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TEMPERATURE AND FLOW REGULATION IN THE SACRAMENTO RIVER AND ITS EFFECT ON THE SACRAMENTO PIKEMINNOW *(Ptychocheilus grandis)*

A LITERATURE REVIEW

by

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INTRODUCTION

The Sacramento pikeminnow (*Ptychocheilus grandis*) – formerly the Sacramento squawfish – is the largest member of the Cyprinidae family native to North America (Brown and Moyle, 1981). Other common names include chub, bigmouth, boxhead, yellowbelly (Moyle, 1976), pike, hardhead (not to be confused with *Mylopharodon conocephalus*), chappaul, and whitefish (Taft and Murphy, 1950; Moyle, 1976).

Pikeminnow have long been considered *trash* fish, both for their being unfavorable to eat and in their potential capacity as competitors and predators of young salmonids (Grant, 1992). Misunderstandings throughout the last century regarding these species' predator-prey relationship have misleadingly labeled pikeminnow with an undue predatory reputation (Moyle, 1976; Vondracek and Moyle, 1982). In natural conditions – notwithstanding exceptional circumstances – , pikeminnow are not a significant predator of salmonids (Vondracek and Moyle, 1982), nor is there an overwhelming degree of dietary overlap (Merz and Vanicek, 1996).

In conjunction with present day restorative measures directed at returning the Sacramento River to its historically natural state, questions have arisen concerning the potential impact such measures might incur upon resident salmonid species; In particular, whether such alterations will be beneficial or detrimental to pikeminnow populations, and the consequent effect on the salmonid-pikeminnow relationship (Cepello, pers. comm.).

The purpose of this literature review is to assess and quantify any possible impacts temperature and flow regulation in the Sacramento River might have on resident pikeminnow populations based on extant literature and research.

BACKGROUND

History of the Sacramento River

The Sacramento River lies nestled within northern California, hemmed in by the Sierra Nevada and the Cascade Range to the east, the Coast Range to the west, and the Cascade Range and Klamath Mountains to the north. Its origins can be traced to the slopes of Mount Eddy of the Scott Mountains, from which it drains approximately 27,000 mi^2 (43,650 km^2) throughout the Central Valley. Flowing in a southerly direction, the Sacramento eventually joins up with the San Joaquin River to form the estuarine Delta, then making its way through the San Francisco Bay and into the Pacific Ocean. Principal tributaries include the Feather, Pit, and American Rivers (Brown, 1979).

Water resource modifications such as agricultural development, deforestation, damming, and channelization for flood control have led to changes in temperature and flow (Deas et al, 1997). Historically, rivers within the Central Valley naturally bore large volumes of cold water in winter and early spring, and smaller volumes of warmer water throughout the rest of the year (Myrick and Cech, 2000).

Prior to the installment of Shasta Dam, downstream portions of the Sacramento River were often unsuitable spawning grounds for some salmonid races due to low stream flow and high water temperature. Shasta Dam's impoundment of the river in 1943 allowed the release of cooler waters during the summer months, and above-normal water temperatures in the fall and winter (Van Vleck et al, 1988). In 1950, Taft and Murphy reported that cold flows from Shasta Dam had forced pikeminnow miles downstream, allowing trout to assume the role of the dominant carnivore.

Nonetheless, heightened agricultural, urban and industrial demands have determined – and greatly altered – natural flow patterns in more recent years (Myrick and Cech, 2000). A 1987 report (Hallock) on the Sacramento River predicted that impending increases in water demand would result in regular low reservoir storage levels and high temperature releases by the year 2020, resulting in an increase in anadromous fish mortality. Agriculture-related flow fluctuations were also cited as a potential threat – sudden cessations in flows disrupt spawning, desiccate eggs and alevins, and strand fry and fingerlings in pools and side channels.

Concern about the adverse effects that such tampering had on the salmonid fisheries, mainly Chinook salmon (*Onorhynchus tshawytscha*) and steelhead (*O. mykiss*), has brought about a temperature/flow regime more sensitive to resident salmonid species. At present, flows are reduced in the winter months, with an increase in cold flows from late spring through summer, and a reduction in warm flows throughout the fall and early winter (Myrick and Cech, 2000).

To address the declining salmonid fisheries, a temperature regulation objective of 13.3°C (56.0°F) has been instituted in key salmonid habitat, in particular the 60 mile (97 km) stretch of Sacramento River between Keswick Dam and the city of Red Bluff. Throughout the majority of spawning season, Shasta Reservoir releases are within the range of 8°C - 10°C (44.8°F – 50.0°F). During dry years, there aren't always sufficient cold water reserves available to maintain objective stream temperatures (Deas et al, 1997).

The Pikeminnow-Salmonid Relationship

Although pikeminnow are a common species throughout the Sacramento River system, they have been experiencing a drop in abundance (Moyle, 1976; Tucker et al, 1998), perhaps related to efforts seeking to eliminate non-game fish such as pikeminnow from the Sacramento River and outlying tributaries through rotenone treatments, (Pintler and Johnson, 1956; Cook and Moore, 1969; Maslin, 1997), removal (Knutsen and Ward, 1999; Ward and Zimmerman, 1999), traps, “permit angler days,” and “squawfish derbies” (Tucker et al, 1998).

The pikeminnow’s ill-deserved reputation as a major predator of salmonids has been investigated at great length (Dettman, 1973; Brown and Moyle, 1981; Merz and Vanicek, 1996; Vondracek and Moyle, 1982; Vondracek and Moyle, 1983). Despite claims of dietary overlap and the predatory nature of pikeminnow (Taft and Murphy, 1950), Dettman (1973) noted a negligible overlap of pikeminnow and trout microhabitat. Further, Merz and Vanicek (1996) found that not only was there a low dietary overlap between pikeminnow and salmonids related to the conspecific dissimilarity in feeding locations, there was instead a considerable dietary overlap of major food items between Chinook and steelhead.

Pikeminnow are opportunistic feeders (Brown and Moyle, 1981; Vondracek and Moyle, 1982). Juveniles’ diets consist predominantly of insects, with a tendency towards fish as they grow larger (Moyle, 1976; Vondracek and Moyle, 1982).

Extensive reviews of extant research and literature has led both Brown and Moyle (1981) and Vondracek and Moyle (1982) to conclude that pikeminnow are not a significant salmonid predator “except under highly localized, seasonal, or unusual circumstances that are often related to the design of dams and diversions or to poorly planned releases of hatchery smolts.”

For example, the peak abundance of Sacramento pikeminnow caught at the Red Bluff Diversion Dam (RBDD), along the upper Sacramento River, corresponds to both their spring spawning season and the “gates in,” restricted-flow conditions. Pikeminnow spawn upstream between April and May in accordance with high stream flow and migrate downstream during reduced summer flows (Grant, 1992). “Gates-in” period falls between May 15th and September 15th each year (McNabb et al, 1998). The impedance of upstream passage results in large congregations of pikeminnow just below the dam (Tucker et al, 1998).

During “gates-out,” free-flowing conditions, juvenile salmonids were of less dietary importance than other non-salmonid fish in the pikeminnow’s diet. However, during “gates-in” flows, the percent composition by weight of juvenile salmonids leapt to 66% of the total stomach content weight, more than double that of the weight of non-salmonid fishes (Tucker et al, 1998).

In addition to the impedance of upstream passage and the concentration of pikeminnow below the RBDD, juvenile salmonid mortality is further augmented by the turbulent flows that escort them under the dam gates, leaving them temporarily disorientated and subsequently exposed to predators (Tucker et al, 1998).

EFFECTS OF TEMPERATURE AND FLOW REGULATION

In altering flow and temperature regimes, it is important to consider how such alterations might effect not only species of concern – in this case salmonids –, but also any potential predators. And while pikeminnow might not be considerable predators of salmonids in their natural environment, the impoundment of the Sacramento River has altered the river's natural dynamics, creating preternatural conditions.

Although there has been considerable research into the temperature and flow regimes critical to salmonid survival (Combs and Burrows, 1957; Banks et al, 1971; Alderdice and Velsen, 1978; Hughes et al, 1978; Boles, 1988; Van Vleck et al, 1988; Campbell and Moyle, 1992), little attention has been paid to how those same influences might interact with salmonid predators. Given that the Sacramento River might be returned to more natural flows, how will such alterations beneficially or detrimentally impact pikeminnow populations and the salmonid-pikeminnow relationship?

FLOW

Studies have shown that pikeminnow prefer deeper, slower habitats characterized by small substrates and less frequent vegetative cover (Grant, 1992). Grant suggested that deeper habitats would be beneficial to pikeminnow; slower velocities would minimize energy expenditure and be energetically favorable, and pools support large populations of important prey items like small fishes.

During conditions of high flow and reduced temperature, Grant found pikeminnow were even more restricted in habitat use (Grant, 1992). Alley and Li (1977, in Grant, 1992) and Knight (1985, in Grant, 1992) reported that adult pikeminnow preferred water velocities of <30 cm/sec and <15 cm/sec, respectively.

TEMPERATURE

Sacramento pikeminnow enjoy a fairly tolerant temperature range. Preferring warm waters, pikeminnow rarely thrive in water temperatures below 15°C (59°F) (Moyle, 1976). Cech et al (1990) noted that while pikeminnow were more tolerable of higher temperatures (>30°C - <35°C [>86°F - <95°F]), they still experienced a high mortality rate during an abrupt temperature increase from 30°C to 35°C (>86°F - <95°F). They also found that pikeminnow had a high rate of resting metabolism, second only to that of the rainbow trout of the fishes included in the study, and that there were no significant metabolic changes between 15°C and 20°C (59°F and 68°F), or 20°C and 25°C (68°F and 77°F).

Myrick and Cech (2000) found that the swimming performance of pikeminnow was lowest at 10°C (50°F), higher at 15°C (59°F), and decreased or constant at 20°C (68°F), suggesting an optimal temperature of 15°C (59°F).

Other studies show that digestive rates are also closely related to temperature. Vondracek and Moyle's (1983) investigation found a 2.7% per hour digestive rate at 10°C (50°F) and 6.3% per hour at 15°C (59°F). Given these rates, pikeminnow could evacuate their digestive tracts in 37 hours at 10°C (50°F) or 17 hours at 15°C (59°F). Based on this temperature dependence, at lower temperatures, the digestive rate and digestive tract evacuation time would be slower, preventing pikeminnow from feeding as often.

Steigenberger and Larkin (1974, in Brown and Moyle, 1981) also observed an increase in digestive rate in northern pikeminnow (*P. oregonensis)* associated with temperature, from ~5% per hour at 4°C - 6°C (39°F - 43°F), to 14% per hour at 10°C - 12°C (50°F - 54°F), to 40-50% per hour at 24°C (75°F).

In situations where stream fishes can select environmental characteristics, temperature might help pikeminnow distribution. Baltz et al (1987) observed that temperature was a better predictor of where species might be found than were other instream flow model variables (i.e. mean water column velocity and substrate). In a study of Deer Creek, California, Dettman (1973) found that as temperatures increased downstream, trout density decreased while pikeminnow density increased.

DISCUSSION

Compared to the optimal temperature ranges of various Chinook and steelhead life stages of Chinook (3°C - 19°C [38°F - 67°F]) and steelhead (4°C - 14°C [39°F - 58°F]) (Flosi et al, 1998), pikeminnow are far more tolerant of warmer waters and conversely less tolerant of cooler waters. And while pikeminnow are tolerant of a wider range of temperatures (4°C - 35°C [39°F - 95°F]), they are still subject to instream temperature restrictions.

Evidence of this can be found in Taft and Murphy's 1950 report that cold flows from Shasta Dam had forced pikeminnow miles downstream, Baltz et al's (1987) observation that temperature was a reliable predictor of species' preferred habitat, and Dettman's (1973) findings that as temperatures increased downstream, trout density decreased while pikeminnow density increased.

The Pacific Lumber Company (PLC) (1998) has projected similar results in their Aquatic Species Conservation Plan. The PLC's Habitat Conservation Plan measures were expected to increase shade levels and reduce water temperatures, thus adversely affecting resident California roach (*Hesperoleucus symmetricus*) and Sacramento pikeminnow populations and positively impacting native fish populations.

Instream water flow and temperature share an intimate association. With increased flows, ambient water temperatures remain cooler longer and further downstream since there is a greater volume of water at greater velocities to acclimate. As flows decrease, smaller volumes of water at slower velocities attain warmer temperatures more rapidly and further upstream (Boles, pers. comm.). Due to this intimate association, any changes in flow directly effect the instream water temperature, and thus pikeminnow and their interrelationship with salmonids.

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