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California Sea Grant College
Program, University of California,
San Diego
9500 Gilman Drive, Dept. 0232
La Jolla, CA 92093-0232
(858) 534-4440
www.csgc.ucsd.edu

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Introduction

California's Ocean Protection Council (OPC) was created in accordance with the 2004 California Ocean Protection Act to improve the management and protection of ocean and coastal resources and ecosystems. One of the many ways the OPC achieves this purpose is by supporting innovative research that directly informs and improves the stewardship of ocean resources through a partnership with California Sea Grant.

The mission of the California Ocean Protection Council (www.opc.ca.gov) is to ensure that California maintains healthy, resilient, and productive ocean and coastal ecosystems for the benefit of current and future generations.



Beginning in early 2007, the OPC awarded funds to California Sea Grant to administer competitive, rigorously peer-reviewed, scientific research to address some of the state's highest marine research priorities. These opportunities were widely advertised in conjunction with California Sea Grant's annual call for research proposals. A mutually beneficial partnership resulted in sharing of scientific expertise and cost-savings to both programs, which collaborated on the scientific peer review of proposals. Both the OPC and Sea Grant place high priority on projects that are expected to contribute to ecosystem-based management, to answer compelling management questions, and to promote the sustainable use of the state's coastal and marine resources.

California Sea Grant is pleased to share this summary of research that it has administered on behalf of the OPC. The first section contains projects for which the research has been completed. Following those are summaries of projects that were ongoing at the writing of this report.

Life History of California Sheephead: Historical Comparisons and Fishing Effects

R/OPCFISH-05

February 2007-February 2010

Jennifer Caselle, UC Santa Barbara, 805.893.5144, caselle@msi.ucsb.edu

Christopher Lowe, CSU Long Beach, 562.985.4918, clowe@csulb.edu

Kelly Young, CSU Long Beach, 562.985.4859, kayoung@csulb.edu



T. Castelazo/Wikipedia

A male California sheephead at the fishmarket in Ensenada, Baja California, Mexico. The removal of males has many deleterious implications for a population, including, paradoxically, a reduction in total egg production.

Summary

Researchers investigated possible causes for the observed decline in the average sizes of both male and female California sheephead (*Semicossyphus pulcher*) in Southern California. The leading theory, borne out in this study, is that sportfishing selectively removes large territorial males and is probably the main reason individuals in heavily fished areas (e.g., Catalina Island) are smaller than their counterparts in more remote regions (e.g., San Nicolas Island).

Because the fish are socially cued to change sex (all fish are born female), the removal of large territorial males triggers sex change in the largest females. As a result, paradoxically, the removal of “trophy” males has the effect of dramatically reducing the number of eggs produced, and hence the total reproductive output of a population. The findings suggest that the usual fisheries management techniques (size limits) don’t work for a species that changes sex during its life. In particular, scientists report that at the popular sportfishing destination of Catalina Island, the entire male population could be legally fished out.

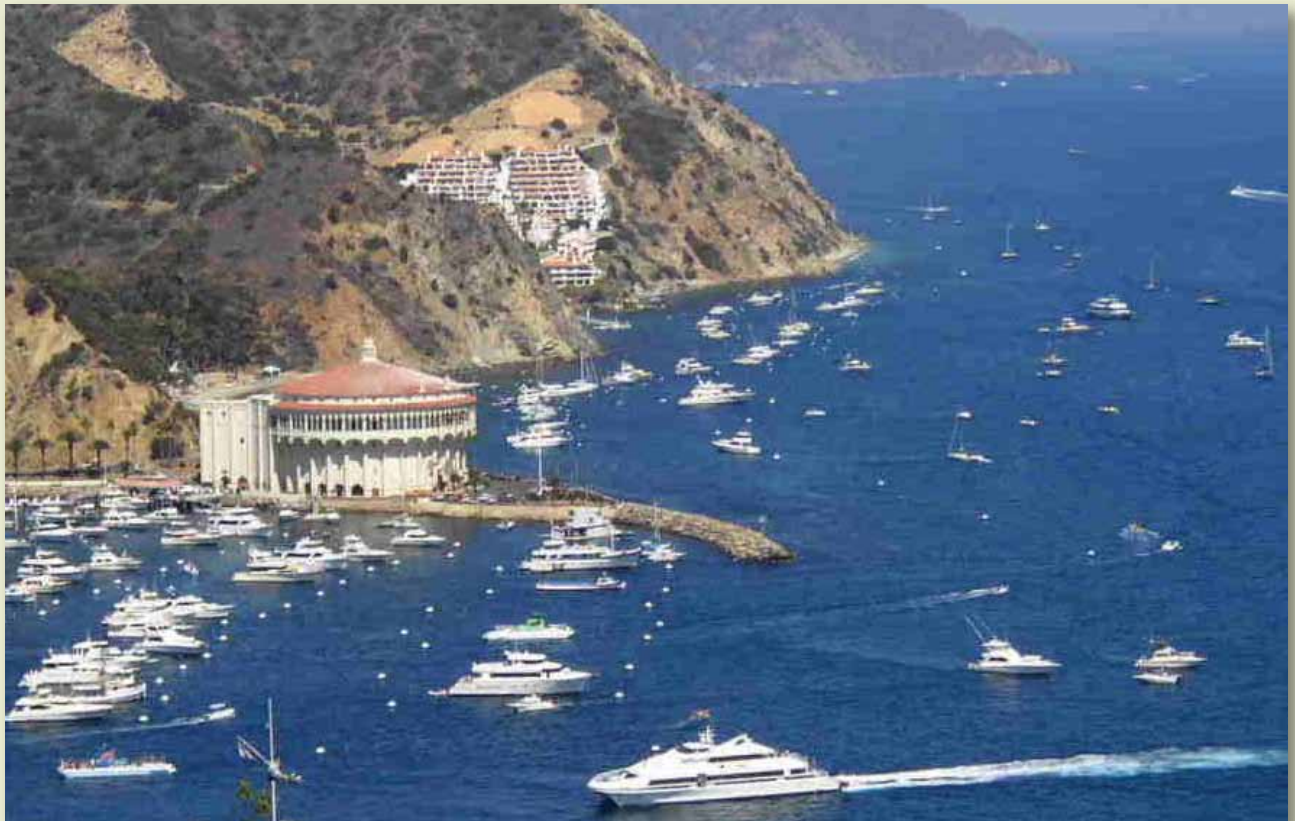
Results

The main finding of this project is that sportfishing is hammering the population of large male sheephead. Off Catalina Island, the most visited of the Channel Islands, for example, there is a virtual absence of large, territorial males. The scientists are recommending that state biologists implement slot limits, which would establish upper and lower bounds on legal-size sheephead, to ensure that both males and females are present to reproduce.

“We see lots of tiny males, which is not the case historically,” says UC Santa Barbara postdoctoral researcher Scott Hamilton. “We believe sportfishing has selectively removed ‘trophy’ fish, which for sheephead means the males almost exclusively,” says UC Santa Barbara researcher Jennifer

Caselle. By contrast, commercial fishing targets smaller females that command the highest prices in the live Asian finfish markets.

The encouraging news is that sheephead seem to recover rather quickly once fishing pressure is alleviated. This was observed off San Nicolas Island, a Navy weapons-testing facility and the most remote of the Channel Islands. From the peak of the commercial fishery in 1998 to 2007, the sizes of the smallest males increased from about 30 centimeters (standard lengths) to 40 centimeters, while the ages of the youngest males rose from about 7–8 years to 9 years old. Around Catalina Island, in contrast, females in 2007 were observed to be turning into males at ages as young as five and at lengths as short as 24 centimeters. Scientists attribute the



T. Hamilton/Log Cabin Republicans

Catalina Island, a popular sportfishing destination in Southern California, where the average size of sheephead has been much reduced by overfishing of large males.

changes at San Nicolas to restricted access to the island post 9-11 and to higher fuel prices, as well as stricter regulations. “The fish keep getting smaller and they are changing sex earlier,” Hamilton says. “The bright spot is that the fish do come back once the fishing pressure is reduced.”

At popular sportfishing destinations such as Catalina, size limits on legal sheephead may be an ineffective and inappropriate strategy for managing the sport fishery, since a single size limit does not protect both males and females, especially for a species that switches sex midway through life, Hamilton adds.

The researchers also noted that because the range of sheephead crosses the borders of the United States and Mexico, this species may need to be managed bi-nationally.



The scientists organized and hosted a workshop in January 2009 for managers and presented their findings and the recommendation that the California Department of Fish and Game revise the 2004 stock assessment in light of the new data.

Cooperating Organizations

California Department of Fish and Game
National Park Service
NOAA Channel Islands National Marine Sanctuary

Students Kerri A. Loke, Master's; Tiana Egloff, Bachelor's; Greer McMichael, Bachelor's

Publications

Hamilton, S.L., J.E. Caselle, D.M. Schroeder, M.S. Love, J.D. Standish, J.A. Rosales-Casian and O. Sosa-Nishizaki. Geographic variation in density, demography, and life history traits of a harvested temperate sex-changing reef fish. *Canadian Journal of Fisheries and Aquatic Science*. In revision.

PISCO. Fish Data Give Managers New Insights. *Coastal Connections*, Vol. 6, 2007.

Two more publications are in preparation.

Presentations

Caselle, J. and S. Hamilton. Size-selective harvesting alters the life history of California sheephead across its biogeographic range. American Fisheries Society, San Francisco, CA, September 2007.

Caselle, J.S., Hamilton, D. Malone, D. Kushner and M. Carr. How do patterns of abundance, size structure and biomass differ between fished and unfished waters in the Channel Islands? Results from SCUBA surveys. California Islands Symposia: special session on first 5 years of monitoring the Channel Islands marine reserves. Ventura, CA, February 2008.

Hamilton, S., J. Caselle, T. Egloff, K. Kondo, K. Loke and C. Lowe. Spatial differences in trophic ecology and life histories of California sheephead have fisheries management implications. Western Society of Naturalists. Vancouver, British Columbia, November 2008.

Hamilton, S., J. Caselle, M. Love, D. Schroeder, K. Loke, K. Young, and C. Lowe. Selective harvesting alters life histories of a temperate sex-changing fish: historical comparisons and current status of California sheephead. Western Society of Naturalists, Ventura, CA, November 2007.

Loke, K., J. Caselle, S. Hamilton, C. Lowe and K. Young. Reproductive parameters of California Sheephead across the Channel Islands. American Society of Ichthyologists and Herpetologists, Montreal, Canada, July 2008.

Binational Studies for Ecosystem-Based Management of Thresher Sharks in the Southern California Bight



O. Santana/CICESE

A CICESE graduate student collects data from a thresher shark caught by commercial gillnetters in Ensenada. Note the absence of its fins.

R/OPCFISH-04

January 2007–February 2010

Jeffrey Graham, *Scripps Institution of Oceanography, UC San Diego, 858.534.8044, jgraham@ucsd.edu*

Oscar Sosa-Nishizaki, *CICESE, Ensenada, Baja California, Mexico, 636.175.0500, ososa@cicese.mx*

Suzanne Kohin, *NOAA Fisheries, 858.546.7104, suzanne.kohin@noaa.gov*

Summary

The thresher shark fishery off California is intrinsically a binational fishery, as the species' natural range includes habitat off the coasts of Baja California, Mexico, and the United States. However, because of an absence of binational fishing data, the U.S. fishery has largely been managed in isolation of Mexico's harvests.

To prevent unintentional overfishing of the shark, biologists in this project were funded to study thresher shark fishing practices and landings in Baja California. This was done by establishing a mini-observer program for the high-seas drift gillnet fishery in Ensenada, Baja California, in which observers documented the numbers and species of animals caught, their sizes/ages, and the geographic extent of fishing activity, among other things. Biologists also collected data at about 50 artisanal fishing camps from which sharks are caught in nearshore drift nets set from small, low-tech skiffs along the Pacific coast of the peninsula. The scientists documented the target species, effort and the biological characteristics of the sharks and rays captured.

Both the observer program and artisanal surveys were done in collaboration with scientists at Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE) and fisheries managers with Mexico's Regional Center of Fishing Research, also in Ensenada.

The project also included a tagging and tracking study of juvenile thresher sharks that documented migration patterns and habitat preferences. In one component of the tracking study, eight juvenile sharks were tagged with depth and temperature sensors and manually tracked from a skiff for up to 75 hours. In the other, 21 sharks were equipped with "pop-up" satellite tags capable of collecting data for several months. Data from four of these tags have been analyzed and published; the data from the remaining 17 are being analyzed.

Results

Acoustic tracking shows that threshers undergo age-related shifts in habitat use. In particular, threshers less than two years of age reside almost exclusively in the shallow waters of the continental shelf. At about the age of two, when the sharks have a fork length of about 1.2 meters (or a total length including tail of 2.4 meters), they move to deeper waters offshore. Satellite tracking shows that the juvenile sharks migrate along the coast from Southern California to as far south as Punta Eugenia (halfway down the 1,250-kilometer Baja California peninsula).

Both tracking studies strengthen the biological rationale for the state's ban on drift gillnetting within three miles of the coast to reduce bycatch and to protect juvenile sharks.



D. Carrami/SIO

About 99 percent of sharks caught by Baja California's artisanal fishers are juveniles less than two years of age.



Daniel Yanagi/NOAA Fisheries

A juvenile thresher shark being tagged off Santa Barbara.

Artisanal catch statistics also illustrate what happens when drift gillnetting is allowed near the shore—fishermen end up targeting juvenile sharks almost exclusively. Specifically, about 99 percent of sharks caught by nearshore skiff fishermen were juveniles less than two years of age. The sharks reach sexual maturity at about age five.

Since the start of this project, Mexico has passed strict fishing regulations that have reduced its high-seas drift gillnet fleet (not to be confused with the artisanal fleet) to only one active boat. As a result, Mexico’s fishermen are now believed to be harvesting very few *adult* thresher sharks. The biologists, however, estimate (very roughly) that artisanal fishers are taking about 4,000 juveniles annually, based on a year’s worth of survey data.

Findings were shared with the Pacific Fishery Management Council’s Highly Migratory Species advisory panel in April

2010. The council manages the U.S. West Coast drift gillnet fishery for swordfish and threshers. The OPC’s interest in the shark fishery stems from the fact that the bulk of landings for the entire West Coast occur in California. (Drift gillnetting gear is banned in Washington.)

Results have also been shared with the Mexican Fisheries and Aquaculture National Commission, which manages all fisheries in Mexican waters.

To foster scientific literacy among schoolchildren, biologists led a workshop on shark biology and conservation for local elementary schoolteachers at the Birch Aquarium in La Jolla, California. Biologists also participated in the aquarium’s 2008 “Shark Week” by hosting a shark science and conservation station for aquarium visitors.



Unknown

Scripps postdoctoral researcher Daniel Cartamil collects data at the Laguna Manuela fishing camp in Baja California.

Cooperating Organizations

Birch Aquarium at Scripps, La Jolla

Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE)

Instituto Nacional de la Pesca, Ensenada, Mexico

NOAA Fisheries SWFSC, La Jolla

Students Daniel Cartamil, Ph.D.; Omar Santana, Master's (Mexico); Miguel Olvera, Master's (Mexico)

Awards

J. Graham and associates, \$120,000, Tinker Foundation, 2007, to extend artisanal surveys into southern Baja California.

J. Graham and associates, \$96,000, Save Our Seas Foundation, 2008, to support genetics study of the connectivity of thresher shark populations in the eastern Pacific Ocean.

Publications

Cartamil, D. P. Dissertation: Movement patterns, habitat preferences and fisheries biology of the common thresher shark (*Alopias vulpinus*) in the Southern California Bight. Scripps Institution of Oceanography (UCSD), October 2009.

Cartamil, D., N. Wegner, S. Aalbers, C. Sepulveda, A. Baquero and J.B. Graham. Diel movement patterns and habitat preferences of subadult and adult thresher shark, *Alopias vulpinus*, in the Southern California Bight. *Marine and Freshwater Research*. In press.

Cartamil, D., N. Wegner, D. Kacev, N. Ben-aderet, S. Kohin and J.B. Graham. Movement patterns and nursery habitat of the juvenile thresher shark *Alopias vulpinus* in the Southern California Bight, *Marine Ecology Progress Series*. 404:249-258. 2010.

Graham, J.B. and D. Cartamil. Southern California Bight Elasmobranch Consortium Website www.sharkbight.com/science/index.php

Olvera, M. Dissertation: Biological analysis of the drift gillnet fishery of Baja California, 1999-2008. Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE), March 2009.

Santana, O. Dissertation: Species composition of elasmobranchs captured by the artisanal fishery in Bahía Sebastián Vizcaino, Baja California, Mexico. CICESE, October 2008.

An additional three publications are in preparation.

Presentations

Teacher education workshop for K-12 educators. Birch Aquarium at Scripps. April 12, 2008.

Third Annual Shark Conservation Conference, for 200 conservationists, scientists and artisanal fishermen in Baja California, some instrumental in collection of the project data. La Paz, Mexico, March 20-22, 2009.

Sosa, O. Seminar, "Elasmobranch fisheries in northwestern Mexico: How far can we go?" Scripps Institution of Oceanography, October 29, 2008.

Tackling Ecological Complexity and Climate Change: Matches and Mismatches in the Seasonal Cycle of California's Marine Flora and Fauna

R/OPCENV-07

January 2008-December 2009

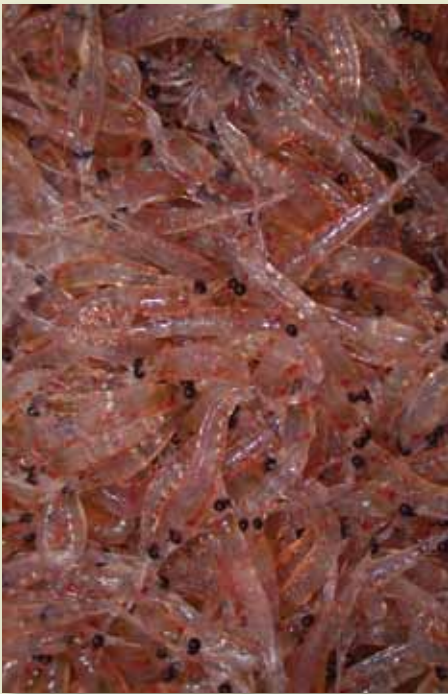
William J. Sydeman, Farallon Institute for Advanced Ecosystem Research, 707.478.1381, wsydeman@comcast.net

Steven J. Bograd, NOAA Fisheries, 831.648.8314, Steven.Bograd@noaa.gov

Summary

There is a growing body of evidence suggesting that climate change is altering upwelling patterns along California's coast and, as a result, the timing of the spring plankton bloom, and by extension the distribution and availability of krill. What happens when the base of the food chain shifts beneath the larger members of the marine community? How do higher trophic level organisms, ones of commercial and aesthetic interest, respond? Which species benefit and which lose out?

This project examined the life-history responses of Central Valley chinook salmon, rockfishes and seabirds around the Gulf of the Farallones in Northern California in relation to changes in their physical environment and the availability of a main food, krill (euphausiid crustaceans). Of particular interest was exploring the theory that bottom-up changes in the marine food chain can throw the ecosystem out of balance by, for example, throwing predator-prey relationships out of whack. To investigate what the lead scientist calls trophic "matches and mismatches," he and the co-investigator on the project retrospectively analyzed existing data for (1) linkages between winds, water temperatures and ocean currents; and (2) krill abundances and availability, and thus seabird reproductive success, rockfish growth rates and salmon recruitment success. Data for the analyses were provided by the cooperating organizations listed on the following page.



B. Saenz/PRBO

Krill are shrimp-like crustaceans that feed on phytoplankton and are key components of the diets of many animals, including baleen whales, seabirds and salmon.



Results

Spring upwelling is well recognized as being a driver of primary productivity and hence fish production off California. Results from this project underscore the importance of upwelling in winter. January and February “pre-condition” the ecosystem for productivity, as wintertime upwelling was shown to be positively correlated with successful seabird breeding and higher rockfish growth rates.

Computer modeling suggests that krill was scarce in the Gulf of the Farallones in 2005 and 2006. Its absence may have contributed to the collapse of Central Valley chinook salmon in 2007-08, the scientists say. Their computer modeling and statistical analyses

are consistent with the theory that changes in the timing and intensity of winter and spring upwelling lead to “mismatches” in the distribution of prey and feeding patterns of predators.



Darrell Whitworth/California Institute of Environmental Studies

Cassin's Auklet discovered in spring 2009 nesting on Santa Barbara Island.

Cooperating Organizations

Farallon Institute for Advanced Ecosystem Research
NOAA Environmental Research Division
NOAA Fisheries SWFSC Santa Cruz
Oregon State University
Pacific Fisheries Management Council
PRBO Conservation Science
U.S. Fish and Wildlife Service

Student Jeffrey Dorman, Ph.D., UC Berkeley

Publications

Bograd, S.J., I.D. Schroeder, N. Sarkar, X. Qiu, W.J. Sydeman and F.B. Schwing. Phenology of coastal upwelling in the California Current. *Geophysical Research Letters*, 36, L01602, 2009.

Bograd, S.J. and W.J. Sydeman, et al. The California Current, Chapter for the North Pacific Ecosystem Status Report, PICES, December 2009.

Schroeder, I.D., W.J. Sydeman, N. Sarkar, S.A. Thompson, S.J. Bograd and F.B. Schwing. Winter pre-conditioning of seabird phenology in the California Current. *Marine Ecology Progress Series*, 393:211-223. 2009.

Sydeman, W.J. Plankton, Section in “Climate Change Site Scenario,” Report to the Gulf of the Farallones and Cordell Bank National Marine Sanctuaries, 2010.

Sydeman, W.J. and S.J. Bograd. Marine ecosystems, climate and phenology: Impacts on top predators. *Marine Ecology Progress Series*, 393:185-188. 2009.

Sydeman, W.J., K.L. Mills, J.A. Santora, S.A. Thompson, D.F. Bertram, K.H. Morgan, B.K. Wells, J.M. Hipfner and S.G. Wolf. Seabirds and climate in the California Current—A synthesis of change. *CalCOFI Report*, 50:82-104, 2009.

Four additional papers are in revision or in press.

Presentations

Presentations were made at 14 local, national and international conferences.

Parasites as Indicators of Coastal Wetland Health

R/OPCENV-01
February 2007-February 2010

Kevin Lafferty, U.S. Geological Survey, 805.893.8778, lafferty@lifesci.ucsb.edu
Armand Kuris, UC Santa Barbara, 805.893.3998, kuris@lifesci.ucsb.edu
Ryan Hechinger, UC Santa Barbara, 805.893.3998, hechinger@lifesci.ucsb.edu



U.S. Geological Survey

*New Zealand mud snails
beside a dime for scale.*

Summary

How healthy is that wetland? Count the parasites in common snails to find out. The more species of parasites, the healthier the marsh. In this project, scientists are testing the validity of this idea for larval trematode parasites in common horn snails collected from California's wetlands. Their hope is that they can develop a snail-parasite index of wetland biodiversity that could supplement or in some cases replace traditional field surveys of fishes and benthic invertebrates. Such a cost-effective, integrative tool would help managers monitor and adaptively manage the progress of various wetland restoration sites in the state.

The scientific underpinning of the project is whether the presence or absence of various species of parasites does indeed accurately reflect the presence or absence of the parasites' requisite hosts. There is also the question of knowing what species might not be vulnerable to trematode infection and the time scales represented by the parasite community (i.e., how quickly do infection rates in snails respond to the presence or absence of host species.)

Results

Scientists have processed field data on the density of fishes and benthic invertebrates for 13 estuaries and their relationship to snail parasites found at the sites. They were able to acquire long-term datasets for sites in San Diego to determine temporal scales indicated by trematodes. They have also analyzed data from a snail/parasite growth study and found that certain parasites do indeed affect snail growth rates. The findings prompted a latitudinal study on snail growth rates at 14 estuaries as part of a doctoral dissertation. With a collaborator, scientists have also used molecular techniques to discover the existence of cryptic parasite species. This is an important finding, because cryptic species may infect different hosts and thus provide even more information on biodiversity. Scientists are in continuing dialog with wetland managers about their research.

As they finish their analyses, scientists will establish the most efficient sampling strategy to calibrate the parasite-as-indicator tool and combine it with standard assessment methods to translate the results into a characterization of wetland biodiversity. The scientists will then develop training materials to teach end-users how to go about using parasites as indicators. They anticipate that their trematode indicator tool will work throughout the world.



R. Hechinger/UCSB

Painting mud snails allows researchers to measure the effects of temperature and light on snail growth rates.

Cooperating Organizations

National Park Service
NSF Ecology of Infectious Diseases Program
Smithsonian Tropical Research Institute, Panama
University of California Natural Reserve System
U.S. Geological Survey

Student Julio Lorda, Ph.D.

Publication

Hechinger, R.F., K.D. Lafferty and A.M. Kuris. Trematodes indicate animal biodiversity in the Chilean intertidal and Lake Tanganyika. *Journal of Parasitology*, 94:966-968, 2008.

Evaluating Ocean Management Systems to Facilitate the Development of Ecosystem-Based Management

R/OPCENV-02
March 2007-January 2009

Oran Young, UC Santa Barbara, 805.893.8747, young@bren.ucsb.edu

Summary

This project was based on the premise that existing laws and regulations pertaining to ocean governance contain redundancies, inconsistencies and gaps impeding ecosystem-based approaches to managing marine resources. To help identify opportunities for fixing these, scientists amassed a searchable online database of all of the laws pertaining to the California Current ecosystem and made it publically available at the Governance of the California Current Large Marine Ecosystem Website (www.cclme.org). With outside funding from the Packard Foundation, researchers combined this database with a search engine and graphing package to create a free, downloadable software package, complete with a user guide, publically accessible at the Management Identifying the Needs of Ocean Ecosystems (MINOE) Website (<http://minoe.stanford.edu/>). MINOE can be viewed as a second-generation tool for assisting with the regulatory and legal implications of ecosystem-based management.

This project had four main components: to compile a database of laws and regulations relevant to the California Current; to develop techniques for quantitatively and objectively providing information about gaps and overlaps in management; to disseminate results to ocean stakeholders; and to make the database accessible to the public at no charge.

Researchers selected more than 1,400 state, federal and international marine laws and regulations of relevance to the California Current Large Marine Ecosystem in 2006. These laws and regulations spanned the geopolitical jurisdictions of the states of Washington, Oregon and California, as well as the federal jurisdiction of the United States and Mexico. The criteria for selecting these laws are outlined in a peer-reviewed journal article referenced at the end of this summary. A second paper explains the techniques employed to identify potential overlaps in laws/regulations and agency jurisdiction. A third paper describes a technique for objectively identifying potential legal/regulatory gaps for a particular ecosystem.



The geographical scope of the California Current Large Marine Ecosystem.

Results

The online legal database developed during this project allows users to perform text analyses on a body of documents relevant to multiple sectors and multiple jurisdictions of ocean governance. Users can perform traditional “Google-like” searches to retrieve lists ranked in order of relevance. They can also graph agencies in charge of the laws/regulations of relevance to their query. From this, jurisdictional overlap by agency and law can be explored. In the past, these types of analyses were the purview of literature reviews or “pay-per-view” access to private legal databases.

The development of the gap analysis, originally programmed in MATLAB for exploratory analyses, led to the more sophisticated software package known as MINOE. The value of MINOE is that it allows users to tailor their legal and regulatory analyses to a particular ecosystem, which the original legal database did not. With MINOE, a user begins by

inputting the ecosystem of interest and choosing jurisdictions for the analysis. The program then analyzes the ecosystem model and outputs the sections of law and/or regulation in which the ecosystem’s linked elements co-occur. Linkages that are not specifically acknowledged in law or regulation are also denoted.

The techniques developed during this project can be applied to existing and emerging environmental problems, such as climate change, ocean acidification, wave-energy platforms and offshore aquaculture. In particular, interested parties may explore whether there is a legal and regulatory framework for dealing with any potential impacts, and if so, under what mandate or regulation.

Cooperating Organizations

California Coastal Conservancy, Communication Partnership for Science and the Sea, Gordon and Betty Moore Foundation, National Center for Ecological Analysis and Synthesis, NOAA National Marine Sanctuaries, NOAA Coastal Services Center, NOAA NW and NE Fisheries Science Centers, PRBO Conservation Science, Stanford University, The Nature Conservancy, Washington Department of Ecology, Washington Sea Grant/University of Washington

Student Julia Ekstrom, Ph.D.

Award

2008, Julia Ekstrom, grant from David and Lucile Packard Foundation Ecosystem-Based Management Tools Initiative Fund to develop the MINOE software package.

Publications

Ekstrom, J.A. California Current Large Marine Ecosystem: Publicly Available Dataset of State and Federal Laws and Regulations. *Marine Policy*, 33:528-531, 2009.

Ekstrom, J. and D. Spiteri. Governance of the California Current (www.cclme.org). 2007-2009.

Ekstrom, J.A. and O.R. Young. Evaluating Functional Fit between a Set of Institutions and an Ecosystem. *Ecology & Society*, 14(2):16, 2009. www.ecologyandsociety.org/vol14/iss2/art16/

Ekstrom, J.A., O.R. Young, S. Gaines, M. Gordon and B. McCay. A Tool to Navigate Overlaps in Fragmented Ocean Governance. *Marine Policy*, 33:532-535, 2009.

Ekstrom, J. Digital Library of Ocean Management Laws: California Current Large Marine Ecosystem, dataset from laws, KNB NCEAS Data Repository, <http://knb.ecoinformatics.org/knb/style/skins/nceas/index.jsp>. 2007.

Presentations

Information was also presented at five conferences, to a high school class and for student’s dissertation.

California Spiny Lobsters and Benthic Community Structure in Southern California: Top-down and Bottom-up Interactions

R/OPCFISH-03

March 2007-August 2010

Kevin Hovel, *San Diego State University, 619.594.6322, hovel@sciences.sdsu.edu*

Christopher Lowe, *CSU Long Beach, 562.985.4918, clowe@csulb.edu*



M. Kjaergaard/Wikipedia Commons

*California spiny lobster
in La Jolla, CA.*

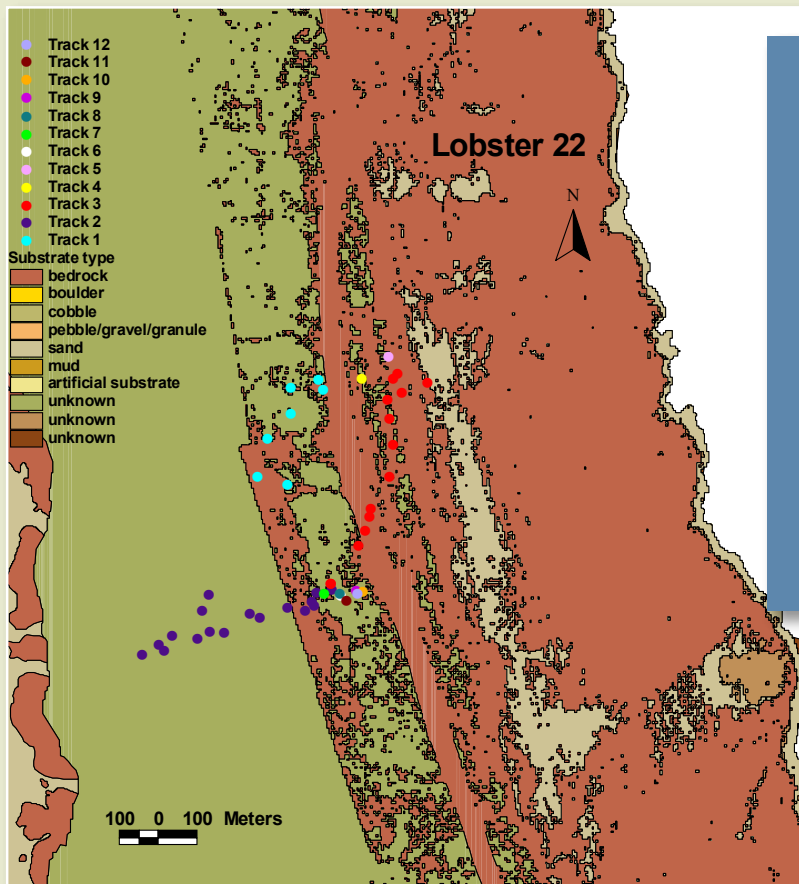
Summary

This project provides much-needed data about a species fished recreationally and commercially. California spiny lobsters were tagged and acoustically tracked in and around a small marine reserve in the La Jolla Cove in San Diego. According to the resulting tracking data, the crustaceans are found in almost all habitats except open sandy ones. Lobsters utilize kelp forests, eelgrass beds, surfgrass and understory algae, hunting at night for red sea urchins and other prey and hiding by day from predators such as sheephead. Their home ranges in the reserve are relatively small, researchers report, possibly because of the greater availability of food and/or a higher

number of large predatory fish. The findings will assist in designing marine reserves to protect a subset of adults from sport and commercial fishing.

The hypotheses tested during this project were: lobster behavior is governed by a combination of forces acting from the bottom-up (i.e., food availability) and from the top-down (i.e., predation risk); and lobsters, by hunting sea urchins, significantly influence benthic communities.

To study urchin movement patterns and their correlation with bottom habitats, scientists acoustically tagged and tracked about 50 lobsters in and around the San Diego-La Jolla Ecological Reserve. About half were manually tracked from a skiff at night (when the animals are active). The other half were passively tracked for up to a year, using moored underwater receivers. Diver surveys were also



Lobster tracks off Point Loma in San Diego. The brown “bedrock” areas represent mostly surfgrass, and green area around purple track is kelp forest. Understory algae and surfgrass are absent in the tan and green areas between the surfgrass. Note how the animals tend to avoid these exposed areas.

conducted to learn more about the distributions and abundances of lobsters in different habitats. The second component of the project was a predation study in which urchins were put on the seafloor at varying densities and in different habitats (i.e., under algal cover or on exposed sandy patches). Scientists then videotaped and measured mortality rates from lobsters and sheephead as a function of habitat type and time of day.

Results

The tracking data show that lobsters utilize all habitats except open sandy areas, and that they attempt to hide from predators by moving beneath understory algae. This strategy reduces mortality rates from daytime visual hunters such as sheephead, but offers no protection from nocturnal hunt-

ers such as octopi or black sea bass. Tagging data also show that lobsters travel between 75 meters and 100 meters a night, on average, and have home ranges of about 1,000 square meters. Previous tracking studies of lobsters off Point Loma, an area both commercially and recreationally fished, showed that the animals traveled as far as a kilometer a night and had home ranges as large as 10,000 square meters. The more constrained movement patterns observed in the La Jolla reserve may be due to the greater food availability and/or higher predation rates because of the greater abundances of larger, protected fishes.

Scientists measured lobsters collected in the various habitats and found no relationship between their size and location. This is likely due to the fact that the animals are mobile and utilize multiple habitats.

In the urchin predation component of the project, urchins were observed to hide under algae or in crevices when either lobster or sheephead were present. This behavior reduced predation by sheephead but not lobsters — perhaps because lobsters also reside beneath algae and/or because sheephead are visual hunters while lobsters are not.

Contrary to expectation, higher urchin densities were observed to reduce an individual urchin's chance of being eaten. In other words, predation did not keep pace with rising urchin numbers. An implication of this is that the current abundance of predators would not be able to prevent urchins from overgrazing seaweeds (creating what are known as urchin barrens) should urchin populations explode for some reason.

The project has resulted in one of only a few datasets of California spiny lobster movement patterns, as well as the only known data on urchin mortality as a function of habitat cover, time of day and urchin density. Findings have applications in designing marine reserves and have led to collaboration with the California Department of Fish and Game to monitor lobster movements and habitat utilization within San Diego Bay.



Laura Francis

Cooperating Organization

California Department of Fish and Game

Students Kathryn Nichols, Master's; Kira Withy-Allen, Master's; Ryan Jenkinson, Ph.D.

Award

2007, Kathryn Nichols, Edna Bailey Sussman Foundation award, for internship at California Department of Fish and Game.

Publications

Nichols, K. The effects of predators and habitat on sea urchin density and behavior in southern California kelp forests. Master's thesis, San Diego State University, 2009.

Withy-Allen, K. Movement and habitat use of California spiny lobsters. Master's thesis, San Diego State University, expected 2010.

Presentations

Hovel, K. and C. Lowe. California spiny lobsters and marine reserves: What can we learn and what do we know? Western Society of Naturalists, Ventura, CA, 2007.

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Ecology and Trophic Interactions of Jumbo Squid (*Dosidicus gigas*) in the California Current Ecosystem

R/OPCFISH-06

March 2008–February 2011

William F. Gilly, Hopkins Marine Station, Stanford University, 831.655.6219, lignje@leland.stanford.edu

John Field, NOAA Fisheries, 831.420.3907, John.Field@noaa.gov

Summary

While globally many fish stocks are dwindling, there is one along the West Coast of North America whose numbers appear to have mysteriously soared—the jumbo squid, also known as the Humboldt squid. While its sighting was rare in California a decade or two ago, the species is now a common favorite among sport fishermen as far north as Alaska. Scientists say the species, *Dosidicus gigas*, may be thriving off the expansion of a mid-depth layer of oxygen-starved water, a physical oceanographic phenomena some link to environmental degradation. In this way, the jumbo squid may represent one of the early “winners” of climate change, able to capitalize on the proliferation of an environment suffocating to its competitors.

This project is assembling a picture of the jumbo squid’s life history in the California Current ecosystem, including an understanding of what its success might mean for other species in the region—particularly commercial species and/or species of concern that may be part of the squid’s diet.

Findings to date suggest that the squid is probably not reproducing in large numbers in the California Current, if at all. Instead, it likely migrates to the region seasonally to feed on a group of highly abundant mid-depth fishes known collectively as lanternfish, and to a lesser extent on commercially important species such as Pacific hake and rockfishes.

In the final year of the project, scientists plan to combine dietary, habitat and movement/diving data to model interactions between the squid and other important species.



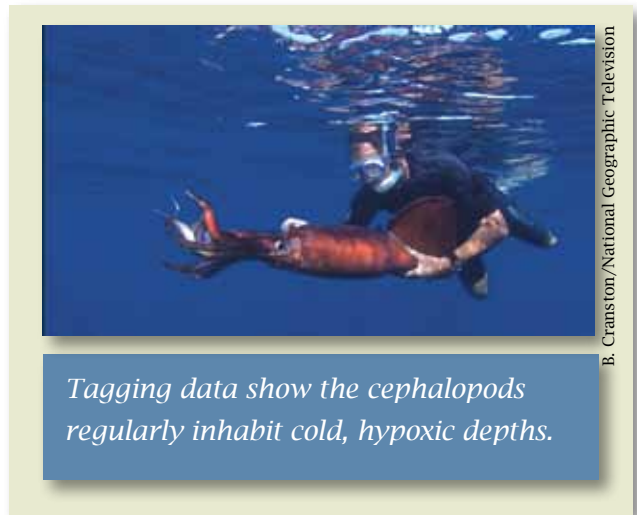
Gregory Auger

NOAA Fisheries biologist John Field holds a jumbo squid, also known in Mexico as “a red devil.” The squid are formidable predators with a physiology that allows them to capitalize on oceanic climate change.

Results

Squid Reproduction — There is not a lot of jumbo squid reproduction occurring in the California Current. Out of 300 squid sampled in 2008, only two females with implanted spermatophores (indicative of mating) were found, while several dozen fully mature males were identified, consistent with observations elsewhere that males reach reproductive maturity earlier than females. Scientists have been unable to document the release of fertilized eggs or the presence of paralarvae in the California Current. A search through archived plankton samples from CalCOFI also failed to reveal any jumbo squid paralarvae. Laboratory experiments suggest that the chilly waters north of Point Conception impair early development of embryos.

Squid Diet — Jumbo squid are primarily feeding on lanternfish, which reside in oxygen-depleted waters, based on an analysis of the stomach contents of more than 1,000 squid from California, Oregon



and Washington. Larger fishes, primarily Pacific hake and several species of pelagic rockfish, are also being consumed. Notably, squid from Washington are also hunting smolt and jack salmon, meaning that the squid is seeking prey in both deep and shallow environments and could potentially impact endangered salmon species.

Squid Movement Patterns — As has been observed in Mexico, jumbo squid are highly competent divers, able to reach impressive depths and to maintain high levels of activity there, too. Nine squid were tagged in 2008–09 in the Monterey Bay and Cordell Bank National Marine Sanctuaries. Five of the tags provided movement data for at least a 2.5-day period. These data showed that normal diel vertical migrations occur from midwater daytime depths of 300–550 meters to near-surface nighttime depths of 10–100 meters. Several deep dives exceeding 1,400-meters were also recorded. Daytime depths are characterized by temperatures of 6–8° C and oxygen concentrations in the range of 20–60 $\mu\text{mol/kg}$ and correspond to the upper boundary of the oxygen-minimum zone. These movement patterns are similar to those observed in the Gulf of California. All of the tagged squid migrated south, moving 6–35 kilometers/day with one animal traveling more than 595 km in 17.5 days and entering Mexican waters. The researchers theorize that squid in the northern California Current migrate south in fall and winter to spawn in warmer water.



Cooperating Organizations

Monterey Bay Aquarium
NOAA Fisheries
NOAA Monterey Bay National Marine Sanctuary

Students Julia S. Stewart, Ph.D.; Danna Staaf, Ph.D.

Publications

Bazzino, G., W.F. Gilly, C.A. Markaida and J. Ramos-Castillejos. Horizontal movements, vertical habitat utilization and diet of the jumbo squid (*Dosidicus gigas*) in the Pacific Ocean off Baja California Sur, Mexico. *Prog. Oceanography*, 2010. In Press

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Presentations

Baltz, K., Squids-4-Kids (presentations/participatory dissections) at numerous K-12 schools; UCSC, Boy Scouts, Santa Cruz, to high school teachers visiting NOAA NMFS Lab, Natural Bridges State Park, and Shared Adventures, Santa Cruz.

Field, J., Monterey Bay National Marine Sanctuary Advisory Council, Monterey, Dec. 2008; Friends of Hopkins Marine Station, Pacific Grove, Jan. 2009; San Francisco Branch, Environmental Protection Agency, Sept. 2009; and 12th Annual Salmon Ocean Ecology Conference, Santa Cruz, Apr. 2010.

Field, J.C., W.F. Gilly, J.S. Stewart and K. Baltz. "Ecology and trophic interactions of the jumbo squid (*Dosidicus gigas*) in the California Current Ecosystem, 4th International Symposium on Pacific Squids, 3rd International Workshop on Squids, Coquimbo, Chile, 2008; and "Ecology of the Jumbo Squid (*Dosidicus gigas*) in the California Current Ecosystem" for the Monterey Bay National Marine Sanctuary Currents Symposium, Mar. 2008.

Gilly, W.F., Teachers' Squid-Focused Workshop, Camp Ocean Pines, Feb. 1-2, 2008. American Fisheries Society Meeting, Toronto CA, Aug. 2008; Stanford University, Admit Weekend, May 2009; St. Andrews School, Saratoga, CA, May 2009; Pacific States Marine Fisheries Commission, Seattle, Aug. 2009; Monterey Maritime Museum, CA, Oct. 2009; Fort Bragg Rotary Club, CA, Oct. 2009; Noyo Harbor District, Fort Bragg, CA, Oct. 2009; Scripps Institution of Oceanography, Nov. 2009; Ocean Sciences Institute, Dana Point, CA, Nov. 2009; COSEE, CSU Long Beach, Jan. 2010; Hatfield Marine Science Center Visitor Center, Newport OR, Mar. 2010; Nifty-Fifty Program, National Science and Engineering Festival, Washington DC, upcoming Oct. 2010.

Stewart, J., S., Marine Bioinvasions, Portland, Aug. 2009; Western Society of Naturalists, Seaside, Nov. 2009; Ocean Sciences, Portland, OR, Feb. 2010; Sanctuary Currents Symposium, Seaside, Apr. 2010.

Web-based:

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Long-Term Faunal Changes in California Nudibranchs: Climate Change and Local Ocean Health

R/OPCENV-08

December 2007–November 2010

Jeffrey H.R. Goddard, UC Santa Barbara, 805.688.7041,
goddard@lifesci.ucsb.edu

John S. Pearse, UC Santa Cruz, 831.648.9245, pearse@biology.ucsc.edu

Terrence M. Gosliner, California Academy of Sciences, 415.321.8300,
gosliner@calacademy.org



G. McDonald/Long Marine Lab

The vibrant colors of a Spanish shawl nudibranch, *Flabellina iodinea*, warn predators it may be unpalatable.

Summary

In the past few years, the abundance and species richness of intertidal nudibranchs (brightly colored, shallow-water mollusks) has declined substantially at a number of sites off Central California (e.g., Asilomar, Scott Creek and Pillar Point). These declines were associated with large-scale, inter-annual and decadal climate variability in the northeast Pacific Ocean. In particular, total abundance of nudibranchs and of southern species was positively correlated with El Niño conditions, warm phases of the Pacific Decadal Oscillation, and elevated sea level and sea surface temperatures. Abundance was negatively correlated with the North Pacific Gyre Oscillation and coastal upwelling. Based on the results of time-series models, the biologists theorize that climate variability affects nudibranch populations by changing the nearshore currents that transport their larvae. They have documented a northward range expansion (since 1977) of the large aeolid, *Phidiana hiltoni*, to Duxbury Reef and a corresponding decline in the species richness and abundance of nudibranchs there. The decline is thought to be caused in part by predation by this species on small nudibranchs and their hydroid prey. In terms of the project's application to management, nudibranchs could potentially be used to detect and monitor fine-scale climate change along the coast and to forecast population changes in other species that have long pelagic larval periods, notably the commercially important red sea urchin.

Student Brenna A. Green, Post-baccalaureate

Presentation

Schultz, S.T., J.H.R. Goddard, T.M. Gosliner, D.E. Mason, W.E. Pence, G.R. McDonald, V.B. Pearse, J.S. Pearse, Going with the Flow: Nudibranch Gastropods Track Large-Scale Fluctuations in Climate, Western Society of Naturalists, 90th Annual Meeting, Seaside, CA, Nov. 14, 2009, and at Ocean Sciences Meeting, Portland, OR, Feb. 22-26, 2010.

Ocean Acidification Exacerbated by Coastal Upwelling: Monitoring of CO₂ and O₂ on the California Shelf, and Studies of Their Effects on Red Sea Urchins, California Mussels and Abalone

R/OPCENV-09

December 2009–November 2012

Victoria Fabry, CSU San Marcos, 760.750.4113, fabry@csusm.edu

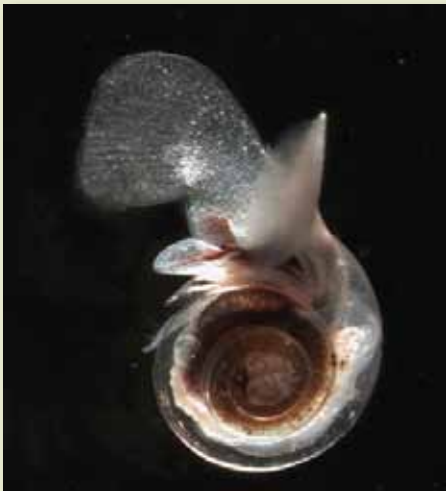
Andrew Dickson, Scripps Institution of Oceanography, UC San Diego, 858.822.2990, adickson@ucsd.edu

Gretchen Hofmann, UC Santa Barbara, 858.893.6175, hofmann@lifesci.ucsb.edu

Summary

In California's coastal waters, carbon dioxide levels are rising in rough concert with atmospheric carbon dioxide concentrations. The chemistry of seawater is such that the added carbon dioxide is lowering the ocean's pH. More acidic seawater can, among other things, corrode the calcium carbonate shells of organisms such as corals, oysters, sea urchins, lobsters and abalone. Shell-building organisms are particularly vulnerable to corrosion during their larval and juvenile stages. Above and beyond the effects of rising carbon dioxide on ocean pH, decomposing organic matter also releases carbon dioxide. Because of this, deeper waters off California are more acidic than the rest of the water column; upwelling further exacerbates acidification along the shelf.

This project will explore these concepts and their implications for shelf ecosystems in the California Current. In particular, a multi-disciplinary team will conduct field and laboratory experiments to: (1) investigate the extent of ocean acidification at a site in coastal California; (2) examine the effects of elevated carbon dioxide on calcification rates in red sea urchins, mussels and abalone at different life stages; (3) use molecular tools to link calcification rates with gene expression, and (4) document changes in gene expression at elevated seawater carbon dioxide levels. Findings will be published in peer-reviewed journals and shared with the public through exhibits at California aquariums.



R. Hopperoff/NOAA Fisheries

A swimming planktonic mollusk known as a pteropod (Limacina helicina) forms a calcium carbonate shell. These shells are vulnerable to corrosion caused by ocean acidification.

The Future of the California Chinook Salmon Fishery: Roles of Climate Variation, Habitat Restoration, Hatchery Practices and Biocomplexity

R/OPCFISH-10

February 2010–January 2013

Brian Wells, NOAA/SWFSC, 831.420.3969, brian.wells@noaa.gov

David Hankin, Humboldt State University, 707.826.3447, dgh1@humboldt.edu

Louis Botsford, UC Davis, 530.752.6169, lwbotsford@ucdavis.edu

Summary

The collapse of West Coast salmon populations led to sweeping closures of both sport and commercial salmon fishing in 2008 and 2009 and to the subsequent appropriation of \$170 million in federal disaster relief aid. The focal points of salmon restoration in California are the Klamath River and Central Valley runs, where dams and water-use conflicts, along with oceanographic and climatic variability, continue to push species to the brink. This project seeks to provide managers with tools for weighing pros and cons of various restoration options for Central Valley and Klamath run chinook salmon.

The project's first phase will involve a retrospective analysis of the links between climate variation, human activities and salmon numbers. The second phase will be a prospective analysis to determine critical stages in the life history of salmon that impact fish production. An overarching theme to be explored is whether promoting a more diverse population structure for chinook salmon could be a management strategy for boosting salmon survival rates. Specific hypotheses to be examined include: salmon survival is becoming increasingly variable; climate variability is increasing; genetic diversity within and among salmon populations is diminishing; improving population structure diversity will reduce swings in salmon survival; and improving diversity will improve the economic viability of fisheries.



R. Walder/SPAWN

Endangered juvenile coho salmon rescued from a drying creek in the Lagunitas watershed in Marin County prior to relocation to suitable habitat downstream.

Fall chinook salmon waiting for rain during a low-flow period in the Smith River.



Z. Larson/Smith River Advisory Council

