A proposal for studying tuna behavior at floating objects in the Indian Ocean: from individuals to aggregations

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Preamble

This is a proposal for studying tuna behavior at drifting floating objects in the Indian Ocean. This is a first step to enhance reactions from the scientific community in order to improve the project. No contact has been developed yet with the partners of this project, neither with the SFA (RV L'Amitié) nor with French purse seiners, as we consider that it is first better to get the reaction of the scientific community. This document exposes the basic ideas of this proposal.

Background

The aggregation behavior of tunas plays a major role in tuna fisheries. Fishermen have known for many years that tunas and other pelagic animals aggregate in several different ways. Purse-seine fisheries utilize drifting natural flotsam (commonly tree parts) and artificial fish-aggregating devices (FADs) to locate and catch tunas. These aggregations typically comprise small, often immature tunas (yellowfin, skipjack, bigeye, and *Auxis* spp.), and also sharks, rays, billfishes, dolphinfishes, wahoo, sea turtles, triggerfishes, and others, which are usually not retained and landed. In 1999 in the Indian Ocean, 75% of the catch of the three main species of tunas (yellowfin, skipjack, bigeye tuna) were done on associated fish.

This striking aggregative behavior modifies the classic methods of fisheries management and necessitates new definitions of fishing effort, catchability, and stock assessment models.

Most of our current knowledge about these aggregations is from fisheries data. Studies of the behavior of tunas near anchored, man-made floating objects have been conducted in coastal areas (Holland et *aL,* 1990; Cayré, 1991; Bach et al*.,* 1998; Josse et *al.,* 1998; Marsac and Cayré, 1998; Brill *et al.,* 1999; Dagorn *et al.,* 2000; Josse et al*.,* 2000), but not on tunas near drifting floating objects in offshore areas. Since most of the world catch of tunas is comprised of fish associated with drifting logs or FADs, there is a clear need to undertake research on tunas associated to these drifting floating objects. This would provide a better understanding of the dynamics of aggregation behavior, which in turn would permit better stock assessment and fishery management. The mechanisms of fish aggregation and association and a detailed understanding of the biological processes involved will contribute to estimating the effects of different densities of FADs on tuna behavior and to deriving meaningful indices of abundance for assessing the level of exploitation of the stock.

The reasons that pelagic fishes aggregate around floating objects are still not known. Seventeen hypotheses have been proposed in the literature to explain the associative behavior of pelagic fishes (Fréon and Dagorn, 2001). Among those hypotheses, Fréon and Dagorn specified the following as the most likely to explain the association between tunas and floating objects: the meeting-point hypothesis (which has been generalized by the authors to all types of aggregations), the indicator-log hypothesis, and the concentration-of-food-supply hypothesis. The meeting-point hypothesis concerns only schooling species (Dagorn and Fréon, 1999), while the concentration-of-food-supply hypothesis might apply mainly to non-schooling species. It is possible that not all the species "utilize" floating objects in the same way (see section "Comparative study of the aggregation behavior; solitary, semi-social and social species"). If true, a unique and general fishery management action might have different consequences on the individuals (different sizes, different species) that aggregate around floating objects.

This project will provide data on the processes leading to aggregations around floating objects, as well as the residence time, and effects of physical and biological variables on these for key species. This project is in accord with the FAO Code of Conduct for Responsible Fisheries (FAO 1995): "*Research into the use of (artificial) structures, including the impacts on living marine resources and the environment should be promoted. States should carry out studies on the selectivity of fishing gear, the environmental impact of fishing gear on target species and on the behaviour of target and non-target species in relation to such fishing gear as an aid for management decisions and with a view to minimizing non-utilized catches as well as safeguarding the biodiversity of ecosystems and the aquatic habitat*."

Our general approach is to study the aggregation behavior of tunas (and other pelagic fishes) at the individual level and at the aggregation level (*in situ* observations), and to link these two scales by creating appropriate models of behavior.

Objectives

The objectives of this project are to study the aggregation mechanisms through different scientific operations:

- study of individual tuna movements in a network of drifting FADs ;
- study of the flows, temporal and spatial dynamics of individuals and schools around a floating object, and in a network of FADs ;
- modeling of the aggregation processes.

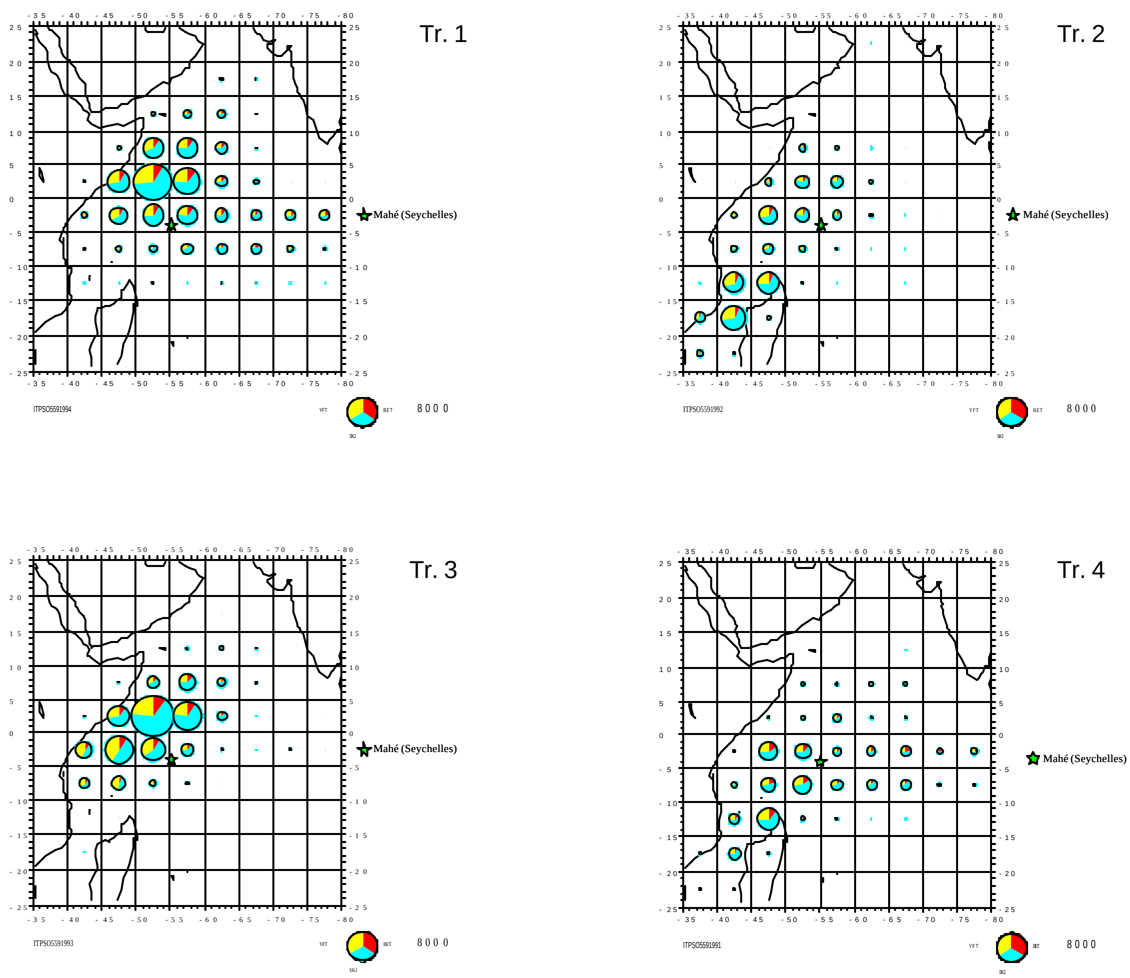
The main studied species will be yellowfin (*Thunnus albacares*) and bigeye tuna (*T. obesus*). Besides understanding the aggregation dynamics, this project will test the meeting point hypothesis. If members of an aggregation arrive at a floating object as solitary animals or in small schools, and if they leave the object in large schools (larger than the arriving schools), it will then be possible to determine if tunas use floating objects to increase the size of their schools.

Logistics: definition of the studied area, research vessels

Studied area: Seychelles

One of the major difficulties in behavioral studies on pelagic animals is the research and identification of good conditions for behavior observations. In order to optimize data collection, the idea is to reduce the searching effort and transit time between harbors and experimental areas. Three drifting floating objects zones have been identified in the Indian Ocean: Somalia, Seychelles, Mozambic channel (see maps below). Considering these areas, the available vessels and possible harbors for conducting the scientific operations, the Seychelles zone seems to be the most appropriate area for developping the scientific observations. The vessel “L’Amitié” of the SFA would be adapted for conducting these operations[1].

Mean catch per trimester (1991-1999) of the three main tuna species (skipjack, yellowfin, bigeye) caught under floating objects.



[1] No contact has yet been made with the RV L’Amitié

Seasons

While floating objects can be found whenever during the year, there are more chances to find them during the summer (October-March), a period during which purse-seiners exploit associated fish in this area. We will therefore favor this period of the year for conducting the scientific *in situ* observations.

Identification of favorable zones

In this project, some French purse-seiners could represent the observers looking for favorable areas[2]. During transits or fishing operations, some purse-seiners could inform the scientific team (based in Victoria, Seychelles) of the presence of good densities of tunas and floating objects. Once informed, the scientific team can reach the identified zone with the RV L'Amitié.

Scientific operations

Ultrasonic telemetry

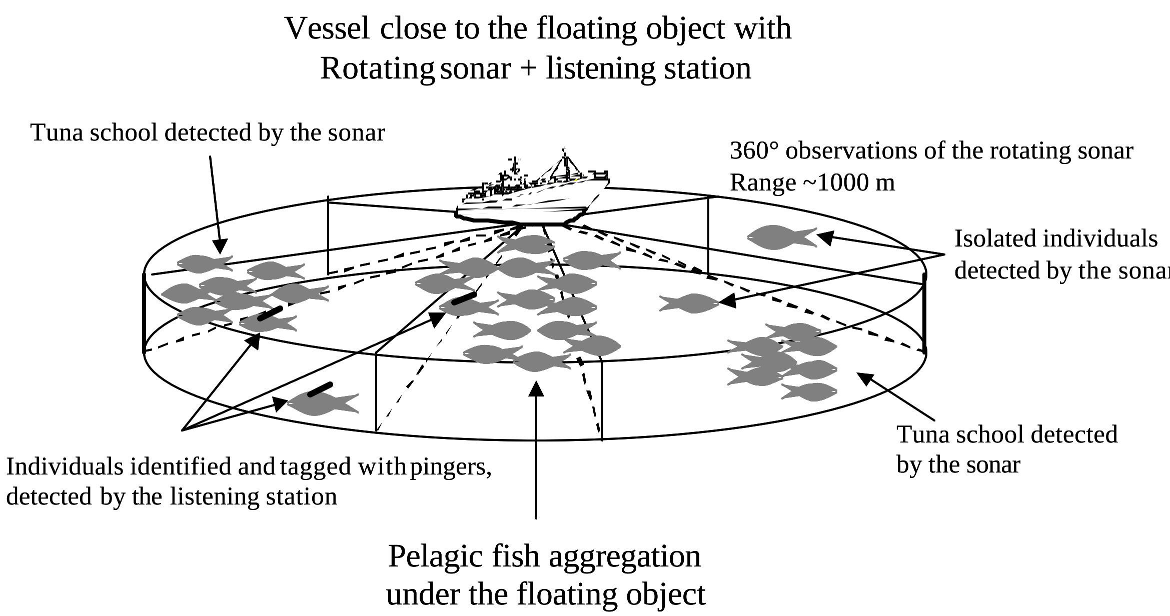
The objective is to track some individuals in a network of driftring floating objects. The drifting floating objects should first be identified and localized and each floating object will be equipped with a GPS to record its exact positions. Fine-scale horizontal and vertical movements of fish in such network will be collected. Results on vertical movements can be used by the UR THETIS of IRD for a movement model integrating vertical and horizontal movements.
The hydrological (temperature, dissolved oxygen) and biological (prey) local environment will be observed simultaneous to tracking. The sound environment could also be recorded, if possible[3].
Different densities of floating objects will be studied. Artificial floating objects can be released by the scientific team during operations in order to examine the effects of new FADs, particular FAD densities or particular spacing between FADs on tuna movements.

Qualitative and quantitative estimates of individual and collective flows around a floating object

The operation will consist to use, for the first time, two complementary tools: sonar and listening station. Those tools will be put onboard the vessel, which will position close to a floating object with a tuna aggregation. The main objectives of these operations are to record time residency of individuals at drifting floating objects and to characterize the aggregation dynamics of individuals and schools.
During the observations, the vessel will drift with the floating object. Some individuals will be caught, identified (species, size), tagged with pingers, and released. The listening station onboard the vessel will detect the presence of those tagged fish when they will be in the detected range around the vessel (around 1000 m). If other floating objects are present in the area (within a radius of 5 nmi), they will be equipped with GPS and listening stations in order to record possible movements between close floating objects (the equipment will be gotten back at the end of each operation).

[2] No contact has yet been made with purse-seiners.
[3] Preliminary experiments will be made in Hawaii to test the faisability and usefulness of recording and identifying sounds produced around floatign objects. Depending on the success of these experiments, this parameter will be recorded during the present experiments.

A rotating sonar onboard the vessel will simultaneously record in-and-out movements of individuals and schools. First, the size of the aggregation will be estimated using a scientific echo-sounder, in order to get the characteristics of the starting conditions, before recording the in-and-out movements. This second method will allow to statistically estimate the number of fish present around the floating object and the individuals and schools movements, but without being able to identify the species nor the size. Coupling these two methods (sonar and listening station) will provide fine-scale information on identified individuals and continuous dynamics of the aggregation. Such experiments should last 2 to 7 days with continuous records by the listening station and the sonar. Local environmental conditions will be regurlaly collected. The following graph describes this protocol.



After some experiments, and in agreement with purse seiners, a sample of the aggregation could be made by purse seiners, seining on the aggregation. Such sample will provide information on the species and size composition of the aggregation, as on the stomach content of some individuals of the aggregation. The stomach content analyses will help us determine the feeding status of aggregated fish and relate these results with the "short" history of aggregated fish (aggregation dynamics). This operation will be done in collaboration with the IRD UR THETIS.
These operations will be conducted with different densities of drifting floating objects. Like in the tracking operations, new FADs can be released by the scientific team in order to examine the effects of new FADs and particular spacings between FADs on aggregation dynamics.

<u>Detection of floating objects by satellites</u>

The exhaustive identification and positionning of floating objects in an area is important in order to precisely control all the aggregative points in the studied area.

This work will be done with the IRD Unit of Service (US) ESPACE. A pilot experiment will first be conducted, to test the faisability of the technique. Truth data will be provided by the scientific team in charge of the *in situ* data (see sections above). According to the success of this pilot experiment, some precise data on positions of floating objects will be collected during experiments on tuna behavior to exhaustively identify the floating objects of the area.

Expected results

- Characterization and typology of individual movements in a network of drifting floating objects ;
- Determinism of fine-scale individual movements: role of the local environment (physical, biological, density of floating objects), feeding behavior ;
- Estimate of the range of influence of a drifting floating object ;
- Time residency of individuals and schools around drifting floating objects; role of the local environment of the time residency ;
- Rhythms of arrivals and departures; role of the local environment on these rhythms ;
- Effects of different densities of floating objects on tuna behavior ;
- Static (spatial organization of schools around the floating object, position regarding the floating object) and dynamic (favored areas for arrivals and departures) spatial analyses;
- Detection of floating objects by satellites;
- Modeling the aggregation processes;
- Tests of the Meeting Point Hypothesis.

Comparative study of the aggregation behavior; solitary, semi-social and social species

The meeting-point hypothesis concerns only schooling species (Dagorn and Fréon, 1999), while the concentration-of-food-supply hypothesis might apply to non-schooling species, and the generic-log hypothesis can apply to either social or non social species. It is possible that not all the species “utilize” floating objects in the same way, leading to different ecological consequences of fisheries actions. It is necessary, therefore, to study schooling species and non-schooling species to better understand these multispecies aggregations. Studying the eco-ethology of such aggregations is of key importance if we want to estimate the impact of this fishery on the pelagic fauna. We propose a PhD thesis dedicated to the comparison of the behavior of different species around floating objects, that could be: tuna (social species), dolphinfish (semi-social species), sharks (solitary species)[4]. The protocols will be the same than those exposed previoulsy for tuna species. Some ultrasonic telemetry experiments will be done on these species to identify the fine-scale movements in a network of drifting floating objects. The aggregation dynamics will be observed using the sonar and listening stations, simultaneoulsy to the tuna observations. This comparison study will necessitate some specific tracking operations, but the study of the aggregation dynamics (sonar and listening stations)

[4] The species will be fixed later after analyses of by-catches.

will only necessitates the capture and tagging of the studied species, as the observations will be similar and simultaneous to the tuna observations.

Time residency, frequency of in-and-out movements, fidelity to FADs, relations to the aggregation dynamics (size of the aggregation, movements of other species) and stomach content analyses will be compared for each studied species. This PhD thesis will provide key information on the behavioral ecology of the associated species.

Planning

Before Feb 2002
Meetings with the SFA and French puirse seiners to define the possibilities of cooperation.
Look for funds.

Feb – June 2002
Definition of the terms of reference for the construction and adaptation of the rotating sonar. This system does not exist and should be adapted from existing tools in order to:

- Observe individuals and schools of large pelagics (Target Strength identification);
- Define a rotating system to observe in a few minutes a disk surrounding the floating object (minimum radius: 500 m);

During this period, the frequency, data transfer mode, graph representation, softwares should be defined. A suty should be dedicated to the identifcation of the targets according to different angles.
This step should be done as soon as the budget is accepted. It does not need the budget to be conducted.

July – Sept 2002
Tests of the rotating sonar

Oct 2002 – March 2003
Data collection in Seychelles (1st season): ultrasonic telemetry and pilot project with the rotating sonar and the listening stations.

April – Sept 2003
Data analyses

Oct 2003 – March 2004
Data collection in Seychelles (2nd season): ultrasonic telemetry and sonar+listening station

April – Sept 2004
Data analyses

Oct 2004 – July 2005
Reports and scientific papers

Potential staff[5]

Principal investigators :

Laurent Dagorn	France	IRD - UR ACTIVE

Development of the rotating sonar (Feb 2002 – Dec 2002)

Erwan Josse	France	IRD – US ACOUSTIQUE
Arnaud Bertrand	France	IRD – UR ACTIVE

Data collection and data analyses (Oct 2002 – Mars 2003 et Oct 2003 – Mars 2004)

Behavior

Kim Holland	U.K.	University Of Hawaiio
Rich Brill	U.S.A.	NMFS Honolulu
Assistant[6]	to be paid by the project	
PhD student [7]	to be paid by the project	
X	Seychelles	
Y[8]	France	IFREMER

Acoustic environment

Miguel Pol	France	ERA Miguel Pol, Nouméa

Stomach content analyses

Frédéric Ménard	France	IRD – UR THETIS
Michel Potier	France	IRD – UR THETIS
X	Seychelles	SFA

Satellite data

Michel Petit	France	IRD - US ESPACE
Antonio Ramos	Espagne	Univ. Las Palmas GC

Modeling the aggregation processes, spatial analyses (April 2004 – July 2005)

Guy Theraulaz	France	Univ. de Toulouse
Stéphane Blanco	France	Univ. De Toulouse
Richard Fournier	France	Univ. de Toulouse
J.-L. Deneubourg	Belgique	Univ. Libre de Belgique
Nicolas Bez	France	ENS Mines de Paris

[5] The X persons have not been identified or contacted yet.
[6] The assistant (2 years) will be in charge of the data collection and data analyses of the rotating sonar.
[7] PhD student on the comparison of the behavior of pelagic species around FADs (3 years).
[8] Marc Taquet (IFREMER) could be a member of this team. He is conducting a PhD thesis on dolphinfish in La Réunion and collaborations should be developed for this project. No official contact has been fixed yet, but preliminary exchanges are in favor of such collaboration.

Budget (in €)

Total 450 000 €

Material

VEMCO ultrasonic telemetry system (4 hydrophones)	13000
Sonic tags	10000
Listening stations (10)	20000
Pingers	12000
GPS (10)	5000
Rotating sonar	100000
Laptops (3)	10000
Total	**170000**

Vessels

Rent vessel for data collection (2 seasons of 50 days at sea)	50000
Total	**50000**

Personnel and analyses

Assistant, 2 years (rotating sonar data)	60000
Grant for a PhD student, 3 years (comparative study of the aggregation behavior in different species)	50000
Observations of the acoustic environment (ERA Miguel Pol)	40000
Geostatistics data analyses (E.N.S. Mines de Paris)	25000
Satellite data	30000
Trips, conferences	25000
Total	**230000**

Budget per year

year 1 (July 2002-June 2003)	270000
year 2 (July 2003-June 2004)	127000
year 3 (July 2004-June 2005)	53000

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