Biscayne Bay Commercial Pink Shrimp, *Farfantepenaeus duorarum*, Fisheries, 1986–2005

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ABSTRACT— The Biscayne Bay bait (1986–2005) and food (1989–2005) fisheries for pink shrimp were examined using dealer-reported individual vessel-trip landings data, separated by waterbody code to represent only catches from Biscayne Bay. Annual landings varied little during the 1980's and early 1990's, and landings of the bait shrimp fishery exceeded those of the food shrimp fishery. The number of trips and landings in both fisheries increased from the late 1990's through 2002 and food shrimp landings exceeded landings of bait shrimp; landings in both fisheries decreased sharply in 2003. Landings in both fisheries increased in 2004 and 2005, but the increase in food shrimp landings was stronger. Annual catch per trip was much lower in the bait fishery than the food fishery. Each fishery exploited shrimp of a different size. The bait fishery targeted shrimp less than 19 mm carapace length (CL), whereas the food fishery caught shrimp greater than 19 mm CL. We compared monthly bait shrimp catch per unit of effort (CPUE) from the fishery to an estimate of shrimp density from a fishery-independent sampling effort over a 3-yr period and found a strong statistical relationship with the density estimate lagged by 3 mo. The relationship supported the use of bait shrimp fishery CPUE as an index of abundance in upcoming assessments of the effect of a massive water-management-based ecosystem restoration project on pink shrimp in Biscayne Bay. Project implementation will affect freshwater inflows to the bay and salinity patterns. An abundance index with a lengthy pre-implementation history that can be carried into the operational phase of the restoration project will be invaluable in assessing project effects and protecting an important fishery resource of Biscayne Bay. The bait shrimp fishery can provide a continuing index of shrimp abundance from late 1986 forward.

Introduction

Shrimp are Florida's most valuable and popular seafood (IFAS[1]). Three commercially important species of penaeid shrimp occur on both Florida coasts: white, *Litopenaeus setiferus*; pink, *Farfantepenaeus. duorarum*; and brown shrimp *F. aztecus*. The average annual Florida shrimp catch for the period from 2000 to 2010 was more than 20 million pounds (9,072 kg) and was worth $40 million at the dock (IFAS[1]). Total annual landings of pink shrimp on the west Florida coast greatly outweigh those on the east coast; however, Miami-Dade County is the only county on the east coast having pink shrimp landings greater than 10,000 pounds (4,536 kg) (FFWCC[2]).

Here we describe the pink shrimp fisheries of Biscayne Bay, Florida, by means of the landings and effort data acquired from dealer records and other information in published and unpublished studies. The pink shrimp is the principal shrimp species caught in Biscayne Bay (Tabb and Kenny, 1968; Campos and Berkeley, 2003; Berkeley et al.[3]). The spotted pink shrimp, *F. brasiliensis*, also occurs in the bay (Criales et al., 2000), but it appears inconsequential in trawl catches (Browder et al.[4]) and is not reported separately in landings data. Biscayne Bay pink shrimp fisheries provide only a small component of Florida's overall pink shrimp landings and ex-vessel value; however, both bait and food shrimp are commercially caught in Biscayne Bay and, together, represent the bay's most important fishery product.

Biscayne Bay is a shallow subtropical lagoon on the southeast coast of Florida adjacent to Miami (Fig. 1). With inclusion of Card and Barnes Sounds, it is 90 km long and connected to the continental shelf waters of the Atlantic Ocean through a network of tidal inlets (Criales et al., 2000). Much of south Biscayne Bay, including areas where the fisheries operate, is within the boundaries of Biscayne National Park (BNP, Fig. 1). The bay north and south of the park, including Card Sound, is designated by the State of Florida as an "Aquatic Preserve." Card Sound also is included in the Florida Keys National

[1]IFAS, University of Florida. Wild vs. farmed shrimp: the choice is yours. Fact sheet. 3 p. Available online at http://collier.ifas.ufl.edu/SeaGrant/pubs/Shrimp%20Fact%20Sheet.pdf.

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[2]FFWCC. 2010. Shrimp (Penaeids) Species Account. Available online at http://myfwc.com/media/195867/penaeid_shrimps.pdf.

[3]Berkeley, S. A., D. Pybas, and W. L. Campos. 1985. Bait shrimp fishery of Biscayne Bay. Fla. Sea Grant Tech. Pap. 40, Fla. Sea Grant College Prog., Gainesville. 16 p. Available online at http://ufdc.ufl.edu/UF00075991/00001.

[4]Browder, J. A., M. B. Robblee, and J. Lorenz. 2005. Biscayne Bay coastal and nearshore community baseline study to develop biological performance measures. Ann. Rep. S. Fla. Water Manage. Dist. Agree. C-13401-A01. NMFS SEFSC, Miami, Fla., PRD-04/05-08, 130 p. Available online at https://grunt.sefsc.noaa.gov/P_QryLDS/download/PRD134_PRD-03_04-12.pdf?id=LDS.

Marine Sanctuary, as are Barnes Sound and Manatee Bay.

An upstream water management system, the Central and Southern Florida Project, discharges fresh water into south Biscayne Bay at several locations. Changes to this system are planned as part of the Comprehensive Everglades Restoration Plan (CERP) (Browder et al., 2005; USACE and SFWMD[5]) and will affect the volume, timing, and spatial distribution of freshwater inflow to the bay and its salinity patterns. We propose that the 20 yr+ time series of relative shrimp abundance from the bait shrimp fishery could help evaluate the potential effect of future changes and provide a baseline against which to assess the effects of the project once implemented.

Postlarval pink shrimp recruiting to Biscayne Bay are thought to originate from the Dry Tortugas population off southwest Florida and are brought to the east coast and Biscayne Bay via the Tortugas Gyre and the Florida Current (Criales et al., 2000). Migration from Florida Bay to the Tortugas fishing grounds has been documented (Costello and Allen, 1966), and transport mechanisms for recruitment into Florida Bay have been explored (Criales and Lee, 1995; Criales et al., 2003), but no transport studies have addressed recruitment to Biscayne Bay, and a 1995 dissertation suggested that the Biscayne Bay and Tortugas pink shrimp are genetically distinguishable (von Sternberg, 1995).

Biscayne Bay's bait shrimp fishery was previously described by Siebenaler (1953), Tabb and Kenny (1968), Campos and Berkeley (2003), and Berkeley et al.[3] These studies predated the routine collection of dealer-reported landings and effort data on this fishery. EDAW Inc.[6] provided an ethnological description of the two Biscayne Bay shrimp fisheries.

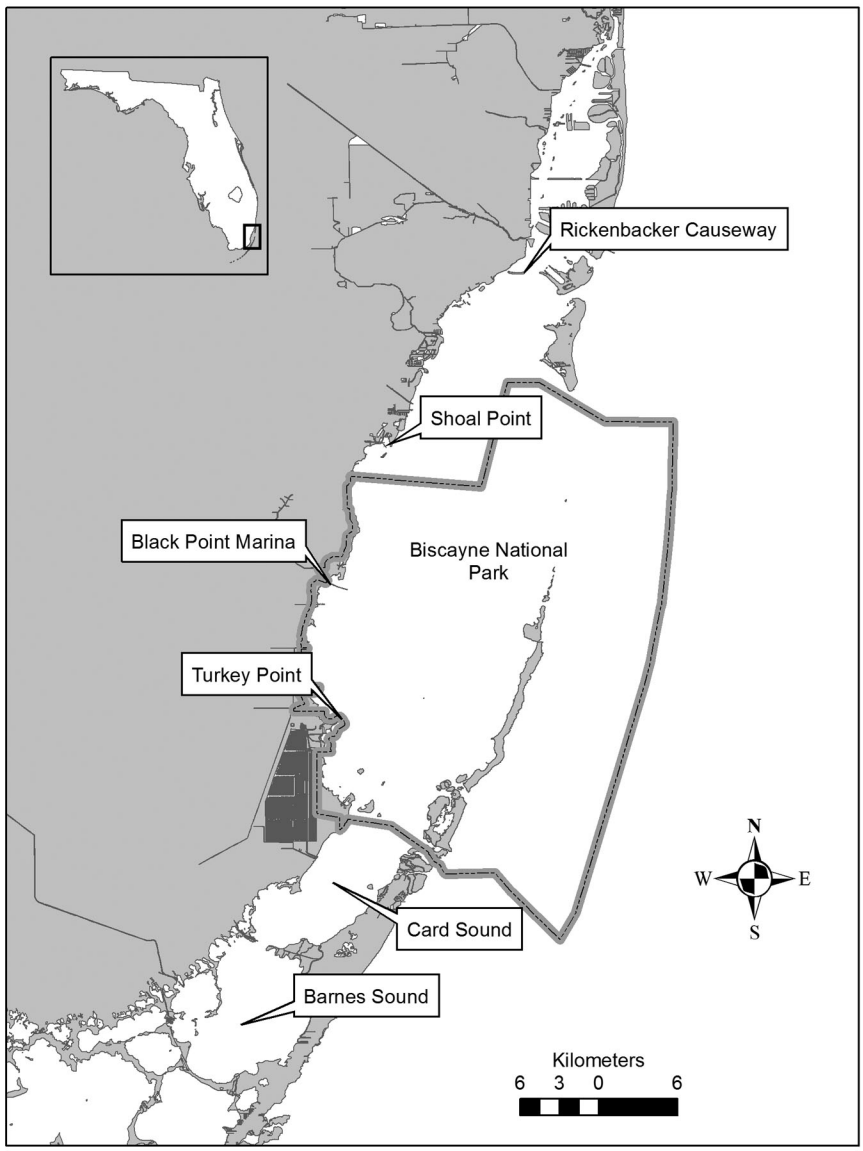


Figure 1.—Biscayne Bay showing Biscayne National Park boundaries.

The two commercial shrimp fisheries in Biscayne Bay operate under different sets of regulations first established in 1959 by the Florida Fish and Wildlife Conservation Commission (FFWCC[7]). FFWCC provides a history of Florida regulations pertinent to the Biscayne Bay shrimp fishery, as summarized for our purposes as follows. A "count" law, first initiated in the 1950's (FFWCC[7]), was revised in 1992 to regulate the minimum size for legally harvested food shrimp at 47 shrimp/lb, heads-on, or 70 tails/lb, heads-off (F.A.C. Rule CH 46-31[8]).

[5]USACE and SFWMD. 1999. Central and Southern Florida Project Comprehensive Review Study Final Integrated Feasibility Report and Programmatic Environmental Impact Statement. U.S. Army Corps Eng., Jacksonville Dist., Jacksonville, Fla., and S. Fla. Water Manage. Dist., West Palm Beach, Fla. (http://www.evergladesplan.org/pub/restudy_eis.aspx)

[6]EDAW Inc., San Diego, Ca. 2003. Final Rep. to Biscayne National Park, ethnographic overview and assessment. 162 p. [Republ. 2006 by Natl. Park Serv., SE Reg. Off. Cult. Resour. Div., Atlanta, Ga. (Available online at http://www.nps.gov/ethnography/research/docs/bisc_ethno.pdf).

[7]FFWCC. 2004. Biscayne Bay wingnet shrimp. Background document and executive summary, Sept., 2004. Fla. Fish Wildl. Conserv. Commiss., 2590 Executive Center Circle East, Tallahassee, Fla., 6 p.

[8]F.A.C. refers to Florida Administrative Code.

The count law was terminated in 2 Dec. 1999 and replaced with a seasonal closure, limiting the wing-net fishery to 15 Oct.–15 May, and a Saturday harvest restriction, prohibiting fishing from 6:00 am Saturday to 6:00 am Sunday (to minimize interactions with the recreational shrimp fishery) (F.A.C. Rule CH 68B-31). The same rule designated shrimp as a "restricted species" statewide, effective 1 Jan. 2001, requiring anyone fishing for shrimp to carry a specific FFWCC-issued "endorsement." The Biscayne Bay food shrimp production season was changed to 1 Nov.–31 May effective 21 Dec. 2000. (F.A.C. Rule 68B-31.0135) (FFWCC[9]).

Biscayne Bay's recreational shrimp fishery may be substantial, but no data have been collected on this fishery. Lights on the water from the Rickenbacker Causeway on full moon winter nights and comments from coworkers at UM and NMFS suggest that large, although unknown, numbers of recreational boats are fishing for shrimp

Bait Shrimp Fishery

The Biscayne Bay bait shrimp fishery supplies live shrimp to the recreational fisheries of southeast Florida, and nightly catches are maintained aboard in live wells. Bait shrimp landings are influenced by seasonal demands from tourism and levels of recreational fishing. First mention of the bait shrimp fishery was by Siebenaler (1953), who noted that three bait shrimp trawlers operated at night in Biscayne Bay illegally during the period of his survey, April 1950 through March 1952.

Tabb and Kenny (1968) provided a history of the bait shrimp fishery and a description of the fishing gears and their evolution in the 1950's and 1960's. As of 1968, the roller-frame trawl replaced the otter trawl in the fishery. The roller-frame trawl was described by Tabb and Kenny (1968) as efficient to operate, catching shrimp with minimal "trash" (algae, sponges, waterlogged coconuts, and other by-catch) at low operating costs. They said that the roller-frame trawl was designed to minimize contact with the bottom or vegetation, thus reducing damage to the root structure of seagrasses. Based on the analyses of 22 shrimp-boat tows, they reported that the average composition of the catch was 82% invertebrates, 9% fish, and 9% plant material. A later study estimated that the roller-frame trawls of the bait shrimp fishery together swept the entire shallow bottom habitat (1.2–1.8 m) of south Biscayne Bay up to four times per year and had a significant impact on sponges and hard and soft corals (Ault et al.[10]).

Tabb and Kenny (1968) reported that bait shrimp trawling was primarily restricted to the bay south of Rickenbacker Causeway during the 1960's. Heaviest trawling was between the Rickenbacker Causeway and Black Point Marina, principally over areas with muddy sand bottoms and relatively high organic content. Tabb and Kenny (1968) noted that only moderate trawling occurred south of Black Point Marina, where the water is shallower and the bottom had sparse to heavy seagrass, because shrimp found there were often too small for market. They reported that trawling was prohibited near the mainland shoreline because these areas were spotted seatrout, *Cynoscion nebulosus,* fishing grounds. However, a later ethnographic study (EDAW Inc.[6]) said that the vessels trawled principally on the western side of the bay in the seagrasses relatively close to the mainland. Our observation was that shrimp vessels have drafts too deep to operate inside of about the 1-m depth contour along the shoreline.

Trawling for bait shrimp is conducted nearly every night of the year, except in bad weather. The bait shrimp fishery operates on a nightly quota system where dealers place orders to fishing operations for delivery of a certain number of live shrimp. Thus, fishing may terminate once nightly orders are met. Shrimpers deliver their catch to dealers that meet them at the dock in trucks with oxygenated saltwater tanks. Markets for the shrimp are bait and tackle stores that range from Key West to well north of Miami, and stores may buy from more than one fishing operation to hedge against decreased performance from any one operation (EDAW Inc.[6]).

Joyce and Eldred (1966), as cited in Tabb and Kenny (1968), reported that annual Miami–Dade County bait shrimp landings from 1963 to 1965 were from 94,000 to 120,000 kg annually. Landings and trips were estimated for 1984–85 from dockside interviews by Campos and Berkeley (2003). Average landings/trip for the period from 1971 to 1984 were summarized by Berkeley et al.[3]

The Food Shrimp Fishery

Vessels targeting shrimp for sale as food use wing-net gear to fish the upper water column in or near passes where tidal currents are strong. Fishing is at night, and effort is highest around the full moon when shrimp are concentrated at the surface. Aaron and Wisby (1964) reported that maximum pink shrimp photo-activation (attraction to light) occurred during the full moon. EDAW Inc.[6], who interviewed Biscayne Bay shrimpers in an ethnographic study, described the fishery. Food shrimpers operate around channels, canals, and bridges. They use 7.6–9.1-m-long skiffs launched from trailers and powered by outboard motors. Wing-net gear consists of a pair of "dipnets," each attached to each side of the vessel, that are lowered into the upper water column as the boat powers slowly through schools of shrimp. The best time for shrimping is during strong winds, especially northers, when shrimp move up into the water column. A Cuban expatriate reportedly invented wing-net apparatus in the Miami area about 25 years ago (EDAW Inc.[6]).

Wing-netters cannot fish in waters shallower than 1.2–1.8 m. According to EDAW Inc.[6], most food shrimpers operate in mid and upper Biscayne Bay (in contrast to bait shrimpers that work in the southern bay) from the Venetian Causeway to the Rickenbacker Causeway, launching at Crandon Park Marina and other places north of BNP.

[9]FFWCC. Available online at http://myfwc.com/fishing/saltwater/recreational/history/q-z/

[10]Ault, J., J. Serafy, D. DiResta, and J. Dandelski. 1997. Impacts of commercial fishing on key habitats within Biscayne National Park. Annual Rep. Coop. Agreement. CA-5250-6-9018. Biscayne Natl. Park, Fla., 80 p.

BNP is not fished, as it is too far south of their base of operations, although some may use the northern edge. The majority of the food shrimp catch is sold to wholesale fish houses that ship it to fish markets around the country. EDAW Inc.[6] reported that the Wingnet Shrimpers of Florida, an organization formed around 1998, had about 95 members but that about 500 people participated in the fishery.

The principal purpose of this paper is to describe the two pink shrimp fisheries in Biscayne Bay based on dealer-reported landings and effort data, supplemented with available data from previous research. Our secondary objective is to demonstrate the potential appropriateness of the data (catch per unit effort, CPUE), as an index of shrimp abundance with which to evaluate the potential effect on pink shrimp of CERP (USACE and SFWMD[5]), a planned water management project that will affect freshwater flow to Biscayne Bay. Fishery CPUE provides a rough index of relative abundance under conditions that appear to apply in this fishery (Ricker, 1978). Other time series of data of similar length for assessing CERP affects on Biscayne Bay shrimp are lacking.

Methods

This paper describes the two pink shrimp fisheries in Biscayne Bay over a 20-yr period, 1986–2005, based on dealer-reported landings and effort data. Where needed, we supplement the information we developed from the statistical database with data from previous studies. We obtained some background information about the two fisheries directly from shrimp vessel operators.

Systematic and routine collection and compilation of dealer-reported Miami–Dade bait shrimp landings and effort began in 1986, and reporting of statistics on food shrimp landings began in 1989. The Biscayne Bay "accumulated landings" data for the period 1986 through 1996 were provided by Steve Brown[11], and accumulated landings data for the period 1997–2005 were obtained from Guy Davenport[12]. Records on shrimp caught in Biscayne Bay (including Card and Barnes Sounds) were separated from the rest of the accumulated landings database using waterbody code, which indicated the specific area fished. The accumulated landings data file is based on Florida trip tickets collected from dealers, who are required to report at the time of sale under F.A.C. Rule 68E-5.002. Dealer, vessel, landings, and other information, including hours fished and waterbody fished, are included for each record.

Food shrimp landings were reported in pounds, which we converted to kilograms. The information includes "heads on count" (number per pound heads on), which helped determine the price. We converted count data to carapace length to prepare a size frequency distribution using Legault[13] conversion table, which applied relationships of Kutkuhn (1966), Teinsongrusmee (1965), and Fontaine.[14]

Bait shrimp landings were reported by dealers in terms of number, rather than weight, and have, historically, been converted to pounds in NMFS and State of Florida databases using the relationship (numbers x 0.01) (Brown[11]). The estimated weight per shrimp, 0.01 pound, represents 100-count shrimp and corresponds to shrimp of about 80 mm total length and 17 mm carapace length (CL), according to Legault.[13] We obtained a sample size distribution of bait shrimp landings using unpublished data from our fishery-independent survey that chartered a bait shrimp vessel and captain. The survey was conducted from August 2002 to February 2004 with bimonthly sampling (Browder et al.[4]). The size distribution from this sample appears later in this report as Figure 7.

Fishery effort data were determined in units of both trips and hours. The number of records supplied us with the number of trips because there was a record for each trip. Hours fished was part of the record. Less than 0.1% of bait records and 2% of food records had missing values for hours fished. We used the modal number of hours reported in the fishery (8 hr and 7.2 hr for bait and food fisheries, respectively) to fill supply missing hour data in order to prevent records with missing hour data from being eliminated in statistical analysis.

For comparison with the data we acquired for the period 1986 through 2005, we included in some of our tables and figures the Campos and Berkeley (2003) interview-based trip data for 1984–85 and summarized the estimated average landings/trip data for 1971 to 1984 from Berkeley et al.[3] Their trip estimates were expanded from subsampling conducted at landing areas; they sampled 3–14 d/mo at Dinner Key, 2–23 d/mo at Black Point, and 3–14 d/mo at Virginia Key (mean effort for March–July was used to estimate Dec.–Feb. effort).

We calculated annual CPUE as catch per trip and as catch per hour for both fisheries. For annual estimates, we summed annual landings and divided by annual effort. Monthly CPUE, which we used for certain purposes, was calculated similarly, total monthly landings divided by total monthly effort.

For a fishery-independent estimate of shrimp abundance in Biscayne Bay, we used density estimates of juvenile pink shrimp we obtained from throw-trap collections taken at approximate 8-wk intervals from October 2002 to November 2005 (Browder et al.[15]). The throw-trap sampling took place in daytime in open water on the western side of southern Biscayne Bay within BNP boundaries

[11] Brown, Steve. FFWCC, 100 8th Ave. SE, St. Petersburg, Fla. 33711. Personal commun., Aug., 2005.

[12] Davenport, Guy, NOAA, NMFS, SEFSC, 75 Virginia Beach Dr., Miami, Fla. 33149 (presently at NMFS Panama City Lab, 3500 Delwood Beach Road, Panama City, Fla. 32408). Personal commun., Aug., 2005 and March, 2007.

[13] Legault, Chris. NOAA, NMFS, SEFSC, 75 Virginia Beach Dr., Miami, Fla. 33149 (presently at NOAA, NMFS, NEFSC, 166 Water St., Woods Hole, Mass. 02543). Personal commun., Nov., 2003.

[14] Fontaine, C. T. 1971. Conversion tables for commercially important penaeid shrimp of the Gulf of Mexico. NOAA NMFS Data Rep. No. 70, 9 p. Available online at http://galveston.ssp.nmfs.gov/publications/pdf/218.pdf.

[15] Browder, J. A., M. B. Robblee, and J. Lorenz. 2003. Biscayne Bay coastal and nearshore community study to develop biological performance measures. Ann. Rep. S. Fla. Water Manage. Dist.. Proj. C13401. NMFS SEFSC, 75 Virginia Beach Dr., Miami, Fla., PRD-03/04-12, 129 p.

in an area fished by commercial trawls (Fig. 1). For each collection, we took a single throw-trap sample at each of 54 randomly located sample points. The throw-trap is an open-end, solid-frame trap with sides 45 cm high that samples an area of 1 m^2. The throw-trap was thrown into undisturbed water, where it dropped to the bottom and was covered by 3 mm mesh netting. We swept the area within the throw-trap four times with a 1 m wide framed sweep-net of 3 mm mesh netting to remove the shrimp. In preliminary sampling, we found that four passes of the sweep-net were sufficient to collect an estimated 95% of enclosed shrimp (Browder et al.[15]). For this reason, we viewed our sampling as a reliable indicator of shrimp abundance.

Bait shrimp fishery data were tested for use as a proxy of shrimp abundance in the bay by examining fishery landings (in kg) and CPUE (in kg/trip) in relation to throw-trap density (number/m^2). We tested relationships with a 1 to 3 mo lag (throw trap data 1 to 3 mo prior) because the throw-trap captures smaller and presumably younger shrimp than the commercial trawl.

We also explored possible relationships between the two fisheries using general linear modeling (GLM). We tested two alternatives, 1) the bait shrimp fishery preempted landings in the food shrimp fishery by reducing shrimp abundance, or 2) the bait shrimp fishery acted as an indicator of current or future fishing success in the food shrimp fishery, either promoting greater effort (i.e., more trips) or predicting higher yields.

We estimated a size-frequency distribution for the Biscayne Bay bait shrimp fishery from fishery-independent data collected with a chartered commercial bait-shrimp vessel at sampling stations randomly located in western south Biscayne Bay between Shoal Point and Turkey Point in water deeper than 1 m. Samples were collected at 2-mo intervals from August 2002 through February 2004 (Browder et al.[4]). We captured 11,125 shrimp in a commercial trawl net of 2.54 m stretch mesh with a cod-end of 1.27 cm stretch mesh. We used reported food shrimp count data to approximate size at capture (carapace length, CL) in the food shrimp fishery. We used the Legault[13] conversion tables to convert count category to carapace length.

We used ordinary least squares (OLS) regression to determine trends in time series of fisheries data. We used GLM to examine the relationship of bait shrimp CPUE to throw-trap density and food shrimp landings to bait shrimp CPUE and landings (Harrell, 2002).

Results

Landings and trips in both the bait shrimp and the food shrimp fisheries increased over most of the record, except for a substantial decline in both fisheries in 2003 (Tables 1–3, Fig. 2A, 2B). Food shrimp landings recovered by 2005, but bait shrimp levels remained below historical levels through 2005. The percent of total landings taken by the food shrimp fishery increased after 1986. The range between low and high total annual Biscayne Bay shrimp landings from both fisheries differed nearly 10-fold, from 48,253 kg in 1990 to 445,398 kg in 2000. Bait shrimp annual landings exceeded food shrimp landings during 1989–96, while food shrimp landings exceeded bait shrimp landings during 1997–2005 except for 2001, 2003, and 2004. Prior to 1996, annual food shrimp landings were relatively small, <50,000 kg/yr.

The positive landings trend for both fisheries is related to increased numbers of trips. The annual number of bait shrimp trips exceeded the number of food shrimp trips during all years (Fig. 2B), however, the catch in weight per trip was substantially greater for food shrimpers (88–340 kg/trip) than for bait shrimpers (25–44 kg/trip) (Fig. 2C).

Table 1.—Total landings (kg) of pink shrimp harvested in Biscayne Bay and quantity and percent landed as bait and food shrimp (from NMFS, Miami, and the Florida Fish and Wildlife Research Institute, St. Petersburg). Bait shrimp landings were estimated from reported number of shrimp (also shown) by NMFS using a conversion factor of 0.01 lb/shrimp. Pounds were converted to kilograms for this study. Bait shrimp data are missing for Nov. 1989. Estimates for 1984-85 are from Campos and Berkeley (2003).

Year	Total landings (kg)	Bait shrimp landings			Food shrimp landings	
		No.	kg	%	kg	%
1984–85		43,257,537				
1986		18,787,450	85,140			
1987		15,715,860	71,287			
1988		17,459,552	79,196			
1989	73,693	14,970,150	67,904	92.1	5,788	7.9
1990	48,253	9,409,850	42,683	88.5	5,571	11.5
1991	78,949	13,305,970	60,355	76.4	18,593	23.6
1992	75,136	12,967,070	58,818	78.3	16,318	21.7
1993	85,525	12,371,376	56,116	65.6	29,409	34.4
1994	101,277	17,886,520	81,133	80.1	20,145	19.9
1995	124,703	21,245,345	96,368	77.3	28,334	22.7
1996	190,474	26,040,797	118,120	62.0	72,354	38.0
1997	322,533	33,776,375	153,254	47.5	169,280	52.5
1998	332,239	35,111,873	159,362	48.0	172,877	52.0
1999	332,234	35,957,832	163,218	49.1	169,016	50.9
2000	445,378	35,353,643	160,546	36.0	284,832	64.0
2001	263,618	35,334,001	160,418	60.9	103,200	39.1
2002	327,032	33,266,802	151,020	46.2	176,012	53.8
2003	101,149	19,013,470	86,339	85.4	14,810	14.6
2004	199,635	24,014,800	108,967	54.6	90,669	45.4
2005	301,581	20,358,617	110,334	36.6	191,247	63.4

Bait Shrimp Fishery

Annual Biscayne Bay bait shrimp landings increased during the 1986–2005 period (OLS, r^2=0.42, p=0.002). Annual landings fluctuated in the 43,000–81,000 kg range from 1986 through 1995, doubled to around 151,000–163,000 kg from 1997 through 2002, then reverted back to an intermediate 86,000–110,000 range from 2003–2005 (Fig. 2A). Higher bait shrimp landings were the result of an increased number of trips (OLS, r^2=0.46, p=0.001). An annual average of approximately 2,000 bait trips were conducted in Biscayne Bay from 1986 through 1994 (Fig. 2B). Annual trips began increasing in 1995 to a high of 5,465 and 5,463 trips in 2000 and 2001, respectively. Seasonally, the most trips were in March–May and the fewest trips were in September.

Annual CPUE (number/trip, OLS, r^2=0.44, p=0.001, number/h not significant) decreased from 1986 to 2005 (Fig. 3A). We found a positive, although insignificant, trend when we included catch/trip data from 1971 to 1985 reported in Berkeley et al.[3] and Campos and Berkeley (2003) to extend the time series backward to 1971 (Fig. 3B).

Number/trip and number/h were highly correlated (Pearson correlation coefficient, r=0.93). The average reported trip was 7.9 h, and 61% of the records had a reported fishing time of 8 h. This suggests a standard reporting response of hours fished that may not reflect actual fishing duration. Reported trips and hours fished, summed by year and month, were highly correlated (r=0.99), suggesting they were similar indices of effort.

The price of bait shrimp increased significantly from 1994–2005, although there was no significant increase in the total value of annual landings (Fig. 3C, 3D). Estimated value of landings during 1995–2005 ranged from $665,000 in 1995 to $1,236,000 in 2002 (Fig. 3D). Annual landings in 2005 were valued at $1,097,548.

Bait shrimp CPUE had a seasonal component; highest CPUE in terms of numbers caught per hour or per trip occurred in the winter months, Dec.–Feb. (1,188 shrimp/h, 9,251 shrimp/trip), and lowest numbers occurred in the summer months, June–July (697 shrimp/h, 5,490 shrimp/trip) (Fig. 4). Highest landings coincided not only with highest CPUE but also with peak tourist season, winter, when the demand for bait to support recreational fishing was greatest.

The number of bait shrimpers operating in Biscayne Bay ranged from 3 to 60 vessels historically. Three bait shrimp boats worked Biscayne Bay during 1952–53 (Siebenaler, 1953), and 12 boats fished the bay year-around in 1958 (Tabb and Kenny, 1968). Forty-six vessels were fishing in the bay in 1966 when bait shrimping was placed under a permit system (Tabb and Kenny, 1968). The same number were shrimping in the bay in 1987 (Fig. 5A). The number of vessels reached a high of 60 in 1988, and then decreased to a low of 23 in 1989. From that time, the annual number of active bait shrimp vessels has fluctuated between 24 and 40 vessels. The databases indicated 34 vessels selling bait shrimp in the Biscayne Bay fishery in 2005.

From 1986 through 1994, the annual number of bait shrimp trips ranged from 1,156 to 5,465 (Fig. 5B). The annual number of trips grew substantially from 1994 through 2001 to around 5,400 then decreased to around 3,000 trips in 2003 and 2005. The average number of trips per vessel ranged from about 30 to about 60 trips per year from 1987 through 1989 (Fig. 5B). Trips per vessel were highest, 103–188 trips/yr, between 1996 and 2002 but then declined to less than 90 in 2003 and 2004. Turnover was high; only 12 permitted shrimp vessels that fished in 1997 were fishing in 2003, and only 9 of these 12 vessels were still fishing in 2004.

Table 2.—Number of bait shrimp trips by year and month. December 1984 – July 1985 estimates from Campos and Berkeley (1986) based on dockside interviews and 1986-2005 data from dealer reports.

	Month												Annual
Year	1	2	3	4	5	6	7	8	9	10	11	12	trips
1984												484	
1985	614	577	558	444	549	465	518						
1984–85													4,209
1986	132	219	239	215	222	210	264	253	229	233	201	161	2,578
1987	191	171	150	152	137	151	145	178	145	144	139	154	1,857
1988	152	181	209	171	143	143	151	139	116	111	116	154	1,786
1989	211	153	152	156	150	112	145	166	177	111		200	1,733
1990	152	137	82	133	93	76	122	100	73	51	86	51	1,156
1991	124	161	93	146	164	133	146	150	155	126	154	193	1,745
1992	130	202	152	175	108	106	239	84	29	117	150	137	1,629
1993	161	111	133	136	158	92	111	166	113	127	156	118	1,582
1994	187	189	210	224	276	250	242	186	234	234	166	208	2,606
1995	231	207	293	276	300	238	96	160	263	298	343	375	3,080
1996	300	382	293	311	401	443	156	248	266	249	296	372	3,717
1997	422	447	539	467	472	324	102	203	290	371	418	373	4,428
1998	406	416	455	434	498	413	418	416	306	361	393	381	4,897
1999	431	426	480	496	482	473	506	432	376	331	385	397	5,215
2000	453	430	397	479	558	458	483	451	392	437	456	471	5,465
2001	536	494	556	502	505	464	458	448	364	339	385	412	5,463
2002	505	463	507	473	512	460	436	428	390	398	355	369	5,296
2003	475	425	450	346	331	304	173	140	128	218	217	259	3,466
2004	259	386	370	365	310	269	62	244	145	179	205	208	3,002
2005	290	227	311	360	381	334	239	189	150	98	81	210	2,870
Average 1986–2005	287	291	304	301	310	273	235	239	217	227	247	260	3,179

Table 3.—Number of trips, by month and year, in Biscayne Bay food shrimp fishery.

	Month												Annual
Year	1	2	3	4	5	6	7	8	9	10	11	12	trips
1989	4	6	1	3								3	17
1990	17	1	3	7	15	7						13	63
1991	11	26	20	7	19						1	11	95
1992	14	48	40	20	15	9	1			1	6	4	158
1993	43	28	39	18	12	5	2					1	148
1994	34	36	43	34	4	2	1			4	4	12	174
1995	28	40	77	58	25	1					2	54	285
1996	101	82	62	40	8	7				2	16	28	346
1997	90	329	157	99	72	9	7	1		1	3	59	827
1998	161	317	250	118	54	21	1	1	1	2	4	44	974
1999	206	285	167	137	40	6					3	52	896
2000	387	150	216	106	62	4					2	71	998
2001	22	169	182	45	104	6	2			5	4	214	753
2002	335	451	149	78	29							3	1,045
2003	13	36	52	9	8	1						3	122
2004	42	93	94	65	59	1					5	24	383
2005	388	156	146	71	76	1				2		95	935
Average trips/yr when not zero	112	133	100	54	38	6	2	1	1	2	5	41	483

The number of bait shrimp dealers increased over time. From 1986 through 1991, there were from 3 to 7 bait shrimp dealers in Miami–Dade County; while, from 1992 through 2005, there were 9 to 15 dealers (Fig. 6).

The Campos and Berkeley (2003) monthly trip estimates for 1984–85, when there were no dealer records, differ substantially from dealer-reported trip numbers for later years (Table 1 and 2). Campos and Berkeley trip numbers, obtained by vessel counts at docks, were much higher than dealer reported trips (which theoretically should have been all trips) in the following two years (1986–87), or averaged for the next 18 years (1988–2005). Estimated total 1984–85 landings from Campos and Berkeley were 1.9 times greater than dealer-reported 1987 landings, and 2.3 times greater than the 1986–2004 dealer-reported average.

Based on our fishery-independent sampling, we found that 86% of the shrimp captured with a roller trawl were <19 mm CL, and 93% were 10–22 mm CL (Fig. 7). The average was 14.3 mm CL, and the mode was 15 mm CL. Trawl-caught shrimp ranged in size from 4 mm to 43 mm CL, although shrimp smaller than 9 mm CL or larger than 24 mm CL were rare.

We tested the assumption that CPUE was an index of abundance in this fishery by comparing monthly average bait shrimp CPUE (number/trip) to average monthly throw-trap catch/m^2 (current, 1-, 2-, and 3-mo lagged data), our fishery-independent index of abundance of younger shrimp in the bay. In our strongest correlation, 3 yr of bimonthly throw-trap data (Oct. 2002–Nov. 2005), lagged 3 mo, were paired with 18 mo of bait shrimp CPUE. Monthly average bait shrimp CPUE was significantly (r^2=0.43; p=0.002) related to 3-mo-lagged average throw-trap catch/m^2 (Fig. 8). We found no significant relationship with current or 1-, or 2-mo-prior throw-trap CPUE.

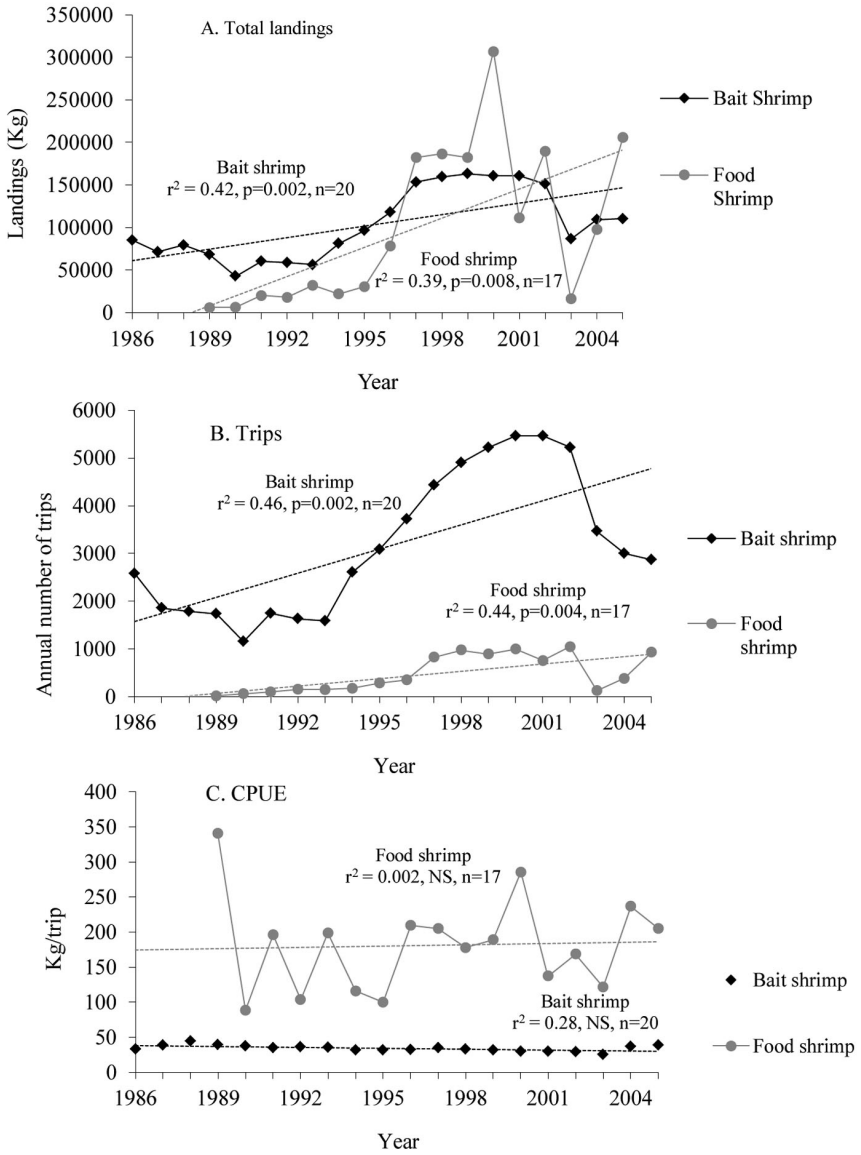


Figure 2.—Annual landings of Biscayne Bay bait and food pink shrimp. (A). Annual number of bait and food shrimp trips. (B). Catch/trip of bait and food fisheries. (C). Bait numbers converted to pounds using 0.01 conversion, then converted to kilograms.

Food Shrimp Fishery

Biscayne Bay food shrimp landings increased significantly (p=0.011) from when first recorded in 1989 through 2005 (Table 1, Fig. 9). Landings were less than 50,000 kg/yr during 1989–1995, grew to over 180,000 kg/yr during 1997–1999, and rose to over 250,000 kg in 2000. After 2000, landings fluctuated between 14,000–181,000 kg/yr. Highest landings were in the months of January and February (Fig. 10A), and summer landings were low, principally due to closures from 16 May–14 Oct. 2000 and June–October thereafter. Monthly CPUE indices (landings/trip and landings/h), varied inversely to average total landings. The highest average CPUE occurred in the summer months whenever the fishery was open (Fig. 10B), but summer averages were based on only a few trips—e.g., August (2), and July (14) (Table 3, Fig. 10A).

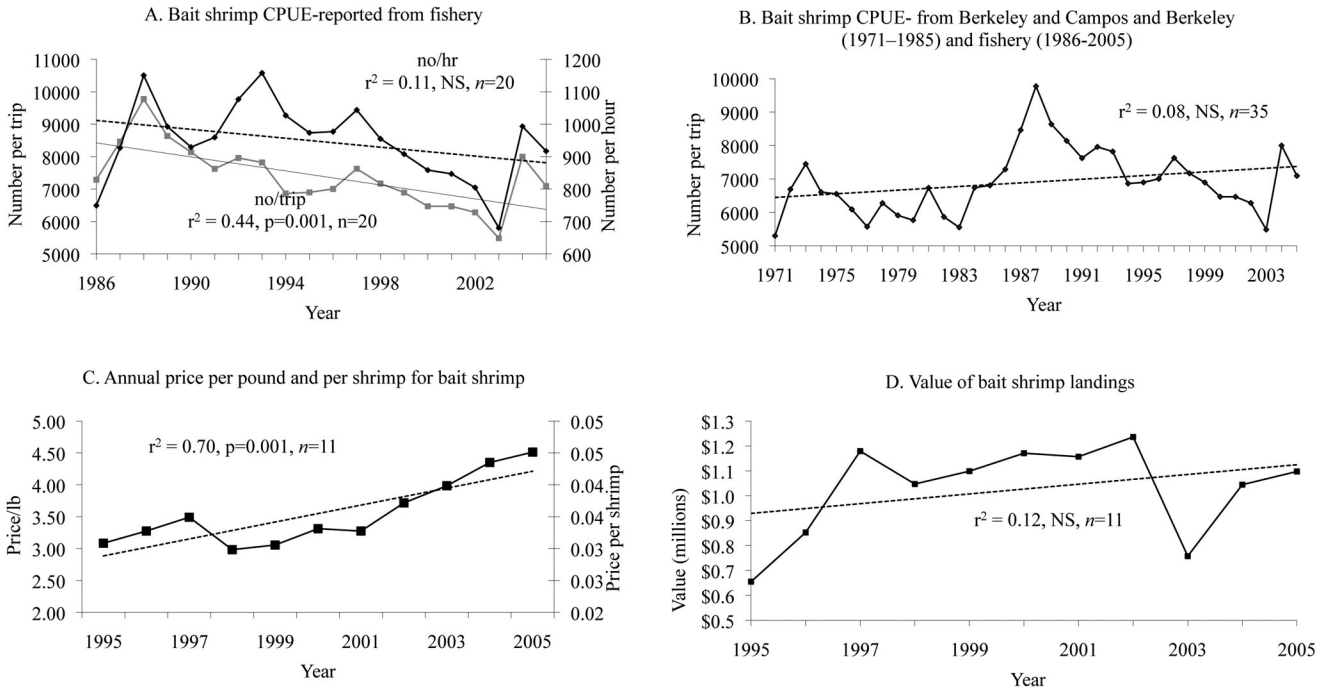


Figure 3.—Biscayne Bay bait shrimp fishery. Annual average (1986–2005) CPUE of bait shrimp (number/hour and number/trip (gray). (A). Annual average CPUE of bait shrimp (number/trip) from 1971–2005. (B). (Data for 1971–83 from Berkeley et al. (see text footnote 3) and data for 1984–85 from Campos and Berkeley (2003)). Annual price per pound and per shrimp for bait shrimp (C). Annual value of bait shrimp landings (D).

Monthly landings were strongly related to the number of trips (r^2=0.83, p<0.0001) and more weakly, although still significantly, related to hours fished (r^2=0.12, p<0.0001) (Fig. 11). Number of trips and number of hours fished were highly correlated (r = 0.99). The average trip length was 7.2 h, and 61% of trips had a reported fishing time of 6–8 h, suggesting a standard answer for hours fished on many records.

The annual number of food shrimp trips increased gradually from 1994 through 1996 and sharply from 1996 to 1997. It remained high through 2002, dropped sharply in 2003, and increased in 2004 and increased even more in 2005 (Fig. 12). The increase in number of trips apparently was due to an increased number of vessels, rather than an increased number of trips by participating vessels, because number of trips and number of vessels had similar year-to-year patterns and were highly correlated (r^2=0.95, $p = 7.8 \times 10^{-9}$) (Fig. 12). The annual average number of trips per vessel was low (1–8 trips/yr), and there was no significant change with time, suggesting that part-time operators continued to dominate the food shrimp fishery (Fig. 13A). The maximum annual number of trips per vessel ranged from 3 to 84 with a slight, but significant, increase with time (Fig. 13B).

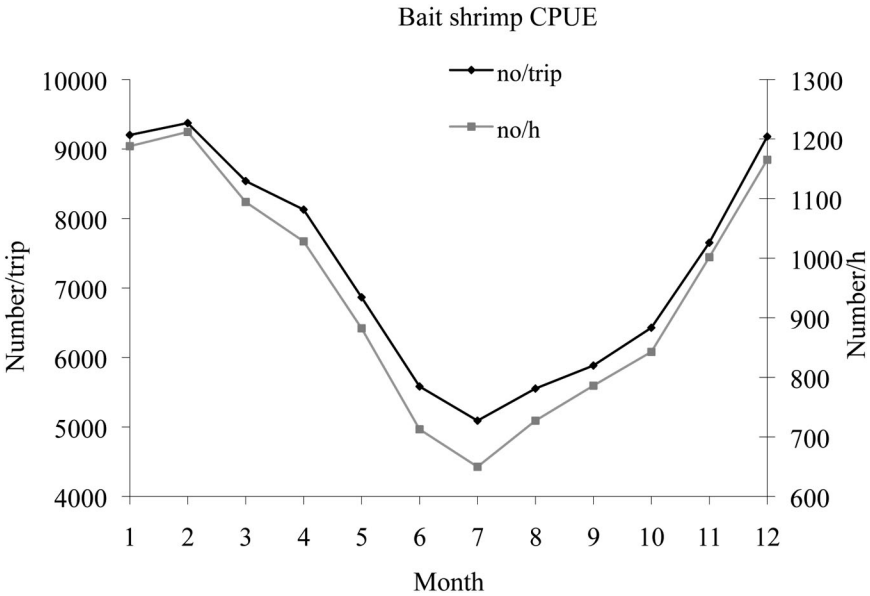
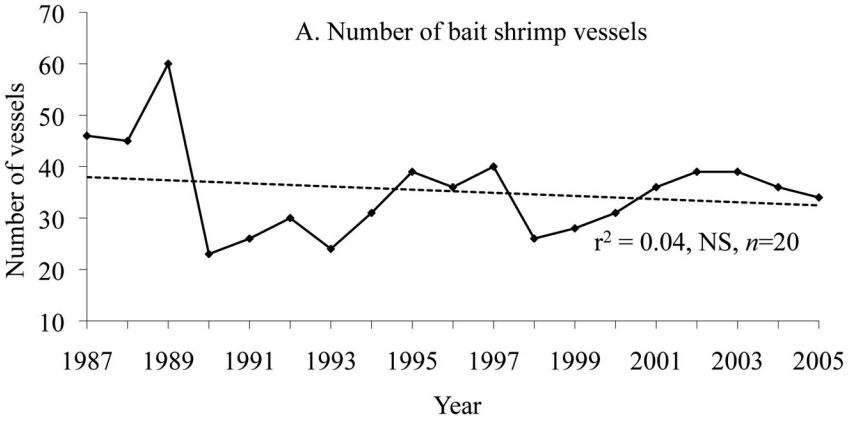


Figure 4.—Biscayne Bay bait shrimp fishery catch per effort (1986–2005). Average monthly bait shrimp number/trip and number/hour.



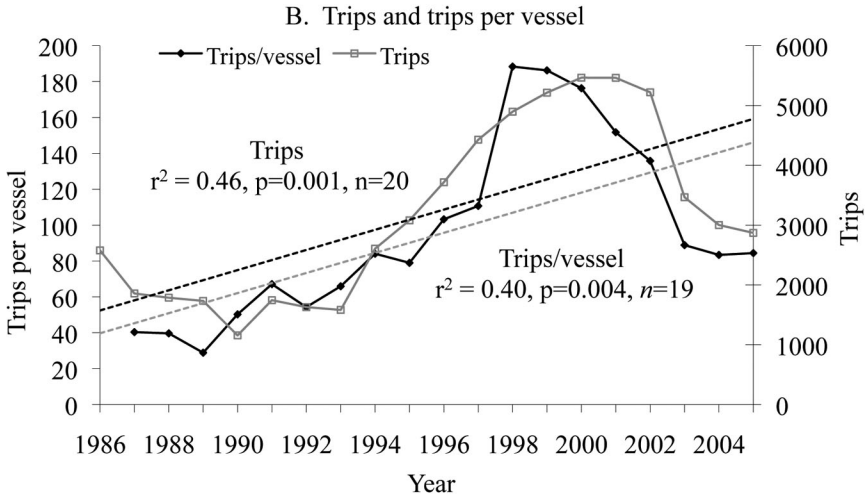


Figure 5.—Biscayne Bay bait shrimp fishery (1986–2005). (A). Annual number of bait shrimp vessels fishing, 1987–2005. (B). Annual number of bait shrimp trips (gray) and trips per vessel, 1986–2005 (Note: Vessel data for 1986 were available only for October through December; therefore the total number of vessels fishing in 1986 was incomplete.).

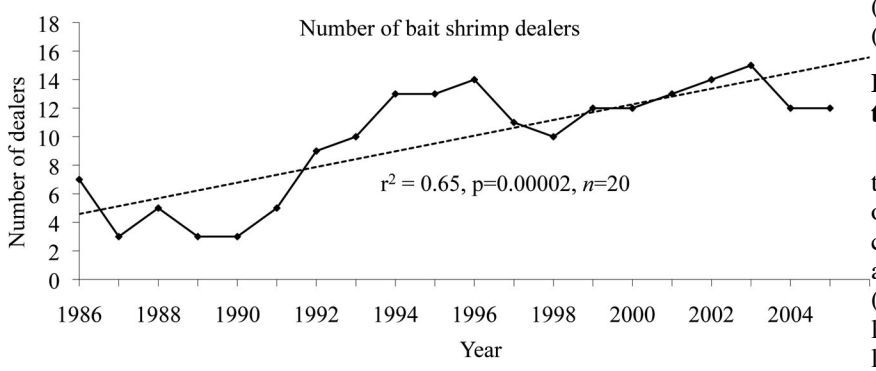


Figure 6.—Biscayne Bay bait shrimp fishery (1986–2005). Annual number of bait shrimp dealers buying catch.

The annual value of food shrimp landings (Fig. 14) showed a similar trend as total landings (Fig. 9) and was strongly correlated (r^2=0.98, p=2.3×10^{-11}). The number of food shrimp dealers rose substantially from 1989 through 1997 and then slowly declined through 2003, although 2005 levels were beyond 1996 levels (Fig. 15).

Shrimp ex-vessel prices, without adjustment for inflation, were relatively constant during 1992–2005 (Fig. 16), although the price for food shrimp in 2005 was lower than the price in 2001. The annual average price per pound fluctuated between $1–2 over the time period examined (Fig. 16). Highest average annual price was in 2001, $1.85/lb. Average annual prices in 2004–2005 ($1.12–1.20/lb) were only lower in 1992 ($1.05/lb).

Annual CPUE (kg/trip) of food shrimp was highest in 1989, the initial year of the record (Fig. 2C); however, effort (number of fishing trips) was lowest that year, only 17 trips. Although the highest CPUE occurred in 1989, it may have been affected by the relatively low effort. Time series of landings and effort in the food shrimp fishery were affected by the summer closure that eliminated summer landings mainly from June through October beginning in 2000, but there often were no catches in some months between June and October even before the closure.

All but a few sales of food shrimp were in count categories corresponding to shrimp sizes greater than 19 mm CL (Fig. 17). The median size range landed in December–March was slightly larger (20.8–21.9 mm CL), than in April–May (19.0–19.7) mm CL.

Interaction Between the Two Fisheries

Using alternative possible lags between the landings, effort, or CPUE of the two fisheries, we found the best correlations between food shrimp trips and same-month bait shrimp landings (Fig. 18A) and between food shrimp landings and same-month bait shrimp landings (Fig. 18B). High season (December–May) food shrimp monthly effort (number of trips) was positive,

and significantly exponentially related (r^2=0.52, p<0.001) to the current month's bait shrimp landings (Fig. 18A). Food shrimp monthly landings also were positive and significantly exponentially related to the current month's bait shrimp landings (r^2=0.44, p<0.0001, Fig. 18B). Bait shrimp CPUE did not significantly explain food shrimp landings. The best, although still insignificant, fit of food shrimp landings to bait shrimp CPUE was when CPUE lagged by two months (Fig. 18C).

Discussion

Changes in the Bait Shrimp Fishery

The annual number of bait shrimp trips per vessel changed over time (Fig. 5A). Shifts in trips per vessel may have resulted from switching from part-time fishing in the early period (1986–97) to near full-time fishing in the middle years (1998–2002), followed by a shift back to part-time fishing in the most recent years of our analysis (2003–2005). EDAW Inc.[6] did not note any change in the structure of this fishery in its ethnographic profile, which apparently covered the period from 1990 through 2001.

The decrease in bait shrimp effort in 2003 through 2005 (Fig. 2B) was accompanied by reduced landings compared to the period 1997–2002 (Fig. 2A). The 2003 decrease in effort may have been a response by the operators to a sharp decrease in CPUE (Fig. 3A). The 2003 bait shrimp CPUE was the lowest in the recorded history of the fishery (Fig. 2C, 3A) and likely reflected low abundance. Our fishery-independent sampling in southern Biscayne Bay in 2003 also indicated low shrimp abundance, compared to 2004, suggesting that a poor recruitment of postlarvae to the bay or poor environmental conditions within the bay caused the low bait shrimp CPUE. Bait shrimp CPUE increased substantially in 2004 and 2005 (as did our fishery-independent CPUE) but was not accompanied by increased effort, raising questions about the reason for continued low effort.

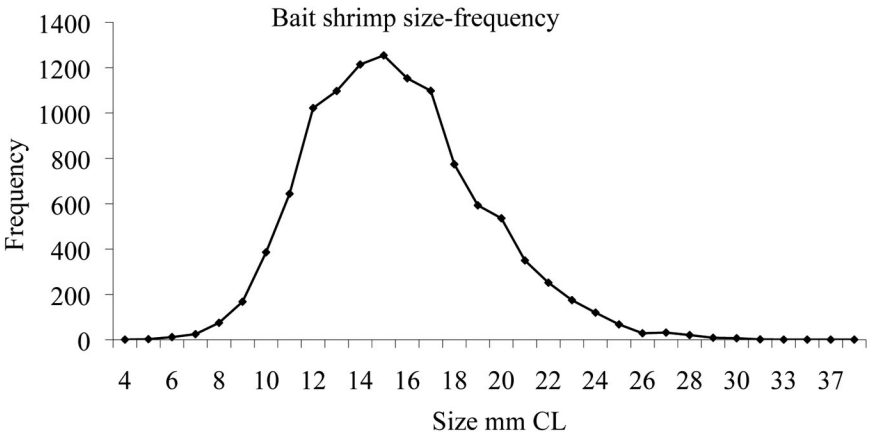


Figure 7.—Size-frequency of bait shrimp in fisheries-independent shrimp trawl (sampling period was bimonthly, August 2002 through February 2004).

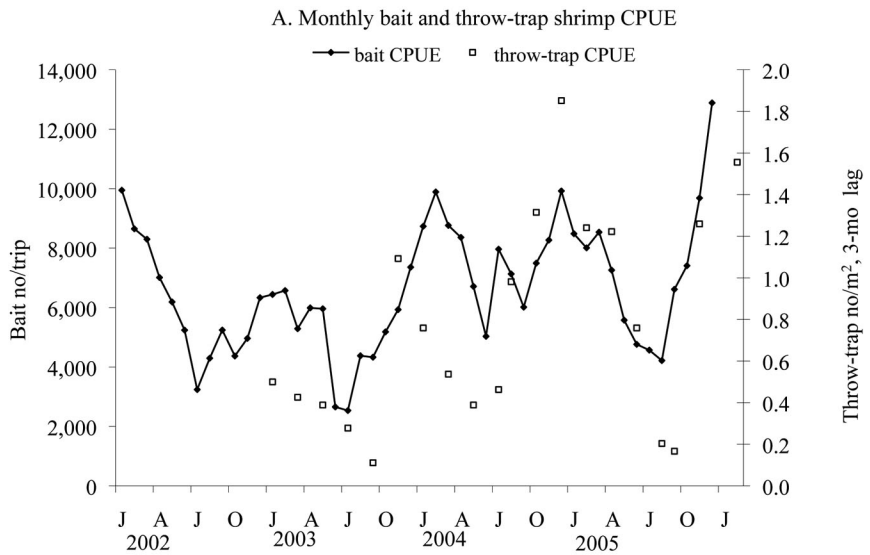


Figure 8.—(A). Average monthly number of shrimp per trip in the Biscayne Bay bait shrimp fishery (2002–2005). (B) *Please see next page*.

Several factors could have been responsible for the low annual bait shrimp effort through 2005. High fuel costs are an obvious reason for decreased participation and effort in fisheries with limited potential for increased gross income. Increased dockage fees also may have contributed to the decreased participation and effort. We heard from an owner of several vessels that he had received notice his dockage fees at Dinner Key Marina were going to be raised (Quinland[16]).

Dinner Key Marina was an important dockage site for the Biscayne Bay bait shrimp fleet through at least 2004. Using 2004 landings data and dockage/dealer location information, we determined that 65% of the Biscayne Bay bait shrimp were landed at Dinner Key, 3% at Virginia Key (both in the central bay), and 33% from south Miami–Dade, where vessels are found at Black Point Marina. We determined that 16 vessels landed bait shrimp in the Black Point/South Dade Area, 18 landed at Dinner Key, and 2 landed on Virginia Key. This differs from EDAW Inc.[6], who reported that the largest concentration

[16]Quinlan, Sam, 11269 SW 164th St., Miami, Fla. 33157, Personal commun., Feb., 2004.

of bait shrimp vessels (12–13) worked out of Black Point Marina (presumably in about 2002).

Demand for live bait shrimp may have decreased due to increased use of artificial lures and imported frozen bait shrimp, discouraging vessel operators from making trips. A popular lure that mimicked shrimp and was very attractive to sport fish came into widespread use in the Miami–Dade County area in about 2003, according to longtime charterboat captain Dan Kipnis.[17]

[17]Captain Dan Kipnis, 555 NE 34th St., Suite 1209, Miami, Fla. 33137, Personal commun., March, 2012.

Interview-based Estimates vs. Later Dealer Records of Bait Shrimp Fishery

Campos and Berkeley (2003) estimated bait shrimp landings and effort from December 1984 through July 1985, before initiation of the dealer reporting system in 1986. Their estimate of 4,208 trips for the 1-yr period 1984–85 seems an overestimate when compared to dealer-reported trip data on the fishery in subsequent years: 1986 (2,578 trips) and 1987 (1,857 trips) (Figure 2B). If the Campos and Berkeley effort estimates are inaccurately high, then their Biscayne Bay fishing mortality rates also are overestimated. Campos and Berkeley (2003) estimated that fishing mortality from the bait shrimp fishery during 1984–85 represented 8–9% of the total mortality of the population in the bay. Even so, they considered the impact of the bait shrimp fishery on the local stock relatively small. They estimated annual total mortality (fishing and ecosystem) at 23% for males and 26% for females. If Campos and Berkeley (2003) overestimated trips and our estimates of trips from dealer records in the next two years are a better approximation, then the fishing mortality from bait shrimp operations, calculated using their monthly population size estimates, is closer to 5.2%, suggesting even less of an impact on abundance than they reported.

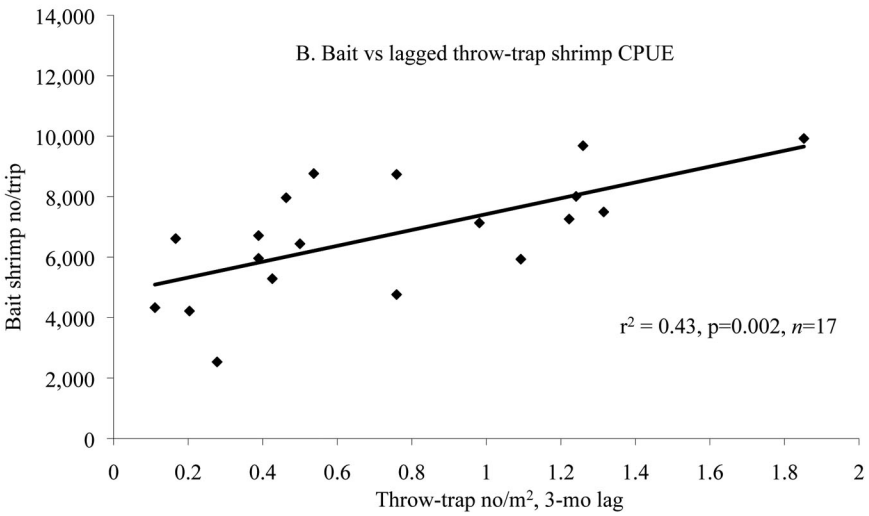


Figure 8.—(B). Average number of shrimp caught in m^2 throw trap, lagged three months (Browder et al., see text footnote 4).

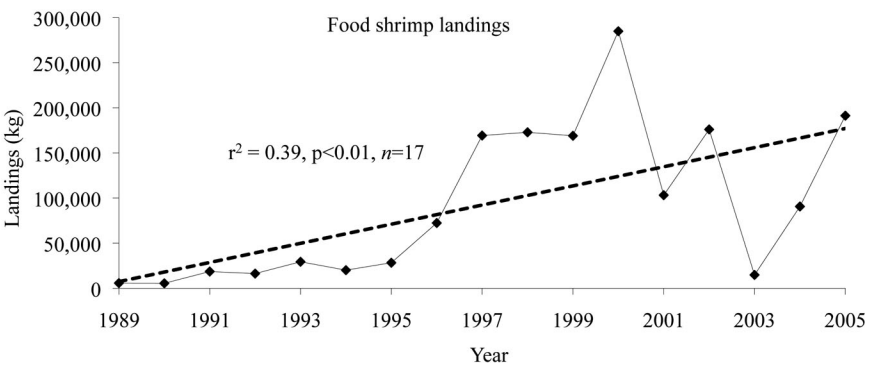


Figure 9.—Biscayne Bay food shrimp landings (1989–2005). Annual landings with trend line.

Changes in Food Shrimp Fishery

The exceptionally low food shrimp CPUE in 2003 (Fig. 2C) reflected the low bait shrimp landings discussed above and was accompanied by low effort, as was the case in the bait shrimp fishery, supporting the suggestion of low shrimp abundance in the bay in 2003. However, unlike the case with bait shrimp, food shrimp landings, effort, and CPUE were substantially higher in 2004 and 2005 than in 2003. In fact, the 2005 food shrimp landings were high enough in relation to previous years that it did not seem that competition from aquaculture or foreign shrimp was discouraging fishing for food shrimp. This was despite a continued decrease in the average price of Biscayne Bay food shrimp in 2004 and 2005 (Fig. 14), as was the case for wild-caught shrimp as a whole (IFAS[1]). Our calculations of number of trips per vessel (Fig. 13A, B) suggested that food shrimp fishing in Biscayne Bay may not have been a full-time activity, even during the 7 mo of the year that wing-net use was legal, and this was the case throughout the history of the fishery, even in periods with high total landings (Fig. 9).

Fishery Index of Shrimp Abundance

Our analysis showed a significant relationship of bait-shrimp-fishery CPUE (Fig. 8A) with existing fishery-

independent data (Fig. 8B) and verified that the fishery CPUE was a good indicator of shrimp abundance, despite the lack of a precise estimate of the length of each bait shrimp trip. Therefore, the 20-yr+ record of bait shrimp CPUE can be used to relate shrimp abundance to environmental variables such as freshwater inflow. Changes in freshwater inflow are expected as part of the new water management strategy associated with CERP (USACE and SFWMD[5]). The abundance of juvenile pink shrimp may be influenced by temporal and spatial salinity patterns, which are affected by changes in the quantity, timing, and spatial distribution of freshwater inflow.

Comparison and Interactions of the Two Fisheries

The size distribution in our sample from the commercial shrimp trawl (Fig. 7) and our conversion of food shrimp sales from count categories to sizes (Fig. 17) suggest that the bait shrimp fishery gets the first opportunity at catching a new shrimp cohort. Our results suggested that most of the landed food shrimp were greater than 19 mm CL (Fig. 17), whereas 86% of the bait shrimp, as represented by our samples, were less than 19 mm CL (Fig. 7). The manner of catching shrimp in the two fisheries also makes it obvious that the bait shrimp vessels fish a cohort first. The roller trawl of the bait shrimp operation catches shrimp residing near the bay bottom during their benthic juvenile stage. The wing-net of the food shrimp operation catches shrimp from the upper water column in places with rapid currents, such as passes, as late juveniles or young adults that soon, or already, are heading offshore for spawning.

Even though the bait shrimp fishery has the first opportunity to catch a shrimp cohort, the significant positive relationship between landings in the two fisheries (Fig. 18B) suggests that they are not competing for a limited resource. Rather, our results suggest that bait shrimp landings influence food shrimp effort by signaling future food shrimp catches (Fig. 18A).

Differences in trip objectives and gear also may reduce competition.

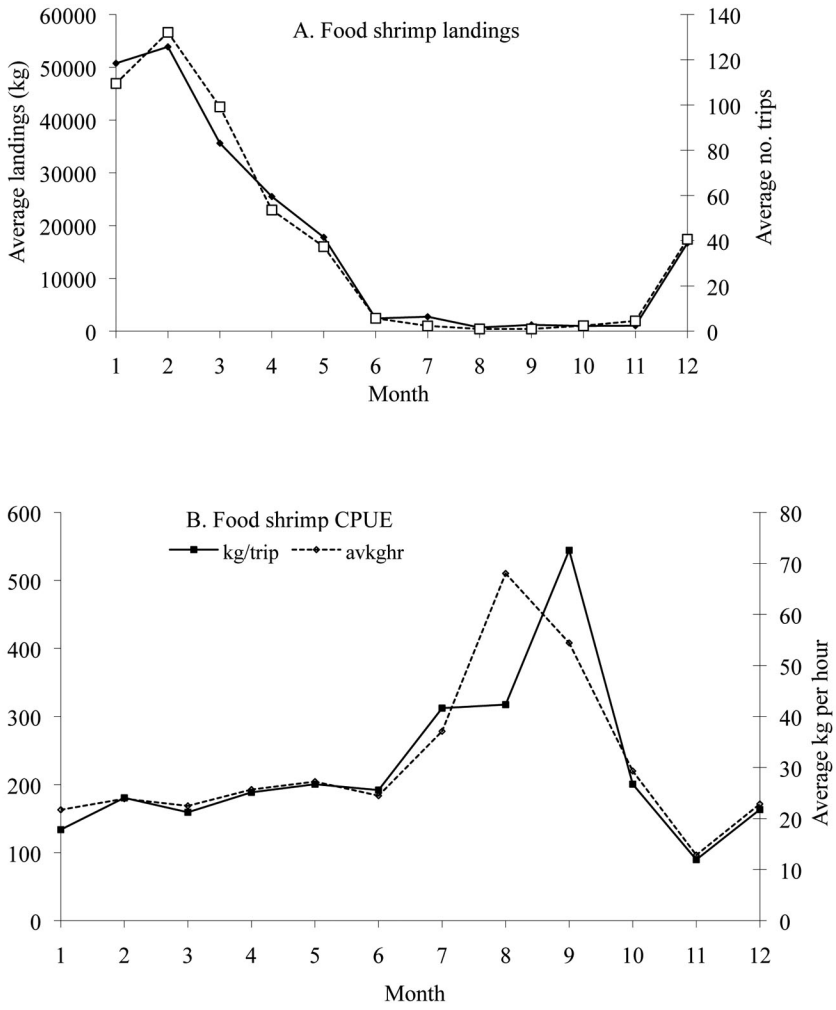


Figure 10.—Biscayne Bay food shrimp fishery (1989–2005). (A). Average monthly landings (kg) and trips. (B). Average monthly kg/trip and kg/h (dotted line) fished (Note that there has been a 5-mo closed season for the wingnet fishery, and the exact dates have varied among years; see Table 2.).

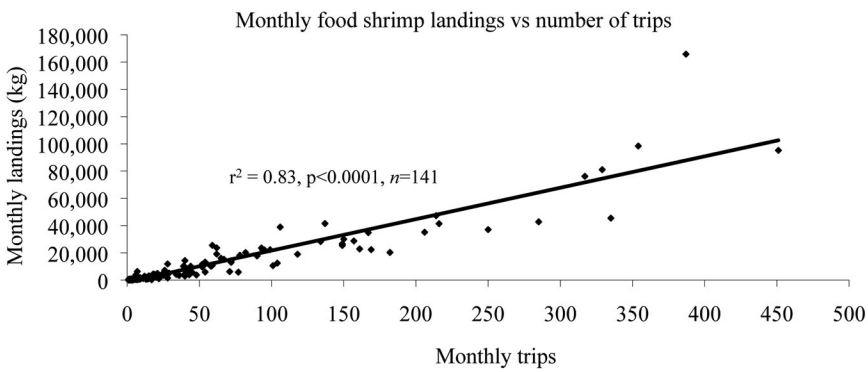


Figure 11.—Biscayne Bay food shrimp landings (1989–2005) vs. effort (number of trips).

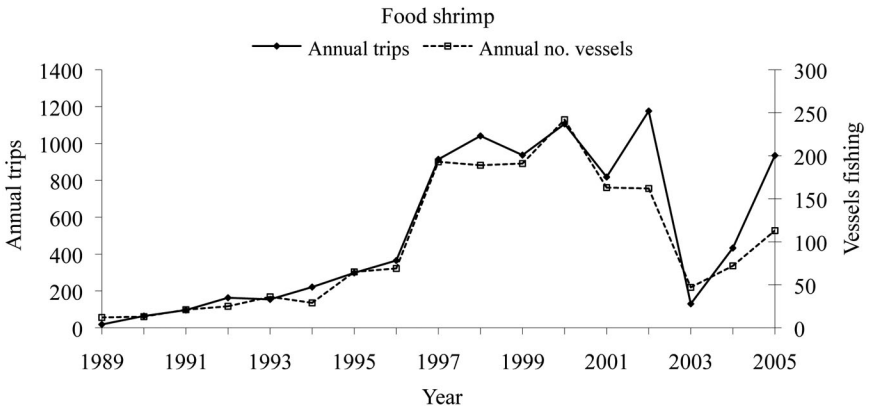


Figure 12.—Biscayne Bay food shrimp fishery (1989–2005): Annual number of shrimping trips and number of vessels shrimping (dotted line).

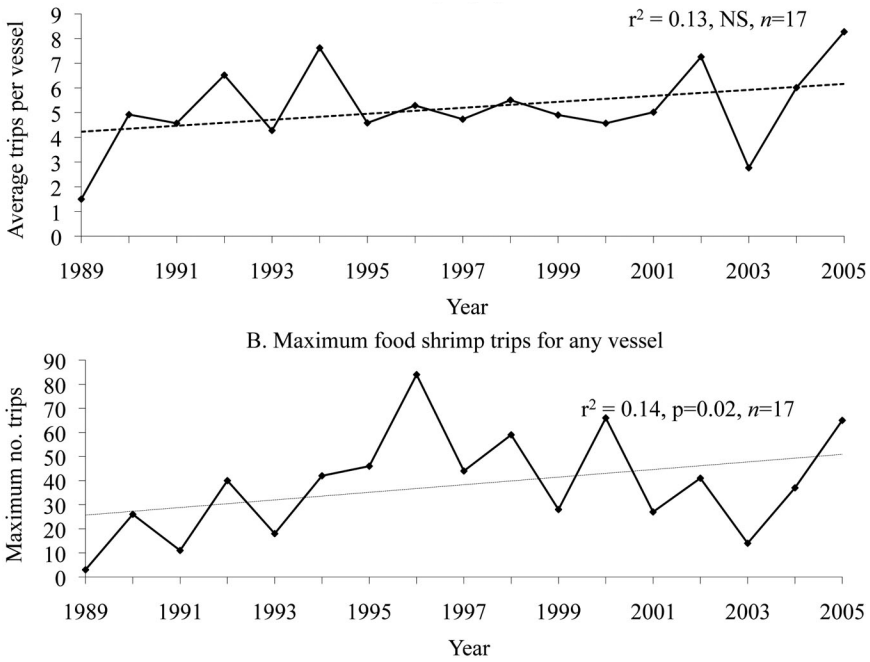


Figure 13.—Biscayne Bay food shrimp fishery (1989–2005). (A). Average trips per vessel. (B). Maximum number of trips per vessel. NS=not significant.

Figure 14.—Biscayne Bay food shrimp fishery 1989–2005: Annual value of landings.

Bait shrimp operators fish to fill predefined orders, rather than until their fishing success declines with resource abundance. Food shrimp operators fish to capture as much as they can when they can because they are restricted to fishing only certain months of the year and days of the week, and, even then, only on nights when shrimp are running. Further reducing potential conflict, the two fisheries are separated spatially; bait shrimp vessels operate in the inner bay and south of the Rickenbacker Causeway, and food shrimp vessels operate mainly north of the causeway.

The effort record in both fisheries through 2005 was characterized by an early, relatively stable, period followed by a period of rapid increase. The period of highest effort in both fisheries was from about 1997 through 2001. Effort in both fisheries declined sharply in 2003. Effort trajectories diverged when food shrimp effort rebounded in 2004 and 2005 while bait shrimp effort did not (Fig. 2B). The pattern of landings roughly mirrored that of effort in both fisheries (Fig. 2A); however, food shrimp annual CPUE (Fig. 2C) suggested highly variable fishing success. Declines in effort and landings in the bait shrimp fishery may have been caused by economic factors that limited or decreased proceeds while increasing costs. Food shrimp operators may have been less detrimentally affected by economic factors.

Summary

Time series of catch and effort data from dealer records provided insight into the history and structure of the two shrimp fisheries of Biscayne Bay. Comparing and contrasting the two Biscayne Bay shrimp fisheries provided additional perspective on each. Fishery-independent data corroborated our initial assertion that bait shrimp CPUE is a good indicator of shrimp abundance in the bay. Bait shrimp landings were a good predictor of future food shrimp effort and landings.

We conclude that 1) the abundance of shrimp in the bay affects the catch

Figure 15.—Biscayne Bay food shrimp fishery (1989–2005): Number of food shrimp dealers.

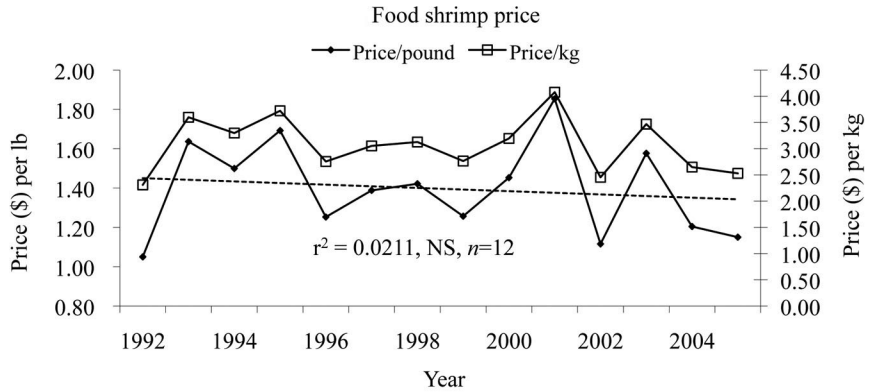


Figure 16.—Biscayne Bay food shrimp fishery (1992–2005): Annual average price per pound for food shrimp, NS=not significant.

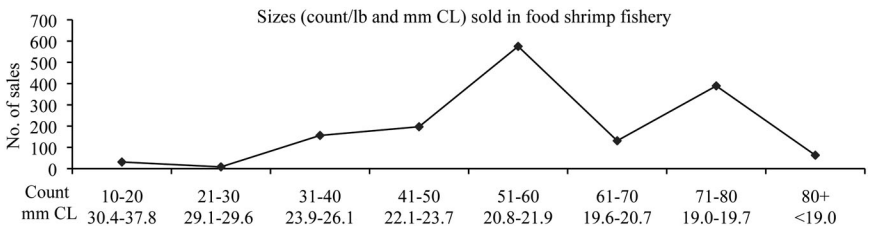


Figure 17.—Biscayne Bay food shrimp fishery (1989–2005): number of pink shrimp sales, by commercial count category (number per/pound) and estimated carapace length (CL, mm).

per trip in the bait shrimp fishery, even though the bait shrimp operations fish to fill orders; 2) perceived success in the bait shrimp fishery provides a gauge of shrimp abundance that may be used to effectively expand or contract food shrimp effort; and 3) bait shrimp CPUE provides a proxy for pink shrimp abundance that could be used in CERP restoration assessments.

Acknowledgments

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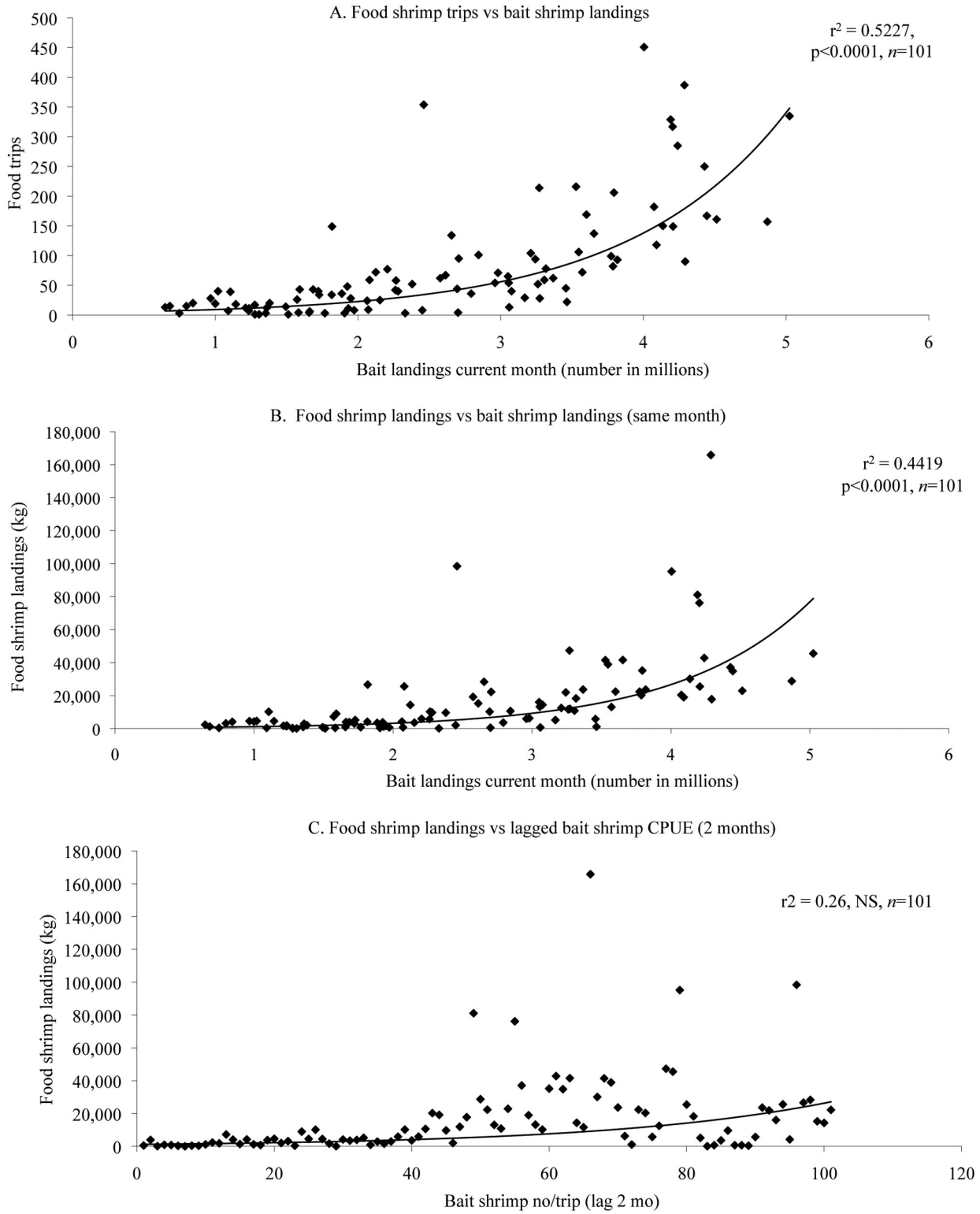

Figure 18.—Relationships between the Biscayne Bay food shrimp fishery and the bait shrimp fishery (December–May). (A). Food shrimp trips vs. bait shrimp landings (no.). (B). Food shrimp landings (kg) vs. bait shrimp landings (no.). (C). Food shrimp landings (kg) vs. bait shrimp CPUE lagged 2-mo (no/trip). NS= not significant. (All are exponential.)

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