4. CONCLUSIONS AND RECOMMENDATIONS

This work was intended to summarize surface layer conditions (both typical and atypical) as depicted from long-term satellite data series. The suite of remote sensing data, presented as conventional maps, Hovmöller diagrams, and statistical plots, afforded simplicity in summarizing conditions for the region. In particular, merged satellite oceanographic data revealed information on:

- seasonal cycles and transition periods
- linkages between seasonal warming and cooling, upwelling/downwelling, transport, and wind influences
- seasonal nutrient sources and physical limiting factors controlling surface layer responses
- interannual cycles and general response to climate oscillations (ENSO)

All surface layer data collected and analyzed near the Olympic Coast National Marine Sanctuary exhibited change during a typical annual cycle. Using climatological summaries of average (expected) conditions, and through correlation maps and Hovmöller diagrams along three respective transect lines, periodic seasonal and subseasonal shifts in surface conditions affecting the OCNMS were interpreted. Five fairly distinct seasonal cycles were evident in the ocean climate data summaries and were consistent with the known literature.

Insights on underlying processes and limiting factors controlling surface response and nutrient sources affecting the sanctuary were documented. The correlation patterns of surface water properties were found to be spatially and temporally tied to upwelling/downwelling cycles, outflow from the Juan de Fuca Strait, the Columbia River, coastal/estuarine influence, and increased light availability (Figure 37).

There is general agreement that January is typically dominated by downwelling favorable winds, precipitation influence (coastal/estuarine), and Columbia River discharge. During May, strengthened upwelling, increased regional heating and Juan de Fuca outflow influence surface layer characteristics most dramatically. In July, surface layer responses are indicative of enhanced upwelling, increased light and temperature, with available nutrients out of the Juan de Fuca Strait promoting chlorophyll production along the entire Olympic Coast. Late September/early October is typically dominated by increased chlorophyll production and westward propagation of SST fronts and eddies. Increased Ekman transport, driven by local alongshore winds, appears to be the governing forcing mechanism on this early fall chlorophyll peak enhancement (Strub, pers. comm.). Numerous surface reflections appear to be coincident with primary chlorophyll peak including decreases in localized SST, suppressed SSHA, and lower turbidity conditions that are evident in a 2-week interval prior to and during chlorophyll peaks. Further investigation is needed to assess the periodicity and predictability of this phenomenon.

The remote sensing data also provided insights on isolating upwelling responses and the nature of frontal features for the region. Since the surface patterns that were represented revealed periodicity and covariability, further testing of relationships could be used to discern specific cues involving upwelling response, based on a combination of surface and subsurface characteristics. In addition, chlorophyll variability indicators were identified as a proxy for phytoplankton activity at specific time periods during the upwelling cycle. This information could also be used to discern specific timing cues for individual species assemblages.

This report reviewed and summarized remotely sensed proxies needed for building appropriate decision support tools, including integrated assessments. General uses of core variables estimated from satellite are shown (Figure 46) as a basis for environmental characterization, resource evaluation and problem detection. Characterization and resource evaluation involve developing baselines of environmental parameters for trend detection, where data is extracted and subsequently integrated with biological and habitat information. Problem detection involves using remote sensing data to identify physical oceanographic and climatological conditions (and/or processes) directly and indirectly related to coastal water quality issues (e.g. low DO conditions and harmful algal blooms). It is suggested that a thorough analysis of expected surface conditions using a suite of merged information is critical in characterization and resource evaluation, problem detection, and trend determination. Assimilation of remotely sensed data for environmental modeling purposes will con-

tinue to evolve through improvements in satellite engineering and optics.

An essential requirement for marine resource evaluation and assessment involves the integration of spatially and temporally resolved oceanographic datasets. Through this work, a merged suite of oceanographic data was summarized to provide a foundation for building assessment capability and design, wherein merged data types are of more significance than singular data types. Integration of this form works in many ways to improve remote sensing utilization through a more spatially and temporally comprehensive assessment of surface patterns and variability, and an increased understanding of interactions between processes, habitats, and resources necessary for sustained ecosystem function. Development of indicators of biological response using a full suite of remote data types should be a priority for future work involving marine resource evaluation and assessments.

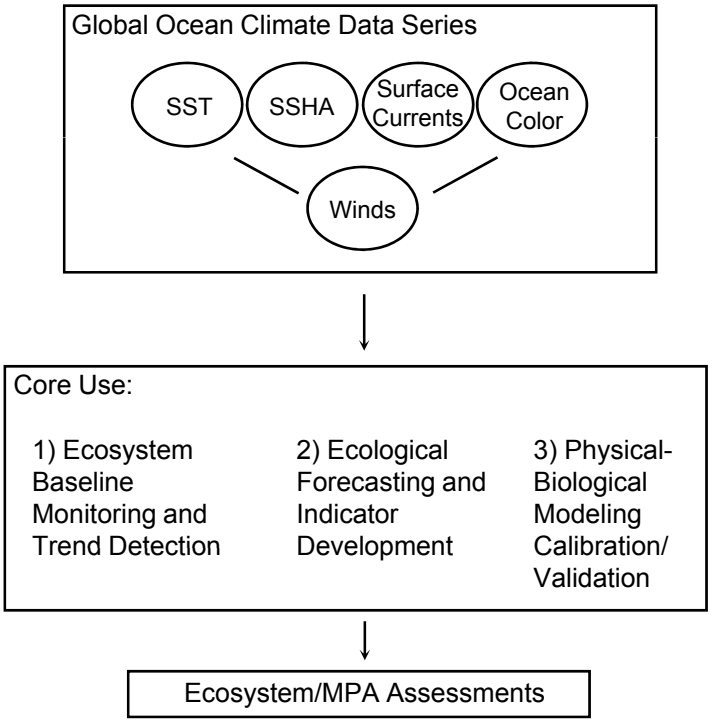

Figure 46. Schematic describing general uses of remotely sensed parameters (proxies) outlined in this report for ecosystem resource evaluation, problem identification, and management decision support.

NOAA's National Center for Coastal Ocean Science (NCCOS), Office of National Marine Sanctuaries, and National Marine Fisheries Service have consistently worked to merge datasets (and disciplines) for improved ecosystem-based management. As an example, NCCOS's Biogeography Program relies on multifaceted data to study the relationship of species distribution patterns relative to geographical differences in the environment, with added specificity to marine-managed boundary concepts (NCCOS, 2005). For many protected areas, basic biological and physical data are lacking in spatial and/or temporal resolution. This remote sensing baseline is central for understanding the region in a broader context and how the biology and oceanographic conditions of a region change through time.

In summary, the data and analysis presented here were intended to be the first of many steps to address present and future management questions posed by the OCNMS. The intent was to demonstrate how long-term data series could contribute to a better understanding of oceanographic variability and processes along the Pacific Northwest and elsewhere. This summary should be used as a vehicle for future discussions and work posed by joint partnerships between funding agencies, including NOAA and the research community vested in ocean science.