<table>
<thead>
<tr>
<th>Family</th>
<th>Number of species</th>
<th>Cumulative percent</th>
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<tbody>
<tr>
<td>Cyprinidae</td>
<td>297</td>
<td>28</td>
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<tr>
<td>Percidae</td>
<td>186</td>
<td>45</td>
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<tr>
<td>Catostomidae</td>
<td>71</td>
<td>51</td>
</tr>
<tr>
<td>Poeciliidae</td>
<td>69</td>
<td>58</td>
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<tr>
<td>Ictaluridae</td>
<td>46</td>
<td>62</td>
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<tr>
<td>Goodeidae</td>
<td>45</td>
<td>66</td>
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<tr>
<td>Atherinopsidae</td>
<td>39</td>
<td>70</td>
</tr>
<tr>
<td>Salmonidae</td>
<td>38</td>
<td>74</td>
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<tr>
<td>Cyprinodontidae</td>
<td>35</td>
<td>77</td>
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<tr>
<td>Fundulidae</td>
<td>34</td>
<td>80</td>
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<tr>
<td>Centrarchidae</td>
<td>31</td>
<td>83</td>
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<tr>
<td>Cottidae</td>
<td>30</td>
<td>86</td>
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<tr>
<td>Petromyzontidae</td>
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<td>88</td>
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<tr>
<td>Cichlidae</td>
<td>16</td>
<td>89</td>
</tr>
<tr>
<td>Clupeidae</td>
<td>10</td>
<td>90</td>
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<tr>
<td>Eleotridae</td>
<td>10</td>
<td>91</td>
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<td>Acipenseridae</td>
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<td>Osmeridae</td>
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<td>92</td>
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<td>Elasmommatidae</td>
<td>6</td>
<td>93</td>
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<td>Gobiidae</td>
<td>6</td>
<td>93</td>
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<td>Amblyopsidae</td>
<td>6</td>
<td>94</td>
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<tr>
<td>Pimelodidae</td>
<td>6</td>
<td>94</td>
</tr>
<tr>
<td>Gasterosteidae</td>
<td>5</td>
<td>95</td>
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Source: Compiled primarily from Mayden (1992), Nelson et al. (2004), and Miller and Norris (2005).
<table>
<thead>
<tr>
<th>Taxa</th>
<th>Pre-Pleistocene distribution</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highland Stoneroller, <em>Camptostoma spadiceum</em></td>
<td>2</td>
<td>Mayden 1987a; Blum et al. 2008; Cashner et al. 2010</td>
</tr>
<tr>
<td>Blacktail Shiner, <em>Cyprinella venusta</em></td>
<td>3</td>
<td>Mayden 1987a</td>
</tr>
<tr>
<td>Steelcolor Shiner, <em>Cyprinella whipplei</em></td>
<td>1</td>
<td>Mayden 1987a</td>
</tr>
<tr>
<td>Redfin Shiner, <em>Lepomis umbratilis</em></td>
<td>4</td>
<td>Mayden 1987a</td>
</tr>
<tr>
<td>Bigeye Shiner, <em>Notropis boops</em></td>
<td>1</td>
<td>Wiley and Mayden 1985; Mayden 1987a</td>
</tr>
<tr>
<td>Bullhead Minnow, <em>Pimephales vigilax</em></td>
<td>4</td>
<td>Mayden 1987a</td>
</tr>
<tr>
<td>Mountain Madtom, <em>Noturus eleutherus</em></td>
<td>2a</td>
<td>Mayden 1985, 1987a</td>
</tr>
<tr>
<td>Creole Darter, <em>Etheostoma collettei</em></td>
<td>2a</td>
<td>Mayden 1985</td>
</tr>
<tr>
<td>Channel Darter, <em>Percina copelandi</em></td>
<td>1</td>
<td>Mayden 1987a</td>
</tr>
</tbody>
</table>

1 = Found in all Central Highlands (some with disjunct populations in central lowlands)
2 = Endemic to Ouachita Highlands
2a = Ouachita Highlands and various adjoining regions
3 = Widespread, primarily lowland species with sister species found in Central Highlands (i.e., cladogenesis likely before uplift of Central Highlands)
4 = Widespread but biogeographically noninformative species
<table>
<thead>
<tr>
<th>Family</th>
<th>Common name</th>
<th>Occurrence in drift</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poeciliidae</td>
<td>Livebearers</td>
<td>Rare—poeciliids are livebearers</td>
<td>Brown and Armstrong 1985; Peterson and VanderKooy 1995; Marchetti and Moyle 2000</td>
</tr>
<tr>
<td></td>
<td>can catfishes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Goodeidae</td>
<td>Goodeids</td>
<td>Rare—goodeids are livebearers</td>
<td>Miller 2005</td>
</tr>
<tr>
<td>Atherinopsidae</td>
<td>New World</td>
<td>Common in <em>Labides-thes</em>; rare in <em>Menidia</em></td>
<td>Frietsche et al. 1979; Peterson and VanderKooy 1995; Slack et al. 1998; Marchetti and Moyle 2000</td>
</tr>
<tr>
<td></td>
<td>silversides</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salmonidae</td>
<td>Trouts and</td>
<td>Present in <em>Coregonus, Prosopium, Thymallus</em>, and perhaps <em>Stenodus</em>; uncommon or of short duration in <em>Oncorhynchus, Salvelinus</em>, and <em>Salmo</em> and varies among species</td>
<td>Scott and Crossman 1973; Randall et al. 1987; Crisp 1988; Thorpe 1988; Winnell and Jude 1991; Pavlov 1994; Moyle 2002</td>
</tr>
<tr>
<td></td>
<td>salmons</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cyprinodontidae</td>
<td>Pupfishes</td>
<td>Uncommon but larvae are free-swimming after hatching</td>
<td>Hardy 1978</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fundulidae</td>
<td>Topminnows</td>
<td>Uncommon</td>
<td>Peterson and VanderKooy 1995; Robinson et al. 1998</td>
</tr>
</tbody>
</table>

(continued)
<table>
<thead>
<tr>
<th>Family</th>
<th>Common name</th>
<th>Occurrence in drift</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Centrarchidae</td>
<td>Sunfishes</td>
<td>Common in all genera</td>
<td>Floyd et al. 1984; Muth and Schmulbach 1984; Peterson and VanderKoo 1995; Marchetti and Moyle 2000</td>
</tr>
<tr>
<td>Cottidae</td>
<td>Sculpins</td>
<td>Common in <em>Cottus</em></td>
<td>Gadomski and Barfoot 1998; Marchetti and Moyle 2000; Harvey et al. 2002; White and Harvey 2003</td>
</tr>
<tr>
<td>Petromyzontidae</td>
<td>Lampreys</td>
<td>Common in all genera</td>
<td>Gadomski and Barfoot 1998; Harvey et al. 2002; White and Harvey 2003</td>
</tr>
<tr>
<td>Cichlidae</td>
<td>Cichlids</td>
<td>Uncommon—Neotropical cichlids are brood guarders</td>
<td>Winemiller et al. 1997; Miller and Norris 2005</td>
</tr>
<tr>
<td>Clupeidae</td>
<td>Herrings</td>
<td>Common in all genera</td>
<td>Muth and Schmulbach 1984; Peterson and VanderKoo 1995; Gadomski and Barfoot 1998</td>
</tr>
</tbody>
</table>
**TABLE 6.1**
Long-Term (≥ 2 years) Studies of North American Stream Fish Assemblages Organized from Low to High Levels of Stress and from Low to High Latitudes

<table>
<thead>
<tr>
<th>Site</th>
<th>Temporal scale (years)</th>
<th>Spatial scale (km)</th>
<th>Latitude (DD)</th>
<th>Longitude (DD)</th>
<th>Potential stressor and stress level</th>
<th>No. of species analyzed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black Creek, MS</td>
<td>Medium stream</td>
<td>9</td>
<td>14.2</td>
<td>31.2</td>
<td>89.5</td>
<td>5</td>
</tr>
<tr>
<td>Pearl River, MS</td>
<td>Large river</td>
<td>16</td>
<td>42</td>
<td>31.5</td>
<td>90.1</td>
<td>8</td>
</tr>
<tr>
<td>Undisturbed streams, Savannah River Site, SC</td>
<td>Small stream</td>
<td>2</td>
<td>1.35</td>
<td>33.4</td>
<td>82</td>
<td>9</td>
</tr>
<tr>
<td>Kiamichi River, OK</td>
<td>Medium stream</td>
<td>6</td>
<td>106</td>
<td>34.5</td>
<td>95.4</td>
<td>6</td>
</tr>
<tr>
<td>Ball Creek, NC (upstream site)</td>
<td>Small stream</td>
<td>4</td>
<td>0.03</td>
<td>35.1</td>
<td>83.4</td>
<td>1</td>
</tr>
<tr>
<td>Ball Creek, NC (downstream site)</td>
<td>Small stream</td>
<td>4</td>
<td>0.03</td>
<td>35.1</td>
<td>83.4</td>
<td>1</td>
</tr>
<tr>
<td>Coweeta Creek, NC</td>
<td>Medium stream</td>
<td>4</td>
<td>0.03</td>
<td>35.1</td>
<td>83.4</td>
<td>1</td>
</tr>
<tr>
<td>Coweeta Creek, NC</td>
<td>Medium stream</td>
<td>10</td>
<td>0.04</td>
<td>35.1</td>
<td>83.4</td>
<td>1</td>
</tr>
<tr>
<td>Piney Creek, AR</td>
<td>Medium stream</td>
<td>15</td>
<td>27</td>
<td>36.1</td>
<td>92.1</td>
<td>5</td>
</tr>
<tr>
<td>Martis Creek, CA</td>
<td>Small stream</td>
<td>11</td>
<td>2.9</td>
<td>39.3</td>
<td>120.1</td>
<td>4</td>
</tr>
<tr>
<td>Author's conclusions</td>
<td>Human disturbance</td>
<td>Low stress</td>
<td>High persistence</td>
<td>High stability</td>
<td>Source</td>
<td></td>
</tr>
<tr>
<td>-------------------------------------------------------------------------------------</td>
<td>-------------------</td>
<td>------------</td>
<td>------------------</td>
<td>----------------</td>
<td>-----------------------------</td>
<td></td>
</tr>
<tr>
<td>Temporal persistence; temporal stability based on numbers of individuals and rank-order data</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Ross et al. 1987</td>
<td></td>
</tr>
<tr>
<td>Temporal persistence overall; temporal stability overall based on similarity analyses; high variation in numbers of individuals (CV = 1.03)</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Gunning and Suttkus 1991; data analyzed by Matthews 1998</td>
<td></td>
</tr>
<tr>
<td>Temporal persistence overall; temporal stability based on rank-order data and similarity analyses; moderate stability based on CV of 0.44</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Paller 2002</td>
<td></td>
</tr>
<tr>
<td>Temporal persistence of common species overall; temporal stability overall based on rank-order data and similarity analyses; stability at 3 individual stations and instability at 3 others based on rank-order data.</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Matthews et al. 1988</td>
<td></td>
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<tr>
<td>Temporal persistence of resident species; moderate temporal stability of resident species based on actual abundances (mean CV = 0.53)</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Freeman et al. 1988</td>
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<tr>
<td>Temporal persistence of resident species; temporal stability of resident species based on relative abundance; moderate to low temporal stability based on actual abundances (mean CV = 0.75)</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Freeman et al. 1988</td>
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<tr>
<td>Temporal persistence of resident species; temporal stability of resident species based on relative abundance; moderate to low temporal stability based on actual abundances (mean CV = 0.62)</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Freeman et al. 1988</td>
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<tr>
<td>Temporal persistence of common species (mean C, =0.79; range = 0.67–1.0); temporal stability altered by drought (predrought, drought, and postdrought assemblages distinct)</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>Grossman et al. 1998; additional analysis by STR</td>
<td></td>
</tr>
<tr>
<td>Temporal persistence overall; temporal stability overall based on rank-order data and similarity analyses; temporal stability at individual stations based on rank-order data</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Ross et al. 1985; Matthews et al. 1988</td>
<td></td>
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<tr>
<td>Temporal persistence overall; low temporal stability based on relative-abundance data (species abundances changed dramatically after 1983 flood)</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>Strange et al. 1992</td>
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</table>

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<table>
<thead>
<tr>
<th>Site</th>
<th>Habitat</th>
<th>Temporal scale (years)</th>
<th>Spatial scale (km)</th>
<th>Latitude (DD)</th>
<th>Longitude (DD)</th>
<th>Stations</th>
<th>Potential stressor and stress level</th>
<th>No. of species analyzed</th>
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</thead>
<tbody>
<tr>
<td>Otter Creek, IN</td>
<td>Medium stream</td>
<td>12</td>
<td>0.12</td>
<td>39.5</td>
<td>87.4</td>
<td>1</td>
<td>Upstream mill dam; no other major impacts (low stress)</td>
<td>18</td>
</tr>
<tr>
<td>French Creek, NY</td>
<td>Small to medium stream</td>
<td>42</td>
<td>43</td>
<td>42.1</td>
<td>79.6</td>
<td>9</td>
<td>Normal seasonal variation in flow and temperature (low stress)</td>
<td>41</td>
</tr>
<tr>
<td>Sagehen Creek, CA</td>
<td>Small stream</td>
<td>10</td>
<td>21</td>
<td>34.4</td>
<td>120.2</td>
<td>11</td>
<td>Periodic flooding; severe winters; no major human disturbances (low to moderate stress)</td>
<td>8</td>
</tr>
<tr>
<td>Bogue Chitto River, LA</td>
<td>Medium stream</td>
<td>27</td>
<td>165</td>
<td>31</td>
<td>90.2</td>
<td>7</td>
<td>Land use changes including increases in human population, dairy farming, cattle ranching, gravel mining, road construction, and silviculture (moderate stress)</td>
<td>95</td>
</tr>
<tr>
<td>Little Uchee Creek, AL</td>
<td>Small stream</td>
<td>35</td>
<td>4</td>
<td>32.5</td>
<td>85.3</td>
<td>2</td>
<td>Increase in pine monoculture; 69% human population increase in region; 39% decline in annual flow; flashier runoff (moderate stress)</td>
<td>12</td>
</tr>
<tr>
<td>Wacoochee Creek, AL</td>
<td>Small stream</td>
<td>35</td>
<td>11</td>
<td>32.6</td>
<td>85.1</td>
<td>4</td>
<td>Increase in pine monoculture; 69% human population increase in region; flashier runoff (moderate stress)</td>
<td>20</td>
</tr>
<tr>
<td>Author’s conclusions</td>
<td>Human disturbance</td>
<td>Low stress</td>
<td>High persistence</td>
<td>High stability</td>
<td>Source</td>
<td></td>
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<tr>
<td>Temporal persistence (mean $C_j = 0.80$); low to moderate stability (PSI = 0.47); low stability based on numbers of individuals (CV = 1.37)</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>Whitaker 1976; Grossman et al. 1982; data reanalyzed by Matthews 1998</td>
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<td></td>
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<tr>
<td>Temporal persistence overall; temporal stability based on species abundances</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Hansen and Ramm 1994</td>
<td></td>
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<tr>
<td>Temporal persistence; moderate temporal stability based on rank-order data; low temporal stability based on changes in standing crop</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>Gard and Flittner 1974</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low to moderate temporal persistence ($C_j = 66–74%$); temporal stability low (27 year comparison) to high (11- and 16-year comparisons)</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Stewart et al. 2005; additional analysis by STR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low to moderate temporal persistence with rare species eliminated (mean $C_j = 0.57$; range 0.22–1.0); moderate temporal stability (mean $I_m = 0.71$; range 0.22–0.96)</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Johnston and Maceina 2009; additional analysis by STR</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Low to moderate temporal persistence with rare species eliminated (mean $C_j = 0.27$; range 0.14–0.50); low temporal stability (mean $I_m = 0.53$; range 0.24–0.88)</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Johnston and Maceina 2009; additional analysis by STR</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(continued)
<table>
<thead>
<tr>
<th>Site</th>
<th>Habitat</th>
<th>Temporal scale (years)</th>
<th>Spatial scale (km)</th>
<th>Latitude (DD)</th>
<th>Longitude (DD)</th>
<th>Stations</th>
<th>Potential stressor and stress level</th>
<th>No. of species analyzed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Halawakee Creek, AL</td>
<td>Small stream</td>
<td>35</td>
<td>8</td>
<td>32.7</td>
<td>85.3</td>
<td>2</td>
<td>Increase in pine monoculture; 69% human population increase in region; flashier runoff (moderate stress)</td>
<td>15</td>
</tr>
<tr>
<td>Martis Creek, CA</td>
<td>Small stream</td>
<td>5</td>
<td>2.9</td>
<td>39.3</td>
<td>120.1</td>
<td>4</td>
<td>Periodic flooding; nonnative predators (moderate stress)</td>
<td>7</td>
</tr>
<tr>
<td>Blue River, KS</td>
<td>Large river</td>
<td>45</td>
<td>350</td>
<td>39.6</td>
<td>96.6</td>
<td>14</td>
<td>Reservoir construction; introduction of nonnative species (moderate stress)</td>
<td>29</td>
</tr>
<tr>
<td>Wabash River, IN</td>
<td>Large river</td>
<td>25</td>
<td>147</td>
<td>39.8</td>
<td>87.4</td>
<td>29</td>
<td>Dam construction; positive and negative changes in water quality; urbanization; periodic flooding (moderate stress)</td>
<td>75</td>
</tr>
<tr>
<td>Cedar Fork Creek, OH</td>
<td>Medium stream</td>
<td>10</td>
<td>0.27</td>
<td>40.6</td>
<td>82.6</td>
<td>1</td>
<td>Annual flooding (moderate stress)</td>
<td>30</td>
</tr>
<tr>
<td>Brier Creek, OK</td>
<td>Small stream</td>
<td>18</td>
<td>15</td>
<td>33.9</td>
<td>96.8</td>
<td>5</td>
<td>Flash flooding and drought (moderate to high stress)</td>
<td>10</td>
</tr>
<tr>
<td>Aravaipa Creek, AZ</td>
<td>Medium stream</td>
<td>15</td>
<td>41</td>
<td>37.6</td>
<td>104</td>
<td>3</td>
<td>Flash flooding and drought (moderate to high stress)</td>
<td>7</td>
</tr>
<tr>
<td>Disturbed streams, Savannah River Site, SC</td>
<td>Small stream</td>
<td>2</td>
<td>1.2</td>
<td>33.4</td>
<td>82</td>
<td>8</td>
<td>Postthermal discharge; periodic anoxic discharge; toxic chemicals (high stress)</td>
<td>14^d</td>
</tr>
<tr>
<td>Purgatoire River tributaries, CO</td>
<td>Small streams; some intermittent</td>
<td>5</td>
<td>41</td>
<td>37.4</td>
<td>103.8</td>
<td>5</td>
<td>Flash flooding and drought (high stress)</td>
<td>11</td>
</tr>
</tbody>
</table>

**Source:** Modified from Matthews (1998) and Ross and Matthews (in press).

a. Relative stream size is based on stream orders when available (small stream: orders 1–3; medium stream: orders 4–6; large river: orders >6)

b. Spatial scale, if not stated, approximated from map of study area

c. Latitude and longitude are from the approximate midpoint of the study area

d. Average over all sites
<table>
<thead>
<tr>
<th>Author’s conclusions</th>
<th>Low stress</th>
<th>High persistence</th>
<th>Human disturbance</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low temporal persistence with rare species eliminated (mean Cj = 0.33; range 0.22–0.40); low temporal stability (mean Im = 0.53; range 0.36–0.71)</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>Johnston and Macêna 2009; additional analysis by STR</td>
</tr>
<tr>
<td>Temporal persistence overall; temporal stability based on rank-order data; number and biomass data showed high variation (last sample in 1983)</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Moyle and Vondracek 1985</td>
</tr>
<tr>
<td>Low to moderate persistence (mean Cj = 0.41; range 0.2–0.54) temporal stability based on relative abundances</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>Gido et al. 2002</td>
</tr>
<tr>
<td>Moderate temporal persistence overall; low temporal stability overall based on Bray-Curtis similarity; similarity decreased with greater time between samples to approximately 0.25; low similarity at individual stations based on multivariate measures using abundances</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Pyron et al. 2006</td>
</tr>
<tr>
<td>Temporal persistence; temporal stability indicated by consistency in rank-order data; high variation in numbers of individuals</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Meffe and Berra 1988</td>
</tr>
<tr>
<td>Temporal persistence overall; low temporal stability overall based on rank-order data and similarity analysis (Im = 0.40)</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>Ross et al. 1985; Matthews et al. 1988</td>
</tr>
<tr>
<td>Temporal persistence of species overall; temporal stability based on rank-order data; actual numbers fluctuated extensively</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>Meffe and Minckley 1987</td>
</tr>
<tr>
<td>Low temporal persistence; low temporal stability overall based on rank-order data and similarity analyses; mean CV based on actual abundance = 0.59</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>Paller 2002</td>
</tr>
<tr>
<td>Temporal persistence at 4 of 5 sites (5th site had intermittent flow); low temporal and spatial stability due primarily to variation in numbers of rare species; stability greater in sites with deep pools than with only shallow riffles</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>Fausch and Bramblett 1991</td>
</tr>
</tbody>
</table>

Cj = Jaccard coefficient  
CV = coefficient of variation  
PSI = proportional similarity index  
Im = Morisita’s Index of Similarity
<table>
<thead>
<tr>
<th>Site</th>
<th>Habitat</th>
<th>Temporal scale (years)</th>
<th>Surface area (ha)</th>
<th>Lat.(^b) (DD)</th>
<th>Lon.(^b) (DD)</th>
<th>Productivity</th>
<th>Potential stressor and (categorization of stress)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Wisconsin Lakes (7)</td>
<td>Lake</td>
<td>11</td>
<td>1–1,608</td>
<td>46.0</td>
<td>89.6</td>
<td>O–M</td>
<td>Natural variation (generally low)</td>
</tr>
<tr>
<td>Little Nauyuk Lake, NW Territory, Canada</td>
<td>Lake</td>
<td>15</td>
<td>44.6</td>
<td>68.4</td>
<td>107.7</td>
<td>O</td>
<td>Initial heavy fishing exploitation followed by cessation of exploitation (low)</td>
</tr>
<tr>
<td>Gavia Lake, NW Territory, Canada</td>
<td>Lake</td>
<td>15</td>
<td>17.4</td>
<td>68.4</td>
<td>107.7</td>
<td>O</td>
<td>Light to moderate fishing exploitation followed by cessation of exploitation (low)</td>
</tr>
<tr>
<td>Lake Texoma</td>
<td>Reservoir</td>
<td>43</td>
<td>36,000</td>
<td>33.9</td>
<td>96.8</td>
<td>M</td>
<td>Natural and human-caused variation in inflow; summer hypoxia; turbid inflows; introduction of nonnative fishes (moderate)</td>
</tr>
<tr>
<td>Chequamegon Bay, Lake Superior; shallow water</td>
<td>Lake</td>
<td>24</td>
<td>16,000</td>
<td>47.7</td>
<td>90.8</td>
<td>M</td>
<td>Changes in water quality; introduction of nonnative species (moderate)</td>
</tr>
<tr>
<td>Chequamegon Bay, Lake Superior; deep water</td>
<td>Lake</td>
<td>24</td>
<td>16,000</td>
<td>47.7</td>
<td>90.8</td>
<td>M</td>
<td>Changes in water quality; introduction of nonnative species (moderate)</td>
</tr>
<tr>
<td>Lake Mendota, WI</td>
<td>Lake</td>
<td>72</td>
<td>3,980</td>
<td>43.1</td>
<td>89.4</td>
<td>E</td>
<td>Shoreline urbanization; introduction of nonnative aquatic plants (moderate to high)</td>
</tr>
<tr>
<td>Wintergreen Lake, MI</td>
<td>Lake</td>
<td>15</td>
<td>15</td>
<td>42.4</td>
<td>85.4</td>
<td>E</td>
<td>High nutrient inflow; loss of native predator due to winterkills in 2 years followed by reintroduction of native predator (high)</td>
</tr>
<tr>
<td>Lake Michigan</td>
<td>Lake</td>
<td>12</td>
<td>5,775,673</td>
<td>43.2</td>
<td>87.1</td>
<td>M</td>
<td>Commercial fishing; fish stocking; introduction of nonnative species (high)</td>
</tr>
</tbody>
</table>

\(^a\) Lakes are natural. Reservoirs are impoundments.

\(^b\) Latitude and longitude are from the approximate midpoint of the study area.

**Source:** Modified from Ross and Matthews (in press).
<table>
<thead>
<tr>
<th>No. of species analyzed</th>
<th>Author's conclusions</th>
<th>Human disturbance</th>
<th>Low stress</th>
<th>High persistence</th>
<th>High stability</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1–22</td>
<td>Moderate temporal persistence (species turnover 0–1.1% per year)</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>N/A</td>
<td>Magnuson et al. 1994</td>
</tr>
<tr>
<td>1</td>
<td>Temporal persistence; temporal stability based on age structure</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Johnson 1994</td>
</tr>
<tr>
<td>1</td>
<td>Temporal persistence; temporal stability based on age structure</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Johnson 1994</td>
</tr>
<tr>
<td>11</td>
<td>Temporal persistence; temporal stability based on rank-order data and similarity analyses; moderate stability based on abundance measures (mean CV = 0.58)</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Gido et al. 2000</td>
</tr>
<tr>
<td>12</td>
<td>Temporal persistence (mean $C_j = 0.80$); temporal stability based on multivariate analyses of abundances</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Hoff and Bronte 1999</td>
</tr>
<tr>
<td>8</td>
<td>Temporal persistence (mean $C_j = 0.83$); low temporal stability overall (3 distinct assemblages over time)</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>Hoff and Bronte 1999</td>
</tr>
<tr>
<td>20</td>
<td>Low temporal persistence (8 species extirpated); low temporal stability based on relative abundance</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Lyons 1989</td>
</tr>
<tr>
<td>8</td>
<td>Moderate temporal persistence (2 species extirpated by winterkill); low temporal stability based on pre- and postwinterkill assemblages and pre- and postpredator introduction assemblages; high temporal stability based on recovery to initial conditions following native predator reintroduction</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Mittelbach et al. 1995</td>
</tr>
<tr>
<td>18</td>
<td>Temporal persistence; low temporal stability based on changes in relative abundance, fishery landings, and catch-per-unit effort</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>Eck and Wells 1987</td>
</tr>
</tbody>
</table>

$C_j =$ Jaccard coefficient  
CV = coefficient of variation  
E = eutrophic  
M = mesotrophic  
O = oligotrophic  
PSI = proportional similarity index
**TABLE 7.1**

*Similarities and Differences among Commonly Recognized Modes of Body and Caudal Fin (BCF) Locomotion*

<table>
<thead>
<tr>
<th>Trait</th>
<th>Anguilliform</th>
<th>Subcarangiform</th>
<th>Carangiform</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of active, ipsilateral red-muscle blocks</td>
<td>Short block</td>
<td>Intermediate</td>
<td>Long block</td>
</tr>
<tr>
<td>Length-specific propulsive wavelength</td>
<td>Low</td>
<td>Intermediate</td>
<td>High</td>
</tr>
<tr>
<td>Wake momentum</td>
<td>Lateral</td>
<td>Primarily downstream</td>
<td>Primarily downstream</td>
</tr>
<tr>
<td>Length-specific body amplitude</td>
<td>Greater anteriorly</td>
<td>Smaller anteriorly</td>
<td>Smaller anteriorly</td>
</tr>
<tr>
<td>Lateral myoseptal tendon</td>
<td>Short</td>
<td>Short</td>
<td>Long</td>
</tr>
<tr>
<td>Epineural myoseptal tendon</td>
<td>Present</td>
<td>Present</td>
<td>Absent</td>
</tr>
<tr>
<td>Epipleural myoseptal tendon</td>
<td>Present</td>
<td>Present</td>
<td>Absent</td>
</tr>
<tr>
<td>Three-dimensional myoseptal shape</td>
<td>Same</td>
<td>Same</td>
<td>Different</td>
</tr>
<tr>
<td>Firing duration of red muscles</td>
<td>Short burst</td>
<td>Short burst</td>
<td>Long burst</td>
</tr>
</tbody>
</table>

**Source:** Based primarily on Danos et al. (2008) with additional information from Lauder and Tytell (2006).
<table>
<thead>
<tr>
<th>Common name</th>
<th>Scientific name</th>
<th>Grasping (G); Suction (S)</th>
<th>Lab (L); Field (F)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bluntface Shiner</td>
<td>Cyprinella camura</td>
<td>G</td>
<td>L</td>
<td>Adams et al. 2003</td>
</tr>
<tr>
<td>Red Shiner</td>
<td>Cyprinella lutrensis</td>
<td>G</td>
<td>L</td>
<td>Leavy and Bonner 2009</td>
</tr>
<tr>
<td>Blacktail Shiner</td>
<td>Cyprinella venusta</td>
<td>G</td>
<td>L</td>
<td>Adams et al. 2003; Leavy and Bonner 2009</td>
</tr>
<tr>
<td>Roundnose Minnow</td>
<td>Diona episcopa</td>
<td>G</td>
<td>L</td>
<td>Leavy and Bonner 2009</td>
</tr>
<tr>
<td>Mississippi Silvery Minnow</td>
<td>Hybognathus nuchalis</td>
<td>G</td>
<td>L</td>
<td>Adams et al. 2003</td>
</tr>
<tr>
<td>Redfin Shiner</td>
<td>Lythrurus umbratilis</td>
<td>G</td>
<td>L</td>
<td>Leavy and Bonner 2009</td>
</tr>
<tr>
<td>Silver Chub</td>
<td>Machybmpsis storeriana</td>
<td>G</td>
<td>L</td>
<td>Adams et al. 2003</td>
</tr>
<tr>
<td>Golden Shiner</td>
<td>Notemigonus crysoleucas</td>
<td>G</td>
<td>L</td>
<td>Adams et al. 2000</td>
</tr>
<tr>
<td>Emerald Shiner</td>
<td>Notropis atherinoides</td>
<td>G</td>
<td>L</td>
<td>Adams et al. 2003</td>
</tr>
<tr>
<td>River Shiner</td>
<td>Notropis blennius</td>
<td>G</td>
<td>L</td>
<td>Adams et al. 2003</td>
</tr>
<tr>
<td>Longnose Shiner</td>
<td>Notropis longirostris</td>
<td>G</td>
<td>L</td>
<td>Adams et al. 2003</td>
</tr>
<tr>
<td>Taillight Shiner</td>
<td>Notropis maculatus</td>
<td>G</td>
<td>L</td>
<td>Adams et al. 2003</td>
</tr>
<tr>
<td>Sand Shiner</td>
<td>Notropis stramineus</td>
<td>G</td>
<td>L</td>
<td>Leavy and Bonner 2009</td>
</tr>
<tr>
<td>Weed Shiner</td>
<td>Notropis texanus</td>
<td>G</td>
<td>L</td>
<td>Adams et al. 2003</td>
</tr>
<tr>
<td>Topeka Shiner</td>
<td>Notropis topeka</td>
<td>G</td>
<td>L</td>
<td>Adams et al. 2000</td>
</tr>
<tr>
<td>Channel Shiner</td>
<td>Notropis wicklifhi</td>
<td>G</td>
<td>L</td>
<td>Adams et al. 2003</td>
</tr>
<tr>
<td>Bluntnose Minnow</td>
<td>Pimephales notatus</td>
<td>G</td>
<td>L</td>
<td>Adams et al. 2003</td>
</tr>
<tr>
<td>Splittail</td>
<td>Pogonichthys macrolepidotus</td>
<td>G</td>
<td>L</td>
<td>Young and Cech 1996</td>
</tr>
<tr>
<td>Creek Chub</td>
<td>Semotilus atromaculatus</td>
<td>G</td>
<td>L</td>
<td>Leavy and Bonner 2009</td>
</tr>
<tr>
<td>Desert Sucker</td>
<td>Catostomus clarkii</td>
<td>S</td>
<td>L</td>
<td>Ward et al. 2003</td>
</tr>
<tr>
<td>Bluehead Sucker</td>
<td>Catostomus discobolus</td>
<td>S</td>
<td>L, F</td>
<td>Ward et al. 2003</td>
</tr>
<tr>
<td>Group</td>
<td>Characteristics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----------------------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Chondrostei</strong></td>
<td>Two muscle couplings for lower jaw opening; premaxilla and maxilla fused to skull and in series; maxilla toothed (Lauder 1982; Rosen 1982; Westneat 2004)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Neopterygii</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amiiformes</td>
<td>Three muscle couplings for lower jaw opening; maxilla free to rotate; suction feeding (Lauder 1982; Rosen 1982; Westneat 2004)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teleostei</td>
<td>Premaxilla and maxilla primitively in series (Rosen 1982)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Osteoglossomorpha</td>
<td>Premaxilla and maxilla in series; small alveolar process on premaxilla overlaps anterior head of maxilla; premaxilla fixed to skull or with limited movement (Rosen 1982; Nelson 2006)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elopomorpha</td>
<td>Premaxilla and maxilla in series; small alveolar process on premaxilla overlaps anterior head of maxilla; premaxilla with limited movement (Schaeffer and Rosen 1961; Rosen 1982)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ostarioclupeomorpha</td>
<td>Premaxilla partially or fully free to rotate; premaxilla and maxilla primitively in series but tandem in more derived forms; ascending process on premaxilla and jaw protrusion in many Ostariophysi but not Clupeomorpha (Harrington 1955; Schaeffer and Rosen 1961; Motta 1984; Nelson 2006)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Euteleostei</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protacanthopterygii</td>
<td>Premaxilla secondarily fused to skull; premaxilla and maxilla usually in series (exceptions in some Southern Hemisphere smelts) (Lauder 1982; Nelson 2006)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neoteleostei</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paracanthopterygii</td>
<td>Jaws in tandem with maxilla excluded from gape; small ascending process on premaxilla; some groups with protrusile jaws (Schaeffer and Rosen 1961; Rosen 1982; Nelson 2006)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acanthopterygii</td>
<td>Unique mechanisms of jaw protrusion; premaxilla and maxilla in tandem with maxilla excluded from gape; well-developed ascending premaxillary process (Schaeffer and Rosen 1961; Rosen 1982; Motta 1984)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### TABLE 8.2

**Basic Mechanisms of Jaw Protrusion in North American Freshwater Fishes**

Families are listed if protrusion mechanism has been described in any member genus

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>Order</th>
<th>Family</th>
<th>Studied genera (source)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type A (protrusion by mandibular depression and not maxillary twisting)</td>
<td>Cypriniformes</td>
<td>Cyprinidae</td>
<td>Abramis*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cyprinus*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Catostomidae</td>
<td>Catostomus</td>
</tr>
<tr>
<td>Gasterosteiiformes</td>
<td></td>
<td>Gasterosteidae</td>
<td>Gasterosteus</td>
</tr>
<tr>
<td>Atheriniformes</td>
<td></td>
<td>Atherinopsidae</td>
<td>Menidia</td>
</tr>
<tr>
<td>Cyprinodontiformes</td>
<td></td>
<td>Poeciliidae</td>
<td>Xiphophorus (Hernandez et al. 2009)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Gambusia (Hernandez et al. 2008, 2009)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Heterandria (Hernandez et al. 2008, 2009)</td>
</tr>
<tr>
<td>Type B (protrusion by maxillary twisting)</td>
<td>Mugiliformes</td>
<td>Mugilidae</td>
<td>Mugil</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gasterosteiiformes</td>
<td>Gasterosteus? described by Alexander (1967b); questioned by Anker (1974)</td>
</tr>
<tr>
<td>Perciformes</td>
<td></td>
<td>Percidae</td>
<td>Perca? described by Alexander (1967b); questioned by Liem and Osse (1975)</td>
</tr>
<tr>
<td>Type A + B (protrusion by mandibular depression and maxillary twisting)</td>
<td>Cyprinodontiformes</td>
<td>Fundulidae</td>
<td>Fundulus (Hernandez et al. 2008)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rivulidae</td>
<td>Kryptolebias (formerly Rivulus; Hernandez et al. 2008)</td>
</tr>
<tr>
<td>Type C (protrusion by neurocranial elevation and mandibular depression)</td>
<td>Perciformes</td>
<td>Centrarchidae</td>
<td>Micropterus</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Lepomis (Gillis and Lauder 1995)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Petrotilapia*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Eretmodus*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Spathodus*</td>
</tr>
</tbody>
</table>

*Source: Compiled from Motta (1984) unless otherwise listed.

*Genera not native to North America
### TABLE 9.1

Approximate Life Table for Fantail Darter (*Etheostoma flabellare*) Based on Adult Survival Determined for an Iowa Population and Survival from Ripe Eggs to Age-1 for an Ontario, Canada, Population

<table>
<thead>
<tr>
<th>Age class ((x))</th>
<th>(n_x)</th>
<th>(l_x)</th>
<th>(d_x)</th>
<th>(q_x)</th>
<th>(s_x)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1000</td>
<td>1.000</td>
<td>965</td>
<td>0.96</td>
<td>0.035</td>
</tr>
<tr>
<td>1</td>
<td>35</td>
<td>0.035</td>
<td>26</td>
<td>0.74</td>
<td>0.263</td>
</tr>
<tr>
<td>2</td>
<td>9</td>
<td>0.009</td>
<td>7</td>
<td>0.74</td>
<td>0.263</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>0.002</td>
<td>2</td>
<td>1.00</td>
<td>0.000</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Source:** Iowa data provided by Karr (1964); Ontario, Canada data provided by Paine and Balon (1986, table 2).

**Note:** Numbers are arbitrarily adjusted to a starting population size of 1,000 and numbers of individuals have been rounded to the nearest whole number.

- \(n_x\) = number of individuals at the beginning of age \(x\)
- \(l_x\) = the proportion of the population surviving to the beginning of age \(x\) \((l_x = n_x / n_0)\)
- \(d_x\) = number dying during the age interval \(x\) to \(x+1\) \((d_x = n_x - n_{x+1})\)
- \(q_x\) = proportion of population dying during age interval \(x\) to \(x+1\) \((q_x = d_x / n_x)\)
- \(s_x\) = age-specific survival rate \((s_x = n_{x+1} / n_x)\)
### Table 9.2
Approximate Life Table for Fantail Darter (Etheostoma flabellare)

<table>
<thead>
<tr>
<th>Age class (x)</th>
<th>n_x</th>
<th>l_x</th>
<th>m_x</th>
<th>l_x * m_x</th>
<th>x * l_x * m_x</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>500</td>
<td>1.000</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>18</td>
<td>0.035</td>
<td>20</td>
<td>0.704</td>
<td>0.704</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>0.009</td>
<td>100</td>
<td>0.924</td>
<td>1.848</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>0.002</td>
<td>100</td>
<td>0.243</td>
<td>0.728</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \sum_{x=0}^{x=4} )</td>
<td></td>
<td>1.871</td>
<td></td>
<td>3.280</td>
<td></td>
</tr>
</tbody>
</table>

**Note:** Females mature at age-1, have an average clutch size of 40, and large females may produce five clutches per breeding season (Lake 1956; Halyk and Balon 1983). For illustration purposes, I assumed a 1:1 sex ratio, and that age-1 females produce one clutch and age classes 2 and 3 produce five clutches per breeding season (half of which are assumed females). In contrast to Table 9.1, this life table only contains data on females. Other terms remain the same as in Table 9.1.

- **n_x** = number of individuals at the beginning of age x
- **l_x** = the proportion of the population surviving to the beginning of age x (l_x = n_x/n_x)
- **m_x** = age-specific natality
<table>
<thead>
<tr>
<th>Family/Species</th>
<th>Climate (location)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atherinopsidae</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Menidia audens</em>, Mississippi Silverside</td>
<td>Temperate (OK)</td>
<td>Hubbs 1976</td>
</tr>
<tr>
<td>Centrarchidae</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Lepomis gibbosus</em>, Pumpkinseed</td>
<td>Cool temperate (Ontario)</td>
<td>Fox and Crivelli 1998</td>
</tr>
<tr>
<td>Characidae</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Hyphessobrycon pulchripinnis</em>, Lemon Tetra</td>
<td>Warm temperate/tropical</td>
<td>Burt et al. 1988</td>
</tr>
<tr>
<td>Cyprinidae</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Cyprinella analostana</em>, Satinfin Shiner</td>
<td>Cool temperate (PA)</td>
<td>Gale and Buynak 1978</td>
</tr>
<tr>
<td><em>Cyprinella leedsii</em>, Bannerman Shiner</td>
<td>Warm temperate (FL)</td>
<td>Heins and Rabito 1986</td>
</tr>
<tr>
<td><em>Cyprinella nivea</em>, Whitefin Shiner</td>
<td>Warm temperate (SC)</td>
<td>Cloutman and Harrell 1987</td>
</tr>
<tr>
<td><em>Cyprinella lutrensis</em>, Red Shiner</td>
<td>Cool temperate (PA)</td>
<td>Gale 1986</td>
</tr>
<tr>
<td><em>Notropis longirostris</em>, Longnose Shiner</td>
<td>Warm temperate (AL and MS)</td>
<td>Heins 1990, 1991</td>
</tr>
<tr>
<td><em>Pimephales notatus</em>, Bluntnose Minnow</td>
<td>Cool temperate (PA)</td>
<td>Gale 1983</td>
</tr>
<tr>
<td><em>Pimephales promelas</em>, Fathead Minnow</td>
<td>Cool temperate (PA)</td>
<td>Gale and Buynak 1982</td>
</tr>
<tr>
<td>Elassomatidae</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Elassoma zonatum</em>, Pygmy Sunfish</td>
<td>Warm temperate (KY)</td>
<td>Walsh and Burr 1984</td>
</tr>
<tr>
<td>Fundulidae</td>
<td></td>
<td></td>
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<tr>
<td><em>Fundulus notatus</em>, Blackstripe Topminnow</td>
<td>Cool temperate (MI)</td>
<td>Carranza and Winn 1954</td>
</tr>
<tr>
<td>Gasterosteidae</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Apeltes quadracus</em>, Fourspine Stickback</td>
<td>Cool temperate (MA)</td>
<td>Wallace and Selman 1979</td>
</tr>
<tr>
<td>Percidae</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Etheostoma grahami</em>, Rio Grande Darter</td>
<td>Warm temperate (TX)</td>
<td>Strawn and Hubbs 1956</td>
</tr>
<tr>
<td><em>Etheostoma lepidum</em>, Greentoth Darter</td>
<td>Warm temperate (TX)</td>
<td>Hubbs and Strawn 1957</td>
</tr>
<tr>
<td><em>Etheostoma lyncum</em>, Brighteye Darter</td>
<td>Warm temperate (MS)</td>
<td>Heins and Baker 1993</td>
</tr>
<tr>
<td><em>Etheostoma olmstedi</em>, Tesselated Darter</td>
<td>Cool temperate (PA)</td>
<td>Gale and Deutsch 1985</td>
</tr>
<tr>
<td><em>Etheostoma Rafinesquei</em>, Kentucky Snubnose Darter</td>
<td>Cool temperate (KY)</td>
<td>Weddle and Burr 1991</td>
</tr>
<tr>
<td><em>Etheostoma spectabile</em>, Orangethroat Darter</td>
<td>Warm temperate (TX)</td>
<td>Hubbs 1985</td>
</tr>
<tr>
<td><em>Nothonotus rubrum</em>, Bayou Darter</td>
<td>Warm temperate (MS)</td>
<td>Knight and Ross 1992</td>
</tr>
<tr>
<td><em>Percina vigil</em>, Saddleback Darter</td>
<td>Warm temperate (MS)</td>
<td>Heins and Baker 1989</td>
</tr>
<tr>
<td>Poeciliidae</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Poecilia latipinna</em>, Sailfin Molly</td>
<td>Warm temperate (FL)</td>
<td>Snelson et al. 1986</td>
</tr>
</tbody>
</table>

*a. The genus *Hyphessobrycon* occurs in Mexico, although *H. pulchripinnis* is native to South America.*
<table>
<thead>
<tr>
<th>Family</th>
<th>Genus</th>
<th>Number of forms</th>
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<tr>
<td>Cyprinidae</td>
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<td><em>Menidia</em></td>
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</tr>
<tr>
<td></td>
<td><em>Fundulus</em></td>
<td>1</td>
</tr>
<tr>
<td>Poeciliidae</td>
<td><em>Poeciliopsis</em></td>
<td>7</td>
</tr>
<tr>
<td></td>
<td><em>Poecilia</em></td>
<td>4</td>
</tr>
</tbody>
</table>

Source: Based on Schultz (1977), Vrijenhoek et al. (1989), and Kraus (1995).
<table>
<thead>
<tr>
<th>Family</th>
<th>Provider</th>
<th>Egg bury</th>
<th>Nest</th>
<th>Egg guard</th>
<th>Larval guard</th>
<th>Fan</th>
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<tbody>
<tr>
<td>Cyprinidae</td>
<td>m</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Percidae</td>
<td>m, f</td>
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<td>bp</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poeciliidae</td>
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<tr>
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<td>x</td>
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<td>x</td>
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</tr>
<tr>
<td>Centrarchidae</td>
<td>m, bp</td>
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<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
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<td>x</td>
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<td>x</td>
<td>x</td>
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<tr>
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<tr>
<td>Osmeridae</td>
<td>f</td>
<td>x</td>
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<tr>
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<td>f</td>
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<tr>
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<tr>
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<tr>
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<td>m</td>
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<td>x</td>
<td></td>
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<td>x</td>
</tr>
<tr>
<td>Characidae</td>
<td>m, f, bp</td>
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<tr>
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<td>m, f</td>
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</tbody>
</table>

**Source:** Unless otherwise listed, the source is Blumer (1982) as are the descriptions of care giving.

bp = both parents at the same time
Brood pouch = incubation of eggs in an external brood pouch
Clean = removing debris from eggs, usually by manipulating eggs in the mouth
Cull = removing dead or diseased eggs from the nest
Egg bury = egg-burying behavior
Egg guard = egg guarding from potential predators
f = female only
Fan = moving water over the developing eggs by fin movements or from the mouth and opercular chamber
IG = internal gestation of embryos in the ovary or oviduct
<table>
<thead>
<tr>
<th>Cull</th>
<th>Clean</th>
<th>MRE</th>
<th>MRL</th>
<th>Brood pouch</th>
<th>Oral brood</th>
<th>IG</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Page and Johnston 1990</td>
</tr>
<tr>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Grier et al. 1990</td>
</tr>
<tr>
<td>x</td>
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<td></td>
<td></td>
<td></td>
<td>Balon 1975</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>DeWoody et al. 2000b</td>
</tr>
<tr>
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</tr>
<tr>
<td>x</td>
<td>x</td>
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<tr>
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<td>x</td>
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<td></td>
<td></td>
<td>Mckaye et al. 1979</td>
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<td>Walsh and Burr 1984</td>
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<td>x</td>
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<td>Fletcher et al. 2004</td>
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<td></td>
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<td>Miller 2005</td>
</tr>
</tbody>
</table>

Larval guard = guarding the larvae from potential predators  
m = male only  
MRE = moving or retrieving eggs that have moved from the nest  
MRL = moving or retrieving larvae that have moved from the nest  
Nest = nest construction  
Oral brood = keeping eggs and/or larvae in oral or opercular chambers  
a. Fertilized eggs are only held for a short time before being deposited  
b. Oral brooding is not documented in North American cichlids  
c. Documented in marine species of the genus *Gobiesox*; no information on freshwater species  
d. Male Pirate Perch only defend the nest area for ≤ 2 h
<table>
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<th>Type of interaction</th>
<th>Effect on sender/giver</th>
<th>Effect on receiver</th>
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<td>Amensalism</td>
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<td>0</td>
</tr>
<tr>
<td>Communication</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Commensalism</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>Competition</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>Mutualism</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(obligatory)</td>
</tr>
<tr>
<td>Neutralism</td>
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<td>Parasitism</td>
<td>+</td>
<td>−</td>
</tr>
<tr>
<td>Predation</td>
<td>+</td>
<td>−</td>
</tr>
<tr>
<td>Protocooperation</td>
<td>+</td>
<td>+ (non-obligatory)</td>
</tr>
<tr>
<td>Spying</td>
<td>0</td>
<td>+</td>
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</tbody>
</table>

*Source*: Based in part on Pianka (1988).

* + = positive effect
  − = negative effect
<table>
<thead>
<tr>
<th>Family/species</th>
<th>Sound</th>
<th>Mechanism</th>
<th>Sex</th>
<th>Purpose</th>
<th>Source</th>
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<tr>
<td>Acipenseridae</td>
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<tr>
<td><em>Clinostomus funduloides</em></td>
<td>Knocks</td>
<td>Unknown</td>
<td>Male</td>
<td>Male-male aggression</td>
<td>Winn and Stout 1960</td>
</tr>
<tr>
<td><em>Codoma ornata</em></td>
<td>Short bursts, low-frequency pulses</td>
<td>Unknown</td>
<td>Male</td>
<td>Male-male aggression associated with courtship and reproduction</td>
<td>Johnston and Vives 2003</td>
</tr>
<tr>
<td><em>Cyprinella analostana</em></td>
<td>Knocks, knock trains, purrs</td>
<td>Unknown</td>
<td>Male</td>
<td>Male-male aggression associated with courtship and reproduction</td>
<td>Winn and Stout 1960; Stout 1975</td>
</tr>
<tr>
<td><em>C. callisema</em></td>
<td>Short pulses, knocks</td>
<td>Unknown</td>
<td>Male</td>
<td>Male-male aggression associated with courtship and reproduction</td>
<td>Phillips and Johnston 2009</td>
</tr>
<tr>
<td><em>C. galactura</em></td>
<td>Knocks, short knocks, pulses</td>
<td>Unknown</td>
<td>Male</td>
<td>Male-male aggression associated with courtship and reproduction</td>
<td>Phillips and Johnston 2008a, 2009</td>
</tr>
<tr>
<td><em>C. gibbsi</em></td>
<td>Short pulses, chirps, rattles</td>
<td>Unknown</td>
<td>Male</td>
<td>Male-male aggression associated with courtship and spawning</td>
<td>Phillips and Johnston 2009</td>
</tr>
<tr>
<td><em>C. lepida</em></td>
<td>Low-frequency bursts</td>
<td>Unknown</td>
<td>Male</td>
<td>Male-male aggression associated with courtship and spawning</td>
<td>Phillips et al. 2010</td>
</tr>
<tr>
<td><em>C. lutrensis</em></td>
<td>Series of knocks</td>
<td>Unknown</td>
<td>Female</td>
<td>Courtship</td>
<td>Delco 1960; Stout 1975</td>
</tr>
<tr>
<td><em>C. spioptera</em></td>
<td>Knocks</td>
<td>Unknown</td>
<td>Male</td>
<td>Male-male aggression</td>
<td>Winn and Stout 1960</td>
</tr>
<tr>
<td><em>C. trichroistia</em></td>
<td>Short pulses, chirps, rattles</td>
<td>Unknown</td>
<td>Male</td>
<td>Male-male aggression associated with courtship and spawning</td>
<td>Phillips and Johnston 2009</td>
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<tr>
<td><em>C. venusta</em></td>
<td>Single knocks</td>
<td>Unknown</td>
<td>Female</td>
<td>Courtship</td>
<td>Delco 1960; Stout 1975</td>
</tr>
<tr>
<td>Family/species</td>
<td>Sound</td>
<td>Mechanism</td>
<td>Sex</td>
<td>Purpose</td>
<td>Source</td>
</tr>
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<tr>
<td><em>Margariscus margarita</em></td>
<td>Knocks</td>
<td>Unknown</td>
<td>Male</td>
<td>Male-male aggression</td>
<td>Winn and Stout 1960</td>
</tr>
<tr>
<td><em>Pimephales notatus</em></td>
<td>Aggressive knocks, purrs, single knocks</td>
<td>Unknown</td>
<td>Male</td>
<td>Male-male aggression associated with courtship and spawning</td>
<td>Johnston and Johnson 2000</td>
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<tr>
<td>Ictaluridae</td>
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<td></td>
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<tr>
<td><em>Ameiurus nebulosus</em></td>
<td>Ratchet</td>
<td>Pectoral stridulation</td>
<td>Unknown</td>
<td>Agonistic behavior</td>
<td>Rigley and Muir 1979</td>
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<tr>
<td>Cyprinodontidae</td>
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<tr>
<td><em>Cyprinodon bifasciatus</em></td>
<td>Not described</td>
<td>Unknown</td>
<td>Male</td>
<td>Aggression associated with courtship and spawning</td>
<td>Johnson 2000</td>
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<td>Cottidae</td>
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<tr>
<td><em>Cottus bairdi</em></td>
<td>Knocks, head slap</td>
<td>Hitting substratum</td>
<td>Male</td>
<td>Courtship and reproduction</td>
<td>Whang and Janssen 1994</td>
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<tr>
<td><em>C. paulus</em></td>
<td>Knocks</td>
<td>Unknown</td>
<td>Male</td>
<td>Courtship, reproduction, and agonistic behavior</td>
<td>Kierl and Johnston 2010</td>
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<td>Centrarchidae</td>
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<tr>
<td><em>Lepomis cyanellus</em></td>
<td>Grunts</td>
<td>Unknown</td>
<td>Male</td>
<td>Courtship and spawning</td>
<td>Gerald 1971</td>
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<tr>
<td><em>L. gibbosus</em></td>
<td>Rasps</td>
<td>Pharyngeal teeth</td>
<td>Male</td>
<td>Courtship and spawning</td>
<td>Ballantyne and Colgan 1978</td>
</tr>
<tr>
<td><em>L. humilis</em></td>
<td>Grunts</td>
<td>Unknown</td>
<td>Male</td>
<td>Courtship and spawning</td>
<td>Gerald 1971</td>
</tr>
<tr>
<td><em>L. macrochirus</em></td>
<td>Grunts, rasps</td>
<td>Pharyngeal teeth</td>
<td>Male</td>
<td>Courtship and spawning</td>
<td>Gerald 1971; Ballantyne and Colgan 1978</td>
</tr>
<tr>
<td><em>L. megalotis</em></td>
<td>Grunts</td>
<td>Unknown</td>
<td>Male</td>
<td>Courtship and spawning</td>
<td>Gerald 1971</td>
</tr>
<tr>
<td><em>L. macrochirus x gibbosus</em></td>
<td>Rasps</td>
<td>Pharyngeal teeth</td>
<td>Male</td>
<td>Courtship and spawning</td>
<td>Ballantyne and Colgan 1978</td>
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<td><em>L. microlophus</em></td>
<td>Pops</td>
<td>Jaw snapping</td>
<td>Male</td>
<td>Courtship and spawning</td>
<td>Gerald 1971</td>
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<tr>
<td><em>L. punctatus</em></td>
<td>Grunts</td>
<td>Unknown</td>
<td>Male</td>
<td>Courtship and spawning</td>
<td>Gerald 1971</td>
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<tr>
<td>Family/species</td>
<td>Sound</td>
<td>Mechanism</td>
<td>Sex</td>
<td>Purpose</td>
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<td><em>Micropterus coosae</em></td>
<td>Low-frequency</td>
<td>Unknown</td>
<td>Both</td>
<td>Aggressive encounters</td>
<td>Johnston et al. 2008; Holt and Johnston 2011</td>
</tr>
<tr>
<td>Percidae</td>
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<tr>
<td><em>Etheostoma flabellare</em></td>
<td>Drums and knocks</td>
<td>Unknown</td>
<td>Male</td>
<td>Male-male aggression associated with reproduction</td>
<td>Speares et al. 2010</td>
</tr>
<tr>
<td><em>E. nigripinne</em></td>
<td>Drums and knocks</td>
<td>Unknown</td>
<td>Male</td>
<td>Male-male aggression associated with courtship, reproduction, and spawning</td>
<td>Johnston and Johnson 2000</td>
</tr>
<tr>
<td><em>E. crossopterum</em></td>
<td>Drums and knocks</td>
<td>Unknown</td>
<td>Male</td>
<td>Male-male aggression associated with courtship, reproduction, and spawning</td>
<td>Johnston and Johnson 2000; Speares et al. 2010</td>
</tr>
<tr>
<td><em>E. nigripinne x E. crossopterum</em></td>
<td>Drums and knocks</td>
<td>Unknown</td>
<td>Male</td>
<td>Male-male aggression associated with courtship, reproduction, and spawning</td>
<td>Johnston and Johnson 2000</td>
</tr>
<tr>
<td>Sciaenidae</td>
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<td><em>Aplodinotus grunniens</em></td>
<td>Drums</td>
<td>Swimbladder</td>
<td>Male</td>
<td>COURTSHIP and spawning</td>
<td>Schneider and Hasler 1960; Schneider 1962; Fine 1977</td>
</tr>
<tr>
<td>Guild</td>
<td>Description</td>
<td>Family</td>
<td>Species</td>
<td></td>
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<td>------------------------------------------------------------------------------</td>
<td>------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Herbivore</td>
<td>Algae, vascular plants, and seeds</td>
<td>Cyprinidae</td>
<td>Blackside Dace, Central Stoneroller, Chiselmouth, Grass Carp, Largesse Stoneroller, Ozark Minnow, Tennessee Dace</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Catostomidae</td>
<td>Bridgelip Sucker</td>
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<td></td>
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<tr>
<td></td>
<td></td>
<td>Petromyzontidae</td>
<td>American Brook Lamprey</td>
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<td></td>
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<tr>
<td>Detritivore</td>
<td>Organic bottom material from various sources: rotting vegetation, animal remains, feces, and pseudofeces; live materials: bacteria, attached algae, benthic diatoms, and resting cysts of plankton</td>
<td>Clupeidae</td>
<td>Gizzard Shad</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Cyprinidae</td>
<td>Bluntnose Minnow, Common Carp, Fathead Minnow, Mississippi Silvery Minnow, Suckermouth Minnow, Weed Shiner</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Catostomidae</td>
<td>Bigmouth Buffalo, Black Buffalo, Bluehead Sucker, Desert Sucker, Flannelmouth Sucker, Highfin Carpsucker, Hogsucker, Mountain Sucker, River Carpsucker, Smallmouth Buffalo, Sonora Sucker</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Omnivore</td>
<td>Wide range of animal and plant food</td>
<td>Cyprinidae</td>
<td>Blacknose Shiner, Bluehead Chub, Bluntnose Minnow, Bonytail Chub, Brassy Minnow, Bullhead Minnow, Common Carp, Common Shiner, Creek Chub, Eastern Blacknose Dace, Fathead Minnow, Gila Chub, Golden Shiner, Goldfish, Headwater Chub, Hornyhead Chub, Little Colorado Spinedace, Longfin Dace, Mimic Shiner, Northern Redbelly Dace, Redfin Shiner, Roundtail Chub, Sand Shiner, Spottail Shiner, Southern Redbelly Dace, Striped Shiner, Utah Chub, Virgin Spinedace, Woundfin</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Catostomidae</td>
<td>Alabama Hogsucker, Black Redhorse, Blacktail Redhorse, Golden Redhorse, Longnose Sucker, Mountain Sucker, Quillback Carpsucker, Razorback Sucker, Rio Grande Sucker, Spotted Sucker, Utah Sucker, White Sucker</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ictaluridae</td>
<td>Black Bullhead, Brown Bullhead, Snail Bullhead, Yellow Bullhead, Channel Catfish</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cyprinodontidae</td>
<td>Desert Pupfish</td>
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(continued)
<table>
<thead>
<tr>
<th>Guild</th>
<th>Description</th>
<th>Family</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planktivore</td>
<td>Catch and/or filter zooplankton and phytoplankton</td>
<td>Polyodontidae</td>
<td>Paddlefish</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Clupeidae</td>
<td>Threadfin Shad</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cyprinidae</td>
<td>Golden Shiner</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Catostomidae</td>
<td>Bighmouth Buffalo</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Salmonidae</td>
<td>Bloater</td>
</tr>
<tr>
<td>Generalized invertebrate</td>
<td>Variety of invertebrate food from bottom, surface, and water column,</td>
<td>Cyprinidae</td>
<td>Bighmouth Shiner, Bonytail Chub, Creek Chub, Finescale Dace, Hornyhead Chub, Lake Chub, Lined Chub, Loach Minnow, Moapa Dace, Pearl Dace, Red Shiner, Redside Shiner, River Shiner, Rosyface Shiner, Roundtail Chub, Silver Chub, Speckled Chub, Spinedace, Spottail Shiner, Striped Shiner</td>
</tr>
<tr>
<td>feeder</td>
<td>including terrestrial and aquatic insects, zooplankton, and benthic</td>
<td>Ictaluridae</td>
<td>Stonecat</td>
</tr>
<tr>
<td></td>
<td>microcrustacea</td>
<td>Salmonidae</td>
<td>Brook Trout, Brown Trout, Cutthroat Trout, Gila Trout, Mountain Whitefish, Rainbow Trout</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Umbridae</td>
<td>Central Mudminnow</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Aphredoderidae</td>
<td>Pirate Perch</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Percopsidae</td>
<td>Trout-Perch</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gadidae</td>
<td>Burbot</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gasterosteidae</td>
<td>Brook Stickleback</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Centrarchidae</td>
<td>Bluegill, Green Sunfish, Longear Sunfish, Orangespotted Sunfish</td>
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<td></td>
<td></td>
<td>Percidae</td>
<td>Blackbanded Darter, Blackside Darter, Iowa Darter</td>
</tr>
<tr>
<td>Surface/water-column</td>
<td>Terrestrial insects, emerging insects, and zooplankton</td>
<td>Hiodontidae</td>
<td>Goldeye, Mooneye</td>
</tr>
<tr>
<td>feeder</td>
<td></td>
<td>Cyprinidae</td>
<td>Alabama Shiner, Bandfin Shiner, Bigeye Shiner, Blacktail Shiner, Coosa Shiner, Emerald Shiner, Lake Chub, Rainbow Shiner, Redfin Shiner, Redside Dace, Ribbon Shiner, Silverstripe Shiner, Spotfin Shiner, Steelcolor Shiner, Tricolor Shiner, Yellowfin Shiner</td>
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</tbody>
</table>

(continued)
<table>
<thead>
<tr>
<th>Guild</th>
<th>Description</th>
<th>Family</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atherinopsida</td>
<td>Brook Silverside, Mississippi Silverside</td>
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<tr>
<td>Fundulidae</td>
<td>Blackspotted Topminnow, Blackstripe Topminnow, Plains Killifish, Plains Topminnow</td>
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<td>Poeciliida</td>
<td>Eastern Mosquitofish, Western Mosquitofish</td>
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<td>Centrarchidae</td>
<td>Bluegill, Longear Sunfish</td>
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<tr>
<td>Acipenserida</td>
<td>Lake Sturgeon, Shovelnose Sturgeon</td>
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<tr>
<td>Benthic invertebrate feeder</td>
<td>Aquatic insect larvae and other small invertebrates associated with hard and soft substrata; snails and clams</td>
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<td></td>
</tr>
<tr>
<td>Cyprinida</td>
<td>Flathead Chub, Longjaw Minnow, Longnose Dace, Longnose Shiner, Riffle Minnow, Silverjaw Minnow, Speckled Dace, Suckermouth Minnow</td>
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<td></td>
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<tr>
<td>Catostomidae</td>
<td>Creek Chubsucker, Greater Redhorse, Hogsucker, Golden Redhorse, Lake Chubsucker, Quillback, River Redhorse, White Sucker, Shorthead Redhorse, Silver Redhorse, Smallmouth Buffalo</td>
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<td></td>
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<tr>
<td>Ictalurida</td>
<td>Brindled Madtom, Freckled Madtom, Speckled Madtom, Stonecat, Tadpole Madtom, Yellow Bullhead</td>
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<tr>
<td>Umbridae</td>
<td>Central Mudminnow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percopsisdae</td>
<td>Trout Perch</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cottidae</td>
<td>Banded Sculpin, Mottled Sculpin, Paiute Sculpin</td>
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<td></td>
</tr>
<tr>
<td>Centrarchidae</td>
<td>Pumpkinseed, Redear Sunfish</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Macro-carnivores/piscivores</td>
<td>Fishes; large active invertebrates such as crayfish and odonate larvae</td>
<td></td>
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</tr>
<tr>
<td>Amiidae</td>
<td>Bowfin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lepisosteida</td>
<td>Alligator Gar, Longnose Gar, Shortnose Gar, Spotted Gar</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Guild</td>
<td>Description</td>
<td>Family</td>
<td>Species</td>
</tr>
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<td>------------------------------</td>
<td>-----------------------------</td>
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</tr>
<tr>
<td>Anguillidae</td>
<td>American Eel</td>
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<tr>
<td>Clupeidae</td>
<td>Alabama Shad, American Shad</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cyprinidae</td>
<td>Creek Chub, Colorado Pikeminnow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ictaluridae</td>
<td>Black Bullhead, Blue Catfish, Brown Bullhead, Channel Catfish, Flathead Catfish, White Catfish, Yellow Bullhead</td>
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<tr>
<td>Esocidae</td>
<td>Chain Pickerel, Grass Pickerel, Northern Pike, Muskellunge</td>
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<tr>
<td>Salmonidae</td>
<td>Arctic Grayling, Brook Trout, Brown Trout, Cutthroat Trout, Lake Trout, Rainbow Trout, Sockeye Salmon</td>
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<td>Gadidae</td>
<td>Burbot</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moronidae</td>
<td>Striped Bass, White Bass, Yellow Bass</td>
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</tr>
<tr>
<td>Percidae</td>
<td>Sauger, Walleye, Yellow Perch</td>
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<td>Sciaenidae</td>
<td>Freshwater Drum</td>
<td></td>
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<tr>
<td>Parasite</td>
<td>Attach to host fishes and feed on host tissue</td>
<td>Petromyzontidae</td>
<td>Chestnut Lamprey, Sea Lamprey, Silver Lamprey</td>
</tr>
</tbody>
</table>

**Source**: Guilds as defined by Benke and Cushing (2005). Colorado River (Olden et al. 2006); Gulf Coast Southwest (Zeug and Winemiller 2008a); Gulf Coast Southeast (Walters et al. 2001); Missouri (Horwitz 1978; Bergstedt and Bergersen 1997); Nelson/Churchill (Poff and Allan 1995); Ohio (Horwitz 1978; Grossman et al. 1982); Southern Plains (Orth and Maughan 1984); Upper Mississippi (Horwitz 1978; Schlosser 1982; Poff and Allan 1995); St. Lawrence (Horwitz 1978); General (Goldstein and Simon 1999; Westneat 2001)

**Note**: Some species are assigned to more than one trophic guild primarily because of size, seasonal, or regional differences, resulting in a total of 261 entries in the table.
### TABLE 12.2

**Percent Occurrence of Feeding Guilds Occupied by a Sample of North American Freshwater Fish Species**

<table>
<thead>
<tr>
<th>Trophic guild</th>
<th>Percent occurrence</th>
</tr>
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<tbody>
<tr>
<td>Omnivores</td>
<td>22</td>
</tr>
<tr>
<td>Benthic invertebrate feeders</td>
<td>21</td>
</tr>
<tr>
<td>Macrocnivores/piscivores</td>
<td>18</td>
</tr>
<tr>
<td>Generalized invertebrate feeders</td>
<td>15</td>
</tr>
<tr>
<td>Surface/water-column feeders</td>
<td>11</td>
</tr>
<tr>
<td>Detritivores</td>
<td>7</td>
</tr>
<tr>
<td>Herbivores</td>
<td>3</td>
</tr>
<tr>
<td>Planktivores</td>
<td>2</td>
</tr>
<tr>
<td>Parasites</td>
<td>1</td>
</tr>
</tbody>
</table>

**Source:** Based on data from Table 12.1.

### TABLE 12.3

**Levels of Identification in 30 Food Habit Studies with an Average of 19 Prey per Study**

<table>
<thead>
<tr>
<th>Percent of prey</th>
<th>Identified to genus</th>
<th>Identified to species</th>
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<tbody>
<tr>
<td>0</td>
<td>11</td>
<td>18</td>
</tr>
<tr>
<td>10</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>20</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>30</td>
<td>2</td>
<td>4</td>
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<td>40</td>
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<td>50</td>
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<tr>
<td>60</td>
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<tr>
<td>70</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>80</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>90</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**Note:** Data show the number of studies that identified different percentages of prey to genus or species (e.g., 11 studies did not identify any prey to genus and 1 study identified 90% of the prey to genus). Based on the first 30 fish taxa appearing in an electronic database search of fish food habits. Only papers with tabular data on fish stomach contents were used and the total number of prey taxa was restricted to animal categories.

### TABLE 15.1

**Large-Bodied Fishes Typical of Floodplain Lakes of Different Sizes and Levels of Connectivity to the Mississippi River**

<table>
<thead>
<tr>
<th>Lake type</th>
<th>Fishes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large and connected</td>
<td>River Carpsucker, White Bass</td>
</tr>
<tr>
<td>Large and disconnected</td>
<td>Yellow Bass, Smallmouth Buffalo, Catfish species, Threadfin Shad</td>
</tr>
<tr>
<td>Small and connected</td>
<td>Gar species</td>
</tr>
<tr>
<td>Small and disconnected</td>
<td>Orangespotted Sunfish, White Crappie, Green Sunfish, Warmouth, Bluegill</td>
</tr>
</tbody>
</table>

**Source:** Based on Miranda (2005).