

8.0 HUMBOLDT BAY AQUATIC ECOSYSTEM ELEMENTS AND ECOSYSTEM DYNAMICS

8.1 BACKGROUND AND SETTING

The District has incorporated an ecosystem-based conceptualization of Humboldt Bay into the Draft Management Plan. That ecosystem-based focus is extended into this EIR. EIR chapters 3.0 through 6.0 present considerations of important physical factors that underlie and affect the bay ecosystem. Chapters 8.0 through 11.0 address biological elements of the bay's ecosystem, as well as the interactions among the biological elements and the interactions among physical and biological elements.

The term "ecosystem," as a scientific construct, explicitly incorporates the biological populations within Humboldt Bay together with the physical environment.¹ That is, the term explicitly incorporates in one concept: (1) the populations of organisms that are affected by the conditions in the bay, (2) the physical conditions in the bay, and (3) the factors and processes that modify the physical conditions and the biological populations.

The Draft Management Plan incorporates basic policy statements about the functionality of the bay ecosystem (e.g., Policy CEP-4), but the Plan does not explicitly direct the District or other parties to achieve specific biological or physical conditions. Rather, the Draft Plan is focused on managing the actions of the people in the Humboldt Bay region, and their interactions with the physical and biological environment of the bay, as those actions affect the Humboldt Bay ecosystem. That is, the Draft Management Plan is an "ecosystem-based management" approach, similar to the directions taken in current planning or management approaches for elements of the marine environment in all parts of the earth.²

8.1.1 The Humboldt Bay Aquatic Ecosystem as a Plan Focus

The Draft Humboldt Bay Management Plan explicitly identifies the subject of the plan to include the Humboldt Bay ecosystem and its management. Describing the ecosystem, however, and identifying all of the elements that should be managed within the ecosystem, is a major consideration, beyond the scope of this EIR. By scientific

1 See, for example, URL: <http://en.wikipedia.org/wiki/Ecosystem> (viewed January 2006). A useful discussion of ecosystem concepts and how these concepts relate to the human environment is included in the documents developed for the Millennium Ecosystem Assessment (see URL: <http://www.millenniumassessment.org/proxy/document.300.aspx>; viewed January 2006):

"These fundamental linkages among organisms and their physical and biological environment constitute an interacting and ever-changing system that is known as an ecosystem. Humans are a component of these ecosystems. Indeed, in many regions they are the dominant organism. Whether dominant or not, however, humans depend on ecosystem properties and on the network of interactions among organisms and within and among ecosystems for sustenance, just like all other species."

2 See, e.g., URL: <http://ebm.nceas.ucsb.edu/faq/definition/> (viewed January 2006). Ecosystem-based management is a central feature in the recommendations of both the 2003 Pew Oceans Report and the 2004 United States Ocean Commission Report.

convention, an aquatic ecosystem characterization for Humboldt Bay includes the entire watershed. Because the bay exchanges water with the nearshore Pacific Ocean twice per day, the bay ecosystem also includes the nearshore Pacific Ocean.³

The term “ecosystem” embodies several intellectual and scientific constructs. An aquatic ecosystem enfolds the variety of living species that occur in a given (bounded) location or region, together with all of the aspects of the physical environment that affect the living elements. The ecosystem concept includes the biology of the constituent biotic elements (growth, reproduction, death, etc.) and biological interactions among species (competition, predation, etc.). The ecosystem concept includes the nutrient relationships between the biological elements and the physical environment, as well as those among the biotic elements. The ecosystem concept includes the energy relationships among the biotic elements (see below). In terms of nutrients and energy, the ecosystem may be considered to be “open,” or connected to conditions beyond the nominal “boundary.” The ecosystem concept incorporates longer-term processes that modify the physical conditions in the system (e.g., soil formation). The ecosystem concept also includes longer-term biological processes (e.g., “succession”) that often are associated with increased “structure” and an “internalization” of some of the nutrient pools within the biological and physical components of the ecosystem.

The ecosystem concept integrates the biotic and physical elements that are the subject of the draft plan. The concept addresses the effects of sedimentation in the bay because of erosion in watershed, as well as the effects of nonpoint source pollution within the developed parts of the watershed on biological elements in the bay. It addresses the relationships of watershed processes on anadromous fish, as well as the effects of activities within the watershed on shorebirds. Because the ecosystem concept incorporates these factors, the Draft Plan includes policies that indicate to the District, as well as to other agencies and to citizens in the region, what are an appropriate set of management actions that protect the ecosystem elements and functions while allowing the District to manage the use of the bay for a variety of human uses.

The approach used in this EIR for identifying potential effects of the Draft Plan on the bay ecosystem is focused, in most respects, on water-related topics. That is, the EIR evaluates potential plan effects on hydrology, on water quality, on biological elements mediated through effects on water, and on human uses of the bay as those uses are concerned with water. The content of this chapter is intended to assist readers in perceiving the essential analytical unity that results from this water-related focus. To accomplish this goal, an additional consideration of energy relationships and nutrient relationships in the bay’s waters are provided in this chapter.

3 The bay’s aquatic ecosystem may well stretch the “nearshore” focus to include oceanic realms far from the north coast, particularly in terms of migratory fish species, and may also include terrestrial drainages in northwestern California far from the bay itself. The participation of truly wide-ranging biological elements within the bay ecosystem’s dynamics means that features of Humboldt Bay are interlinked with conditions and events that occur far from the bay itself.

8.1.2 Trophic Dynamics and Energy Relationships in Humboldt Bay

One conception of how an ecosystem functions has, since the 1940s, concerned the energy-flow relationships among the ecosystem's component species and the environment. This conception is heuristically useful in understanding how an ecosystem (such as Humboldt Bay) functions.

All of the energy that flows through, or that is stored in, ecosystems is ultimately derived from the nuclear fusion reactions that occur in the sun. Plants and some similar organisms (e.g., photosynthetic bacteria) produce the energy they need to survive and grow through a process called "photosynthesis;" these organisms are known as "autotrophs" because they provide the energy that they need through their own actions.⁴ All other organisms derive their necessary energy through consuming the autotrophs, or by consuming other organisms that consumed the autotrophs (note that there may be many steps of consumption between the autotrophs and the ultimate consumers); these organisms are known as "heterotrophs."

The vision of an ecosystem's structure and function that emerges from considering the production, storage, consumption, and transfer of energy within an ecosystem context has been called "trophic dynamics," and it is a conceptualization that is widely understood by scientists. The "primary producers" (generally but not exclusively green plants) characteristically are more abundant, have more physical mass, or are more productive (have higher sustained population growth rates), in aggregate, than do the organisms that consume them. There is an inescapable inefficiency in the ecological transfer of food energy from the plants to the "consumers" that limits the biomass of the initial consumers to about 10 percent of the biomass of the plants. This inefficiency is transmitted to any succeeding levels of consumers, and the general relationships among the trophic levels resembles a pyramid, with the producers (plants) at the lowest level and each successive consumer level smaller than the level below it. Clearly this relationship ultimately limits the amount of food energy that is available at high trophic levels, and thus the trophic dynamics of a particular ecosystem have an important role in determining both the structure and the function of the ecosystem.

The food-energy dynamics of an ecosystem help observers to identify which groups of organisms hold important places in the ecosystem. For example, the relative production (measured, for example, in units of kilograms or pounds of biomass produced per unit area per unit time) of different groups of plants is a direct index of the relative importance of the plant groups to the functioning of that ecosystem. Similarly, the relative biomass stored in one group of consumers (pelagic clupeoid fish such as herrings, say) demonstrates the structure of the ecosystem when compared to the biomass of other groups at the same trophic level (demersal flatfish, say), or at different trophic levels (e.g., piscivorous birds). When the relative magnitude of the energy transferred from one trophic level to another can be identified, the functioning of the ecosystem can be characterized.

⁴ There are also organisms that make "food" for themselves that do not use photosynthesis. These "chemosynthetic" species are generally found deep in the substrate or deep in the oceans. It is unclear how much contribution such organisms provide to the trophic processes in Humboldt Bay.

Humboldt Bay's ecological dynamics were described generally in the Draft Management Plan, in Subsection 4.4.4 of Chapter 4, Section II, Volume I (this Plan description was crafted to serve as a partial description of the ecological setting for this EIR):

The habitat conditions that occur in Humboldt Bay have been summarized in a variety of reports (Monroe 1973, Shapiro and Associates 1980, Proctor and others 1980, Barnhart and others 1992). The reports by Proctor and his colleagues and by Barnhart and his colleagues also consider the general ecological relationships that exist within the Bay. No additional depiction of Humboldt Bay ecosystem functions that is more apt than those in the cited reports has been created since the publication of the report by Barnhart and others.

In a general sense Humboldt Bay functions as do other terrestrial and aquatic ecosystems (EIR Figure 8-1). The essential energy that powers the ecosystem is derived from the photosynthetic production of reduced carbon compounds.⁵ Energy fixed by macroalgae, microalgae, phytoplankton, saltmarsh vegetation, and eelgrass (plus whatever enters the Bay in terrestrial runoff or from the Pacific Ocean) represents the "*producer*" trophic level; this energy sustains the entire trophic web. The sources of the fixed energy represent an essential component for understanding the Humboldt Bay ecosystem, and Barnhart and others (1992:53) provided approximate estimates of the magnitudes of the primary production (EIR Table 8-1):

EIR Table 8-1. Primary Production from Humboldt Bay Sources.

Source	Area (Hectares)	Annual Production (10 ⁶ kg)
Salt marshes:		
<i>Spartina</i> dominated	223	2.790
<i>Salicornia</i> + <i>Distichlis</i> dominated	167	1.220
Mudflat microalgae and macroalgae	2878	9.066
Eelgrass beds (mostly <i>Zostera</i>)	1178	11.920
Phytoplankton	2205	3.000
<i>Bay Total</i>	<i>6651</i>	<i>27.996</i>

Source: Barnhart and others (1992).

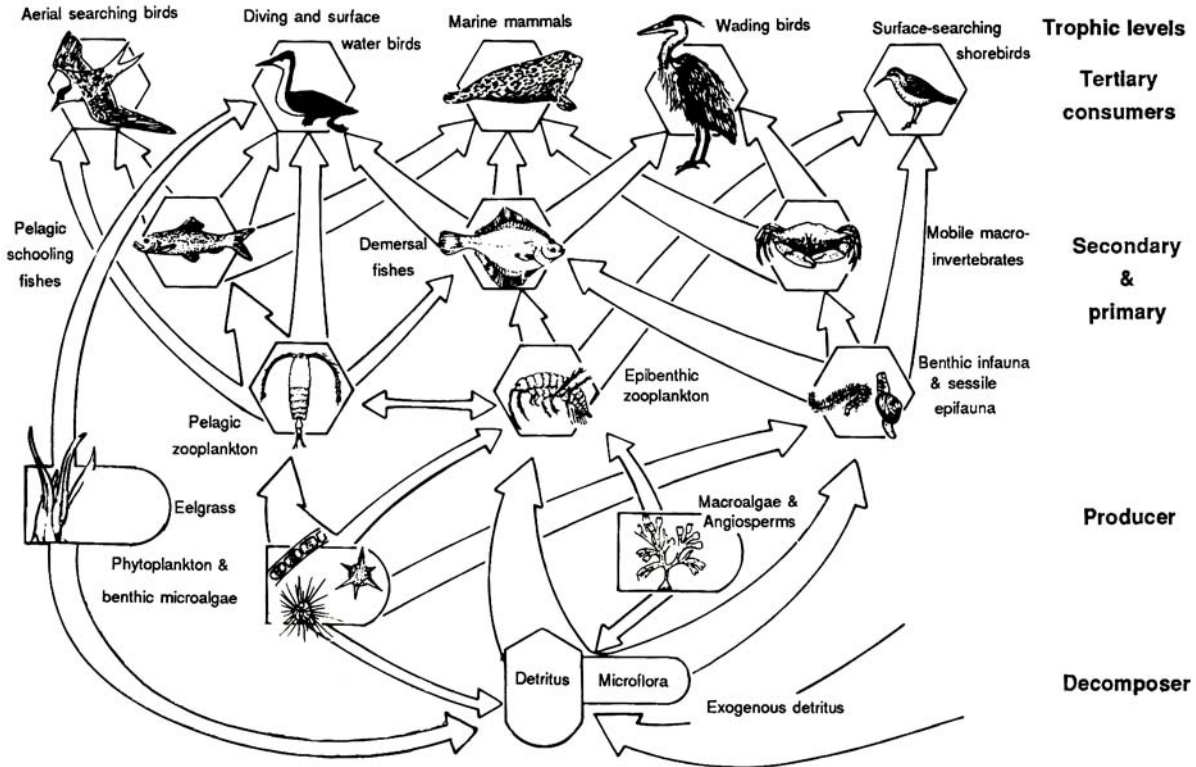
In a general sense, the basic productivity within Humboldt Bay is strongly dominated by the organic material produced by eelgrass beds and the algae and diatoms that grow on the Humboldt Bay mudflats. Nonetheless, as noted in Barnhart and others (1992:54) phytoplankton production may be more directly available to invertebrates in Humboldt Bay than is production from the other sources.

The primary production passes from the initial producers through a variety of trophic pathways, including species that consume plants or bacteria (the "*primary consumers*"), and

⁵ In the deep ocean some trophic webs are supported primarily on the basis of organic material that results from chemosynthetic production. This general pathway is not indicated in EIR Figure 8-1, but could function analogously to a "decomposer" element. Such chemosynthetic pathways exist in Humboldt Bay, but their trophic web significance is unknown.

species that consume other organisms that have consumed the plants (the "secondary consumers") or that consume the organisms that consumed the organisms that consumed the plants (the "tertiary consumers"). The "decomposer" pathway is typically a significant element in aquatic food webs; decomposers are organisms that consume organic material, known as "detritus," that drifts over, rests on, or is covered by bottom sediments.

EIR Figure 8-1. A generalized food web for Humboldt Bay; the sizes of linkage arrows indicate the relative biomass transfer through that linkage. (Source: Barnhart and others 1992).



Many of the fish or wildlife species that are a conservation concern for Humboldt Bay's management depend on the dynamic processes identified in EIR Figure 8-1 for sustenance. Commercially and recreationally important fish and invertebrate species are mostly primary and secondary consumers. The commercially important but non-native Pacific oyster (*Crassostrea gigas*) is a filter-feeding organism that consumes whatever organic material, phytoplankton, and zooplankton that may drift by. Some waterfowl, including Pacific brant (*Branta bernicla*) and various species in the genus *Anas* (including pintail, wigeon, and teal), are primary consumers;⁶ many other waterfowl species (such as those in the genus *Aythya*) are secondary consumers, feeding upon bottom-dwelling invertebrates; yet other waterfowl feed primarily on fish. Almost all shorebirds are secondary (or even tertiary) consumers of invertebrates, although some (such as the American avocet, *Recurvirostra americana*) apparently feed as much on mudflat algae as on

⁶ Pacific brant are primary consumers that forage almost exclusively on eelgrass (*Z. marina*). Approximately 40 percent of the members of this species stop at Humboldt Bay during spring migration for forage on eelgrass, primarily but not exclusively in South Bay.

invertebrates. In a very real sense, the “health” of the elements, and of the entire system, portrayed in EIR Figure 8-1 is essential for the continued functioning of a productive Humboldt Bay ecosystem.

Notwithstanding their importance, the great majority of the ecosystem processes summarized in EIR Figure 8-1 are not well understood for Humboldt Bay. The schematic diagram in EIR Figure 8-1 represents a conceptual view of the ecological food web in the Bay, excerpted from Barnhart and others (1992:61). Those authors include the following statement regarding this figure:

“The fauna and flora of Humboldt Bay are integrally linked through trophic and other ecological relations. However, no quantitative data on the carbon or energy flow through the food web are available. Figure (8-1) is an adaptation of a generalized food web for estuarine channels of the Pacific Northwest coast (reference omitted); with the addition of an eelgrass component, this food web is a probable representation of the general trophic relations in Humboldt Bay.”

This statement remains a valid general summary of expected trophic webs within the waters of Humboldt Bay. However, the diagram in EIR Figure 8-1, the summary paragraph above, and the EIR Table 8-1 also substantially under-represent the complexity in the food webs in the larger Humboldt Bay ecosystem. As noted in Barnhart and others (1992:52-55), the importance of detrital organic material in the Bay ecosystem is substantial; it is likely that much of the gross primary production is not directly usable by organisms in Humboldt Bay (particularly invertebrates) until it has passed into the “detritus” compartment, and it is also certainly possible that a substantial fraction of the Bay ecosystem’s gross primary production is lost from the Bay to the nearshore Pacific.

The above summary is also inadequate in another respect, because it also omits the importance of production imported into the Bay ecosystem from the uplands surrounding the Bay, particularly from riparian areas (some of which are wetlands, and are thus part of the aquatic ecosystem complex in the Bay area). Organic matter also enters the Bay that results from production in the aquatic ecosystem elements in the diked former tidelands and the streams themselves. Riparian forests dominated by deciduous species may yield a gross primary production per unit area that is as high as any of the production sources in EIR Table 8-1 (Mitsch and Gosselink 2000:556). Primary production from the diked former tidelands is likely lower per unit area, approximately equivalent to the productivity of saltmarshes (see, e.g., Kantrud and others 1989:Table 10).

These highly productive wetland and riparian areas exist in abundance in the Bay’s watershed, and their contributions to the ecosystem productivity in the Bay are undoubtedly substantial. However, because the ecological productivities and other characteristics of the streams, riparian areas, and seasonal wetlands near Humboldt Bay have not been adequately studied, the relative contributions that these areas make to the Bay’s ecology are uncertain.

The Humboldt Bay ecosystem must be understood as incorporating the elements in the entire watershed, because the physical and biological processes within the Bay simply do not stop at the Bay’s margin. Recent concerns about the life cycle dynamics of anadromous fish in the basin, particularly coho, indicate a need to consider the streams in which coho

spawn and rear, as well as the Bay itself. Also, research on the uses of Humboldt Bay by shorebirds has confirmed the long-held belief that the seasonal wetlands behind the levees (i.e., the diked former tidelands) play a significant role in the ecology of these species (e.g., Colwell and Dodd 1997), and the designation of Humboldt Bay as a site in the Western Hemisphere Shorebird Reserve Network lists all of the wetlands in the Humboldt Bay “complex” (i.e., the Bay, the diked former tidelands, and aquatic elements in the Mad River and Eel River estuaries) as elements.

The summary above is undoubtedly an oversimplification of the actual trophic dynamics in Humboldt Bay. Ecological studies of trophic webs such as that illustrated in EIR Figure 8-1 are methodologically and logistically difficult. Results from a variety of research projects carried out in different parts of the United States indicate that estuarine trophic webs may not demonstrate such simple relationships:

- Biological production in some west coast estuaries appears to be apportioned among consumer groups in such a way that generalized consumers that broadly “sample” the production from various sources throughout an estuary account for a significant fraction of the secondary production (Simenstad and others 1990).
- Other research in west coast estuaries indicates that consumers in the open water column may derive a significantly higher proportion of their food from open-water primary producers (e.g., phytoplankton), while near-shore and bottom-dwelling consumers may gain most of their food from near-shore sources such as marshland plants (Simenstad and Wissmar 1985).
- Research in trophic dynamics in eastern estuaries has demonstrated that the first level of consumers in several parts of an estuary all utilize primary production from (a variety of) producers within the estuary, while production contributed to the estuary from the terrestrial environment may not be utilized effectively (Deegan and Garritt 1997).
- Other east-coast studies indicate that consumers in marsh areas consume organic material from a variety of sources according to its availability, including marshland plants and terrestrial input (e.g., Peterson and others 1985).
- Research from the Gulf of Mexico indicates that consumers in seagrass (eelgrass) meadows may derive a greater food production from algae growing on the seagrasses than from the seagrasses themselves (Kitting and others 1984).
- Conceptually, it appears possible that the ability of aquatic ecosystem to “recycle” nutrients like nitrogen and phosphorus may act as a potential limit on the ecosystem’s productivity; thus an “ecosystem-level” property may affect the overall productivity of the various components within the estuary (Capblancq 1989).

These observations are not inconsistent with other research results for estuarine ecosystems, whether in the United States and in other parts of the world. This EIR concludes that the portrayal in EIR Figure 8-1 is useful for generally characterizing the food web dynamics in Humboldt Bay, but that it would be inappropriate scientifically to attempt more detailed characterizations of the bay’s food web dynamics at the present time. Indeed, it is unclear that the example food web shown in EIR Figure 8-1 is even a valid representation of the bay’s food web; that is, it’s not clear whether all of the real food web elements in the bay are shown in the figure, or that all of the elements included in the figure actually exist in Humboldt Bay. Further, it’s unknown whether the food web in Humboldt Bay is relatively invariant or whether it changes significantly through time.

Thus, one conclusion of this EIR is that there is a significant need for additional information about the food web in the bay. The uncertainty about the food web's details notwithstanding, this EIR also concludes that a trophic-dynamic approach remains a useful conceptual framework for the bay ecosystem's functioning.

8.1.3 Important Biogeochemical Processes in the Bay Ecosystem

Ecosystem dynamics also include a number of biological and physical processes that affect nutrients. The biological components in ecosystems require a number of chemical elements in order that their tissues can grow and carry on cellular enzymatic processes. Carbon, oxygen, nitrogen, phosphorus, and hydrogen are all essential in abundance for organic cellular activity. For many microorganisms in wetland ecosystems, sulfur is also an essential nutrient that is needed in abundant quantity. One of the empirical characteristics of well-integrated ecosystems is that the biophysical processes operating in the ecosystem tend to develop a relatively high degree of internal nutrient retention. Nutrient dynamics on watershed scales have been a subject of important ecological concern in forested watersheds for several decades [see, for instance, Likens and others 1977, Bormann and Likens 1979, and the websites of the Hubbard Brook Ecosystem Study (<http://www.hubbardbrook.org/>; viewed January 2006) and the H. J. Andrews Experimental Forest (<http://www.fsl.orst.edu/lter/>; viewed January 2006)],⁷ but knowledge about the Humboldt Bay ecosystem is substantially less-well established.

In a larger sense, the Humboldt Bay ecosystem, including the diked former tidelands, the uplands, and the nearshore Pacific, are components that participate in the "pool" of nutrients for species that occur within the bay. The nutrients are important constituents in the proper or "healthy" functioning of the biota in the bay and its watershed. The nutrient pool incorporates the watershed's soils, the instream and floodplain wetlands in tributary drainages, the soils in the diked former tidelands, the sediments and water column in the bay itself, and the sediments and water column in the nearshore Pacific Ocean. Of course, the nutrient pool also includes all of the living organisms in each of these elements.

Many of the organisms within the bay ecosystem are physiologically capable of internally controlling their biochemical composition. In addition, the ecosystem includes a number of physical and "primitive" biological components that chemically regulate the "storage" of nutrients in ways that make them more available for the biota in the ecosystem. The processes that occur in aquatic sediments or "soils" are inextricably linked to the biological processes of plant, animals, and microorganisms. That is, the chemical dynamics in wetlands (including Humboldt Bay, the diked former tidelands and aquatic areas adjacent to the bay, and many of the aquatic areas even some distance from the bay's direct influence) are jointly affected by inorganic processes in the soil and water and by organic influences of the living biota.

Describing the processes and relationships in detail that "regulate" the nutrient pool is beyond the scope of this EIR, but a brief mention of the nature of these relationships

⁷ The "internalization" of nutrient pools and cycles within an ecosystem is a fundamentally important construct in ecology, and there are literally thousands of publications that address various aspects of this subject.

helps in understanding the complexity of the bay ecosystem [see chapter 6 in Mitch and Gosselink (2000) for a clear explication of the biogeochemical processes that occur in wetlands]. Water is the medium in which the chemical reactions important for living organisms occur; the vast majority of the important chemical reactions for estuarine organisms occurs in water or saturated soil. The water and/or soil may be “oxidized” or “reduced.”⁸ Depending on the redox potential, some chemical reactions that are biologically important may be favored or disfavored. These redox-related reactions may be very significant in determining the availability of the compounds that are important for the biota in the wetlands.

The redox state and chemistry in wetlands and estuaries varies according to soil depth.⁹ Every wetland or estuary bottom has an oxidized layer present near the surface and an anoxic layer present below the oxidized layer. The redox potential in the anoxic layer decreases with depth, which is a significant factor in the chemistry in wetland and estuarine sediments.

The chemical “pools” in wetland and estuarine sediments are subject to a constantly shifting balance among a variety of compounds and a range of environmental conditions. In some ways the biochemical activity in estuarine sediments resembles the biochemical activity inside cells. EIR Figure 8-2 is included here partly to illustrate the variety of estuarine chemical pathways that involve nitrogen (see below), but also to indicate the complexity of the biochemical reactions in estuarine sediments: similarly complex diagrams exist for the other elements considered here – each of the elements considered below is subject to similarly complex dynamics (see Mitch and Gosselink 2000 for additional information).

Nitrogen. Nitrogen is an essential nutrient for biological systems (without it there would be no amino acids). The aquatic biogeochemistry of nitrogen is quite complex, and nitrogen can be present in a variety of forms, depending on pH and the mass-balance of reactions occurring in the ecosystem. Nitrogen is characteristically the most limiting nutrient in marine ecosystems and in many estuaries, in part because there is typically an ongoing loss of inorganic nitrogen to the denitrification process;¹⁰ potentially an excess

8 Chemically these terms are typically defined in terms of the “redox potential” in the water or the soil. This term refers to a chemical property, the electrical state of the soil or water micro-environment, and is associated with the likelihood that an electron will be given up or accepted by chemical or biological compounds in the soil or water. Positive redox potentials and elevated pH are typical of “oxidizing” conditions, and negative redox potentials and low pH are typical of “reducing” (often “anoxic” or “anaerobic”) conditions. See Mitch and Gosselink (2000) for additional information.

9 Most surface waters have a positive dissolved oxygen concentration (and elevated redox potential), and the upper sediment layers are in dynamic equilibrium with the overlying water column. It is possible that the water column can become anoxic; for example, the decay of abundant organic material can consume all of the dissolved oxygen in a water body. Such an event would have significant effects on the organic chemistry in the water body, and on the chemistry in the underlying sediment as well.

10 Some scientists (e.g., Capblancq 1990) have concluded that ecosystems that include species that can rapidly “recycle” nitrogen (and potentially phosphorus) into biologically available forms develop greater productive capability and standing biomass than do ecosystems that lack species

of nitrogen in runoff or in wastewater effluent discharges could augment the supply of this limiting nutrient and significantly enhance biological productivity in the ocean or in some estuaries.¹¹

EIR Figure 8-2. Nitrogen transformations in wetlands. SON indicates soluble organic nitrogen. (After Figure 6-11 from Mitch and Gosselink 2000).

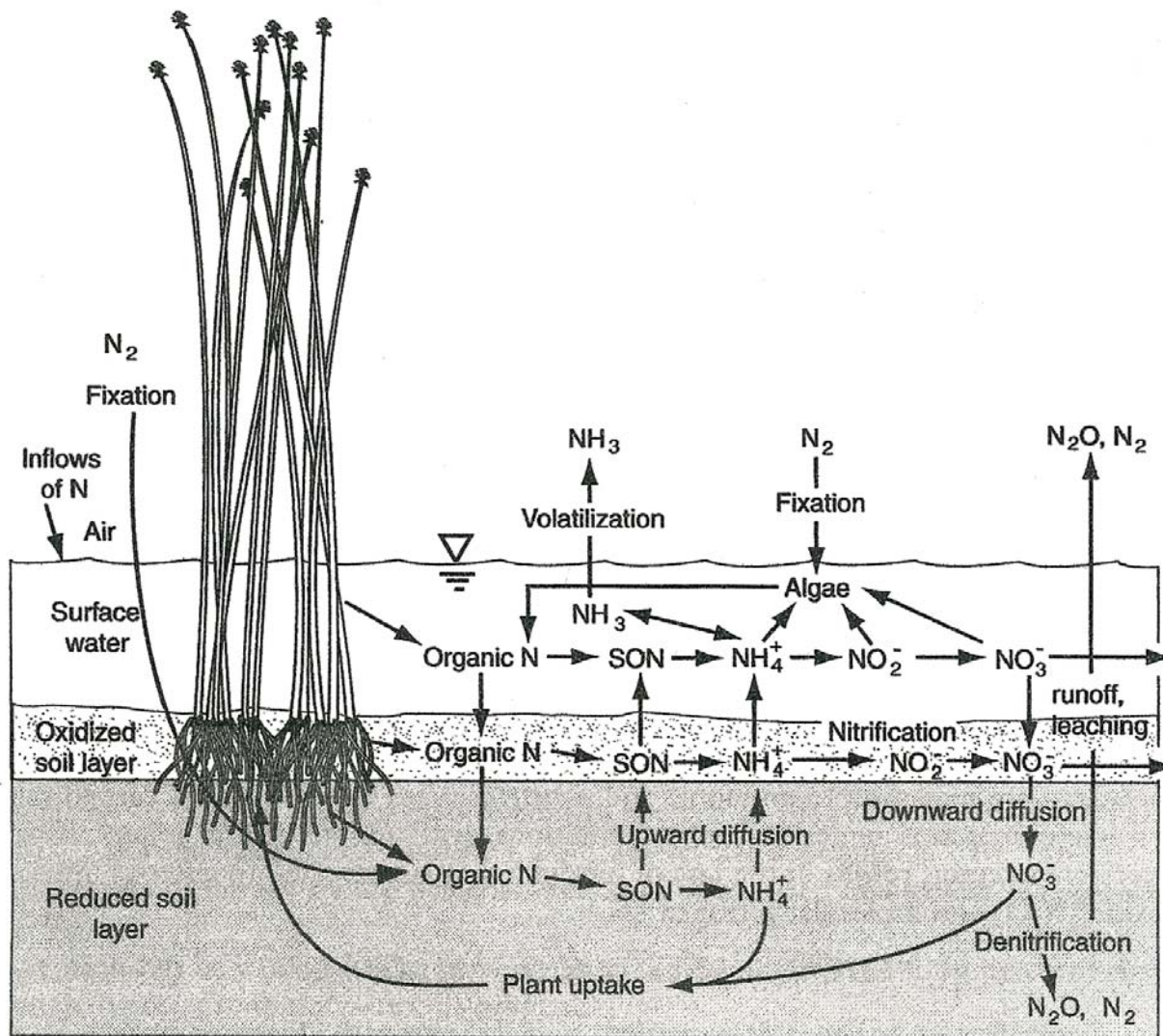


Figure 6-11 Nitrogen transformations in wetlands. SON indicates soluble organic nitrogen.

having this ability.

11 This productivity augmentation may be beneficial in some conditions. However, if the augmentation led to a plankton “bloom” that was associated with a subsequent population collapse and the death of the plankton, the result would be a significant depletion of dissolved oxygen. In these circumstances the added nitrogen would be a pollutant.

Nitrogen is important in wetland soils and estuarine sediments because it is the most common “electron receptor” in anaerobic sediments after all free oxygen is consumed. Nitrogen is added to aquatic ecosystems (and to terrestrial ecosystems) via nitrogen fixation by certain bacteria, through the decomposition of biological materials, in rainfall, and by way of surface water inflow from upland areas; the presence of abundant anthropogenic nitrogen in the atmosphere of most of the planet constitutes a significant pollution source in many estuaries. Ammonia, a reduced form of nitrogen, results from some biochemical processes in wetlands; usually present as ammonium, which is readily used by aquatic plants, under high pH this form of organic nitrogen may be converted to dissolved ammonia, which is very toxic to many aquatic organisms.

Carbon. Carbon is one of the elements that compose the essential structure of biological organisms, and its availability is essential for maintaining the productivity of the Humboldt Bay ecosystem. Carbon is characteristically available in abundant supply in the sediments in Humboldt Bay, especially as bicarbonate ion, which is important in the buffering reactions that maintain the pH stability in the sediment and the water column. Shifts in carbonate abundance, as may occur as a consequence of photosynthesis by phytoplankton (associated with the oxygen released by photosynthesis), can shift pH to highly oxidizing conditions in a period as short as a few hours; or highly reducing conditions can result from the decay of organic material in the water column in equally short periods. Organic carbon is essential in the biologically mediated “denitrification” reactions that produce nitrogen gas from dissolved nitrite under anoxic conditions in sediments. Carbon occurs in dissolved (ionic) and particulate forms in aquatic ecosystems; the ionic forms are chemically essential for photosynthesis. The dissolved carbon in water is in a form of equilibrium with the dissolved carbon in the sediment and the carbon dioxide concentration in the atmosphere; this relationship may be important in the overall global carbon balance.

Phosphorus. Phosphorus is an essential element for all biological organisms because of its participation in physiological processes related to cellular energy transfers. In a different sense, phosphorus is also important for some marine and estuarine invertebrate organisms and for vertebrates as a primary skeletal component. Most phosphorus is present in aquatic environments as inorganic phosphate, which has a low solubility in water but a high affinity for sediment particles, particularly charged clays. Thus phosphorus, which is essential for all organisms, is usually taken up through absorption from sediments by plants, and it is then passed through the food web as consumed organic material. Phosphorus generally is available to the extent that it is needed in most estuarine and marine ecosystems, and additional phosphorus in tributary flows does not normally spur rampant phytoplankton growth that leads to subsequent die-offs and water quality degradation (this sequence of events does occur in bodies of fresh water, and phosphorus may be a significant pollutant for many interior watersheds).

Sulfur. Sulfur, like nitrogen, occurs in many forms in wetland biogeochemistry. An essential element biochemically, sulfur is seldom a limiting element in wetlands because it is abundant in wetland soils. Sulfur is biogeochemically important in estuaries because it is commonly used by many specialized bacteria instead of oxygen in a respiratory pathway that takes place in anoxic sediments (the primary reaction product is hydrogen sulfide, the “rotten egg” gas). Sulfides may be locally toxic to plants and invertebrates if present in the sediment in high concentration.

Iron and manganese. Iron and manganese are usually abundant elements in wetland soils. Biogeochemically both elements are important electron receptors, with the acceptance occurring in the redox potential range between nitrogen and sulfur [the gray color in most wetland soils is iron sulfide; the occasional “rusty” color is, in fact, rust (iron oxide)]. Thus the biological activity in these soils occurs in large part because of the presence of these elements.

In summarizing some of the element biogeochemistry occurring in wetland and estuarine sediments, the picture that emerges is one demonstrating a constantly shifting chemical balance, with the oxidation state, or redox potential, sometimes favoring chemical oxidation and sometimes chemical reduction. Many somewhat unusual microorganisms are directly and intimately involved in these chemical transformations, and the biological activity in wetland and estuarine substrates is very complex as a consequence. Because the water quality or oxidation state of the estuarine waters can be affected by a variety of circumstances (pollution, broad influxes of ocean water, and similar factors), this variability in wetland and estuarine biogeochemistry must be considered to be as important an aspect of Humboldt Bay’s ecology as the energy dynamics summarized above.

8.1.4 The Bay and the Adjacent Pacific Ocean

As noted in Chapter 6.0, the water quality in Humboldt Bay is closely related to the status of ecological and physical dynamics in the adjacent nearshore Pacific Ocean. Entrance Bay exchanges the water that occupies the channels at high tide with the Pacific twice each day, so that the “quality” of tidewater in Entrance Bay at high tide is essentially equal to the quality of the water in the Pacific Ocean at the bay’s entrance. When seasonal winds from the northwest in spring and summer produce upwelling in the ocean, the water in the bay (particularly in Entrance Bay) is often colder and saltier than at other times.¹² Water in Arcata Bay and South Bay typically is fresher than water in Entrance Bay in winter¹³ and saltier (and warmer) in summer than the water in Entrance Bay and the ocean. As a general conclusion, it appears that the physical conditions in Entrance Bay, at least, are determined as much by the water that enters the bay from the Pacific Ocean as by factors intrinsic to the bay and its watershed.

The significance of the oceanic water for the bay is consistent with the bay’s identification as a “marine embayment” more than as an “estuary.” The total computed annual freshwater inflow to Humboldt Bay from all of its tributaries is approximately the same as the volume of seawater that enters the bay in only two days of normal tidal exchanges with the nearshore Pacific Ocean (Barnhart and others 1992:19). Physically, Humboldt

¹² The west coast near Humboldt Bay appears to be “a physically controlled ecosystem, wherein plankton assemblages and carrying capacities are regulated by ocean currents and upwelling events rather than biological interactions” (Bottom and others 2005:27). This dominance by physical conditions is considered by those authors as likely to influence salmonid life history patterns in this region (see Chapter 11.0).

¹³ It is also possible, however, that the water in Entrance Bay may be significantly influenced by the freshwater in the Eel River plume during major flood events, which would enter Humboldt Bay on incoming tides; see Chapter 5.0.

Bay is a pocket of ocean water behind two long sand-spits, with a limited intermixture of freshwater during the winter that hardly reduces the bay's salinity.

The practical importance of Humboldt Bay for the nearshore Pacific Ocean ecosystem appears, however, to be associated more with biological elements than with physical elements. Chapter 11.0 briefly summarizes some of the interrelationships that exist between the bay and the Pacific Ocean with respect to fish habitat and population dynamics. Almost all of the fish species that occur in Humboldt Bay are adapted for an existence that includes the ocean's shoreline or the bottom; that is, almost all of the fish species that are present in the bay are members of taxonomic groups that have a primarily marine ecology associated with shallow waters and/or coastal embayments or estuaries. A number of fish species, including many of the species that are important commercially, spend parts of their lives in the bay and parts of their lives in the ocean (see Chapter 11.0).

Because the bay is a "pocket" of the ocean, the bay appears to provide habitat value for non-fish marine species as well as for fish. The bay is well known to provide habitat for harbor seals (*Phoca vitulina*), and the seals that are sometimes seen in the bay appear to belong to a seal population that uses most of the coastal region between the Eel River delta and the Patrick's Point area (Loughlin 1974). The appearance of California sea lions (*Zalophus californianus*) in the bay is common enough to be mostly unremarkable, and a number of other marine mammal species have been observed within the bay at various times. The regular movements between offshore waters and Humboldt Bay by scoters (*Melanitta* spp.) is so common as to be beneath notice, and a number of other waterbird groups (e.g., gulls and terns, cormorants and pelicans, and some waterfowl) that are generally considered to have a marine affinity [not the least of which is the Pacific brant (*Branta bernicla nigricans*); see Chapter 10.0] are also commonly sighted within the bay. Less commonly, piscivorous alcids, particularly the common murre (*Uria aalge*) and the marbled murrelet (*Brachyramphus marmoratus*), may be observed foraging in Humboldt Bay's waters (primarily in the marine conditions that occur in Entrance Bay).¹⁴

Humboldt Bay almost certainly does affect the nearshore Pacific Ocean ecosystem in trophic-dynamic and biogeochemical terms, but the extent of the influence is not well documented. Some of the biological production that occurs within Humboldt Bay is clearly exported from the bay to the nearshore Pacific Ocean on outgoing tides, although the magnitude of the export and its ecological significance are uncertain; this subject has been little-studied.

The coastal Pacific Ocean has intrinsic sources of primary biological production, including phytoplankton, macrophytic brown algae [important species include "bull kelp" (*Nereocystis luetkeana*) and "feather-boa kelp" (*Egregia menziesii*), although there is quite a diversity of marine macroalgae present along the Humboldt County coastline], a number of red algae, some green algae, and marine grasses (*Phyllospadix torreyi* and *P. scouleri*).

¹⁴ The observations of these species appear to be related to conditions in the open Pacific Ocean that cause a decline or near-absence of the fish on which these species forage. Long periods in the spring and summer without coastal upwelling may cause a virtual collapse in the fish populations on the nearshore Pacific, and under such circumstances the presence of the estuarine fish in Humboldt Bay may be an essential element for the seabirds.

In the littoral region along the immediate coast, the biological productivity that arises from these intrinsic sources of fixed carbon is supplemented by organic matter exported from coastal river basins and lagoons, including Humboldt Bay.

The benefits derived by the oceanic ecosystem elements from the export are not well characterized, and likely differ according to the specific production elements considered. The biological production and the physical structure derived from “wrack” (coarse organic debris, such as eelgrass clumps) do have an effect on beach habitat values (see, e.g., Dugan and others 2003). As noted above, the organic production in oceanic river plumes appears to differ according to whether the oceanic production occurs in the water column or close to the seabed. This result is consistent with a model that water-column production by phytoplankton depends on dissolved nutrients and that seafloor production is based on particulate matter. Without additional study the significance of the biological production from Humboldt Bay to the trophic structure of the nearshore Pacific cannot be addressed satisfactorily.

The oceanic environment outside the bay is incompletely characterized. Generally, the immediate coastline has variable areas that are sandy (such as the area west of the bay) and areas that are rocky (such as the Trinidad region). The physical environment varies because of wave patterns and water depths, currents, and the influence of river discharges. The biological communities in these differing physical environments vary substantially (see, e.g., Boyd and DeMartini 1977, and Proctor and others 1980), although the communities that occur in these areas have not been characterized scientifically in much detail. These offshore and coastal biological communities are not expected to be affected by the Humboldt Bay Management Plan, and additional descriptions exceed the coverage requirements for this EIR.

It is evident that Humboldt Bay provides physical habitat elements for species that also use offshore habitat elements (e.g., demersal fish that utilize the bay when young but then move offshore as adults). It also appears to be true that the bay provides energy and nutrients to species in the nearshore ocean. Thus it is appropriate to identify at least some elements of the nearshore Pacific Ocean as ecologically coupled with the bay, and it is a valid statement that activities that affect the bay also affect the nearshore Pacific, although the full extent of the bay-ocean coupling or the full reach of the bay-related effects cannot be specified at the present time.

In a larger context, it should be noted that the ocean near Humboldt Bay is part of a larger-scale ecosystem complex that includes all of the northeast Pacific Ocean, and that this larger area is subject to major shifts that have essentially nothing to do with events or conditions within the bay or with the contributions of the bay to the Pacific Ocean. El Niño-Southern Oscillation (ENSO) events, the changes related to the Pacific Decadal Oscillation (PDO), and other large-scale or long-term climatic and oceanographic trends produce changes in current and upwelling patterns that significantly alter the ocean off northern California, and the conditions in the ocean then directly affect the conditions in Humboldt Bay (e.g., see EIR Chapter 4.0). The ecologically significant effects of ENSO events and PDO regime shifts on the northeastern Pacific Ocean are not well characterized scientifically, and studies of the potential effects of climate-driven changes in the Pacific Ocean are only beginning. The management of Humboldt Bay may need to address these results in the future, but at the present time there is insufficient knowledge

of their consequences, and this EIR avoids speculating about the potential relationship between these trends and the current Draft Plan.

8.1.5 Non-Tidal Wetlands, Streams, and Riparian Areas

A description of these elements of the bay's ecosystem is included in Chapter 9.0, which is focused primarily on how activities that take place within these elements can affect the bay "resources" that are the focus of the Plan's policies. The fringing wetlands, streams, and watershed areas are elements of the Humboldt Bay ecosystem; Humboldt Bay receives water, nutrients, and pollutants that are exported by the watershed. In gross-area terms, only about 11 percent of the entire 223-square mile area of the bay's watershed is "bay;" the rest is watershed. While most of the water (and most of the sediment) that enters Humboldt Bay enters the bay from the ocean, most of the pollutants that enter the bay apparently arrive via runoff from the bay's watershed.

8.1.5.1 Productivity

In ecological terms, the bay's watershed likely makes a substantial but largely undocumented contribution to the bay's net ecological activity level. For example, the area of the diked former tidelands (nontidal emergent wetlands) adjacent to Humboldt Bay was identified by Monroe (1973) as approximately 4330 hectares (11,000 acres). The EIR's preparers did not locate documentation that identified the possible trophic contributions of the diked former tidelands to the bay's ecosystem dynamics; the subject appears not to have been studied.¹⁵ With respect to these areas, the Draft Plan includes the following summary statement:

Organic matter also enters the Bay that results from production in the aquatic ecosystem elements in the diked former tidelands and the streams themselves. ... Primary production from the diked former tidelands is likely ... approximately equivalent to the productivity of saltmarshes (see, e.g., Kantrud and others 1989:Table 10).

Assuming a productivity approximately equal per unit area to the saltmarshes in EIR Table 8-1 (approximately 1.2 kg/m²), the gross annual primary production in the diked former tidelands would be approximately 54.1 x 10⁶ kg, a figure that exceeds the sum of the biological production from all of the tidal baylands. However, Shapiro and Associates (1980) reported productivity in the grasslands of <0.5 kg/m², placing the annual production from these areas as about 21 x 10⁶ kg, which still exceeds the annual production from most of the tidal baylands. That is, owing to the extensive area of the diked former tidelands, the potential productivity of these lands and the potential production exported to Humboldt Bay is in the same order of magnitude as the existing production from the tidal baylands. The extent to which any of this production is actually

¹⁵ It should be noted that the generalized discussion in this subsection ignores the nature of the biological material exported to the aquatic environment. Based on general principles, most of the biological material contributed by the watershed would be expected to be particulate matter, which would enter detritus-based food webs in the bay and the Pacific Ocean, while relatively little of the exported material would be expected to be dissolved material that would contribute to subsequent phytoplankton production in the bay or the ocean. In addition, this discussion doesn't consider possible differences in the "refractoriness" to decomposition that would be associated with organic material from different sources, although such effects would likely be germane to scientific considerations of ecosystem dynamics.

exported from the diked former tidelands to the bay is unknown,¹⁶ but the diked former tidelands clearly constitute a possibly significant contribution to the bay ecosystem's trophic dynamics (the diked former tidelands are well known to be an important habitat type for wildlife; see Chapter 11.0).

The biological productivity from riparian wetlands (including floodplain marshlands as well as shrub and tree canopies in riparian forests and shrublands) is an additional source of biological production for the bay's aquatic ecosystem elements. As noted in Chapter 4.0 of Section II of the Draft Plan:

Riparian forests dominated by deciduous species may yield a gross primary production per unit area that is as high as any of the production sources in EIR Table 8-1 (Mitsch and Gosselink 2000:556).

The discussion in the Shapiro and Associates (1980) report indicated a similar expected productivity (about 1.0 to 1.2 kg/m² per year for woody vegetation and as much as 1.9 kg/m² for freshwater marshes), indicating that riparian habitat areas are probably highly productive assets for the bay ecosystem. Not all of the gross production would be exported to the bay, but the deciduous canopies of the riparian species would assure a high export to downstream wetlands. The areal extent of riparian and/or floodplain wetlands (see Chapter 9.0 for a discussion of wetlands in the Plan area) in the bay watershed is not known, however, and even close approximations of the production from riparian ecosystems cannot be estimated.

The "uplands" near the bay also produce organic material that could assist in sustaining the bay's aquatic ecosystem. The great majority of these watershed lands are covered in coniferous forest. Productivity estimates for coniferous forests in the Shapiro and Associates (1980) report suggested that coniferous forests produce approximately 1.0 kg/m², much of which would be wood fiber; assuming that only one-quarter of the biomass produced by coniferous forests reached the aquatic ecosystem, and assuming ca. 40,000 ha of forestland, the forestlands would still export about 120 x 10⁶ kg of biomass to the aquatic ecosystem each year, a number that dwarfs the autochthonous production from wetlands.

In summary, given the apparent significance of the productivity estimates from the bay's watershed, this EIR concludes that it would be inappropriate for the Humboldt Bay Management Plan to avoid considering the importance of the watershed with respect to the biological productivity in the tidal portions of the bay's aquatic ecosystem.

8.1.5.2 Watershed Biogeochemical Processes and Water Quality

Because Humboldt Bay is located at the "bottom" of the bay's watershed, nutrients and pollutants that are entrained in surface runoff (and to a lesser extent in subsurface flow) may reach Humboldt Bay. As a CEQA subject, water pollution is considered in Chapter 6.0 of this EIR, and this discussion simply notes that some elements, if present in concentrations outside the range of those desired by regulatory requirements, are identified as adverse environmental effects.

¹⁶ Because most of the diked former tidelands are seasonally grazed, it is possible that relatively little of the annual productivity from these perennial grasslands reaches the bay.

From an ecosystem perspective, however, it is important to note that the bay's watershed would always have produced nutrients that reached the bay's (or the ocean's) aquatic ecosystem. Weathering and soil formation processes in the bay's watershed result in freeing nutrients required by plants and animals from their geological matrix, and these nutrients characteristically are mobilized within the aquatic environment. The ecosystem studies, noted previously, at the Andrews Experimental Forest in Oregon and the Hubbard Brook Experimental Forest in New Hampshire have documented the kinds of nutrient fluxes that occur in forested landscapes, including some of the effects of human modifications of the forest ecosystem [see Likens (2004) for an overview of the effects of forest manipulations on nutrient fluxes and other aspects of these long-term ecosystem studies].

Ecosystems that have extensive, undisturbed forest cover (or other unbroken land cover) tend to maintain highly internalized nutrient dynamics, and runoff from such ecosystems tends to carry little excess nutrient loading. Even moderate disturbances of forest cover can, however, adversely affect the ecosystem's regulation or retention of nutrients. The extensive logging that has been occurring in the Humboldt Bay watershed for decades has undoubtedly already affected the ability of the watershed's forest ecosystem elements to fully retain some nutrients (e.g., "exchangeable cations" in the soil). This EIR assumes that a millennium of human uses in the watershed have resulted in at least some enhancement of nutrient fluxes from the watershed's slopes into the bay's wetlands.

Based on existing understanding of the bay's dynamics, however, there is no clear evidence that the nutrient fluxes into the aquatic environment that have resulted from logging and similar "resource-based" land uses within the watershed has adversely affected the aquatic ecosystem in Humboldt Bay. The nutrients released by watershed-based extraction activities already appear to be present in the aquatic environment at concentrations higher than those needed by ecosystem components; that is, the nutrient supply already appears to be above thresholds that would limit ecosystem productivity. As noted above, nitrogen may be the only (or the most important) limiting nutrient for the bay ecosystem, and nitrogen mobilization and delivery do not appear to be enhanced by typical resource-extraction activities; farming activities generally practiced in the bay's watershed involve little or no application of nitrogen fertilizers.¹⁷ See Chapter 6.0 for a consideration of potential water quality concerns because of other possible water pollutants.

8.2 ISSUES TO BE ADDRESSED AND THRESHOLDS OF SIGNIFICANCE

The Initial Study prepared for the Management Plan EIR identified potential effects on a number of elements of the Humboldt Bay ecosystem in the queries about "biological resources:" item IV.a - sensitive species, item IV.b - riparian areas and other sensitive community types, item IV.c - wetlands, and item IV.d - nursery areas and migratory corridors. The comments received by the District in response to the Notice of Preparation

¹⁷ Nitrogen from animal wastes associated with dairy operations and grazing activities may, in fact, be considered a "pollutant" if it is provided in excessive amounts, or if it reaches the bay as ammonia (a toxic form for aquatic life).

did not add specific elements or concerns that were not already included within these Environmental Checklist items.

These Environmental Checklist categories reflect a project-specific focus in typical CEQA contexts, but it is unclear that the categories serve the planning context of this EIR well. In addition, most of the specific elements that are the subjects of these queries are covered in this EIR in chapters 9.0, 10.0, and 11.0. In terms of the overall ecosystem focus that's the subject of this chapter, the issues of concern can be better differentiated as a more general question: does the policy focus in the Draft Plan incorporate policy elements that would likely have adverse effects on the Humboldt Bay ecosystem? The specific subjects described in this chapter thus form an analytical framework within which the Plan's potential ecosystem-related effects can be assessed.

As in other chapters, the thresholds of significance convention used in this chapter is that a potential environmental effect of the Plan is judged to be significant if the proposed policies increase the potential for occurrence of possible environmental impacts beyond the degree that would exist if the policies were not carried out. This assessment requires a judgement regarding the likelihood that the Plan will lead to actions that will create or exacerbate adverse conditions that would not occur without the policies. If a reasonable argument is possible that the Plan's policies would exacerbate a possible adverse condition, or create a new adverse condition that does not occur at the present time, then the effect is judged to be significant.

8.3 ENVIRONMENTAL EFFECTS OF PLAN ALTERNATIVES

8.3.1 "No Project" (Existing Master Plan)

The 1975 Master Plan incorporated "use" designations that included "conservation" purposes. Virtually all of Arcata Bay and South Bay were included in areas that were identified as better allocated to "conservation" purposes than to more intensive uses. The 1975 Master Plan also recognized the intrinsic interrelationship between watershed processes and the quality of the bay's aquatic ecosystem, and recommended that the bay's management be cognizant of the need to protect the bay's watershed. The Master Plan did not explicitly invoke an ecosystem-based relationship to the Pacific Ocean, treating the bay as the focus of the Master Plan's planning effort without identifying the functional connection to the ocean.

In implementing the Master Plan the District adopted Ordinance No. 7 in 1976. This ordinance incorporated the Master Plan's essential designation of Arcata Bay and South Bay for conservation (i.e., ecosystem-protection) purposes. The "water use" classification assigned by the ordinance to the designated "conservation" use authorizes "natural resources habitat, wildlife refuges, mariculture, public access, and scenic vistas." However, Ordinance No. 7 does not explicitly recognize the ecosystem-based focus to the watershed that the Master Plan recognized, and ordinance No. 7 includes no references to the ecological coupling between the bay and the Pacific Ocean.

Ordinance No. 7 echoes the Master Plan in the range of uses authorized for Entrance Bay, and most of the "water-dependent industrial" uses of the bay are included here. The eastern part of Entrance Bay and the water areas near Indian Island are designated for

conservation purposes, but the remainder of Entrance Bay is designated for one or more of a variety of uses that do not explicitly include conservation or ecosystem-management purposes.

Notwithstanding the “use” designations, Ordinance No. 7 does include the following policy direction regarding Environmental Quality in Section 9 of the ordinance:

“(a) Maintenance and improvement of environmental quality shall be primary objectives for the use and development of all areas of Humboldt Bay and not just those designated as ‘Conservation Water’ and ‘Public Open Space Lands.’ ”

On the bases of the Master Plan commentary and the content of Ordinance No. 7, this EIR finds that the “No Project” alternative does have an intent to maintain, protect, and enhance ecosystem processes in the Humboldt Bay watershed, even though this concept is not named specifically. However, the policy direction provided in this alternative is far less explicit and well-focused than is the policy direction provided by the proposed Management Plan, and the 1975 Master Plan is far less effective at focusing the bay’s management on an ecosystem-based process.

8.3.2 Proposed Management Plan

As a management plan for all of the varied resources and uses for the bay, the Draft Humboldt Bay Management Plan includes many policies that may have adverse effects on elements of the bay ecosystem. These adverse effects may arise in several ways. Some effects may be direct and adverse, and activities that may be approved pursuant to the Draft Plan may be immediately responsible for adverse impacts on wetlands, eelgrass, fish, or other ecosystem elements. In other cases the potential ecosystem impacts from the Plan’s policies may be indirect, and the impacts may occur because an action authorized by the Plan (such as recreational access to the bay) subsequently results in impacts to ecosystem elements (e.g., clams or other invertebrates, or marine algae) that were not initially anticipated.

The following policies in the Draft Plan appear to have a potential for producing adverse effects on elements and functions of the Humboldt Bay ecosystem (it should be noted that a number of other policies in the Draft Plan would have positive or beneficial effects on the bay ecosystem).

Harbor Policies:

- HLU-3: Assist in removing potential constraints for marine-dependent or coastal-dependent land uses along the Samoa Peninsula, Fields landing Channel, Eureka shoreline, and other harbor-related areas (from Harbor Revitalization Plan)
- HLU-6: Develop “specific plans” for District-owned parcels
- HSM-2: Develop standards for new and existing Humboldt Bay shoreline protection
- HSM-6: Require the use of non-structural shoreline protection where feasible and appropriate
- HWM-2: Dredging may be authorized to meet Plan purposes
- HWM-3: Re-deposition of dredged materials within Humboldt Bay may be authorized to meet Plan purposes

- HWM-4: Placement of fill within Humboldt Bay may be authorized to meet Plan purposes
- HWM-5: Potential dredged-material management options and alternative disposal methods shall be identified in a Long Term Management Strategy for Humboldt Bay
- HWM-6: Sediment dynamics in Humboldt Bay shall be identified and a sediment management approach for Humboldt bay shall be identified
- HFA-4: Identify additional aquaculture opportunities in Humboldt Bay
- HFA-5: Designate a Preferred Aquaculture Use Area in Arcata Bay, and require Best Management Practices to meet environmental constraints

Recreation Policies:

- ROP-3: Identification of designated recreational use areas
- RFA-2: Project approvals shall incorporate public access and associated services and amenities where appropriate
- RFA-3: Water-oriented recreation facilities; access for fishing and shellfish harvesting
- RFA-5: Environmentally sensitive areas
- RFA-8: Minor amounts of fill authorized
- RSA-1: Improvement and provision of boat launch sites
- RSA-2: Assistance to, maintenance of, and consideration of marinas
- RSA-6: Protect District-owned beaches for recreational uses
- RSA-9: Support for a water trails program for Humboldt Bay
- RIO-3: Directing recreational users toward appropriate areas of the Bay

Conservation Policies:

- CAE-3: Work cooperatively to develop and implement a restoration and enhancement plan for Humboldt Bay's aquatic ecosystems
- CAS-5: Fill placement may be used for habitat enhancement purposes
- CEP-1: Impacts to streams, wetlands, estuaries, and coastal waters may be authorized for specific purposes or project types
- CEP-2: Dredging may be approved under specified conditions
- CEP-3: Revetments, breakwaters, and other shoreline structures may be approved under specified conditions

The Draft Management Plan is intended to provide a “self-mitigating” programmatic management program for Humboldt Bay. The goal in that approach is to assure that policies that could result in adverse effects are accompanied by other policies that moderate or prevent possible adverse effects. For example, while the policies listed above could be associated with activities having adverse effect on the bay's aquatic ecosystem elements and functions, policies CEP-4 through CEP-11 in the Management Plan explicitly assure that the District will identify and adopt appropriate measures to assure that no adverse long-term impacts remain as a consequence of Plan implementation. However, as noted throughout this EIR, the Plan's success in avoiding impacts depends entirely on the full implementation of all of the Plan's policies.

8.3.2.1 Trophic Dynamics, Energy Relationships, and Ecosystem-Based Effects

The Draft Plan does not explicitly address trophic dynamic relationships in the bay. Some of the Plan's policies could, however, result in inadvertent effects on trophic relationships.

Mariculture. The effects of existing and potential future mariculture operations on the bay's energy relationships are not well characterized (see Chapter 10.0 regarding physical effects on eelgrass and Chapter 11.0 regarding mariculture's relationships to fish habitat functions). As indicated in Chapter 10.0, mariculture operations in areas of the bay with standing eelgrass do result in reductions in the eelgrass coverage, an effect that the National Marine Fisheries Service has identified as significant with respect to Essential Fish Habitat in the bay. As filter-feeders, oysters and clams also reduce the "standing crop" of phytoplankton in the bay, which results in a reduction in the bay's productivity; a similar removal effect is likely for drifting detritus. The degree or significance of these effects on productivity for the ecosystem as a whole is unknown. Expanding shellfish mariculture operations in the bay could adversely affect the availability of nutrients and energy for the estuarine ecosystem as a whole, but the extent of shellfish mariculture operations that would produce significant effects is not clear. At the present time there is no available information that addresses the extent of the trophic-dynamic impacts of mariculture on Humboldt Bay.

Mariculture of other types, such as those involving food provisioning rather than a dependence on natural ecosystem productivity (e.g., finfish mariculture), appears to be less likely to have an effect on the bay ecosystem's trophic structure. However, it is also possible that food provisioning could produce adverse effects because of nutrient "enrichment" that leads to adverse water quality effects (see Chapter 6.0).

The Draft Plan includes policies that are intended to lead District decision-makers to look at potential ecosystem dynamics (e.g., policies CAE-1 and CAE-3), and it is expected that additional future research will be focused on these concerns. Generally the effects of mariculture on the bay ecosystem's structure and dynamics are not known well, and the EIR is unable to determine whether the potential adverse effects on the bay ecosystem's functions because of mariculture activities will be fully avoided or offset in either the near-term or the long-term future.

The EIR finds, however, that the existing policy compliment in the Management Plan provides clear and adequate guidance to the District's decision-makers and other interested parties regarding the need for additional information, and additional management policies do not appear to be necessary.

Fishing. Fishing is an activity that largely relies on the natural population dynamics of the fished species in order to maintain the stocks that sustain the activity. In recent years it has become clear that natural populations may not be fished too heavily without depleting the capability of the populations to sustain fishing activities.¹⁸ Depleting the populations of the fished species is an ecosystem-based effect. The severity of the effect could be exacerbated if activities in the bay were to adversely affect the life-history stages

18 See, for example, the PFMC Groundfish Management Plan (URL: <http://www.pcouncil.org/groundfish/gffmp.html>, viewed February 2006).

of important fish species that occur in the bay (see Chapter 11.0). The Plan's recommended policies (e.g., CAE-1) are intended to assure that an adequate understanding of the bay's importance to exploited species and their habitats is developed as part of the Management Plan.

The EIR generally concludes that management actions by the PFMC, the Department of Fish and Game, the National Marine Fisheries Service, and other affected agencies and interested parties are likely to increase the understanding of population and habitat dynamics that maintains these fish populations. It is unclear, however, that management practices currently in effect will assure that fishing does not produce a long-term adverse impact on fished stocks. Nonetheless, it does not appear that additional policies are necessary within the Plan to address this concern.

Dredging and Spoil Disposal. Some harbor-maintenance actions have a potential for affecting the bay ecosystem's structure and functions beyond the effects of the actions themselves. Dredging activities have an effect on the species that occupy the bay-bottom locations at which dredging occurs, largely removing eelgrass, other primary producers, and a variety of invertebrate species that may occupy the dredged areas. Similarly, depositing dredge spoil within the bay (should such actions be approved in the future) could bury these primary and secondary producers, removing their contributions to the remainder of the bay's trophic web.

The Draft Plan contains a variety of policies that authorize dredging (e.g., HWM-2) and spoil disposal (e.g., HWM-3) within the bay. As noted in Chapter 5.0, it seems that almost any extensive human use of the bay requires some degree of dredging, so it is clear that managing Humboldt Bay will have some ongoing level of effect on the bay's trophic-dynamic relationships.

The Plan includes a number of policies (e.g., CEP-4 through CEP-11) that are intended to assure that the potential adverse effects of management activities are identified, considered, and mitigated to the greatest extent feasible. It may often not be possible to avoid or fully offset (say, by planting eelgrass or marsh vegetation) the short-term losses of production that result from dredging activities. This EIR is, however, unable to identify in a categorical sense the degree of ecosystem productivity loss that constitutes a threshold of significance for this effect, and the EIR thus cannot determine whether the minor unmitigated loss is environmentally significant. Nonetheless, it appears that there are effectively no additional policies that could be added to the Management Plan that would increase the likelihood that adverse effects would be avoided.

8.3.2.2 Biogeochemical Processes

The Draft Plan does not explicitly address biogeochemical processes in the bay. Generally the EIR concludes that Plan policies that will be implemented by the District should not affect those processes. However, the EIR also finds that processes that occur within the bay watershed may significantly affect the bay's functions with respect to biogeochemical cycles, particularly the introduction of nutrients, fertilizers, pesticides, and a host of nonpoint source (NPS) pollutants from the uplands as water contaminants.

The Draft Plan contains one policy to address this potential impact; Policy CAE-4 directs the District to participate in collaborative discussions with the Regional Water Quality

control Board, the County, the cities of Arcata and Eureka, and other affected agencies and interested parties in order to develop a coherent water quality management plan. One focus of this plan would be reducing the delivery of NPS pollutants into the bay's waters or their tributaries.

At the present time it is unknown whether this policy focus will be adequate to assure a lack of significant adverse effects on biogeochemical ecosystem processes in Humboldt Bay. However, there are no clearly evident policy additions that would increase the probability that these concerns would be resolved effectively.

8.3.2.3 Relationships among the Bay and the Pacific Ocean

The Draft Management Plan does not include any explicit policy guidance directing the District to incorporate the known and likely relationships between the bay and the Pacific Ocean into management decision-making. The Draft Plan does, however, include the following statements of objectives in Plan Section 5.2:

Objectives:

- Protect, maintain, and enhance the biological populations and processes in Humboldt Bay, in the nearshore Pacific Ocean, and in the Bay's watershed
- Protect and maintain the physical, chemical, and hydrological processes in Humboldt Bay, in the Pacific Ocean near the Bay, and in the Bay's watershed

These objectives constitute a core direction in the Management Plan, because they effectively define the goals of ecosystem-based management, the overriding conceptual basis for the Management Plan and for nearly all ocean-based management plans under discussion at this time. In order to accomplish these objectives, this EIR finds that an additional policy should be included within the Plan directing District decision-makers to incorporate the relationships among the bay, the bay's watershed, and the Pacific Ocean as a primary functional policy direction for the Management Plan (see Subsection 8.4.1).

In substantive terms, the policy concerns identified in both of the preceding two subsections for the bay ecosystem elements also apply fully to the aquatic ecosystem elements for the Pacific Ocean. Management actions and uses of the waters or the resources of the bay ecosystem also have a potential for affecting the Pacific Ocean, and the lives and livelihoods of the people who depend on the ocean in this region.

8.2.3.4 Nontidal Streams, Wetlands, and Riparian Areas

The Plan's potential effects on these ecosystem elements are considered in Chapter 9.0. In general, the Plan does not address these areas directly, because the District does not have regulatory jurisdiction in nontidal streams, wetlands, and riparian areas. The Plan (Policy CAE-3) identifies the District's concerns for these areas as part of the bay ecosystem, and establishes guidance for District decision-makers to develop additional collaborative relationships with directly responsible agencies and other interested parties to assure that relevant ecosystem-based concerns are identified.

This EIR cannot determine whether the limited policy focus in the Management Plan will be sufficient to assure that possible adverse ecosystem impacts are avoided that would be related to impacts within nontidal stream, wetlands, and riparian areas. Based on the general effects on areas like this that occur within contemporary American culture (see,

e.g., Dahl 2000), it appears unlikely that the Humboldt Bay watershed can escape some degree of adverse impact to these ecosystem elements. However, it does not appear that additional policies in the Management Plan will change this result, which is largely beyond the Plan's reach.

8.4 POLICY CONSIDERATIONS FOR MITIGATING POTENTIALLY SIGNIFICANT EFFECTS

The policies recommended in the Draft Management Plan already largely address the Plan's potential environmental consequences, and the EIR generally finds that additional policy elements are unnecessary. However, the EIR finds that a policy addition to the proposed Plan that directs the District to consider the overall relationship between the uses designated in the Plan for the bay and the underlying ecosystem processes will clarify the basis for decision-making as the Plan is implemented, for District decision-makers and staff as well as for decision-makers and staff in other agencies, for applicants for District approvals, and for interested members of the public.

8.4.1 Ecosystem-Based Management

The Draft Management Plan currently lacks a policy that addresses the identified functional basis for the Management Plan, which is that management should be focuses upon the bay's ecosystem in order to maintain long-term functionality in the ecosystem in order to secure the befits of the functioning ecosystem for current and future residents in the region. In addition, the Plan currently lacks a policy focus that directs management attention to possible effects of management actions on the Pacific Ocean, even though it is generally known that activities within the bay may affect ocean resources. In order to remedy what is essentially a policy defect, the following new policy should be added to the Plan.

The new policy is designated as CAE-1. The policy should be inserted at the beginning of Subsection 5.2.2, Chapter 5.0, Section III, of the Management Plan, and existing policies numbered CAE-1 through CAE-4 should be renumbered as CAE-2 through CAE-5 (added text underlined):

CAE-1: Base management decisions on maintaining the Humboldt Bay ecosystem, including the bay, the watershed, and the nearby ocean

Policy: The District shall actively focus its implementation of the Management Plan on protecting, maintaining, and enhancing the biological, physical, hydrological, and human-oriented characteristics of the Humboldt Bay ecosystem. The bay's ecosystem includes the bay's watershed and the nearby Pacific Ocean, and management actions that affect any part of this aquatic ecosystem complex may affect all parts of the ecosystem. Many bay uses only affect ecosystem processes and structural elements indirectly, but the Management Plan recognizes that effects on ecosystem processes and structural elements may be significant even if indirect or attenuated. Decisions regarding the bay's management shall incorporate the understanding that the integrity of the bay's ecosystem elements determines many of the values that are important to the bay's users.

The incorporation of this additional policy into the Plan will avoid leaving an issue of likely CEQA significance unaddressed in the Plan.