

Saltwater Fish in the Era of Climate Change

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I. Changes in climate patterns caused by global climate change that will significantly affect saltwater fish.

From a pure survival standpoint, human beings are adaptable to almost any climate. Our species has been able to survive in almost all the regions of our planet – from dry deserts to frigid tundra to stifling rainforests to snowcapped mountains, humans have been able to migrate to and inhabit almost every habitat Earth has to offer. Our ability to adapt in nearly all the planet's extremes in climate no doubt has led to our population boom and worldwide expansion.

For fish, however, things are not so easy. The ocean's environments are at least as extreme as on land, and fish lack many of the adaptive advantages we humans have (such as, with few exceptions, the ability to control their internal body temperature). In other words, fish are more or less at the mercy of their environment. In order to survive in the diverse conditions of the oceans, fish have adapted over millennia to the conditions of relatively specific regional areas. Slight alterations in environment, such as changes in temperature, habitat, and salinity, can be overwhelming for the many fish species with a small home range and narrow habitat requirements.

Unfortunately, many of the means by which humans have been able to survive in various climates are making things even more difficult for fish. The fossil fuels burned for human purposes like heating and cooling our homes may negatively affect the oceans and the fish that live in them. And the more we remove forests to inhabit new areas, the more difficult we make it for nature to recycle the carbon dioxide that human activities are adding to the atmosphere.

The net effects of climate change may actually be beneficial for some saltwater fishes that are able to adapt to the new conditions, but for those that cannot, the results may be overwhelming. This news will bring change for saltwater anglers who may have to abandon their favorite species and fishing locations. While the overall effects of climate change are often difficult to predict, scientists have projected, based on current data, several broad ways in which climate change will significantly affect saltwater fish.

Ocean warming

While scientific models vary as to the future extent, what they all agree on is that the oceans are getting warmer as a result of a net increase in atmospheric temperature. If we do nothing to curtail our carbon emissions, by the end of the century scientists predict the temperature of the oceans to increase 6-8° F. Even under lower emissions predictions, the oceans may still warm 4-5° F. While these relatively slight increases may not seem like much to us, to marine fishes these warmer waters could mean significant changes in habitat, food sources and life cycles.

Sea level rise

Along with warming atmospheric and oceanic temperature, climate change scenarios also predict a rise in sea level through the expansion of water as it warms, and from polar and glacial ice melting on land. In the 20th century, average sea level was estimated across the globe to have risen 4 to 8 inches. The magnitude of sea level rise varies among regions, but sea levels in the mid-Atlantic region are rising at almost twice the global average, and are expected to rise by over two feet by the end of the century.

Increased precipitation and storm intensity

Although anglers in some regions of the country who have recently witnessed their favorite lakes and rivers at record low water levels may find it hard to believe, precipitation on average has increased over the last hundred years, and is expected to continue to do so. This is because the atmosphere is capable of holding more moisture as it gets warmer. Additionally, global warming is predicted to result in more frequent and severe storm events, such as hurricanes. All of this will result in more fresh water being dumped into the oceans, which may alter ocean currents, estuary dynamics, and other regional salinity gradients.

Acidification

While oceans play a vital role in combating global warming by dissolving atmospheric carbon dioxide, it is not without a price. Through this process the oceans are gradually becoming more acidic. Between pre-industrial times and 1994, the average pH of ocean water near the surface decreased (i.e., became more acidic) by approximately 0.1 pH unit. This trend is especially concerning for calcifying organisms that fish are dependent upon, like coral reefs and bivalves, as lower water pH disrupts the chemical processes vital to their existence. While most fish appear to be tolerant of modest increases in water acidity, the loss of the coral reef as habitat and shellfish as food sources would be detrimental to the fish that rely on them.

II. Effects of changing climate patterns on saltwater fish habitat, food sources and phenology.

Water temperature is one of the most critical factors affecting fish life processes. Warming oceans may be a welcomed change to some fish, specifically those at the northern end of its species' range. For those individuals that previously had been living in relatively cold water given the species thermal range, warmer waters may improve growth, survival, and reproductive success. However, many fish, which had previously evolved and adapted to the specific conditions in its area, could face undesirably or dangerously warm conditions.

As any saltwater angler knows, fishing is usually best around structures like reefs, mangroves and sea grass beds, because many fish are associated with these types of habitats. With rising sea levels, coastal mangroves and marshes may move inland, although the extensive and ever-increasing development surrounding much of our coastlines will block this movement in many areas. In addition, some mangroves and marshes may not be able to keep pace with the rapid rate of sea level rise, and will become inundated before natural succession can move them along the changing shoreline.

Coral reefs also provide key habitat for many recreationally important fish, such as snapper, grouper, and tarpon. Reefs also provide nursery refuge for their young and house a variety of prey species. However, corals reefs face threats from two fronts: warming and acidification. When water temperatures get too warm, corals expel the symbiotic algae that provide their primary source of nutrition – a process called coral bleaching. This phenomenon can kill the corals if it lasts too long, and has become more frequent in recent decades. On top of that, more acidic oceans may disrupt the ability of

corals and other calcifying organisms, such as mollusks, to form shells, thereby reducing their growth and survival. These factors combined provide an uncertain future for corals and the myriad of species found on them.

III. Likely responses, or adaptations, of saltwater fish to their changing habitat.

Ultimately, climate change could have significant effects on saltwater fish and anglers. Not all fish will react the same, as some may be able to withstand the elevated temperatures in their home range, while others will have to move to new areas. These shifts will alter community assemblages, bringing together previously separated species that must then compete for shared food and habitat resources. Native fishes may disappear from certain areas as invasive species become more prevalent. Additionally, those sedentary species that are not capable of migrating may suffer reduced growth, poorer reproductive success, and greater mortality in the unfavorably warm water. As the loss of critical habitat, like coral, mangroves, and submersed aquatic vegetation occurs, species like grouper, snook, and spotted sea trout that are dependent upon these habitats will find it more challenging to survive in the same areas.

Many aspects of saltwater fish life history rely on environmental cues related to temperature, currents, and precipitation. Slight changes in any of these factors can lead to a loss of correspondence between key life history events and appropriate environmental conditions. The spawning runs of anadromous fish, such as salmon, striped bass, and shad, are cued by temperature and are precisely timed to provide the best chance for survival for their offspring. Warmer temperatures will prompt some fish species to migrate earlier, and may displace adults or their young from other events

critical for reproductive success and survival. As a result of greater precipitation, anadromous fish will also have to face increased stream flow. For these species, the success of a spawning run is dependent on a relatively narrow range of stream flow, and if flow changes are too great, reproductive success may be compromised. Similar timing patterns could be disrupted for highly migratory fish that traverse vast regions of the oceans, such as bluefish and tuna. For these species, climate change could result in mismatches between the timing of food production or availability and fish life history patterns.

Saltwater anglers will also have to adapt to the changing climate. As warmwater species expand their range, anglers may have to target these new species, or travel longer distances to reach old favorites. Warmer weather could boost the number of fishable days, though a counterbalance may come in the form of more frequent and intense storms, which in addition to causing anglers to put away their rods and reels for the time-being, may also damage docks, piers, and marinas. Rising sea levels will diminish and in some cases eliminate fishable shoreline for surf casters. Fishing regulations will have to be adjusted to match the new population dynamics and community assemblages of marine fisheries. Cumulatively, these challenges threaten to change the tradition of sportfishing, and the sooner we start dealing with the causes of global climate change, the sooner we can begin to mitigate the negative effects looming over the horizon for saltwater sportfish.

IV. Projects that wildlife managers might use to promote the success of saltwater fish adapting to global climate change.

How do we avoid the consequences of climate change? Saltwater fish and their habitats will probably be affected to some degree even if we could completely cut off the factors that contribute to climate change. What we can do is minimize the amount of climate change that does occur and invest in projects that help saltwater fish adapt to the changes that cannot be avoided. We can work to create conditions that make it easier for saltwater fish to adapt to climate change by reducing other human influenced stresses. These projects can focus on improving and restoring fish habitat, as well as on boosting stocks by aiding reproduction and carefully controlled supplemental stockings.

Coastal wetlands

Over half of the U.S. population lives within 50 miles of the coast. The intense development that is associated with high population densities has stressed coastal ecosystems and reduced the amount of quality habitat available to saltwater fish. For many recreationally important fish species, coastal wetlands represent critically important spawning, rearing, and feeding areas. In addition, wetlands can absorb flood waters and act as a barrier to storm surges. Restoring native wetlands can therefore protect both aquatic and terrestrial organisms from some of the impacts of climate change.

Many such projects are already underway, and serve as good examples to follow and expand upon. Coastal wetlands restoration projects work to remove undesirable invasive plants, replant native vegetation, and prevent shorelines from erosion through protective barriers like breakwaters. The Galveston Bay Foundation, for example, has restored thousands of acres of wetlands in Galveston Bay, Texas through partnering with other organizations and agencies and by involving the community in restoration projects.

Such projects can go a long way in halting the degradation of coastal wetlands and provide essential habitat for fish.

Oyster reefs

Further from shore, oyster reefs serve as vital habitat for saltwater fish. Species such as striped bass, sea trout, and croaker often rely on the plethora of prey that flock around oyster reefs. Oysters also benefit marine ecosystems by filtering excess nutrients from the water. However, overharvesting and pollution have significantly reduced oyster populations in many areas. In the Chesapeake Bay, for example, the oyster population has been reduced to less than 2% of historic levels. Oyster reef restoration projects involve transplanting oyster shells, either from dredging them from the ocean floor or by acquiring them from the oyster shucking and packing industry, and building them into reefs. The shells in the reefs are then recolonized either by natural oyster larvae or via transplanting larvae from hatcheries. Oyster reef restoration projects have been carried out with some success by many federal and state agencies, as well as non-government organizations and community groups, though there is still much room for improving the abundance of this valuable fish habitat and economic resource.

Fish passage

Several of the most valuable recreational saltwater fishes, such as salmon and striped bass, migrate into fresh water to spawn. Many of these fish are unable to make it through this arduous journey, however, because of man-made barriers. Dams serve several purposes including water retention, flood control and generating hydroelectric

power, but they also make it nearly impossible for anadromous fish to reach spawning grounds. Throughout the country, many old and unused dams have been removed, restoring essential spawning habitat for migrating fish. Methods have also been developed and successfully implemented to allow fish to migrate around and through dams. These fish passage structures enable fish to pass around dams by swimming and leaping up a series of low steps until reaching the waters on the other side. While some dams are a valuable source of renewable energy, it is important to take measures to facilitate anadromous fish migrations by allowing fish to move around those dams that serve important purposes and removing dams that are no longer of use.

Riparian buffers

Riparian buffers are vegetated areas next to streams and rivers that help control erosion, temperature and excessive nutrient input. Because inland water quality inevitably affects ocean water quality, controlling these pollutants is also important for saltwater fish. Construction and agricultural practices have removed riparian buffers across the country, and the consequences have been seen downstream. Ocean dead zones are areas of water without enough oxygen to support aquatic life, and are primarily caused by fertilizer runoff, which leads to harmful algal blooms that deplete the amount of dissolved oxygen in the water. Aquatic organisms that are unable to move away from the dead zone fast enough suffocate and die.

Restoring riparian buffers around streams and rivers by replanting native vegetation can significantly reduce the amount of runoff that enters the water, greatly improving water quality in the surrounding area and downstream. The shading they

provide also helps cool water, which can be very important for those anadromous fish whose reproductive success is highly dependent upon suitable water temperature.

Coral reef restoration

The effects of ocean warming and acidification will endanger these valuable, but vulnerable resources. Factors already contributing to the decline of coral reefs have included hurricanes, disease, nutrient loading, sedimentation, various forms of pollution, coral mining, trampling by tourists and divers, and damage caused by ship anchors and groundings. Additionally, overfishing of certain species has thrown off the balance of food webs, accelerating bioerosion of corals or leading to overgrowth of algae. Projects undertaken to help restore coral reefs may involve re-establishing coral reef species assemblages to natural states, mitigating physical damage caused by man, and transplanting cultured corals from nurseries to degraded sites. Managers are faced with the challenge of finding approaches to help corals cope with warmer temperatures and more acidic waters, but current restoration strategies can help repair and rebuild coral reefs and the fish populations that depend on them, thereby helping them to become more resilient to future threats.

Besides the direct benefits to saltwater fish and their habitats, the projects outlined above also help aquatic ecosystems by prompting collaboration between groups and agencies. These partnerships can be built upon to spark other projects and ideas that will further benefit marine resources. Additionally, the backbone of many of these restoration

projects is community involvement, and getting citizens involved at the ground level helps to create a more interested and involved public. Similarly, involving schoolchildren early on in these types of projects can help them grow into more environmentally aware and educated adults.

V. Comprehensive description of a single, on-the-ground, landscape-level project that managers might use to promote the success of saltwater fish adapting to habitat changes.

Generalized Management Situation

Many anthropogenic effects have caused significant harm to salmon populations on the Pacific coast of the United States. Overfishing, pollution, and water diversions have all played a role in reducing Pacific salmon abundances, to the point that a moratorium was called on the fishery in California and southern Oregon in 2008 and 2009 because of such low population numbers. Climate change predictions indicate that conditions will only get worse for salmon, whose reproductive success is so dependent upon precise environmental conditions. In an effort to help boost salmon stocks in both the near term and to further help them cope with the additional stressors they are expected to face in the not-too-distant future, many groups and organizations have taken the initiative to remove some of the numerous dams that pose major threats to juvenile and adult salmon trying to migrate to and from rivers and streams. It has been estimated that dams account for as much as 92% of the mortality of salmon moving out to sea, and up to 25% of the losses of salmon on their way back upstream. Clearly, the removal of these threats can go a long way towards rebuilding salmon stocks, allowing for a greater potential of resiliency to the effects of a changing climate.

Geographic and Biological Setting

White's Gulch, a tributary of the North Fork Salmon River, is located in Siskiyou County, California, near the Oregon border. The White's Gulch watershed, located within the 1.7 million acre Klamath National Forest, is rural, mountainous, coniferous terrain. The flow in White's Gulch is highly variable across seasons, being nearly dry in the summer months, with the greatest average monthly flow occurring in February at approximately 30 cubic feet per second.

Historically, the Salmon River experienced tremendous runs of Chinook salmon, Coho salmon, and Steelhead trout, with accounts of "being able to walk across the river on the backs of salmon." Recreational salmon fishing on the Salmon River was a highly popular activity in the region, and salmon canneries existed on the river in the past. White's Gulch was an important spawning tributary on the river, offering approximately 1.5 miles of prime spawning grounds with its dense riparian habitat, numerous pools, and a low percentage of fine sediments (which can bury and suffocate eggs if overly abundant). However, due to multiple pressures exerted on their populations mentioned above, salmon abundances are greatly reduced to the point that fishing for salmon is no longer allowed on the river.

Two dams located on White's Gulch are considered the primary driver contributing to the decline of salmon in the watershed. An upper dam, located approximately a mile up from the confluence with the North Fork Salmon River, dates back to the late 1800's. The upper dam blew out in 1984 and was re-built in 1986, at

which time another dam was constructed about half a mile downstream to supply water for a pond for a private landowner.

Project Tasks

In early 2006, the Salmon River Restoration Council (SRRC), in conjunction with the U.S. Forest Service (USFS), California Department of Fish and Game (CDFG), and local private landowners, partnered to begin the process of removing the two dams blocking fish passage on White's Gulch. Project design was prepared in 2006 by the partners, followed by the permitting process. Several environmental assessments and permits had to be obtained prior to dam removal in order to be in compliance with a host of state and federal environmental protection laws (e.g., National Environmental Policy Act, Clean Water Act, Wild and Scenic Rivers Act). These permits, issued by the appropriate state and federal agencies, are to ensure that the dam removal will not pose a significant environmental or public health risk. As part of the permitting process, sediment that has built up behind the dam and therefore will be released downstream after dam removal must be tested for heavy metals. For the White's Gulch dam removal, all permits were applied for and granted in 2007. Additional funding for the dam removal project was granted by the FishAmerica Foundation through its partnership with the NOAA Restoration Center. Additional project partners included the California Department of Fish and Game, the U.S. Forest Service, and a private landowner.

Goals and Objectives

The overall goal of the White's Gulch dam removal was to restore access to spawning grounds for Chinook salmon, Coho salmon, and Steelhead trout. The specific objectives were to remove the two concrete dams along White's Gulch, relocate a water inlet (which previously was adjacent to the upper dam) for a small hydroelectric project further upstream, and there construct a headstock and fish screen to prevent mortality of larval fish through the water inlet. This project is part of a larger White's Gulch barrier removal project that also involved replacing a culvert located between the lower dam and confluence with the North Fork Salmon River which presented another barrier to fish passage.

In 2008, the lower dam area was de-watered during the low water season, and the dam was removed by an excavator. The 7-foot tall upper dam, which was larger and of better construction than the lower dam, was blasted out by the CDFG using explosives. The new inlet and fish screen were put in place by CDFG and SRRC personnel. All of the in-stream construction took place over the course of two months in the fall of 2008. Post-removal monitoring has included water temperature and flow monitoring, heavy metal testing above and below the former upper dam site, and fish surveys.

Implementation Barriers

Oftentimes, dam removal projects face resistance from several fronts. Many communities feel strong ties to a nearby dam, either for its recreational or aesthetic values, and will oppose removing the dam despite the long-term benefits that its removal may provide. Additionally, the lengthy and oftentimes tedious permitting process can slow down or halt a proposed dam removal project. In the case of the White's Gulch dam

removal, relatively few barriers arose throughout its implementation. Local landowners supported the removal of the dams, going as far as lending their time and money to assist with the project. Also, all permits were submitted and approved within a reasonable timeframe. One unexpected delay in the project was the large wildfires that occurred in the area in the summer of 2008 which forced a stoppage of work. Fortunately, the project was able to resume a few months later after the fires had subsided.

Conservation Outcomes

The removal of the two dams on White's Gulch, in combination with the removal of the culvert barrier downstream, opened up 1.5 miles of spawning and rearing habitat for spring Chinook salmon and threatened Coho salmon and Steelhead trout. The project provided benefits to native riverine fish and wildlife by restoring natural habitat, and improved safety for nearby communities.

Climate change will significantly alter the environmental conditions that migratory fish need to successfully reproduce. By eliminating manmade barriers, such as dams, that further diminish the ability of migratory fish to make their spawning runs, we can help these fish better adapt to the effects of climate change. Collectively, dam removals throughout the country like the project on White's Gulch can go a long way in helping migratory salt water fish cope with the additional stressors that climate change will bring.

VI. Analysis of the cost components of the project and estimate of the project's total cost.

Step #1, Year 1: Coordinating partners and volunteers, developing landowner relationships, determining project design. Cost estimated at \$15,000

Step #2, Year 2: Applying for permits, pre-project monitoring including sediment testing for heavy metals. Cost estimated at \$20,000

Step #3, Year 3: In-stream construction, installation of water supply pipe, fish screen and headstock, transportation costs, physical dam removal including excavator renting and blasting equipment. Cost estimated at \$75,000

Step #4, Year 3 and beyond: Post-project monitoring and evaluation. Sediment was retested for heavy metals to assure there is no risk to the public or environment. Stream conditions (flow, temperature, quality) will continue to be monitored, and annual fish surveys will be conducted in the winter and spring to evaluate dam removal success. Cost estimated at \$5,000 annually.

Total costs are estimated for the White's Gulch watershed over a 10-year implementation period at \$160,000.

VII. Limitations of existing state and federal programs in addressing the threat to saltwater fish caused by climate change.

The White's Gulch dam removal project was primarily funded by two sources - the California Department of Fish and Game, the FishAmerica Foundation and the NOAA Restoration Center. These partners provided over 90% of the funding needed for

the project. Community based, partnership-driven fish habitat restoration projects funded through sources like the FishAmerica Foundation, the NOAA Restoration Center, and the National Fish Habitat Action Plan serve as prime examples of the types of on-the-ground projects that will be needed if we hope to see saltwater fish adapt to climate change.

Individually, dam removals such as the project at White's Gulch can provide major boosts to fish populations at a local level, but more financial resources must be put towards such projects at a greater scale, both in number and size of dams removed, and in conjunction with other habitat restoration projects (such as those described in Section Five), in order to see significant benefits to sport fish at a regional and population level. Due to its relatively small size and ease of removal, the costs of the White's Gulch project were much less than many other dam removal projects. While these small dam removal projects are beneficial and necessary to improve some fish stocks, the much larger hydroelectric dam facilities that are blocking fish passage further downstream are a significantly greater detriment to migratory fish, and are exponentially more complicated and expensive to remove or retrofit for adequate fish passage.

Dams and other human-caused threats to fish have placed a major burden on fish populations throughout the country. Despite the efforts made thus far through projects like dam removals, research estimates that 40 percent of the U.S.'s fish populations are currently in decline and half of our waters are impaired. Climate change will place an even greater burden on our nation's marine fish populations. Fisheries conservation projects conducted by state natural resource agencies are largely funded within the agencies through license sales and the Sport Fish Restoration and Boating Trust Fund. Both state license sales and receipts into the Trust Fund have remained relatively static

over the past decade. Additionally, while fish habitat restoration programs like those mentioned above have done laudable work in restoring and enhancing coastal fish habitats at local and regional levels, these programs currently do not have the financial resources to sufficiently address all of the current and expected problems facing our nation's fish and their habitat. Clearly, given the magnitude and extent of the impacts that climate change could have on saltwater fish, continuing at status quo will not be enough to address the additional threats that climate change poses to saltwater fish. Large-scale regional plans that incorporate a suite of projects and tools to help saltwater fish adapt to climate change could have a long-term price-tag of several billion dollars.

Despite the costs, a significantly greater investment towards helping saltwater fish adapt to climate change is not only prudent because of the high economical value of these resources, but is also our responsibility as stewards of the environment. As anyone who has stalked tarpon in crystal clear tropical waters, witnessed marlin majestically soaring through the air at the end of the line, or simply enjoyed watching the sun set after a peaceful day on the water can attest, saltwater fish are valuable for reasons less tangible than economics. It is our duty to ensure that these treasured resources are available for future generations to enjoy, even if the conditions they are found in are not the same as today.