



Knowledge Co-production to Inform Fish Habitat Conservation: A Case Study Highlighting Engagement With Local Government

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Abstract

Recreational fishing contributes substantially to the local economies of Southwest Florida. The northern half of the Charlotte Harbor estuary includes nursery habitat for snook and tarpon, both of which are economically important sport fish in the region. The nursery habitats consist of tidal creeks and coastal ponds that lie at the interface of accelerating coastal development; however, there are no explicit habitat protections to guide conservation for tarpon and snook. To provide a framework for place-based habitat conservation, researchers are actively partnering with resource and land use managers that govern at fine spatial scales (e.g., county government). This case study describes how workshops supported by the National Oceanic and Atmospheric Administration RESTORE Science Program facilitated a co-production process to identify uncertainties that were prohibiting action on management and restoration of snook and tarpon habitat, and plan actionable science focused on bridging science and policy gaps to reduce decision uncertainties. A research plan is being implemented to develop site-specific information for wetland-dependent sport fish by (1) documenting their use of natural and restored habitats, (2) developing hydrologic models, and (3) creating a habitat vulnerability analysis. The resulting decision-support tools will be co-designed with land use planners for proposed revisions of county comprehensive planning policy. Early outcomes include prioritization of lands for conservation and creation of species-targeted habitat features within large habitat restoration projects.

Keywords Charlotte Harbor · Common Snook · Tarpon · Coastal restoration · Land use planning

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Introduction

Masselink and Lazarus (2019) describe coastal resilience as the capacity of both natural and socioeconomic systems to withstand and adapt to disturbances while providing essential functions. These functions include productive coastal fisheries, which are coupled human-environmental systems consisting of biotic, abiotic, and socioeconomic components (Lynch & Liu, 2014). Healthy fish populations and habitats are needed to support recreational fisheries generating local expenditures and tourism (Ditton et al., 2002), and contributing to the economic resilience of communities.

Plans, strategies, and actions developed for coastal fisheries management may range widely in geographic scale from international to localized. Fisheries that are traditionally managed through stock assessment and rulemaking are often conducted at scales that are international (e.g., highly migratory species) or regional in scope. In many fisheries, environmental disturbances (e.g., red tides, hurricanes,

cold events, heat waves) have as much effect on population abundance as fisheries landings (e.g., Flaherty & Landsberg, 2011; Stevens et al., 2016). Moreover, anthropogenic disturbances can directly impact fish habitat and fisheries and exacerbate the severity of environmental disturbances. Red tide and algal blooms, which are made more severe by nutrient pollution and lead to declines in seagrass habitat, have been documented across Florida estuaries (Beck et al., 2022; Lapointe et al., 2020; Morris et al., 2022), including this study's focal area of Southwest Florida (Medina et al., 2022, 2025). Hydrologic alterations can impact coastal fish habitat by changing the timing and quantity of freshwater flows, exacerbating the effects of meteorological stressors (Beck et al., 2024; Hall et al., 2016). The underlying causes of environmental impacts often fall outside the purview of fisheries management governance; however, addressing anthropogenic disturbance may be within the scope of regional or local authorities.

As fishery management agencies increasingly consider ecosystem function and habitat during fishery assessments, it is becoming apparent that local inputs are necessary (Harvey et al., 2025) and that engagement with local government can be beneficial for place-based management. Most land use planning decisions in the United States of America (USA) are made at the local government level, and this holds true for Florida (Pannozzo et al., 2015; Brody, 2016). Local land use decisions (e.g., development, land acquisition, restoration policies) can directly affect the hydrology and water quality of fish habitat, and may also cause physical loss of habitat. In particular, degradation or loss of juvenile fish habitat to coastal development is an issue that typically needs to be addressed at the local level, particularly when unique habitats exhibit a need for conservation.

The life history attributes and economic value of snook and tarpon, in combination with ongoing habitat impacts, emphasize the need for protection of coastal mangrove, salt marsh and, particularly, coastal wetland ponds in the Charlotte Harbor estuary (Wilson et al., 2019, 2023). Snook and tarpon are included broadly within the definition of Aquatic Resources of National Importance, and some intertidal wetland is considered "Essential Fish Habitat" for federally managed species such as gray (mangrove) snapper (*Lutjanus griseus*) and red drum (*Sciaenops ocellatus*) within the Magnuson-Stevens Act. However, the use of coastal habitats, particularly ponds, by snook and tarpon does not trigger any special regulatory protections within our study area. County and municipal land use plans that include incentives or regulations represent one strategy to ensure development is compatible with environmentally sensitive areas. Land parcels associated with high-value habitat can also be identified for conservation at the local government level. One example of local land use planning to protect fish habitat

occurs in the state of Washington, USA, where all cities and counties must use comprehensive planning to designate fish and wildlife habitat conservation areas (Copsey, 1992; Laschever, 1998). Support for such parcel-level designation is provided by studies that show degradation of the reaches of individual streams due to land development, which in turn impacts Pacific salmon spawning habitat (Burnett et al., 2007; Lohse et al., 2008). As a result, localities within the state of Washington have implemented riparian buffering through growth management plans. This example illustrates how place-based habitat protection through local governance represents a viable method to ensure the sustainability of a community's ecologically and economically valuable natural resources.

The process of place-based habitat protection may be facilitated by boundary spanning organizations that provide a neutral and trusted framework to address transdisciplinary needs (Nel et al., 2016). These organizations can provide opportunities to address specific management decisions through transparent and science-informed processes, such as knowledge co-production, often by convening federal, state, and local government with non-governmental organizations (NGOs) and stakeholders through formal, place-based, planning and management processes. Examples of boundary spanning organizations in Florida, USA, include the National Estuary Programs and regional planning councils, which facilitate interlocal planning.

Here, we provide a case study of how local government can be engaged in a knowledge co-production process to conserve fish habitat. Co-production of actionable science is recommended as a method to close knowledge-practice gaps, define the information needs of natural resource managers, and ensure transfer of knowledge and decision support tools from researchers (knowledge generators) to decision makers (or knowledge users; Cooke et al., 2021; Piczak et al., 2022; Räsänen et al., 2024). The co-production process is similar to forms of participatory science, but also emphasizes incorporation of non-scientific experiential knowledge (e.g., local or indigenous ecological knowledge) to inform and evaluate decisions or policies (Bandola-Gill et al., 2023).

One example of engagement of a local government in conservation of fish habitat is Charlotte County, which borders the Charlotte Harbor estuary in Southwest Florida. Here, nursery habitats for two economically important sport fish, common snook (*Centropomus undecimalis*) and tarpon (*Megalops atlanticus*), are known to exist in close proximity to accelerating coastal development. Preservation and enhancement of nursery habitats and juvenile recruitment are necessary to ensure these fish populations remain resilient to environmental stressors (Schrandt et al., 2023) and continue to support the respective sector of the local

economy. Implementing a localized approach to conservation of fish habitat would allow resource managers to develop and identify specific resource management actions, information needs, and decision points.

To this end, we used the co-production process to develop a research plan that reduces uncertainties related to (1) the locations and quality of juvenile sport fish habitat, including elevations and flooding regimes needed for nursery function, (2) direct losses of juvenile habitat to development, (3) hydrologic impacts due to expected build-out of parcels adjacent to nurseries, (4) habitat changes expected due to sea-level rise, and (5) the effectiveness of recent habitat enhancement projects. This plan goes beyond a traditional, linear approach of information flowing from research into management, and includes feedback loops from managers to researchers as the process develops (Fig. 1). The process differs from a traditional linear approach as it is iterative and stimulates collaboration between researchers and managers

to refine the management issues, decisions, and information needs, while also encouraging input from outside stakeholders (Beier et al., 2016; Nel et al., 2016).

Methods

Study Area, Focal Species, and Conservation Needs

As the “Tarpon Capital of the World”, Charlotte Harbor draws thousands of anglers annually to experience the region’s vibrant recreational fisheries, which include both common snook (hereafter, snook) and tarpon. Charlotte Harbor is known for excellent sport fishing, with almost 150 charter fishing guides and over 16,000 resident licensed anglers in 2020 (Florida Fish and Wildlife Conservation Commission data). The total economic impact of the Charlotte Harbor Basin is approximately \$493.9 million

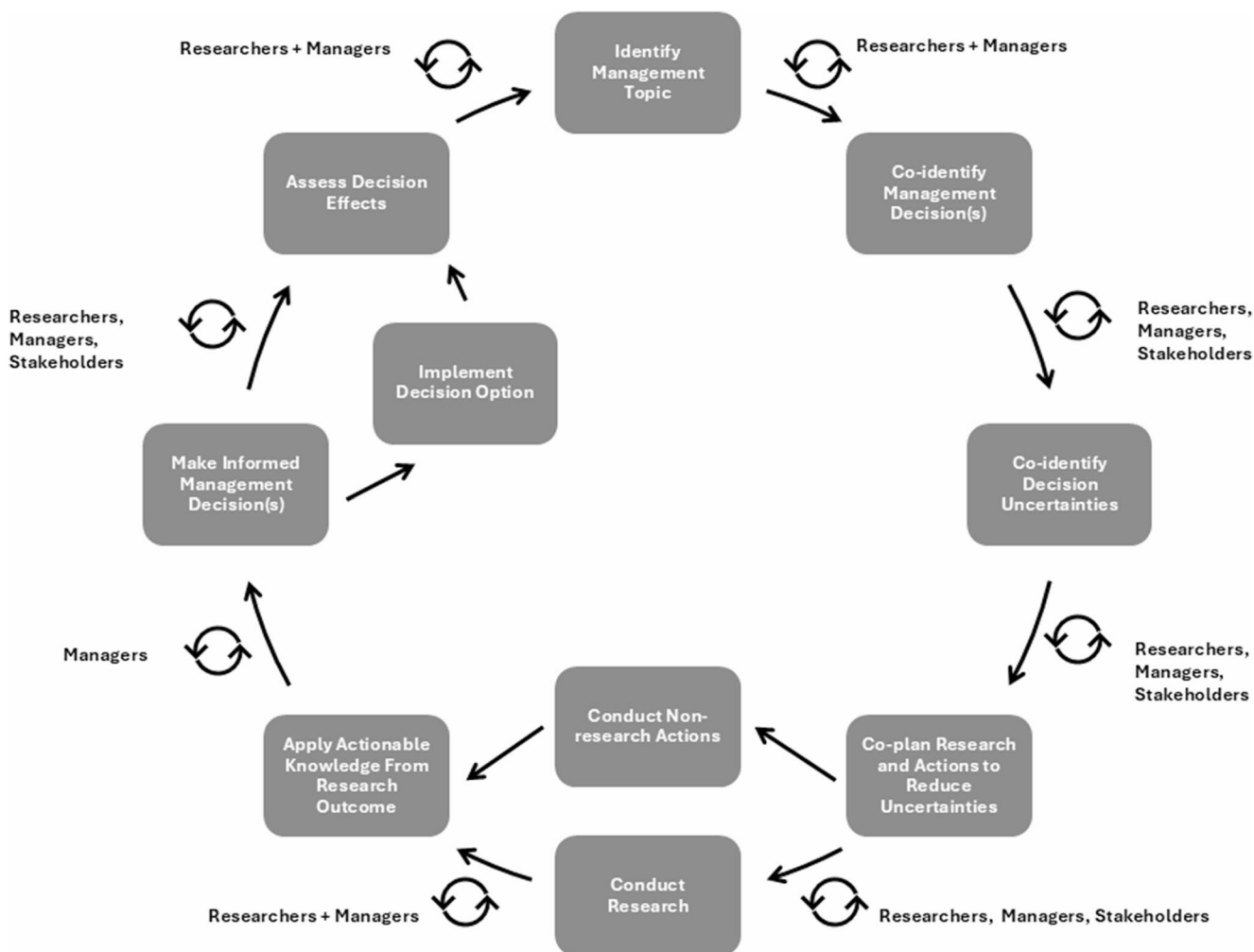


Fig. 1 The co-production process used to plan, implement, and adapt actionable science for conservation of sport fish habitat in Charlotte Harbor, Florida. Typical entry points are the stages of identifying management topics and resource management decisions. Loops between

stages serve to check that previous stages are relevant and provide opportunities to adapt the direction of the process as knowledge is generated

annually, with the principal drivers being natural resource-based recreation — primarily tourism related to water-based recreation and charter fishing (Fedler, 2011; Cortez et al., 2020).

The reproductive life histories of snook and tarpon suggest they spawn during summer and early fall, in synchronicity with wet season patterns that allow access via hydrologic connections within a habitat mosaic (Wilson et al., 2019). Snook spawn in coastal passes and nearshore areas (Taylor et al., 1998) and their eggs are typically transported into estuarine mangrove habitats (Peters et al., 1998). In contrast, tarpon spawn offshore and their (leptocephali) larvae are transported inshore by coastal currents (Crabtree et al., 1992). Juvenile snook and tarpon are found in tidal creeks (Barbour et al., 2014; Wilson et al., 2023) and in small, ephemerally connected, shallow ponds within a habitat mosaic of intertidal wetlands (Saari et al., 2025). The ephemerally connected ponds are isolated during the dry season and only hydrologically connected during high wet-season flows or extraordinary seasonal high tidal events (Bunting et al. 2024; Stevens et al. 2024a). The relative isolation of the tidally connected creeks and ponds, and the higher level of isolation of the ephemerally connected ponds, are thought to provide ample prey and high levels of protection from aquatic predators (Saari et al., 2025).

While many of the intertidal wetlands containing tidal creeks and coastal ponds in Charlotte Harbor occur within a State Preserve system, platted (i.e., defined and mapped) but

undeveloped subdivisions of land around the coastal preserves create habitat threats (Fig. 2). In addition, intertidal wetlands, in general, are becoming increasingly vulnerable to sea-level rise, sediment starvation, eutrophication, and limits on landward migration (Osland et al., 2022; Day et al., 2024). Future development of the platted subdivisions in Charlotte Harbor will limit the potential for landward expansion of the coastal wetlands in response to expected sea-level rise. The location of these plats will necessitate the sites being elevated using fill, which will reduce the capacity for stormwater retention. In addition, older developed areas route stormwater into the preserve, which increases the potential for nutrient pollution, algal blooms, and pulses of unseasonal freshwater in the existing preserved ponds. While juvenile snook and tarpon are highly adapted to survive in hypoxic or anoxic conditions (Adams et al., 2014; Adams & Murchie, 2015; Wilson et al., 2019), habitat degradation caused by altered freshwater flows (e.g., increased total discharge volumes and “flashiness”) and associated increases in pollutant loadings threaten the ecological integrity of the juvenile habitat (Adams et al., 2009; Wilson et al., 2019). Recognizing the ecological sensitivity of these coastal habitats, particularly the ponds, and the fact that regional development is rapidly increasing, it became apparent to resource managers and researchers that a novel interdisciplinary planning effort was needed to address the resulting fish habitat conservation challenges.



Fig. 2 Coastal development abutting sport fish nursery habitat at Charlotte County, on Florida’s Cape Haze Peninsula

The Knowledge Co-production Effort: Development of a Research Plan

Workshops supported by the National Oceanic and Atmospheric Administration RESTORE Science Program used a facilitated co-production process to identify uncertainties that were prohibiting action related to the management and restoration of snook and tarpon habitat, and plan actionable science focused on bridging science and policy gaps to reduce decision uncertainties. Project investigators and resource managers developed a planning project designed to adhere to the co-production practices recommended by Beier and co-authors (2016). The scope of this project included a neutral professional facilitation consultant and — as a firmly established, regionally trusted boundary spanning organization — the Coastal & Heartland National Estuary Partnership (CHNEP) provided the platform to host this initiative.

Actionable science planning co-production workshops were conducted as an ad hoc advisory Habitat Conservation Subcommittee (HCS). In the period from November 2021 to July 2022, four half-day public workshops were held with stakeholders including relevant agencies, NGOs, and members of the public (Table 1) in a hybrid in-person and virtual format to maximize participation. HCS workshops focused on efforts to bridge the science and policy gaps on sport fish nursery habitat in order to advance efforts on landscape conservation and management of coastal fish habitat in Charlotte County.

Table 1 List of partners involved with the Habitat Conservation Subcommittee, including the types of organizations and the roles of participants

Organization name	Type	Participant roles
Big Waters Land Trust	NGO	Subject matter expert
Bonefish & Tarpon Trust	NGO	Subject matter expert
Charlotte County	Local government	Resource manager
Coastal & Heartland National Estuary Partnership	Place-based program	Boundary spanner, subject matter expert
Florida Department of Environmental Protection	State government agency	Subject matter expert
Florida Fish and Wildlife Conservation Commission	State government agency	Resource manager, researcher, subject matter expert
Florida Sea Grant	University program	Subject matter expert
National Oceanic and Atmospheric Administration	Federal government agency	Funder, subject matter expert
Southwest Florida Water Management District	Local government	Subject matter expert
Punta Gorda Isles Fishing Club	NGO	Stakeholder

The workshops progressed through a sequence from providing information on the resources and purpose, to building consensus about management decisions and decision points, to collaborative planning of feasible research necessary to produce decision support products for resource managers. The discussions within the HCS workshops established a group understanding of the roles required to successfully execute actionable science, and led to formation of a cooperative team of state and federal agency researchers and managers, NGOs, individual stakeholders, boundary spanning collaborators, and local government managers. The consensus-based outcomes of the HCS workshops were captured in a Research and Application Plan that outlines the research and policy gaps, specific methodologies, and work plan summaries for conducting actionable research and the transfer of knowledge from researchers to managers. The plan was further vetted and approved by CHNEP’s management conference committees, which include county administrative and political leaders.

Two principal management questions leading to decisions related to sustaining these natural resources were defined: (1) Should environmentally sensitive land zoning policies that conserve snook and tarpon nursery habitats (i.e., coastal ponds) be adopted in the 2028 Charlotte County Comprehensive Plan? (2) Where and how should targeted habitat restoration be implemented in 2028 by the state fish & wildlife agency, Florida Fish and Wildlife Conservation Commission, to ensure sufficient and sustainable snook and tarpon nurseries in Charlotte Harbor?

Results

The project team developed several research and policy themes to reduce management uncertainties, and created work plans to generate the knowledge needed to fill the identified gaps. These themes included: (1) Fish Biology: sport fish and fish community ecology, habitat locations and utilization, growth, movement, and recruitment; (2) Habitat Function and Management: hydrology, and projection of development impacts and effects of sea-level rise on functionality and quality; and (3) Habitat Protection, Conservation and Preservation: strategies and methods to maximize conservation incentives, influence policies, and improve the effectiveness of conservation efforts for estuarine sport fish habitat in Charlotte Harbor. These themes were further developed by the HCS into specific applications that inform the two resource management decisions and define potential decision options (Fig. 3).

The co-produced research plan emphasized the need for: (1) additional surveys to document the full extent of juvenile sport fish habitat within the study area, (2) a

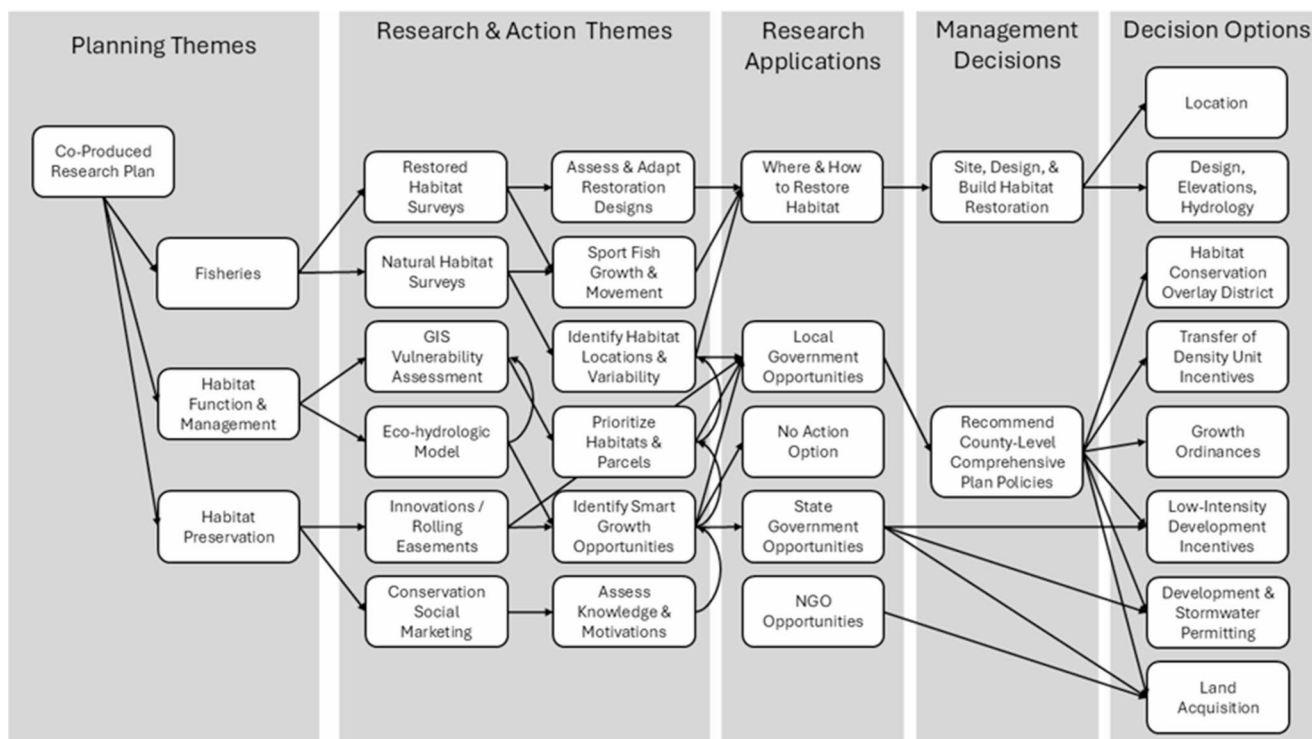


Fig. 3 Decision framework diagram developed during the co-production process. Uncertainties (information gaps) surrounding management decisions were co-identified by a group of resource managers, researchers, and stakeholders. The research needs and the application of research outputs to inform the management decisions are mapped

into a workflow process, which is organized into planning themes that reflect the participants' areas of expertise. Potential decision options were devised by resource managers as a reference for the participants of the co-production process to understand the component parts of the decisions

vulnerability analysis to help prioritize habitats for management, (3) hydrologic modeling of a key drainage basin to address alternative conservation policies, (4) development of a downscaled coastal habitat evolution model to predict migration in response to sea-level rise, and (5) functional monitoring of recently completed restoration projects to inform future efforts. The research plan is to complete a series of projects in a stepwise framework, focusing on sport fish nursery habitat in Charlotte County, Florida, with the goal of using sport fish socioeconomic status as leverage to improve land use and growth management practices (Wilson et al., 2023). The products will be included in planning county comprehensive land use policies and state agency habitat restoration projects.

(1) Define the extent of juvenile sport fish habitat in the study area.

First, the plan aims to identify the extent and quality sport fish nursery habitat via fisheries monitoring. This includes broad-scale surveys to refine the extent of the habitat where juvenile snook and tarpon occur in the landscape; intensive sampling at a subset of sites to determine long-term patterns of juvenile snook and tarpon abundance and the prey

resources needed to support these species; and evaluation of optimal inundation for successful emigration from coastal ponds. Both broad-scale and intensive sampling will be performed to inform the GIS-based vulnerability analysis by identifying which coastal ponds support juvenile sport fish. The resulting improved understanding of the amount of marsh flooding needed to allow for emigration of sport fish will inform stormwater engineering and identify which upstream habitats may be used by juvenile sport fish in the future under projected sea-level conditions. Acoustic telemetry of fish movement and emigration from habitats will inform both the hydrologic and coastal evolution models.

(2) Identify vulnerable habitats that managers should prioritize.

Mapped fish nursery habitat locations and land use map layers — including developable land, wastewater outflows, watershed delineations, and habitat coverage and type — will be used to create a vulnerability analysis (decision-making support tool). This map-based tool will be used to prioritize locations identified as nursery habitats for additional research, rank degraded habitats for restoration, and prioritize habitats for protection and conservation. The

outcomes of these assessments will inform land use planning policy proposals; for example, the application of specific development regulations or incentives to a distinct geographic area using planning tools such as zoning overlay districts.

(3) *Predict how land development will affect the hydrology of existing sport fish nursery habitats.*

A key pressing question is how the expected housing development on Charlotte County's Cape Haze Peninsula (an area without a stormwater master plan) will affect coastal pond hydrology and function of the sport fish nurseries. To answer this question, ecohydrology modeling will be performed to simulate catchment-scale hydrologic processes and also test alternative development scenarios to inform land use policy recommendations.

(4) *Predict how sea-level rise will affect sport fish nursery habitats.*

The research planning process identified uncertainty related to the impacts of sea-level rise and evolution of the coastal habitat. We will model local habitat evolution and flooding under sea-level rise scenarios to forecast coastal habitat migration and determine if natural and restored waterbodies could become accessible to sport fish due to tidal flooding.

(5) *Evaluate a recently completed restoration project as a model for future sport fish nursery habitat restoration projects.*

An intensive sampling strategy and fish telemetry methods applied to natural pond habitats will be used at Lemon Creek Wildflower Preserve, a former golf course that was restored to a natural area in 2021 to provide habitat for juvenile snook and tarpon (Wilson et al., 2019). Fish movement data and water level information will be used to determine if juvenile tarpon successfully emigrate from the restoration site and contribute to the adult stock. An important benchmark of restored nursery habitat is that juvenile fish grow at comparable rates to those in natural habitats. A study conducted at the golf course ponds prior to their restoration found the growth of juvenile sport fish to be substandard (Wilson et al., 2019). To assess whether the restoration has improved the conditions for juvenile sport fish, we will compare the growth of juvenile snook (using the methods in Stevens et al., 2024b) between the restoration site and nearby natural habitats. The resulting comparisons between this site and other regional habitat restoration projects are intended to inform the siting and design of a new habitat restoration project in the study area in 2028.

Discussion

Science-Informed Management

The decision to enact land conservation amendments to the County Comprehensive Plan to preserve snook and tarpon nursery habitat requires knowledge of where exactly the habitat is located and the nature of the threats to proper nursery function. The new, broad-scale fisheries sampling defined in the co-produced research plan will reduce the uncertainty related to knowledge of where juvenile snook and tarpon occur in the landscape. To meet the contemporary definition of nursery habitat, it is important to show that juvenile fish can move out of the nursery when the time is right and contribute to the adult population in the estuary (Beck et al., 2001; Dahlgren et al., 2006; Barbour et al., 2014). The possibility of juvenile fish remaining trapped in a habitat is especially concerning for snook and tarpon, which can be found far into the margins of the coastal landscape at the interface with urban development. One misplaced stormwater structure can separate a nursery from either its headwaters or the open estuary. Thus, the proposed hydrologic modeling of the drainage basins and development of a model that evaluates existing zoning and permitted land use and the potential effects of sea-level rise on these habitats are necessary to fully evaluate the risk to these habitats.

The model components above, along with the fish biology data, will be used to develop a habitat vulnerability analysis. This tool is intended to incentivize science-based protections for sport fish nursery habitats in county and municipal Comprehensive Plans. The results of the habitat vulnerability analysis will provide site-specific habitat scores that reflect both the value of the specific habitat to overall sport fish productivity in the system, as well as the risks imposed on the habitat by future anthropogenic and climatic effects. The final habitat vulnerability analysis will produce an electronic map that can be overlaid on existing spatial data layers, including permitted land use, existing infrastructure, and zoning information. The results of this analysis will integrate information on the natural resource requirements of these species and can be used as a tool to support local ordinances and market-based incentive programs associated with Charlotte County's development planning. Creative solutions are required to implement actions to protect these habitats, such as the county's Transfer of Density Units program — which encourages a shift of new residential housing away from environmentally sensitive areas into designated locations to promote efficient compact development. To inform and optimize the effectiveness of such solutions, the outcomes of the habitat vulnerability analysis will be combined with current ordinances and recommended land use practices to produce an

overlay district (map layer) for Charlotte County. Overlay tools are widely used in land use planning to apply specific regulations to distinct geographic areas. Determination of the county policies that would be most protective of sport fish nursery habitat is ongoing, pending the outcomes of the co-production research phase.

The decision to select and site a wetland restoration design targeted at snook and tarpon nursery habitat in Charlotte County requires a better understanding of which design features work for these species. To reduce uncertainties related to design specifications, a restoration completed in 2021 that specifically attempted to create habitat for juvenile snook and tarpon will be evaluated. To demonstrate the success of restoration efforts targeting juvenile fish, it is important to confirm that obligate users of coastal wetlands — such as snook and tarpon — are using the site, growing at the correct rates, and are able to leave when needed to complete their life cycle (Schulz et al., 2020). The planned study design, which utilizes metrics of juvenile growth and emigration, will determine if the restoration site properly functions as nursery habitat. The elevations and connection types for the restoration site were designed so that juvenile fish would be protected from aquatic predators, have access to productive prey resources, and could leave the site when needed. If one of these conditions is not met, adaptive management may be required (i.e., changes in a culvert design or elevations). Ultimately, ensuring that this already completed restoration design is compatible with juvenile sport fish will help reduce the uncertainties associated with the siting and design of a new restoration project in 2028.

Preliminary Outcomes

The preliminary outcomes of the co-production effort include progress toward habitat conservation. Regional land trusts and county government have shown interest in incorporating sport fish habitat location data when prioritizing land for conservation. Nine parcels of land, comprising 419 hectares, have been identified as high priority for conservation through conservation easement or fee-simple acquisition. Charlotte County government has already employed the co-produced knowledge to inform the establishment of coastal elevation monitoring locations and conducted compound flood modeling for properties that surround habitat. Each of these approaches is creating outputs that will help to better assess the vulnerability of these sport fish nursery habitats and inform conservation decisions. Without the involvement of local government planners and knowledgeable stakeholders, the progress realized to date would not be possible. Uninformed decisions may have resulted in ineffective conservation efforts by the state fish and wildlife agency. In addition, the financial support for planning

actionable science from the National Oceanic and Atmospheric Administration's RESTORE Science Program was invaluable to enable professional facilitation of the HCS and allowed the knowledge co-production process to occur.

This study demonstrates that engagement in a co-production process can lead to increased investment in research that informs habitat conservation and restoration. Restoration within the study area includes a disused golf course (Lemon Creek Wildflower Preserve; Wilson et al., 2019), relic canals converted to fish habitat (Coral Creek Phase 2 restoration; Stevens et al. 2024a; Wilson and Adams, in preparation), and creation of coastal ponds in a ditched marsh (Coral Creek Phase 3, currently ongoing). In interactions with restoration practitioners and engineers dating back a decade, it became apparent that more detailed information was needed on how best to restore habitat for juvenile snook and tarpon, as flagship species that use coastal wetlands in Southwest Florida. Research priorities shifted to address this issue (Wilson et al., 2019; Schulz et al., 2020; Stevens et al., 2023; Bunting et al. 2024; Stevens et al. 2024a, b; Saari et al. 2025). For example, the results of fish sampling efforts combined with a detailed habitat assessment (Stevens et al. 2024a) found that juvenile snook used coastal ponds that were directly connected to tidal creeks (e.g., elevation -0.12 m relative to Mean Low Water). In contrast, juvenile tarpon were more likely to be present in coastal ponds separated from tidal creeks by dense mangrove forest (e.g., elevation >0.48 m above Mean Low Water) and characterized by highly organic sediment and low dissolved oxygen, to which tarpon are well adapted. These types of details can be used by restoration practitioners and engineers to improve restoration design that targets the creation of habitat for these species. Ideally, determining the success of restoration that includes fish habitat should include assessments of growth (are fish growing at the rates they should be?) and estimates of emigration (are enough fish surviving and do they contribute to adult populations in the open estuary?). Protocols have been developed for the assessment of snook growth (Stevens et al. 2024b) and emigration studies in coastal wetland habitat have been conducted (Wilson et al., 2019; Bunting et al., 2024).

The results of this research have also spread beyond the initial study area and are being applied by managers and researchers to co-design habitat restoration in adjacent estuaries. For example, new research is being conducted to inform hydrologic restoration at Terra Ceia Preserve State Park, which contains numerous coastal ponds along the shorelines of Tampa Bay, Florida. Ideally, an adaptive restoration approach should be adopted to create juvenile snook and tarpon habitat, in that engineers and restoration practitioners should plan on returning to the site to potentially make adjustments after a period of post-restoration monitoring.

Such an approach is being used at Robinson Preserve in Bradenton, Florida, where snook and tarpon habitat was created from disused farmland. Backwater lagoons and coastal ponds designed as snook and tarpon habitat were found to be more connected than originally planned after conducting circulation modeling and fish sampling post-restoration. To reduce connectivity within the habitat mosaic, changes are being made to connection points (e.g., elevation, culvert size) and efforts are underway to encourage high-relief oyster habitat and mangrove expansion at the entrances to estuarine features.

Challenges

As this co-production process that includes local government continues over the next decade, we expect to face challenges and barriers. Piczak et al. (2022) described expected challenges in co-production, which include: (1) agency participation and meaningful engagement, (2) the stability of time commitments and financial resources, (3) closed or exclusive networks, and (4) evolving political landscapes.

The state fish and wildlife agency involved in this co-production effort is implementing a strategic initiative to better engage in landscape conservation. This effort has identified where communication can be improved between different sections of the agency and with conservation partners that have experience in the appropriate level of land use planning. Due to organizational siloing, many partners have experienced challenges connecting with the appropriate personnel. Co-production provides more opportunities for intra-agency and external partner coordination. Staff turnover is an additional hurdle to bridging the gap between agency sections, as it contributes to loss of institutional knowledge and management inefficiencies (e.g., Fulton, 2023). Conservation efforts, such as land acquisitions, can take up to a decade or more and require a network of professional relationships across the agency and its partners to be effective (Vangen & Huxham, 2003). Therefore, although agency participation and meaningful engagement is currently high, the stability of time commitments from veteran staff is expected to become a challenge. The challenge of sustained staff engagement becomes heightened as interactions with partners, including local government, are considered. Early and mid-career members of local government who have become knowledgeable about the importance of conserving and restoring fish habitat, and are motivated to implement meaningful actions, are likely to move on to other jobs within a five-year time span (Minzlaff et al., 2025). Due to this frequent turnover, and redundancy between roles, communication plans and the institutionalization of co-production are necessary to quickly integrate new staff into co-production efforts.

Time commitments can also present an issue if there are large time gaps between the steps in the planning-to-decision making pipeline. Conducting actionable science can take years, and participants may become disengaged with a slow process. Keeping multiple staff members with diverse expertise engaged over the long term is a challenge for multifaceted fisheries and wildlife agencies in particular. Maintaining active engagement with the process allows staff designated as single points of contact to pull in additional experts from their organization when an issue or opportunity emerges. Commitment to a lengthy co-production process may also be challenging for unpaid participants. While the co-production described in this case study did not rely heavily on unpaid members of the HCS, additional stakeholders may have been able to participate if monetary compensation was provided to those who otherwise volunteer their time and expertise.

Another challenge related to the co-production process described here is the lack of long-term dedicated funding for both the processes and the proposed outcomes (i.e. aquatic habitat restoration and local government policy implementation). Local land use policy operates at decadal timescales, and restoration actions can take a full decade with additional time needed for post-monitoring and adaptive restoration.

Additional challenges associated with exclusive networks and evolving political landscapes are relevant to land use planning and stormwater infrastructure. Conceptual plans for large subdivisions, for example, can be approved 20 years before the first actions at the site begin. Further progress is needed to develop avenues for knowledge generators and knowledge users to interact with urban and suburban developers at an early enough stage in the planning process to influence site planning, particularly with respect to the siting of hydrologic corridors and selection of stormwater infrastructure. These plans were often developed under a different political and regulatory landscape than the current landscape. In Cape Haze Peninsula, one of the study areas associated with this effort, a portion of the landscape was platted and sold as properties designated for individual single-family homes. Roads and drainage infrastructure were put in place to allow access to those properties; however, the stormwater management requirements at that time differ substantially from current mandates. It is unclear if the stormwater treatment will be improved to modern standards; although home construction has yet to occur throughout much of the area, single family homes are exempt from most modern stormwater management requirements. In addition, the state legislature has passed statutes placing a one-year moratorium on any changes to local government-development regulations or their Comprehensive Plan that might be more restrictive or “burdensome” to development or reconstruction activities if the local government is

included in a federal disaster declaration due to hurricane impacts. The frequency with which coastal communities are impacted by hurricanes presents the risk that local governments may be regularly constrained by this statute.

During the co-production process described here, it became apparent that regulatory and policy hurdles frequently come into play when attempting to execute legally defensible protection measures for snook and tarpon habitat. As conservation opportunities are identified, it can be difficult to identify the appropriate people to notify and educate. Regulatory authority and conservation work are scattered across various government agencies and NGOs, making this case a poor fit with a traditional ‘loading dock’ approach from science to action (Beier et al., 2016), but highly suited to the co-production of actionable science. However, boundary organizations can serve as a critical conduit between agencies, local government departments, NGOs, and engaged stakeholders.

Conclusions

Implementation of the co-produced research plan is being conducted until the end of 2028 with funding from the RESTORE Science Program, to address the research questions identified above. Decision-support products are being produced to coincide with the next planned revision of Charlotte County’s Comprehensive Plan. Land use policies designed to protect fish habitat, watersheds, wetlands, and drainage features are likely to also have co-benefits for flood attenuation and water quality management. Land acquisition policies can further prioritize coastal zone buffering, and thus add value to developments built to complement rather than conflict with fish habitats. Habitat restoration or creation inland could mitigate the functional loss of discrete nursery habitats that is predicted by sea-level rise models. All strategies of this effort aim to sustain resource productivity and community economic benefits stemming from incorporating management of juvenile sport fish habitat as a component of fisheries management and local land use planning.

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Declarations

Ethics Approval and Consent to Participate Not applicable.

Consent for Publication Not applicable.

Competing interests The authors declare no competing interests.

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