PROJECT NAME: Advancing Hybrid Striped Bass Culture in the North Central Region

FUNDING LEVEL: Year 1 - Grant 1: $68,296
Year 2 - Grant 2: $66,864

DURATION: 2 Years

ADMINISTRATIVE ADVISOR: Dr. James Seeb, Fisheries Research Laboratory and Department of Zoology, Southern Illinois University, Carbondale, IL 62901

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JUSTIFICATION

Per capita consumption of seafood products has grown steadily in the United States, a demand largely being met by increased imports. For example, the U.S. purchased $4.8 billion in seafood from abroad in 1986 while only selling $1.3 billion worth overseas (U.S. Department of Commerce statistics). Thus, seafood imports represent a major cause of the U.S. balance of trade deficit. States within the North Central Region are a major source of demand for imported seafood. The North Central Region is rich in terrestrial resources, and not surprisingly, agriculture is a dominant industry. However, the movement of agriculture in the region toward production of commodities, such as corn and soybeans, with ultra-high efficiency has been accomplished at great cost; now surpluses in all major crops, combined with land devaluations and financial strains, have forced both the agriculture system and its participants to investigate other farm technologies (Illinois Department of Agriculture 1986). Aquaculture is perceived within the region as a logical vehicle for diversification. Indeed, it is this perception and desire for aquaculture development that provided the impetus to establish a USDA regional aquaculture center in the Midwest.

The immediate concern for aquaculture development in the North Central Region is the identification of suitable species/hybrids for culture, development of broodstocks, and modification of existing technologies for rapid deployment within the emerging industry. The striped bass (*Morone saxatilis*) x white bass (*M. chrysops*) hybrid offers considerable commercial potential within much of the region. As a clear indication of its regional market potential, seafood processors in Chicago are willing to pay a minimum of $7.72/kg ($3.50/lb) in the round for fresh hybrid striped bass (personal communication from Andy Roberts, Illinois Department of Agriculture).

The striped bass is a temperate-water anadromous fish that is native to the Atlantic coast and is widely stocked in large lakes and reservoirs in many parts of the U.S., including the North Central Region. The striped bass is prized as a game fish throughout most of its range and commands high market prices as a food fish (Norton et al. 1983). In 1983, the striped bass was identified at the national level (JSA 1983) as having significant potential for commercial aquaculture development.

Since 1983, research related to the development of commercial striped bass aquaculture has focused increasingly on the culture of striped bass x white bass hybrids. Numerous studies have demonstrated that both the female striped bass x male white bass (SB x WB, original cross) and the female white bass x male striped bass (WB x SB, reciprocal cross) hybrids are faster growing (at least during the first 2 years of life), more robust and more resistant to disease and environmental extremes than purebred striped bass (Kerby 1986).

The identification of the hybrid striped bass as a candidate for commercial aquaculture development in the North Central Region is appropriate because: (1) a number of fish farmers are producing this fish; and (2) much of the southern half of the region is at approximately the same latitude and has about the same seasonal water temperature conditions as the mid- and southern Atlantic states, where hybrid striped bass culture is also being pursued. Indeed, the potential for future collaboration between the North Central, Northeastern and Southern Regions in the development of a national hybrid striped bass industry seems clear, particularly in light of the fact that the white bass is a native species and fairly common in the North Central Region.

According to the National Aquaculture Development Plan (JSA 1983), the principal constraint on commercial striped bass aquaculture in the U.S. is the "nonavailability of seed stock." Recent declines in the striped bass fisheries along the Atlantic coast, as well as legal constraints, have increasingly limited the availability of wild broodstock (especially females) as a source of gametes (Harrell 1984). In part, the problem of limited availability of striped bass gametes in the North Central Region could be greatly reduced by utilizing female white bass crossed with male striped bass to produce reciprocal cross hybrids. White bass are native and fairly common throughout much of the region (Scott and Crossman 1973; Becker 1983). However, legal constraints also limit access to wild white bass stocks (though not so much as for striped bass on the Atlantic coast).

To resolve the dilemma of gamete availability, strategies for domesticating broodstocks and associated methods of controlling reproduction need to be developed (Donaldson and Hunter 1983; Idler et al. 1987). The development of female white bass and male striped bass broodstocks for production purposes would obviate the need to use wild fish as gamete sources. Two additional benefits of using female white bass as broodstock are that they normally mature at an earlier age (Age 3) and are much smaller (i.e., 250-580 g body weight) than female striped bass, which typically mature at Age 4 or older and weigh 2-7 kg or more (Scott and Crossman 1973; Smith 1988). Earlier age-at-maturity and smaller size are characteristics that should greatly reduce the cost and effort of broodstock rearing and maintenance, and facilitate the development of methods to manipulate sexual maturation and out-of-season spawning.

The development of efficacious procedures to manipulate sexual maturation and induce out-of-season spawning is an important component of optimal broodstock management. The potential benefits of such procedures include: (1) greater predictability of gamete production; (2) reduced incidence of failed spawnings, gamete resorption and subsequent broodfish losses (e.g., due to toxemia); and (3) the production of fertilized eggs and fry at predetermined times throughout the year. The availability of fertilized eggs outside the normal spawning season would greatly facilitate research on the intensive culture of both hybrid and purebred striped bass 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.

This proposal describes a cooperative regional research project that will be interdisciplinary in scope and involve investigators from two institutions in two states: Southern Illinois University and the University of Wisconsin-Madison. A commercial operation, Fountain Bluff Fish Farm (Gorham, IL), will also participate. The principal goal of the project is to address key problems that pertain to the development of commercial hybrid striped bass culture in the North Central Region. Problem areas to be addressed include: (1) broodstock development, (2) mechanisms regulating the natural reproductive cycle, and (3) manipulation of gonadal maturation and out-of-season spawning. Significant progress on these problem areas should be achievable within the proposed 2-year period of the project. However, a third and fourth year of funding will probably be needed for the proposed line of research to reach full fruition and thus yield maximum benefits.

RELATED CURRENT AND PREVIOUS WORK

The conventional method of propagating striped bass involves capturing wild broodfish immediately before or during their normal spawning season and transporting them to a holding facility (Bonn et al. 1976; Kerby 1986). There, the females are usually injected with human chorionic gonadotropin (HCG) to ensure final ovarian maturation and ovulation. The males may also be injected with HCG to increase semen volume. Subsequently, either the ripe fish are artificially propagated (sperm and eggs are manually stripped and mixed), or males and females are allowed to spawn naturally together in tanks.

Similar propagation techniques have been utilized with white bass (W.E. Jenkins of the South Carolina Department of Wildlife and Marine Resources, personal communication; also Smith 1988; Smith and Jenkins 1986). Genetically and taxonomically, the striped bass and white bass are closely related; both spawn naturally in spring and early summer (Scott and Crossman 1973). However, the opposite sexes of the two species will not normally spawn when placed together. Because of this, artificial propagation techniques are used to produce both the SB x WB and WB x SB (female x male, respectively) hybrids (Kerby 1986).

In recent years, captive striped bass broodstock programs have been initiated and maintained by a few private producers and government agency fish hatcheries and laboratories, primarily along the Atlantic coast and in the South. Examples include: the Baltimore Gas and Electric Company's Crane Aquaculture Facility, the Marine Resources Research Institute of the South Carolina Department of Wildlife and Marine Resources, and the U.S. Fish and Wildlife Service's Southeastern Fish Cultural Laboratory in Marion, Alabama.

The Marine Resources Research Institute in South Carolina and Osage Catfisheries, Inc. in Missouri are two of the very few entities that maintain white bass broodstocks. For both species, the broodstocks developed to date consist almost entirely of "parental" (P) generation fish (white bass and striped bass) captured from the wild and acclimitized to pond or tank culture facilities, or "first filial" (F1) generation fish (primarily striped bass) raised from eggs. Typically, these broodstocks are maintained under ambient seasonal photoperiod/temperature conditions and become sexually mature during the normal spawning season.

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.

The production of hybrid striped bass was first made practicable when researchers discovered that HCG could be used to (pharmacologically) induce final maturation and ovulation in female striped bass (reviewed by Kerby 1986). Numerous life history studies have been reported on the reproductive habits and fecundity of striped bass and white bass (Scott and Crossman 1973; Becker 1983). However, to our knowledge, no definitive investigations characterizing hormonal events and gonadal development during the annual reproductive cycle of either species has been published.

To help rectify this deficiency, Drs. Cheryl A. Goude and Nick C. Parker of the U.S. Fish and Wildlife Service initiated a study to examine changes in circulating levels of the steroid hormones estradiol-17β (E2) and testosterone (T), gonadal development and pituitary histology during the annual reproductive cycle of broodstock striped bass maintained under ambient photoperiod/temperature conditions (C.A. Goude and N.C. Parker, personal communications). As of this writing, the data from this study have not yet been analyzed.

In a similar investigation, Dr. Roger C. Cochran, formerly of the John Hopkins University, collected blood and gonad samples at regular intervals during the annual reproductive cycle of striped bass in Chesapeake Bay, (R.C. Cochran, personal communication). The findings of his study have not yet been published. However, preliminary examination of the data indicate that E2 levels in the females and T and 11-ketotestosterone (11-KT) levels in the males were elevated during autumn and winter, then peaked prior to spawning in May (R.C. Cochran, personal communication). Gonadal recrudescence was well under way in autumn in this species.

As part of this study, Dr. Cochran also collected pituitary glands from Chesapeake Bay striped bass. These pituitary preparations have since been forwarded to Dr. Peter Thomas of the University of Texas Marine Science Institute at Port Aransas, who is currently working to purify and develop an immunoassay for striped bass gonadotropin(s) (GTH[s]). Dr. Thomas (personal communication) has indicated that an immunoassay for striped bass GTH should be operational sometime in 1989.

Considerable scientific evidence indicates that reproductive function and the initiation and maintenance of most, if not all, phases of the reproductive cycles of most fishes are controlled by specific "predictive" environmental cues, the exact nature of which may vary depending on species, and on entraining and modifying factors in the environment (Billard and Breton 1978; Lam 1983; Lam and Munro 1987). Photoperiod and temperature are thought to be the primary entraining factors for most temperate-water species, though other cues, such as the presence of reproductively active conspecifics or spawning substrate, may also be involved in synchronizing reproductive events.

The extent to which reproduction in broodfish can be controlled depends in large part on the degree to which management techniques reflect an understanding of the species' reproductive biology (Lam 1982; Donaldson and Hunter 1983; Idler et al. 1987). "First generation" procedures, such as those presently used with striped bass and white bass, typically involve treating fish in near-spawning condition with crude fish pituitary extracts or mammalian hormones, such as HCG, to induce or ensure final gonadal maturation and gamete release. Many fish species do not respond to treatment with mammalian gonadotropins, or require very high doses to elicit a response. In particular, high doses of HCG (e.g., 1,550 to 2,200 IU/kg) are used to induce gonadal maturation and ovulation in female white bass (Smith and Jenkins 1986).

The effectiveness of such first generation techniques, when they do work, is normally limited to the spawning season (Lam 1982; Donaldson and Hunter 1983). Depending on fish species, a frequently encountered problem with using mammalian gonadotropins to accelerate gonadal development is that they may disrupt the normal sequence of developmental events or stimulate some, but not all, stages of maturation. Thus, their use may induce the release of immature ova (i.e., ovulation without maturation) or final maturation without ovulation, which can result in egg resorption (see Lam 1982; Goetz 1983; also T.B. Kayes, personal observation). Repeated treatment with either crude pituitary extracts or mammalian gonadotropins can also potentially cause immune reactions in broodfish, resulting in hormone inactivation, or worse, anaphylactic shock. Both egg resorption and strong immune reactions can have lethal consequences for broodfish.

"Second generation" procedures to control broodstock reproduction typically involve the use of photoperiod/temperature manipulations to shift, compress or expand the annual cycle of gonadal development (Lam 1983; Lam and Munro 1987). Such techniques have been successfully applied to a number of commercially cultured species, including the rainbow trout, common carp and turbot (Bye 1987; Lam and Munro 1987). Subjecting female rainbow trout to constant long-day length starting before or during their first spawning season (i.e., puberty) can result in subsequent spawnings as frequently as every 26 weeks (Bromage et al. 1984; Duston and Bromage 1986). Compressed annual photoperiod/temperature cycles have been used to produce spawnings every 20 to 42 weeks in a variety of temperate-water species that normally reproduce only once a year (Lam 1983; Bye 1987).

Second generation methods of inducing spawning typically involve the use of partially purified fish GTHs, or more often, pharmacological agents that stimulate the production and/or release of endogenous GTH. Much research along this line has focused on the use of mammalian luteinizing-hormone releasing hormone (LHRH), salmon gonadotropin releasing hormone (sGnRH) and their analogues (LHRH-As and sGnRH-A), some of which are far more potent than the natural hormones (Donaldson and Hunter 1983; Peter et al. 1986; Idler et al. 1987). Recently, investigators have found that the dopamine receptor antagonists "pimozide" and "domperidone" potentiate the effects of LHRH-A or sGnRH-A on GTH release and subsequent ovulation in goldfish and several species of Chinese carp, some of which do not respond well to LHRH-A or sGnRH-A alone (Peter et al. 1986, 1987). Dopamine appears to act as a GTH release-inhibiting factor, at least in some species (Peter 1983; Peter et al. 1986). Thus, blocking the effects of dopamine may be another way of stimulating GTH release.

The advantage of employing techniques that stimulate endogenous GTH release is that they obviate many of the problems of species specificity and variable responsiveness inherent with the use of mammalian gonadotropins like HCG. Also, as small peptides, the gonadotropin releasing hormones and their analogues are comparatively easy to synthesize; several are available commercially (Donaldson and Hunter 1983). These releasing agents do not appear to trigger negative immune reactions in the fish species tested to date. Accordingly, second generation procedures applied to striped bass and white bass might ensure not only better, more predictable spawning, but also fewer problems with spawning-related mortality.

To our knowledge, the only published accounts of controlled out-of-season spawning of striped bass are those of Smith and Jenkins (1984, 1986) of the South Carolina Department of Wildlife and Marine Resources. These investigators found that striped bass and F1 generation SB x WB hybrid broodfish maintained on a compressed (9-month) annual photoperiod/temperature cycle could, after an HCG injection, be spawned 2 to 3 months earlier than normal. However, the exact significance of their findings was clouded somewhat by: (1) the small numbers of fish examined, (2) differences in age and maturity between individual fish, (3) a fairly high incidence of pre- and post-spawning mortality and spawning failures, and (4) great variability in egg fertilization or hatching.

No published reports on the control of the reproductive cycle of white bass appear to exist. In a field study on the ovarian cycle and fecundity of white bass, Ruelle (1977) observed that oocyte development began in late summer, proceeded rapidly in autumn, then went through a rapid final growth phase immediately prior to spawning in late spring. He also noted that the ovaries of freshly spent females contained large numbers of developing but unripe "recruitment" ova, which were subsequently resorbed. Collectively, this information suggests that properly managed white bass broodfish might be induced to spawn more than once a year.

OBJECTIVES

1. Obtain and maintain (in captivity) populations of spawning size white bass and striped bass.
2. Define reproductive development in wild and captive white bass by characterizing seasonal changes in hormone titers and gonadal histology.
3. Evaluate the effects of selected photoperiod/temperature and hormonal manipulations on gonadal development and spawning in white bass broodstock.

PROCEDURES

Objective 1

The proposed project will be done collaboratively by investigators from Southern Illinois University (SIU) and the University of Wisconsin-Madison (UW-Madison). Specific methods of capturing and/or maintaining white bass broodfish, 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 field collection and sampling, maintaining experimental broodfish in the laboratory and ponds, and the fish cultural aspects of the project. The UW-Madison will be responsible for the analysis of blood and tissue samples and interpretation of endocrinological data, and will assist SIU in the collection of blood and tissue samples from laboratory broodfish, when appropriate. White bass will be collected from either Rend Lake or Kincaid Lake, Illinois, both of which are within 48 km of SIU. Depending on time and the availability of (additional) funds, or alternatively the assistance of the Wisconsin Department of Natural Resources, some limited field sampling of white bass may also be done by the UW-Madison from Lake Mendota, Dane County, Wisconsin. Striped bass sub-adults will be obtained from the U.S. Fish and Wildlife Service at either Leetown, West Virginia or Marion, Alabama. Striped bass broodfish will be maintained at the Fountain Bluff Fish Farm, Gorham, Illinois.

Two 0.6-hectare ponds on the SIU campus will be used to hold the white bass broodfish. A third, larger pond will also be used if broodfish are obtained in numbers sufficient to warrant its use. A number of other ponds will be employed to provide supplemental forage fish for the broodfish if necessary. However, threadfin shad and rosy red minnows will be stocked into the broodfish ponds, and we believe natural reproduction will provide sufficient forage. Forage fish populations and broodfish condition will be routinely monitored in both ponds to ascertain whether additional forage organisms are needed. Approximately 120 white bass broodfish of each sex will also be held in a 9,460-L recirculated-water culture system containing six 1,325-L circular tanks.

Objective 2

The principal (null) hypothesis of Objective 2 is that the annual reproductive cycles of wild white bass, and captive white bass broodfish maintained in the laboratory under a simulated natural photoperiod/temperature cycle, will not differ appreciably. As an alternative hypothesis, we suggest that captivity will impair normal reproductive function in the white bass. Regardless of hypothesis, these comparisons should provide valuable insight on the extent to which captivity and different environmental conditions influence the white bass reproductive cycle, and will yield essential baseline information for studies involving photoperiod/temperature and hormonal manipulations.

For a period of about 6 to 9 months prior to the initiation of field and laboratory sampling, efforts will be focused on developing standardized sample collection techniques, setting up appropriate assay systems for hormone analysis, capturing wild adult white bass using minimum stress procedures, and acclimatizing about 120 fish of each sex to laboratory conditions. These fish will be habituated to a high-protein, high-oil commercial salmon diet ground with raw fish to produce a moist pellet, and will be maintained on a simulated annual photoperiod/temperature cycle in synchrony with and similar to that of their original natural environment.

Fish in the field and laboratory will be sampled over about a 2-year period, through two spawning seasons. In general, sampling will be done monthly from mid-June to mid-November, every 2 or 3 months from late November to April, and monthly or biweekly from early April to mid-June. In the second year of sampling, weekly samples may be collected during key periods of the reproductive cycle -- e.g., the prespawning and spawning periods. For each time of year and place (field or laboratory), samples will be collected from a minimum of four fish of each sex. Additional samples of up to ten fish of each sex will be collected, when and if they are available.

Sampling procedures will include measurements of total fish length, total body weight, liver and eviscerated carcass weights, and collection of the gonads, pituitary gland 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 histometric and histological procedures (employing light microscopy).

Titers of GTH in the pituitary glands and blood samples will be analyzed by Dr. Peter Thomas of the University of Texas Marine Science Institute (under a subcontract with the UW-Madison), using an immunoassay developed for striped bass GTH. Levels of E2 and T in the blood samples will be measured by UW-Madison investigators employing existing radioimmunoassay (RIA) or enzyme-linked immunosorbant assay (ELISA) procedures (e.g., Cochran et al. 1988; Mao 1988), adapted for use with white bass serum. Depending on time and the availability of (additional) funds, serum titers of 11-KT may also be determined.

All immunoassay procedures will be carefully 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.

Objective 3

Studies on the effects of selected photoperiod/temperature and hormonal manipulations on gonadal development, maturation, and spawning in white bass will also be done collaboratively by investigators from SIU and the UW-Madison. In general, institutional responsibilities and methods of capturing and maintaining fish, taking and analyzing blood and tissue samples, and evaluating data will be as previously described. Here also, GTH, E_2 and T will be the hormones measured. All long-term experiments, such as those evaluating the effects of different photoperiod/temperature regimes, will be done at SIU. Some short-term experiments on the effects of various endocrine manipulations on final gonadal maturation and gamete release may be done at the UW-Madison using Lake Mendota fish.

Principal hypotheses for this aspect of the project are: (1) maintenance of white bass broodfish on compressed annual photoperiod/temperature cycles of 8- and 10-months duration will shorten their cycle of gonadal development to 8-9 and 10-11 months, respectively; (2) the cycle of gonadal development in broodfish maintained on a constant long-day photoperiod and summer water temperature (24 °C) will be 11-13 months long; (3) specific LHRH-As, used in concert with pimozide or domperidone, will be more efficacious than HCG at inducing final gonadal maturation and gamete release, particularly in brood fish subjected to the indicated compressed photoperiod/temperature cycles and constant photoperiod/temperature regime. Hypothesis 2 is based on the proposition that adult white bass have an endogenous circannual rhythm that functions (normally in concert with zeitgebers) in regulating reproductive cycling. As an alternative hypothesis, we suggest that the gonads of fish maintained on the constant long-days/summer temperature regime will be arrested in an early autumnal (early recrudescent) stage of development.

To assess the effects of different photoperiod/temperature regimes, at least 25 fish of each sex (all previously acclimatized to laboratory conditions and with prior spawning experience) will be assigned at the summer solstice (about June 22) to each of the following: (1) a simulated natural 12-month photoperiod/temperature cycle, (2) a compressed 8-month cycle, (3) a compressed 10-month cycle, and (4) a constant photoperiod/temperature regime of 18-hours light/6 hours dark and 24 °C. These regimes will be maintained for 2 years, or two complete cycles.

For each of the four regimes, blood and tissue samples from four fish of each sex will be collected at the midpoint or winter solstice of each year or cycle. Thus, sampling that requires the sacrifice of fish will be conducted twice for each treatment regime. At other times, particularly during the final quarter of each year or cycle, maturational status will be assessed by taking blood and anlyzing hormone titers, by attempting to express semen from males, and by the catheterization of females and examination of oocytes, as described by Bonn et al. (1976) and Smith and Jenkins

(1986). In making these assessments, minimum stress procedures, including anesthesia, will be used to ensure good health and normal reproductive function.

Experiments on the effects of hormonal manipulations will focus on comparing the efficacy of selected high-potency LHRH-As, pimozide and domperidone with that of HCG. Different dosages plus appropriate combinations of the LHRH-As, pimozide and domperidone will be tested. Initial experiments will utilize near-mature but unripe wild fish captured immediately before or during the natural spawning season. Primary end-points examined will include: the response patterns of endogenous GTH levels in circulation, final maturation and release of gametes, numbers of ova and volume of semen released, fertilization success, embryo development and hatching success.

Once the general response patterns of white bass to the selected LHRH-As, pimozide and domperidone are known, carefully targeted experiments will be conducted to compare the efficacy of these agents and HCG at inducing final maturation and release of gametes in the experimental fish subjected to the four different long-term photoperiod/temperature regimes. Particular attention will be focused on the induction of final maturation and release of gametes in fish subjected to the compressed photoperiod/temperature cycles and the constant photoperiod/temperature regime.

Collectively, these experiments will yield specific methodologies to manipulate and optimize the reproductive performance of white bass broodfish, and provide a firm foundation of further improvements in this technology as future needs demand. Many of the methods developed will no doubt also prove useful in the management of striped bass broodstock, given the close genetic and taxonomic relatedness of these two species.

Dissemination of Results

Data collected by SIU and UW-Madison investigators will be collated on an ongoing basis, and the findings jointly (as appropriate) published in a timely manner in 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. The industry will be kept apprised of progress.

FACILITIES

Southern Illinois University

All activity involving obtaining and/or capture, acclimatization and long-term maintenance of broodfish will be done at the SIU Fisheries Research Laboratory in Carbondale, Illinois. The 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 white bass. 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 haul tanks. Equipment, boats, vehicles, and other 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 white bass broodfish populations anywhere in the state.

Two 0.6-hectare ponds on the SIU Campus will be used to hold broodfish. A third, larger pond will also be used if broodfish are obtained/captured in numbers sufficient to warrant its use. A number of other ponds will be used to provide supplemental forage fish if necessary.

An indoor recirculated-water culture system will be used for photoperiod/temperature manipulations. Currently, five 9,460-L systems, each containing six 1,325-L circular tanks, are in operation at the SIU wet lab facility. One of these systems will be devoted to the proposed study for the full duration.

University of Wisconsin-Madison

Blood and tissue samples collected in the field or at SIU, after appropriate preliminary processing, will be shipped or transported to the UW-Madison. All hormone and tissue analyses will be done by (or through) the UW Aquaculture Program, which has its main research facilities at the Lake Mills State Fish Hatchery, Lake Mills, Wisconsin. These facilities include--in addition to ponds, raceway tanks and a "wet" laboratory--an analytical laboratory that is well equipped for histological, cytological and endocrinological research.

UW Aquaculture Program facilities available for short-term holding of white bass include numerous 0.76- to 1.9-m diameter circular tanks equipped for flow-through of temperature-regulated (10 to 30 $\pm$ 0.5 °C) well or carbon-filtered city water. After July 1989, the Aquaculture Program will have additional analytical and wet laboratory facilities on the main UW-Madison campus. The Program also has a live-haul truck, a work boat, plus 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.

Collectively, these facilities and the support personnel operating them, coupled with the personnel and equipment requested, are more than adequate to meet the needs of the research proposed.

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Scott, W.B., and E.J. Crossman. 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada Bulletin 184, Ottawa.

Smith, T.I.J. 1988. Aquaculture of striped bass and its hybrids in North America. Aquaculture Magazine 14(1):40-49.

Smith, T.I.J., and W.E. Jenkins. 1984. Controlled spawning of F_1, hybrid striped bass (*Morone saxatilis* x *M. chrysops*) and rearing of F_2 progeny. Journal of the World Mariculture Society 15:147-161.

Smith, T.I.J., and W.E. Jenkins. 1986. Culture and controlled spawning of striped bass (*Morone saxatilis*) to produce striped bass and striped bass x white bass (*M. chrysops*) hybrids.

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PROJECT LEADERS

State	Name/Institution	Area of Specialization
Illinois	Christopher C. Kohler Southern Illinois University	Aquaculture/Ecology
	Robert J. Sheehan Southern Illinois University	Physiology/Aquaculture
Wisconsin	Terrence B. Kayes University of Wisconsin-Madison	Physiology/Endocrinology

INDIVIDUAL BUDGETS FOR PARTICIPATING INSTITUTIONS

Illinois

Southern Illinois University
Christopher C. Kohler
Robert J. Sheehan

Wisconsin

University of Wisconsin-Madison
Terrence B. Kayes

PROPOSED HYBRID STRIPED BASS BUDGET SHEET
FOR SOUTHERN ILLINOIS UNIVERSITY

(Kohler and Sheehan)

Objectives 1-3

	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	0.15	2	0.15	$0	$0
b. Senior Associates						
2. No. of Other Personnel (Non-Faculty) & FTEs						
a. Research Assoc./Postdoc						
b. Other Professionals	1/3		1/2		$3,200	$5,400
c. Graduate Students	2		2		$18,500	$20,160
d. Prebaccalaureate Students	1		1		$2,056	$1,880
e. Secretarial-Clerical	1		1		$1,800	$1,890
f. Technical, Shop, and Other	1					
Total Salaries and Wages					$25,556	$29,330
B. Fringe Benefits					$994	$1,340
C. **Total Salaries, Wages and Fringe Benefits**					$26,550	$30,670
D. Nonexpendable Equipment					$5,000	$2,500
E. Materials and Supplies					$5,000	$4,000
F. Travel - Domestic (*Including Canada*)					$4,500	$4,750
G. Other Direct Costs					$1,300	$1,350
TOTAL PROJECT COSTS (*C through G*)					$42,350	$43,270

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

PROPOSED HYBRID STRIPED BASS BUDGET SHEET
FOR UNIVERSITY OF WISCONSIN-MADISON

(Kayes)

Objectives 1-3

	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	0.12	1	0.12	$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	1	0.12			$1,980	$0
Total Salaries and Wages					$13,480	$12,075
B. Fringe Benefits (24% of 2b and 8.9% of 2f)					$2,936	$2,898
C. **Total Salaries, Wages and Fringe Benefits**					$16,416	$14,973
D. Nonexpendable Equipment					$3,000	$0
E. Materials and Supplies					$3,000	$4,000
F. Travel - Domestic (*Including Canada*)					$1,700	$2,021
G. Other Direct Costs					$1,830	$2,600
TOTAL PROJECT COSTS (*C through G*)					$25,946	$23,594

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

HYBRID STRIPED BASS

Budget Summary for Each Participating Institution at 68.3K for Year 1

	SIU	UW-M	TOTALS
Salaries and Wages	$25,556	$13,480	$39,036
Fringe Benefits	$994	$2,936	$3,930
Total Salaries, Wages and Benefits	$26,550	$16,416	$42,966
Nonexpendable Equipment	$5,000	$3,000	$8,000
Materials and Supplies	$5,000	$3,000	$8,000
Travel	$4,500	$1,700	$6,200
Other Direct Costs	$1,300	$1,830	$3,130
TOTAL PROJECT COSTS	$42,350	$25,946	**$68,296**

HYBRID STRIPED BASS

Budget Summary for Each Participating Institution at 66.9K for Year 2

	SIU	UW-M	TOTALS
Salaries and Wages	$29,330	$12,075	$41,405
Fringe Benefits	$1,340	$2,898	$4,238
Total Salaries, Wages and Benefits	$30,670	$14,973	$45,643
Nonexpendable Equipment	$2,500	$0	$2,500
Materials and Supplies	$4,000	$4,000	$8,000
Travel	$4,750	$2,021	$6,771
Other Direct Costs	$1,350	$2,600	$3,950
TOTAL PROJECT COSTS	$43,270	$23,594	**$66,864**

RESOURCE COMMITMENT FROM INSTITUTIONS[1]

(Salaries, Supplies, Expenses and Equipment)

Institution/Item		Year 1	Year 2
Southern Illinois University			
Salaries and Benefits: SY @ 0.15 FTE		$6,000	$7,000
Supplies, Expenses and Equipment		$14,000	$13,000
	TOTAL PER YEAR	**$20,000**	**$20,000**
University of Wisconsin-Madison			
Salaries and Benefits:			
SY @ 0.1 FTE		$4,420	$4,641
TY @ 0.1 FTE		$1,190	$1,250
Supplies, Expenses and Equipment		$22,570	$19,365
	TOTAL PER YEAR	**$28,180**	**$25,256**
	GRAND TOTAL	**$48,180**	**$45,256**

[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 completed 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 Objectives 2 and 3 during Years 1 and 2. However, a third and fourth year of effort will probably be needed to fully complete the research proposed and thus yield maximum benefits.

LIST OF PRINCIPAL INVESTIGATORS

Terrence B. Kayes, University of Wisconsin-Madison

Christopher C. Kohler, Southern Illinois University

Robert J. Sheehan, Southern Illinois University

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.

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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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Southern Illinois University
Carbondale, IL 62901-6511

EDUCATION

B.S. St. Mary's College of Maryland 1973
M.S. University of Puerto Rico 1975
Ph.D. Virginia Polytechnic Institute and State University 1980

POSITIONS

Research Associate to Assistant Professor of Zoology, Southern Illinois University at Carbondale (1981-present)
Assistant Professor of Fisheries Science, Virginia Polytechnic Institute and State University (1980)

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

American Fisheries Society (Past President of Exotic Fish Section)
World Aquaculture Society
Sigma Xi
Phi Kappa Phi

SELECTED PUBLICATIONS

Stickney, R.R., and C.C, Kohler. (In Press). Maintaining fishes for research and teaching. Chapter 20 *in* C. Schreck and P. Moyle, editors. Methods for fish biology. American Fisheries Society.

Neto, J.R., C.C. Kohler, and W.M. Lewis. 1987. Water re-use system for production of fingerling fishes in Brazil, with emphasis on South American catfishes (*Rhamdia quelens* and *R. sapo*). Tropical Agriculture 64:2-6.

Kohler, C.C., and S.P. Krueger. 1986. Use of pressed brewer's grain as feed for freshwater shrimp (*Macrobrachium rosenbergii*). Journal of the World Mariculture Society 16:181-182.

Kohler, C.C., R.L. Ferry, and P.B. Welle. 1986. Tank culture of tilapia in Haiti: an assessment of biological and chemical constraints. Pages 611-623 *in* R. Day, and T.L. Richards, editors. Proceedings of the Second International Symposium on Warm Water Aquaculture-Finfish.

Kohler, C.C., and F.A. Pagan-Font. 1978. Evaluation of rum distillation wastes, pharmaceutical wastes, and chicken feed for rearing *Tilapia aurea* in Puerto Rico. Aquaculture 14(4):339-347.

VITA

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Cooperative Fisheries Research Laboratory — Phone: (618) 536-7761
Southern Illinois University
Carbondale, IL 62901-6511

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.