equatorial moorings of the Tropical Atmosphere Ocean/TRIangle Trans Ocean buoy Network (TAO/TRITON) are presented. These data are a by-product of the horizontal current processing and, as such, several approximations are made resulting in relative backscatter values. Nevertheless, different vertical distributions are clearly evidenced in the oligotrophic and mesotrophic ecosystems of the equatorial Pacific. Variability of the signal varies from diurnal to interannual scales. It depends on variations of the physical environment and on animals' behavior. ADCP backscatter strengths are representative of a "bulk" biomass of organisms that constitute the preys of top predators. Despite limitations (no identification of species, no universal relationship with biomass), ADCPs are useful to deliver biological information in integrated approaches including environmental *in situ* data, simulations… In the equatorial Pacific, the available several-year-long time series at high frequency benefit from temperature and meteorological data from the surrounding moorings and constitute a starting point for inter-annual studies.

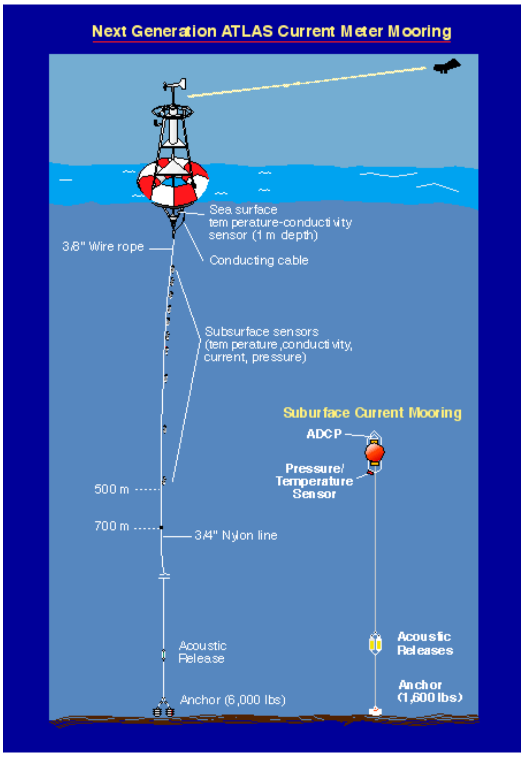

Fig. 6 : Scheme of a ATLAS Current Meter Mooring.

2.8. Hiroki Yasuma (HOKKAIDO UNIVERSITY, Japan),

Diaphus theta is the most abundant mesopelagic fish in the northwestern Pacific. Day and night field acoustic data and biological samples were obtained off Hokkaido, Japan. Differences of target strength (TS) between 38 kHz and 120 kHz were applied to identify echoes from *D. theta*. Theoretical estimates showed that the TS difference (TS_{120-38}) of larger fishes (>60 mm) was between –4 and 2 dB; that of smaller fishes (<60 mm) was less than –4 dB. These values differed from those of other major component of the deep-scattering layer, such as krill and pollock, suggesting that the echo from *D. theta* is acoustically identifiable. Schools of *D. theta* were observed around 400-m depth during daytime, although fishes were scattered widely in surface layer (>100-m) at night. In the surface layer, the fish densities were about ten-fold higher at nighttime than in daytime.

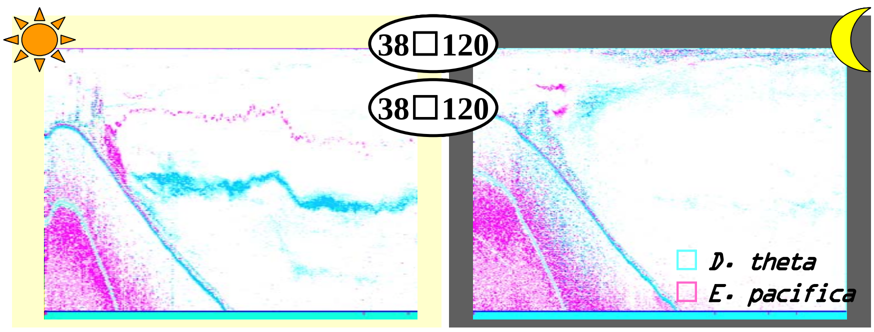

Fig. 7 : Acoustic identification and density estimate of *Diaphus theta (blue) and Euphausia pacifica (pink)* off Hokkaido, Japan.

2.9. Meng Zhou (UMB, USA), A future global array of acoustic sensors for mesozooplankton

A Lagrangian Bio-acoustic Drifter system is being developed, using a novel combination of acoustic sensors, drifters and associated software designed to remotely sense zooplankton in the upper ocean (100 m) and provide real-time data via satellite telemetry. The success of the project will ultimately lead to integration of this new sensor system into the Global Drifter Program, an array of ≈1000 drifters that now provides continuous oceanographic information to the international scientific community through a program jointly managed by the Joint Institute for Marine Observations (JIMO) at Scripps Institution of Oceanography and the Atlantic Oceanographic and Meteorological Laboratory (AOML). The Lagrangian Bio-acoustic Drifter array will provide the first truly synoptic visualization of zooplankton distributions in the ocean.

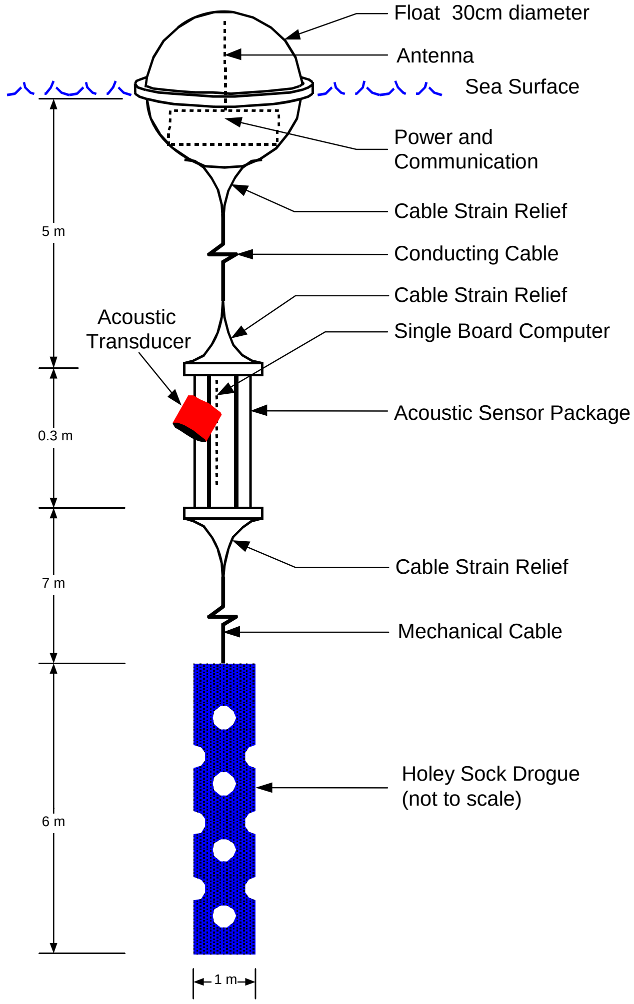

Fig. 8 : Scheme of the Lagrangian Bio-acoustic Drifter System.

2.10. Lars Nonboe Andersen (Simrad, Norway)

Simrad presented a new type of echo sounder ES10 used in a buoy concept for commercial tuna FAD's. The buoy echo sounder is developed by Simrad, whereas SatLink is responsible for the complete buoy and the satellite data communication. Some of the concepts used for the echo sounder may be of interest for the CLIOTOP-MAAS project.

3. The MAAS: constraints and expected limitations:

During the discussions following the talks of the participants, several critical points were identified. They are listed in the three following sections

3.1. Acoustic problems and constraints

3.1.1. The depth range of the observations

The maximal depth range of the observations should be 1000 m, keeping in mind that most of the biomass lies in the first 800 m and that zooplankton occupies mostly the first 100-200 m of the water column during the night.

⇒ A good vertical resolution (less than 5m) is required to resolve both the movements of the vertical layers and the potential vertical patchiness.

⇒ Low frequency (38 or 70khz?) is needed for coarse deep observations and high frequency (120-200khz, more?) for detailed surface observations:

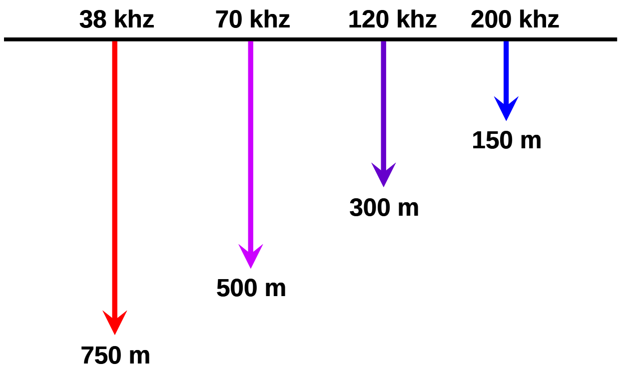

Fig. 9 : Schematic decrease of the depth range when the frequency increases.

⇒ An alternative solution would be to use a profiler. This has not been considered to be feasible in the CLIOTOP-MAAS framework.

⇒ The question *what do we need to "see" in deep waters?* has been raised. It is suggested to work with 2 levels of details: high level at the surface (targeting absolute abundance levels) and low level (targeting only the mean depth of the layer) in deep waters.

3.1.2. Absolute versus relative abundance measures

⇒ The effect of temperature on the acoustic signal has to be taken into account to achieve unbiased estimates. Appropriate calibration experiments have to be organized. SST should be measured by the drifter and temperature profiles could be derived from outputs of circulation models when post-processing the data.

⇒ Ambient noise should be monitored and accounted for (routine passive listening).

⇒ Motion sensor for sea condition should also be monitored routinely.

⇒ Inter-calibration experiments (sample testing) should be organized.

⇒ Specific inverse models should be developed in collaboration with CLIOTOP WG4 to derive probabilistic estimates of abundance given assumptions about species composition.

⇒ The problem of fouling has been mentioned without identifying miracle solutions. Tests should be conducted to estimate the potential impacts of bio-fouling on the acoustic signal.

3.1.3. Identifying species or taxa groups

⇒ It has been noted that the amount of data needed to identify species could be a limiting point and should be precisely investigated.

⇒ In the absence of large scale *in situ* sampling, only the identification of rough taxonomic groups can be expected (*e.g.:* myctophids, crustaceans, cephalopods, jellyfish, etc…).

⇒ Several frequencies (at least 2) are needed to identify species and *ad-hoc* experiments should be conducted to identify the best combination of frequencies (38-70-120-200khz, else?).

⇒ Inverse modelling (cf. WG4) should be used to derive probabilistic estimates of species composition on the basis of published biological sampling studies.

⇒ The problem of zoo-attraction which is critical for large organisms shouldn't be a problem for the small organisms which are the target of the MAAS. It implies that the signature of large organisms should be filtered.

3.1.4. Size distributions

The range of organisms to be measured by the MAAS is approximately [0.1mm; 20cm]. Frequencies have to be chosen accordingly. Hydro-acoustics can be used to estimate the size-distribution of organisms in the sea. However, several technical limitations make it difficult to envision precise measurement of size distributions on the large scale. To be able to derive size distributions, the following requirements have indeed to be considered:

⇒ In situ TS measurements and calibration with a split beam echosounder are needed.

⇒ The density of organisms has to be low (which is the often the case in SSL, especially at night when organisms are more dispersed).

⇒ Species/taxa identification is a prerequisite (video).

⇒ For small organisms such as zooplankton, the use of optical equipments such as LOPC (Laser Optical Plankton Counter) can be more easily envisioned to derive the size-spectrum.

⇒ A depth profile with the instruments is needed

A realistic solution to measure the size-distribution of the biomass could be to use a small number of highly sophisticated equipment (on fixed moorings) for size resolved measures and a large number of less sophisticated equipment (on drifters) not designed for size measurements.

3.1.5. Validation

A precise validation of the equipments developed as well as a precise quantification of their performance is necessary. For that purpose:

- Specific surveys will have to be organized.
- Measurement error and bias[1] will have to be precisely estimated using experiments in controlled conditions, buoy-to-buoy comparisons, *in-situ* surveys, video?, other data sources?

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[1] Expected errors in well designed and properly calibrated acoustic surveys (from Simmonds and MacLennan, Fisheries Acoustics (2005))

A. Errors affecting both relative and absolute biomass estimation

Source of error	Random error	Bias	Comment
Instrument platform			
Instrument calibration	± 2 to 5%	± 2 to 5%	Worse at higher frequencies
Vessel motion		0 to 25%	Narrow beams are more biased
Bubble attenuation		0 to 90%	Keel mounted and deep towed systems are less sensitive

- Observation models specific to the MAAS data will have to be developed in collaboration with WG4 ("modelling the echograms") to be able to use the data in a quantitative way.
- Bias related to animal behaviour is probably not a big problem for the micronekton and zooplankton size range considered.

3.2. Mooring / energy problems

Two kinds of platforms can be envisioned for the MAAS. Using simple and easy to deploy drifters is the easiest solution for covering large regions (Fig. 10). A drifter has to be cheap and hence to carry less sophisticated equipments with a limited life-time. The horizontal resolution of the observations (number of floats) depends on the objectives of the second phase (spatial deployment) of the project.

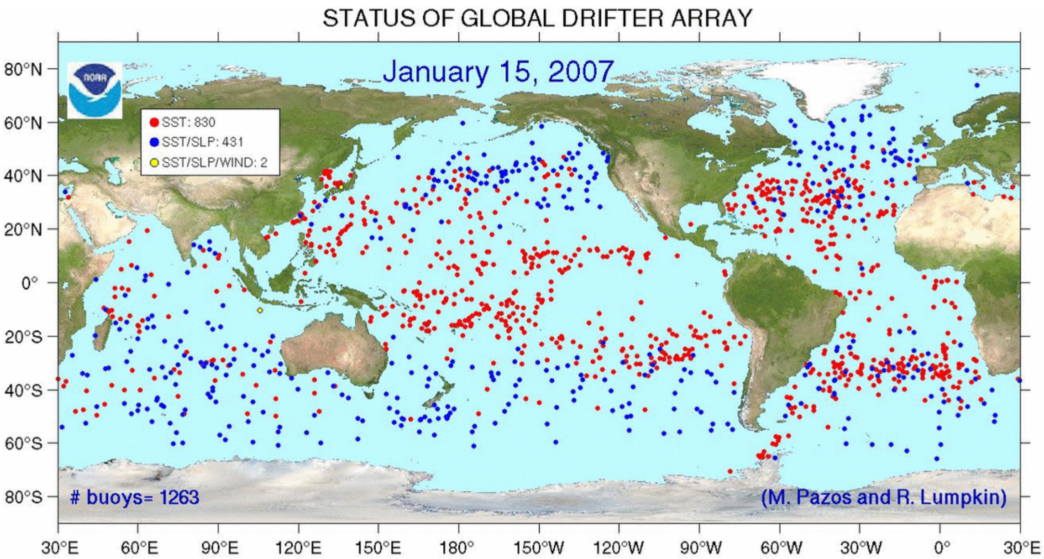

Fig. 10: Exemple of a global drifter network: the NOAA drifter program

Conversely, ships of opportunity, AUV or fixed moorings (Fig. 11) can be used to carry more sophisticated equipments.

Hydrographic conditions	± 2 to 5%	0 to 25%	High frequencies and deep targets are stronger biased
Fish behaviour			
Target Strength	± 5 to 25%		Uncertainty in fish size and fish orientation
Species identification	± 0 to 50%		Depends on species and level of species mix
Random sampling	± 5 to 20%		Depends on spatial distribution and school size distribution
Migration		0 to 30%	Depends on timing between survey and fish movement
Vertical movements	± 0 to 50%		Depends on TS change due to pressure variations
Vessel avoidance		0 to 50%	Stronger in shallow areas and noisy vessels

B. In addition errors affecting only the absolute biomass estimation

Source of error	Bias	Comment
Instrument calibration	± 3 to 10%	Worse at higher frequency and narrow beam
Hydrographic conditions	±2 to 25%	High frequencies and deep targets are stronger biased
Target Strength	0 to 50%	Best for well investigated swimbladdered species.

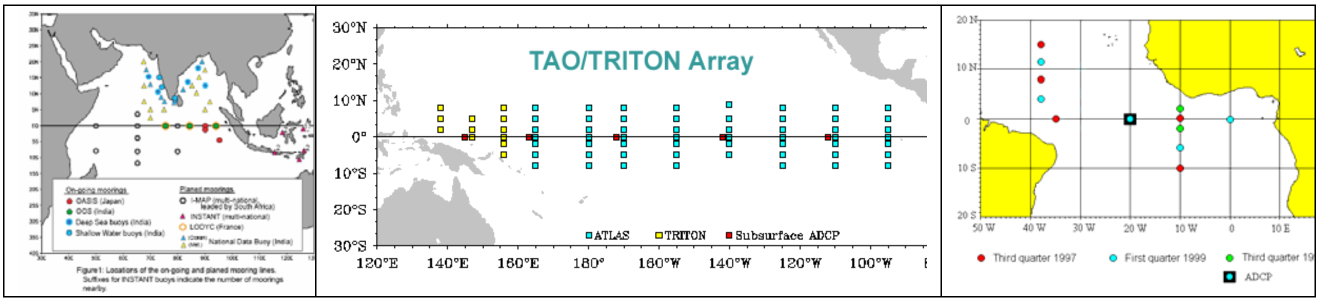

Fig. 11: Tropical Indian Ocean mooring array; TAO/TRITON array in the Pacific Ocean, PIRATA mooring array in the Atlantic Ocean.

The group decided that, depending on the platform used for its deployment, the MAAS should enable two levels of technological sophistication: a high level adapted to large platforms such as fixed moorings or vessels (the question would then be to develop collaborations with the projects in charge of those moorings to add sensors on it) and a low level adapted to autonomous drifters. The present project should give priority to the development of the low level drifter. Several points have been raised in this perspective:

- Various projects (such as the NOAA drifter program cf. Fig. 12 below, FADIO, Simrad Tuna buoy(?) etc…) already designed instrumented drifters for scientific purposes. Their experiences should be used.

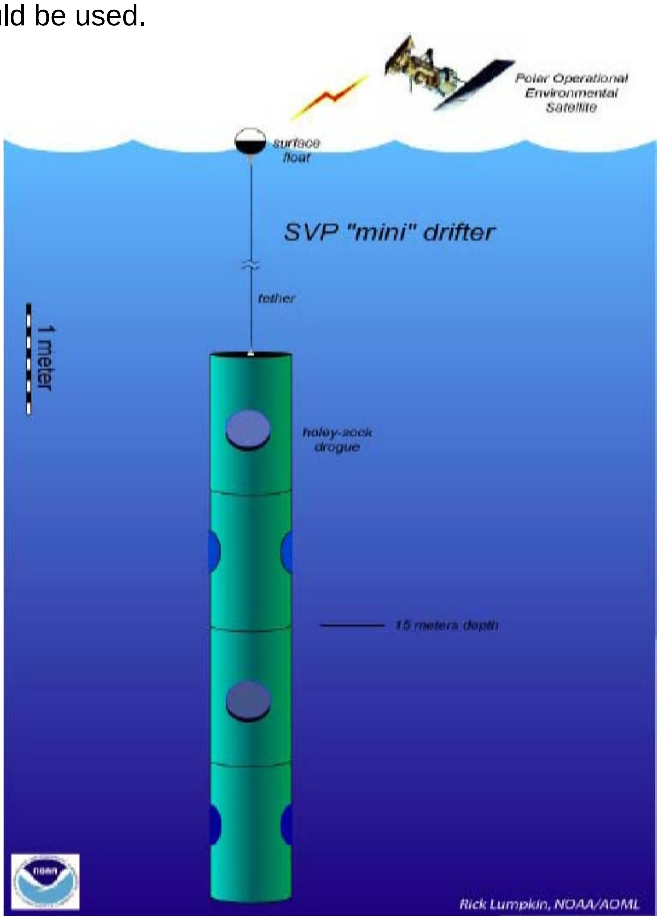

Fig. 10: Exemple of a drifter used in the framework of the Global Drifter Program

- A key point is the cost of a single drifter given specific constraints which have to be precisely specified. Expected cost should be less than 5-10,000 US$ per float to allow for the deployment of at least 1,000 buoys.
- The autonomy of a buoy should be at least 2 years which seems to be *a priori* a good compromise between the lifetime of the acoustic sensor and the quality of the data collected.

- Non acoustic sensors could be added to provide complementary information (GPS, light, SST, movements, background noise, LOPC, etc).
- Complementary equipments have to be taken into account for the design of the buoy.
- Solar panels? Experience exists.
- The size of the buoy has to be defined given the constraints of the dimensions of the container, the handling capabilities, etc…
- The effects of sea movements on the drifter have to be minimized by the design of the buoy and accounted for using motion sensors.

3.3. Data pre-processing, transmission, post-processing:

This is a crucial point. Three steps have to be considered:

1. Data collection and integration inside the buoy (pre-processing),
2. Data compression and transmission,
3. Integration among buoys (post-processing).

- An adaptive temporal sampling scheme should allow to optimizing data collection by increasing sampling rhythm during periods of interest (such as dusk and dawn for instance).
- The software for data integration inside the buoy should combine and synthesize acoustic information using a pre-defined adaptive protocol specifying the vertical and temporal sampling scheme to be used, the noise thresholds, etc…
- Standard methods for signal processing and image compression should be used given that the information which can be lost in the process is well identified. The goal is to keep a minimum processing level inside buoy.
- The "low-level buoys" will not store data and the "high level buoys" should allow a raw data storage.
- Concerning data transmission, the new ARGOS 3 system was presented to the group by P. Gaspar (CLS). Given the amount of data that can presently be transmitted by the system, data transmission should not be too constraining.
- Data quality, archiving & distribution is an important point. Several levels of data post-processing can be envisioned and appropriate data sharing policies should be developed in the GLOBEC context to ensure a maximal availability of the data collected.
- Model for data post processing have to be elaborated.
- Concerning the automatic treatment of the large amount of data collected, existing post processing programs and algorithms should provide the baseline for more specific developments (e.g. Alaska Fisheries Sci. Centre, NOAA Seattle; Echoview, etc…).
- Archiving of data in well designed data-bases with internet access to be envisioned.

4. General technical specifications of the MAAS

The MAAS project has dual objectives. One is to develop a simple and cheap pelagic drifter to be deployed widely and the other is to develop a more sophisticated system for more detailed studies, to be deployed on moorings or ships. On the basis of the various points listed above, the group attempted to define the technical specifications of the “simple” system to be targeted:

⇒ **Depth range**: detailed observations should be possible up to 100-150 m. The maximum depth should be 800 m. At least two or three frequencies should be used (e.g. 38, 120 and 200 kHz to be confirmed through experiments)[2]; a questionnaire could be sent to experts in the field to choose the appropriate frequencies combination (SIMFAMI, etc.)

- ⇒ **Threshold**: -80 dB with a noise ratio of 10 dB
- ⇒ **Beam angle**: the same for all frequencies (preferably narrow beam angle)
- ⇒ **High power**
- ⇒ **For taxa identification**: consider the need for an optional additional 400 kHz frequency for zooplankton?
- ⇒ **Dynamic range:** 97 dB is efficient for this use, 40-50 dB is still acceptable.
- ⇒ **Other sensors needed on board:**
  - o GPS
  - o Surface temperature
  - o Motion sensor
  - o Background noise (passive listening)
  - o Light sensor
  - o Optional sensors for additional sponsored users (e.g. Laser Optical Plankton Counter).
- ⇒ **Processor inside buoy**: A power efficient processor is required. A specially designed microprocessor or a simple PC, selected according to particular needs such as power consumption (low clock frequency, etc.).
- ⇒ **Minimum sampling intensity**
  - o Vertically: adaptive depending on data distribution and compression system.
  - o Temporally: adapted to animal distribution variability
  - o Sampling and data compression: direct adaptive sampling with experimental definition of bounding parameters according to biomass variability (i.e. from ping-to ping). Use statistic simulations to optimize the sampling scheme.
  - o OR: data compression through retrospective analysis (e.g. image compression methods): this requires high ping rate (increase power consumption) but allows low data transmission with high precision information.
- ⇒ **Power capacities:** "Disposable" drifting buoys are to be developed, i.e. power is needed for at least 2 years. Ask buoy manufacturers about solar panels? A rough calculation[3] make us think that it is feasible
- ⇒ **Data cleaning** before transmission.
- ⇒ **Data transmission**
  - o The limiting factor,
  - o ARGOS3 seems ok, compare with iridium potentialities and cost
- ⇒ **Buoy specification**
  - o Size and volume: must accept 20 kg battery + PC and transceiver + the sensors listed above + transducers
  - o Structure: the transducer has to be placed well below the buoy, ideally below the drogue
- ⇒ **No data storage** after transmission to satellite

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[2] The range to which the echo sounder can be used depends on a variety of adjustable parameters such as: transmit power, transducer opening angles, threshold, pulse length, frequency, sound speed, noise level, etc. However, calculations of the estimated ranges assuming a set of operational and environmental parameters can be made. For a set of operational and environmental parameters and an Sv threshold of -80 dB and required S/N level of 10 dB with the transducers with wide opening angles (31 degrees) we will probably only obtain ranges of approximately 400 m for the 38 kHz and 60 m for the 200 kHz. If the Sv threshold is increased to e.g. -70 dB we will probably obtain ranges of approximately 650 m for the 38 kHz and 100 m for the 200 kHz. By increasing the pulse length from the assumed 1ms to e.g. we can probably obtain approximately 850 m for 38 kHz and an Sv threshold of -70 dB for sea state 3.

[3] 20 kg ion lithium batteries + 140watts acoustic power = 1 ping every 20sec with1 ms pulse during 2 years (power consumption by other instruments is not taken into account)

5. Organizational framework of the MAAS project

The development of the mid-trophic automatic acoustic sampler (MAAS) constitutes the phase 1 of the project. Its large scale oceanic deployment and use is the phase 2.
Given the long term perspective needed to implement the MAAS project and the strong interest expressed by the participants of the workshop, the group decided to submit an official request to the CLIOTOP Steering Committee asking for the official creation of a CLIOTOP-MAAS Working Group responsible for the implementation of the project.

The group also noted that there is potential for a consortium to submit a proposal for a MAAS project to EU FP7. A subgroup leaded by Nils Olav Handegard (IMR, Norway) agreed to consider launching such an initiative in 2007.
In parallel, other national or international funding agencies should be actively investigated by the workshop participants.

A general proposal synopsis for a 2-years project addressing phase 1 has been defined. It implies to organize the work around an appropriate selection of partners including private companies such as SIMRAD and buoy manufacturers and to set up bilateral agreements between the companies and the consortium.

The CLIOTOP-MAAS Project. Phase 1: Development and testing of a prototype
The project could be organized around 3 interacting work packages to be implemented more or less in parallel:

1 Building the prototype
2 Field testing and system refinement
3 Specification for large scale deployment

WP1 (2 year): build a first prototype

⇒ List all the equipments needed. Identify existing components. Define and build the new components to be specifically developed (e.g. new transducers, specific electronic devices, specific buoy, etc).
⇒ Define the data acquisition protocols (sampling schemes) and develop the associated pre-processing and data compression algorithms adapted to satellite transmission requirements.
⇒ Assemble the different elements of the first prototype (sensors, pc, transmission, batteries, etc…) in the dedicated buoy. Specify and select optimal settings. Try to keep as generic as possible (use modules re-usable by other projects or purposes).
⇒ Debugging and construction of the final prototype

WP2 (2 years): field testing and system refinement;

⇒ Begin field work using existing "similar" equipments for data acquisition and analysis (1 year) in interaction with WP1.
⇒ Conduct field tests using the actual prototype developed in WP1 (1 year)
  - Field testing = small scale application; in situ work in the real open ocean environment;
  - Small scale deployment to resolve fish and zooplankton fields using a network of drifters in different environmental settings

⇒ Applicability to (existing) moored platforms
⇒ Comparison between the drifter prototype and a standard system (what do we lose?)
⇒ Testing the full data flow from data collection, cleaning, compression, transmission, collection, post-processing in connexion with the CLIOTOP modelling WG4 which will be using those data.
⇒ Demonstration of the final product using a mini-drifter network

WP3 (1 year): specifications for large scale deployment: toward the MAAS2 project
WP3 has to be organized in close connexion with the CLIOTOP modelling WG4.

⇒ Coverage specifications: number of buoys, location, network architecture
⇒ Costing of the large scale deployment on a long term basis, integration into global observing and monitoring programs (GEOSS, GOOS), search for funds.
⇒ Towards MAAS 2: full scale implementation

6. Annex

6.1. List of related projects:

This CLIOTOP project is not isolated since several projects of autonomous observatories are being developed in the world with different objectives (for instance the ICES "Study Group on the use of acoustic data from fishing vessels"). Connections should be established for potential collaborations.

- MarEco
- SCOR Technical Panel
- FADIO
- NSF ORION
- Deep Monitor Project
- "British AUV", A. Brierley
- NOAA (surface drifter data)
- EUREKA, IMARPE-Peru
- SWFSC advance survey technologies
- Climate program, CSIRO
- SAFE, CSIRO
- ….

6.2. Participants to the workshop

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CLIOTOP (CLimate Impacts on Oceanic TOp Predators) is a ten year program implemented under the international research program GLOBEC (Global Ocean Ecosystem Dynamics, http://www.globec.org), a component of the International Geosphere-Biosphere Programme (IGBP). CLIOTOP is devoted to the study of oceanic top predators within their ecosystems and is based on a worldwide comparative approach, i.e. among regions, oceans and species. It requires a substantive international collaborative effort.

The project aims at identifying, characterising and modelling the key processes involved in the dynamics of oceanic pelagic ecosystems in a context of both climate variability and change and intensive fishing of top predators. The goal is to improve knowledge and to develop a reliable predictive capacity for single species and ecosystem dynamics at short, medium and long term scales.

CLIOTOP is based on the idea that the variety of climatic and oceanographic conditions in the three oceans (Atlantic, Indian and Pacific) provides a unique opportunity for large-scale comparative analysis of open ocean ecosystem functioning.

CLIOTOP Working Group 3 focuses on trophic pathways in open-ocean ecosystems and Working Group 4 focuses on Synthesis and Modeling (http://web.pml.ac.uk/globec/structure/regional/cliotop/cliotop.htm).

Please contact Olivier Maury maury@ird.fr or Patrick Lehodey plehodey@cls.fr for information about the CLIOTOP Program.