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EDITORIAL

OPPORTUNITIES FOR ICHTHYOLOGICAL MUTUALISM

Martin R. Brittan

Over recent years I have received and read many bulletins put out by local aquarium societies. Most were dittoed or mimeographed and devoted to society news and notices, but many contained articles on the keeping and breeding of aquarium fishes. Some of this material was worthy of further attention by "professionals". Many of the contributors, almost all amateur aquarists, write poorly, but they are often capable people with intimate knowledge of certain fishes not possessed by ichthyologists. Much of the work goes to waste because the writers lack the training and acumen to fully appreciate and exploit their opportunities and because their hobbyist readers lack the same characteristics. As much goes unnoticed because far too many ichthyologists are too busy or too snobbish to be bothered with amateurs. Once in awhile a young aquarist develops into an ichthyologist, or a young ichthyologist begins to keep live fishes in connection with some scientific problem, and both fields consequently benefit enormously. But, in totality, this is, unfortunately, not anywhere near common enough. One group is not much involved in the problems of the other, and through lack of communication much is lost.

Many an ichthyologist looks down his nose at "naive and uneducated amateurs", and many an aquarist looks up in intimidated awe or impatient boredom at the "impractical" expert.

What all this is leading up to is a plea: Ichthyologists should not overlook the leads, clues, and genuine information which may be supplied by hobbyists or dealers who keep and breed fishes, especially those fishes that are rare, unusual, or thought to be "difficult". Botanists have been willing to learn from, and quick to give credit to, the plant breeder, agriculturalist, and even the green-thumb garden-

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er (and a lot of aquarists have the watery equivalent of a green thumb). Aquarists, in turn, should learn to write down or tape-record their observations, and, more than that, do it systematically and accurately. If they do not, facts worthy of being recorded and passed on are simply forgotten and lost either to the hobby or science. In publishing their results, even in mimeographed publications, truly pertinent information should be given. An amateur can write interestingly without being cute or coy, distractingly breezy or chatty, long-winded or irrelevant. Information can be put in a form (with the help of a better writer, if necessary) such that a serious aquarist, not to mention a scientist, will not gag on it!

There can be many dividends in increased communication and cooperation. For example, a key group in the work of fish behaviorists is, and has been for a long time, the family Cichlidae. Almost all species in this group were imported for and are still supplied by the aquarium trade. The earliest information about the group was gleaned not by ethologists but by aquarists and professional breeders. Behaviorists please note — there are several dozen other families commonly kept by aquarists.

On the other side of the coin, it should be pointed out that most of the really technical problems were, or ultimately will be, solved by experts, beginning with the fact that without the ichthyologist the aquarist would not even know what species of fishes he had in his tanks. It is, however, the aquarist who is most likely to appreciate his debt and his opportunity to learn. The ichthyologist surely has opportunities potentially as great.

THE FUNCTIONAL SIGNIFICANCE OF THE SPLIT-HEAD COLOR PATTERN AS EXEMPLIFIED IN A LEAF FISH, *POLYCENTRUS SCHOMBURGKII*

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It is the habit of illustrators of fishes to present their subjects as seen from the side. This is reasonable because fishes, being typically compressed, are most distinctive viewed in that way. Yet many fishes have markings on their heads that can only be appreciated in an adaptive context when seen from the front. Baerends and Baerends-van Roon (1950) created some awareness of this when they studied the hostile displays of cichlid fishes. They illustrated (p. 43, fig. 14) the frontal displays of certain species as they would be seen by their opponents, facing with the opercles extended; then the significance of the opercular flags as large pseudo-eyes was fully appreciated. In a similar fashion, Abel (1964) figured the masks on the fronts of the faces of various male blennies.

Many other special signals would be discovered if more fishes were viewed from the front. As an example in passing, certain surf perches (Embiotocidae) have white lower lips. When seen from the side this feature is hardly noticed. But when a school turns and faces a diver the effect is dramatic, his eye being deflected to the many white spots in the water.

The focus of this article, however, is on the striking interorbital stripe as exemplified by a South American leaf fish, *Polycentrus schomburgki* Müller and Troschel. An argument will be advanced for its function. This argument will be extended to other fishes evincing similar color patterns. Finally, some exceptions will be described.

Acknowledgments: I would like to take this opportunity to thank the people at the meeting of the American Society of Ichthyologists and Herpetologists who responded so enthusiastically (see below). For a stimulating discussion of the paper presented there I am particularly grateful to John Magnuson and Henry Feddern. Edmund S. Hobson generously made available his knowledge and photographs garnered from underwater observations. Karel Liem offered supplemental observations on the feeding behavior of another leaf fish; Thomas Frazzetta, John Mertz, and Peter Skaller read the manuscript.

The basic observations were made under the auspices of a post-doctoral fellowship (MF 8244) from the National Institute of Mental Health. This was undertaken at the Max-Planck-Institut für Verhaltensphysiologie; I am eternally indebted to Konrad Z. Lorenz who made this possible, and who inspired me to learn about the behavior of animals. The writing itself was done under the support of a grant (GB 2210) from the National Science Foundation.

MATERIALS AND METHODS: The conditions under which the *Polycentrus* were kept are of little consequence to the behavior to be described here. Suffice it to say that the fish were kept in well-planted aquaria with conditions of water, temperature, and light appropriate to their natural environment. Details can be found in another article, one dealing with the social behavior of *Polycentrus* (Barlow 1967).

This paper was presented at the annual national meeting of the American Society of Ichthyologists and Herpetologists, during June, 1965, in Lawrence, Kansas. Taking advantage of the assembled body of knowledge present in the audience, I invited further examples of the kind of color pattern to be discussed in what follows (designated *A.S.I.H.*). For some time thereafter I continued to receive comments through the mail from ichthyologists who had heard about the paper; these will be marked *pers. comm.* Recently I observed several examples at the Steinhart Aquarium in San Francisco.

OBSERVATIONS: For approximately three months the diet of the *Polycentrus* had consisted largely of small amphipods, tubificid worms, and insect larvae. There was nothing remarkable about the feeding behavior during that time. The fish simply swam to the object to be eaten, paused, fixed on it, and engulfed it.

Then the fish were fed a school of young cichlids, *Etroplus maculatus* (Bloch). These small cichlids were difficult for the *Polycentrus* to catch by comparison with their previous food items. The cichlids hid among the plants, and fled and dodged artfully when approached by the *Polycentrus*.

For the first time I observed what is evidently the full feeding response of *Polycentrus*. An idealized account follows, but it is one based on repeated observations of feeding behavior.

When hunting, *Polycentrus* drifts slowly toward its intended prey. The only moving parts of its body are the lobes of the dorsal and anal fins and the pectoral fins; occasionally the caudal fin may also contribute to the locomotion. All of these structures are transparent. As the *Polycentrus* glides toward the prey the median fins and the paired pelvic fins become fully extended. A slight partial flexing and extending of the spines of the dorsal fin can sometimes be seen. When about one to two body lengths away from its prey, the fish pauses. A slight lateral curvature forms in the region of the caudal peduncle, imparting what I have termed a sickle-shape in another article (Barlow 1961). The *Polycentrus* then darts forward, engulfing the prey if successful. The lunge finishes in a sharp turn to one side, starting at about the point where the prey is grasped. Details of the strike cannot be observed because of its extreme speed. But the mouth is apparently extended forward while the buccal cavity is expanded. In effect, the fish projects a tube toward the prey and sucks it in.

A remarkable aspect of the behavior of *Polycentrus* while hunting small fishes is the distinctive color pattern that appears. Both sexes show the color change, although the general color of the female does not become as dark as does that of the male; he often becomes nearly black while she becomes dark brown. Both sexes may show various white and black spots on this dark background (Fig. 1). The head in particular becomes nearly

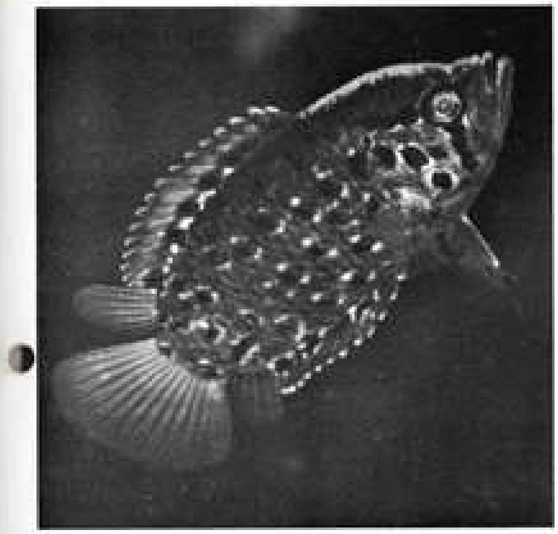

Fig. 1—Side view of a foraging **Polycentrus schomburgkii** showing the spotted pattern, the darker top of the head, and the inconspicuousness of the interorbital stripe seen from this angle. Photo by the author.

black, although the heavy black markings that run through it are still apparent. In juveniles the body may remain pale while the head darkens.

The singular feature of the color change is that which takes place on the top of the head. A cream-colored stripe develops, running from the junction of the premaxillaries, back between the eyes, and up the nape, ending at the insertion of the dorsal fin. It is narrowest, less than one eye diameter, on the snout, widening to a little more than an eye diameter on the nape. In frontal view (Fig. 2) the white stripe is continued onto the tips of the dorsal spines. The leading edges of the pelvic fins are also creamy white.

Thus seen from in front, from the prey's point of view (Fig. 3), *Polycentrus* gives the appearance of a vertical black ellipse, split by a white stripe running from its middle up to its top, and having two thin white stripes leading the pelvic fins.

DISCUSSION: More than any other single effort, Cott's book (1940) on adaptive coloration has persuaded biologists to accept the principle of disruptive coloration in animal camouflage. His arguments of interest to us on this point can be summarized in a few lines: "It is this *continuity of surface, bounded by a specific contour or outline*, which enables us to recognize any object with whose shape we are familiar." (p. 48). So if *Polycentrus* is to minimize detection by its prey, it must break up its outline in some way.

Fig. 3—Front view of a foraging **Polycentrus schomburgkii** showing the extension of the white stripe onto the edge of the dorsal fin. Photo by the author.

Fig. 2—Front view of a lurking **Polycentrus schomburgkii** moments before engulfing a young **[illegible] [illegible]** (slightly out of focus, directly before the mouth of the **Polycentrus**). Photo by the author.

Again, as Cott put it on page 52, "Broadly speaking . . . we may say that white marks on dark animals living in dark surroundings (such as forests) . . . will be the most effective in breaking up the continuity of their surface, and in masking by contrast tell-tale half-tones of surface structure and modelling." On pages 48 to 49 Cott discussed a frog (Plate 9) that has a prominent mid-dorsal stripe, in many respects the functional counterpart of the interorbital stripe in *Polycentrus*. The emphatic stripe was said to achieve its effect in three ways: (1) it stands out, detracting the eye from the profile of the frog; (2) this strong incidence of color tends to flatten the half-tones by which the frog is recognized; and (3) the stripe bisects the frog—two half frogs do not resemble a frog.

In Cott's logic, the interorbital stripe of *Polycentrus* serves to break up its characteristic frontal profile. Evidently it is an adaptation to reduce detection while slowly approaching its prey.

In addition to the frog, Cott also discussed some insects (p. 79) that employ median stripes for disruptive effects. (His comments here about coincident disruptive patterns may also be extended to *Polycentrus* but need not concern us.) In these instances there is no suggestion of camouflage for predation, but just for protection.

For the sake of economy the discussion should be confined to fishes, yet one instance among mammals is especially worth noting. Charles Long drew my attention to the case of the badger. It is a predaceous burrower (Richardson 1929) with a split-head color pattern, and one that may lie in ambush for ground squirrels (Balph 1961).

Illustrations of fishes with disruptive stripes running up the interorbital space are difficult to find, but are not rare. Not only are fishes conventionally shown in side view, but they are usually drawn from dead specimens. If the pattern is seen only in the live fish, as in *Polycentrus*, even a figure depicting the frontal aspect will be of no avail. The grass pickerel (*Esox americanus vermiculatus* LeSueur) bears a permanent split-head pattern (Crossman 1966; pers. observ.), as must fishes that retain the interorbital stripe as museum material, *e.g.*, *Acanthoplesiops indicus* (Day) (Smith 1950, fig. 409).

Longley (in Longley and Hildebrand 1941) photographed in nature two species with disruptive interorbital stripes, a trumpet fish *Aulostomus maculatus* Valenciennes, and a Nassau grouper *Epinephelus striatus* (Poey). An unidentified marine eel also has such an interorbital stripe in life (Roughly 1951, pl. 40) as does the cleaner wrasse *Labroides dimidiatus* (Clupaty 1963, fig. 3).

The presentation of this paper at the meeting of the American Society of Ichthyologists and Herpetologists stimulated the following further examples: The split-head pattern is found in the pomocentrid fish *Amphiprion akallopisus* Bleeker, and in some long-snouted chaetodontid fishes (L. P. Woods). It has also been seen (D. P. DeSilva) in the tripletail, *Lobotes surinamensis* (Bloch). Further examples are found in eelpouts of the genus *Lycodes* occurring in the Bering Sea (N. Wilomovsky), in at least three gobiesocid fishes (J. C. Briggs), and in some gobies from the Philippine Islands (G. S. Myers). Preserved specimens of a sunfish, *Pomoxis nigromaculatus* (LeSueur), have been found with a ". . . distinct brown line extending from the gular region up across the snout onto the dorsal spines. This bisecting line is not characteristic of most of the members of this species . . ." (W. H. Walker, Jr., A.S.I.H. and pers. comm.). Finally, isospondylous fishes of the genus *Dixonina* lack the split-head color pattern but do have a conspicuous pale spot on the tip of the snout which may serve a similar end (F. H. Berry).

A visit to the Steinhart Aquarium in San Francisco resulted in several variations on the same theme. In the large squirrel fish *Holocentrus spinifer* (Forskål), the forehead is lighter red than the rest of the fish and is split by a brown-red line running from the mouth to just behind the interorbital space. The split-head effect is extremely pronounced in the lobotid fish *Datnioides microlepis* Bleeker; the leading edges of the pelvic fins are white, the posterior portions black. Adults of the serranid fish *Grammistes sex-*

Fig. 4—A Nassau grouper **Epinephelus striatus**. Photo courtesy T.F.H. Pub.

Fig. 5—**Datniodes microlepis**. Photo by Peter Tsang.

lineatus (Thunberg) are black with many white stripes and lack an interorbital stripe; it is present in the younger specimens, however. A reef-dwelling jack, *Caranx* sp., has a thin but distinct median stripe starting just above the eyes and running to the top of the head; I tried to view this species head on, but the fish always dropped down and looked slightly up at me, which placed the stripe in the middle of the obliquely-presented frontal profile. Two striking examples were seen among the anemone fishes of the genus *Amphiprion*: In both species a white middorsal stripe runs the length of the orange fish; in *A. akallopisos* Bleeker the stripe starts at the mouth, but in *A. perideraion* Bleeker it starts further back at the interorbital space. The stripe bisecting the face of the long-snouted butterfly fish *Chelmon rostratus* (Linnaeus) is noteworthy for its border; the face is clear white and the stripe is gold, but set off from the white by a dark brown margin. A short but distinct split-head stripe was also observed in a pipefish *Syngnathus griseolineatus* (Ayres), a klipfish *Gibbonsia elegans* (Cooper), a file fish *Monacanthus* sp., and in an agonid fish. Among several eel blennies only one species, the pholid *Apodichthys flavidus* Girard, had a split-head pattern, a pronounced thin white line running middorsally from the mouth to the tail; the same pattern, however, was noted in another pholid, *Xererpes fucorum* (Jordan & Gilbert), seen at the Bodega Marine Laboratory of the University of California.

In most of the cases just cited the fishes are thought to be predaceous, but useful observations are not readily available. In the following some examples are given where the split-head pattern has been seen, together with observations on the feeding habits of the animals.

The feeding behavior and color patterns of another leaf fish, and a closely related one, *Monocirrhus polyacanthus* Heckel, has been described by Cott (1940: 311–313, fig. 63). Cott dwelled on the appearance of the side of this fish in relation to its hunting behavior, although the prey must view the front end of the leaf fish (pers. observ.). The side view of *Monocirrhus* in Cott shows the pale interorbital region, although he failed to mention it. Upon hearing the presentation of the paper in hand, G. S. Myers ventured the suggestion that this leaf fish may be so thin that the split-head pattern could not function because the white stripe would occupy the entire frontal aspect of the head. With this in mind I asked Karel Liem to observe his leaf fish to establish whether or not this is so. He reported that the split-head pattern operates perfectly well in *Monocirrhus*. In fact, when it feeds the head may blacken around the interorbital stripe, increasing the split-head effect, while the color of the rest of the body may remain relatively unchanged.

I have observed in a related nandid fish, *Nandus* sp., that a split-head pattern appears during feeding. *Polycentropsis abbreviata* Boulenger, is an

African nandid fish and a species that looks much like *Polycentrus*; it also manifests the split-head pattern when feeding (G. S. Myers, A.S.I.H.).

A further example is the serranid fish *Promicrops lanceolatus* (Bloch). The young are black with yellow blotches and have a pronounced split-head marking. This species has been characterized as a lurking predator (Chlupaty 1963, fig. 2).

Dermatolepis punctatus Gill is another serranid fish, having a split-head pattern (fig. 7). Hobson (pers. comm.) observed that this grouper is secretive by day but that it comes out to feed during the crepuscular periods. "It is usually active close to the bottom during these periods, yet it not infrequently ranges up into midwater. Although I have not observed this fish feeding, it is a sluggish swimmer with a manner that certainly suggests it to be a stalking predator." As in the case of *Promicrops*, the split-head pattern is more evident in the smaller fish (less than 350 mm.).

Hobson has also written to me about another serranid fish with a striking split-head pattern, the soap fish *Rypticus bicolor* (Valenciennes). It too is a stalking predator that is active primarily during the crepuscular or nocturnal periods, eating mainly benthic crabs and crustaceans, although some fishes are taken.

Still another marine fish showing the split-head pattern is the giant kelpfish, *Heterostichus rostratus* Girard (Hobson 1965, figure on p. 510). Hobson (pers. comm.) found that "*H. rostratus* stalks small crustaceans and fishes, moving very slowly and not darting forward for the capture until within a few inches of its prey."

The sternarchid fish *Apteronotus albifrons* (Linnaeus) is a velvety black animal having a creamy white stripe running dorsally from the snout back about one-third of the body length (pers. observ.). It is nocturnal, perhaps crepuscular in habits, feeding on small fishes, shrimp, and insect larvae (Walker 1965).

These examples, coupled with the observations on *Polycentrus* and *Nandus*, led me to believe that fishes with a disruptive interorbital stripe might be characterized collectively as lurking or slow-moving predators. This generalization, however, had to be modified in light of a report by Magnuson and Prescott (1966; my thanks to them for sending the unpublished manuscript).

Part of their study dealt with the bonito, *Sarda chiliensis* (Cuvier), a schooling pelagic fish. When fed, the bonito manifests 9 to 10 vertical black bars on the body. More germane, a prominent yellow stripe appears extending from the tip of the snout to the base of the first dorsal fin. Nakamura and Magnuson (in Magnuson and Prescott) have observed nearly the same color change in the skip-jack tuna, *Euthynnus pelamis* (Linnaeus). In both of these oceanic species the bars and the interorbital stripe fade as the animals finish feeding.

The male bonito also expresses these body bars and the interorbital stripe when engaging with another male in lateral display, a hostile act, or when maneuvering to spawn with a female. It is important to note here that bonito do not display frontally, probably because they cannot back up well.

Nakamura, Magnuson, and Prescott all endorse the idea that the primary signal value of this color change relates to hostile and spawning behavior. But they suggest it may have acquired the secondary significance of indicating the presence of food.

The bars may communicate something in a school of bonito, whatever the message sent. That the interorbital stripe has signal value, however, is unlikely. Seen from the side, as it must be most of the time by other bonito, it is a poor signal; its effect is only to flatten the head slightly. It must be viewed from in front to be of use, and only the prey regularly sees this aspect of the bonito. The split-head color pattern of the bonito probably serves to disrupt its frontal profile, just as it does in *Polycentrus*.

If this is so, then why does the interorbital stripe appear when the bonito is involved in social, nonfeeding behavior? The reason might be that this is the simplest solution for the bonito. Any major arousal could activate the color change, only one kind of change being necessary. Since the interorbital stripe is not seen well, it is of little consequence in intraspecific interactions.

Now in *Polycentrus* a similar situation prevails. When spawning they develop the interorbital stripe, strikingly so in the female. This, too, could be accounted for by general arousal. But when two males fight, the inter-

Fig. 6—*Promicrops lanceolatus.* Photo by H. Hansen.

Fig. 7—*Dermatolepis punctatus* in its lair. Photographed by E. S. Hobson near La Paz, Baja California.

orbital stripe is lacking, the space being darkly colored as is the rest of the "face."

The explanation is that *Polycentrus* engages in frontal displays when aggressive. A distinctive intraspecific signal, in this case the head plus extended opercles, should be relatively solid in color to emphasize the profile, and/or have an uninterrupted profile. An interorbital stripe would work against this because of the splitting of the head and disruption of the profile.

The spawning female, who must swim toward the male, takes advantage of the interorbital stripe to avoid the hostile signal that the uninterrupted face conveys. Similarly, the various female toothcarps of the genus *Cyprinodon* show a split-head color pattern in the context of sexual or aggressive behavior (R. K. Liu, pers. comm.).

Another indication of the role of arousal lies in the closer observation of feeding behavior. It is only when the prey is difficult to capture, or the *Polycentrus* very hungry, that the interorbital stripe appears. When they have been fed small fish a few days in a row, the stripe is turned on as the feeder enters the aquarium room. But lest the point be made too strongly, recall that arousal involving aggressive behavior inhibits the appearance of the interorbital stripe.

Thus the contrast-rich interorbital stripe, the split-head color pattern, seems to characterize certain predaceous fishes, particularly those lying in ambush. In some it occurs only when foraging. In others it is a fixed part of the color pattern.

This discussion of the split-head color pattern would be incomplete if I did not point out some exceptions. There are fishes possessing such a color pattern that one would not ordinarily conceive of as being predators. One of the best examples is presented by the browsing marine angel fishes. Henry Feddern (A.S.I.H.) has pointed out to me this remarkable exception, based on his studies of these fishes in the Caribbean Sea. In *Pomacanthus paru* (Bloch) yellow encircles the mouth, then runs up from the circle through the interorbital space back onto the nape, reaching the insertion of the dorsal fin; the background color is dark brown or blue. In *P. arcuatus* (Linnaeus) there is also a yellow circle around the mouth; similarly a stripe runs up from the circle between the eyes and back to the insertion of the dorsal fin; but the stripe also extends ventrally along the chin. Juvenile fishes of this genus feed on sponges and algae; they are blue with a yellow split-head pattern. When either the juveniles or adults are approached they tend to face the intruder. Thus while they may not be using the split-head pattern as a concealment device to allow them to approach prey, they may be using it to permit them to look directly at a potential predator while making themselves more difficult to locate visually.

I have observed another interesting exception in the loach *Botia horae* Smith. This is a pale-colored fish with a black line running from the tip of the snout back along the entire dorsal surface, curving down along the insertion of the caudal fin, and terminating at the ventral surface of the caudal peduncle (Sterba 1962, fig. 452). Seen from in front, the fish has a split-head pattern. Seen from the side, it has a black line at the base of the short dorsal fin and a black bar along the base of the caudal fin. The habits of the fish could be summarized as follows: It nibbles on plants and along the bottom, probably finding its food largely by virtue of the taste buds on the small barbels around the mouth. Prepared commercial fish food is taken visually, however, as it falls through the water. It is a fish that might be characterized as an active, nervous swimmer, but it is not a lurking predator. On the other hand, it frequently chases and apparently disturbs large fish in an aquarium. It is also vicious in the way it persistently attacks members of its own species. Conceivably, it could be nipping mucus from large fishes, although I doubt this. Perhaps more significant, the snout is long and relatively flat. The fish is mostly on or near the bottom. Thus the split-head effect could be part of a more general pattern which is to bisect the fish altogether when seen from above. (*Anableps dowei* Gill is a dark fish with a pale middorsal stripe running from the back of the head to the tail; living just under the water surface, it would often be seen from above by potential predators such as birds.) The black at the insertions of the dorsal and caudal fins of *B. horae* probably serves in species recognition.

The pomacentrid fishes of the genus *Amphiprion* do not fit the scheme of a lurking predator. While carnivorous, they tend to hover, dart and turn, occurring together in small groups in the open. The clue is that the several species differ most immediately in the distribution of a few bold white marks on an orange to brownish background. The number of possible placements of these few white marks on the sides of the bodies of the species must reach some limit set by the abilities of the species to distinguish them. Having a white stripe in the middorsal area increases the number of possible combinations. Since members of the species move slowly, hovering and facing one another, recognition from the front presents no problem. A parallel pattern of species-specific markings can be seen in the white discs on the foreheads of pomacentrid fishes of the genus *Dascyllus*; they are remarkably similar in behavior.

Two further comments need to be made. The first is to point out that in three serranid fishes (*Grammistes sexlineatus*, *Promicrops lanceolatus*, and *Dermatolepis punctatus*) the young animals have the split-head pattern while it is lacking in the adults. Knowledge of any associated change in feeding habits would illuminate the significance, or lack of it, of the split-head pattern in these fishes.

The final comment is to draw attention, though fleetingly, to the problems of phyletic and ecologic correlations. Why is it that some kinds of ambush predators are not known to show the split-head pattern? A good example is the large genus *Sebastodes*. I suspect this is simply another example of different phyletic groups having different solutions to the same problems. Also, other considerations may prevail, such as species recognition. It is also my impression that the split-head pattern is more widely distributed among marine fishes than among freshwater fishes. This may be no more than a consequence of the great species diversity of the tropical shore fishes.

In conclusion, whenever the typical thin splitting coloration is seen, one can probably be safe in assuming first that it is for the purpose of concealment. When this is on the front end of the fish, chances are that the fish is a predator, and more likely of the lurking, ambush type than an active feeder such as the bonito. In some instances, a fish will have a split-head color pattern in order to observe a potential predator while remaining unseen. In a few species it may even be important as an intraspecific signal. And finally, some fishes, and particularly those that tend to feed on the bottom or near the surface in open areas, may have a dorsal line splitting them along their length to better conceal them.

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Fig. 1—A rare deepwater hawkfish, *Oxycirrhites typus*, found in Hawaii. This specimen was photographed in an aquarium after being captured alive at a depth of 120 feet. Many Cirrhitidae exhibit this characteristic pose of resting on the pectoral fins. Photo by R. A. [illegible], Jr.

A RARE HAWKFISH *OXYCIRRHITES TYPUS* BLEEKER FOUND IN HAWAII

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Two specimens of the long-snouted hawkfish *Oxycirrhites typus* Bleeker, never collected previously in Hawaii, were obtained in July, 1961. These two cirrhitids were collected alive from 120 feet of water off Maili Point, Oahu, Hawaii. They were observed resting on the branches of a "black coral" tree *Antipathes grandis* Verrill (Class Anthozoa, Subclass Zoantharia, Order Antipathidea).

The genus *Oxycirrhites* previously had been divided into three species, *Oxycirrhites typus* Bleeker, *O. morrisi* Fowler, and *O. seftoni* Böhlke and Briggs on the basis of color pattern, preopercular serrations, pectoral ray combinations, and comparative lengths of spines. Randall (1963), however, resolved the genus to a single species, *O. typus*, the type locality of which is Amboina, East Indies. Other localities are Sumatra; Philippines; Mauritius; Baja, California; Panama; and Gorgona Islands, Colombia. The two speci-

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[1] Our gratitude is extended to Dr. John E. Randall, Director of the Oceanic Institute for his suggestions concerning the preparation of this manuscript.

mens collected (and here reported) by the authors, therefore, represent not only the first record for the Hawaiian Islands but for all of Oceania.

Taxonomic notes of the two Hawaiian specimens are presented below:

Specimen I (Bernice P. Bishop Museum No. 5557)

Standard length 100 mm; sex female; dorsal rays X, 13; anal rays III, 7; pectoral rays right side ii, 7, v; left pectoral rays ii, 6 vi; second lower unbranched pectoral ray equal to snout; second lower unbranched pectoral ray longest on left side; first unbranched pectoral ray longer on right side; lateral-line scales 51 or 52; large scale rows above lateral line 4; large scale rows below lateral line 10; tenth dorsal spine much shorter than 3rd dorsal spine; second anal spine equal to postorbital part of head and ½ eye; preopercular serrations 20 left side, 23 right side. Body length 4.2 in standard length; snout length 1.9 in head length.

Specimen II (Bernice P. Bishop Museum No. 5593)

Standard length 83 mm; sex undetermined; dorsal rays X, 13; anal rays III, 7; pectoral rays ii, 7, v (both sides); lateral-line scales 51 or 52; large scale rows above lateral line 4; large scale rows below lateral line 10; tenth dorsal spine much shorter than 3rd dorsal spine; second anal spine equal to postorbital part of head and ½ eye; preopercular serrations 16 left side, 18 right side. Body depth 3.8 in standard length; snout length 1.8 in head length.

The taxonomic characteristics of the Hawaiian specimens fall within the range of *Oxycirrhites typus*. Variations were noted in the number of preopercular serrations between the right and left sides of both fish and also between the two specimens themselves. The combination of branched and unbranched pectoral rays differed also between the right and left side in specimen number I. This demonstrates that these characteristics cannot be relied on to distinguish one species from another.

Oxycirrhites typus is apparently a deep-water tropical species living in waters ranging from 55 to 318 feet in depth. Four other specimens have been observed in Hawaiian waters. Brock, Fujimura, and Takata observed a specimen resting in black coral in 90 feet of water off Lahilahi Point, Oahu in 1957. This is probably the earliest sighting recorded for the species in Hawaii. Three specimens have been sighted since then in 180 feet of water off Waikiki, Oahu. Two of these were observed resting on the branches of "black coral" trees and a third was living within the wreck of a small boat. The Hawaiian observations indicate that this long-nosed hawkfish has an affinity for the black coral growth either for protection or concealment.

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SULFAMERAZINE RESIDUES IN TROUT TISSUES

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In the trout industry, sulfamerazine has been used primarily to control furunculosis. However, it is useful as a prophylactic treatment against kidney disease (*Corynebacterium*) and has been reported to be of help in the control of some *Aeromonas*, *Pseudomonas* and *Columnaris* infections.

A review of the literature concerning the use of sulfamerazine for the treatment of disease in trout revealed a lack of the tissue residue data necessary for approval of the drug by the Federal Food and Drug Administration (F.D.A.). Snieszko and Friddle (1951, 1952) have shown that sulfamerazine concentrations drop rapidly in trout tissues when the drug is removed from the diet. However, these studies were not carried much beyond the point where the drug concentration fell below the minimum therapeutic level. Therefore the Eastern Fish Disease Laboratory and the Wisconsin State Conservation Commission conducted a series of experiments to fill this gap in the information required by the F.D.A.

METHODS

Rainbow, brook, and brown trout were randomly selected from the production stocks at the Leetown and Bowden National Fish Hatcheries (W. Va.) and the Nevin State Fish Hatchery (Wisconsin).

Rainbow and brook trout tests were carried out at 54°F. constant temperature (Leetown) and 45°F. average temperature (Bowden). Tests with brown trout were carried out at 50°F. constant temperature (Nevin) and 45°F. average temperature (Bowden) (table 1).

Sulfamerazine was fed in pelleted diets to all test fish except the Wisconsin brown trout. These fish had to be put on a medicated meat-meal mixture when they refused to eat the medicated pellets. The medicated pellets were prepared by coating commercial pellets with a slurry of sulfamerazine in hot (120-140°F.) 4% gelatin-water. The dosage rate was 10 grams per 100 pounds of fish per day. The medicated food was fed for 14 consecutive days with the exception of one lot of Wisconsin brown trout fed only 12 days and the brown trout at the Bowden National Fish Hatchery which were

TABLE 1. A listing of the hatcheries where tests were conducted, the species of fish and their age, and the water temperature.

	Test number	*Species*	*Water temperature*	*Age (months)*
Eastern Fish Disease Laboratory, Leetown, West Va.	1-5	Rainbow trout	54°F. (12°C.) constant	15
		Brook trout		15
	1-8	Rainbow trout	54°F. (12°C.)	18
		Brook trout		18
Bowden National Fish Hatchery, Bowden, West Va.	1-9	Rainbow trout	45°F. (7.2°C.) average	17
		Brook trout		16
		Brown trout		15
Nevin State Fish Hatchery, Madison, Wisconsin	1	Brown trout	50°F. (10°C.) constant	8
	2	Brown trout		8
	3	Brown trout		10
	4	Brown trout		10

fed on a three-days-on and three-days-off schedule during the 14 days. All feeding was on a free choice basis.

Controls fed non-medicated diets were carried in all tests.

The tissue residue analyses were done by one of the following methods depending on the expected amount of drug and the laboratory doing the analyses.

Modified Bratton and Marshall clinical method (1939)

The tissue is extracted with and diluted 1 : 20 with water, the protein precipitated with trichloroacetic acid, and color developed with N-(1-Naphthyl)-ethylenediamine. Because the sample is diluted only high tissue concentrations of drug can be measured by this procedure. Values below 10 ppm would be questionable.

Modified Goth clinical method (1942)

This is a modification of the Bratton and Marshall method. Acetone replaces the water for extraction of the drug. The use of acetone allows concentration of the sample and, consequently, analysis of lower tissue concentrations is possible.

Modified Mooney and Pasarela analytical method (1964)

This method employs an ion exchange column to remove interfering tissue constituents which react similar to sulfonamides. Color is developed as in the Bratton and Marshall method. A minimum of 2.5 micrograms of a sulfonamide can be accurately determined. However, a 25-gram sample is necessary.

RESULTS

The several experiments, reported here, provided data from rainbow and brook trouts at two temperatures but only one age group. The brown trout experiments provided two age groups in addition to the two temperatures.

As a rule, in all three species, the highest levels of sulfamerazine were found in the liver, with kidney, blood, and muscle following in that order. These results are similar to those reported by Snieszko and Friddle (1951, 1952) although they found the blood levels to be slightly higher than the kidney levels.

The three trout species presented a very similar pattern of drug elimination. Withdrawal of the drug from the diet resulted in a rapid decrease of the drug levels in all tissues to a relatively low range of values within 7 to 10 days. However, residues were present for a considerable length of time thereafter (figs. 1, 2, 3).

The comparison of figures 1, 2 and 3 indicates that the rate of elimination of sulfamerazine from brown trout muscle was slower at 45°F. than at 50°F., but indicates little difference in the rates of elimination from rainbow and brook trout muscle at 45°F. and 54°F.

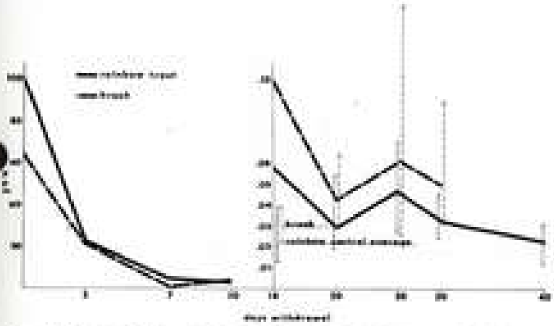

Fig. 1—Average total (free & bound) sulfamerazine levels in the muscle of rainbow and brook trouts post treatment. Water temperature 54°F (12°C). The vertical bars indicate the range of values. Test 1-8 Leetown Hatchery.

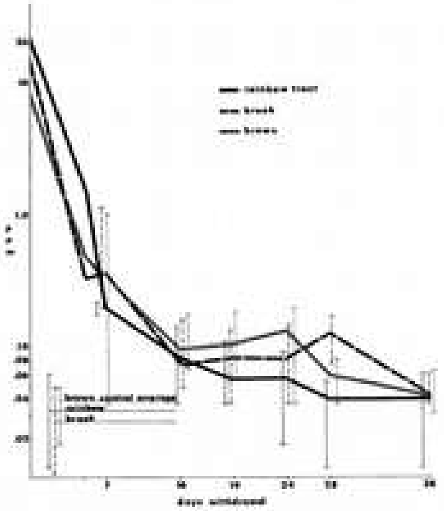

Fig. 2—Average total (free + bound) sulfamerazine levels in the muscle of rainbow, brook and brown trout post treatment. Water temperature 45°F (7.2°C) average. The ordinate scale is logarithmic. The vertical bars indicate the range of values. Test 1-9 Bowden Hatchery.

Rainbow trout and brown trout acetylate (bind) only small amounts of sulfamerazine whereas the brook trout acetylate large quantities, especially in the liver (table 2). The levels of acetylated (bound) drug drop as rapidly as the free drug levels after withdrawal of the drug.

DISCUSSION

Broadcast feeding (free choice) results in uncontrolled consumption of feed and, hence, drug. This, plus the probable uneven distribution of drug in the feed results in a wide range of drug levels among individual fish at any one time.

The validity of the temperature effect on the rate of elimination of sulfamerazine from brown trout muscle shown by the data is open to question.

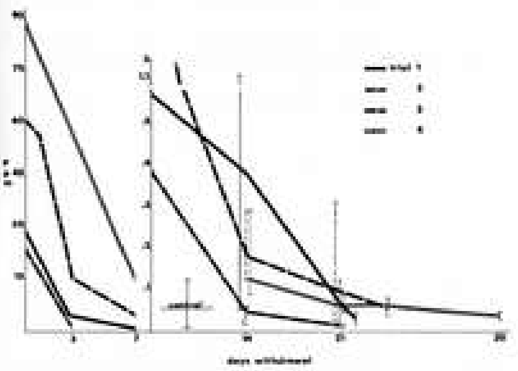

Fig. 3—Average total (free + bound) sulfamerazine levels in the muscle of brown trout post treatment. The vertical bars indicate the range of values. Trials 1, 2, 3, 4 Nevin Hatchery.

This difference in the rates of elimination may have been the effect of age rather than temperature. One generally assumes that, within limits, the younger a fish the higher is its rate of metabolism. Theoretically, the rate of metabolism governs the rate of drug elimination. The age of the brown trout used in these two experiments differed by seven months. This age difference may have been sufficient to cause a significant difference in the rate of metabolism and thus drug elimination.

The procedures used at high levels in the two tests for the tissue analyses were not identical. Recovery data (tables 3, 4) from samples of muscle with a known drug content indicates that the modification used in the Wisconsin tests had a lower recovery rate (average 72%) than the method used in the West Virginia tests (average 82%). This apparent difference in accuracy may have contributed to the difference in elimination rate shown.

Figures 1 and 2 show an increase in muscle residues for all three species at both temperatures about 25 days post treatment. This could represent a procedural error but tests 1-8 and 1-9 were analyzed six months apart. Identical errors are unlikely. This apparent increase probably represents

TABLE 2. Percentage of total sulfamerazine acetylated (bound).

		Tissue		
Species	*Blood*	*Liver*	*Muscle*	*Kidney*
Rainbow	11.06	30.53	28.40	14.93
Brook	32.53	60.58	23.19	33.59
Brown	2.52	11.60	2.96	8.77

TABLE 3. Validation of methodology, recovery of sulfamerazine from fortified rainbow trout muscle samples. (Modified Mooney-Pasarela performed by the Diablo Laboratories.)

ppm Added Sulfamerazine	*ppm Total Sulfamerazine Recovered*	*Percent Recovery*
0.05	.035	70
0.05	.047	94
0.10	.090	90
0.10	.072	72
0.20	.170	85
0.20	.176	88
1.00	.835	83
1.00	.799	80
		Ave. 82.75

TABLE 4. Validation of methodology, recovery of sulfamerazine from fortified brown trout muscle samples. (Modified Mooney-Pasarela performed at Nevin State Fish Hatchery.)

Micrograms Added Sulfamerazine	*Micrograms Total Sulfamerazine Recovered*	*Percent Recovery*
10.0	8.15	81.5
20.0	12.96	64.8
30.0	21.29	70.9
		Ave. 72.4

the release of drug from a small storage pool in the visceral fat. Unfortunately, this could not be verified since the visceral fat was not analyzed due to the sampling difficulties involved. Plasma protein bound drug is not a likely source since such binding is not particularly strong and the data (table 2) show only brook trout bind a significant amount of sulfamerazine. The liver does not appear to be a source since composite liver samples presented a similar increase.

The fact that the sulfamerazine levels in the blood and the kidney drop as rapidly as the levels in the other tissues leads to the speculation that sulfamerazine may be eliminated primarily across the gills of trout rather than through the kidneys as in mammals.

In brief, it was found that:

Sulfamerazine residues approach zero in rainbow trout muscle between 20 and 30 days after withdrawal of the drug from the diet.

Sulfamerazine residues approach zero in brook trout muscle between 30 and 40 days after withdrawal of the drug from the diet.

Sulfamerazine residues approach zero in brown trout muscle between 20 and 40 days after withdrawal of the drug, depending on the temperature. This is assuming the temperature difference shown by the data is valid. If it is not, zero residue may be reached between 20 and 30 days as with the rainbow trout.

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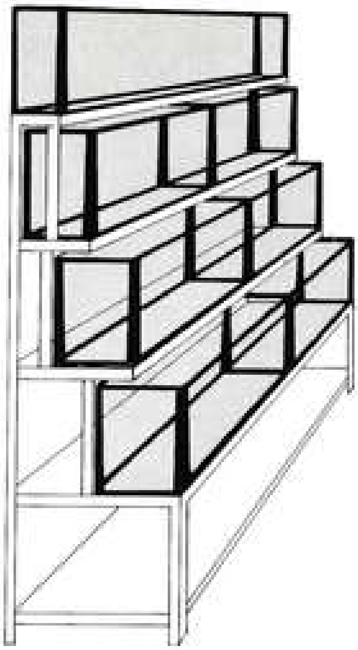

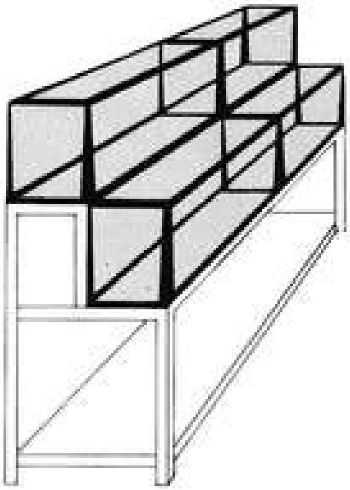

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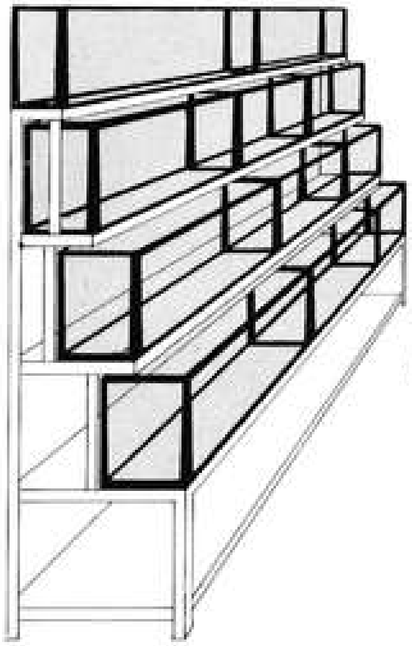

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THE DEATH VALLEY FISHES— AN ENDANGERED FAUNA

Martin R. Brittan

One of the features of modern times has been the widespread alteration, replacement, extirpation, and extinction of existing native biotas through the direct and indirect activities of man. Countless examples may be found among fish faunas, resulting, as with terrestrial faunas and floras, from simple human predation (hunting, fishing, or trapping), destruction of the habitat (irrigation, farming, logging, construction work), or introduction of competing species, either domesticated (sheep and cattle) or wild (game and non-game birds, mammals, and fishes).

Some of the examples are well known, such as the destruction of the virgin Great Lakes forests by overlogging; others are obscure, such as the present case. Some are widespread, occurring over vast areas, such as the near extinction of the bison; others are limited to small areas, as with the Everglades Kite, or the present case. Some are complex, such as the decline of native fishes, both primary and anadromous, in the waters of the Sacramento-San Joaquin river systems; others are relatively simple, as in the present case: the threatened total extinction of five species of cyprinodont fishes in the Death Valley region of California and Nevada (and of a subspecies of a more widely spread cyprinid species).

The "Death Valley ichthyofauna", as we may call this assemblage, is limited to three species of *Cyprinodon* in the Amargosa River drainage of Ash Meadows and Death Valley, two species of *Empetrichthys*, one in Ash Meadows and one in adjacent but unconnected Pahrump Valley, and the cyprinid, *Rhinichthys osculus nevadensis* in Ash Meadows.

Empetrichthys is apparently a relict genus, perhaps derived in late Miocene or early Pliocene times from a species of *Fundulus*, while *Cyprinodon* probably penetrated into the area from the Colorado River drainage during he Pliocene. It is presumed most of the speciation has been Pleistocene and Recent. *Rhinichthys* may have entered from the Colorado basin during Pluvial times. The taxonomic and zoogeographic aspects of the Death Valley chthyofauna have been dealt with by Miller in a classic study (1948, 1950).

The species in question are normally threatened by the progressive dessication of bodies of water in arid climates; the lake and river systems in his part of the world have steadily shrunk since the last Pluvial period, nd the forms are probably "on borrowed time" as it is, so it seems a double rime that man is hastening their extinction a hundred-fold.

Miller (1961: 394–8) gives seven factors in the depletion and extinction of he fish fauna of the southwest: (1) destruction of vegetation, (2) irrigation nd dams, (3) mining operations, (4) depletion of ground water, (5) intro-

Fig. 1—Deep Spring on Tubbs Ranch, Ash Meadows, Nevada.

Fig. 2—Pond at Tubbs Ranch, Ash Meadows.

duction of exotics, (6) chemical treatment, and (7) changing climate. Industrial pollution is discussed under mining operations; it and pollution by domestic sewage, pesticides, and similar agents are bound to increase alarmingly in the future. The Death Valley ichthyofauna has been affected by only a few of these, but added to them must be the threat of vandalism.

In December, 1964, Dr. John Mizelle and I examined the status of the fish faunas in a number of springs, ditches, and creeks in Ash Meadows, Pahrump Valley, and Death Valley. In Ash Meadows we found that Deep Spring, on the property of Robert M. Tubbs, still had a good population of *Cyprinodon nevadensis mionectes*, as did the irrigation ditch leading from it, but in both environments the black molly, *Poecilia latipinna* (formerly known as *Mollienisia latipinna*) was present. In the spring, on the day we examined t at least, the mollies outnumbered the pupfish about three to one; in the ditch there was about a 60–40 ratio in favor of the mollies, the *Poecilia* occupying the middle and upper levels, with the *Cyprinodon* occupying the bottom. Approximately two miles downstream where the irrigation ditch passes adjacent to Tubb's ranchhouse, the ditch possesses an additional exotic, *Gambusia affinis*, the mosquitofish, which far outnumbers both *Poecilia* and *Cyprinodon*; the mosquitofish had not, as of the date of our visit, migrated up the ditch to its source in Deep Spring. A farm pond immediately south of the ranch-house contained an extremely heavy population of *Gambusia*, a small population of mollies, and a very small number of *Cyprinodon*, in a rough proportion of 1000:20:1. There are now black bass n Crystal Spring (R. R. Miller, 1966, *in litt.*). A good population of *Cyprinodon nevadensis* survives below the main spring, and, according to James Deacon (1966, *in litt*), the Nevada Dept. of Fish and Game has plans to eradicate the bass and allow the pupfish to reestablish themselves.

We did not examine other springs in Ash Meadows, but we fear the eventual contamination of all of them. Mr. Tubbs informed us that the exotic fishes appeared about a dozen years ago in the case of *Gambusia* and ive or six years later in the case of *Poecilia*; he was unable to tell us how they got into the ditch or spring. In his opinion, the pupfish are steadily losing ground, though less rapidly than at first; this is probably because the two exotic poeciliids are not actively competing in the bottom environment. It eems unnecessary to point out that the introduction of any bottom-adapted fish in such a limited environment may quickly wipe out the surviving reduced *Cyprinodon* population.

Deacon adds further that the molly was also in Point-of-Rocks and Deep Spring, and associated ditches, in 1961, and had reached Jackrabbit (Eagle) Spring by 1965, probably by human transferrence, since the outlet is so swift.

A representative of a hatchery in Santa Ana, California, was to have visited Ash Meadows in early April, 1966, to stock aquarium fish and make

Fig. 3—Seining in ditch leading from Deep Spring on Tubbs Ranch.

Fig. 4—Overflow ponds adjacent to Saratoga Springs, Death Valley National Monument, California.

preliminary plans for buying land to be used for a wholesale hatchery operation. Dr. Deacon contacted Nevada Fish and Game, who at least temporarily stopped the stocking, but the company apparently still plans to set up the hatchery.

Another endemic cyprinodont, *Empetrichthys merriami*, known only from Ash Meadows, may now be virtually extinct. We observed a single, goldfish or pale yellowish fish in Deep Spring, about the size of a large *Cyprinodon* and more elongate, but it was too deep for positive identification; however, we are certain that it was neither a pupfish, molly, mosquitofish, *Rhinichthys osculus nevadensis* (of which we observed a single example), or goldfish or other familiar species. However, Deacon has trapped extensively in Deep Spring without turning up any *Empetrichthys*, especially in 1963, 1964, and 1965. Traps were very successful on *E. latos* in Pahrump Spring. Crayfish are probably predators on *Empetrichthys*, since both are generally bottom dwellers. Deacon has also seen crayfish take *Cyprinodon*. *Empetrichthys merriami* was apparently excessively rare even before the white man came to Ash Meadows, the last capture being in 1957 (Miller, 1950:158), but the ntroduction of exotics will likely hasten total extinction, even if this has not already occurred.

The population of *Cyprinodon nevadensis nevadensis* in Saratoga Spring near the southern border of Death Valley National Monument appears normal, but the presence of a half-used box of laundry detergent near the wooden dock would indicate that the chance of this spring being contaminated is not at all remote. The area is surprisingly heavily-used by tourists (generally several camping parties per night, concentrated near the spring), but because of its remoteness from monument headquarters is only infrequently supervised by Park Service rangers. The removal of *Ceratophyllum* by campers (swimmers) may be ecologically important. The *Cyprinodon* population in the overflow lake is high, fortunately.

Devils Hole, a deep isolated spring on the edge of Ash Meadows, is encompassed in a separated segment of the monument, and was at the time of our visit protected by a stout wire-mesh fence with a steel gate with a padlock and chain. The total population of *Cyprinodon diabolis* is restricted o Devils Hole, and fluctuates between perhaps 100 and 500 individuals. While the population was in good condition, numbering, we estimated, about 350 (in January, 1966, Miller estimated the population at about 200), here were evidences of human disturbance. The chain on the gate had been cut and several dozen photographic flashbulbs and tin cans floated in the water. A piece of sounding line arched into the depths. Several months ater, two scuba divers drowned in Devils Hole. It is my understanding that ince then the monument authorities have planned to roof over the entire area with heavy wire screening.

Fig. 5—Devils Hole (beyond sign), Death Valley National Monument, Nevada.

Fig. 6—Explanatory sign at Devils Hole.

Fig. 7—Devils Hole, Death Valley National Monument, Nevada.

The Devils Hole population could easily be destroyed by introduction of exotic species or by accidental or deliberate vandalistic contamination by pollutants. The Park Service is making great efforts to save this species, but any form existing in such small numbers in such a restricted environment is threatened sufficiently by nature without the presence of so potentially destructive a factor as man.

The population of *Cyprinodon salinus* in Salt Creek is probably safe from man, since there are no campgrounds nearby and the creek has an appreciable flow; however, a trail runs alongside, so there is always the possibility of accidental or deliberate contamination. The Pupfish Slough population is presently isolated and safe from man. However, both populations are threatened by long-term progressive aridity, since Salt Creek is live for only a few hundred yards and is, in most places, only two or three feet wide and a foot or so deep, while Pupfish Slough, though several acres in extent, is only a few inches deep in most places.

In Pahrump Valley, where most of the cotton in Nevada is grown, *Cyprinodon* is absent. *Empetrichthys latos* is restricted to three localities in he valley, each supporting a distinct subspecies. *Empetrichthys latos latos*

Fig. 8—Entrance to Devils Hole.

Fig. 9—Salt Creek, Death Valley National Monument, looking downstream (south).

occurs in the main spring pool at the Manse (Bowman) Ranch, where the population was estimated at 200 by Deacon in April, 1965 (*in litt.*, 1966) and by Miller (*in litt.*, 1966) as "pretty good." This pool is heavily contaminated with goldfish, *Carassius auratus*, which had been introduced to the pool several years previously by ranch employees (according to the employees). The Manse Ranch situation is discussed in considerable detail by Deacon, Hubbs, and Zahuranec (1964: 384-8). Two other subspecies of *Empetrichthys* are now extinct. *Empetrichthys latos pahrump* had disappeared with the drying up of a spring-fed ditch on the Pahrump Ranch, and *Empetrichthys latos concavus* with the going-dry of Raycraft Springs. Both events were supposedly connected with well-drilling operations (verbal communication with Mr. Frank Warner, foreman of Pahrump Ranch, who informed me that both of the springs and the irrigation ditch went dry after another landowner apparently accidentally drilled through an impervious bed underlying an aquifer; the owner at Raycraft Springs, however, told Deacon that he filled in the spring because, about 1957, he got tired of mosquitoes).

It appears to the writer that while accidental damage to fish faunas in the course of human activities of a "constructive" nature (such as the above well drilling, irrigation, dam building, insect control, etc.) are unfortunate enough, but the accidental or deliberate introduction of exotics is especially deplorable. Such introduction represents gross thoughtlessness, to say the least, ranging on through irresponsibility to downright selfishness and malice. When done by a government agency, with intelligent forethought, should the results not be as planned, it can be considered as simply unfortunate; when done by individuals with no thought to the future, it can be regarded as completely irresponsible, and in some cases downright criminal.

The introductions of exotics fall mainly into the following categories: (1) introduction of game or forage fish, or fishes for insect control, by government agencies; (2) introduction of aquarium or pondfishes by aquarists or pond-keepers, either to avoid the necessity of destroying them or to create a natural stock for subsequent exploitation; (3) accidental escape into new waters from the place of initial introduction. The initial introduction of the mosquitofish may be due to either of the first two factors, that of the molly is almost certainly due to the second (as is that of the goldfish).

Aquarists and live fish dealers are presently agitated over the action of fish and game authorities in several states in seeking and obtaining legislation making illegal not only the planting of exotic fishes except by constituted authorities (the fish and game agencies themselves), but also the importation and even the keeping of certain species. They are in large part responsible for their own dilemma, since in carelessly allowing exotics to

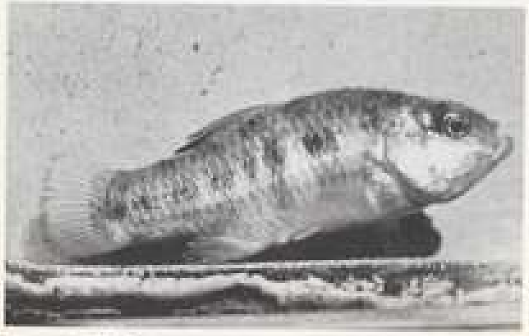

Fig. 10—**Cyprinodon n. nevadensis**, male, from Saratoga Springs.

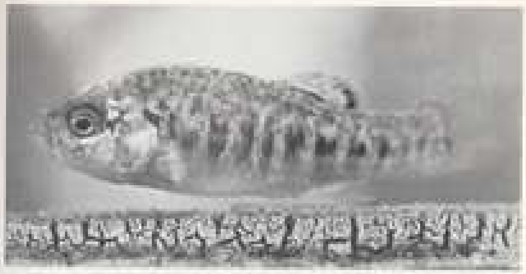

Fig. 11—**Cyprinodon n. nevadensis**, female, from Saratoga Springs.

Fig. 12—**Cyprinodon diabolis**, male, the Devils Hole pupfish (note the absence of ventral fins in this species).

Fig. 13—**Cyprinodon salinus**, the Salt Creek pupfish, probably a subadult female.

›r in dumping them into native waters to avoid the trouble of properly
ng of them, they are damaging native and long-existing introduced
and forcing conservation agencies to react against the threat. The
re is full of examples of the introduction of exotics, and the results
een as often harmful as beneficial by human standards, but to the
faunas affected the results have almost always been deleterious. In
here exotics are introduced into a large resilient fauna the results
serious, but where the introductions are into a depauperate fauna
ng of highly specialized species with low ecological valences, the
e can only be disastrous. The near-total depletion, extirpation, or
on of the existing fauna can be regarded as particularly tragic when
emblage is as restricted and unique as is the fish fauna of the Death
region.

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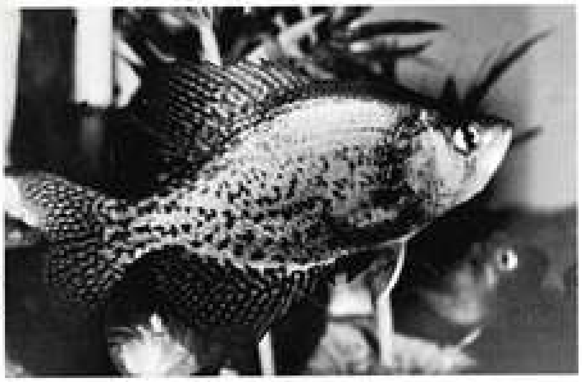

Fig. 1—A black crappie, *Pomoxis nigromaculatus*. Photo by Al Giddings.

OBSERVATIONS ON THE FOOD HABITS OF ADULT BLACK CRAPPIE IN A CALIFORNIA LAKE

Robert N. Lea
Wildlife-Fisheries
Museum of Vertebrate Zoology
University of California, Berkeley

The stomach contents of 31 adult black crappie, *Pomoxis nigromaculatus*, were analyzed by the gravimetric and the frequency of occurrence methods outlined by Lagler (1956). These fish were collected by standard angling methods at Kelly Lake, 2 miles east of Watsonville, Santa Cruz County, during late March and early April of 1964. The fish varied from 155 to 260 mm in standard length and 141.9 to 496.9 g in weight, with mean values of 191.5 mm for length and 240.0 g for weight. All fish were in prime spawning condition. Coefficients of condition, *K*, were calculated for all specimens. An average *K* value of 3.36 indicated their excellent state, with values ranging from 2.77 to 3.88.

Of the 31 stomachs examined, 24 contained food items. Entomostraca were found in 21 of the 24 stomachs and composed 95.0 percent by weight of all food taken. Of the two organisms recognized as entomostraca, a cladoceran (*Daphnia sp.*) represented approximately 90 percent of the diet, and a copepod of the genus *Diaptomus* comprised the other 5 percent.

Only one form of insect was found in the stomachs, a chironomid (*Pelopia* sp.). Chironomid pupae were the second most important food item utilized, composing 4.3 percent of the total stomach content by weight, and found in 17 stomachs. Chironomid larvae formed only an insignificant part of the food taken, composing 0.1 percent of the total mass by weight.

The amphipod *Hyalella azteca* was found in three of the 24 stomachs and composed 0.2 percent of the total weight.

Plant material was found in four stomachs. However, it seems likely that this matter was ingested inadvertently.

A summary of the food contents of the 24 stomachs is given in Table 1.

TABLE 1

Stomach contents of 24 adult black crappie taken in Kelly Lake

Food Item	Frequency of occurrence		Percentage composition of food by weight
	f	percent	
Crustacea			
Entomostraca	21	87.5	95.0
Amphipoda	3	12.5	0.2
Insecta			
Chironomidae			
Pupae	17	70.8	4.3
Larvae	2	8.3	0.1
Plant matter	4	12.5	0.4

No definite conclusions can be drawn on the basis of so restricted a sample, but it may be significant that other food-habit studies of black crappie, made in their native range, indicate a similar preference for entomostraca and immature insects (Ewers, 1933; Neal, 1962).

The author is grateful to Robert P. Dempster, Steinhart Aquarium, California Academy of Sciences, for allowing the use of facilities for photographic work.

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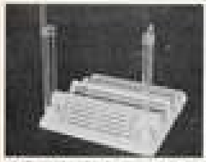
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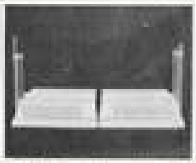
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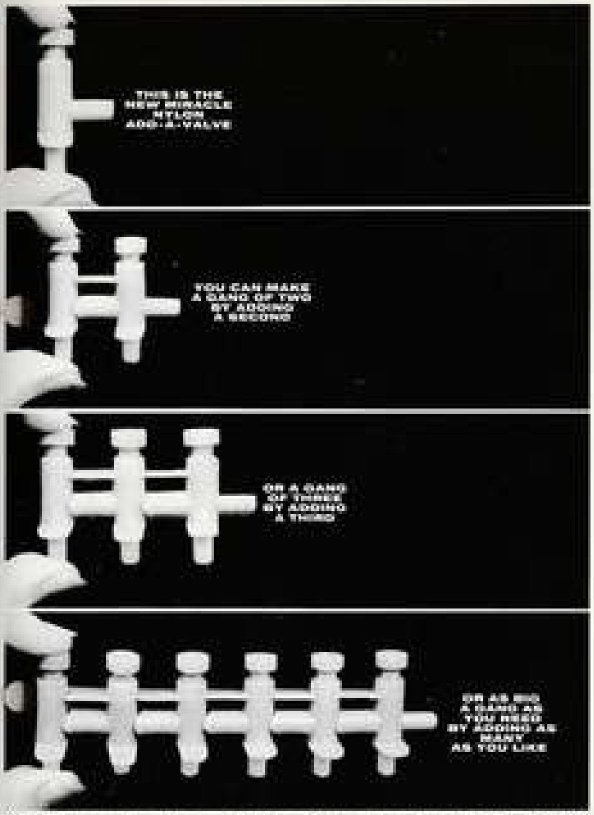
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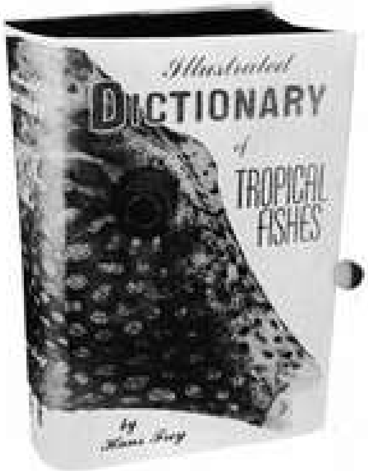

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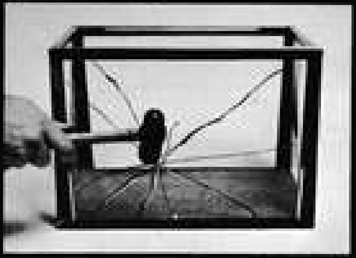

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