PROJECT NAME: Cultural Technology of Walleye

FUNDING LEVEL: Year 1 - Grant 2: $91,636
Year 2 - Grant 2: $86,095

DURATION: 2 Years

ADMINISTRATIVE ADVISOR: Dr. Donald L. Garling, Department of Fisheries and Wildlife, Michigan State University, East Lansing, MI 48824-1222

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JUSTIFICATION

The coolwater percid fishes (Family Percidae) have been designated a priority candidate group for commercial aquaculture development in the North Central Region (Joint meeting of the Industry Advisory Council and the Technical Committee for Extension and Research, May 1988, East Lansing, Michigan). The coolwater fishes that have significant potential for commercial aquaculture are the yellow perch (*Perca flavescens*), walleye (*Stizostedion vitreum vitreum*) and the walleye-sauger (*S. v. vitreum* X *S. canadense*) hybrid ("saugeye"). Research planning for the percids, under the auspices of the North Central Regional Aquaculture Center (NCRAC), has been divided into one work group for yellow perch and a second for walleye. This proposal concerns the walleye.

The yellow perch and walleye are the most exploited percid species in North American commercial and recreational fisheries (Kendall 1978). Although a small commercial fishery for yellow perch still exists on the Great Lakes, commercial harvest of walleye in the U. S., except for a few tribal fisheries, has been eliminated in favor of sport fishing. The walleye has been recognized by the National Aquaculture Development Plan (Joint Subcommittee on Aquaculture 1983) as an important recreational and commercial fish with substantial aquaculture potential. In 1983 and 1984, state, federal and provincial fisheries management agencies in North America stocked more than one billion walleye fry and fingerlings (Conover 1986).

Given the numbers of walleye fry and fingerlings reared for maintenance stocking, various fisheries management agencies in the U.S. and Canada have conducted applied research on various phases of walleye aquaculture for many years (Coolwater Culture Workshop 1985, 1986, 1987, 1988). The fish culture activities traditionally associated with producing walleye includes spawning of wild broodstock, hatching fry, and rearing small fingerlings in ponds. Numerically, fry comprises 98% of walleye stockings in the U.S. and Canada (Conover 1986). However, the relative survival of fingerling walleye after stocking is 16 to 60 times greater than with fry (Heidinger et al.1985). Thus, most fisheries management agencies prefer fingerling stockings; and large numbers of fingerlings can be produced to a size of 35-50 mm total length (TL) by traditional methods. Increasingly, the focus of regional research is being directed toward developing techniques for rearing the small (35-50 mm TL) pond-reared walleye fingerlings to a larger size (100-150 mm TL). Procedures developed involve training pond-reared fingerling walleye to intensive culture conditions and formulated diets. However, success is variable and affected by many factors, including temperature, light, size of the fingerling, diet, feeding frequency and other factors (Nickum 1986; Summerfelt 1988b).

Commercial walleye aquaculture is also mainly geared to the production of eggs, fry and pond-reared fingerlings. Over the past 27 years, the Lac du Flambeau Tribal Fish Hatchery, Lac du Flambeau, Wisconsin, has produced 373 million walleye fry for stocking in tribal waters and for sale. Commercially, walleye fry and fingerlings are sold to lake associations, sportsman clubs and individual lake and pond owners for maintenance stocking. Given the incentive of market prices for individual fry of 1 to 1.5 cents, and $0.25 to $0.75 for fish of 35 to 100 mm TL, respectively, commercial walleye production has expanded rapidly in the past 5 years. The growth of private-sector pond production has been particularly marked in Minnesota, Nebraska, Wisconsin, Iowa and Michigan. Experience with rearing walleye to food-size has been largely limited to a few researchers in the region (primarily at Iowa State University, Southern Illinois University and the University of Wisconsin-Madison). However, the high retail prices of walleye fillets that have prevailed throughout the region ($16.09-25.35/kg) have been a strong stimulus to private sector interest in the production of food-size fish. Although total production has been small, some commercial culture of food-size walleye has been underway for several years (e.g., Walleye Farms, Knoxville, Iowa).

For commercial walleye aquaculture to expand, especially in the direction of food-fish production, research needs to be focused on critical bottlenecks; and a sustained, collaborative, interdisciplinary effort is essential to resolve the many complex problems that exist. Major bottlenecks include: (1) the lack of procedures for manipulating reproduction and inducing spawning in walleye broodstock; (2) the lack of captive, domesticated broodstock; (3) the unreliability of pond management and harvesting strategies for fingerling production; (4) disease identification and FDA-approved therapeutics to control disease problems; and (5) the lack of commercially-produced diets for rearing advanced fingerlings to food-sized fish. Many aspects of the production process need further study to permit the development of a commercial aquaculture industry based on sound scientific principles.

This proposal describes a cooperative regional research project by the North Central Regional Aquaculture Center Walleye Work Group that will be interdisciplinary in scope and involve investigators from six institutions in six states: Southern Illinois University at Carbondale, the University of Notre Dame, Iowa State University, Michigan State University, the University of Minnesota at St. Paul and the University of Wisconsin-Madison. The principal goal of the Work Group is to address key problems that pertain to the development of commercial walleye culture in the North Central Region. The focus of the proposed project will be on: (1) characterization of the natural reproductive cycle of walleye; (2) the evaluation of various zooplankton seeding and clam shrimp control strategies for their effects on the pond production of walleye fingerlings; and (3) examination of the incidence and etiology of gas-bladder inflation problems in intensively cultured walleye fry. Significant progress on these problem areas should be achievable within the proposed 2-year period of the project. However, a third year of funding will probably be needed for the proposed lines of research to reach full fruition and thus yield maximum benefits.

1. Characterization of the Natural Reproductive Cycle

Strategies for manipulating reproduction are needed to insure the availability of "seed stock" for commercial aquaculture and for selective breeding and other types of genetic manipulations such as gene implantation (see Donaldson and Hunter 1983; Idler et al. 1987). In turn, the development of efficacious procedures to manipulate sexual maturation and induce out-of-season spawning is an important component of optimal broodstock management. The benefits of such procedures include: (1) greater predictability of gamete production; (2) reduced incidents of failed spawnings, gamete resorption and subsequent broodfish losses (e.g., due to toxemia); and (3) the production of fertilized eggs and fry at multiple and predetermined times during the year.

The availability of fertilized eggs outside the normal spawning season would greatly facilitate research on the intensive culture of walleye fry. On a larger scale, the production of fertilized eggs out-of-season could facilitate a fuller, more efficient use of culture facilities and equipment, and might allow such innovative techniques as the double- or triple-cropping of fry in rearing ponds.

Considering the walleye's importance as a food and game fish, remarkably little is known about its reproductive physiology. Baseline information on the physiological mechanisms regulating the natural reproductive cycle of walleye is essential to the development of efficacious procedures for managing captive broodstock and manipulating walleye reproduction (Donaldson and Hunter 1983; Idler et al. 1987). A starting point for obtaining such information is to characterize changes in specific circulating hormone titers and gonadal development during the annual reproductive cycle. Thereafter, with appropriate experimentation, precise practical methods of controlling reproduction and inducing out-of-season spawning can be developed.

2. Zooplankton Seeding and Clam Shrimp Control Strategies

Ideally, walleye fry collected from hatching jars would be reared in hatchery troughs and first-feeding begun directly on a formulated diet. Unfortunately, poor survival and non-inflation of the gas bladder are so prevalent in walleye fry reared intensively that pond culture is the only practical method for producing large numbers of healthy fingerlings at this time. The size of walleye fingerling harvested from ponds for stocking and training purposes varies widely throughout the geographic range where the fish is cultured (northeastern United States to North Central United States and southern Canada), but is typically 30-100 mm TL. However, to maximize the number of fish harvested, the typical size at harvest is 35-50 mm TL. At this size, fingerlings can be harvested for stocking from ponds and transferred to indoor, intensive culture facilities where they can be trained to accept formulated feeds (Nickum 1978; Beyerle 1979a; Krise 1986). Thus, present practice requires a combination of extensive (pond culture) and intensive culture (flowing water, tank culture) techniques to rear walleye fingerlings to 100 mm TL and larger (Colesante et al. 1986).

The successful production of walleye fingerlings in ponds is dependent on pond-management practices that develop and sustain large populations of microcrustaceans and chironomids used by the walleye as their principle food supply (Mathias and Li 1982; Buttner and Kirby 1986) until they attain or exceed 30 mm TL (Merna 1977; Nickum 1978; Raisanan and Applegate 1983). An abundance of zooplankton is the single most important factor affecting desirable survival and growth of walleye in rearing ponds. In addition, there will be minimal abundance of undesirable animal and plant species (e.g., organisms that prey on fish or compete with fish for food), and good water quality (e.g., adequate dissolved oxygen).

However, the success rate of pond culture from fry to fingerlings is still unpredictable and highly variable (Beyerle 1979b; Coolwater Culture Workshop 1987, 1988). The ability to predictably produce walleye fingerlings in large quantities is one of the most important problems in the culture of coolwater fishes today (National Task Force for Public Fish Hatchery Policy 1974; Nickum 1978; Joint Subcommittee on Aquaculture 1983; Coolwater Culture Workshop 1984, 1985, 1986, 1987, 1988). The North Central Regional Aquaculture Center (NCRAC) has recognized the need to solve this problem and recently identified development of effective culture procedures for the walleye as one of its nine research priorities (Announcement, Culture Technology of Walleye and its Hybrids, NCRAC, 26 July 1988).

High fry stocking density, which is required to optimize capital costs for pond construction, requires highly fertile ponds, and chemical or mechanical control or manipulation of desirable or undesirable organisms. Well-timed filling of ponds, zooplankton seeding (inoculation with Cladocera), and pond fertilization have produced and maintained large numbers of desirable zooplankton in drainable/undrainable, natural and plastic lined ponds for the 50 days+ that walleye are routinely cultured (Coolwater Culture Workshop 1984, 1985; Buttner and Kirby 1986; Kuss 1988). Organic and/or inorganic fertilizers are routinely applied to walleye fingerling production ponds to improve primary and secondary production, and ultimately to provide a large zooplankton forage base (Dobie 1956; Buttner and Kirby 1986; Richard and Hynes 1986). However, a fertilization-inoculation regime that is successful at one hatchery is not optimal in walleye culture ponds at other sites. Although procedures to culture walleye fingerlings in ponds have not been standardized, site-specific methods are based on management of zooplnakton populations (Coolwater Culture Workshop 1984, 1985; Buttner and Kirby 1986; Richard and Hynes 1986). Thus, a diverse complex of edaphic factors -- soil type, water fertility, time between filling and stocking -- affect the abundance and composition of the zooplankton community in ways that are still unpredictable.

The west-north central part of North Central Region of the U.S. is prime habitat for walleye production (Colby et al. 1979). Therefore, it is not surprising to find that a substantial proportion of all fingerling walleye produced by the U.S. Fish and Wildlife Service are reared in ponds at coolwater fish hatcheries located in North (Valley City National Fish Hatchery and Garrison Dam National Fish Hatchery) and South Dakota (Gavins Point National Fish Hatchery). Each of these hatcheries utilizes pond filling and fertilization regimens that best suit local circumstances. The personnel (Monty Millard, Tom Pruitt, and Roger Cooper) of the three hatcheries in North and South Dakota are interested in participating in experiments to evaluate the factors limiting walleye fingerling production in ponds. Monty Millard has identified several research objectives related to pond ecology and management.

(1) Determine the relationship between growth and survival of fingerlings to plankton composition and density.
(2) Evaluate the effects of clam shrimp competition on production of walleye fingerlings.
(3) Evaluate methods (chemical or physical) to control clam shrimp populations.
(4) Evaluate the effects of herbicides on plankton densities.
(5) Evaluate and compare soil and water analyses with plankton densities.
(6) Evaluate the effects of various kinds and application rates of organic fertilizers (chopped alfalfa hay, alfalfa pellets and alfalfa meal) to production of fish and plankton.
(7) Evaluate effects of plankton seeding on plankton densities and fish production.

The managers of the three federal coolwater fish hatcheries have offered a large number of pond units, availability of fry, other facilities (housing for the graduate students and laboratory space) and personnel for stocking, pond management and harvesting. Because of logistics, in this study, only the two hatcheries in North Dakota will be involved. Their collaboration offers a unique opportunity for research on a variety of questions, of which pond fertilization, zooplankton seeding and competitive interactions between clam shrimp and other zooplanktors are of greatest concern. The goal of zooplankton seeding is to enhance the rapid development of Cladoceran populations as a means for establishing community dominance and reducing the clam shrimp problem. Zooplankton seeding may also be a special need where the interval between pond filling and stocking of walleye fry is limited, and less than the optimum length of time is available to maximize zooplankton populations. The form of organic fertilizer can affect the rate of bacterial decomposition, and perhaps the rate and composition of the zooplankton.

3. Etiology of Non-inflated Gas-Bladder Inflation

Considerable interest exists in rearing walleye from hatch (first feeding larvae) to fingerling size under intensive culture conditions (tank culture) (Nickum 1978; Colesante et al. 1986; Krise and Meade 1986). Research on this phase of walleye aquaculture has included evaluation of live foods and formulated diets (nutrition), design of cultural systems, and stocking density. Fry mortality has been associated with failure to initiate feeding, cannibalism, and the problem of noninflation of the gas bladder. The latter problem results in high mortality of young fish, even among those that have initiated feeding. Noninflation of the gas bladder is a major factor influencing intensive culture of walleye from first feeding through 1-month posthatch (Nickum 1978; Summerfelt 1988a). Failure of gas-bladder inflation is also a major problem in the intensive culture of striped bass (*Morone saxatilis*) (Bulak and Heidinger 1980; Cornacchia 1981; Chapman et al. 1988).

Direct observation of larval walleye indicate that the hydrostatic function of the gas bladder is important to maintenance of body position in the water column and in feeding. Walleye without an inflated gas bladder can be seen to struggle to maintain position. Eventually, the high energy cost of swimming and the difficulty in capturing food results in death of fish without an inflated gas bladder before reaching juvenile stage. Noninflation of the gas bladder occurs when the fish are in transition from yolk-sac respiration to gill respiration (McElman and Balon 1979). Walleye larvae absorb the yolk sac within 5 days of hatching, and the oil globule disappears by the end of 10 days (Li and Mathias 1982). The time of gas-bladder inflation in walleye is not known, but it is assumed to occur between the fifth and twelfth day after hatching. In striped bass, gas-bladder inflation must occur within the first 2 weeks of larval life if it is to occur at all (Bennett et al. 1987; Doroshev and Van Eenennaam 1987).

Both nutritional and environmental factors have been considered to be important in gas-bladder inflation. Although an attractive, nutritionally balanced diet is important for survival, even diets containing live brine shrimp or daphnia do not prevent noninflation of the gas bladder (Burrows 1987). In striped bass and striped bass x white bass hybrids, access of fry to the water surface is necessary for initial gas-bladder inflation (Chapman et al. 1988). Walleye may also require contact with the air to undergo initial inflation (Chapman et al. 1988). The strong phototactic response of larval walleye tends to support this hypothesis. In tanks, newly-hatched fry initially hang vertically in the water column near the surface; meter-net catches of walleye fry in lakes indicates that they are closely associated with the water surface. In Oneida Lake, New York, larval walleye concentrate near the surface, both day and night (Forney 1980). It has been suggested that an oil film on the water surface (originating from the feed or from yolk of dead larvae) in intensive culture systems increases the surface tension and prevents the larvae from breaking the surface and inflating their gas bladders (Colesante et al. 1986). A feeding ring, which retains the feed within a prescribed area, has been suggested as a mechanism for reducing the spread of oil films from formulated feeds (Barrows et al. 1988). Further research on the oil-film hypothesis at Iowa State University in 1987-1988 did not produce evidence in the form of improved gas-bladder inflation or survival in tanks supplied with an oil-skimming absorbent pad. Thus, various hypotheses as to the cause of noninflation of the gas bladder have not been validated, and the etiology of an important problem affecting the intensive culture of walleye fry has not been identified (Nickum 1978; Colesante et al. 1986; Coolwater Culture Workshop 1987, 1988; Summerfelt 1988a). The trial-and-error experiments of fish culturists with diets and cultural systems have not been able to uncover the etiology of the gas-bladder inflation problem.

An active research effort on intensive (tank culture) rearing of walleye fry has been underway at Iowa State University for the past 7 years - initially under the direction of John Nickum and his graduate student F.T. Barrows, and for the past 2 years by Robert Summerfelt and Kent Kuipers (Summerfelt 1988a). In the last 2 years, the percentage survival of fry through 24-days posthatch has averaged 7.1%, slightly better than the 5-6% reported to be state-of-the-art, and far above the 1% that is typical for walleye fry reared on formulated diets through 1-month posthatch (Nickum 1986). Tank design, the use of feeding rings, oil-absorbant pads, gas supersaturation and various commercial and experimental diets have all been studied in terms of their effects on larval gas-bladder inflation and survival.

As a starting point, a collaborative effort between Iowa State and Michigan State Universities is proposed to initiate studies to further the basic understanding of the gas-bladder inflation problem in walleye fry. Together, the two universities can combine expertise in fry culture of walleye (Iowa State University) and fish pathology (Michigan State University) to effectively study this problem. Thomas Bell, the co-principal investigator at Michigan State has experience with histopathology of fish gas bladders in relation to gas-bubble disease (Machado et al. 1987, 1989).

RELATED CURRENT AND PREVIOUS WORK

1. Mechanisms Regulating the Natural Reproductive Cycle

To develop maximally effective methods of managing broodstock, baseline information on the physiological mechanisms regulating reproduction is needed (Donaldson and Hunter 1983; Idler et al. 1987). A starting point for obtaining such information is to characterize changes in specific circulating hormone titers and gonadal development during the annual reproductive cycle. Thereafter, with appropriate experimentation, precise practical methods of controlling reproduction and inducing out-of-season spawning can be developed.

At the functional level, reproduction in fish is controlled by the brain and mediated by the endocrine system. The hypothalamus produces gonadotropin-releasing and (apparently at least in some species) release-inhibiting hormones that regulate the secretion of one or more gonadotropic hormones (gonadotropins) from the pituitary glands (Peter 1983; Peter et al. 1986; Sherwood 1987). At least one gonadotropin (GTH), in turn, stimulates the production and release of sex steroid hormones from the gonads and possibly other steroidogenic tissues, such as the interrenal (Idler and Ng 1983; Fostier et al. 1983, 1987; Fontaine and Dufour 1987; Kunimasa et al. 1988). Estradiol-17β (E_2) appears to be the primary steroid hormone responsible for ovarian growth and development in female fishes (Fostier et al. 1983; Lazier et al. 1987). Testosterone (T) and 11-ketotestosterone (11-KT) appear to be the primary steroid hormones responsible for testicular growth and development in male fishes (Fostier et al. 1983; 1987).

Typically, the reproductive cycles of annually spawning fishes, such as the walleye, are divided sequentially into periods of spawning, gonadal involution and quiescence, gonadal growth and recrudescence, final gonadal maturation and gamete release (ovulation or spermiation), which again leads to spawning (Billard and Breton 1978; Lam 1983; Lam and Munro 1987). During the period of gonadal quiescence, circulating levels of GTH and the sex steroids are usually quite low (Idler and Ng 1983; Fostier et al. 1983, 1987; Fontaine and Dufour 1987). During the period of gonadal growth and recrudescence in females, increasing concentration of GTH and E_2 stimulate vitellogensis (yolk protein formation and deposition) and oocyte growth (Fostier et al. 1983; Nagahama 1983; Idler and Ng 1983; Lazier et al. 1987; Wallace et al. 1987). In males, increasing levels of GTH and T and/or 11-KT stimulate spermatogenesis (Idler and Ng 1983; Fostier et al. 1983, 1987).

Sometime after completion of the gonadal growth phase in most species examined to date, a GTH rise (or surge) triggers final maturation and subsequent gamete release (Billard and Breton 1978; Idler and Ng 1983; Goetz 1983; Fostier et al. 1987). In females, final maturation typically involved migration of the oocyte nucleus (termed the germinal vesicle) to the cell periphery, followed by dissolution of the nuclear membrane and dispersal of the chromosomes (collectively termed germinal vesicle breakdown or GVBD) and by a resumption of meiosis. Concurrently, during final maturation, yolk globules and oil droplets in the cytoplasm of the oocytes coalesce, the degree of coalescence depending on species (Goetz 1983).

The release of ova (ovulation) and sperm (spermiation) from their investing tissues in the ovaries and testes, respectively, are typically preceded and/or accompanied by a fluid shift (hydration) into these organs (Nagahama 1983; Goetz 1983; Fostier et al. 1987; Wallace et al. 1987). A growing body of experimental evidence indicates that the stimulatory effects of the GTH surge on final maturation and ovulation in the females of many species is partially mediated by C-21 steroids produced in the ovaries (Goetz 1983). The principal steroid identified as functioning in this role is 17β, 20α-dihydroxy-4-pregnene-3-one (17,20-DHP)(Goetz 1983; Goetz et al. 1987; Scott and Canario 1987). In some species, both 17,20-DHP and 11-KT have been implicated as playing major roles in spermiation in males (Fostier et al. 1983, 1987).

Numerous life history studies have reported on the reproductive habits and fecundity of walleye (see Scott and Crossman 1973; Colby 1977; Colby et al. 1979; Becker 1983). Hokanson (1977) and Colby et al. (1979) have discussed circumstantial evidence that female walleye, at least of certain "races", may require an over-winter period of cold temperatures to successfully reproduce.

Hearn (1980) and Nagel (1985) have reported successfully raising walleye broodfish in ponds; the Ohio Department of Natural Resources presently has F_2-generation broodstock at its London Fish Hatchery (T. Nagel, personal communication). Iowa State University and the Fisheries Research Laboratory at Southern Illinois University at Carbondale have raised walleye to reproductive size/age in tanks on formulated feed, but these fish have not yet yielded progeny.

To date, endocrine studies on walleye reproduction have focused almost entirely on the pharmacological induction of final oocyte maturation and ovulation, generally during the normal spawning season. Agents, such as carp pituitary extracts, mammalian luteinizing hormones and human chorionic gonadotropin (HCG), have been used to induce final maturation and ovulation, both in vivo (Nelson et al. 1965; Lessman 1978; Hearn 1980) and in vitro (Goetz and Bergman 1978). R. C. Heidinger of Southern Illinois University is presently assessing various methods of inducing final oocyte maturation and ovulation and the effect of these methods on egg fertilization and hatchability (personal communication).

In a recent study, Pankhurst et al. (1986) observed that HCG, "LHRH-A" (a synthetic luteinizing hormone-releasing hormone analogue) and "pimozide" (a dopamine antagonist and presumptive blocker of endogenous GTH release-inhibiting hormone) all stimulated final oocyte maturation and ovulation in prespawning female walleye. An examination of plasma steroid dynamics in relation to changes in oocyte development in fish treated with LHRH-A or pimozide (either alone or in combination) revealed that E_2 and T declined prior to final maturation, but that 17,20-DHP levels increased coincident with GVBD. The latter finding suggests that 17,20-DHP is a maturation-inducing steroid in walleye.

To our knowledge, no definitive investigations characterizing hormonal events and gonadal development during the natural reproductive cycle of walleye have been published. Also not known is whether, and the extent to which, captivity or holding adult walleye in ponds alters their reproductive endocrinology and annual cycle of gonadal development.

2. Zooplankton Seeding and Clam Shrimp Control Strategies

Production and harvest of healthy walleye fingerlings from ponds is often unpredictable and extremely variable (Beyerle 1979b; Coolwater Culture Workshop 1987, 1988). Survival and growth of walleye in high density (e.g., 50,000-400,000 fish/hectare) rearing ponds is dependent on pond management strategies that result in: (1) maintenance of good water quality (e.g., adequate dissolved oxygen); (2) establishment and maintenance of a large population of desirable zooplankton as a food source; and (3) minimization of undesirable animal and plant species that compete with the fish for food or which are predators on the fry.

Organic fertilizers, including animal manures, seed meals and hays, have been commonly used in walleye pond culture. Such fertilizers provide nutrients and substrates for detrital bacterial and protozoa, which in turn are consumed by zooplankton (Geiger 1983b; Buttner and Kirby 1986).

Walleye production records from the Garrison Dam National Fish Hatchery, 1964-1987, covering 900 pond records, were recently analyzed by J. E. Call, assistant hatchery manager (personal communication). Conclusions from this analysis suggest directions for research.

(1) Ponds stocked after June 1 have not produced as many fingerlings as ponds stocked before June 1 (late pond stocking was necessary because the ponds were double cropped, used first for northern pike, then walleye). When two walleye crops were produced in the same ponds, the yield in the second crop was less than the first crop.

(2) Ponds which received inorganic fertilizer averaged 37% more fingerlings than ponds that had not been treated with inorganic fertilizer, but the average size was 50% smaller in the ponds with the higher density.
(3) The amount of organic fertilizer added per pond, from less than 560 to 5044 kg per hectare, did not affect numbers of walleye fingerlings harvested, unless the application rate was less than 227 kg per hectare. However, the average size of fingerlings harvested increased in proportion to the amount of organic fertilizer used.
(4) An abundance of Concostracods (clam shrimp), but not their presence or absence, reduced the number of fingerlings harvested.
(5) There was an inverse relationship between average size and the number of days from stocking to harvest; a rearing period of 30-35 days appears to yield the optimum number and size of fish harvested.
(6) There was an inverse relationship between average size and number of fish harvested; when fish were allowed to get larger than 3304/kg production numbers suffered. A size of 3304 to 4405 fish per kg was regarded as optimum.
(7) Fingerling production was not increased by fry stocking densities of more than 220,264-292,951 per hectare. Average survival to 26 days at a fry stocking density of 146,841-220,264 per hectare ranged from 52-69%, whereas at densities between 440,528 and 550,661 fry per hectare survival was only 30-33%.

Among the most troublesome problems encountered in pond-culture of fingerling fish is the occurrence of invertebrate predators and competitors. Control of air breathing invertebrate insect predators have focused on the use of oil films; gill breathing invertebrates have been controlled with pesticides. However, control of microcrustacean predators (copepods) and competitors (Concostracods) is more difficult because means useful for control of these organisms would have negative effects on microcrustaceans used as food by walleye (i.e., daphnids). Not all microcrustacea are of equal value as food resource for larval walleye, some, such as the rotifers, are too small and some are either too large or their exoskeleton too tough for larval fish to handle. The optimization of environmental and biological conditions requires understanding of competitive interaction and differential response of the invertebrate community to various pond fertilization schemes (kinds, amounts and balance between inorganic and organic fertilizers), timing of pond filling, fertilization, zooplankton seeding (inoculation), and specific strategies undertaken to control predacious insects and competitive organisms (drain and fill, and use of pesticides).

Zooplankton seeding is a strategy for shifting the zooplankton community in favor of the preferred crustacean prey organism needed by the larval fish as they begin active feeding (Geiger 1983a, 1983b). The food supply for the zooplankters, and therefore the composition of the zooplankton population, is influenced by the kind and amounts of inorganic and organic fertilizers used in the ponds. At the Garrison Dam National Fish Hatchery site in North Dakota, both inorganic and organic fertilizers have been used because the water is of low fertility (Lake Sakakawea), but at the Valley City National Fish Hatchery, which derives its water from a highly fertile source (Sheyenne River), alfalfa pellets have been the principle form of fertilizer. In the recent past, the Garrison Dam National Fish Hatchery has been using only chopped alfalfa hay for fertilization. Different forms of alfalfa may influence the decomposer community upon which the desirable zooplankton are dependent for their food supply.

3. Development and Etiology of Gas-Bladder Inflation Problems

The gas bladder of fish, called the swim bladder by some because of its hydrostatic function, develops as an outpocketing of the foregut, the anterior portion of the alimentary tract (Jones and Marshall 1953). Even physoclistous fishes, which as juveniles and adults lack a direct connection between the esophagus and the gas bladder but possess retia mirabilia to extract oxygen from the blood to maintain oxygen levels in the gas bladder, are initially physostomous with a direct connection from the gas bladder to the esophagus. The hydrostatic function of the bladder is important to maintenance of body position in the water column and in feeding. Observations suggest that absence of an inflated gas bladder causes the fish to struggle to maintain position in the water column, and eventually, the high energy cost for swimming and the difficulty in capturing food results in death. Failure of gas-bladder inflation is also a major problem in culture of striped bass *Morone saxatilis* (Bulak and Heidinger 1980; Cornacchia 1981; Chapman et al. 1988).

Li and Mathias (1982) illustrate (line drawing) a prolarval walleye (stage with yolksac present) with a gas bladder, however, the gas bladder would not be visible until inflation, which does not seem to occur until the postlarval stage.

We know of no studies which endeavored to determine the age at which larval walleye develop a gas bladder. It is important to note that the time of gas-bladder inflation is a small window of opportunity in the early posthatch interval, and if not developed at that time, it will probably not develop at all. In striped bass, gas-bladder inflation must occur within the first 2 weeks of larval life if it is to occur at all (Bennett et al. 1987; Doroshev and Van Eenennaam 1987). In the logperch, *Percina caprodes*, another member of the Percidae, yolk is depleted 5 days posthatch and the gas bladder is first seen 7-days posthatch, so it seems that the gas bladder develops soon after yolk is depleted (Grizzle and Curd 1978). This hypothesis seems supported by the timing of gas-bladder inflation in some other perciform fishes: Chapman et al. (1988) reported that larval striped bass first inflated their gas bladder on Day 7 posthatch; Cornacchia (1981) reported initial inflation in striped bass occurred 5-7 days posthatch. Walleye larvae absorb the yolk sac within 5 days of hatching and the oil globule disappears by the end of 10 days (Li and Mathias 1982). As a working hypothesis, it is assumed that gas-bladder inflation in walleye occurs between 5 and 10 or 12 days posthatch. This 5-7 day interval begins with the disappearance of the yolk sac (Day five) and the tenth to twelfth day which coincides with the disappearance of oil globule (Li and Mathias 1982). This interval coincides with the transition from endogenous to exogenous feeding and a transition from yolk sac respiration to gill respiration.

The critical factors in gas-bladder inflation in walleye are not known, but many factors have been considered. The most widely accepted hypothesis is one presuming that the larval fish must gulp air at the air-water interface in order to inflate their gas bladder. Access to the water surface is necessary for striped bass and striped bass x whitebass hybrids to inflate their gas bladder (Chapman et al. 1988). Because walleye are physoclistous fishes they may also require contact with the air to effect initial inflation (Chapman et al. 1988). The strongly phototactic response of larval walleye supports an air-water relationship; in tanks they initially hang vertically in the water column near the surface and meter net catches of walleye fry in lakes indicates that they are closely associated with the lake surface until they are juveniles (Forney 1980). Thus, it is generally assumed that walleye, as striped bass, require direct access to the water surface to allow larvae the opportunity to gulp air and pass it via the pneumatic duct into the rudimentary gas bladder for initial inflation (Chapman et al. 1988).

If access to the air-water interface is essential, as generally accepted, then factors influencing surface tension may be important. It has been suggested that an oil film, derived from the feed (Colesante et al. 1986) or oil released from the oil globules of dead fish, may collect on the surface of the culture vessels, and prevent the larvae from breaking through the air-water interface. A feeding ring, which retains the feed within a prescribed area, has been suggested as a mechanism for reducing the spread of an oil film from oily formulated feeds such as W-16 (Barrows et al. 1988). Half of the total fish oil content of the W-16 feed is applied to the surface of the feed rather than incorporated in the mixture in order to maintain pellet quality (Dewey Klaustermeier, Glencoe Mills, Minnesota, personal communication).

However, aside from direct contact with the air-water interface, Chapman et al. (1988) acknowledged that substantial variation in inflation rate is from "extraneous" variables. There are other options for filling the gas bladder which cannot be ruled out: secretion of gases into the gas bladder by the retia mirabile, and direct intake of gas bubbles by the larval fish from bubbles in the water column (Hadley et al. 1987). Chapman et al. (1988) found that turbulence in the water in aerated aquaria produced consistently higher inflation rates in larval striped bass compared to fish reared in unaerated aquaria. In intensive culture, the water surface may be made turbulent by release of air bubbles from the bottom of the tank. In addition to the turbulence produced at the surface, the release of air or oxygen at the bottom of the culture vessel provides an abundance of small air or oxygen bubbles which may be utilized by larval walleye to fill their gas bladder. In rivers, air bubbles may be available to fish larvae below water falls and in pool areas downstream of riffles; in lakes, surface turbulence from toppling of waves (white-caps) provide opportunities for gas-bubble formation near the surface.

Gas-bladder inflation may also be influenced by gas pressure in the water column. Gas-bubble disease (GBD) is caused by hyperbaric total dissolved gas pressure (gas supersaturation) produced by natural and human-induced causes. One clinical sign of GBD is gas-bladder hyperinflation (see review by Cornacchia and Colt 1984). Cornacchia and Colt (1984) reported overinflation of the gas bladder of striped bass at total gas pressure as low as 102.9% and increased mortality at total gas pressure of 105.6-106.0%. Summerfelt (1988a) obtained negative results in an effort to use oxygen supersaturation as a mechanism to enhance gas-bladder inflation of larval fish.

An infectious disease etiology for noninflation of the gas bladder has not received much attention. Kindschi (1988) stated that heavy bacterial levels produced by overfeeding from 5-11 day posthatch when the walleye fry are inflating the gas bladder may physically prevent gas-bladder inflation by closing off the pneumatic duct.

OBJECTIVES

1. Develop baseline information on the mechanisms regulating the natural reproductive cycle of wild and pond-held walleye by characterizing seasonal changes in hormone titers and gonadal histology --- characterization of the natural reproductive cycle.

2. Evaluate zooplankton seeding and clam shrimp control strategies for pond culture of walleye fingerlings.

3. Determine the etiology of non-inflation of the gas bladder in intensively cultured walleye fry.

PROCEDURES

Objective 1

Research to characterize the natural reproductive cycle of walleye will be done collaboratively by investigators from Southern Illinois University (SIU), the University of Minnesota (UM), University of Wisconsin-Madison (UW-Madison) and the University of Notre Dame (UND). Specific methods of capturing and/or maintaining fish, taking and processing blood and tissue samples, and collecting and analyzing data will be agreed upon, or developed jointly, prior to implementation. In general, SIU will be responsible for collecting blood and tissue samples from (brood-size and -age) adult walleye captured from the wild in Illinois and maintained (by SIU) in large holding ponds on forage fish. The UW-Madison will be responsible for the analysis of blood tissue samples and interpretation of endocrinological data. The UM, working with the Minnesota and Wisconsin Departments of Natural Resources and the Red Lakes Indian Reservation, will be responsible for the collection of blood and tissue samples from wild walleye in Minnesota and/or Wisconsin. Dr. F.W. Goetz of the UND will assist UW-Madison researchers with hormone assay procedures and the analysis of endocrinological data. Year-round sample collection will be done from specifically identified walleye populations, agreed upon in advance.

The principal (null) hypothesis of Objective 1 is that the annual reproductive cycles of walleye held in ponds in Illinois and walleye in the wild in Minnesota and/or Wisconsin will not differ significantly. As an alternative hypothesis, we suggest that holding walleye in ponds alters hormonal dynamics and gonadal development (e.g., changes in hormone levels will not be as great in pond held fish as in wild fish, at the time of final maturation in spring). Regardless of hypothesis, this comparison will provide valuable insights on the mechanisms regulating walleye reproduction and on the extent to which captivity and pond holding (which includes the possible effects of latitudinal temperature differences) influence the reproductive cycle of walleye.

For a period of about 10 months prior to the initiation of pond and field sampling, efforts on Objective 1 will be focused on developing standardized sample collection techniques, setting up appropriate assay systems for hormone analysis, capturing wild adult walleye using minimum stress procedures, and acclimatizing these fish to the holding ponds. Also during this period, because the walleye is highly valued as a game fish, considerable time may be required to identify appropriate wild populations from which to collect fish and take blood samples. These populations will be identified in cooperation with the Minnesota and Wisconsin Department of Natural Resources, the Illinois Department of Conservation and the U.S. Fish and Wildlife Service.

Fish will be sampled over a 20-month period, through two spawning seasons. In the first year, sampling will be done about every 8 to 10 weeks from mid-May to mid-November, once in mid-winter (January-February), and shortly before, during and shortly after the spawning season.

In the second year of sampling, critical or weak data sets from the first year will be replicated as needed, and more frequent sampling may be done during key periods of the reproductive cycle (e.g., the prespawning and spawning periods). At each sampling time and location, blood and tissue samples will be collected from a minimum of four fish of each sex. Additional blood samples from up to ten fish of each sex will be collected, when and if they are available, using nonlethal procedures (e.g., see Wingo and Muncy 1984).

Sampling procedures will include measurement of total fish length, total body weight, liver and eviscerated carcass weights, and collection of the gonads and blood. Representative portions of the gonads will be fixed in Bouin's fluid, embedded in paraffin or plastic, sectioned and stained with alum hemotoxylin and eosin, or "azure II", according to standard methods. Maturational state of the gonads will be assessed gravimetrically and by routine histological, histometric and cytometric procedures (employing light microscopy). Levels of E_2 T in the blood samples will be measured by existing radioimmunoassay (RIA) or enzyme-linked immunosorbant assay (ELISA) procedures (e.g., Scott et al. 1982; Cochran et al. 1988; Mao 1988), adapted for use with walleye plasma or serum. Depending on time and the availability of funds, serum titers of 17,20-DHP and 11-KT may also be determined.

All immunoassay procedures will be validated, and intra-and interassay coefficients of variation calculated. Whenever possible, parametric statistical methods will be used to analyze numerical data. Nonparametric statistics will be employed when the application of parametric methods is found to be inappropriate or unfeasible.

Data collected by SIU, UM and UW-Madison investigators will be collated on an ongoing basis, and the findings published in a timely manner in appropriate peer-reviewed national or international scientific journals. Extension information will be published through regional and station bulletins, in collaboration with the NCRAC Aquaculture Extension Work Group.

Objective 2

Research to improve walleye fingerling production methods by evaluating selected fertilization strategies and zooplankton seeding will be a collaborative effort between Iowa State University and the U.S. Fish and Wildlife Service National Fish Hatcheries in North Dakota. Actual pond experiments will be conducted at U.S. Fish and Wildlife Service coolwater fish hatcheries located in North Dakota:

(1) Valley City National Fish Hatchery - 12, 0.30 hectare ponds (0.75 acre).
(2) Garrison Dam National Fish Hatchery - 12, 0.61 hectare ponds (1.50 acre).

The variation in operational schedules, procedures, and problems at the two hatcheries provide a range of problems and opportunities for research on basic issues involved in walleye pond culture. The two fish hatcheries, (located about 322 km apart) differ by about 2-3 weeks in timing of stocking and harvest: the Garrison Dam National Fish Hatchery utilizes cold nutrient poor water from Lake Sakaka whereas the Valley City National Fish Hatchery uses nutrient rich water from the fertile Sheyenne River. They have both utilized alfalfa as an organic fertilizer but chopped alfalfa hay is used at the Garrison Dam National Fish Hatchery and alfalfa pellets at Valley City National Fish Hatchery. The Garrison Dam National Fish Hatchery has had problems with clam shrimp (Conchostraca) and in their ponds the zooplankton bloom is mainly rotifers and copepods. In contrast, the Valley City National Fish Hatchery rarely has clam shrimp problems and they have zooplankton blooms dominated by cladocerans.

In the first year, the experiments at the two North Dakota National Fish Hatchery sites will involve a 2 x 2 x 3 factorial treatment design: sites (2) x with and without zooplankton seeding (2) x kinds of organic fertilizers (3).

Site	Zooplankton Seeding	Fertilizer Type	Number of Ponds
Garrison Dam National Fish Hatchery (12 ponds)	with seeding (inoculation)	chopped alfalfa hay	2
		alfalfa meal	2
		alfalfa pellets	2
	without seeding	chopped alfalfa hay	2
		alfalfa meal	2
		alfalfa pellets	2
Valley City National Fish Hatchery (12 ponds)	with seeding (inoculation)	chopped alfalfa hay	2
		alfalfa meal	2
		alfalfa pellets	2
	without seeding	chopped alfalfa hay	2
		alfalfa meal	2
		alfalfa pellets	2
		TOTAL	24

At each site, three forms of organic fertilizer will be used with two ponds of each type: chopped alfalfa hay, alfalfa meal and alfalfa pellets. The alfalfa meal is ground alfalfa pellets, but the smaller particle size of the meal facilitates bacterial decomposition and rapid development of a zooplankton bloom. Application rates and the schedule for application will be the same at both sites. Both sites will use chopped hay and alfalfa products from the same source to avoid differences in nitrogen and moisture content which is known to vary from lot to lot. A proximate analysis will be done on moisture, total nitrogen, and energy content of each feed type by taking random samples of the feeds as they are applied.

The experimental design will allow comparisons between the two sites with the same and different kinds of alfalfa formulations -- neither site has used alfalfa meal in the recent past. The application rates (kg/hectare) of alfalfa hay and pellets represent the typical rates in use at these hatcheries in recent years; the rate for alfalfa meal is equal to that used for the pellets. These application rates are about the maximum input of organic matter that the ponds can sustain without going anoxic; i.e. in prior years, some ponds have had oxygen depletion as low as 3 mg/L by early morning. The hay is purchased in the fall, stored over winter in bales and chopped before application. Due to the difficulty in handling, alfalfa hay is applied to only one spot, and distributed about the pond by the wind. By contrast, the pellets and the meal will be blown around the pond fairly uniformly.

In 1989, the application will be by biomass of the particular oganic fertilizer, in 1990, application rates in terms of biomass will be adjusted to provide uniform nitrogen application rates of each form of alfalfa.

The proposed schedule for application (number of days after filling) of organic fertilizers to walleye fry culture ponds at the two national fish hatcheries in North Dakota is given in the table below.

Application Schedule	Chopped Alfalfa Hay (kg/hectare)	Alfalfa Meal (kg/hectare)	Alfalfa Pellets (kg/hectare)
1st day	524	269	269
9th day	524	269	269
18th day	524	269	269
27th day	524	269	269
TOTAL	2,096	1,076	1,076

Ponds at the Valley City National Fish Hatchery will be filled about May 5-10 and those at the Garrison Dam National Fish Hatchery from May 20-25, 1989. The fry will be offspring of parents collected at Devil's Lake, North Dakota. At both hatcheries, walleye fry will be stocked at an age 1 to 3 days posthatch and 2 days after filling the ponds (one day after application of the first fertilization treatment). Harvest will be done when fingerlings are about 35-50 mm TL (about 30-40 days posthatch). Fry stocking density will be 411,667 per hectare.

Zooplankton for pond inoculation will be collected with a modified propeller-lift pump as described by Graves and Morrow (1988) or an air-lift pump. The propeller-lift pump allows directional flow of the discharge water into a floating basket (1 m x 0.5 m x 0.1 m) with 0.5 mm mesh Saran™ screen. Zooplankton harvesting will be done at night (0100-0700 hours) with a light as suggested by Graves and Morrow (1988). Ponds at both hatcheries will be seeded with about 1 kg/hectare of zooplankton once per week for the first 2 weeks. Seeding will be done with zooplankton collected from fertilized earthen ponds without fish at the Valley City National Fish Hatchery. Plankton from this source will provide both sites with stock of the same species composition.

Zooplankton populations in the ponds will be sampled once weekly over the 30-40 day rearing interval at 0800 hours using a 4-L, Schindler-Patalas trap with a plankton bucket having an 80-µm mesh. Three trap samples will be collected from each pond at the deep, middle and shallow ends of the ponds. They will be preserved individually in 70% isopropyl alcohol and enumerated at Iowa State University at a later date. Counts of rotifers will be made from aliquots on a Sedgwick-Rafter cell on a light microscope at suitable magnification to determine the density (number/L) of rotifers. Cladocerans, copepods, and clam shrimp will be counted in a plankton counting wheel using the total count method. Three subsamples will be averaged to determine the count for each sample.

Twice weekly measurements will be made in each pond of Secchi disk transparency, water level, temperature, and dissolved oxygen, pH, and ammonia nitrogen (NH_3-N). We acknowledge that hay may color the water and result in lower Secchi readings, however, Secchi disk transparency is a useful measure of chlorophyll concentration (Jones and Bachmann 1978). Water samples will be collected from the deepest end of the ponds at 0.5 m from the pond surface. Lake water temperature will be measured with a thermistor thermometer; dissolved oxygen with a temperature-compensating, membrane electrode calibrated by comparison with sodium azide modification of the Winkler procedure (American Public Health Association 1981); ammonia nitrogen by the direct Nesslerization method (American Public Health Association 1981), and pH with a glass electrode. Oxygen samples may be collected at more frequent intervals if they reach critically low levels.

Survival will be measured at the termination of the rearing interval, and growth will be observed by samples of 20-50 fish collected 10 and 20 days posthatch; fish will be collected by seining with a 10 m, 3 mm bag seine 11.8 m deep. Fish collected for growth measurements will be fixed in 10% buffered formalin and saved for stomach content analysis. Total volume of stomach contents will be determined and the percent of each major food item estimated. The size range of each taxonomic group will be measured from random samples and percent frequency of occurence will be enumerated.

In the second year, the design will be modified to fertilize the experimental ponds on a uniform total nitrogen basis, and zooplankton inoculation rate will be increased. Zoobenthos may be sampled in the second year if they are shown to be a significant dietary item. The second year will also provide replication of selected components of the first year, to determine year-to-year variation as well as for validation. Other factors for experimental evaluation in the second and third years include use of a fill-drain-fill strategy to overcome the rapid hatching and turnover rate of the Conchostra if their dominance cannot be overcome by inoculation and differential fertilization strategies.

Objective 3

Research to determine the etiology of noninflation of the gas bladder of walleye will be done using samples of known-age fry collected at daily intervals during the first 20 days posthatch. Samples will be collected from fry rearing tanks from three different fry sources. Eggs or newly hatched fry will be obtained from Milford Hatchery, Kansas or Oklahoma for the first trial, from Spirit Lake Hatchery, Iowa for a second trial and Garrison Dam National Fish Hatchery or Valley City National Fish Hatchery, North Dakota for a third trial.

Fry will be reared in tanks of similar volumes. Water quality and current will be maintained with a complete exchange of once per hour. A water current will be maintained to provide a uniform orientation of swimming fish into the current, but not strong enough to cause swimming problems. Compressed air will be added to the tanks with caution to avoid creating excessive turbulence. Water temperature will be 15 °C for the first 10 days posthatch, then 17 °C for 11-20 days posthatch and 20 °C thereafter. Constant 24 hour light regimes will be used at about 240 lux.

A distinctive feature of the intensive rearing will be the exclusive use of formulated diets. Fish will be fed "Fry Feed Kyowa," Series B (Kyowa Hakko Kogyo Company, Ltd., Japan). Three sizes will be used: B-250, B-400 and B-700. The particle size of this feed, as given by the manufacturer, is as follows: B-250, less than 250 μm; B-400, 250-400 μm; and B-700, 400-700 μm. Feed will be presented every 3.0 minutes on a 24-hour basis (480 feedings per day) for the first 30 days. Vibrator type feeders (Model AF6, Sweeney Enterprises, Inc., Boerne, TX) will be used to dispense the feed by electronic time-clock. Feeding will begin when the fry are 4-days posthatch.

Experience indicates the importance of frequent upgrading of feed size to accommodate bioenergetics. Failure to incrementally increase feed size results in cannibalism. The initial daily amount of food (10 mg/fish) must be incrementally increased by 2 mg/fish/day on a regular schedule. It is obvious that these amounts are in excess of calculated energetic needs if the fish consume what is given. However, experience indicates that the fish consume only a fraction of the feed. Because the feed does not remain in suspension, feeding is done in excess in order to maintain feed density.

During the rearing interval, waste feed and dead fish will be siphoned from the bottom of the tanks daily and counts of dead fish will be made to relate daily mortality to fish age and environmental conditions. Waste feed will be separated from the dead fish using a number 30 standard sieve with 600 μm openings (the sieve retains the fish but passes the waste feed). Survival over the fry rearing phase (first 30 days) will be determined from a final count of fish in the tank at the end of 30 days. At the end of 30 days, a sample of 25 fish from each tank will be used to measure total length and occurrence of an inflated gas bladder. Gas-bladder inflation will be observed under a dissecting microscope with transmitted light.

FACILITIES

Objective 1

Blood and tissue samples relevant to Objective 1 will be collected, preliminarily processed, and shipped or transported to the UW-Madison. All hormone and tissue analyses will be done by the UW Aquaculture Program, which has its main research facilities at the Lake Mills State Fish Hatchery, Lake Mills, Wisconsin. These facilities include an analytical laboratory that is well equipped for histological, cytological and endocrinological research. After July 1989, the Aquaculture Program will have additional analytical and wet laboratory facilities on the main UW-Madison campus. The Program also has access to much of the laboratory facilities, equipment and instrumentation of the UW-Madison Endocrinology-Reproductive Physiology Program, Department of Poultry Science and Center for Limnology.

The Fisheries Research Laboratory on the SIU campus has several 4.3-plus m electrofishing and net boats available for collecting broodfish. The Laboratory also has a number of gill nets, trap nets and other collection gears suitable for capturing walleye. Three pickup truck hauling tanks are available for transport. These are equipped with surface agitator/aerators and compressed oxygen diffusers. Two of the hauling tanks are insulated. Four pickup trucks are operated by the Laboratory which can be used to transport boats, collection gear, and hauling tanks. Equipment, boats, vehicles and facilities at the Laboratory's two satellite research stations in northern and central Illinois parallel those of the SIU campus laboratory. The two field stations, the campus facilities, and a good working relationship with the Illinois Department of Conservation permit ready access to walleye broodfish populations anywhere in the state.

Two 0.6 hectare ponds on the SIU campus will be used to hold walleye broodfish. A third, larger pond will also be used if broodfish are captured in numbers sufficient to warrant its use. A number of other ponds will be used to provide supplemental forage fish for the walleye if necessary. However, threadfin shad and rosy red minnow broodfish will be stocked into the walleye ponds, and we believe natural reproduction will provide enough forage. Forage fish populations and broodfish condition will be routinely monitored in both ponds to ascertain whether additional forage organisms are needed.

Objective 2

This research will use the pond facilities of the U.S. Fish and Wildlife Service coolwater fish hatcheries located at (1) Valley City and (2) Garrison Dam, North Dakota. The Valley City National Fish Hatchery will make available a trailer which can be used for laboratory activities and for housing university personnel while they are working in North Dakota. The State of North Dakota has promised a travel trailer for use by personnel while they are working at the Garrison Dam National Fish Hatchery. Campus facilities at Iowa State University include standard laboratory space for conducting the zooplankton and data analysis. Dissecting and compound microscopes are available with camera attachments for photomicrography.

Objective 3

Fry Culture Facilities

The Iowa State University fry culture facilities consist of seven 180-200 L tanks; each tank has access to two water supplies capable of providing different water of different temperature and oxygen content. The tanks are provided with individual feeders and lights.

Histopathology

The College of Veterinary Medicine, Michigan State University has extensive facilities for preparation of tissues for histopathology, as well as research-grade microscopes and apparatus for photomicrography. The histopathology studies will be conducted at facilities of the Animal Health Diagnostic Laboratory of Michigan State University. The equipment includes microtomes, stainers, blade sharpeners, heaters, microscopes, photomicroscopes and photocopiers.

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PROJECT LEADERS

State	Name/Institution	Area of Specialization
Illinois	Robert J. Sheehan Southern Illinois University	Aquaculture/Environmental Physiology of Fishes
	Bruce L. Tetzlaff Southern Illinois University	Finfish Aquaculture
Indiana	Frederick W. Goetz University of Notre Dame	Reproductive Endocrinology of Fishes
Iowa	Robert C. Summerfelt Iowa State University	Finfish Aquaculture
Michigan	Thomas G. Bell Michigan State University	Veterinary Pathology
	Allan L. Trapp Michigan State University	Veterinary Pathology
Minnesota	Anne R. Kapuscinski University of Minnesota	Quantitative Genetics
Wisconsin	Terrence B. Kayes University of Wisconsin-Madison	Finfish Aquaculture Physiology/Endocrinology
	Jeffrey A. Malison University of Wisconsin-Madison	Walleye and Yellow Perch Culture Physiology/Endocrinology

INDIVIDUAL BUDGETS FOR PARTICIPATING INSTITUTIONS

Illinois

Southern Illinois University
Robert J. Sheehan
Bruce L. Tetzlaff

Indiana

University of Notre Dame
Frederick W. Goetz

Iowa

Iowa State University
Robert C. Summerfelt

Michigan

Michigan State University
Thomas G. Bell
Allan L. Trapp

Minnesota

University of Minnesota
Anne R. Kapuscinski

Wisconsin

University of Wisconsin-Madison
Terrence B. Kayes
Jeffrey A. Malison

PROPOSED WALLEYE BUDGET SHEET FOR SOUTHERN ILLINOIS UNIVERSITY

(Sheehan and Tetzlaff)

Objective 1

	Yr 1 No.	Yr 1 FTEs	Yr 2 No.	Yr 2 FTEs	Year 1	Year 2
A. Salaries and Wages						
1. No. of Senior Personnel & FTEs[1]						
a. (Co)-PI(s)	2	0.10	2	0.10	$0	$0
b. Senior Associates						
2. No. of Other Personnel (Non-Faculty) & FTEs						
a. Research Assoc./Postdoc						
b. Other Professionals	1/3		1/2		$800	$1,040
c. Graduate Students	2		2		$9,360	$10,080
d. Prebaccalaureate Students						
e. Secretarial-Clerical						
f. Technical, Shop, and Other						
Total Salaries and Wages					$10,160	$11,120
B. Fringe Benefits					$0	$0
C. **Total Salaries, Wages and Fringe Benefits**					$10,160	$11,120
D. Nonexpendable Equipment					$0	$0
E. Materials and Supplies					$3,000	$2,500
F. Travel - Domestic (*Including Canada*)					$840	$1,000
G. Other Direct Costs					$2,300	$2,000
TOTAL PROJECT COSTS (*C through G*)					$16,300	$16,620

[1] FTEs = Full Time Equivalents based on 12 months.

PROPOSED WALLEYE BUDGET SHEET FOR UNIVERSITY OF NOTRE DAME

(Goetz)

Objective 1

	Yr 1 No.	Yr 1 FTEs	Yr 2 No.	Yr 2 FTEs	Year 1	Year 2
A. Salaries and Wages						
1. No. of Senior Personnel & FTEs[1]						
a. (Co)-PI(s)	0	0	0	0	$0	$0
b. Senior Associates						
2. No. of Other Personnel (Non-Faculty) & FTEs						
a. Research Assoc./Postdoc						
b. Other Professionals						
c. Graduate Students						
d. Prebaccalaureate Students						
e. Secretarial-Clerical						
f. Technical, Shop, and Other ..						
Total Salaries and Wages					$0	$0
B. Fringe Benefits					$0	$0
C. **Total Salaries, Wages and Fringe Benefits**					$0	$0
D. Nonexpendable Equipment					$0	$0
E. Materials and Supplies					$100	$150
F. Travel - Domestic (*Including Canada*)					$750	$700
G. Other Direct Costs					$0	$0
TOTAL PROJECT COSTS (*C through G*)					$850	$850

[1] FTEs = Full Time Equivalents based on 12 months.

PROPOSED WALLEYE BUDGET SHEET FOR IOWA STATE UNIVERSITY

(Summerfelt)

Objectives 2 and 3

	Yr 1 No.	Yr 1 FTEs	Yr 2 No.	Yr 2 FTEs	Year 1	Year 2
A. Salaries and Wages						
1. No. of Senior Personnel & FTEs[1]						
a. (Co)-PI(s)	1	0.10	1	0.10	$0	$0
b. Senior Associates						
2. No. of Other Personnel (Non-Faculty) & FTEs						
a. Research Assoc./Postdoc						
b. Other Professionals						
c. Graduate Students	1	0.50	1	0.50	$10,800	$11,880
d. Prebaccalaureate Students	3	0.875	3	0.875	$10,385	$11,423
e. Secretarial-Clerical	1	0.08	1	0.08	$1,700	$1,785
f. Technical, Shop, and Other						
Total Salaries and Wages					$22,885	$25,088
B. Fringe Benefits (On 2c)					$300	$300
C. **Total Salaries, Wages and Fringe Benefits**					$23,185	$25,388
D. Nonexpendable Equipment					$8,600	$0
E. Materials and Supplies					$8,100	$5,700
F. Travel - Domestic (*Including Canada*)					$4,100	$4,440
G. Other Direct Costs					$1,000	$1,000
TOTAL PROJECT COSTS (*C through G*)					$44,985	$36,528

[1] FTEs = Full Time Equivalents based on 12 months.

PROPOSED WALLEYE BUDGET SHEET FOR MICHIGAN STATE UNIVERSITY

(Bell and Trapp)

Objective 3

	Yr 1 No.	Yr 1 FTEs	Yr 2 No.	Yr 2 FTEs	Year 1	Year 2
A. Salaries and Wages						
1. No. of Senior Personnel & FTEs[1]						
a. (Co)-PI(s)	2	0.10	2	0.10	$0	$0
b. Senior Associates						
2. No. of Other Personnel (Non-Faculty) & FTEs						
a. Research Assoc./Postdoc						
b. Other Professionals						
c. Graduate Students	1	0.25	1	0.25	$4,416	$4,800
d. Prebaccalaureate Students						
e. Secretarial-Clerical						
f. Technical, Shop, and Other ..						
Total Salaries and Wages					$4,416	$4,800
B. Fringe Benefits					$0	$0
C. **Total Salaries, Wages and Fringe Benefits**					$4,416	$4,800
D. Nonexpendable Equipment					$0	$0
E. Materials and Supplies					$650	$600
F. Travel - Domestic (*Including Canada*)					$700	$715
G. Other Direct Costs					$600	$717
TOTAL PROJECT COSTS (*C through G*)					$6,366	$6,832

[1] FTEs = Full Time Equivalents based on 12 months.

PROPOSED WALLEYE BUDGET SHEET FOR UNIVERSITY OF MINNESOTA

(Kapuscinski)

Objective 1

	Yr 1 No.	Yr 1 FTEs	Yr 2 No.	Yr 2 FTEs	Year 1	Year 2
A. Salaries and Wages						
1. No. of Senior Personnel & FTEs[1]						
a. (Co)-PI(s)	1	0.03	1	0.03	$0	$0
b. Senior Associates						
2. No. of Other Personnel (Non-Faculty) & FTEs						
a. Research Assoc./Postdoc						
b. Other Professionals						
c. Graduate Students						
d. Prebaccalaureate Students						
e. Secretarial-Clerical						
f. Technical, Shop, and Other	1	0.17	1	0.17	$2,780	$2,855
Total Salaries and Wages					$2,780	$2,855
B. Fringe Benefits (25% of 2f)					$695	$714
C. **Total Salaries, Wages and Fringe Benefits**					$3,475	$3,569
D. Nonexpendable Equipment					$0	$0
E. Materials and Supplies					$150	$200
F. Travel - Domestic (*Including Canada*)					$1,000	$1,100
G. Other Direct Costs					$150	$200
TOTAL PROJECT COSTS (*C through G*)					$4,775	$5,069

[1] FTEs = Full Time Equivalents based on 12 months.

PROPOSED WALLEYE BUDGET SHEET FOR UNIVERSITY OF WISCONSIN-MADISON

(Kayes and Malison)

Objective 1

	Yr 1 No.	Yr 1 FTEs	Yr 2 No.	Yr 2 FTEs	Year 1	Year 2
A. Salaries and Wages						
1. No. of Senior Personnel & FTEs[1]						
a. (Co)-PI(s)	2	0.14	2	0.14	$0	$0
b. Senior Associates						
2. No. of Other Personnel (Non-Faculty) & FTEs						
a. Research Assoc./Postdoc						
b. Other Professionals	1	0.50	1	0.50	$11,500	$12,075
c. Graduate Students						
d. Prebaccalaureate Students						
e. Secretarial-Clerical						
f. Technical, Shop, and Other ..						
Total Salaries and Wages					$11,500	$12,075
B. Fringe Benefits (24% of 2b)					$2,760	$2,898
C. **Total Salaries, Wages and Fringe Benefits**					$14,260	$14,973
D. Nonexpendable Equipment					$0	$0
E. Materials and Supplies					$3,000	$3,373
F. Travel - Domestic (*Including Canada*)					$700	$1,200
G. Other Direct Costs					$400	$650
TOTAL PROJECT COSTS (*C through G*)					$18,360	$20,196

[1] FTEs = Full Time Equivalents based on 12 months.

CULTURAL TECHNOLOGY OF WALLEYE

Budget Summary for Each Participating Institution at 91.6K for Year 1

	SIU	UND	ISU	MSU	U MINN.	UW-MAD.	TOTALS
Salaries and Wages	$10,160	$0	$22,885	$4,416	$2,780	$11,500	$51,741
Fringe Benefits	$0	$0	$300	$0	$695	$2,760	$3,755
Total Salaries, Wages, and Benefits	$10,160	$0	$23,185	$4,416	$3,475	$14,260	$55,496
Nonexpendable Equipment	$0	$0	$8,600	$0	$0	$0	$8,600
Materials and Supplies	$3,000	$100	$8,100	$650	$150	$3,000	$15,000
Travel	$840	$750	$4,100	$700	$1,000	$700	$8,090
Other Direct Costs	$2,300	$0	$1,000	$600	$150	$400	$4,450
TOTAL PROJECT COSTS	$16,300	$850	$44,985	$6,366	$4,775	$18,360	**$91,636**

CULTURAL TECHNOLOGY OF WALLEYE

Budget Summary for Each Participating Institution at 86.1K for Year 2

	SIU	UND	ISU	MSU	U MINN.	UW-MAD.	TOTALS
Salaries and Wages	$11,120	$0	$25,088	$4,800	$2,855	$12,075	$55,938
Fringe Benefits	$0	$0	$300	$0	$714	$2,898	$3,912
Total Salaries, Wages, and Benefits	$11,120	$0	$25,388	$4,800	$3,569	$14,973	$59,850
Nonexpendable Equipment	$0	$0	$0	$0	$0	$0	$0
Materials and Supplies	$2,500	$150	$5,700	$600	$200	$3,373	$12,523
Travel	$1,000	$700	$4,440	$715	$1,100	$1,200	$9,155
Other Direct Costs	$2,000	$0	$1,000	$717	$200	$650	$4,567
TOTAL PROJECT COSTS	$16,620	$850	$36,528	$6,832	$5,069	$20,196	**$86,095**

RESOURCE COMMITMENT FROM INSTITUTIONS[1]

(Salaries, Supplies, Expenses and Equipment)

Institution/Item		Year 1	Year 2
Southern lllinois University			
Salaries and Benefits: SY @ 0.10 FTE		$3,624	$3,624
TY @ 0.10 FTE		$800	$800
Supplies, Expenses and Equipment		$18,100	$18,100
	TOTAL PER YEAR	**$22,524**	**$22,524**
lowa State University			
Salaries and Benefits: SY @ 0.10 FTE		$7,788	$7,788
Supplies, Expenses and Equipment		$0	$0
	TOTAL PER YEAR	**$7,788**	**$7,788**
Michigan State University			
Salaries and Benefits: SY @ 0.10 FTE		$8,911	$9,943
Supplies, Expenses and Equipment		$0	$0
	TOTAL PER YEAR	**$8,911**	**$9,943**
University of Minnesota			
Salaries and Benefits: SY @ 0.03 FTE		$1,682	$1,776
TY @ 0.03 FTE		$750	$769
Supplies, Expenses and Equipment		$1,418	$1,599
	TOTAL PER YEAR	**$3,913**	**$4,134**
University of Wisconsin-Madison			
Salaries and Benefits: SY @ 0.14 FTE		$4,783	$5,023
TY @ 0.04 FTE		$1,190	$1,250
Supplies, Expenses and Equipment		$13,478	$14,286
	TOTAL PER YEAR	**$19,451**	**$20,559**
	GRAND TOTAL	**$62,587**	**$64,948**

[1]Since cost sharing is not a legal requirement and due to the difficulty in accounting for small items, documentation will not be maintained.

SCHEDULE FOR COMPLETION OF OBJECTIVES

Objective 1: Initiated in Year 1 and continued in Year 2.

Objective 2: Initiated in Year 1 and continued in Year 2.*

Objective 3: Initiated in Year 1 and continued in Year 2.*

*Significant progress will be made on all three objectives during Years 1 and 2. However, a third year of effort will probably be needed to fully complete the research proposed and thus yield maximum benefits.

LIST OF PRINCIPAL INVESTIGATORS

Thomas G. Bell, Michigan State University

Frederick W. Goetz, University of Notre Dame

Anne R. Kapuscinski, University of Minnesota

Terrence B. Kayes, University of Wisconsin-Madison

Jeffrey A. Malison, University of Wisconsin-Madison

Robert J. Sheehan, Southern Illinois University

Robert C. Summerfelt, Iowa State University

Bruce L. Tetzlaff, Southern Illinois University

Allan L. Trapp, Michigan State University

VITA

Thomas G. Bell
Professor of Pathology — Phone: (517) 353-5275
Project Leader
College of Veterinary Medicine
Michigan State University
East Lansing, MI 48824-1316

EDUCATION

B.A.	University of Arizona	1964
D.V.M.	Washington State University	1969
Internship	University of Minnesota	1970
Ph.D.	Washington State University	1976

POSITIONS

Professor, Michigan State University (1986-present)
Associate Professor, Michigan State University (1980-1986)
Assistant Professor, Michigan State University (1976-1980)
Assistant Professor, Washington State University (1971-1974)

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

Sigma Xi
Phi Zeta
American Association of Veterinary Laboratory diagnosticians
American Association of Pathologists

SELECTED PUBLICATIONS

Machado, J.P., T.G. Bell, D.L. Garling, Jr., N.R. Kevern, and A.L. Trapp. (In Press). Effect of carbon monoxide exposure on gas-bubble trauma in rainbow trout (*Salmo gairdneri*). Canadian Journal of Fisheries and Aquatic Sciences.

Schultze, A.E., I. Sonea, and T.G. Bell. 1988. Primary malignant pulmonary neoplasia in two horses. Journal of the American Veterinary Medical Association 193(4):477-480.

Machado, J.P., D.L. Garling, Jr., N.R. Kevern, A.L. Trapp, and T.G. Bell. 1987. Histopathology of the pathogenesis of embolism (gas-bubble disease) in rainbow trout (*Salmo gairdneri*). Canadian Journal of Fisheries and Aquatic Sciences 44(11):1985-1994.

Bell, T.G., W.L. Smith, and W.D. Oxender. 1986. Biologic interaction of prostaglandin, thromboxane and prostacyclin. *In* J.J. Kabara, editor. Advances in human nutrition, volume 3, Pathrox Publication, Chicago.

Bell, T.G., A.L. Trapp, J. Machado, and D.L. Garling. 1985. A method for rapid fixation for preservation of tissue emphysema: diagnoses of gas-bubble disease in hatchery reared rainbow trout. 28th Annual Proceedings of the American Association of Veterinary Laboratory Diagnoses.

VITA

Frederick W. Goetz, Jr.
Associate Professor and
Director of Graduate Studies
University of Notre Dame
Department of Biological Sciences
Notre Dame, Indiana 46556-0369

Phone: (219) 239-5545

EDUCATION

B.A. Colgate University 1972
Ph.D. University of Wyoming 1976

POSITIONS

Associate Professor and Director of Graduate Studies, Department of Biological Sciences, University of Notre Dame (1984-present)
Assistant Professor, Department of Biological Sciences, University of Notre Dame (1977-1983)
Postdoctoral Fellow, Fisheries and Marine Service, West Vancouver, British Columbia, Canada (1976-1977)
Research Assistant, Zoology Department, University of Wyoming (1974-1976)

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

American Association for the Advancement of Science
American Society of Zoologists: Division of Comparative Endocrinology
American Fisheries Society
Society for the Study of Reproduction
Indiana Academy of Science

SELECTED PUBLICATIONS

Goetz, F.W., A.Y. Fostier, B. Breton, and B. Jalabert. 1987. Hormonal changes during meiotic maturation and ovulation in the brook trout (*Salvelinus fontinalis*). Fish Physiology and Biochemistry 3:203-211.

Goetz, F.W. 1983. Hormonal control of oocyte final maturation and ovulation in fishes. Pages 117-170 *in* W.W. Hoar, D.J. Randall, and E.M. Donaldson, editors. Fish physiology, volume 9, part B. Academic Press, New York.

Goetz, F.W., and F. Cetta. 1983. Ovarian and plasma PGE and PGF levels in naturally ovulating brook trout (*Salvelinus fontinalis*) and the effects of indomethacin on prostaglandin levels. Prostaglandins 26:387-395.

Goetz, F.W., D.C. Smith, and S.P. Krickl. 1982. The effects of prostaglandins, phosphodieterase inhibitors and cyclic AMP on ovulation of brook trout (*Salvelinus fontinalis*) oocytes. General and Comparative Endocrinology 48:154-160.

Goetz, F.W., and G. Theofan. 1979. In vitro stimulation of germinal vesicle breakdown and ovulation of yellow perch (*Perca flavescens*) oocytes. Effects of 17α-hydroxy-20β-dihydroprogesterone and prostaglandins. General and Comparative Endocrinology 37:273-285.

Goetz, F.W., and H.L. Bergman. 1978. The effects of steroids on final maturation and ovulation of oocytes from brook trout (*Salvelinus flavescens*). Biology of Reproduction 18:293-298.

VITA

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Assistant Professor of Fisheries and Extension Specialist in Aquaculture
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EDUCATION

B.A.	Swathmore College	1976
M.S.	Oregon State University	1980
Ph.D.	Oregon State University	1984

POSITIONS

Assistant Professor/Extension Specialist (Aquaculture), University of Minnesota (1984-present)
Instructor/Project Leader/Research Assistant, Oregon State University (1980-1984)
Research Assistant, Oregon State University (1977-1980)
Aquaculture Research Technician, Weyerhaeuser Company (1976-1977)

SCIENTIFIC AND PROFESSIONAL MEMBERSHIPS

American Fisheries Society: Fish Culture Section, Genetics Section, NCD Fish Genetics Technical Committee
Genetics Society of America
International Association of Genetics in Aquaculture (Charter Member)
Society for the Study of Evolution
World Aquaculture Society
Sigma Xi, Phi Kappa Phi, Gamma Sigma Delta

SELECTED PUBLICATIONS

Kapuscinski, A.R. (In Press). Integration of transgenic fish into aquaculture. Food Reviews International.

Phillips, R.B., and A.R. Kapuscinski. (In press). High frequency of translocation heterozygotes in odd year populations of pink salmon (*Oncorhynchus gorbuscha*). Cytogenetics and Cell Genetics.

Yoon, S.J., E.M. Hallerman, M.L. Gross, Z. Liu, J.F. Schneider, A.J. Faras, P.B. Hackett, A.R. Kapuscinski, and K.S. Guise. (In Press). Transfer of the gene for neomycin resistance into goldfish, *Carrassius auratus*. Aquaculture.

Kapuscinski, A.R., and L.D. Jacobson. 1987. Genetic guidelines for fisheries management. Minnesota Sea Grant, St. Paul, Minnesota.

Kapuscinski, A.R.D., and J.E. Lannan. 1986. A conceptual genetic fitness model for fisheries management. Canadian Journal of Fisheries and Aquatic Sciences 43:1606-1616.

Lannan, J.E, and A.R.D. Kapuscinski. 1986. Application of a genetic fitness model to extensive aquaculture. Aquaculture 57:81-87.

VITA

Terrence B. Kayes
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EDUCATION

B.A. Chico State College 1968
M.A. California State University at Chico 1972
Ph.D. University of Wisconsin-Madison 1978

POSITIONS

Assistant Director, University of Wisconsin Aquaculture Program, University of Wisconsin-Madison (1979-present)
Project Biologist, Aquaculture Research Laboratory, University of Wisconsin-Madison (1974-1979)
Teaching Assistant, Department of Zoology, University of Wisconsin-Madison (1972-1974)
EPA Trainee, Laboratory of Limnology, University of Wisconsin-Madison (1970-1972)
Instructor, Department of Biological Sciences, Chico State College (1968-1970)

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

American Society of Zoologists: Divisions of Comparative Endocrinology, Comparative Physiology and Biochemistry, Ecology and Comparative Immunology
American Fisheries Society: Fish Culture, Bioengineering, Fish Health, Water Quality and Early Life History Sections
World Aquaculture Society

SELECTED PUBLICATIONS

Malison, J.A., T.B. Kayes, C.H. Amundson, and B.C. Wentworth. 1988. Growth and feeding responses of male and female yellow perch (*Perca flavescens*) treated with estradiol-17β. Canadian Journal of Fisheries and Aquatic Sciences 45:1942-1948.

Kim, K.I., T.B. Kayes, and C.H. Amundson. 1987. Effects of dietary tryptophan levels on growth, feed/gain, carcass composition and liver glutamate dehydrogenase activity in rainbow trout (*Salmo gasirdneri*). Comparative Biochemistry and Physiology 88B:737-741.

Malison, J.A., T.B. Kayes, B.C. Wentworth, and C.H. Amundson. 1987. Control of sexually related dimorphic growth by gonadal steroids in yellow perch (*Perca flavescens*). Page 206 *in* D.R. Idler, L.W. Crim, and J.M. Walsh, editors. Proceedings of the Third International Symposium on the Reproductive Physiology of Fish. Memorial University of Newfoundland, St. John's, Newfoundland.

Heidinger, C.C., and T.B. Kayes. 1986. Yellow perch. Pages 103-113 *in* R.R. Stickney, editor. Culture of nonsalmonoid freshwater fishes. CRC Press, Boca Raton, Florida.

VITA

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EDUCATION

B.S. University of Wisconsin-Stevens Point 1976
M.S. University of Wisconsin-Madison 1980
Ph.D. University of Wisconsin-Madison 1985

POSITIONS

Associate Researcher, University of Wisconsin Aquaculture Program, University of Wisconsin-Madison (1987-present)
Project Associate, University of Wisconsin Aquaculture Program, University of Wisconsin-Madison (1985-1987)

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

American Association for the Advancement of Science
American Fisheries Society
American Society of Zoologists

SELECTED PUBLICATIONS

Malison, J.A., T.B. Kayes, B.C. Wentworth, C.H. Amundson. 1988. Growth and feeding responses of male versus female yellow perch (*Perca flavescens*) treated with estradiol-17β. Canadian Journal of Fisheries and Aquatic Sciences 45:1942-1948

Malison, J.A., T.B. Kayes, B.C. Wentworth, and C.H. Amundson. 1987. Control of sexually related dimorphic growth by gonadal steroids in yellow perch (*Perca flavescens*). Page 206 *in* D.R. Idler, L.W. Crim, and J.M. Walsh, editors. Proceedings of the Third International Symposium on the Reproductive Physiology of Fish. Memorial University of Newfoundland, St. John's, Newfoundland.

Malison, J.A., C.D. Best, T.B. Kayes, C.H. Amundson, and B.C. Wentworth. 1986. Sexual differentiation and the use of hormones to control sex in yellow perch (*Perca flavescens*). Canadian Journal of Fisheries and Aquatic Sciences 43:26-35.

Malison, J.A. 1985. Growth promotion and the influence of sex-steroids on sexually related dimorphic growth and differentiation in yellow perch (*Perca flavescens*). Doctoral dissertation. University of Wisconsin, Madison.

Malison, J.A., C.D. Best, C.H. Amundson, and B.C. Wentworth. 1985. Hormonal growth promotion and evidence for a size-related difference in response to estradiol-17β in yellow perch (*Perca flavescens*). Canadian Journal of Fisheries and Aquatic Sciences 42:1627-1633.

Malison, J.A., C.D. Best, and T.B. Kayes. 1983. Hormonal control of growth and size dimorphism in yellow perch (*Perca flavescens*). American Zoologist 22:955.

VITA

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EDUCATION

B.S. Northeastern Illinois University 1973
M.A. Southern Illinois University at Carbondale 1976
Ph.D. Southern Illinois University at Carbondale 1984

POSITIONS

Assistant Professor, Department of Zoology, Southern Illinois University at Carbondale (1986-present)

Assistant Professor, Department of Fisheries and Wildlife Sciences, Virginia Polytechnic Institute and State University (1983-1986)

Researcher, Cooperative Fisheries Research Laboratory, Southern Illinois University at Carbondale (1981-1982 and 1983)

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

American Fisheries Society: Fish Culture, Fisheries Educators, Water Quality, Exotic Fishes, and Early Life History Sections; Illinois Chapter

SELECTED PUBLICATIONS

Nielsen, L.A., R.J. Sheehan, and D.J. Orth. 1987. Impacts of navigation on riverine fish roduction in the United States. Proceedings of the International Symposium on Fish Production in Rivers. Polish Archives of Hydrobiology 33(3/4):277-294.

Sheehan, R.J., and W.J. Lewis. 1986. Relationships between the toxicity of aquenous ammonia solutions, pH, ammonia salt formulations, and water balance in channel catfish fingerlings. Transactions of the American Fisheries Society 115:891-899.

Helfrich, L.A., R.J. Sheehan, and J.S. Odenkirk. 1986. Fishing for sale: fee-fishing opportunities in Virginia. Virginia Cooperative Extension Service Publication 420-898.

Heidinger, R.C., B.L. Tetzlaff, R.J. Sheehan, R. Monaghan, and J. Waddell. 1983. Illinois Walleye Research, Quarterly and Annual Performance Reports. Fisheries Research Laboratory, Southern Illinois University, Carbondale, Illinois and Illinois Department of Conservation.

Lewis, W.M., and R.J. Sheehan. 1977. Channel catfish culture: state of the art 1976. Proceedings of the Southeastern Conference of Game and Fish Commissioners 31(1976):234-238.

VITA

Robert C. Summerfelt
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Iowa State University
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EDUCATION

B.S. University of Wisconsin-Stevens Point 1957
M.S. Southern Illinois University 1959
\- Duke University Marine Laboratory Summer 1962
Ph.D. Southern Illinois University 1964

POSITIONS

Professor, Department of Animal Ecology and Associate Director, North Central Regional Aquaculture Center (NCRAC), Iowa State University (1988-present)
Professor, Department of Animal Ecology, Iowa State University (1985-1988)
Professor and Chairman, Department of Animal Ecology, Iowa State University (1976-1985)
Leader (Fishery Research Biologists, U.S. Fish and Wildlife Service, GS-13), Oklahoma Cooperative Fishery Research Unit, Oklahoma State University (1966-1976)
Assistant Professor, Department of Zoology, Kansas State University (1964-1966)

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

American Fisheries Society
Fish Culture, Fish Health (Charter member), Education (Charter member), Bioengineering, Computer User, and Fisheries Management Sections; Iowa Chapter
American Institute of Fishery Research Biologists (Fellow)
Fisheries Society of the British Isles
Iowa Academy of Sciences
North American Lake Management Society
Societas Internationalis Limnologiae
Honorary: Sigma Xi, Phi Kappa Phi, and Gamma Sigma Delta

SELECTED PUBLICATIONS AND PRESENTATIONS

Summerfelt, R.C., and L.S. Smith. (In Press). Anesthesia and surgery. Chapter 8 *in* C.B. Schreck and P. Moyle, editors. Methods for fish biology. American Fisheries Society, Bethesda, Maryland.

Summerfelt, R.C. 1988a. Effect of oxygen saturation levels on swim bladder inflation of larval walleye. Iowa Department of Natural Resources, Federal aid in fish restoration, F-121-R, Job Number 1, Des Moines.

Summefelt, R.C. 1988b. High density culture of fingerling walleye. Iowa Department of Natural Resources, Federal aid in fish restoration, F-121-R, Job Number 2, Des Moines.

Summerfelt, R.C., and G.E. Hall, editors. 1987. Age and growth of fish. Iowa State University Press, Ames, Iowa.

Cross, T.K., and R.C. Summerfelt. 1987. Oxygen demand of lakes: sediment and water column BOD. Lake and Reservoir Management 3:109-116.

VITA

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EDUCATION

B.S. Southern Illinois University at Carbondale
M.A. Southern Illinois University at Carbondale

POSITIONS

Research Project Director, Fisheries Research Laboratory, Southern Illinois University, Carbondale, Illinois (1980-present)
Researcher, Fisheries Research Laboratory, Southern Illinois University (1976-1980)

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

American Fisheries Society
- Fish Culture Section
- Bioengineering Section
- Fish Management Section

SELECTED PUBLICATIONS

Heidinger, R.C., J.H. Waddell, and B.L. Tetzlaff. 1985. Relative survival of walleye fry versus fingerlings in two Illinois reservoirs. Proceedings of the Annual Conference Southeast Association of Fisheries and Wildlife Agencies 39:306-311.

Miller, S.J., and B.L. Tetzlaff. 1985. Daily growth increments in otoliths of larval walleye (*Stizostedion vitreum*). Transactions of the Illinois Academy of Science 78(1 and 2):115-120.

Heidinger, R.C., B.L. Tetzlaff, and J. Stoeckel. 1985. Evidence of two feeding subpopulations of white crappie (*Pomoxis annularis*) in Rend Lake, Illinois. Journal of Freshwater Ecology 3(1):133-143.

Heidinger, R.C., L.J. Wawronwicz, and B.L. Tetzlaff. 1983. Application of water reuse technology for overwintering threadfin shad (*Dorosoma petenense*) at northern latitudes. Aquacultue Engineering 2:153-162.

Lewis, W.M., R.C. Heidinger, and B.L. Tetzlaff. 1981. Tank culture of striped bass produciton manual. Southern Illinois University, Fisheries Research Laboratory, Carbondale, Illinois.

VITA

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Professor of Pathology — Phone: (517) 353-5275
Project Leader
Department of Pathology
College of Veterinary Medicine
Michigan State University
East Lansing, MI 48824-1316

EDUCATION

B.S.	Michigan State University	1954
D.V.M.	Michigan State University	1956
Ph.D.	Iowa State University	1960

POSITIONS

Professor, Michigan State University (1970-present)
Associate Professor, Michigan State University (1960-1970)
Associate Professor, Ohio Research and Development Center (1965-1966)
Assistant Professor, Ohio Research and Development Center (1960-1965)
Research Associate, Iowa State University (1957-1960)

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

Wildlife Disease Association
American Veterinary Medical Association
American Association of Veterinary Laboratory Diagnosticians
Phi Zeta
Sigma Xi

SELECTED PUBLICATIONS

Machado, J.P., T.G. Bell, D.L. Garling, Jr., N.R. Kevern, and A.L. Trapp. (In Press). Effect of carbon monoxide exposure on gas-bubble trauma in rainbow trout (*Salmo gairdneri*). Canadian Journal of Fisheries and Aquatic Sciences.

Machado, J.P., D.L. Garling, Jr., N.R. Kevern, A.L. Trapp, and T.G. Bell. 1987. Histopathology of the pathogenesis of embolism (gas-bubble disease) in rainbow trout (*Salmo gairdneri*). Canadian Journal of Fisheries and Aquatic Sciences 44(11):1985-1994.

Bell, T.G., A.L. Trapp, J. Machado, and D.L. Garling. 1985. A method for rapid fixation for preservation of tissue emphysema: diagnosis of gas-bubble disease in hatchery reared rainbow trout. 28th Annual Proceedings of the American Association of Veterinary Laboratory Diagnosis.

Lass, R.E., D.E. Ullrey, and A.L. Trapp. 1982. A study of calcium requirements of the red-eared slider turtle (*Pseudemys scripta elegans*). Journal of Zoo Animal Medicine 3:62-65.

Bartkiewicz, S.E., D.E. Ullrey, A.L. Trapp, and P.K. Ku. 1982. A preliminary study of niacin needs of the bull snake (*Pituohis malanoleucus saqi*). Journal of Zoo Animal Medicine 13:55-58.