Activity Plan - Postdoc

1. **Title of project:** *Relationship between the phytoplankton diversity and light availability, a case study for Amazon "whitewater" rivers and lakes*.

2. **Researcher Responsible:** Evlyn Márcia Leão de Moraes Novo

3. **Institution:** National Institute of Space Research

4. **Summary:** To assess the impact of water transparency (Kd and secchi) on space-time phytoplankton biodiversity in the Amazon floodplain, the Postdoc candidate will carry out a study in three previously selected areas of the Amazon floodplain. Initially, the Posdoc will organize the available data set, comprised of optical (Kd and Rrs), limnological (Chl-a, turbidity, secchi) and phytoplankton taxonomies, collected over the last decade, additionally, the candidate will carry out complementary in situ data. Then, using remote sensing satellite imagery the candidate will develop empirical and semi-analytical models to estimate chlorophyll-a concentration and water transparency. The development of models for identification of phytoplankton functional groups from the water transparency models will be the next step. As the final activity, the candidate will generate maps of chlorophyll, of light availability in the water column and of phytoplankton community for the Amazon floodplain on local and regional scale. The results of this study will be published as scientific articles and presentation in congresses.

5. **Description of objectives**:

   The selected candidate will work within a broad and interdisciplinary project involving researchers from national and international institutions. The work will be developed in the context of the larger project " Balancing *B*i*O*diversity Co*N*servation with *D*evelopment in Amazonian Wetland*S"* (BONDS)" and will contribute to achieving its objectives. The objective of this activity, within the BOND project, is to develop and calibrate a model, based on satellite images, to map the temporal space distribution of water transparency, chlorophyll a and phytoplankton groups predominant in the Amazon floodplain. The activities related to the objective listed above correspond to Task 1.2 of the BONDS proposal, contributing secondarily to the Tasks 2.1, 2.2 and 2.4 It is expected that the results of this study, which will be conducted by the selected Postdoc, will answer the following question: What is the impact of light availability, on the water column, in the predominant phytoplankton groups in the Amazon floodplain? To answer this question the following specific objectives will pursue by the candidate:

   a) Organize the in-situ dataset gathered by the Labisa team in the last decade and gathering additional in situ data;

   b) Carry out a survey of remote sensing optical images available which coincide with the dates of the previous in situ gathering and to perform the atmospheric correction of these images;

   c) Develop a water transparency model from these selected images;

d) Develop models for identification of phytoplankton functional groups from water transparency models;

e) Generate maps of light availability in the water column and the phytoplankton community for the Amazon floodplain;

f) Write scientific articles for dissemination of results in international journals

5.1. Workplan

5.2. Study sites

Three sites, within the BONDS project Study Region, were selected to investigate the relationship between the phytoplankton diversity and light availability: the Grande do Curuai floodplain (LGC), the Mamirauá Sustainable Development Reserve (RDSM) lakes and the medium Juruá Extractive Reserve (Médio Juruá RESEX) session of the Juruá river floodplain. The LGC is located near Óbidos and Santarém cities (2,25 ° S 55,33 ° W), 900 km upstream of the Atlantic Ocean. It has around 3,500 km² of flooded area, containing a complex system with 30 shallow, interconnected lakes. The RDSM was created by the state of Amazonas in 1996 and is one of the Brazilian units represented at the United Nations Ramsar Convention. It is located at the confluence of the Japurá and Solimões rivers (2,26 ° S 65,68 ° W), near the city of Tefé. This one has around 11,000 km ², containing more than 5000 lakes of up to 9 km ² of area. The Medium Juruá RESEX was created by the state of Amazonas in 1997 and is located along the middle stretch of the Juruá river, near the city of Caruaru (5,73 ° S 67,78 ° W). It has around 14,000 km² with 80 floodplain lakes. For the first site, transparency and taxonomy data are available, for the second optical measurements, limnologies and of taxonomy data are also available, and for the third site there are no in situ data.

Figure 1 Amazon basin, showing floodplains of Amazon river and major tributaries and focus sites in Brazil (1-Curuai; 2-Janauaca; 3-Jurua; 4-Leticia)

5.3. Methodology:

To assess the impact of light availability on the predominant phytoplankton groups in the Amazon floodplain lakes, the selected candidate should carry out the following steps (Figure 1): (i) organize the database, plan and gathering additional in situ data; ii) Develop a chlorophyll-a and water transparency models from remote sensing satellite images; iii) Develop models of phytoplankton functional groups from water transparency models; iv) Generate maps of chlorophyll-a, availability of light in the water column and phytoplankton community for the Amazon floodplain lakes from the models developed. The steps listed above are detailed below:

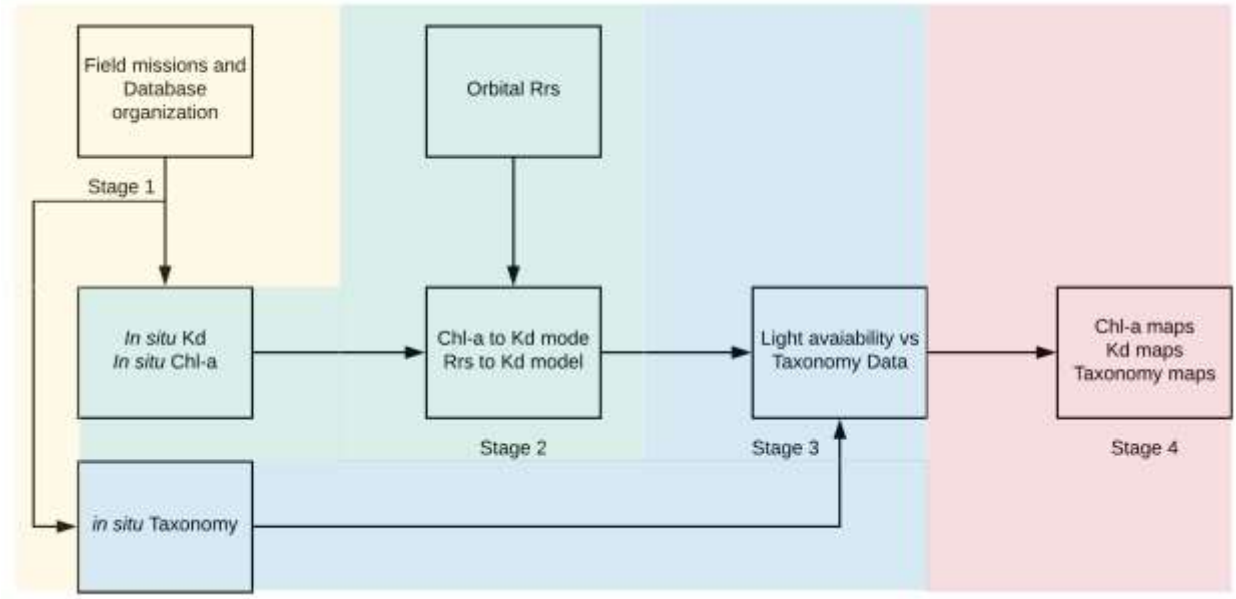

Figure 1- Methodology stages to be applied

i) To complete the in-situ database, which will be used to validate the models, additional in situ data will be gathered in the Curuai and Juruá floodplains and integrated to the data already available in the database. Optical (Kd and Rrs) measurements, limnological (Chl-a, turbidity, secchi) measurements and phytoplankton taxonomy (Micro and Nanoplankton) will be gathered. Each gathering mission will take 6 days. Additionally, the candidate should carry out a survey of available satellite images which coincide with the dates of the previous in situ gathers.

ii) To develop chlorophyll-a and water transparency models, the candidate will carry out the atmospheric correction of the images identified in the previous step, process the in-situ optical data, calibrate and validate the chlorophyll-a and transparency models available in the literature and evaluate which ones have better perform;

iii) To develop a phytoplankton functional group model from water transparency models, the candidate will carry out correlation analyzes between taxonomic data and transparency measurements both gathered in situ;

iv) To generate maps of chlorophyll-a, light availability in the water column and the phytoplankton community for the Amazon floodplain lakes, the candidate will carry out a survey of all available images of Sentinel-2/MSI and Sentinel-3/OLCI sensors, carry out the atmospheric correction of the images and to implement the three models developed, obtaining a historical series of maps of chlorophyll-a, water transparency and phytoplankton community for the plains of inundation.

5.4. Schedule of expected results:

The research activities will follow the following schedule.

Atividades	Year 1				Year 2			
	Trim 1	Trim 2	Trim 3	Trim 4	Trim 1	Trim 2	Trim 3	Trim 4
Organize the database, plan and gathering additional in situ data and process data	X	X	X	X				
Development of water transparency model from satellite optical images and in situ data			X	X				
Development of phytoplankton functional groups models from water transparency models					X	X		
Maps generation: chlorophyll-a, light availability in the water column, phytoplankton community							X	X
Dissemination of results in international journals							X	X

5.5 Justification for post-doc scholarship level

I am requesting a Post-Doc scholarship because the development of this research depends on a candidate with extensive experience in the field of Optical remote sensing and collaborative work with a large multidisciplinary team. The candidate must have a wide experience in planning and executing field missions, including the operation, calibration of a large suite of optical equipment and experience in processing the data. The candidate must have a wide experience on remote sensing and on the integration of in situ data to geophysical variables extract from images. The candidate must have also programming skills and strong statistical background. This project proposes innovation, so the candidate's experience and ability to work independently will be critical. Finally the candidate must have ability to effectively communicate with an interdisciplinary set of international collaborators and to communicate the results in competitive journals.

5.6 Justification for the plan for the objectives of the Post-Doc scholarship program

This project meets the objectives of the FAPESP program to temporarily incorporate a promising scientist early-career scientists who will contribute his/her knowledge of Remote Sensing to support studies on Fish Ecology and fisheries management in order to preserve the provision of ecosystem services to the riverine population. The candidate will have the opportunity to develop his research skills, collaborate with an international team of scientists from various disciplines and publish important research results.

Activity Plan - Postdoc

1. Title of project: Effects of hydrological connectivity on floodplain fisheries in Amazonia

2. Researcher Responsible: Evlyn Márcia Leão de Moraes Novo

3. Institution: National Institute of Space Research

4. Summary: The candidate will work to assess the effects of hydrological connectivity on floodplain fisheries of Amazonian whitewater rivers, under both current conditions and projections under climate change scenarios. The study area will be located on the middle Juruá River, Amazonas, Brazil. The candidate will collect fisheries and habitat data in the field and from the literature using a variety of methods. Using advanced statistical methods, the candidate will model fisheries catch in floodplains lakes as a function of hydrological connectivity and vegetation data, topography, water levels, depth and area of the lakes, among other variables. The candidate will collaborate in analyzing the effects of hydrologic connectivity on spatiotemporal patterns of fish, phytoplankton, and zooplankton diversity as characterized using environmental DNA metabarcoding (eDNA). The results will lead to the development of high-caliber scientific manuscripts for submission to international journals.

5. Description of objectives: The selected candidate will work within a broad and interdisciplinary project involving researchers from various international institutions (e.g., Dr. Leandro Castello, Virginia Tech). The work will contribute to achieving the objectives of a larger project, which is entitled "Balancing BiOdiversity Co-operation with Development in the Amazonian Wetlands" (BONDS). The objective is to develop biodiversity scenarios and ecosystem services scenarios for Amazonian whitewater floodplains. The listed objectives correspond primarily to Task 2.4 of the BONDS proposal, with secondary collaborative roles with Tasks 1.1, 2.2, 2.3, and 2.5. Specifically, the candidate will work to assess the effects of hydrological connectivity on the productivity of floodplain fisheries for a study area on the middle Juruá River. The candidate will pursue the following specific research objectives:

a) Collect fisheries data by local fishermen during a complete hydrological year;
b) In situ data acquisition supported by Geographic Information Systems, existing databases, and remote sensing products from the BONDS project to integrate data on vegetation, relief, water levels, depth and area of the lakes, adjoining floodplain, and connecting waterways.
c) Collaborate with project participants to integrate field data and remote sensing into GIS to map and quantify levels of hydrological connectivity in the study area.
d) Use statistical regression methods to model fisheries catch in floodplains lakes as a function of hydrological connectivity and vegetation data, topography, water levels, depth and area of the lakes, among other variables.
e) Use BONDS project hydroclimatic modeling products to assess the effects of future climate change on hydrologic connectivity and fisheries.
f) Develop scientific manuscripts for submission to high-ranking international journals.

6. Workplan

6.1. Methodology:

The study area (Figure 1) includes 80 floodplain lakes, within and downstream of two large contiguous reserves along the middle stretch of the Juruá River, the second largest tributary of the Amazon River (Campos-Silva & Peres 2016). The study landscape of approximately 14,000 km^2 contains two main forest types: 17.7% of seasonally flooded (floodplain) forest along the broad floodplain and 82.3% of terra firme forest that is not flooded. Wet and dry seasons coincide with periods of high- (January-June) and low floodplain water levels (August-November), with a prolonged flood pulse often exceeding 10m in amplitude. In this area, the Médio Juruá Extractive Reserve (Médio Juruá RESEX) is occupied by about 2000 people distributed in 23 villages. Also, there is the Uacari Sustainable Development Reserve (UDS), managed by the state of Amazonas, where about 1,200 people live in 32 villages (Campos-Silva & Peres 2016).

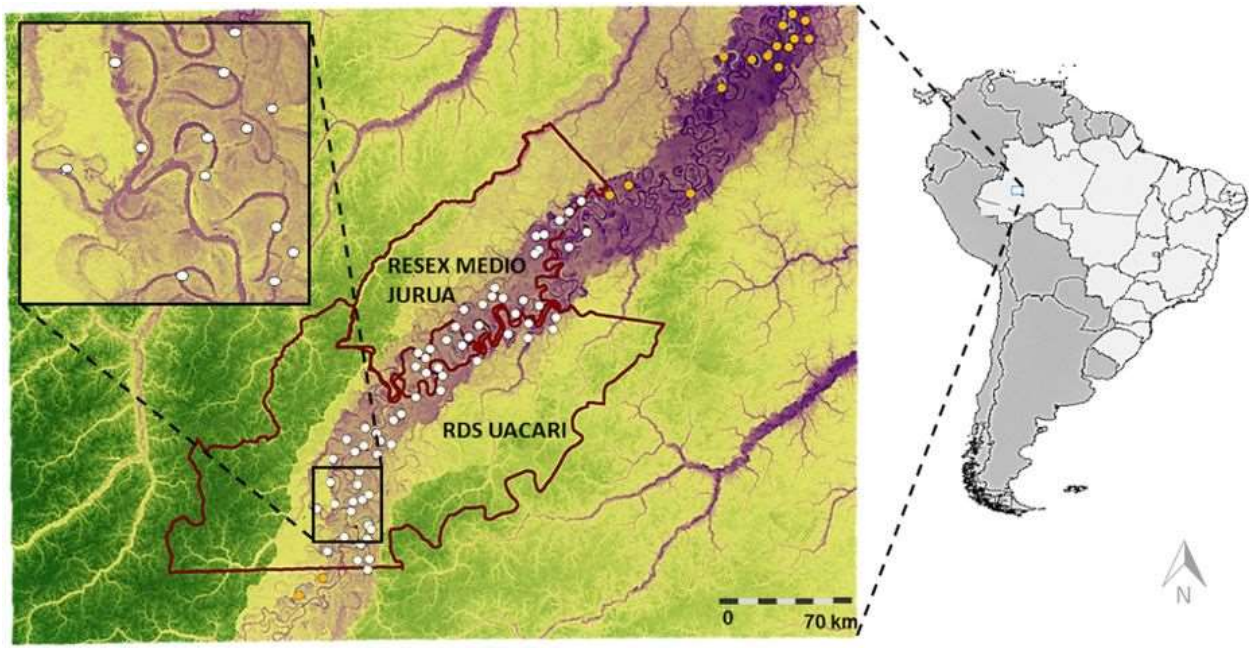

Figura 1. Area de estudo no Rio Juruá. (Figura adaptada de Campos-Silva & Peres 2016).

To assess how hydrological connectivity affects the fishery productivity of floodplain lakes, the selected candidate will: (i) develop a fishery data collection system, (ii) collect vegetation data, relief, and lake water levels, depth and area; (iii) map and quantify levels of hydrological connectivity in the study area; and (iv) model fishery productivity in lakes as a function of hydrological connectivity.

(a) In order to collect fishing data, the candidate will develop a system to carry out household interviews with fishers about their fishing activities. The data collected will include: fishing lake, weight of fish catch by species, number of fishers involved, time spent fishing, travel time to access lakes, gear, and habitat. It is estimated that about 10,000 interviews will be done.

(b) The candidate will collect field data on vegetation, relief, water levels, and lake morphometry, for entry into a GIS database, expanding the database previously compiled for a subset of the lakes by Campos-Silva (2016) under the umbrella of Projeto Médio Juruá (http://www.projetomediojurua.org/). Field activities will include data collection of

lake bathymetric profiles at maximum, minimum, rising, and falling water stages; water transparency estimated using a Secchi disk; conductivity measured in µS/cm using a conductivity meter; coverage of macrophytes, initially mapped in the field and then measured independently using satellite images. Vegetation data will be obtained from prior mapping (Hawes et al. 2012) and new mapping to be carried out by IRD as part of the BONDS project. Water-level data will be collected in situ and related to gauge data provided by the National Water Agency and "virtual gauge" data from satellite altimetry (provided by IRD). Relief data will be obtained from the NASADEM (reprocessed SRTM) dataset.

(c) To map and quantify levels of hydrological connectivity of the study area, the candidate will collaborate with project participants from IRD, UCSB, and F.S. Univ. Jena to integrate field observations with remote sensing data and hydrological modeling. Four types of hydrologic connectivity will be considered: lake-to-lake, via floodplain channels; lake to river, via floodplain channels; lake-to-floodplain, via floodplain inundation; and lake-to-upland, via upland streams. Primary satellite data sets will be contemporary Sentinel-1, Sentinel-2, Landsat OLI, and RapidEye, as well as historic ALOS PALSAR, Landsat, and RapidEye. Connectivity in terms of duration of connection will be evaluated for current and future climate conditions.

(d) In order to model fishery productivity of lakes according to their respective levels of hydrological connectivity, the candidate will use spatial analysis and/or regression techniques such as generalized linear regression models (GLM). Habitat variables will be "spatialized" before analysis. This approach will explain spatial autocorrelation without sacrificing degrees of freedom in subsequent models because of the need to include separate spatial variables. An Euclidean distance matrix of sample location coordinates (latitude and longitude) will be calculated. The distance matrix will be subjected to a coordinate analysis of neighborhood matrices (PCNM). This procedure will identify significant gradients in the spatial clustering of sampling sites by testing the significance in the spatial autocorrelation of Moran eigenvectors. All significant spatial eigenvectors with positive eigenvalues produced by the PCNM analysis will be retained and used as potential independent variables in multiple linear regression models to predict the effect of each habitat variable, including connectivity, on fishery productivity. The optimal model(s) for each habitat variable will be identified.

(e) The candidate will collaborate with BONDS teams for Tasks 1.1, 2.2, 2.3, and 2.5, in terms of providing ground truth for remote sensing analyses (1.1) and assessing effects of current and future hydrologic connectivity on fish movement (2.2), fish-fruit networks (2.3), and spatiotemporal patterns of fish, phytoplankton, and zooplankton (2.5).

(f) The results of the above analyses will be described in manuscripts and submitted for consideration for publication.

6.2. Schedule of expected results:

The primary research activities (Task 2.4) will follow the following schedule.

Tasks	Yr 1				Yr 2			
	Trim 1	Trim 2	Trim 3	Trim 4	Trim 1	Trim 2	Trim 3	Trim 4
Collect fisheries data	X	X	X	X				
Collect habitat data		X	X	X				

Map and integrate hydrological connectivity		X	X	X	X			
Model fisheries productivity					X	X	X	
Develop manuscripts for publication						X	X	X

6.3. Justification for post-doc scholarship level

I am requesting a Post-Doc scholarship because the development of this research depends on a candidate with extensive experience in the field of Fish Ecology that is able to collaboratively work with a large multidisciplinary team. The candidate must have a multidisciplinary profile and well-developed skills for fieldwork and quantitative analysis. This project proposes innovation, so the candidate's experience and ability to work independently will be critical. Not only should the candidate understand fishery and fish ecology in freshwater systems, but he/she should also integrate remote sensing, GIS, hydrology, and habitat data. The statistical integration of these data sets will be complex, and requires intellectual maturity and advanced data organization and modelling skills. Ability to effectively communicate with an interdisciplinary set of international collaborators is a must.

6.4. Justification for the plan for the objectives of the Post-Doc scholarship program

This project meets the objectives of the FAPESP program to temporarily incorporate promising early-career scientists who will contribute his/her knowledge of applied Fish Ecology to the project that the INPE team proposes. The candidate will have the opportunity to develop his/her research skills, collaborate with an international team of scientists from multiple disciplines, and publish important research fundings.

References:

Campos-Silva, J.V. (2016). Manejo participativo nas várzeas amazônicas e seus efeitos multi-tróficas. Tese de Doutorado, Universidade Federal do Rio Grande do Norte.

Campos-Silva, J. V., & Peres, C. A. (2016). Community-based management induces rapid recovery of a high-value tropical freshwater fishery. *Scientific reports*, *6*, 34745.

Hawes, J.E., Peres, C.A., Riley, L.B. and Hess, L.L. (2012). Landscape-scale variation in structure and biomass of Amazonian seasonally flooded and unflooded forests. Forest Ecology and Management, 281, 163-176.