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(Gregory 1933, Fig. 283). Development of the upper jaw in the Iniomi is similar initially to that in the Isospondyli, but while still in the larval stage the premaxillaries continue to grow posteriad and force the maxillaries completely out of the gape. The presence of transitory teeth on the maxillaries in larval *Scopelosaurus* may be indicative of a close phylogenetic association of this family with the Isospondyli. Representatives of other, higher orders of fishes studied develop the upper jaw structure in a manner similar to that in the Iniomi. This indicates that fishes in most of the evolutionary lines more advanced than the Isospondyli reflect or pass through the primitive condition of upper jaw structure during their larval period, and differ from this primitive condition only by a continued extension posteriad of the premaxillaries.

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Some Effects of Introduced Fishes on the Native Fish Fauna of Southern Nevada[1]

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A number of fishes have been introduced into the depauperate fish fauna of southern Nevada. Many of the introductions have had adverse effects on localized endemic species. Introduction of a cichlid and 5 poeciliids near Lake Mead seems to have resulted in elimination of a local race of *Rhinichthys osculus*; introduction of guppies at Preston endangers the resident population of *Crenichthys baileyi*; and introduction of goldfish at Manse Ranch threatens the remaining stock of *Empetrichthys latos*. Three of the introduced fishes, *Cichlasoma nigrofasciatum*, *Lebistes reticulatus*, and *Mollienesia mexicana*, do not seem to have been previously recorded to be established in the United States.

Fishes have been moved about by man for many years, often far beyond their native waters. The resulting benefits to commercial and sport fisheries have been thoroughly documented. Likewise, the inherent dangers to the established fish faunas have been discussed repeatedly. Whereas larger sport or food fishes dominated the earlier introductions, small bait or ornamental fishes are now becoming established

[1] Contribution from the Scripps Institution of Oceanography.

far beyond their native ranges. The effects of each introduction are difficult to assess, but the possibility of extermination of native species accompanies every one. This is particularly true in areas where a depauperate fish fauna contains localized endemic species, such as that typical of much of Nevada. Inasmuch as most of the endemic species are small, the more recent introductions of small bait or ornamental fishes are likely to be more critical than earlier introductions of large fishes (see Hubbs and Brodrick 1963 for a contrast between the effects of an introduced competitor and a predator on a localized endemic). Miller (1952), who discussed the bait fishes in the Colorado River system, pointed out the dangers to sport fishing inherent in use of live bait. Introductions of exotic ornamental fishes can be equally dangerous and should be avoided when possible.

Miller and Alcorn (1946) listed attempts to introduce 28 species of fishes (18 successful) into Nevada. Subsequently, La Rivers (1962) listed 27 of 63 known fish species in Nevada as having been introduced. Parenthetically, in this paper we cast doubt upon the success of one of the introductions; however, we record the successful introduction of 3 other species, increasing the introduced fraction to nearly 45%. Obviously, the addition of more than 3 exotic species for every 4 native species may cause the extermination of some of the native fishes. In fact, Miller and Hubbs (1960) attributed the extermination of 1 local Nevada species and 2 races in large part to introduction of exotics.

In this paper we document the successful introduction of 2 poeciliids and 1 cichlid into Nevada and discuss some of the possible effects of such introductions on the native fish fauna. We also discuss the apparently unsuccessful introduction of an additional poeciliid reported as successful by La Rivers (*loc. cit.*). He reported the recent introduction of black (= sailfin) mollies, *Mollienesia latipinna* Le Sueur, swordtails, *Xiphophorus helleri* Heckel, and platys, *X. maculatus* (Günther). He stated that the mollies "can be found in small numbers in warm water roadside drains near the Ash Meadows Ranch in the southeast part of the Meadows." He also said that all 3 had been successfully introduced into Rogers Spring, Clark County (near the Overton Arm of Lake Mead), according to Robert Sumner. Subsequent collections in Rogers Spring, 23 March 1961, and 14 February, 9 and 14 March 1963, do not contain either species of *Xiphophorus* but do include numbers of *M. latipinna*. Both March 1963 collections also contain numbers of convict cichlids, *Cichlasoma nigrofasciatum* (Günther). Therefore, it is apparent that only 1, *M. latipinna*, of the 3 reported introductions was successful. We have also taken *M. latipinna* in Blue Point Spring (1 mile northeast of Rogers Spring). All of the collected sailfin mollies are melanistic.

Collections from Blue Point Spring, 23 December 1960, 14 February, 9 and 14 March 1963, also contain young and adult guppies, *Lebistes reticulatus* (Peters), shortfin mollies, *M. mexicana* (Steindachner), and platys, *X. maculatus*. It is possible that La Rivers' report was for this spring, not for Rogers Spring. These fish apparently were descended from stocks released by an aquarium-fish-rearing establishment at Blue Point Spring. This business ceased operation in 1956 or 1957, and the remaining stocks must have maintained themselves for more than 6 years. Therefore, there is no reason to suspect that all 3 species will not maintain themselves there indefinitely.

Guppies have been taken also at the Preston Town Spring, White Pine County, on 30 August 1961, and 2 February 1963. Survival of this tropical species there for more than a year indicates that they are firmly established. Moreover, the fish obtained from the springs in February 1963, when nearby roadside pools were covered with ice, were healthy and included both pregnant females and young, indicating that circumstances at Preston are well within the toleration limits of guppies. The actual source of the Preston guppies is not known; however, they must be descendants of released home aquarium fishes. The 1963 collection included a number of highly colored, long-tailed males as well as several golden guppies.

Because the establishment of a cichlid, *Cichlasoma nigrofasciatum*, in Lake Mead might well adversely affect the sport fishery, we recommend an attempt to eradicate the fish fauna in Rogers Spring with the intent of forestalling any release of the cichlid. There is no possibility of damage to the native fish fauna as the single known native species *Rhinichthys osculus* (Girard) is ab-

sent from all of our collections, and that population is undoubtedly extinct at that locality. In addition to the fishes reported here, Rogers Spring contains goldfish, *Carassius auratus* (Linnaeus), golden shiners, *Notemigonus crysoleucas* (Mitchill), and mosquitofish, *Gambusia affinis* (Baird and Girard). At present, 4 cichlids are known to have been introduced into the United States. Bailey *et al.* (1960) listed *Astronotus ocellatus* (Agassiz), Brown (1961) reported the release of *Tilapia mossambica* Peters, and Springer and Finucane (1963) recorded the presence of *Tilapia heudeloti* in Florida.

Five species of poeciliids, *Gambusia affinis* (Baird and Girard), *Xiphophorus maculatus, Mollienesia latipinna, M. mexicana,* and *Lebistes reticulatus,* have been successfully introduced into Nevada waters. *G. affinis* is widespread (La Rivers, *loc. cit.*), but its effects on the native fauna have not yet been assessed adequately. The black form of *M. latipinna* is found in 2 localities in southern Nevada. We fear the consequences of its introduction into Ash Meadows where three endemic cyprinodonts might be affected. The Preston population of another localized cyprinodont, *Crenichthys baileyi* (Gilbert), appears to have been adversely affected by the recent establishment of guppies there. We are less disturbed about the introductions of poeciliids into Blue Point Spring as it is not known to have contained localized endemics and the general biota of the nearby waters had already been drastically changed by Lake Mead.

The results of collecting trips on 2 February and 9 March 1963 perhaps provide the best indexes of the effects of introduced fishes. On the first trip our objective was to collect stocks of poolfish, *Empetrichthys latos* Miller, from Manse Ranch, *Crenichthys baileyi* from a spring 0.25 mile north of Warm Spring near Moapa, from Crystal Spring, from Hiko Spring, and from Preston, and *C. nevadae* Hubbs from Lockes. There were no introduced fishes at Crystal, Hiko, and Lockes and our stocks were easy to obtain. In fact, a single haul with a 10-ft seine was adequate for most of our needs. Goldfish were introduced into Manse Ranch in late fall 1961 and had reproduced successfully by July 1962. Perhaps as a result, an hour of seining obtained only 16 poolfish. We discuss below some disturbing changes in the population of this only remaining stock of *E. latos;* the springs containing the other 2 subspecies have dried or have been filled. Mosquitofish had been introduced into the Moapa region as early as 1938 (Miller and Alcorn, *loc. cit.*). Apparently conditions have stabilized because *G. affinis, C. baileyi,* and *Moapa coriacea* Hubbs and Miller seem to have more or less separated habitats in the spring area collected. However, *G. affinis* was dominant in open, quiet water, a habitat occupied by *C. baileyi* elsewhere and formerly occupied by that species in the Moapa region (Carl L. Hubbs, personal communication 1963). Conditions appeared critical at the Preston Town Spring where *L. reticulatus* was far more abundant than *C. baileyi* and we did not find *L. reticulatus* scarce in any habitat occupied by *C. baileyi.* Therefore, there was a distinct reduction in population density of the endemic *Crenichthys* in the presence of an introduced carnivorous poeciliid adapted to the same or similar habitats.

The March trip was designed to replenish some of the stocks and to establish more firmly the population densities of *C. baileyi.* In addition to the stations at Rogers and Blue Point springs discussed above, collections were made at the Moapa station, Ash Springs, Crystal Spring, Preston Big Spring, and at Duckwater. The circumstances at Moapa and Crystal were as discussed above. Ash Springs has an introduced population of *G. affinis.* The date of this introduction is unknown, but is later than that at Moapa, as Miller and Alcorn (*loc. cit.*) did not record mosquitofish from Ash Springs in 1946; however, they were recorded from there in 1959 by Miller and Hubbs (*loc. cit.*). Guppies were not found at Preston Big Spring, probably because its outflow drops 5 ft where it joins the small Preston Town Spring containing the guppies. *Crenichthys nevadae* was the only species obtained at Duckwater. The collecting success followed the predicted pattern: more *Crenichthys baileyi* were seined per effort involved in the absence of *G. affinis.* Quantitative data on the *C. baileyi* population density were obtained by trapping effort. Standard minnow traps baited with bread were placed in the spring pools for 15 min. Eleven traps at Moapa contained 86 *C. baileyi* or 31 fish per trap-hour. The same traps at Ash Springs contained 27 *C. baileyi*

TABLE 1. NUMBERS OF ADULT *E. latos* CAPTURED BY STANDARD MINNOW TRAPS AT MANSE RANCH. Bread used as bait except as designated.

	Trapping Time	Traps	Adults	Adults per Trap	Adults per Trap-hour	Adults Removed[3]
22–23 April 1961	1030–1930	1[1]	50	50.00	1.50	50
27 October 1961						19
30 November 1961	1515–1545	1[2] 2[1]	20 4	20.00 2.00	40.00 4.00	18
1 February 1962	1515–1545	3	12	4.00	8.00	12
10 May 1962	1000–1030					5
24 July 1962						24
21–22 August 1962	1445–0915	4	93	23.25	1.26	19
27–28 September 1962	1530–0900	2[1]	25	12.50	0.71	6
9 November 1962	0900–1000	3	86	28.67	28.67	12
6 December 1962	1200–1300	4	29	7.25	7.25	14
24 January 1963	1500–1600	5	51	10.20	10.20	23
2 February 1963	0800–0900	4	20	5.00	5.00	36
8 March 1963	0930–1100	4	5	1.25	0.80	5
11–12 April 1963	1430–1000	4	2	0.50	0.03	2
24–25 April 1963	1530–0945	4	5	1.25	0.07	5

[1] No bait.
[2] Also one grape.
[3] B. Brattstrom removed 5 in May 1962 and R. K. Liu collected and removed 19 in 12 seine hauls on 25 November 1962 (R. K. Liu, personal communication 1963).

or 10 fish per trap-hour. The difference may result from the more recent introduction of mosquitofish into Ash Springs and less time for *Crenichthys* to respond to the interspecific competition. One trap could not be located at Crystal Springs so that the 10 traps recovered contained 156 *C. baileyi* or 62 per trap-hour and 225 *C. baileyi* at Preston Big Spring or 90 per trap-hour. The greater success, 62 and 90 fish per trap-hour, in the 2 springs without *Gambusia*, than in the 2 springs with the introduced relative, 10 and 32 native fish per trap-hour, supports the hypothesis that native fishes are reduced in numbers following the introduction of exotics. The results at Preston are probably most significant in that Town Spring with guppies had fewer *Crenichthys* in the entire spring source area than were obtained in a single trap set for 15 min in a comparable area at the Big Spring, where no guppies occurred.

The introduction of goldfish at Manse Ranch also may have had an adverse effect on the resident native fish. Minnow traps have been set there to obtain specimens for life history studies on the local poolfish (*E. latos*) since April 1961 (Table 1), slightly before the goldfish were introduced. Because the collections were designed for other purposes, the collection effort varied between samples. Moreover, the trapping intervals are approximated, not precise as were those described above. It is probable that most poolfish captured enter the trap in the first hour and trapping for less than a half hour may not be very successful. Nevertheless, trapping success has been notably poor in recent months, especially since February 1963. Both fish per trap and fish per trap-hour show the same pattern. Because few adults have been observed in the pool since February, we feel that these data do not reflect trap-shy actions of the poolfish and do show a marked decline in the population. The available data do not show when the decline started, but it is possible that it occurred since November 1962.

There are at least 3 possible causes for the population decline. The first is the removal of adults for various studies by the authors. Obviously, the removal of 274 adults over a 2-year span may have depleted the population; however, adult females produce 10–30 eggs per week in the laboratory for over 2 months. If other factors were favorable, this "predation" should not have been of major import. The second is the removal of most of the previously dense floating and submerged aquatic vegetation from the spring pool between 10 May and 24 July 1962, well before the population decline became obvious. Probably the most significant ecologic change that affected the poolfish was the introduction of goldfish. The first year class of goldfish were of sufficient size in late fall 1962 to compete with the poolfish adults and perhaps eat the young. Obviously, the adverse effects of the introduced goldfish would be magnified by the vegetation removal (less primary productivity and cover for young) and removal of poolfish for our studies.

Apparently, *L. reticulatus, M. mexicana,* and *C. nigrofasciatum* have not been considered to be established in the United States as Bailey *et al.* (1960), Moore (1957), and Eddy (1957) did not record any of them. We suspect that one or more species have been established near aquarium rearing operations in Florida; however, Carr and Goin (1955) also did not list the species. Parenthetically, *X. maculatus* also is not listed in any of the above references. However, Brown (1962) recorded the presence of a relative, *X. variatus,* in Montana. We have also found Baughman's (1950) report of *M. sphenops* (perhaps = *M. mexicana*) being collected near Houston, Texas, shortly after flooding of another aquarium rearing operation; however, there is no evidence of subsequent collections of that fish near Houston.

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