

The Impact of Diet on the Survival Skills of Hatchery Red Drum (*Sciaenops ocellatus*)

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ABSTRACT

Red drum, *Sciaenops ocellatus*, larvae (10 - 12 mm standard length, SL) were collected from a Texas Parks and Wildlife Department (TPWD) hatchery and reared on either artificial pellets (Rangen and Otohime feeds) or live prey (enriched *Artemia franciscana*, mysid shrimp) for a 14 day period. High-speed video was then used to evaluate differences in prey-capture (attack distance, mean attack velocity, capture time, and gape cycle duration) and anti-predator (reaction distance, response distance, maximum velocity, and maximum acceleration) performance between the two rearing groups. Repeated-measures analysis of variance (RM-ANOVA) indicated that red drum reared on pellets exhibited significantly longer gape cycle duration while feeding on a natural prey item (mysid shrimp), while red drum reared on live prey exhibited significantly greater maximum velocity and maximum acceleration when responding to a visual stimulus. Results of this study suggest that diet may influence certain behaviors linked to survival success in hatchery red drum.

KEY WORDS: Anti-predator, prey-capture, survival success

El Impacto de la Dieta en las Habilidades de Supervivencia del Corvinón Ocelado (*Sciaenops ocellatus*) Criado en Estanques

Larvas del Corvinón Ocelado, *Sciaenops ocellatus*, (10-20 mm) fueron extraídas de un estanque mantenido por el Texas Parks and Wildlife Department (TPWD) y luego criadas con dietas de pastillas artificiales (alimento Rangen y Otohime) o presas vivas (Camarón enriquecido, *Artemia franciscana*) por un periodo de 14 días. Se utilizó video de alta velocidad para evaluar diferencias en la captura de presas (distancia de ataque, velocidad promedio de ataque, tiempo de captura, y duración del ciclo de apertura de la boca) y (distancia de la reacción, distancia de la respuesta, velocidad máxima, y aceleración máxima) a una acción anti-predador entre los dos grupos en cultivo. El análisis de medidas-repetidas de la variación (RM-ANOVA) indicó que el Corvinón Ocelado criado con pastillas artificiales exhibió una duración más larga del ciclo de apertura de la boca cuando se alimentaba con una presa natural (camarón), mientras que el Corvinón Ocelado criado con presa viva exhibió una velocidad máxima y una aceleración máxima más larga al responder a un estímulo visual. Los resultados de este estudio sugieren que la dieta puede influenciar ciertos comportamientos ligados al éxito de la supervivencia en el Corvinón Ocelado de criadero.

PALABRAS CLAVES: Anti-predador, captura de presa, éxito de supervivencia

INTRODUCTION

The influence of diet on the behavior and post-release survival of hatchery fishes has been well documented for salmonids (Sosiak *et al.* 1979, Nordeide and Salvanes 1991, Maynard *et al.* 1996). However, information regarding the impact of diet on other species that are the focus of similar enhancement efforts, such as the red drum (*Sciaenops ocellatus*), is limited. Red drum is heavily targeted by recreational anglers in the U.S., and several red drum hatcheries currently exist along the Gulf of Mexico and Atlantic coasts (Woodward 2000, Smith *et al.* 2001). Supplemental pellet diets may be used in the culture of red drum for stocking purposes (Davis 1990, Colura *et al.* 1991), yet the potential impact(s) of these diets on the survival of hatchery red drum is largely unknown. In this study, we reared hatchery red drum on a diet of either pellets or live prey for a pre-determined period after which time survival skills (i.e. prey-capture and anti-predator performance) of the two rearing groups were evaluated.

METHODS

Rearing Exposure and High-speed Videography

Red drum larvae (10 - 12 mm standard length, SL) were dip-netted from a single 2-acre polyethylene lined pond at the Texas Parks and Wildlife Department's (TPWD) SeaCenter hatchery (SCT) in Lake Jackson, Texas. These individuals were 17 days post-hatch (dph) at collection and were the progeny of captive SCT broodstock. While in TPWD rearing ponds, larvae had access to natural prey types (e.g. copepods, nauplii and rotifers) from time of stocking, as well as three lbs of pellet feed (#0 crumble, Nelson and Sons, Inc.) daily beginning at 12 dph. After collection, red drum were transferred into wet lab tanks in Galveston, Texas representing either pellet (Otohime B1, B2, and Rangen #1) or live prey (one and two day old *Artemia franciscana*, mysid shrimp) treatments (two treatments x four replicates = eight tanks, 60 fish per tank). Red drum were reared on the two diets for a 14 day period until they were 25 - 30 mm SL, coinciding with current TPWD release sizes (Robert Vega, Texas Parks and Wildlife Department, personal communication).

Three red drum (n = 3) were then randomly chosen from each tank and placed into separate chambers (18 cm x

10 cm) for high-speed video trials. Prey-capture and anti-predator performance events for each fish were recorded using a high-speed Redlake MotionScope PCI videocamera at 250 frames per second (fps). For prey-capture, lateral feeding events on mysid shrimp, a natural prey item for red drum larvae and juveniles (Soto *et al.* 1998) were recorded. Four variables were recorded for each prey-capture event:

- i) Attack distance, distance from the tip of the premaxilla to the closest point on the prey at the beginning of prey capture (mm),
- ii) Mean attack velocity, average red drum velocity from time zero to when prey completely entered the mouth (mm/s),
- iii) Capture time, time to when prey completely entered the mouth (ms), and
- iv) Gape cycle duration, time elapsed from time zero to when mouth completely closes (ms).

Several hours later, anti-predator performance of these individuals was recorded in a separate control box. We used a visual stimulus modeled after Batty (1989) which has been shown to produce anti-predator behaviors in red drum larvae and juveniles (Fuiman and Cowan 2003, Smith and Fuiman 2004). Four variables were recorded for each anti-predator event:

- i) Reaction distance, distance between red drum and center of target at time zero (mm),
- ii) Response distance, distance traveled during the first 100 ms of response (mm),
- iii) Maximum velocity, maximum velocity reached during response (mm/s), and
- iv) Maximum acceleration, maximum acceleration reached during a response (mm/s²).

Events were referenced to time zero, corresponding to the frame prior to mouth opening during feeding, and the frame immediately preceding the first movement of the fish during an anti-predator response. Video footages were analyzed at 2 - 4x magnification using Redlake MotionScope 2.30.0 and Peak Motus 8.0 software and a generalized cross-validatory (GCV) quintic spline algorithm was applied to displacement data to accurately estimate velocity and acceleration values (Walker 1998).

Data Analysis

Data were tested for normality and homogeneity of variances using Kolmogorov-Smirnov and Levene's tests, respectively, and three variables (attack distance, capture time and gape cycle duration) were ln-transformed in order to meet the assumptions of parametric statistics. Values for prey-capture and anti-predator variables were regressed against the length for each individual to correct for any size-related differences, and the size-removed residuals were used in all further analyses. Differences in prey-capture and anti-predator performance variables between diets were tested using repeated-measures analysis of variance

(ANOVA), since individuals from the same tank were not truly independent measures. Separate univariate contrasts were also conducted on tank means (i.e. average response of three red drum from each tank) for each prey-capture and anti-predator performance variable. Results of univariate contrasts for tank mean data were identical to that of repeated-measures ANOVA for all performance variables measured, therefore only repeated-measures findings are presented.

RESULTS

Red drum prey-capture events resulted in successful acquisition of a prey item more than 90% of the time, regardless of rearing exposure. Repeated-measures ANOVA indicated that red drum reared on pellets had significantly longer gape cycle duration than individuals reared on live prey (ANOVA, $p = 0.040$) (Table 1). Although not statistically significant, attack distance ($p = 0.562$, power = 0.082) as well as capture time ($p = 0.417$, power = 0.115) were higher for red drum reared on pellets (Table 1), while the reverse was true for mean attack velocity ($p = 0.620$, power = 0.073) (Table 1). During anti-predator events, red drum reared on live prey exhibited significantly greater maximum velocity (ANOVA, $p = 0.012$) and maximum acceleration ($p = 0.027$) compared to individuals reared on pellets (Table 1). Maximum velocity (mean \pm S.E.) for red drum reared on live prey was 562 ± 35 versus 423 ± 35 mm/s for individuals reared on pellets, while maximum acceleration was $60,932 \pm 5,325$ versus $39,564 \pm 8,926$ mm/s², respectively. Reaction distance ($p = 0.057$, power = 0.503) (Table 1) and response distance ($p = 0.587$, power = 0.078) (Table 1), however, did not differ significantly between red drum reared on the two diets.

DISCUSSION

Red drum reared on pellets demonstrated significantly longer gape cycle duration (~26 ms) compared to fish reared on live prey (~24 ms). Although this did not appear to impact capture rates in this study, more rapid feeding bouts by fish reared on live prey may enhance capture probability in the wild by reducing the amount of time for prey to escape (Wintzer and Motta 2005). This behavior would be especially beneficial when targeting more elusive prey types such as fish, shrimp, and copepods, all of which are important prey items for red drum larvae and juveniles (Bass and Avault 1975, Peters and McMichael 1987, Soto *et al.* 1998). All other prey-capture variables remained similar for red drum reared on the two diets and this may be linked to the presence of live prey in TPWD ponds in the weeks prior to collection, as previous experience with live prey may have reduced the magnitude of diet-induced differences in this study.

Table 1. Repeated-measures ANOVA results for variables associated with prey-capture and anti-predator performance for hatchery red drum reared on pellet and live prey diets.

Variable	Mean \pm S.E.		
	Pellet	Live prey	p-value
<i>Prey-capture performance:</i>			
Attack Distance (mm)	0.79 \pm 0.13	0.76 \pm 0.12	0.562
Mean Attack Velocity (mm/sec)	159.36 \pm 13.94	167.25 \pm 28.66	0.620
Capture Time (ms)	9.83 \pm 0.37	9.33 \pm 0.61	0.417
Gape Cycle Duration (ms)	26.25 \pm 0.19	24.83 \pm 0.92	0.040 *
<i>Anti-predator performance:</i>			
Reaction Distance (mm)	93.91 \pm 10.37	49.30 \pm 12.27	0.057
Response Distance (mm)	25.53 \pm 1.40	26.30 \pm 1.60	0.587
Maximum Velocity (mm/sec)	423.30 \pm 35.24	562.96 \pm 35.47	0.012*
Maximum Acceleration (mm/sec ²)	39,565 \pm 8,927	60,932 \pm 5,325	0.027*

* p < 0.05

Hatchery red drum reared on the two diets exhibited differences in terms of their anti-predator performance. Specifically, maximum velocity and maximum acceleration values were approximately 25% greater for red drum reared on live prey versus individuals reared on pellets. Greater maximum velocity and maximum acceleration values have been shown to contribute to faster starts in the guppy (*Poecilia reticulata*) leading to a 2.3-fold increase in the odds of surviving strikes by pike cichlid predators (*Crenicichla alta*) (Walker *et al.* 2005). Likewise, the greater velocities and accelerations exhibited by hatchery red drum reared on live prey could also reduce capture probability for these individuals during predator-prey encounters. In previous studies, the use of pellet feeds has been shown to compromise swimming performance in fishes. For example, prolonged exposure to artificial pellet feeds has been linked to an increase in fat levels (Kucska *et al.* 2006) as well as a reduction in swimming stamina in fishes (Vincent 1960, Green 1964, Thorstad *et al.* 1997). Still, other aspects of the live prey diet, such as increased activity associated with pursuit and capture of moving prey, may have impacted swimming ability and/or condition in these individuals, possibly resulting in higher maximum velocity and acceleration values during anti-predator events.

Results of this study indicate that red drum reared on live prey exhibit faster feeding (e.g. gape cycle duration) and anti-predator (e.g. maximum velocity, maximum acceleration) behaviors compared to fish reared on pellets. Thus, it appears that exposure to live prey may enhance certain behaviors linked to survival success in these individuals and this is consistent with pre-release exposure studies for other hatchery-reared fishes (Colgan *et al.* 1986, Maynard *et al.* 1996, Sundström and Johnsson 2001). Hatchery fish reared on artificial pellet diets may experience a reduction in feeding ability as well as suffer from high levels of mortality following release (Olla *et al.* 1998, Brown and Day 2002). Our findings suggest that the use of live prey during the rearing process may reduce mortality

rates on hatchery red drum by enhancing both prey-capture and anti-predator performance in these fishes and this may positively impact survival success of stocked individuals.

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