

Scientific project

Scaled Bioacoustic Monitoring in Ligurian:
automatic speed, direction & size of *P. Macrocephalus*
for behavioral and biopopulation studies
[LigEars]

CNRS, LSIS université de Toulon
CIBRA, University of Pavia
CNRS LAM, université Sorbonne - Paris 6

supported by **Institut Universitaire de France**

& **SABIOD.org**



Sanctuaire pour mammifères marins Méditerranéens
2013-2014

to secretariat@sanctuaire-pelagos.org

Pj :

- a. Lettre d'accompagnement
- b. CV du chef d'équipe
- c. Résumé du projet (1 500 mots environ)
- d. Formulaire de présentation détaillée du projet

30 janvier 2014

Pr. H. Glotin
Institut Universitaire de France & univ. Toulon-Var
glotin@univ-tln.fr

To : the executive Pelagos secretary,
Object : English version of the Pelagos 2013-14 project

Dear Pelagos officers,

it is an honor to submit to your judgment our research project « LigEars » aiming to enhance our knowledge on the sperm whale population in the Pelagos sanctuary. Our team is composed of three international experts in bioacoustics on *P. macrocephalus*. LigEars is in the continuation of the Pelagos 2013 DECAN project univ Toulon and will allow enhanced analyses on *P. macrocephalus*, that will be compared on the two North nodes of Pelagos triangle: West and East North. Some of the processes will be done in real-time. Other species of interest may process, like *B. Physalus* for example.

One of the most important objectives of LigEars is to standardize same theoretical methods on different distant datasets, yielding to coherent and scaled analyses. LigEars will use new bioacoustic methodologies that we developed in the SABIOD interdisciplinary CNRS mission*. Analyses of sperm whale sounds give information about their anatomy, their behaviour, their presence, their localization and the number of present individuals. Since the beginning of the 2000's, scientific teams are still working on these clicks to define robust real-time methods that can be applied to datasets from different sonobouy arrays in different recording configuration, especially variant ambient noise. My team works on fine IPI and size estimation, sparse coding, and 3D tracking. We published them in international journal or workshops. We also compared them with the state of the art during the workshop that we organized with Cornell and New-York universities in 2013 in Atlanta and Tahoe-Nevada (see proceedings in *).

LigEars aims also to complete other Pelagos projects, as the project « SUIVI ACOUSTIQUE ET EVALUATION DE L'IMPACTS POTENTIEL DU BRUIT D'ORIGINE ANTHROPIQUE SUR LES MAMMIFERES MARINS ET LEUR HABITATS DANS LE SANCTUAIRE PELAGOS (CETAC) ». Therefore, we planified with G. Pavan to organize a cooperation between these two projects, in order to show relevant correlations between anthropic noises and the statistics from LigEars.

LigEars aims to run from March 2014 to March 2015. The methods are ready to run. The recording systems are being connected in March 2014. We got agreement for ODAS buoy and ANTARES observatory (see joint letter). Bombyx is installed and will receive its hydrophones in March. Most of the hydrophone systems are bought using financial fundings from the IUF and the TPM / UTLN and CIBRA (40K€). Meso computer from UTLN will be used for free, and the permanent salaries reach 92k€. We require to PELAGOS 1-year salaries for a PostDoc student /ing and furniture for a total of 54k€.

Sincerely,

Toulon 30th of january

H. Glotin

- <http://sabiody.org>



ps: We join below the CV of the leader and of the two main collaborators. The CV of the other partners are linked into the sabiod* cnrs web pages (Giraudet, Razik, Paris, Chamroukhi).

Annexel : CV of H. Glotin [PI, 40%]

Hervé Glotin (<http://glotin.univ-tln.fr>) is Professor at the Institut Universitaire de France (2% acceptance rate) within the chair in complex acoustic scene. At the Systems & Information Sciences CNRS LSIS lab, he is the leader of the DYNI Team working on stochastic multimodal information retrieval since he created it in 2008. This team includes today 6 permanent researchers and 10 non-permanent researchers.

After his Master in artificial intelligence at PARIS VI university, and in cognitive sciences at Polytechnic National Institute of Grenoble (INPG), he obtained in 2001 his PhD focused on robust automatic multistream speech recognition (ASR) and computational auditory scene analysis. His PhD took place at Artificial Perceptual Intelligence Inst. IDIAP-EPFL CH and at Inst. of Speech Communication (ICP) at INPG, within EU ESPRIT projects. In 2000, he was invited at the John Hopkins summer workshop as expert in the human language team of IBM, developing new audio-visual models for Via Voice audiovisual ASR (NFS grant). In 2001, he got a tenure position in the Semantics & Syntax CNRS lab. ERSS as CNRS engineer-researcher. In 2002, he was invited at the NATO advances studies in speech perception and production dynamics (NATO and ISCA grants).

H. Glotin is currently carrying researches on bioacoustics and robust multimodal information retrieval. He has mentored or mentors twelve PhD in biometrics, pattern recognition, speech processing including four in bioacoustics (Benard 2008-11, Abeille 2010-13, Doh 2011-14, Dufour 2012).

His current scientific interests include statistical learning for mislabeled and miss-segmented massive data bases with application in environmental sciences.

He was the Head of the Department of Computer Science at USTV from 2003 till 2006. In 2001 he co-founded AFCP, a technical society for francophone speech communication that includes over 150 members from academia.

He is the co-author of one hundred of international refereed articles, and of an international (USA) patent on a real-time bio-acoustic indexing algorithm. H. Glotin is heading the CNRS interdisciplinary project 2012-2016, Scaled Acoustic Biodiversity <http://sabiody.org> with LIP6 Paris 6, the CNRS, MNHN and CIBRA.

He was invited discussant at Institut des Hautes Etudes Scientifiques IHES workshop on Mathematical Models of Sound Analysis in June 2012. He was recently invited as a keynote speaker at the American Society of Acoustics workshop in June 2013 in Montreal for the special session on "Conditioning, Segmentation and Feature Extraction in Bioacoustics", and at the ERICE ethological school "Cetacean echolocation outer space neutrinos" in Oct. 2013.

Grants he obtained for his Team: Pelagos Boussole 2009-11 (coPI, 11K€), Pelagos DECAV 2011-13 (PI, 50 k€), Pelagos grant DECAN 2013 (PI, 7 K€). He got also various research grant on signal processing / classification / tracking, like: ANR Neurocomputational signal processing 2007-09 (120k€); ANR MDCA AVEIR Automatic annotation and Visual concept Extraction for Image Retrieval 2007-09 (80 k€); ANR Cognilego on automatic reading (PI, 120 K€, 2010-14).

He obtained various PhD grants (100 K€ each) : 2007-2010 from Region PACA on whale tracking, 2005-2007 biometry with DCN industry, 2006-2009 speech with Piovra EU grant, 2010-13 QR UTLN on Physeter biosonar, 2011-14 PACA region for cetacean survey; 2012-15 Ministry Grant on advanced clustering, 2012-15 DGA Grant on hierarchical classification.

Recent events: he was the chair of the two 2013 workshops in Machine Learning for Bioacoustics: at ICML Atlanta 16-21 June 2013 (with Y. LeCun NY univ., C. Clark Cornell univ.), and at NIPS Nevada in December 2013. Two challenges on whale automatic detection / clustering were conducted (details are in <http://sabiody.org>).

He is PI of the Scaled Acoustic Biodiversity Interdisciplinary Big Data CNRS, 2012-2017 (MNHN) (sabiody.org), grouping 30 researchers in bioacoustics signal processing and data sciences. He is officially involved in the ANTARES data bioacoustic analysis, and he is PI of the Bombyx bioacoustic Buoy deployed in the South of Port-Cros, 2013-2017.

Current elective positions:

- Vice president of the university faculty council (2011-2014)
- Elected at the executive board of LSIS lab (2009-13)
- Member of the LSIS scientific council of the LSIS (2009-14)
- Reviewer of several peer reviewed journal (Plos one, JASA, IEEE MM...) and conferences.

- Member of the national committee of Pelagos FR.

Selected Glotin's bibliography is given at the end of the project.

Annex 2 - Short CV of Pr Gianni Pavan [15%]

Pr G. Pavan has a degree in Nature Science and since 1980 he is working on bioacoustics with digital signal processing techniques. After 11 years teaching ecology at the Univ. of Venice (IUAV), since 2006 he teaches bioacoustics at the Univ. of Pavia and runs the Centro Interdisciplinare di Bioacustica e Ricerche Ambientali (CIBRA) he contributed to create in 1989. With a large experience on towed arrays for passive acoustic detection of marine mammals, cooperates with several international institutions (NURC, ONR, WHOI, ACCOBAMS) and since 2004 he is associated to the NEMO Project to supervise bioacoustic research with deep underwater cabled platforms. He also has a large experience in recording terrestrial soundscapes and in the use of sound recording and analysis hardware and software. He runs the Italian Stranding Network Online Database on behalf of the Ministry of the Environment <http://www.unipv.it/cibra> He will be central in AMBIO to provide reference recordings of marine mammals species of the Mediterranean Sea and creation of a reference sound library for developing/testing/validating acoustic analysis and classification algorithms, acoustic data collection from multiple sources, support to the development of data acquisition systems for marine and terrestrial soundscape analysis.

Pavan's selected publications :

Gazzonis A.L., Pavan G., Podestà M., Musella V., 2012. Cetacei presenti nel Mar Mediterraneo. Pp 149-181 In: “Cetacei dei mari italiani. Diffusione, spiaggiamenti e problematiche sanitarie.” Eds. Manfredi M.T., Gazzonis A.L., Merella P., Garippa G., Musella V. Mappe Parassitologiche, vol 16: 183 pp. ISBN 978-88-89132-58-6.

Pavan G., 2012. Paesaggi sonori terrestri e marini. In: “Filogenesi e ontogenesi della musica”, a cura di Avanzini G., Longo T., Majno M., Malavasi S., Martinelli D., pp 45-54. Franco Angeli Editore. ISBN 978-88-204-1130-5.

Paolo Favali, Francesco Chierici, ...,and Gianni Pavan, 2013. NEMO-SN1 Abyssal Cabled Observatory in the Western Ionian Sea. IEEE J. of Oceanic Engineering 38(2):358 – 374.

La Manna G., Manghi M., Pavan G., Lo Mascolo F., Sarà G., 2013. Behavioural strategy of common bottlenose dolphins (*Tursiops truncatus*) in response to different kinds of boats in the waters of Lampedusa Island (Italy). Aquatic Conserv: Mar. Freshw. Ecosyst.: DOI: 10.1002/aqc.2355

Pavan G., Fossati C., Caltavuturo G., 2013. Marine Bioacoustics and Computational Bioacoustics at the University of Pavia (Italy). Pp 3-25 in “Detection Classification and Localization of Marine Mammals using passive acoustics. 10 years of international research.”, Adam O., Samaran F. (editors), DIRAC NGO (Paris, France): 1-298. ISBN 978-2-7466-6118-9.

Lanfredi C., Azzellino A., D'amico A., Podestà M., Pavan G., 2013. Valutazione degli impatti delle emissioni acustiche sottomarine di origine antropica sui cetacei: sviluppo di modelli predittivi di habitat per la specie *Ziphius cavirostris* (G. Cuvier, 1823). Atti 44 Congresso SIBM. Biol. Mar. Mediterr. 20 (1):

Pavan G., Bernuzzi E., Cozzi B., Podestà M., 2013. La rete nazionale di monitoraggio degli spiaggiamenti di mammiferi marini. Atti 44 Congresso SIBM. Biol. Mar. Mediterr., 20 (1): 262-263.

Pavan G., 2013. Listening Underwater. In: On Listening (Edited by Carlyle A. & Lane C.), Uniformbooks: 63-70. ISBN 978-1910010-01-3.

Annex 3 – CV Pr Olivier ADAM [20%]

Pr O. Adam in LAM UMR CNR Paris 6 and at CNPS Orsay, expert in signal processing and bioacoustics. He is member of SABIOD team. He is Professor at “Université Pierre et Marie Curie” (UPMC Paris). He teaches

signal processing, adaptive filters, analogical and numeric filters, transmission, algorithm, and acoustics. Member of the bioacoustics Team at the CNPS Lab (Univ Paris Sud Orsay), he is the leader of many projects on whale signal recordings and analysis in the Caribbean Sea, the Atlantic Ocean, the Indian and Southern Oceans.

He is the organizer of the International Workshop on Detection and Localization of Marine Mammal using Passive Acoustics in 2005-Monaco. He got his PhD at UPMC on comparative approaches of neuronal processes for Lidar waves processing, in 1995, under the supervision of Prof Milgram. He is a key member in LigEars to characterize cetacean behavior from acoustics: for sperm whale, he provided the full description of their dives, including the different steps of its huntings [Laplanche 2005, 2006]. He also contributes in signal processing, as demonstrated with novel approach based on the Hilbert Huang Transform [Adam 2006]. He has also supervised a PhD student together with the PI (Doh) in bioacoustics.

Adam's selected publications:

[Kennedy, A. S., Zerbin, A. N., Vasquez, O. V., Gandilhon, N., Clapham, P. J., and Adam, O. (2014)], Local and migratory movements of humpback whales (*Megaptera novaeangliae*) satellite tracked in the North Atlantic Ocean, Canadian Journal of Zoology, Can. J. Zool., 92: 8-17

[Adam, O., and Samaran, F. (2013)] Detection, Localization and Classification of Marine Mammals using Passive Acoustics, 2003-2013: 10 years of international research, ed. Dirac Ngo, ISBN 978-2-7466-6118-9, 324 p.

[Cazau, D., Adam, O., Laitman, J. T., Reidenberg, J. S. (2013)] Understanding the intentional acoustic behavior of humpback whales: a production-based approach, Journal of the Acoustical Society of America (JASA), 143(3): 2268-2273

[Adam, O., Cazau, D., Gandilhon, N., Fabre, B., Laitman, J. T., and Reidenberg, J. S. (2013)], New acoustic model for humpback whale sound production, Applied Acoustics, 74(10): 1182–1190

[Samaran, F., Gandilhon, N., Doh, Y., Pace, F., Cazau, D., Laplanche, C., Lopatka, M., Glotin, H., White, P., Zarzycki, J., Motsch, J. F., and Adam, O. (2013)] Inside the sounds emitted by some cetacean species, Detection, classification, localization of marine mammals using passive acoustics, ed. Dirac Ngo, 267-286

[Samaran, F., Gandilhon, N., Prieto Gonzalez, R., Pace, F., Kennedy, A., and Adam, O. (2012)] Passive hydro-acoustics for cetacean census and localisation, Sensors for ecology, Towards integrated knowledge of ecosystems, CNRS Paris, ISBN: 978-2-9541683-0-2, 63-82

[Adam, O. (2006)] The use of the Hilbert-Huang transform to analyse transient signals emitted by sperm whales 2006 Applied Acoustics 67 (11), cited 10

[Laplanche, C., Adam, O., Lopatka, M., and Motsch, JF (2006)] Measuring the off-axis angle and the rotational movements of phonating sperm whales using a single hydrophone, The Journal of the Acoustical Society of America 119, 4074, cited 16

[Laplanche, C., Adam, O., Lopatka, M., and Motsch, JF (2005)] Male sperm whale acoustic behavior observed from multipaths at a single hydrophone; The Journal of the Acoustical Society of America 118, 2677, cited 20

1 - Abstract of the project

LigEars project aims to automatically detect, cluster, classify and index bioacoustic data, at multiple space and time scales in the Ligurian Sea, in order to reveal accurate information on the health of key species, and to deliver information for other program like anthropic noise effects. LigEars can be achieved given the recent major technological improvements allowing us to get high precision recordings combined with advanced machine learning for scaled indexing and mining.

LigEars is based on three recording stations: ODAS buoys, our Bombyx Buoy deployed at the South of Port Cros, and the real-time ANTARES observatory at South of Toulon (see joint letter in annex). This association of these recordings allows efficient monitoring of key species at the scale of the Ligurian Sea.

During these last years, our primary goal was to develop transferable methodologies in the area of advanced machine learning and automatic recognition to cetacean bioacoustics. We have now several running methods for accurate sperm whale detection, and to provide some individual information, including their size estimation and their position tracking. They are running in tools on GPU or GRID computing. This will include both mechanisms for data processing using high performance computing, algorithm design, algorithm integration and data analysis as well as a conceptual framework.

The LigEars Team is composed of experts in ecology, marine biology, bioacoustics and machine learning. They are highly qualified research professionals, with interdisciplinary experience ranging from ecology, acoustical modeling, signal processing, and bioacoustics. This project is also supported by the IUF and the SABIOD CNRS project (Scaled Acoustic Biodiversity - 2012-2017) from the Interdisciplinary CNRS Mission - BIG DATA MASTODONS CNRS program.

LigEars is in the continuation of the Pelagos 2013 DECAN project univ Toulon (7K€) and will allow enhanced analyses on *P. macrocephalus*, that will be compared on the two North nodes of Pelagos triangle: West and East North. Some of the processes will be provide in real-time. Other species of interest may process, like *B. Physalus* for example.

One of the most important objectives of LigEars is to standardize that same theoretical methods will run on different distant datasets, yielding to coherent and scaled analyses. LigEars will use new bioacoustic methodologies that we recently developed. Analyses of sperm whale sounds give information about their anatomy, their behaviour, their presence, their localization and the number of present individuals.

Finally, LigEars aims also to complete other Pelagos projects, as the project « SUIVI ACOUSTIQUE ET EVALUATION DE L'IMPACTS POTENTIEL DU BRUIT D'ORIGINE ANTHROPIQUE SUR LES MAMMIFERES MARINS ET LEUR HABITATS DANS LE SANCTUAIRE PELAGOS (CETAC) ». Therefore, we planified with G. Pavan to organize a collaboration between these two projects, in order to show relevant correlations between anthropic noises and the statistics from LigEars.

2- GENERALITIES

PI : **Nom : GLOTIN**

Prénom : HERVE

Fonction : Professeur des universités

Organisme : Institut Universitaire de France, Bd St Michel Paris

Université de Toulon – France

UMR CNRS LSIS

Tel: 04 94 14 28 24

Email : glotin@univ-tln.fr

The project involved three partners :

a) LSIS UMR CNRS & Université de Toulon, Établissement Public à Caractère Scientifique, demeurant avenue de l'Université - B.P. 20 132 - 83957 La Garde cedex, président Monsieur Marc SAILLARD, N° de SIRET 198307662, Code APE 8542Z, resp. scientifique H. Glotin, glotin@univ-tln.fr tel : 04 94 14 28 24

b) CIBRA, University of Pavia, Italy, with Pr. Gianni Pavan, president of CIBRA, Centro Interdisciplinare di Bioacustica e Ricerche Ambientali, Via Taramelli 24 - 27100 Pavia – Italy, e-mail : gianni.pavan@unipv.it, cibra@unipv.it tel : +39-0382-987874

c) LAM UMR CNRS & Université Paris Sorbonne, with Pr O. Adam, Institut Jean le Rond d'Alembert, Equipe LAM 11 rue de Lourmel 75015 Paris, [olivier.adam\(at\)upmc.fr](mailto:olivier.adam(at)upmc.fr) ; tel = (+33) 01 53 95 43 35

3 - PROJECT DESCRIPTION

3.1 Objectives

The Ligurian Sea can be distinguished from all the other basins in the Mediterranean as to the number and variety of great pelagic fish and strongly diversified. This project is focussing on target species in this Sea, mostly the *Physeter macrocephalus* (Pm), using long term continuous bioacoustics. It aims to collect scaled features in time and space, in one main target species, to monitor their population and seasonality, and will produce features that will be useful in other Pelagos projects on noise effects on the marine environment.

Also *B. Physalus* (Bp) shall be recorded, and potentially Tursiops and striped dolphins, so we will also produce detections of these cetacean species with the similar systems, but without size estimation.

3.2 Expected results

This study will generate new data in two complementary points on the Ligurian Sea, with coherent protocols. It will allow homogeneous processing, and comparatives results, on two main species: Pm and Bp. It will contribute to knowledge about Pm movements and when, from East-West Ligurian places, or mainly stay all the year in specific areas of our acoustic observatories.

3.3 Interest of the studies

This study is the first in the Pelagos Sanctuary that brings together three experts in bioacoustics focussed on target species, and based on recordings of two complementary sites in the Ligurian Sea, with state of the art bioacoustics methods.

3.4 Communication

Our team will publish as usual results in high level conference or/and journal, and may continue some TV / radio interviews, some are available at <http://sabiod.org/tv> .

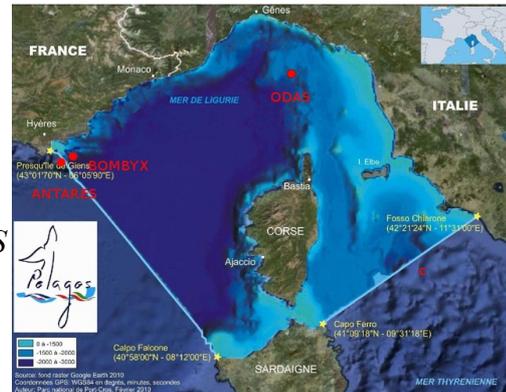
4. METHODS

Global description

The project is decomposed in 4 tasks: (1) detection, (2) IPI and size signature for Pc, (3) Tracking (speed and orientation), (4) Density estimation, and (5) the West-East correlations and synthesis for other studies in Pelagos programs like for correlation with noises.

The recording systems are placed in West and East of the Ligurian Sea (fig. 1).

Figure 1: localization of the three recording stations. We have direct access to real-time ANTARES high frequency recordings, all the year, all the day. We are fixing our hydrophones to our BOMBYX sonobuoy in March 2014, for the whole year. We will also set similar recorder to the ODAS buoy.

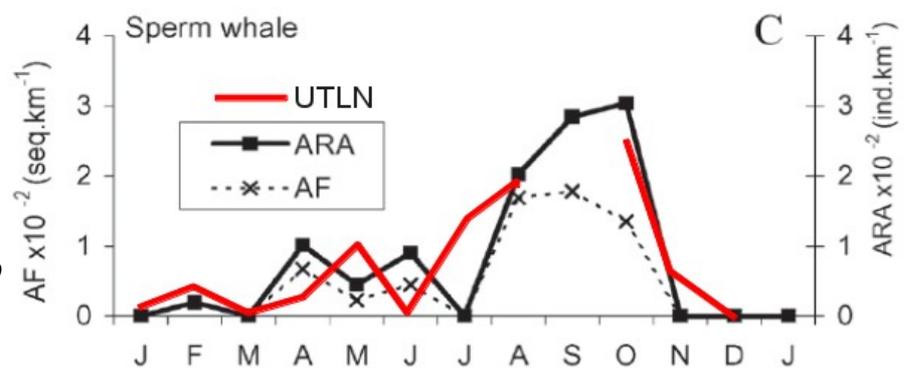


4.1 Task 1 : Detection

The objectives of LigEars are to establish large scale monitoring of the Pm using acoustics. *B. Physalus* may also be observed from the same acoustic recordings. We have developed various detection techniques, (including some for Bp) in our previous Pelagos Boussole project, and DECAV, using quadratic detector or Stochastic Matching Filter. Our methods (fig. 2 and 3) are scaled (faster than real-time) and show accurate detections [Laran, Glotin *et al.*, Boussole Pelagos report, Benard *et al.*, 2011, Abeille, 2013].

We will then process long term series analysis to demonstrate the presence of Pm. These detections can give basic information on their seasonal presence, on the population structure and their behavior (see fig. 2 [Laran, Glotin *et al.*, 2011 Pelagos project]).

Figure 2 : Evolution from January to January of *P. macrocephalus* relative acoustic presence (ARA) : 'UTLN'=ARA given by automatic process of LSIS Toulon univ on 2008 and 2009 data recorded during the Pelagos Boussole project [cf. Laran & Glotin 2011]. '- ARA' (resp 'x AF') : ARA (resp. visual counting) between Corsica and continent from Laran & Drouot-Dulau 2007.



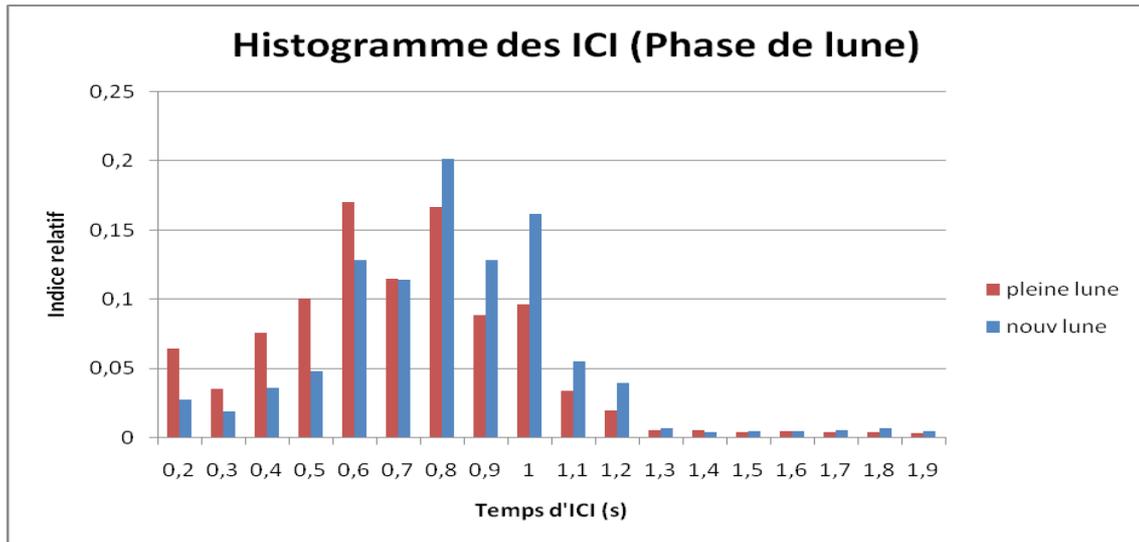
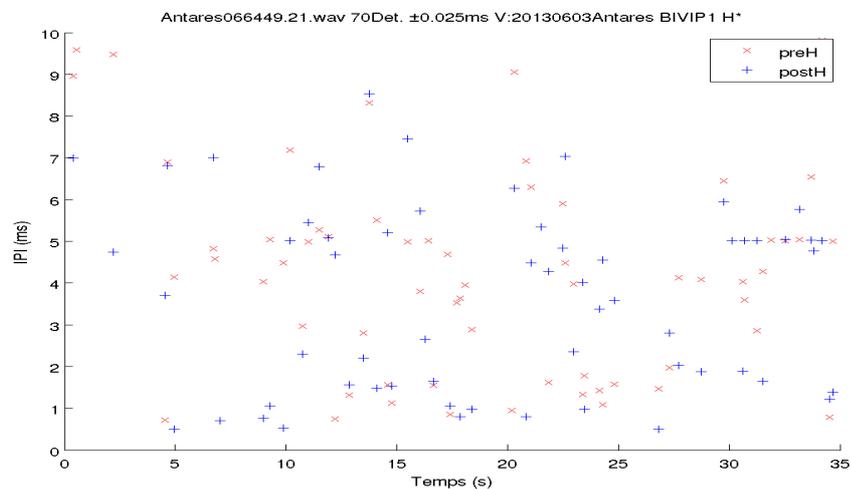


Figure 3: The Interval InterClick statistics of SP near the Boussole buoy, in 2008-2011 [Laran, ..., Glotin et al 2011 Pelagos project]. Simple detections of Sm allow behavioral analyses.

4.2 - Task 2 : Fine Inter Pulse Interval automatic extraction

The nature of the Pm clicks is strongly linked with its anatomy. Each click is the combination of successive pulses. During 2012 and 2013, in conjunction with Gianni Pavan, we worked in new methods for Pm size estimation based on accurate IPI measurements. The Abeille 2013 Phd proposes such efficient methods, illustrated in figure 4 for an ANTARES data set of 2012. We see that we are able to identify Pm by their size each year, and the composition of the groups is then most of the time possible (figure 5). We will work with this system, and others in Pavan team, to generate robust description of the Pm population on each of the three recording points.

Figure 4: The BIVIP algorithm [Abeille et al 2013] run on ANTARES recordings 250 kHz. We see clearly the PreH=PostH=5ms from sec. 30 to 35. That is a perfect detection of a Pm, of 12,02 meters according to Growcott allometric rules. Other pulse detections are false positive. This is demonstrating that our IPI measurement generate more accurate detection, and in the same time allows length measurement of the Pc, which signs it for a given season.



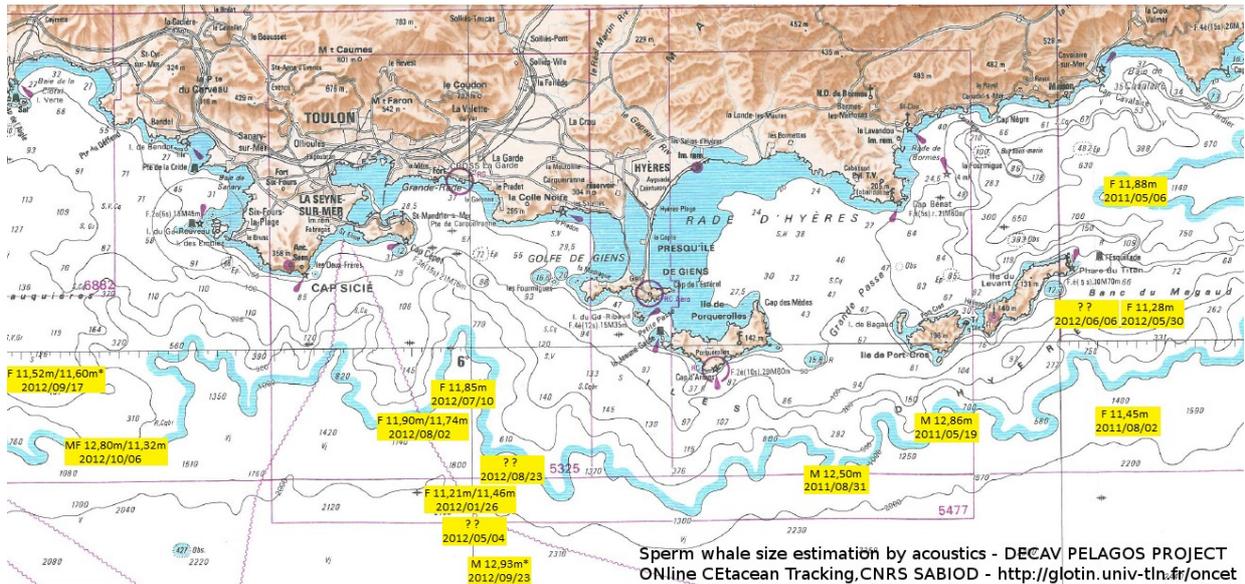


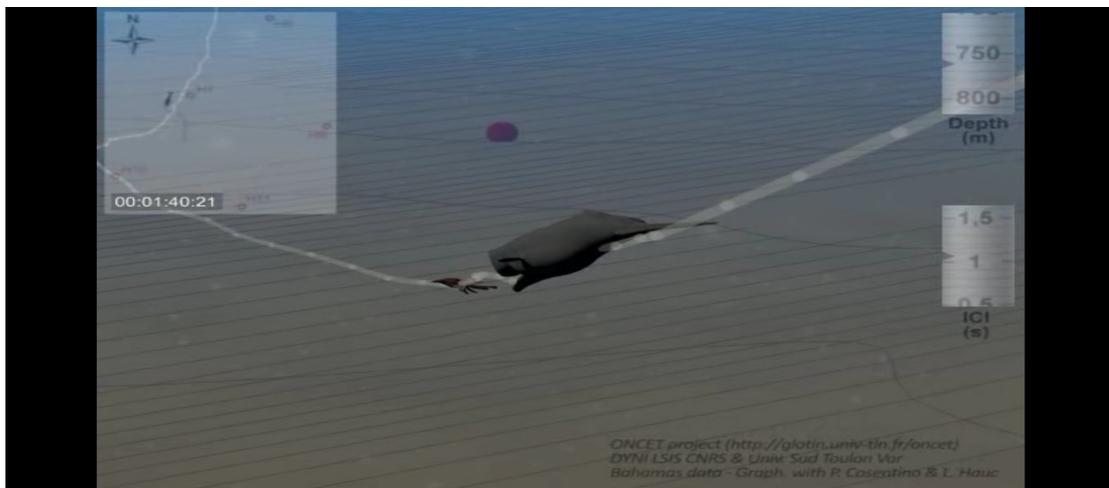
Figure 5: example of the results of your IPI system [Abeille Phd 2013, and in preparation Abeille, Glotin, Giraudet, Pavan 2014], on the records 2011-2013 from PNPC or other boats. The current project will allow more precise results due to long term monitoring.

4.3 - Task 3 : 3D localization, 3D Tracking

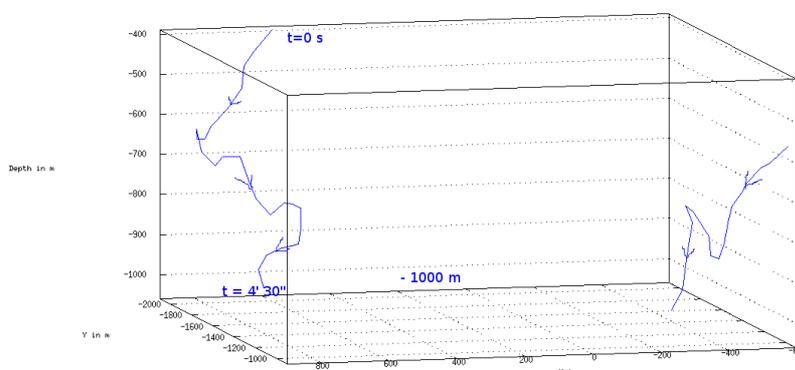
The whale diving orientations can efficiently be computed from the ANTARES data set, in real-time (using Glotin *et al.* patent). Actually, ANTARES (see joint letter) has more than 4 hydrophones lines using high frequency sampling, allowing to produce Pm tracks, and to give their swimming orientation. This orientation can be correlated to Bombyx detection or non-detection, because of the only 10 km that separate ANTARES to Bombyx. This couple of system enhance the quality of the study, and allows to tracking individuals Over large areas.

These statistics will be mapped into 2D or 3D representations, to contribute to anti-collision programs like REPCET in front on Toulon, and will also be correlated with anthropic noises in other projects.

Our system is also efficient in the case of multiple tracking (fig 6) of simultaneous sources, for example the PI's patent on multiple cetacean tracking can be seen online at <http://glotin.univ-tln.fr/oncet>.



Result the 2005 15h00, Sicile Est : 2PC dive together from -400 m to -1000 m in 5 minutes



[Benard Glotin Applied Acoustics 2011]

Figure 6: (Top) Illustration of the 3D tracker system from LSIS UTLN, also in video on sabiiod.org/tv and details on [oncet](http://oncet.org) web pages. (Bottom) Result of the same system on short base Nemo recorder (with thanks to G. Pavan and INFS for the data). Nemo observatory is 2 meters large, these two tracks of Pm diving are showing that our system will also be efficient on the 12 ANTARES hydrophone array to which we are now connected (see letter).

4.4 - Task 4 : Density estimation

The LigEars objective is not only to provide presence/absence of emitted species but to give more information about the size of their population. The density estimation could be used to characterize the frequentation of the areas we are recording them and to follow the increasing, decreasing or constant size of the population.

Acoustic based density estimates are being increasingly used. Usually density estimation methods require one to evaluate the effective survey area of the acoustic sensors, or equivalently estimate the mean detection probability of detecting the animals or cues of interest. This is often done based on an estimated detection function, the probability of detecting an object of interest as a function of covariates, usually distance and additional covariates.

Estimation of the population density using passive acoustics is actually under investigation. Two approaches seem more advanced. The first method is an adaptation of the method "distance sampling" classically used for visual observations to acoustic observations (Marques *et al.*, 2009; 2011). The difficult task is 1) to have an estimation of the range of the emitted cetacean species, especially when the individuals are far from the hydrophone and 2) to fix the call rate, because this criterion is not already known for the most number of species. This information could be obtained from the use of an acoustic tag fixed on the back of the individual.

We proposed a second approach to estimate the density estimation. This new approach is based on Poisson process with 2 parameters: one spatial that deals with the density of whales in an area and the other one temporal which measures the intensity of sounds detected by a unitary whale in an interval of time (Prieto Gonzalez *et al.*, 2010). Contrary to the first method, we do not need the range of the source, but we need the time of the detected calls.

Other a priori information could be used to reach this goal: individual information (especially estimation of the sperm whale individual length) and estimation of localizations (if the individuals

are enough far away from each other). These methods will be used to estimate the Pm density in West and East of the Ligurian Sea.

References:

Marques, T. A., and L. Thomas (2009). Estimating cetacean population density using fixed passive acoustic sensors: An example with Blainville's beaked whales. *J. Acoust. Soc. Am.*, 125(4): 1982-1994.

Marques, T. A., L. Munger, L. Thomas, S. Wiggins and J.A. Hilderbrand (2011). Estimating North Pacific right whale *Eubalaena japonica* using passive acoustic cue. *Andandered species research*, 13: 163-172.

Prieto Gonzalez, R., M.C. Valsero Balnco, F. Samaran, and O. Adam (2010). Comparacion de métodos de estimacion de poblacion de Ballena Azul del océano Antartico mediante un modelo espacio-temporal de Poisson, *Revista del XXXII Congreso Nacional de Estadistica e Investigacion Operativa, SEIO 2010*. Orbigraf, s.l. ISBN: 978-84-693-6152-8, 11 pages

Prieto González, R., M. C. Valsero Blanco, F. Samaran, and O. Adam (2011). Estimate the density of Antarctic blue Whales (*Balaenoptera musculus intermedia*) using their calls. *Fifth International Workshop on Detection, Classification, Localization and Density Estimation of Marine Mammals using Passive Acoustics*, Oregon, USA

Valsero, M. C., R. Prieto Gonzalez, F. Samaran, and O. Adam (2010). A spatio-temporal Poisson model to estimate the density of the Antarctic blue whales in the Austral Ocean, *International Workshop on Applied Probability*, Espagne

4.5 -Task 5 : Synthesis

Combination of results obtained from acoustic observations in different areas are useful to provide relevant information on sperm whale population and in a larger goal about cetacean presence. Acoustic recordings are a complementary method to observe cetacean species, and sometimes are the only possible approach, especially during winter season and/or when areas are difficult to reach and/or when 24/7 observations are required. In the Ligurian Sea, knowledge on sperm whale population is still needed, especially because we are weak information about their resident status in the Occidental Mediterranean Sea.

We need more details about their population, especially if the size is stable, increasing or decreasing. These results are important from biological point of view, but also to estimate the potential impact of anthropogenic activities on this cetacean population, especially because some sperm whale individuals are present close to overpopulated coasts with strong professional marine activities.

We would like to place this project not only for a one year shot but in a long term study. This project would be the link with Boussole projects that the new one will be started in 2016.

Moreover, all the results could be used in comparison with conclusions from projects about resident sperm whale in other Oceans. Our Teams are in contact with other Teams working in the French West Islands, and we will be able to provide some comparisons with the sperm whale of the AGOA Sanctuary.

5 -Details: (projections, use of existing data, missions)

We did run already some processes on the ANTARES data set 2012, during the DECAN Pelagos project, and we'll use these processes for the tuning of the runs on 2014 data. We did also have a dataset of 1 year and a half of record of Pm and Bp from Boussole Pelagos project we had in 2009. These data will help us also to get some density of population in the area.

Then we will record a full year the ANTARES data (250 kHz x 12 hydrophones x 24 bits), and Bombyx (48 kHz x 16 bits). We will set ODAS with the same equipment, for continuous recordings (with expected 15% of maintenance time) from March 2014 to 2015 too.

6 - Logistics, Material, Statistics

6.1- Meso computer

This project will be managed on the UTLN meso computer, 12000 GPU resources, 52 processors, over 256 GB RAM and 80 TB of storage), and external web applications with our common <http://sabiod.org> website (paid and installed, 50 K€).

6.2 - ANTARES

Most oceanographic instruments on the seafloor are not connected with the surface: they have to run on batteries and store data locally. Scientists have access to their data after the recovery of the instrument.

Cabled observatories like ANTARES, or MARS (Monterey Bay, USA) or NEPTUNE Canada (West Coast of Vancouver, Canada), remove these restrictions in providing not only electrical power and real-time data acquisition but also the possibility for scientists to interact directly with their sensors. They can control and monitor them in reaction to the observation of peculiar events. New opportunities are also given to marine sciences and geosciences: listening to mammals, bioluminescent organism observation, global change studies and its consequence on marine circulation and biodiversity.

6.3 - BOMBYX BUOY

BOMBYX has been deployed in 2012-13 by LSIS UTLN in the South of Port-Cros, and is an excellent complement to ANTARES recordings. It is composed of a simple tube with 3 weeks of autonomous recording with CR55 hydrophone, 48 kHz. A version with 500 kHz hydrophone and recordings is currently done. We have the support of PNPC with diver rotations that could dive every two months for extensive recording periods.

6.4 - ODAS BUOY

The W1-M3A off-shore observing system operates in the Ligurian basin at the centre of the Gulf of Genoa, 70 km far from the coast on a 1200 m deep seabed. It is based on an existing large spar buoy called “ODAS Italia 1” and it was partially set-up and upgraded during previous European projects (MFSTEP and MERSEA). Its naval design (e.g. total mass, unity buoyancy at sea level, and presence of a large damping disk) makes it a stable platform with negligible sensitivity to sea heave and height. The mooring position is at the crossroads of different commercial routes from Genoa to the South and the Islands and the routes crossing the Ligurian-Provencal basin from Spain and France to the Italian Riviera and Tuscany. Our recording equipment may be upgraded with solar panel for this station.

6.5 - Human resources

The academic permanent researchers will be involved in the project at different research time ratio:

- + Pr H. Glotin, 40% research time, equivalent to 28 k€ (paid by UTLN)
- + MC J. Razik, 20% research time, equivalent to 12 k€ (paid by UTLN), expert in sequence analysis
- + MC S. Paris, 20% research time, equivalent to 12 k€ (paid by AMU), expert in tracking
- + MC Chamroukhi, 20% research time, equivalent to 10 k€ (paid by UTLN), expert in + statistics
- + PRAG P. Giraudet 20% research time, equivalent to 12 k€ (paid by UTLN), bioacoustics of Pm.
- + Gianni Pavan 15%, cost paid by CIBRA = 9k€
- + O. Adam 20%, cost paid by Paris 6= 14k€

Thus the total of permanent salaries is near 94k€.

An engineer working all the time in this project is required, that is why we specifically require 40K€ from Pelagos to pay him/her.

6.6 - Schedule

The project will start end March 2014, until end March 2015.

The first step (March-May 2014) will consist in the deployment of the ODAS buoy, with similar material of the BOMBYX acoustic station. The standardisation of the hydrophone (CR55), that are the same than the Port-Cros equipment, will allow comparative studies between the three sites. All the recordings will run from May to September 2014. We will process in real-time the ANTARES data, and off line the others. From October to January, we will compute cross analysis over the three recording datasets. February 2015 will be dedicated to discussion with the other projects on noise effects.

7 -BUDGET

The permanent salaries are already paid (cf section 6)
BOMBYX is already equiped (25 k€ in total invested in 2013 and 2014).
CIBRA can also add 15k€ in instruments (hydrophones and recorders).

Required budget =

9k€ = for ODAS we need 6k€ for a recording buoy from Wildlife acoustics, and 3k€ for deploy/recover 6 times a year. For the same price the Wildlife buoy could be replaced by and hydrophone + cable + waterproof case with recorder and maybe a battery with solar panel.

40 k€ = as described we require 10 months of eng. CDD.

5 k€ = we need kK€ of mission, publication and managing.

The total required is 54 K€.

Selected (recent) citations related to the target species (we do not list the Pavan's nor Adam's previously cited ref).

ACL – International journal

XC Halkias, S Paris, H Glotin, "Classification of mysticete sounds using machine learning techniques", The Journal of the Acoustical Society of America 134 (5), 3496-3505

S Paris, Y Doh, H Glotin, X Halkias, J Razik, "Physeter catodon localization by sparse coding", arXiv preprint arXiv:1306.3058, 2013, similar content in ICML4B /NIPS4B proceedings

H Glotin, J Razik, S Paris, X Halkias, "Sparse coding for large scale bioacoustic similarity function improved by multiscale scattering", Proceedings of Meetings on Acoustics 19, 010015, 2013

H Glotin, J Sueur, T Artières, O Adam, J Razik, "Sparse coding for scaled bioacoustics: From Humpback whale songs evolution to forest soundscape analyses.", The Journal of the Acoustical Society of America 133 (5), 3311-3311, 2013

S. Mazzariol, ... G. Pavan, ..., 'Sometimes Sperm Whales (*Physeter macrocephalus*) Cannot Find Their Way Back to the High Seas: A Multidisciplinary Study on a Mass Stranding.', PLoS ONE . 2011, Vol. 6 Issue 5, p1-17. 17p

F. BENARD, GLOTIN H., GIRAUDET P., "Sperm whale localization with the astrophysic NEMO ONDE short-baseline platform" in Internat. Journal of Applied Acoustics, nov 2010, 16p

F. BENARD, GLOTIN H., "Automatic Indexing for Content Analysis of Whale Recordings and XML Representation," EURASIP Journal on Advances in Signal Processing, vol. 2010, Article ID 695017, 8 pages, 2010. doi:10.1155/2010/695017. Special Issue, Advances in Signal Processing for Maritime Applications, Ed.: Ehlers NATO Undersea Research Center <http://www.hindawi.com/journals/asp/2010/695017.html>

F. Pace, Benard, H. Glotin, Adam O., White P. "Automatic clustering of humpback whale songs for subunits sequence analyses" in Internat. Journal of Applied Acoustics, nov 2010, 19 pages

H. Glotin, F. Caudal, P. Giraudet, "Whales cocktail party: a real-time tracking of multiple whales", in International Journal Canadian Acoustics, Vol. 36, pp. 139-145 Mar 2008 ISSN 0711-6659

P. Giraudet, H. Glotin, "Real-time 3D tracking of whales by precise and echo-robust TDOAs of clicks extracted from 5 bottom-mounted hydrophones records of the AUTECH", Applied Acoustics, Vol. 67, pp. 1106-1117 2006 11-12, 5Y Impact Factor : 0.93

G. Pavan, Marco Priano, Michele Manghi and Claudio Fossati, 'Analysis of long clicking sequences of sperm whales *Physeter macrocephalus*', Journal bioacoustics, 1997

Conferences

R. Abeille, Pascale Giraudet, Hervé Glotin, "Precise Inter-Pulse-Interval estimation in the biosonar of *Physeter Catodon*, application to population survey", in int. Conference IEEE OCOSS 2013

F. BENARD - Hervé Glotin - Castellote Manolo. - Laran Sophie. - Lammers Marc., "Passive acoustic monitoring in the Ligurian Sea", "4th International Workshop on Detection, Classification and Localization of Marine Mammals using Passive Acoustics" 2009

F. BENARD- Hervé GLOTIN - Sébastien PARIS "Physeter catodon clicks train rebinding using HMM" , Navy Research ONR & CIBRA, 4th International Workshop on Detection, Classification and Localization of Marine Mammals using Passive Acoustics, sep 2009

F. BENARD - Hervé Glotin, "Sperm whales records indexation using passive acoustics localization", IEEE Content Based MI 2009, 6p, ISBN 978-0-7695-3662-0, Jui 2009

O. Adam, Hervé Glotin, "Passive acoustic storey of the ANTARES neutrino detector for real-time cetaceans detection, localization and behavior studies" , PASSIVE'08 IEEE explorer online access, 6p Oct 2008

F. Caudal, Hervé Glotin, "Stochastic Matched Filter Outperforms Teager-Kaiser-Mallat for Tracking a Plurality of sperm whales" , PASSIVE 08 IEEE explorer online access, 9p Oct 2008

F. Caudal, Hervé Glotin, "High Level Automatic Structuration of Ocean Passive Data : from click sequence modulations to whale behavior" , Int Workshop PASSIVE 08 IEEE explorer online access, 7p Oct 2008

F. Caudal - Hervé Glotin, "Accuracy analyses of passive tracking of several Clicking Sperm Whales : A case of complex sources binding", "International Conference on Signal Processing and Multimedia Applications", pp. 8p, ISBN: 978--989-8111--62-3 Jui 2008

F.Caudal - Hervé Glotin, "Multiple real-time 3D tracking of simultaneous clicking whales using hydrophone array and linear sound speed profile" , "ICASSP IEEE", 4p Mar 2008

F. Lelandais- Hervé Glotin, "Mallat's Matching Pursuit of Sperm Whale Clicks in Real-Time using Daubechies 15 wavelets" , "PASSIVE'08", IEEE explorer online access, 5p Oct 2008

P. Giraudet - Hervé Glotin, "Echo-Robust and Real-Time 3D Tracking of Marine-Mammals using their Transient Calls recorded by Hydrophones Array", IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP), Vol. IV, pp. 1161-1164 Mai 2006

OS - Ouvrages scientifiques (ou chapitres de ces ouvrages)

F. BENARD - GLOTIN H. Highly defined whale group tracking by passive acoustic Stochastic Matched Filter", Intech Book, ADVANCES IN SOUND LOCALIZATION, www.intechopen.com, SBN 978-953-307-224-1, 23p

Collectif GIS3M (incl. Glotin et Bénard), Bilan du programme scientifique BOUSSOLE du GIS dans PELAGOS 2008-2010, Ed. Parc National de Port Cros, 120 pages, mars 2010.

H. Glotin et al., Advanced cetacean tracking. in "Detection Classification and Localization of Marine Mammals using passive acoustics. 2003-2013: 10 years of international research.", Adam O., Samaran F. (editors), 2013. DIRAC NGO (Paris, France): 1-298. ISBN 978-2-7466-6118-9.

ACTN - Communications avec actes dans un congrès national

S. Laran, M. Castellote, H. Glotin, F. Benard, M. Lamers, "Comparaison de trois méthodes d'échantillonnage", Actes du 11ème Séminaire du Réseau National Echouages, Nov 2009

S. Laran, Castellotte M.,H. Glotin,F. Caudal - Lammers M., "PROGRAMMES DE MONITORING DES CETACES DANS LESANCTUAIRE PELAGOS: suivi acoustique des populations de cétacés en Mer Ligure", 10ème Séminaire du Réseau National Echouages, Stratégies de suivi de l'état des populations de mammifères marins, 5p, 2008

ACLN - Autres articles en revue avec comité de lecture non répertoriée à l'international

H. Glotin, Giraudet, Bénard, « Les chercheurs Toulonnais traquent les cétacés dans Pelagos », Var Matin, Juillet 2009, p2-3.

AP - Patent, TV talk

SABIOD project for Pelagos cetacean sanctuary on Thalassa (France 3 04/12/2013) YouTube: <http://www.youtube.com/watch?v=INt3-SRE1ik>

SABIOD project for Pelagos cetacean sanctuary (excerpt from France 3 March 2013) shown in february 2013 at Oceanographic Museum of Monaco. <http://www.youtube.com/watch?v=BSvn1gVDWng>

H. Glotin, P. Giraudet, F. Benard, "Procédé de trajectographie en temps réel sur ordinateur portable, de plusieurs cétacés par acoustique passive", dépôt à L'institut National de la Propriété Intellectuelle, INPI N° 2007/06162. Cette demande de brevet a ensuite fait l'objet d'extensions en Europe (N° 08852320.4), Etats-Unis (N°12/676,055 Acceptée), Nouvelle-Zélande (N°584428), Canada (N°2,697,864) et Australie (N°20080327744).



Centre de Physique des Particules de Marseille
163, Avenue de Luminy – Case 902 – 13288 Marseille Cedex 9
Tél. : (33) 04 91 82 72 00 – Fax : (33) 04 91 82 72 99
<http://marwww.in2p3.fr>

Marseille, 29 January, 2014

Dear Prof. Glotin,

I am very happy to inform you that the request of your group at the University of Toulon-Sud (Dyny UTLN LSIS CNRS) to join the ANTARES Collaboration as a full collaborator has been unanimously accepted by the ANTARES Institute Board. This will allow you full access to all ANTARES data, and in particular that from the acoustic hydrophones.

So welcome to ANTARES and I look forward to a fruitful collaboration in the future.

Yours sincerely,

Dr. Paschal Coyle
(Director of Research-CNRS, ANTARES Spokesperson, KM3NeT Deputy Spokesperson)