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## Life Skills Training for Hatchery Fish: Social Learning and Survival

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### ABSTRACT

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Recent investigations of social-learning processes have clear relevance for hatchery practice in the rearing of some species of fish. Research findings show that many fish learn to recognize the stimulus features of food, predators and habitat. The behavior of these fish may then serve as a source from which naïve conspecifics can acquire recognition of the same stimulus. Learned behavior can result from simple exposure of fish to conspecifics engaged in particular activities. Fish that observe a conspecific consume a novel food later show an increased tendency to eat that food themselves. Fish that observe conspecifics displaying alarm behavior in the presence of a novel chemosensory stimulus (pseudopredator) later themselves display alarm behavior to the chemosensory stimulus. Fish that visually observe predators preying on conspecifics, later show enhanced ability to evade such predators. These findings suggest that large scale training of food and predator recognition may be feasible, effective, and economically undertaken before hatchery fish are released to the wild.

### INTRODUCTION

Extensive research has shown that fish learn to recognize many stimuli, including food, predators and habitat (see Suboski, 1988, for a recent review). Such learning appears to be relatively simple, often consisting of little more than a broadening of the stimuli that can elicit or "release" a pre-organized sequence of behavior (Suboski, 1988). If learned recognition behavior is displayed by experienced fish then acquisition of recognition of similar stimuli may be initiated in nearby conspecific observers. We argue here that simple underlying learning mechanisms can act sequentially to enable naïve fish to acquire stimulus recognition from experienced conspecifics in a continuing process of social transmission over time and space.

We propose that behaviorally transferred and maintained cultural traditions

may provide practical solutions to problems of post-release mortality of hatchery-reared fish. Social learning mechanisms have the potential to orchestrate the en masse training of fish to recognize and respond appropriately to biologically important stimuli that will be encountered after release from the hatchery. In some circumstances, social-learning training procedures are likely to be simple, rapid and inexpensive as well as cost effective in increasing post-release survivorship. Miller (1954, p. 130), for example, remarked "It would be better economy to kill a large number of fry at the start rather than spend money feeding them, rearing them, ... and then turning them loose in a stream for nature to eliminate."

The purpose of this paper is limited to the identification of basic mechanisms and general principles from which specific procedures may be developed for individual species. In most cases, application of social-learning techniques will require further natural history study of feeding habits and predators of target species, as well as laboratory research, and evaluation by field study.

#### HATCHERY PRACTICE AND PROBLEMS

Hatcheries very successfully rear large numbers of various species of economically important fish. Intensive aquaculture produces large healthy fish at low cost with minimal losses. However, high mortality rates often occur later when fish are released to fend for themselves (e.g. Wales, 1954). Although exceptional successes can be claimed, post-release mortality of hatchery-reared fish is often considered to be undesirably high (e.g. Fraser, 1972; Sosiak et al., 1979; Dickson and MacCrimmon, 1982). For example, trout species stocked in streams at legally catchable sizes are typically gone within a month with about 40% return to anglers (e.g. Shetter and Hazzard, 1941; Smith and Smith, 1945; Miller, 1954). Such trout virtually never survive their first winter in the wild (e.g. Shetter and Hazzard, 1941; Smith and Smith, 1945; Miller, 1954; Reimers, 1963). The outcome of these and other problems is that stocking of trout is frequently on a "put and take" basis with no effort to re-establish a self-sustaining resident population.

Problems of post-release mortality appear to be widespread; other recent examples include Atlantic salmon (*Salmo salar*, Dickson and MacCrimmon, 1982; Sosiak et al., 1979) and Pacific salmon (*Oncorhynchus gorbuscha*, *O. keta*, Kanid'yev et al., 1970; however cf. Paszkowski and Olla, 1985), white sturgeon (*Acipenser transmontanus*, Lindberg and Doroshov, 1986) and esocids (*Esox lucius*, *E. masquinongy*, Johnson, 1978).

Behavioral differences between hatchery-raised and wild fish are often found (e.g. Symons, 1969; Sosiak et al., 1979; Dickson and MacCrimmon, 1982) but their origin and significance are often obscure. Other differences, however, are clearly the product of rearing environments that are impoverished of the natural stimuli that elicit fish behavior. Such differences arise in part because

of post-release mortality of hatchery fish have the potential to orchestrate and respond appropriately to biological factors after release from the hatchery. Training procedures are likely to be most effective in increasing post-release mortality. For example, remarked "It would be better to spend money at the start rather than spend money when turning them loose in a stream

The identification of basic mechanisms and specific procedures may be developed through the application of social-learning techniques, observation of feeding habits and predators of hatchery fish, and evaluation by field study.

Numbers of various species of hatchery fish that produce large healthy fish at release and low mortality rates often occur later in life (e.g. Wales, 1954). Although post-release mortality of hatchery-reared fish (e.g. Fraser, 1972; Sosiak et al., 1979) is high, for example, trout species stocked in hatcheries die within a month with about 50% mortality (Ford, 1941; Smith and Smith, 1945; Smith, 1945; Miller, 1954; Reintjes, 1978). One problem is that stocking of trout in hatcheries with no effort to re-establish a self-sustaining population.

to be widespread; other recent studies (e.g. Dickson and MacCrimmon, 1982) on *Oncorhynchus gorbusha*, *O. mykiss* (Kozłowski and Olla, 1985), white perch (Gardner and Doroshov, 1986) and esocids (Reintjes, 1978).

Released and wild fish are often found to differ (e.g. Dickson and MacCrimmon, 1982) but other differences, however, are not. That hatchery fish are impoverished of the natural differences arise in part because

hatchery practice is largely guided by hatchery experience rather than by knowledge and understanding of the natural history of the species under cultivation. A practice that increases growth and decreases mortality in the hatchery may easily result in exactly the opposite effect after the fish are released. According to Ersbak and Haase (1983), for example, hatchery fish are fed to provide maximal growth within the shortest time-period. These larger, portly fish have a higher basal metabolism, greater difficulty in satisfying their food needs and consequently often show a decline in condition after release. "The larger and fatter the fish, the faster this rate of decline" (p. 148; cf. Sosiak et al., 1979 p. 1408).

Wales (1954) noted that hatchery fish are protected from the hazards that "cull" physically inferior wild fish and that provide the experience that increases ability to cope with similar hazards in the wild. Wales (1954, p. 126) concluded that "hatchery fish may suffer considerably higher loss because the hatcherymen have actually given them better care than these same fish would have had in nature" (see also Miller, 1954, p. 130). This is not the main message of the present discussion but does offer a starting point for evaluation of the role of learning in survival.

#### THE OVERHEAD FRIGHT RESPONSE

Hatchery fish are often raised under cover with constant daytime illumination and a constant duration for the day-night cycle. What that does to the development of the sun compass mechanism (Hasler et al., 1958; Goodyear, 1973) and subsequent ability of the fish to localize within their habitat is unknown, but is unlikely to be beneficial. In addition, initiation, control and cessation of numerous endogenous physiological processes depend on environmental conditions such as day length or the relationship between day/night lengths (Schwassman, 1980). Fish raised under constant lighting conditions may not develop normally and consequently may be released in an inappropriate physiological state (Roadhouse et al., 1986).

Rearing fish with overhead cover has other implications for the development of normal responses to natural behavior-eliciting stimuli. It is certainly not the case that all behavior is learned. In fact, behavior of fishes often appears to consist of pre-organized behavior sequences (modal action patterns) released by specific environmental stimuli with little or no involvement of learning at all (see e.g. Barlow, 1977). Nevertheless, some releasing-stimulus/released-response sequences appear to require early exercise in order to develop normally (e.g. Dill, 1974; Ginetz and Larkin, 1976; Gillen et al., 1981). The overhead fright response in fish subject to avian predators seems to be one example (Ritter and MacCrimmon, 1973). Although hatchery fish are likely to experience movement above the tank that initiates the overhead fright response occasionally, that is unlikely to solve the problem.

Natural overhead fright sequences involve three steps. First, the releasing stimulus, overhead movement, occurs. Second, the initially released response, swimming directed away from the overhead stimulus and toward a dark area follows, and third, swimming ceases when the fish is under an overhead cover or above a dark area. The use of rearing tanks with white or reflecting bottoms and no overhead cover at all provides little opportunity for completion of the natural sequence. Whether or not this impairs subsequent use of the overhead fright response to avoid predation is likely but not yet established. What is clear is that hatchery-reared fish often fail to seek cover after release (e.g. Raney and Lachner, 1942; Vincent, 1960; see also Roadhouse et al., 1986), possibly resulting from an attenuated or absent overhead fright response. Thus, the protection from disease, predators, and weather gained from rearing under cover may well come at a considerable cost in ultimate loss of fish.

#### ACQUISITION OF STIMULUS RECOGNITION

Two major sources of mortality in hatchery fish after release are starvation and predation. Starvation may occur because of a diminished ability of hatchery fish to compete for available food resources and predation may occur because of failure to develop appropriate antipredator responses. In the ensuing discussion, however, we are concerned with the possibility that post-release mortality sometimes occurs because hatchery fish fail to acquire learned recognition of natural food and predators. We assume that feeding responses and antipredatory behaviors are largely unlearned but rather are elicited by releasing stimuli (Suboski, 1988). It is not usually necessary to teach a fish to eat, only what to eat (MacCrimmon and Twongo, 1980). Similarly, fish have to learn to recognize predators, not how to evade them (e.g. Brown, 1984).

Successful food recognition will usually depend on an interaction between unlearned released responses and learning based on individual experience. Only species with highly restricted natural diets are likely to have the stimulus features of every accepted food item encoded as releasing stimuli for feeding behavior and thus not depend on learned food recognition at all. On the other hand, even for the most omnivorous of fishes, stimuli that release unlearned preparatory feeding responses, such as approach and oral contact, can serve to initiate individual learning mechanisms based on palatability of the novel food (e.g. MacCrimmon and Twongo, 1980; Kruse and Stone, 1984). Transplanting fish into an environment where little or none of the available food releases feeding behavior is likely to have dire consequences for the naïve fish (Gunn and Keller, 1981). With no mechanism to bring the fish into ingestive contact with unfamiliar food, starvation will inevitably result. Indeed, starvation amidst plenty appears to be a not uncommon fate of hatchery-reared fish (e.g. Kani-d'yev et al., 1970; Johnson, 1978; Gillen et al., 1981; Ersbak and Haase, 1983).

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## SOCIAL LEARNING OF FOOD RECOGNITION

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The straightforward solutions to the problem of unrecognized food may not be feasible or practical. Any solution that involves training of each individual fish or requires large amounts of various live natural food items is unlikely to be useful. Fortunately, two very powerful behavioral phenomena, social facilitation (Olla and Samet, 1974) and local enhancement (Godin, 1978; Magurran, 1984), provide simple mechanisms that can be used to train food recognition. Social facilitation refers to "contagious behavior", where certain biologically important behaviors, including feeding and predator evasion, often function as releasing stimuli for exactly the same behavior in observing conspecifics (see Suboski, 1988). Because the released behavior is, in turn, itself a releasing stimulus, the behavior can quickly spread among a group of conspecifics.

Feeding behavior is a powerful social facilitator of feeding in observing conspecifics (e.g. Olla and Samet, 1974; Godin, 1978; Magurran, 1984). Local enhancement refers to the recruitment effect of behavioral releasing stimuli. The same behaviors that attract conspecifics may also direct their actions toward particular stimuli. Thus, feeding behavior attracts conspecifics to a feeding animal where the recruits may attempt to share the recruiter's food (Godin, 1978; Magurran, 1984). Social facilitation and local enhancement, together with reinforcement-based learning, are assumed to comprise a process whereby naïve fish may acquire recognition of a novel foodstuff as a consequence of a behavioral interaction with an experienced conspecific (Suboski, 1988). An underlying assumption of this traditional social-learning model is that the actual learning involved in the recognition of novel food critically depends on the ingestion of prey (Suboski, 1988).

Recently, however, it has become clear that gustatory stimulation is not always necessary to the acquisition of food recognition (Templeton, 1987; Suboski, 1988). Mere visual exposure to a conspecific feeding on a novel foodstuff may suffice to produce subsequent recognition of and feeding on that foodstuff by the observer. Templeton (1987) obtained such results with juvenile rock bass (*Ambloplites rupestris*) given visual access to an experienced conspecific consuming a novel food (live white worms, *Enchytraeus albidus*). When tested later by themselves, the observers readily displayed approach, capture and consummatory responses to the novel prey. A non-observation group given equal access to white worms did not acquire recognition of the novel prey as food over the course of 7 daily sessions of 10 min each. Thus, observation of a conspecific eating a novel food object enhanced the subsequent release of feeding on similar objects by the observer fish (see also Santapaga and Ringler, cited by Ringler, 1983, p. 161).

In light of the foregoing, teaching novel food recognition to hatchery fish could be perfectly straightforward—place a few fish that accept the food in

question into the tank with the trainees along with the novel food and let nature take its course. With everything else under control; trainees a little hungry, no social hierarchy problems, reasonably palatable novel food, a sufficient number of trainer fish, etc., recognition of the novel food should spread rapidly to all of the fish in the tank including those that did not have an opportunity actually to ingest the novel food during the demonstration. In reality, of course, nothing is ever that simple.

A series of problems may need solution before social-learning processes can be effectively exploited. Both learned and unlearned preferences will undoubtedly produce constraints on social-learning effects. First, acceptability of food will be limited by palatability (see e.g. Lindberg and Doroshov, 1986, pp. 167-168). Second, feeding behavior may be released by stimulus features of food such as prey movement (Paszkowski and Olla, 1985) or even particular patterns of prey movement (Dunlop, 1987) that are hard to duplicate with artificial food. Third, unlearned preferences change with ontogeny. Species that feed on a succession of different prey types appear to have releasing mechanisms for feeding that appear in concert with the prey (e.g. Parmley et al., 1986). It may be necessary to devise special training procedures in order to bridge the successional gap.

The results of early learning further complicate the picture. Primacy effects, the development of strong preferences for the foods initially consumed (Bryan, 1973; Clarke and Sutterlin, 1985), are certainly responsible for most failures of hatchery fish to recognize natural food (Raney and Lachner, 1942, p. 108; Johnson, 1978; Sosiak et al., 1979; Ersbak and Haase, 1983; Lindberg and Doroshov, 1986). Primacy effects induced by the availability of highly palatable artificial food may produce "blocking" (Tennant and Bitterman, 1975), an inability to acquire recognition of additional food items and consequent restriction in choice of natural prey. Thus hatchery fish may fail to thrive as a result of foraging that is restricted to natural foods that resemble their rearing diet (Ramey and Lachner, 1942; Ersbak and Haase, 1983).

Social-learning procedures should help to find solutions to these problems, particularly since only a few elicitation of a released response appear necessary to establish the interaction. Thus, although development of feeding responses appropriate to the environment at the eventual release site may require exposure to a sequence of one or more natural foods, only very brief exposure to conspecific demonstrator fish and small amounts of food are likely to be required if training is conducted during the formation of primacy effects. The persistence of primacy effects could even prove useful. Early training on natural foods may develop preferences that transcend a long period of feeding on artificial food. Although easily learned initially, food habits are not soon lost (Tarrant, 1964). Once solutions to the various problems are found, application of social learning procedures in aquaculture should prove reasonably simple and economically attractive (e.g. Miller, 1954, p. 130; Kanid'yev et al., 1970).

Recently, cultural communication from conspecifics (Kanid'yev et al., 1970; Kanid'yev and Boski, 1988). Direct evidence for social learning in *Brachydanio rerio* (Zebrafish) released pheromone, tipredator defensive behavior control over elicited behaviorally neutral stimulus serves as a response. Moreover, a maintained by behavior fish is visually transmitted (Kanid'yev, 1985). More remarkable socially facilitated a chemosensory stimulus upon encountering the

The behavioral modification among conspecifics in a system of very considerable fact occur. Naïve fish upon subsequently exposed (Kanid'yev et al., 1968; Kanid'yev et al., 1976) or possibly exposed (Kanid'yev, 1976; Volkova, 1976; Patten (1977), which that were first exposed to conspecifics (see also

The benefits of social learning are not restricted to the work of Kanid'yev and Patten (1977) apparent nonproductive (Kanid'yev et al., 1979). Nevertheless, direct predator attack of cultural tradition

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## SOCIAL LEARNING OF PREDATOR RECOGNITION

Recently, cultural traditions of predator recognition based on social communication from conspecific behavior have been shown for several fishes (Suboski, 1988). Direct evidence was provided by Suboski et al. (in press). Zebra danios (*Brachydanio rerio*), like other Ostariophysan fishes, possess an injury-released pheromone, "alarm substance", that releases "alarm behavior", antipredator defensive responses. In zebra danios, alarm substance acts to transfer control over elicitation of alarm behavior to a co-occurring novel and behaviorally neutral chemosensory stimulus. Afterward, that chemosensory stimulus serves as a learned "surrogate" predator in precipitating alarm responses. Moreover, a cultural tradition instigated by alarm substance can be maintained by behavioral processes alone. Alarm behavior in many species of fish is visually transmitted by social facilitation (see e.g. Godin and Morgan, 1985). More remarkable yet, fish that visually observe and participate in a socially facilitated alarm reaction in the presence of an innocuous and novel chemosensory stimulus will subsequently themselves engage in alarm behavior upon encountering that chemosensory stimulus (Suboski, et al., in press).

The behavioral mechanism for transferring acquired predator recognition among conspecifics can be expected to provide an antipredator defensive system of very considerable utility and evidence suggests that such benefits do in fact occur. Naïve fish that have visually observed conspecifics being preyed upon subsequently display enhanced ability to avoid predation (Leshcheva, 1968; Kanid'yev et al., 1970; Volkova, 1976). Such findings may reflect no more than the effect of culling out weaker prey by the predator (Ginetz and Larkin, 1976) or possibly even residual alarm substance in the test tank (Leshcheva, 1968; Volkova, 1976). However, these objections do not apply to the results of Patten (1977), who found substantially improved survivorship in naïve fish that were first exposed to a predator in the company of predator-experienced conspecifics (see also Sugita, 1980).

The benefits of social experience on the acquisition of predator recognition are not restricted to commercially unimportant Ostariophysan species. The work of Kanid'yev et al. (1970) and Patten (1977) was on Pacific salmonids, apparent nonproducers of alarm substance. Some non-ostariophysans have been reported to react with alarm behavior to conspecific skin extract (Smith, 1979). Nevertheless, social facilitation from alarm reactions precipitated by direct predator attack (e.g. Radakov, 1973, p. 100) is the most likely instigator of cultural traditions of predator recognition among non-ostariophysan fish.

That hatchery fish could be trained to recognize food and predators in advance of release has been suggested by Russian (Kanid'yev et al., 1970; Vol-



kova, 1976) and western (see e.g., Ritter and MacCrimmon, 1973) researchers alike. The general lack of response to these suggestions is not difficult to understand. Social learning of predator and food recognition seems, a priori, quite unlikely in the absence of either a plausible theoretical model or a firm empirical data base. Both appear to be developing rapidly.

#### ACKNOWLEDGEMENT

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## Seasonal and Diel Change for Acoustic Surveys of Fish Lakes

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### ABSTRACT

Unger, P.A. and Brandt, S.B., 1989. Seasonal and diel changes in acoustic surveys of fish abundance in small lakes. *Fish. Res.*

Acoustic techniques have difficulty detecting fish in small lakes. This limitation may be particularly critical in small, shallow lakes. This report here on the effects of seasonal and diel changes in *Chaoborus*, on acoustic measures of abundance in small lakes.

Fish abundances were measured using echosounders at three frequencies (70, 120 and 420 kHz). Fish densities, dissolved oxygen concentrations and water temperatures were also measured.

During summer stratification in the lakes, fish densities were high at some, but not all, lakes. Fish density was high in the epilimnion. Following autumn overturn, fish distribution was more uniform because fish moved to shallow water or to the bottom.

Acoustic scattering in the lakes was often dominated by *Chaoborus* larvae, which vertically migrate. When *Chaoborus* was abundant, acoustic detection of fish was difficult.

Acoustic techniques proved useful in small lakes. However, they can affect data reliability and must therefore be used with caution. Fish and plankton distributions are somewhat different from those used in strategies for acoustic sampling.

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