Received: 29 January 2021 | Revised: 25 April 2021 | Accepted: 10 May 2021

DOI: 10.1111/jwas.12809

REVIEW ARTICLE

Journal of the World Aquaculture Society Open Access | WORLD AQUACULTURE Society | WILEY

The status of Florida pompano, *Trachinotus carolinus*, as a commercially ready species for U.S. marine aquaculture

Charles R. Weirich[1] | **Kenneth L. Riley**[2] | **Marty Riche**[3] | **Kevan L. Main**[4] | **Paul S. Wills**[3] | **Gonzalo Illán**[3] | **David S. Cerino**[5] | **Timothy J. Pfeiffer**[6]

[1]NOAA, OAR, National Sea Grant Office, Silver Spring, Maryland

[2]NOAA, NOS, National Centers for Coastal Ocean Science, Beaufort, North Carolina

[3]Harbor Branch Oceanographic Institute, Florida Atlantic University, Fort Pierce, Florida

[4]Mote Aquaculture Research Park, Mote Marine Laboratory, Sarasota, Florida

[5]Aquaculture Technology Program, Carteret Community College, Morehead City, North Carolina

[6]USDA Agricultural Research Service, Warmwater Aquaculture Research Unit, Stoneville, Mississippi

Correspondence
Charles R. Weirich, NOAA, OAR, National Sea Grant Office, 1315 East-West Highway, Room 11735, Silver Spring, MD 20910, USA.
Email: charles.weirich@noaa.gov

Abstract

Owing to their high value, in the 1950s researchers and commercial ventures began investigating the potential of Florida pompano, *Trachinotus carolinus*, for aquaculture; however, initial efforts did not result in commercialization. In the early 2000s, a renewed interest in pompano as a candidate for aquaculture occurred, and over the last two decades, protocols have been developed that have allowed commercialization of pompano aquaculture. Florida pompano broodstock can be readily conditioned to spawn (26–28°C) to produce large numbers of fertilized eggs year-round via hormonally induced volitional tank spawning. Larval rearing is straight forward using a standard feeding regime of rotifers, then *Artemia*, followed by co-feeding and weaning to microparticulate diets with metamorphosis occurring at approximately 18–25 days post hatch. Pompano readily consume formulated diets and growout of

juveniles to produce marketable fish for consumption is fairly rapid (<12 months) and has been achieved mainly via recirculating aquaculture system technologies and ocean net pens. To expand industry development, there is an ongoing need for research directed towards topics including broodstock domestication, selective breeding, and genetic improvement; delayed maturation; diet development and refinement; disease management; economics and business planning; and marketing strategies.

KEYWORDS
commercial status, Florida pompano, marine finfish aquaculture, *Trachinotus carolinus*

1 | INTRODUCTION

Florida pompano, *Trachinotus carolinus*, are members of the jack (family Carangidae) and are highly prized by both commercial and recreational anglers. Also commonly referred to as pompano, Atlantic pompano, *pompaneau sole* (French), and *pompano amarillo* (Spanish), this species is a deep, thin-bodied marine finfish that is predominately silver in color with green to gray dorsal and yellow ventral surfaces (Main, Rhody, Nystrom, & Resley, 2007, Figure 1). Pompano are schooling warm-water pelagic finfish and are found in shallow near-shore waters along sandy beaches as well as estuarine areas adjacent to the coasts of the eastern Atlantic Ocean from Massachusetts to Brazil and throughout the Gulf of Mexico (Gilbert & Parsons, 1986; Main et al., 2007; C. Smith, 1997). In U.S. coastal waters, pompano are found mainly from North Carolina to Florida with their highest abundance along the coasts of Florida (Gilbert & Parsons, 1986; Smith-Vaniz, 2002; Solomon & Tremain, 2009). In the northern hemisphere, pompano migrate north in the spring and south in the winter (Gilbert & Parsons, 1986). Despite the relative wide range of this species, what is known with respect to their life history and environmental requirements is based primarily on surveys of populations occurring in southeastern U.S. coastal waters (Finucane, 1969; Gilbert & Parsons, 1986; Main et al., 2007).

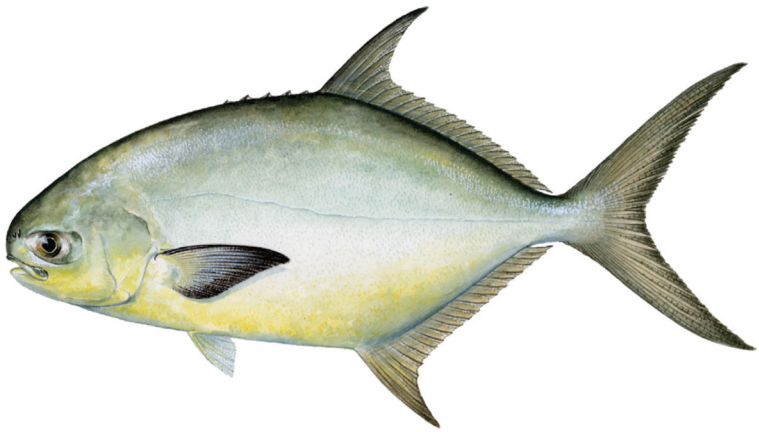

FIGURE 1 Florida pompano, *Trachinotus carolinus* (©Diane Rome Peebles)

Although spawning of Florida pompano has not been observed in the wild, it is thought that reproduction occurs offshore from February to October in southeastern U.S. coastal waters with peaks in April to May and September to October (Fields, 1962; Solomon & Tremain, 2009). It is speculated that spawning of this species may occur year-round in the Gulf of Mexico as well as in the Caribbean Sea (Berry & Iverson, 1967; Main et al., 2007). It is thought that developing pompano larvae spend approximately 1 month offshore under high salinity conditions until reaching metamorphosis and their transition to juveniles, after which they exploit near-shore environments, especially those associated with beach surf zones (Finucane, 1969; Smith-Vaniz, 2002; Solomon & Tremain, 2009) until water temperatures are <20°C, when they then migrate offshore (Fields, 1962; Iverson & Berry, 1969).

In the wild, juvenile and adult pompano are diurnal feeders consuming a diet composed primarily of small mollusks and crustaceans such as coquina clams, *Donax variabilis*, mole crabs, *Emerita* spp., and other invertebrates (Armitage & Alevizon, 1980; Bellinger & Avault Jr., 1971; Finucane, 1969; Pattillo, Czapla, Nelson, & Monaco, 1997; Wheeler, Stark, & Heard, 2002). Pompano mature at 1–3 years of age and normally attain a maximum weight ranging from 0.7 to 2.3 kg, although individuals with weights up to 3.7 kg have been reported (Gilbert & Parsons, 1986; Smith-Vaniz, 2002; Weirich, Wills, Baptiste, Woodward, & Riche, 2009). Weirich et al. (2009) observed no gender-based morphological differences of market-sized pompano produced during a research trial. It has been estimated that most pompano live from 3 to 4 years under natural conditions (Berry & Iverson, 1967).

Regarding environmental requirements, juvenile and adult pompano have been shown to tolerate a relatively wide range of environmental conditions. Pompano can withstand dissolved oxygen levels as low as 4 mg/L (Moe Jr., Lewis, & Ingle, 1968), and although adults seem to prefer salinities from 28 to 37 g/L (Gilbert & Parsons, 1986), both juveniles and adults can tolerate much lower salinities, at least for short durations, and properly acclimated fish have been successfully reared to market size at a salinity of 5 g/L (Weirich et al., 2009). The most constraining environmental variable relative to Florida pompano aquaculture is water temperature. As a warm-water marine finfish species, pompano are cold intolerant and avoid water temperatures <20°C with mortality occurring at 10–12°C (Moe Jr. et al., 1968). Optimal temperatures for spawning, larval development, and juvenile growth appear to range from 25 to 30°C, although juveniles have tolerated exposure to temperatures as high as 34°C (Main et al., 2007).

Pompano are highly esteemed among culinary circles as they are an exceptional tasting fish with a mild flavor and flakey texture and are traditionally prepared in whole form grilled with varying presentations, or baked in parchment paper with vegetables and shrimp, crab, or oyster meat to create the iconic New Orleans dish *pompano en papillote*. In fact, Mark Twain, the renowned American writer and historian, described pompano that he dined on in New Orleans in 1883 "as delicious as the less criminal forms of sin." Pompano remains a prominent menu item at a number of high-end restaurants on the U.S. East coast as well as the Gulf of Mexico.

Because of its reputation as one of the most desirable marine table fish, pompano has historically commanded a significantly higher price than many other U.S. marine and freshwater finfish species (W. O. Watanabe, 1995) and demand has continued to exceed supply because of the relatively small and unpredictable wild harvest of this species (Main et al., 2007). In 2019, approximately 184 m.t. of pompano were wild caught in the United States, predominately from the states of Florida, Virginia, and Louisiana, with an average dockside price of whole fish over U.S. $10/kg, and farm-raised whole gutted fish currently obtain a retail price up to $40/kg.

2 | POMPANO AQUACULTURE RESEARCH AND DEVELOPMENT (1950s–1980s)

Because of their superior market value coupled with their limited supply, efforts toward development of culture methods for Florida pompano were initiated in the 1950s. These initial efforts extended to the early 1980s (Craig, 2000; W. O. Watanabe, 1995).

The first attempts to culture pompano were initiated in Florida in the early 1950s and evaluated pond production of wild-caught juveniles (Berry & Iverson, 1967; Cuevas Jr., 1978; Fielding, 1966; Moe Jr. et al., 1968). Efforts

by several public and private ventures in Florida continued in the 1960s to culture this species using ponds, coastal impoundments, and tanks (Berry & Iverson, 1967; Finucane, 1970a, 1970b, 1971; Iverson & Berry, 1969; Moe Jr. et al., 1968). In the early 1970s, the potential of rearing juvenile pompano using floating cages in coastal Alabama (Swingle, 1972; Tatum, 1972, 1973), Texas (Marcello Jr. & Strawn, 1972), and Florida (T. I. J. Smith, 1973) was assessed. In addition, commercial tank-based production was evaluated in the Dominican Republic as well as in Florida (McMaster, 1988). In the late 1970s, pond-based polyculture of pompano and shrimp was assessed in Alabama (Tatum & Trimble, 1978; Trimble, 1980), and in the late 1970s and early 1980s work in Venezuela evaluated polyculture of pompano and shrimp using seawater tanks (Gomez & Scelzo, 1982) as well as production of pompano in floating cages (Gomez & Cervigon, 1987).

A common thread shared by most of these initial studies was poor growth and feed conversion of fish greater than 200 g, usually coupled with poor survival, resulting in the inability to consistently produce fish ≥450 g. This was attributed to a number of factors including inadequate diets, disease outbreaks, and sub-optimal water temperatures.

Initial efforts were made in Florida during the 1970s focusing on reproduction and larviculture of Florida pompano. Hoff, Rowell, and Pulver (1972), Hoff, Mountain, Frakes, and Halscott (1978) and Hoff, Pulver, and Mountain (1978) demonstrated that broodstock pompano can be conditioned to spawn (by strip and volitional spawning methods) under varying photothermal conditions via administration of human chorionic gonadotropin, and Kloth (1980) described the spawning behavior of two female pompano that were induced to spawn. Although large quantities of eggs were produced in these groundbreaking studies, Hoff, Mountain, et al. (1978) reported that fertilization rates were highly variable and many eggs exhibited abnormal development, which was attributed to poor egg quality. Hormone-induced spawning of photothermal conditioned broodstock pompano with mass production of eggs was also reported in the 1970s by a commercial operation in the Dominican Republic (McMaster, 1988).

Hoff, Mountain, et al. (1978) reared Florida pompano larvae produced by hormone-induced spawning to metamorphosis (24 days post-hatch [DPH]) using a diet consisting of natural plankton, protozoans, rotifers, and copepod nauplii, followed by *Artemia* nauplii. However, considerable larval mortality was observed at 8–10 DPH and only a small number of juveniles were produced. Similarly, initial methods for larviculture of pompano were demonstrated at a commercial hatchery facility in the 1970s in the Dominican Republic using a live feeds regimen of rotifers followed by *Artemia* with metamorphosis occurring at 22 DPH (McMaster, 1988).

3 | POMPANO AQUACULTURE RESEARCH AND DEVELOPMENT (EARLY 2000s TO THE PRESENT)

The initial public and private efforts focused on the development of Florida pompano aquaculture provided a baseline of information to spur research interest, but consistent, reliable, and commercial scale production of this species was not demonstrated. As a result, for the most part, interest waned for two decades regarding efforts toward commercialization of pompano aquaculture. However, beginning in the early 2000s, a renewed interest in pursuing development of pompano aquaculture occurred, which was largely fueled by advancements made toward the culture of other marine finfish species (Tucker Jr., 1998).

3.1 | Reproduction and larviculture

A major constraint to the culture of marine finfish is the complexity of reproduction and subsequent larval rearing to produce reliable sources of juveniles to supply production operations (Planas & Cunha, 1999). With respect to Florida pompano, a number of strides have been made over the last two decades regarding development of reproduction and larviculture methods toward achieving mass production of juveniles.

To expand on work conducted in the 1970s that focused on development of spawning methods for pompano (Hoff et al., 1972; Hoff, Mountain, et al., 1978; Hoff, Pulver, et al., 1978; Kloth, 1980; McMaster, 1988), beginning in the early 2000s efforts were undertaken at research and commercial facilities, some of which utilized recirculating aquaculture system (RAS) technologies. RAS technologies offer a controlled environment for marine finfish broodstock to reach advanced stages of maturation, vitellogenesis, and spermiation from which spawning can be achieved with adequate egg quality and quantity for hatchery production (Duncan, Sonesson, & Chavanne, 2013).

Weirich and Riley (2007) collaborated on a joint research effort of the United States Department of Agriculture (USDA)'s Agricultural Research Service and Harbor Branch Oceanographic Institute (HBOI; FL) and demonstrated that pompano broodstock maintained under controlled photothermal conditions using RAS technologies could be induced to spawn volitionally year-round via hormonal (gonadotropin-releasing hormone analog [GnRHa]) induction. Their results indicated that mean batch fecundity (eggs produced/female) ranged from 234,000 to 302,000 eggs/female, which was substantially greater than that reported by Hoff, Mountain, et al. (1978) and Kloth (1980) and approximated fecundity values reported for female pompano in the wild (Finucane, 1969; Moe Jr. et al., 1968). These values also approximated or exceeded fecundity values reported for other carangids of interest or currently in aquaculture production including greater amberjack, *Seriola dumerili* (Mylonas, Papandroulakis, Smboukis, Papadaki, & Divanach, 2004); Japanese yellowtail, *Seriola quinqueradiata* (Mushiake, Kawano, Sakamoto, & Hasegawa, 1994; T. Watanabe, Verakunpiriya, Mushiake, Kawano, & Hasegawa, 1996); silver pomfret, *Pampus argenteus* (Almatar & James, 2005); palometa, *Trachinotus goodei* (Gomez, 2002); snubnose pompano, *Trachinotus blochii* (Du & Luo, 2004a, 2004b); and derbio, *Trachinotus ovatus* (Du & Luo, 2004b). Egg fertilization rates observed by Weirich and Riley (2007) were greater and less variable than those previously observed by Hoff et al. (1972), Hoff, Mountain, et al. (1978), and findings demonstrated that viable quantities of pompano eggs could be achieved to support larviculture of this species.

Main et al. (2007) summarized efforts conducted by the Mote Marine Laboratory (MOTE; FL) and demonstrated similar findings to those reported by USDA/HBOI researchers. One interesting aspect of the work conducted at MOTE revealed that natural spawning of captive pompano using RAS technologies can be achieved as an alternative to hormonal induction. Specifically, mature broodstock subjected to an abrupt change in water temperature from 24–26°C to 30–31°C resulted in eight natural spawning events. However, this spawning protocol was not as predictable as hormonal induction (K. Main, personal communication, February 5, 2021).

A number of efforts to date have been conducted using photothermal manipulation to initiate natural spawning of Florida pompano with limited success. There are likely impediments to realizing the natural spawning behavior of captive Florida pompano that are associated with factors such as tank size, water depth, stocking density, and perhaps substrate. Indeed, authors Weirich and Riley have observed that fish held in larger environs such as aquarium exhibits with natural bottom substrate exhibit calm behavior, suggesting that there may be a density/environmental effect restricting natural spawning of this species in captivity. Reynolds (2010) noted that production of mature gametes from captive brood males is highly variable and possibly the root cause of the lack of natural spawning activity of fish held in RAS. The author also suggested that strong flow rates in tanks could perhaps restrict natural spawning behavior.

In another recent study conducted at MOTE, Ma et al. (2017) evaluated the spawning performance of captive pompano broodstock using microsatellite-based DNA profiling in an effort to determine parentage assignment of offspring. The authors recommended employment of a genetically rigorous breeding plan, with optimal numbers of dams and sires (e.g., one or two females to three males), in order to ensure genetic diversity of offspring.

Additional work is needed to refine reproduction protocols for Florida pompano, especially efforts toward establishing natural reproduction as well as breeding of stocks to achieve genetic improvement. There are no current sources of domesticated Florida pompano broodstock available in the United States. All broodfish used in research and commercial production to date have been wild-caught adults, animals produced from wild-caught juveniles, or animals produced from offspring (F1 generation) of wild-caught adults.

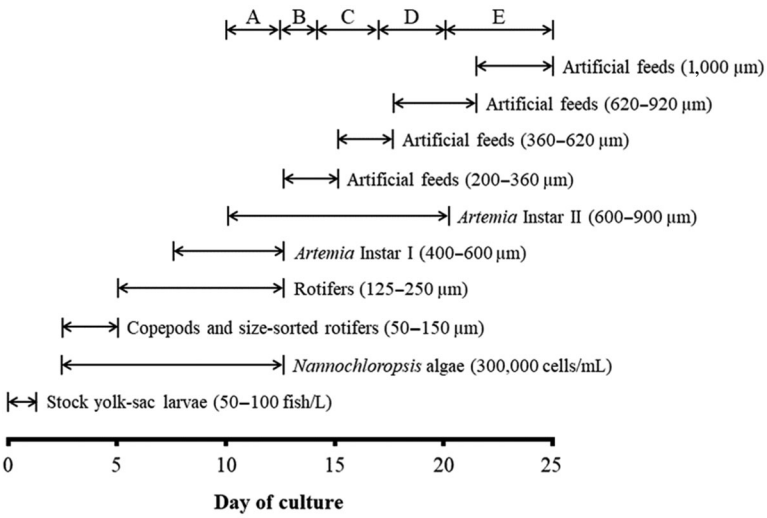

FIGURE 2 Recommended hatchery feeding regimen for production of Florida pompano, *Trachinotus carolinus*, from hatching through transformation/metamorphosis. Chronological stages of development are noted by the upper bar: A–preflexion; B–flexion; C–postflexion; D–metamorphosis, and E–juvenile

Despite the current lack of information regarding natural spawning and genetic improvement of Florida pompano, work conducted by public and private entities has resulted in development of hatchery methods for the consistent and reliable supply of juvenile pompano required for growout operations. The recent advances regarding pompano larviculture have been largely accomplished through application and refinement of hatchery protocols developed for other temperate and subtropical marine finfish species such as red drum, *Sciaenops ocellatus*; southern flounder, *Paralichthys lethostigma*; cobia, *Rachycentron canadum*; gilthead seabream, *Sparus aurata*; and seabass, *Dicentrarchus labrax* (Chamberlain, Miget, & Haby, 1990; Daniels & Watanabe, 2003; Moretti, Pedini Fernandez-Criado, Cittolin, & Guidastri, 1999; Nazar, Jayakumar, Tamilmani, & Sakthivel, 2013).

Prior to 2000, there had been a limited number of studies directly addressing topics relevant to larval production of Florida pompano; since 2000 research has documented and described development and growth of hatchery-reared larvae (Riley, Weirich, & Cerino, 2009); compared performance of larvae fed rotifers, *Brachionus plicatilis*, enriched with different commercial diets (Cavalin & Weirich, 2009); assessed copepod, *Pseudodiaptomus pelagicus*, nauplii as initial prey for first-feeding larvae (Cassiano, Ohs, Weirich, Breen, & Rhyne, 2011); evaluated different microparticulate diets on weaning success, growth, fatty acid (FA) incorporation, and enzyme activity (M. R. Hauville, Zambonino-Infante, Bell, Migaud, & Main, 2014); demonstrated the importance of probiotics in larval nutrition (M. R. S. Hauville, 2014); determined FA acid utilization of early-stage larvae (M. R. Hauville, Main, Migaud, & Gordon Bell, 2016); and investigated the effect of dietary taurine to improve larval performance (Derbes Jr., 2017).

Riley et al. (2009) tracked pompano larval development via photography and image analysis of cultured specimens, determining projected mouth gape that resulted in the development of a larval feeding regime for this species. Based on this work, pompano larvae require exogenous feeding as yolk reserves are diminished at 2–3 DPH and require small rotifers or copepod nauplii initially before they can be transitioned to larger prey/feed (Figure 2). The following paragraphs provide a description of methods relevant to pompano broodstock acquisition, quarantine, and feed training; broodstock inventory; reproduction and spawning; egg incubation; and larviculture that were developed and utilized by the USDA/HBOI program in the 2000s.

3.1.1 | Broodstock acquisition, quarantine, and feed training

Broodstock acquired by hook and line capture were transported and held in 8,000–12,000 L tanks (19–29°C; salinity, 28–30 g/L; natural photoperiod) for at least 2 months and were subjected to additions of copper sulfate

(to achieve a concentration of 0.25 mg/L as Cu^{+2}; Cutrine®-Plus Algaecide/Herbicide; Applied Biochemists, Milwaukee, WI) and biweekly additions of praziquantel (2.5 mg/L; PondRx.com; Morganton, GA) to eradicate protozoan and monogenetic trematode parasites, respectively. Although praziquantel has been used with success within research and ornamental fish hatcheries, it is not approved for use with food fish in the United States. During the quarantine period, fish were feed-trained by gradual transition from natural prey items to a formulated diet. Specifically, peeled shrimp and hard clam meats were offered for the first 2 to 3 weeks after capture, followed by food deprivation for 4–5 days, before being offered a gelatin-based diet (Gelly Belly™ Food Mix; Florida Aqua Farms, Dade City, FL), which was normally accepted within 1 week of food deprivation.

3.1.2 | Broodstock inventory

Upon completion of quarantine and feed training, the individual weight and sex of fish were determined after sedation. Passive integrated transponder tags were implanted subcutaneously in the lateral musculature for identification of individuals. The presence or absence of an oviduct through visual inspection of each fish was used to determine sex. Sex ratio approximated 1:1.

3.1.3 | Reproduction and spawning

Broodstock for spawning trials were conditioned to and maintained at 26–28°C, a salinity of 34–35 g/L, and a photoperiod of 14L:10D (light level approximated 200–300 lx) in RAS technologies. To induce spawning, females with a mean oocyte diameter >500 μm (determined via oviduct cannulation) and spermiating males were sedated and implanted subcutaneously in the lateral musculature with a 75 μg GnRHa pellet (Ovaplant; Syndel, Ferndale, WA). Fish spawned approximately 36 hr after implantation.

3.1.4 | Egg incubation

Eggs (typically at the neurula stage) were collected from tank spawns and prepared for incubation. In full-strength seawater from spawning tanks, floating and sinking eggs were separated to determine viability and fertilization rates. There were approximately 1,200 floating eggs/ml, with a mean diameter of 1.0 mm, and fertilization rate of floating eggs was normally >90%. Floating eggs were subsequently stocked into static incubation tanks (26°C, salinity ~35 g/L) at a rate of 1,000–1,500 eggs/L with minimal aeration. Hatching was observed at approximately 30–36 hr after fertilization and hatch rate was normally >80%.

3.1.5 | Larviculture

Within 12 hr after hatching, larvae were quantified volumetrically and stocked into RAS-based larval rearing tanks (1.5 m, 1,100 L, 27–28°C, salinity ~35 g/L) at a rate of 50–100 larvae/L. Initial light levels were maintained at <200 lx at the water surface with minimal aeration. Water flow was maintained to achieve a full-tank exchange every 6 hr using a 250 μm drain screen. At 2 DPH, greenwater culture was employed via addition of *Nannochloropsis oculata* algae paste (Reed Mariculture, San Diego, CA), aeration was increased, light levels were increased to ~1,000–1,500 lx (photoperiod = 14L:10D), water flow was increased to achieve a full-tank exchange every 4 hr, and enriched rotifers, *B. plicatilis*, were initially added at a concentration of 1.0–1.5/ml. From 3–6 DPH rotifers were fed at 2.5/ml/feeding four times daily at 8:00 a.m., 12:00 p.m., 4:00 p.m., and 8:00 p.m. At 7 DPH, first instar *Artemia*

nauplii were offered at 0.5–1.0/ml, aeration was increased, and water flow was increased to achieve a full-tank exchange every 3 hr using a 750 μm drain screen. From 7–9 DPH, first instar *Artemia* were fed at 2.5/ml/feeding, and at 10 DPH enriched second instar *Artemia* were first offered along with first instar nauplii to achieve a total of 3.5 *Artemia*/ml/feeding. From 7–11 DPH rotifer feeding was gradually reduced along with maintenance of greenwater, which were both discontinued at 12 DPH, along with the addition of first instar *Artemia*. At 14 DPH larval flexion was typically observed, aeration was increased, water flow was increased to achieve a full-tank exchange every 2 hr, and co-feeding of microparticulate diets was initiated. The size of microparticulate diets offered was gradually increased (14–15 DPH = 200–360 μm; 16–18 DPH = 360–620 μm; 19–21 DPH = 620–920 μm; 22 + DPH = 1,000 μm) and addition of *Artemia* was discontinued at 20 DPH. Active feeding on microparticulate diets was normally observed at or near the onset of postflexion and metamorphosis, which occurred at 16–19 DPH. At 20 DPH water flow was increased to achieve a full-tank exchange every 1 hr using a 1-mm slotted standpipe. Estimated 10,000–15,000 juveniles/tank (12.5–18.8/L) were harvested with survival rates ranging from 9 to 27% (based on larvae that were stocked). Juveniles were held in tanks until 30–40 DPH (mean weight ~ 5 g) at which time they were graded and moved from hatchery tanks to initiate production of advanced juveniles for stocking ongrowing tanks.

Improvements in larviculture of warm water marine finfish are an ongoing process. It is possible hatchery protocols for pompano could be improved through the use of recently developed protocols and technologies such as the use of clay instead of algae (greenwater) for larvae/prey contrast, new feeds and enrichments, and the use of self-cleaning tank systems.

3.2 | Rearing and growout

Initial research efforts that focused on rearing and growout of Florida pompano were largely unsuccessful due to poor growth, feed conversion, and survival, resulting in the inability to produce market-size fish. One of the most limiting factors encountered initially was suboptimal water quality conditions, especially temperature. However, in recent years, production technologies that offer more environmental control, among additional attributes, have been employed to successfully rear a number of marine finfish species, including Florida pompano such as RAS technologies and ocean net pens.

The use of RAS technologies has revolutionized aquaculture production of a number of finfish species because of several attributes. RAS technologies provide a controlled environment to maximize fish growth and survival; effective biosecurity and disease control; ease of harvest; and flexibility to site operations to take advantage of opportunities relevant to market access, skilled labor, and real estate opportunities.

Evaluation of RAS technologies toward rearing of Florida pompano was first initiated by Weirich, Groat, Reigh, Chesney, and Malone (2006) who investigated culture densities and feeding frequency of pompano reared in RAS using juveniles captured from the wild. Although culture densities utilized were lower than that required for commercial culture, pompano were grown from 17 g to >450 g in 4–5 months and >700 g in 8–9 months. Later work conducted by Weirich et al. (2009) revealed that hatchery produced pompano (260 g at stocking) could be reared using RAS technologies at low salinity (5 g/L) to market size in 2 months using commercial-scale tanks. Based on these observations, additional experiments were conducted to further assess and refine methods for the culture of pompano at low salinities. Results indicated that under higher densities low-level chronic mortalities at salinities below 5 g/L were mitigated by increasing the culture salinity to 12 g/L (M.A. Riche, Pfeiffer, Wills, Amberg, & Sepulveda, 2012). Similar observations were noted at MOTE, where researchers determined that salinities of 12–15 g/L were better than lower salinities for optimal survival and growth (K. Main, personal communication, February 5, 2021). Next-generation transcriptomics of fish reared under lower salinity conditions (3 g/L) and after salinity increase (12 g/L) indicated that genes related to osmoregulation, solute carriers, and oxidative stress were affected. In addition to this work, Wills (2013) demonstrated successful pompano production in a commercial-scale RAS at

salinities beginning at 8 g/L and ending at >20 g/L. Early chronic losses that were apparently due to stress subsided once the salinity was increased in the system (M.A. Riche et al., 2012). Fish were grown from egg to harvest with all inputs accounted for to conduct an economic production model (Wills, 2013). The production cycle required 507 days from egg to harvest. Survival was 89.1% and 5,884 fish were harvested at a mean weight of 425 g (ranging 100–898 g; mode 430 g). The experiment concluded with purging fish for 2 weeks to alleviate off-flavor prior to harvest and local distribution (Wills, 2013).

Recent studies at MOTE and HBOI have focused on next-generation marine RAS that incorporates the principles of integrated multi-trophic aquaculture (IMTA) (Boxman et al., 2015; Hanisak & Wills, 2013; Laramore, Baptiste, Wills, & Hanisak, 2018; Wills et al., 2012). The MOTE IMTA has produced pompano and marine wetland plants (Boxman et al., 2015) while the HBOI experimental system incorporates tank-based culture of pompano or other marine finfish species (e.g., cobia and red drum) in conjunction with marine shrimp, *Litopenaeus vannamei*, and macroalgae (e.g., *Ulva lactuca*). Two interesting observations of this experimental IMTA system have included: (a) after 7 years of operation the system consistently only requires approximately 0.5% per day of makeup water (much of which comes from rainfall), and (b) there has never been any off-flavor issues regarding fish compared with fish produced in other studies using RAS.

Realizing pompano production in RAS usually entails multiple phases of production to grade fish, assess condition, and select fast growing individuals. This usually means obtaining juveniles from the hatchery at approximately 10–15 g or from nursery systems at 50–200 g. Fish are then stocked into RAS (27–29°C) for ongrowing to market size (Figure 3). Purging fish is a common practice when utilizing RAS as fish may develop off-flavor that is caused by compounds produced by certain algae, fungi, or bacteria in recycled water (Azaria & van Rijn, 2018). Screening product for off-flavor is an important part of production planning associated with RAS and may require growing fish beyond a target size and purging fish or systems to remove off-flavor. It is important for fish to be in optimal condition and healthy prior to purging as it can require an extensive period of time (days to weeks) when fish are deprived of food.

Regarding the use of ocean net pens, moving fish farms offshore is a technological challenge, but a promising frontier for aquaculture development given the continued expansion of the industry around the globe in some rather inhospitable locations where the ocean climate is extreme. However, the transition to offshore aquaculture may afford opportunities to capture efficiencies and economies of scale that have been observed in other offshore industry sectors (e.g., oil and gas production, wind energy, commercial fisheries). Decades of research and numerous aquaculture demonstration projects in the United States and other countries have shown there are environmental benefits of working in the open ocean, where organic discharge from farms is effectively dispersed by natural oceanographic processes and assimilated into nutrient-limited food webs.

Although aquaculture of Florida pompano has yet to be evaluated for marine net pen culture in the United States, with new policies and plans for offshore aquaculture development, the United States could potentially support Florida pompano aquaculture in the Gulf of Mexico and Caribbean. Up to 750 m.t. of Florida pompano annually have been commercially produced in marine net pens in the Bahamas (2004–2006), the Dominican Republic (2009–2016), and Panama (2006–present) (Figure 4). In these locations, operations have placed sited floating marine net pens (10–40 m diameter) in sheltered areas with limited exposure to offshore conditions for nursery production, whereas growout has also been demonstrated in marine net pens with more exposed locations. Industry reports and observations suggest fish are best grown in multiple phases with densities ranging from 10–25 kg/m^3 (K. Riley, personal communication, January 31, 2021). Vaccination to control viral diseases (e.g., Red Sea Bream Iridovirus [RSIV]) on net pen farms has shown some success at sites with limited water circulation (K. Main, personal communication, February 5, 2021). Methods are similar to those for the production of other temperate marine finfish species where fish are first stocked at 10–15 g and grown to 100–150 g. Fish are then graded and stocked for ongrowing to market size (Alvarez-Lajonchère & Ibarra-Castro, 2013). Fish are typically selected for harvest within three size categories: (a) small 350–450 g; (b) medium 450–600 g; and (c) large 600–800 g (R. Reed, personal communication, September 5, 2018).

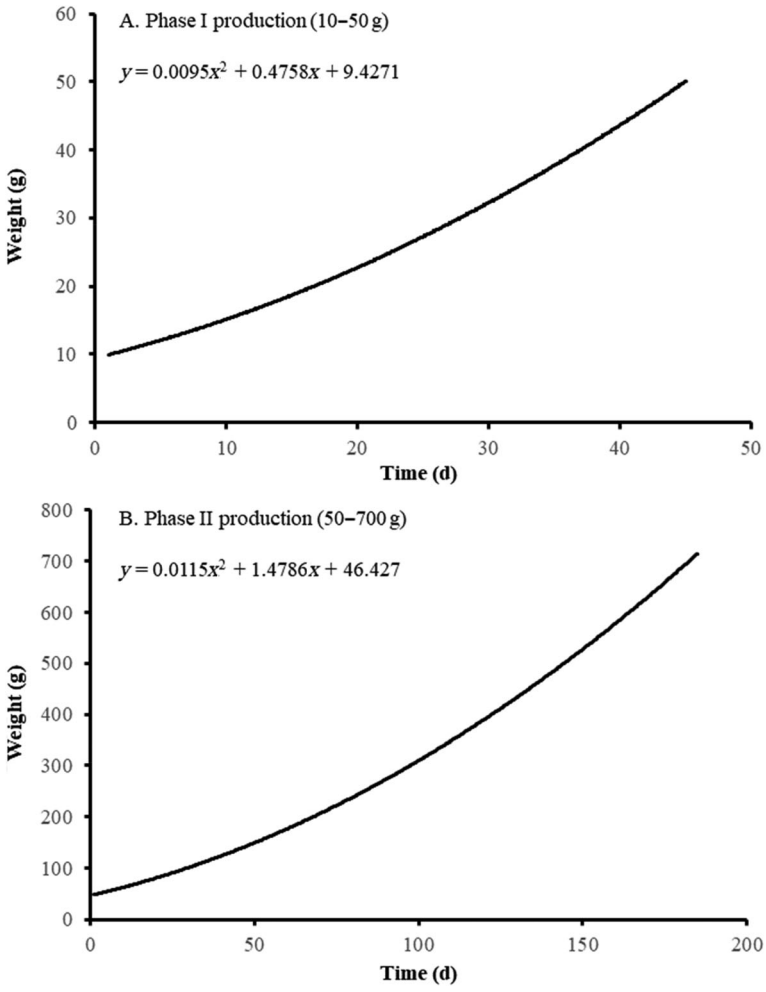

FIGURE 3 Projected growth rates of Florida pompano, *Trachinotus carolinus*, for use in production planning. Pompano have been consistently grown to 700 g in approximately 275 days at 27–29°C. Estimates were derived from research observations of pompano produced in recirculating aquaculture systems over the past 20 years. Actual results may vary with production format, feeds, and culture environment

A third potential growout method for Florida pompano that has yet to be evaluated may be through the use of in-pond raceways placed in inland low-salinity ponds. Such ponds are present in southern Texas, western Alabama, southern Florida, and other inland areas and are currently utilized for the production of marine shrimp and red drum (T. Pfeiffer, personal communication, February 8, 2021).

3.3 | Nutrition and feed development

Prior to the early 2000s, little was known about the nutrient requirements of Florida pompano. More recently, attention has focused on investigating optimum dietary protein, lipid, and energy utilization; digestibility of various feed ingredients; amino acid (AA) availability; and reduction of dietary fish meal (FM) and fish oil (FO) utilizing alternative plant and industry coproducts. Research into carbohydrate utilization and metabolism, AA and FA requirements, larval and broodstock requirements, and diets tailored to specific life stages remains the areas for further research.

Florida pompano, as with other members of the Carangidae family, are considered carnivorous species and in the wild prey primarily on small mollusks, crustaceans, and other invertebrates (Armitage & Alevizon, 1980; Bellinger & Avault Jr., 1971; Finucane, 1969; Pattillo et al., 1997; Wheeler et al., 2002). Similar to other marine carnivores, pompano have a high requirement for dietary protein and have met much of their energy needs with dietary

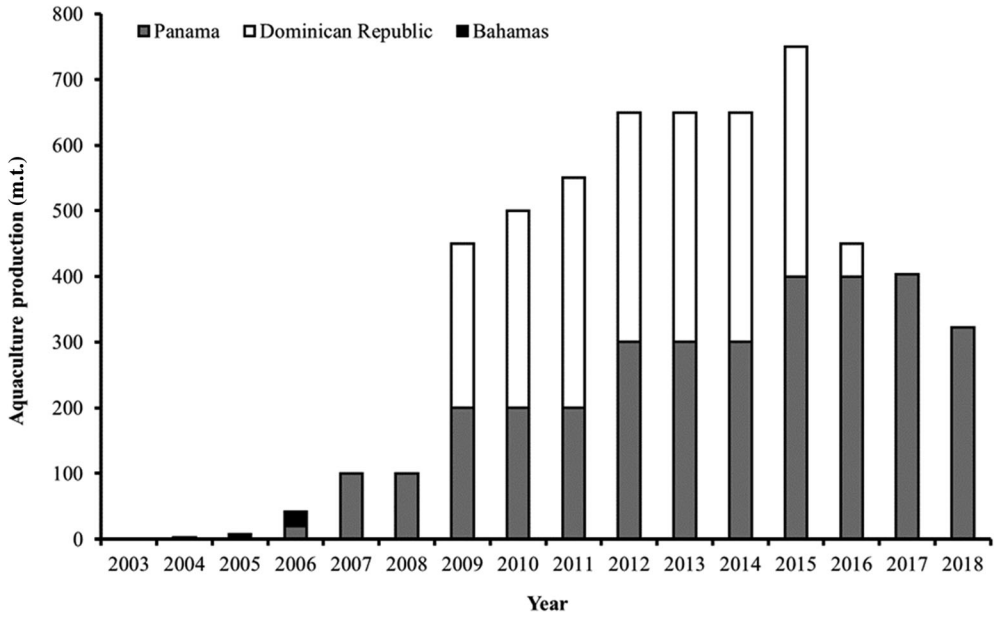

FIGURE 4 Evolution of the commercial production of Florida pompano, *Trachinotus carolinus*. Data on production volume (m.t.) were extracted and analyzed from 1950 to 2018 from FAO (2020)

protein and lipid. As with many marine finfish species, carbohydrates are poorly digested and not well utilized, and the degree of carbohydrate utilization is highly variable because of biological, environmental, and nutritional factors. For a more in-depth discussion regarding functional use of dietary carbohydrate in finfish, the reader is referred to Kamalam, Medale, and Panserat (2017).

Florida pompano continue to exhibit relatively poor feed efficiency (FE). One proposed reason for this observation is high metabolic demand due to their highly active nature. An alternative hypothesis is inefficient digestion as the result of their short digestive tract (Gothreaux, 2008) and rapid (3 hr) gut evacuation rate (M. Riche, 2009; S. Williams, Lovell, & Hawke, 1985). However, digestibility and availability coefficients from dietary ingredients reported thus far (Tables 1 and 2) neither support nor refute this hypothesis. Recently, pompano feeding mechanics have been suggested as a contributing factor to poor FE and this topic is currently being investigated (P. Wills, personal communication, January 22, 2021). Pompano also exhibit a wide size variation among cohorts, with slower growing fish depressing overall FE, suggesting a genetic component that could be potentially be addressed through a selective breeding program. Recent evidence suggests this is a much needed and viable approach (Ma et al., 2017). Regardless, poor conversion efficiency in *Trachinotus* spp. remains elusive and a much needed area for further investigation to make Florida pompano commercially competitive.

A significant effort has been made regarding determination of nutrient requirements of juvenile Florida pompano and broodstock and larval nutrition. The following sections provide information with respect to dietary requirements of crude protein (CP), AA, carbohydrates, taurine, and alternatives to FM. In addition, broodstock and larval diets are discussed.

3.3.1 | Crude protein

The dietary CP requirement for Florida pompano is estimated as 46% CP with a digestible protein level not less than 360 g/kg dry diet (M. Riche, 2009), similar to the 45.8% dietary CP reported for *T. ovatus* (Liu, Lang, Tao, &

TABLE 1 Apparent digestibility coefficients for selected feed ingredients fed to Florida pompano, *Trachinotus carolinus*

Feedstuff	CP	GE	DM	Weight (g)	Salinity (g/L)	References
Barley protein concentrate	78.5	68.5	51.3	36	3	M. Riche, Barrows, & Gaylord, 2017
	84.3	77.7	51.8	36	28	M. Riche et al., 2017
Canola meal	38.6	21.3	—	83	10	Lech & Reigh, 2012
Canola protein concentrate	70.7	59.5	46.0	36	3	M. Riche et al., 2017
	67.2	59.3	34.4	36	28	M. Riche et al., 2017
Corn gluten meal	81.9	77.4	—	75	3	M. Riche & Williams, 2010
	83.4	77.4	—	75	28	M. Riche & Williams, 2010
	57.2	57.1	—	83	10	Lech & Reigh, 2012
Corn grain	71.4	41.4	—	76–226	10–15	Gothreaux, 2008
	—	71.4	58.1	112	20	González-Félix, Davis, Rossi, & Perez-Velazquez, 2010
Corn protein concentrate	69.3	67.6	67.5	97	29	Cook, Zhou, Rhodes, & Davis, 2016
	37.2	53.7	40.2	36	3	M. Riche et al., 2017
	56.0	68.9	48.7	36	28	M. Riche et al., 2017
Cottonseed flour	93.3	84.9	71.3	97	29	Cook et al., 2016
	97.2	80.4	59.0	97	20	Cook et al., 2016
Cottonseed flour, extracted	86.1	76.7	57.3	97	20	Cook et al., 2016
Cottonseed flour, glandless	96.4	90.0	76.2	97	20	Cook et al., 2016
Distillers dried grains	54.0	63.5	—	50–70	3	T. N. Williams, 2008
	60.5	66.2	—	50–70	28	T. N. Williams, 2008
Distillers dried grains w/solubles	20.6	30.7	—	83	10	Lech & Reigh, 2012
Fish meal—menhaden meal	95.3	105.1	—	75–110	10–15	Gothreaux, 2008
	91.5	87.4	71.8	97	29	Cook et al., 2016
Fish meal—menhaden, special select	70.7	83.4	61.6	36	3	M. Riche et al., 2017
	83.3	93.4	75.3	36	28	M. Riche et al., 2017
Fish processing by-product[a]	57.8	69.7	59.8	36	3	M. Riche et al., 2017
	67.5	83.4	61.1	36	28	M. Riche et al., 2017
Meat and bone meal	62.4	65.7	—	73	10–15	Gothreaux, 2008
	63.3	66.3	—	50–70	3	T. N. Williams, 2008
	61.5	64.9	—	50–70	28	T. N. Williams, 2008
Poultry by-product meal, feed grade	71.7	75.9	—	50–70	3	T. N. Williams, 2008
	67.4	72.1	—	50–70	28	T. N. Williams, 2008
Rice bran, defatted	—	44.6	63.8	112	20	González-Félix et al., 2010

TABLE 1 (Continued)

Feedstuff	CP	GE	DM	Weight (g)	Salinity (g/L)	References
Rice bran, full fat	—	64.7	42.2	112	20	González-Félix et al., 2010
Sorghum grain	—	63.9	45.4	112	20	González-Félix et al., 2010
Soybean meal, solvent extracted	92.2	70.5	—	75	3	M. Riche & Williams, 2010
	87.1	62.2	—	75	28	M. Riche & Williams, 2010
	84.3	67.4	—	45	10–15	Gothreaux, 2008
	81.9	63.1	46.1	79	28	Roe et al., 2019
Low-oligosaccharide, soybean meal[b]	80.0	64.7	48.9	89	28	Roe et al., 2019
Soybean meal, fermented[c]	87.5	63.9	28.7	106	34	Roe et al., 2019
Soybean meal, low oligosaccharides[d]	87.7	58.0	25.0	106	34	Roe et al., 2019
Soy protein isolate	93.1	93.4	—	75	3	M. Riche & Williams, 2010
	85.0	78.1	—	75	28	M. Riche & Williams, 2010
Spirulina	63.4	68.0	62.6	36	3	M. Riche et al., 2017
	73.2	81.4	67.5	36	28	M. Riche et al., 2017
Wheat bran	—	70.1	51.5	112	20	González-Félix et al., 2010
Wheat flour	—	74.1	63.3	112	20	González-Félix et al., 2010
Wheat middlings	—	58.6	24.4	112	20	González-Félix et al., 2010
Yeast protein	39.9	43.8	32.9	36	3	M. Riche et al., 2017
	49.3	56.1	37.8	36	28	M. Riche et al., 2017

Abbreviations: CP, crude protein; DM, dry matter; GE, gross energy.
[a]Salmon by-product meal (Montlake Meal; NOAA Northwest Fisheries Science Center, Seattle, WA).
[b]Selectively bred (Schillinger Genetics, Queenstown, MD).
[c]Fermented soybean meal (Pepsoygen; Nutraferma, Sioux City, IA).
[d]Enzymatically treated low-oligosaccharide soybean meal (NutriVance; Midwest Ag Enterprises, Marshall, MN).

Dan, 2011) and 42–45% reported in early trials with Florida pompano (Lazo, Davis, & Arnold, 1998; S. Williams et al., 1985). However, it should be noted in the trails conducted by S. Williams et al. (1985) and Lazo et al. (1998) that these were the highest CP levels evaluated. Gothreaux (2008) fed Florida pompano diets ranging from 36 to 56% CP with a consistent dietary digestible energy (DE)/CP ratio of 9 kcal/g CP. A broken-line regression suggested that the dietary requirement was 46.3% CP (Gothreaux, 2008). It should not be overlooked that the predictive model utilized to determine the requirement also influences the estimated requirement.

The determination of protein requirements not only requires knowing the protein composition of the diet and availability of its constituent components, but the DE level of the diet as well. Too much energy can restrict dietary intake resulting in insufficient protein intake to reach the animal's genetic potential for protein deposition. Conversely, insufficient energy may lead to catabolism of dietary protein to meet the animal's metabolic demand. M. Riche (2009) determined that dietary digestible protein (DP) to maximize growth and nitrogen gain is between 356 and 366 g/kg diet, and DE to attain maximum growth in juvenile Florida pompano is at least 15.4 MJ/kg diet resulting in an optimum DP/DE between 23.8 and 25.1 mg/kJ. Similarly, in *T. ovatus* DP/DE is 24.4 mg/KJ (Liu et al., 2011).

TABLE 2 Apparent indispensable amino acid availability coefficients for select feed ingredients fed to Florida pompano, *Trachinotus carolinus*

Feedstuff	Arg	Hist	Ile	Leu	Lys	Met	Phe	Thr	Trp	Val	References
Barley protein conc.	89.6	87.8	98.4	96.5	86.1	105.2	101.5	73.9	—	90.8	M. Riche et al., 2017
Canola meal	53.8	46.9	50.4	46.8	48.4	91.9	54.2	44.6	—	48.1	Lech & Reigh, 2012
Canola protein conc.	83.9	80.9	82.8	84.0	81.0	103.4	93.1	75.0	—	77.4	M. Riche et al., 2017
Corn gluten meal	81.9	79.3	75.0	80.6	66.6	70.4	73.2	68.5		72.1	Gothreaux, 2008
	89.0	84.4	79.6	92.0	77.4	92.9	90.2	87.6	—	84.6	M. Riche & Williams, 2010
	68.5	58.7	62.5	70.8	47.9	84.9	70.9	56.9	—	64.7	Lech & Reigh, 2012
Corn protein conc.	72.9	75.1	77.0	77.8	73.2	82.4	88.0	61.6	—	73.0	M. Riche et al., 2017
Distillers dried grains	84.1	76.7	78.7	85.6	79.2	85.2	83.1	75.4	—	78.5	T. N. Williams, 2008
Distillers dried grains (w/solubles)	35.0	30.0	40.9	55.6	50.4	91.5	55.5	37.6	—	50.4	Lech & Reigh, 2012
Fish by-product meal[a]	87.3	79.4	89.4	89.1	86.8	95.1	97.8	76.4	—	84.5	M. Riche et al., 2017
Fish meal	105.0	94.7	100.7	101.7	106.3	101.9	98.1	103.2	—	100.5	Gothreaux, 2008
Menhaden meal	91.0	97.0	98.2	97.3	95.1	94.5	102.3	83.7	—	92.8	M. Riche et al., 2017
Meat and bone meal	69.0	73.1	70.8	70.3	84.7	63.2	73.6	63.0		67.5	Gothreaux, 2008
	82.9	72.7	75.0	82.1	73.0	79.5	81.5	68.6	—	81.1	T. N. Williams, 2008
Poultry by-product	82.8	75.2	74.3	82.2	78.7	85.9	81.6	73.2	—	79.1	T. N. Williams, 2008
Soybean meal[b]	96.5	88.8	94.7	94.2	93.4	94.3	94.9	91.1	—	94.8	Gothreaux, 2008
	78.1	88.7	84.6	85.6	95.6	93.9	79.6	105.3	—	75.7	M. Riche & Williams, 2010
Soy protein isolate	79.4	83.6	91.9	85.4	83.8	90.2	85.2	87.7	—	88.1	M. Riche & Williams, 2010
Spirulina	78.8	87.6	88.7	86.1	90.2	98.2	99.4	86.9	—	81.9	M. Riche et al., 2017
Yeast protein	64.7	60.8	70.4	64.6	66.9	86.2	83.8	48.6	—	63.5	M. Riche et al., 2017

Note: Ingredient coefficients from fish reared in isosmotic or full strength salinity.

[a]Salmon by-product meal (Montlake Meal; NOAA Northwest Fisheries Science Center, Seattle, WA).

[b]Dehulled, solvent extracted.

3.3.2 | Amino acids

In addition to indispensable amino acids (IAA) composition of potential feed ingredients, the availability of individual IAA is required to predict suitability as a dietary feed ingredient. Apparent AA availability provides greater resolution into the nutrient quality of a feed ingredient than apparent protein digestibility. Table 2 provides apparent availability of IAA to Florida pompano for a variety of plant and animal protein products. The IAA availability is similar in Florida pompano to other carnivorous species from those ingredients generally considered high quality (e.g., FM, soy products, barley products, Spirulina). However, the availability values for protein ingredients considered marginal (e.g., corn products, yeast, distillers dried grains) are similar or slightly lower than for other carnivorous species.

Many plant proteins are limiting in the AA lysine (Lys) and/or methionine (Met). For this reason, these are generally the first AA requirements established. Following the establishment of one AA requirement, the remaining IAA can be predicted from the whole body IAA profile of the species under investigation (Hossain, Almatar, & James, 2011; Kaushik, 1998; Mambrini & Kaushik, 1995). A test diet for the evaluation of IAA requirements for Florida pompano was developed (M. Riche, 2014), and the requirement for available Lys was determined as 22.5 g/kg in a 46% CP diet (M. Riche, 2011), which is similar to that of *T. blochii* (Ebeneezar et al., 2019). The Lys requirement and ratio of Lys to total whole body IAA were used to estimate requirements for the remaining IAA (Table 3). The estimated requirement for Met is 1.10% of the diet (M. Riche & Williams, 2011), similar to 1.17% experimentally determined in Florida pompano (Patro, Reigh, & Williams, 2011) and 1.06% of the diet in *T. ovatus* (Niu et al., 2013). Conversely, Belfranin (2016) was unable to determine a Met requirement in Florida pompano with graded levels of Met from 0.5 to 1.6% of the diet. However, this was likely due to the high level of dietary cellulose or another limiting AA. This suggests that the estimated requirements are a good approximation until experimentally determined requirements are available.

3.3.3 | Lipids

As with most marine fish species, Florida pompano have a dietary requirement for highly unsaturated fatty acids (HUFA), particularly docosahexaenoic acid (DHA, 22:6n-3), and eicosapentaenoic acid (EPA, 20:5n-3). It is generally accepted that growth suppression following FO replacement is not typically encountered as long as essential FA are provided in adequate levels to meet physiological demands. To our knowledge, the dietary requirements for DHA and EPA remain unknown, which is a much needed area for investigation.

TABLE 3 Estimated dietary indispensable amino acid requirements for Florida pompano, *Trachinotus carolinus*, based on the ratio of the pompano lysine requirement to the whole body amino acid profile

Amino acid	Whole body profile (%)	Estimated requirement (available g/kg diet)
Arginine	3.40	20.6
Histidine	1.15	7.0
Isoleucine	2.05	12.4
Leucine	3.52	21.3
Lysine	3.73	22.5
Methionine	1.69	10.2
Phenylalanine	1.9	11.5
Threonine	2.29	13.9
Tryptophan	0.22	1.3
Valine	2.39	14.5

Rombenso, Trushenski, and Schwarz (2016) fed juvenile Florida pompano diets with menhaden FO or various blends of FO and non-FO in a 25:75 ratio. Growth performance was unaffected by dietary oil source; however, all tissues examined were affected and tissue FA profiles mirrored dietary intake. The investigators suggested that oils high in saturated FA blended with menhaden oil offer a strategic advantage in maintaining fillet FA profiles relative to blends with other non-marine-based oils (Rombenso et al., 2016). Diets incorporating only beef tallow or FO resulted in no differences in growth, and thus beef tallow can serve as a suitable primary lipid source for juvenile Florida pompano. The high concentrations of saturated FA and monounsaturated FA in beef tallow were thought to exert a "sparing effect" on DHA and EPA. It is estimated that EPA and DHA, each at 0.4% of the diet, may be adequate to meet the metabolic needs of Florida pompano when fed diets rich with saturated and monounsaturated FA (Rombenso, Trushenski, & Schwarz, 2017).

3.3.4 | Carbohydrates

As stated earlier, Florida pompano do not have a biological requirement for carbohydrates. However, under certain circumstances, carbohydrates can meet some of pompano's energy needs with simple carbohydrates (glucose > dextrin > starch), but this ability is diminished with greater carbohydrate complexity (Kamalam et al., 2017). It is assumed, as with other finfish, that Florida pompano are unable to digest non-starch polysaccharides (NSP) due to a lack of sufficient enzymes (Sinha, Kumar, Makkar, de Boeck, & Becker, 2011), and evidence bears this out (Lech & Reigh, 2012). At sufficient dietary levels, NSP act as anti-nutritional factors (ANF; National Research Council [NRC], 2011). Also, as with other marine carnivorous finfish, Florida pompano are sensitive to the oligosaccharides stachyose, raffinose, and verbascose, which act as additional ANF. Low oligosaccharide soybean products through enzyme treatment, fermentation, and selective breeding have been evaluated for increasing production efficiency in Florida pompano diets (Roe et al., 2019).

Carbohydrates are utilized as an energy source to a limited extent to spare protein. However, they do also serve a functional purpose as a binder in pelleted feeds and are essential in the production of expanded pellets. The heat, moisture, and pressure encountered in the pellet production process substantially influences the level of carbohydrate availability.

S. Williams et al. (1985) estimated that carbohydrate digestibility in Florida pompano was about 50%. Similarly, González-Félix et al. (2010) demonstrated low digestibility values for dry matter and energy in Florida pompano from ingredients derived from corn, sorghum, wheat, and rice. Dietary supplementation of chromium polynicotinate improved starch utilization facilitating the glycolysis pathway in golden pompano leading to a protein-sparing effect (Wang et al., 2019). It is not unreasonable to imagine a similar effect in Florida pompano. The utilization and metabolism of carbohydrates in *Trachinotus* spp. are poorly understood and remain a rich area for further research.

3.3.5 | Taurine

Taurine is a dietary requirement for many marine carnivorous species, but requirements, if any, are highly species specific (Salze & Davis, 2015). Although marine products such as FM contain sufficient taurine to meet this requirement, many plant proteins and other alternatives to FM are deficient. Typically poor growth and efficiency are cited as indicators of dietary taurine deficiency. Salze, Spangler, Cobine, Rhodes, and Davis (2016) screened for metabolic and physiological biomarkers for indicators of taurine deficiency in Florida pompano, but no overt indicators were identified. It was speculated that longer term studies may be required for deficiency symptoms to become evident.

Salze, Davis, and Rhodes (2014) reported that the estimated dietary taurine requirement for Florida pompano was 0.54–0.65% of the diet. Further refinement of the investigation and model fitting indicates the requirement for taurine as 0.49% of the diet to maximize growth and half of that to maximize FE (Salze, Rhodes, & Davis, 2019).

3.3.6 | Alternatives to FM

Partial substitution of FM with alternative protein sources depends on the composition, digestibility, palatability, and bioavailability of nutrients from the proposed alternative. The higher accessibility and lower costs of plant-based feed ingredients for aquaculture feeds make them attractive alternatives to FM protein. However, many plant-based-proteins contain ANF limiting their potential utilization in practical diets for some aquatic species (Hertrampf & Piedad-Pascual, 2000). Although new ingredients are being evaluated constantly, technological advances are being introduced to concentrate protein and other desirable components and/or the removing of ANF.

3.3.7 | Cottonseed meal

Cottonseed meal (CM) is a by-product of fiber production for the textile industry. One of the ANF of CM is gossypol and CM is fairly low in Lys and Met. Apparent crude protein digestibility of cottonseed products is fairly high in Florida pompano relative to other carnivorous species (Cook et al., 2016). Although IAA availability from cottonseed products has not been determined in Florida pompano, availability is generally high for most aquaculture species, particularly arginine, although Lys availability is low due to residual gossypol (Hertrampf & Piedad-Pascual, 2000). This suggests cottonseed products resulting either through gene manipulation and/or following processing along with supplemental Lys are suitable as a partial FM substitute up to 20% of the diet in practical diets for Florida pompano (Cook et al., 2016).

3.3.8 | Barley

Barley contains NSPs such as β-glucans that increase intestinal transit time and slows nutrient digestion and absorption (Sinha et al., 2011), resulting in slower growth and reduced efficiency. Younger fish seem to be more susceptible than older fish to NSP. The concentration of Lys and Met in barley protein concentrate (BPC) is comparable if not better than most other plant proteins, and the concentration of Met is higher than in soybean products. Although BPC has not been evaluated in growth trials as a potential substitute for FM in Florida pompano, it has performed well in trials with rainbow trout, *Oncorhynchus mykiss*, Atlantic salmon, *Salmo salar*, Arctic char, *Salvelinus alpinus*, and others (Bell et al., 2016; Bruce, Sindelar, Voorhees, Brown, & Barnes, 2017; Rossi Jr., Moxley, Buentello, Pohlenz, & Gatlin, 2013). The high availability of IAA in Florida pompano suggests BPC as a partial FM substitute merits further investigation.

3.3.9 | Soybean products

Soybean proteins are by-products from soybean oil extraction, and the most common and least expensive is soybean meal (SBM). SBM is the most common plant protein utilized as a partial FM substitute in aquaculture feeds. For most carnivorous marine fish, SBM is considered limiting in Lys and Met, and for some species, threonine is the next limiting AA (NRC, 2011).

Recent developments in processing can increase the level of SBM that can be substituted for FM in *Trachinotus* spp. (Nahashon & Kilonzo-Nthenge, 2011; Novriadi, Spangler, & Davis, 2019; Roe et al., 2019; Wu et al., 2016). Florida pompano fed a low-oligosaccharide soy product produced through extraction and enzyme treatment was used to reduce dietary FM incorporation from 15 to 9% (Novriadi, Salze, Abebe, Hanson, & Davis, 2019). Similarly, FM can be reduced from 30 to 15% of the diet with soy protein concentrate and SBM without an effect on growth and efficiency (Quintero, Davis, & Rhodes, 2012). Fermentation is another process to increase SBM utilization efficiency.

Fermented SBM was exchanged for dehulled, solvent extracted SBM in a practical diet with 15% poultry by-product meal (PBM). No differences in performance were detected, and although some microbial fermentation organisms can decrease IAA in SBM, dietary IAA appeared to be sufficient (Novriadi, Rhodes, Powell, Hanson, & Davis, 2018).

Beyond a certain level of incorporation, soy products can reduce feed intake and thereby growth and efficiency in Florida pompano. Fish meal could be reduced to 6.3% of the diet with SBM (80% FM protein replacement), and 12.5% of the diet with soy protein isolate (SPI) (40% FM replacement). The lower acceptable substitution rate with the SPI was attributed to poor palatability and its effect on feed intake (M. Riche & Williams, 2011). An enzyme treated and solvent extracted soybean meal was utilized in conjunction with squid hydrolysate to replace PBM in a diet with 15% PBM. Growth and efficiency were decreased with removal of PBM until squid hydrolysate was incorporated at 4% of the diet (Novriadi, Spangler, Rhodes, Hanson, & Davis, 2017). It was postulated free AAs, taurine, or betaine produced during the hydrolysis process acted as a palatability enhancer in the soy-based diets (Novriadi et al., 2017; Rhodes, Zhou, Salze, Hanson, & Davis, 2017). However, betaine and its sulfonium analog, dimethyl-β-propiothetin, did not act as palatability enhancers in SBM- or SPI-based diets with recently weaned Florida pompano (M. Riche, personal communication, January 25, 2021).

3.3.10 | Poultry by-product meal

A drawback to PBM utilization in aquaculture feeds is its heterogeneous nature that can lead to formulation issues (Hertrampf & Piedad-Pascual, 2000). PBM is also low in Lys and Met relative to FM products (NRC, 2011). Pompano digest PBM fairly well with high AA availability (T. N. Williams, 2008). Improvements in manufacturing, monitoring of product quality, and blending of products have led to improved product quality and reduced variability. A standard pet food grade PBM, two chicken by-product concentrates, and two poultry by-product blends were substituted for 67% of the FM in a FM-based diet. Substitution of poultry products (67–75% CP) decreased the requirement of dietary Lys (M. Riche, 2015). Growth, efficiency, digestibility, and AA availability were unaffected by poultry product substitution, and ammonia and urea excretion were relatively unaffected (M. Riche, 2015). This suggests poultry by-product blends and concentrates make suitable ingredients for substitution of FM at up to 67% for Florida pompano.

A FM-free diet with PBM, SBM, and corn gluten meal as the principal protein sources were supplemented with Met, Lys, and taurine to match AA in a 15% FM diet, and no significant differences in fish performance were observed. Florida pompano fed a FM-free diet with taurine supplemented at 0.75% of the diet performed better than those with no taurine supplementation (Rossi Jr. & Davis, 2012).

3.3.11 | Other alternatives to FM

Dried fermented biomass is the coproduct resulting from the manufacturing processes utilizing fermentation technology, principally from the pharmaceutical, chemical, energy, and agriculture sectors. A bacterial fermentation product from the production of threonine replaced up to 12.8% of the diet as a FM replacement in Florida pompano without negative effects on growth and performance. However, it was noted the functional viability as a FM replacement may depend on the fermentation process and end product (Rhodes, Zhou, & Davis, 2015).

Meat and bone meal is the rendered product from the meat processing industry. Similar to poultry by-products, it is highly variable in its composition (41–71% CP; 3–16% lipid) and quality of available raw material (Hertrampf & Piedad-Pascual, 2000). As a result, it is not as well digested by Florida pompano as other alternatives, and IAA availability coefficients vary widely (T. N. Williams, 2008). Meat and bone meal with blood substituted for FM resulted in no significant difference in growth and efficiency until FM was reduced to 5% in a 50% SBM diet. The lower performance observed in the FM-free diet (0% FM) was reversed when the diet was supplemented with 0.25–0.75% taurine (Rossi Jr. & Davis, 2014).

3.3.12 | Broodstock/larval diets

Florida pompano produce pelagic eggs, and as in other marine fish it is expected that free amino acids (FAA) are utilized as metabolic fuel during their embryonic stage. The degree to which FAA can be molded in pompano eggs through dietary manipulation in broodstock remains an area for further investigation. It is anticipated that the optimal levels of dietary AA and FA, particularly HUFAs, will increase reproductive performance and larval quality. This line of investigation is currently underway in a collaborative research effort between HBOI and the USDA's Agricultural Research Service.

Little is known about the nutrient requirements and larval nutrition of Florida pompano. As with other larval marine finfish species, pompano require live prey at first exogenous feeding, typically rotifers enriched to increase their nutritional value. Growth, survival, and FA composition differentially respond when larvae are fed rotifers incubated with different enrichment products. The FA composition of larvae generally reflect those of the enrichment products other than EPA (Cavalin & Weirich, 2009). Pompano larval FA profiles responded similarly to the enriched rotifer-fed pompano when fed different microdiets with different compositions (M. R. Hauville et al., 2014). In addition, the results also suggested the DHA:EPA ratio may be more important in Florida pompano than the actual concentration of either FA individually (M. R. Hauville et al., 2014). It was suggested a microdiet with 55% CP, 20% lipid, and a DHA:EPA ratio greater than 1.0 and an arachidonic acid acid (ARA):EPA ratio of at least 0.08 is appropriate for weaning Florida pompano (M. R. Hauville et al., 2014). Based on utilization/conservation of HUFA in pompano eggs and unfed larval pompano, it is also suggested there is a high requirement for ARA (M. R. Hauville et al., 2016). Microdiets to evaluate such requirements are well accepted by Florida pompano (Rust et al., 2015). For a thorough review of estimated HUFA requirements in Florida pompano, the reader is referred to Mejri, Tremblay, Audet, Wills, and Riche (2021).

It is generally accepted that further research is warranted to elucidate appropriate qualitative and quantitative AA levels in enrichment products to meet the energetic and nutritional requirements of rapidly developing pompano larvae (Cavalin & Weirich, 2009; M. R. Hauville et al., 2014). As noted by Derbes Jr. (2017), there is much needed research to understand the dietary requirements for Florida pompano larvae. Preliminary investigations suggest taurine may not be necessary for enhancing oocyte maturation, fertilization, and hatch rate in pompano. However, the author suggests the period the fish received the taurine-containing maturation diet may have been insufficient to elicit the desired effect; therefore, the results remain inconclusive (Derbes Jr., 2017). Conversely, the yolk and oil globule of eggs were significantly larger while total egg size was smaller in eggs from broodstock fed taurine-supplemented feed relative to nonsupplemented broodstock (Derbes Jr., 2017). Further research on the effects of supplemental dietary taurine on reproductive efficiency and egg and larval quality is warranted.

Probiotics when administered through the diet can confer health benefits and result in a more robust population. *Bacillus* spp. administered to Florida pompano as a probiotic in feed or the tank environment improves growth and early onset and activity of digestive enzymes (M. R. S. Hauville, 2014), but no benefit was detected regarding survival. However, early extended benefits of exposure to probiotics may be conferred in later stages since the early benefits observed resulted in increased larval quality. Determining if the benefits gained in the early larval stage have long-term implications for growth, efficiency, and survival throughout the growout period remains a needed area for further research.

3.4 | Diseases and their management

In the wild, Florida pompano can host numerous pathogens. Some are acquired through their diet of crustaceans, bivalve mollusks, and other marine invertebrates (Froese & Pauly, 2021; Iverson & Berry, 1969), potential intermediate hosts of microsporidian protozoans, acanthocephalans, aspidogastreans, nematodes, cestodes, and digenean trematodes (Alves, Borges, Santos, & Luque, 2015; Casal, Matos, García, Al-Quraishy, & Azevedo, 2012;

González-Solís, Moravec, Vidal-Martínez, & Zárate-Pérez, 2002; Overstreet & Brown, 1970; Pinto, Vicente, & Noronha, 1984; Ribeiro, de São Clemente, Lopes, & Knoff, 2014; Sánchez-Ramírez & Vidal-Martinez, 2002), while others such as small crustacean parasites (Bunkley-Williams, Williams, & Bashirullah, 2006; Parker & Booth, 2013) and monogenean trematodes (Kohn, Santos, & Baptista, 1992; Kohn, Santos, & Lebedev, 1996; Sánchez-Ramírez & Vidal-Martínez, 2002) can be transmitted directly from fish to fish, especially during spawning.

During the warmer months of summer, when water temperatures rise above 20–25°C, some viruses such as the Red-Spotted Grouper Nervous Necrosis Virus (RSGNNV) (Pakingking, Mori, Bautista, de Jesus-Ayson, & Reyes, 2011) and bacteria such as *Vibrio anguillarum*, *Flavobacterium maritimus* (syn. *Tenacibaculum maritimum*), and *Mycobacterium marinum* (Austin & Austin, 1999; Hacking & Budd, 1971; Reichenbach-Klinke, 1972; Ross, Martin, & Bressler, 1968; Rucker, 1959) find the ideal conditions to thrive. Also, some protozoan parasites such as *Cryptocaryon irritans* and *Amyloodinium ocellatum* accelerate their life cycles and proliferate with higher temperatures and salinities above 14 g/L (P. Cheung, 1993; P. Cheung, Nigrelli, & Ruggieri, 1979; P. J. Cheung, Rugggieri, & Nigrelli, 1978; Colorni, 1985; Lom & Dykova, 1992; Paperna, 1984).

Under farming conditions, only broodstock and juveniles collected from the wild will present this microbial diversity. Although less diverse, especially in RAS, pathogens present in farmed Florida pompano (Table 4) can cause significant mortalities and affect fish health and growth. Viruses such as RSIV (López-Porras et al., 2018) and the aforementioned RSGNNV, which affects the culture of *T. blochii* in Southeast Asia (Pakingking et al., 2011; Ransangan et al., 2011), are of major concern. At the cellular level, viruses disrupt fish physiology leading to anorexia, anemia, and abnormal behavior (López-Porras et al., 2018; Nakai et al., 2009; Roberts, 2012). In tropical and subtropical areas of the American continent, the bacteria causing red pest (*V. anguillarum*) (Hawke, 1976) and fish tuberculosis (*M. marinum*) (Yanong et al., 2010), and the trophonts or feeding stages of the ectoparasites *C. irritans* (white spot disease) (Gomez, 1987) and *A. ocellatum* (velvet disease) (E. Williams, 1974) also affect fish health at different levels. Although bacteria can cause inflammation, hemorrhages, ulceration, or tissue necrosis (Austin & Austin, 1999; Yanong, Curtis, Terrell, & Case, 2003), protozoans attach to the fish surface and inflict mechanical damage to the skin and gill epithelium, leading in both cases to pathological changes (P. Cheung, 1993; Lom & Dykova, 1992; Roberts, 2012) and may predispose fish to secondary infections.

Some microorganisms, such as *Aeromonas hydrophila* and *F. maritimus*, can behave as opportunistic secondary pathogens. Together with ciliate protozoa such as *Scyphidia* spp. and *Trichodina* spp., ectocommensals on the surface of fish are usually present in aquaculture systems (Hawke, 1976; E. Williams, 1974). Outbreaks of some of these diseases are often stress-related and can be prevented by improving culture conditions (e.g., water quality and flow) (Brown, 2000; Handlinger, Soltani, & Percival, 1997; Hanson & Grizzle, 1985; McVicar & White, 1979; Roberts, 2012) and husbandry practices, such as avoiding overcrowding (Austin & Austin, 1999; Baticados & Quinitio, 1984; Lawler, 1980). Debilitated fish and larvae and early developmental stages are usually the most susceptible (Lom & Dykova, 1992).

As part of biosecurity measures, it is recommended to perform measures toward early detection and rapid treatment of the pathogen targeted. A variety of techniques are available to promptly detect the presence of pathogens that affect Florida pompano including selective culture media for the isolation of bacteria such as Rimler-Shotts agar for *A. hydrophila* (Austin & Austin, 1999; Roberts, 2012), Anacker and Ordal's medium with peptone for *F. marinum* (Pazos, Santos, Nunez Macias, & Toranzo, 1996; Roberts, 2012), media for fastidious mycobacteria such as *M. marinum* (Dulin, 1979; Lansdell, Dixon, Smithin, & Benjamin, 1993), cell line viruses (E-11, GPS, and BF-2) (Pakingking et al., 2011; Yu et al., 2016), and specific staining for bacteria (e.g., acid-fast from tissue squash) (Yanong et al., 2010).

With respect to parasites, early detection may be achieved by Klein's silver impregnation or protargol impregnation for *Trichodina* spp. (Lom & Dykova, 1992), together with electron microscopy, histopathology, serological (Baxa, Kawai, & Kusuda, 1988), and molecular techniques such as amplification and sequencing of specific fragments of the pathogen's DNA/RNA (Chakroun, Grimont, Urdaci, & Bernadet, 1998; López-Porras et al., 2018; Oshima et al., 1998;

TABLE 4 . Pathogens of farmed Florida pompano, *Trachinotus carolinus*

Pathogen	Etiology/disease	Region	References
Viruses			
Red Sea Bream Iridovirus (RSIV)	Iridovirosis disease	Central America	López-Porras et al., 2018
Red-Spotted Grouper Nervous Necrosis Virus (RSGNN) or Viral Necrosis Virus (VNV)	Viral nervous necrosis	Philippines and Malaysia[a]	Pakingking et al., 2011 Ransangan, Manin, Abdullah, Roli, & Sharudin, 2011
Bacteria			
Vibrio anguillarum	Vibrionaceae—red pest	Alabama, United States	Hawke, 1976 FAO, 2020
Aeromonas hydrophila	Vibrionaceae—Motile Aeromonas septicemia	Alabama, United States	Hawke, 1976
Flavobacterium spp. (syn. *Tenacibaculum* spp.)	Flexibacter group—gill disease	Alabama, United States	Hawke, 1976
Mycobacterium marinum	Mycobacteria—fish tuberculosis	Florida, United States Pennsylvania, United States Italy	Yanong, Pouder, & Falkinham, 2010 Aronson, 1926 Giavenni & Finazzi, 1980
Protozoan parasites			
Cryptocaryon irritans	Ciliate—white spot disease	Venezuela	Gomez, 1987
Trichodina sp.	Ciliate—trichodiniasis	Alabama, United States	E. Williams, 1974
Scyphidia sp. (syn. *Ambiphyra* sp.)	Ciliate disease	Alabama, United States	E. Williams, 1974
Protozoan parasites			
Amyloodinium ocellatum	Protozoan dinoflagellate—velvet disease	Venezuela Alabama, United States	Gomez, 1987 E. Williams, 1974
Metazoan parasites			
Cymothoid isopods	Crustacean parasites	Alabama, United States	E. Williams, 1974
Bicotylophora trachinoti	Monogenean trematode	Alabama, United States New York, United States	E. Williams, 1974 MacCallum, 1921

[a]Included in the list as a serious potential pathogen to *T. carolinus*.

Pakingking et al., 2011; Ransangan et al., 2011), as well as bioinformatic tools to analyze and organize this information (Rocha et al., 2014).

Different vaccines have proven effective in *Trachinotus* spp., conferring protection against viral nervous necrosis in *T. blochii* (Pakingking et al., 2011) and *A. ocellatum* in different species of pompano (*T. carolinus*, *Trachinotus goodie*, and *Trachinotus falcatus*) (Gomez, 1987). In other finfish species (mostly salmonids), vaccines against bacteria such as *V. anguillarum* (Horne, Tatner, Roberts, & Ward, 1984; Roberts, 2012; Tatner & Horne, 1983), and *Flavobacterium* spp. (Austin & Austin, 1999; Kajita, Sakai, Atsuta, & Kobayashi, 1990; Stoskopf, 1993) are readily available, with potential cross reactivity against pompano pathogens, and some are under investigation after immunity has been recognized in affected fish, (e.g., for *Mycobacterium* spp.) (Bartos & Sommer, 1981). To protect against some infectious diseases, a wide variety of probiotics and other immunostimulants have been tested in other species (Austin, Stuckey, Robertson, Effendi, & Griffith, 1995; Dopazo et al., 1988; Kajita et al., 1990; Stoskopf, 1993; Westerdahl, Olsson, Kjelleberg, & Conway, 1991). In addition, genetic selection has been shown to improve salmonid resistance to diseases such as Vibriosis (Roberts, 2012).

Finally, when prevention does not work, some other measures can be taken. Antibiotics can be helpful if administered before fish cease feeding and become anorexic to treat red pest, motile aeromonas septicemia, and gill disease (Austin & Austin, 1999; Roberts, 2012). However, bacteria's ability to generate resistant strains (Aoki, 1988; Aoki, Egusa, & Arai, 1974; Austin & Austin, 1999; Stoskopf, 1993) should be considered. To treat parasite infestations, some chemical products are available, such as formalin and copper compounds for ciliates, dinoflagellates, and small crustacean parasites such as *Cymothoid* isopods (Birdsong & Avault Jr., 1971; P. Cheung, 1993; Food and Agriculture Organization [FAO], 2021; E. Williams, 1974); and monogenetic trematodes such as *Bicotylophora trachinoti* can be treated with compounds such as trichlorfon (E. Williams, 1974). Dipping fish in freshwater for 5–10 min can also be a good practice to reduce the level of infestation (FAO, 2021).

Much progress has been made with respect to documenting pathogens affecting Florida pompano. However, additional research is warranted to develop and refine biosecurity, early detection and prevention, and treatment methods.

4 | ECONOMICS AND MARKETING

Currently, there is a paucity of information available with respect to the economics of Florida pompano aquaculture using the primary production systems presently employed. There has been little research undertaken to date to develop economic models for the commercial production of pompano utilizing ocean net pens and what information available is considered proprietary. As the level of investment and financial risks required for any aquaculture venture is high, it is considerably higher for offshore operations. Economics will play an important role in permitting and legal review, site selection, engineering, production planning, and market evaluation as the aquaculture industry moves into the open ocean in the United States. Although a compelling case can be made and many experts argue for growing the offshore sector, it is important to underscore the value of socioeconomic considerations and the social acceptability (e.g., social license) for any aquaculture project sited in public trust waters (Knapp & Rubino, 2016). Not to mention the capital costs of not only the nets but boats for transferring personnel, feed, and site maintenance. As observed over the past decade, engagement with key stakeholders and the public can alleviate many concerns for offshore aquaculture projects when coupled with rigorous plans for site selection and environmental review, and when commercial development grows gradually and in parallel to adaptation with the environment, regulations, management, and markets.

In addition to the lack of information with respect to economics of ocean net pens, there is limited information available regarding land-based RAS production of Florida pompano.

Much of the commercial-scale data that are available is considered proprietary information by commercial producers. Wills (2013) developed an economic model for pompano growout using RAS that suggested that a breakeven price of $13.11/kg for whole pompano was possible indicating that RAS culture of pompano could be profitable

under specific scenarios, especially when cost savings due to economies of scale are considered. Although RAS aquaculture of Florida pompano offers opportunities to increase aquaculture production with limited land and water resources, factors such as increasing stocking densities and reducing system energy cost should be investigated to offset investment as well as operational costs (Martins et al., 2010; Pfeiffer & Riche, 2011). A recent study identified cost drivers of RAS as compared to pond and raceway production (Engle, Kumar, & van Senten, 2020). The greatest cost for RAS production was that of capital, followed by feed costs, labor for larger-scale RAS and fingerlings for smaller-scale RAS, and then energy costs. The efficiency of capital and labor costs in RAS was less than that of intensive pond and raceway production, suggesting that improving capital and labor efficiencies would improve profitability of RAS. The RAS technologies analyzed by Engle et al. (2020) were for the production of Atlantic salmon, rainbow trout, and tilapia, *Oreochromis* spp. Additional work is planned for 2022 on RAS production of several marine finfish species, including Florida pompano (C. Engle, personal communication, April 24, 2021).

Although much information with respect to marketing farmed Florida pompano is still lacking, several commercial ventures have been involved in the development of markets for farmed Florida pompano since 2005. At present, farmed whole fish are imported from net pen operations in Panama and are distributed in the United States to select markets, grocery retailers, "big box" wholesale stores, and online retailers. In addition, commercially farmed pompano from a recently established land-based RAS operation in Florida are currently available in local Florida markets with increasing frequency (Global Aquaculture Advocate, 2019). In a market assessment of pompano sponsored by a potential commercial RAS operation, Riley and Weirich (2010) conducted a survey of 25 seafood distributors and processors across 12 states. Companies of varying scales (moderate-size to largest) were surveyed from Massachusetts, New York, New Jersey, Pennsylvania, Illinois, Washington D.C., Maryland, North Carolina, Texas, Louisiana, Georgia, Alabama, and Florida. Through telephone interviews, seafood brokers and managers were queried with the following questions:

1. Do you process or distribute Florida pompano or other pompano species?
2. Are fish from domestic sources or imported?
3. Are fish caught from the wild or farmed?
4. Are fish marketed as a "sustainable" product?
5. What are wholesale market values for whole fish and fillets?

Results from the survey indicated that 92% of the companies offered pompano with limited seasonal availability (April–November). Pompano were most highly valued in the northeast United States, Florida, and Louisiana, and whole fish and fillets were preferred fresh, not frozen. At the time of the survey, imported Florida pompano from both wild fisheries and aquaculture were available from Mexico, Brazil, and the Dominican Republic. Other species of pompano, *Trachinotus* spp., were available from China, Thailand, Vietnam, and Australia. Market value of whole fish averaged U.S. $11/kg and ranged from $7 to $18/kg. Wholesale market values for pompano fillets averaged U.S. $21/kg and ranged from $14 to $31/kg. At the time of the survey, most seafood distributors were instituting sustainability campaigns and marketing seafood with ecolabels focused on traceability, food safety, and environmental responsibility (Ward & Phillips, 2009). A 2021 survey of consumers in southern-tier states in the United States was underway at the time this article was written to examine preferences for 20 species of marine finfish, including Florida pompano (C. Engle, personal communication, April 24, 2021). A survey of seafood distributors is also planned in late 2021 to seek windows of market opportunity for farmed Florida pompano and other marine finfish species (C. Engle, personal communication, April 24, 2021).

It is important to note that at present wild-caught Florida pompano are of minor importance to the overall U.S. market, as landings are small and fish are seldom shipped far beyond their port of landing. Although this species is well known and held in high regard as a food fish along the U.S. East coast and Gulf of Mexico region, most potential consumers located in inland areas are unfamiliar with pompano as they are also unfamiliar with many seafood products that are regionally sourced or have limited availability. In a national survey of seafood consumers, Love

et al. (2020) suggested that food sourcing preferences may be related to consumers' perceived ability or comfort to cook certain species at home or the availability of products at different venues. This should be kept in mind with respect to continued efforts toward increasing market awareness and acceptance of Florida pompano as aquaculture of this species continues to expand.

5 | COMMERCIAL STATUS

Integrated hatchery and pond-based production of Florida pompano has been reported by a commercial venture in Florida established in the 1980s (McMaster, Kloth, & Coburn, 2004). The first reported aquaculture-based production and international trade of this species were in 2004 from net pen culture in the Bahamas with juveniles produced in Florida (Figure 4; FAO, 2020). However, commercial activity in the Bahamas ceased by 2007 after a series of hurricanes impacted the farm and hatchery. In 2006, production of farmed pompano began in Panama, followed by production from a commercial net pen operation in the Dominican Republic from 2009 to 2016. Presently, in addition to the aforementioned Florida-based pond operation, on a commercial scale, there exists one breeding/juvenile production facility based in Florida, a recently established RAS-based production facility also located in Florida, and a fully integrated net-pen operation located in Panama. With respect to marketable fish, the Florida RAS operation is initially targeting production of 60 m.t. of whole pompano/year while the net pen operation in Panama is currently producing approximately 250–300 m.t. of whole fish/year. Although, on a much smaller scale, there is also some production of Florida pompano for the ornamental trade as well (E. Cassiano, personal communication, April 21, 2021).

6 | RESEARCH NEEDS

Considerable progress has been made over the years to advance pompano aquaculture to its current state; however, there are several topical areas that warrant continued investigation. In the following, a brief overview of needs with respect to six categories (four biological and two nonbiological) is presented.

6.1 | Broodstock domestication, selective breeding, and genetic improvement

Currently, there are no current sources of domesticated Florida pompano broodstock available in the United States, and to date all broodfish used in research and commercial production have been wild-caught adults, animals produced from wild-caught juveniles, or animals produced from offspring (F1 generation) of wild-caught adults. As with other animal production industries, significant gains can be realized with development of selective breeding programs that can increase growth, reduce size variability, and increase disease resistance, among other factors. It is essential that for pompano aquaculture development and expansion to occur, efforts are needed to develop domesticated broodstock strains through selective breeding programs for genetic improvement.

6.2 | Delayed maturation

There is growing evidence that early sexual maturation of Florida pompano, especially females, may reduce somatic growth of fish nearing market size and decreasing overall production. In addition to breeding and genetic improvement, manipulation of puberty and polyploidy should be explored.

6.3 | Diet development and refinement

Although the bulk of research conducted to date regarding Florida pompano has focused on nutrition of this species and diet formulation, there are a number of topics that have not been explored in great detail. As mentioned previously, additional research is needed to further investigate and explore FE, carbohydrate utilization and metabolism, AA and FA requirements, larval and broodstock requirements, and diets tailored to specific life stages. Regarding the latter, the vast majority of nutrition research involving Florida pompano has focused on juvenile fish, largely due to their availability coupled with culture systems accessible to investigators. As such, while there is a need to investigate nutritional requirements in order to refine diets for larger fish, achieving this is difficult without access to commercial scale production systems and on farm validation trials.

6.4 | Disease management strategies

Pathogens can deleteriously affect production of Florida pompano. Two current major disease-related concerns are bacterial infections of fish cultured in RAS due to *Mycobacterium* spp. and viral outbreaks of fish reared in ocean net pens due to RSIV. As the industry continues to expand, there will be a continued need for research to better understand pathogens coupled with development of preventative measures such as vaccines as well as disease treatments.

6.5 | Economics and business planning

There is an urgent need for information with respect to economics and business planning for expansion of commercial production of Florida pompano in the United States as well as abroad. Although there is some baseline data available, government supported studies and data compilation would support future investment toward successful operations.

6.6 | Market development and expansion

Although Florida pompano remains a prominent menu item at a number of high-end restaurants on the U.S. East Coast as well as the Gulf of Mexico, this species is not well known outside of these regions. While farmed pompano are currently difficult to market inland, there is considerable room to develop and expand the market for this species targeting these locales. However, to achieve this, there is a need to increase chef, as well as consumer awareness of pompano, and these efforts will be crucial as additional product becomes available with industry expansion.

7 | CONCLUSIONS

After several decades of research and development, commercial aquaculture of Florida pompano has been established, albeit currently on a relatively small scale. Although there is good potential for further development and expansion of pompano farming in the United States as well as abroad, there remains a continued need to build upon the knowledge base with respect to this species to address biological, economical, and social issues in the future.

ACKNOWLEDGMENTS

We are grateful to and thank the following individuals who contributed to work and information described in this article including J. Adams, M. Anderson-Page, D. Asche, R. Baptiste, R. Becker, L. Beecher, K. Belhadjali, S. Boxman,

F. Bueno, D. Burris, J. Burris, J. Cardenas, F. Cavalin, M. Chambers, E. Chesney, G. Coates, C. Cordary, J. Corsaut, A. Davis, M. Davis, J. Dempsey, C. Engle, D. Farkas, R. Ferraro, D. Forbes-Taylor, D. Freeman, B. Garr, J. Goldstein, C. Gothreaux, D. Groat, D. Haley, J. Hawke, F. Hoff, R. Laramore, S. Laramore, T. Lenger, G. Ludwig, G. Luisi, R. Malone, J. Milchman, J. Mountain, D. Mowry, C. O'Neal, R. Reed, R. Reigh, M. Resley, N. Rhody, M. Rhodes, C. Robinson, J. Scarpa, M. Segovia, A. Shawl-Garr, J. Spencer, P. Stock, B. Summerlin, P. Tracy, K. Trosvik-Wood, P. Van Wyk, T. Wadley, E. Wagner, C. Watts, J. White, M. Williams, P. Woodward, and A. Zwemer.

The scientific results and conclusions, as well as any views or opinions expressed herein, are those of the author and do not necessarily reflect the views of the United States Department of Commerce or the National Oceanic and Atmospheric Administration. The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the USDOC, NOAA, USDA, or USDA-ARS.

ORCID

Charles R. Weirich https://orcid.org/0000-0001-9555-0096
Gonzalo Illán https://orcid.org/0000-0003-2647-2113

REFERENCES

Almatar, S. M., & James, C. M. (2005, January/March). Present status in the development of culture technology for the silver pomfret. *Pampus argenteus*. *Asia-Pacific Marine Finfish Aquaculture Network Magazine*, 12–15.

Alvarez-Lajonchère, L., & Ibarra-Castro, L. (2013). Aquaculture species selection method applied to marine fish in the Caribbean. *Aquaculture*, *408*, 20–29.

Alves, P. V., Borges, J. N., Santos, C. P., & Luque, J. L. (2015). A redescription of *Lobatostoma kemostoma* (MacCallum and MacCallum, 1913) (Trematoda: Aspidogastrea) from the Florida pompano fish *Trachinotus carolinus* (Linnaeus, 1766) off the Brazilian coast. *Journal of Helminthology*, *89*(3), 335–344.

Aoki, T. (1988). Drug-resistant plasmids from fish pathogens. *Microbiological Sciences*, *5*, 219–223.

Aoki, T., Egusa, S., & Arai, T. (1974). Detection of R factor in naturally occurring *Vibrio anguillarum* strains. *Antimicrobial Agents and Chemotherapy*, *6*, 534–538.

Armitage, T. M., & Alevizon, W. S. (1980). The diet of the Florida pompano, *Trachinotus carolinus* along the east coast of central Florida. *Florida Science*, *43*(1), 19–26.

Aronson, J. D. (1926). Spontaneous tuberculosis in salt water fish. *Journal of Infectious Diseases*, *39*, 315–320.

Austin, B., & Austin, D. A. (1999). *Bacterial fish pathogens. Disease of farmed and wild-fish*. London, England: Springer.

Austin, B., Stuckey, L. F., Robertson, P. A. W., Effendi, I., & Griffith, D. R. W. (1995). A probiotic strain of *Vibrio alginolyticus* effective in reducing diseases caused by *Aeromonas salmonicida, Vibrio anguillarum* and *Vibrio ordalii*. *Journal of Fish Diseases*, *18*, 93–96.

Azaria, S., & van Rijn, J. (2018). Off-flavor compounds in recirculating aquaculture systems (RAS): Production and removal processes. *Aquacultural Engineering*, *83*, 57–64.

Bartos, J. M., & Sommer, C. V. (1981). In vitro cell mediated immune response to *M. tuberculosis* and *M. salmoniphilum* in rainbow trout (*Salmo gairdneri*). *Developmental and Comparative Immunology*, *5*, 75–83.

Baticados, M. C. L., & Quinitio, G. F. (1984). Occurrence and pathology of an Amyloodinium-like protozoan parasite on gills of grey mullet, *Mugil cephalus*. *Helgoländer Wissenschaftliche Meeresuntersuchungen*, *37*, 595–601.

Baxa, D. V., Kawai, K., & Kusuda, R. (1988). Detection of *Flexibacter maritimus* by fluorescent antibody technique in experimentally infected black sea bream fry. *Fish Pathology*, *23*, 29–32.

Belfranin, C. M. (2016). *Growth performance of adult Florida pompano, Trachinotus carolinus fed semi-purified diets with graded levels of methionine*. (M.S. thesis). University of Miami, Miami, Florida, U.S.

Bell, J. G., Strachan, F., Roy, W. J., Matthew, C., McDonald, P., Barrows, F. T., & Sprague, M. (2016). Evaluation of barley protein concentrate and fish protein concentrate, made from trimmings, as sustainable ingredients in Atlantic salmon (*Salmo salar* L.) feeds. *Aquaculture Nutrition*, *22*, 326–334.

Bellinger, J. W., & Avault, J. W., Jr. (1971). Food habits of juvenile pompano, *Trachinotus carolinus* in Louisiana. *Transactions of the American Fisheries Society*, *100*, 486–494.

Berry, F., & Iverson, E. S. (1967). Pompano: Biology, fisheries and farming potential. *Proceedings of the Gulf Caribbean Fisheries Institute*, *19*, 116–128.

Birdsong, C. L., & Avault, J. W., Jr. (1971). Toxicity of certain chemicals to juvenile pompano, *Trachinotus carolinus*. *Progressive Fish Culturist*, *33*(2), 76–80.

Boxman, S. E., Kruglick, A., McCarthy, B., Brennan, N. P., Nystrom, M., Ergas, S. J., … Trotz, M. A. (2015). Performance evaluation of a commercial land-based integrated multi-trophic aquaculture system using constructed wetlands and geotextile bags for solids treatment. *Aquacultural Engineering*, *69*(2015), 23–36.

Brown, L. (2000). *Acuicultura para Veterinarios: Producción y clínica de peces*. Zaragoza, Spain: Editorial Acribia S.A.

Bruce, T. J., Sindelar, S. C., Voorhees, J. M., Brown, M. L., & Barnes, M. E. (2017). Performance and immunological responses of rainbow trout (*Oncorhynchus mykiss*) fed bioprocessed plant-based proteins. *Aquaculture Nutrition*, *23*, 1160–1168.

Bunkley-Williams, L., Williams, E. H., & Bashirullah, A. K. M. (2006). Isopods (Isopoda: Aegidae, Cymothoidae, Gnathiidae) associated with Venezuelan marine fishes (Elasmobranchii, Actinopterygii). *Revista de Biología Tropical*, *54*(Suppl. 3), 175–188.

Casal, G., Matos, E., García, P., Al-Quraishy, S., & Azevedo, C. (2012). Ultrastructural and molecular studies of *Microgemma carolinus* n. spp. (Microsporidia), a parasite of the fish *Trachinotus carolinus* (Carangidae) in Southern Brazil. *Parasitology*, *139*(13), 1720–1728.

Cassiano, E. J., Ohs, C. L., Weirich, C. R., Breen, N. E., & Rhyne, A. L. (2011). Performance of larval Florida pompano fed nauplii of the calanoid copepod, *Pseudodiaptomus pelagicus*. *North American Journal of Aquaculture*, *73*(2), 114–123.

Cavalin, F. G., & Weirich, C. R. (2009). Larval performance of aquacultured Florida pompano, *Trachinotus carolinus* fed rotifers, *Brachionus plicatilis* enriched with selected commercial diets. *Aquaculture*, *292*(1–2), 67–73.

Chakroun, C., Grimont, F., Urdaci, M. C., & Bernadet, J.-F. (1998). Fingerprinting of *Flavobacterium psychrophilum* isolates by ribotyping and plasmid profiling. *Diseases of Aquatic Organisms*, *33*, 167–177.

Chamberlain, G. W., Miget, R. J., & Haby, M. G. (1990). Red drum aquaculture, Texas A&M University Sea Grant College Program, TAMU-SG-90-603, College Station, TX.

Cheung, P. (1993). Parasitic diseases of marine tropical fish. In M. K. Stoskopf (Ed.), *Fish medicine* (pp. 646–658). Philadelphia, PA: W.B. Saunders Company.

Cheung, P., Nigrelli, R. F., & Ruggieri, G. D. (1979). Effects of temperature, salinity, and pH in endozootics of protozoan diseases in captive fishes (abstract). *Wildlife Disease Association Conference*, Stillwater, OK.

Cheung, P. J., Rugggieri, G. D., & Nigrelli, R. F. (1978). Effects of temperature and salinity on the developmental cycle of *Oodinium ocellatum* Brown (Mastigophora: Phytomastigophorea: Dinoflagellida) (abstract). *Fourth International Congress of Parasitology, a Conference of the World Federation of Parasitologists*, Warszawa, Poland.

Colorni, A. (1985). Aspects of the biology of *Cryptocaryon irritans*, and hyposalinity as a control measure in cultured gilthead sea bream, *Sparus aurata*. *Diseases of Aquatic Organisms*, *1*, 19–22.

Cook, R. L., Zhou, Y., Rhodes, M. A., & Davis, D. A. (2016). Evaluation of various cottonseed products on the growth and digestibility performance in Florida pompano, *Trachinotus carolinus*. *Aquaculture*, *453*, 10–18.

Craig, S. R. (2000). Pompano culture. In R. R. Stickney (Ed.), *Encyclopedia of aquaculture* (pp. 660–663). New York, NY: John Wiley and Sons.

Cuevas, H., Jr. (1978). *Economic feasibility of Florida pompano, Trachinotus carolinus and rainbow trout* (*Salmo gairdneri* production in brackish water ponds. M.S. thesis). Auburn University, Auburn, AL.

Daniels, H. V., & Watanabe, W. O. (2003). *A practical hatchery manual: Production of southern flounder fingerlings*. Raleigh, NC: North Carolina Sea Grant.

Derbes, T. J., Jr. (2017). *Supplementing broodstock and larval diets for Florida pompano, Trachinotus carolinus with taurine to improve egg, larval, and weaned juvenile quality* (M.S. thesis). Auburn University, Auburn, AL.

Dopazo, C. P., Lemos, M. L., Lodeiros, C., Bolinches, J., Barja, J. L., & Toranzo, A. E. (1988). Inhibitory activity of antibiotic-producing marine bacteria against fish pathogens. *Journal of Applied Bacteriology*, *65*, 97–101.

Du, T., & Luo, J. (2004a). Study on techniques of artificial breeding of *Trachinotus blochii*. *Marine Fisheries Research/Haiyang Shuichan Yanjiu*, *25*(4), 46–50.

Du, T., & Luo, J. (2004b). Comparison study on artificial breeding between *Trachinotus ovatus* and *T. blochii*. *Marine Fisheries Research/Haiyang Shuichan Yanjiu*, *28*(7), 76–78.

Dulin, M. P. (1979). A review of tuberculosis (mycobacteriosis) in fish. *Veterinary Medicine, Small Animal Clinician*, *1979*, 735–737.

Duncan, N. J., Sonesson, A. K., & Chavanne, H. (2013). Principles of finfish broodstock management in aquaculture: Control of reproduction and genetic improvement. In G. Allan & G. Burnell (Eds.), *Advances in aquaculture hatchery technology* (pp. 23–75). Cambridge, England: Woodhead Publishing Limited.

Ebeneezar, S., Vijayagopal, P., Srivastava, P. P., Gupta, S., Kumar, S., Varghese, T., … Wilson, L. (2019). Dietary lysine requirement of juvenile Silver pompano, *Trachinotus blochii* (Lacepede, 1801). *Aquaculture*, *511*, 1–8.

Engle, C. R., Kumar, G., & van Senten, J. (2020). Cost drivers and profitability of U.S. pond, raceway, and RAS aquaculture. *Journal of the World Aquaculture Society*, *51*(4), 847–873.

FAO. (2020). *Fishery and aquaculture statistics. Global production by production source 1950–2018 (FishStatJ)*. Rome, Italy: FAO Fisheries and Aquaculture Department www.fao.org/fishery/statistics/software/fishstatj/en

FAO. (2021). *Cultured aquatic species information program - Trachinotus spp*. World Wide Web electronic publication, available online (01/2021).

Fielding, J. R. (1966). New systems and new fishes for culture in the United States. *FAO World Symposium on Warm-water Pond Fish Culture*. FR:VIII/RZ.

Fields, H. M. (1962). Pompanos (*Trachinotus spp*.) of south Atlantic coast of the United States. *U.S. Fish and Wildlife Service Fishery Bulletin*, *207*, 189–222.

Finucane, J. H. (1969). Ecology of the pompano (*Trachinotus carolinus*) and the permit (*T. falcatus*) in Florida. *Transactions of the American Fisheries Society*, *98*(3), 478–486.

Finucane, J. H. (1970a). Pompano mariculture in Florida. *American Fish Farmer*, *1*(4), 5–10.

Finucane, J. H. (1970b). *Pompano mariculture in Florida*. Contribution No. 54. St. Petersburg Beach, FL: Bureau of Commercial Fisheries Biological Laboratory.

Finucane, J. H. (1971). Progress in pompano mariculture in the United States. *Proceedings of the World Mariculture Society*, *1*, 69–72.

Froese, R., & Pauly, D. (2021). *FishBase*. Kiel, Germany: World Wide Web electronic Publication www.fishbase.org

Giavenni, R., & Finazzi, M. (1980). Tuberculosis in marine tropical fishes in an aquarium. *Journal of Wildlife Diseases*, *16*, 161–168.

Gilbert, C., & Parsons, J. (1986). *Species profile: Life histories and environmental requirements of coastal fishes and invertebrates (South Florida): Florida pompano* (U.S. Fish and Wildlife Report 82 (11.42)). Washington, DC: U.S. Fish and Wildlife Service.

Global Aquaculture Advocate. (2019). *Full speed ahead for Florida pompano RAS farm*. Portsmouth, NH: Author https://www.aquaculturealliance.org/advocate/full-speed-ahead-for-florida-pompano-ras-farm/

Gomez, A. (1987). Some diseases of experimentally-cultured pompano in Venezuela. *Revista Latinoamericana de Acuicultura Lima*, *33*, 26–34.

Gomez, A. (2002). Selection of marine fish for intensive culture in northeast Venezuela. *Boletin de Investigaciones Marinas y Costeras*, *31*, 53–63.

Gomez, A., & Cervigon, F. (1987). Perspectives of the culture of marine fishes from the south Caribbean Sea and northeastern South America. *Revista Latinoamericana de Acuicultura*, *34*, 40–50.

Gomez, A., & Scelzo, M. (1982). Polyculture experiments of pompano *Trachinotus carolinus* (Carangidae) and red spotted shrimp *Penaeus brasiliensis* (Penaeidae) in concrete ponds, Margarita Islands, Venezuela. *Journal of the World Mariculture Society*, *13*, 146–153.

González-Félix, M., Davis, D. A., Rossi, W., & Perez-Velazquez, M. (2010). Evaluation of apparent digestibility coefficient of energy of various vegetable feed ingredients in Florida pompano, *Trachinotus carolinus*. *Aquaculture*, *310*(1–2), 240–243.

González-Solís, D., Moravec, F., Vidal-Martínez, V. M., & Zárate-Pérez, S. E. (2002). Parasitic nematodes of the Florida pompano, *Trachinotus carolinus*, from the Peninsula of Yucatán, Mexico. *Helminthologia*, *39*(1), 35–40.

Gothreaux, C. (2008). *Measurement of nutrient availability in feedstuffs for Florida pompano and development of formulated diets for pompano aquaculture* (M.S. thesis). Louisiana State University, Baton Rouge, LA.

Hacking, M. A., & Budd, J. (1971). *Vibrio* infection in tropical fish in a freshwater aquarium. *Journal of Wildlife Diseases*, *7*, 273–280.

Handlinger, J., Soltani, M., & Percival, S. (1997). The pathology of *Flexibacter maritimus* in aquaculture species in Tasmania, Australia. *Journal of Fish Diseases*, *20*, 159–168.

Hanisak, M. D., & Wills, P. S. (2013). Macroalgal component of a novel marine recirculating land-based integrated multitrophic aquaculture system. *Phycologia*, *52*(4), 41–41.

Hanson, L. A., & Grizzle, J. M. (1985). Nitrite-induced predisposition of channel catfish to bacterial diseases. *Progressive Fish-Culturist*, *47*, 98–101.

Hauville, M. R., Main, K. L., Migaud, H., & Gordon Bell, J. (2016). Fatty acid utilization during the early larval stages of Florida pompano (*Trachinotus carolinus*) and common snook (*Centropomus undecimalis*). *Aquaculture Research*, *47*(5), 1443–1458.

Hauville, M. R., Zambonino-Infante, J., Bell, G., Migaud, H., & Main, K. L. (2014). Impacts of three different microdiets on Florida pompano, *Trachinotus carolinus*, weaning success, growth, fatty acid incorporation and enzyme activity. *Aquaculture*, *422*, 268–276.

Hauville, M. R. S. (2014). *Larviculture and nutrition of three of Florida's high value food and stock enhancement finfish, common snook (Centropomus undecimalis), Florida pompano (Trachinotus carolinus) and red drum (Sciaenops ocellatus)* (Doctoral Dissertation). University of Stirling, Institute of Aquaculture, Stirling, England.

Hawke, J. P. (1976). A survey of the diseases of striped bass, *Morone saxatilis* and pompano, *Trachinotus carolinus* cultured in earthen ponds. *Proceedings of the Annual Meeting - World Mariculture Society*, *7*, 495–509.

Hertrampf, J. W., & Piedad-Pascual, F. (2000). *Handbook on ingredients for aquaculture feeds*. Dordrecht, The Netherlands: Kluwer Academic Publishers.

Hoff, F. H., Mountain, J., Frakes, T., & Halscott, K. (1978). Spawning, oocyte development and larval rearing of the Florida pompano, *Trachinotus carolinus*. *Proceedings of the World Mariculture Society*, *9*, 279–297.

Hoff, F. H., Pulver, T., & Mountain, J. (1978). Conditioning Florida pompano, *Trachinotus carolinus*, for continuous spawning. *Proceedings of the World Mariculture Society*, *9*, 299–309.

Hoff, F. H., Rowell, C., & Pulver, T. (1972). Artificially induced spawning of the Florida pompano under controlled conditions. *Proceedings of the World Mariculture Society*, *3*, 53–64.

Horne, M. T., Tatner, M., Roberts, R. J., & Ward, P. D. (1984). The effects of the use of potassium alum adjuvant in vaccines against vibriosis in rainbow trout *Salmo gairdneri* Richardson. *Journal of Fish Diseases*, *7*, 91–99.

Hossain, M. A., Almatar, S. M., & James, C. M. (2011). Whole body and egg AAcomposition of silver pomfret, *Pampus argentus* (Euphrasen, 1788) and prediction of dietary requirements for essential amino acids. *Journal of Applied Ichthyology*, *27*, 1067–1071.

Iverson, E. S., & Berry, F. H. (1969). Fish mariculture: Progress and potential. *Proceedings of the Gulf and Caribbean Fisheries Institute*, *21*, 163–176.

Kajita, Y., Sakai, M., Atsuta, S., & Kobayashi, M. (1990). The immunomodulatory effects of levamisole on rainbow trout, *Oncorhynchus mykiss*. *Fish Pathology*, *25*, 93–98.

Kamalam, B. S., Medale, F., & Panserat, S. (2017). Utilisation of dietary carbohydrates in farmed fishes: New insights on influencing factors, biological limitations and future strategies. *Aquaculture*, *467*, 3–27.

Kaushik, S. J. (1998). Whole body AAcomposition of European seabass (*Dicentrarchus labrax*), gilthead seabream (*Sparus aurata*) and turbot (*Psetta maxima*) with an estimation of their IAA requirement profiles. *Aquatic Living Resources*, *11*, 355–358.

Kloth, T. C. (1980). Observations of the spawning behavior of captive Florida pompano, *Trachinotus carolinus*. *Copeia*, *4*, 884–886.

Knapp, G., & Rubino, M. C. (2016). The political economics of marine aquaculture in the United States. *Reviews in Fisheries Science & Aquaculture*, *24*(3), 213–229.

Kohn, A., Santos, C. P., & Baptista, M. d. F. D. (1992). New host records and localities of some Monogenea from Brazilian marine fishes with scanning electron microscopy of *Bicotylophora trachinoti* (Mac Callum, 1921). *Memórias do Instituto Oswaldo Cruz*, *87*(1), 109–114.

Kohn, A., Santos, C. P., & Lebedev, B. (1996). *Metacamopiella euzeti* gen. n., sp. n., and *Hargicola oligoplites* (Hargis, 1957) (Monogenea: Allodiscocotylidae) from Brazilian fishes. *Journal of the Helminthological Society of Washington*, *63*(2), 176–180.

Lansdell, W., Dixon, B., Smithin, N., & Benjamin, L. (1993). Isolation of several *Mycobacterium* species from fish. *Journal of Aquatic Animal Health*, *5*, 73–76.

Laramore, S., Baptiste, R., Wills, P. S., & Hanisak, M. D. (2018). Utilization of IMTA-produced *Ulva lactuca* to supplement or partially replace pelleted diets in shrimp, *Litopenaeus vannamei*, reared in a clear water production system. *Journal of Applied Phycology*, *30*, 3603–3610.

Lawler, A. R. (1980). Studies on *Amyloodinium ocellatum* (Dinoflagellata) in Mississippi Sound: Natural and experimental hosts. *Gulf Research Reports*, *6*(4), 406–413.

Lazo, J. P., Davis, D. A., & Arnold, C. R. (1998). The effects of dietary protein level on growth, feed efficiency and survival of juvenile Florida pompano (*Trachinotus carolinus*). *Aquaculture*, *169*(3–4), 225–232.

Lech, G. P., & Reigh, R. C. (2012). Plant products affect growth and digestive efficiency of cultured Florida pompano (*Trachinotus carolinus*) fed compounded diets. *PLoS One*, *7*(4), e34981.

Liu, X. W., Lang, W. H., Tao, Z. H., & Dan, X. (2011). Optimum dietary protein to energy ratio in juvenile pompano, *Trachinotus ovatus*. *Fisheries Science (Dalian)*, *30*, 136–139.

Lom, J., & Dykova, I. (1992). *Parasites of fishes*. Amsterdam, The Netherlands: Elsevier.

López-Porras, A., Morales, J. A., Alvarado, G., Koda, S. A., Camus, A., Subramaniam, K., … Soto, E. (2018). Red seabream iridovirus associated with cultured Florida pompano *Trachinotus carolinus* mortality in Central America. *Diseases of Aquatic Organisms*, *130*, 109–115.

Love, D. C., Asche, F., Conrad, Z., Young, R., Harding, J., Nussbaumer, E. M., & Neff, R. (2020). Food sources and expenditures for seafood in the United States. *Nutrients*, *12*(6), 1810.

Ma, Q., Seyoum, S., Tringali, M. D., Resley, M. J., Rhody, N. R., Main, K. L., & Leber, K. M. (2017). Evaluating spawning performance among captive Florida pompano *Trachinotus carolinus* broodstock using microsatellite-based parentage assignment. *Aquaculture Research*, *48*(11), 5506–5516.

MacCallum, G. A. (1921). Studies in helminthology. Part I. Trematodes. *Zoopathologica*, *1*, 135–184.

Main, K. L., Rhody, N., Nystrom, M., & Resley, M. (2007). *Species profile — Florida Pompano*. USDA Southern Regional Aquaculture Center, Publication No. 7206. Soneville, MS.

Mambrini, M., & Kaushik, S. J. (1995). Indispensable amino acid requirements of fish: Correspondence between quantitative data and amino acid profiles of tissue proteins. *Journal of Applied Ichthyology*, *11*, 240–247.

Marcello, R. A., Jr., & Strawn, R. K. (1972). *The cage culture of some marine fishes in the intake and discharge canals of a semi-electric generating station, Galveston Bay, Texas*. Texas A&M University Sea Grant Publication 72-20b, College Station, TX.

Martins, C. I. M., Eding, E. H., Verdegem, M. C. J., Heinsbroek, L. T. N., Schneider, O., Blancheton, J. P., … Verreth, J. A. J. (2010). New developments in recirculating aquaculture systems in Europe: A perspective on environmental sustainability. *Aquacultural Engineering*, *43*(3), 83–93.

McMaster, M. F. (1988). Pompano aquaculture: Past success and present opportunities. *Aquaculture Magazine*, *14*(3), 8–34.

McMaster, M. F., Kloth, T. C., & Coburn, J. F. (2004). Pompano mariculture – 2004. *Aquaculture Magazine*, *30*(4), 25–29.

McVicar, A. H., & White, P. G. (1979). Fin and skin necrosis of cultivated Dover sole *Solea solea* (L.). *Journal of Fish Diseases*, *2*, 557–562.

Mejri, S., Tremblay, R., Audet, C., Wills, P. S., & Riche, M. (2021). Essential fatty acids in tropical and cold-water marine fish larvae and juveniles. *Frontiers in Marine Science*. https://doi.org/10.3389/fmars.2021.680003.

Moe, M. A., Jr., Lewis, R. H., & Ingle, R. M. (1968). *Pompano mariculture: Preliminary data and basic considerations*. State of Florida Board of Conservation Technical Series No. 55. Florida Board of Conservation, Tallahassee, FL.

Moretti, A., Pedini Fernandez-Criado, M., Cittolin, G., & Guidastri, R. (1999). *Manual on hatchery production of seabass and gilthead seabream* (Vol. 1). Rome, Italy: Food and Agriculture Organization of the United Nations.

Mushiake, K., Kawano, K., Sakamoto, W., & Hasegawa, I. (1994). Effects of extended day length on ovarian maturation and HCG-induced spawning in yellowtail fed moist pellets. *Fisheries Science*, *60*, 647–651.

Mylonas, C. C., Papandroulakis, N., Smboukis, A., Papadaki, M., & Divanach, P. (2004). Induction of spawning of cultured greater amberjack, *Seriola dumerili*, using GnRHa implants. *Aquaculture*, *237*, 141–154.

Nahashon, S. N., & Kilonzo-Nthenge, A. K. (2011). *Advances in soybean and soybean by-products in monogastric nutrition and health*. London, UK: InTech Retrieved from: https://www.intechopen.com/books/soybean-and-nutrition/advances-in-soybean-and-soybean-by-products-in-monogastric-nutrition-and-health

Nakai, T., Mori, K., Sugaya, T., Nishioka, T., Mushiake, K., & Yamashita, H. (2009). Current knowledge on viral nervous necrosis (VNN) and its causative betanodaviruses. *Israeli Journal of Aquaculture – Bamidgeh*, *61*, 198–207.

National Research Council. (2011). *Nutrient requirements of fish and shrimp*. Washington, DC: National Academy of Sciences Press.

Nazar, A. A., Jayakumar, R., Tamilmani, G., & Sakthivel, M. (2013). Hatchery protocols for seed production of cobia and pompano. In I. Joseph & E. Joseph (Eds.), *Customized training in mariculture for Maldivian officials* (pp. 140–143). Kerala, India: Central Marine Fisheries Institute.

Niu, J., Du, Q., Lin, H.-Z., Cheng, Y.-Q., Huang, Z., Wang, Y., … Chen, Y.-F. (2013). Quantitative dietary methionine requirement of juvenile golden pompano *Trachinotus ovatus* at a constant dietary cystine level. *Aquaculture Nutrition*, *19*, 677–686.

Novriadi, R., Rhodes, M., Powell, M., Hanson, T., & Davis, D. A. (2018). Effects of soybean replacement with fermented soybean meal on growth, serum biochemistry and morphological condition of liver and distal intestine of Florida pompano *Trachinotus carolinus*. *Aquaculture Nutrition*, *24*, 1066–1075.

Novriadi, R., Salze, G., Abebe, A., Hanson, T., & Davis, D. A. (2019). Partial or total replacement of fish meal in the diets of Florida pompano *Trachinotus carolinus*. *Aquaculture Research*, *50*, 1527–1538.

Novriadi, R., Spangler, E., & Davis, D. A. (2019). Comparative effect of advanced soy products or corn protein concentrate with porcine meal on growth, body composition, and distal intestine histology of Florida pompano, *Trachinotus carolinus*. *Journal of the World Aquaculture Society*, *50*, 433–447.

Novriadi, R., Spangler, E., Rhodes, M., Hanson, T., & Davis, D. A. (2017). Effects of various levels of squid hydrolysate and squid meal supplementation with enzyme treated soy on growth performance, body composition, serum biochemistry and histology of Florida pompano *Trachinotus carolinus*. *Aquaculture*, *481*, 85–93.

Oshima, S., Hata, J., Hirasawa, N., Otaka, T., Hirono, I., Aoki, T., & Yamashita, S. (1998). Rapid diagnosis of red sea bream iridovirus using the polymerase chain reaction. *Diseases of Aquatic Organisms*, *32*, 87–90.

Overstreet, R. M., & Brown, C. E. (1970). *Lasiotocus trachinoti* sp. n. (Digenea: Monorchiidae) from the Pompano, *Trachinotus carolinus* (Linnaeus), along the East Coast of Florida. *The Journal of Parasitology*, *56*(5), 941–943.

Pakingking, R. J., Mori, K.-L., Bautista, N. B., de Jesus-Ayson, E. G., & Reyes, O. (2011). Susceptibility of hatchery-reared snubnose pompano *Trachinotus blochii* to natural betanodavirus infection and their immune responses to the inactivated causative virus. *Aquaculture*, *311*, 80–86.

Paperna, I. (1984). Reproduction cycle and tolerance to temperature and salinity of *Amyloodinium ocellatum* Brown, 1931 (Dinoflagellida). *Annales de Parasitologie Humaine et Comparée*, *59*, 7–30.

Parker, D., & Booth, A. J. (2013). The tongue-replacing isopod *Cymothoa borbonica* reduces the growth of largespot pompano *Trachinotus botla*. *Marine Biology*, *160*(11), 2943–2950.

Patro, B., Reigh, R. C., & Williams, M. B. (2011). *Dietary methionine requirement of Florida pompano*. New Orleans, LA: Aquaculture America Retrieved from https://www.was.org/MeetingAbstracts/ShowAbstract/21275

Pattillo, M., Czapla, T., Nelson, D., & Monaco, M. (1997). *Distribution and abundance of fishes and invertebrates in Gulf of Mexico estuaries*, *Volume II: Species life history summaries*. ELMR Rep. No. 11. NOAA/NOS Strategic Environmental Assessments Division, Silver Spring, MD.

Pazos, F., Santos, Y., Nunez Macias, A. R., & Toranzo, A. E. (1996). Evaluation of media for the successful culture of *Flexibacter maritimus*. *Journal of Fish Diseases*, *19*, 193–197.

Pfeiffer, T. J., & Riche, M. A. (2011). Evaluation of a low-head recirculating aquaculture system used for rearing Florida Pompano to market size. *Journal of the World Aquaculture Society*, *42*(2), 198–208.

Pinto, R. M., Vicente, J. J., & Noronha, D. (1984). First report of *Ascarophis* Van Beneden, 1871: *A. brasiliensis* n.sp. (Nematoda, Ascarophidinae) and *Procamallanus* (*Spirocamallanus*) Pereira/Annereaux, 1946 (Nematoda, Procamallaninae) in South America. *Memórias do Instituto Oswaldo Cruz*, *79*(4), 491–494.

Planas, M., & Cunha, I. (1999). Larviculture of marine fish: Problems and perspectives. *Aquaculture*, *177*(1–4), 171–190.

Quintero, H. E., Davis, D. A., & Rhodes, M. A. (2012). Soy protein concentrate as an alternative ingredient in Florida pompano (*Trachinotus carolinus*) diets. *Journal of Applied Aquaculture*, *24*(3), 247–261.

Ransangan, J., Manin, O., Abdullah, A., Roli, Z., & Sharudin, E. F. (2011). Betanodavirus infection in golden pompano, *Trachinotus blochii*, fingerlings cultured in deep-sea cage culture facility in Langkawi, Malaysia. *Aquaculture*, *315*, 327–334.

Reichenbach-Klinke, H. H. (1972). Some aspects of mycobacterial infections in fish. *Proceedings of the Zoological Society of London*, *30*, 17–24.

Reynolds, E. A. (2010). *Analysis of spawning behavior and gamete availability of the Florida pompano (Trachinotus carolinus) in a recirculating aquaculture system* (Master Thesis). University of Florida.

Rhodes, M. A., Zhou, Y., & Davis, D. A. (2015). Use of dried fermented biomass as a fish meal replacement in practical diets of Florida pompano, *Trachinotus carolinus*. *Journal of Applied Aquaculture*, *27*, 29–39.

Rhodes, M. A., Zhou, Y., Salze, G. P., Hanson, T. R., & Davis, D. A. (2017). Development of plant-based diets and the evaluation of dietary attractants for juvenile Florida pompano, *Trachinotus carolinus* L. *Aquaculture Nutrition*, *23*, 1065–1075.

Ribeiro, J., de São Clemente, S. C., Lopes, L. M. S., & Knoff, M. (2014). Nematode larvae of hygienic importance infecting *Chaetodipterus faber* (Broussonet, 1782) and *Trachinotus carolinus* (Linnaeus, 1766) (Pisces: Teleostei) in Brazil. *Revista Brasileira de Medicina Veterinária*, *36*(2), 121–124.

Riche, M. (2009). Evaluation of digestible energy and protein for growth and nitrogen retention in juvenile Florida pompano, *Trachinotus carolinus*. *Journal of the World Aquaculture Society*, *40*, 45–57.

Riche, M. (2011). *Estimated quantitative amino acid requirements for Florida pompano reared in low-salinity*. Aquaculture America 2011, New Orleans, LA. Retrieved from https://www.was.org/MeetingAbstracts/ShowAbstract/2135

Riche, M. (2014). Development of a semipurified test diet for determining amino acid requirements of Florida pompano *Trachinotus carolinus* reared under low salinity conditions. *Aquaculture*, *420–421*, 49–56.

Riche, M. (2015). Nitrogen utilization from diets with refined and blended poultry by-products as partial fish meal replacements in diets for low-salinity cultured Florida pompano, *Trachinotus carolinus*. *Aquaculture*, *435*, 458–466.

Riche, M., Barrows, F. T., & Gaylord, T. G. (2017). Digestibility of feed ingredients in Florida pompano, *Trachinotus carolinus* adapted to either sea water or low salinity. *Aquaculture Nutrition*, *23*, 339–349.

Riche, M., & Williams, T. N. (2010). Apparent digestible protein and amino acid availability of three plant proteins in Florida pompano, *Trachinotus carolinus* L. in seawater and low-salinity water. *Aquaculture Nutrition*, *16*, 223–230.

Riche, M., & Williams, T. N. (2011). Fish meal replacement with solvent-extracted soybean meal or soy protein isolate in a practical diet formulation for Florida pompano (*Trachinotus carolinus*, L.) reared in low salinity. *Aquaculture Nutrition*, *17*, 368–379.

Riche, M. A., Pfeiffer, T. J., Wills, P. S., Amberg, J. J., & Sepulveda, M. S. (2012). Inland marine fish culture in low salinity recirculating aquaculture systems. *Bulletin of Fisheries Research Agency*, *35*, 65–75.

Riley, K. L., & Weirich, C. R. (2010). *History, current status, and potential of Florida pompano aquaculture*. San Antonio, TX: Triennial conference and exposition of the World Aquaculture Society.

Riley, K. L., Weirich, C. R., & Cerino, D. (2009). Development and growth of hatchery-reared larval Florida pompano (*Trachinotus carolinus*). *Fishery Bulletin*, *107*(3), 318–328.

Roberts, R. J. (2012). *Fish pathology*. Philadelphia, PA: WB Saunders Company.

Rocha, S., Casal, G., Garcia, P., Matos, E., Al-Quraishy, S., & Azevedo, C. (2014). Ultrastructure and phylogeny of the parasite *Henneguya carolina* sp. Nov. (Myxozoa), from the marine fish *Trachinotus carolinus* in Brazil. *Diseases of Aquatic Organisms*, *112*(2), 139–148.

Roe, C. M., To, V. P. T. H., Zhou, Y., Salze, G., Rhodes, M. A., Hanson, T., & Davis, D. A. (2019). Improving high soy feed formulations for the Florida pompano *Trachinotus carolinus* through newer soy products and carbohydrase supplementation. *Journal of the World Aquaculture Society*, *50*, 406–419.

Rombenso, A. N., Trushenski, J. T., & Schwarz, M. H. (2016). Fish oil replacement in feeds for juvenile Florida pompano: Composition of alternative lipid influences degree of tissue fatty acid profile distortion. *Aquaculture*, *458*, 177–186.

Rombenso, A. N., Trushenski, J. T., & Schwarz, M. H. (2017). Beef tallow is suitable as a primary lipid source in juvenile Florida pompano feeds. *Aquaculture Nutrition*, *23*, 1274–1286.

Ross, A. J., Martin, J. E., & Bressler, V. (1968). *Vibrio anguillarum* from an epizootic in rainbow trout (*Salmo gairdneri*) in the U. S. *Bulletin de l'office International des Epizooties*, *69*, 1139–1148.

Rossi, W., Jr., & Davis, D. A. (2012). Replacement of fishmeal with poultry by-product meal in the diet of Florida pompano *Trachinotus carolinus* L. *Aquaculture*, *338*, 160–166.

Rossi, W., Jr., & Davis, D. A. (2014). Meat and bone meal as an alternative for fish meal in soybean meal-based diets for Florida pompano, *Trachinotus carolinus* L. *Journal of the World Aquaculture Society*, *45*, 613–623.

Rossi, W., Jr., Moxley, D., Buentello, A., Pohlenz, C., & Gatlin, D. M. (2013). Replacement of fishmeal with novel plant feedstuffs in the diet of red drum *Sciaenops ocellatus*: An assessment of nutritional value. *Aquaculture Nutrition*, *19*, 72–81.

Rucker, R. R. (1959). *Vibrio* infections among marine and fresh-water fish. *Progressive Fish Culturist*, *21*, 22–25.

Rust, M. B., Barrows, F. T., Drawbridge, M., Hart, E. R., Stuart, K., Webb, K., … Johnson, R. B. (2015). Development and characterization of several open formula reference diets for marine fish larvae. *Bulletin of Fisheries Research Agency*, *40*, 75–77.

Salze, G. P., & Davis, D. A. (2015). Taurine: A critical nutrient for future fish feeds. *Aquaculture*, *437*, 215–229.

Salze, G. P., Davis, D. A., & Rhodes, M. (2014). *Estimation of the quantitative requirement for dietary taurine in Florida pompano, Trachinotus carolinus juveniles*. Seattle, Washington: Aquaculture America 2014 Retrieved from https://www.was.org/MeetingAbstracts/ShowAbstract/31765

Salze, G. P., Rhodes, M., & Davis, D. A. (2019). Quantitative taurine requirement for juvenile Florida pompano (*Trachinotus carolinus*) fed soy-based practical diets. *Aquaculture Nutrition*, *25*, 388–395.

Salze, G. P., Spangler, E., Cobine, P. A., Rhodes, M., & Davis, D. A. (2016). Investigation of biomarkers of early taurine deficiency in Florida pompano *Trachinotus carolinus*. *Aquaculture*, *451*, 254–265.

Sánchez-Ramírez, C., & Vidal-Martínez, V. M. (2002). Metazoan parasite infracommunities of Florida pompano (*Trachinotus carolinus*) from the coast of the Yucatan Peninsula, Mexico. *The Journal of Parasitology*, *88*(6), 1087–1094.

Sinha, A. K., Kumar, V., Makkar, H. P. S., de Boeck, G., & Becker, K. (2011). Non-starch polysaccharides and their role in fish nutrition – A review. *Food Chemistry*, *127*, 1409–1426.

Smith, C. (1997). *National Audubon Society Field Guide to tropical marine fishes of the Caribbean, the Gulf of Mexico, Florida, the Bahamas, and Bermuda*. New York, NY: Alfred A. Knopf, Inc.

Smith, T. I. J. (1973). *The commercial feasibility of rearing pompano Trachinotus carolinus (Linnaeus) in cages*. Gainesville, FLorida: Florida Sea Grant, Technical Bulletin 26.

Smith-Vaniz, W. F. (2002). Carangidae. In K. E. Carpenter (Ed.), *The living marine resources of the Western Central Atlantic, Volume 3: Bony fishes part 2 (Opistognathidae to Molidae)* (pp. 1426–1440). Rome, Italy: FAO Species Identification Guide for Fishery Purposes and American Society of Ichthyologists and Herpetologists Special Publication No. 5.

Solomon, J. J., & Tremain, D. M. (2009). Recruitment timing and spatial patterns of estuarine use by young-of-the-year Florida pompano, *Trachinotus carolinus*, in northeastern Florida. *Bulletin of Marine Science*, *85*(2), 133–148.

Stoskopf, M. J. (1993). *Fish medicine* (p. 882). Philadelphia, PA: W.B. Saunders Co.

Swingle, W. E. (1972). Alabama's marine cage culture studies. *Proceedings of the World Mariculture Society*, *3*, 75–81.

Tatner, M. F., & Horne, M. T. (1983). Factors influencing the uptake of 14C-labelled *Vibrio anguillarum* vaccine in direct immersion experiments in rainbow trout, *Salmo gairdneri*. *Journal of Fish Biology*, *22*, 585–591.

Tatum, W. M. (1972). Comparative growth, mortality and efficiency of pompano *Trachinotus carolinus* receiving a diet of ground industrial fish with those receiving a diet of trout chow. *Proceedings of the World Mariculture Society*, *3*, 65–74.

Tatum, W. M. (1973). Comparative growth of pompano *Trachinotus carolinus* in suspended net cages receiving diets of a floating trout chow with those receiving a mixture of 50% trout chow and 50% sinking ration. *Proceedings of the World Mariculture Society*, *4*, 125–141.

Tatum, W. M., & Trimble, W. C. (1978). Monoculture and polyculture pond studies with pompano Trachinotus carolinus and shrimp (*Penaeus aztecus*, P. duorarum, and *P. setiferus*) in Alabama, 1975–1977. *Proceedings of the World Mariculture Society*, *9*, 433–446.

Trimble, W. C. (1980). Production trials for monoculture and polyculture of white shrimp (*Penaeus vannamei*) or blue shrimp (*P. stylirostris*) with Florida pompano (*Trachinotus carolinus*) in Alabama, 1978-1979. *Proceedings of the World Mariculture Society*, *11*, 44–59.

Tucker, J. W., Jr. (1998). *Marine fish culture*. Norwell, MA: Kluwer Academic Press.

Wang, J., Gatlin, D. M., III, Li, L., Wang, Y., Jin, N., Lin, H., … Guo, Y. (2019). Dietary chromium polynicotinate improves growth performance and feed utilization of juvenile golden pompano (*Trachinotus ovatus*) with starch as the carbohydrate. *Aquaculture*, *505*, 405–411.

Ward, T., & Phillips, B. (Eds.). (2009). *Seafood ecolabelling: Principles and practice*. Hoboken, NJ: John Wiley and Sons.

Watanabe, T., Verakunpiriya, V., Mushiake, K., Kawano, K., & Hasegawa, I. (1996). The first spawn-taking from broodstock yellowtail cultured with extruded dry pellets. *Fisheries Science*, *62*, 388–393.

Watanabe, W. O. (1995). Aquaculture of the Florida pompano and other jacks (Family Carangidae) in the Western Atlantic, Gulf of Mexico, and Caribbean basin: Status and potential. In K. L. Main & C. Rosenfeld (Eds.), *Culture of high-value marine fishes* (pp. 185–205). Honolulu, HI: Oceanic Institute.

Weirich, C. R., Groat, D. R., Reigh, R. C., Chesney, E. J., & Malone, R. F. (2006). Effect of feeding strategies on production characteristics and body composition of Florida pompano reared in marine recirculating systems. *North American Journal of Aquaculture*, *68*(4), 330–338.

Weirich, C. R., & Riley, K. L. (2007). Volitional spawning of Florida pompano, *Trachinotus carolinus*, induced via administration of gonadotropin releasing hormone analogue (GnRHa). *Journal of Applied Aquaculture*, *19*(3), 47–60.

Weirich, C. R., Wills, P. S., Baptiste, R. M., Woodward, P. N., & Riche, M. A. (2009). Production characteristics and body composition of Florida pompano reared to market size at two different densities in low-salinity recirculating aquaculture systems. *North American Journal of Aquaculture*, *71*(2), 165–173.

Westerdahl, A., Olsson, J. C., Kjelleberg, S., & Conway, P. L. (1991). Isolation and characterization of turbot (*Scophtalmus maximus*) associated bacteria with inhibitory effects against *Vibrio anguillarum*. *Applied and Environmental Microbiology*, *57*, 2223–2228.

Wheeler, K. N., Stark, C. C., & Heard, R. W. (2002). A preliminary study of the summer feeding habits of juvenile Florida pompano (*Trachinotus carolinus*) from open and protected beaches of the northeastern Gulf of Mexico. In R. Creswell (Ed.), (pp. 659–673). Ft. Pierce, FL: Proceedings of the Gulf and Caribbean Fisheries Institute, c/o Harbor Branch Oceanographic Institution, Inc.

Williams, E. (1974). Treatments employed for control of parasites of selected fishes stocked in mariculture (1969–1972). *Proceedings of World Mariculture Society*, *5*(1–4), 291–295.

Williams, S., Lovell, R. T., & Hawke, J. P. (1985). Value of menhaden oil in diets of Florida pompano. *Progressive Fish-Culturist*, *47*(3), 159–165.

Williams, T. N. (2008). *An assessment of alternative feed ingredients in practical diets for Florida pompano (Trachinotus carolinus) held in low salinity recirculating systems* (M.S. thesis). University of Maine, Orono, ME.

Wills, P. S. (2013). *Commercialization of Florida Pompano Production in Inland Recirculating Systems: Final Report* (FDACS Contract No. 18490). Tallahassee, FL: Florida Department of Agriculture and Consumer Services.

Wills, P. S., Beiser, G., Scarpa, J., Hannisak, D., Laramore, S., & Garr, A. (2012). A new design concept for a land-based integrated multi-trophic aquaculture system. In T. T. Rakestraw, & L. S. Lawson (Eds.), *Proceedings of the Ninth International Conference on Recirculating Aquaculture* (pp. 178–180). Roanoke, VA: Department of Food Science and Technology, Virginia Polytechnic Institute and State College.

Wu, Y., Ren, G., Qin, J. G., Han, H., & Wang, Y. (2016). The suitable dose of gamma irradiation on soybean meal as a fish meal substitute in diets for golden pompano (*Trachinotus ovatus*). *Aquaculture Research*, *47*, 1944–1953.

Yanong, R. P. E., Curtis, E. W., Terrell, S. P., & Case, G. (2003). Atypical presentation of mycobacteriosis in a collection of frogfish *Antennarius striatus*. *Journal of Zoo and Wildlife Medicine*, *34*, 400–407.

Yanong, R. P. E., Pouder, D. B., & Falkinham, J. O. (2010). Association of mycobacteria in recirculating aquaculture systems and mycobacterial disease in fish. *Journal of Aquatic Animal Health*, *22*(4), 219–223.

Yu, Y., Wei, S., Wang, Z., Huang, X., Huang, Y., Cai, J., … Qin, Q. (2016). Establishment of a new cell line from the snout tissue of golden pompano *Trachinotus ovatus*, and its application in virus susceptibility. *Journal of Fish Biology*, *88*(6), 2251–2262.

How to cite this article: Weirich, C. R., Riley, K. L., Riche, M., Main, K. L., Wills, P. S., Illán, G., Cerino, D. S., & Pfeiffer, T. J. (2021). The status of Florida pompano, *Trachinotus carolinus*, as a commercially ready species for U.S. marine aquaculture. *Journal of the World Aquaculture Society*, *52*(3), 731–763. https://doi.org/10.1111/jwas.12809