SUMMARY

THE ROLE OF WATER DIVERSIONS IN THE DECLINE OF FISHERIES OF THE DELTA-SAN FRANCISCO BAY AND OTHER ESTUARIES*

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(with Preface by Joel W. Hedgpeth)

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SUMMARY, CONCLUSIONS & RECOMMENDATIONS

Estuaries, the meeting places of fresh and salt water, are among the world's most important natural habitats. Throughout history such areas have been critically significant because they provide fishing, transportation and recreation, as well as fresh water for drinking, power, irrigation, and waste disposal dilution.

Today, over half the people in the world live within 125 miles of a coast. Eighty percent of the global and 70-80% of the U.S. fish and shellfish catch come from areas influenced by fresh water and nutrient inflow from streams, rivers and estuaries. Many thousands of tons of salmon and other anadromous fishes caught each year migrated long distances from the ocean to their home rivers to spawn.

Published results regarding water development in rivers entering the Black Sea, the Sea of Azov, Caspian and Mediterranean Seas in Europe and Asia all point to the conclusion that when successive spring and annual water withdrawals exceeded 30% and more than 40-50% of the normal unimpaired flow respectively, (computed as the average for 50-60 years of observations), water quality and fishery resources in the river-delta-estuary-coastal zone (ocean) ecosystem deteriorated to levels which overrode the ability of the system to restore itself.

Commercial and recreational catches of Russian sturgeon, pike-perch, brim, mackerel, sprat, etc. have been extinguished in the Dniester and Dnieper Estuaries and the most productive Western part of the Black Sea since the late 1960's.

In the Sea of Azov (once the most productive sea in the World), the commercial catch of Russian sturgeon, as well as numerous other valuable semi-anadromous and anadromous fish, dropped from hundreds of thousands to several thousand tons over the last two decades of runoff regulation. (Their requirements for sufficient quantity and quality of water during migration and spawning are almost the same as for the Chinook salmon, striped bass and shad in the San Francisco Bay Area.) The same phenomena were observed in the Caspian Sea as well as with the commercial catch of Salmon in Northern Europe.

In the Nile Delta-Mediterranean Sea coastal zone, the coastal commercial catch of Sardinnela and other species that are dependent on runoff have dropped from more than one hundred thousand tons in the 1950's to several thousand tons since the Aswan Dam operation (1964).

The commercial catch of striped bass in the Chesapeake Bay region has declined up to 70% due to water regulation and pollution. The same percentage decline of fish and shellfish has been observed in the Delaware Bay and the Texas lagoons.

The impoundment of the Murray-Darling River system in Australia and construction of the salt barrier in its Delta has eliminated the fisheries in this area since the 1940's.

Comparable studies and many publications have reached similar conclusions; namely, despite reproductive cycles and behavioral and physiological differences among the estuarine fish species, historic catch levels for each appear to reflect underlying relationships which require specific volumes of runoff discharges, particularly in late winter and spring.

Under natural conditions approximately 60%-70% of the flow takes place during this period, and this flow is responsible for:

1) Repelling the intrusion of sea water into the Delta;

2) Providing necessary levels of nutrients (organic and inorganic materials, phosphate, silicates, nitrogen, etc.);

3) Producing flow conditions necessary for anadromous fish migration, spawning and rearing;

4) Creating a large entrapment zone which optimizes survival of fry and the food on which they feed;

5) Providing flushing and mixing flows to maintain water quality conditions (dissolved oxygen and temperature throughout the water column); and

6) Entraining large amounts of salty water as it flows through the estuary to the ocean, creating a dynamic salinity equilibrium within the system.

Although all of these conditions play important roles in the hatching and development of fish of a given year class, <u>it is extremely important to note that the state of the estuary during this period is heavily influenced by past runoff conditions as well</u>.

Despite the more than $2 billion spent over the past twenty-five years on the evaluation and management of <u>the Delta-San Francisco Bay ecosystem</u>, the basic understanding necessary to preserve its health has not been achieved. Without a clear picture of the complex factors that influence the Delta and Bay living resources and water quality, management decisions have been unable to reverse the decline of resources.

The research program of the Romberg Tiburon Center over the past three years was designed to (1) provide in-depth evaluation of freshwater inflow to the Delta and Bay, (2) assess the manner in which flow has been modified since the early part of this century (especially during the period following the completion of the major components of the Central Valley Project (CVP) and State Water Project (SWP)), and (3) assess the impacts of flow modification on the fishery resources of the system.

Purpose

The purpose of this report is to utilize the results of the previous investigation on the modification of freshwater flow to the Delta and Bay (Rozengurt et al., 1987a) to analyze the relationship between flow and commercial and recreational fish catches.

Methods

Our analysis was performed in two stages:

1) Annual commercial landings of salmon, striped bass and shad (mainly data for the pre-project period) were compared with spring and annual flows several years earlier. (The use of this procedure is based on the premise that flow has the greatest impact during the first seasons of an organism's life. This technique has been successfully used to show high correlations between flow during egg and larval stages and lobster catches as

long as 8-9 years later, as well as with shorter lag times for fish species generally landed 2-4 years after spawning.) Correlations between fish catch and the annual and seasonal flow conditions for a number of years preceding a given year's catch were calculated in order to examine cumulative effects of flow on fish from year of hatch to year of catch (3-5 years later).

2) The relationships between salmon fall run, Striped Bass Index of abundance and recreational catches (for the post-project period) vs. runoff were also examined with the same technique.

Findings

Modification of Freshwater Flow Conditions

As result of construction of the sophisticated CVP and SWP water storage facilities (with an accumulation capacity equal to 71% of normal unimpaired runoff) and conveyance systems into and out of the Delta (15-20% of the normal Delta outflow), the post-project period natural water supply to the Delta-San Francisco Bay estuarine system has been reduced to unprecedented levels:

1. Since 1967, absolute values of total diversions with predominant range of 10-12 MAF per year (with maximum values of 14-21 MAF) are 2.8 - 3.2 times (and up to 3-5 times) higher than before the CVP and SWP were completed (pre-project period 1915-1943). (Fig. 3-2)

2. The absolute values of predominant upstream diversion of 6-12 MAF for the post-project period, 1944-1984, are 3-5 times higher than for 1915-1943.

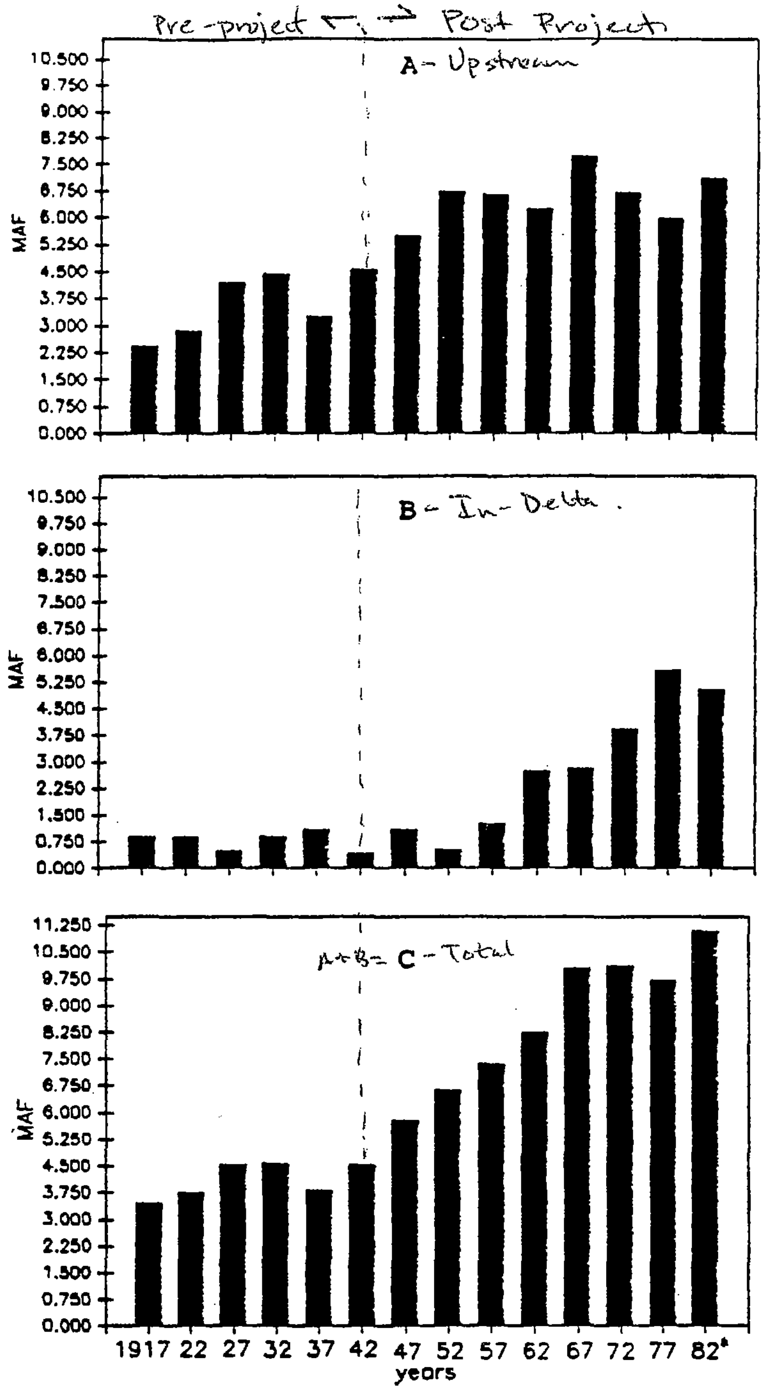


Fig. 3-2 The mean annual volume of water diverted for 5-year periods from the Sacramento-San Joaquin River basin during pre-project (1915-1943) and post-project (1943-1983) periods: A) Upstream, B) Inner Delta, C) Total Diversions. The years marked are the pivotal years of the period, e.g., 1917 = 1915-1919. (* = 4-year period)

Absolute values of downstream diversions (Delta consumptive use and export) were in some years, e.g., 1975, of the same magnitude as the upstream diversion, a phenomenon never observed in the pre-project period. The predominant range of annual Delta diversions since 1967 was 4-5 MAF. These values are almost 5 times higher than Delta water withdrawals before the projects were completed.

3. The major cause of these persistent decreases in annual runoff is that diversions in winter (primarily upstream) range between 15 and 45% and in spring (upstream and downstream) between 30 and 80% or more of the natural water supply of the Sacramento-San Joaquin River-Delta subsystem.

4. Since the projects' (CVP and SWP) operations began (especially from the late 60's on), winter and spring regulated water supply to the system was reduced 1.2-1.4 and 1.6-2.4 times in comparison with unimpaired mean winter and spring water supply to the Delta-Bay system, respectively, for 5-year periods (prevailing range of unimpaired runoff is equal to 3-4 MAF). Therefore, for the period 1967-1984, residual winter and, especially spring Delta outflow in the majority of cases corresponded to subnormal and below subnormal wetness when compared with statistics for unimpaired runoff. (Fig. 3-10)

5. Between 1944 and 1983, the upstream, downstream and total cumulative losses due to diversions reached 262, 104 and 366 MAF respectively. Cumulative upstream and downstream water losses amounted to 202 and 80 times, respectively, the volume of the Delta (1.3 MAF) while the total diversions account for 61 times the volume of the San Francisco Bay (6 MAF).

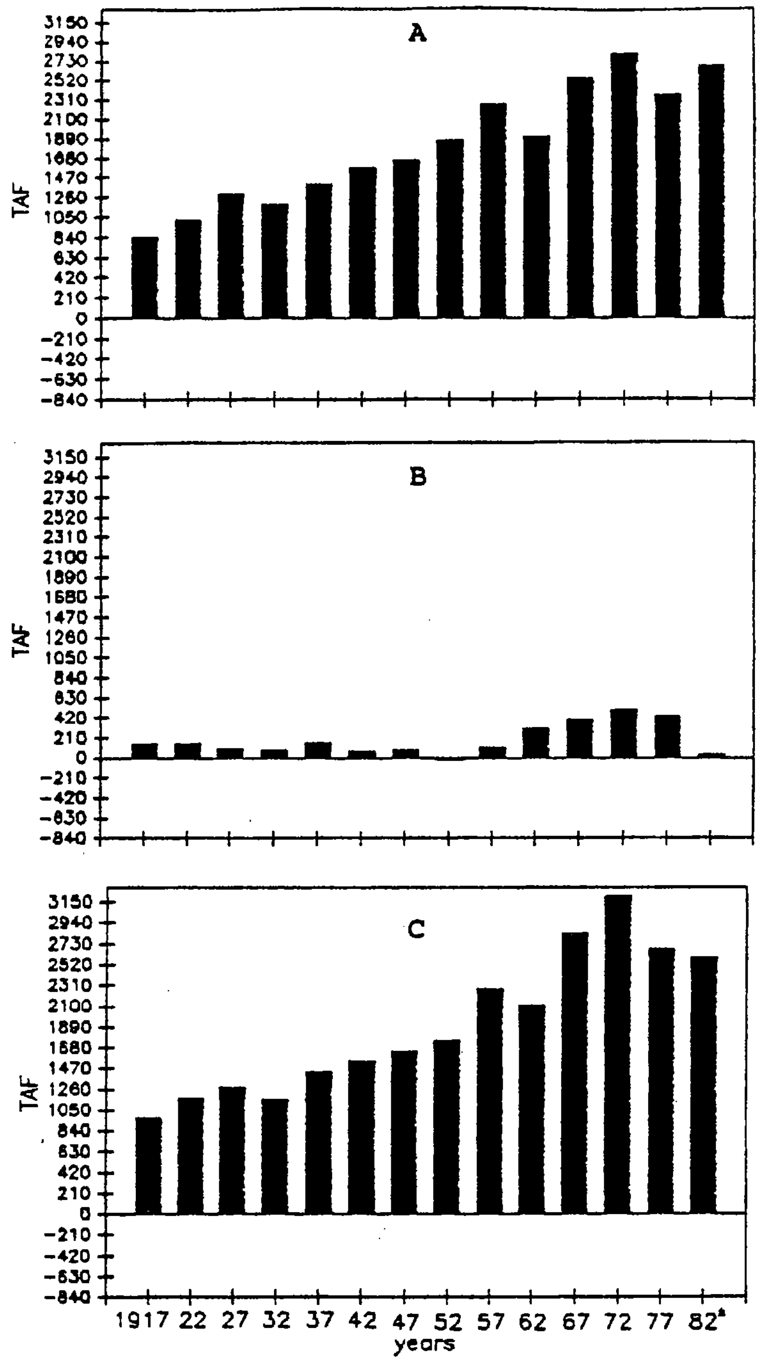


Fig. 3-10 The mean volume of water diverted for 5-year periods from the Sacramento-San Joaquin River basin during pre-project (1915-1943) and post-project (1943-1983) periods: A) Upstream, B) Inner Delta, C) Total Diversions, for the month of May. Negative diversions represent returning water from storage facilities and agricultural drainage network. The years marked are the pivotal years of the period, e.g., 1917 = 1915-1919. (* = 4-year period)

6. Analysis indicates that for the majority of 5-year periods, the mean regulated runoff is much less than normal, and has been replaced by volumes corresponding to subnormal and dry conditions. This water supply is 35-55% less than the natural mean Delta outflow (27.2 MAF).

It should by emphasized that the above-mentioned losses in water supply sustained by the river-Delta-San Francisco Bay ecosystem infer concomitant losses, in millions of tons, of the organic and inorganic matter required to provide adequate ecological conditions for living resources. Moreover, the chronic freshwater deficit may result, as it was documented for the San Francisco Bay and many other estuaries throughout the world, in unfavorable changes in circulation patterns, mixing processes, salinity and other regime characteristics.

7. Based on the experiences of 1924 and 1976-77, it should be emphasized that under natural conditions, annual and spring residual runoff to San Francisco Bay of 3-5 MAF and <1.5 MAF, respectively, would occur only very rarely (once per 100 or more years). If such extreme conditions occur on a regular basis, the Delta-Bay system will cease to function as an estuary and ultimately Delta agriculture, the fresh water quality (for drinking and irrigation), and the estuarine living resources will severely deteriorate.

8. Current decisions (including D-1485) regarding water distribution in California are based on a water year-type classification system (the Four-River Index) which excludes 25% of the Sacramento-San Joaquin river watershed. As a result, the normal (long-term mean) Four-River Index runoff ($\bar{Q}$ = 17.2 MAF;

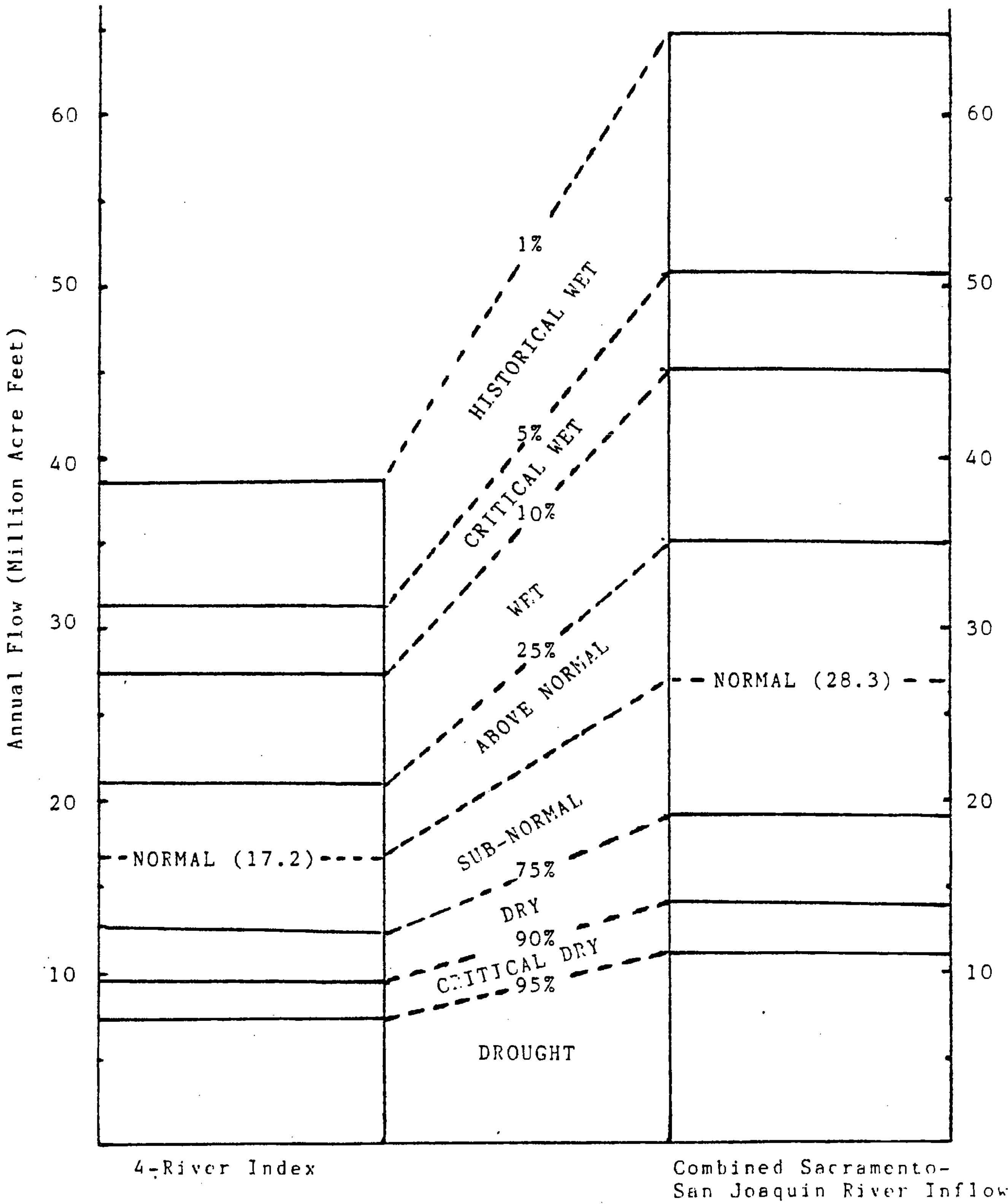
1921-1978) accounts for only 61% of the normal Sacramento-San Joaquin River inflow to the Delta originating from 100% of the basin area ($\bar{Q}$ = 28.2 MAF; 1921-1978). Therefore, evaluation of wetness of the year, residual runoff and consequent planning for water diversions, based on the Four-River Index, overestimate the level of water availability in a manner incompatible with the relatively meager natural levels of runoff. It follows that in normal, and especially in sub-normal and dry years , the Four-River Index classification system influences decision-makers towards permitting higher (and potentially damaging) levels of diversions.

Recommendations: Runoff

We strongly recommend (as in our previous report, Rozengurt, Herz & Feld, 1987a) that the SWRCB discontinue the use of the Four River Index classification system and substitute it with a system which utilizes flow from the entire watershed for the determination of natural seasonal and annual wetness type, and subsequently, volumes of water available for diversion and correspondance of residual flows to natural flow statistics (i.e., water year-type). Only if total outflow is used as the basis for classification will it be possible to provide the flows needed to protect and maintain the fish and other resources of the Delta-San Francisco Bay system (Fig.3-1).

In our opinion, the recommendations contained in Decision 1485 (based on the Four River Index system) have resulted in spring flow levels that are unprecedented in the recorded history of the system (frequency of occurrence less than once per 100

Fig. 3-1
Comparison of Combined Sacramento-San Joaquin River Inflow and 4-River Index Water Year-Type Classification Systems. (% = probability of occurence)



years). The excessive spring water withdrawals, compounded by the late winter water diversions, have significantly reduced annual river and Delta discharges and contributed greatly to the deterioration of the resources of the system during the past decade.

Modification of landings

Chinook salmon (*Oncorhynchus tshawytscha*)

Between 1874 and 1914, commercial salmon catches in the Bay and Delta ranged from 2-11 million pounds per year (average = 6), and from 0.3 - 6 million pounds (average = 2) from 1915-1957 (when commercial fishing became restricted to the ocean). Since this span of time encompasses the pre-project and the beginning of post-project periods in water development, it affords an opportunity to assess the relationship between flow and salmon landings by examining catch/flow correlations.

1. For the 1916-1931 period, commercial salmon catch was highly correlated with annual mean regulated Delta outflow for the 5 years preceding (RDO_5) the year of catch ($r = 0.86$; $p<0.01$), indicating that the volume of annual flow (19-23 MAF) during the years between spawn and maturity influenced catch success. Similar results, but with a slightly lower correlation, were obtained for the 1944-1957 period.

2. Correlations between spring flows and salmon catch, especially during the 1916-1930 period, indicated that even stronger relationships existed between mean regulated spring (April+May+June/3) flows and commercial landings lagged by 3-5

years of the spring runoff (r's = 0.80-0.97; $p < 0.05$). Successful catches resulted when spring flows averaged 2.5-4 MAF (or 42,014-67,222 cfs or 1,189-1,903 m^3/sec). (Fig. 5-9)

3. The number of fall-run salmon returning to spawn at Red Bluff (Sacramento River) also demonstrated reasonable correlation with annual and spring runoff for the years preceding the migration of a given year class and subsequent influence of high volumes of runoff on spawning success and survival.

Successful migration appears to require spring flows of 2.3-2.8 MAF (or 38,653-47,056 cfs or 1,094-1,332 m^3/sec).

In this case the total regulated spring Delta outflows of 6.9-8.4 MAF correspond to 40.6% and 44.2% of mean RDO of 17-19 MAF for several preceding years, respectively. (Here, as further in our discussion, the above-mentioned spring and annual volumes of RDO represent the statistics for years of subnormal wetness, e.g., 75-80% of probability of exceedence or recurrence interval of 4-5 years under conditions of unimpaired runoff.)

Striped bass (Loccus saxatilis)

1. Between 1889 and 1935 (when commercial fishing was banned), striped bass catches ranged from 0.5 and 1.4 million pounds. Populations have declined since that time and the recreational catch, which totaled approximately 60,000 fish per year in the early 1960s, dropped to 1,400 fish in 1980. The total Striped Bass Index of abundance has declined from a maximum of 117 in 1965 to a low of 6.5 in 1985.

2. Correlations between commercial striped bass catch and mean annual regulated flow for the 5 preceding years indicated a

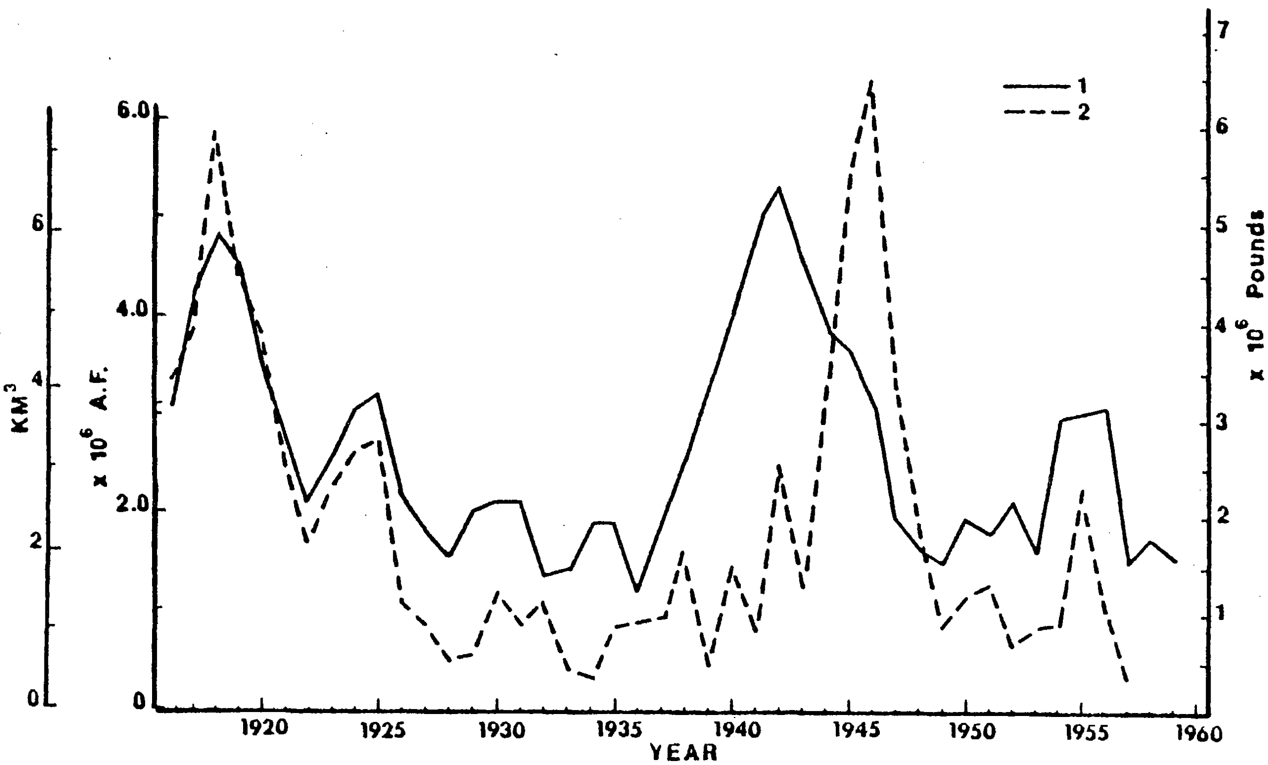


Fig 5-9 Relationship between (1) regulated Delta outflow for three moving months (April-May-June) and (2) commercial salmon catch in the Sacramento and San Joaquin Rivers. The salmon catch is based on a lag outflow period of 2 years; e.g., salmon catch for 1916 is based on outflow for 1912-14.

good association for the periods 1918-1929 and 1916-1935 (r's= 0.70 and 0.79; p<0.01) while for spring, mean flow for 3 years (5 years before catch) showed slightly lower correlations (r's= 0.67 and 0.65; p <0.01) for the same periods.

3. These results indicate that optimal averaged commercial catches of striped bass (0.5 to 0.6 million pounds per year) were observed when average spring flows (April+May+June/3) for the preceding 3-5 years (lagged by 2-3 years) were in the range of 2.3-3.4 MAF, (38,653-57,139 cfs or 1,082-1,412 m^3/sec) and total spring RDO averaged between 6.9-10.2 MAF (or 38.3% and 46.4%, respectively, of mean annual regulated Delta outflow (RDO) of 18-22 MAF for 3-5 years prior to the year of catch) despite many regulations.

4. Correlations between recreational catch of striped bass and mean spring (April+May+June/3) and annual RDO for the preceding years (lagged by 3 years) illustrate that optimal recreational catch correspond to 2.0-3.0 MAF (i.e., total spring RDO of 6.0-9.0 MAF, or 35.3% and 42.9% of mean annual RDO of 17-21 MAF, respectively).

5. For the 1967-1981 period, correlations between the Striped Bass Index of abundance and 5-year running mean annual regulated Delta outflow yielded one of the highest correlations (r = 0.97; p<0.05), indicating that knowledge of the average flow conditions for 5 running years is a good predictor of Striped Bass Index level and therefore, abundance of fish suitable for recreational catch. These analyses indicate that five years of average annual regulated Delta outflow (RDO_5) of 15 MAF will be

followed by marginal bass abundance, while 18-21 MAF for 5 years will be followed by optimal bass populations.

6. Average spring (April+May+June/3) RDO_5 also were highly correlated with the Striped Bass Index for the 1959-1981 period ($r = 0.82$; $p<0.05$). As with annual flow, the results indicate that 3-5 years with average spring flows of 2-2.5 MAF (33,611-42,014 cfs or 951-1,189 m^3/sec) will result in optimal populations (total spring Delta outflows of 6.0-7.5 MAF correspond to 33.3-35.7% of mean annual Delta outflows for 3-5 years).

American Shad (Alosa sapidissima)

1. Between 1916 and 1957 (when commercial fishing was prohibited), landings ranged between 113,000 (1941) and 5.7 million pounds (1916). Correlations for the 1916-1931 period (when level of effort and techniques were relatively constant), indicate that average annual and spring regulated flows for the previous 3-4 years correlated quite well with the commercial shad catch ($r = 0.88$; $p<0.05$ for annual and $r = 0.89$, $p<0.05$ for spring flows).

2. During 1916-1931, landings of 1.5-2 million pounds followed 3- and 5-year periods with average spring Delta outflows of 2.5-3.5 MAF (42,014-58,819 cfs or 1,176-1,665 m^3/sec), i.e., for those periods total spring outflows of 7.5-10.5 MAF correspond to 41.7 and 42.0% of the mean annual flows of 8-25 MAF.

Conclusions

1. The similarities in the correlations between seasonal and annual regulated Delta outflow for the three species of anadromous fish suggest that a specific range of mean flows during consecutive springs, as well as consecutive years, have both a predictable effect on reproduction, recruitment in stock and catch success, and thereby supports the argument that there are cumulative effects of flow on fish (and perhaps on other species as well) in this and other estuaries.

2. In sum, for all three of the most valuable species of anadromous fish of the San Francisco Bay ecosystem (Chinook salmon, striped bass and American shad), the highest correlations between commercial catch and average spring and annual regulated outflows of the pre-project period of 1915-1943 (characterized by predominant upstream diversion) were obtained for catch of a given year against seasonal and annual regulated Delta outflow averaged for the preceding 3-5 years (RDO_3RDO_5).

3. As a rule, the mean spring RDO of 2.3-3.5 MAF (38,653-58,819 cfs or 1,082-1,665 m^3/sec), which correspond to 64-97% of the normal (unimpaired) spring Delta outflow of 3.6 MAF (for 1921-1978), provided the optimal commercial catch.

Under these conditions the prevailing range of annual averaged regulated Delta outflow was equal to 19-22 MAF (or 70-81% of the normal unimpaired Delta outflow = 27.2 MAF for the period of 1921-1978).

4. The highest correlations between production indices (salmon fall run and SBI), as well as striped bass recreational catch, and averaged spring and annual regulated Delta outflow for

several consecutive years of the post-project period of 1944-1985 may indicate that the range of 3- and 5-year running mean spring of 2.3-2.5 MAF (38,655-42,014 cfs) was able to maintain relatively tolerant ecological conditions for eggs, larvae and juvenile survival up to 1975. That is, total spring and annual RDO for the 3-5 years preceding the year of catch or index were 6.9-7.5 MAF and 17-19 MAF, respectively. (These ranges of spring and annual $RDO_{3,5}$ correspond to 64-70% and 62-70% of their normals, 3.6 and 27.2 MAF, respectively.)

When the gradual reduction of water supply exceeded these thresholds and reached mean spring and annual regulated volumes of 1.0-1.5 MAF and 11-15 MAF, respectively (or 27-40% and 40-45% of their normals), the signs of deterioration of environment of the riverine-estuarine system and its living resources became obvious.

It seems likely that the average spring water supply for several consecutive years contributes significantly to the adequate ecological conditions for eggs, larvae and juvenile survival. Therefore it is not surprising that these cumulative average regulated Delta outflows (with concomitant influence on nutrient level, salinity, temperature, dissolved oxygen, etc.) affect the overall estuarine environment and, as a result, the reproductive success of fish.

However, the predominant ranges of mean annual and spring water supply to the Bay for the 3- and 5-year periods were 1.5-2.5 times less (annual) and 2.5-3.5 times less (spring) than their normal levels for the last 10-15 years.

In our opinion, this, in combination with less visible man-induced factors, has resulted in a 19- and 60-fold reduction of SBI and salmon fall run between 1959-1985, respectively, as well as in the overall drastic decline of recreational catch of striped bass, recreational and commercial catch of salmon, shad, and steelhead trout in the Sacramento-San Joaquin river-Delta-Bay-coastal zone ecosystem.

The total economic losses due to declines in catch (between 1965-1986) of striped bass and salmon account for 1.6 billion dollars, or 2.6 billion dollars, if steelhead trout decline is taken into consideration (Meyer Resources, 1985; T. Beuttler, presentation at "Fish and Wildlife in the Bay-Delta Estuary" SWRCB Conference #4, 1986).

5. These and other similar historical examples of the relation between human needs for freshwater and protection of estuarine environments indicate that special consideration should be given to the consequences of timing and volume of spring and annual water withdrawals on recruitment and landings of anadromous fish because of their known sensitive response to cumulative fluctuations in freshwater supply. It may be possible to alleviate these problems and to protect water intakes in the Delta if limits to water diversion can be agreed upon, perhaps through the establishment of salinity and flow standards for San Francisco Bay (neither of which currently exist).

Recommendations

Based on this evaluation of modifications in regulated flows and their impacts on salmon, striped bass and shad populations and catches in the Delta and San Francisco Bay, we propose the following criteria for mean spring and annual regulated Delta outflows which must be maintained for periods of at least 2-3 consecutive years to ensure adequate water quality, seasonal displacement of the entrapment zone and optimal conditions for fish migration and spawning, as well as for juvenile survival and success in recreational and even commercial catch in the Delta-San Francisco Bay coastal zone ecosystem (Fig. 8-1, 8-2.; Table 8-1):

A. Total spring regulated Delta outflow = 6.9-7.5 MAF or mean spring (April+May+June/3) flows of at least 2.3-2.5 MAF (64.1-69.6% of the normal spring delta outflow, $\bar{Q}$ = 3.59 MAF) or 38,653-42,014 cfs.

B. Total annual regulated Delta outflows no less than 17-19 MAF (62.5-69.8% of the $\bar{Q}$ = 27.2 MAF).

Table 8-1 summarizes our recommendations for water standards and criteria to safeguard fisheries resources, based on our findings.

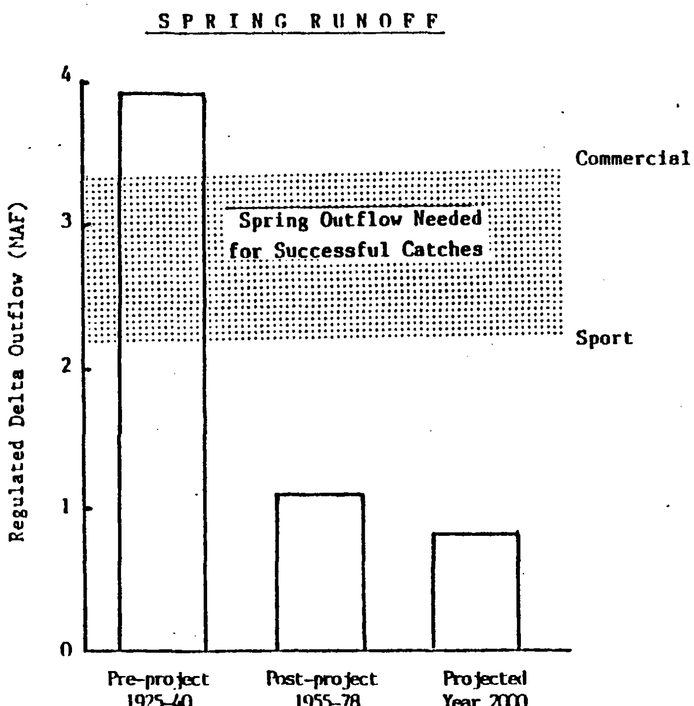


Figure 8-1
Pre-project (1925-40), post-project (1955-78) and projected (year 2000) spring regulated Delta outflow compared with outflow levels needed for successful commercial and sport fish catches (based on correlations between flow and catch for the 1915-40 period).

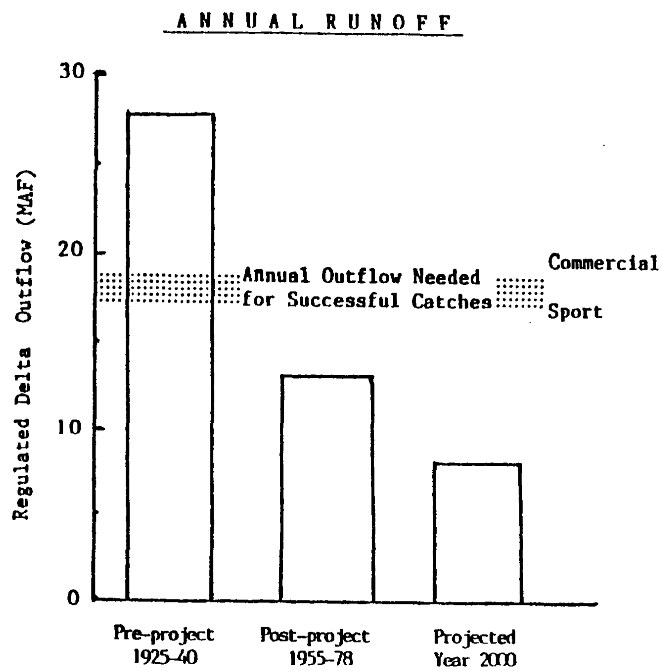


Figure 8-2
Pre-project (1925-40), post-project (1955-78) and projected (year 2000) annual regulated Delta outflow compared with outflow levels needed for successful commercial and sport fish catches (based on correlations between flow and catch for the 1915-40 period).

Table 8-1 Regulated Delta outflow and living resources of the river-Delta-San Francisco Bay ecosystem: pre- and post project observed values and recommendations*

Pre-Project Period - Observed Values:

Parameter\Fish	Commercial Catch		
	Salmon	Striped Bass	Shad
Total Spring Regulated Delta Outflow (RDO):			
MAF	7.5-12.0	6.9-10.2	7.5-10.5
(km^3)	(9.2-14.8)	(8.5-12.6)	(9.2-13.0)
Mean Spring RDO:			
MAF	2.5-4.0	2.3-3.4	2.5-3.5
cfs	42,014-67,222	38,653-57,139	42,014-58,819
(km^3)	(3.1-4.9)	(2.8-4.2)	(3.1-4.3)
(m^3/sec)	(1,189-1,904)	(1,094-1,618)	(1,189-1,666)
Annual RDO:			
MAF	19.0-23.0	18.0-22.0	18.0-25.0
(km^3)	(23.4-28.4)	(22.2-27.1)	(22.2-30.8)

-------------------- All 3 Species --------------------

Parameter	All 3 Species
Total Spring RDO:	
MAF	6.9-12.0
(km^3)	(8.5-14.8)
Mean Spring RDO:	
MAF	2.3-4.0
cfs	38,653-67,222
(km^3)	(2.8-4.9)
(m^3/sec)	(1,094-1,904)
Annual RDO:	
MAF	18.0-25.0
(km^3)	(22.2-30.8)

Table 8-1 continued

Post-Project Period - Observed Values:

Parameter\Fish	Salmon Fall Run	Striped Bass Index	Striped Bass Recreational Catch
Total Spring Regulated Delta Outflow (RDO):			
MAF	6.9-8.9	6.0-7.5	6.0-9.0
(km^3)	(8.5-11.0)	(7.4-9.2)	(7.4-11.1)
Mean Spring RDO:			
MAF	2.3-2.8	2.0-2.5	2.0-3.0
cfs	38,653-47,056	33,611-42,014	33,611-50,417
(km^3)	(2.8-3.4)	(2.5-3.1)	(2.5-3.7)
(m^3/sec)	(1,094-1,332)	(952-1,189)	(952-1,428)
Annual RDO:			
MAF	17.0-19.0	18.0-21.0	17.0-21.0
(km^3)	(21.0-23.4)	(22.2-25.9)	(21.0-25.9)

Recommendations for all 3 species:
Recreational and Limited Commercial Catch

Total Spring RDO:	
MAF	6.9-7.5
(km^3)	(8.5-9.2)
Mean Spring RDO:	
MAF	2.3-2.5
cfs	38,653-42,014
(km^3)	(2.8-3.1)
(m^3/sec)	(1,094-1,189)
Annual RDO:	
MAF	17-21
(km^3)	(21.0-25.9)

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* Note:

The recommended total spring RDO for several years prior to migration and spawning of anadromous fish accounts for 63.9-69.4% of the normal spring Delta outflow of 10.8 MAF. The recommended total annual RDO accounts for 62.5-69.8% of the normal annual Delta outflow of 27.2 MAF. In this case, total

Table 8-1 continued

winter RDO of 8.5-9.5 MAF will account for 61.5-68.7% of the normal winter Delta outflow of 13.8 MAF; the total summer-autumn RDO of 1.6-2.0 MAF will account for 62.0-77.5% of the normal summer-autumn Delta outflow of 2.6 MAF.

The monthly redistribution of regulated outflows may differ from the seasonal averages (especially for winter and spring) provided that their volumes are able to maintain optimal balanced water quality conditions for the different water users.

Because, in our investigation, fish landings and indices are indicators of the health of the environment, the 3- and 5-year running mean RDO are assumed to be responsible for providing optimal conditions for:

- Landward migration, spawning and rearing,
- Seaward migration of juvenile fish,
- Physical, chemical and biological parameters of the entrapment zone (including nutrient supply) as well as its ultimate - spatio-temporal dynamics within the Suisun Bay - Carquinez Strait area,
- Adjustment of juvenile to salinity fluctuations in transition zones of the Delta-Suisun Bay subsystem,
- Water quality in the Delta suitable for different water users,
- Flushing intensity necessary to maintain adequate water quality in the esuarine system.

The recommended optimal range of Delta outflow discharges do not preclude the possibility of additional man-regulated releases, provided these releases will not result in the destabilization of the Delta levees (which have adjusted to impaired runoff and sediment load over the last forty years) or in the development of "shock" conditions for eggs, larvae and juvenile fish.

CONVERSIONS:

Cubic feet per second (cfs) x .028317 = cubic meters per second (m^3/sec)

Acre feet x 1.233 x 10^{-6} = cubic kilometers (km^3)

In our view, any statement published in the past claiming that it is possible to restore a historical level of fish population should be considered erroneous.

The restoration of historical fish levels would only be possible if historical levels of unimpaired runoff discharges, by season and year, as well as historical migration routes of spawning fish and their habitats were also restored.

Moreover, based on worldwide experience, as well as on the development of commercial and recreational fisheries on the Delta-San Francisco Bay ecosystem, future success in fish landings will depend upon the amount of water discharged into the estuarine system especially in the late winter-spring, rather than on the production of hatcheries. Hatcheries may create the illusion of preventing the extinction of a species but cannot restore the historical level of natural fish populations.

Therefore, only economically and ecologically balanced water management can adequately guard the interests of the estuarine environment and its water users. We cannot restore but we can preserve.

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(This study follows our previous technical report, "Analysis of the Influence of Water Withdrawals on Runoff to the Delta-San Francisco Bay Ecosystem (1921-83)," as part of a series on the impact of water regulation on estuarine resources.)