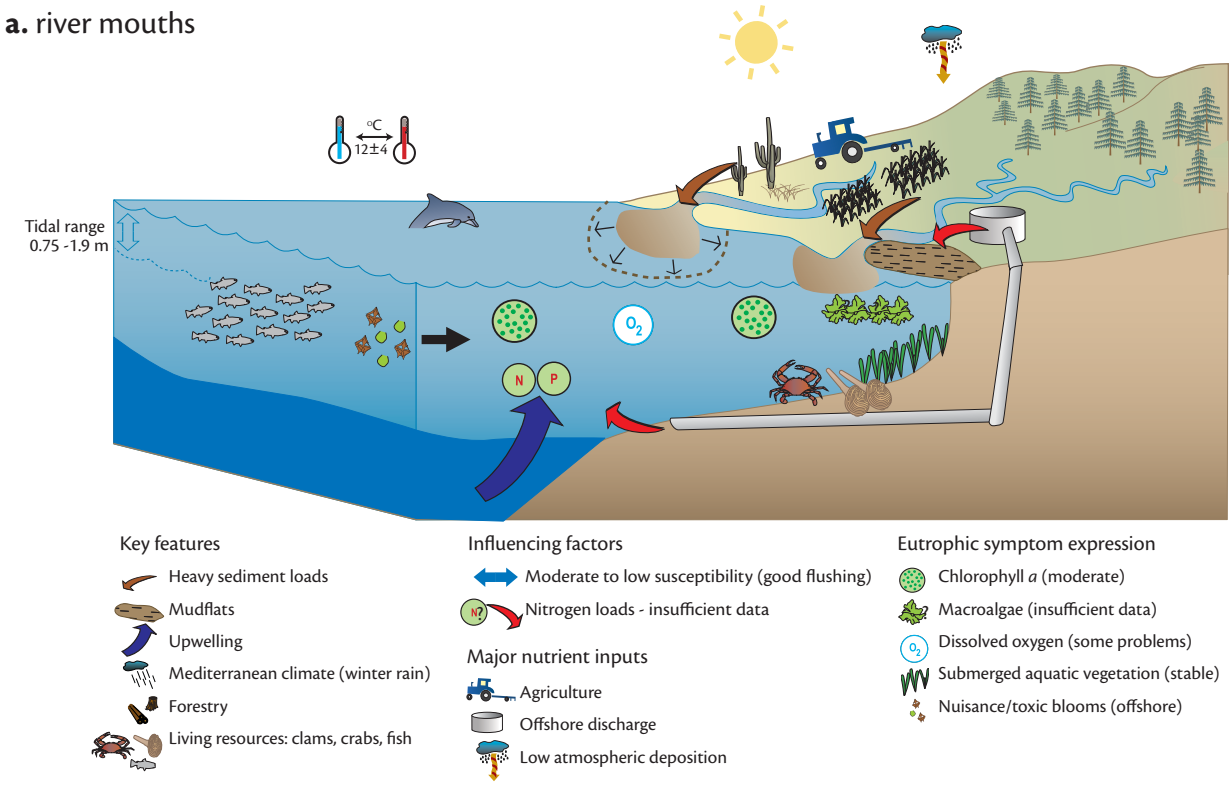
PACIFIC COAST REGION

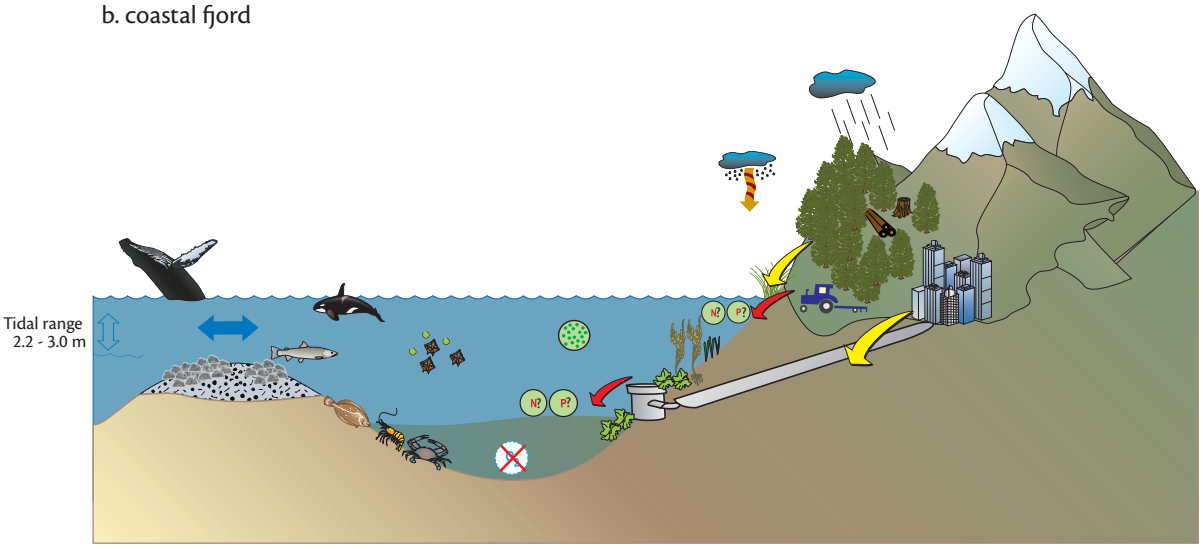
- Very few estuaries have nutrient load data available.
- Most estuaries with reported problems were located in Washington State and central California, with chlorophyll *a* and dissolved oxygen being the major eutrophic symptoms.
- Only one system was rated with a high overall eutrophic condition.

The Pacific Coast region includes 39 estuaries, encompassing more than 7,113 km² of water surface area. The region consists of a relatively straight and uninterrupted shoreline with rocky shores, sandy beaches, and occasional river outlets (Figure 4.17a-c). Limited areas of flat, lowland environments support estuaries, bays, and lagoons. The river mouth estuaries are found in Oregon (Figure 4.17a), the fjord systems in northern Washington State (Figure 4.17b), and the lagoons are mostly found in California (Figure 4.17c). The water bodies along the Pacific coast are typically small and separated by large distances. Estuarine circulation patterns are dominated mainly by seasonal freshwater inflow in southern California and by freshwater inflow and tides in the larger estuaries of central California and Washington. Tidal range is variable (0.75–3.0 m), with higher averages found in the fjord systems (2.4 m). Likewise, the depth range is large (0.2–96m), with higher average depths found in the Washington State fjord systems (66 m). Precipitation in the northern part of the region (1.7 m yr^{-1}) is more than

Figure 4.17. Conceptual diagram of Pacific Coast key features, major nutrient sources, and resulting symptoms.



b. coastal fjord



Key features

- Rocky
- Mediterranean climate
- Fringing marsh and seagrass
- Kelp beds
- Forestry
- Living resources: crabs, fish

Influencing factors

- Moderate to low susceptibility (good flushing)
- Nitrogen loads - insufficient data

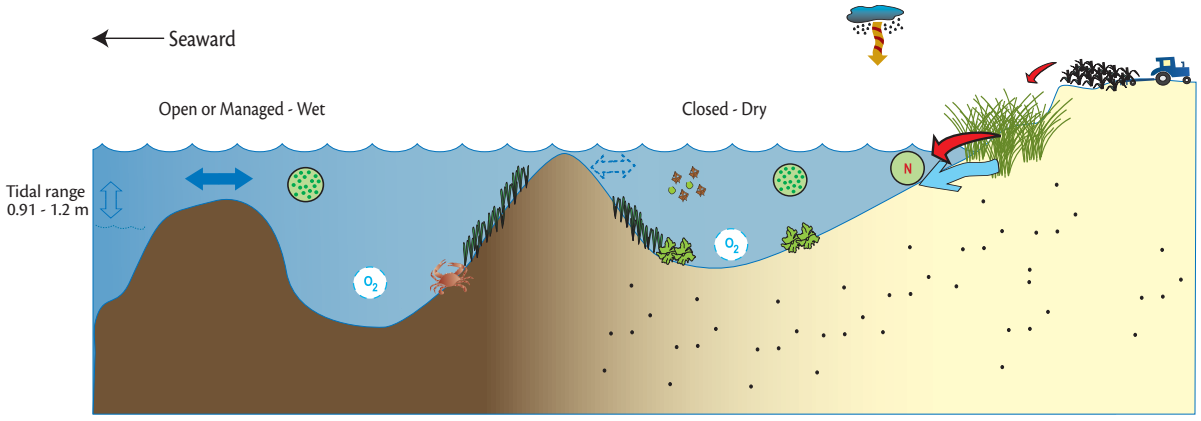
Major nutrient sources

- Agriculture
- Urban; offshore discharges
- Stormwater
- Low atmospheric deposition

Eutrophic symptom expression

- Chlorophyll *a* (high)
- Macroalgae (moderate)
- Dissolved oxygen (moderate to low expression)
- Submerged aquatic vegetation (stable or nonexistent)
- Nuisance/toxic blooms (low)

c. lagoons



Key features

- Freshwater inflow
- Muddy and sandy bottoms
- Small marsh
- Seagrass beds
- Living resources: crabs

Influencing factors

- Moderate to low susceptibility (poor flushing)
- Hign nitrogen loads

Major nutrient inputs

- Agriculture
- Low atmospheric deposition

Eutrophic symptom expression

- Chlorophyll *a* (high)
- Macroalgae (mostly low)
- Dissolved oxygen (some problems)
- Submerged aquatic vegetation (stable)
- Nuisance/toxic blooms (moderate)

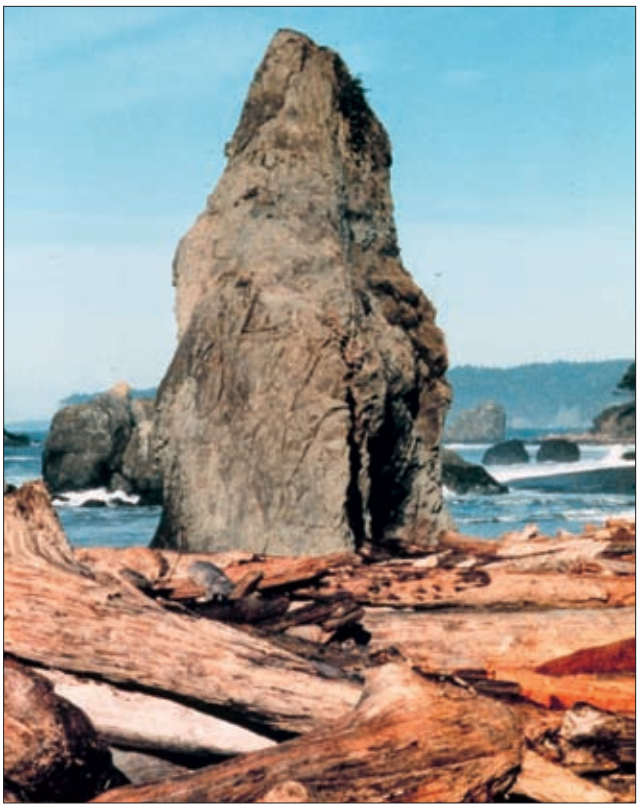
twice that recorded in California (0.57 m yr^{-1}). Air temperature and frost days show a similar pattern in Washington and Oregon, with average annual temperatures of 10°C and 79 frost days per year, while California averages annual temperatures of 15°C and 35 frost days per year. Some of the major population centers include Los Angeles, San Diego, San Francisco, and Seattle. Average population densities are also distinctly different in the northern and southern part of this region, with an average of 106 people per km^2 in California compared to 10 people per square kilometer in Washington and Oregon. The regional average population density is 33 people per km^2. Forestry, agriculture, and industry are the dominant land uses in the region (Figure 4.17a-c).

Influencing factors

- There were insufficient data to make conclusions about influencing factors in this region.

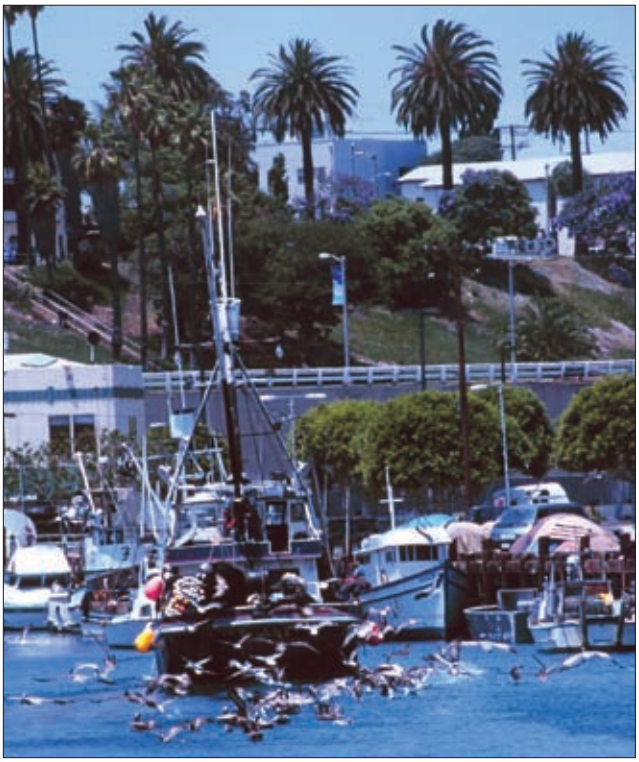
There were very little nutrient loading data for the Pacific Coast region; only four systems had load estimates (Figure 4.18). The load to Newport Bay, San Francisco Bay South, and Hood Canal are all classified as high. The susceptibility of systems in this region is varied, with the lagoonal systems in California characterized mostly by high susceptibility, due to low dilution and flushing capability. Alternatively, the river mouth estuaries in Oregon and Washington state are moderately susceptible on account of high flushing but low dilution capability. The fjord type systems in Washington State are in general less susceptible than other systems, due to high dilution and moderate flushing capability. These combinations lead to high values for influencing factors in Newport Bay and Hood Canal and moderate low in San Francisco Bay North.

It is not possible to conclude anything about influencing factors in this region, due to a lack of data. However, it is expected that the human influence on the expression of eutrophic symptoms is very high. Southern California systems in particular have high human influence because they are among the top ten U.S. estuaries with respect to watershed population density. Tijuana Estuary is also notable because three-quarters of the watershed is located in Mexico, making management an international challenge.



National Oceanic and Atmospheric Administration

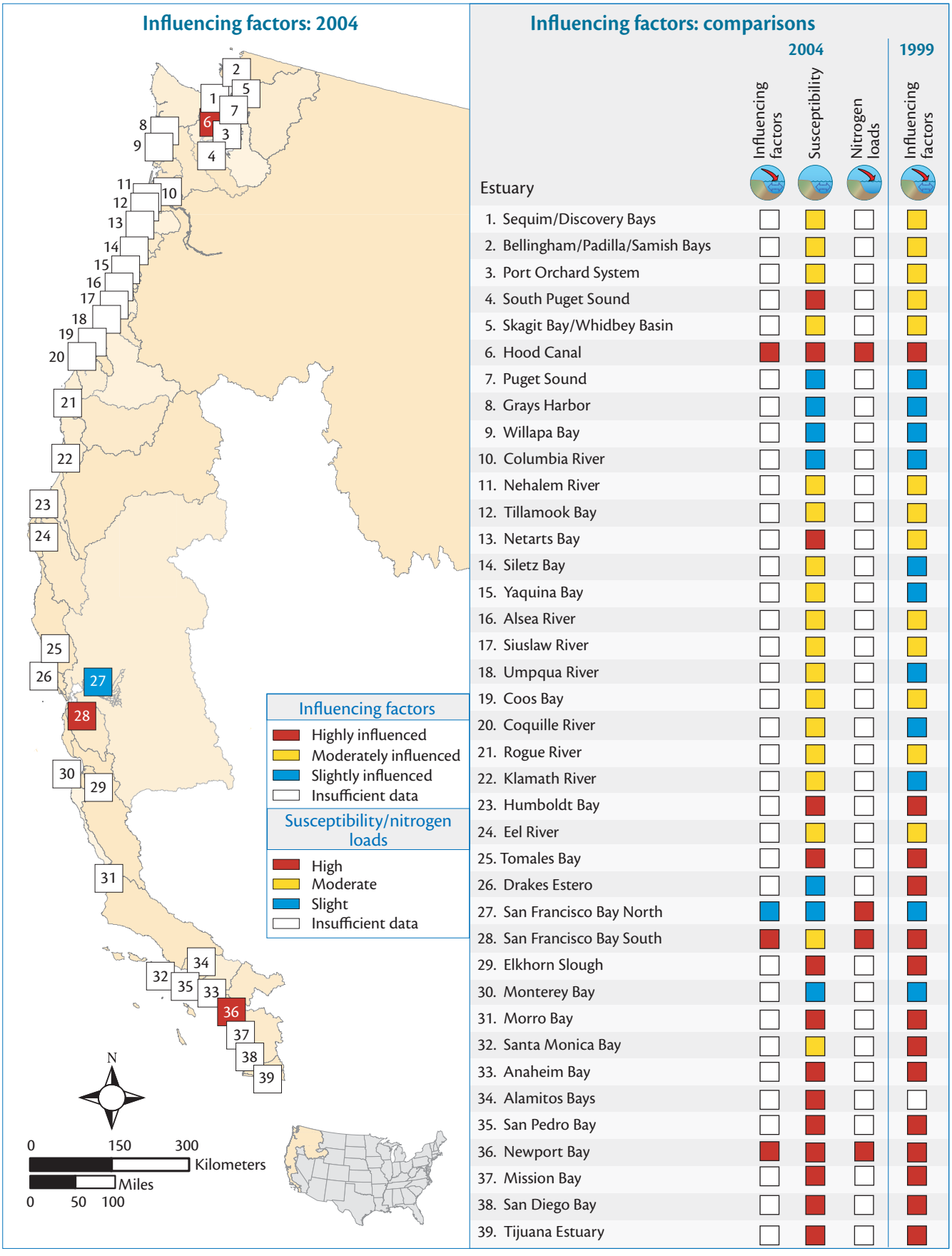
Pinnacle rocks and weather-beaten logs are characteristic of water bodies in Oregon and Washington.



National Oceanic and Atmospheric Administration

Pelicans following a fishing boat in San Pedro Bay, California. California estuaries are typically lagoons.

Figure 4.18. Map of influencing factors ratings, ratings of components of influencing factors, and 1999 ratings in the Pacific region.



Overall eutrophic condition

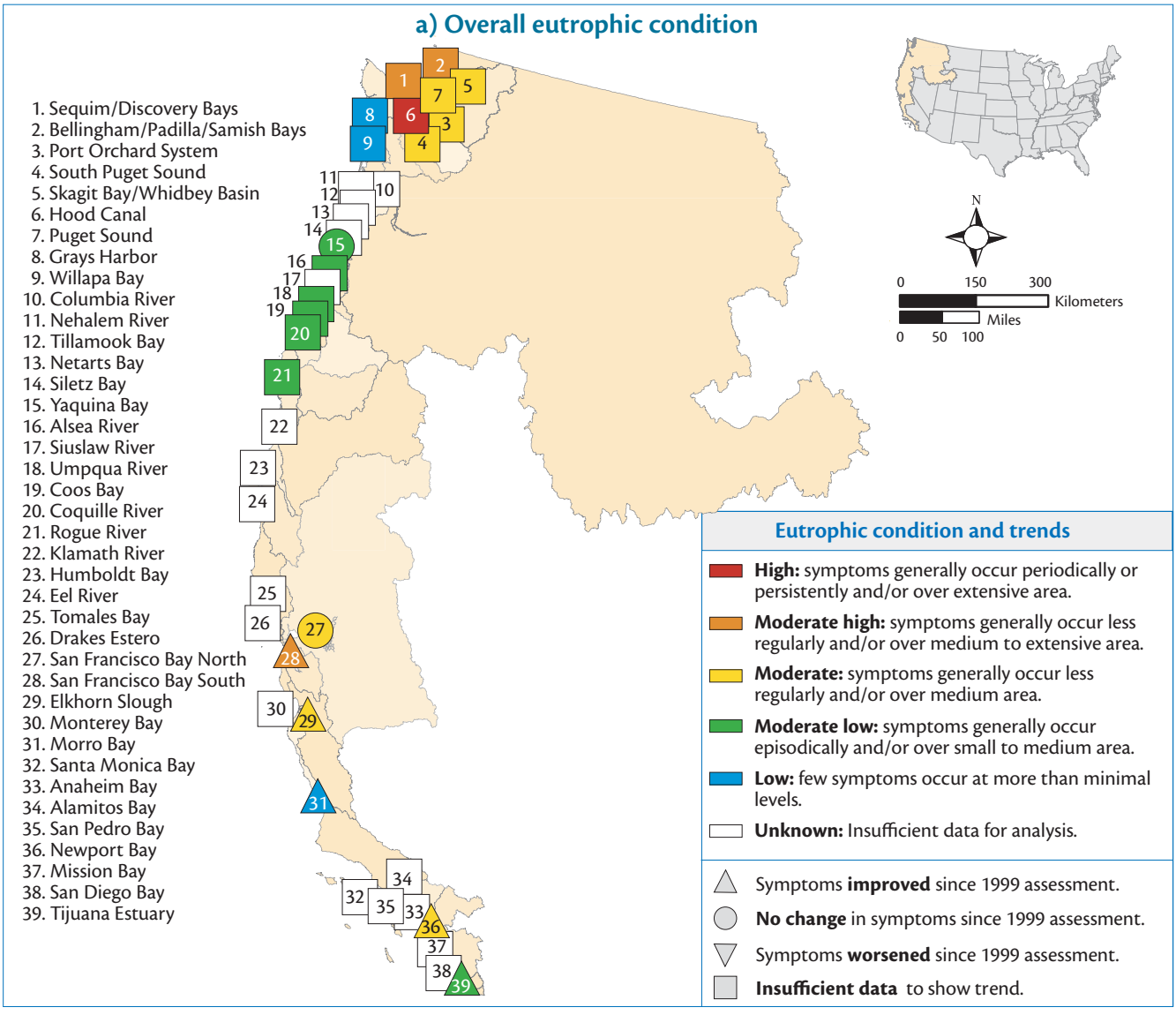
- Only one system had an overall eutrophic condition (OEC) rating of high.
- Most of the eutrophic estuaries in this region are located in Washington State and central California, with chlorophyll *a* and dissolved oxygen as the major symptom expressions.

Due to a lack of data, only half of the systems in this region were assigned an overall eutrophic condition rating (OEC). Of the assessed systems, those with moderate high to high OEC were located in the Puget Sound and San Francisco areas (Figure 4.19). In contrast, estuaries in the Oregon region all had moderate low overall eutrophic condition ratings.

Tim Carruthers, University of Maryland Center for Environmental Science

Estuarine mud flat at Morro Bay, California, showing extensive macroalgae growth.

Figure 4.19. (a) Map of overall eutrophic condition (OEC) and (b) the combination of individual eutrophic symptoms which constitute OEC ratings in the Pacific Coast.



b) Overall eutrophic condition & eutrophic symptoms

Estuary	Overall eutrophic condition	Overall confidence expression	Chlorophyll *a*	Macroalgae	Dissolved oxygen	Nuisance/toxic blooms	SAV
1. Sequim/Discovery Bays	Moderate high	**	High	Low	Moderate	Moderate	Low
2. Bellingham/Padilla/Samish Bays	Moderate high	**	High	Moderate	Moderate	Low	Low
3. Port Orchard System	Moderate	**	High	Moderate	Moderate high	Low	Low
4. South Puget Sound	Moderate	*	High	Moderate	Moderate high	Low	Low
5. Skagit Bay/Whidbey Basin	Moderate	**	High	Moderate	Moderate	Low	Low
6. Hood Canal	High	**	High	Moderate	High	Low	Low
7. Puget Sound	Moderate	**	High	Moderate	Moderate high	Low	Moderate high
8. Grays Harbor	Low	**	Low	Low	Moderate high	Low	Low
9. Willapa Bay	Low	*	Low	Low	Moderate high	Low	Low
10. Columbia River	Insufficient data	*	Insufficient data	Insufficient data	Insufficient data	Insufficient data	Insufficient data
11-13 (Nehalem River, Tillamook Bay, and Netarts Bay are unknown for all indicators)							
14. Siletz Bay	Insufficient data	*	Insufficient data	Insufficient data	Insufficient data	Insufficient data	Insufficient data
15. Yaquina Bay	Moderate low	*	Moderate	Insufficient data	Moderate high	Insufficient data	Insufficient data
16. Alsea River	Moderate low	*	Moderate	Insufficient data	Moderate high	Insufficient data	Insufficient data
17. Siuslaw River	Insufficient data	*	Insufficient data	Insufficient data	Insufficient data	Insufficient data	Insufficient data
18. Umpqua River	Moderate low	*	High	Insufficient data	Moderate high	Insufficient data	Insufficient data
19. Coos Bay	Moderate low	*	Moderate	Insufficient data	Moderate high	Insufficient data	Insufficient data
20. Coquille River	Moderate low	*	High	Insufficient data	Moderate high	Insufficient data	Insufficient data
21. Rogue River	Moderate low	*	Moderate	Insufficient data	Moderate high	Insufficient data	Insufficient data
22. Klamath River	Insufficient data	*	Insufficient data	Insufficient data	Insufficient data	Insufficient data	Insufficient data
23-25 (Humboldt Bay, Eel River, and Tomales Bay are unknown for all indicators)							
26. Drakes Estero	Insufficient data	*	Insufficient data	Insufficient data	Insufficient data	Insufficient data	Insufficient data
27. San Francisco Bay North	Moderate	**	High	Low	Moderate high	Moderate	Low
28. San Francisco Bay South	Moderate high	*	High	Low	Moderate high	High	Low
29. Elkhorn Slough	Moderate	**	Low	High	Low	Insufficient data	Moderate high
30. Monterey Bay	Insufficient data	*	Insufficient data	Insufficient data	Insufficient data	Insufficient data	Insufficient data
31. Morro Bay	Low	**	Insufficient data	Low	Moderate high	Low	Low
32. Santa Monica Bay	Insufficient data	*	Insufficient data	Insufficient data	Insufficient data	High	Insufficient data
33. Anaheim Bay	Insufficient data	*	Insufficient data	Insufficient data	Insufficient data	Insufficient data	Insufficient data
34. Alamitos Bay	Insufficient data	*	Insufficient data	Insufficient data	Insufficient data	Insufficient data	Insufficient data
35. San Pedro Bay	Insufficient data	*	Insufficient data	Insufficient data	Insufficient data	Insufficient data	Insufficient data
36. Newport Bay	Moderate	*	Insufficient data	High	Low	Insufficient data	Low
37. Mission Bay	Insufficient data	*	Insufficient data	Insufficient data	Insufficient data	Insufficient data	Insufficient data
38. San Diego Bay	Insufficient data	*	Insufficient data	Insufficient data	Insufficient data	Insufficient data	Insufficient data
39. Tijuana Estuary	Low	**	Low	Low	Low	Moderate high	Moderate high

Eutrophic condition in 2004
- High
- Moderate high
- Moderate
- Moderate low
- Low
- Insufficient data

Overall confidence expression in 2004
- *** High
- ** Moderate
- * Low

Change in eutrophic condition since 1999 assessment
- Improved
- No change
- Worsened
- Insufficient data

Shih-Nan Chen, University of Maryland Center for Environmental Science

An algal bloom in the Columbia River near Astoria, Oregon.

In general, the symptoms contributing most to the higher level eutrophic conditions were elevated levels of chlorophyll *a* and dissolved oxygen problems. The confidence in the assessment of individual systems and overall confidence in the region was mostly low due to low availability of data (Figure 4.19).

Eutrophic symptom expressions

Of the primary symptoms, chlorophyll *a* was expressed at high levels in nine systems, and at moderate levels in seven systems. Macroalgae data were reported for 15 systems, with a symptom expression of high in two, moderate in seven, and low in six estuaries. Of the secondary symptoms, dissolved oxygen was high in one system, moderate in three, and low or no problem in 17 systems. However, in a few systems (Bellingham/Padilla/Samish and Sequim/Discovery Bays), these ratings may not be effective at representing dissolved oxygen conditions. These particular systems are influenced by inflows of upwelled oceanic water which is low in dissolved oxygen, and therefore contributes to dissolved oxygen problems which might otherwise be attributed to human influence. Nuisance/toxic blooms were reported for only five systems, with moderate level problems observed in only two systems. Loss of submerged aquatic vegetation was reported as low or no problem for nine systems, while the remaining 30 systems were unknown. Part of the reason for the paucity of data for the Oregon systems is that other issues, such as contaminants, are considered more of a pressing concern than eutrophication.

Changes in eutrophic condition since the 1990s

Comparison of data with the 1999 assessment shows that five systems have improved, mostly due to improved chlorophyll *a* and dissolved oxygen conditions. Two systems have remained the same since the 1999 assessment but for most systems a change could not be determined (Figure 4.19). It is difficult to draw any conclusions about patterns in this region due to a lack of data for recent conditions and thus trends analysis.

Future outlook

- There were insufficient data to make any conclusions about future outlook.
- Of the eight systems for which future outlook was reported, most are expected to worsen.

Five estuaries in the Pacific Coast region were predicted to develop worsening conditions in the future, while three were predicted to improve. There was no information for 31 systems.

The reported reasons for worsening conditions were onsite septic tanks, urban runoff, and forestry (the latter in Hood Canal only). The potential reasons for future improvement were noted as changes to industry, urban runoff (Newport Bay), and agriculture. Expected improvements in Santa Monica Bay are attributed to the Total Maximum Daily Load (TMDL) for Malibu Creek, which is expected to decrease the nutrient loads. However, these may be offset by increased atmospheric inputs. Consequently, the decrease is expected to be small.

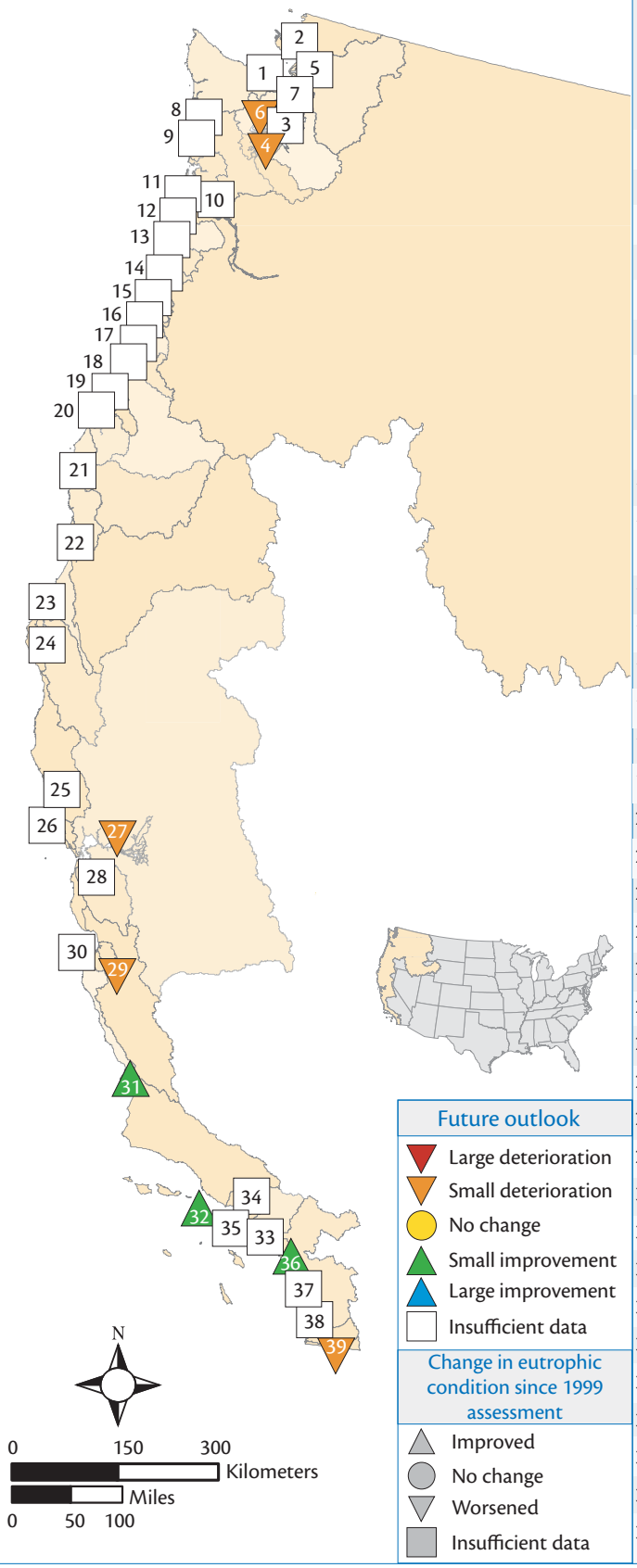
There is insufficient data to make overall conclusions about future outlook. Of the seven systems for which a comparison could be made, only one was consistent with future outlook predictions from 1999 (San Francisco Bay North). This result may stem from the fact that these expected changes are for the year 2020. While some areas demonstrate condition changes sooner than others, the accuracy of these particular predictions should be addressed in 2020, or predictions should be made for a shorter time scale.

Assessment of Estuarine Trophic Status (ASSETS)

Only three systems received an ASSETS rating, which combines influencing factors, overall eutrophic condition, and future outlook. Hood Canal was characterized as bad, and both Newport and San Francisco Bay as moderate.

Figure 4.20. Future outlook in 2004 and comparison with 1999 future outlook.

Future outlook in 2004



Future outlook comparisons

Estuary	Future outlook in 2004	Actual change in eutrophic condition (1999 - 2004)	Future outlook in 1999
1. Sequim/Discovery Bays			
2. Bellingham/Padilla/Samish Bays			
3. Port Orchard System			
4. South Puget Sound			
5. Skagit Bay/Whidbey Basin			
6. Hood Canal			
7. Puget Sound			
8. Grays Harbor			
9. Willapa Bay			
10. Columbia River			
11. Nehalem River, Tillamook Bay, and Netarts Bay are unknown for future outlook and overall eutrophic condition.			
14. Siletz Bay			
15. Yaquina Bay			
16. Alsea River			
17. Siuslaw River			
18. Umpqua River			
19. Coos Bay			
20. Coquille River			
21. Rogue River			
22. Klamath River			
23. Humboldt Bay			
24. Eel River			
25. Tomales Bay			
26. Drakes Estero			
27. San Francisco Bay North			
28. San Francisco Bay South			
29. Elkhorn Slough			
30. Monterey Bay			
31. Morro Bay			
32. Santa Monica Bay			
33. Anaheim Bay			
34. Alamitos Bay			
35. San Pedro Bay			
36. Newport Bay			
37. Mission Bay			
38. San Diego Bay			
39. Tijuana Estuary			

Impaired uses

- Six systems had impacts to living resources.
- Human uses were reported to be impaired in only one system, for commercial and recreational fishing; other systems are unknown.

Considerable impacts to living resources were reported for Newport Bay, moderate impacts for Elkhorn Slough and Hood Canal, and slight for Klamath River, Tijuana Estuary, and Morro Bay. The reasons for impacts to living resources, noted only for Klamath River, were agriculture, upstream land use, and upriver hydroelectric and diversion projects that reduce flow downstream.

Potential management concerns

Potential sources to target for improvements to overall eutrophic condition in Washington estuaries are wastewater treatment, urban runoff, on-site animal operations, agriculture, and forestry. In southern California, wastewater treatment, urbanization, stormwater, industry, agriculture, and forestry were cited.

Data gaps and research needs

Monitoring

The estuaries of the Pacific Coast are predominantly understudied. Therefore, there is a need for baseline monitoring of basic water quality parameters on an annual time frame in these areas. Additionally, better loading estimates should be a top priority. Forecasting models for prioritization of systems for management, integration of sampling technologies, assessment of variation among current indicators,

USDA National Resources Conservation Service

Downtown Seattle, Washington. As urbanization and impervious surfaces increase, more research and monitoring, and better nutrient management will be needed.

USDA Forest Service, National Wild and Scenic Rivers System

Living resources in the Klamath River, California, are impacted by river diversions and reduced flow.

and use of restoration effectiveness measures should be encouraged. *In situ* sampling should be coordinated with programs designed for satellite and remotely sensed observations, such as the U.S. Integrated Ocean Observing System (IOOS) to maximize data resources. Data and results should also be shared with programs like the National Water Quality Monitoring Network (NWQMN) for coordinated wide distribution.

Research

Priorities for research in this region include improving the understanding of: (1) improve understanding of the mechanisms involved with nutrient loads, including the role of groundwater pulses, hydrologic alteration, impervious surfaces, and significant weather events; (2) the interactions of complicating and synergistic factors such as food web and predator alterations, climate change, and shoreline hardening; (3) the development of operational forecasting models, and (4) development of better techniques for load and flushing estimates, and (5) refinement of the susceptibility index.

Management

It is important to evaluate impacts of various nutrient sources, including population, onsite septics (exurban areas), agriculture, wastewater treatment, atmospheric loading and deposition, impervious surfaces, and urban runoff in order to implement appropriate management measures. Integration of EPA (regulatory) and NOAA and USGS (assessment) approaches should also be explored. A much better understanding is needed of the linkages between nutrient inputs, productivity, and eutrophication.