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ACHOTINES LABORATORY: FUTURE DIRECTIONS

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1. INTRODUCTION

Since the cohort strength of nearly all marine fish species is determined during the egg, larval, or early-juvenile life stages, identifying and understanding the key biotic and environmental influences on pre-recruit survival is a main goal of fishery management. The Early Life History (ELH) Group of the IATTC conducts most of its research on pre-recruit life stages of tunas at the Achotines Laboratory in the Republic of Panama. The Achotines Laboratory provides the IATTC a unique research facility for both field-based and experimental research designed to identify and quantify important factors that determine pre-recruit survival.

As part of ongoing efforts to update the Strategic Science Plan (SSP), the ELH group initiated discussions on a plan to strengthen and provide future direction for the research program conducted by the ELH group at the Achotines Laboratory. At this stage, the plan which is still under construction addresses areas to strengthen the research, infrastructure, staffing, collaborative agreements and funding of the ELH group's research, consistent with the goals of the SSP. At a later stage, and taking into consideration the input from other IATTC scientific Programs, the Scientific Advisory Committee (SAC) and the Commission, the plan should consider further expanding beyond the early life history of tunas. A summary of the main elements currently included in the draft plan is presented here.

2. THE ACHOTINES LABORATORY: HISTORY AND FUTURE DIRECTIONS

The history and evolution of research activities conducted at the Achotines Laboratory is described in detail in Scholey (1997) and Margulies et al. (2016). Important milestones in the history of the Laboratory are provided here.

In the early 1980's, the Director of the IATTC, Dr. James Joseph, decided to establish a research facility for the express purpose of studying the early life histories of tropical tunas and tuna-like fishes, and Achotines Bay, located on the southern coast of the Azuero Peninsula in the Los Santos Province of the Republic of Panama, was selected. The original 10-hectare laboratory site was purchased in 1982, and in 1999, the IATTC purchased 121 hectares of adjacent forest around Achotines Bay to protect water quality and as a buffer against development.

During the periods of 1994-2001 and 2011-2016, the Laboratory underwent major expansions of infrastructure, including the construction of large, in-ground broodstock tanks, a large expansion of the seawater system, new offices and analytical laboratory, expansion of communication systems, a pier with boat-launching platform, and a large expansion to the algae/zooplankton culture wing. Funding for the expansion was provided mostly by the Overseas Fishery Cooperation Foundation (OFCF)of Japan and the Japan International Cooperation Agency (JICA), with annual operating funding provided by the IATTC. Beginning in 1994, the Achotines Laboratory staff grew to accommodate the increased at-sea and laboratory research activities.

Recommendation: During the next 10 years, the Achotines Laboratory should continue to be supported by its annual operating budget, reviewed annually with adjustments for inflation. Supplementary funding will be provided from research projects of IATTC collaborating scientists or external research collaborators.

3. SCIENTIFIC RESEARCH PROGRAM

3.1 Past research

From 1984 to 1995, both field-based and laboratory studies were conducted at the Achotines Laboratory on coastal species of scombrids, mainly black skipjack *Euthynnus lineatus*, bullet and/or frigate tuna *Auxis* spp., sierra *Scomberomorus sierra*, and striped bonito *Sarda orientalis*. These studies included field surveys and collection at sea of scombrid larvae and juveniles, plus laboratory experiments that investigated the growth, nutrition, and physiology of coastal scombrids (Lauth and Olson 1996; Olson and Scholey 1990; Margulies, 1993). Methods were developed for the collection and husbandry of late-larval and juvenile scombrids (Wexler 1993; Scholey 1997; Margulies et al. 2007a; Margulies et al. 2016).

A major expansion of the laboratory was initiated in 1994 with funding provided primarily by the OFCF of Japan. Construction of new broodstock and rearing tanks and a large expansion of the seawater intake system was carried out from 1994 through 1996, and the broodstock and rearing tanks were operational by early 1996 (Margulies et al., 2016). A concrete pier and boat ramp were constructed in 1999 to facilitate boat operations. Since 1996, the research focus of the ELH group has been on the reproductive biology and early life history of yellowfin (YFT) tuna (*Thunnus albacares*). Major publications from this research can be found at the Achotines Laboratory Publications page. In 1996, for the first time worldwide, YFT spawned in a landbased tank at the Achotines Laboratory (Margulies et al. 2007b), and this sustained spawning has supported important studies on reproductive biology and early life history of YFT since 1996.

Since 2011, the ELH group has collaborated on comparative research of the early life histories of YFT and Pacific bluefin tuna (PBF) with colleagues at Kindai University in Japan. The collaborative studies were part of joint studies funded in part by JICA and the Japan Science and Technology Agency (JST) from 2011-2016, and the collaborative research has continued to present with organizational funding from the IATTC and Kindai University.

3.2 Current research

A detailed summary of priority research topics currently under investigation at the Achotines Laboratory is provided in the document SAC-14 INF-N. In recent years, the field- and experimental results of Achotines-based research have provided promising fishery-independent tools for forecasting YFT recruitment. These potential tools include estimates of optimal wind speeds for YFT larval survival (which have been incorporated into wind speed-recruitment analyses), the development of larval and early-juvenile growth indices that can be used as a predictor of recruitment strength, and estimates of water temperature and dissolved oxygen tolerance of YFT eggs and larvae, which can be utilized to develop habitat indices for YFT (Margulies et al., 2007a; Wexler et al. 2011; Margulies et al. 2016). The Laboratory is also available for use by scientists from IATTC member countries for individual or collaborative research projects.

Tuna populations are key components of pelagic ecosystems, but the effects of climate change on tuna biomass, distributions and recruitment are almost unknown. In recent years, the Achotines Laboratory has provided an essential experimental center where IATTC scientists can test the effects of climate change factors on multiple life stages of YFT (Scholey et al. 2012; Bromhead et al. 2015). These studies have included investigations of the effects of ocean acidification, ocean warming and anoxia on early life stages of YFT. Results of the experimental trials with YFT are currently being incorporated into models that predict how changes in ocean chemistry will alter the distribution and abundance of YFT (Bromhead et al. 2015; Frommel et al. 2016; Lehodey et al. 2017; Nicol et al., 2022). Current research on climate change effects includes collaborations with the Secretariat of the Pacific Community (SPC) and the University of Miami.

3.3 Future research considerations

The goal of considerations for future research is to strengthen the scientific program conducted by the ELH group, without prejudice to the expansion of that research into other areas of interest for the Commission in response to its evolving needs and circumstances. This includes for now improving the links between the ELH research program and other key research programs of the IATTC, consistent with the SSP of the IATTC.

Recruitment forecasting

Increased collaboration between the ELH group and the Stock Assessment Program will be essential to improve the analysis and modeling of recruitment variability and ecological topics of interest to the IATTC. This will improve the scientific understanding of pre-recruit life processes of tunas and provide linkage to stock assessment findings, while providing great return value to the IATTC.

Density processes and their influence on the stock-recruitment relationship for YFT can now be simulated experimentally at the Achotines Laboratory, focusing on studies of survival and growth occurring from the egg stage through the early-juvenile stage. Specific stock-recruitment questions could address the following concepts:

- How does very strong density dependence occur in the open ocean?
- Can a very few adults saturate the “habitat” for eggs/larvae/juveniles?
- Is the same number of recruits obtained no matter how many eggs are produced down to a very small number of eggs?

Additional focus on early-juvenile life stages

From 1996-2020, the focus of early life history research of YFT conducted at the Achotines Laboratory has been on the egg and larval stages. During the next 5- to 10 years, the research focus of the ELH group at the Achotines Laboratory will expand to include investigations of the early-juvenile stages (0.5 to 6 months of age) of YFT. The recent success in rearing of juvenile YFT at the Achotines Laboratory now provides an opportunity to experimentally study, for the first time, the growth, survival and feeding dynamics of all pre-recruit life stages (0-6 months of age) of YFT. Research topics that could be addressed experimentally include:

- For YFT, does density-dependent mortality weaken any relationship between egg production and recruitment consistent with the IATTC stock assessment of YFT (Aires-da-Silva and Maunder 2012; Minte-Vera *et al*. 2014)?
- Does relative growth rate or density-dependence in feeding success and growth during the larval or early-juvenile stages contribute to variations in recruitment of YFT?
- Can laboratory-reared early-juvenile YFT be utilized be tagged and released in the Panama Bight, thus providing new information on movements and behavior in the EPO of these little-studied early-juvenile stages?

Climate change studies

With a changing climate becoming an increasing factor influencing tuna populations in the EPO, the Achotines Laboratory will continue to provide an essential experimental center where IATTC scientists can test the effects of climate change factors on multiple life stages of tunas. Ocean acidification, ocean warming, and anoxia are of concern for their potential effects on the growth, development, and survival of early life stages of tunas in oceanic habitats and on the spatial extent of suitable nursery habitat for tunas. Future research at the Achotines Laboratory will continue to provide experimental results that can be used to parameterize models used to estimate future climate effects on pre-recruit survival of tunas and spawning-habitat availability (Nicol et al. 2022). Climate change effects will be studied experimentally to address the following research questions:

- What are the interactive effects of ocean warming and acidification on pre-recruit stages of YFT?
- What are the effects of ocean acidification and ocean warming on the physiology and ecology of tuna early life stages (joint studies with University of Miami)?
- What are the effects of pollutants such as microplastics and persistent organic pollutants (POPs) on the early life stages of tunas?

Biology and behavior research

The Achotines Laboratory can be utilized for the following types of biological research:

- Validation studies of microchemical incorporation into the otoliths of larval and early-juvenile YFT, thus providing validation of the environmental contribution in otoliths and providing insights into the geographic origin of the fish
- The study of isotopic turnover rates in the tissues of larval and juvenile YFT
- Tagging of spawning broodstock with 3-dimensional accelerometer tags to validate courtship, spawning and feeding events

Bycatch mitigation research

The Achotines Laboratory will continue to provide a unique setting for pilot studies and field-testing of bycatch-reduction technologies of interest to the IATTC. Projects related to bycatch reduction technologies such as sorting grids, biodegradable FADs and acoustic methods for minimizing the catch of undersized fish have been conducted by IATTC and ISSF scientists, supported by the EU, ISSF, and Achotines Laboratory, and these types of research will be supported in the future following the research recommendations of the IATTC's Scientific Advisory Committee (SAC). These studies could include:

- Improvements in remote discrimination of species: acoustics (echo-sounders, species-specific noise profiles, etc.), and image analyses (identification of sensitive bycatch species remotely)
- Attraction/deterrents for sharks (magnets, light, smell, etc.)
- Attraction/deterrents for tunas (light, noise, etc.).
- Experiments on different gear configurations and degradability (hooks, steel lines, different FAD structures)

4. LABORATORY INFRASTRUCTURE AND OPERATIONS

Priority infrastructure recommendations for the Laboratory are briefly described here.

From 1984-2004, all electricity was provided by on-site generators. The Laboratory was connected to the local electric grid in 2004. Due to the frequent, and at times prolonged, power outages that occur in the area, it remains necessary to maintain two standby generators. In early 2022, a new standby generator, paid for by a Panama SENACYT grant, was installed. Both the existing generators are in need of serious maintenance or overhaul and one should be selected to restore to good condition. There is hope that the power outage situation will improve in the next year or two as the utility company is upgrading the distribution system in the area, but this is not guaranteed.

About 1.5 km of unpaved (crushed and compacted rock) roads run from the main road throughout the Laboratory site and to the beach boat ramp. It is recommended that a paved road (oil/gravel road surface) replace the unpaved road.

Recommendations:

- A paved road (oil/gravel road surface) should be constructed to replace the unpaved road.
- The boat ramp and operating platform in Achotines Bay must be repaired and maintained with funding previously committed by the ARAP
- The annual operating funding for the Laboratory should be increased, in order to move from a reactionary system that replaces infrastructure components only when they fail, to a system of long-term planning with 1-3 year replacement milestones.

5. MOU's AND COLLABORATIVE AGREEMENTS

The ELH Group and the Achotines Laboratory maintain a diverse set of collaborative research agreements and Memoranda of Understanding in order to plan and conduct research relevant to the Antigua Convention. The background and specific goals of these collaborative agreements are summarized in Margulies and Scholey (2022), and a listing of the current agreements and their durations is presented here.

- IATTC – OFCF of Japan (1993 to present)
- IATTC – Kindai University of Japan - ARAP (2010 – 2016, with draft extension exchanged in 2018)
- IATTC – University of Miami (2002 to present)

- IATTC – ARAP (2010 to present)
- IATTC – Smithsonian Tropical Research Institute (STRI) (2002 to present)
- IATTC – Yale University/ELTI Program (2017 to present)
- IATTC – AZTI (pending agreement for joint research at the Achotines Laboratory)

5.1 Increased opportunities for scientific research dissemination and social media

Besides scientific publication opportunities for research conducted by the ELH group, studies conducted at the Achotines Laboratory will continue to provide a unique base for projecting the scientific image of the IATTC to the public and media. Innovative research findings from research of the ELH group, particularly those related to climate change and novel findings related to captive spawning and rearing success of juvenile tunas, will be of interest to the public, member countries of the IATTC and the media. These research findings should be made available to the public on a much larger scale than provided in the past. The ELH group will pursue expanded opportunities for dissemination of its own research findings and results from collaborative research on tunas, thus providing new opportunities to describe the IATTC's research to the public and media. Key research findings from Achotines research will be provided to scientific news websites and wire services. In addition, an updated and expanded website section describing research activities at the Achotines Laboratory is now available on the new IATTC website, and Achotines research is also described periodically on the IATTC pages of Facebook, Twitter and Instagram.

6. ACHOTINES FOREST INITIATIVE

In 2007, an initiative was undertaken to permanently protect the surrounding Achotines Forest and potentially convert the Forest into a source of funding for the Laboratory. The Achotines Forest is composed of a remnant parcel of rare coastal tropical dry forest, one of the most endangered terrestrial ecosystems in Central America. Multiple research organizations and universities have conducted terrestrial research and maintained long-term study sites in the forest in order to promote reforestation and watershed restoration.

A full Donor Prospectus was prepared in 2008 resulting in a pledge of financial support from the Grantham Family Foundation. To develop a full donor-derived foundation and protection of the forest in perpetuity, it is recommended that additional donors be secured or a transfer be made of the forest management to a NGO; these new efforts will require updates to the Donor Prospectus, letters of support, area descriptions and supporting information on the Achotines Forest.

Specific information related to the Achotines Forest and the Donor Prospectus can be obtained from the IATTC's ELH Group.

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