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# Using the Fishes of Texas Project Databases and Recent Collections to Detect Range Expansions by Four Fish Species on the Lower Coastal Plain of Texas

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# USING THE FISHES OF TEXAS PROJECT DATABASES AND RECENT COLLECTIONS TO DETECT RANGE EXPANSIONS BY FOUR FISH SPECIES ON THE LOWER COASTAL PLAIN OF TEXAS

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**Abstract:** The Fishes of Texas project online database is a large, freely available quality controlled fish occurrence database of museum vouchered specimens. We used data from it, the same project's separate database of occurrences extracted from published literature and our own recent survey data to examine range stability for four fish species inhabiting the Texas Lower Coastal Plain: *Fundulus chrysotus, Fundulus jenkinsi, Heterandria formosa* **and** *Poecilia formosa*. A weakness of our data is that they consist of presences only and species absences can only rarely be inferred. To help adjust for this we used common widespread species as proxies for the four target species by using captures of these proxy species as indicators that the collecting methods used were appropriate to capture the target species, assuming then that large numbers of occurrences of the proxies with contemporaneous absence of the target species in the same samples supports inferences of probable absence of target species. We here report new and previously unpublished occurrences for these species and document westward range expansions for *H. formosa* and *F. chrysotus*, an eastward range expansion for *P. formosa,* and a pattern of possible range contraction and expansion for *F. jenkinsi*.

**Key Words:** *Fundulus chrysotus, Fundulus jenkinsi, Heterandria formosa, Poecilia formosa*

## Introduction

Species range expansions are often difficult to determine (West 1968, Smida and Wilson 1985, Dennis 2001). Spatially and temporally comprehensive surveys allow strong inferences regarding absences with minimal subjectivity, but typically surveys are inadequately comprehensive either spatially or temporally for use in detecting range expansions. Large datasets that cover long time periods and large geographic space are needed for this purpose. The Fishes of Texas Project database (FoTX; Hendrickson and Cohen 2011), which has been highly controlled as to quality and represents the most complete database of historical fish occurrences in Texas, is the best source for data to address range expansions and contractions for Texas' fish species. Museum data clearly and unambiguously document presence (Chapman 2005) but typically cannot rigorously address absences (West 1968). For various reasons specimens deposited in museums do not always represent the entire community present at a given location (West 1968). Susceptibility to capture varies among species, among collecting methods, and as a function of effort. Furthermore, sampling methods and effort are inconsistently reported in museum records. Additionally, collectors may deposit only selected specimens from their collections, thus creating pseudoabsences. However, the museum data are numerous, cover a large time span, and specimens can be examined for positive identification. Museum data are thus often the best data readily available for assessing changes in distributions.

We used FoTX's database of museum—vouchered species occurrences to examine potential range expansions. A "species occurrence" is the presence of a species from a single collecting event, which is defined by a unique combination of collector(s), location and date. Species occurrences were garnered from the FoTX database of records from 40 donor institutions, coupled with the same project's database of species occurrences gathered from published literature, and our own post—2007 collections from the lower coastal plain of Texas. These are used in an attempt to detect recent spatial changes in fish distributions. Our recent collections are all backed by museum voucher specimens and are otherwise typical of museum specimen—based occurrence data in that they come from collecting events conducted irregularly over space and time using non—standardized methods and effort. Our preliminary analyses of these combined data sets identified *Fundulus jenkinsi, F. chrysotus* (Fundulidae*), Heterandria formosa* and *Poecilia formosa* (Poeciliidae*)* as likely to have experienced range expansions within the time—frame of our data and we report on our detailed explorations of that hypothesis for these target species. We are aware of other freshwater native species with apparently expanding ranges along the coast (e.g., *Herichthys cyanoguttatum* and *Astyanax mexicanus*), as well as non—natives (e.g., *Lucania goodei, Oreochromis aureus, Ctenopharyngodon idella, Pterygoplicthys* sp.) but we do not address those here.

## Materials and Methods

Our study area (Figure 1) includes the following ecoregions described by Griffith et al. (2004): Texas—Louisiana Coastal Marshes, Northern Humid Gulf Coastal Prairies, Southern Humid Gulf Coastal Prairies, Flatwoods, Coastal

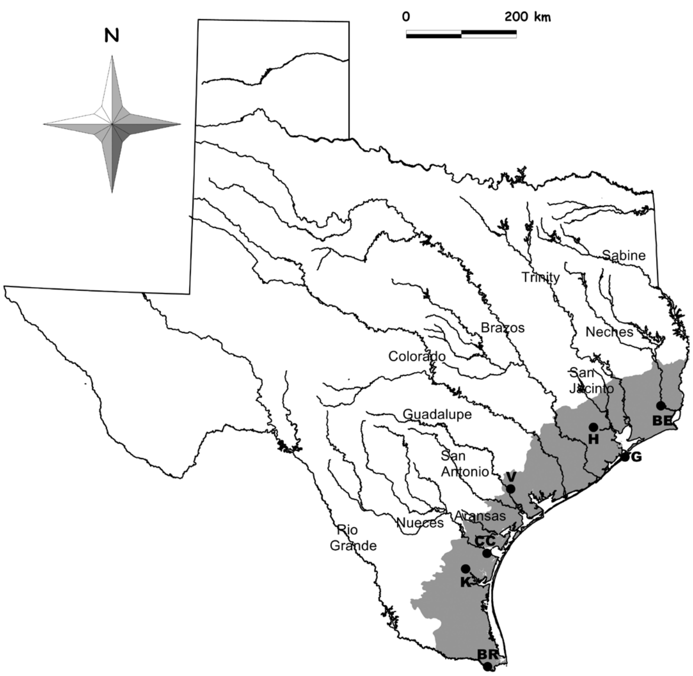


**Figure 1.** *Texas Lower Coastal Plain (TLCP) with geographic features (river drainages) to aid in orientation. The TLCP is indicated by gray. TLCP cities: BE = Beaumont; BR = Brownsville; CC = Corpus Christi; G = Galveston; H = Houston; K = Kingsville; V = Victoria.*

Sand Plain, Lower Rio Grande Valley, Lower Rio Grande Alluvial Floodplains, and Floodplains and Low Terraces associated with each of these ecoregions. We refer to this area as the Texas Lower Coastal Plain (TLCP).

Species absences cannot typically be inferred from museum—vouchered occurrence data but we here explore a way to ameliorate that inherent bias to at least some degree. We chose to analyze presences of target species against a collection background defined by the occurrences of a proxy species. Proxy species are those species that, if collected, constitute evidence that collection methods were likely not biased against collection of the target species and can be used to approximate absences of a target species when the proxy species is collected and the target species is not. While this logic is not necessarily always appropriate, we believe it is effective in this application where many collection locations are included in the analysis. Proxy species were chosen based on: 1) they must be generally as easily collected as the target species (i.e., they would be similar to the target species in size and general body shape and occur in the same micro—habitats); and 2) they must be more commonly collected and wider—spread than the target species, but where ranges overlap, known to frequently co—occur with the target species.

To analyze ranges of our target species *H. formosa, F. chrysotus* and *F. jenkinsi*, we use *Gambusia affinis* as proxy, and for *Poecilia formosa* we use *P. latipinna* as proxy. We queried for species occurrence records (a "species occurrence" is the presence of a single species from a single collecting event) of the target and proxy species on the TLCP in the FoTX's database of 124,390 museum—vouchered species, together with the project's database of 12,037 species occurrence records gathered from published literature (FoTX Literature and Other Unvouchered Database; https://sites.google.com/site/fishesoftexasdocumentation/future—directions/addition—of—literature—and—other—non—vouchered—sources) as well as our recent collection records not yet in the FoTX database. Species occurrence records having georeferencing errors greater than 10 km were discarded prior to analysis. Because the boundaries between the study area and the adjacent ecoregions are not precise and because there is an error associated in georeferencing the capture locations (Hendrickson and Cohen, 2011), specimens from neighboring ecoregions captured within 5 km of the border of our study area are included in our analyses. As part of the FoTX project, many specimens had been previously examined for accurate identifications but we also identified an additional 312 lots of *P. latipinna* cataloged at University of Texas at Austin's Texas Natural History Collection (TNHC) from unopened jars in an effort to find misidentifications of *P. formosa* and other coastal species.

In addition to these data sets available currently from the FoTX project, we included our own recent survey data in our analysis. Over 4 years (2008 — 2011) we sampled at 60 locations on the TLCP. Inspection of the FoTX database indicated that most of these locations were either previously unsampled or had not been sampled in 20 or more years. We generally used a 3 m seine with 4.8 mm delta mesh and/or a 1 m x 1 m frame net with 3.2 mm delta mesh. At 5 locations we exclusively sampled with a 3.2 mm delta mesh dip net. Sites were sampled until all available major habitat types had been sampled or for 5 seine hauls after the last new species for the site was collected. Vouchers of all species from each site were deposited in the TNHC and will eventually be added to the FoTX database.

For analysis we combined all 3 data sets. Less than a quarter of the total collecting events occurred in the first 100 years (1850 to 1949) and more than three—quarters were in the last 60 years. The collection effort was examined by era: 1850 to 1949 (738 total collecting events), 1950 to 1969 (997), 1970 to 1989 (1392) and 1990 to 2010 (539). However, because there are no known records of *H. formosa* in Texas before the 1980s, for that species the temporal data set was divided into only two eras; "before 1980"(2570 total collecting events) and "after 1980" (1160 collecting events). Maps of all collections of target species and their proxies were produced for each species and era and are the basis of our analysis.

## Results and Discussion

Our query of the FoTX museum vouchered database produced 1,351 occurrence records, 295 of which had been previously verified by the FoTX project staff (via examination of preserved specimens). These newly verified records included 15 records cataloged as *F. jenkinsi*, 5 records cataloged as *F. chrysotus*, 33 records cataloged as *P. latipinna*, and a single record of *H. formosa*. The later record, from the Sabine River collected in 1986, represents the first documented occurrence of this species in Texas. In our estimation, no records of *P. formosa* from this database required verification. Only one of the TNHC's 312 lots of *P. latipinna* examined contained any misidentified specimens. The same query of the FoTX literature database added 216 records and our recent surveys added 111 more occurrence records. All records were combined (Table 1) and used in the analysis.

**TABLE 1.** *Numbers of data records used in analysis from the Fishes of Texas (FoTX) vouchered data (V), FoTX literature data (L) and our recent collections.*

| | FoTX (V) | FoTX (L) | Recent | TOTAL |
|---|---|---|---|---|
| **Date Range** | **1891—2004** | **1950—2011** | **2008—2011** | **1891—2011** |
| No. of Locations | 679 | 143 | 60 | 882 |
| No. of Species Occurrence Records | 1351 | 216 | 111 | 1678 |
| *H. formosa* Occurrence Records | 3 | 0 | 6 | 9 |
| *F. jenkinsi* Occurrence Records | 16 | 7 | 2 | 25 |
| *F. chrysotus* Occurrence Records | 78 | 6 | 21 | 105 |

Collecting effort and geographic distribution varied over time (Figure 2). The collecting events prior to the 1950s were concentrated in the areas around the Galveston—Trinity Bay complex tributaries, Corpus Christi and the bays and streams immediately east and northeastward, and the lower Rio Grande valley with its associated resacas and irrigation ditches. Over the same time period the area between the Aransas River (about 35 km east of Corpus Christi) and the Galveston Bay drainages experienced comparatively much less collecting effort. The same area appears still to be slightly less intensively sampled during the most recent sixty years of sampling effort, thus compromising to some degree our ability to make inferences regarding distributions over time. Note that there are records of sampling events on the TLCP as early as 1851 but neither our target species nor the proxy species have collection records prior to 1891 despite 88 collection events for the time period.

It is helpful to examine occurrence records in the context of a background of known absences. One could easily define a range on a map of presence and absence points, but since we lack true absences we also examine plots of proxy species occurrences that we posit represent probable target species absences. Use of *P. latipinna* as a proxy for *P. formosa* is particularly appropriate since *P. formosa* is gynogenetic and dependent on males of *P. latipinna* to activate its eggs; thus its distribution is entirely restricted to locations where *P. latipinna* occurs. Use of G. *affinis* as a proxy for our other target species is appropriate because it meets the requirements specified above. Use of G. *affinis* (usually freshwater) as a proxy species for *F. jenkinsi* (usually brackish water) is supported both by similarity in size and by general habitat preferences. It has been observed that G. *affinis* is better adapted physiologically to brackish marshes than it is to freshwater (Martin et al. 2009), as is *F. jenkinsi*. Simpson and Gunter (1956) reported G. *affinis* and *F. jenkinsi* from nearly the same salinity range in Texas marshes and streams as did Peterson and Ross (1991) for Mississippi locations. Furthermore, in Texas all known locations for *F. jenkinsi* are also locations where G. *affinis* has been collected, not necessarily at the same collecting event. This method does not eliminate all subjectivity but we believe it the best available method for detecting range changes over time.

**Fundulus chrysotus** (Figure 3) — This species had not been reported west of Houston, TX prior to 1973, but in 1973 it was reported about 8 km west of Houston and from the Guadalupe River near Victoria, TX, about 200 km southwest of Houston. By 1979 it was reported from the Aransas National Wildlife Refuge (ANWR), about 240 km southwest of Houston. Recently *F. chrysotus* has been found to be locally abundant at sites adjacent to the ANWR (H.D. Hoese, pers. comm., University of Louisiana at Lafayette, Lafayette, LA, retired), but our collections from further west failed to include it indicating perhaps that the western edge of the range may currently be more or less stabilized.

Whiteside and Berkhouse (1992) reported this species from the Guadalupe River drainage based on collections from 1991. They referred to this as an eastern Texas species and appear to have been unaware that it had been collected in 1973 from the Guadalupe River near Victoria, TX and in 1979 further west on the ANWR. While our data cannot rule out introduction at their Guadalupe location, which was further inland and off the lower coastal plain, our data indicate that this species was well—established in the drainage basin before their report. Lack of collections of *F. chrysotus* despite a strong collecting effort in the Guadalupe drainage from 1950—1969, indicated by more than 40 captures of this species' proxy, G. *affinis* (Figure 3B), support our conclusion that the species most likely expanded into the Guadalupe drainage sometime between 1950 and 1973. The expansion appears to be a physical range expansion since the species has now been reported from the Guadalupe River basin 5 times between 1973 and 2011, a sure indication of a reproducing population.

**Fundulus jenkinsi** (Figure 4) – Except for one specimen collected near the Sabine River in 1953, all pre—1969 Texas records of *F. jenkinsi* were from the Galveston—Trinity Bay


**Figure 2.** *Numbers of collecting events through time and their distribution. Total number of collecting events was 3666.* ***A.*** *Distribution of collecting events, 1851 – 1949, 738 collecting events;* ***B.*** *Distribution of collecting events, 1950 – 1969, 997 collecting events;* ***C.*** *Distribution of collecting events, 1970 – 1989, 1342 collecting event; and* ***D.*** *Distribution of collecting events, 1999 – 2010, 538 collecting events.*

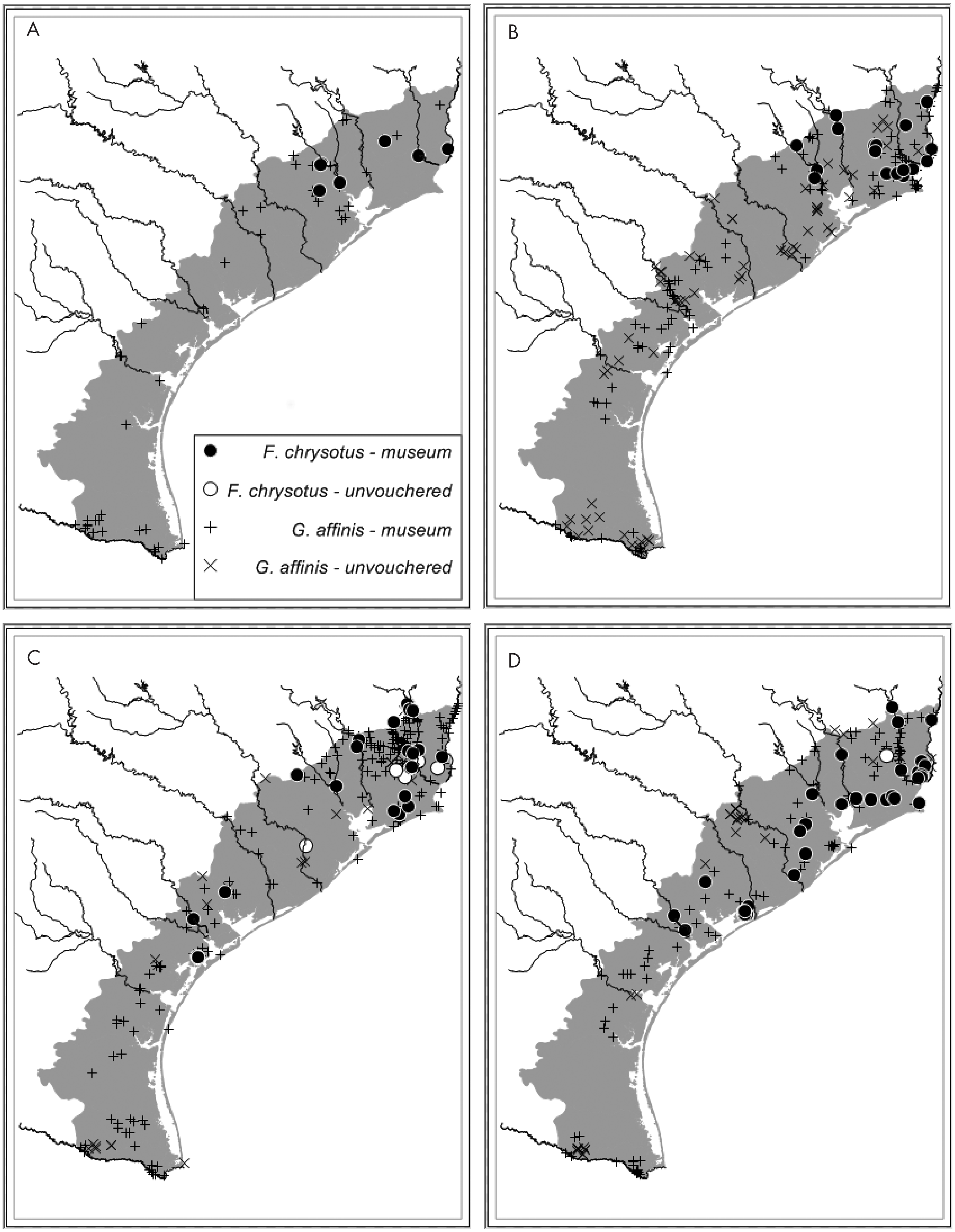


**Figure 3.** *Distribution* of Fundulus chrysotus *and its proxy,* Gambusia affinis *through time. The total number of occurrence records for this species is 105 compared to 718 occurrences for G. affinis within the total geographic range occupied by* F. chrysotus *through the entire period.* ***A.*** *1851 – 1949.* F. chrysotus *– 7 occurrence records; G. affinis – 13 occurrence records within the* F. chrysotus *range for the time period and 27 within the total* F. chrysotus *range;* ***B.*** *1950 – 1969.* F. chrysotus *– 19 occurrence records; G. affinis – 98 occurrence records within the* F. chrysotus *range for the time period and 147 within the total* F. chrysotus *range;* ***C.*** *1970 – 1989.* F. chrysotus *– 40 occurrence records; G. affinis – 395 occurrence records within the* F. chrysotus *range for the time period and 395 within the total* F. chrysotus *range;* ***D.*** *1999 – 2010.* F. chrysotus *– 39 occurrence records; G. affinis – 149 occurrence records within the* F. chrysotus *range for the time period and 149 within the total* F. chrysotus *range.*

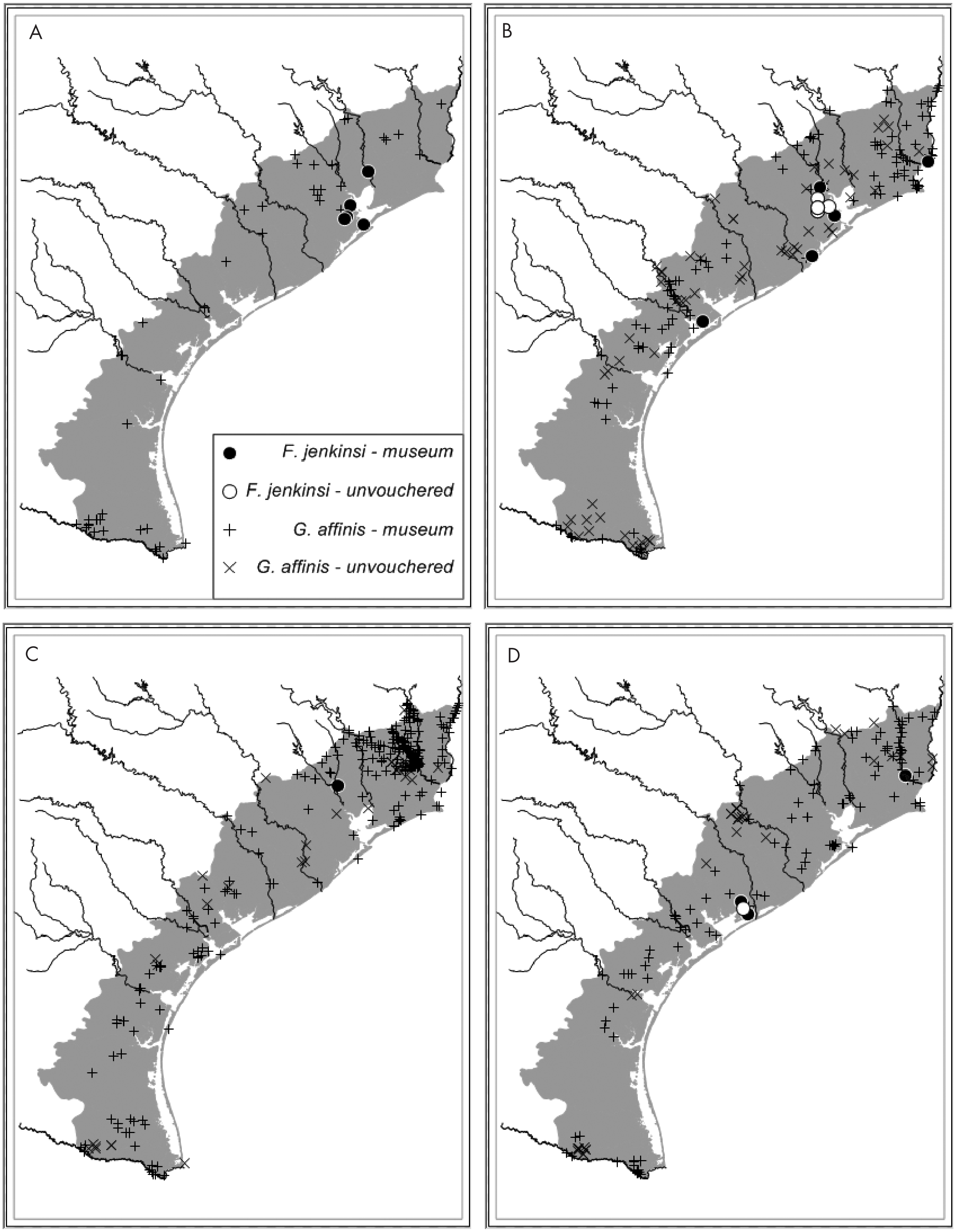


**Figure 4.** *Distribution of* Fundulus jenkinsi *and its proxy,* Gambusia affinis *through time. The total number of occurrence records for this species is 25 compared to 239 occurrences for* G. affinis *within the total geographic range occupied by* F. jenkinsi *through the entire period.* ***A.*** *1851 – 1949.* F. jenkinsi *– 5 occurrence records;* G. affinis *– 6 occurrence records within the* F. jenkinsi *range for the time period and 20 within the total* F. jenkinsi *range;* ***B.*** *1950 – 1969.* F. jenkinsi *– 11 occurrence records;* G. affinis *– 83 occurrence records within the* F. jenkinsi *range for the time period and 83 within the total* F. jenkinsi *range;* ***C.*** *1970 – 1989.* F. jenkinsi *– 1 occurrence record;* G. affinis *– 65 occurrence records within the* F. jenkinsi *range for the time period and 65 within the total* F. jenkinsi *range;* ***D.*** *1999 – 2010.* F. jenkinsi *– 8 occurrence records;* G. affinis *– 71 occurrence records within the* F. jenkinsi *range for the time period and 71 within the total* F. jenkinsi *range.*

complex. In 1969 the species was taken about 50 km WSW of Galveston in Salt Lake, Brazoria County, TX, and 24 km SE of Green Lake, Calhoun County, TX, about 190 km SW from Galveston. Since then it appears that the westernmost record of *F. jenkinsi* was in 2010 in the Tres Palacios River about 135 km SW of Galveston. From 1970 to 1989 there was only one report (in 1981 from the San Jacinto drainage) of *F. jenkinsi* from the whole of the TLCP despite 83 records of *G. affinis* (Figure 4C) within the range of *F. jenkinsi*. There are no reports of this species from the Galveston—Trinity Bay complex since 1951 despite 231 records of *G. affinis* within the overall range of *F. jenkinsi.*

*Fundulus jenkinsi* is generally considered sporadic in distribution and rare where found; however, Peterson et al. (2003) found it much more abundant than expected in eastern Mississippi and western Alabama coastal areas. Rozas (1992) and Rozas and Reed (1993) reported it rare in a Louisiana marsh; however, when Peterson and Turner (1994) sampled the same marsh less than 9 months earlier using a different sampling method (flume nets), they found it to be the ninth most abundant species captured. Recently, Lopez et al. (2011) found *F. jenkinsi* from Louisiana through the panhandle of Florida to be patchy but more abundant when salinity was <16. We collected it in 2010 in the Tres Palacios River in Texas, a new freshwater location for the species, and found it locally abundant. However, our recent collections in the Galveston—Trinity Bay drainages, where it was historically collected, failed to include it. Thus, our data support a hypothesis that populations of this species may fluctuate dramatically.

Extensive human development in the Galveston—Trinity Bay drainages may explain why there have been no collections reported for this species in this area for 30 years. Because proxy data show that since the most recent record of *F. jenkinsi* there has been a large amount of sampling (30 occurrences of *G. affinis*) in Galveston—Trinity Bay drainages that would likely have detected *F. jenkinsi*, this species may have been extirpated from these drainages. We sampled only lightly in this area and believe that more sampling is necessary to rule out its presence. Existing museum collections should also be re—examined since our limited examination of some of them found this species often confused with *G. affinis*, *F. chrysotus* and *Fundulus pulvereus*. It is possible that populations of this species persist in the Galveston—Trinity Bay drainages, and that lack of evidence of persistence could be attributable to misidentifications.

**Poecilia formosa** (Figure 5) — The first records of *P. formosa* from the TLCP are from the Rio Grande drainage in 1923 in spite of 16 collecting events prior to 1923 in this drainage. The earliest records for *P. formosa* outside the Rio Grande valley are from the Nueces River and include a museum—vouchered 1952 collection from the Nueces River, a published record from 1964 (Martin 1964), and an unvouchered collection of 199 individuals (Menn 1965). Specimens from Petronila Creek (1965) and San Fernando Creek (1966), both near the Nueces River but not in its drainage, suggest that the species was widely distributed in the area between Kingsville and the Nueces River in the 1960s. A 1975 collection from the Rob and Bessie Welder Wildlife Foundation Refuge in the Aransas River drainage extended the perceived range eastward by a little more than 35 km. More eastern records were unknown until we collected this species in 2008 in the Brazos River near Rosharon, TX, an expansion in perceived range of a bit more than 200 km. The proxy species, *P. latipinna*, was reported between the Aransas and Brazos rivers in 60 collections from 1970 through 2010, indicating that the species was likely not present in this area until recently.

Darnell and Abramoff (1968) indicate that one reason why there is so much confusion regarding the native range of this species in Texas is because until 1932, when C.L. Hubbs clarified the systematics of this species, all Texas specimens were attributed to *Poecilia sphenops*. Darnell and Abramoff consider populations in the few minor drainages of the Laguna Madre in Texas and in the lower Nueces River to be native. They used presence of *P. formosa* in the creeks around Kingsville to suggest that Martin (1964) was probably wrong in his speculation that *P. formosa* had been introduced into the lower Nueces between 1953 and 1960. The historic record includes only two pre—1953 records of *P. latipinna* from the Nueces so it is likely that the species was in fact present in the Nueces, but not detected due to limited sampling. A hypothesis that *P. formosa* is native to the Nueces is not ruled out by our data.

**Heterandria formosa** (Figure 6) – This species was first collected from Texas in 1986 and again in 1987 from the Sabine River at the I—35 bridge. In 2003 it was again documented in the Sabine River in Jefferson County, TX. Our 2010 targeted efforts to collect *H. formosa* consisted of 2 days collecting that resulted in 6 new locations for the species as far west as Ogden Ditch in Chambers County, TX between the Neches and Trinity basins.

This small species, with females sometimes reaching a maximum of only 30 mm SL (Boschung and Mayden 2004), can be easily missed using standard collecting methods. However in Texas, collectors have sampled extensively and often using appropriate gear (as estimated by the 158 occurrence records of its proxy species, *G. affinis*, within the current known range of *H. formosa*) for many years prior to its first collection and failed to find it. The first specimens were collected by Hanks and McCoid (1988) who state that bi—annual sampling at the Sabine River site for 10 years before 1986 provided strong circumstantial evidence that it was previously absent at that site. In addition, they cite 10 years of collection by other personnel on the Texas side of the Sabine with no reports of *H. formosa*, further supporting their contention that this population was the result of

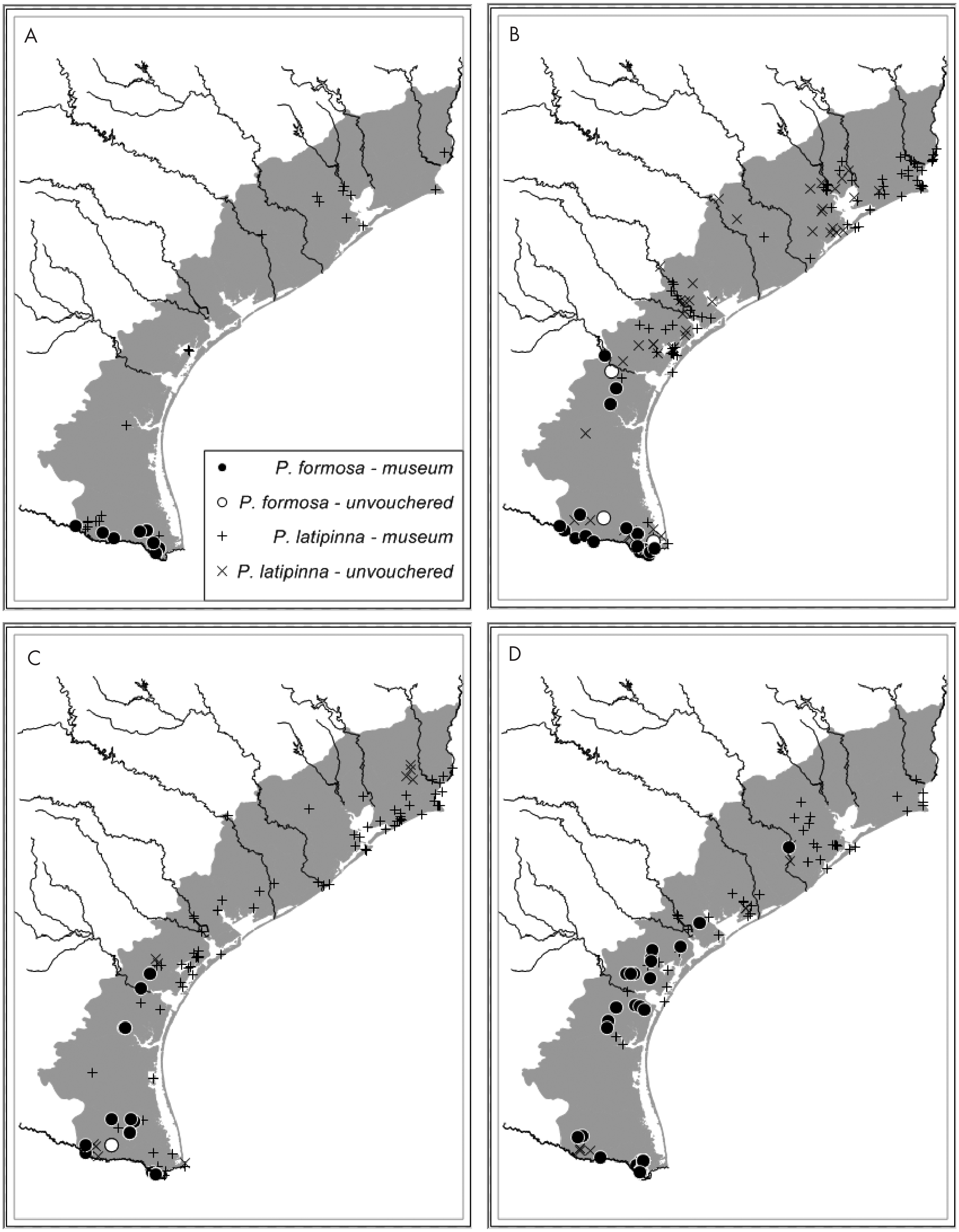


**Figure 5.** *Distribution* of Poecilia formosa *and its proxy,* P. latipinna *through time. The total number of occurrence records for this species is 131 compared to 332 occurrences for* P. latipinna *within the total geographic range occupied by* P. formosa *through the entire period.* ***A.*** *1851 – 1949.* P. formosa *– 13 occurrence records;* P. latipinna *– 24 occurrence records within the* P. formosa *range for the time period and 29 within the total* P. formosa *range;* ***B.*** *1950 – 1969.* P. formosa *– 36 occurrence records;* P. latipinna *– 67 occurrence records within the* P. formosa *range for the time period and 126 within the total* P. formosa *range;* ***C.*** *1970 – 1989.* P. formosa *– 23 occurrence records;* P. latipinna *– 31 occurrence records within the* P. formosa *range for the time period and 70 within the total* P. formosa *range;* ***D.*** *1999 – 2010.* P. formosa *– 59 occurrence records;* P. latipinna *– 107 occurrence records within the* P. formosa *range for the time period and 107 within the total* P. formosa *range.*

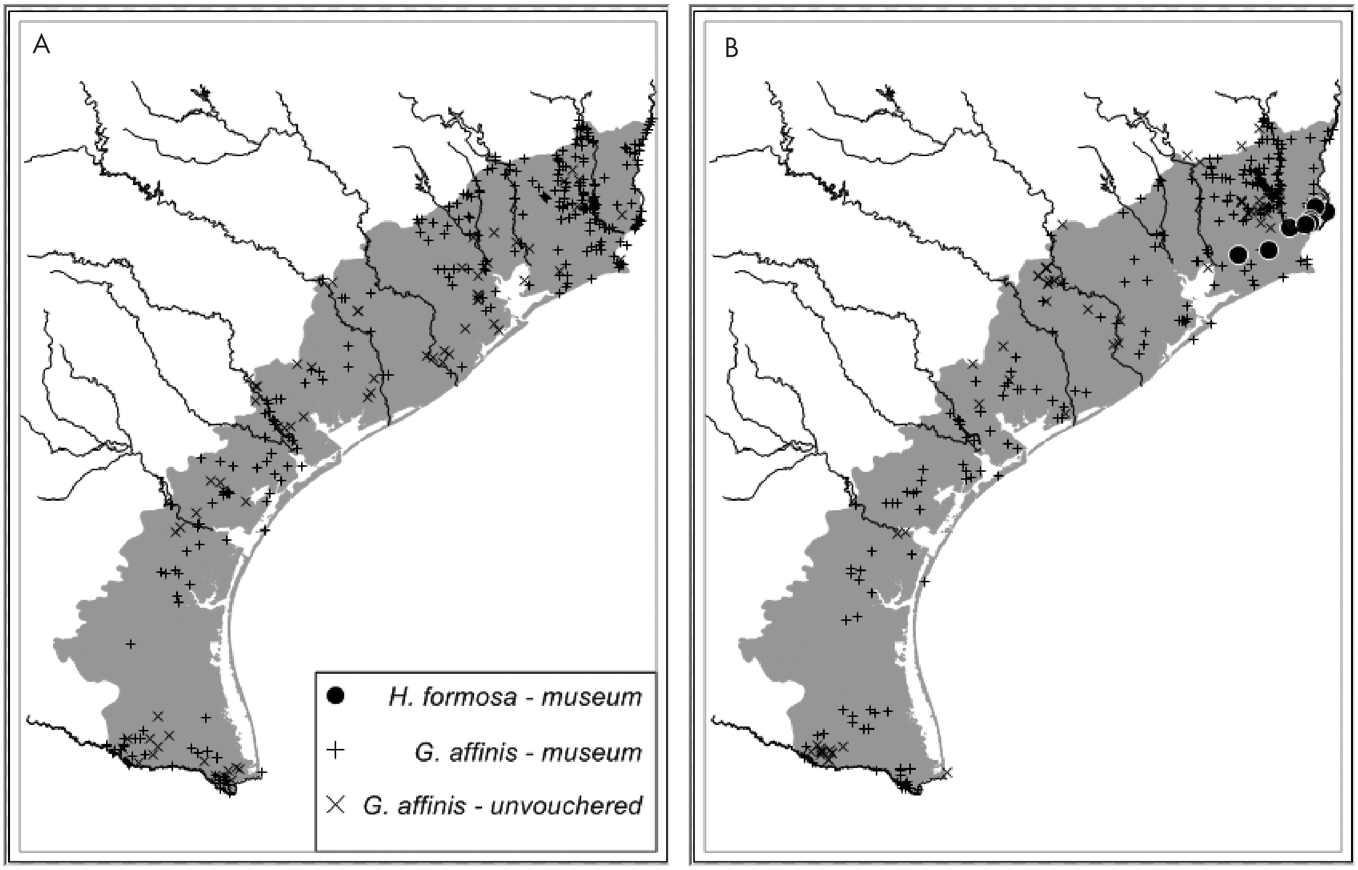


**Figure 6.** *Distribution of* Heterandria formosa *and its proxy,* Gambusia affinis *through time. The total number of occurrence records for this species is 13 compared to 158 occurrences for G.* affinis *within the total geographic range occupied by* H. formosa *through the entire period.* ***A.*** *1851 – 1979.* H. formosa *– 0 occurrence records; G.* affinis *– 0 occurrence records within the* H. formosa *range for the time period and 103 within the total* H. formosa *range;* ***B.*** *1980 – 2010.* H. formosa *– 13 occurrence records; G.* affinis *– 55 occurrence records within the* H. formosa *range for the time period and 55 within the total* H. formosa *range.*

a recent colonization event. Also supporting the hypothesis that the Texas populations are the results of recent colonization rather than early sampling bias that failed to document them, D.L. Bechler (pers. comm., Valdosta State University, Valdosta, GA) collected extensively in southeastern TX from 1982—1995 and failed to find *H. formosa* in any locations other than that reported by Hanks and McCoid.

Chaney and Bechler (2006) speculate that *H. formosa* is often missed in collections because standard collecting seines usually have mesh sizes that *H. formosa* can pass through. While this may be true, we have collected the species (especially large gravid females) in Texas with mesh sizes as large as 4.8 mm (delta mesh). This species occurs in dense vegetation which tends to clog nets and reduce the effective mesh size. While inappropriate gear may explain overlooking some individuals, this alone cannot explain the total absence of *H. formosa* in the many collections (163 collection records for *G. affinis* from within the current range of *H. formosa*) prior to 1986.

Because of the preference for backwaters which are often ephemeral and which frequently dry, this species may be especially good at both colonization and recolonization (Baer 1998). Chaney and Bechler (2006) consider the flatwoods ecoregion of Georgia to be the most utilized ecoregion for *H. formosa* in that state. If this is true in Texas, we would predict that this species will soon expand its range up the Neches and Sabine Rivers further into the Texas Flatwoods ecoregion.

## Summary

The distribution patterns over time seen for these 4 species are consistent with there being no direct intentional movement by humans. However, we can only speculate as to what events and factors have allowed these changes in distribution. Climate change may be one factor aiding range extension or contraction via creation of preferred environmental conditions in uncolonized areas and degradation of historic habitats, but for all of our target species the causes for range expansions are unknown and difficult to determine. We believe they are probably natural events rather than the result of human introductions. All of our target species are fairly tolerant of high salinities and can cross basins by travelling along the coast, especially during times of relatively low salinity. Inland fish populations are highly restricted to their basin of origin and not able to cross basin divides, despite what may be favorable conditions in neighboring basins. However, along the coast these divides are not well defined and individuals can move between basins during high water events that connect basins or freshen bays, thus creating freshwater connections between basins. Human modifications of drainage basins through flood control channelization, ditching for drainage of farm land, and building canals for irrigation water transfer and commercial transportation certainly contribute as well. Bait bucket releases cannot be ruled out, but are not likely for these species (except perhaps *P. formosa*, which is occasionally used as bait).

The data this study is based upon are less complete than we might hope, and we find, for example, relatively large spatial and temporal gaps in coverage, especially along the Texas coast between the Guadalupe and Brazos River basins. More historical data are needed to obtain a complete picture. Published scientific articles, dissertations, theses and government reports represent a large source of historic occurrence data but extracting and entering those occurrences into a data base is a large task, which the FoTX is beginning to do.

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