BIOLOGICAL ASSESSMENT OF GREEN STURGEON IN THE SACRAMENTO-SAN JOAQUIN WATERSHED

Project Information

1. **Proposal Title:**

BIOLOGICAL ASSESSMENT OF GREEN STURGEON IN THE SACRAMENTO-SAN JOAQUIN WATERSHED

2. **Proposal applicants:**

Peter Klimley, University of California, Davis

3. **Corresponding Contact Person:**

Ahmad Hakim-Elahi
The Regents of the University of California
Office of the Vice Chancellor for Research Sponsored Programs,
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4. **Project Keywords:**

At-risk species, fish
Fish, Anadromous
Sturgeon biology

5. **Type of project:**

Research

6. **Does the project involve land acquisition, either in fee or through a conservation easement?**

No

7. **Topic Area**:

At-Risk Species Assessments

8. **Type of applicant:**

University

9. **Location - GIS coordinates:**

Latitude: 38.575
Longitude: -121.592
Datum:

Describe project location using information such as water bodies, river miles, road intersections, landmarks, and size in acres.

The biology of the green sturgeon will be studied throughout the Sacramento/San Joaquin River and Klamath watersheds.

10. **Location - Ecozone:**

3.1 Keswick Dam to Red Bluff Diversion Dam, 3.2 Red Bluff Diversion Dam to Chico Landing, 3.3 Chico Landing to Colusa, 3.4 Colusa to Verona, 3.5 Verona to Sacramento, 12.1 Vernalis to Merced River, 12.2 Merced River to Mendota Pool, 12.3 Mendota Pool to Gravelly Ford, 12.4 Gravelly Ford to Friant Dam, 1.1 North Delta

11. **Location - County:**

Colusa, Fresno, Glenn, Merced, Sacramento, San Joaquin, Stanislaus, Sutter, Tehama, Yolo

12. **Location - City:**

Does your project fall within a city jurisdiction?

Yes

If yes, please list the city: Davis

13. **Location - Tribal Lands:**

Does your project fall on or adjacent to tribal lands? No

If yes, please list the tribal lands:

14. **Location - Congressional District:**

3rd

15. **Location:**

California State Senate District Number: 4

California Assembly District Number: 8

16. **How many years of funding are you requesting?** 2

17. **Requested Funds:**

a) **Are your overhead rates different depending on whether funds are state or federal?**

Yes

If yes, list the different overhead rates and total requested funds:

State Overhead Rate: 10.0
Total State Funds: 98,222
Federal Overhead Rate: 48.5
Total Federal Funds: 1,320,039

b) Do you have cost share partners already identified?

Yes

If yes, list partners and amount contributed by each:

Univ. of California, Davis 85,478

c) Do you have potential cost share partners?

No

d) Are you specifically seeking non-federal cost share funds through this solicitation?

No

If the total non-federal cost share funds requested above does not match the total state funds requested in 17a, please explain the difference:

18. **Is this proposal for next-phase funding of an ongoing project funded by CALFED?**

Yes

If yes, identify project number(s), title(s) and CALFED program (e.g., ERP, Watershed, WUE, Drinking Water):

98-C15 (B81738)	Phase 1- Biological Assessment of Green Sturgeon in the Sacramento-San Joaquin Watershed	ERP, CMARP, Anadromous Fisheries Research Program
00FC200142 (CalFed agreement No.)	Phase 2 - Biological Assessment of Green Sturgeon in the Sacramento-San Joaquin Watershed	ERP, CMARP, Anadromous Fisheries Research Program

Have you previously received funding from CALFED for other projects not listed above?

No

19. **Is this proposal for next-phase funding of an ongoing project funded by CVPIA?**

Yes

If yes, identify project number(s), title(s) and CVPIA program (e.g. AFRP, AFSP, b(1) other).

11332-1-G005 Phase 3&4 - Biological Assessment of Green Sturgeon in the Sacramento-San Joaquin Watershed

Have you previously received funding from CVPIA for other projects not listed above?

No

20. **Is this proposal for next-phase funding of an ongoing project funded by an entity other than CALFED or CVPIA?**

No

Please list suggested reviewers for your proposal. (optional).

21. **Comments:**

Environmental Compliance Checklist

BIOLOGICAL ASSESSMENT OF GREEN STURGEON IN THE SACRAMENTO-SAN JOAQUIN WATERSHED

1. **CEQA or NEPA Compliance**

a) Will this project require compliance with CEQA?

No

b) Will this project require compliance with NEPA?

No

c) If neither CEQA or NEPA compliance is required, please explain why compliance is not required for the actions in this proposal.

The Green Sturgeon is not an endangered or threatened species.

2. **If the project will require CEQA and/or NEPA compliance, identify the lead agency(ies).** *If not applicable, put "None".*

CEQA Lead Agency: None
NEPA Lead Agency (or co-lead:) None
NEPA Co-Lead Agency (if applicable): None

3. **Please check which type of CEQA/NEPA documentation is anticipated.**

CEQA

-Categorical Exemption
-Negative Declaration or Mitigated Negative Declaration
-EIR
X none

NEPA

-Categorical Exclusion
-Environmental Assessment/FONSI
-EIS
X none

If you anticipate relying on either the Categorical Exemption or Categorical Exclusion for this project, please specifically identify the exemption and/or exclusion that you believe covers this

project.

4. **CEQA/NEPA Process**

a) Is the CEQA/NEPA process complete?

Not Applicable

b) If the CEQA/NEPA document has been completed, please list document name(s):

5. **Environmental Permitting and Approvals** (*If a permit is not required, leave both Required? and Obtained? check boxes blank.*)

LOCAL PERMITS AND APPROVALS

Conditional use permit
Variance
Subdivision Map Act
Grading Permit
General Plan Amendment
Specific Plan Approval
Rezone
Williamson Act Contract Cancellation
Other

STATE PERMITS AND APPROVALS

Scientific Collecting Permit

Obtained: Collecting (and Tagging) Permits from California Department of Fish and Game.

Klimley, A. Peter (PI, Phase 5, Task 1), 2001 California Resident Scientific Collecting Permit – 801171-03.

Kelly, John T. (Graduate Research Assistant, Phase 5, Task 1), 2001 California Student Scientific Collecting Permit – 801171-03803052-04 (Sponsor: A.P. Klimley, Adjunct Assoc. Professor, UC Davis).

CESA Compliance: 2081
CESA Compliance: NCCP
1601/03
CWA 401 certification
Coastal Development Permit
Reclamation Board Approval
Notification of DPC or BCDC
Other

FEDERAL PERMITS AND APPROVALS

ESA Compliance Section 7 Consultation
ESA Compliance Section 10 Permit
Rivers and Harbors Act
CWA 404
Other

PERMISSION TO ACCESS PROPERTY

Permission to access city, county or other local agency land.
Agency Name:

Permission to access state land.
Agency Name:

Permission to access federal land.
Agency Name:

Permission to access private land.
Landowner Name:

6. **Comments.**

Land Use Checklist

BIOLOGICAL ASSESSMENT OF GREEN STURGEON IN THE SACRAMENTO-SAN JOAQUIN WATERSHED

1. **Does the project involve land acquisition, either in fee or through a conservation easement?**

No

2. **Will the applicant require access across public or private property that the applicant does not own to accomplish the activities in the proposal?**

Yes

3. **Do the actions in the proposal involve physical changes in the land use?**

No

If you answered no to #3, explain what type of actions are involved in the proposal (i.e., research only, planning only).

The proposed project will study the green sturgeon and does not involve changes in land use.

4. **Comments.**

Conflict of Interest Checklist

BIOLOGICAL ASSESSMENT OF GREEN STURGEON IN THE SACRAMENTO-SAN JOAQUIN WATERSHED

Please list below the full names and organizations of all individuals in the following categories:

- Applicants listed in the proposal who wrote the proposal, will be performing the tasks listed in the proposal or who will benefit financially if the proposal is funded.
- Subcontractors listed in the proposal who will perform some tasks listed in the proposal and will benefit financially if the proposal is funded.
- Individuals not listed in the proposal who helped with proposal development, for example by reviewing drafts, or by providing critical suggestions or ideas contained within the proposal.

The information provided on this form will be used to select appropriate and unbiased reviewers foryour proposal.

Applicant(s):

Peter Klimley, University of California, Davis

Subcontractor(s):

Are specific subcontractors identified in this proposal? Yes

If yes, please list the name(s) and organization(s):

C.C. Crocker San Francisco State University
D.W. Kohlhorst Calif Dept of Fish and Game

Helped with proposal development:

Are there persons who helped with proposal development?

Yes

If yes, please list the name(s) and organization(s):

J.J. Cech, Jr., UCD
S.I. Doroshov, UCD
B.P. May, UCD
I. Werner, UCD

Budget Summary

BIOLOGICAL ASSESSMENT OF GREEN STURGEON IN THE SACRAMENTO-SAN JOAQUIN WATERSHED

Please provide a detailed budget for each year of requested funds, indicating on the form whether the indirect costs are based on the Federal overhead rate, State overhead rate, or are independent of fund source.

State Funds: 10% X Direct Costs Year 1

Task No.	Task Description	Direct Labor Hours	Salary *(per year)*	Benefits *(per year)*	Travel	Supplies & Expendables	Services or Consultants	Equipment	Other Direct Costs	Total Direct Costs	Indirect Costs	Total Cost
1	Telemetric Studies	1,900	52,035	7,280	2,000	87,602	28,000	8,334	4,928	176,917	17,692	207,871
2	Sturgeon Capture and Tagging	0	0	0	0	0	25,000	0	17,474	25,000	2,500	44,974
3	Physiological Studies	4104	84,321	7,446	3,000	19,500	0	0	9,856	114,267	11,427	135,550
4	Developmental Studies	984	23,700	5,475	1,500	5,000	0	0	0	35,675	3,568	39,243
5	Genetic Studies	1,565	48,090	10,931	1,500	8,100	11,000	2,400	0	79,721	7,972	90,093
6	Management of Project	320	13,002	3,380	0	0	0	0	0	16,382	1,638	18,020
		8,873	221,148	34,512	8,000	120,202	64,100	10,734	32,258	447,962	44,796	535,750

Year 2

Task No.	Task Description	Direct Labor Hours	Salary *(per year)*	Benefits *(per year)*	Travel	Supplies & Expendables	Services or Consultants	Equipment	Other Direct Costs	Total Direct Costs	Indirect Costs	Total Cost
1	Telemetric Studies	1,900	53,334	7,619	4,000	44,048	28,000	0	4,928	137,001	13,700	155,629
2	Sturgeon Capture and Tagging	0	0	0	0	0	25,000	0	17,474	25,000	2,500	44,974
3	Physiological Studies	2,844	59,902	7,245	3,000	17,500	0	0	4,928	87,647	8,765	101,340
4	Developmental Studies	984	24,648	5,694	1,500	5,000	0	0	0	36,842	3,684	40,526
5	Genetic Studies	1,565	48,090	10,931	1,500	11,100	11,000	0	0	82,621	8,262	90,883
6	Management of Project	320	13,651	3,549	2,000	0	0	0	8,000	19,200	1,920	29,120
		7,613	199,625	35,038	12,000	77,648	64,000	0	52,330	388,311	38,831	462,472

Grand Total=$998,222

Budget Justification

BIOLOGICAL ASSESSMENT OF GREEN STURGEON IN THE SACRAMENTO-SAN JOAQUIN WATERSHED

Direct Labor Hours. Provide estimated hours proposed for each individual.

Total Year 1 & Year 2

Task 1. Adjunct Associate Professor IV, 1,280 hrs; Graduate Student Researcher, 2,520 hrs.
Task 2. None (see subcontract).
Task 3. Assistant Research Scientist, 1056 hrs; Laboratory Assistant II, 2,112 hrs; Graduate Student Researcher, 2,520 hrs; Graduate Student Researcher, 1,260 hrs.
Task 4. Staff Research Associate IV, 984 hrs; Postgraduate Researcher III, 984 hrs.
Task 5. Adjunct Professor, 1,050 hrs; Postgraduate Researcher I, 2,080 hours.
Task 6. Adjunct Associate Professor IV, 640 hrs.

Salary. Provide estimated rate of compensation proposed for each individual.

Task 1. Adjunct Associate Professor IV, $40.63/hr (Yr 1), $42.66/hr (Yr 2); Graduate Student Researcher, $21.08 (Yrs 1 & 2).
Task 2. None (see subcontract).
Task 3. Assistant Research Scientist, $32.05/hr (Yr 1), $$33.65/hr (Yr 2); Laboratory Assistant II, $14.52 (Yr 1), $15.25/hr (Yr 2); Graduate Student Researcher, $21.08/hr (Yrs 1 & 2); Graduate Student Researcher, $21.08/hr (Yr 1).
Task 4. Staff Research Associate IV, $29.88/hr (Yr 1), $31.07/hr (Yr 2); Postgraduate Researcher III, $18.29/hr (Yr 1), $19.02/hr (Yr 2).
Task 5. Adjunct Professor, $50/hr (Yrs 1 & 2); Postgraduate Researcher I, $21.00/hr (Yrs 1 & 2).
Task 6. Adjunct Associate Professor IV, $40.63/hr (Yr 1), $42.66/hr (Yr 2).

Benefits. Provide the overall benefit rate applicable to each category of employee proposed in the project.

Task 1. Adjunct Associate Professor IV, 0.26; Graduate Student Researcher, 0.02.
Task 2. None (see subcontract).
Task 3. Assistant Research Scientist, 0.17; Laboratory Assistant II, 0.23; Graduate Student Researcher, 0.02; Graduate Student Researcher, 0.02.
Task 4. Staff Research Associate IV, 0.25; Postgraduate Researcher III, 0.20.
Task 5. Adjunct Professor, 0.25; Postgraduate Researcher I, 0.20.
Task 6. Adjunct Associate Professor IV, 0.26.

Travel. Provide purpose and estimate costs for all non-local travel.

Task 1. Yr 1: Mileage for telemetric studies, $2,000; Yr 2: Mileage for telemetric studies, $2,000; Travel and per diem for 2 to attend scientific meeting: $2,000.
Task 3. Yrs 1 & 2: Travel and per diem to attend scientific meeting, $3,000; Travel to collect samples, $3,000.
Task 4. Yrs 1 & 2: Travel to collect wild broodstock and transport to UCD or spawn on river; field trips to biopsy tagged fish, $3,000.
Task 5. Yrs 1 & 2: Travel and per diem for scientific meeting, $3,000.
Task 6. Yr 2: Travel of investigators to symposium at BML, $2,000.

Supplies & Expendables. Indicate separately the amounts proposed for office, laboratory, computing,and field supplies.

Office:

Task 4. Yrs 1 & 2: Supplies, $2,700.

Laboratory:

Task 3. Yrs 1 & 2: Fish foods, reagents, chemicals, steroid analysis supplies, hsp supplies, assays, tank rental, $37,000.
Task 4. Yrs 1 & 2; Supplies for broodstock collection and spawning, laboratory supplies for embryo/larval studies, histology recharges, tank recharges, water, and feed costs for fish, $10,000.
Task 5. Yrs 1 & 2: Molecular reagents, $14,000.

Computing:

Task 5. Yr: Computing, $2,500.

Field:

Task 1. Yr 1: 40 X Vemco VR-02 tag detecting monitors, $43,020; 40 X Onset Tidbit temperature loggers, $5,150; 40 X moorings for monitors, $3,000; 60 X Vemco ultrasonic tags, $22,430; 60 X ATS radio transmitters, $11,330; 2 X ATS airplane antennas, $298; 2 X airplane mounts, $374; supplies, gasoline, and maintenance of tagging boat, $2,000.
Yr 2: 8 X Vemco VR-02 tag detecting monitors, $8634; 8 X Onset Tidbit temperature loggers, $1,054; 8 X moorings for monitors, $600; 60 X Vemco ultrasonic tags, $22,430; 60 X ATS radio transmitters, $11,330.

Services or Consultants. Identify the specific tasks for which these services would be used. Estimate amount of time required and the hourly or daily rate.

Task 1. Yrs 1 & 2: Subcontract to SFSU, $36,000, (salaries for students, $12,000, travel to tracking sites, $2,500, and supplies and expendables, $3,500, total $18,000/yr); Subcontract for air flights to detect radio-tagged GS, $20,000 (2 yr @ $10,000/yr).

Task 2. Yrs 1 & 2: Subcontract to CDFG to fish for GS, $84,948 (2 mon/yr @ $21,237/mon (personnel, $12,224, benefits, $1,970, equipment operating expenses, $3,518, and overhead, $3,525).
Task 5. Yrs 1 & 2: Subcontract for use of sequence/genotype instrument, $22,000 (lease of sequencer/genotyper, $7,000, equipment maintenance, $4,000, $11,000/yr).

Equipment. Identify non-expendable personal property having a useful life of more than one (1) year and an acquisition cost of more than $5,000 per unit. If fabrication of equipment is proposed, list parts and materials required for each, and show costs separately from the other items.

Task 1. Yr 1: Flowmeter for measuring current speed, $5357; ATS scanning receiver, $2,977.
Task 3. Yr 1: Freezer, $2,400.

Project Management. Describe the specific costs associated with insuring accomplishment of a specific project, such as inspection of work in progress, validation of costs, report preparation, giving presentatons, response to project specific questions and necessary costs directly associated with specific project oversight.

Task 6 – Yr 1: 2 mon of salary for PI (Adjunct Associate Professor) for coordinating the project, preparing the quarterly reports, organizing the workshops (320 hr, $40.63/hr, $13,002 salary, $3,380 benefits).
Yr 2: 2 mon of salary for PI (Adjunct Associate Professor) for coordinating the project, preparing the quarterly reports, and organizing symposium at the Bodega Marine Laboratory (of UCD) and editing scientific articles submitted for publication in resulting proceedings (320 hr, $42.66/hr, $13,651 salary, $3,549 benefits).

Other Direct Costs. Provide any other direct costs not already covered.

Task 1. Yrs 1 & 2: Graduate Student Fee Remissions, $9,866.
Task 3. Yrs 1 & 2: Graduate Student Fee Remissions, $14,784.

Indirect Costs. Explain what is encompassed in the overhead rate (indirect costs). Overhead should include costs associated with general office requirements such as rent, phones, furniture, general office staff, etc., generally distributed by a predetermined percentage (or surcharge) of specific costs.

Overhead rates for UCD are federally negotiated.

The current rates are: State, 10%, and Federal, 48.5%.

Executive Summary

BIOLOGICAL ASSESSMENT OF GREEN STURGEON IN THE SACRAMENTO-SAN JOAQUIN WATERSHED

The green sturgeon (GS, *Acipenser medirostris*) is an anadromous, native fish that occurs in low numbers in our Bay/Delta system. It is classified as a CALFED At-Risk Species (Priority Group I), but very little is known about its life history. Basic GS life history information is critical to this species' protection, and our project's targeted research focus is on describing the biological characteristics of this species and its habitats for conservation and potential restoration.

We have completed Phase 1 & 2 studies of GS and given technical presentations of our results at two workshops, at the annual meeting of the California-Nevada Chapter of the American Fisheries Society, and at the 4th International Sturgeon Symposium. One M.S. thesis has been completed on GS developmental biology and another is nearing completion, a manuscript has been published, another accepted for publication in the same journal, and several others on the genetics and physiology of sturgeon are in preparation. We are currently conducting Phases 3 and 4 of GS research. Phase 5 will have six tasks: 1. determine the movements and distribution of adult GS, tagged with ultrasonic and radio beacons and tracked either by listening stations, airplane, automobile, or boat, within the Sacramento and San Joaquin Rivers, and describe the physical properties (geomorphology, water temperatures, and flow regime) of their habitats with particular attention directed at identifying GS spawning sites and characterizing their physical characteristics; 2) capture subadult and adult GS during a one month period in winter (Jan./Feb.) and a similar period in summer (Aug.) in San Pablo Bay (using trammel net samples) to provide GS for Tasks, 1, 3-5; 3) determine juvenile GS developmental stage-related swimming performance, salinity tolerance, salinity preference, gill chloride cell activation, osmoregulatory responses, and stress responses (i.e., heat-shock proteins) to environmental change. 4. establish reliable artificial reproduction for research and methodology for determining sex and stage of gonadal maturity, which will aid in inferring when and where individuals spawn in the Sacramento and San Joaquin Rivers; 5. use unique genetic markers to identify sibling among GS located on their breeding areas by telemetry, plankton tows, and egg traps in order to estimate the number of breeding adults at each spawning: 6. supervise and ensure integration among these multidisciplinary studies as well as organize a symposium, to be held at the Bodega Marine Laboratory, with scientific talks given on the biology of the GS that will result in peer-reviewed scientific articles included in a benchmark reference volume on the general biology of the species to be published in the scientific literature (ideally by a major book publisher such as Academic Press). Fisheries biologists from UC Davis, CDFG, NMFS, SFSU, and the Yurok Tribe will join in this collaborative effort to provide valuable information for adaptive management approaches to increase our Bay-Delta GS stocks. This project will provide valuable information to decision-makers using adaptive management to resolve scientific uncertainties in our GS life history conceptual model and assist in GS recovery, a specific ERP, "…Evaluating green sturgeon habitat, including barriers, diversions, flows and temperatures…is a high priority (Strategic Goal 1, At-risk Species Assessments (p. 31)."

Proposal

University of California, Davis

BIOLOGICAL ASSESSMENT OF GREEN STURGEON IN THE SACRAMENTO-SAN JOAQUIN WATERSHED

A. Peter Klimley, University of California, Davis

BIOLOGICAL ASSESSMENT OF GREEN STURGEON IN THE SACRAMENTO-SAN JOAQUIN WATERSHED

Amount Requested: $998,222 (@ 10% overhead) or $1,320,039 (@48.5% overhead) for 2 yrs.
Applicant: A.Peter Klimley, Department of Wildlife, Fish, and Conservation Biology, University of California, Davis, 1 Shields Ave., Davis, CA 95616; ph: 530-752-7530, FAX: 530-752-4154, e-mail: apklimley@ucdavis.edu.
Participants and Collaborators: J.J. Cech, Jr. (UCD), S.I. Doroshov (UCD), B.P. May (UCD), A.P. Klimley (UCD), C.E. Crocker (SFSU), D.W. Kohlhorst (CDFG), R.G. Schaffter (CDFG), I. Werner (UCD).

C. PROJECT DESCRIPTION

The green sturgeon (GS, *Acipenser medirostris*) is an anadromous, native fish that occurs in low numbers in our Bay/Delta system (Moyle, 1976). While GS has a lower value in commercial fisheries of the Pacific Coast, compared to white sturgeon (WS, *A. transmontanus*), it is highly valuable species in traditional tribal fisheries and in the biodiversity of Pacific Northwest's ecosystems. The GS is classified as a CALFED At-Risk Species (Priority Group I), but very little is known about its life history. Basic GS life history information is critical to this species' protection. Hence, we propose to use a multidisciplinary approach to elucidate the general biology of GS within the Sacramento/San Joaquin River System, conducting studies of the: 1) movements and distribution, 2) physiology, 3) reproductive biology, and 4) genetics of GS.

1. Statement of the Problem

Movements and Distribution. We know very little about the movements and distribution of GS throughout the Sacramento/San Joaquin River System. Subadults have been caught in San Pablo Bay in CDFG trammel net surveys during the late summer. Yet it is not known how long these individuals stay in the estuary. GS tagged in the bay have been caught along the coast of California north of San Francisco during winter and spring after a decline in the rate of capture of GS in the bay. How long do subadults GS actually remain in the estuary? When precisely do they leave? Adult female GS, which are ready to spawn, are frequently caught during spring in the Klamath River; fewer mature GS females are caught in the Sacramento and San Joaquin rivers. Trammel net surveys need to be carried out during the spring season, when female GS presumably move up the Sacramento River to spawn. What are the physical features (temperatures and flows) conducive to GS reproduction within the river system. Disturbingly, during "wet" years, adult GS are being stranded at the Fremont Weir (unable to enter the Sacramento River channel after apparently migrating up the Yolo Bypass), and information is vitally needed on GS (and WS) movements and swimming performance to assess proposed solutions to this stranding problem.

We will place coded ultrasonic and radio beacons on adult females during their spring upstream spawning migration and on individuals of varied age and sex during their downstream migration in the fall. We will record the passage of GS with automated monitors placed at points where main tributaries branch away from the main river. We will attempt to relate migratory movements of GS to fluctuations in water temperature from the melting snowpack of the Sierra Nevada mountains using water temperature loggers on the monitors. We will track GS up the

tributaries in an airplane equipped with a scanning receiver to detect their radio tags. Sites on the river, at which the GS remain, will be visited by boat or inflatable and sampled for eggs, to verify recent spawning. The physical properties (temperature and flow speed) of the GS spawning sites will be recorded using a bathythermograph and flow meter. We intend to describe habitat suitable for GS spawning, and determine the amount of such habitat that exists within the river system. This baseline information will permit us to assess the effect of water release (or its absence) on the reproductive success of GS in the river system.

Physiology. Studies on GS are planned to reveal more about their vulnerability to environmental stressors. Juvenile fish can be more susceptible physiologically to changes in their environment and stand a greater risk of predation than adult fish. Because fish populations are heavily influenced by the success of young life history stages, the study of the juveniles' responses to environmental stressors (e.g., temperature, dissolved oxygen, salinity, water velocity) are particularly important. Unfortunately, we know very little about juvenile GS' environmental tolerance limits and "preferences" (affinities). Information about their tolerance limits, affinities, and stress responses regarding important environmental variables would significantly assist our understanding of the GS' behavior in natural habitats, including their movements in freshwater and to the estuary and ocean. These "environmental requirements" data are quantitatively linked via bioenergetic models (Jobling, 1994) that allow predictions of physiological shortcomings (e.g., reduced growth, swimming performance, reproduction, survival) associated with environmental stresses that lead to populational declines (Wedemeyer et al., 1990). A greater understanding of the GS' stress responses is needed, including measures that are usable from field-caught individuals from various environments. This proposal includes laboratory approaches that will quantitatively describe GS' environmental requirements and its stress responses, including molecular (e.g., glucocorticoid receptor, heat shock protein) assays that are usable to assess stress in wild-caught individuals from Sacramento-San Joaquin Watershed habitats.

Reproductive Biology. Late sexual maturity, long gonadal cycles, and conservative spawning behavior make reproductive potential of sturgeons highly sensitive to fishing mortality (Boreman, 1997) and changes in river flow (Dettlaff et al., 1993). While all species of sturgeon have generally a similar reproductive strategy, they differ in sexual maturation rates, spawning migration patterns, selection of spawning habitat, and larval/juvenile ecology (Holcik, 1985; Bemis and Kynard, 1997). Information on the American GS reproduction is limited to our studies on the Klamath River (CalFed and USDI/USFWS/AFRP Projects). We initiated development of artificial spawning techniques (Van Eenennaam et al., 2001), evaluated reproductive conditions of Klamath River broodstock (Van Eenennaam and Doroshov, 2001), and characterized early development (Deng, 2000; Deng et al., 2002). However, some important aspects of GS reproduction remain unknown. The artificial spawning, supporting research on physiology, reproduction, and genetic markers of GS (Phase 1, Tasks 1,2, and 3) was hindered by the low egg fertility and hatchability (Van Eenennaam et al., 2001). We obtained representative data on gonads and gametes of mature broodstock (Van Eenennaam and Doroshov, 2001) but not on the intermediate stages of gonad development needed to elucidate the GS' sexual maturation and reproductive potential. The low adhesivity of GS' eggs, poor pigmentation of hatched larvae, and their behavior (photonegative, demersal, limited mobility) indicate that GS require specific spawning habitat (rocky substrate with the crevices, Deng et al., 2002). However, the GS' spawning sites and embryo/larval habitat remain unknown. Resolving these uncertainties will significantly improve our capabilities to protect reproductive potential of GS.

Genetics. Egg, fry, and juvenile green sturgeon are sometimes difficult to tell apart except by expert sturgeon biologists. We know this to be true because each year we find some samples sent to us labeled as green sturgeon are in fact white sturgeon. When eggs or fry are captured in a

river, how many parents contributed to that collection? Two parents? Twenty parents? The answer is very important to measure the spawning success in a river system. How genetically different are the fish that spawn in the Klamath versus the Sacramento rivers? How does the genetic variability as measured by heterozygosity and alleles per locus compare between the Klamath and the Rogue River populations? Is genetic variability correlated with population size? Where do the sturgeon captured in ocean fisheries (e.g., off the coast of Oregon) or in esturies with no apparent source population (e.g., mouth of the Columbia) come from? We have found the fish in mouth of the Columbia and in San Pablo Bay in the Sacramento/San Joaquin Bay Delta to be very similar and yet both are quite distinct from the fish that are spawning in the Klamath River. The only true way to identify spawning populations is to capture fish while spawning or to capture fry or juveniles before outmigration. This is difficult to do with sturgeon.

a. Results to Date. American GS are known to spawn in the Sacramento and Klamath Rivers (Moyle et al., 1994), and the adults are present in the lower reaches of the Columbia and Fraser Rivers (Houston, 1988). Artyukhin and Andronov (1990) described spawning runs of the Asian GS (considered the same species *A. medirostris* Ayres or, as subspecies *A. medirostris mikadoi* Hilgendorf) in the Tumnin River and succeeded in the artificial spawning of two females. However, they provided no detailed descriptions of early GS development. Our CALFED project's (Project No. 98-C15 [B81738], Phases 1 and 2) concentrated on measuring GS' food consumption, metabolic, and growth responses; determining its spawning, egg fertility, and larval survival characteristics; developing genetic techniques for distinguishing GS (from WS and between GS stocks), and searching Feather River habitats for evidence of GS spawning. M Through these activities, we collected samples of gonads and finrays from 30 wild-caught adults (Klamath River) and 14 subadults (San Pablo Bay) to examine gonadal development in relation to age, body size, and sex. We also conducted the first artificial spawning of North American GS (May 1999) on the Klamath River (in collaboration with the Yurok Tribe), reared GS juveniles at UC Davis campus, and characterized developmental stages of the embryos and larvae (Deng et al., 2001), and are preparing a manuscript describing their normal development. The resulting juvenile GS were used in studies of ration size and temperature effects on food consumption rate, growth rate, and food conversion efficiency (Mayfield and Cech, submitted). Studies were also conducted on GS juveniles' metabolic (oxygen consumption) rates, and preliminary data were collected on the developing GS' stress responses.

In addition, we have determined GS' growth responses to elevated temperatures (24^{o} C), and we have made juvenile GS available for the Fish Treadmill research project (CALFED Project # 99-N02) at UC Davis investigating fish swimming performance and behavior in the complex flows in front of fish screens. We have characterized the GS' response to acute stressors by measuring changes in plasma cortisol (Daly et al., 1999), glucose, and lactate concentrations, as well identifying environmental factors (temperature and time of day) that modify the stress response.

Phases 3 and 4 (CVPIA/AFRP, USFWS Agreement No. 11332-1-G005) continue these studies and include preliminary studies of GS movements in the Sacramento-San Joaquin/Bay Delta Watershed. These phases (October, 2001 through September, 2003) have five objectives: 1. To determine juvenile GS' temperature, dissolved oxygen, and salinity tolerance limits (using laboratory tanks/assays) and behavioral tendencies (using annular gradient tank); swimming performance (using swimming flumes); and stress responses (using laboratory tanks/assays, Task 1); 2. To characterize GS gonadal sex differentiation, stages of gametogenesis, fecundity and egg size in relation to age and body size (using samples from captive and wild populations); investigate GS egg chorion function and substrate attachment in fertilized eggs (using histochemical staining for glycoproteins and scanning electron microscopy); and determine optimal temperature ranges for GS larval development, growth, and survival (using laboratory

tanks, Task 2); 3. to develop genetic techniques to accurately identify GS at all life history stages and examine the uniqueness of GS stocks (using nuclear microsatellite and mitochondrial DNA markers, Task 3); 4. To determine the directions and rates of movement of adult/subadult GS in San Pablo Bay, the Yolo Bypass Toe Drain, and the Klamath River and the relative importance of temperature, salinity, and water current direction (using ultrasonic and radio telemetry, Task 4); and 5. To assess the distribution and abundance of GS in San Pablo Bay (using trammel net samples) and provide GS for Tasks 1-4.

b. Conceptual Model. Phase 5 will have five objectives: 1. To determine the movements and distribution of adult GS tagged with ultrasonic and radio beacons, and tracked either by airplane, automobile, boat or listening stations, within the Sacramento and San Joaquin Rivers and describe the habitats, in which they reside, with particular attention paid to their spawning grounds; 2) to capture and tag subadult and adult GS during one month period in late winter (Jan./Feb.) and a similar period in summer (Aug.) in San Pablo Bay (using trammel net samples); 3. To determine juvenile GS' absolute (tolerance limits), stressful (physiologically responsive, but sublethal), and selected ("preferred") environmental characteristics to assist in our understanding of their movements and the effects of environmental stressors (including temperature, dissolved oxygen, salinity, and water velocity-related effects) on their life stages; 4. To establish reliable artificial reproduction for research and the methodology for determining sex and gonadal maturity; 5. To use unique genetic markers to identify sibling among GS located on their breeding areas by telemetry, plankton tows, and egg traps in order to estimate the number of breeding adults at each spawning. Fisheries biologists from UC Davis, CDFG, SFSU, and Yurok Tribe will join in this collaborative effort to provide valuable information for adaptive management approaches to increase our Bay-Delta GS stocks through resolution of current scientific uncertainties in our GS life history conceptual model (Figure 1).

Figure 1 shows our conceptual model linking the GS' life history in the Sacramento-San Joaquin watershed ecosystems (river, including bypass, and estuary) to the Pacific Ocean. The rectangles represent the known ecosystems that the anadromous GS occupy at various life stages, yet many scientific uncertainties exist regarding their spatio-temporal pattern(s) and movements (arrows) in this system. The questions raised and samples/experiments started and proposed (see Statement of the Problem, above) are shown as the question marks (regarding distribution of the juveniles) and (lettered) approaches listed near the various life stages. Resolving more of the key spatio-temporal patterns (i.e., putting approximate dates [times of year] and/or fish ages with life stages in the various ecosystem components) will remove these uncertainties and provide valuable information to decision-makers using adaptive management to assist Sacramento-San Joaquin watershed GS population recovery, a specific ERP (Vol. 1, WS and GS, pp. 146-148; Vol. 2, WS and GS, p. 276) and AFRP (pp. 40-41, 70-71, and 95) objective of CALFED and CVPIA.

c. Hypotheses Being Tested. We will test several hypotheses to help achieve the CALFED Ecosystem Restoration Goal (#1) for GS: recovery towards large, self-sustaining populations, minimizing the need for future listing as an endangered species (CALFED Ecosystem Restoration Program Plan, Strategic Plan for Ecosystem Restoration, p. 21). Hypotheses letters refer to lettered approaches in conceptual model (Figure 1).

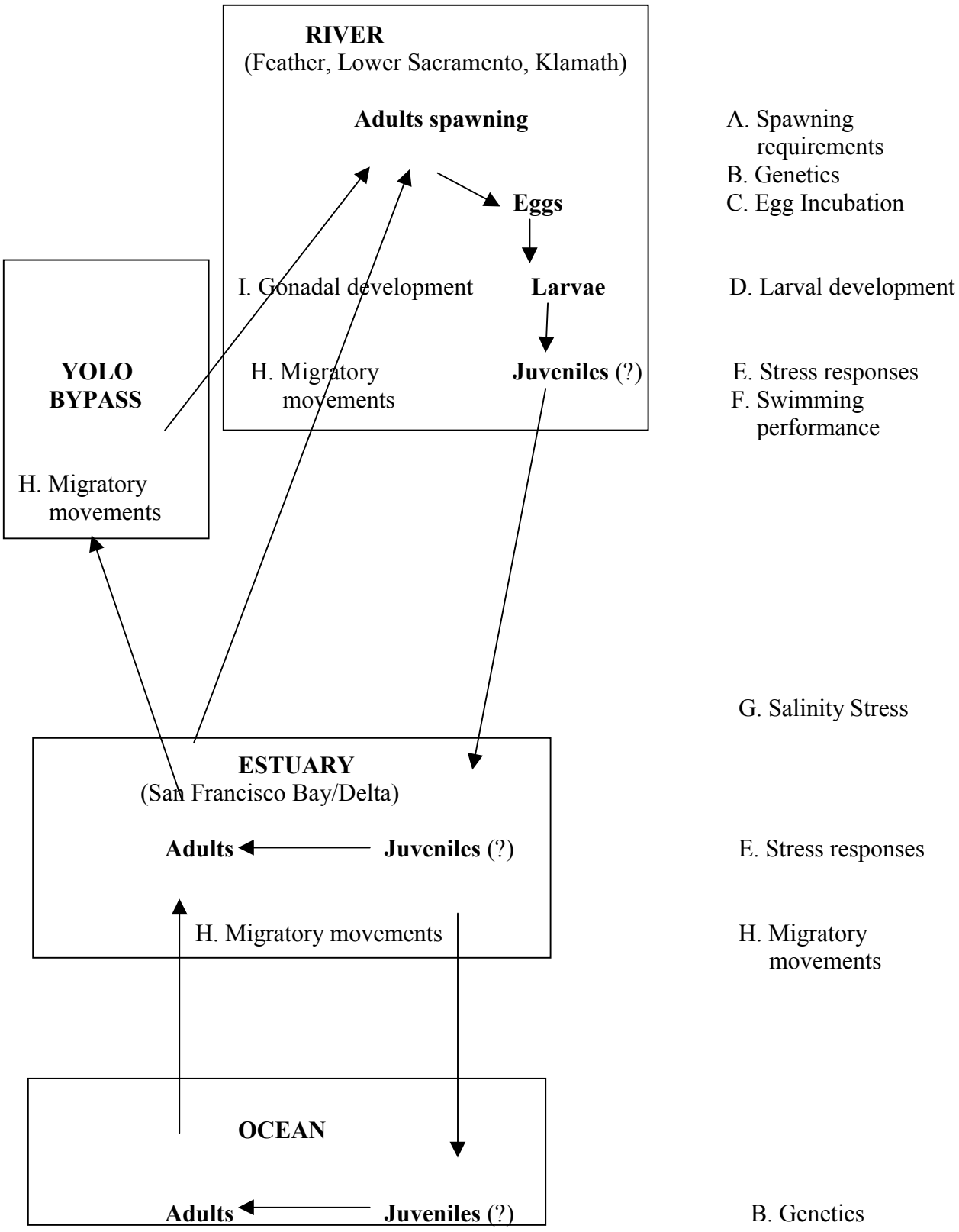

Figure 1. Conceptual model, with (lettered) targeted research elements, for GS distribution and movements in the Sacramento-San Joaquin watershed and linked ecosystems. (and, therefore, likely distribution) in the system for a particular year (and its river temperature regime).

A. GS are the seasonal breeders (spring-early summer) requiring specific temperature, current velocity, and spawning substrate (bedrock or gravel) dependent on river flow (Phase 5, Tasks 1,3,4.
B. While GS account for <10% of the sturgeon egg production in the Feather/Sacramento Rivers, the recruitment from Feather/Sacramento River GS supports the Oregon and Washington ocean fisheries. The relative contribution of each GS stock to a mixed stock ocean fishery will be determined during Phase 5 (Task 5).
C. Egg incubation occurs in bedrock crevices, indicated by the weak adhesion of eggs to substrate, limited mobility, and poor pigmentation of hatched larvae (Phases 3 & 4, Task 2).
D. Optimal river temperature range of GS larvae is most likely within 14-20^{o}C (Phases 3, 4, Task 2).
E. GS are significantly more sensitive to increased temperature and decreased dissolved oxygen stressors than to increased salinity stressors (Phase 2, Task 1). Chronic and acute stress responses are sensitive to environmental changes and are measurable (using hormonal and molecular techniques, including heat-shock, protein, concentrations) in wild-caught GS (stress levels calibrated from performance-affecting, laboratory-determined levels in captive GS).
F. Swimming performance, in terms of critical swimming velocity (cm/s, Brett 1964) significantly increases as the fish grow in length, and increases as temperature increases (to some maximum within its temperature tolerance range, Phases 2 & 4, Task 1, and Phase 5, Task 3).
G. Juvenile GS become tolerant of estuarine salinities (20-25 ppt) when 4-6 months old and show affinities for higher velocity water, compared with younger life stages (Phase 5, Task 3).
H. Subadult GS move extensively throughout the mouth of the Sacramento River and San Pablo Bay Straits. Their movements are correlated with the temperature, oxygen, or salinity gradients within the estuary (Phases 3 & 4, Tasks 4,5). Subadults leave the estuary and enter the sea during the fall (Phase 5, Task 5).
I. Adult GS females, ready to spawn, enter San Pablo in the early spring and migrate up the Sacramento River (Phase 5, Tasks 1,2,& 4) and enter the tributaries leading eastward toward the Sierra Nevada mountains. Movement of reproductively mature GS into the tributaries is correlated with more rapid flows and colder water temperatures, caused by the spring melt of winter snowpack. Adult female GS discontinue their upstream migration when they reach deep, slow moving pools near the headwaters of the tributaries and remain there during the early spring and summer. GS eggs can be found within these pools during reproductive season indicative of recent spawning.

Our coordinated approach of testing these hypotheses will resolve key scientific uncertainties in the conceptual model (Figure 1) and will significantly assist in GS recovery, a specific ERP (Vol. 1, WS and GS, pp. 146-148; Vol. 2, WS and GS, p. 276) and AFRP (pp. 40-41, 70-71, and 95) objective of CALFED and CVPIA. (regarding distribution of the juveniles) and (lettered) approaches listed near the various life stages. Resolving more of the key spatio-temporal patterns (i.e., putting approximate dates [times of year] and/or fish ages with life stages in the various ecosystem components) will remove these uncertainties and provide valuable information to decision-makers using adaptive management to assist Sacramento-San Joaquin watershed GS populational recovery, a specific ERP (Vol. 1, WS and GS, pp. 146-148; Vol. 2, WS and GS, p. 276) and AFRP (pp. 40-41, 70-71, and 95) objective of CALFED and CVPIA.

d. Adaptive Management. The various samples and experiments that comprise this project should systematically remove the scientific uncertainties shown in the conceptual model. Also, as data are collected and analyzed, more quantitative hypotheses can be posed to more accurately determine the spatio-temporal patterns of GS distribution and abundance in the Sacramento-San

Joaquin watershed ecosystems. For example, the salt water tolerance (Phase 3) and the growth rate responses to temperature experiments (Phases 1 and 2) on developing, juvenile GS will better define their environmental (niche) requirements and indicate their emigratory timing capabilities

e. Educational Objectives. UC Davis and SFSU graduate and undergraduate students will be part of the research team. We will organize a symposium at the Bodega Marine Laboratory (of UC Davis) to report the results of the various studies described here and will later be published in a book. Regular reports at other workshops, meetings, and in the IEP Newsletter, and peer-reviewed publications will help disseminate results to the interested public and to professionals. Dr. Carlos Crocker brings SFSU students (as well as increased ethnic diversity) to the project.

2. Proposed Scope of Work

a. Location. Project field locations will be in San Pablo Bay, the Sacramento River, and the Yolo Bypass system. Broodstock for artificial spawning will be caught in the Klamath River.

b. Approach.

Task 1, Telemetric Monitoring. Future plans to restore GS populations must be formulated with knowledge of the spatial distribution of the species as well as its environmental requirements. Radio and ultrasonic telemetry has been used effectively to track various species of sturgeon (Kieffer and Kynard, 1996; Schaffter, 1997; Auer, 1999; Fox et al., 2000; Erickson et al., unpub. man.). Phases 3 and 4 describe the movements of GS in their natural habitat by tagging and tracking individuals carrying depth-sensing ultrasonic transmitters within San Pablo Bay (and associated Delta waters). CDFG have been sampling GS in San Pablo Bay during late summer and fall over the last dozen years. The decrease in rate of capture between Sept. and Oct. and later recapture of GS with fin-tags north of San Francisco after 3 mo to >1 year indicate that adults leave the bay in late fall and migrate along the coast northward toward the coast of Oregon (D. Kohlhorst, pers. com.).

During the past two years, we have tracked GS in the estuary of the Sacramento/San Joaquin River system and these tracking activities will be continued through Nov, 2002. The purpose of this component of the study is to relate the movements of subadult GS in San Pablo Bay and the lower Sacramento River to gradients of temperature, salinity, and dissolved oxygen in the species' physical environment. The geographic coordinates and depths of the GS are being recorded by an automated telemetry system (directional hydrophone interfaced with an ultrasonic receiver, laptop computer, and differential-corrected global positioning system to automatically pair the temperature measurements with geographic coordinates). GS tracks are being superimposed on bathymetric maps and satellite images of sea surface temperature using ArcView software to identify their thermal preferences. GS dive patterns are also being superimposed on contour maps of temperature, salinity, and dissolved oxygen to further understand the species' physiological preferences. Physical data is currently being measured at hourly intervals at various depths using a bathythermograph lowered from the surface to the bottom. This methodology has been used to describe the movements and habitat preferences of widely migratory species (for tunas, see Block et al., 1997, Brill et al., 1999; for sharks, see Klimley, 1993, and Klimley et al., 2002). We are finding that subadult GS move extensively throughout the Delta region during both day and night. These move large distances from one apparent feeding site (indicated by slow movement in a restricted area) to other sites with rates at times exceeding 4 km/hr. Shipboard tracking of individuals is restricted to 1-3 days because of observer fatigue. The next logical step, and the objective of the proposed study (Phase 5), is to increase the duration of GS monitoring to an

interannual time scale and the geographic scope to the entire Sacramento/San Joaquin River watershed.

During Phases 3 & 4, we also are attempting to monitor sturgeon Yolo Bypass, the primary floodplain of the Sacramento Delta. Before flowing into this basin, water must pass over the Fremont Weir, where, at all but the highest flow levels, there is an elevation difference between the Yolo Bypass and the Sacramento River at the weir. During high flow periods, upstream-migrating GS are attracted into the basin and become concentrated in a 2.4-km reach below the Fremont Weir and unable to proceed further upstream because the inadequate fish ladder at the center of the weir. During the first year of the current grant period (Phase 3, Task 4), we attempted capture and tag GS in the Yolo Bypass (in cooperation with T. Sommer, DWR). The year was dry, and DWR did not catch any green sturgeon, yet tag-detecting monitors were temporarily installed in the Toe Drain to determine their range of reception (i.e., within a 300-m reach of the river). During the last year of the current grant period (Phase 4, Task 4), we hope to determine the GS residence time in the Bypass, and track them as they proceed upstream. These studies will be continued during Phase 5. This stranding problem is well known by CDFG wardens and recently made local TV news as a lead story. We will provide CDFG with movements (and swimming performance, see Task 1) data that may be critical in their solution of this problem.

The main objective during next two years (Phase 5) will be to describe the thermal and flow characteristics underlying the movements of subadult and adult sturgeon throughout the Sacramento/San Joaquin River system. Particular attention will be directed at identifying spawning sites of GS and characterizing their physical characteristics. There is a strong precedent for conducting this type of study in a western coast watershed. Nineteen GS were recently tagged and tracked in the Rogue River, Oregon (Erickson et al., unpub. man.). These individuals stayed in deep, low-gradient reaches on the river and migrated upstream to river km 39. Individuals' home ranges were restricted within the reaches, making the species very vulnerable to habitat modifications.

We will track the movements of subadult and adult GS within the Sacramento/San Joaquin watershed and describe the physical properties of their microhabitats. Sixty GS will be tagged with ultrasonic and radio beacons in San Pablo Bay. Thirty subadult and adult GS will be captured during their downstream migration using trammel nets during August by CDFG (or a comparable contractor), a time when 39 subadult and adult GS were captured during 2,001. Another 30 adult GS will be captured on their anticipated upstream migration during a 1-month period during winter (Jan./Feb.). The ultrasonic beacons will be inserted into the peritoneal cavity of the GS; radio beacons will be attached to GS by inserting a dart tethered to the units into the dorsal musculature of GS. We will determine the sex and stage of reproductive maturity of each GS captured by examining by examination of its gonads through the ventral incision. The state of the gonads will provide an estimate of when GS might be expected to later spawn within the river system (Van Eenennaam et al., 2001). The beacons will be long lived (36 mon) and coded for individual identification.

We will detect the passage of GS with 40 automated tag-detecting monitors positioned at key constrictions along the Sacramento/San Joaquin River system. Monitors will be placed in the Carquinez Straits, the fork between the Sacramento and San Joaquin Rivers, and at the junctions between the main stem of both rivers and their main tributaries. The monitors (Vemco, Ltd., VR-01) are capable of detecting tags at a distance of 500 m in the open ocean, and, placed in the center of a river, will detect the passage of tagged fish on either side. Steve Lindley, a fisheries biologist at the Monterey Laboratory of NMFS is requesting internal funds for a collaborative study, in which 30 monitors will be placed throughout San Pablo and San Francisco Bay. An array of monitors will be placed at the mouth of the bay to detect the outward passage of tagged

GS. He is also requesting for funds to purchase additional ultrasonic tags for the study. Additional GS are being tagged, detectable by our monitors, and additional monitors are being deployed in other river systems along the coasts of California, Oregon, and Washington such as the Klamath, Rogue, and Columbia Rivers. Dave Hillemeier is overseeing the placement of 25 monitors at river junctions throughout the Klamath River by biologists of the Yurok Tribe. Dan Erickson of the Wildlife Conservation Society has put a similar number of monitors throughout the Rogue River. Carl Schreck of Oregon State University has placed several arrays of monitors across the Columbia River to detect the movements of salmon smolts. These monitors (and those in the other rivers) are all capable of detecting GS tagged with coded ultrasonic tags. We plan to coordinate our tagging of GS with the other complementary research programs mentioned here.

We will track the movement of the tagged GS upstream or downstream based on the times of passage recorded by the monitors. Attached to them will be thermal loggers that will continuously measure water temperature. The temperature recorded during the passage of the GS can be compared to the temperatures acquired before and after its transit to determine whether the GS is migrating in response to fluctuations in water temperature due to the snow pack melting. Once a GS is identified moving into a tributary, it will be located by a plane equipped with a radio antenna and flying over the river weekly. If GS stay in a particular reach of the tributary, identified by river mile, we will visit that reach of the river by car or inflatable. We will then determine whether the GS are in a riffle, run, or pool within the reach and characterize the physical properties (water temperature, flow rate, conductivity, and pH) of the habitat with a bathythermograph and flow meter. To confirm that spawning has occurred, we will tow a plankton net in order to catch larval GS and set out traps to collect eggs. The egg samples will also be used for genetic analysis (Phase 5, Task 5).

Task 2, Sturgeon Capture and Tagging. CDFG has monitored WS mortality rates and abundance since 1954 using mark-recapture techniques. Sturgeon are generally captured for tagging using trammel nets in San Pablo Bay during September and October and recaptured by anglers and during subsequent tagging operations. GS have also been captured and tagged, but in much lower numbers than WS. We suspect that higher catches of GS in September than in October is related to migratory behavior, either because of summer estuary use, as in the Columbia River estuary, or post-spawning movement out of the estuary. We will contract CDFG (or a commercial fisherman) to set trammel nets during winter (Jan./Feb.) to capture upmigrating adult sturgeon as well set nets during the summers (Aug.) of 2003 and 2004. GS were frequently captured during this period in 2,001.

Task 3, Physiological Studies. The study of juvenile GS' environmental tolerance limits, affinities, and stress responses will include 4 parts. **(1)** The environmental tolerance limits and affinities of GS from post-larval to saltwater-tolerant juvenile stages will be measured (completion of initial studies started in Phase 3). Temperature and dissolved oxygen tolerance limits will be assessed in flow-through chambers (Swanson et al., 2000). Salinity tolerances will be assessed using replicated, individual and group GS containers of aerated water. Container water will be changed (2 ppt salinity increase, from seawater dilutions, every 8 h for experimental fish and 0 ppt increase for controls) until 50% of the fish lose equilibrium (endpoint), following Young and Cech (1996). For GS showing initial tolerance to hypertonic salinities (e.g., >10 ppt), gills will be examined histologically for development of saltwater (alpha) chloride cell development (McEnroe and Cech, 1985, 1987, Karnaky, 1997). Because it is known that chinook salmon smoltification (transition of juveniles to seawater) may be delayed by exposure to warm (>17.5º C) water (Clarke and Shelbourn, 1985), these studies will be conducted at warm (24º C), as well as moderate (19º C) temperatures. Temperature, dissolved oxygen, and salinity affinities

will be measured using an annular, environmental gradient chamber, incorporating suitable ranges of these variables (from current, range-finding studies). **(2)** Water velocity tolerance limits will be determined by critical swimming velocity (U_{crit}, a measure of swimming performance) measurements of post-larval to saltwater-tolerant juvenile GS (Brett , 1964; Beamish, 1978) and will be compared with those of older, larger (> 1 kg) GS (Mayfield and Cech, submitted ms.). These critical swimming velocity measurements are an established measure of performance for bottom-oriented, as well as mid-water-oriented river species (Myrick and Cech, 2000). Water velocity affinities will be determined by videotape analyses of GS situated on a flow table, incorporating a velocity gradient, to determine their preferred velocities, as they develop.

GS responses to 3 stress regimes: no stress (control), acute stress, and chronic stress will be assessed using organismal and biochemical/molecular approaches. **(3)** Fish performance (U_{crit}) and metabolic scope for activity (Brett, 1964; Cech, 1990) will be measured in GS subjected to the 3 regimes. In addition, metabolic substrates (glucose, lactate, and liver glycogen), and the acute plasma (cortisol) response to the stress regimes and to ACTH (a cortisol precursor) infusion (Belanger et. al., 2001) will be measured in each group as recognized performance indicators. Quantification of glucocorticoid receptor (GR) density and affinity in the liver, red blood cells and gills of fish from each stress regime will determine if down-regulation of GR occurs with chronic stress and if it is a tissue-specific or a widespread phenomenon in GS (Maule and Shreck, 1990). In addition, heat-shock proteins (hsp), which are involved in folding, repair and trafficking of intracellular proteins and are indicative of a disruption in cellular protein homeostasis (Feder and Hofmann 1999), will be analyzed in red blood cells, muscle, and fin tissues using Western blotting techniques. Monoclonal antibodies for hsp70 and hsp90 (1:500; Affinity Bioreagents, StressGen) and a polyclonal antibody for hsp60 (1:1000; StressGen) will be used as probes, and bound antibody will be visualized with a chemiluminescent substrate (CDP-Star; Tropix, Bedford, MA) and quantified by densitometry. Our recent study on juvenile steelhead found strong correlations of an hsp70 protein with mean weekly and monthly maximum temperatures (r=0.96 and r=0.99, respectively) measured at multiple collection sites throughout the Navarro River Watershed (California), demonstrating that hsp70s are excellent tools to detect sublethal temperature stress (Werner et al., in preparation). Data will be collected from the environmental tolerance limits and affinities GS to calibrate results from samples (i.e, non-destructive blood samples) from wild-caught fish from Sacramento/San Joaquin Watershed habitats (see Phase 5, Tasks 1,2). This approach will link the laboratory (known stressors) and field (unknown stressors) investigations. The GR density and hsp data are especially useful for these assessments of wild GS stress levels (e.g., in Tasks 1 & 2), because they reflect fairly recent (i.e., the past 0.5 hours to several days range) stress responses associated with relevant environmental exposures, and not the more immediate (i.e., the past 2-15 minutes) stresses that mostly reflect the those inherent in capture (masking environmental responses). Appropriate statistical models (ANOVA, Kruskal-Wallis, and post-hoc tests) will be used to compare means. This information is critical for adaptive fish and water management efforts currently underway. **(4)** GS size (length, weight) and corresponding hydrographic (water salinity, temperature, velocity) data will be collected from on-going field research/monitoring studies (Archimedes screw traps in freshwater locations and seining and fyke trap methods in slow water pre-estuary and estuarine reaches of drainages), catching GS from the Sacramento and Klamath Watersheds, providing important “ground-truthing” for the laboratory data on environmental requirements and habitat-related stress levels. Cooperation is being arranged with various agencies (e.g., USFWS, Curt Brown & George Guillen; CDFG) and the Yurok Tribe (Dave Hillemeier). In addition, previous data obtained as bycatch from salmon-based surveys will be used to help pinpoint GS sampling locations. This research will clarify the early life history of GS, and provide guidance for preserving GS in our Sacramento/San Joaquin Watershed.

Task 4: Reproductive Studies. Studies will include three parts. **(1)** We will optimize hormonal induction of ovulation, fertilization, and egg incubation techniques. Methods developed for WS (Conte et al., 1988; Webb et al., 1999) were generally successful with GS (particularly larval rearing techniques) but the low and variable egg fertility (<50%) and hatchability (< 25%) affected supply of GS' offspring for research (Van Eenennaam et al., 2001). Achieving egg fertility ≥ 70% and hatchability ≥50% will be sufficient for reliable artificial reproduction. We observed that low egg fertility was caused by egg over ripeness (likely due to high dose in hormonal treatment) and by the coelomic fluid (collected with ova) inhibiting in vitro fertilization (noted by Dettlaff et al., 1993 for European sturgeon). The low hatchability was due to high mortality of the GS'embryos possessing thin and fragile chorions during the incubation in MacDonald jars with turbulent flow. To improve egg fertility, we will reduce hormonal treatment dose and rinse the ova with water to remove coelomic fluid before fertilization (sturgeon ova retain fertilization capacity in water, Dettlaff et al., 1993). To improve hatchability, we will test new incubators, in which upwelling flow is distributed more evenly (trout-type jars). Spawning trials will be conducted with at least four females (and four males) from the Klamath River transported in insulated tank with oxygenated water to the UC-Davis. Two females will be administered GnRHa alone (10-20 $\mu g\ kg^{-1}$) and two other GnRHa + domperidone (dopamine antagonist). The ova from each female will be rinsed (with non-rinsed control), fertilized, and incubated in trout-type incubators (with McDonald jars control). Eggs will be sampled (n ≥ 200) at stages of second cleavage (fertilization rate), neurulation (survival through gastrulation), and hatching (hatchability), as reported by Deng et al. (2002. The effects will be evaluated by analysis of variance. **(2)** We will characterize gametogenesis and gonadal cycle of GS, using histological observations and gonadosomatic index (relative measure of gonadal growth). Since representative samples of wild fish are difficult to obtain, we will sample two GS stocks reared at UC Davis (offspring from the 1999 and 2000 spawnings, mean weight 3 and 6 kg at age 1 and 2 years). Since the stage of gametogenesis in sturgeon is dependent on body size and season (Doroshov et al., 1997), observations on cultured stock will be used as a template for the wild fish of similar size. We will sample individually marked fish (n=50 in each stock) at least twice a year (spring and fall) to account for seasonality. Histological techniques and gonadal stages will follow procedures for the WS (Doroshov et al., 1991; Chapman et al., 1996; Doroshov et al., 1997) and Atlantic sturgeon (Van Eenennaam and Doroshov, 1998). Photographs will illustrate stages of the ovarian and testicular development, correlated with body size and season. **(3)** We will determine sex and gonadal maturity of wild GS used for tracking study (Task 1). Knowing sex and maturity will add important information to GS' movements and tracking sturgeon to spawning sites. Feeding and reproductive behavior of sturgeon are supported by the acute olfactory sense (Kasumyan, 1999) and acoustic communication (Tolstoganova et al., 1999). The GS's foraging movements are likely to occur in the early and mid- stages of gonadal cycle, while the spawning migrations are expected in the late stages. The GS's gonads will be biopsied during the capture and radiotagging (Phase 5, Task 1,2) via 1-2 cm abdominal incision closed with a PDS Ethicon suture (Van Eenennaam et al., 2001a). Fully grown fixed eggs will be bisected to measure oocyte polarization index (nucleus migration to the animal pole), indicating female's spawning readiness. This index will be used to estimate spawning time and proximity of capture site to spawning grounds (Van Eenennaam et al., 1997).

Task 5, Genetic Analyses. In Phases 1 and 2, nuclear and mitochondrial DNA markers were developed to distinguish between early life history stages of GS and WS. In addition, nuclear microsatellite markers were developed that could characterize genetic variation within and between GS populations along the western coast of the U.S. In this phase, our evaluation of genetic variation in green sturgeon populations indicated that estuarine green sturgeon samples

from the Columbia River are very different from the Klamath River breeding population. Some biologists have argued that GS caught at the mouth of the Columbia River are exclusively composed of Klamath River green sturgeon. Phases 3 and 4 are continuing this effort by enlarging the suite of microsatellite loci that we have to examine genetic variation among green sturgeon, paying special attention to developing disomic vs. tetrasomic loci. We are using these markers and those already developed to characterize allele frequencies distributions of possible component populations from the Sacramento/San Joaquin Delta, Klamath, Rogue, and other basins where adult spawning and juvenile green sturgeon samples have been collected by our cooperators. This comparison of stocks is essential to determine the uniqueness of our Sacramento-San Joaquin basin GS and gain insight into the seasonal migrations of this species. Our results should be corroborated by records of inter-river movement detected by automated tag-detecting monitors placed the Delta, Klamath, Rogue, and Columbia rivers (see Phase 5, Tasks 1,2).

During Phase 5 we will continue to resolve component population samples and identify eggs and larval stage samples as they are received from CDFG and other cooperating departments and programs. The markers we currently possess can uniquely differentiate between individuals. The telemetric monitoring of GS on their breeding areas, plankton tows and egg traps in the Sacramento/San Joaquin Rivers (Phase 5,Task 1) will provide opportunity for identifying siblings. This will provide information for estimating the number of breeding adults at each breeding location. Currently, computer programs are being developed in the Genomic Variation Laboratory to evaluate the relatedness among a cohort for estimating parental contribution (Beyer and May, unpublished). For this analysis, we propose to build a database of juvenile green sturgeon genotypes that can also be cross-referenced by future sampling efforts for understanding migration patterns and oceanic movement of individual fish. In addition, we will focus our efforts on analyzing oceanic mixed stocks of GS through estimates of individual pair-wise relatedness between each individual in the mixed stock and each individual from a known stock. We hope this procedure will provide another way for us to estimate component populations present in the mixed-stock fishery in the Sacramento/San Joaquin Delta, at the Columbia River mouth, and off the Oregon coast. This type of analysis is necessary because few breeding individuals are obtained from some of the component populations. This type of pairwise relatedness measure for estimating component populations will be used as a second estimate to be compared to traditional mixed stock analysis estimates. This analysis will allow us to understand each stock's contribution to the total catch and monitor oceanic movement.

Task 6, Project Management. Klimley and Cech will manage the project jointly. This will involve frequent inspection of the work in progress. They will work with the co-investigators and supervise graduate students, give scientific presentations, and prepare jointly authored publications. They will also organize a symposium, to be held at the Bodega Marine Laboratory, with scientific talks given on the biology of the GS that will result in peer-reviewed scientific articles included in a benchmark reference volume on the general biology of the species to be published in the scientific literature (ideally by a major book publisher such as Academic Press).

c. Monitoring and Assessment Plans. CALFED-supported biological studies with GS are ongoing (Project No. 98-C15). For aspects of Tasks 1-3, the experimental approach, design, methods, and analyses have already been subjected to rigorous discussion and review. Detailed descriptions of all aspects of these tasks are provided in the Biological Monitoring/Research and Quality Assurance Plan submitted to CALFED earlier this year and attached as Appendix 2. For Tasks 4 and 5, data collection, monitoring and assessment use standard field, laboratory, and statistical techniques (briefly described in Approach above) that will be similarly described in an

updated Biological Monitoring/Research Plan. Descriptions of the current work and preliminary results have been presented at two workshops (Davis, CA, and Weitchpec, CA) and at the annual meeting of the California-Nevada Chapter of the American Fisheries Society (Ventura, CA). In addition, a manuscript describing GS spawning, egg fertility, and larval survival has been recently submitted to the peer-reviewed *Transactions of the American Fisheries Society*.

d. Data Handling and Storage. Data handling and storage are described in the Biological Monitoring/Research Plan, attached as Appendix 2. These protocols will be updated as necessary for this next-phase research program.

e. Expected Products and Outcomes. Quarterly reports will include financial status, activities during the quarter, tasks completed, deliverables produced, problems encountered, and a description of modifications to the contract. A final technical report describing results of the studies will be submitted by the end of the project (March 31, 2006). Results of these studies have been and will continue to be presented at scientific and technical meetings (see Monitoring and Assessment Plan, above). Results of these studies will also be described in IEP Newsletter articles, and in manuscripts submitted for publication in peer-reviewed scientific journals. One manuscript from the project has been accepted for publication in the *Canadian Journal of Fisheries and Aquatic Sciences* and another submitted to the *Transactions of the American Fisheries Society*.

f. Work Schedule. Funding for this next-phase targeted research is requested for a two-year period beginning October 1, 2003 (expected completion date of Phase 3). The proposed work and schedule outlined below are based on seasonal sampling and year-round laboratory studies as detailed above and contingent on adequate funding, personnel, and fish availability. For this period, six tasks are identified (Table 1, and see Approach for activities involved in Tasks 1-5).

Table 1. Tasks and schedule for proposed biological assessment of GS studies.

TASK	SCHEDULE
Task 1. Telemetry	Sacramento/San Joaquin, 2003-2005
Task 2. Extension of CDFG Sturgeon Tagging Period to Increase GS Captures	Sacramento/San Joaquin 2003-2005
Task 3. GS Environmental Tolerance Limits and Behavioral Tendencies, Stress	Oct. 2003-Sept. 2005
Task 4. Reproductive Biology of GS	Oct. 2003-Sept. 2005
Task 5. Genetic Analysis	Oct. 2003-Sept. 2005
Task 6. Project Management	April 2003-Sept. 2005

g. Feasibility. This proposal requests next-phase funding for continuation and expansion of a successful, ongoing research program that addresses uncertainties associated with the life history of an At-Risk Priority 1 CALFED species. The project has already produced detailed quantitative data that will be used to develop GS management and conservation strategies.

D. APPLICABILITY TO CALFED ERP GOALS AND IMPLEMENTATION PLAN AND CVPIA PRIORITIES

Relationship to ERP/CVPIA Priorities, Restoration, and System-Wide Ecosystem Benefits

The GS is a CALFED at-risk species (Priority Group I, ERP Strategic Plan for Ecosystem Restoration, Table 4-1), and the proposed assessments will focus on the biological characteristics of this species and its habitats with the objective of providing information useful for their eventual recovery and protection. Our coordinated approach will resolve scientific uncertainties regarding GS life history and their spatio-temporal use of linked ecosystems (Figure 1). This will assist in GS recovery, included in CALFED Goals 1 and 3, at-risk species and harvestable species recovery and protection, as a specific ERP objective (Vol. 1, White and Green Sturgeon, pp. 146-148), and as a CVPIA goal (AFRP, pp. 40-41, 70-71, and 95). This next-phase, targeted research also contributes to the overall CALFED effort to restore ecological health and improve water management for beneficial uses of the Bay-Delta system (e.g., improved management of the Yolo Bypass for fisheries resources). This project also relates to the CALFED-funded Fish Treadmill Project (#99-N02), which aims to quantify the adverse impacts of water diversions and fish screens on GS as well as other priority species through targeted research on fish screen design and operation.

E. QUALIFICATIONS (2 pages)

JOSEPH J. CECH, JR., Ph.D., Professor of Fisheries Biology, UC Davis, 1987 to present.
Five Selected Publications: 1. Young, P.S. and J.J. Cech, Jr. 1996. Environmental tolerances and requirements of splittail. Trans. Am. Fish. Soc. 125:664-678. **2.** Crocker, C.E. and J.J. Cech, Jr. 1997. Effects of environmental hypoxia on oxygen consumption rate and swimming activity in juvenile white sturgeon, *Acipenser transmontanus*, in relation to temperature and life intervals. Env. Biol. Fish. 50:383-389. **3.** Swanson, C., P.S. Young, and J.J. Cech, Jr. 1998. Swimming performance of delta smelt: maximum performance, and behavioral and kinematic limitations on swimming at submaximal velocities. J. Exp. Biol. 201:333-345. **4.** Crocker, C.E. and J.J. Cech, Jr. 1998. Effects of hypercapnia on blood-gas and acid-base status in the white sturgeon, *Acipenser transmontanus*. J. Comp. Physiol. B168:50-60. **5**. Crocker, C.E., A.P. Farrell, A.K. Gamperl, J.J. Cech, Jr. 2000. Cardio-respiratory responses of white sturgeon to environmental hypercapnia. Am. J. Physiol. 279:R617-R628.

CARLOS E. CROCKER, Ph.D., Assistant Professor of Biology, SFSU, 2000 to present.
Five Selected Publications: **1**. Deng, D.D., Refstie, S., Hemre, G.I., Crocker, C.E., Chen, H.Y., Cech, J.J., and Hung, S.S. 2000. A new technique for feeding, repeated sampling of blood and continuous collection of urine in white sturgeon. Fish Physiol. Biochem. (in press). **2.** Crocker, C.E., Cech, J.J., Jr., Farrell, A.P., and Gamperl, K. 2000. The Effects of Hypercapnia on Cardiovascular Performance in White Sturgeon, *Acipenser transmontanus*. Am. J. Physiol. (in press). **3.** Crocker C.E. and Cech J.J., Jr. 1998. Effects of Hypercapnia on Blood-Gas, Acid-Base Balance in White Sturgeon, *Acipenser transmontanus*. J. Comp. Physiol. B. 168:50-60. **4.** Crocker, C.E. and Cech, J.J., Jr. 1997. The effects of environmental hypoxia on oxygen consumption rate and swimming activity in juvenile white sturgeon, *Acipenser transmontanus*: temperature and life stage effects. Env. Biol. Fish 50:383-389. **5.** Crocker, C.E. and Cech, J.J., Jr. 1996. The effects of hypercapnia on growth of juvenile white sturgeon, *Acipenser transmontanus*. Aquacult. 47: 293-299.

SERGE I. DOROSHOV, Ph.D., Professor of Animal Science, UC Davis: 1983 to present.
Five Selected Publications: **1.** Chapman, F.A., J.P. Van Eenennaam, and S.I. Doroshov**.** 1996. The reproductive condition of white sturgeon, *Acipenser transmontanus*, in San Francisco Bay, California. Fish. Bull. 94:628-634. **2.** Doroshov, S.I., G.P. Moberg and J.P. Van Eenennaam. 1997. Observations on the reproductive cycle of cultured white sturgeon, *Acipenser transmontanus*. Env. Biol. Fish. 48:265-278. **3.** Van Eenennaam and S.I. Doroshov. 1998. Effects of age and body size on gonadal development of Atlantic sturgeon. J. Fish Biol. 53: 624-637. **4.** Doroshov, S.I., J.P. Van Eenennaam and G.P. Moberg. 1999. Development of white sturgeon broodstock. J. Appl. Ichthyol. 15: 326-327; **5.** Webb, M.A.H., J.P. Van Eenennaam, G.W. Feist, J. Linares-Casenave, M.S. Fitzpatrick, C.B. Schreck, and S.I. Doroshov. 2001. Effects of thermal regime on ovarian maturation and plasma sex steroids in farmed white sturgeon, *Acipenser transmontanus*. Aquaculture 201: 137-151.

A. PETER KLIMLEY, Ph.D., Adjunct Associate Professor, UC Davis, 1998 to present.
Five Selected Publications: **1.** Klimley, A.P., S. C. Beavers, T. Curtis, and S.J. Jorgensen. 2002. Movements and swimming behavior of three species of sharks in La Jolla Canyon, California. Envir. Biol. Fish. 63:117-135. **2.** Klimley, A.P., B.J. Le Boeuf, K.M. Cantara, J.E. Richert, S.F. Davis, S. Van Sommeran, and J.T. Kelly. 2001. The hunting strategy of white sharks at a pinniped colony. Mar. Biol. 13:617-636. **3.** Klimley, A.P. and C. Holloway. 1999. Homing synchronicity and schooling fidelity by yellowfin tuna. Mar. Biol. 133:307-317. **4**. Klimley, A.P., F. Voegeli, S.C. Beavers, and B.J. Le Boeuf. 1998. Automated listening stations for tagged marine fishes. Mar. Tech. J., 32:94-101. **5.** Klimley, A.P. 1993. Highly directional swimming by scalloped hammerhead sharks, *Sphyrna lewini*, and subsurface irradiance, temperature, bathymetry, and geomagnetic field. Mar. Biol. 117:1-22.

DAVID W. KOHLHORST, M.A., Senior Biologist (Specialist), CDFG, 1995 to present.
Five Selected Publications: **1.** Kohlhorst, D.W. 1979. Effect of first pectoral fin ray removal on survival and estimated harvest rate of white sturgeon in the Sacramento-San Joaquin Estuary. Calif. Fish Game 65:173-177. **2.** Kohlhorst, D.W. 1980. Recent trends in the white sturgeon population in California's Sacramento-San Joaquin Estuary. Calif. Fish and Game 66:210-219. **3.** Kohlhorst, D.W., L.W. Miller, and J.J. Orsi. 1980. Age and growth of white sturgeon collected in the Sacramento-San Joaquin Estuary, California, 1965-1970 and 1973-1976. Calif. Fish Game 66:83-95. **4.** Kohlhorst, D.W., L.W. Botsford, J.S. Brennan, and G.M. Cailliet. 1991. Aspects of the structure and dynamics of an exploited central California population of white sturgeon (*Acipenser transmontanus*). Pages 277-292 *in:* P. Willoit, editor. Acipenser: First International Symp. on the Sturgeon. CEMAGREF, Bordeaux, France. **5.** Stevens, D.E., D.W. Kohlhorst, L.W. Miller, and D.W. Kelley. 1985. The decline of striped bass in the Sacramento-San Joaquin Estuary, California. Trans. Am. Fish. Soc. 114:12-30.

BERNARD (BERNIE) PAUL MAY, Ph.D, Adjunct Professor, 1999 to present.
Five Selected Publications: **1.** McQuown, E., C.C. Krueger, H.L. Kincaid, G.A.E. Gall, and B. May. In Press. Genetic comparison of lake sturgeon (*Acipenser fulvescens*) populations: differentiation based on allelic frequencies at seven microsatellite loci. J. Great Lakes Res. **2.** Rodzen, J.A. and B. May. In Press. Inheritance of microsatellite loci in the white sturgeon (*Acipenser transmontanus*).Genome. **3.** Tranah, G.J., H.L. Kincaid, C.C. Krueger, D.E. Campton, B. May. 2001. Reproductive isolation in sympatric populations of pallid and shovelnose sturgeon. N. Am. J. Fish. Man. 21:367-373. **4.** Ludwig, A., B. May, L. Debus, and I, Jenneckens. 2000. Heteroplasmy in the mtDNA Control Region of Sturgeon (*Acipenser*, *Huso*

and *Scaphirhynchus*) Genetics 156:1933-1947. **5.** McQuown, E.C., B.L. Sloss, R.J. Sheehan, J. Rodzen, G. Tranah, and B. May. 2000. Microsatellite analysis of genetic variation in sturgeon: new primer sequences for *Scaphirynchus* and *Acipenser*. Trans. Am. Fish. Soc. 129:1380-1388.

RAYMOND G. SCHAFFTER, M.S., Biologist, California Dept. Fish and Game, 1973-present. **Five Selected Publications: 1.** Schaffter, R. G. 1980. Fish occurrence, size and distribution in the Sacramento River near Hood, California during 1973 and 1974. CDFG, Anadromous Fisheries Branch Report No 80-3. **2**. Schaffter, R.G., P.A. Jones, and J.G. Karlton. 1983. Sacramento River and tributaries bank protection and erosion control report. CDFG. Sacramento, CA. **3.** Schaffter, R. G. 1997. White sturgeon spawning migrations and location of spawning habitat in the Sacramento River. Calif. Fish Game 83:1-20. **4.** Schaffter, R. G. 1997. Growth of white catfish in California's Sacramento-San Joaquin Delta. Calif. Fish Game 84:57-67. **5.** Schaffter, R.G. 1997. Mortality rates of white catfish in California's Sacramento-San Joaquin Delta. Calif. Fish Game 84:45-56.

INGEBORG WERNER, Ph.D., Assistant Research Scientist, UC Davis, Veterinary Medicine, **Five selected publications:** (1) Werner I., Smith T., Feliciano J., Johnson M.L. (in preparation). Heat-Shock proteins indicate thermal stress in juvenile steelhead trout (*Oncorhynchus mykiss*) in the Navarro River watershed, California, USA. (2) Werner, I., Koger, C.S., Hamm, J. T. and Hinton, D.E. (2001). Ontogeny of the heat shock protein, hsp70 and hsp60, response and developmental effects of heat-shock in the teleost, medaka (*Oryzias latipes*). *Environmental Sciences* 8(1):13-30. (3) Soimasuo, M.R., Werner, I., Villalobos, A. and Hinton, D.E. (2001). Cytochrome P450 1A1 and stress protein induction in early life stages of medaka (*Oryzias latipes*) exposed to trichloroethylene (TCE) soot and different fractions. *Biomarkers* 6(2):133-145. (4) Werner, I. and Nagel, R. (1997) Stress proteins hsp60 and hsp70 in three species of amphipods exposed to cadmium, diazinon, dieldrin and fluoranthene. *Environmental Toxicology and Chemistry* 16(11): 2393–2403. (5) Werner, I., Kline K.F. and Hollibaugh, J. T. (1998). Stress protein expression in *Ampelisca abdita* (Amphipoda) exposed to sediments from San Francisco Bay. *Marine Environmental Research* 45(4/5): 417–430.

F. COST

a. Budget. CALFED next-phase funding is requested for a two-year period to support continued GS research. Cost of the project depends on funding source: $998,222 if funded through a State agency and $1,320,039 if funded through a federal agency. Details of the overall budget, including state and federal overhead rates, are described in Tables 2 and 3 (MS Excel file name: GS.CF.BD.02.xls, Table 1=budget with state overhead rates, Table 2=budget with federal overhead rates); Budget Justification with expenses itemized, including subcontracts. Items in subcontracts, their direct and indirect costs, are in separate Excel files.

b. Budget Justification.

Task 1: Funding is requested for a Adjunct Associate Professor (100% time, 4 mon/yr, benifits) and Graduate Research Assistant (50% time, 9 months, 100% time, 3 months/year, benefits, and student fee remission for 2 years. We are requesting support for supplies/rentals (60 ultrasonic and radio transmitters during Yr 1 & 2, 40 tag-detecting monitors during Yr 1, 8 replacements during Yr 2, 40 temperature loggers during Yr 1, 8 replacements during Yr 2, mooring hardware (anchors, line, and buoys), office supplies, and airplane rental). Funds are also

requested for travel (field sampling and scientific meeting attendance) and equipment (scanning radio receiver), and UCD overhead.

Sub a: Funding is requested for support of one graduate student (50% time, 6 months/year, and benefits for 2 years) and San Francisco State University overhead (see SFSU.Task 1.Yr1&2).

Task 2 (sub): Funding is requested for one CDFG boat operator (100% time, 2 mon/yr for 2 years), supplies/rentals (nets and net repair supplies), and CDFG and UCD overhead.

Task 3: Funding is requested for support of Graduate Research Assistants (2 @ 50% time, 9 months, 100% time 3 mon/yr, benefits, and student fee remissions during Yr 1; 1 @ similar rate during Yr 2), 25% of Dr. Werner's and 50% of a Laboratory Assistant's salary and benefits, supplies/rentals (fish food, reagents, chemicals, gases, molecular biology supplies, steroid and hsp analyses supplies, and physiological measurements supplies, assays, office supplies, tank rental charges), travel for specimen collection and meeting attendance, and UCD overhead.

Task 4: Funding is requested for a Staff Research Associate and Postgraduate Researcher (50% time, 6 mon/yr, benefits for 2 years), supplies/rentals (fish food, reagents, chemicals, histological supplies, film and developing, assays, office supplies, tank rental charges), travel for specimen collection and meeting attendance, and UCD overhead.

Task 5: Funding is requested for a Adjunct Associate Professor (100% time, 3.3 months/year, and benefits for 2 years), one Postgraduate Researcher (100% time, 6.5 month/year for 2 years), sequencer/genotyper lease and maintenance, supplies (reagents, chemicals, gases, office supplies), equipment (one freezer), travel for specimen collection and meeting attendance, and U.C. Davis overhead.

Task 6 (sub): Funding is requested for salary for an Adjunct Associate Professor (100% time, 2 mon/yr, and benefits) to supervise the studies, prepare quarterly progress reports, and organize a symposium, which will result in a book with peer-reviewed chapters, as well as UCD overhead.

c. Cost Sharing. "Leveraged" support ($85,478) will be provided by UC Davis (5% of two investigators' salaries and benefits while working on the GS project).

G. LOCAL INVOLVEMENT

Most of the infrastructure/equipment required for this project is already available at UC Davis, SFSU Romberg Center, and CDFG Bay Delta and Special Water Projects Division.

H. COMPLIANCE WITH STANDARD TERMS AND CONDITIONS

The University of California, Davis, and the California Department of Fish and Game are public organizations of the State of California. Both organizations comply with the standard terms and conditions of non-discrimination and non-collusion. There are no conflicts of interest.

I. LITERATURE CITED (*FROM RESULTS OF STUDY)

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Beamish, F.W.H. 1978. Swimming capacity. pp. 101-187. In: Fish Physiology, Vol.7: Locomotion (W.S. Hoar and D.J. Randall, eds.), Academic Press, New York; Bemis W.E. & B. Kynard.1997. Sturgeon rivers: an introduction to acipenseriform biogeography and life history. Env. Biol. Fish. 48:167-183; Becker, C.D. and R.G. Genoway. 1979. Evaluation of critical thermal maxima for determining thermal tolerance of freshwater fish. Env. Biol. Fish. 4:245-256; Beer, K. E. 1981. Embryonic and larval development of white sturgeon (*Acipenser transmontanus*). M. S. Thesis, University of California, Davis, California, USA; Belanger, J. M., J. H. Son, K. D. Laugero, G. P. Moberg, S. I. Doroshov, and J. J. Cech, Jr. 2001. Effects of short-term management stress and ACTH injections on plasma cortisol levels in cultured white sturgeon. Aquaculture 203:165-176; Bemis W.E. & B. Kynard.1997. Sturgeon rivers: an introduction to acipenseriform biogeography and life history. Env. Biol. Fish 48:167-183; Block, B.A., J.E. Keen, B. Castillo, H. Dewar, E.V. Freund, D.J. Marcinek, R.W. Brill & C. Farwell. 1997. Environmental preferences of yellowfin tuna (Thunnus albacares) at the northern extent of its range. Mar. Biol. 130:119-132. Boreman, J. 1997. Sensitivity of North American sturgeons and paddlefish to fishing mortality. Env. Biol. Fish 48:399-405; Brett, J. R. 1964. The respiratory metabolism and swimming performance of young sockeye salmon. J. Fish. Res. Bd. Can. 21:1183 – 1126; Brill, R.W., B.A. Block, C.H. Boggs, K.A. Bigelow, E.V. Freund & D.J. Marcinek. 1999. Horizontal movements and depth distribution of large adult yellowfin tuna (Thunnus albacares) near the Hawaiian Islands, recorded using ultrasonic telemetry: implications for the physiological ecology of pelagic fishes. Mar. Biol. 113:395-408.

Cech J.J., Jr. 1990. Respirometry. In: Schreck CB and Moyle PB. (eds.), Methods for Fish Biology. American Fisheries Society, Bethesda, MD; pp. 335-362; Chapman, F.A., J.P. Van Eenennaam, & S.I. Doroshov. 1996. The reproductive condition of white sturgeon, *Acipenser transmontanus*, in San Francsco Bay, California. Fish. Bull. 94: 628-634; Cherr, G. N. and W. H. Clark, Jr. 1985. Gamete interaction in the white sturgeon: a morphological and physiological review. pp. 11-22. In: North American Sturgeons (F. P. Binkowski and S. I. Doroshov, eds.) Dr. W. Junk Publishers, Dordrecht; Conte, F.S., S.I. Doroshov, P.B. Lutes, E.M. Strange. 1988. Hatchery manual for the white sturgeon (*Acipenser transmontanus*), with application to other North American Acipenseridae. Cooperative Extension University of California, Division of Agriculture and Natural Resources, Publ. 3322, 104 pp; Clarke, W.C. and J.E. Shelbourn. 1985. Growth and development of seawater adaptability by juvenile fall chinook salmon (*Oncorhynchus tshawytscha*) in relation to temperature. Aquaculture 45:21-31.

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Williot, Cemagref, Bordeaux. Pp. 129-136; Doroshov, S.I., G.P. Moberg & J.P. Van Eenennaam. 1997. Observations on the reproductive cycle in cultured white sturgeon. Env. Biol. Fish. 48: 265-278; Doyle, J.J., and J.L. Doyle. 1987. A rapid DNA isolation procedure for small quantities of fresh leaf tissue. Phytol. Bull. 19: 11-15.

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Faulkner, I.N. and G.P. Moberg. 1997. Effects of short term management stress on the ability of GnRHa to induce gonadotropin secretion in male white sturgeon, *Acipenser transmontanus*. Aquaculture 159:159-168; Feder M.E., Hofmann G.E. 1999. Heat shock proteins, molecular chaperones and the stress response: Evolutionary and ecological physiology. *Ann. Rev. Physiol*. 61:243-82. Fox, D.A., J.E. Hightower, F.M. Parauka. 2000. Gulf sturgeon spawning migration and habitat in the Coctawhatchee River system, Alabama-Florida. Trans. Am. Fish. Soc., 129: 811-826.

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Iwama, G.K., A.D. Pickering, J.P. Sumpter, and C. B Schreck. 1997. Fish Stress and Health in Aquaculture. Soc. Exp. Biol. Sem. Ser. No. 62.

Jobling, M. 1994. Fish bioenergetics. Chapman and Hall. London.

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J. THRESHOLD REQUIREMENTS

UC Davis and San Francisco State University are State-assisted public research and educational institutions. Tax Identification Number for UC Davis is 94-603-64.

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southwest Fisheries Science Center
Santa Cruz Laboratory
110 Shaffer Road
Santa Cruz, California 95060

September 30, 2002 F/S

To Whom It May Concern,

I am writing to express my support for the continued funding of "ABiological assessment of green sturgeon on the Sacramento-San Joaquin watershed", led by Dr. Peter Klimley of UC Davis. At NMFS, we recently conducted a status review of green sturgeon. It was a difficult task because so little is known about green sturgeon. Much of the information used in the status review came from the results of Klimley et al. project. Continued funding of this project should yield more useful information on the basic biology of green sturgeon, greatly increasing our ability to manage this species.

Another reason I am interested in this project is because of the potential to leverage it to address some large-scale questions about green sturgeon. The distribution of green sturgeon is poorly known. Green sturgeon tagged in the Sacramento have been recovered in the Columbia, indicating that they are wide ranging in the ocean. The details of this migration are not known, but are critical to managing fisheries where green sturgeon are taken as bycatch. There are a variety of projects on the west coast, like that of Klimley et al, that are tracking animal migrations in lower rivers and estuaries with acoustic tags. These studies all have a regional focus. We would like to work with these studies, using them to gain a coast-wide acoustic coverage sufficient for monitoring the movements of green sturgeon throughout their range. Initiating such a project from scratch would be expensive and logistically difficult, but filling in some gaps between existing projects is quite feasible. The Klimley et al. project on the Sacramento would be a key component of this large-scale study, supplying coverage of the Sacramento-San Joaquin delta and a ready supply of green sturgeon for tagging.

To summarize, the Klimley et al project is providing valuable information for management of green sturgeon in the Sacramento-San Joaquin now, and coast-wide in the future. I hope that it will receive continued support from CALFED. Thank you for considering my input.

Sincerely,

Steven T. Lindley, PhD