

Ecological Processes

The Bay is composed not only of physical, biological, and chemical components but also active processes that link them to produce a functioning ecosystem. Examples of these processes include the movement of nutrients in the food chain as predators consume their prey, decomposition of dead animals and plants, sediment being transported to nourish wetlands and maintain channels, and freshwater flows mixing fresh and salt water to create aquatic habitat of varying salinity.

This section of the report identifies and evaluates indicators of two key ecological processes in San Francisco Bay: flood events and food availability to breeding birds. Identifying indicators that track ecological processes over time is a scientific challenge. We expect that in the future the indicators described here will be further refined, and more will be developed.

Flood events

Following winter rainstorms and during the height of the spring snowmelt in the San Francisco Bay's vast watershed, Bay tributary rivers may flood, spilling over their banks to create ecologically important floodplain habitat and high



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flows of fresh water into the Bay. These high seasonal flows transport organisms, sediment, and nutrients to the Bay, increase mixing of Bay waters, and create productive brackish water habitat in the Suisun and San Pablo regions—conditions favorable for many native fish and invertebrate species. Flood events trigger reproduction and migration for many estuarine fishes and for anadromous species like salmon that migrate between the ocean and rivers through the Bay.

■ HEALTH INDICATORS

Freshwater flows into the Bay have been greatly altered by dams built on most of the Bay’s tributary rivers in the Sacramento–San Joaquin watershed (see Freshwater Inflow Index, Water Quantity Section). Many of these dams were built for the purpose of reducing damaging flood events and to store mountain runoff for later use and export to other regions in the state. However, these upstream water management operations have interrupted an important

ecological process—regular seasonal flooding—that we now know is critical to the health of the Bay, its watershed, and the plants and animals that depend on these habitats. The Flood Events Index uses these measurements to assess the frequency (how often?), magnitude (how much?), and duration (how long?) of flood events and high inflows into the Bay.

BENCHMARKS

The benchmarks for the three measurements that comprise the Flood Events Index were based on review of historical flow data for the years before most of the major storage dams were completed on the Bay’s largest tributary rivers. This showed that flows in excess of 50,000 cubic feet per second corresponded to inundation of floodplain habitat upstream of the Bay and that these high flows occurred in half of all years, with average duration of about 90 days. Flood frequency is measured as the number of years in the past decade in which inflows

exceeded 50,000 cubic feet per second for a total of 90 days during the year.

Magnitude is measured as the average flow during the 90 days of highest flow in the year, and duration as how many days during this period flows exceeded the 50,000 cubic foot per second flood threshold. Measured conditions that exceeded the benchmarks were considered to indicate good conditions while those that were lower were considered to indicate fair or poor conditions. For each year, the Flood Events Index was calculated by combining the results of the three measurements into a single score (1–3).

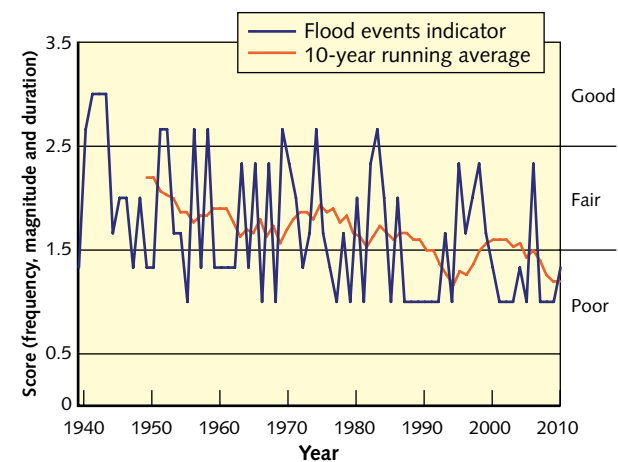
■ KEY RESULTS AND TRENDS

Results of the Flood Events Index (Figure 23) track the steady decline in the occurrence of this key ecological process, from good to fair and, by the 1980s, mostly poor. During the last 20



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Figure 23. The frequency and duration of flood events in the San Francisco Estuary’s watershed has declined during the past 60 years.



THE YOLO BASIN AS REARING HABITAT FOR SENSITIVE FISH SPECIES

The law of unintended consequences has been known to work in nature's favor. The Yolo Bypass, a natural floodplain reengineered to convey floodwaters around Sacramento, is one case in point. UC Davis fish scientist Peter Moyle has observed that the Bypass was entirely a flood control area in concept, with the floodplain graded to facilitate draining; yet it has become increasingly important for fish and wildlife. In winter, the floodplain teems with waterfowl. It is also recognized as prime habitat for sensitive native fish species at a critical stage in their life histories. Fifteen native species and 27 non-natives, including popular game species like striped bass, use the Bypass.

The Sacramento splittail, a California-endemic cyprinid, spawns in the flooded Bypass. Young splittail rear there and move out to river channels as the floodwaters recede. Although it is not currently on the federal endangered species list, the splittail is still considered by some wildlife advocates to be of conservation concern.

Biologists have also documented the floodplain's importance to Chinook salmon. Juveniles move into the floodplains during high-flow events, seeking out low-velocity areas. Research by Ted Sommer of the California Department of Water Resources and others indicates that juvenile salmon grow faster in the Bypass than in the adjacent Sacramento River, in part because of the seasonal abundance of a recently described species of chironomid midge on the floodplain and the warmer water and greater habitat complexity of the Bypass. The dispersal of the fish over the extensive flooded area limits the impact of predation by wading birds. The juveniles move out during later flood events or when the inundated portion of the floodplain drains. Historical grading for agriculture enhances drainage, which may help the young salmon make their way out.



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years there were no years with good conditions, and fair conditions occurred in only seven years during a particularly wet sequence of years in the late 1990s and in 2006. Most of the decline is driven by reductions in the frequency of flood events. In the 1940s, floods and high flows into the Bay occurred in more than half of all years (an average of 56 percent of years). For the last 20 years, flood frequency averaged less than two flood events per decade (14 percent of years). Magnitudes of the maximum flows measured during the year were also lower, averaging more than 80,000 cubic feet per second in the 1940s but just 48,000 cubic feet per second in the last decade. And flood durations were lower. In the 1940s, flows into the Bay exceeded 50,000 cubic feet per second for an annual average of 82 days, but these high flows occurred for only an average of 27 days per year by the 2000s.

■ SUMMARY

Reductions in the frequency and intensity of flood events over the past several decades have impaired the health of the Bay, reducing its productivity and dampening the year-to-year and seasonal variability that help native species thrive and restrain expansion of invasive non-natives. As with the changes in other aspects of the freshwater flows into the Estuary (measured by the Freshwater Inflow Index), declines in this important ecological process probably have their greatest effect on the upstream regions of the Bay, which directly receive the flood flows. However, the effects of periodic flood flows are also important in the downstream regions of the Bay, as well as in coastal environments outside the Golden Gate. For example, success-

ful restoration of tidal marshes along the Bay's perimeter depends on deposition of sediment, most of which is transported to the Bay during floods. Therefore, achieving the CCMP goal of restoring healthy estuarine habitat will take more than improving minimum freshwater inflows, it will require restoration of some larger flow events calibrated so as not to threaten people and property along the affected river corridors. Such carefully managed events would greatly help to nourish habitats and drive the ecological processes of a healthy estuary.

Food web

The food web of the estuary represents an important ecological process. Since fish-eating birds need a functioning food web so they can feed themselves and their young, the reproductive success of these birds is an indicator of the health of the aquatic food web of the Estuary.

■ HEALTH INDICATORS

Two indicators reflect the availability of food to breeding birds:

- the number of young reared per great blue heron and great egret successful breeding attempt, based on a large number of breeding colonies in the wetlands of San Francisco Bay
- the number of young reared per Brandt's cormorant breeding pair on Alcatraz Island, inside San Francisco Bay

Both of these indicators reflect the availability of food (specifically, fish) in the Estuary's baylands (for great blue herons and great egrets) or in open water (Brandt's cormorants), and thus assess the functioning of the food web.

The time series for the great heron and great egret brood size began in 1991, and is based on observations of those species at numerous breeding colonies distributed throughout Central San Francisco Bay, San Pablo Bay, and Suisun Bay. The time series for Brandt's cormorant began in 1995 and comes from the only breeding colony of this species within San Francisco Bay at Alcatraz Island. All three species forage widely when rearing young, and thus the indicators reflect the food web beyond the immediate vicinity of the breeding colony.

BENCHMARKS

The benchmark for the number of young reared per heron and egret brood is the average value observed during the earliest five-year reference period, 1991 to 1995, calculated across all regions of the Estuary, combining data for great blue heron and great egret: 2.17 young per brood. Compared to the benchmark value, the number of young per brood for the most recent three years (2006 to 2008) was reduced by 5.4 percent in Central San Francisco Bay, by 1.8 percent in San Pablo Bay, and by 7.7 percent in Suisun Bay.

The benchmark for the number of young reared per breeding pair of Brandt's cormorants is the long-term average value obtained at a reference site for this species (Southeast Farallon Island, 1991–2005) of 1.69 chicks fledged per pair (PRBO, unpublished). While prior to 2008,

12 out of 13 years were above this value, from 2008 to 2010, the three-year average was only 39 percent of the long-term benchmark.

■ KEY RESULTS AND TRENDS

Great blue heron and great egret brood sizes have shown declines since 1991 (Figure 24), but the pattern differs somewhat depending on the region of the Bay. The decline in brood size is more pronounced for great egrets, whose brood size has declined 17 percent in the Bay as a whole, when comparing the most recent three years (2006–2008) to 1991–1995. Combining results from the two species reveals no decline in the Central Bay, but a pronounced decline in



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Suisun Bay of more than 15 percent over the 17-year period. In San Pablo Bay, a decline in brood size during the mid to late 1990s was followed by an increase from 1998 to 2006. These results suggest declines in the availability of prey, particularly in Suisun Bay, a result consistent with observations of fish populations in the same regions and time period (see the Fish Index, Living Resources section).

In marked contrast, Brandt's cormorants on Alcatraz Island demonstrated relatively high and relatively stable reproductive success between 1995 and 2007, comparing favorably to the long-term reproductive success of this species on the Farallon Islands. This healthy performance changed during 2008–2010, when reproductive success was severely impaired (Figure 25).

Whereas such low reproductive success is unprecedented for the Alcatraz population, it is

not unusual on the Farallon Islands, where reproductive failure (or near-failure) is a definitive sign of prey shortage for breeding cormorants.

■ SUMMARY

The two indicators of reproductive success, brood size of great blue herons and great egrets, and chicks fledged per breeding pair of Brandt's cormorants, both demonstrate some reduction in prey availability. The brood size indicator reveals a consistent long-term population decline in one of the three Bay regions, while the fledgling indicator reveals high prey availability in the aquatic food web up to 2007, and then a drop beginning in 2008 and accelerating in 2009 and 2010. The years 2009 and 2010 may represent only a two-year anomaly, but if this extremely low production of cormorant young continues, it will be of grave concern.



Figure 24. Heron and egret brood size, Suisun Bay

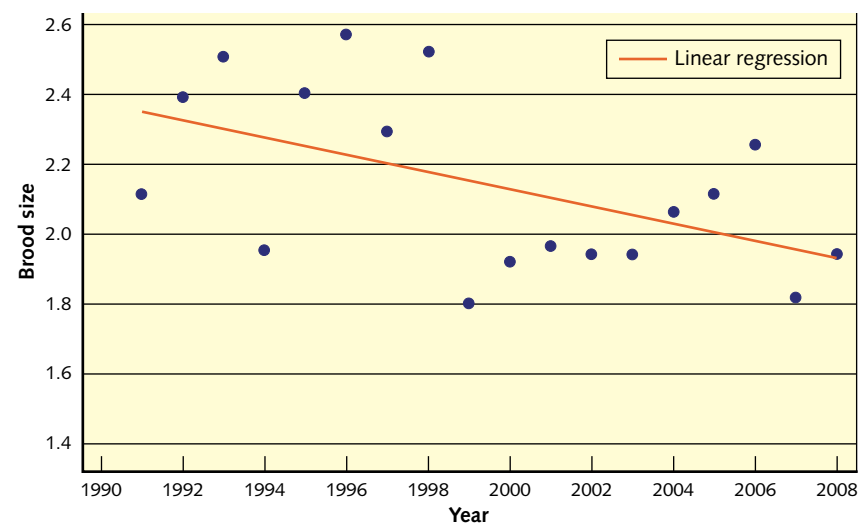


Figure 25. Brandt's cormorant reproductive success, San Francisco Bay

