

Four Decades of Scientific Advances at the Tropical Aquaculture Laboratory: From Native Fish Biology to Biotechnology for Aquaculture and Conservation

Cuatro décadas de desarrollo científico en el Laboratorio de Acuicultura Tropical: de la biología de los peces nativos a la biotecnología para la producción y conservación

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Abstract

The history of the Tropical Aquaculture Laboratory (LAT) at Universidad Juárez Autónoma de Tabasco (UJAT) reflects four decades of research focused on understanding the sustainable use and conservation of native fish species in southeastern Mexico. Since its early studies on regional ichthyofauna, reproductive biology, and feeding habits, the Laboratory has evolved to develop technologies for the culture, reproductive management, and production of species of ecological and economic importance. Research on the tropical gar (*Atractosteus tropicus*), the bay snook (*Petenia splendida*), and the mayan cichlid (*Mayaheros urophthalmus*) laid the basis for integrating knowledge of nutrition, physiology, reproduction, and conservation. Subsequently, work with snooks of the genus *Centropomus* consolidated lines of research on hormonal induction of spawning, gamete quality, larviculture, live feed production, and sex control, recently incorporating histological, endocrinological, and molecular tools to understand the mechanisms of sex change. This trajectory has been made possible by the continuity of its researchers, the training of new generations, and collaboration with national and international institutions. Beyond its scientific contributions, the LAT's experience shows that developing aquaculture for native species requires sustained research, integration across disciplines, and a close connection to the needs of the productive sector. Amid current environmental, technological, and economic challenges, its primary commitment is to continue generating knowledge and solutions that enable responsible food production, strengthen fishing communities, and contribute to the conservation of aquatic resources.

Keywords: tropical aquaculture; native fish; reproductive biotechnology; *Centropomus*; fry production; conservation of aquatic resources.

Resumen

La historia del Laboratorio de Acuicultura Tropical (LAT) de la Universidad Juárez Autónoma de Tabasco refleja cuatro décadas de investigación orientada al conocimiento, al aprovechamiento sustentable y a la conservación de los peces nativos del sureste de México. Desde sus primeros estudios sobre ictiofauna regional, biología reproductiva y alimentación, el Laboratorio ha evolucionado hacia el desarrollo de tecnologías para el cultivo, el manejo reproductivo y la producción de especies de importancia ecológica y económica. Las investigaciones sobre el pejelagarto (*Atractosteus tropicus*), la tenguayaca (*Petenia splendida*) y la castarrica (*Mayaberos urophthalmus*) sentaron las bases para integrar conocimientos de nutrición, fisiología, reproducción y conservación. Posteriormente, los trabajos con robalos del género *Centropomus* consolidaron líneas de investigación sobre inducción hormonal del desove, calidad de gametos, larvicultura, producción de alimento vivo y control sexual, incorporando recientemente herramientas histológicas, endocrinológicas y moleculares para comprender los mecanismos del cambio de sexo. Esta trayectoria ha sido posible gracias a la continuidad de sus investigadores, a la formación de nuevas generaciones y a la colaboración con instituciones nacionales e internacionales. Más allá de sus contribuciones científicas, la experiencia del LAT demuestra que el desarrollo de la acuicultura de especies nativas requiere investigación sostenida, la integración de distintas disciplinas y una vinculación estrecha con las necesidades del sector productivo. Ante los desafíos ambientales, tecnológicos y económicos actuales, su principal compromiso es continuar generando conocimientos y soluciones que permitan producir alimentos de manera responsable, fortalecer las comunidades pesqueras y contribuir a la conservación de los recursos acuáticos.

Palabras clave: acuicultura tropical; peces nativos; biotecnología reproductiva; *Centropomus*; producción de semilla; conservación de recursos acuáticos.

Editorial

Reaching forty years of scientific output in a laboratory represents an opportunity to look back, but also to ask what remains after four decades of research. In the case of the Tropical Aquaculture Laboratory at Universidad Juárez Autónoma de Tabasco (UJAT), the answer is not found solely in a collection of scientific articles, theses, or projects. Its history can be traced, above all, through the species studied, the problems addressed, and how scientific questions evolved as knowledge grew.

The Tropical Aquaculture Laboratory emerged in a region where water is integral to daily life. Tabasco is a region of lagoons, rivers, wetlands, and coastal environments, where artisanal fishing has historically been economically, food-security, and culturally important. In this context, studying the region's fish was not merely an academic pursuit. It meant generating information about the resources that sustained local fisheries and that, at the same time, might hold potential for aquaculture.

The scientific origins of this research can be traced back to the mid-1980s, when the regional ichthyofauna and various aspects of the biology of native cichlids began to be documented (Páramo-Delgadillo, 1984). Those studies addressed seemingly simple questions: which species were present, how to distinguish males from females, what they ate, how they grew, and what their reproductive characteristics were (Páramo-Delgadillo, 1985). Over time, these questions became more specific and gave rise to lines of research that remain active today. One of the early studies focused on developing balanced feed formulations using local ingredients was conducted by Quintero-Mármol and Córdova-Loreto (1988), in which the authors investigated alternative animal feed sources for inclusion in feed for native cichlids and tilapia.

The tropical gar, *Atractosteus tropicus*, was one of the first organisms that helped the laboratory establish its own identity. The choice was not accidental, as this species has been overexploited since then because it is closely associated with the culture and cuisine of southeastern Mexico, particularly Tabasco; however, for many years, little information supported the idea of controlled production. Early research focused on its diet, growth, biology, and aquaculture potential. Subsequently, studies were conducted on gonadal histology, reproduction, nutrition, physiology, genetics, stocking densities, and conservation strategies (Pérez-Sánchez and Páramo-Delgadillo, 1998; Pérez-Sánchez and Páramo-Delgadillo, 2008; Arias-Rodríguez et al., 2009; Méndez-Marín et al., 2009; Huerta-Ortíz et al., 2009).

Work with the tropical gar revealed, from the very beginning, a characteristic that would later become a hallmark of the Laboratory: not completely separating basic research from its practical application. Understanding the structure of the gonads or the reproductive cycle made sense because it could help determine when and how to breed a species in captivity. Understanding its genetic variability was relevant for both breeding and conservation. The result was a gradual accumulation of information that was, to a large extent, shared at national and international conferences and ultimately took shape not only in scientific articles but also in manuals, community projects, production initiatives, and works aimed at

systematizing the available knowledge (Martínez-García et al., 2013; Márquez-Couturier et al., 2013). During this stage, students' contributions through their theses were fundamental.

In the late 1990s and early 2000s, other lines of research that would significantly influence the Laboratory's subsequent development were strengthened: reproductive physiology and sexual control in fish. Research on the effects of stress on reproduction, gamete quality, and offspring quality helped incorporate a broader physiological perspective. At the same time, studies on the masculinization of tilapia using steroids, immersion treatments, and various hormone administration strategies led to the development of experimental tools that would later be adapted for native species (Contreras-Sánchez et al., 1998; Fitzpatrick et al., 1998; Schreck et al., 2001; Vidal-López et al., 2008). In this area, tilapia played an important methodological role, and although it was not a native species of the region, it allowed researchers to work with sex-reversal techniques, evaluate hormone administration routes, and also study an issue that received much less attention at the time: the environmental fate of steroids used in production systems. Studies on the removal of methyltestosterone using activated charcoal, ultraviolet radiation, solar irradiation, or bacterial degradation already reflected a concern for reducing the potential impacts associated with certain aquaculture technologies (Contreras-Sánchez et al., 1997; Contreras-Sánchez et al., 1999; Contreras-Sánchez et al., 2001; Fitzpatrick et al., 1999; Gale et al., 1999; Bart et al., 2003; Contreras-Sánchez et al., 2002). This expertise was subsequently transferred to regional organizations. The bay snook, *Petenia splendida*, and the mayan cichlid, *Mayaheros urophthalmus*, became model species for studying larviculture, growth, nutritional requirements, digestive physiology, the sex ratio of breeders, and hormonal control of sex (Jiménez-Martínez et al., 2009; Uscanga Martínez et al., 2012; Vidal-López et al., 2009; Contreras García et al., 2018). In these studies, a significant shift began to emerge clearly. Research was no longer limited to describing a species' biology. The goal shifted to controlled interventions in specific processes to improve aquaculture: increasing juvenile availability, establishing appropriate stocking densities, determining protein levels, partially substituting costly ingredients, improving larval survival, or controlling sex ratio. The Laboratory's participation in international programs such as the Pond Dynamics/Aquaculture Collaborative Research Support Program and, later, the AquaFish-CRSP was particularly important during this stage. The technical reports preserved from these programs allow us to reconstruct a part of history that is not always found in conventional bibliographic databases. Through these projects, work was conducted on the selection of tilapia and native cichlid strains in polyculture systems, on reducing the environmental impact of hormonal treatments, on seed production, and, progressively, on the development of technologies for species of the genus *Centropomus*. Workshops, courses, technical meetings, and symposia were also organized, helping to connect the research conducted in Tabasco with groups in Latin America and other regions. This “gray literature”—reports, proceedings, annual reports, and technical documents—is particularly valuable for understanding the Laboratory's history. Many technological advances first appear in these types of documents before becoming

scientific articles or manuals. A recent bibliographic review, conducted to mark LAT's 40th anniversary, identified more than 200 scientific, technical, editorial, and technology-transfer outputs linked to seven researchers who have played a significant role in the Laboratory's development. This figure does not refer solely to peer-reviewed articles; it includes articles, books, chapters, manuals, CRSP and AquaFish reports, conference proceedings, documented presentations, training materials, and other outputs that provide a more comprehensive view of the activities carried out over four decades.

While the tropical gar represents one of the Laboratory's historical roots, the snooks likely represent the line along which the evolution of accumulated knowledge can best be observed. Research on Centropomidae began with questions about reproductive biology, broodstock distribution, and differences between environments. Subsequently, research progressed to the evaluation of gametes, hormonal induction, embryonic development, and larval production (Contreras-Sánchez et al., 2009; Contreras-García et al., 2011; Contreras-Sánchez et al., 2012; Perera García et al., 2011; Perera García et al., 2013; Hernández-Vidal et al., 2014a; Hernández-Vidal et al., 2014b; Contreras-García et al., 2015; Vidal-López et al., 2019).

The common snook, *Centropomus undecimalis*, became particularly important. Its economic value, regional demand, and the decline of some wild populations made it clear that technologies to reduce dependence on wild organisms were needed. However, breeding a marine or estuarine species in captivity is far from simple. Maintaining broodstock, identifying the appropriate time to induce final maturation, obtaining high-quality gametes, achieving fertilization, producing larvae, and ensuring their survival during the first few weeks requires resolving numerous challenges in sequence. We needed to characterize semen quality and establish methods for evaluating males. It was also necessary to study the reproductive physiology of populations inhabiting environments with different salinities. Protocols for inducing spawning using GnRH analogs were developed, and progress was made in captive breeding not only of the common snook but also of the fat snook (*C. parallelus*) and the Mexican snook (*C. poeyi*). Larviculture opened up a new set of challenges. Producing eggs is not the same as producing juveniles. The availability and quality of live feed, digestive system ontogeny, enzyme emergence, stocking density, and weaning timing became central questions. This led to studies on zooplankton, copepods, gene expression during ontogeny, and live feed production. This body of experience ultimately gave rise to manuals and technical works. The publication of a manual on Common snook production—now in its second edition—and, subsequently, a book dedicated to live feed production reflects a key characteristic of applied research: knowledge must be organized in such a way that it can be utilized by others (Contreras-Sánchez et al., 2012; Vidal-López et al., 2012; Vidal-López et al., 2018; Kubicek et al., 2018; Cruz-Rosado et al., 2020; Contreras-Sánchez et al., 2022; Contreras-García et al., 2024; Vázquez-Gómez et al., 2026).

One of the most recent chapters in this story stems from a biological peculiarity of snooks: their reproductive strategy. Several species of the genus *Centropomus*

have been reported as protandrous hermaphrodites. Individuals initially mature as males and later become females. For aquaculture, this characteristic poses a practical problem. Males can be obtained relatively early, whereas reproductive females are typically larger and older. This possibility thus became a research question. Studies on feminization in *C. poeyi* using 17β -estradiol showed that hormonal intervention could produce functional females. Subsequently, the research progressed toward inducing sex change in adult males of *C. undecimalis*. What is significant about this stage is not merely the success in modifying sex. The research began to integrate different levels of biological organization. It was no longer sufficient to observe the appearance of the gonads. Histological analyses, steroid hormone profiles, and the expression of genes associated with sexual differentiation were incorporated.

In 2025, the study of induced sex change in *C. undecimalis* integrated gonadal morphology, hormone concentrations, and gene expression. In 2026, the analysis of the interaction between salinity and 17β -estradiol expanded this approach through histological, hormonal, and molecular evaluation. This trajectory is illustrative: a program that began by studying when fish reproduced ended up asking what cellular and molecular mechanisms regulate their sex change. The applied question was not abandoned. On the contrary, it was explored in greater depth. Understanding these mechanisms enables better strategies to manage broodstock and reduce one of the main obstacles in snook broodstock production (Contreras García et al., 2025; Gaitán-Ibarra et al., 2026a; Gaitán-Ibarra et al., 2026b).

After forty years, perhaps one of the main lessons from LAT is that applied research takes time. Complex problems are rarely solved by a single project. The domestication of a species, for example, can take decades. First, one must understand its biology; then, keep it in captivity; next, breed it; produce larvae; develop feed; control diseases; and, finally, make the process economically viable. For this reason, it is important to maintain long-term research lines. It is also important to remember that the social utility of research should not be measured solely by the potential to develop a commercial technology. Aquaculture can also play a role particularly relevant for regions with a strong fishing tradition: it can support the management and conservation of natural populations. Many artisanal fisheries face problems of overfishing, habitat degradation, pollution, and environmental fluctuations. Under these circumstances, developing the capacity to reproduce native species can open up new possibilities. One of these is reducing fishing pressure through the production of farmed organisms. Another is developing small-scale aquaculture as a complementary activity for fishing communities, and a third -particularly delicate- is using controlled juvenile production to support restoration or restocking programs. The latter requires caution. Restocking does not simply mean producing fish and releasing them. A responsible intervention must consider genetic diversity, broodstock origin, population structure, health risks, carrying capacity, habitat quality, and subsequent monitoring.

This is precisely why the involvement of universities and research centers is indispensable. Aquaculture can strengthen small-scale fisheries, but only if it is integrated with ecological knowledge and appropriate fisheries management strategies. From this perspective, production and conservation are no longer opposing concepts. The very knowledge that makes it possible to breed a tropical gar or a snook can be used to produce food, generate income, or support conservation programs. The purpose will depend on the context and how each intervention is designed.

University laboratories do not survive for forty years solely because of their facilities. They endure because there are people capable of passing on questions, techniques, and ways of working to new generations. The history of LAT can also be seen as a continuity among researchers. The early work of Salomón Páramo-Delgadillo, Wilfrido Contreras-Sánchez, and Gabriel Márquez-Couturier contributed to our understanding of regional species and to the development of the first experiments with native fish. Arlette Hernández-Franyutti provided a solid foundation in histology and reproductive morphology. Ulises Hernández-Vidal, María de Jesús Contreras-García, and Alejandro Mcdonal-Vera helped consolidate breeding lines, manage broodstock, and produce native cichlids, strengthening research on reproductive physiology and sex control and, subsequently, the breeding program for groupers and snappers. Leonardo Cruz Rosado has also studied native plankton and its production as live feed. Numerous students, technicians, collaborators, and researchers from other institutions have also contributed to this history. Many appear as co-authors of articles, theses, dissertations, and projects; others participated in theses and activities that were likely never documented in publications. A scientific school is built when knowledge does not end with the person who initiates a line of research. It is built when a student takes up a previous question, modifies it, and takes it to another level. This is clear in the history of LAT. The biology of the tropical gar led to aquaculture, nutrition, and conservation; research on sexual inversion in tilapia led to techniques later applied to native fish; the first studies of the reproductive biology of sea bass led to broodstock management and induced spawning. Reproduction gave rise to larviculture, which in turn focused on live feed and digestive physiology. Sexual differentiation led to endocrinology, which, in turn, led to gene expression and molecular biology. These research lines are not isolated. They are stages of the same history.

Tropical aquaculture faces different challenges than it did four decades ago. Water availability, feed costs, climate change, emerging diseases, the need to reduce environmental impacts, and growing pressure on wild populations are forcing us to rethink how we produce aquatic organisms. The scientific challenges are no less significant. Simply closing a species' production cycle is no longer enough.

We must improve efficiency, reduce mortality, optimize resource use, maintain genetic diversity, and demonstrate economic viability. With native species, we also face the challenge of ensuring that technological development does not outpace our understanding of their natural populations. The Tropical Aquaculture Laboratory can draw on four decades of experience to address these issues from

an integrated perspective. Future work with tropical gar, native cichlids, sea bass, and other native fish can integrate reproduction, nutrition, health, genetics, recirculating aquaculture systems, environmental physiology, and economic analysis. It can also establish more direct connections with fishermen, producers, and agencies responsible for managing aquatic resources. The relationship with the production sector will be particularly important. Applied research often begins with a question raised in a laboratory, but it can also stem from a producer's day-to-day problems: high mortality, poor-quality fry, expensive feed, broodstock that fail to spawn, or insufficient growth. Listening to these problems does not diminish the research's scientific value; often, it leads to more interesting questions.

After forty years, the history of the Tropical Aquaculture Laboratory can be summarized as a continuous transformation: from knowledge of native fish to the control of their reproduction and production. But perhaps one final part still needs to be added to that sentence. Knowledge and technological control only take on their full meaning when they contribute to something broader: producing food responsibly, conserving species, strengthening communities, and offering alternatives to those who depend on aquatic ecosystems. That is likely to be one of the most important challenges of the coming decades. May research continue to advance toward increasingly complex questions, but may it never lose sight of the problems that exist outside the laboratory. Because, in the end, one of the best ways to measure the trajectory of a research center is not just to ask how much it published. We must also ask: What problems did it help solve? What capabilities did it build? And what new questions was it able to generate? Forty years after its founding, these are perhaps the most pertinent questions for evaluating the past and, above all, for envisioning the future of the Tropical Aquaculture Laboratory.

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