Reference No. 5

DRAFT

EVALUATION OF POTENTIAL EFFECTS OF THE PROPOSED EPA SALINITY STANDARD ON THE BIOLOGICAL RESOURCES OF THE SAN FRANCISCO BAY/SACRAMENTO-SAN JOAQUIN ESTUARY

Prepared for

The California Urban Water Agencies
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By

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NOTICE

This draft report was prepared as a technical document for reference use by California Urban Water Agencies and others in preparing their comments to the US Environmental Protection agency on "Water Quality Standards for Surface Waters of the Sacramento River, San Joaquin River, and San Francisco Bay and Delta of the State of California, January 6, 1994." This draft technical report is not part of the CUWA formal comment to EPA.

EXECUTIVE SUMMARY

The overall objective of the Environmental Protection Agency (EPA) salinity standard is to protect the estuarine resources found in the upper portion of the Sacramento-San Joaquin Estuary. The salinity standard relies on the relative position of the 2 ppt isohaline within the upper estuary as a means to promote the overall health of the estuarine community. While several species of estuarine organisms will likely benefit with the implementation of the currently proposed EPA salinity standard (X2), the potential exists for unanticipated effects on other aquatic resources of the estuary.

This assessment was conducted with the purpose of determining the potential biological impacts (either positive or negative) that might be expected with the implementation of the X2 standard. A broad compliment of freshwater, marine, and estuarine species were selected for impact analysis to allow for a holistic assessment of potential impacts across the entire estuarine community. Life history information and life-stage specific salinity tolerance requirements were compiled to determine species that may potentially be impacted by the X2 standard. This analysis was designed to:

- Determine the spatial and temporal distribution patterns for a variety of estuarine organisms utilizing the upper estuary based upon a review of life history information and a review of California Department of Fish and Game catch records;
- Identify ranges for the 5, 10 , 15, 20, and 25 ppt isohalines when X2 is located at each of the EPA criteria locations (the confluence of the Sacramento and San Joaquin Rivers, Chipps Island, and Roe Island);
- Complete an assessment of the total linear amount and the relative change in suitable habitat for each species and life-stage under each of the EPA assigned X2 locations and use this information to serve as an indicator of the species and life-stages that may potentially be impacted by the standard.

This report details the results of this analysis including an identification of species and life stages that may be potentially impacted either beneficially or adversely under each of the three proposed X2 locations and a discussion of community level changes that might be expected with implementation of the standard.

At each X2 location, certain species benefit while others are adversely impacted. The results of this assessment indicate that gross changes in community composition as well as intensified species interactions may be expected with the implementation of the proposed standard. This assessment indicates that the number of species potentially affected is greatest when X2 is located at Roe Island. The results of the analysis further indicate that the number of potentially adversely impacted species is greatest when X2 is at Roe Island. In addition, while certain species (i.e., Delta smelt) may benefit when X2 is positioned downstream (at Chipps or Roe Island) competitive interactions with other benefitting species (i.e., Inland silverside) may be exacerbated to the detriment of either or both species.

This assessment points to the need for a broad ecological perspective when considering the potential biological implications related to the implementation of the X2 standard, and that the EPA standard, as proposed, has not fully considered the biological implications that may result from its implementation.

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1.0 INTRODUCTION

The implementation of the EPA salinity standard to benefit a particular group of aquatic fish and invertebrate species could have unanticipated effects on other aquatic resources of the Sacramento-San Joaquin Estuary. Identification and evaluation of such positive or negative effects relies on a thorough understanding of the life history requirements of all or most of the species found in the system. A relatively simple procedure was developed to consider appropriate life history requirements and provide a preliminary list of species and corresponding life history stages that could either be potentially at risk or could benefit from implementation of the salinity standard. The procedure consisted of a comparison of biological salinity requirements, physical salinity distributions, and known distributions of a large number of fish and aquatic invertebrate species over the year. Specific locations of X2 would be expected to be associated with a range of salinity gradients depending on delta outflows, tides, and other mixing processes. Consequently, habitat availability would be expected to vary for each species with particular salinity tolerance ranges. By matching general species distributions, salinity tolerances, and salinity gradients, it should be possible to identify species and life history stages for which habitat amounts could be affected.

For this simplified evaluation, habitat was quantified based purely on the longitudinal distribution of suitable salinity waters for each species. The effects of habitat depth, area, and volume were not considered nor was food availability. Thus, this evaluation is merely an initial step in a habitat based approach to understanding the potential impacts of the X2 standards on all of the aquatic resources in the Bay-Delta system.

2.0 METHODS

The flowchart that is presented in Figure 2-1 outlines the basic steps that were taken in completing this impact assessment. These steps are described in detail in the remainder of this section.

2.1 SELECTION OF SPECIES

Species were selected from each of a variety of ecological niches occurring in the Sacramento-San Joaquin estuary. A broad complement of species was selected with the goal of representing the entire estuarine ecological community. The selection process included fresh, brackish, and salt water inhabitants, anadromous and resident species, benthic and pelagic dwellers, and species with broad diet differences. Considerations were made for the availability of life cycle, distribution, and salinity tolerance information. Databases maintained by the California Department of Fish and Game (CDFG) (fall mid-water trawl and summer tow net surveys) were assessed for species known to occur in the estuary system. Less emphasis was placed on invertebrate species because of the limited amounts of detailed information that was available in the literature. In all, thirty-nine fish species and two invertebrate species were selected for evaluation (Table 2-1).

2.2 SPECIES PERIODICITY AND DISTRIBUTION

Spatial and temporal distribution patterns of fish and invertebrate species were used to represent life history habitat distributions. A comprehensive analysis was completed in which information on life cycles, habitat requirements, and spatial and temporal distributions was compiled and interpreted. The CDFG is presently completing a similar evaluation that, when released, should be reviewed to supplement the information presented here.

Concise life history summaries were written for each species that detailed how and when each species uses the estuary, and the specific habitat types that are utilized. The summaries included specific life history requirements that were thought to be related directly to estuarine population distributions. Sources of information included both published and unpublished (gray) scientific literature. Research summary reports generated by the Interagency Ecological Studies Program were of particular utility in the compilation of the life history summaries. Table 2-2 presents a listing of references used and cited in the compilation of species life history summaries. Literature sources were reviewed for specific mentions of occurrences, general salinity tolerance ranges, optimal salinity ranges, habitat requirements,

Table 2-1. List of fish species used in the species periodicity/distribution analysis.

Common Name	Family Name	Species Name
Leopard shark	Carcharinidae	Triakis semifasciata (Girard)
Green sturgeon	Acipenseridae	Acipenser medirostris (Ayres)
White sturgeon	Acipenseridae	Acipenser transmontanus (Richardson)
American shad	Clupeidae	Alosa sapidissima (Wilson)
Pacific herring	Clupeidae	Clupea harengus pallasi (Valenciennes)
Threadfin shad	Clupeidae	Dorosoma petenense (Gunther)
Northern anchovy	Engraulididae	Engraulis mordax (Girard)
Chinook salmon	Salmonidae	Oncorhynchus tshawytscha (Walbaum)
Rainbow trout	Salmonidae	Oncorhynchus mykiss
Delta smelt	Osmeridae	Hypomesus transpacificus (McAllister)
Longfin smelt	Osmeridae	Spirinchus thaleichthys (Ayres)
Hitch	Cyprinidae	Lavinia exilicauda (Baird and Girard)
Splittail	Cyprinidae	[illegible]s (Ayres)
Sacramento squawfish	Cyprinidae	[illegible]s)
White catfish	Ictaluridae	[illegible]
Channel catfish	Ictaluridae	[illegible]que)
Plainfin midshipman	Batrachoidida	[illegible]
Topsmelt	Atherinidae	[illegible]
Jacksmelt	Atherinidae	[illegible] (Girard)
Inland silverside	Atherinidae	Menidia beryllina (Cope)
Threespine stickleback	Gasterosteidae	Gasterosteus aculeatus (Linneaus)
Bay pipefish	Syngnathidae	Syngnathus leptorhynchus (Girarad)
Striped bass	Serranidae	Morone saxatilis (Walbaum)
White croaker	Sciaenidae	Genyonemus lineatas (Ayres)
Barred surfperch	Embiotocidae	Amphistichus argenteus (Agassiz)
Shiner (surf)perch	Embiotocidae	Cymatogaster aggregata (Gibbons)
Black (surf)perch	Embiotocidae	Embiotoca jacksoni (Agassiz)
Tule perch	Embiotocidae	Hysterocarpus traski (Gibbons)
Dwarf (surf)perch	Embiotocidae	Micrometrus minimus (Gibbons)
White sea(surf)perch	Embiotocidae	Phanerodon furcatus (Girard)
Pile (surf)perch	Embiotocidae	Rhacochilus vacca (Girard)
Yellowfin goby	Gobiidae	Acanthogobius flavimanus (Temminck and Schlegel)
Bay goby	Gobiidae	Lepidogobius lepidus (Girard)
Pacific staghorn sculpin	Cottidae	Leptocottus armatus (Girard)
Speckled sanddab	Bothidae	Citharichthys stigmaeus(Jordan and Gilbert)
California halibut	Bothidae	Paralichthys californicus (Ayres)
Diamond turbot	Pleuronectidae	Hypsopsetta guttulata (Girard)
English sole	Pleuronectidae	Parophrys vetulus (Girard)
Starry flounder	Pleuronectidae	Platichthys stellatus (Pallas)
Bay shrimp	Cragonidae	Crangon franciscorum
Dungeness crab	Cancridae	Cancer magister

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Table 2-2. List of sources referenced in the compilation of species-life history summaries.

SPECIES	REFERENCES
Chinook Salmon	WRINT-USFWS-7; NOAA 1991; Turner and Kelley 1966
Steelhead	Hallock et al. 1961; Wang 1986; NOAA 1991;
Green Sturgeon	Moyle 1976; Doroshov et al. 1983; Fry 1973; Kohlhorst 1976; Wang 1986; NOAA 1991; Turner and Kelley 1966;
White Sturgeon	Moyle 1976; Aplin 1967; Ganssle 1966; Messersmith 1967; Radtke 1966; Stevens and Miller 1970; Miller 1972; Wang 1986; NOAA 1991; Turner and Kelley 1966
Channel Catfish	Christmas and Waller 1973; Turner 1966
White Catfish	Wang 1986; Schwartz 1964; Turner and Kelley 1966
Sacramento Splittail	Messersmith 1966; Caywood 1974; Turner and Kelley 1966
Hitch	Moyle 1976; Wang 1986; Turner and Kelley 1966
Sacramento Squawfish	Moyle 1976; Turner and Kelley 1966
Striped Bass	CDFG 1985; Meyer Resources Inc. 1985; Moyle 1976; Turner 1972; Wang 1986; NOAA 1991; Turner and Kelley 1966
Delta Smelt	Radtke 1966; Moyle 1976; Ganssle 1966; Messersmith 1966
Longfin Smelt	Ganssle 1966; Messersmith 1966; NOAA 1991
Inland Silverside	Wang 1986
Threadfin Shad	Ganssle 1966; Turner 1966; Wang 1986; Turner and Kelley 1966
Pacific Herring	Eldridge and Kaill 1973; Wang 1986; Ganssle 1966; Miller and Schmidtke 1956; NOAA 1991
American Shad	Stevens 1972; Ryder 1887; Scott and Crossman 1973; Moyle 1976; Mansueti 1958; NOAA 1991; Turner and Kelley 1966
Jacksmelt	Ganssle 1966; Wang 1986; NOAA 1991
Topsmelt	Wang 1986; NOAA 1991
White Croaker	Wang 1986; Ganssle 1966; Messersmith 1966; NOAA 1991
Leopard Shark	NOAA 1991;
Starry Flounder	Moyle 1976, Fitch and Lavenberg 1971; Bane and Bane 1971; McGinnis 1984; Wang 1986
English Sole	Bane and Bane 1971
California Halibut	Fitch 1958; Fitch and Lavenberg 1971; Bane and Bane 1971; Wang 1986
Diamond Turbot	Fitch and Lavenberg 1975
Speckled Sanddab	Fitch 1958; Fitch and Lavenberg 1971; Fitch and Lavenberg 1975; Wang 1986
Bay Pipefish	Moyle 1976; Bane and Bane 1971; Wang 1986
Threespine Stickleback	Moyle 1976; Bane and Bane 1971; Eschmeyer et al. 1983; Wang 1986; McGinnis 1984
Staghorn Sculpin	Moyle 1976; Fitch and Lavenberg 1971; Fitch and Lavebnberg 1975; Bane and Bane 1971; Wang 1986
Bay Goby	Wang 1986
Yellowfin Goby	Moyle 1976; Eschmeyer et al. 1983; McGinnis 1984; Wang 1986
Shiner Surfperch	Moyle 1976; Fitch and Lavenberg 1975; Bane and Bane 1971; Eschmeyer et al. 1983; Wang 1986
Pile Surfperch	Wang 1986
Black Surfperch	Fitch and Lavenberg 1971; Wang 1986
White Surfperch	Bane and Bane 1971; Wang 1986
Tule Perch	Moyle 1976; McGinnis 1984; Wang 1986
Barred Surfperch	Fitch and Lavenberg 1971; Eschmeyer et al. 1983; Wang 1986
Plainfin Midshipman	Fitch and Lavenberg 1971; Fitch and Lavenberg 1975; Bane and Bane 1971; Wang 1986

time of spawning, length of egg incubation period, age and size at maturity, migrations, importance to sport or commercial fisheries, and behavioral traits that might influence responses to salinity. In addition to providing specific occurrence information, the life history summaries represented a synopsis of the available information on each species related to how physical and biological needs ultimately influence distributions.

Fisheries data collected by the California Department of Fish and Game were also reviewed for fish distribution patterns. Specific monthly occurrences were noted within the upper estuary and in the lower portions of the Sacramento and San Joaquin rivers. Species presence or absence was determined at 93 Mid Water Trawl and 28 Summer Tow Net Stations within the upper estuary over the entire sampling period (1959-1992). The evaluation also included an analysis of seasonal and monthly catch patterns to determine temporal patterns in species distribution.

The estuary was divided into 2.5 km long sections reference to the distance from the Golden Gate Bridge. Between km 55 at the upstream end of the Carquinez Strait and km 100 in the Delta region of the lower Sacramento and San Joaquin rivers, locations were referenced to five kilometer divisions presented by Kimmerer (1992). Because the salinity gradients extended well downstream into San Pablo Bay for X2 at Roe Island, analyses were extended to approximately the middle of San Pablo Bay. The region between San Pablo Bay and the lower Delta was that portion of the estuary in which salinity gradients were considered most likely to be influenced by the implementation of the EPA X2 standard, which calls for the two ppt isohaline to occur at or downstream of the confluence, Chipps Island, and Roe Island. Historical and current species distributions and occurrences were interpreted for each 2.5 km section. Four general life history stages were assessed: eggs and larvae, juveniles (immature), adults (mature), and spawning. Presence/absence was assigned on an all or none basis for each section. There was considerable room for biological interpretation, so the analysis was conducted by two scientists working together. Figure 2-2 depicts a representative periodicity / distribution chart. Periodicity/distribution charts for all species and life stages analyzed are presented in Appendix A.

2.3 OBSERVED SALINITY GRADIENTS

The positions of other isohalines associated with X2 were determined from previous studies for each of the three locations specified in the EPA standards; i.e., at the confluence, Chipps Island, and Roe Island. Although the standards call for X2 to be located at or downstream of each point a certain number of days of the year, it was assumed that water resource allocations would be designed to maintain X2 in the vicinity of each location should the

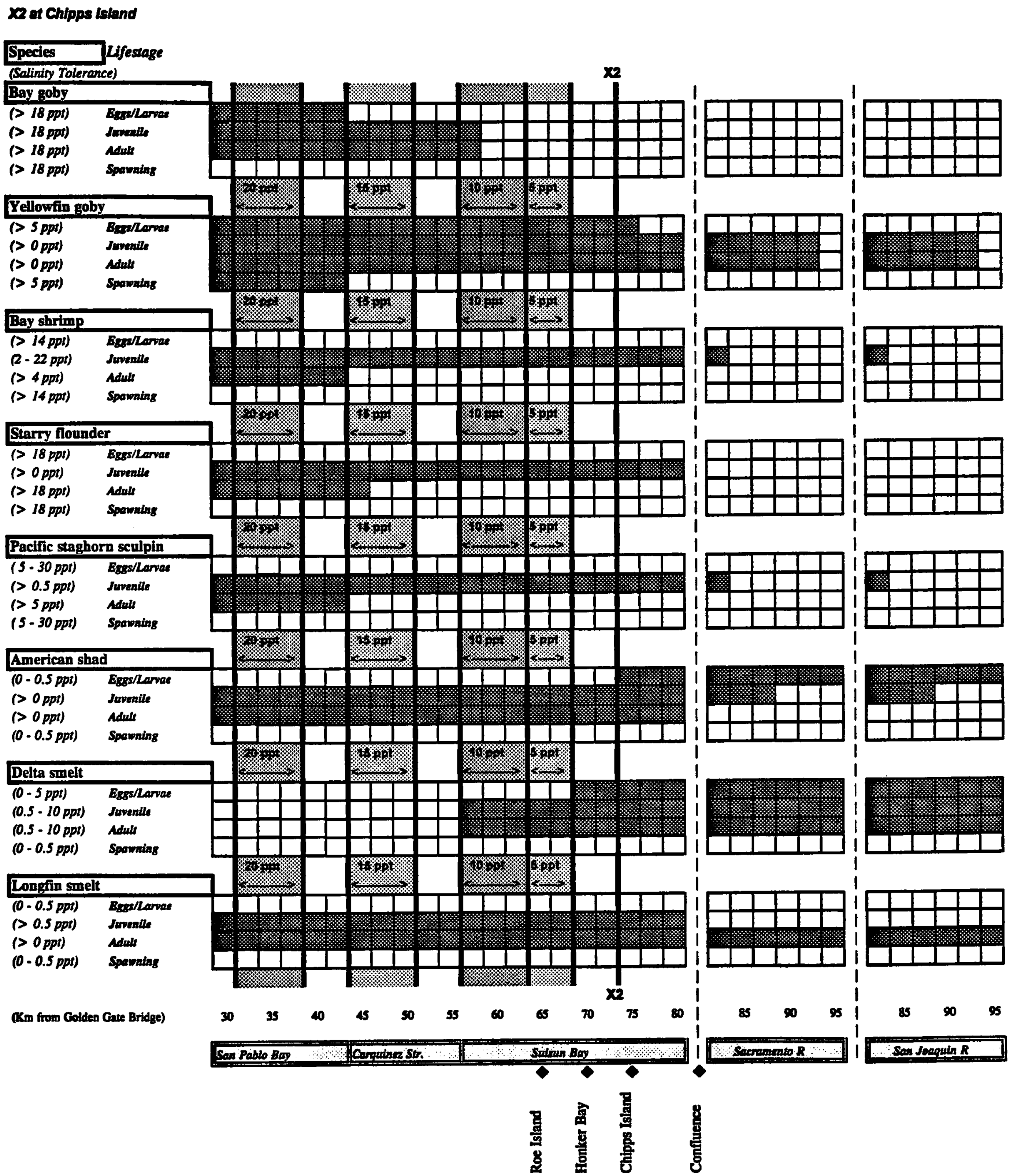

Figure 2-2. Representative species periodicity/distribution chart for July in the Bay-Delta region with X2 at Chipps Island, and associated ranges of isohalines.

standards be implemented. Hence, it would be expected that the locations of the other isohalines would occur within a general range depending on Delta outflow, local inflows, tides, and mixing processes.

The literature was searched for studies depicting isohaline plots and salinity data. Although there appeared to be several documents containing such information, only one could be obtained at the time: the report by Dedini et al. (1981) provided summary isohaline data collected by the USGS throughout 1980. Data collected in mid-August, early September, and mid-December of 1980 corresponded to X2 located at the confluence. Data collected in early July and early August corresponded to X2 located at Chipps Island. Data collected in April, June, and mid July corresponded to X2 at Roe Island. The ranges of occurrence of the 5 ppt, 10 ppt, 15 ppt, 20 ppt, and 25 ppt isohalines were determined for each X2 standard location. To determine longitudinal isohaline position in the estuary, the approximate mid-depth location (about 5 m from the surface) was used. This criterion was felt to be reasonable for addressing salinity effects on both demersal and pelagic species. The results are presented in Figure 2-3. It can be seen that the isohaline locations can vary for each standard, but that they generally fall within a defined range. Salinity data were also provided by F. Chung of DWR. These data were reviewed and used to confirm the ranges determined from the USGS study.

2.4 COMPARISON OF OBSERVED SALINITY GRADIENTS AND SPECIES DISTRIBUTIONS

General salinity tolerance ranges were compiled for each species and life history stage from the results of the literature review (Table 2-3). These data were used to compare the periodicity / distribution charts (eg. Figure 2-2) with the general occurrence ranges for the 5, 10, 15, 20, and 25 ppt isohalines (Figure 2-3). Each 2.5 km section in which a particular species life history stage might be found was evaluated to see if the expected salinity concentration associated with a particular X2 fell outside of the salinity tolerance range. The total number of 2.5 km section were counted for which salinity values were beyond tolerance limits.

From the results of the above comparison, it was possible to identify possible salinity effects of the proposed X2 standards. The one-dimensional representation of the estuary in the distribution and periodicity evaluation allowed an initial determination of species and life history stages that could benefit or be at risk from implementation of the EPA X2 standard. These data were used to compile a habitat index based on the percentage of the linear historical geographical range (for each species/life stage combination) that was suitable based

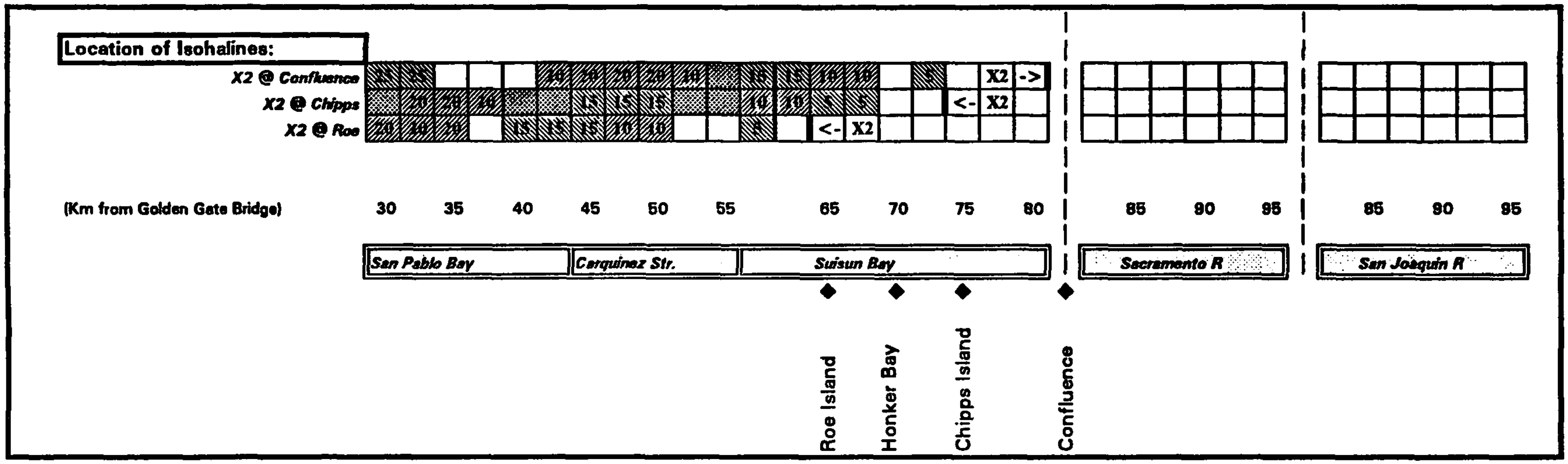

Figure 2-3. Expected ranges of occurrences of 5, 10, 15, 20, and 25 ppt isohaline locations approximately 5 meters below the surface for X2 located at the confluence of the Sacramento-San Joaquin rivers, at Chipps Island, and at Roe Island.

Table 2-3. Salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

SPECIES	SPAWNING	EGG	LARVAE	JUVENILE	ADULT
Green Sturgeon	0 to 0.5	0 to 0.5	0 to 0.5	≥ 0	≥ 0
White Sturgeon	0 to 0.5	0 to 0.5	0 to 0.5	≥ 0	≥ 0
American Shad	0 to 0.5	0 to 0.5	0 to 0.5	≥ 0	≥ 0
Pacific Herring	8 to 18	≥ 5	≥ 5	≥ 5	≥ 5
Threadfin Shad	0 to 0.5	0 to 0.5		0 to 5	0 to 5
Northern Anchovy	> 30	> 30	≥ 5	≥ 5	≥ 5
Chinook Salmon	0 to 0.5	0 to 0.5	0 to 0.5	≥ 0	≥ 0
Steelhead	0 to 0.5	0 to 0.5	0 to 0.5	≥ 0	≥ 0
Delta smelt	0 to 0.5	0 to 5	0 to 5	0.5 to 10	0.5 to 10
Longfin smelt	0 to 0.5	0 to 0.5	≥ 0	≥ 0.5	≥ 0
Hitch	0 to 0.5	0 to 0.5	0 to 0.5	0 to 0.5	0 to 0.5
Splittail	0 to 5	0 to 5	0 to 5	0 to 5	0 to 5
Squawfish	0 to 0.5	0 to 5	0 to 5	0 to 5	0 to 5
White Catfish	0 to 0.5	0 to 0.5	0 to 0.5	0 to 14.5	0 to 14.5
Channel Catfish	0 to 2	0 to 2	0 to 2	0 to 10	0 to 10
Topsmelt	≥ 18	≥ 18	≥ 5	≥ 2	≥ 5
Jacksmelt	≥ 18	≥ 18	≥ 5	≥ 5	≥ 5
Inland Silverside	0 to 5	0 to 5	0 to 5	0 to 5	0 to 5
Striped bass	0 to 0.5	0 to 18	≥ 0	≥ 0	≥ 0
White Croaker	> 30	> 30	≥ 5	≥ 5	≥ 5
Leopard Shark	≥ 18	≥ 18	≥ 18	≥ 18	≥ 18
Starry Flounder	> 18	> 30	≥ 5	≥ 0	≥ 18
English Sole	> 30	>30	≥ 18	≥ 5	> 30
Calif. Halibut	> 30	> 30	> 30	≥ 18	> 30

Table 2-3. Continued.

SPECIES	SPAWNING	EGG	LARVAE	JUVENILE	ADULT
Diamond Turbot	> 30	> 30	> 30	≥ 5	≥ 5
Speckled Sanddab	> 30	> 30	> 30	> 30	> 30
Bay Pipefish	≥ 9	≥ 9	≥ 9	≥ 9	≥ 9
3 Spine Stickleback	0 to 18	0 to 18	0 to 18	≥ 0	≥ 0
Staghorn Sculpin	5 to 30	5 to 30	5 to 30	≥ 0.5	≥ 5
Plainfin Midshipman	> 30	> 30	> 30	> 0.5	> 30
Bay Goby	>18	>18	>18	>18	>18
Yellowfin Goby	> 5	> 5	> 5	> 0	> 0
Bay Shrimp	≥ 14	≥ 14	≥ 14	2 to 22	≥ 4
Dungeness Crab	> 30	> 30	> 15	15 to 30	> 30
Shiner Surfperch	≥ 9	≥ 9	≥ 9	≥ 9	≥ 9
Barred Surfperch	> 30	> 30	> 30	> 30	> 30
Dwarf Surfperch	>18	>18	>18	>18	>18
Pile Surfperch	>18	>18	>18	>18	>18
Black Surfperch	≥ 30	≥ 30	≥ 30	≥ 30	≥ 30
White Surfperch	>18	>18	>18	>18	>18
Tule Perch	0 to 0.5	0 to 0.5	0 to 0.5	0 to 0.5	0 to 5

on water quality (salinity) preference criteria. Indices were compiled for each of the X2 operational scenarios. This analysis provides a means of determining the relative cost / benefit for individual species that might be expected when X2 is in a particular location and also provides a means of determining critical life stages that may be influenced under each management scenario.

The results were therefore assessed to see whether or not the predicted impacts would have a substantial effect on each species. For example, a particular species might be distributed widely throughout the Bay-Delta system and be intolerant of relatively low salinities. Although the implementation of the X2 standard was predicted to preclude a large portion of the upper estuary because of decreased salinity, the overall effect on the population might not be considered severe because that species was well distributed.

Impacts were evaluated monthly for each species for the egg/larval, juvenile, adult, and spawning life history stages, for each of the three X2 locations. The results could thus be useful for operations studies, where the monthly position of X2 could be varied for different water export and hydrology scenarios. The end product of the analysis was a listing of the (monthly) impacts to representative fish and invertebrate species for each X2 scenario. In this report, the analysis focuses on the determination of potential impacts during the months of February to June which is considered by the EPA to be the biologically critical period.

3.0 RESULTS

The results of this preliminary assessment of the potential biological impacts related to X2 position are presented below in the following two sections. The information presented in Section 3.1 consists primarily of a distillation of the pertinent life history information for each species as well as a coarse level determination of potential impacts related to the X2 standard. The information presented in Section 3.2 are the results of the more detailed, semi-quantitative, life stage specific analysis. The data presented in Section 3.2 are the results of the analysis focused on determining impacts within the biologically critical period between February and June.

3.1 SPECIES LIFE HISTORY SUMMARIES AND LIFE STAGE HABITAT USAGE

This section presents basic life history and habitat requirements for a broad complement of marine, estuarine, and freshwater species which utilize the upper portion of the Sacramento-San Joaquin estuary. This information was used initially to make a qualitative assessment of both species and community level responses related to implementation of the X2 Standard and to evaluate the relative level of potential impacts. The results of this assessment for each species (all life stages combined) are presented in Appendix B.

The following species life history summaries present a compilation of information from a variety of sources. The intent of this section is to provide supportive information which explains the observed patterns of distribution and occurrence of these species in the Sacramento-San Joaquin estuary. A more comprehensive presentation of life history information is presented in Wang (1986) and in Moyle (1976). These references proved invaluable in the completion of the following section. The section is organized by species and is loosely arranged in a ranked order of salinity preference with the discussion commencing with species found in freshwater.

3.1.1 White catfish

White catfish are not native to California and apparently were introduced into the San Joaquin river system in the 1870's (Skinner 1962). Their current distribution includes nearly all major drainage systems in California. White catfish are predominantly fresh water inhabitants but they can tolerate salinities as high as 14.5 ppt (Schwartz 1964). They are the only catfish commonly found in Suisun Bay.

White catfish spawn during the months of June and July, when water temperatures approach 21°C (Moyle 1976). Within the Sacramento-San Joaquin estuary, spawning occurs near banks and in the shallow waters throughout the Delta including Suisun Bay (Wang 1986). Eggs hatch in approximately 7 days at water temperatures between 24 and 29°C. Prolarvae initially remain in the nest under parental care, later dispersing into shallow waters with muddy bottoms, in both tidal and nontidal waters of upper Suisun Bay and the Delta (Wang 1986). Juveniles are distributed in stagnant or slow current habitats in the Sacramento-San Joaquin River system, including the upper estuary and the oligohaline portion of San Pablo Bay. Wang (1986) observed juvenile white catfish at the Clifton Court Forebay, throughout the Delta, Suisun Bay, and in San Pablo Bay. Adult fish prefer slow moving currents and back water sloughs and are typically most abundant in these areas. Turner (1966) found that the relative abundance of white catfish was greater in the San Joaquin River than in the Sacramento and Mokelumne rivers and attributed this to the availability and their preference for slow water habitats.

White catfish are omnivorous, feeding on a variety of organisms including large invertebrates, amphipods, opossum shrimp, and fish. Amphipods (Corophium) and opossum shrimp (Neomysis) are the most important items in the diet of catfish residing in the Delta (Turner 1966).

Potential Biological Impacts Related to X2 Position: The spawning requirements and early life stage needs of the white catfish rely on the availability of freshwater in the 0 to 0.5 ppt salinity range. Therefore, the influence of X2 position imposes the greatest limitation to these life stages when residing in the upper estuary. White catfish would benefit when the greatest amount of freshwater is available. However, the proportional increase in habitat and subsequent relative benefit attained by extending X2 position downstream to Chipps or Roe Island is inconsequential, given the vast expanse of freshwater habitat present in the Sacramento and San Joaquin rivers.

3.1.2 Channel Catfish

Channel catfish are not native to California, being first introduced in the 1870's. The channel catfish population in the Sacramento-San Joaquin system did not become firmly established until the 1940's (Moyle 1976). Their current distribution includes nearly every major drainage throughout the state. Channel catfish prefer fresh water but can tolerate waters of moderate salinity (10 ppt) (Christmas and Waller 1973).

Channel catfish spawn between the months of April and July, in the rivers and in the upper portion of the Sacramento-San Joaquin estuary. Spawning occurs in fresh water and in brackish water habitats with salinities less than 2 ppt. Suitable spawning sites for the channel catfish require cave like features that are usually found in undercut banks, debris jams, or in muskrat burrows (Scott and Crossman 1973). The male is solely responsible for the parental care of the developing eggs and newly hatched fry.

Larvae are found throughout the Sacramento-San Joaquin river system, particularly in the sloughs of the Delta. Juveniles are distributed throughout the Sacramento-San Joaquin river system and the upper oligohaline portion of the estuary. Channel catfish prefer habitats found in large rivers with a preference for swift waters. Turner (1966) stated that the majority of the channel catfish captured, during his survey of the Sacramento-San Joaquin system, were found in areas of fast water in rivers and channels upstream from the central Delta. The channel catfish is omnivorous, utilizing almost any organism available for its diet.

Potential Biological Impacts Related to X2 Position: The life stage salinity requirements of the channel catfish are similar to those of the white catfish suggesting that the potential biological implications related to the position of X2 on the species are similar. Channel catfish are slightly more tolerant of brackish waters in their early life stages and during spawning, than white catfish.

3.1.3 Sacramento Splittail

Splittail are native to California, however, their current distribution is significantly reduced from what it was historically (Moyle 1976). Splittail are primarily a freshwater inhabiting species but are extremely tolerant of brackish water.

Splittail spawn in the tidal freshwater and oligohaline portions of the Sacramento-San Joaquin estuary from late January or early February to July (Wang 1986). Spawning occurs in sloughs, flooded rivers and streams in the Delta, with eggs presumably being deposited on beds of submerged aquatic vegetation (Caywood 1974). Planktonic larvae are euryhaline and have been found from freshwater to oligohaline portions of the estuary, such as the Delta in the vicinity of the Pittsburg Power Plant and Montezuma Slough of Suisun Bay (Wang 1986). Juvenile splittail have been collected by beach seine in Suisun Bay and most of the Delta sloughs in late winter and spring months (Wang 1986). Adult splittail live mostly in the slow moving stretches of the main rivers and in the Delta. The distribution of adult splittail includes San Pablo Bay, the lower reaches of the Sacramento River, and the Delta.

Potential Biological Impacts Related to X2 Position: All life stages of the Sacramento splittail will likely benefit the further downstream that X2 is positioned. As all life stages occupy the fresh and oligohaline portions of the estuary, any increase in the quantity of these habitats may potentially benefit the species. The potential incremental benefit to splittail habitat remains constant as X2 is positioned downstream to Roe Island.

3.1.4 Sacramento Squawfish

The Sacramento squawfish is native to California, inhabiting the freshwaters throughout the Sacramento-San Joaquin River system. In addition to their freshwater distributions, Wang (1986) reported that large squawfish are common in San Pablo Bay, Suisun Bay, and the sloughs of the Delta.

The spawning season of the Sacramento squawfish extends from April to July (Moyle 1976). Ripe fish migrate upstream and typically spawn within riffle type habitats. In their observations of squawfish spawning behavior, Taft and Murphy (1950) described the construction of an egg nest in the section of a stream immediately downstream of a pool. Embryo development is believed to be similar to that of the northern squawfish, with incubation times lasting between four and seven days at 18°C (Moyle 1976). Newly hatched larvae initially occupy habitats along the stream margins, moving to deeper (pool) habitats as development proceeds. Larvae are often transported downstream under high flows. Juvenile and adult fish are found within freshwater and oligohaline environments. The diet of juvenile squawfish includes insect larvae, small insects, and fish. Adult squawfish are predatory, feeding heavily upon crayfish and fish.

Potential Biological Impacts Related to X2 Position: Given the preference and tendency of the Sacramento squawfish towards freshwater, it is one of several species that would likely benefit as X2 is moved to downstream locations and populations would likely expand in the lower portions of the Bay-Delta. The absolute benefit derived by positioning X2 downstream is difficult to quantify.

3.1.5 Hitch

The hitch is a freshwater fish native to California inland waters, and is common throughout the Sacramento-San Joaquin drainage system although populations have declined from historical levels (Moyle 1976). Observations by Wang et al. (1986) indicated that "hitch have a patchy distribution in the warm waters on the Sacramento-San Joaquin drainage system while local populations may be very dense".

Spawning takes place in streams between March and July, when water temperatures are between 14 and 18°C. Females seek out areas with cleaned fine to medium sized gravel bottoms to deposit their eggs. The males fertilize the eggs which eventually drop into the interstitial gravel spaces. Hatching occurs in seven days at 16 to 17°C (Swift 1965). Post larvae and juvenile hitch occupy vegetated areas and shaded pools for rearing (Wang 1986). "Juvenile hitch have been observed near the shoreline of Suisun Bay, probably having come from adjacent tributaries" (Wang 1986). The diet of juvenile and adult hitch includes phytoplankton, algae, crustaceans, and insects (Moyle 1976).

Potential Biological Impacts Related to X2 Position: The life history requirements of the hitch suggest that the location of X2 will have little effect on the species distribution or abundance.

3.1.6 Threadfin Shad

Threadfin shad are freshwater dwellers and become progressively less abundant in the Delta as salinity increases (Ganssle, 1966). In the Delta, they are most abundant where there are high concentrations of crustaceans such as in warm, quiet, turbid sloughs (Turner 1966).

Spawning occurs primarily in sloughs in the Delta and shoreline of Suisun Bay (Wang 1986). Larvae are planktonic and are found distributed in the shallow and open water of the Delta and in Suisun Bay. Juvenile threadfin shad are typically distributed in the shallow and open water of the Sacramento-San Joaquin river system and to a lesser extent in the estuaries. Ganssle (1966) observed that juvenile threadfin shad were abundant in the Delta and Suisun Bay from September through November. Wang (1986) reported that threadfin shad was the most abundant clupeid in the Delta and upper estuary. Although threadfin shad are found in water of various salinities, they seem to prefer the oligohaline-to-freshwater ranges. Ganssle (1966) reported a decreasing catch of threadfin shad with increasing distance into the salinity gradient downstream in the estuary.

Potential Biological Impacts Related to X2 Position: Juvenile and adult threadfin shad will likely be unaffected by the relative position of X2, although spawning and early life stages would continue to benefit as X2 is moved in a downstream direction.

3.1.7 Inland Silverside

The inland silverside is not native to California being first introduced in 1967 into Blue Lake and Clear Lake (Cook and Moore 1970). The silverside population in Clear Lake grew quickly after introduction, expanding rapidly into the adjacent drainages. Currently, "the inland silverside is one of the most common species collected by beach seine in the Delta, Suisun Bay, and Montezuma Slough" (Wang 1986).

Inland silverside spawn from April through September, often spawning more than once in a given season. The silverside is short-lived and typically die after spawning at one year of age. Spawning takes place over beds of aquatic plants or near emergent vegetation. The eggs possess filamentous structures which, upon deposition, adhere to aquatic vegetation. The incubation time ranges from 4 to 30 days, depending on water temperature (Moyle 1976). Larvae are initially planktonic, shifting their orientation to vegetated littoral habitats as they grow older.

The diet of the silverside consists chiefly of zooplankton, instars of chironimid larvae, and chaoborid gnats (Moyle 1976). Wang (1986) hypothesized that "the successful establishment of this species in the Sacramento-San Joaquin estuary and adjacent waters is probably due in part to their tolerance of various salinities and to the surface feeding habitats of the inland silverside larvae, which reduces competition from other fish species".

Potential Biological Impacts Related to X2 Position: Juvenile and adult silverside will likely benefit significantly when X2 is positioned downstream of the confluence.

3.1.8 Tule Perch

The tule perch is the only freshwater member of the surfperch family in California (McGinnis 1984, Wang 1986). This species seldom ventures into brackish water, although it seems to be tolerant of it. Tule perch have been found in the lower Sacramento-San Joaquin river system, but may be extinct in the San Joaquin River at present (Moyle 1976). Tule perch have also been reported in the lower Napa River, in Carquinez Strait, and Suisun Bay (Wang 1986). Tule perch become sexually mature shortly after birth, when they are about 3 to 4 cm long and reach 5 to 8 cm by the end of their first summer. Maximum age appears to be about 5 yrs. Mating occurs from July through September, and birth occurs in May and June (Moyle 1976; McGinnis 1984; Wang 1986).

Potential Biological Impacts Related to X2 Position: The tule perch would probably be unaffected by the position of X2, as it is primarily a freshwater inhabiting species.

3.1.9 Green Sturgeon

Green sturgeon are anadromous and native to the Sacramento-San Joaquin estuary (Moyle 1976). Green sturgeon are not commonly found within the estuary, and the life history of the species is poorly documented (Doroshov et al. 1983).

Spawning takes place in the upper Sacramento River (Fry 1973) and tributaries to the Sacramento River such as the Feather, Yuba, and American rivers. Spawning typically occurs in the season between mid-February and late May (Kohlhorst 1976). The distribution of juvenile green sturgeon includes the Delta, Suisun Bay, San Pablo Bay, and San Francisco Bay. Juvenile green sturgeon have been collected in San Francisco Bay up to the lower reaches of the Sacramento-San Joaquin rivers and the Delta, including the intakes of the Tracy Pumping Station (A. Pickard, CDFG, as cited in Wang 1986).

Radtke (1966) reported that juvenile green sturgeon feed on opossum shrimp (Neomysis) and amphipods (Corophium), with the latter being of greatest importance. The diet of the adult green sturgeon includes bottom invertebrates and small fish (Ganssle 1966).

Potential Biological Impacts Related to X2 Position: The green sturgeon does not appear to have the potential to be impacted, either beneficially or adversely, by the location of X2. Juvenile and adult green sturgeon are euryhaline, capable of inhabiting waters with a broad range of salinities. The early life and spawning requirements of this species are met in fresh water habitats suggesting that a slight benefit may be attained with the downstream positioning of X2. However, given their preference for fresh waters found in the upper river systems, any increase in the availability of fresh water under either a Chipps or Roe Island standard would likely translate into a minimal benefit.

3.1.10 White Sturgeon

White sturgeon are native to the Sacramento-San Joaquin estuary (Moyle 1976). Although white sturgeon are anadromous, they are capable of completing their life cycle entirely within freshwater.

Sturgeon are extremely long-lived with some individuals living as long as 100 years (Brown 1971). White sturgeon spend the majority of their lives in the estuaries of large rivers, moving up into fresh water to spawn. Spawning occurs from February through June (Kohlhorst 1976; Moyle 1976) when water temperature ranges between 10 and 24 °C. The majority of the white sturgeon larval population is believed to reside in the upper Sacramento River. Stevens and Miller (1970) collected 85 yolk-sac larvae and larvae of Acipenser spp. in the lower reaches of the Sacramento River, the lower San Joaquin River, the Delta, and Suisun Bay during their 1966-1967 sturgeon survey.

In the Bay-Delta study area, white sturgeon have been reported in San Francisco Bay (Aplin 1967), San Pablo Bay (Ganssle 1966), Carquinez Strait (Messersmith 1967), the lower reaches of the Sacramento and San Joaquin rivers and in the Delta (Radtke 1966, Stevens and Miller 1970; Miller 1972). White sturgeon are bottom feeders and consume a wide variety of organisms including fish, crustaceans, molluscs, worms, and plant material (Brown 1971). Neomysis and Corophium were reported as important food items for white sturgeon in the Delta (Radtke 1966).

Potential Biological Impacts Related to X2 Position: Similar to green sturgeon; in general not affected by either Chipps or Roe Island Standard.

3.1.11 Striped Bass

Striped bass were initially introduced into the San Francisco Bay-Delta in 1879. The population of striped bass rapidly became established and within 20 years, the commercial net catch alone was averaging well over a million pounds per year, largely attributable to the excellent reproductive potential of this species. Striped bass are anadromous and can move regularly between salt and fresh water, usually spending much of their life cycle in estuaries (Moyle 1976). Striped bass are tolerant and capable of withstanding a wide range of environmental conditions.

Striped bass spawning occurs during the months of April, May, and June when water temperature reaches 16 °C. Striped bass spawn in fresh water where there is moderate to swift current necessary for successful egg incubation. River streamflows dictate the availability and location of spawning areas. Historically, the section of the San Joaquin River between the Antioch Bridge and the mouth of Middle River, together with other channels in this area, have provided important spawning grounds. Another important spawning area is the Sacramento River, between Sacramento and Colusa. About one-half to two-thirds of the eggs are spawned in the Sacramento River, and the remainder in the San Joaquin River system (CDFG 1985). The eggs of the striped bass are semi-buoyant, being slightly heavier than fresh water and requiring current to keep eggs moving and to promote successful incubation. Eggs hatch in 48 hours at 19 °C.

Eggs and larvae are found in both the lower riverine (freshwater) and upper estuarine (oligohaline) areas. Young of the year (YOY) also occur in these areas, with many moving to more saline environments. Larval and juvenile bass are reportedly most abundant where salt and fresh water meet, which is the most productive portion of the estuary (Turner 1972).

Striped bass feed on the most available and abundant invertebrates and forage fish. Initially, small bass feed on tiny crustacean plankton, but after a few weeks, a large portion of their diet consists of Neomysis. Neomysis are typically most abundant in the upper (oligohaline) portion of the estuary. The diet of adult bass in San Francisco Bay is comprised largely of anchovies, shiner perch, and herring. Anchovies, sculpins, and shrimp make up the bulk of the diet in San Pablo Bay (CDFG, 1985) . In the Delta and upriver areas larger bass feed mainly on threadfin shad, young striped bass, and other small fish (CDFG, 1985).

Most adult bass move downstream after spawning into brackish and salt water where they reside during the summer and fall. Some fish enter the ocean, while some may remain in the estuary for a large portion of their life (Chadwick, CDFG pers. comm. to J. Wang 1986). During late fall and winter some fish move back upstream into the fresh water of the Delta and the lower stretches of the Sacramento and San Joaquin rivers.

Potential Biological Impacts Related to X2 Position: The early life stages of striped bass would benefit (via increased habitat availability based on salinity requirements) as X2 is moved from the confluence downstream to Chipps Island. In addition, spawning habitat would increase as X2 is moved from the confluence to Chipps, and Chipps to Roe Island.

3.1.12 Chinook Salmon

There are four races of chinook salmon that utilize the Delta as an adult and juvenile migration corridor, to and from upstream spawning and rearing habitats. These races are identified by the time of year that their upstream migration occurs and include fall-run, late fall-run, winter run, and spring run. In addition to the use of upstream habitats, some rearing of chinook (particularly fall run) salmon actually occurs within the Delta.

Adult salmon migrate through the Delta during all months of the year, with the greatest numbers of adults being present between the months of July and November (Fall-run) while the federally endangered/threatened winter run adults are present in the late winter and early spring. Migrating smolts (fall run) are most abundant during the April through June period. Winter-run smolts are most numerous in the Delta during the January to April period.

Potential Biological Impacts Related to X2 Position: In general, chinook salmon would be largely unaffected by the location of the X2 isohaline, although direct benefits may occur relative to the high flows (needed to maintain the standard) thus improving outmigration survival. An added concern relates to the quantity of carryover storage that will remain to ensure standard compliance and the effects of streamflow habitats. Changes in salinity within rearing habitats found in the Delta will likely not prove to be detrimental to the species but is dependent upon the degree of smoltification.

3.1.13 Steelhead

Steelhead are the anadromous form of rainbow trout and are native to California. Currently, both native and artificial stocks are found within the Sacramento-San Joaquin system.

The spawning habits of the steelhead are similar to those of other anadromous salmonids. Adult steelhead migrate upstream through the Sacramento-San Joaquin Estuary, beginning in spring and continuing through the fall, en route to their freshwater spawning grounds. Spawning occurs during the months of December through April in the Sacramento-San Joaquin drainage (Hallock et al. 1961). Spawning activity and redd construction typically takes place within the loose gravels commonly found in the lower end of a pool. Fertilized eggs hatch within the gravel interstitial spaces in about 3 to 4 weeks at 10 to 15° C (Moyle 1976). Larvae remain within the gravels until their yolk sacs are fully absorbed. Juvenile steelhead remain in freshwater streams from one to three years before entering the ocean. Downstream migration occurs in most months of the year, but peaks occur in the fall and spring (Hallock et al. 1961). Mature steelhead return to their natal streams to spawn in approximately 2 to 3 years (Moyle 1976). Important food items for this species during its freshwater and estuarine rearing phases include terrestrial and aquatic insects, amphipods, crustaceans, and small fish (Sasaki 1966).

Potential Biological Impacts Related to X2 Position: Similar to Chinook Salmon.

3.1.14 Bay Goby

The bay goby has been collected in San Francisco Bay, and in most parts of the Sacramento-San Joaquin estuary below Suisun Bay. Individuals have been found occasionally above the Carquinez Straits. The majority reach maturity by the end of their second year, and live to about seven years (Wang 1986).

Spawning appears to occur from November through May, with peak activity occurring in April and May in waters with salinities greater than about 18 ppt. The eggs are negatively buoyant and are adhesive at their point of contact with the substrate. Larvae spend three to four months as ichthyoplankton, and juveniles descend to the bottom at a length of about 25 mm. Larvae have not been found above San Pablo Bay; juveniles are seldom found in Suisun Bay (Wang 1986).

Potential Biological Impacts Related to X2 Position: Within its upper estuarine distribution, the bay goby would probably be adversely impacted, as X2 is moved downstream. Due to their preference for waters of salinity >18 ppt, significant increases in the amount of freshwater habitat in the upper estuary (resulting from implementation of a Chipps or Roe Island standard) would restrict their total amount of suitable habitat (based on salinity).

3.1.15 Yellowfin Goby

The yellowfin goby is an extremely euryhaline species that is found in fresh, brackish, and salt water, and is capable of withstanding abrupt salinity changes (Moyle 1976). This species is native to East Asia but was probably introduced in the late 1950's via ballast water. Since then, the species has flourished (Wang 1986). Specimens have been collected in the Delta-Mendota Canal (Moyle 1976). Yellowfin goby are the largest goby species on the west coast and are similar to the bay goby (Eschmeyer et al. 1983). This species has been noted to be a potential competitor with staghorn sculpin (Moyle 1976). Maturity may be reached after one or two years. Maximum age is believed to be three to four years (Wang 1986).

Spawning is thought to occur from December through July in water with salinities higher than 5 ppt (Wang 1986). The eggs are negatively buoyant, adhesive at the point of contact with the substrate, and hatching takes approximately one month (Moyle 1976; McGinnis 1984; Wang 1986). The larvae are pelagic at first and then settle to the bottom at about 15-20 mm lengths (Moyle 1976). Larvae have not been found in the upper estuary, and there may be a spawning migration from fresher to more saline water (Wang 1986).

Potential Biological Impacts Related to X2 Position: Because the species is euryhaline, the yellowfin goby would be largely unaffected by the X2 standard regardless of its location. The potential adverse impacts to the early life stages under both the Chipps and Roe Island standards are slight, although the magnitude of impact would increase as X2 is extended downstream from Chipps to Roe Island.

3.1.16 Bay Shrimp (Crangon franciscorum)

C. franciscorum is an estuary dependent species that spends its immature life in San Francisco Bay and the lower Sacramento-San Joaquin estuary. A fishery existed prior to 1985 upstream of the Carquinez Strait, indicating the presence of adults there as well. Larvae hatch in relatively high salinity water in San Francisco Bay, but the post-larvae and juveniles migrate upstream into San Pablo Bay and Suisun Bay, with highest numbers observed from April to June, and occasionally in the fall. During low outflow years, distributions have been observed in Honker Bay and the lower portions of the Sacramento and San Joaquin rivers. The maturing juveniles migrate back out to San Francisco Bay and the Gulf of Farallones in the fall (WRINT 1992; Herrgesell 1993). Spawning has been noted to occur from December through May or June (Smith and Kato 1979). Males live between 1 and 1.5 years, females between 1.5 and 2 years. Juvenile salinity tolerance ranges between 2 and 22 ppt, with a median value of 9.5 ppt. Older, but still immature *C. franciscorum* have a salinity tolerance that ranges between 2 and 21 ppt. Adult shrimp appear to have a salinity tolerance between about 4 and 25 ppt. Ovigerous females are found in waters with salinities ranging from 14 to 30 ppt, with a median of 21 ppt (WRINT 1992; Herrgesell 1993).

Potential Biological Impacts Related to X2 Position: Based solely on their salinity preference, the potential exists for bay shrimp to be adversely impacted (in terms of its distribution in the upper estuary) under implementation of either a Chipps or Roe Island standard.

3.1.17 Starry Flounder

Starry flounder is an estuary-dependent species that is found throughout the Sacramento-San Joaquin estuary and San Francisco Bay (Wang 1986; WRINT 1992). This species is common in the Delta during the summer, less common in the winter, and has passed through the CVP-SWP system. Fish found in freshwater have been mostly immature and under 2 years of age. Very small juveniles have been found in the lower San Joaquin River (Moyle 1976). Juveniles and young adults appear to migrate to more saline water once they reach about 15 cm in length. Adults found in freshwater have generally been in poor condition, and it has been hypothesized that osmotic changes occur in juveniles as they mature (McGinnis 1984). Starry flounder mature at age two or three, or approximately 33-35 cm in length (Fitch and Lavenberg 1971; Bane and Bane 1971; Moyle 1976).

Spawning occurs from September through March with the majority of activity between November and February (Fitch and Lavenberg 1971; Bane and Bane 1971; Moyle 1976; Wang 1986). Spawning occurs mostly in shallow coastal waters with salinities greater than 18 ppt (Wang 1986). Spawning may also occur in the lower Sacramento-San Joaquin estuary, and possibly in the lower Delta (Moyle 1976; Wang 1986). Eggs are buoyant and hatch in about three days (Fitch and Lavenberg 1971; Wang 1986). The larvae are pelagic and juveniles appear to migrate upstream, settling by roughly the end of April (Wang 1986).

Potential Biological Impacts related to X2 Position: Based on the salinity preference of starry flounder, they may be negatively impacted by the X2 standard.

3.1.18 Staghorn Sculpin

The staghorn sculpin is a euryhaline species that is common in San Francisco Bay and San Pablo Bay, but is rarely found more than 2 miles from saltwater (Moyle 1976; Wang 1976). Staghorn sculpin have been found to be among the most abundant of bottom-dwelling species in San Pablo and Suisun Bays (Fitch and Lavenberg 1975). In the tidal freshwater sections of the estuary, almost all individuals are juveniles or newly mature adults that are from 2 to 14 cm long, with most under 2 years of age (Moyle 1976; Wang 1986). Staghorn sculpin mature at age 1 and live to three to five years (Fitch and Lavenberg 1975; Moyle 1976). Juveniles are tolerant of lower salinity water than are adults. In upper reaches of estuaries they are associated with threespine stickleback, and anadromous salmonids. In lower reaches, they are associated with starry flounder and shiner surfperch (Moyle 1976).

Spawning occurs from October through April, with a peak around January and February, in the higher salinity areas of the bay (between 5 and 30 ppt, optimum around 26 to 28 ppt); spawning is unlikely in streams (Fitch and Lavenberg 1975; Moyle 1976; McGinnis 1984; Wang 1986). Individuals probably spawn only once in a season (Wang 1986). The optimum salinity for egg development is about 26 ppt (Moyle 1976). Eggs are negatively buoyant, are adhesive, and hatch in about ten days (Fitch and Lavenberg 1975; Wang 1986). Newly hatched juveniles become demersal at about 10-15 mm in length, and move into freshwater in the spring (Moyle 1976; Wang 1986).

Potential Biological Impacts Related to X2 Position: The staghorn sculpin would be largely unaffected by the relative position of X2.

3.1.19 American Shad

The American shad is native to the Atlantic Coast and was first introduced to the Pacific Coast in 1871. They were initially introduced into the Sacramento River and were repeatedly planted there over a ten year period. Since then, the American shad has proliferated and is now abundant throughout western rivers and estuaries. American shad are anadromous, moving into larger river systems to spawn during the months of April, May, and June (Stevens 1972). Eggs are semi-demersal (Mansueti 1958) and hatch in 8 to 12 days at 11-15 °C (Scott and Crossman 1973). Newly hatched larvae are pelagic and gradually move downstream from the spawning grounds spending from several weeks to several months in the Delta (Moyle 1976, Stevens 1972). As the season progresses, juvenile shad move into higher salinity water. Some small juveniles apparently move directly through the estuary in the summer months (Stevens 1972; Moyle 1976). The entry into salt water takes place in September, October, and November (Moyle 1976).

Potential Biological Impacts Related to X2 Position: American shad would be largely unaffected by the relative position of X2.

3.1.20 Delta smelt

Delta smelt are native to the Sacramento-San Joaquin estuary and are primarily found below Mossdale on the San Joaquin River and below Isleton on the Sacramento River (Moyle 1976). While the Delta smelt is a euryhaline fish, it is most commonly found at salinities of less than 10 ppt with the majority being found at salinities of less than 2 ppt (Ganssle, 1966).

Delta smelt are usually found concentrated in schools within shallow water areas near the entrapment zone or in the river channels immediately above it. Prior to the onset of spawning, there is an upstream migration into the river channels and backwater sloughs of the Delta. Delta smelt spawn mostly in fresh water within rivers under tidal influence (Radtke 1966). Spawning occurs both in shallow fresh waters of the Delta and Suisun Bay and in sloughs (Radtke 1966). General locations include Montezuma Slough, vicinity of Pittsburg and Contra Costa power plants on Suisun Bay, the lower reaches of the Sacramento and San Joaquin rivers and in the Delta (Wang 1986). Recent research (Wang 1991) indicates that the San Joaquin River is used more intensively than the Sacramento River for spawning. Spawning takes place between the months of January to June and most adults die after spawning. Many researchers hypothesize that the Delta smelt is especially susceptible to changes in estuarine conditions because of its short (1 year) life cycle and low fecundity.

After hatching, the buoyant larvae are transported downstream by river currents into the upper end of the mixing zone of the estuary. Larvae are typically found near the surface of the water column (Moyle 1976) from Montezuma Slough and upper Suisun Bay to the lower Sacramento-San Joaquin river system. Juvenile Delta smelt range from the lower reaches of the Sacramento and San Joaquin rivers, through the Delta, and into Suisun Bay (Ganssle 1966, Moyle 1976). The larger juvenile and adult Delta smelt were found to be abundant in the trawl and trap net catches during spring and summer in Suisun Bay and the Delta. Juvenile smelt move downstream (Radtke 1966; Moyle 1976) to San Pablo Bay and Carquinez Strait (Ganssle 1966; Messersmith 1966) before turning back to Suisun Bay for spawning. Thus, the seasonal movement occurs within a short section of the upper estuary.

Potential Biological Impacts Related to X2 Position: Delta smelt would likely benefit with the implementation of an X2 standard, with the greatest incremental benefit occurring when X2 is moved from the confluence to Chipps Island (i.e., Chipps standard).

3.1.21 Longfin smelt

The longfin smelt is an anadromous, euryhaline species, although landlocked populations do exist. The longfin smelt are a short-lived species with an average life expectancy of two years.

Longfin spawn in the freshwater section of the lower Delta including portions of Suisun Bay, Montezuma Slough, lower reaches of the Sacramento and San Joaquin rivers, and the Delta. Spawning takes place during the months of December, January and February. Eggs are adhesive and are deposited on rocks or aquatic vegetation. Hatching time varies but typically is about 40 days at 7 °C. The majority of adults die after spawning. Larvae are distributed pelagically near the surface of the water column from Carquinez Strait to the lower reaches of the Sacramento and San Joaquin rivers and the Delta. Juveniles are distributed in the middle to bottom of the water column from Suisun Bay to San Francisco Bay (Ganssle 1966; Messersmith 1966).

Potential Biological Impacts Related to X2 Position: Longfin smelt would probably benefit as X2 is positioned downstream, with the greatest benefit occurring under a Roe standard.

3.1.22 Threespine Stickleback

Threespine stickleback are extremely euryhaline (Bane and Bane 1971), and have been found in the Pacific Ocean and in freshwater (Wang 1986). They are widely distributed in the Sacramento-San Joaquin estuary and river system and in the Central Valley, but are found infrequently in turbid water (Moyle 1976; Wang 1986). The life cycle is completed in one year, but individuals have been known to live to three years (Moyle 1976). Maturity is generally attained within a year (Wang 1986).

Spawning occurs mostly in freshwater, or in water with a salinity less than about 18 ppt (Eschmeyer et al. 1983; Wang 1986). Anadromous forms move first into shallow regions of estuaries, then into freshwater (Moyle 1976). The breeding season has been noted to last usually two to three months in the spring and summer (McGinnis 1984; Moyle 1986). However, multiple spawning may occur from March through October (Wang 1986). Eggs are self-adhesive (but non-adhesive to substrate), negatively buoyant, and hatch in six-eight days (Moyle 1976; Wang 1986). Few larvae are found in open water (Wang 1986).

Potential Biological Impacts Related to X2 Position: The threespine stickleback would likely benefit as X2 is positioned downstream. Some adverse impacts may occur, although these would be minimized when X2 is positioned at Roe Island.

3.1.23 Shiner Surfperch

The shiner surfperch is a viviparous, euryhaline species that is tolerant of salinities as low as 1 ppt, but is usually found in waters with salinities greater than 9 ppt. Most shiner surfperch that have been found at low salinities have been young of year, or about 4 to 6 cm long. Adults are about 8 to 14 cm long, and are common in San Pablo Bay when salinities drop to

9 to 14 ppt (Moyle 1976). Shiner surfperch have been found throughout the lower Sacramento-San Joaquin estuary to Suisun Bay and are common along the Pacific coast (Wang 1986). Males are mature at birth while females mature at age 1, at about 8 cm length (Bane and Bane 1971; Fitch and Lavenberg 1975). Individuals may live up to 5 years in age (Wang 1986).

Mating occurs year-round, but the females become gravid in December and the young are born in May through August, primarily. The young are about 1.5 inches long at birth (Bane and Bane 1971; Fitch and Lavenberg 1975; Moyle 1976; Eschmeyer et al. 1983).

Potential Biological Impacts Related to X2 Position: Based on salinity preferences, the shiner surfperch (as well as other surfperch species) would be adversely impacted by the downstream positioning of X2, especially under a Roe standard.

3.1.24 Bay Pipefish

The bay pipefish has been found in association with eel grass, kelp beds, and other forms of cover in San Francisco Bay and Suisun Bay (Wang 1986). This species is not found at salinities less than 9 ppt in general, although it probably experiences less on occasion (Moyle 1976).

Bay pipefish spawn from May through August (Moyle 1976; Wang 1986). The male incubates eggs for approximately 1-3 weeks and then releases the young as juveniles (Bane and Bane 1971; Moyle 1976).

Potential Biological Impacts Related to X2 Position: The bay pipefish would be adversely impacted as X2 would be positioned downstream, with the greatest impact occurring under the Roe Island standard.

3.1.25 Plainfin Midshipman

The plainfin midshipman is primarily a benthic species, but it has been noted to emerge at night from the bottom to search for food (Fitch and Lavenberg 1971). Specimens have been collected from San Francisco Bay, San Pablo Bay, and Suisun Bay (Wang 1986). Individuals may reach 3-4 years in age (Fitch and Lavenberg 1971); age at maturity is unknown (Wang 1986).

This species may die after spawning in late spring/early summer (Fitch and Lavenberg 1971). Spawning has been noted to occur in San Francisco Bay in high salinity water (>30 ppt) from April through August (Wang 1986) with hatching reported in July (Bane and Bane 1971). Males guard the eggs (Wang 1986). Larvae settle to the bottom soon after hatching and have been reported in San Francisco Bay. Juveniles have been reported in the fresh water or oligohaline ranges of the Sacramento-San Joaquin estuary (Wang 1986).

A related species, the specklefin midshipman, spawns in April through June. The male does not feed while guarding the eggs, which take a month or more to hatch (Fitch and Lavenberg 1975).

Potential Biological Impacts Related to X2 Position: The distribution of habitats of the plainfin midshipman does not change when X2 is moved from the confluence to Chipps Island. However, under a Roe Island standard, the potential for adverse impacts increases (i.e., habitats are reduced).

3.1.26 Barred Surfperch

The barred surfperch is a viviparous marine species that has been found in San Francisco Bay. Males mature in their first year, females by about age two (Wang 1986). Individuals may live to nine years and migrate less than 2 miles in general (Fitch and Lavenberg 1971). Mating occurs in fall and early winter, mostly during November and December (Fitch and Lavenberg 1971; Wang 1986). The young are approximately 1.75 inches long at birth, which occurs from March through July (Fitch and Lavenberg 1971; Eschmeyer et al. 1983).

Potential Biological Impacts Related to X2 Position: Similar to shiner surfperch

3.1.27 Dwarf Surfperch

The dwarf surfperch is a viviparous, marine and polyhaline species that has been found in San Francisco Bay and San Pablo Bay in salinities above 18 ppt. Male dwarf surfperch mature at birth, females at age one. Females may live to three years. Mating occurs in summer months, and birth occurs from June through August (Fitch and Lavenberg 1975; Wang 1986). The young are approximately 1 inch long at birth (Fitch and Lavenberg 1975).

Potential Biological Impacts Related to X2 Position: Similar to shiner surfperch.

3.1.28 Pile Surfperch

The pile surfperch is a viviparous, marine and polyhaline species that has been found in San Francisco Bay and San Pablo Bay in salinities above 18 ppt. Juveniles have been found up to Suisun Bay. Pile perch constitute an important sport and commercial fishery. They mature at about age two, and may reach 10 years in age. Mating occurs in fall months from September through November, and birth occurs from May through August (Wang 1986).

Potential Biological Impacts Related to X2 Position: Similar to shiner surfperch.

3.1.29 Black Surfperch

The black surfperch is a viviparous, primarily marine species that has been found in San Francisco Bay and San Pablo Bay in salinities below 30 ppt (possibly to above 18 ppt). Black surfperch mature at age one (Wang 1986). Individuals may live to ten years (Fitch and Lavenberg 1975). Mating occurs year round, but birth occurs in spring and summer months (Fitch and Lavenberg 1975; Wang 1986). The young are approximately 2 inches long at birth (Fitch and Lavenberg 1975).

Potential Biological Impacts Related to X2 Position: Similar to shiner surfperch.

3.1.30 White Surfperch

The white surfperch is a viviparous, marine and polyhaline species that has been found in San Francisco Bay, San Pablo Bay, and in the Carquinez Strait in salinities above 18 ppt. White surfperch constitute one of the most important commercial and sport fisheries along the California coast. Males mature in their second year, and females about a year later. Individuals may reach seven years in age. Birth occurs from May through August, and the young are approximately 1.5 inches long at birth (Bane and Bane 1971; Wang 1986). Mating occurs probably in late summer and fall months, assuming similarities exist with pile and dwarf surfperch life histories (*this study*).

Potential Biological Impacts Related to X2 Position: Similar to shiner surfperch.

3.1.31 English Sole

English sole is an important commercial fishing species. This species is primarily saltwater (> 30 ppt) and can be found in San Francisco Bay and San Pablo Bay. Larvae have been occasionally found up to Suisun Bay (Wang 1986). This species appears to rely on bay environments as nurseries, particularly during the first year of life (Bane and Bane 1971; Wang 1986). English sole appear to mature at about two to three years in age (Wang 1986)

Spawning occurs in the ocean from November through May (Bane and Bane 1971; Wang 1986). The eggs are buoyant, but begin to sink slowly shortly before hatching (Wang 1986). The larvae are pelagic and are carried by currents. Early juveniles settle to the bottom (Wang 1986).

Potential Biological Impacts Related to X2 Position: The english sole would be largely unaffected by the X2 standard regardless of its location.

3.1.32 California Halibut

California halibut constitute an important sport and commercial fishery (Bane and Bane 1971; Wang 1986). Adult halibut live primarily in coastal waters. Larvae and juveniles have been found in San Francisco Bay and San Pablo Bay (Wang 1986). Males mature at about age two (about 230 mm), females at about age five or six (about 430 mm), and individuals may live to thirty years (Bane and Bane 1971; Wang 1986).

Spawning occurs in shallow coastal water from January through July (Fitch 1958; Fitch and Lavenberg 1971; Bane and Bane 1971; Wang 1986). The eggs are buoyant, and the larvae are pelagic until metamorphosis, at a size greater than about 9 mm in length, at which point the juveniles settle to the bottom (Wang 1986). Eggs and larvae have been collected in the bay in summer, fall, and winter months (Wang 1986). Younger fish do not migrate much, having a range of less than a mile (Fitch 1958; Wang 1986).

Potential Biological Impacts Related to X2 Position: The California halibut would be largely unaffected by the X2 standard regardless of its location.

3.1.33 Diamond Turbot

The diamond turbot is a primarily marine species, although it may tolerate salinities in the range of 18 to 30 ppt (Wang 1986). A population appears to reside in San Francisco Bay. Larvae have been found in San Pablo Bay and Suisun Bay (Wang 1986). The species is thought to prefer quiet back-bay and slough waters (Fitch and Lavenberg 1975). Individuals mature at age 2 to 3 years and live to about 9 years (Fitch and Lavenberg 1975).

Spawning appears to occur year-round offshore with some spawning activity possible in San Francisco Bay (Fitch and Lavenberg 1975; Wang 1986). The eggs are buoyant and are carried by currents. Larvae are pelagic until metamorphosis, at a size greater than about 10 mm in length, at which point the juveniles settle to the bottom (Wang 1986).

Potential Biological Impacts Related to X2 Position: Since diamond turbot tolerate water salinities in the range of 18 to 30 ppt, they may be adversely impacted as the X2 moves downstream.

3.1.34 Speckled Sanddab

The speckled sanddab lives in seawater (> 30 ppt) and has been noted to be among the most abundant species in San Francisco Bay. Specimens have been noted in Suisun Bay as well (WRINT 1992). This species may mature at age one and live to at least four years (Fitch and Lavenberg 1975; Wang 1986). Sanddabs may be tolerant of sewage pollution (Fitch and Lavenberg 1975).

Spawning occurs in coastal waters from November through April, according to Wang (1986), or from March through September according to Fitch and Lavenberg (1975). Larvae have been collected year-round (Wang 1986). The pelagic larvae find their way into San Francisco Bay where they mature to adults (Fitch 1958; Wang 1986.)

Potential Biological Impacts Related to X2 Position: The speckled sanddab would be largely unaffected by the X2 standard regardless of its location.

3.1.35 Leopard Shark

The leopard shark is generally a marine species relying upon estuaries primarily for use as rearing and pupping areas. The leopard shark is abundant within San Francisco Bay and is the most common shark found there. Tagging studies in San Francisco Bay showed that most sharks resided in the Bay from March to September, but dispersed both inside and outside of the Bay from October through March (NOAA 1991). While little information is available regarding their specific salinity tolerances, dispersal in fall and winter in San Francisco Bay is associated with the period of high freshwater outflows (NOAA 1991).

The leopard shark is a live-bearing species with both fertilization and early development occurring internally. Mating appears to occur soon after females give birth primarily in April and May. The gestation period for the leopard shark appears to be 10-12 months (Ackerman 1971).

Juvenile and adult leopard sharks are demersal and are most commonly found in waters > 3.7 m deep (Eschmeyer et al. 1983). The leopard shark is carnivorous feeding primarily upon benthic and epibenthic crustacea (NOAA 1991). Pelagic fish species are also utilized in the diet of the adult leopard shark.

Recent reductions in shark numbers in San Francisco Bay are believed to be partially attributable to reduced salinity, warm water, and/or overharvesting (Ebert 1986). As this species is marine and exhibits a preference for polyhaline and euhaline waters (i.e., >18 ppt), the biological impacts related to the implementation of the EPA Water Quality Standard are believed to be relatively small.

Potential Biological Impacts Related to X2 Position: The leopard shark would be largely unaffected by the X2 standard regardless of its location.

3.1.36 Dungeness Crab

Dungeness crab use the lower Sacramento-San Joaquin estuary as a nursery ground (Brown 1987). Mating and egg release occurs in the ocean (Emmett et al. 1991). Juveniles begin moving into San Francisco Bay in May and move out again seven to ten months later (Brown 1987). During their stay, juvenile dungeness crab may be found in San Pablo Bay, the lower Napa River, Carquinez Strait, and lower Suisun Bay through the summer and fall months. Preferred salinity ranges during that time are between 15 and 30 ppt (Herrgesell 1993).

Potential Biological Impacts Related to X2 Position: Overall, the effects of X2 on Dungeness Crab would be low.

3.1.37 White Croaker

The white croaker occupies habitats found inshore and offshore and is found to depths up to 100 meters. Wang (1986) observed that all life stages occur within the Sacramento-San Joaquin estuary.

Bays and estuaries are used as spawning and nursery grounds for this species. White croaker larvae are pelagic and are thought to drift into the bay and estuary on the incoming tide. Wang (1986) reported that larval croaker were not only observed in the higher-salinity waters of San Francisco Bay, but also in the less-saline waters of Suisun Bay and the south end of Tomales Bay. Power plant impingement studies showed that juvenile croaker move into the ocean during the summer and fall, although juvenile croaker were reported in San Pablo Bay and Suisun Bay (Ganssle 1966; Messersmith 1966).

Potential Biological Impacts Related to X2 Position: Based on salinity, the overall impact on white croaker would be low.

3.1.38 Pacific Herring

Eldridge and Kaill (1973) described the larvae of Pacific herring moving out the bay soon after hatching. However Wang (1986) provided evidence that not all larvae move directly to the ocean. Some larvae remain in the estuary for a longer period of time than previously reported. Young-of-the-year herring have been observed in the vicinity of Port Chicago and Pittsburg (Ganssle 1966)

The peak spawning period in San Francisco Bay is from January to March (Miller and Schmidtke (1956). Mature fish return to the bays approximately two months before they spawn (Eldridge and Kaill 1973). San Pablo Bay and Carquinez Strait have been used for spawning during dry periods (Miller and Schmidtke 1956).

Potential Biological Impacts Related to X2 Position: The potential for adverse impacts occurring to the pacific herring are probably small but may increase as X2 is positioned downstream.

3.1.39 Northern Anchovy

Spawning locations within the Sacramento-San Joaquin estuary include the open waters of San Francisco Bay and San Pablo Bay. Salinity tolerance for spawning from seawater to mesohaline, occasionally found in oligohaline, such as Suisun Bay. Northern anchovy were common in San Pablo Bay and Suisun Bay (Ganssle 1966; Messersmith 1966). Wang (1986) observed northern anchovy eggs in Suisun Bay during the summer months, as seawater intruded up the river. As the salt wedge moves up to the estuary in the summer months, anchovy larvae were found in Suisun Bay and the lower Delta, and they were abundant through the fall months. Juveniles, in schools, are collected from seawater to freshwater in the Sacramento-San Joaquin estuary, where they are particularly common in July and August.

Potential Biological Impacts Related to X2 Position: Based on salinity preferences the potential for adverse impacts occurring to the northern anchovy increases as X2 is positioned downstream.

3.1.40 Topsmelt

The topsmelt is primarily a marine fish and is commonly found in estuarine environments. Within the Sacramento-San Joaquin estuary, topsmelt are particularly abundant in the shallow waters of the south Bay. Young of the year are also common is the mesohaline and oligohaline portions of estuary. Topsmelt are among the most abundant atherinids in San Francisco Bay.

Topsmelt have a prolonged spawning period from April through October, with a peak in May and June (Wang 1986). Spawning takes place in shallow vegetated areas where the deposited eggs become entangled with and adhere to aquatic vegetation. Hatching time varies from 35 days at 13 °C

Juveniles and adults are pelagic but are found over a wide range of habitats depending on time of year (Feder et al. 1974). Juvenile topsmelt generally move into the open water of the estuary and coastal kelp beds. Some may ascend into Suisun Bay in the summer and early fall as the salt wedge moves to the upper reaches of the estuary (Wang 1986). Topsmelt can withstand extreme salinities (80 ppt) (Carpelan 1955). Juvenile topsmelt feed on small crustaceans, diatoms, filamentous algae, detritus, chironomid larvae, and amphipods (Moyle 1976).

Potential Biological Impacts Related to X2 Position: The potential impacts to the topsmelt in the upper estuary appear minimal.

3.1.41 Jacksmelt

Within the Sacramento-San Joaquin estuary, jacksmelt are commonly found in waters with salinity values ranging from 5 ppt to that of seawater. The distribution of juvenile and adult jacksmelt in San Francisco Bay shows a preference for polyhaline and euhaline waters (>18 ppt). Jacksmelt are common in the open water of San Pablo Bay (Ganssle 1966) and San Francisco Bay (Baxter 1966; Aplin 1967), as well as shallow coastal waters (Boothe 1967). Estuaries provide important spawning and rearing environments for the species.

Spawning occurs during late winter and early spring when jacksmelt move inshore and into estuaries and in coastal embayments (Wang 1986). Spawning occurs in shallow vegetated areas. Eggs hatch within seven days at water temperatures of 10 to 12 °C. Juveniles and adults are surface oriented pelagic schooling fishes that are typically found within estuarine environments in the summer, moving into coastal waters in the fall. Jacksmelt appear to be more sensitive to salinity and temperature fluctuations than topsmelt. The diet of the jacksmelt is similar to that of the topsmelt.

Jacksmelt distributions within the Sacramento-San Joaquin estuary are heavily influenced by freshwater inflow. Jacksmelt are found in San Pablo Bay and Carquinez Strait during years of low outflow as the salt wedge moves upstream and conversely are distributed in Central and South Bay during years of high outflow (CDF&G 1987).

Potential Biological Impacts Related to X2 Position: Based on salinity jacksmelt distribution should not be substantially impacted by X2 position under the confluence or Chipps Island operational scenarios. The level of impact may increase slightly when X2 is positioned at Roe Island.

3.2 RESULTS OF PERIODICITY/DISTRIBUTION ANALYSIS

The following section summarizes the results of the periodicity/distribution analysis. The results represent qualitative predictions of changes in linear amount of suitable habitat present within the upper estuary based on salinity preferences that would be expected with the implementation of the standards at different locations; Chipps Island, Roe Island.

3.2.1 Chipps Island Standard

3.2.1.1 Species Beneficially Impacted under Chipps Island Standard

A total of 14 of the 41 (34%) species for which potential impacts were determined, had at least one life stage which would potentially benefit when X2 is extended downstream to Chipps Island (Table 3-1).

Table 3-1. Species and life stages beneficially impacted when X2 is located at Chipps Island.

Species	Egg/Larval	Juvenile	Adult	Spawning
White catfish	X	X		X
Channel catfish	X			X
Sac. splittail	X	X	X	X
Sac. squawfish		X	X	
Threadfin shad	X			X
Inland silverside		X	X	
Tule perch		X		
Green sturgeon	X			
White sturgeon	X			
Striped bass				X
American shad	X			
Delta smelt	X	X	X	X
Longfin smelt	X			X
Threespine stickleback	X			X
Total number	10	6	4	8

Beneficial Impacts to Early Life Stages

Of the 41 total species for which the potential impacts to early life stages (egg/larvae) were determined, 10 species would benefit when X2 is extended downstream from the confluence to Chipps Island. These would include: white catfish, channel catfish, Sacramento splittail, threadfin shad, green sturgeon, white sturgeon, american shad, Delta smelt, longfin smelt, and threespine stickleback. The species having the greatest potential benefit (either in magnitude or duration of benefit) were splittail, threadfin shad, green sturgeon, white sturgeon, longfin smelt, and threespine stickleback. Table 3-2 summarizes the results of this analysis.

Table 3-2. Synopsis of potential benefits to the early life stages of estuarine species under the Chipps Island standard.

Species	Confluence Habitat Index*	Chipps Island Habitat Index*	Magnitude of Impact (%change)	Duration of Impact
White catfish	0.71	0.88	25	1 month
Channel catfish	0.86	1.00	16	2 months
Sac. splittail	0.19	0.33	74	4 months
Threadfin shad	0.36	0.57	58	3 months
Green sturgeon	0.36	0.45	25	4 months
White sturgeon	0.36	0.45	25	3 months
American shad	0.80	1.00	25	1 month
Delta smelt	0.94	1.00	6	3 months
Longfin smelt	0.44	0.56	27	4 months
Threespine stickleback	0.73	0.85	16	4 months

* Habitat Index equals the linear amount of suitable habitat (based on species salinity requirements) divided by total linear amount of habitat.

Beneficial Impacts to Juvenile Life Stages

The results of the assessment for of juvenile life stage indicate that six species would potentially benefit under the Chipps standard; white catfish, Sacramento splittail, Sacramento squawfish, inland silverside, tule perch, and Delta smelt (Table 3-3). Of these, the Sacramento splittail and inland silverside would benefit the greatest (Table 3-3).

Table 3-3. Synopsis of potential benefits to the juvenile life stage of estuarine species under the Chipps Island standard.

Species	Confluence Habitat Index*	Chipps Island Habitat Index*	Magnitude of Impact (%change)	Duration of Impact
White catfish	0.67	0.82	22	5 months
Sac. splittail	0.19	0.33	74	3 months
Sac. squawfish	0.73	0.86	18	5 months
Inland silverside	0.44	0.67	52	5 months
Tule perch	0.78	1.00	28	5 months
Delta smelt	0.86	1.00	16	5 months

* Habitat Index equals the linear amount of suitable habitat (based on species salinity requirements) divided by total linear amount of habitat.

Beneficial Impacts to Adult Life Stages

Results of the adult life stage analysis indicated that four species of fish would potentially benefit by the Chipps Island standard; Sacramento splittail, Sacramento squawfish, inland silverside, and Delta smelt (Table 3-4). Of these species, the is greatest potential benefits is for the inland silverside, the least for Delta smelt.

Table 3-4. Synopsis of potential benefits to the adult life stage of estuarine species under the Chipps Island standard.

Species	Confluence Habitat Index*	Chipps Island Habitat Index*	Magnitude of Impact (%change)	Duration of Impact
Sac. splittail	0.48	0.58	21	5 months
Sac. squawfish	0.48	0.58	21	5 months
Inland silverside	0.50	0.70	40	5 months
Delta smelt	0.86	1.00	16	5 months

* Habitat Index equals the linear amount of suitable habitat (based on species salinity requirements) divided by total linear amount of habitat.

Beneficial Impacts to Spawning Life Stages

The analysis of spawning habitats within the upper estuary indicated that eight species may potentially benefit under the Chipps Island standard, including white catfish, channel catfish, Sacramento splittail, threadfin shad, striped bass, Delta smelt, longfin smelt, and threespine stickleback. The greatest potential benefit would occur for Delta smelt, longfin smelt, striped bass, splittail, and threadfin shad inhabiting the upper estuary.

Table 3-5. Synopsis of potential benefits to the spawning life stage of estuarine species under the Chipps Island standard.

Species	Confluence Habitat Index*	Chipps Island Habitat Index*	Magnitude of Impact (%change)	Duration of Impact
White catfish	0.55	0.68	24	1 month
Channel catfish	0.86	1.00	16	3 months
Sac. splittail	0.48	0.58	21	5 months
Threadfin shad	0.29	0.50	72	3 months
Striped bass	0.55	0.68	24	3 months
Delta smelt	0.55	0.68	24	5 months
Longfin smelt	0.55	0.68	24	3 months
Threespine stickleback	0.73	0.85	16	4 months

* Habitat Index equals the linear amount of suitable habitat (based on species salinity requirements) divided by total linear amount of habitat.

3.2.1.2 Species Adversely Impacted Under Chipps Island Standard

The periodicity analysis indicated that 10 species may be adversely impacted. For at least one life stage, when X2 was extended downstream to Chipps Island (Table 3-6). Because many of these species are marine, they are restricted to the lower (San Pablo Bay, Carquinez Strait) portion of the estuary. Decreased salinity associated with downstream positioning of X2 could thus, adversely impact these species in these locations.

Table 3-6. Species and life stages which may be adversely impacted when X2 is located at Chipps Island.

Species	Egg/Larvae	Juvenile	Adult	Spawning
Bay goby		X	X	
Yellowfin goby	X			
Bay shrimp	X	X		
Starry flounder	X		X	X
Threespine stickleback		X		
Shiner surfperch		X		
Bay pipefish	X	X	X	X
White croaker		X		
Pacific herring		X		
Topsmelt		X		
Total Number	4	8	4	3

Adverse Impacts to Early Life Stages

Under the Chipps Island standard, the early life stages of four species of fish would potentially be adversely impacted, including: yellowfin goby, bay shrimp, starry flounder, and bay pipefish (Table 3-7). Of these, the bay shrimp and starry flounder would be impacted the greatest based on either the magnitude of habitat lost or the duration of time at which lost habitat would occur (Table 3-7).

Table 3-7. Synopsis of potential adverse impacts to the early life stages of estuarine species under the Chipps Island operational standard.

Species	Confluence Habitat Index*	Chipps Island Habitat Index*	Magnitude of Impact (%change)	Duration of Impact
Yellowfin goby	0.95	0.84	- 12	3 months
Bay shrimp	0.74	0.47	- 35	2 months
Starry flounder	0.73	0.40	- 45	3 months
Bay pipefish	1.00	0.87	- 13	5 months

* Habitat Index equals the linear amount of suitable habitat (based on species salinity requirements) divided by total linear amount of habitat.

Adverse Impacts to Juvenile Life Stages

The analysis indicated that the juvenile life stages of 11 species of fish may be negatively impacted under a Chipps standard. These species include: bay goby, bay shrimp, threespine stickleback, shiner surfperch, bay pipefish, white croaker, pacific herring, and topsmelt (Table 3-8). The greatest potential impact to the juvenile fishes inhabiting the upper estuary exists for pacific herring, bay pipefish, threespine stickleback, and bay goby (Table 3-8).

Table 3-8. Synopsis of potential adverse impacts to the juvenile life stage of estuarine species under the Chipps Island operational standard.

Species	Confluence Habitat Index*	Chipps Island Habitat Index*	Magnitude of Impact (%change)	Duration of Impact
Bay goby	0.92	0.50	- 46	5 months
Bay shrimp	0.87	0.78	- 10	3 months
Threespine stickleback	1.00	0.74	- 26	5 months
Shiner surfperch	0.84	0.74	- 13	5 months
Bay pipefish	1.00	0.87	- 13	5 months
White croaker	0.86	0.76	- 12	1 month
Pacific herring	0.86	0.76	- 12	5 months
Topsmelt	0.86	0.76	- 12	1 month

* Habitat Index equals the linear amount of suitable habitat (based on species salinity requirements) divided by total linear amount of habitat.

Adverse Impacts to Adult Life Stages

The adult life stage of four species of fish may be adversely impacted under the Chipps standard, including: bay goby, starry flounder, shiner surfperch, and bay pipefish (Table 3-9).

Table 3-9. Synopsis of potential adverse impacts to the adult life stage of estuarine species under the Chipps Island standard.

Species	Confluence Habitat Index*	Chipps Island Habitat Index*	Magnitude of Impact (%change)	Duration of Impact
Bay goby	0.92	0.50	- 46	5 months
Starry flounder	1.00	0.86	- 14	5 months
Shiner surfperch	0.84	0.74	- 13	5 months
Bay pipefish	1.00	0.87	- 13	5 months

* Habitat Index equals the linear amount of suitable habitat (based on species salinity requirements) divided by total linear amount of habitat.

Adverse Impacts to Spawning Life Stage

Species in for which spawning habitat quantity or quality may be reduced under a Chipps standard include: starry flounder, shiner surfperch, and bay pipefish. While these species are "at risk" due to their salinity preferences and tolerances, the overall magnitude of the impact is relatively low (Table 3-10).

Table 3-10. Synopsis of potential adverse impacts to the spawning life stage of estuarine species under the Chipps Island standard.

Species	Confluence Habitat Index*	Chipps Island Habitat Index*	Magnitude of Impact (%change)	Duration of Impact
Starry flounder	1.00	0.86	- 14	2 months
Shiner surfperch	0.84	0.74	- 13	5 months
Bay pipefish	1.00	0.87	- 13	5 months

* Habitat Index equals the linear amount of suitable habitat (based on species salinity requirements) divided by total linear amount of habitat.

3.2.2 Roe Island Standard

Extending the 2 ppt isohaline (X2) to Roe Island would results in additional benefits (quantity of habitat, and duration at which habitat available) for many of the same species that benefitted under the Chipps Island standard. However, several species are more adversely impacted when X2 is at Roe Island than at Chipps Island. In addition, there is a greater potential for additional species to be adversely impacted under the Roe Island standard (Figures 3-1 and 3-2).

3.2.2.1 Species Benefitting Under Roe Island Standard

In general, species and life stages benefitting are the same as those that benefit when X2 is at Chipps Island. The greatest differences between a Chipps and Roe standard relate to the magnitude of benefit attained. As expected, certain freshwater and oligohaline species and life stages do exhibit an incremental benefit in the amount of suitable habitat (based on salinity) available under the Roe standard.

Beneficial Impacts to Early Life Stages

The results of the periodicity/distribution analysis indicate that the early life stages of 11 species would benefit when X2 is positioned at or near Roe Island. In addition to the 10 species that would benefit from a Chipps standard, the early life stages of striped bass would also benefit. Overall, the Sacramento splittail and threadfin shad would benefit the greatest when X2 is positioned at Roe Island.

The potential incremental benefit of a Roe standard is substantial for seven of the 11 species affected (Table 3-11), but is either non existent or slight for channel catfish, american shad, Delta smelt, and the threespine stickleback (Table 3-11).

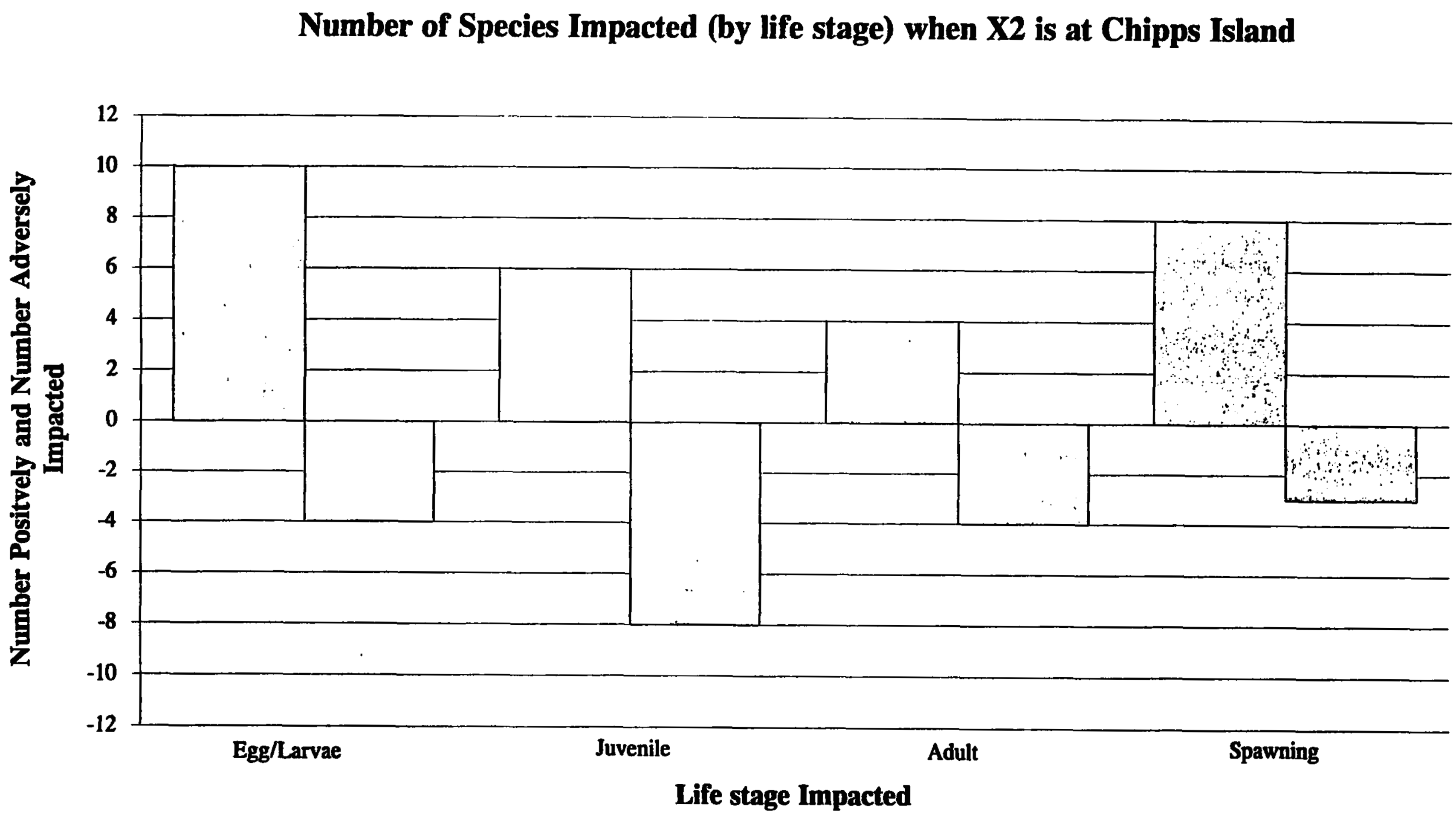

Figure 3-1. Number of species beneficially and adversely impacted (by lifestage) under the Chipps Island Operational Scenario.

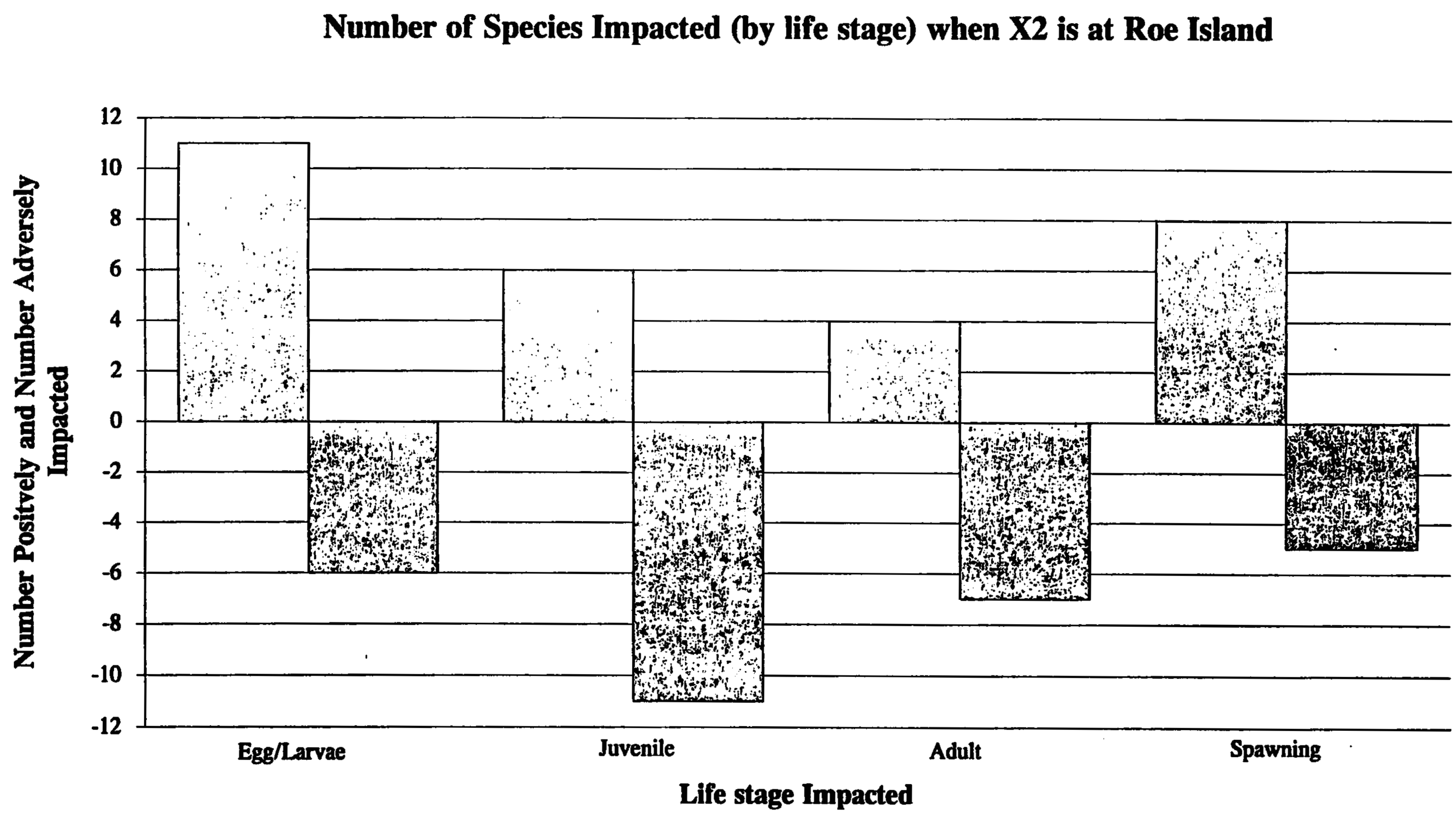

Figure 3-2. Number of species beneficially and adversely impacted (by lifestage) under the Roe Island Operational Scenario.

Table 3-11. Synopsis of potential beneficial impacts to the early life stage of estuarine species under the Roe Island standard.

Species	Habitat Index *		Impact		
	Confluence	Roe Island	Magnitude (% change)	% Contributed at Chipps Is.	Duration of Impact
White catfish	0.71	1.00	41	60	1 month
Channel catfish	0.86	1.00	16	100	2 months
Sac. splittail	0.19	0.48	152	50	4 months
Threadfin shad	0.36	0.86	139	42	3 months
Green sturgeon	0.36	0.58	61	43	4 months
White sturgeon	0.36	0.58	61	43	3 months
Striped bass	0.85	1.00	18	0	2 months
American shad	0.80	1.00	25	100	1 month
Delta smelt	0.94	1.00	6	100	3 months
Longfin smelt	0.44	0.70	60	42	4 months
Threespine stickleback	0.73	0.91	25	67	4 months

* Habitat Index equals the linear amount of suitable habitat (based on species salinity requirements) divided by total linear amount of habitat.

Beneficial Impacts to Juvenile Life Stage

The juvenile life stage of six of 41 species (the same as benefited under Chipps standard) would potentially benefit when X2 is positioned at Roe Island. Of these the Sacramento splittail and the inland silverside would achieve the greatest benefit (Table 3-12). The incremental benefit would be substantial for Sacramento splittail, Sacramento squawfish, and inland silverside (Table 3-12), but only slight for white catfish, tule perch, and Delta smelt (Table 3-12).

Table 3-12. Synopsis of potential beneficial impacts to the juvenile life stage of estuarine species under the Roe Island standard.

Species	Habitat Index *		Impact		
	Confluence	Roe Island	Magnitude (% change)	% Contributed at Chipps Is.	Duration of Impact
White catfish	0.67	0.88	31	71	5 months
Sac. splittail	0.19	0.48	153	50	4 months
Sac. squawfish	0.73	1.00	37	50	5 months
Inland silverside	0.44	1.00	127	40	5 months
Tule perch	0.78	1.00	28	100	2 months
Delta smelt	0.86	1.00	16	100	5 months

* Habitat Index equals the linear amount of suitable habitat (based on species salinity requirements) divided by total linear amount of habitat.

Beneficial Impacts to the Adult Life Stage

Four species of adult fish would potentially benefit when X2 is positioned at Roe Island (increased availability of optimal salinities). The greatest potential benefit would occur for inland silverside; adult Sacramento splittail and Sacramento squawfish would benefit moderately (Table 3-13). Delta smelt exhibit a slight overall benefit in the amount of optimal salinity waters available to them and would benefit slightly overall, although the incremental benefits are no greater than what occurred when X2 was at Chipps Island.

Table 3-13. Synopsis of potential beneficial impacts to the adult life stage of estuarine species under the Roe Island standard.

Species	Habitat Index *		Impact		
	Confluence	Roe Island	Magnitude (% change)	% Contributed at Chipps Is.	Duration of Impact
Sac. splittail	0.48	0.67	40	50	5 months
Sac. squawfish	0.48	0.67	40	50	5 months
Inland silverside	0.50	1.00	100	40	5 months
Delta smelt	0.86	1.00	16	100	5 months

* Habitat Index equals the linear amount of suitable habitat (based on species salinity requirements) divided by total linear amount of habitat.

Beneficial Impacts to Spawning Life Stages

Eight species of fish may benefit from an increased availability of optimal spawning habitat (based on salinity), under a Roe Island standard. The species are the same as those benefitting when X2 is at Chipps Island, however, the magnitude of the benefit is different. Overall, the greatest benefit would occur for threadfin shad, the least for channel catfish (Table 3-14). The incremental benefit attained under a Roe Island standard results in substantial increases in spawning habitat of white catfish, Sacramento splittail, threadfin shad, striped bass, Delta smelt, and longfin smelt (Table 3-14); incremental benefits to channel catfish and threespine stickleback are non existent or slight (Table 3-14).

Table 3-14. Synopsis potential beneficial impacts to the spawning life stage of estuarine species under the Roe Island standard.

Species	Habitat Index *		Impact		
	Confluence	Roe Island	Magnitude (% change)	% Contributed at Chipps Is.	Duration of Impact
White catfish	0.55	0.86	56	44	1 month
Channel catfish	0.86	1.00	16	100	3 months
Sac. splittail	0.48	0.67	40	50	5 months
Threadfin shad	0.29	0.86	197	37	3 months
Striped bass	0.55	0.86	56	44	3 months
Delta smelt	0.55	0.86	56	44	5 months
Longfin smelt	0.55	0.86	56	44	3 months
Threespine stickleback	0.73	0.91	25	67	4 months

*** Habitat Index equals the linear amount of suitable habitat (based on species salinity requirements) divided by total linear amount of habitat.**

3.2.2.2 Species Adversely Impacted Under the Roe Island Standard

The potential adverse biological impacts associated with positioning X2 under a Roe Island standard include the same species adversely impacted by a Chipps standard as well as several additional species. The additional species are those that prefer waters of greater salinity; jacksmelt, dwarf surfperch, pile surfperch, and white surfperch.

Adverse Impacts to Early Life Stages

Of the 41 species analyzed, six species may potentially be adversely impacted when X2 is at Roe Island (Table 3-15), with the most adverse impacts occurring for the bay goby and starry flounder. Four species, yellowfin goby, bay shrimp, starry flounder and bay pipefish, were likewise adversely impacted under a Chipps Island standard, but not to the same magnitude (Table 3-15). Of these, the largest incremental detriment (when X2 is extended to Roe Island), occurs for the yellowfin goby and the bay pipefish. Both the bay goby and jacksmelt were not impacted under a Chipps Island standard.

Table 3-15. Synopsis of potential adverse impacts to the early life stages of estuarine species under the Roe Island standard.

Species	Habitat Index *		Impact		
	Confluence	Roe Island	Magnitude (% change)	% Contributed at Chipps Is.	Duration of Impact
Bay goby	1.00	0.50	- 50	0	5 months
Yellowfin goby	0.95	0.63	- 34	34	3 months
Bay shrimp	0.74	0.37	- 50	70	2 months
Starry flounder	0.73	0.27	- 63	72	3 months
Bay pipefish	1.00	0.60	- 40	33	5 months
Jacksmelt	1.00	0.67	- 33	0	5 months

* Habitat Index equals the linear amount of suitable habitat (based on species salinity requirements) divided by total linear amount of habitat.

Adverse Impacts to the Juvenile Life Stage

Ten species of fish and one invertebrate species, may be adversely impacted when X2 is located at or near Roe Island (Table 3-16). The juvenile life stages of the bay goby and the threespine stickleback have the potential to be the most adversely impacted under a Roe standard. Of the 11 species affected, 8 were identified as having the potential to be negatively impacted when X2 was at Chipps Island. The incremental reduction in the habitat index was substantially greater when X2 was extended to Roe Island (Table 3-16). Three of the species (dwarf surfperch, pile surfperch, and white surfperch) impacted under the Roe standard were not impacted when X2 was located at Chipps Island.

Table 3-16. Synopsis of potential adverse impacts to the juvenile life stages of estuarine species under the Roe Island standard.

Species	Habitat Index *		Impact		
	Confluence	Roe Island	Magnitude (% change)	% Contributed at Chipps Isl.	Duration of Impact
Bay goby	0.92	0.33	- 64	72	5 months
Bay shrimp	0.87	0.70	- 20	53	3 months
Threespine stickleback	1.00	0.47	- 53	49	5 months
Shiner surfperch	0.84	0.47	- 44	30	5 months
Bay pipefish	1.00	0.60	- 40	33	5 months
Dwarf surfperch	1.00	0.67	- 33	0	5 months
Pile surfperch	1.00	0.67	- 33	0	5 months
White surfperch	1.00	0.67	- 33	0	5 months
White croaker	0.86	0.57	- 34	34	1 month
Pacific herring	0.86	0.57	- 34	34	5 months
Topsmelt	0.86	0.57	- 34	34	1 month

* Habitat Index equals the linear amount of suitable habitat (based on species salinity requirements) divided by total linear amount of habitat.

Adverse Impacts to the Adult life stage

The adult life stage of seven species of fish found in the upper estuary could be negatively impacted when X2 is positioned at Roe Island. Of these, four were negatively impacted under the Chipps Island standard, including: bay goby, starry flounder, shiner surfperch, and bay pipefish (Table 3-17). Three of the species impacted (dwarf surfperch, pile surfperch, and white surfperch) were not affected under the Chipps Island standard.

Table 3-17. Synopsis of potential adverse impacts to the adult life stages of estuarine species under the Roe Island standard.

Species	Habitat Index *		Impact		
	Confluence	Roe Island	Magnitude (% change)	% Contributed at Chipps Is.	Duration of Impact
Bay goby	0.92	0.33	- 64	71	5 months
Starry flounder	1.00	0.57	- 43	33	5 months
Shiner surfperch	0.84	0.47	- 44	30	5 months
Bay pipefish	1.00	0.60	- 40	33	5 months
Dwarf surfperch	1.00	0.67	- 33	0	5 months
Pile surfperch	1.00	0.67	- 33	0	5 months
White surfperch	1.00	0.67	- 33	0	5 months

* Habitat Index equals the linear amount of suitable habitat (based on species salinity requirements) divided by total linear amount of habitat.

Adverse Impacts to the Spawning Life Stage

The spawning habitats of five species of estuarine fish may be adversely impacted when X2 is at or near Roe Island. Three of these species, starry flounder, shiner surfperch, and bay pipefish were likewise, adversely impacted under the Chipps Island standard, but not to the same magnitude (Table 3-18). The spawning habitats of bay goby and jacksmelt were not impacted under the Chipps Island standard, but would be under a Roe Island standard (Table 3-18).

Table 3-18. Synopsis of potential adverse impacts to the spawning life stage of estuarine species under the Roe Island standard.

Species	Habitat Index		Impact		
	Confluence	Roe Island	Magnitude (% change)	% Contributed at Chipps Is.	Duration of Impact
Bay goby	1.00	0.67	- 33	0	3 months
Starry flounder	1.00	0.57	- 43	33	2 months
Shiner surfperch	0.84	0 47	- 44	30	5 months
Bay pipefish	1.00	0.60	- 40	33	5 months
Jacksmelt	1.00	0.67	- 33	0	5 months

* Habitat Index equals the linear amount of suitable habitat (based on species salinity requirements) divided by total linear amount of habitat.

4.0 DISCUSSION

The salinity standards proposed by the EPA for the Sacramento-San Joaquin estuary were developed in response to the perceived "shortcomings" of the California State Water Resources Control Board's criteria for protecting the biological resources in the Bay and Delta. The EPA cited the continued deterioration of the estuary's resources as evidence of this shortcoming and need for additional criteria. Based on a designated use of "estuarine habitat", the EPA has proposed specific salinity standards based on the 2 ppt isohaline being located for specific periods of time at two locations in the Bay, Chipps Island, and Roe Island. The EPA has emphasized estuarine habitat as a designated use "because of its importance to the whole spectrum of fish and wildlife uses in the estuary". Further, "this emphasis is consistent with the Interagency Statement of Principles' recommendation that restoration efforts focus on habitat protection".

The proposed standard provides summary technical information which describes the basis and foundation for the standard, and which serves to illustrate the biological importance of the 2 ppt isohaline relative to certain estuarine species. These included the Delta smelt, Sacramento splittail, longfin smelt, striped bass, starry flounder, and bay shrimp. While acknowledging that other factors also influence species abundance, the EPA made no attempt to address these, but rather selected a single salinity standard as encompassing "a number of important estuarine properties". Although the EPA indicated that the proposed standard was developed under an ecosystem concept and that all species which utilize the system stood to benefit (some more than others), the EPA provided no evidence that potential adverse impacts were evaluated or even considered. In addition, there was no attempt to quantify the relative gains or losses in habitats (as a function of salinity) that would occur under the different standard locations, information which could be used in an optimization study to select the "best" location of X2 based on habitat gains relative to water costs. The analysis herein was completed as an initial step in addressing these latter two questions, i.e., 1) potential adverse impacts; and 2) relative gains and losses of habitat.

A comprehensive understanding of the individual needs of each species inhabiting a given ecosystem is fundamental in attempting to predict species and community level responses relative to changes in the environment. This assessment relied on data which describes the life history and habitat use of each species in the upper estuarine community to broadly classify the suitability of habitats based on salinity across the entire segment of the Bay-Delta potentially affected by the EPA standard. By examining species life histories, periodicity information, and species/life history tolerances to environmental factors (e.g., temperature, dissolved oxygen, salinity), an assessment of impacts (resulting from a shift in one or more environmental parameters) on a given species and life stage can be made, based on the suitability of the resulting habitat. The analysis was completed for a broad range of species known to inhabit the Bay-Delta system, including both euryhaline and stenohaline species.

The stated objective of the proposed EPA salinity standard is to restore the abundance of certain Bay-Delta species back to those representative of historical conditions; circa late 1960's-early 1970's. The mechanism for achieving this is to institute a level of protection (salinity standard - surrogate for outflow) for the estuarine resources which presumably will restore the natural balance to the flora and fauna present in the upper estuary. For this, the EPA has selected the 2 ppt isohaline (X2) as an indicator of suitable estuarine habitat for organisms found in the upper estuary. The EPA decision to select the 2 ppt isohaline (X2) was based on available scientific evidence and testimony, and results of a series of workshops focused on criteria development.

The biological significance of the spatial and temporal location of the 2 ppt isohaline was summarized in the proposed standard and is described in detail by Jassby (1993). While many of the species reported by Jassby (1993) exhibited increased abundance when X2 was positioned downstream, the relationships discussed were done so mono-specifically and without considering other species in the system. Thus, there was no evaluation of whether the benefits realized by one species (or group of species) may put other species at risk in terms of changes in habitat quality and quantity (as a function of salinity). Prior to the implementation of any water quality standard, the EPA should fully evaluate both positive and negative impacts associated with the standard, thereby considering the entire ecosystem.

The intent of this assessment was to single out the potential effects of a change in one factor, salinity, on the aquatic organisms of the upper estuary. While the studies of Jassby (1993) indicated that species abundance of several members of the estuarine community are correlated with X2 position and that X2 position provides the best habitat indicator, we used a broad based approach to evaluate the response of all important fish species in the ecosystem to the direct effects (measured as a function of location of salinity isohalines) of this standard. It is recognized that salinity is but one of many factors that serve to shape and control an ecosystem and that the ultimate community response is as result of numerous complex interactions between species and their environments.

Indications are that the overall number of species impacted by salinity changes, either beneficially or adversely, may be greatest when X2 is positioned at Roe Island rather than at Chipps Island or the confluence. The implications of this conclusion are that the most substantial change would be expected when X2 is positioned at Roe Island. As the number of species impacted increases, it becomes exceedingly difficult to predict biological responses at the community level. In addition to the implications associated with the total number of species impacted under the Roe Island scenario, the total number of adversely impacted species is greatest under the Roe Island scenario. The implications of an increase in the number of adversely impacted species are reduced species diversity, altered species composition, and lowered abundance of certain species. The results of the analysis further indicate that under the Roe Island Standard, the number of adversely impacted life stages far outweigh the number beneficially impacted, during the months of February and March. The number of life stages benefitting and the number adversely impacted during the remainder of the EPA identified biologically sensitive period (April to June) are nearly equal.

Several species may benefit under the currently proposed standard. The magnitude of the benefit attained under each scenario is highly variable between species. The implications of this variation in benefit are that certain favored species may dominate the composition of the upper estuarine community. The potential therefore exists that the interaction among benefitting species may actually be detrimental to certain species when considering the population dynamics at the community level.

The potential for competitive interactions between the inland silverside and the Delta smelt provides a good example of how the net effect of two individually identified species showing a benefit may actually be detrimental when the species are considered together. Bennett and Moyle (1993) suggest that competition between these species is highly probable given their similarities in physical size and diet. The results of the life history (periodicity/distribution) analysis indicate that the relative benefit, in terms of the availability of suitable habitat, for inland silverside is two times and three times greater than that for the Delta smelt, for the juvenile and adult life stages, respectively. This alone suggests that the Chipps Island standard may provide a competitive advantage for the inland silverside over the Delta smelt. This competitive advantage becomes especially important when considering the Roe Island standard because the inland silverside exhibits a substantial incremental benefit (for both the juvenile and adult life stages) when X2 is positioned at Roe Island, whereas the Delta smelt does not.

The results of this preliminary analysis suggest that the EPA standard, as proposed, has not fully considered the biological implications that may result from its implementation. Changes in salinity distributions in the upper estuary result in changes in the quantity and quality of habitats found in other locations within the Bay-Delta. Such changes may be beneficial to certain species and adverse to others, and may be inadvertently setting up conditions which lead to competitive interactions between native and introduced species (e.g., Delta smelt and inland silverside). The development of a biologically sound water quality standard should be based on knowledge regarding individual species and how they will respond relative to the overall community of organisms. Ecosystem health is the product of the well being of its individual inhabitants and their interactions among each other. This must be carefully considered when proposing a new water quality standard.

As previously mentioned, competitive species interactions may be exacerbated by the respective location of the X2 isohaline. The potential for localized competition for space, i.e., specific habitats, exists in the upper estuary however, the greatest potential for competition to take place is for limited food resources. The direct interactions between the inland silverside and the Delta smelt are only one example of competition for food resources. Competition in the upper estuary may be especially intense among the zooplankton feeders; young striped bass, American shad, threadfin shad, inland silverside, Delta smelt, longfin smelt, and threespine stickleback. Many of these species are favored under the currently proposed standard suggesting the possibility of intensified competition for potentially limited food resources. In addition, increased habitat suitability for the Sacramento splittail may introduce the potential for competition to occur among species with the same diet of amphipods and opossum shrimp.

Predatory interactions may also be influenced by the respective location of the X2 isohaline. Natural populations of predators and prey have often evolved to co-exist in dynamic equilibrium. However, changes that occur in their environment may disrupt this balance. The potential for this type of disruption to occur exists within the X2 standard. The habitat requirements of many predatory species; Sacramento squawfish, striped bass, white catfish, channel catfish, and inland silverside are enhanced under the currently proposed standard. The benefit for the majority of these species is maximized when X2 is at Roe Island, suggesting that predatory interactions may be significant when X2 is positioned there.

In attempting to understand community ecology, it is often easiest and most convenient to focus our analysis on the response of individual species to environmental factors. However, we must determine if the communities are tightly integrated and highly interactive or are they merely assemblages of species more influenced by environmental factors and their own autecology? If we determine that environmental factors plays the most significant role in determining ecosystem health, we need to examine multiple hypotheses and consider interactions among processes that influence community structure and function. Throughout this process, we must remain focused on the real objective which is to maintain the ecosystem.

The setting of an X2 standard would be promulgated under the assumption that it is the location of the 2 ppt isohaline in the Bay and Delta that influences the *overall* ecosystem health. The Status and Trends reports have noted repeatedly that there are other factors (many of them unquantifiable) which are influencing certain fish populations, and for which the X2 standard will have no effect. A review of biological requirements suggests that the greatest influence of the X2 standard would be on the Delta smelt and certain other euryhaline species. Some researchers believe this species has an affinity for the 2 ppt isohaline, which occurs in close association with the entrapment zone (ET) zone (Moyle et al. 1992; Moyle 1992a). Although Jassby's analysis indicates there are other species which likewise have a relationship to X2, the disaggregation of data demonstrates that X2 explains just a part of the variability in relative abundance for these species below a certain location in the Delta (i.e., below Chipps Is.). Thus, there is a real potential that the setting and implementation of the X2 standard as is presently defined, will not achieve the overall desired effect of maintaining total ecosystem health, but would rather have the most applicability to 1 or 2 species including Delta smelt and splittail. This begs the Question: should the EPA develop and mandate standards which have a high degree of biological uncertainty and are most applicable to 1-2 species, and which have high resource use costs associated with its implementation? Given the uncertainty of the biological relationships to X2 and the increased variability in the relationships with distance below Chipps Island, at best, the X2 standard should perhaps be implemented on an interim basis, and then only after it is modified so it can be efficiently and realistically administered.

The statement of principles put forth by the NMFS, USFWS, EPA call for the use of an ecosystem or habitat based approach to the management of the upper estuary. The ecosystem approach is a broad based approach which shifts some of the focus off of individual species and puts emphasis on preserving the integrity of the functional ecosystem thereby preventing species from becoming endangered. This assessment of qualitative changes in habitat (based on species salinity requirements) that might be expected under each of the proposed operational scenarios is patterned along a habitat based approach to the management of the upper estuary.

The interaction between individual species and their environment as well as the interactions among species are important factors in understanding community ecology. The evidence presented here suggests that in addition to the direct environmental influence of the relative position of X2, the possibility exists for many potential interactions among the inhabitants of the upper estuary. An comprehensive understanding of the role and relative importance of these interactions in determining community structure as well as an understanding of the influence of the EPA standard on these interactions is critical before implementation is proposed.

Based on our assessment, we suggest and recommend that EPA evaluate the following considerations prior to promulgating the proposed salinity standard:

- Species interactions may play a larger role than biogeographic factors in determining the composition of the community; evaluate potential adverse impacts and interactions that may develop.
- Preservation of the current ecosystem with endangered species and introduced species co-existing may not be wholly compatible with the proposed standard.
- The currently proposed standard may be biased towards the management of select species - is the standard truly an "ecosystem standard"?
- Quantify gains and losses of habitat on an individual species and a community level, and target criteria toward achieving highest benefits overall (most habitat) with consideration for water costs; optimize B/C ratio.
- Elimination of the Roe Standard should be considered for reasons noted above; adverse impacts increase; benefits are lower; potential benefits high to undesirable species (e.g., inland silverside).
- Prior to the implementation of any water quality standard, the EPA should fully evaluate both positive and negative impacts associated with the standard, thereby considering the entire ecosystem.

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APPENDIX A

SPECIES PERIODICITY AND DISTRIBUTION CHARTS

APPENDIX A

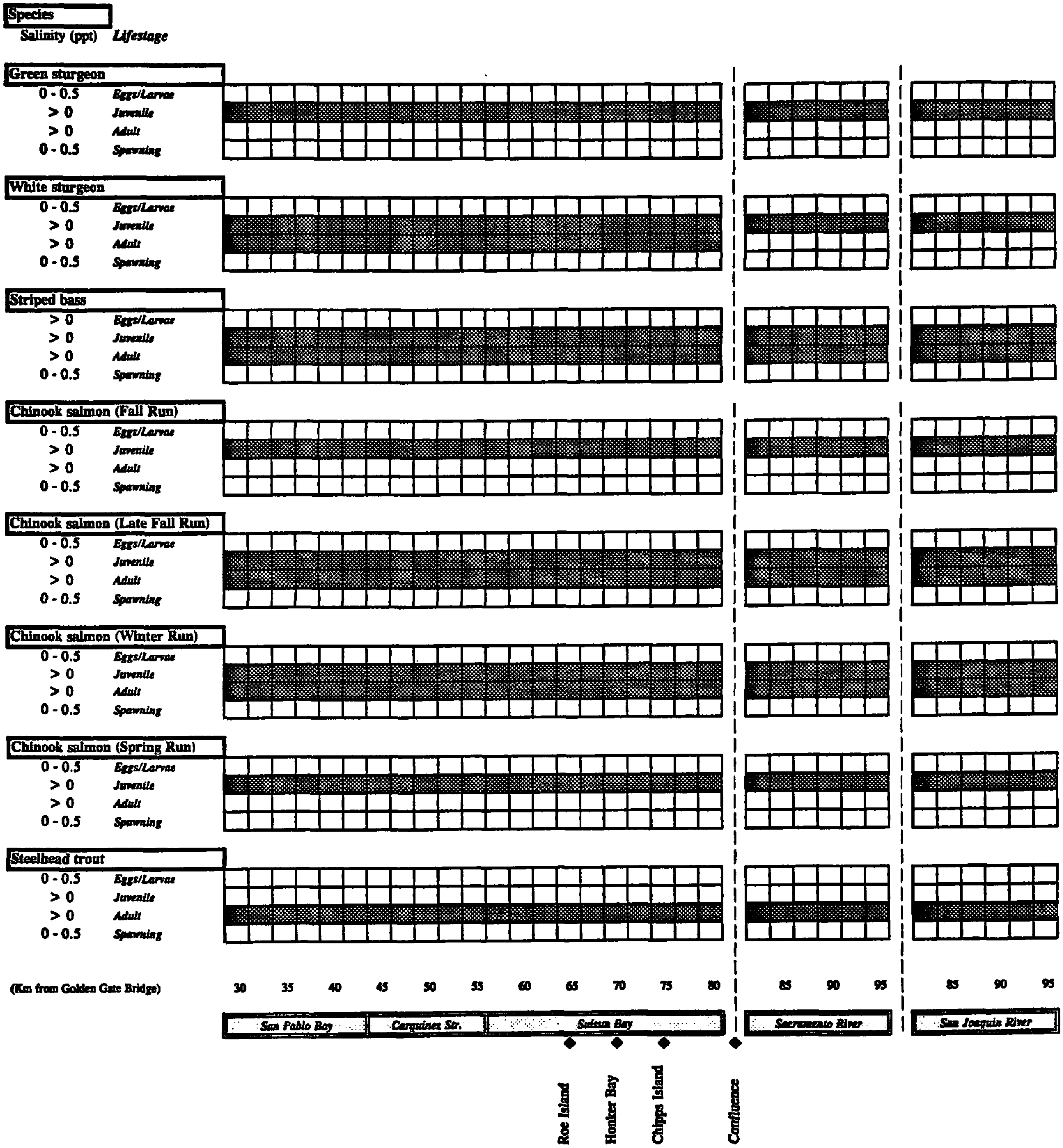
SPECIES PERIODICITY AND DISTRIBUTION CHARTS

Subappendix A-1

Monthly Life Stage Distributions:

Green Sturgeon
White Sturgeon
Striped Bass
Chinook Salmon
Steelhead Trout

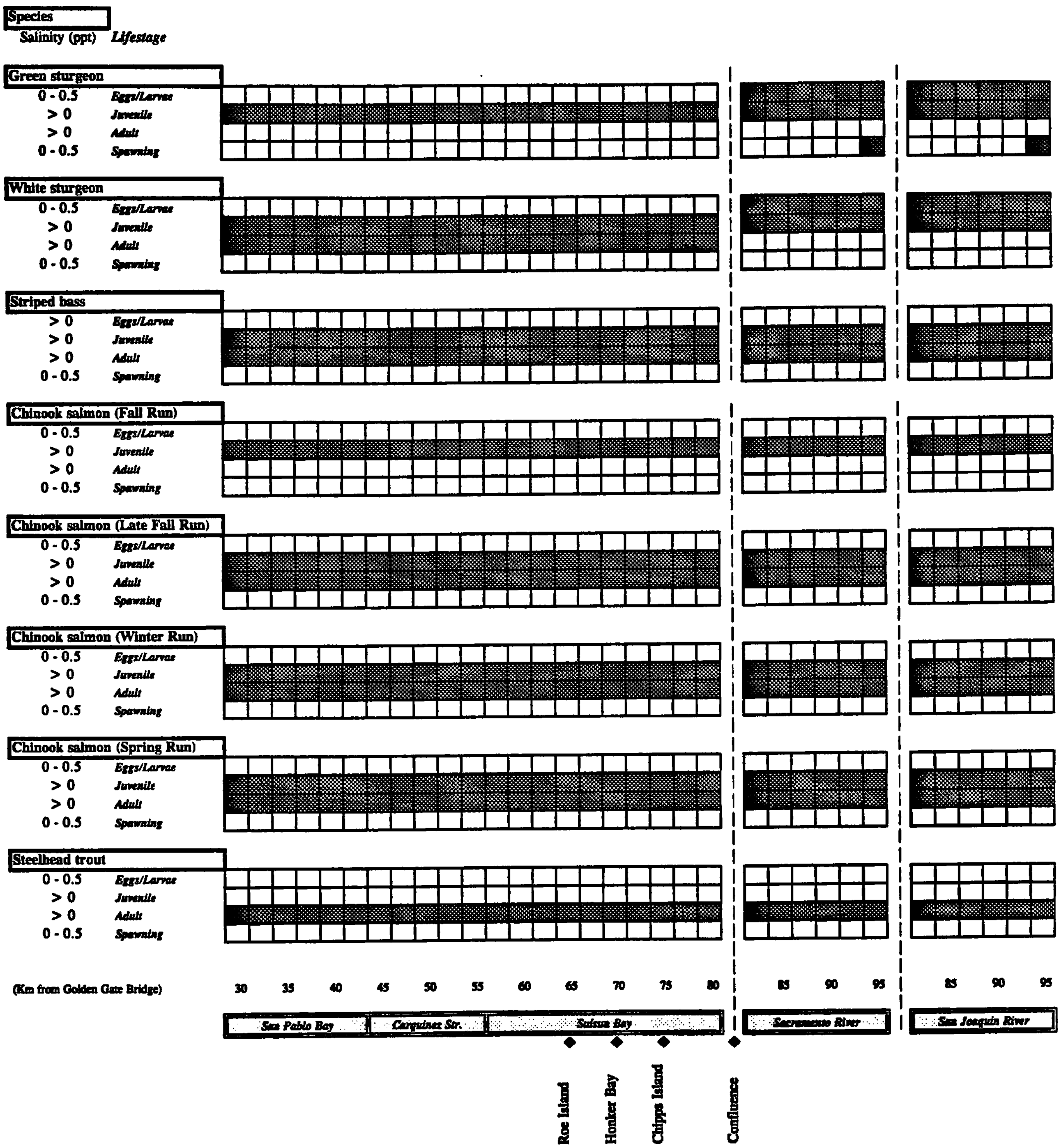
Month: JANUARY



Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

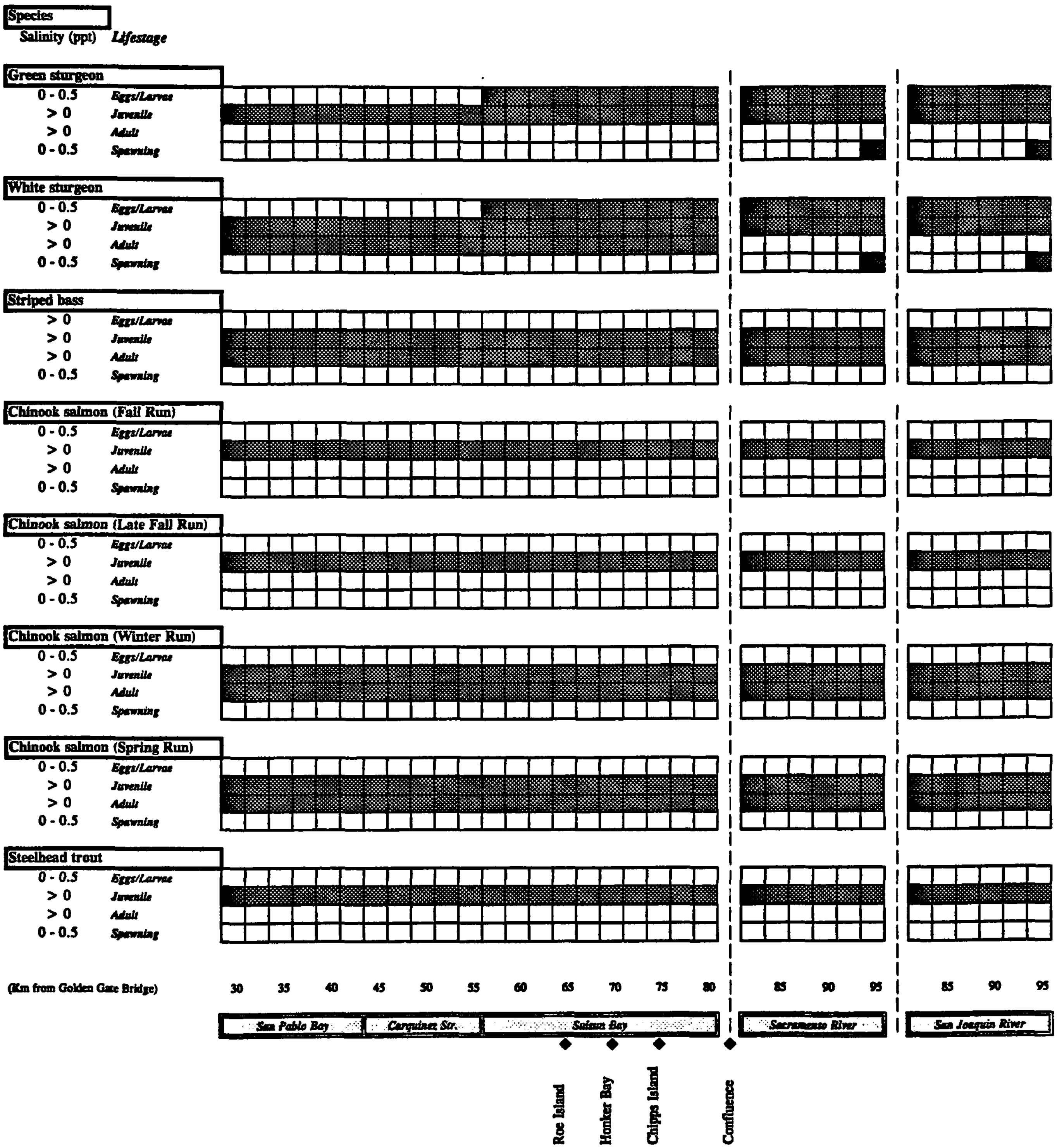
R2 Resource Consultants, Inc.

Month: FEBRUARY



Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

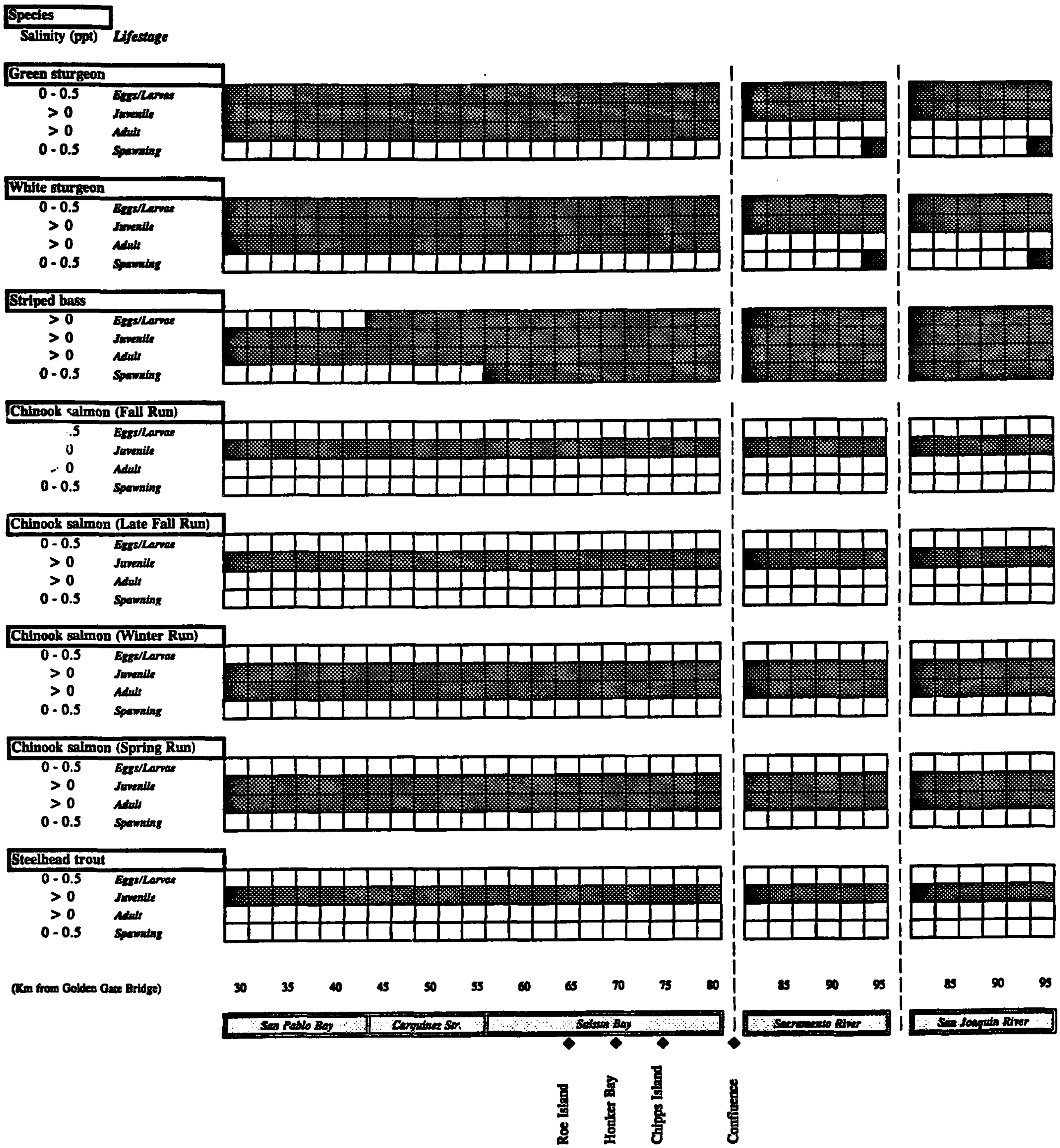
Month: MARCH



Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

R2 Resource Consultants, Inc.

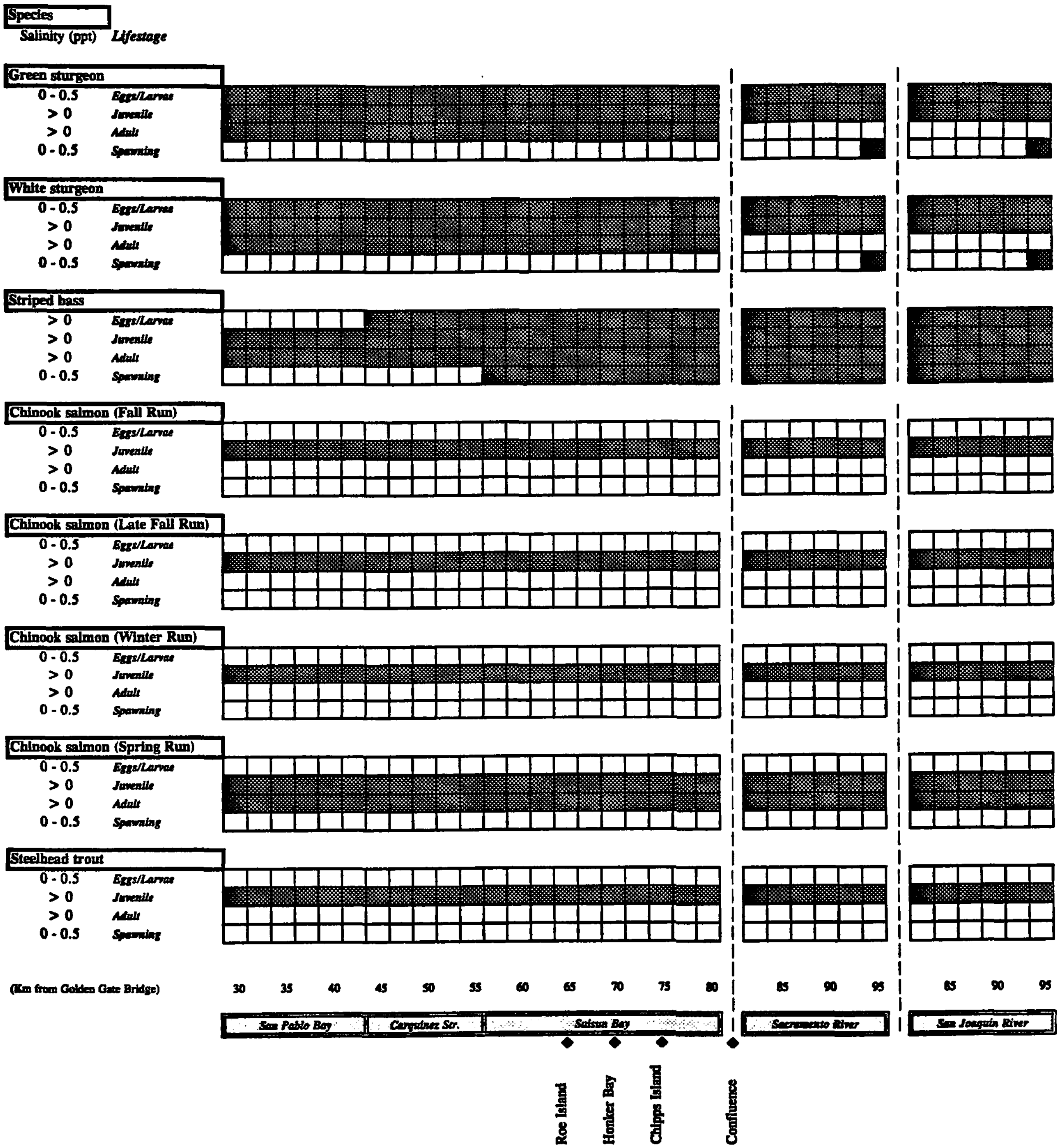
Month: APRIL



Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

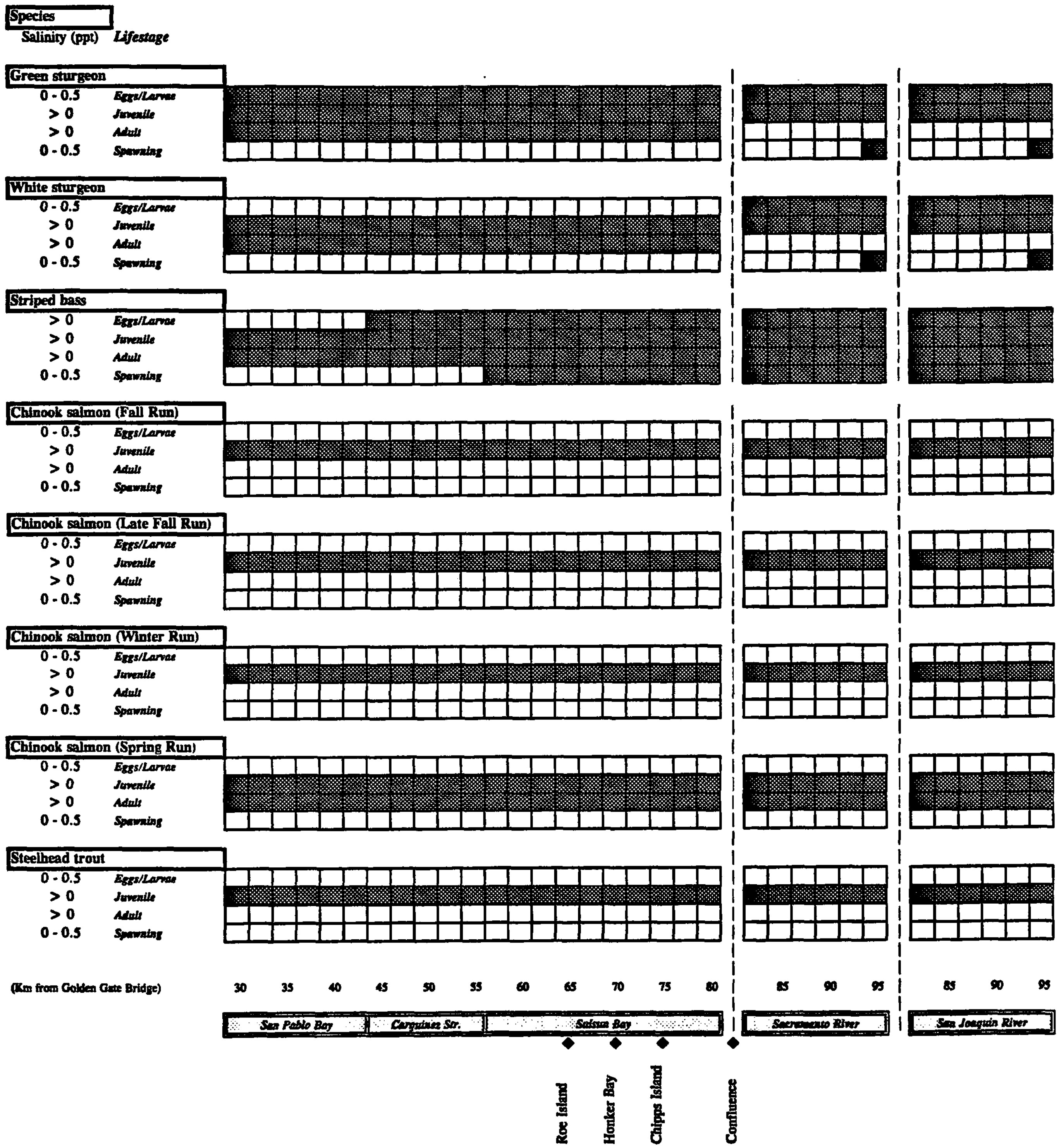
R2 Resource Consultants, Inc.

Month: MAY



Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

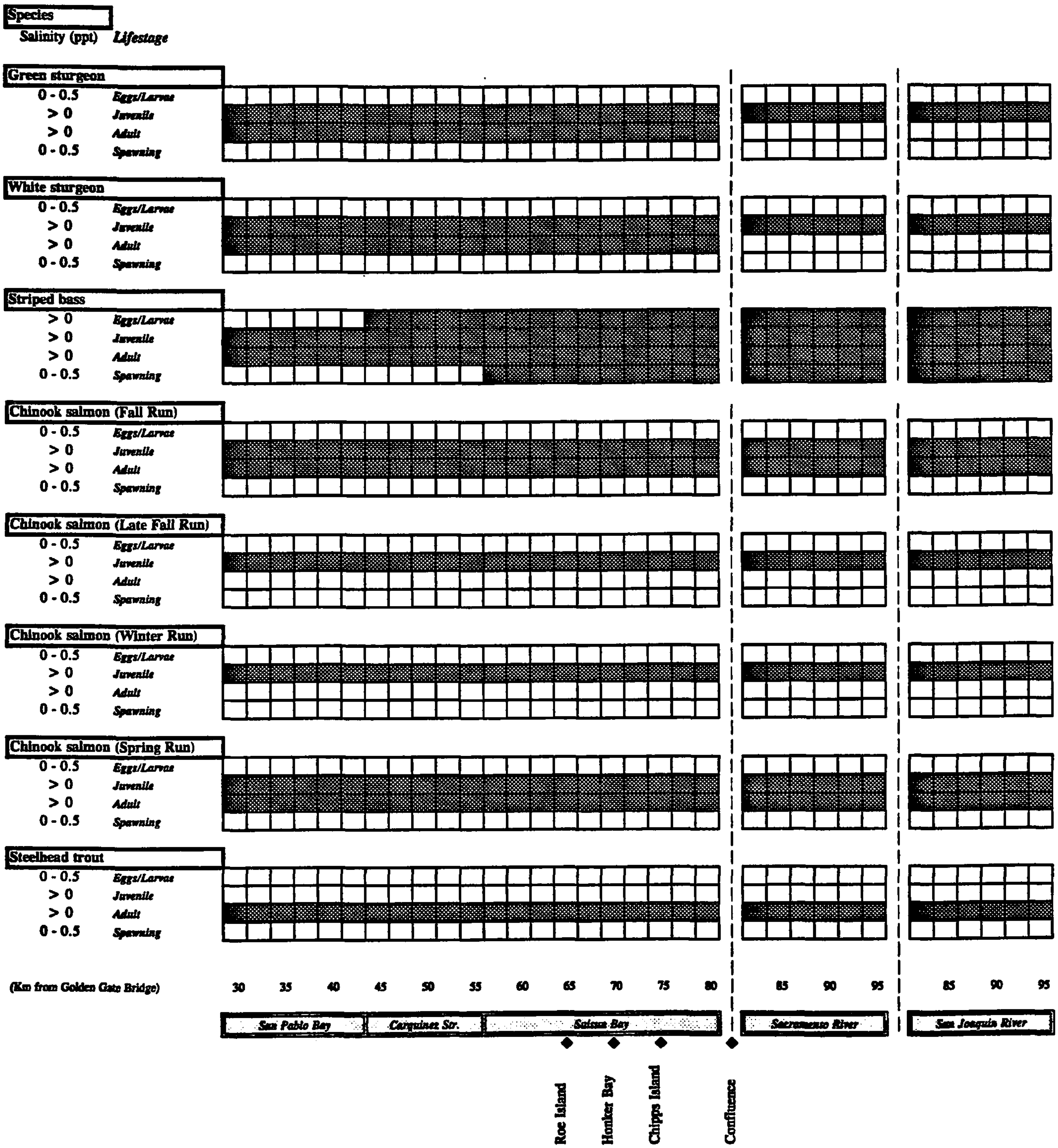
Month: JUNE



Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

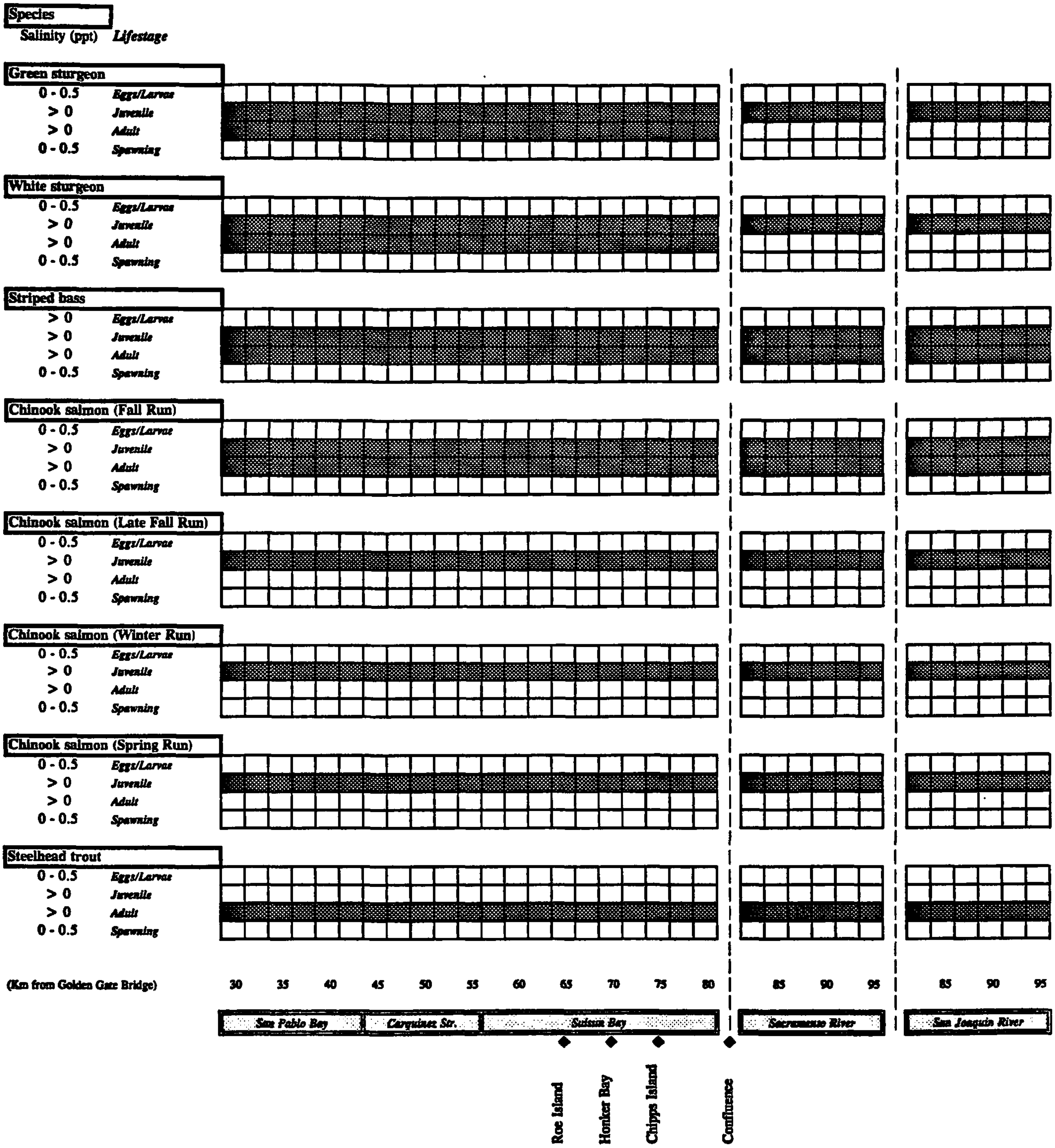
R2 Resource Consultants, Inc.

Month: JULY



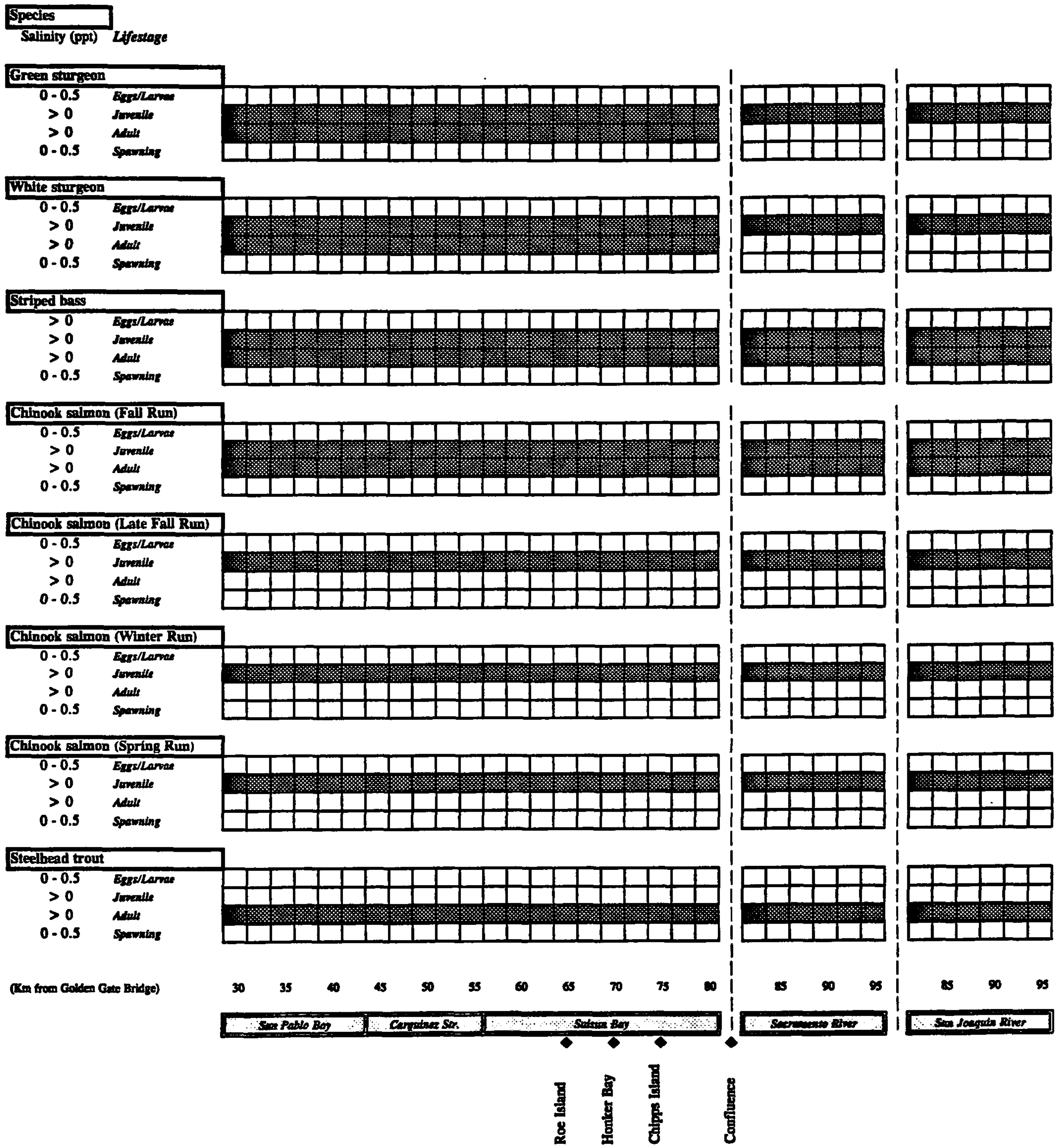
Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

Month: AUGUST



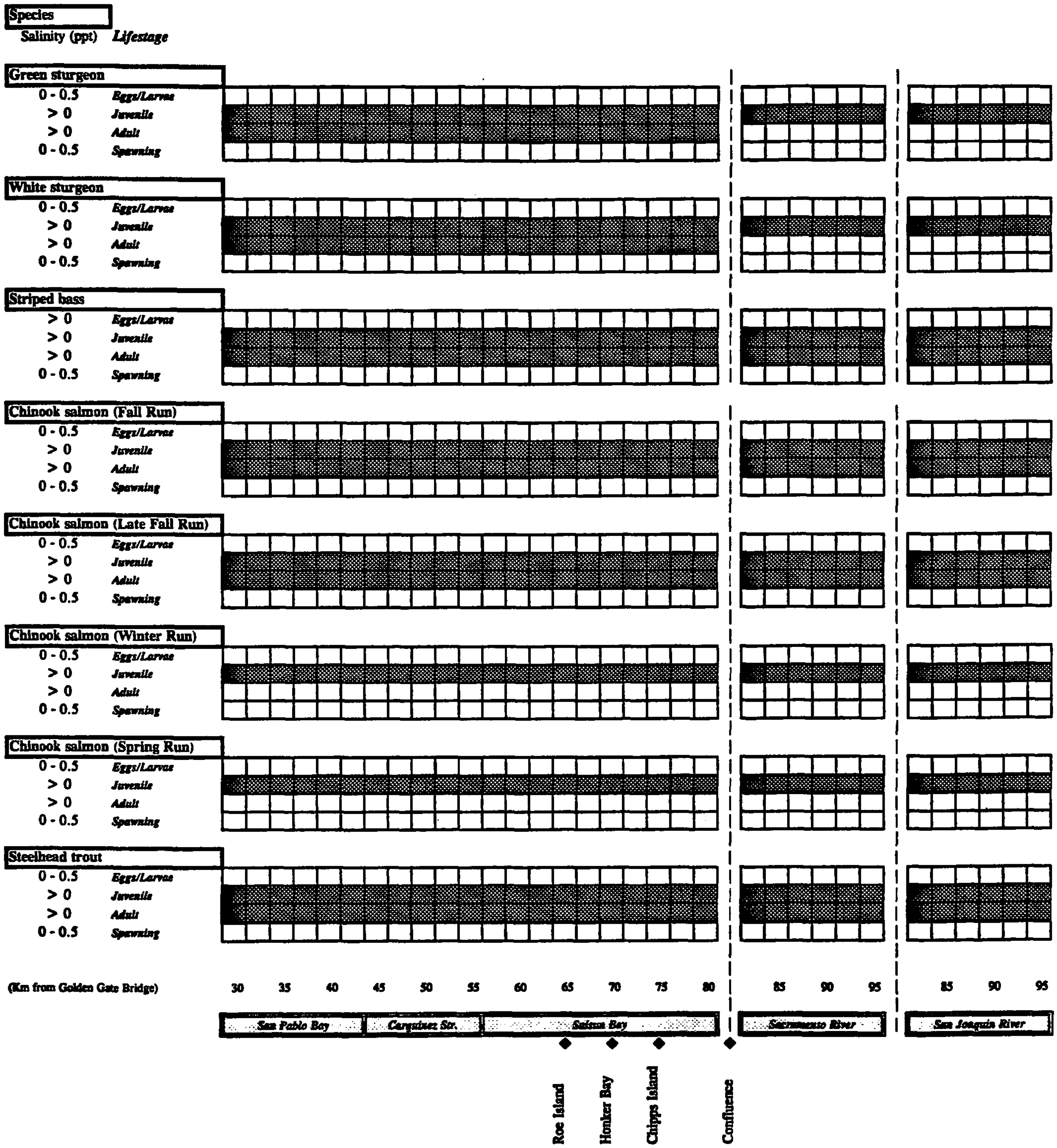
Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

Month: SEPTEMBER



Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

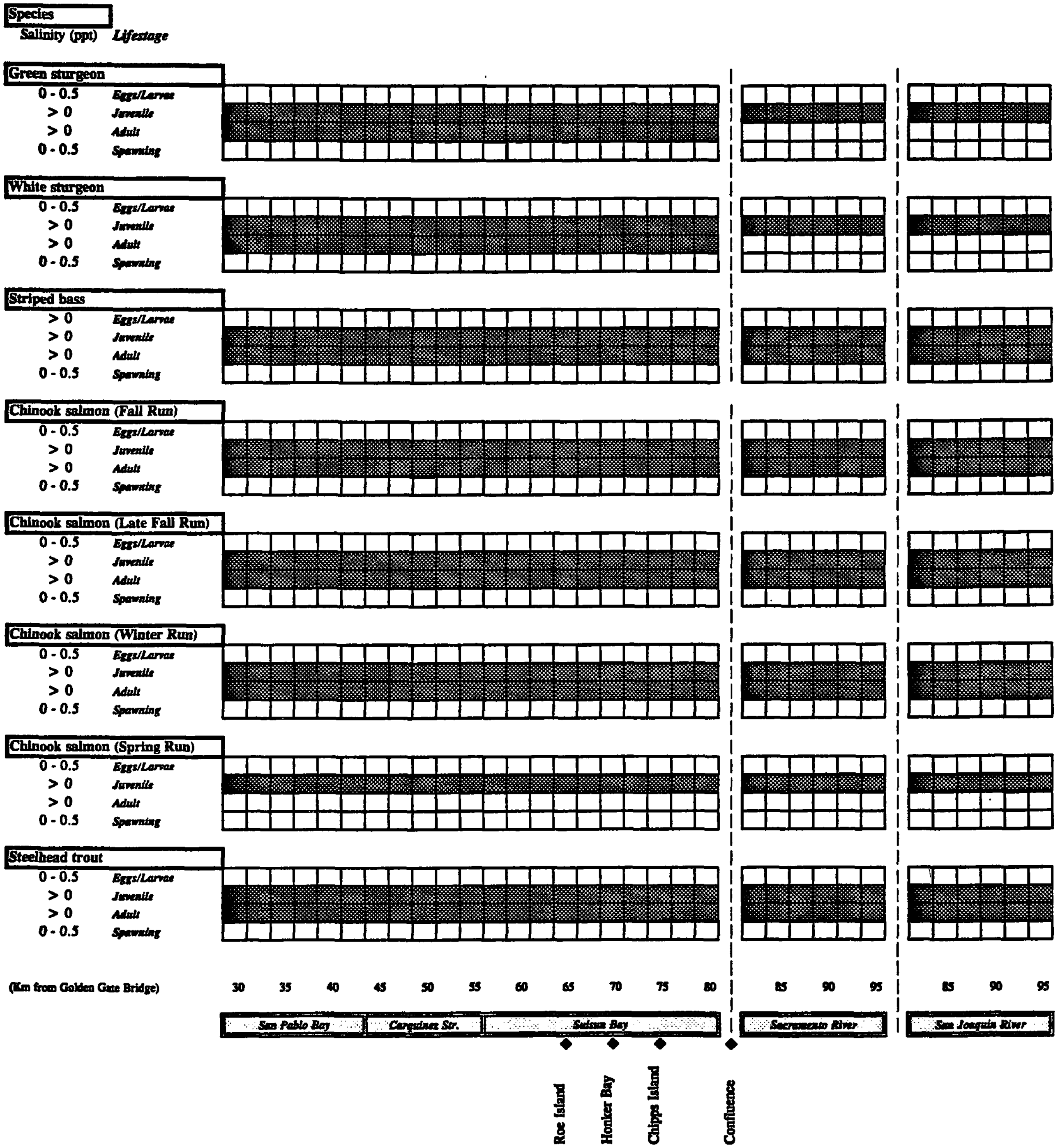
Month: OCTOBER



Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

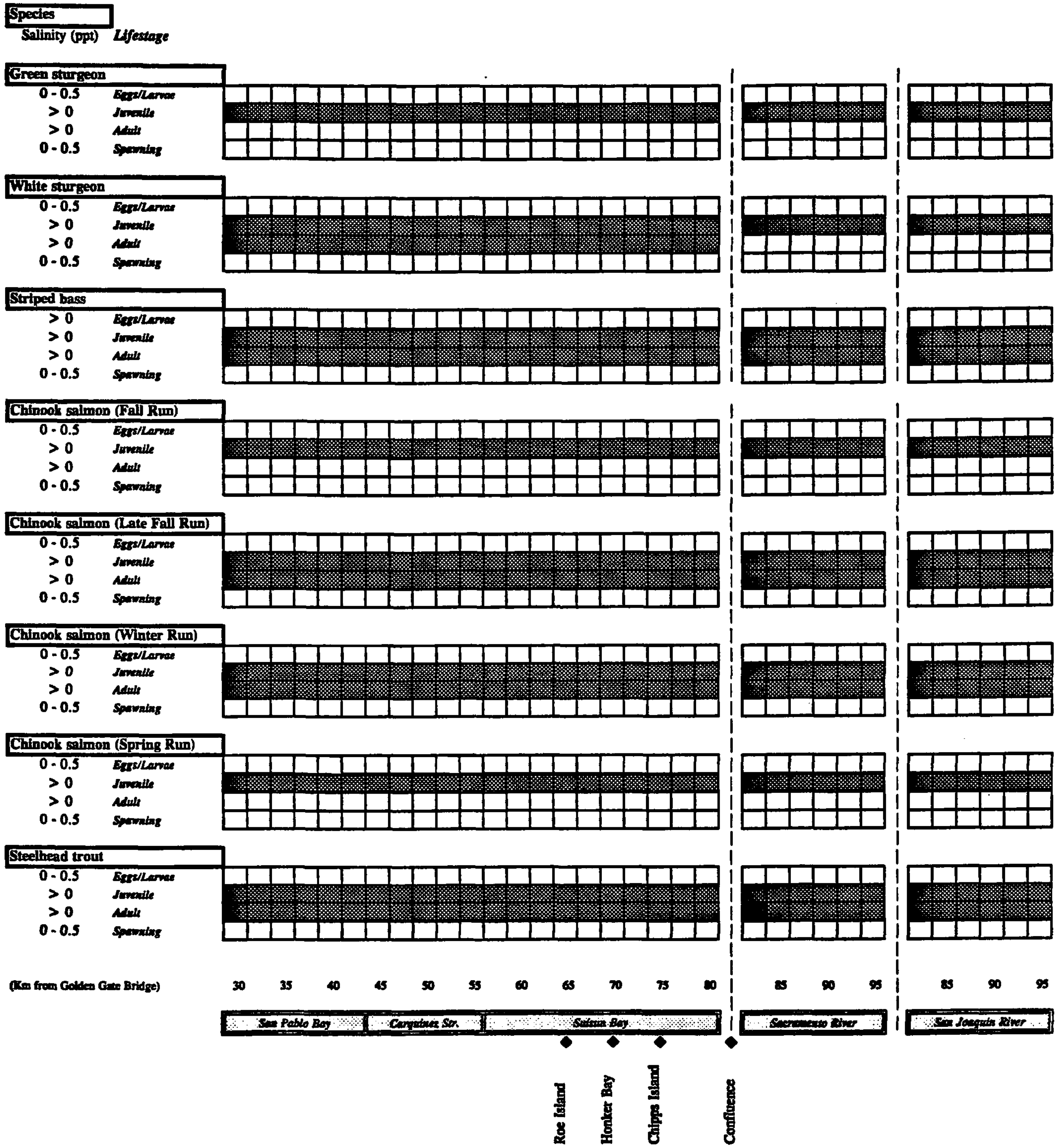
R2 Resource Consultants, Inc.

Month: NOVEMBER



Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

Month: DECEMBER



Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

APPENDIX A

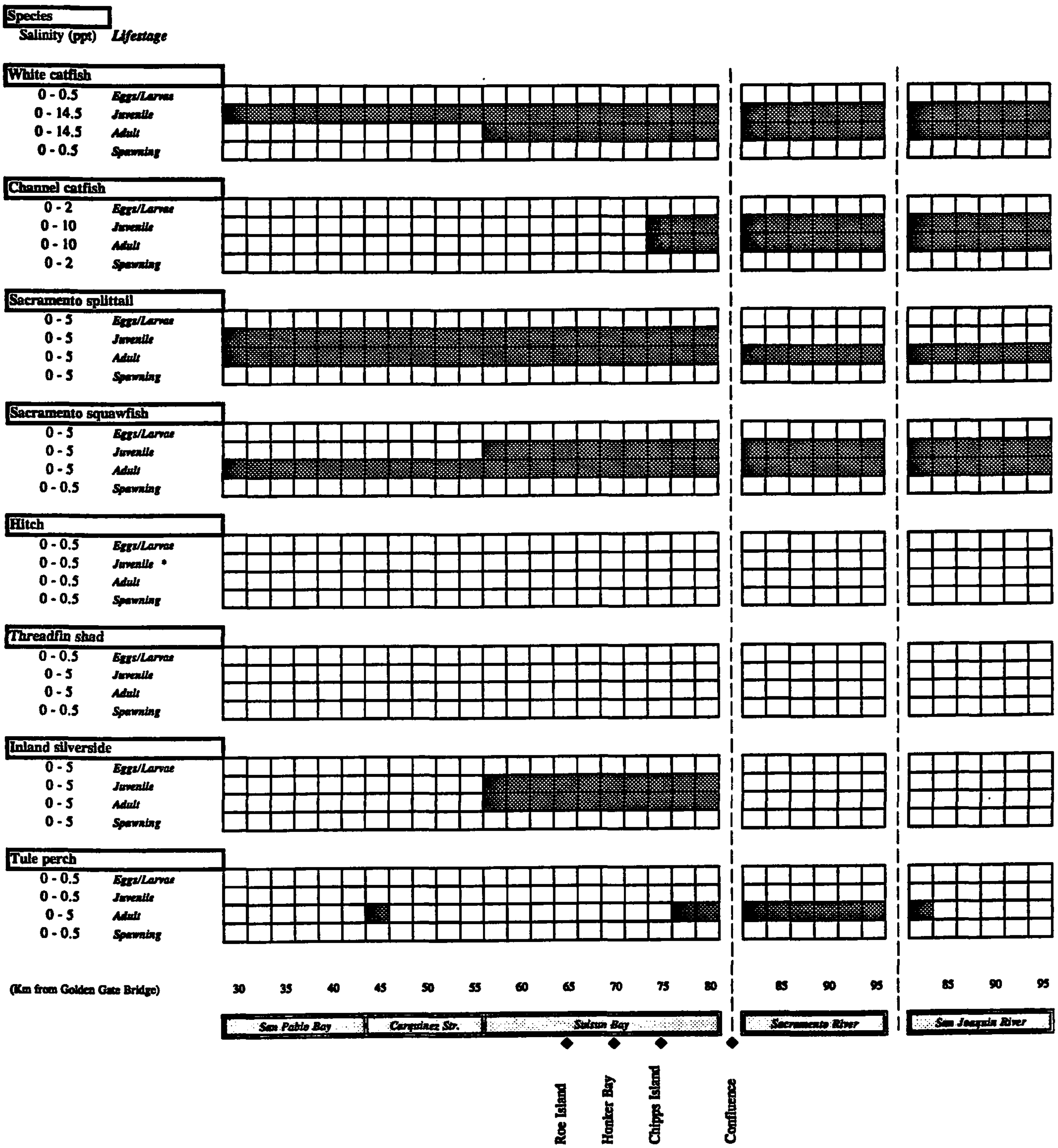
SPECIES PERIODICITY AND DISTRIBUTION CHARTS

Subappendix A-2

Monthly Life Stage Distributions:

White Catfish
Channel Catfish
Sacramento Splittail
Sacramento Squawfish
Hitch
Threadfin Shad
Inland Silverside
Tule Perch

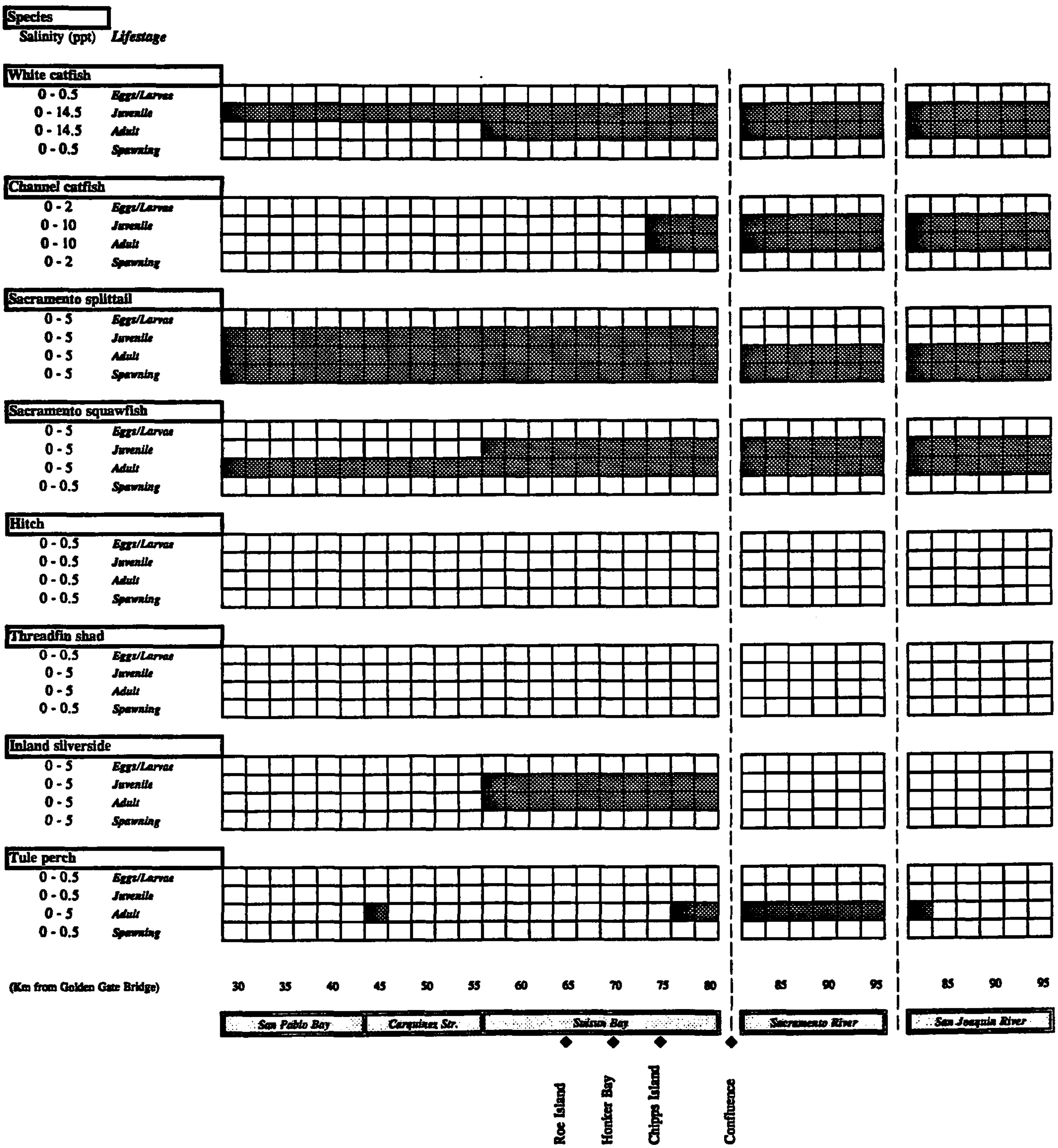
Month: JANUARY



* Sole reference (Wang 1986) Juveniles have been observed near the shoreline of Suisun Bay.

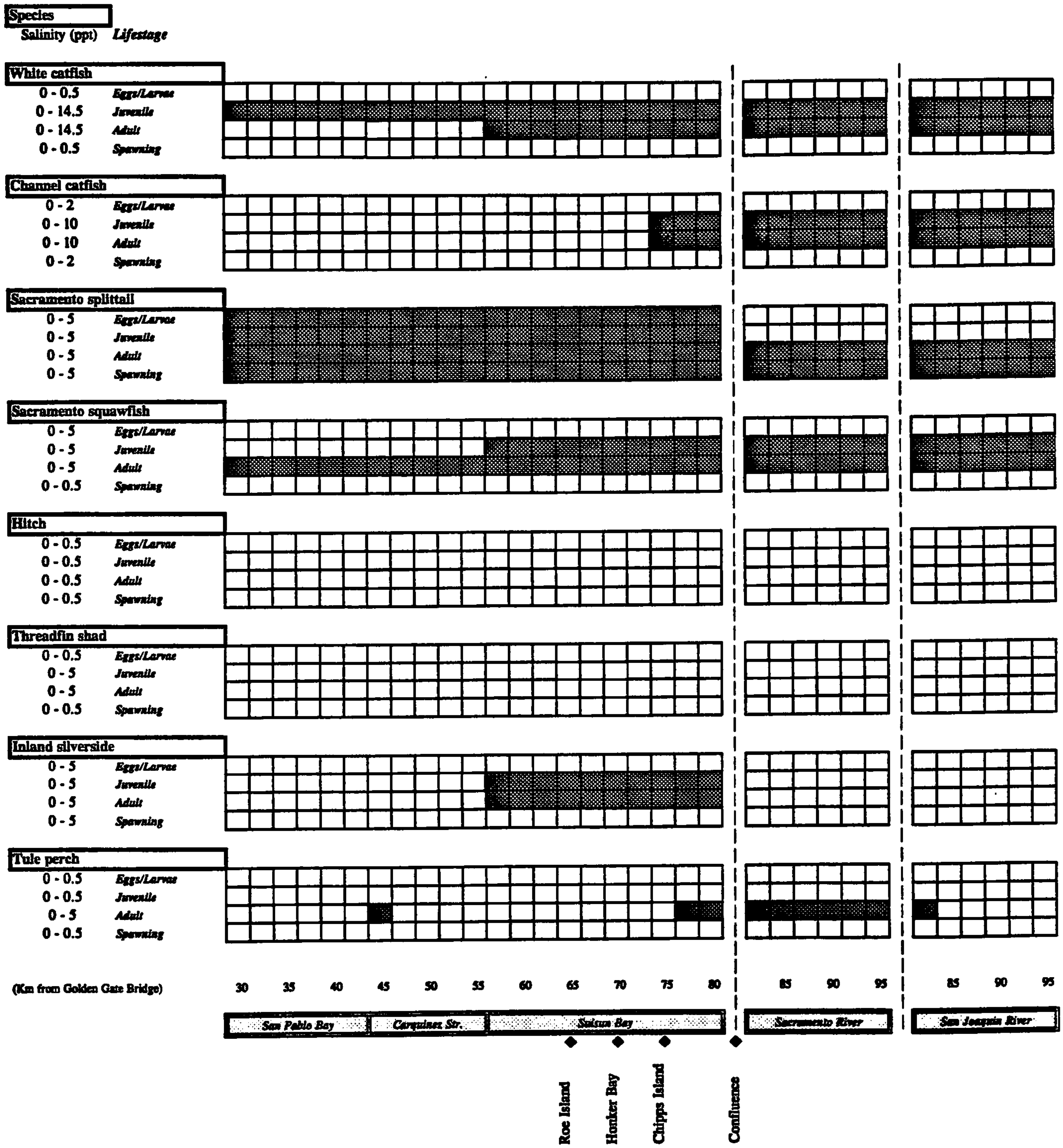
Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

Month: FEBRUARY



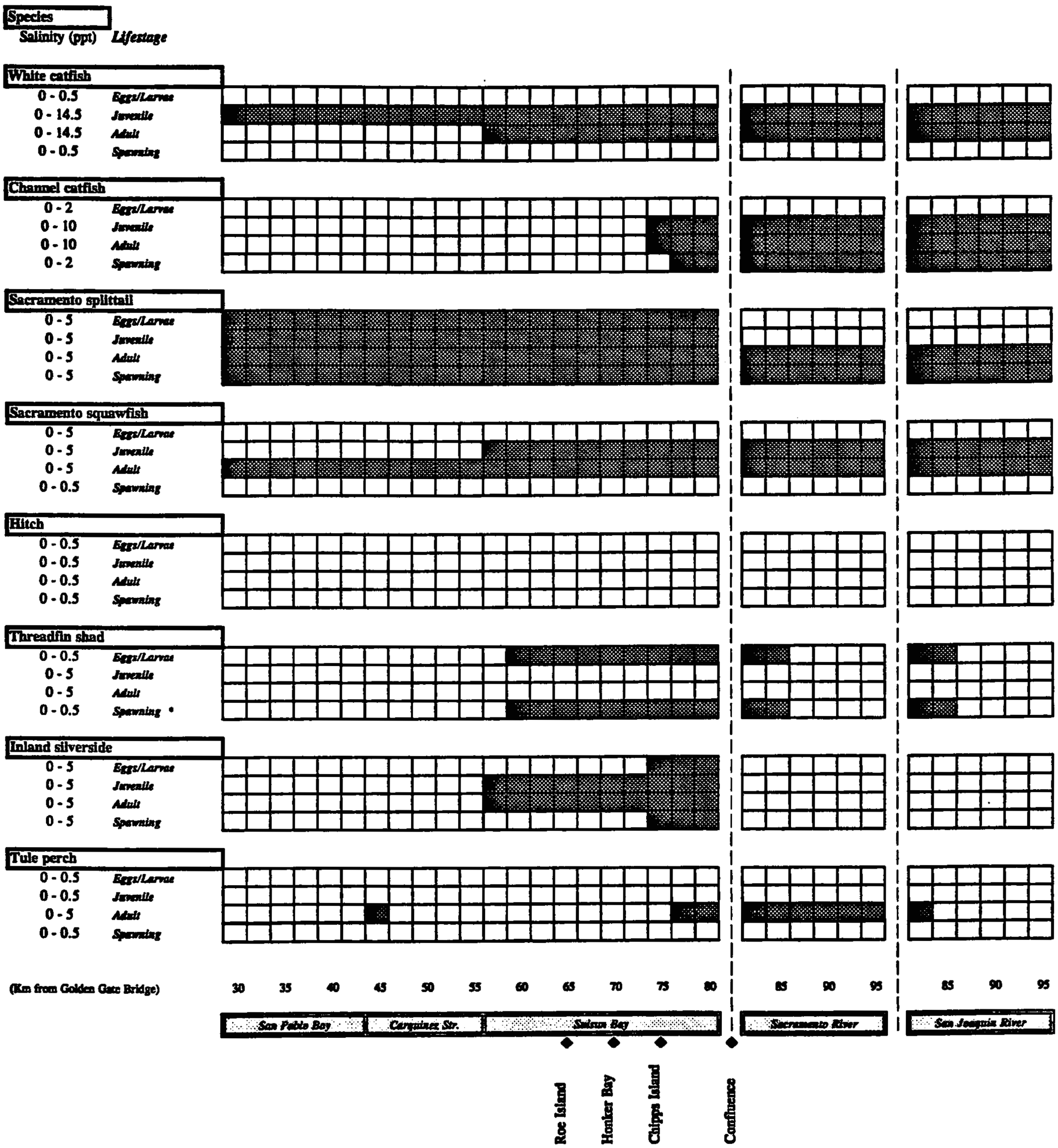
Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

Month: MARCH



Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

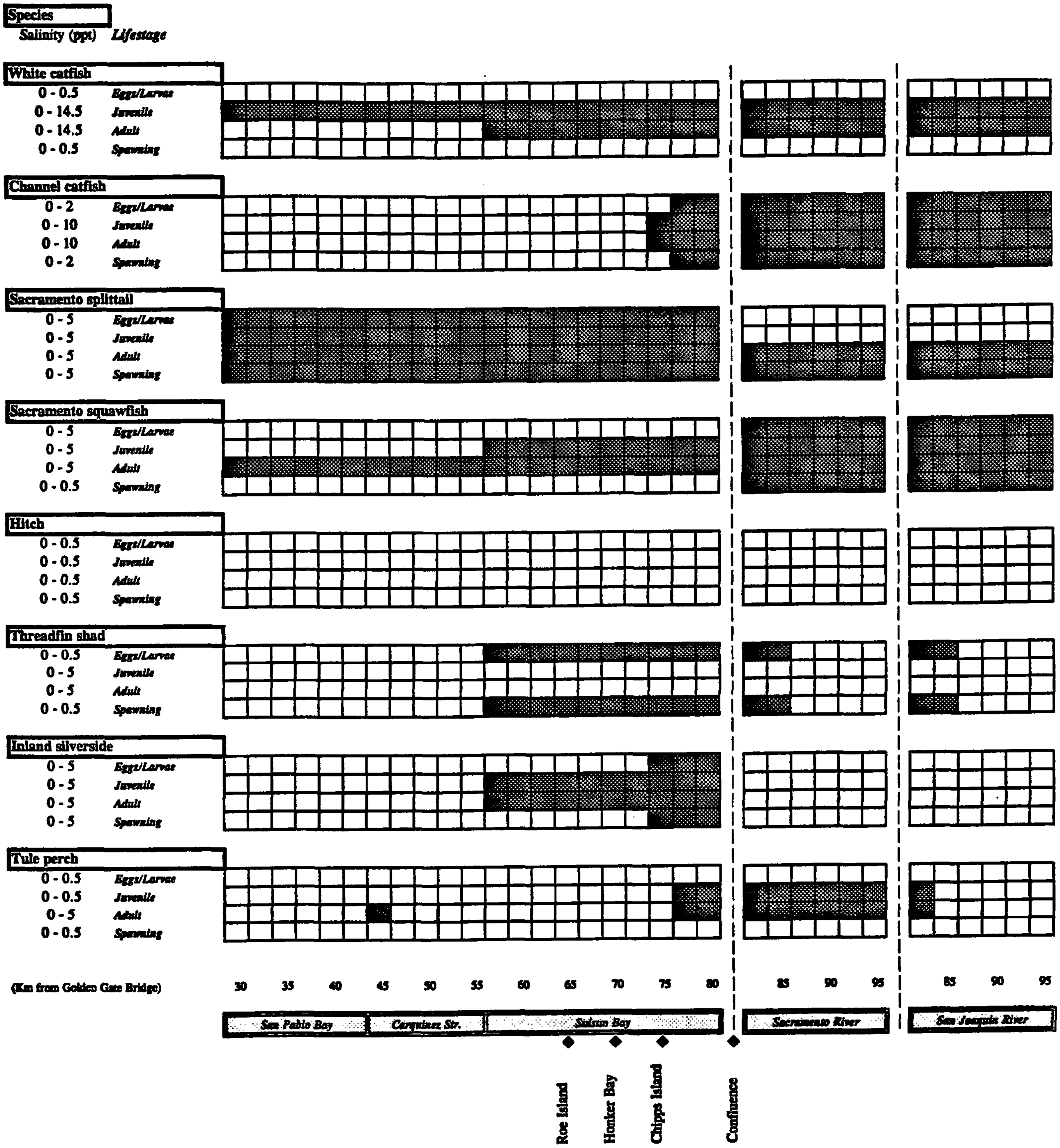
Month: APRIL



* Threadfin shad spawning occurs in the sloughs of the Delta and inshore of Suisun Bay.

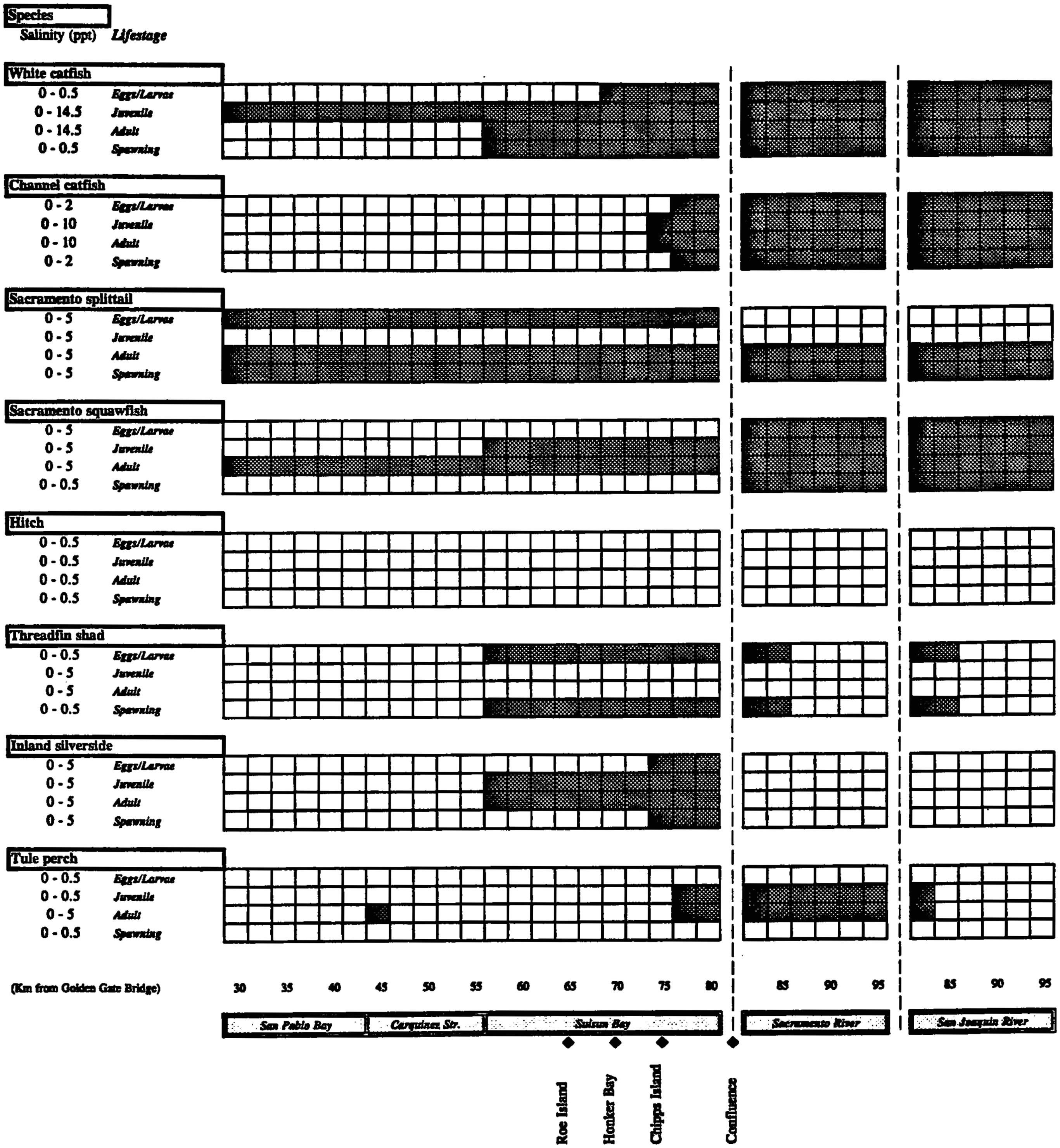
Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

Month: MAY



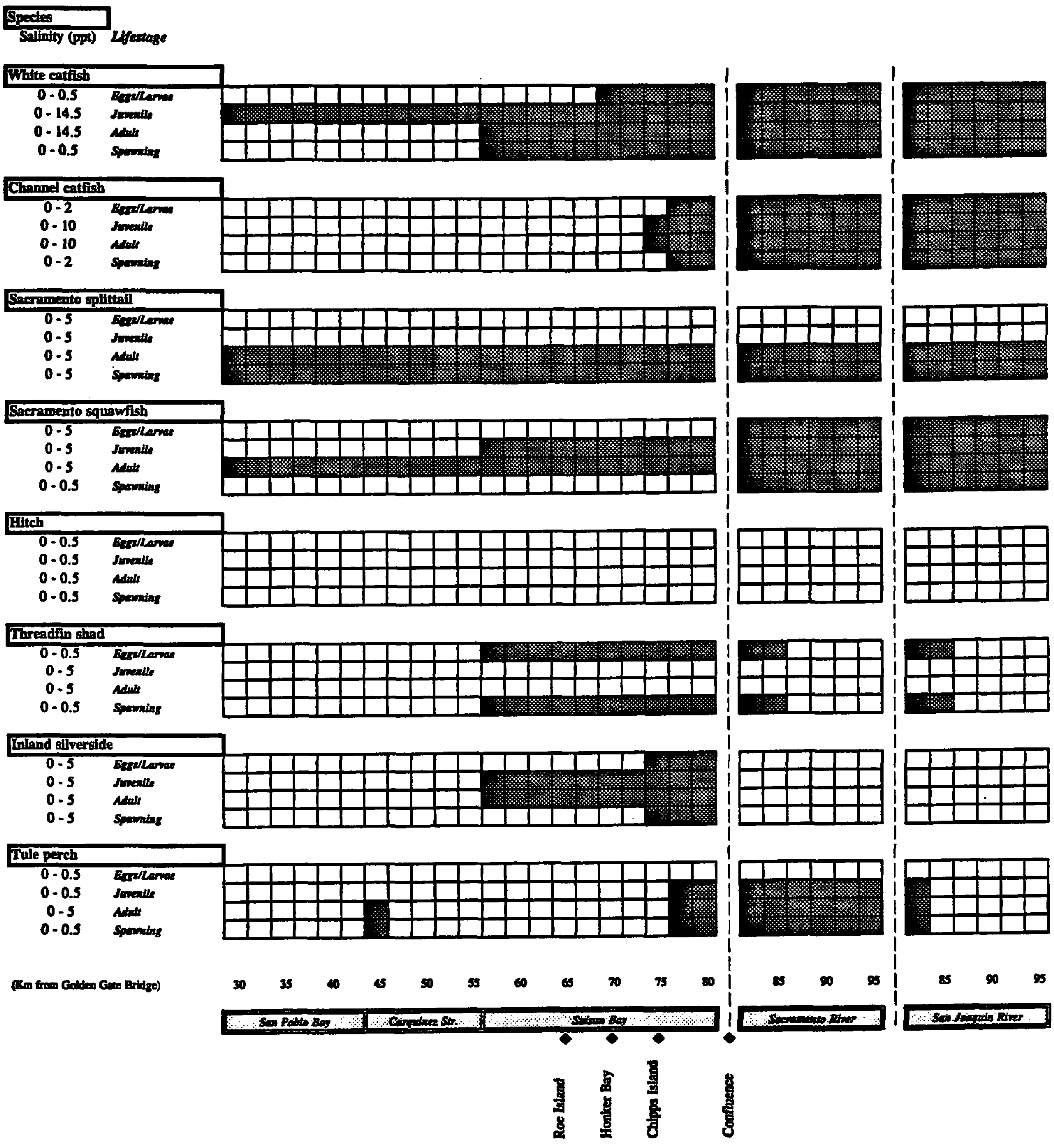
Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

Month: JUNE



Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

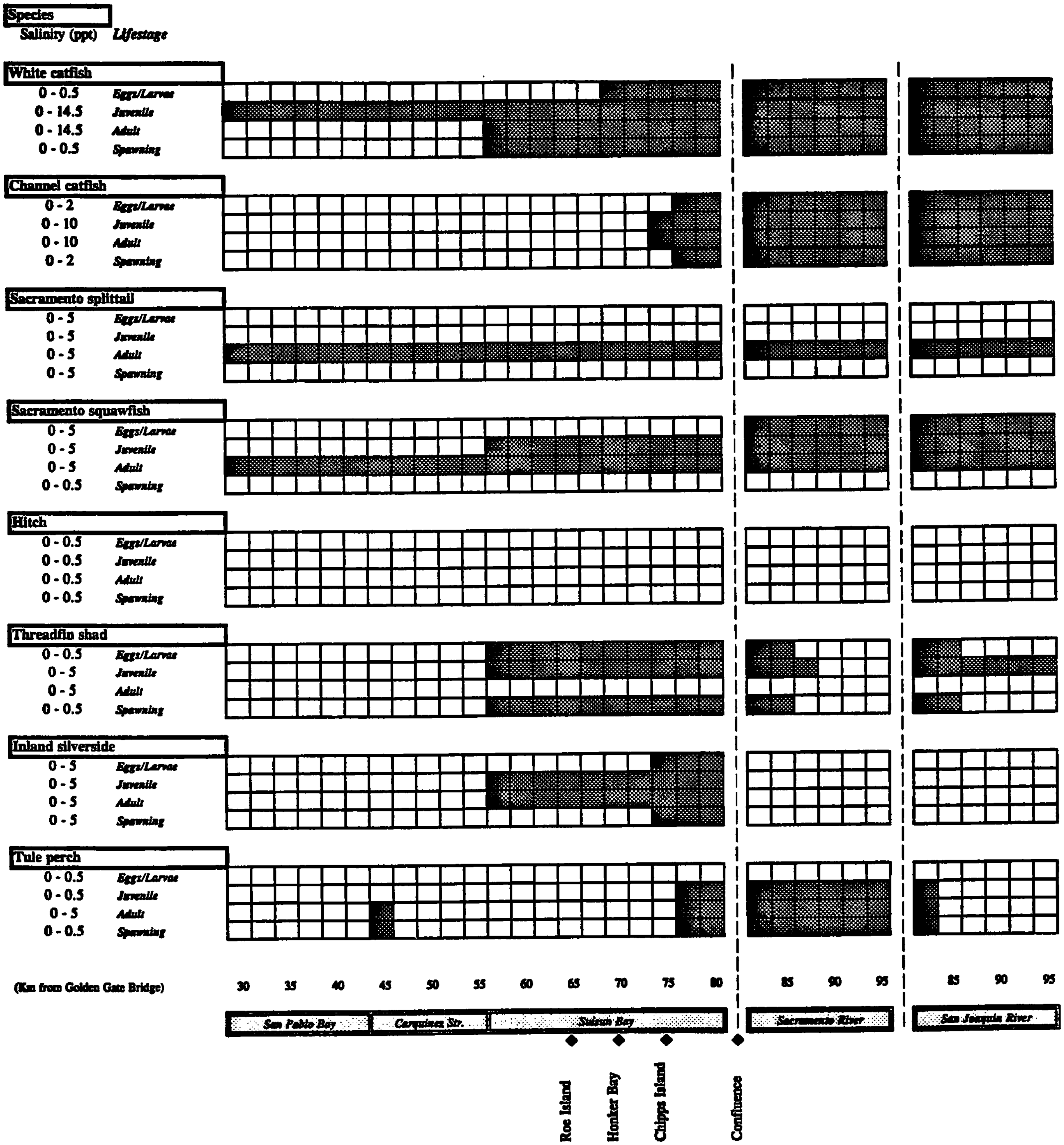
Month: JULY



Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

R2 Resource Consultants, Inc.

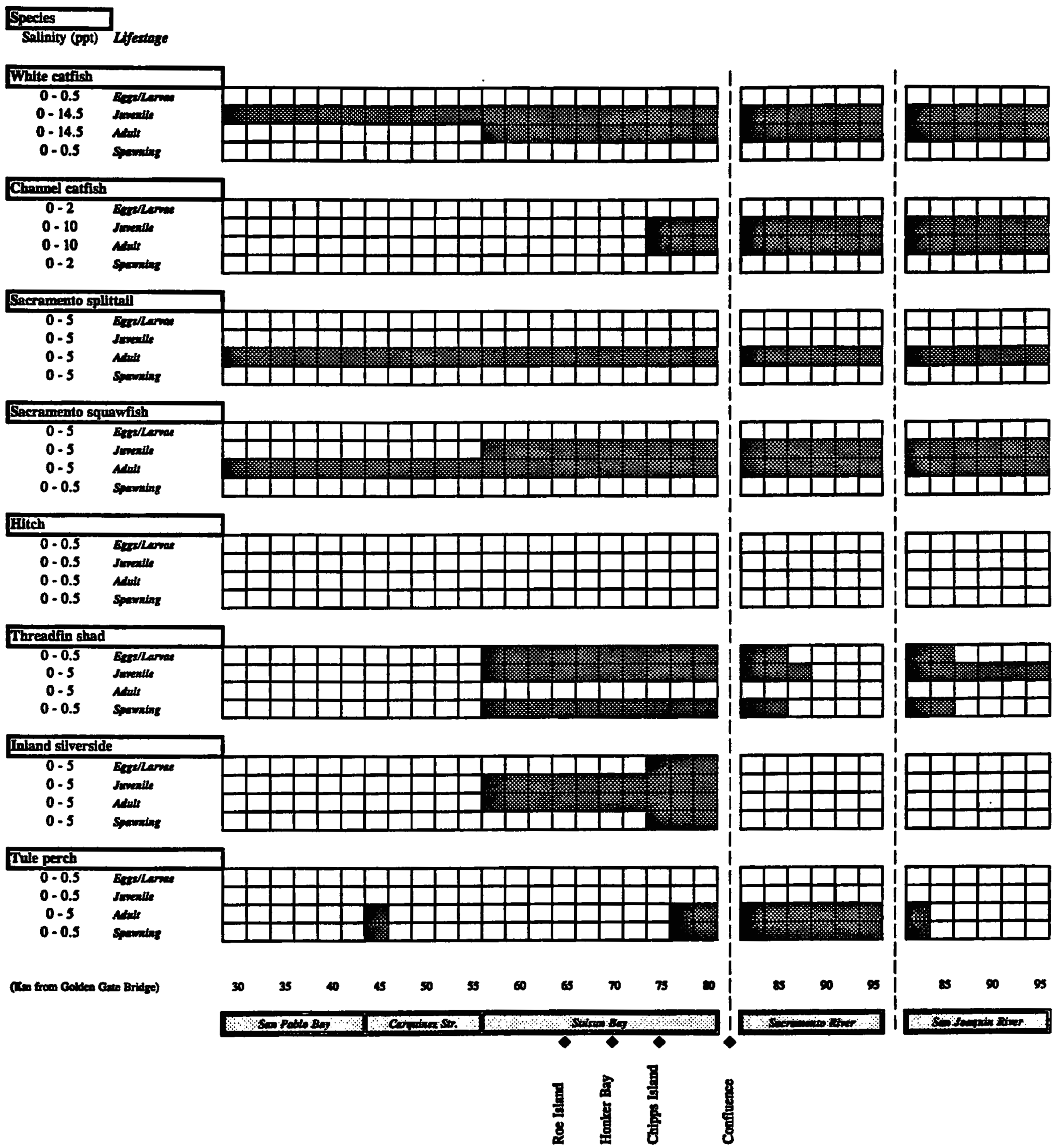
Month: AUGUST



Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

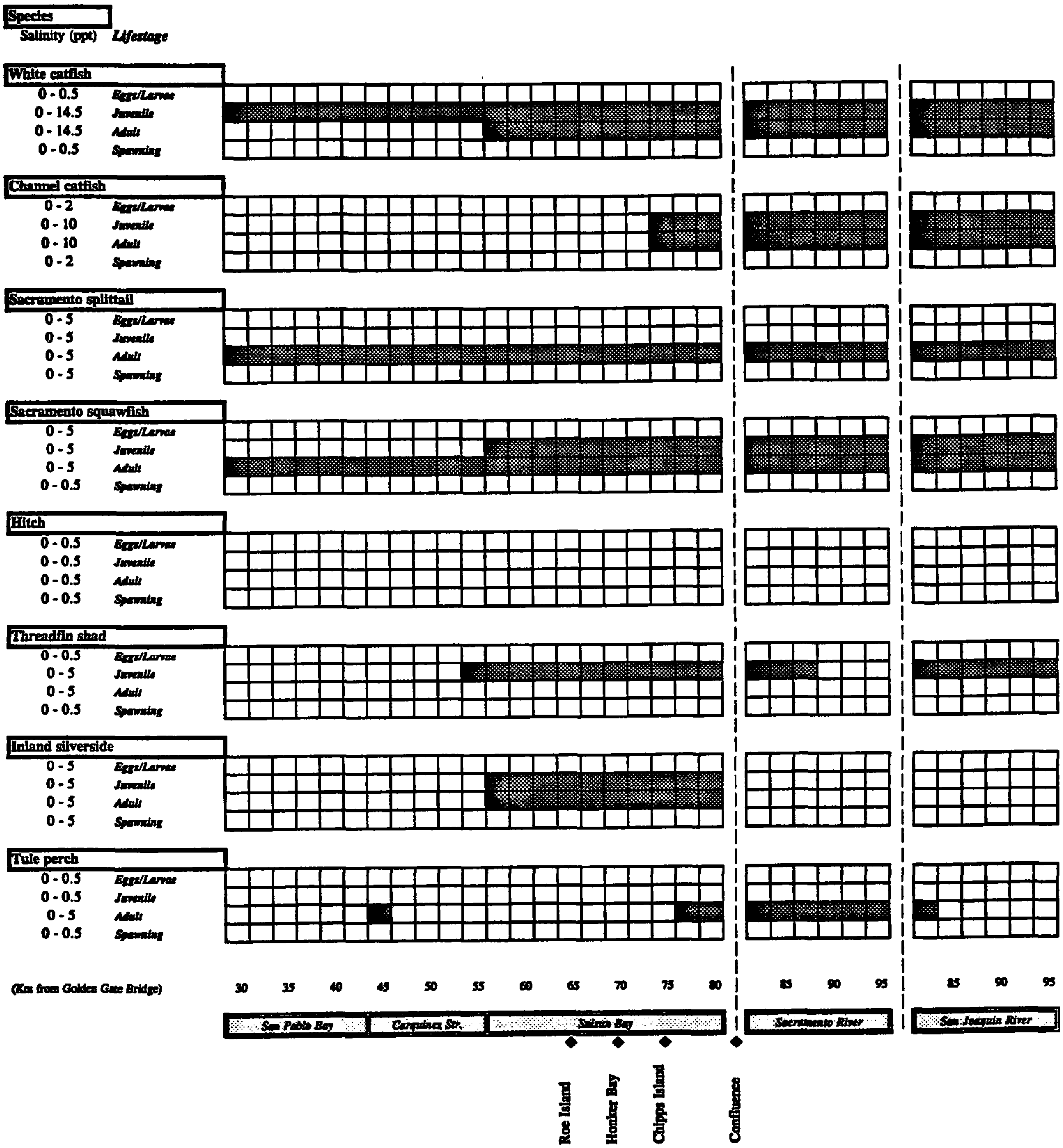
R2 Resource Consultants, Inc.

Month: SEPTEMBER



Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

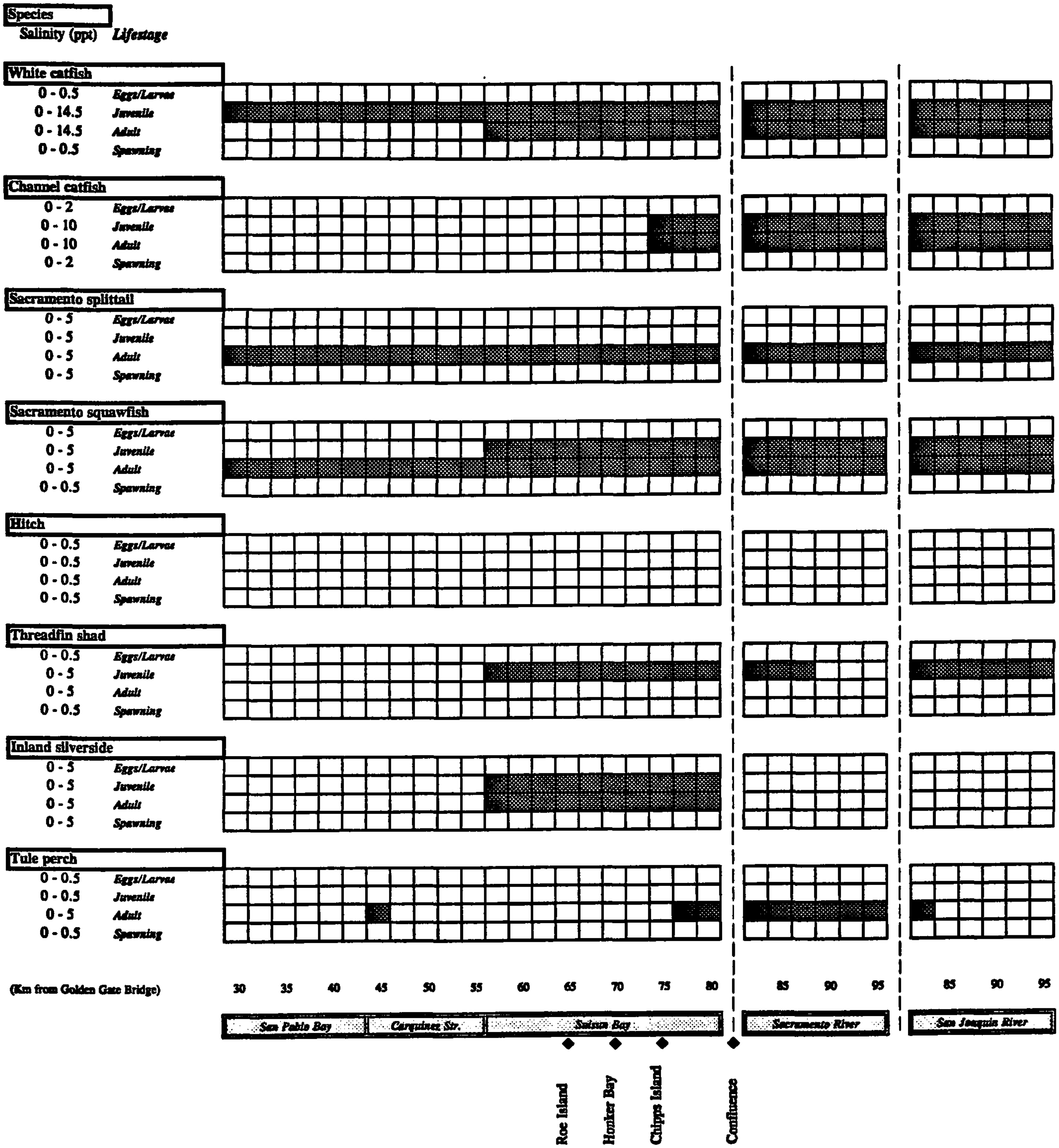
Month: OCTOBER



Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

R2 Resource Consultants, Inc.

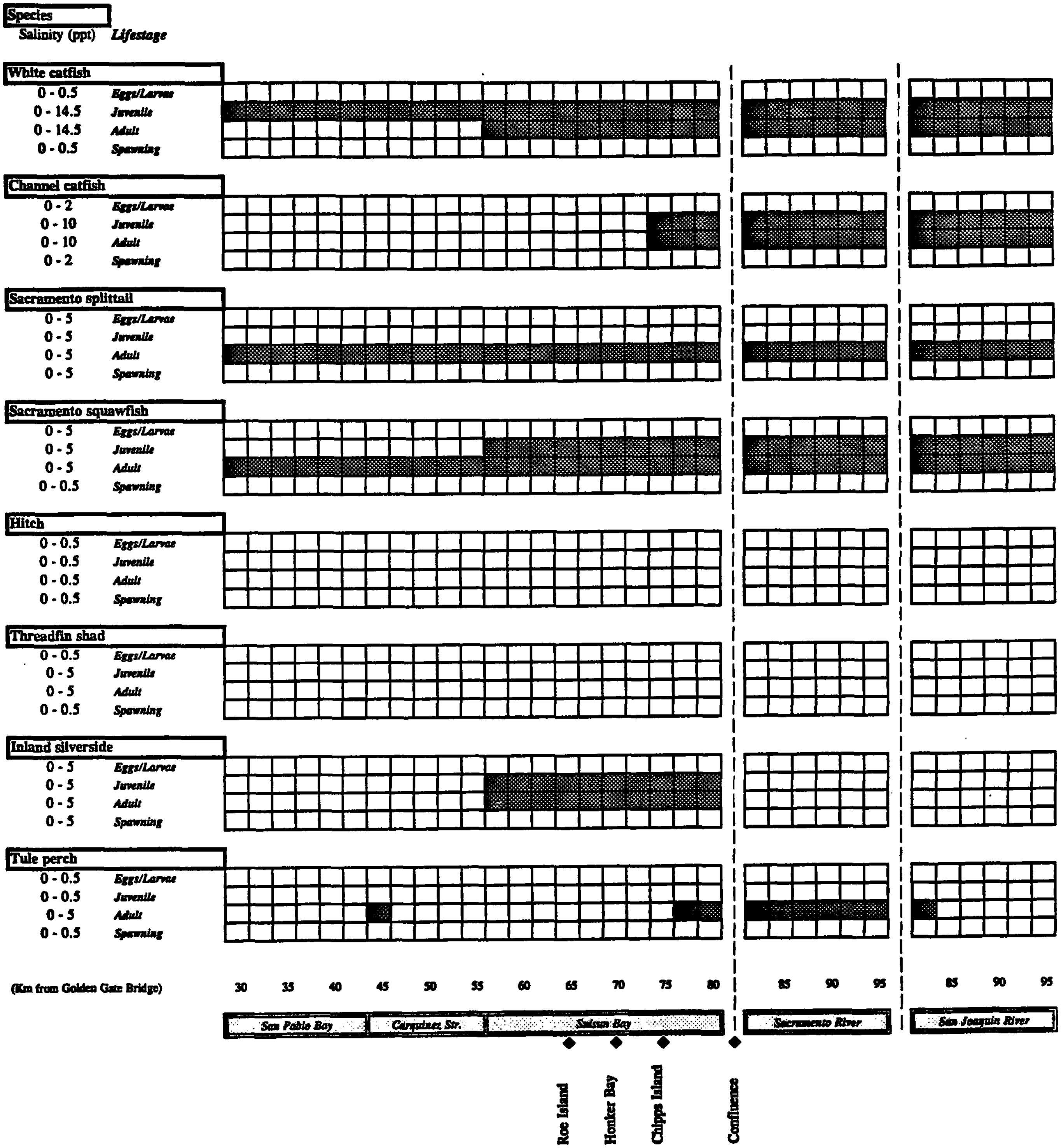
Month: NOVEMBER



Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

R2 Resource Consultants, Inc.

Month: DECEMBER



Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

APPENDIX A

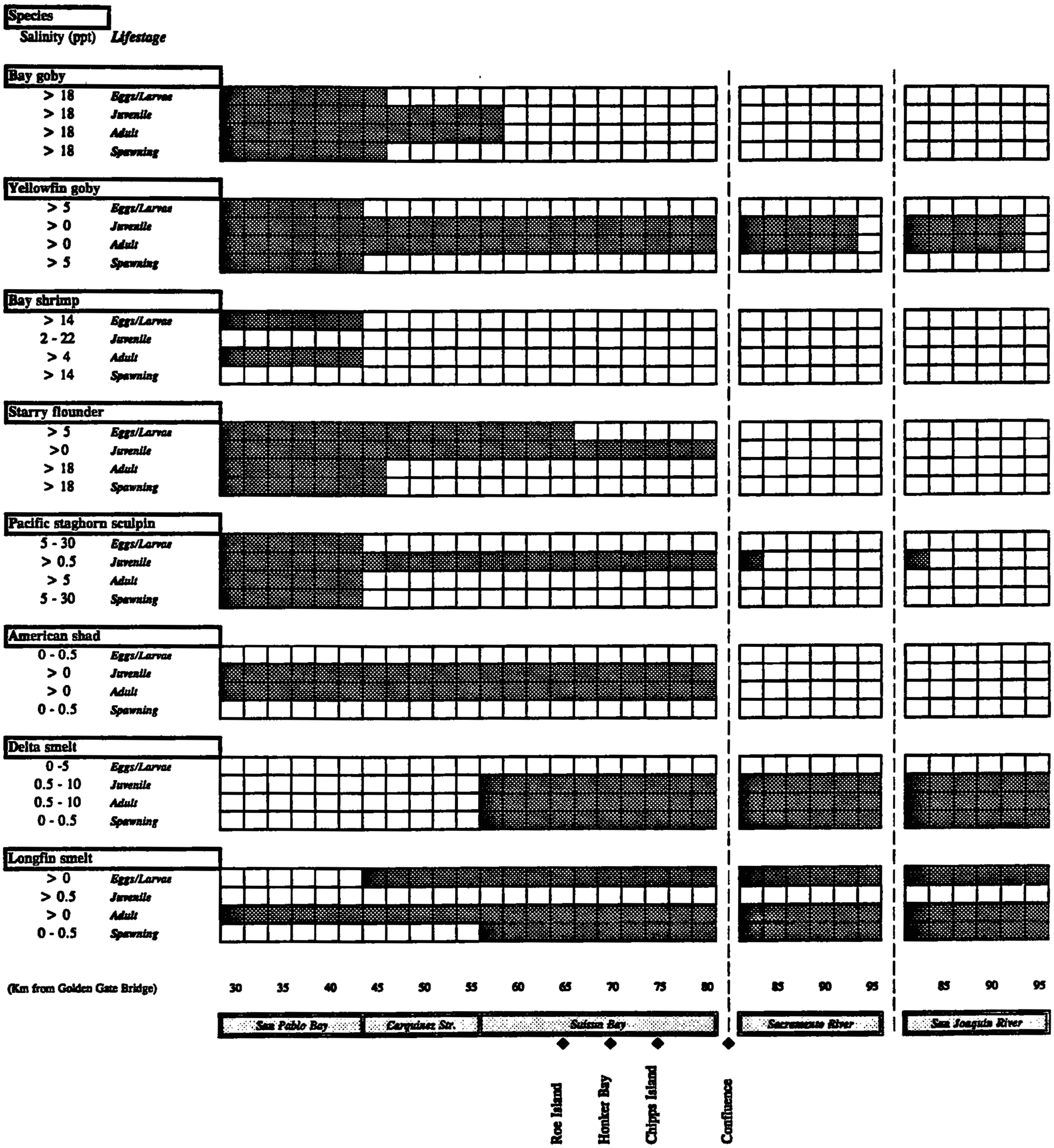
SPECIES PERIODICITY AND DISTRIBUTION CHARTS

Subappendix A-3

Monthly Life Stage Distributions:

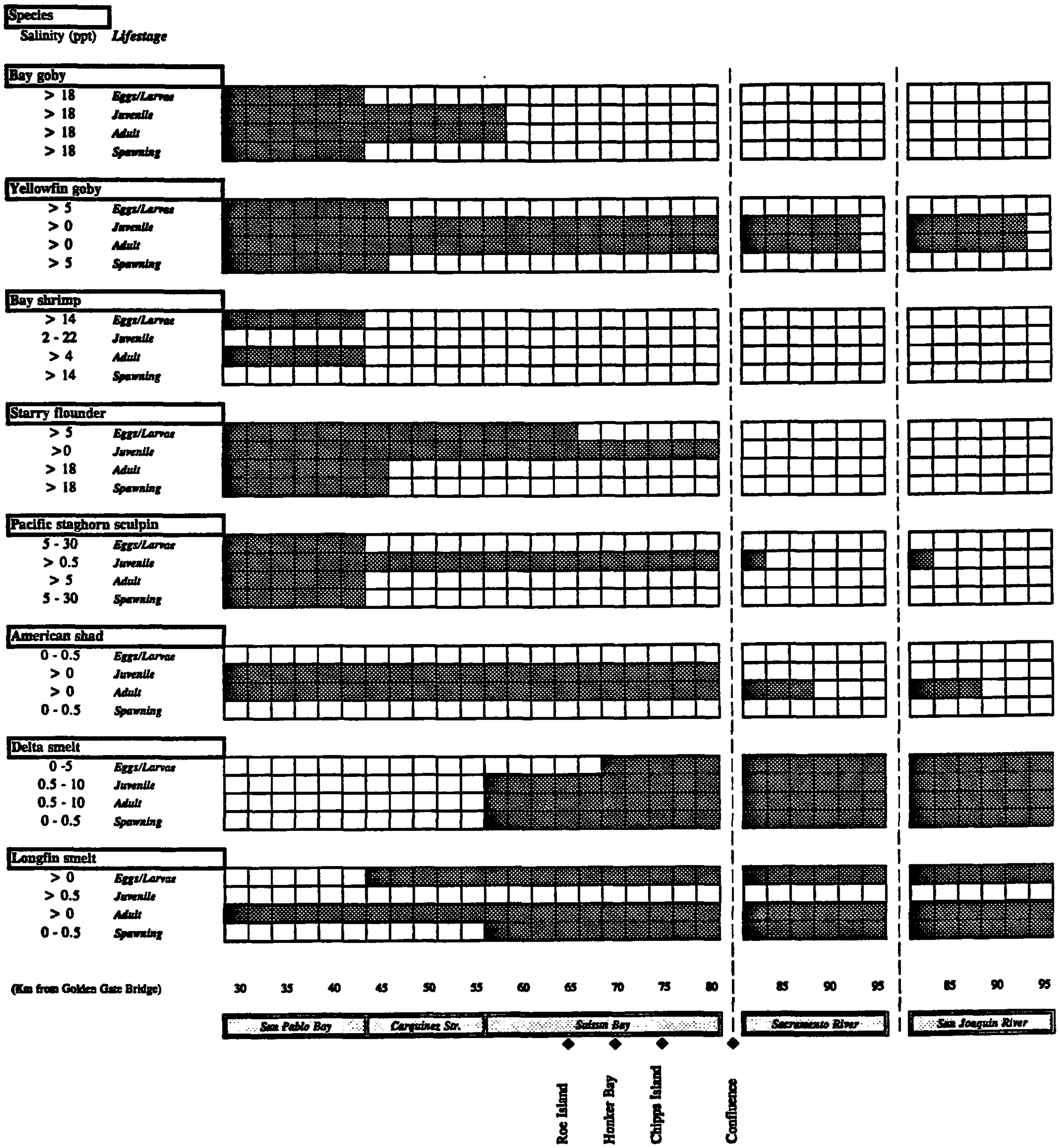
Bay Goby
Yellowfin Goby
Bay Shrimp
Starry Flounder
Pacific Staghorn Sculpin
American Shad
Delta Smelt
Longfin Smelt

Month: JANUARY



Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

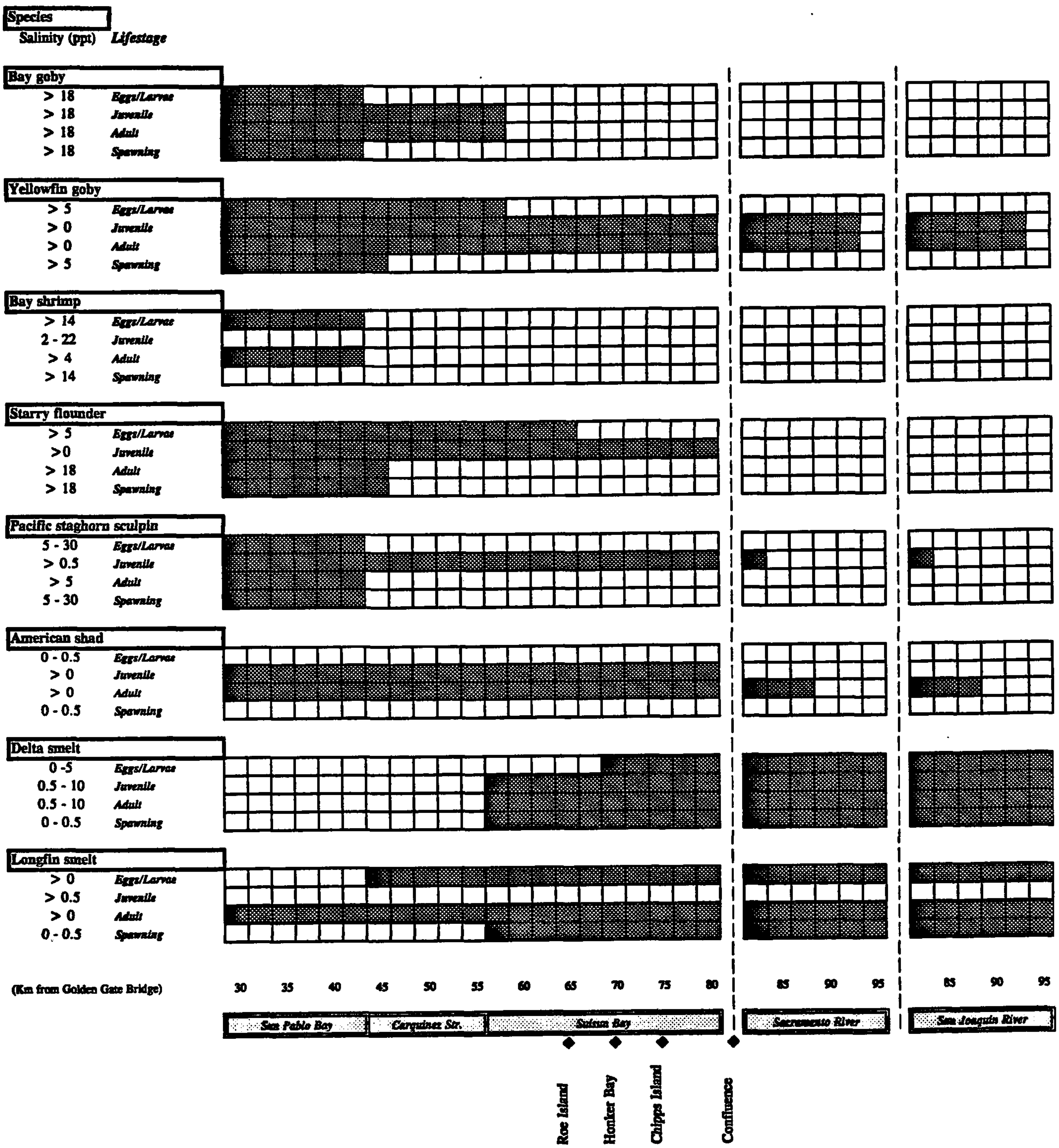
Month: FEBRUARY



Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

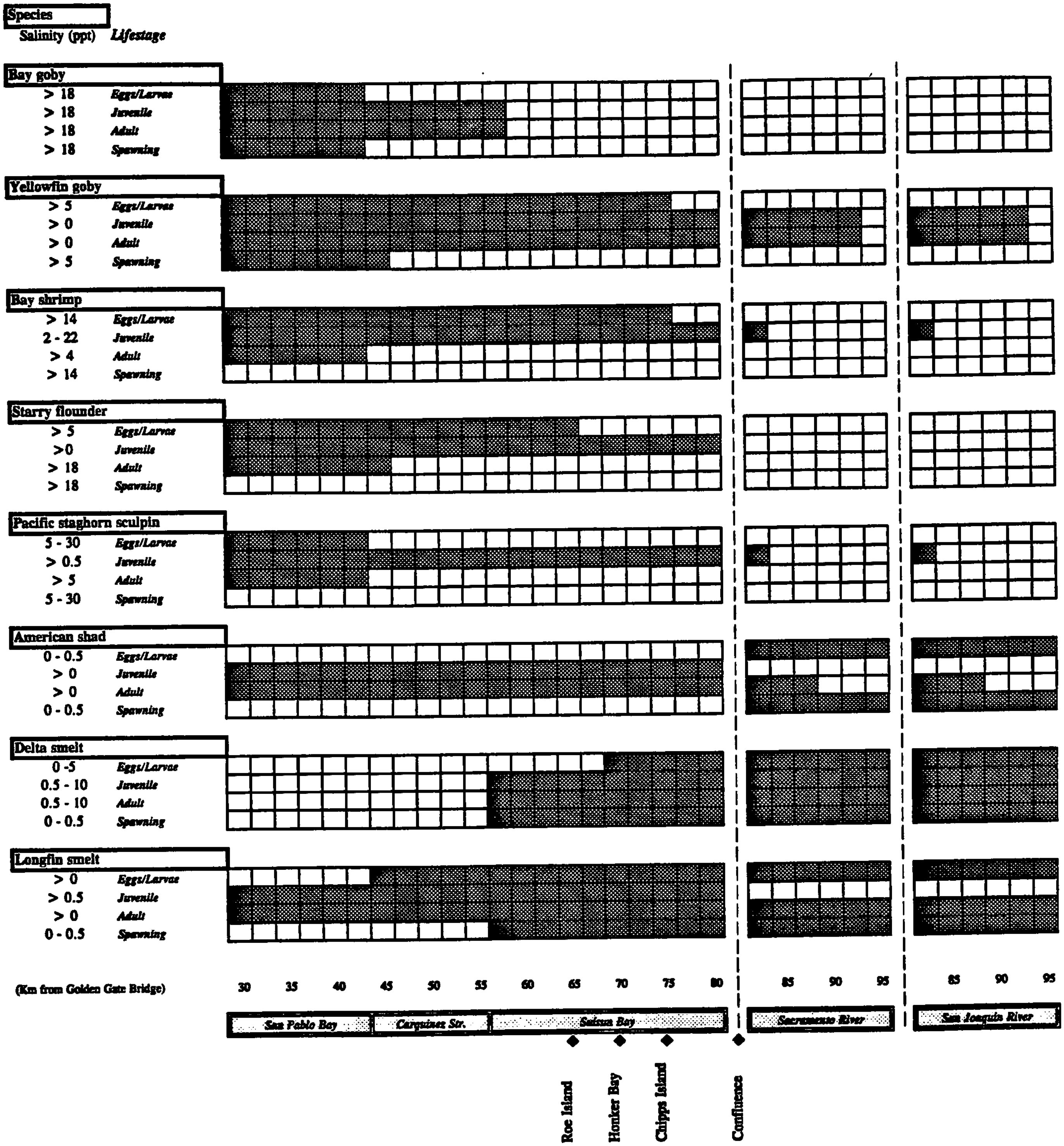
R2 Resource Consultants, Inc.

Month: MARCH



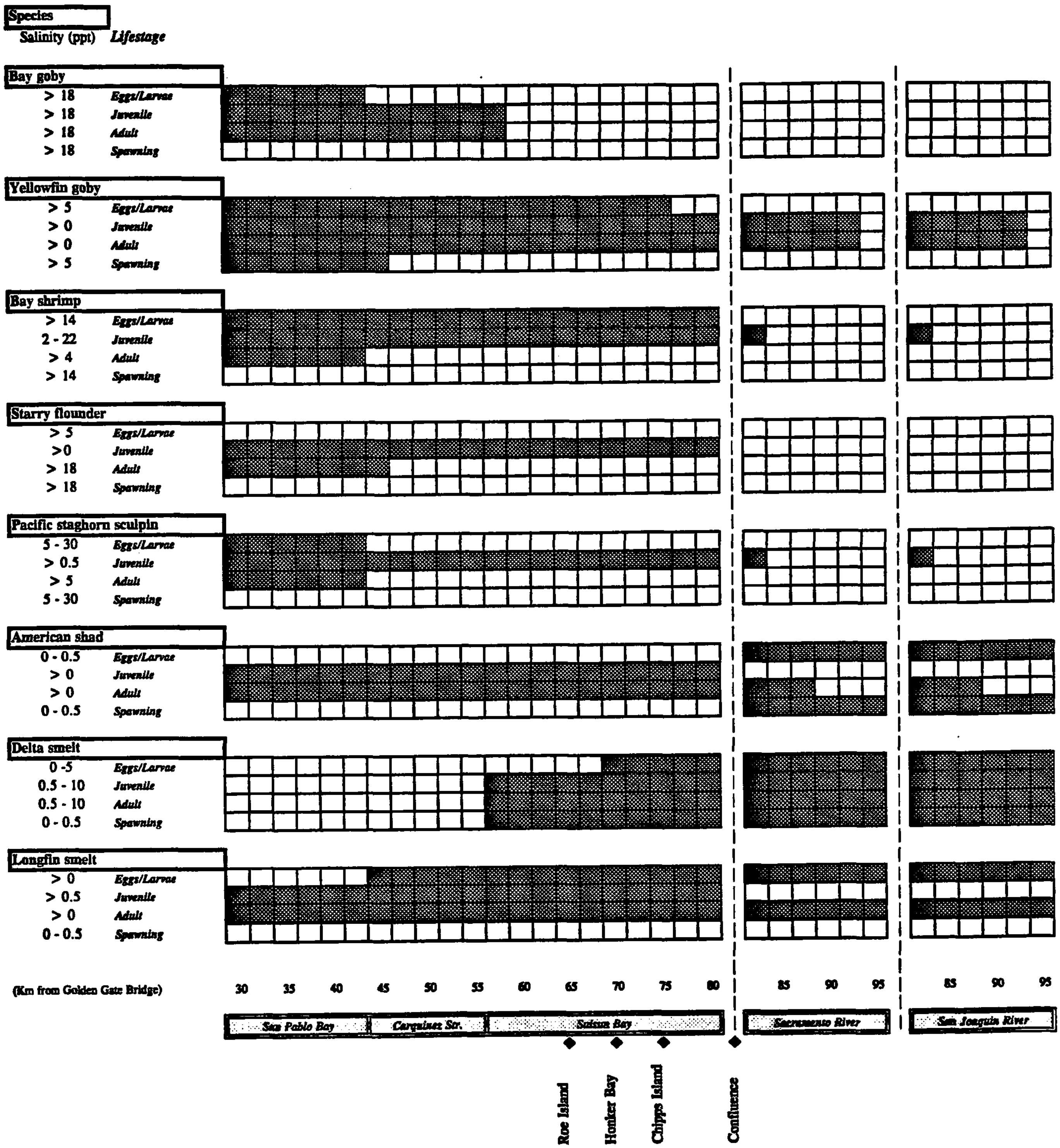
Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

Month: APRIL



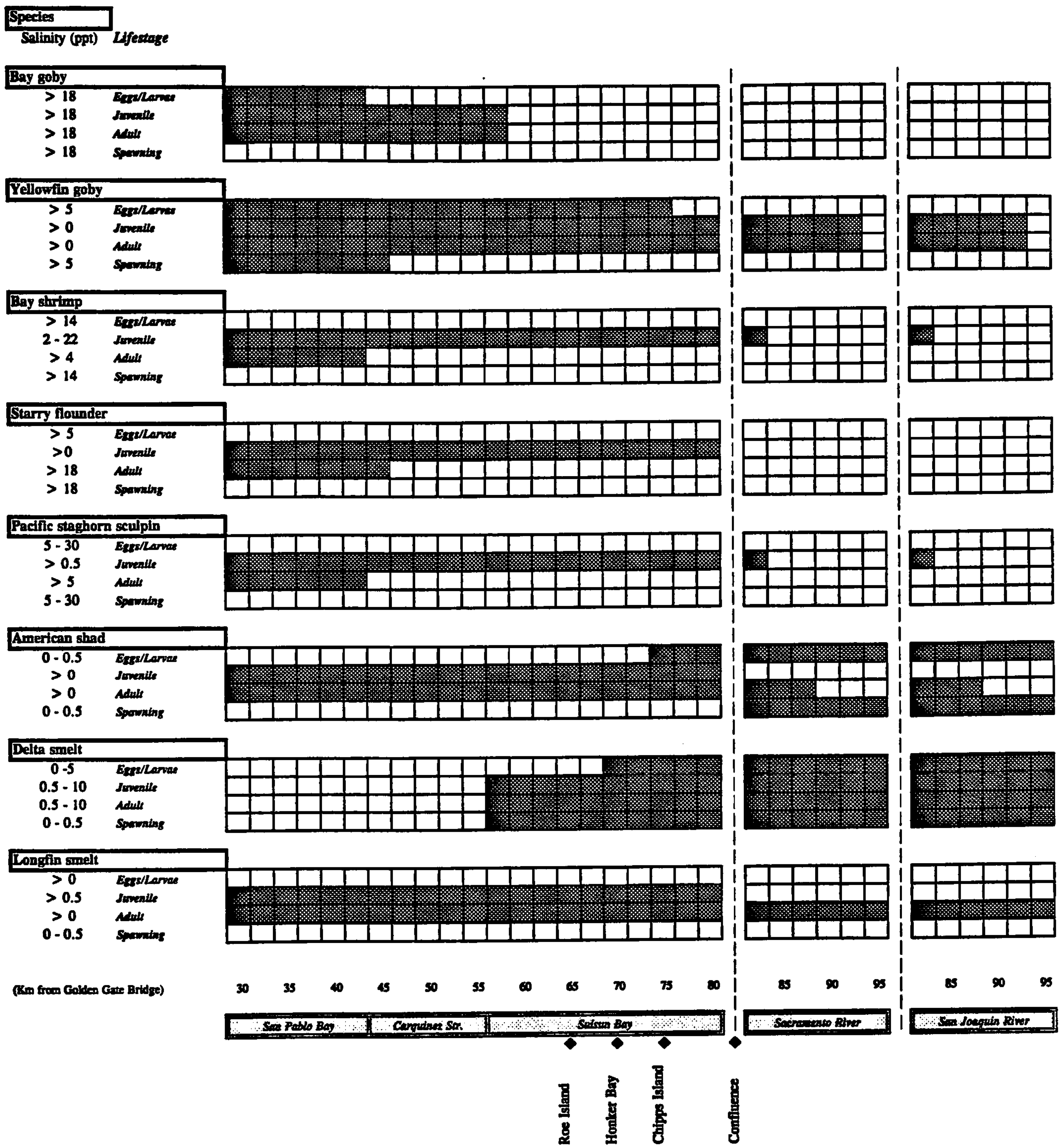
Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

Month: MAY



Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

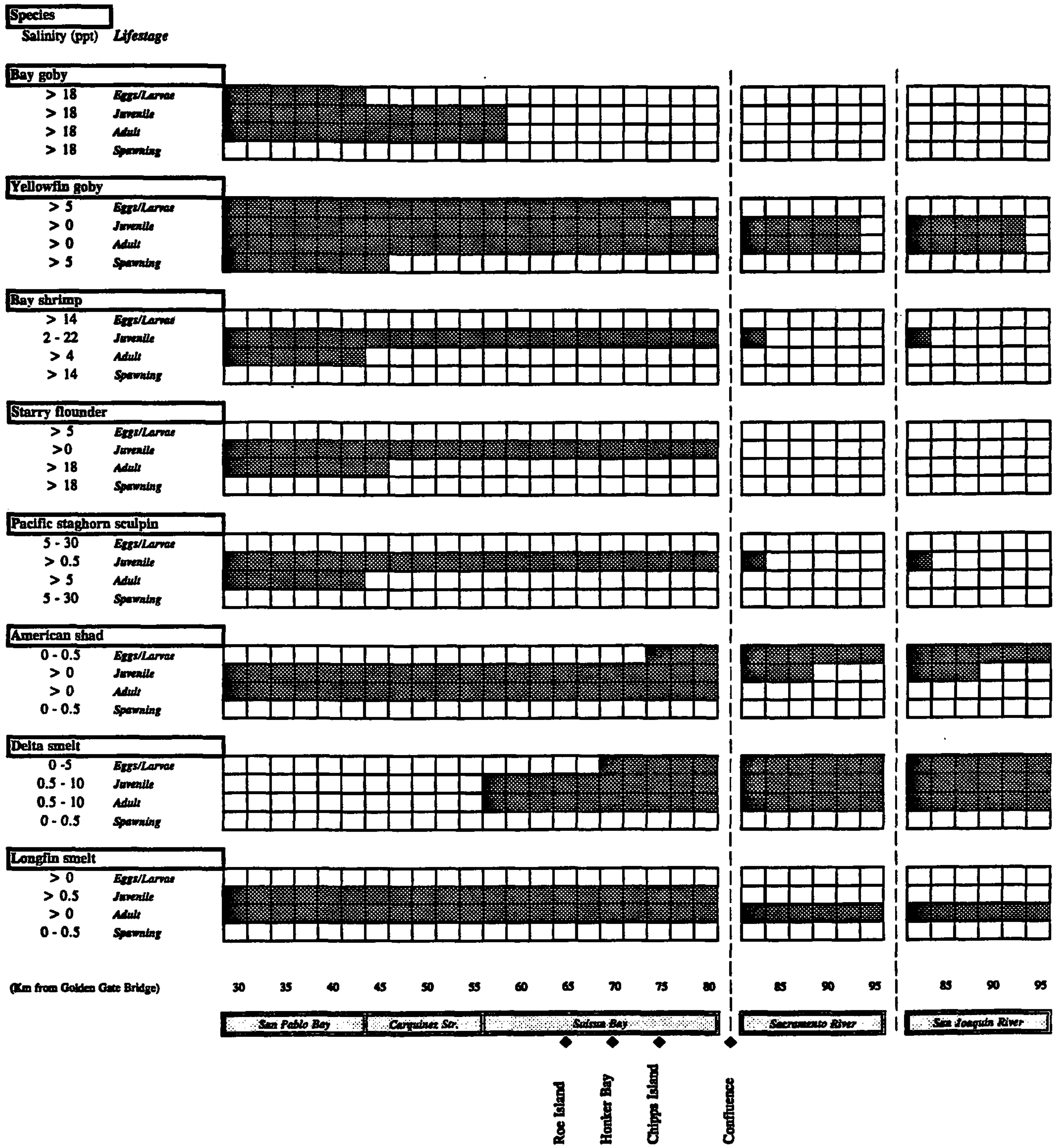
Month: JUNE



Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

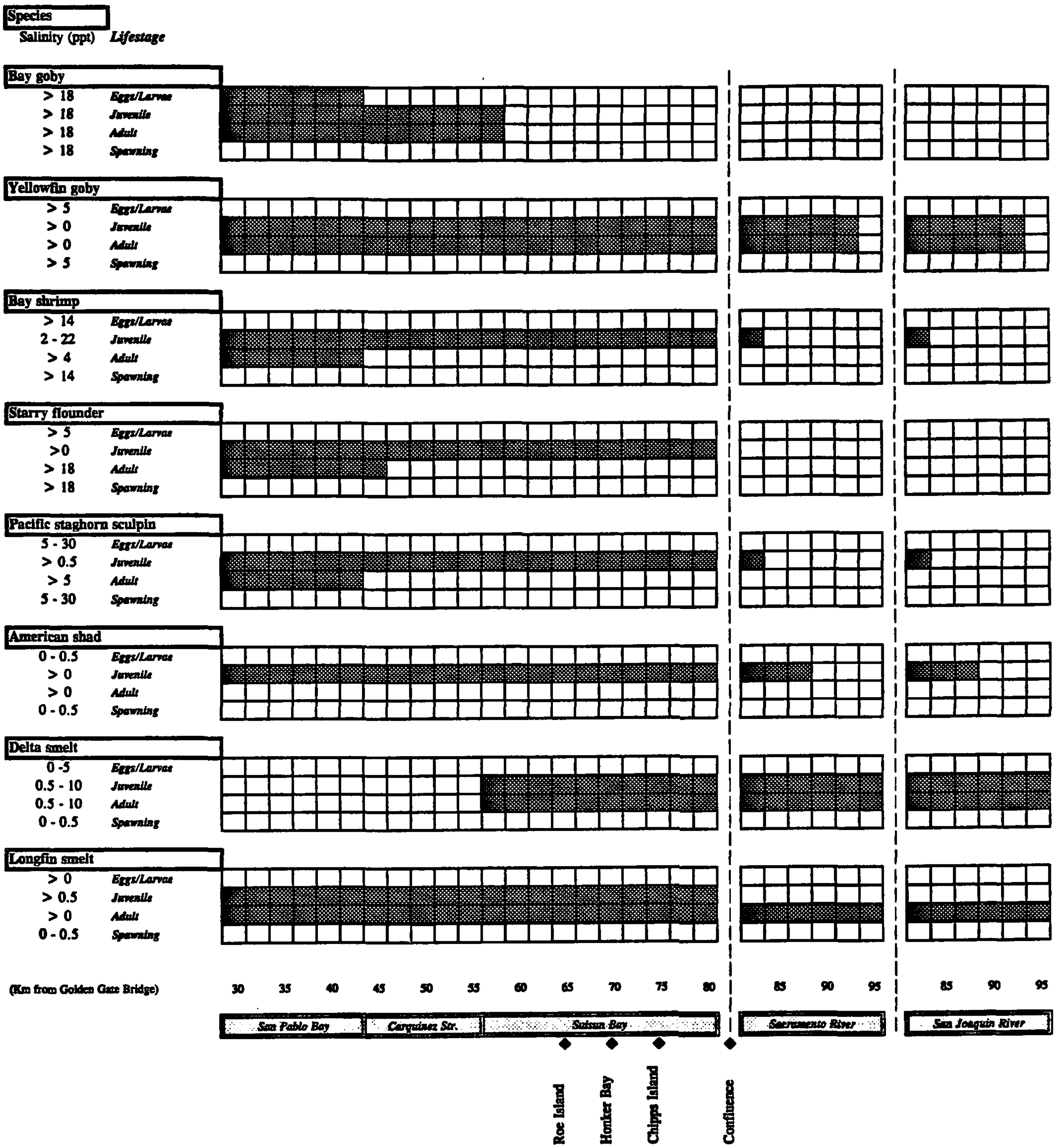
R2 Resource Consultants, Inc.

Month: JULY



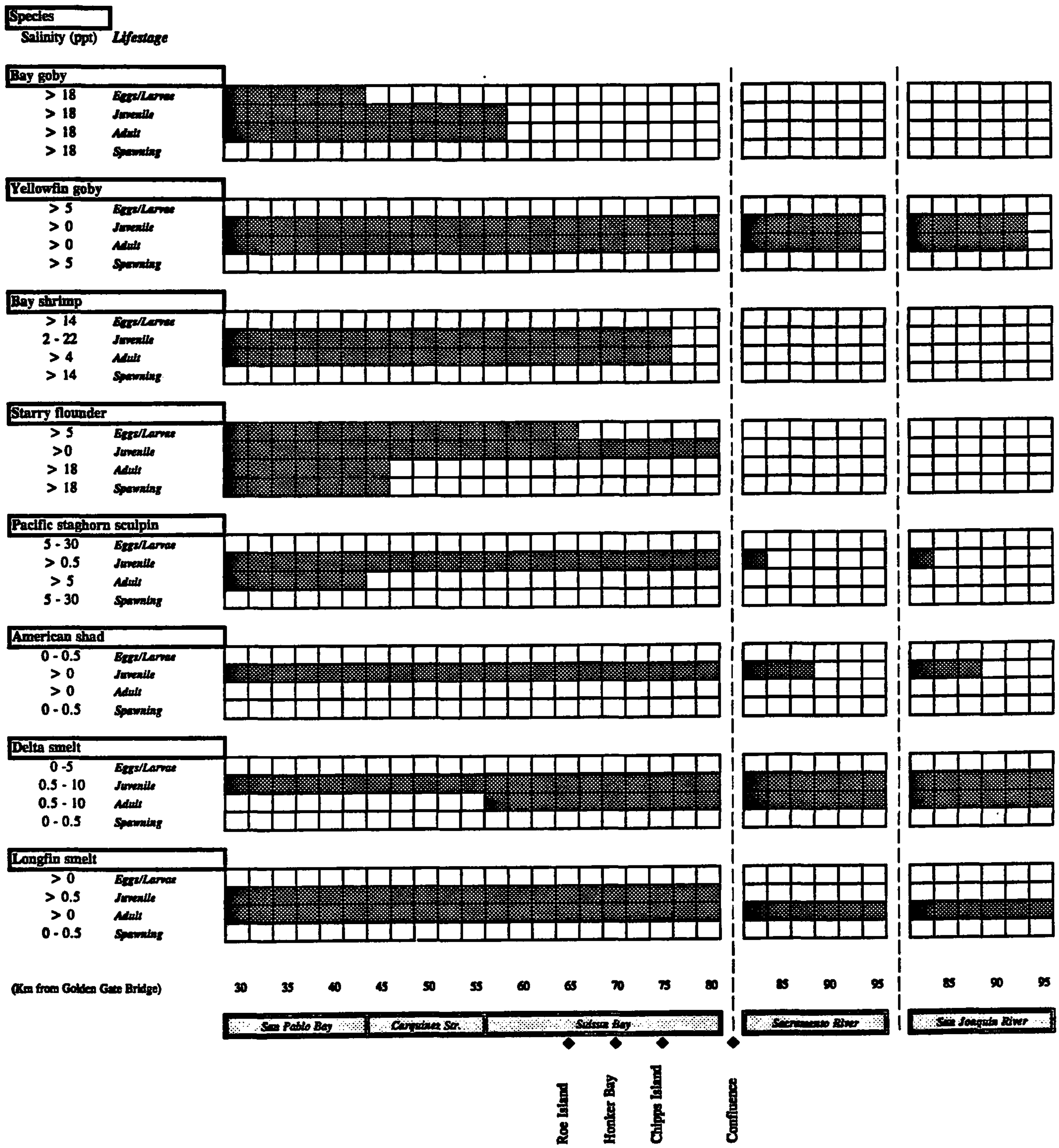
Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

Month: AUGUST



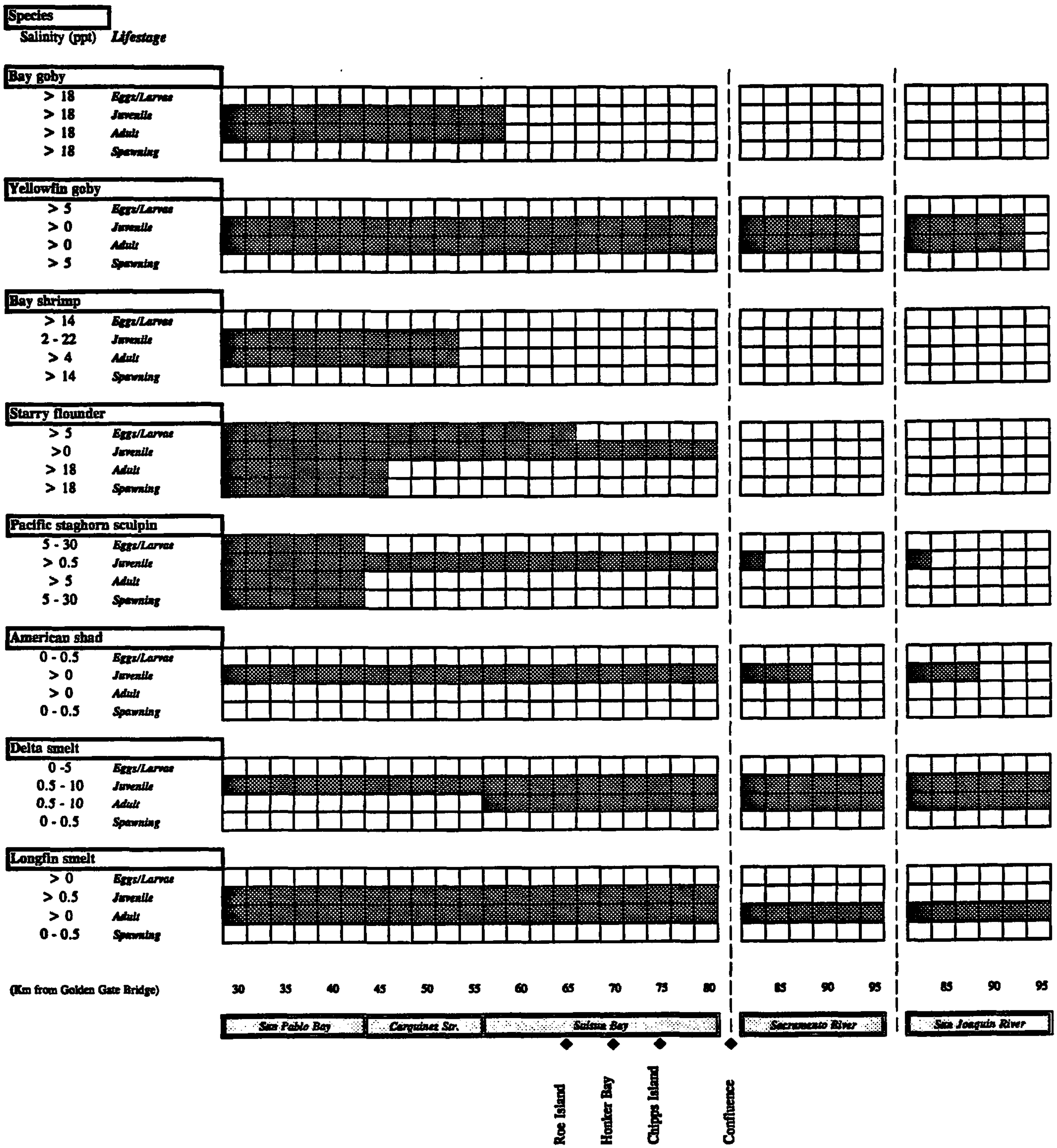
Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

Month: SEPTEMBER



Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

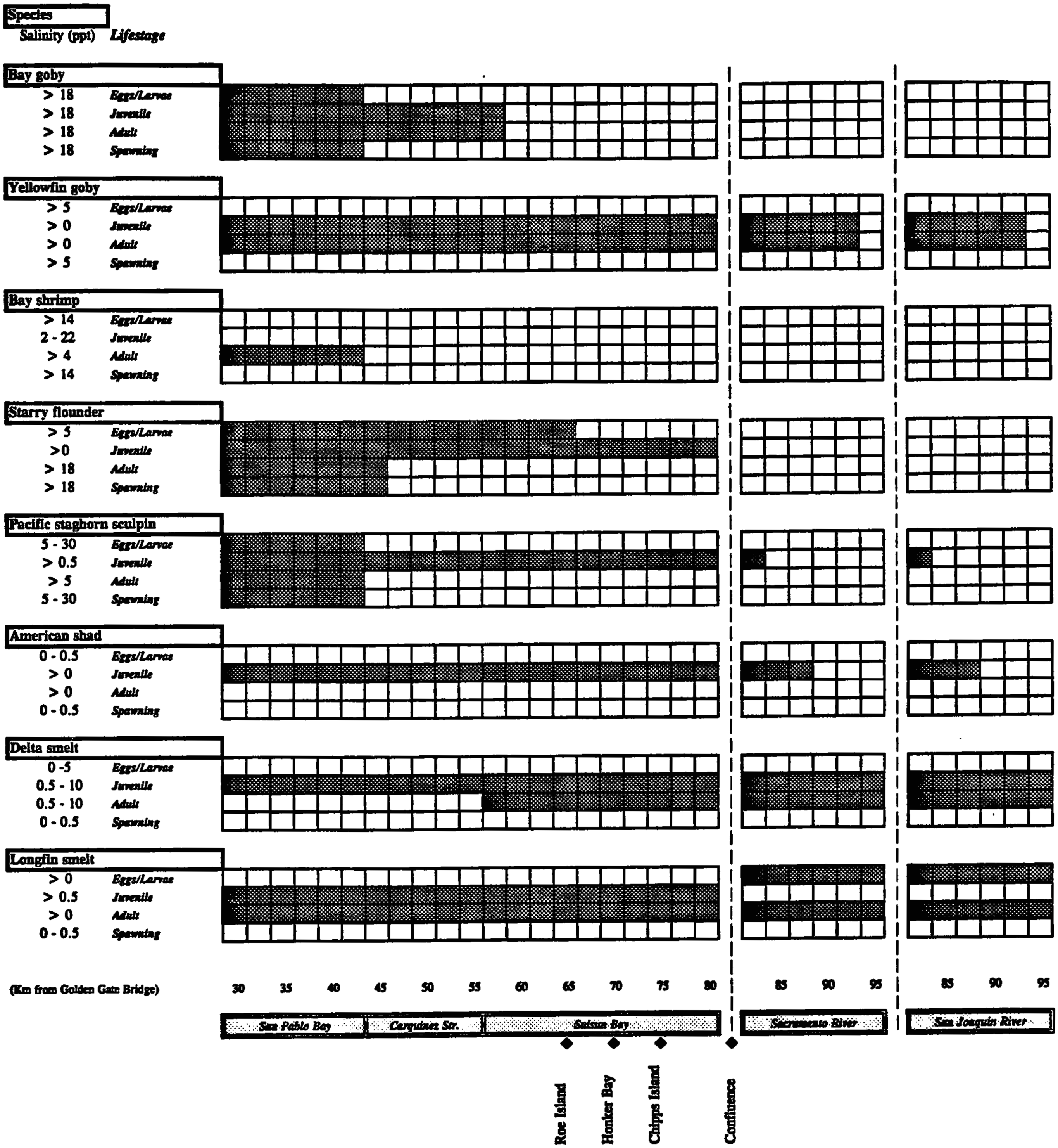
Month: OCTOBER



Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

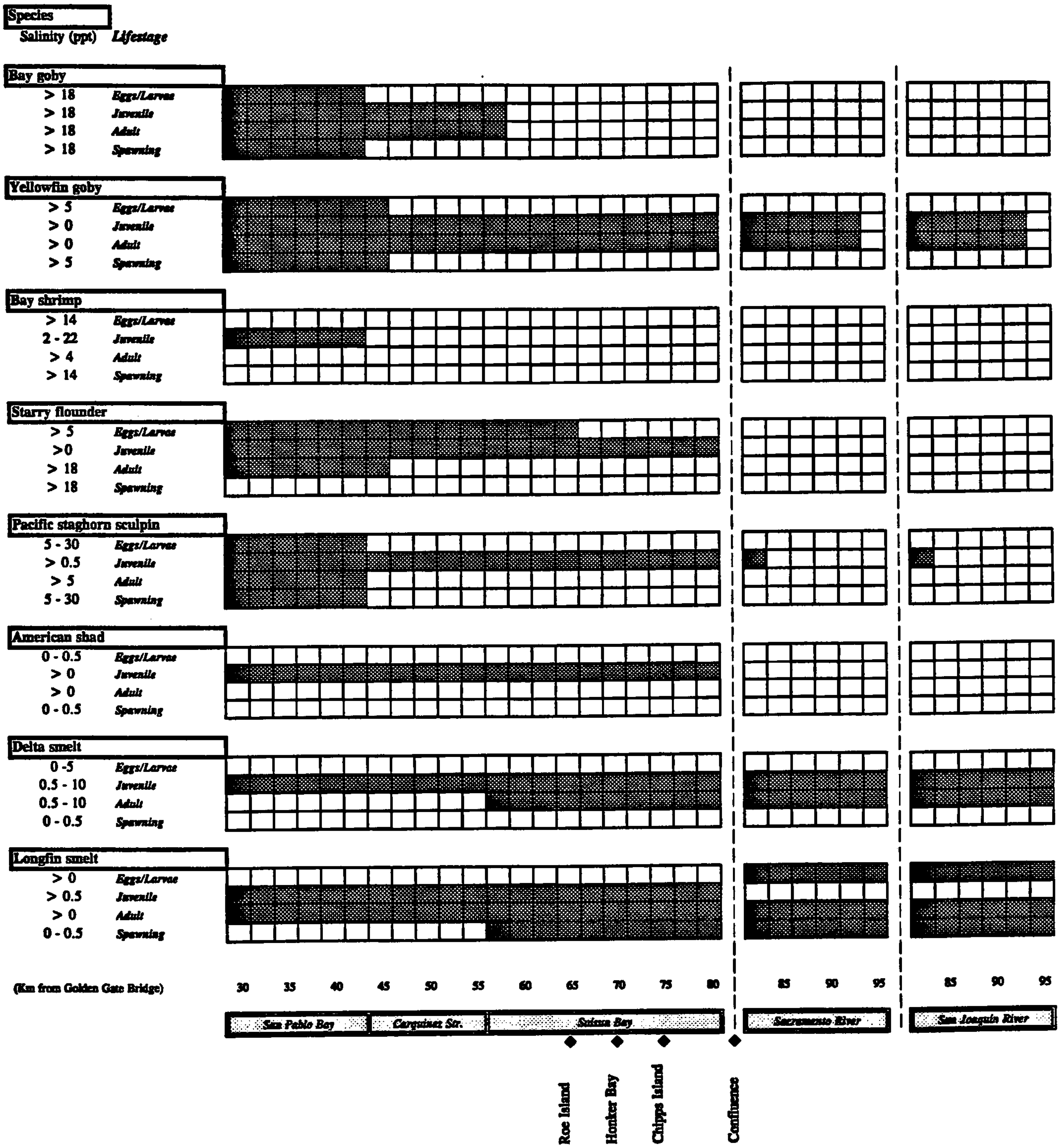
R2 Resource Consultants, Inc.

Month: NOVEMBER



Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

Month: DECEMBER



Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

APPENDIX A

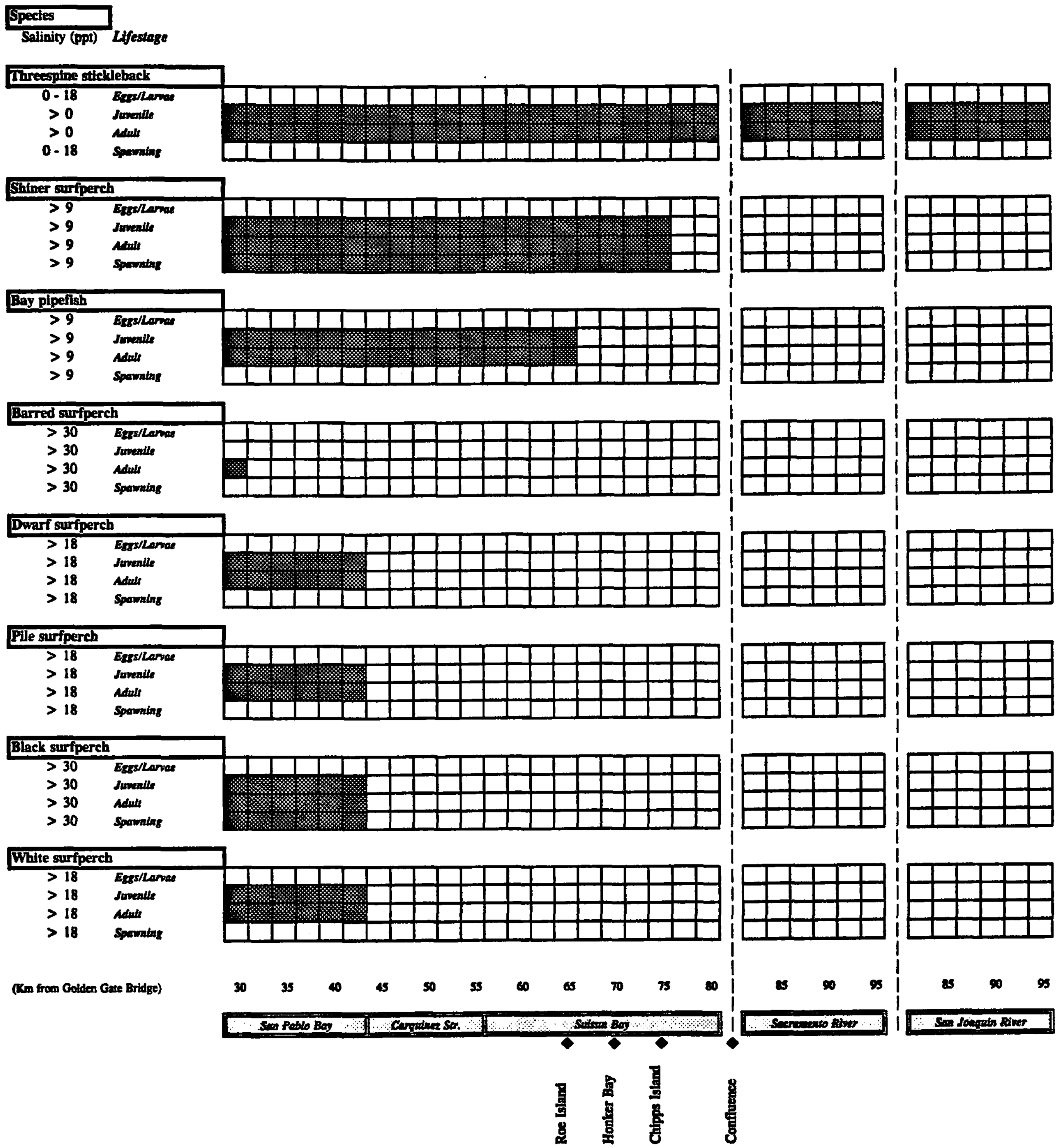
SPECIES PERIODICITY AND DISTRIBUTION CHARTS

Subappendix A-4

Monthly Life Stage Distributions:

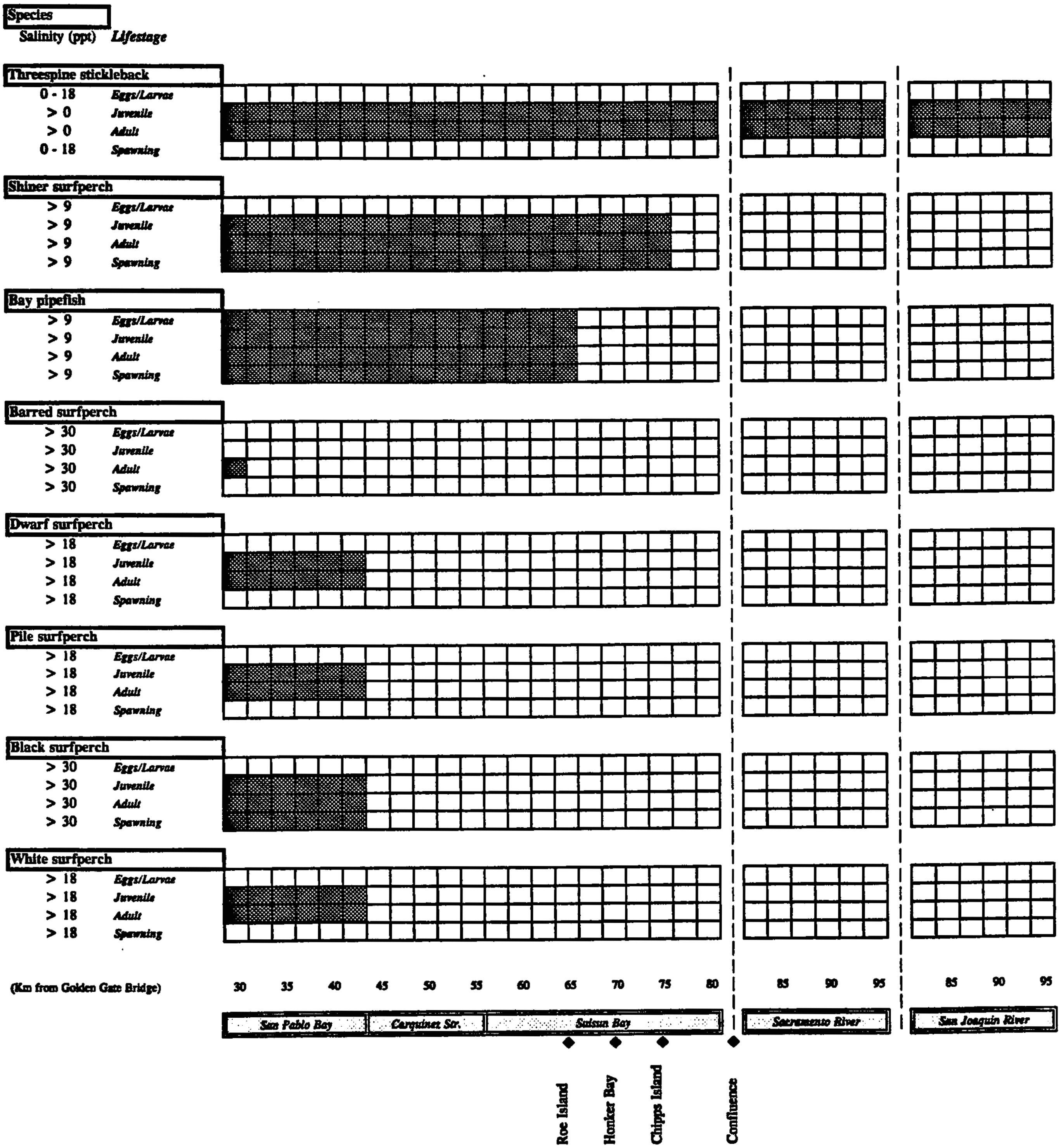
Threespine Stickleback
Shiner Surfperch
Bay Pipefish
Barred Surfperch
Dwarf Surfperch
Pile Surfperch
Black Surfperch
White Surfperch

Month: JANUARY



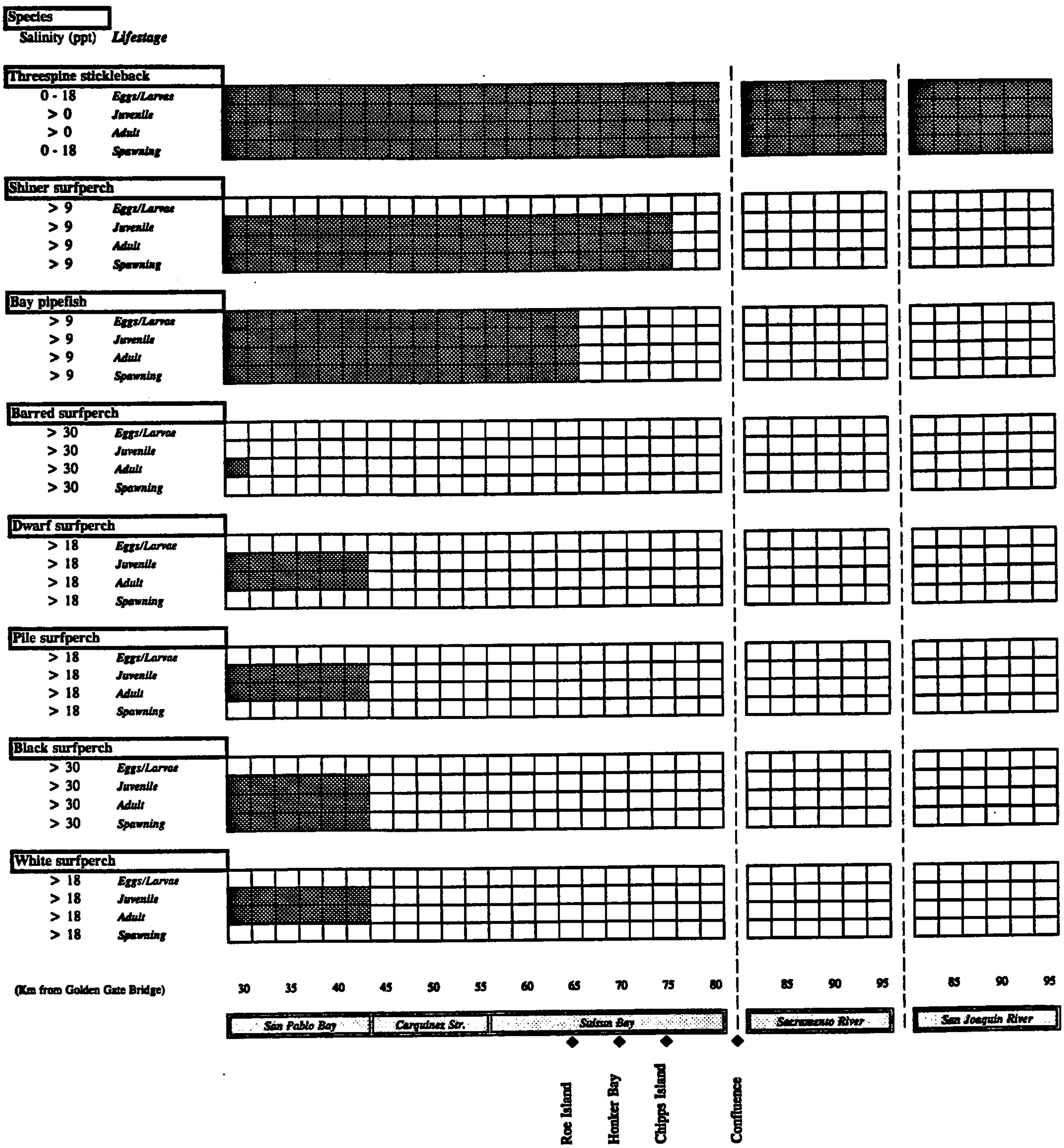
Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

Month: FEBRUARY



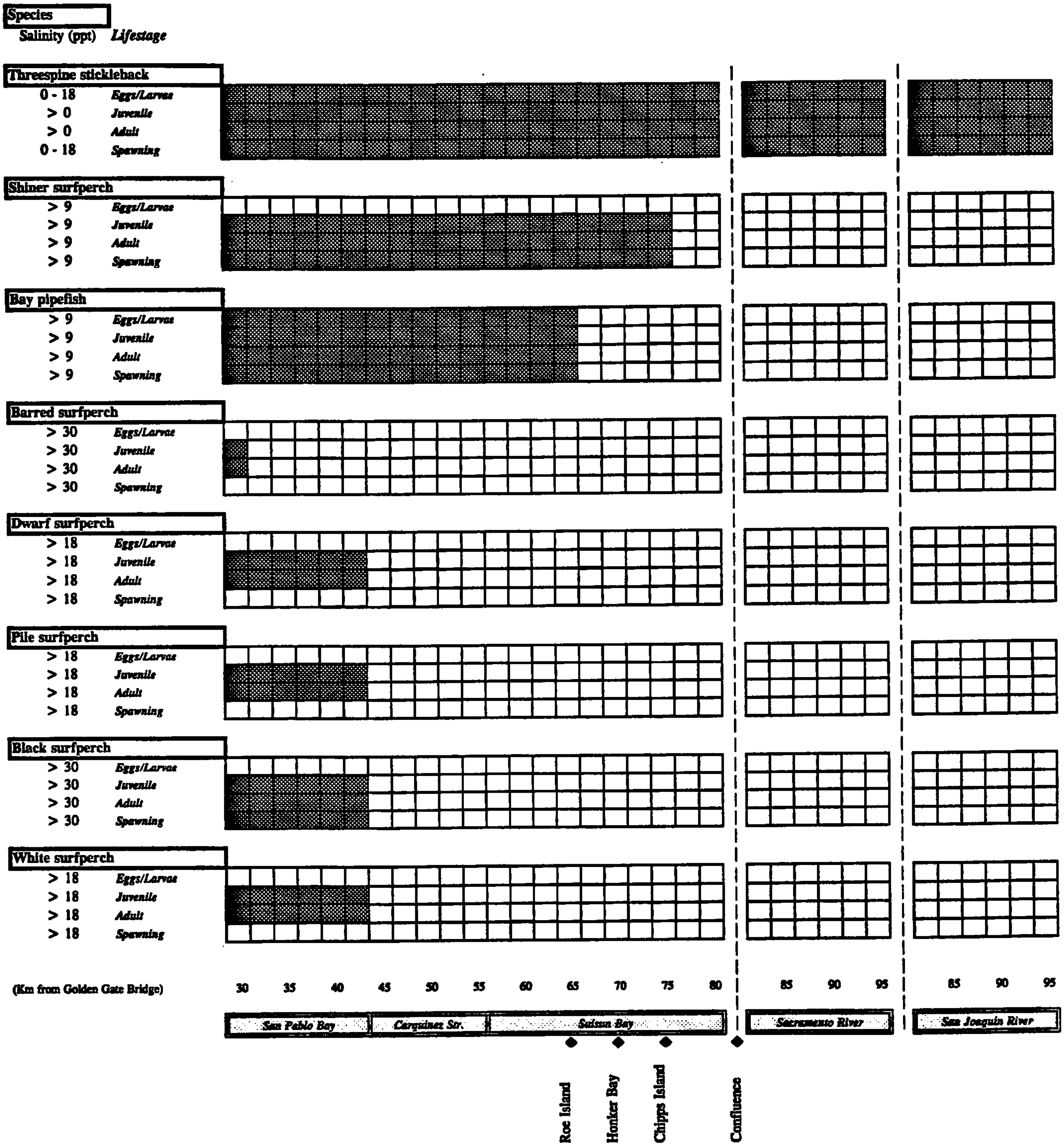
Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

Month: MARCH



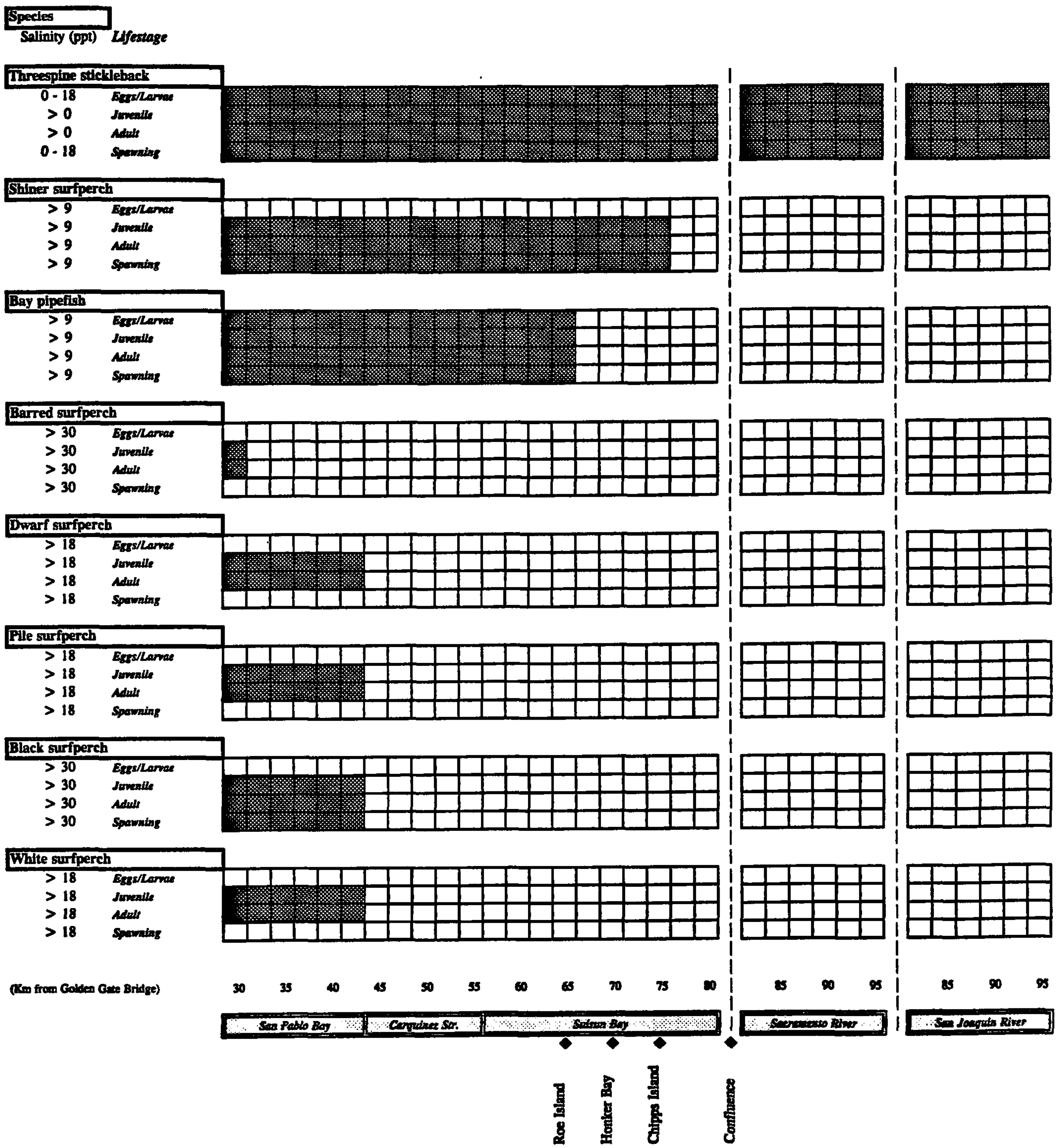
Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

Month: APRIL



Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

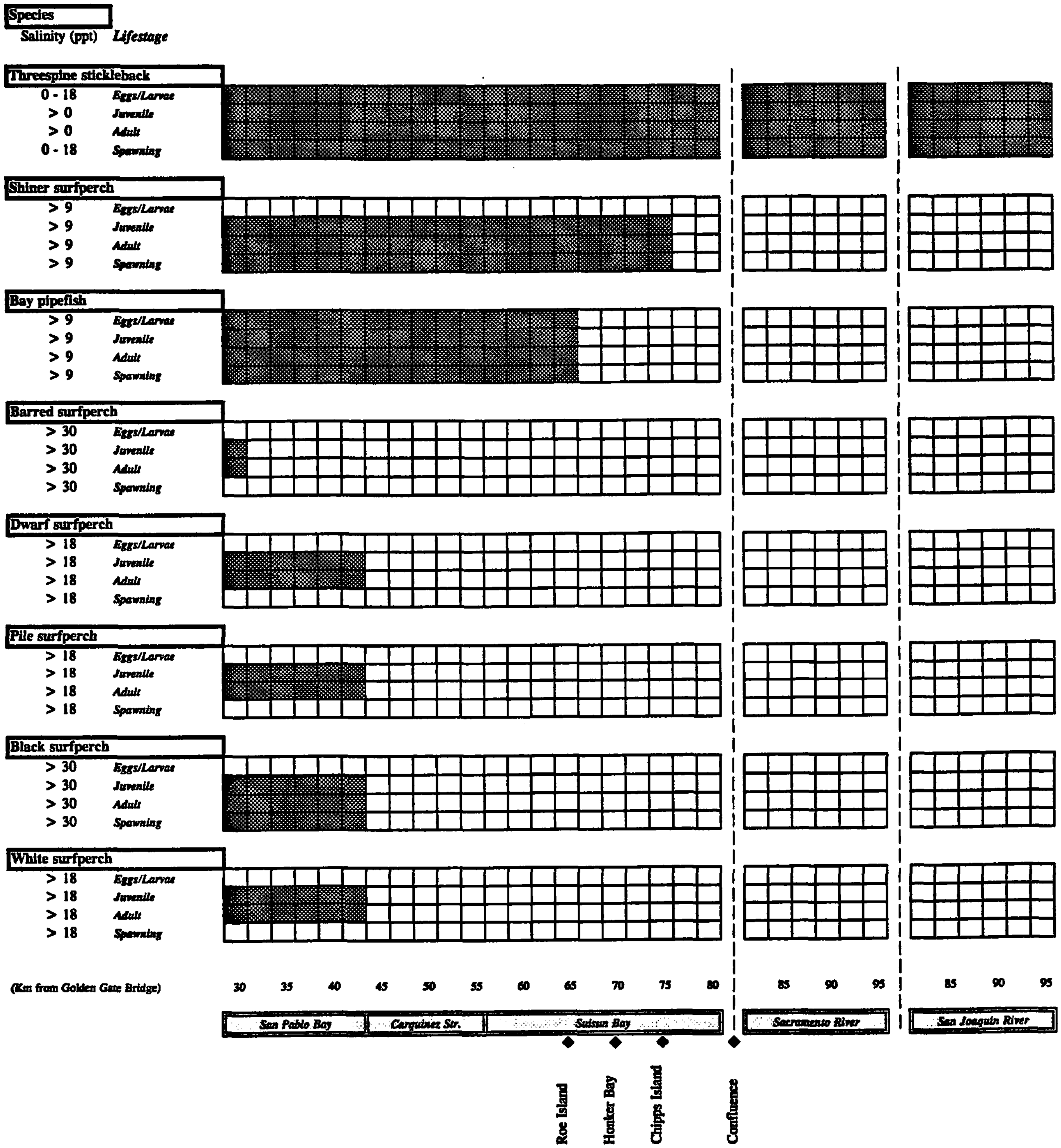
Month: MAY



Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

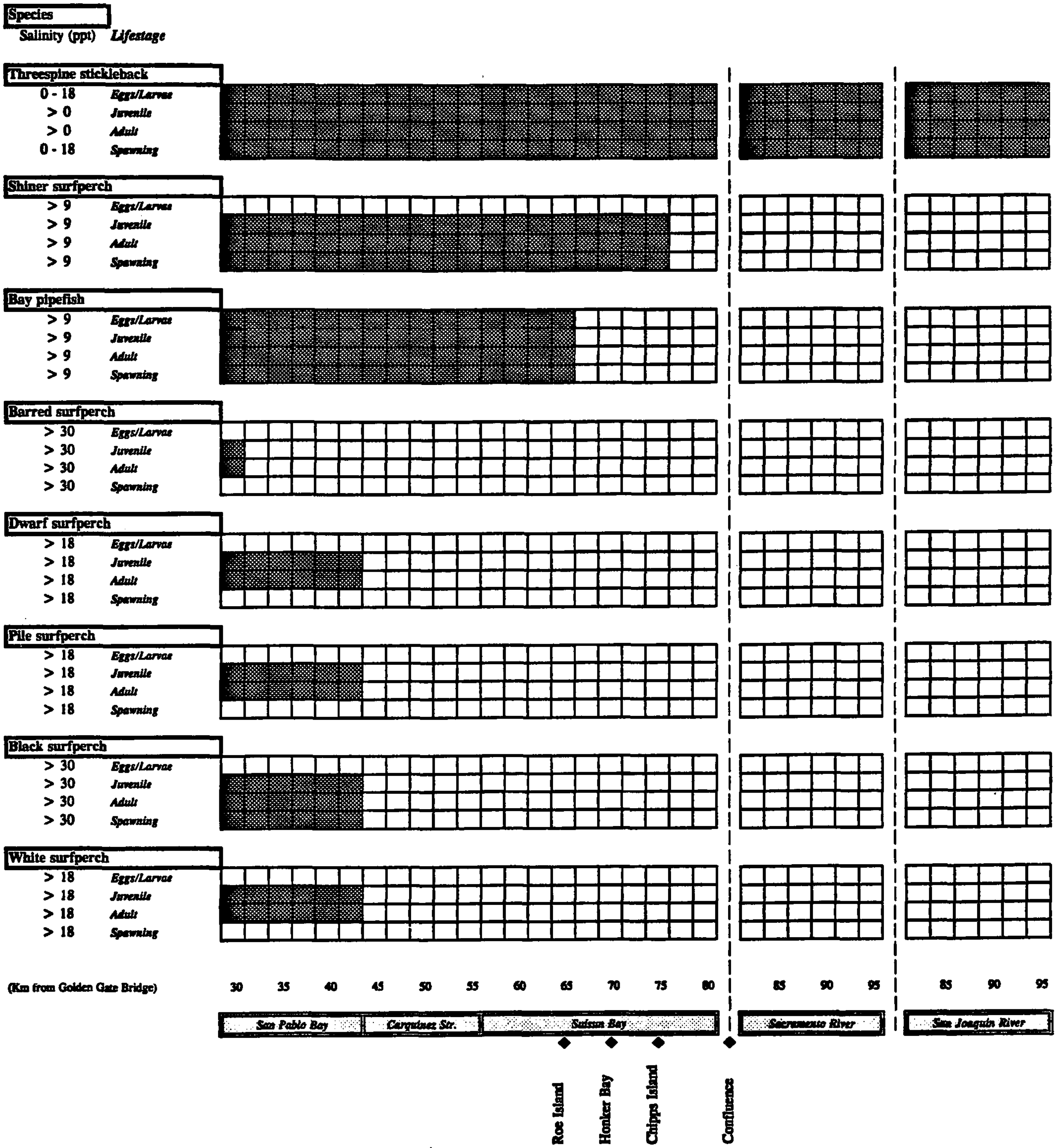
R2 Resource Consultants, Inc.

Month: JUNE



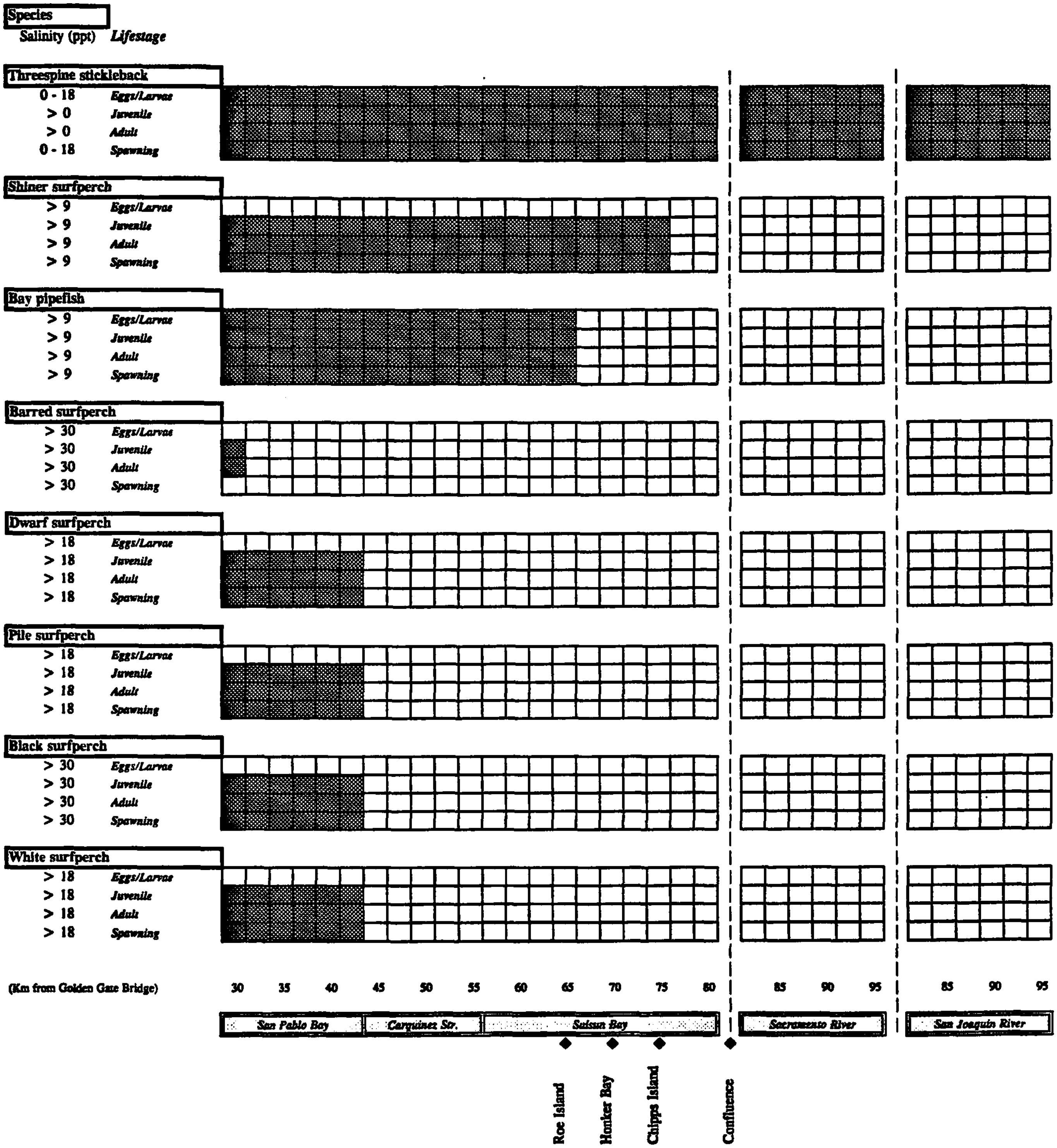
Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

Month: JULY



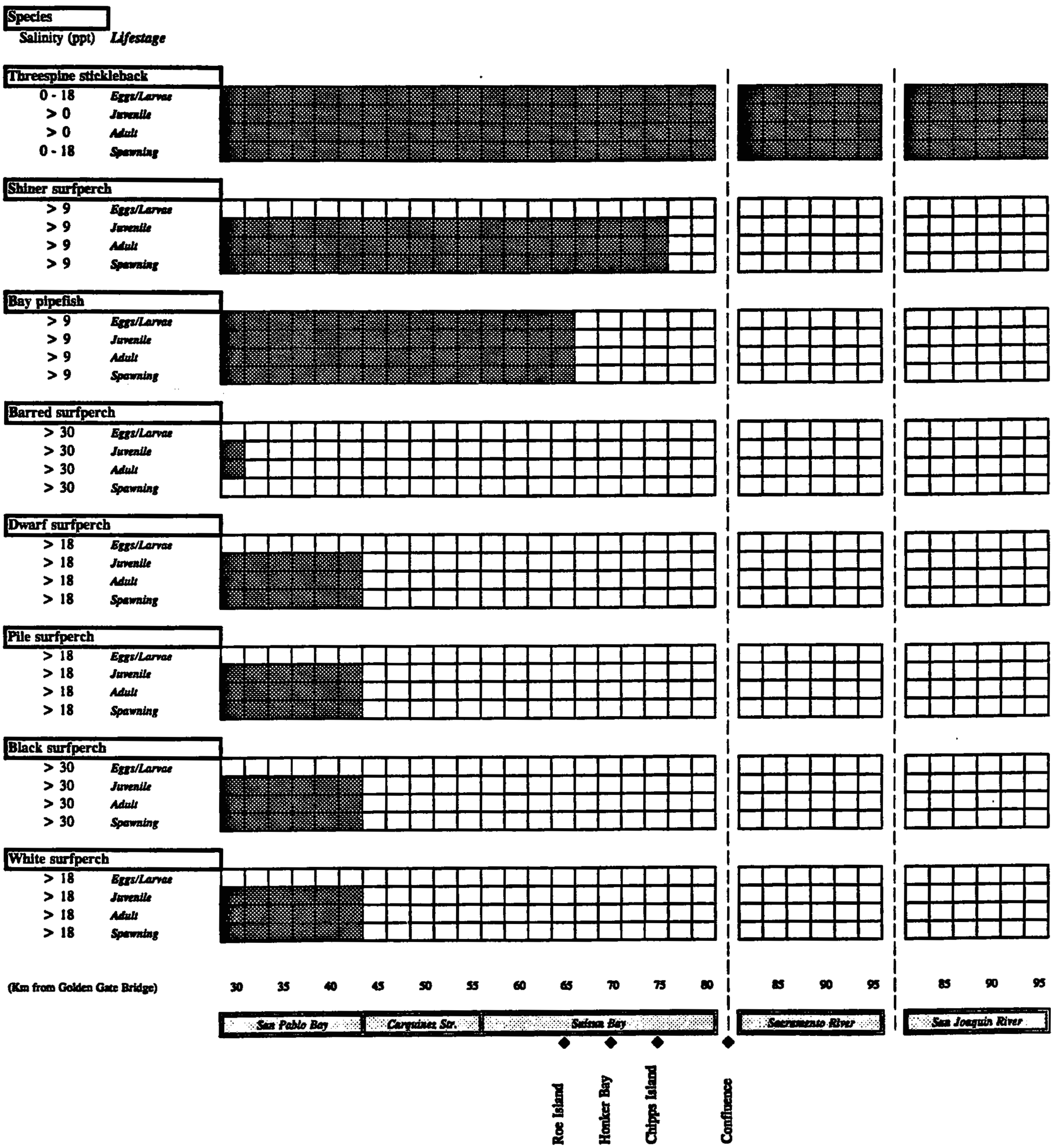
Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

Month: AUGUST



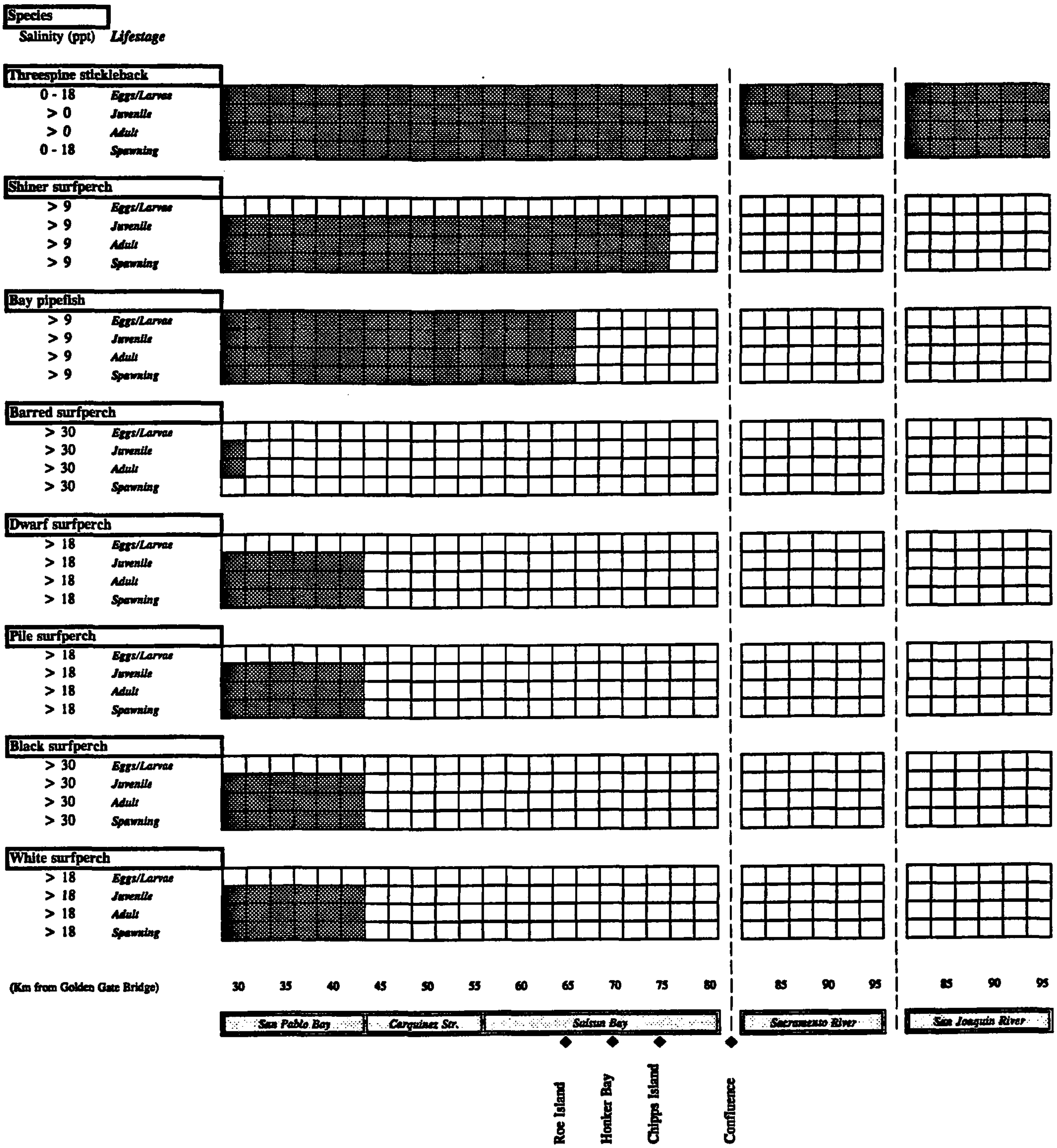
Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

Month: SEPTEMBER



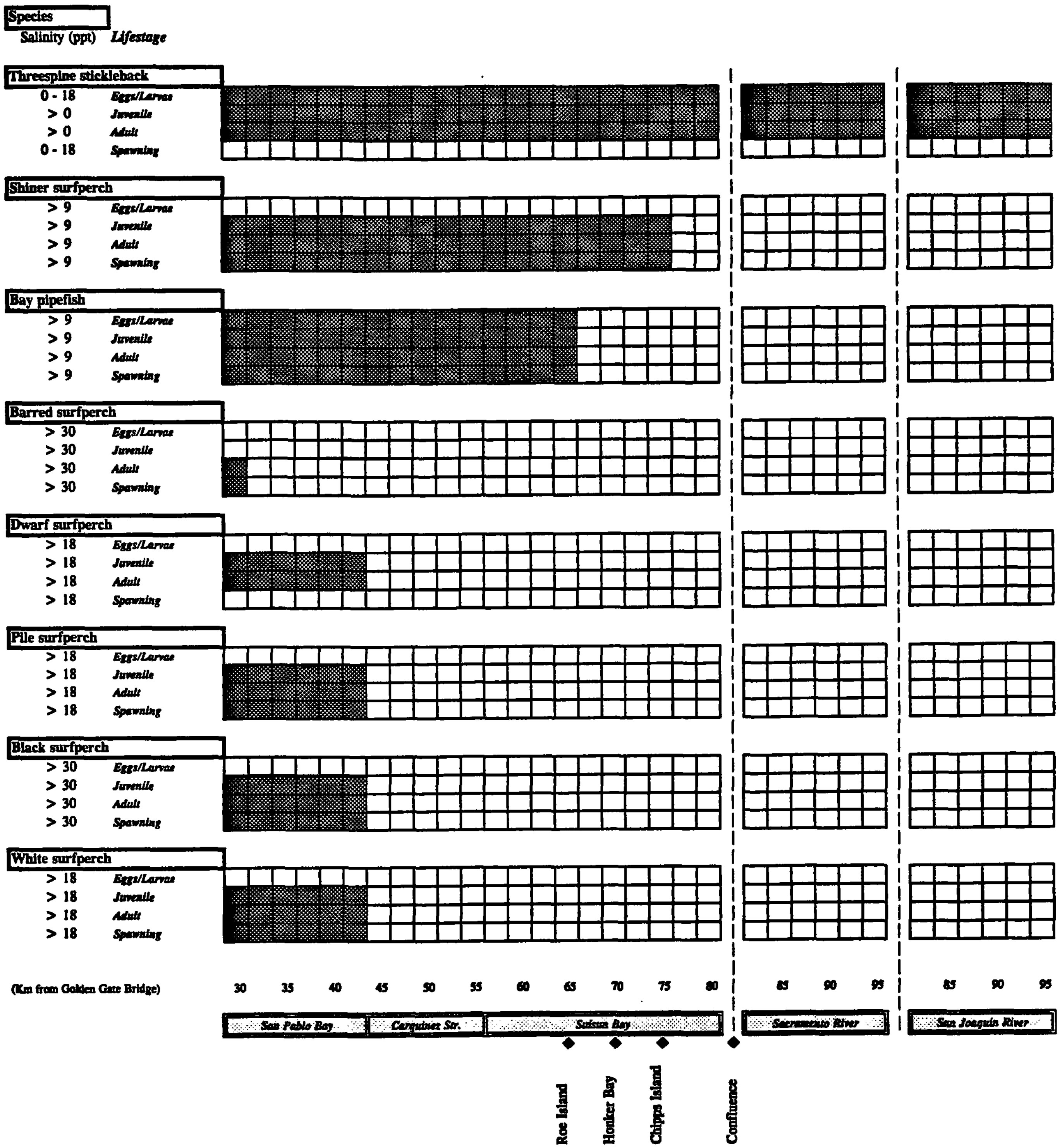
Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

Month: OCTOBER



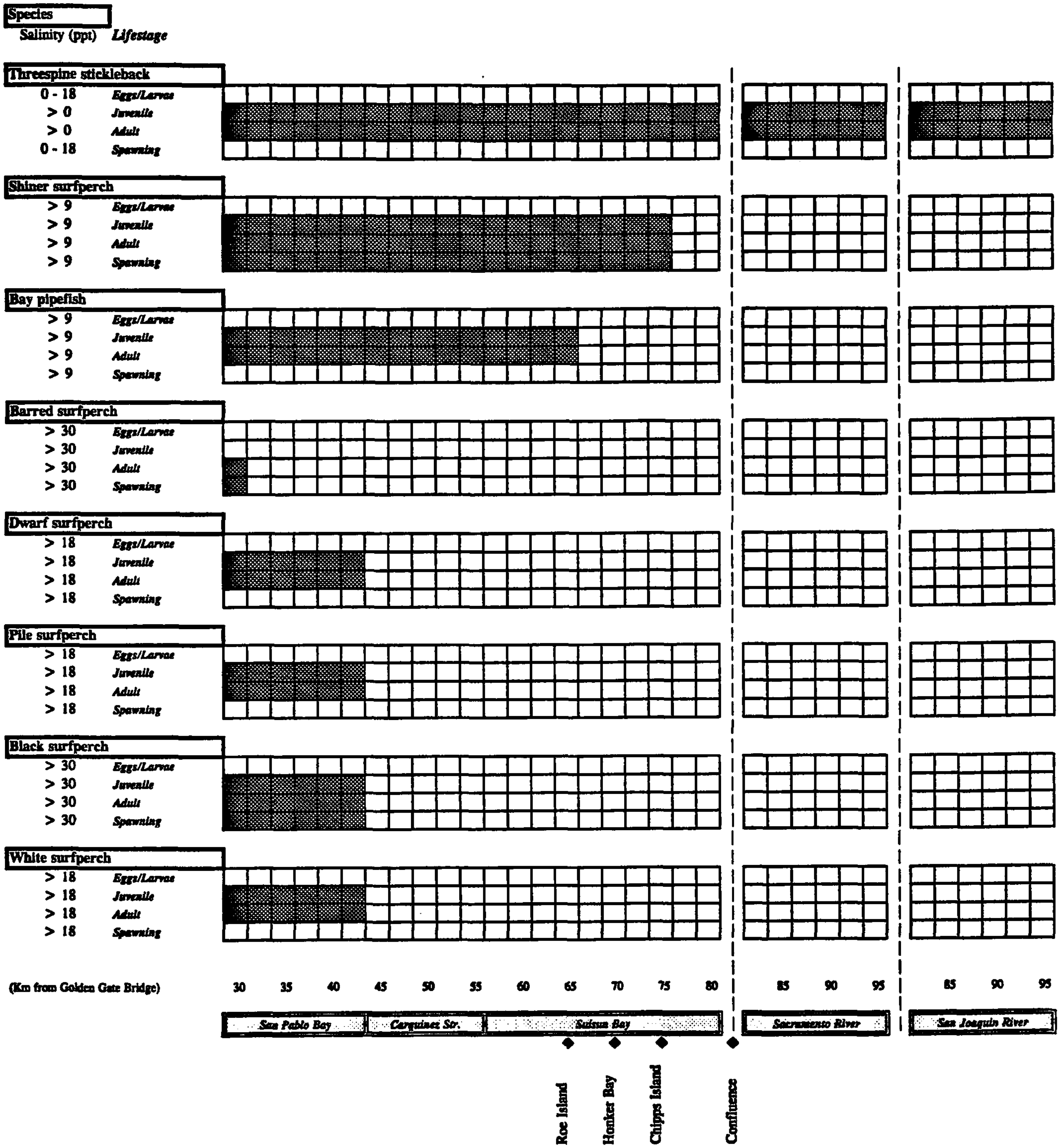
Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

Month: NOVEMBER



Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

Month: DECEMBER



Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

APPENDIX A

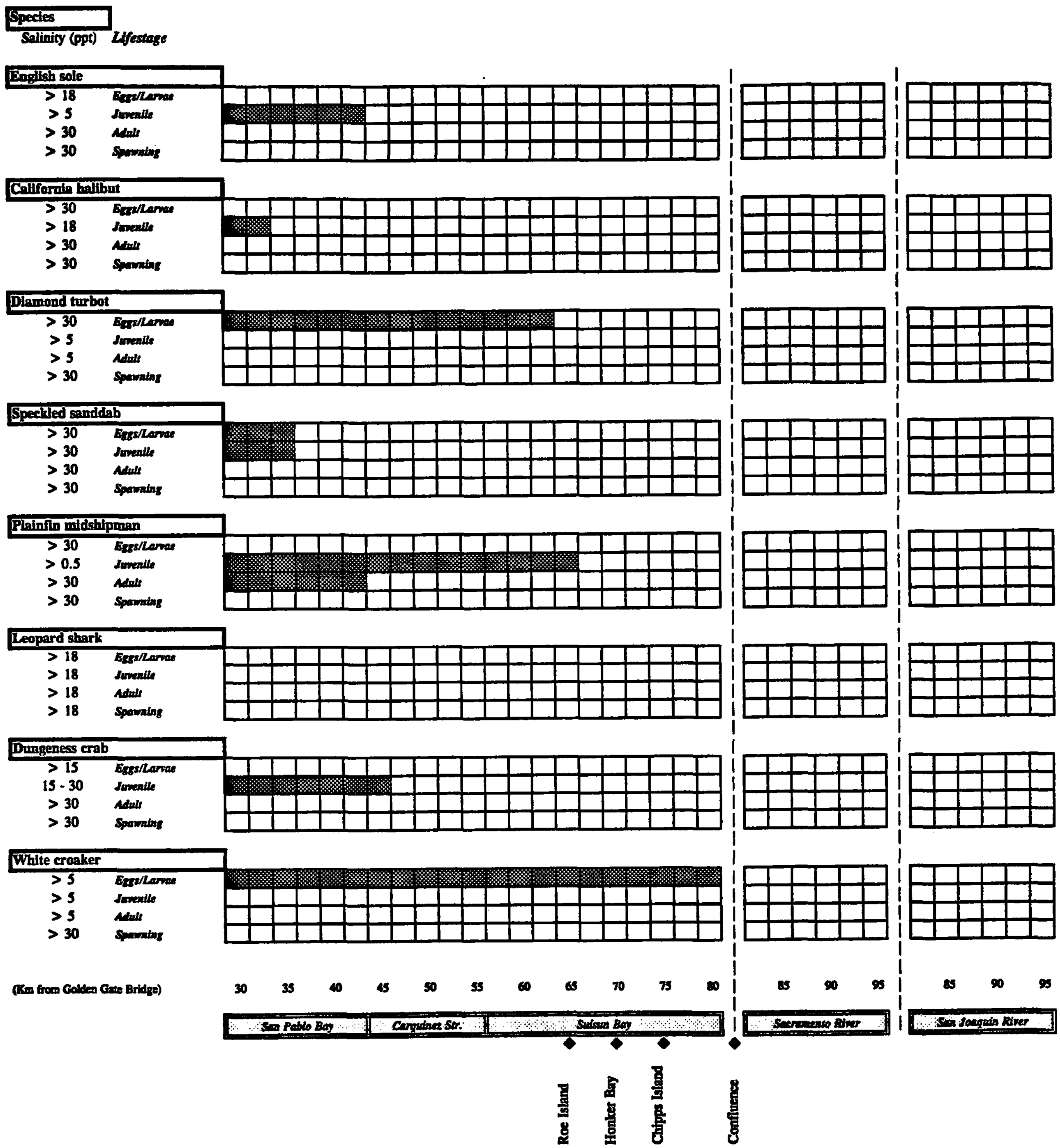
SPECIES PERIODICITY AND DISTRIBUTION CHARTS

Subappendix A-5

Monthly Life Stage Distributions:

English Sole
California Halibut
Diamond Turbot
Speckled Sanddab
Plainfin Midshipman
Leopard Shark
Dungeness Crab
White Croaker

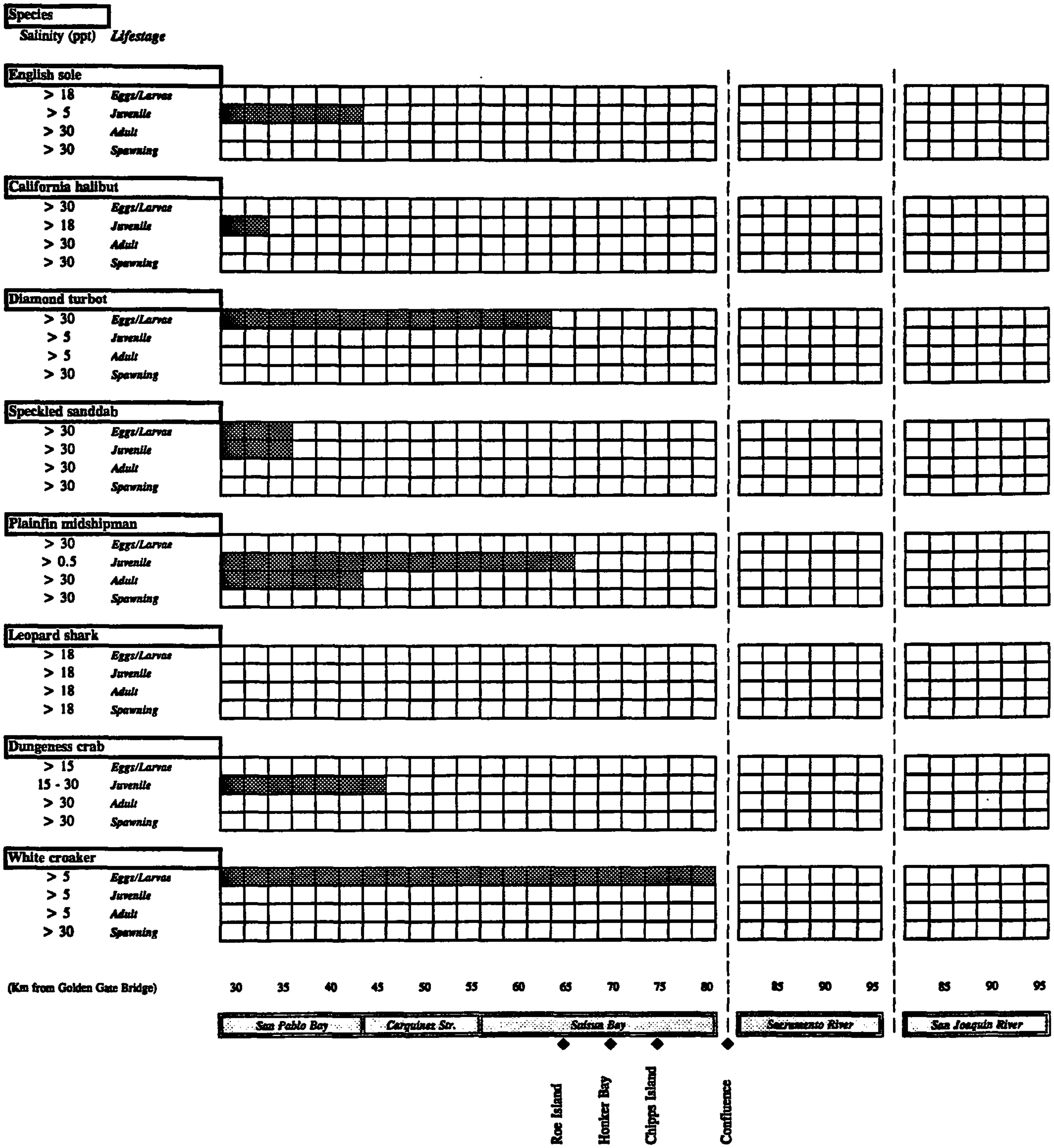
Month: JANUARY



Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

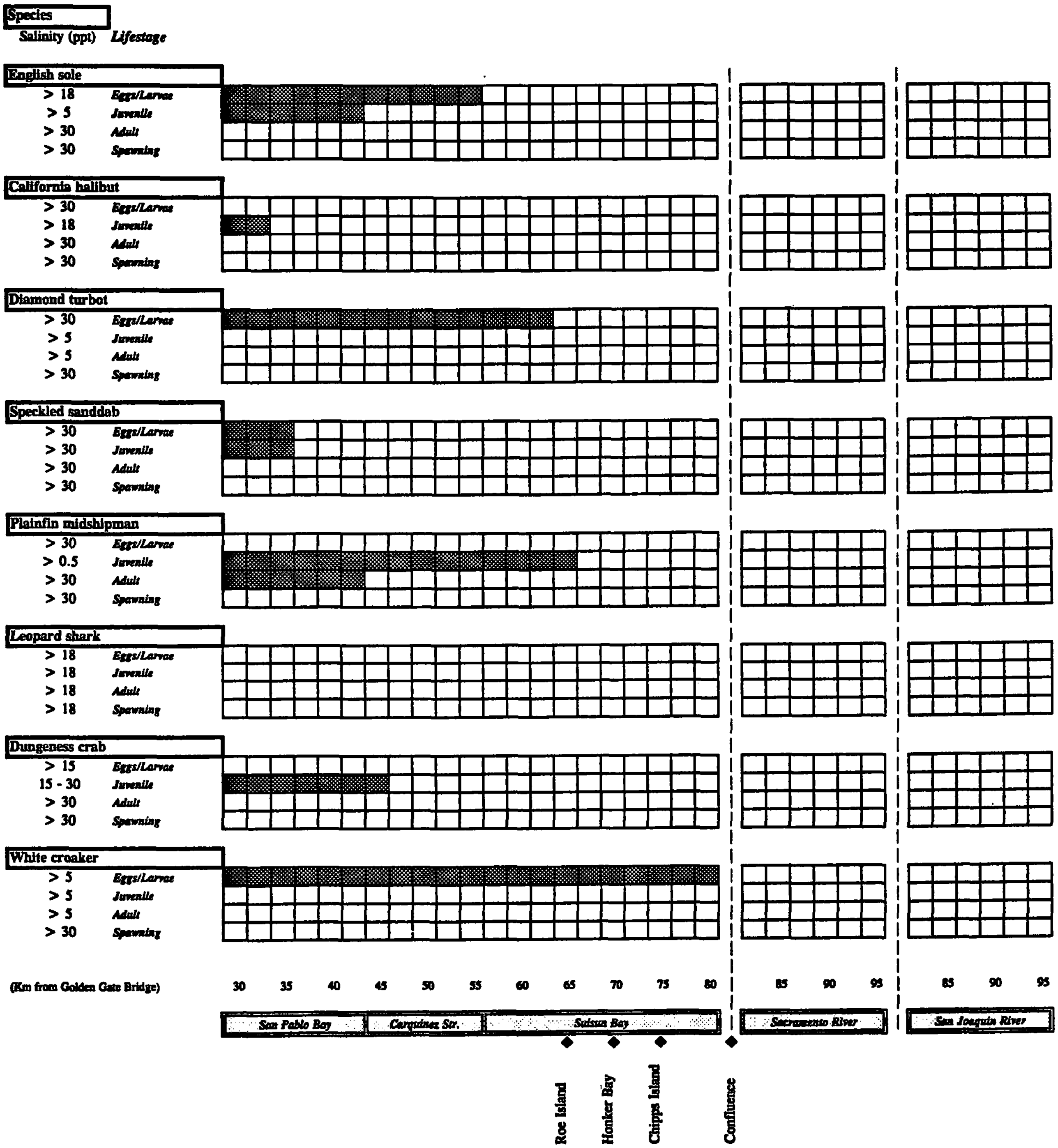
R2 Resource Consultants, Inc.

Month: FEBRUARY



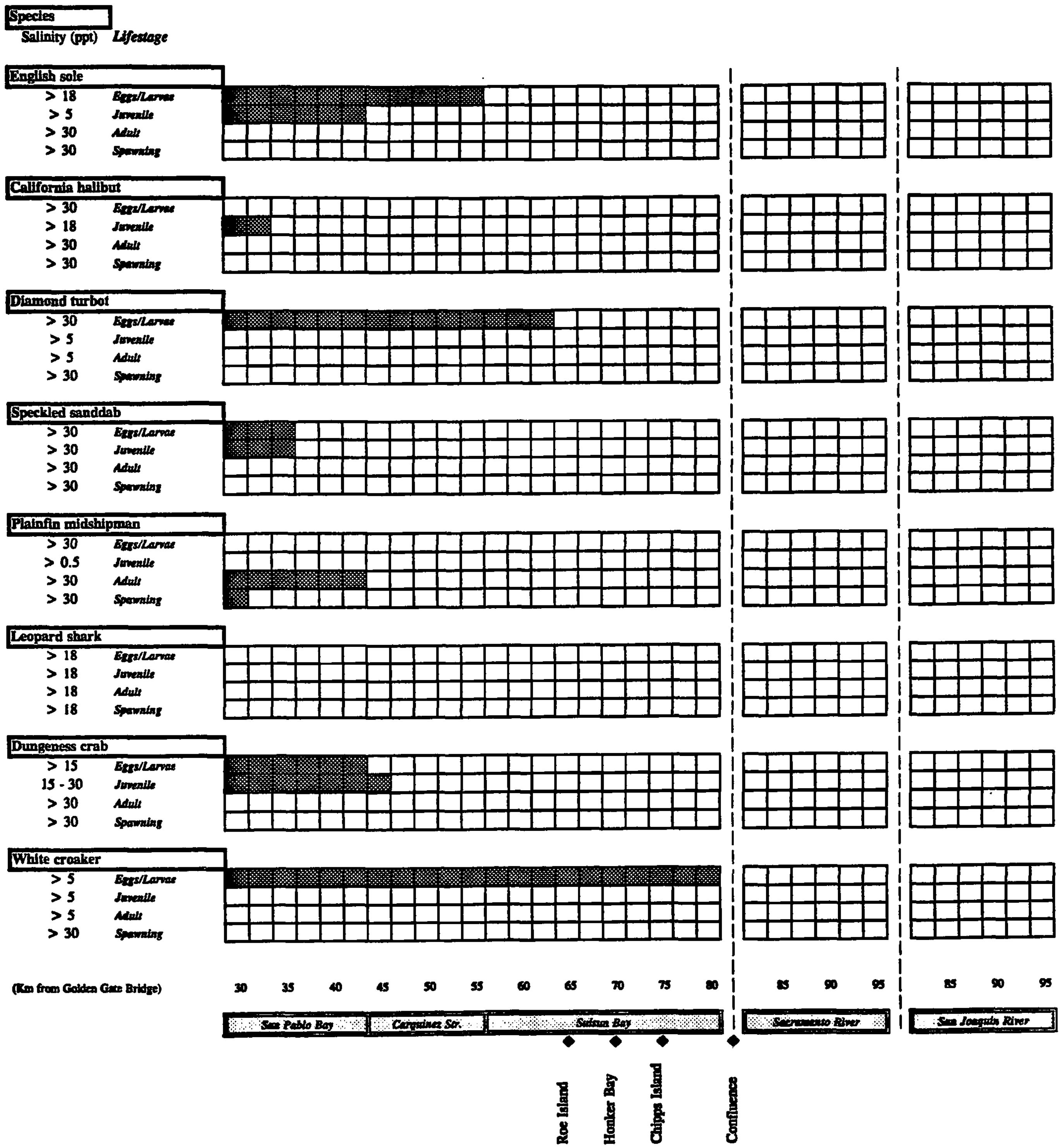
Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

Month: MARCH



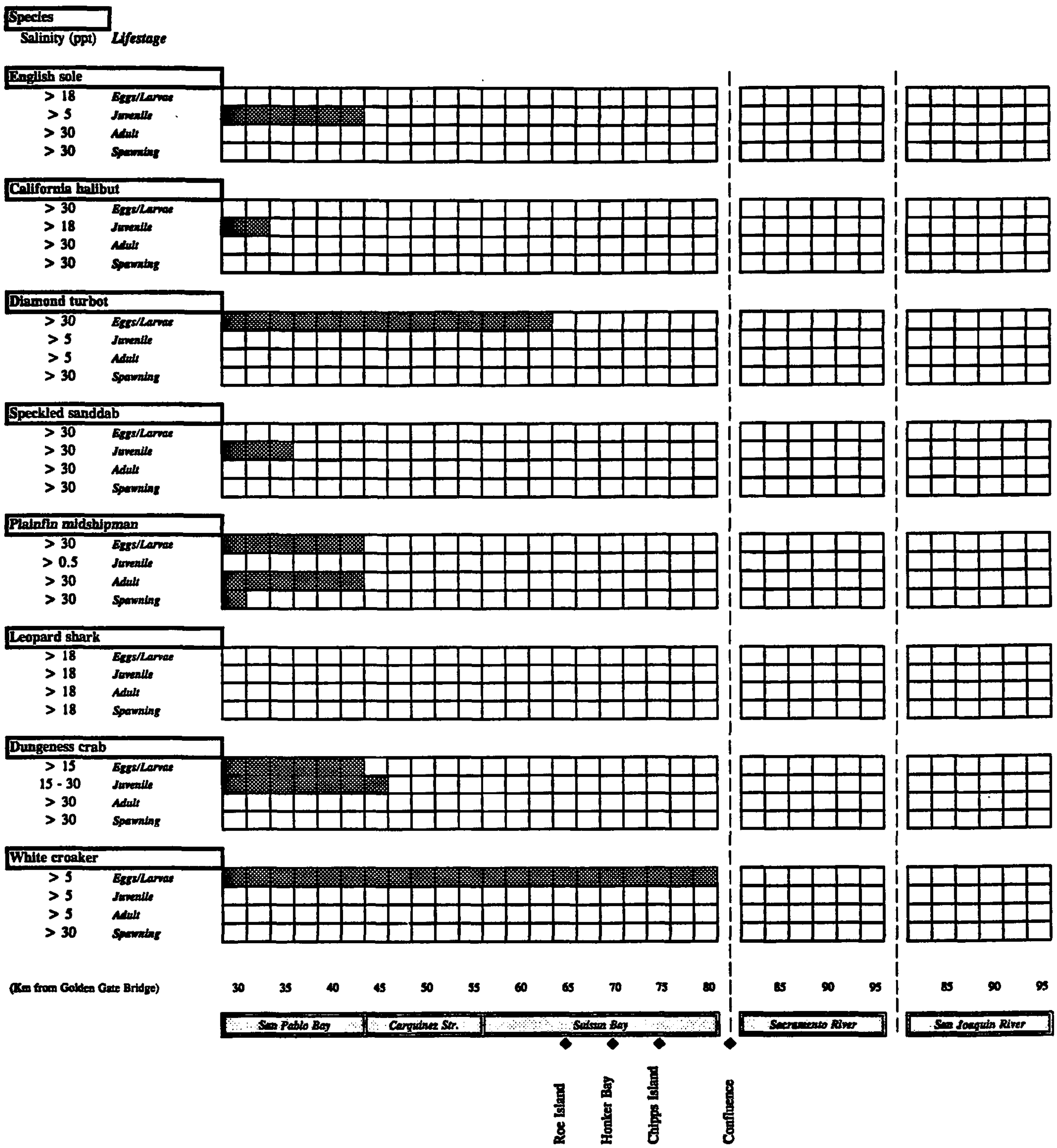
Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

Month: APRIL



Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

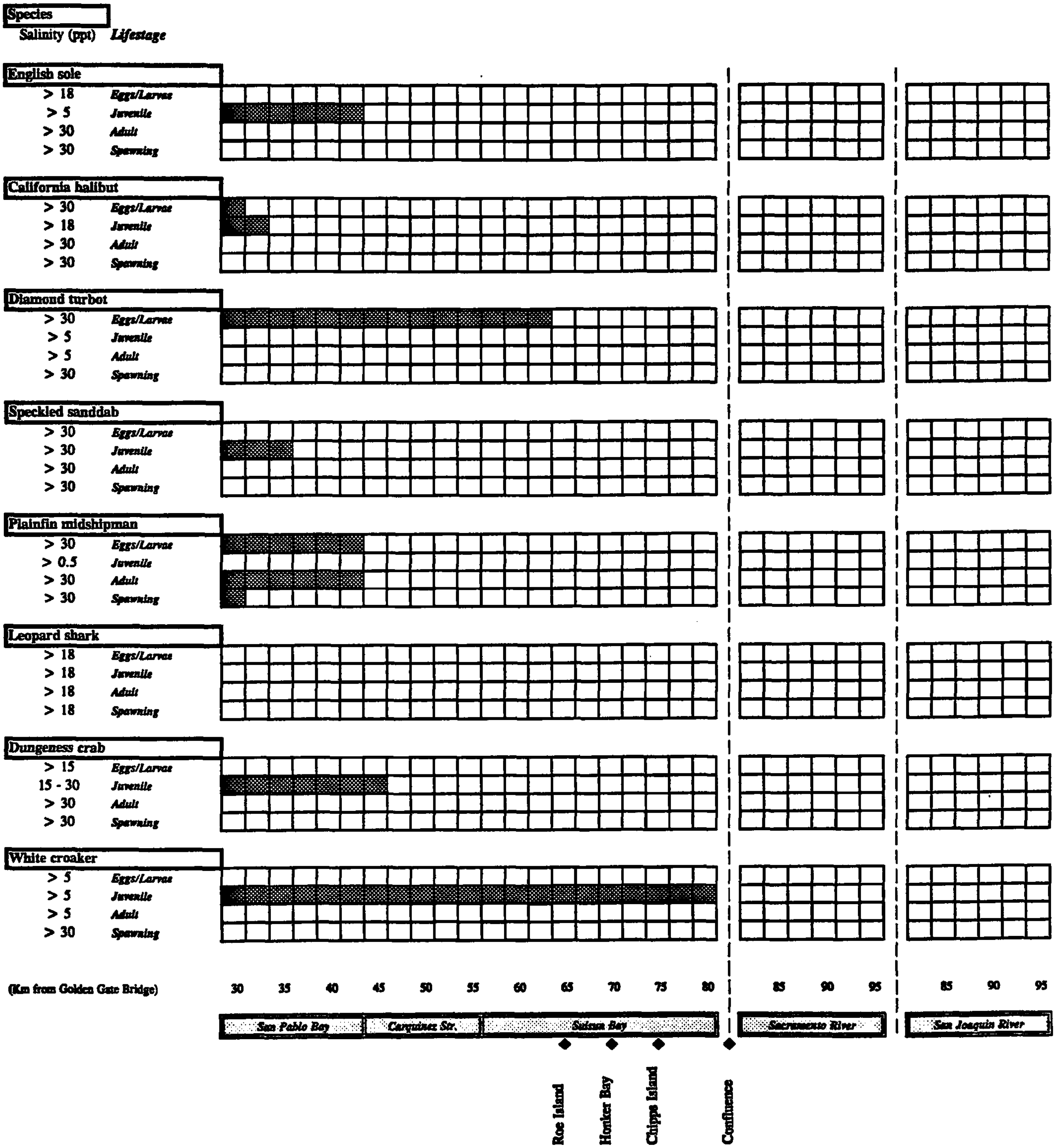
Month: MAY



Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

R2 Resource Consultants, Inc.

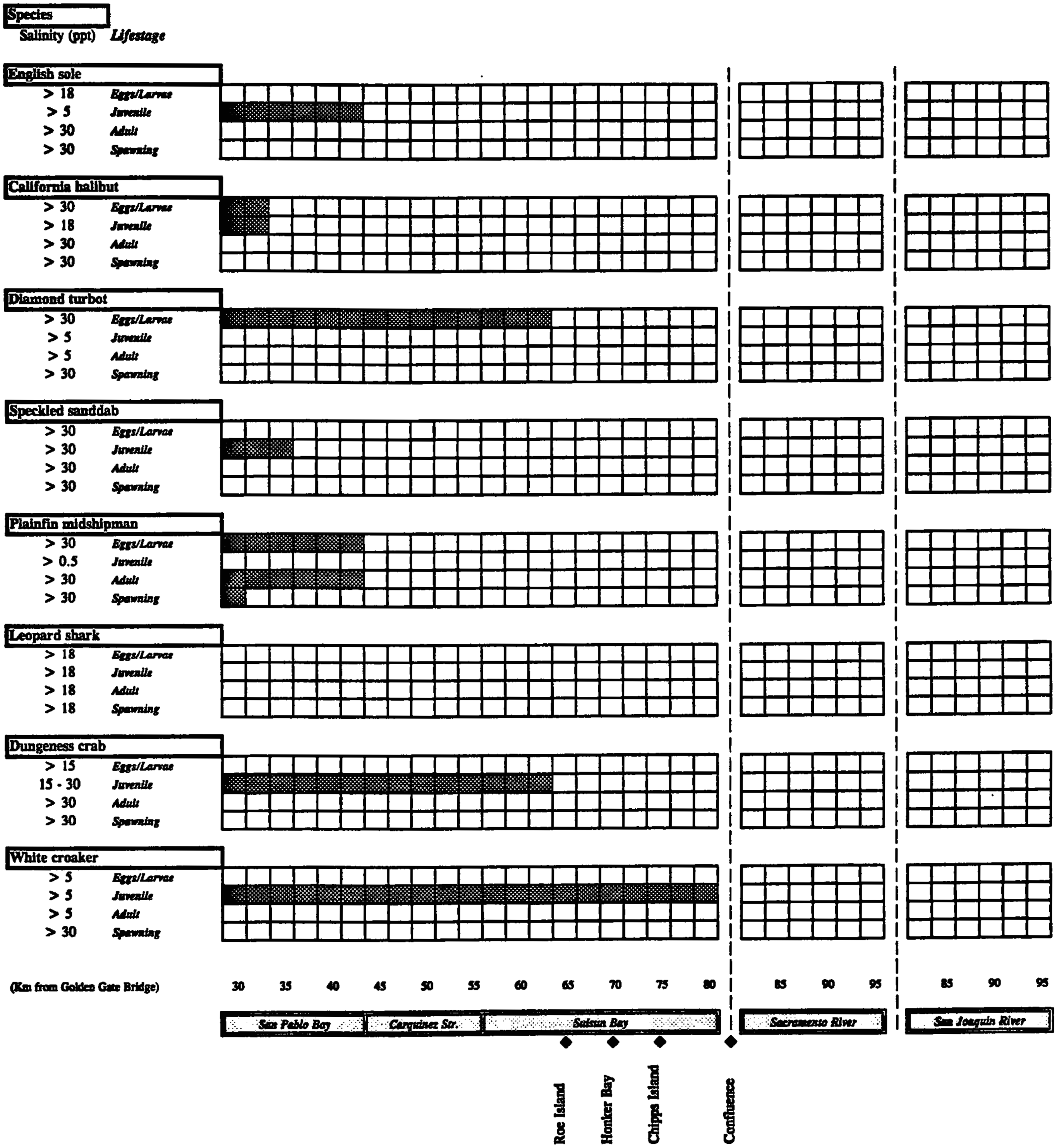
Month: JUNE



Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

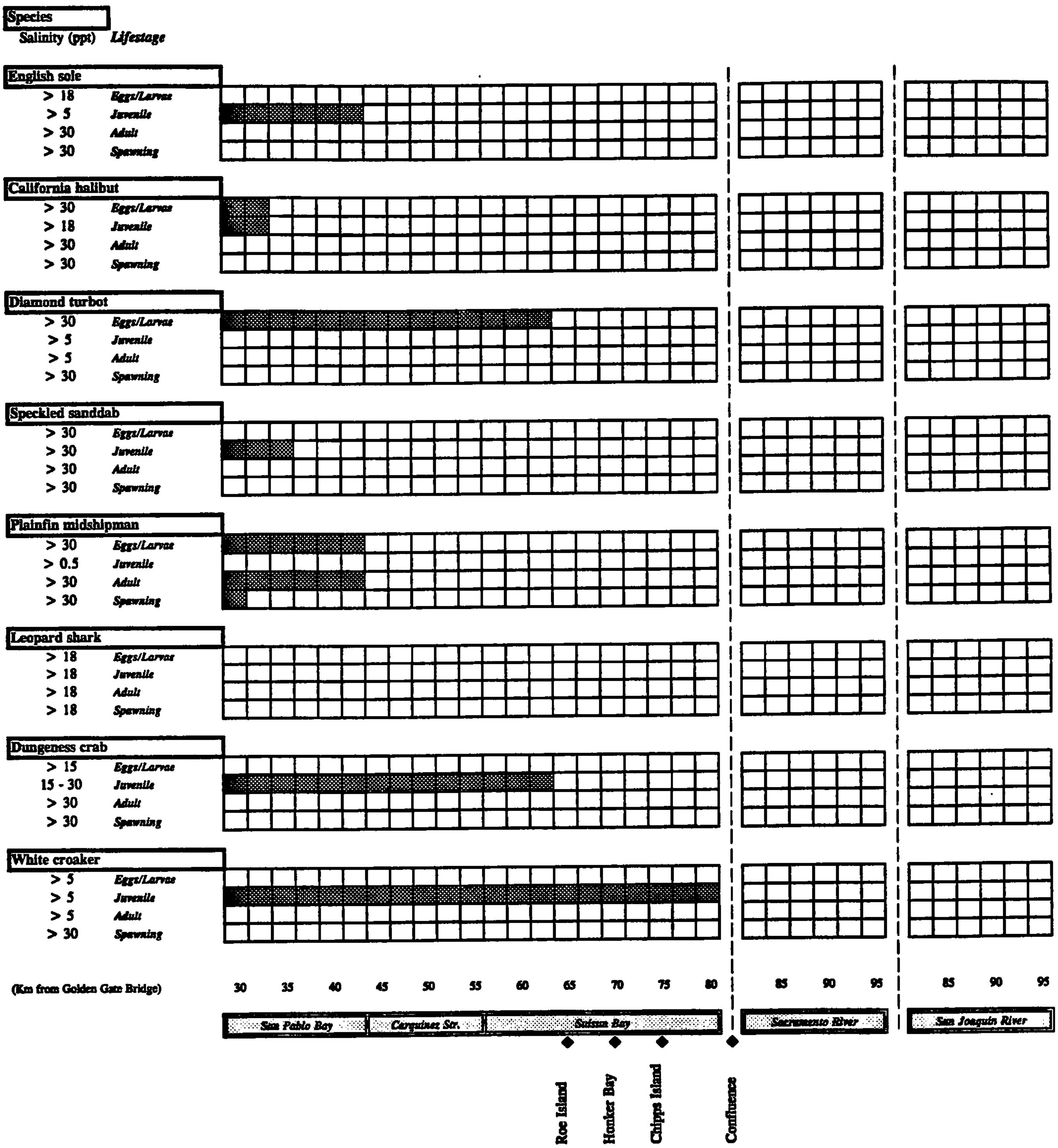
R2 Resource Consultants, Inc.

Month: JULY



Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

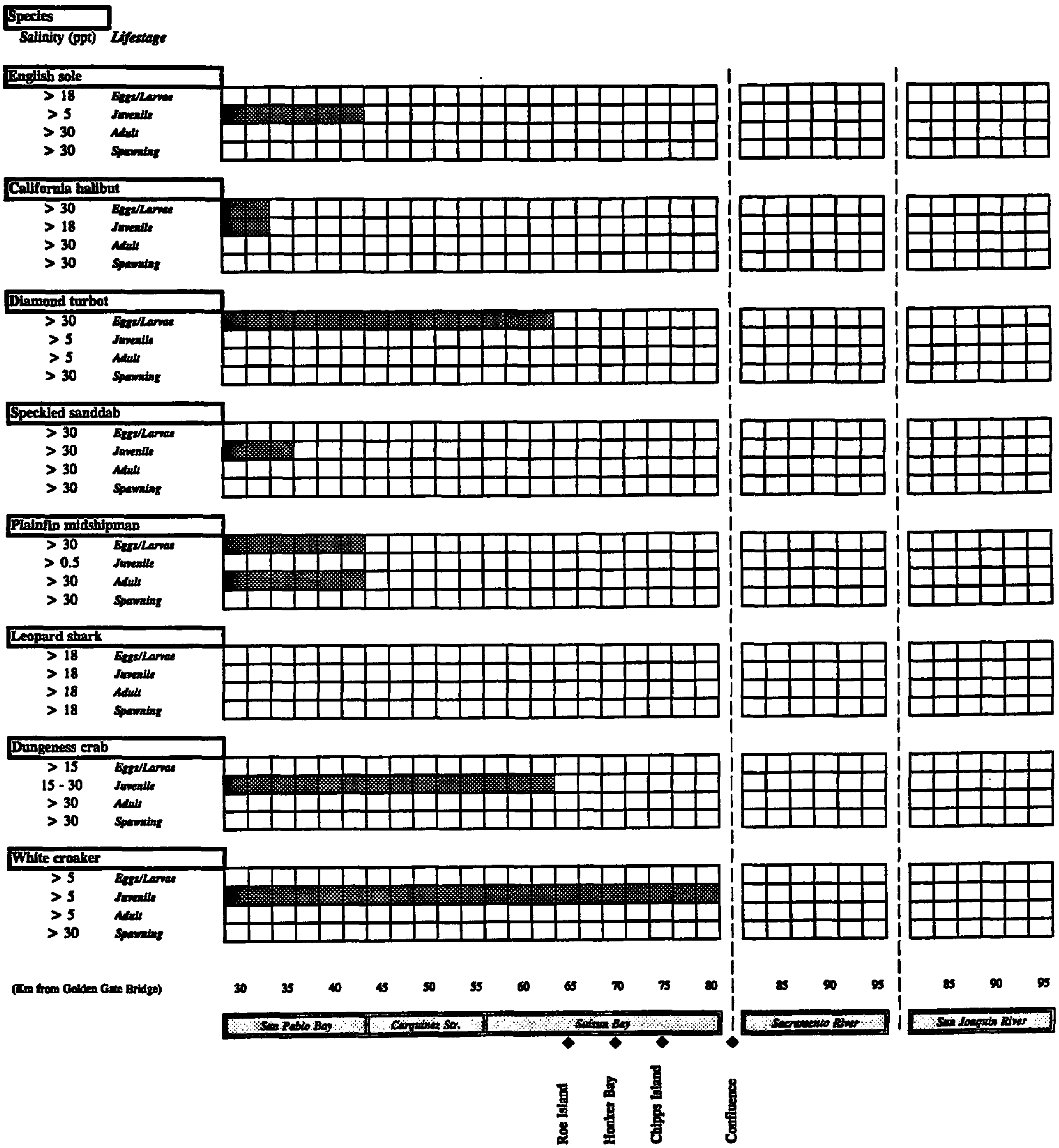
Month: AUGUST



Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

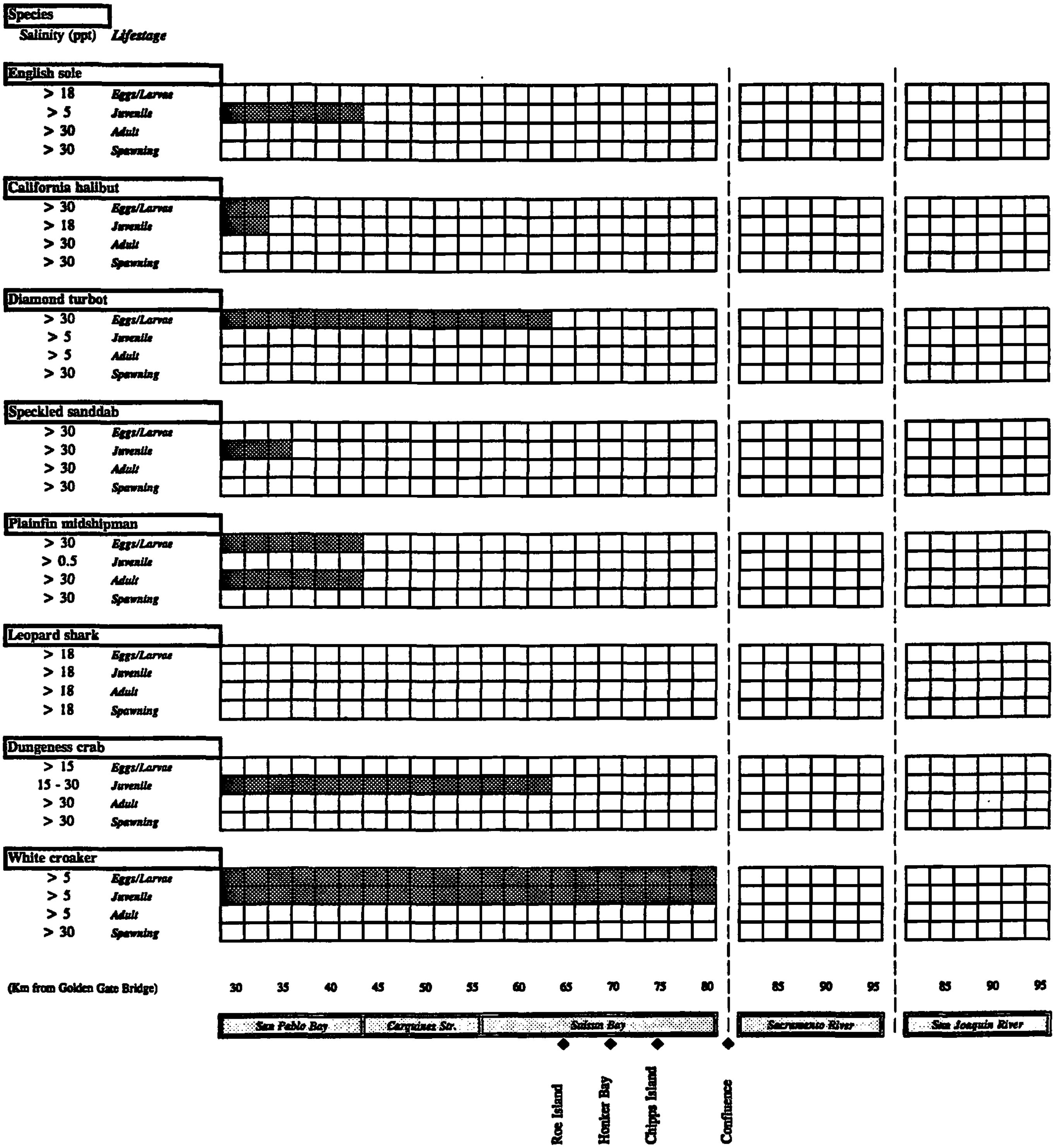
R2 Resource Consultants, Inc.

Month: SEPTEMBER



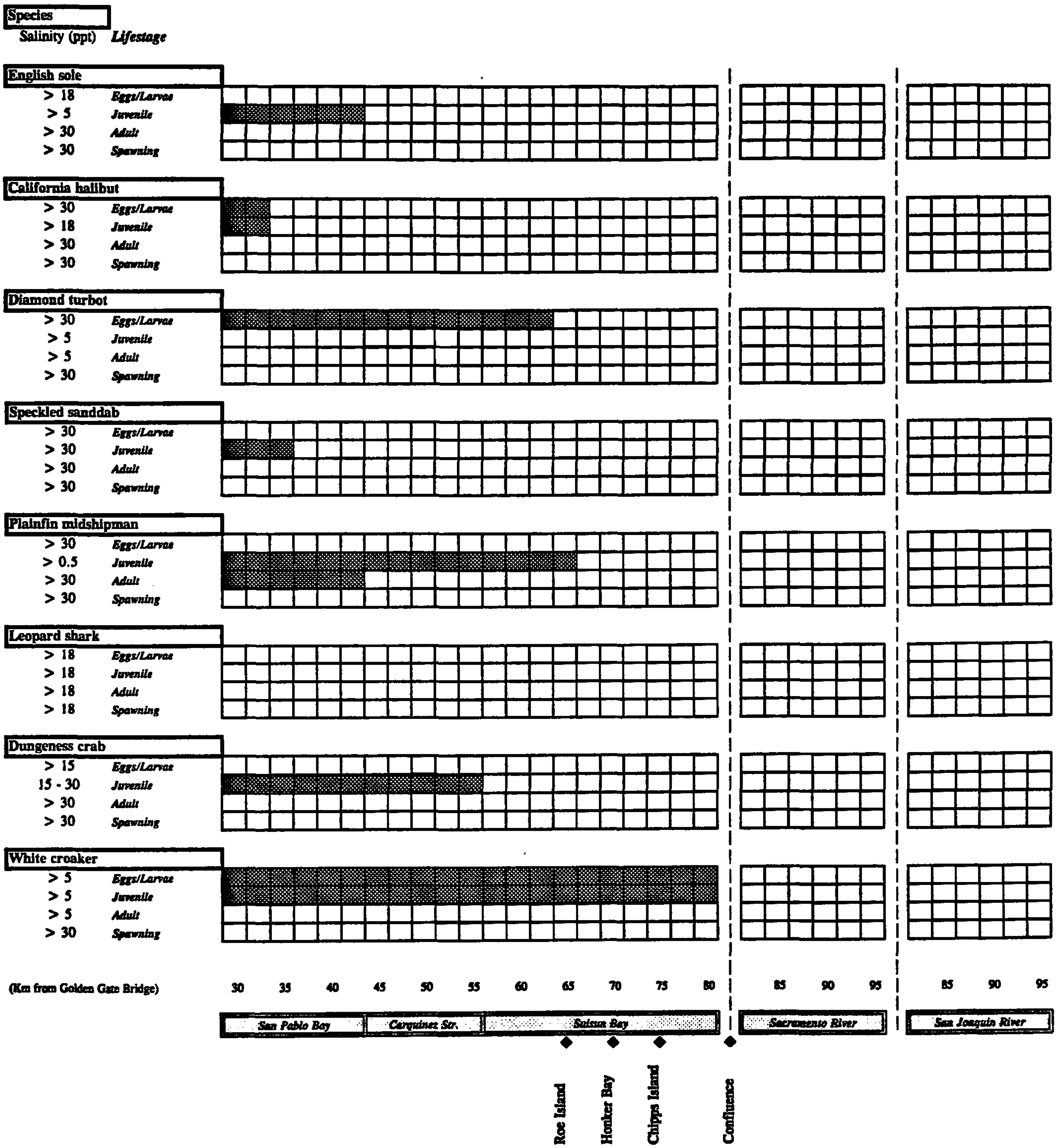
Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

Month: OCTOBER



Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

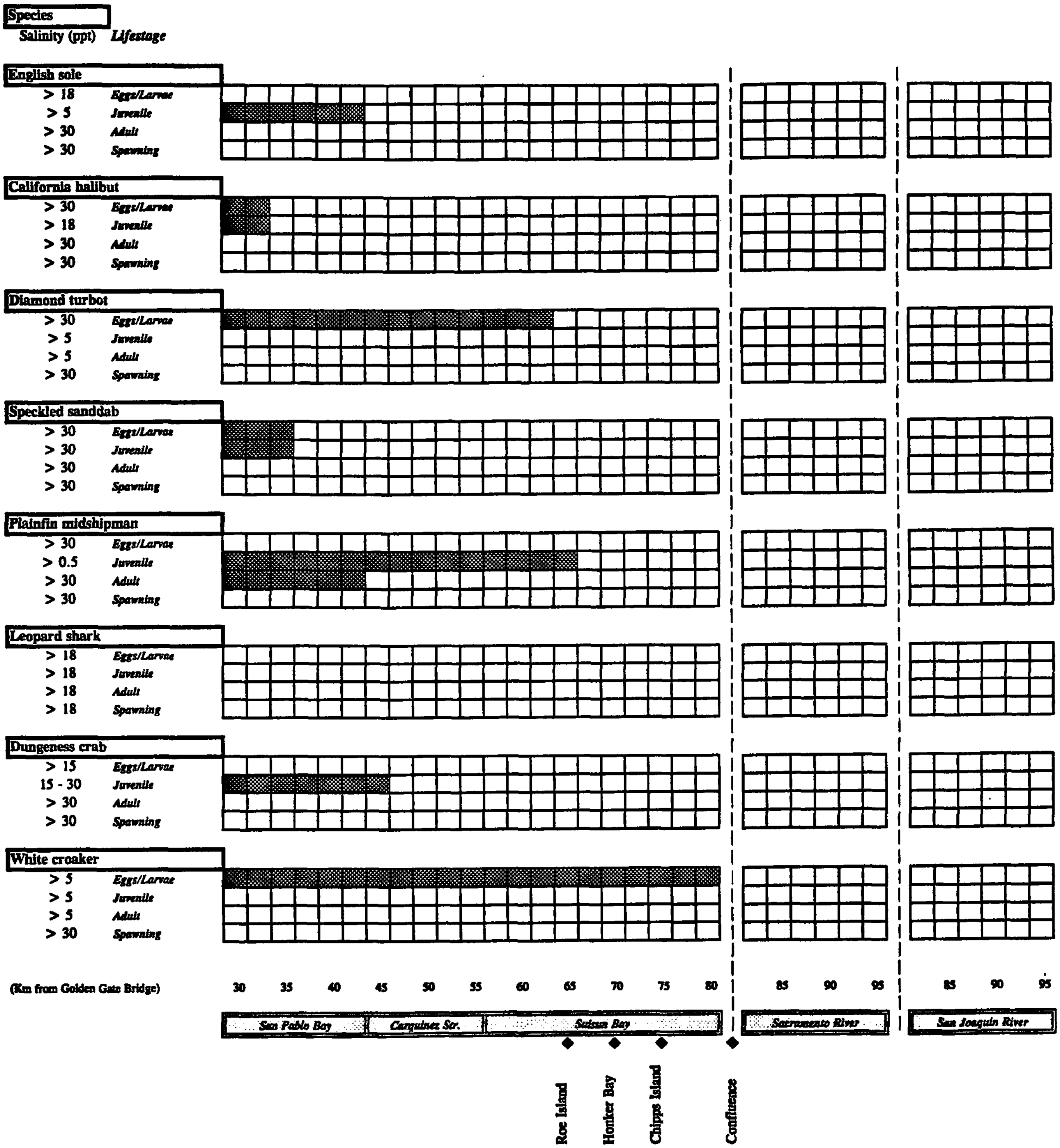
Month: NOVEMBER



Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

R2 Resource Consultants, Inc.

Month: DECEMBER



Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

APPENDIX A

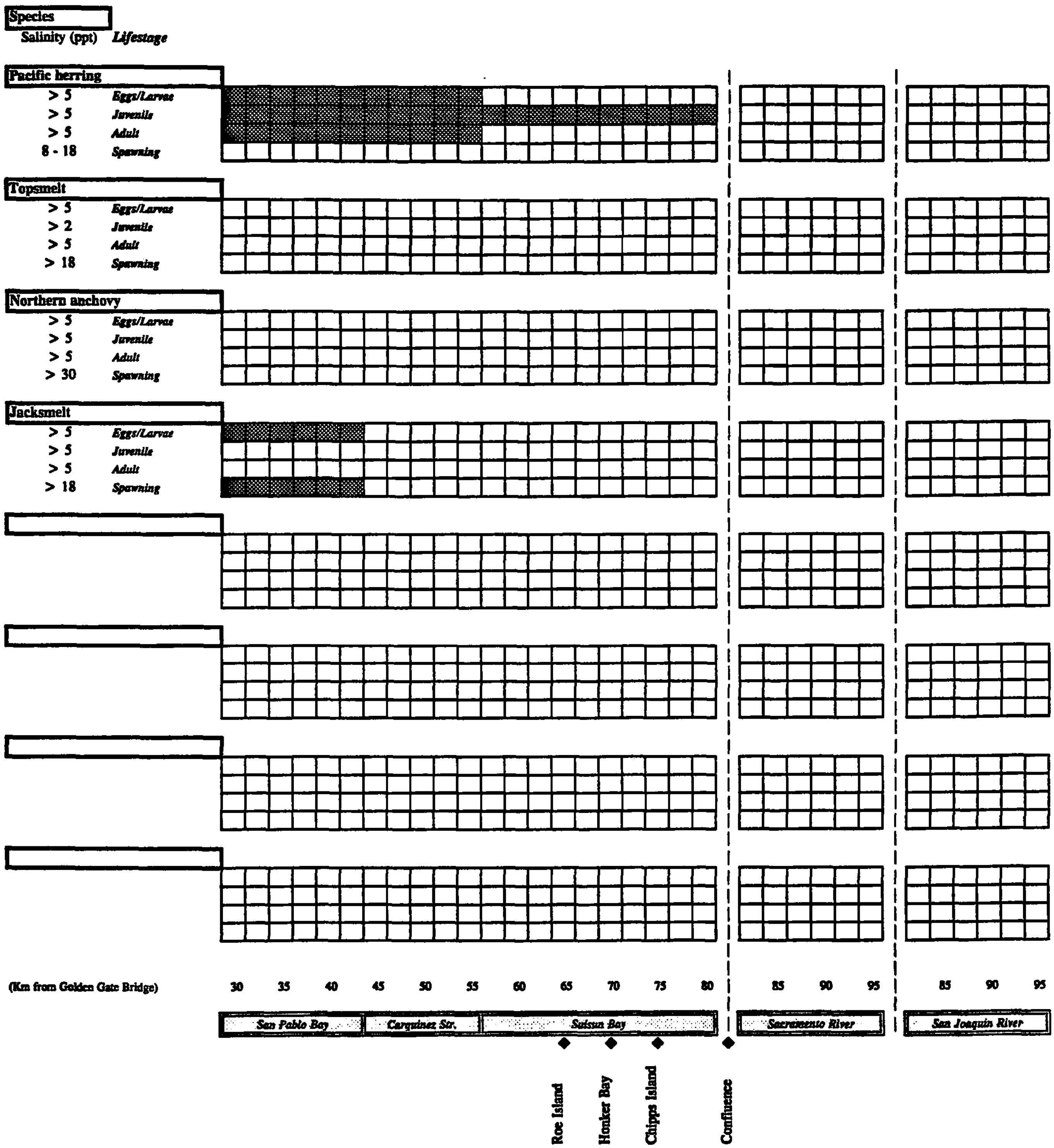
SPECIES PERIODICITY AND DISTRIBUTION CHARTS

Subappendix A-6

Monthly Life Stage Distributions:

Pacific Herring
Topsmelt
Northern Anchovy
Jacksmelt

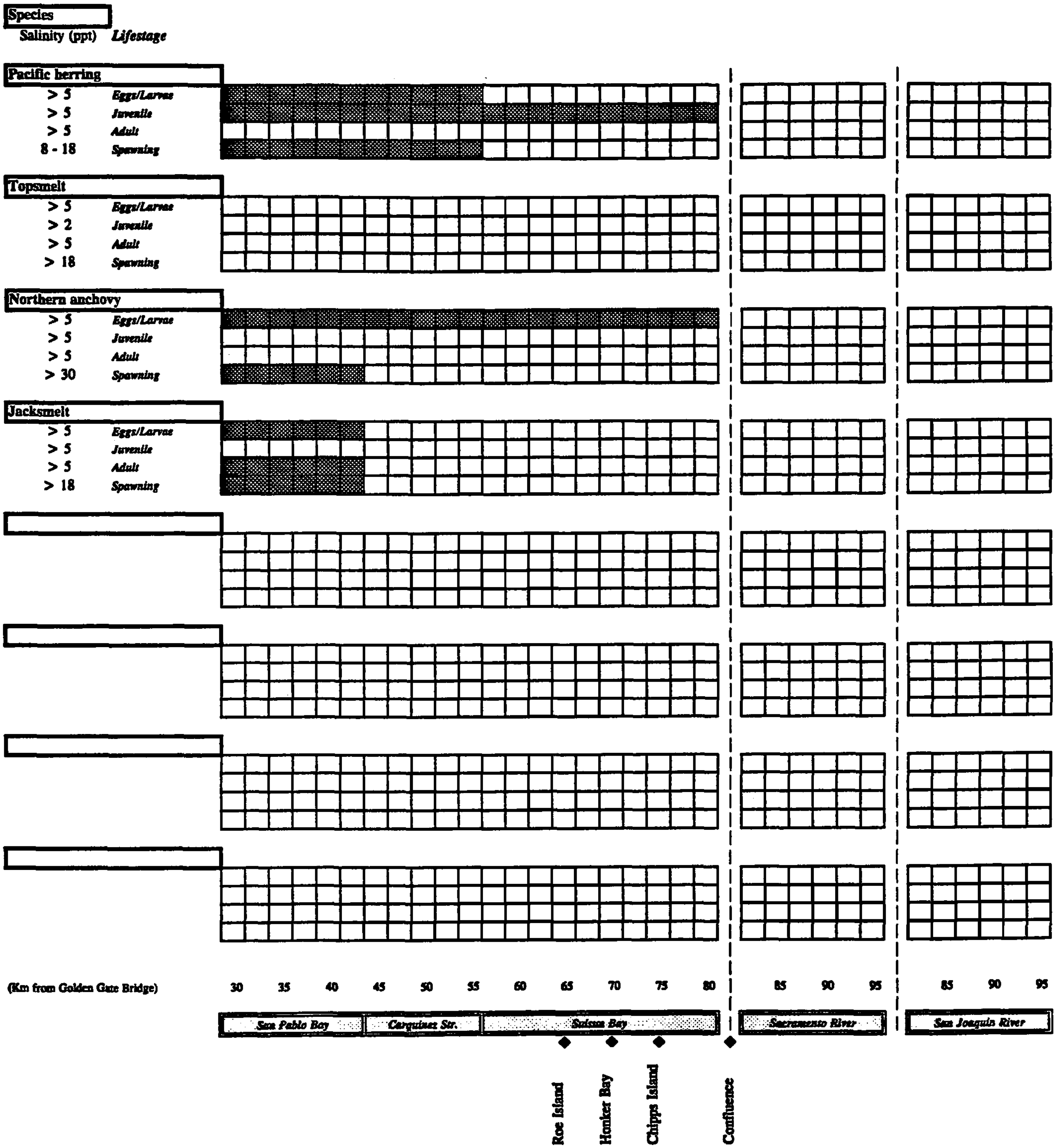
Month: JANUARY



Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

R2 Resource Consultants, Inc.

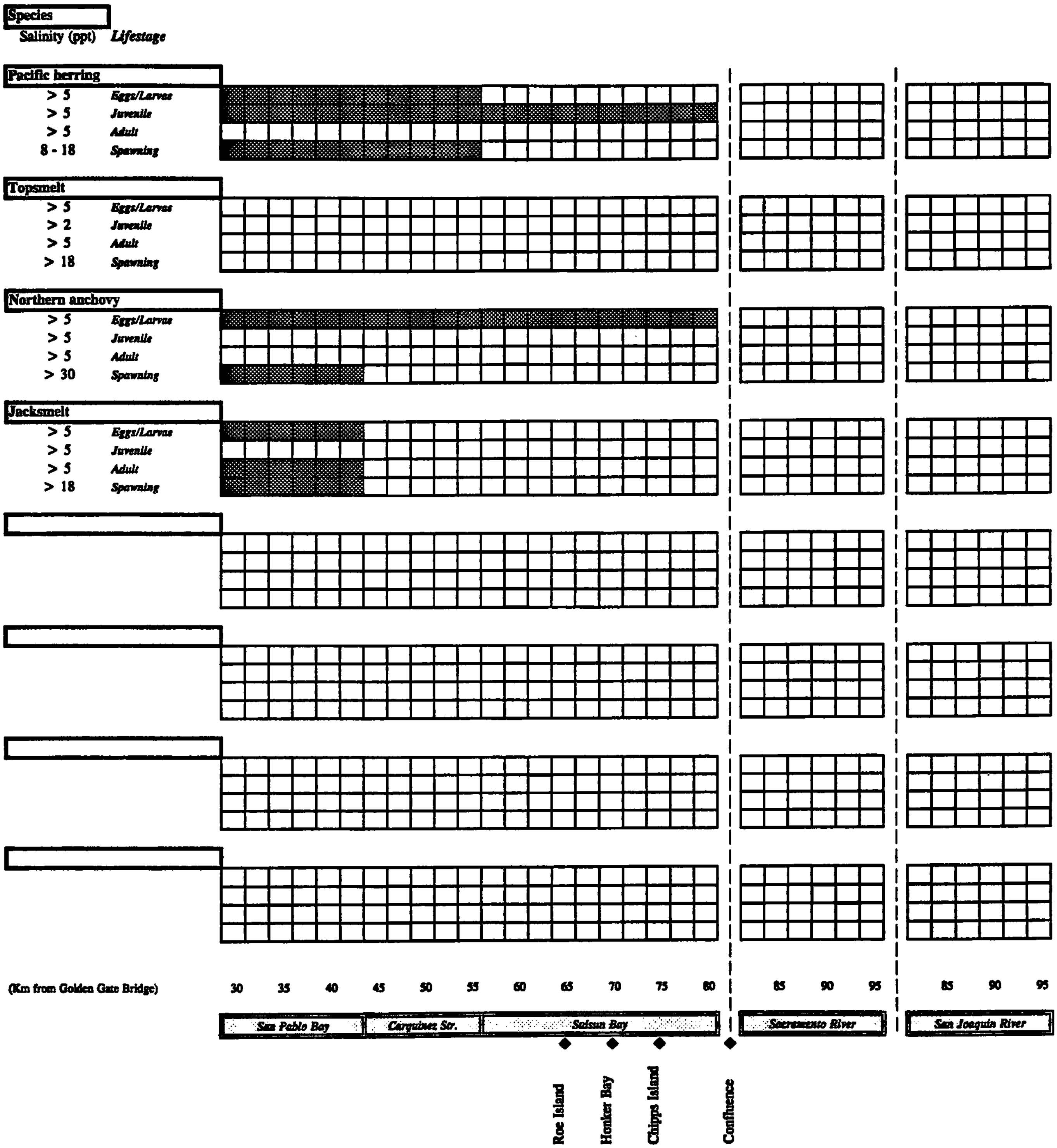
Month: FEBRUARY



Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

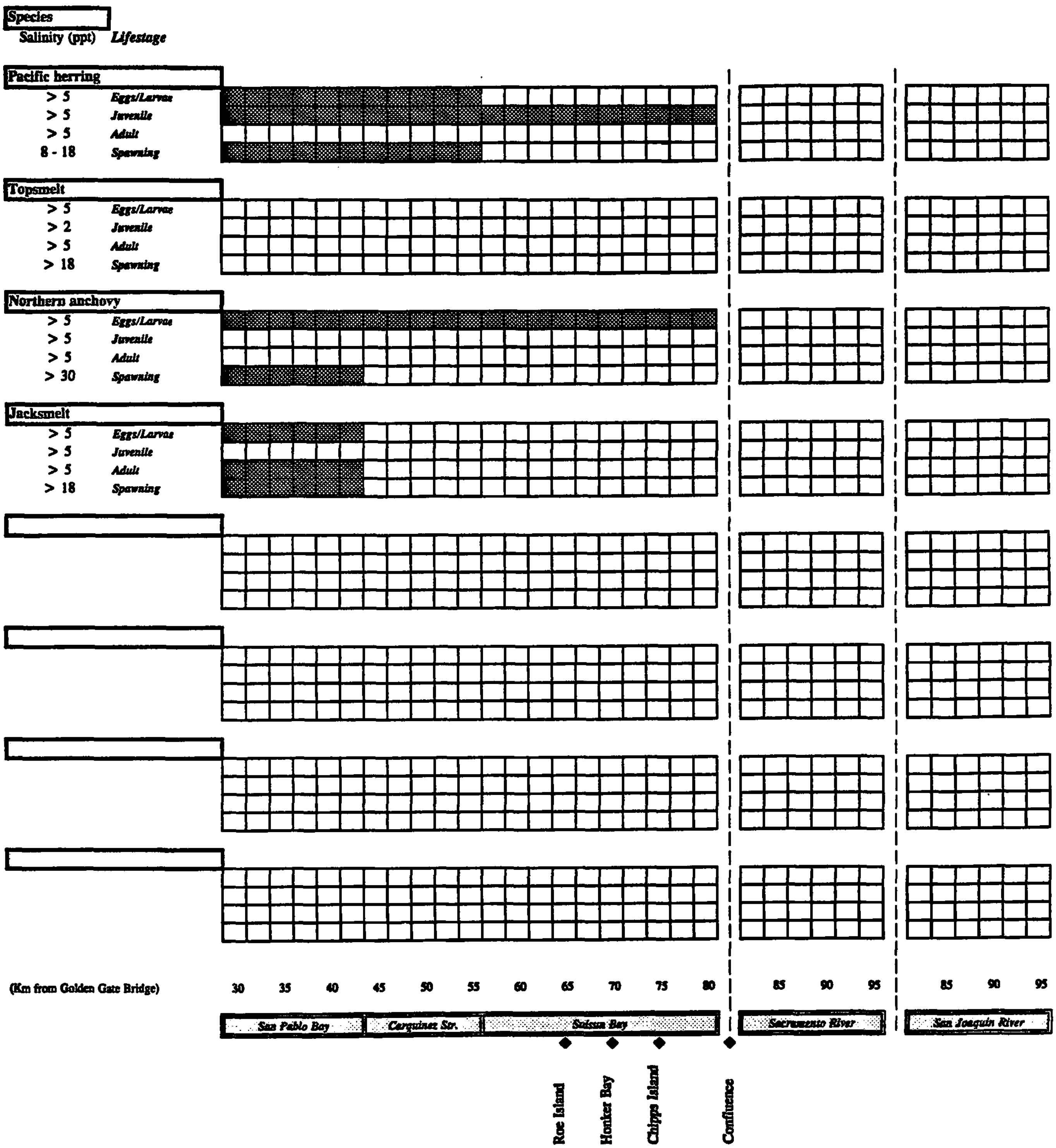
R2 Resource Consultants, Inc.

Month: MARCH



Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

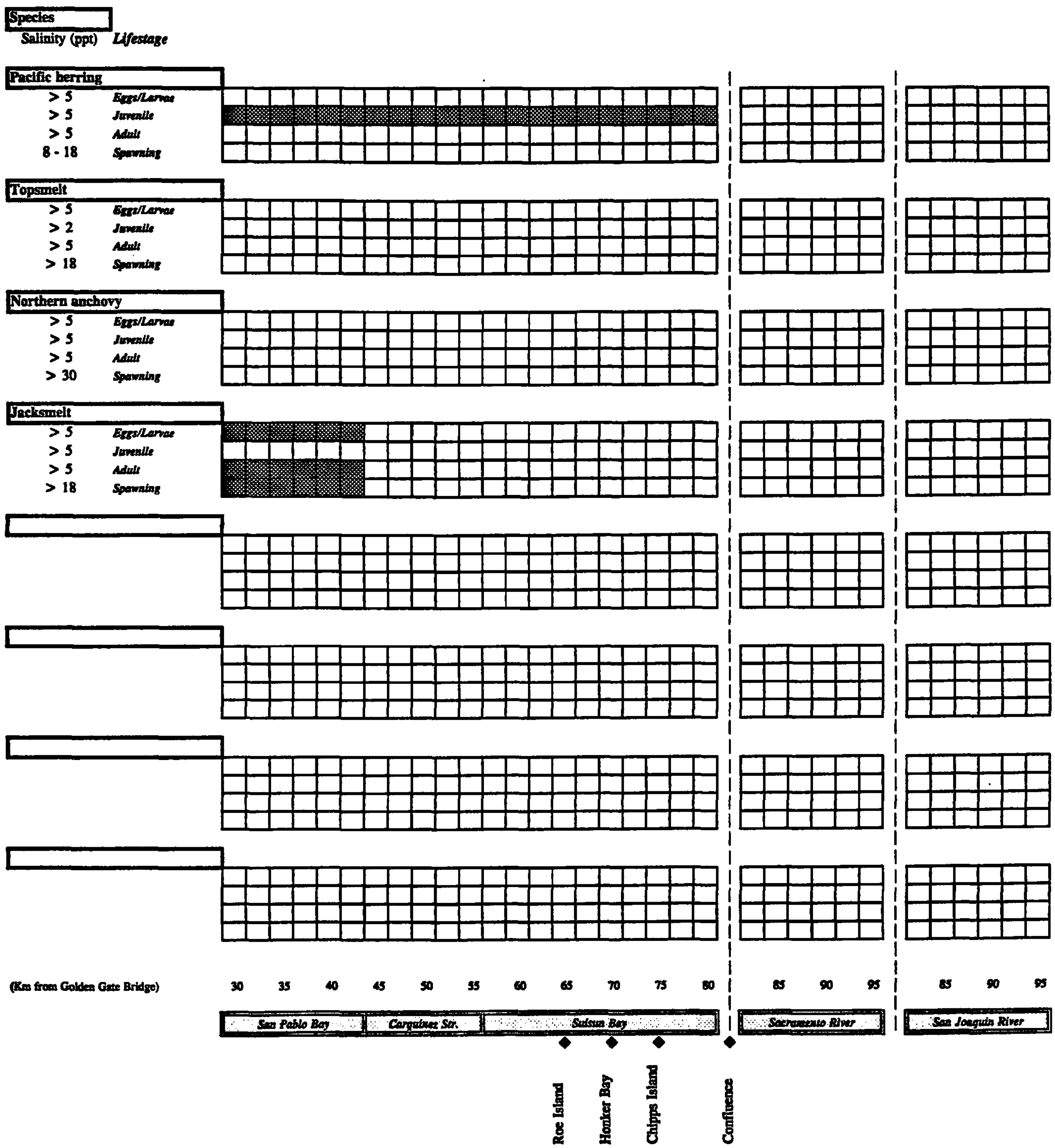
Month: APRIL



Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

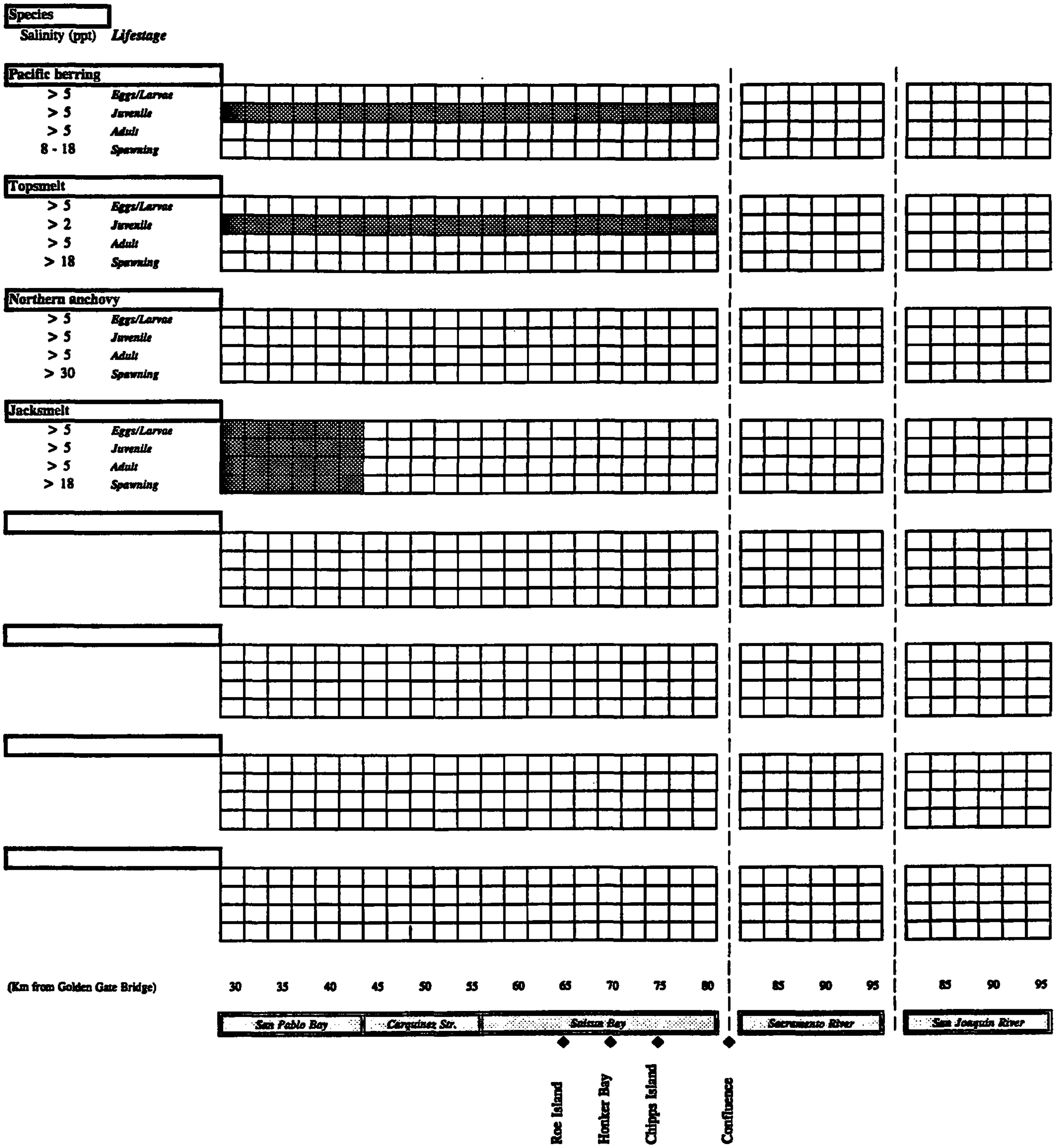
R2 Resource Consultants, Inc.

Month: MAY



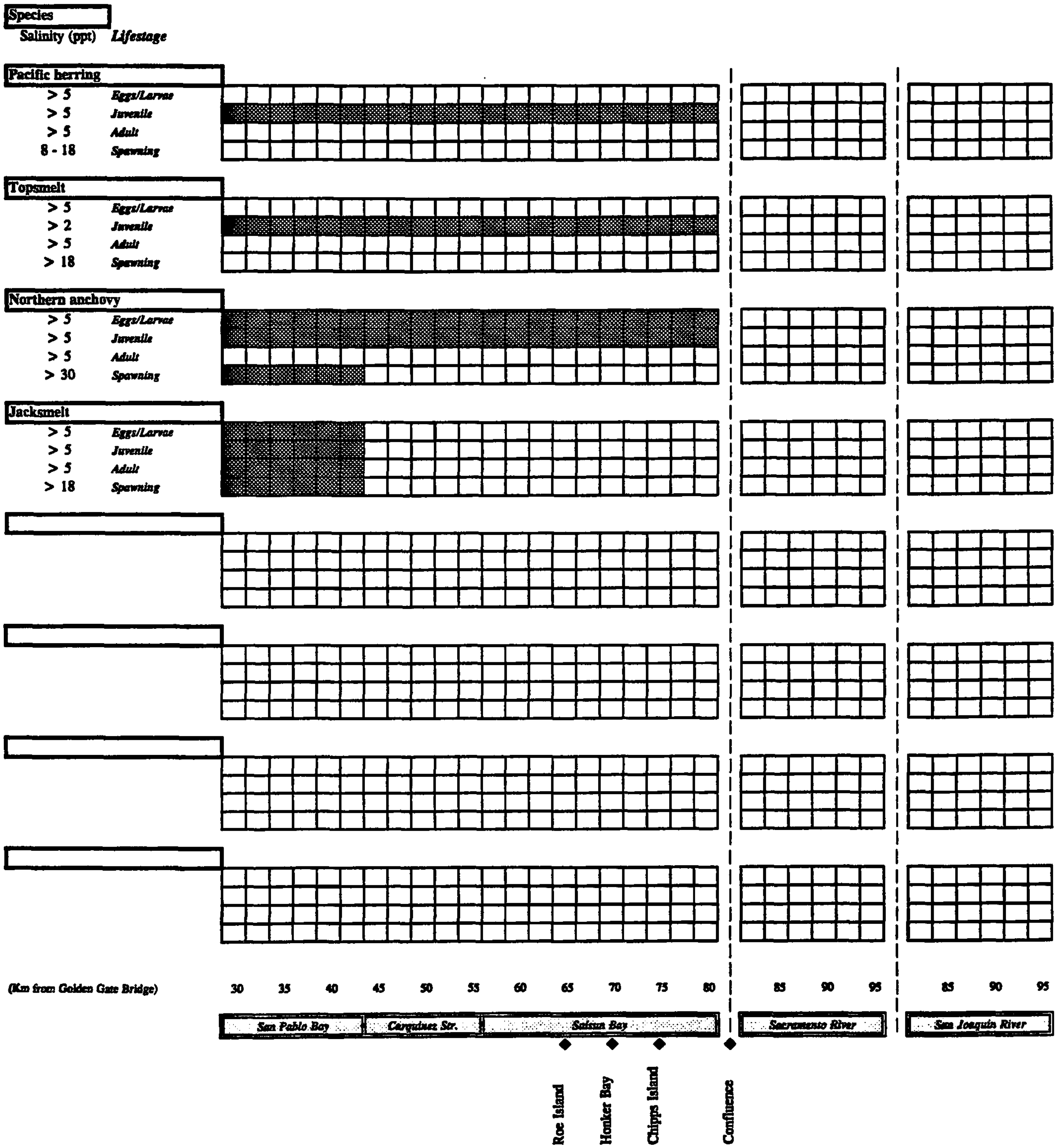
Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

Month: JUNE



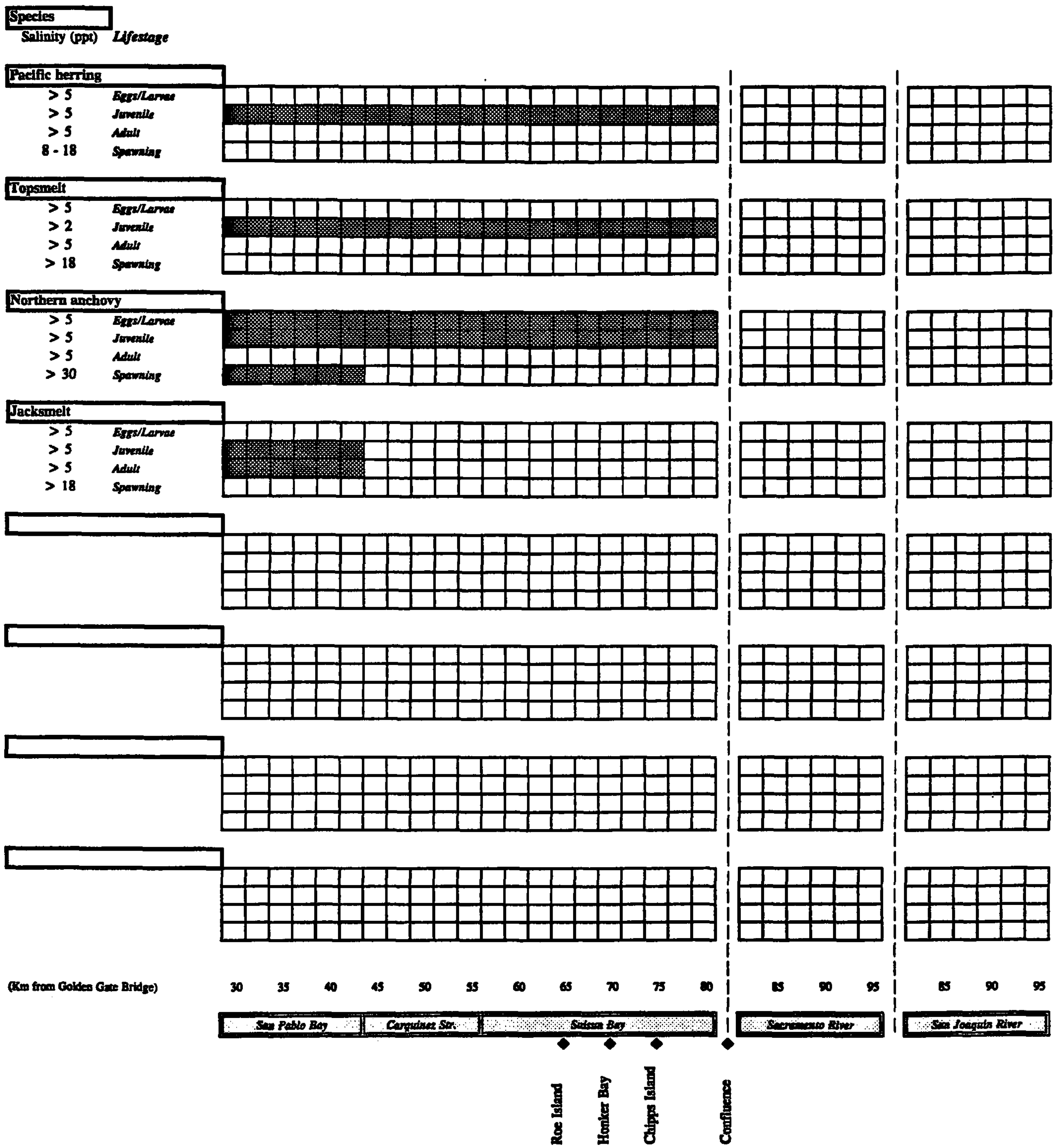
Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

Month: JULY



Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

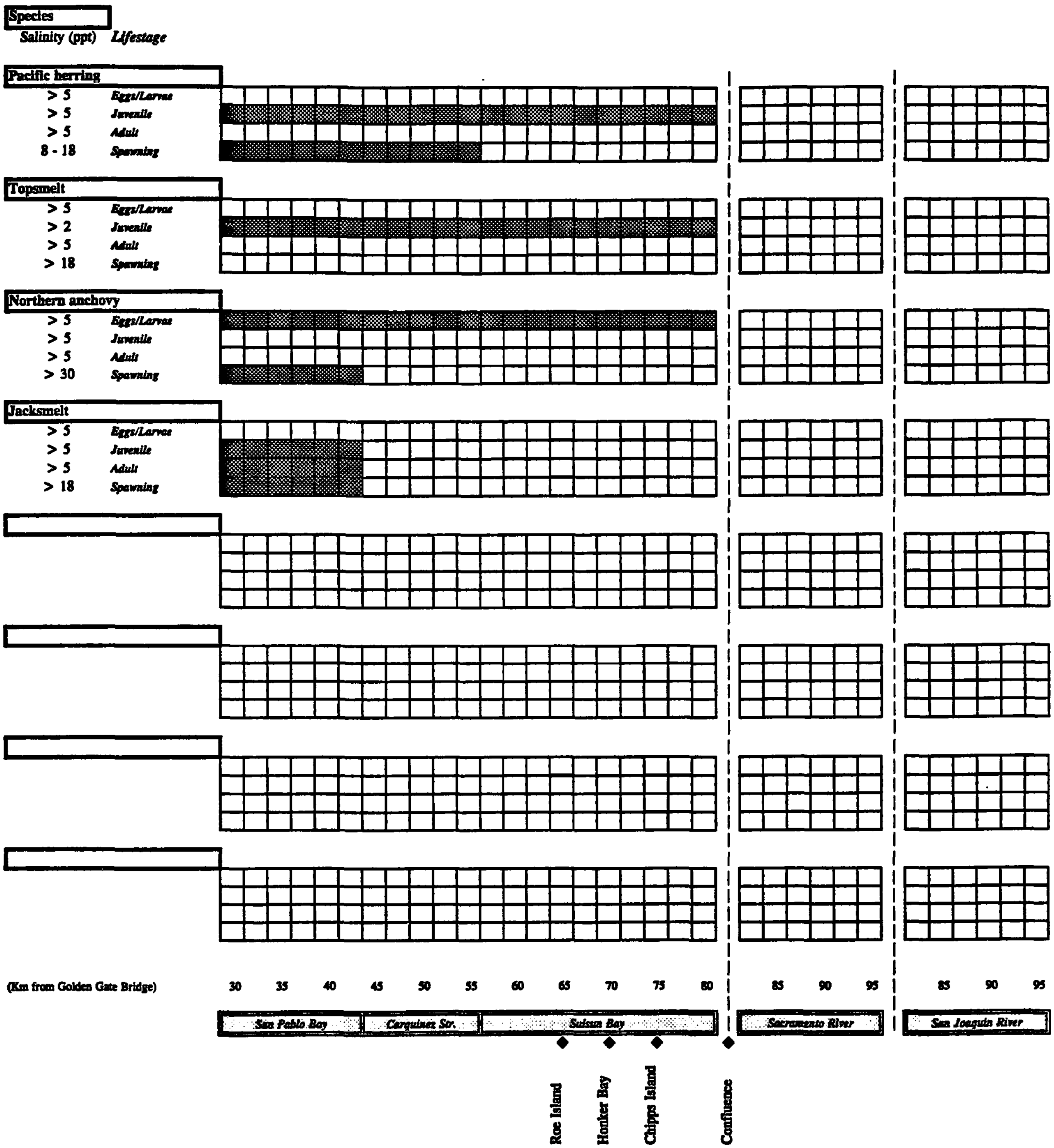
Month: AUGUST



Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

R2 Resource Consultants, Inc.

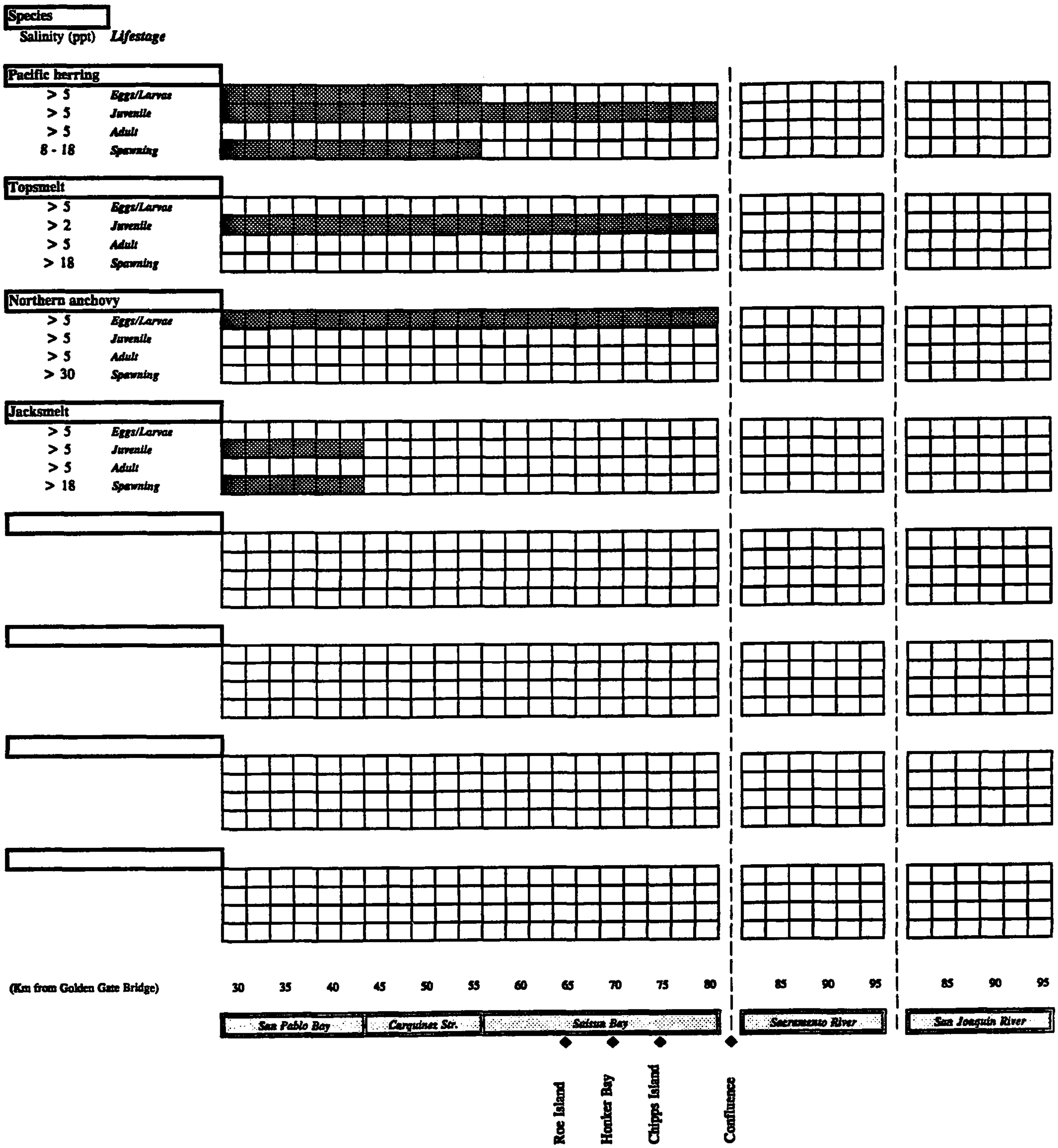
Month: SEPTEMBER



Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

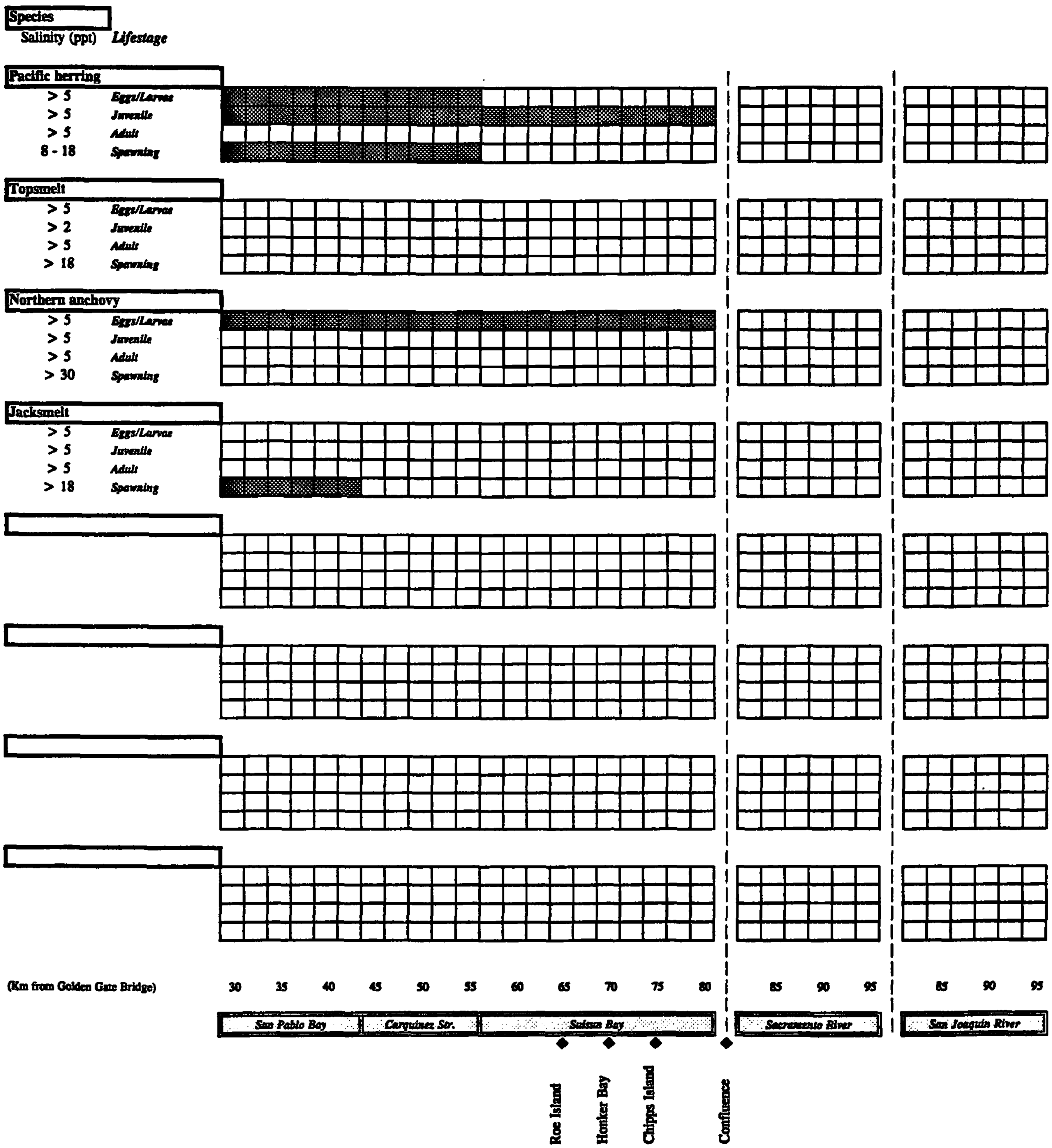
R2 Resource Consultants, Inc.

Month: OCTOBER



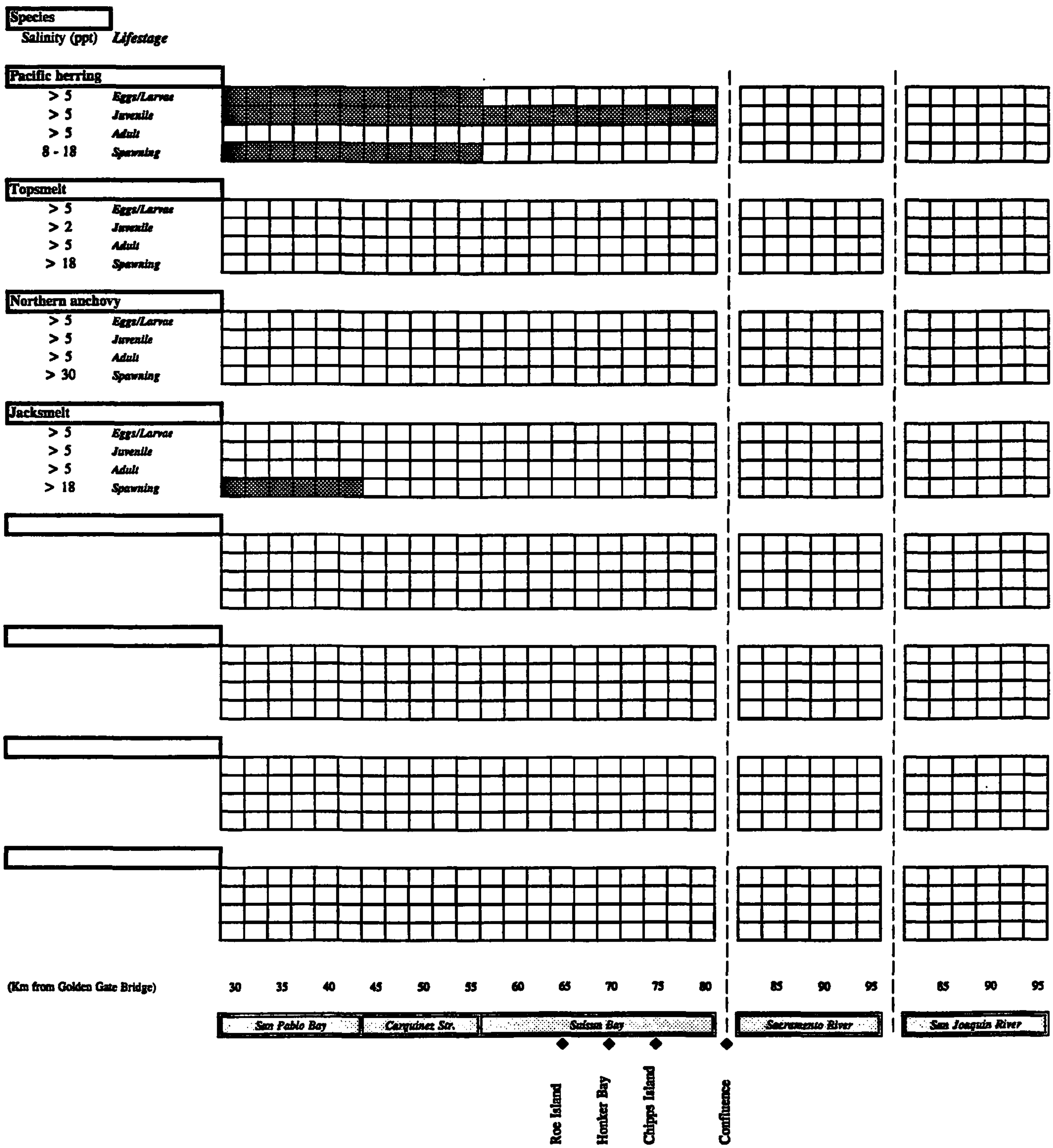
Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

Month: NOVEMBER



Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

Month: DECEMBER



Species periodicity/distribution chart and salinity (ppt) ranges for selected species found in the Sacramento-San Joaquin Estuary.

APPENDIX B

MONTHLY IMPACT ASSESSMENT BY SPECIES FOR ALL LIFE STAGES COMBINED

LIFESTAGE IMPACT ASSESSMENT: X2 @ CONFLUENCE

SPECIES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
White catfish	M	M	M	M	M	H	H	H	M	M	M	M
Channel catfish	0	0	0	L	L	L	L	L	0	0	0	0
Sacramento splittail	H	H	H	H	H	H	H	M	M	M	M	M
Sacramento squawfish	H	H	H	H	H	H	H	H	H	H	H	H
Hitch	0	0	0	0	0	0	0	0	0	0	0	0
Threadfin shad	0	0	0	H	H	H	H	H	H	L	L	0
Inland silverside	M	M	M	M	M	M	M	M	M	M	M	M
Tule perch	L	L	L	L	L	L	L	L	L	L	L	L
Green sturgeon	0	0	M	M	M	M	0	0	0	0	0	0
White sturgeon	0	0	M	M	M	0	0	0	0	0	0	0
Striped bass	0	0	0	M	M	M	M	M	L	0	0	0
Chinook salmon (fall)	0	0	0	0	0	0	0	0	0	0	0	0
Chinook salmon (late fall)	0	0	0	0	0	0	0	0	0	0	0	0
Chinook salmon (winter)	0	0	0	0	0	0	0	0	0	0	0	0
Chinook salmon (spring)	0	0	0	0	0	0	0	0	0	0	0	0
Steelhead	0	0	0	0	0	0	0	0	0	0	0	0
Bay goby	L	L	L	L	L	L	L	L	L	L	L	L
Yellowfin goby	0	0	0	L	L	L	L	0	0	0	0	0
Bay shrimp	0	0	0	M	M	L	L	L	L	L	0	L
Starry flounder	M	M	M	M	0	0	0	0	M	M	M	M
Pacific staghorn sculpin	0	0	0	0	0	0	0	0	0	0	0	0
American shad	0	0	0	0	0	L	L	0	0	0	0	0
Delta smelt	M	M	M	M	M	M	L	L	M	M	M	M
Longfin smelt	H	H	H	H	M	0	0	0	0	0	0	M
Threespine stickleback	0	0	M	H	H	H	H	H	H	H	M	0
Shiner surfperch	L	L	L	L	L	L	L	L	L	L	L	L
Bay pipefish	0	0	0	0	0	0	0	0	0	0	0	0
Plainfin midshipman	L	L	L	M	M	M	M	M	M	M	L	L
Barred surfperch	L	L	L	L	L	L	L	L	L	L	L	L
Dwarf surfperch	0	0	0	0	0	0	0	0	0	0	0	0
Pile surfperch	0	0	0	0	0	0	0	0	0	0	0	0
Black surfperch	H	H	H	H	H	H	H	H	H	H	H	H
White surfperch	0	0	0	0	0	0	0	0	0	0	0	0
English sole	0	0	M	M	0	0	0	0	0	0	0	0
California halibut	0	0	0	0	0	L	L	L	L	L	L	L
Diamond turbot	M	M	M	M	M	M	M	M	M	M	M	M
Speckled sandab	L	L	L	L	L	L	L	L	L	L	L	L
Leopard shark	0	0	0	0	0	0	0	0	0	0	0	0
Dungeness crab	0	0	0	L	L	0	0	0	0	0	0	0
White croaker	M	M	M	M	M	L	L	L	L	M	M	M
Pacific herring	M	M	M	M	L	L	L	L	M	M	M	M
Northern anchovy	0	H	H	H	0	0	H	H	H	M	M	0
Topsmelt	0	0	0	0	0	L	L	L	L	L	0	0
Jacksmelt	0	0	0	0	0	0	0	0	0	0	0	0

LIFESTAGE IMPACT ASSESSMENT: X2 @ CHIPPS

SPECIES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
White catfish	L	L	L	L	L	M	M	M	L	L	L	L
Channel catfish	0	0	0	0	0	0	0	0	0	0	0	0
Sacramento splittail	H	H	H	H	H	H	M	M	M	M	M	M
Sacramento squawfish	M	M	M	M	M	M	M	M	M	M	M	M
Hitch	0	0	0	0	0	0	0	0	0	0	0	0
Threadfin shad	0	0	0	H	H	H	H	H	H	L	L	0
Inland silverside	L	L	L	L	L	L	L	L	L	L	L	L
Tule perch	L	L	L	L	L	L	L	L	L	L	L	L
Green sturgeon	0	0	L	M	M	M	0	0	0	0	0	0
White sturgeon	0	0	L	M	M	0	0	0	0	0	0	0
Striped bass	0	0	0	L	L	L	L	0	0	0	0	0
Chinook salmon (fall)	0	0	0	0	0	0	0	0	0	0	0	0
Chinook salmon (late fall)	0	0	0	0	0	0	0	0	0	0	0	0
Chinook salmon (winter)	0	0	0	0	0	0	0	0	0	0	0	0
Chinook salmon (spring)	0	0	0	0	0	0	0	0	0	0	0	0
Steelhead	0	0	0	0	0	0	0	0	0	0	0	0
Bay goby	H	H	H	H	H	H	H	H	H	H	H	H
Yellowfin goby	0	0	0	L	L	L	L	0	0	0	0	0
Bay shrimp	0	0	0	M	M	L	L	L	L	0	0	0
Starry flounder	M	M	M	M	L	L	L	L	M	M	M	M
Pacific staghorn sculpin	0	0	0	0	0	0	0	0	0	0	0	0
American shad	0	0	0	0	0	0	0	0	0	0	0	0
Delta smelt	L	L	L	L	L	L	0	0	M	M	M	M
Longfin smelt	H	H	H	H	M	0	0	0	0	0	0	H
Threespine stickleback	0	0	M	M	M	M	M	M	M	M	L	0
Shiner surfperch	M	M	M	M	M	M	M	M	M	M	M	M
Bay pipefish	L	L	L	L	L	L	L	L	L	L	L	L
Plainfin midshipman	L	L	L	M	M	M	M	M	M	M	L	L
Barred surfperch	L	L	L	L	L	L	L	L	L	L	L	L
Dwarf surfperch	0	0	0	0	0	0	0	0	0	0	0	0
Pile surfperch	0	0	0	0	0	0	0	0	0	0	0	0
Black surferch	H	H	H	H	H	H	H	H	H	H	H	H
White surfperch	0	0	0	0	0	0	0	0	0	0	0	0
English sole	0	0	M	M	0	0	0	0	0	0	0	0
California halibut	0	0	0	0	0	L	L	L	L	L	L	L
Diamond turbot	M	M	M	M	M	M	M	M	M	M	M	M
Speckled sandab	L	L	L	L	L	L	L	L	L	L	L	L
Leopard shark	0	0	0	0	0	0	0	0	0	0	0	0
Dungeness crab	0	0	0	L	L	0	L	L	L	L	L	0
White croaker	M	M	M	M	M	L	L	L	L	M	M	M
Pacific herring	L	L	L	L	L	L	L	L	L	L	L	L
Northern anchovy	0	H	H	H	0	H	H	H	H	M	M	0
Topsmelt	0	0	0	0	0	L	L	L	L	L	0	0
Jacksmelt	0	0	0	0	0	0	0	0	0	0	0	0

LIFESTAGE IMPACT ASSESSMENT: **X2 @ ROE**

SPECIES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
White catfish	L	L	L	L	L	L	L	L	L	L	L	L
Channel catfish	0	0	0	0	0	0	0	0	0	0	0	0
Sacramento splittail	H	H	H	H	H	H	H	M	M	M	M	M
Sacramento squawfish	M	M	M	M	M	M	M	M	M	M	M	M
Hitch	0	0	0	0	0	0	0	0	0	0	0	0
Threadfin shad	0	0	0	L	L	L	L	L	L	L	0	0
Inland silverside	0	0	0	0	0	0	0	0	0	0	0	0
Tule perch	L	L	L	L	L	L	L	L	L	L	L	L
Green sturgeon	0	0	M	M	M	M	0	0	0	0	0	0
White sturgeon	0	0	M	M	M	0	0	0	0	0	0	0
Striped bass	0	0	0	L	L	L	L	L	0	0	0	0
Chinook salmon (fall)	0	0	0	0	0	0	0	0	0	0	0	0
Chinook salmon (late fall)	0	0	0	0	0	0	0	0	0	0	0	0
Chinook salmon (winter)	0	0	0	0	0	0	0	0	0	0	0	0
Chinook salmon (spring)	0	0	0	0	0	0	0	0	0	0	0	0
Steelhead	0	0	0	0	0	0	0	0	0	0	0	0
Bay goby	H	H	H	H	H	H	H	H	H	H	H	H
Yellowfin goby	0	0	0	L	L	L	L	0	0	0	0	0
Bay shrimp	0	0	0	H	H	L	L	L	M	0	0	0
Starry flounder	M	M	M	M	L	L	L	L	M	M	M	M
Pacific staghorn sculpin	0	0	0	0	0	0	0	0	0	0	0	0
American shad	0	0	0	0	0	0	0	0	0	0	0	0
Delta smelt	L	L	L	L	L	L	0	0	L	L	L	L
Longfin smelt	M	M	M	M	M	0	0	0	0	0	0	0
Threespine stickleback	0	0	L	L	L	L	L	L	L	L	L	0
Shiner surfperch	H	H	H	H	H	H	H	H	H	H	H	H
Bay pipefish	H	H	H	H	H	H	H	H	H	H	H	H
Plainfin midshipman	L	L	L	M	H	H	H	H	H	H	H	L
Barred surfperch	L	L	L	L	L	L	L	L	L	L	L	L
Dwarf surfperch	L	L	L	L	L	L	L	L	L	L	L	L
Pile surfperch	L	L	L	L	L	L	L	L	L	L	L	L
Black surferch	H	H	H	H	H	H	H	H	H	H	H	H
White surfperch	L	L	L	L	L	L	L	L	L	L	L	L
English sole	0	0	M	M	0	0	0	0	0	0	0	0
California halibut	0	0	0	0	0	L	L	L	L	L	L	L
Diamond turbot	H	H	H	H	H	H	H	H	H	H	H	H
Speckled sandab	L	L	L	L	L	L	L	L	L	L	L	L
Leopard shark	0	0	0	0	0	0	0	0	0	0	0	0
Dungeness crab	0	0	0	L	L	0	L	L	L	L	L	0
White croaker	H	H	H	H	H	M	M	M	M	H	H	H
Pacific herring	M	M	M	M	M	M	M	M	M	M	M	M
Northern anchovy	0	H	H	H	0	0	H	H	H	H	H	L
Topsmelt	0	0	0	0	0	M	M	M	M	M	0	0
Jacksmelt	L	L	L	L	L	M	L	0	L	L	L	L