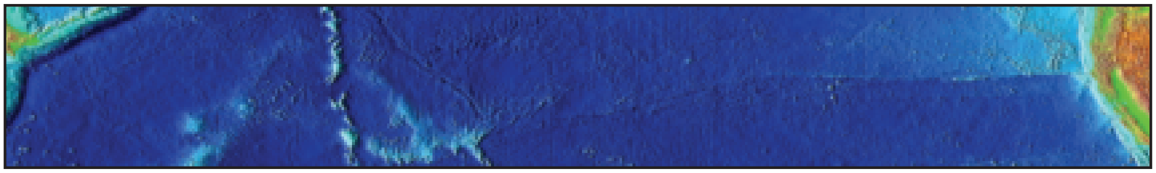
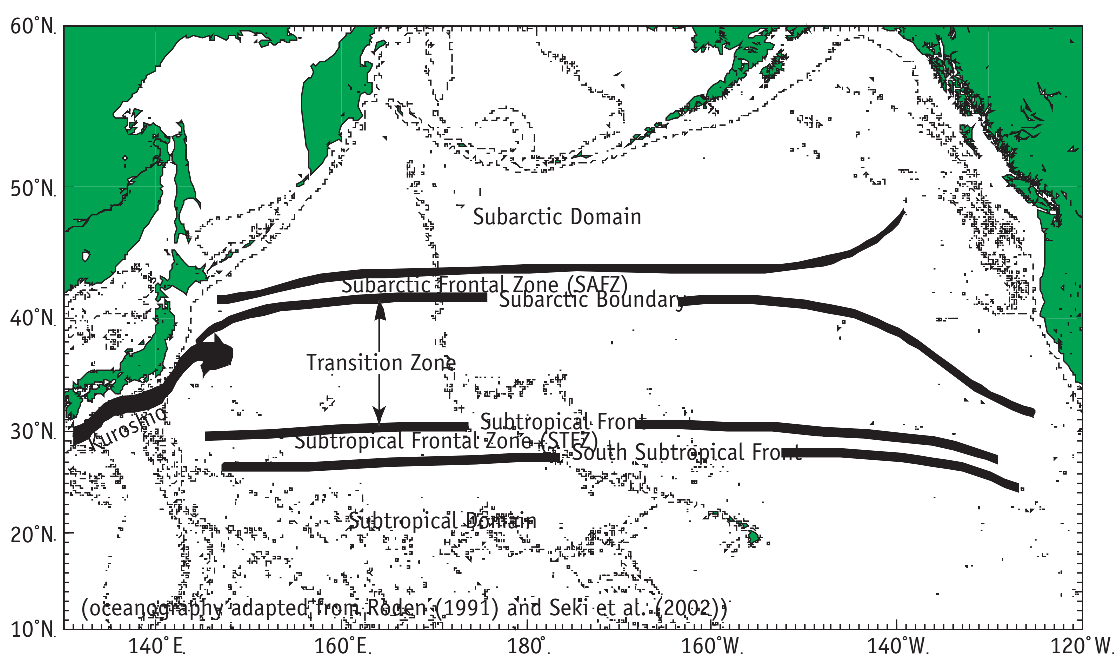
Transition Zone

background



The central North Pacific Transition Zone (hereafter the Transition Zone) (Figure 137), is climatologically positioned between the 32°N and 42°N latitudes. Large-scale frontal systems that bound the Transition Zone to the north and south play a key role in defining the biology of the region. Many animals, including some of the most populous species (e.g., flying squid, Pacific pomfret, blue sharks, Pacific saury) that inhabit the Transition Zone undergo extensive seasonal migrations from summer feeding grounds at the subarctic fronts or within subarctic waters to and from winter spawning grounds in the subtropics.

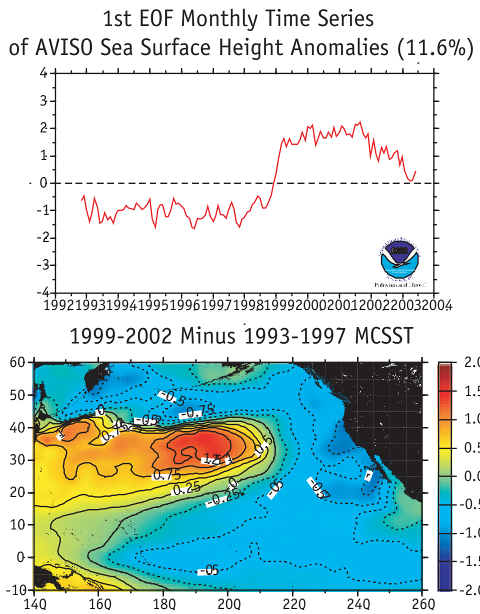
Several commercial fisheries currently operate in Transition Zone waters, including Japanese and U.S. vessels targeting tunas and billfishes, Japanese and U.S. troll vessels targeting tunas (notably albacore tuna), and a distant water Japanese (and much lesser extent U.S.) jig fishery for squid. The now defunct multinational Asian high-seas driftnet fishing fleets targeting squid and tunas and billfishes also operated in Transition Zone waters until 1992. Information gleened from the observer program tasked with monitoring the driftnet fisheries provided much of our current understanding of the region's nektonic faunal composition.



[Figure 137] Schematic representaiton of the North Pacific transition zone and its relation to the major features of the North Pacific ocean.

Status and Trends

The central Pacific region that includes most of the Transition Zone generally exhibits a low-frequency oscillation between anomalously cooler and warmer phases. Presently, the central Pacific region appears to be in a warm phase with elevated temperatures and increased sea level height (SLH); a rapid phase shift from cooler, lower SLH was observed in 1998-99 (Figure 138). These temperature phases have been shown to be in generally good coherence with indices from an empirical orthogonal function (EOF) analysis on detrended sea level height (SLH) data from the TOPEX/JASON satellites and with the Pacific Decadal Oscillation (PDO) index.



[Figure 138] The magnitude of the detrended variation in the first mode of the EOF analysis of sea level height is illustrated in the top panel. The bottom panel presents the difference in SST (°C) anomalies of the period 1993-98 subtracted from the period 1999-2000.[368]

Hydrography

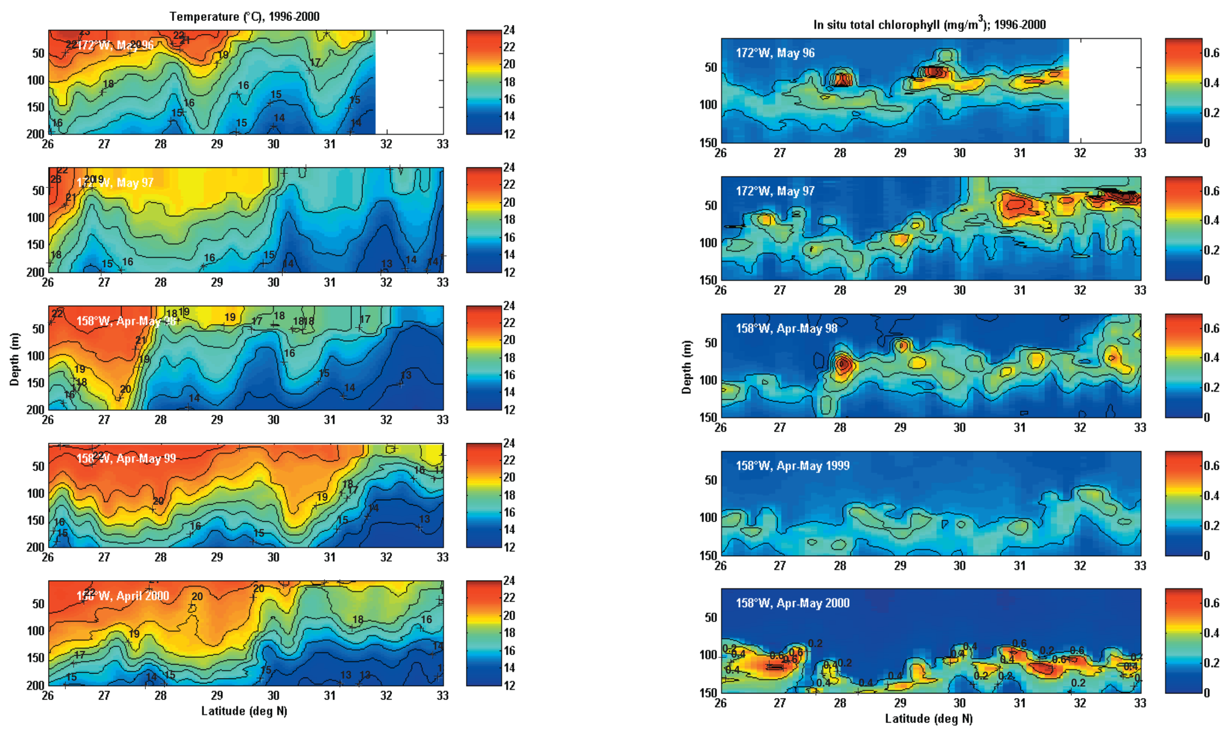
Transition Zone waters are characteristically of both subarctic and subtropical origin and are present in proportions reflecting lateral mixing along isopycnal surfaces and distance from their source regions.[369,370] Surface temperatures and salinities gradually increase from north to south and the vertical distribution of properties is highlighted by a deep salinity minimum of about 33.9 ± 0.02 that slopes gradually southward from about 400-450 m north (ca. 40°N) to about 550-600 m at the southern bounds; the salinity minimum is reportedly associated with a σ_t of 26.70±0.04 $g \cdot l^{-1}$.[371,369,372] Additionally, there is no shallow temperature minimum, high-stability layer (hydrostatic stabilities are lower here than anywhere else in the open North Pacific), nor a well developed halocline.

At the northern and southern boundaries of the Transition Zone are the Subarctic (SAFZ) and Subtropical (STFZ) Frontal Zones, respectively (Figure 137). These frontal zones, stretching laterally across the central North Pacific, are typically regions embedded with multiple individual surface fronts that signify abrupt changes in thermohaline properties with change in latitude. Climatologically, the SAFZ is located at about 40° to 43°N latitudes, a region of strong eastward wind stresses (i.e., the Westerlies). The STFZ, on the other hand typically occupies the region around 28°N to 34°N latitudes, an area of minimum zonal wind stress and just north of the area corresponding to the strongest net evaporation gradients in the region dynamically influenced by the Ekman transport convergence from the subtropical easterly tradewinds.[372,373,374] The dynamics and structure of the Transition Zone and its frontal zones are thus principally driven by the large scale convergent wind-driven currents.

The SAFZ extends from about 40°N to 43°N latitudes and separates the cold (<8°C), low salinity (33.0) subarctic water from the transitional region and subtropical waters to the south. The limits of the SAFZ are defined by the surface outcroppings of the 33.0 isohaline to the north (the southern bound of unadulterated subarctic water) and the 33.8 isohaline to the south. These isohalines generally form the bottom and top of the halocline in the Subarctic Domain. The southern limit of the SAFZ, historically referred to as the Subarctic Front[375] or the Subarctic Boundary[376] can also be characterized by the vanishing of large temperature inversions that might exist in the subarctic halocline and by the rapid increase in the depth of the 9° and 10°C isotherms.[370] Since horizontal temperature and salinity gradients in the surface layer exist in near balance, fronts at the SAFZ are almost totally density compensated (i.e., only weak density gradients exist) and baroclinic flow dynamics do not play a major role in defining the region's oceanographic patterns.[369,372,375]

Considerably different characteristics are found associated with the STFZ. The STFZ is a broad, generally zonal band between about 28°N and 34°N latitudes.[377] At the surface, cooler, lower salinity water from the north, converges with and sinks below warmer, saltier subtropical water found to the south resulting in a broad geographic region of physical gradients. Accordingly, multiple, large-scale, individual, semi-permanent fronts form, the most prominent climatologically located at 32°-34°N and at 28°N-30°N latitudes.

These particular fronts, nominally referred to as the Subtropical Front and the South Subtropical Front, respectively,[377] are typically associated with the meridional bounds of the frontal zone.[373,378] Roden[374,370] describes the STFZ as the latitudinal belt that divides cooler (<18°C), lower saline (<34.8) surface water from warm (>18.5°C), higher-saline (>35.1) water. Considerable interannual variability in the latitudinal position and intensity is apparently characteristic of the STFZ fronts, as evidenced in annual springtime surveys conducted along the 172°W (1996-97) and 158°W (1998-2000) longitudes (Figure 137).



[Figure 139] Comparative vertical sections of (left) temperature (°C) and (right) chloropigment (mg m^{-3}) from annual surveys 1996-2000; 1996-97 surveys conducted along 172°W and 1998-2000 along 158°W longitudes.

The fronts of the STFZ differ from those at the SAFZ in other respects. First, the STFZ fronts tend to exhibit moderate to significant density gradients in the upper 100m in response to the incomplete balance that exists between the meridional temperature and salinity gradients. The resultant baroclinic flow field has significant influence on the three dimensional mesoscale dynamics and is thus instrumental to the formation of the frontal structure observed on synoptic time scales.

Explicitly, the subtropical fronts are characterized by strong, meandering west to east current flow patterns, with pervasive mesoscale cyclonic activity to the north and anticyclonic rotating features to the south of the strongest streamlines. Unlike subarctic fronts, surface temperature (and thus density) fronts at the STFZ are not present all year round. Intense insolation during summer obliterates horizontal temperature gradients and inhibits the manifestation of the STFZ temperature fronts in months outside the cooler periods from late fall through winter to spring (Figure 140). Surface salinity fronts, however, are present at both the SAFZ and STFZ throughout the year.

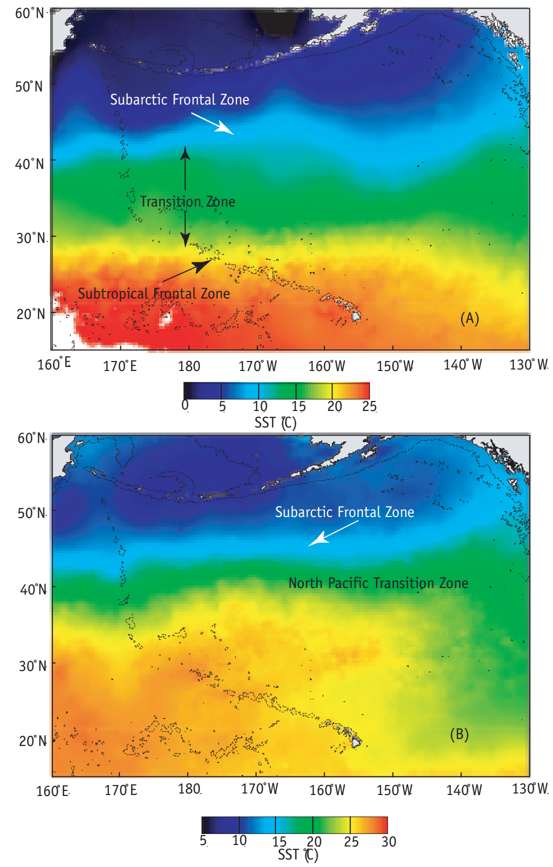
Chemistry

Concentrations of nutrients (e.g., nitrate, phosphate, and silicate) in the Transition Zone generally reflect the gradient between the high levels found in the Subarctic and low levels in the Subtropics. During the summer, the stratified, oligotrophic waters of the Transition Zone are generally thought to be N-limited.[379]

Plankton

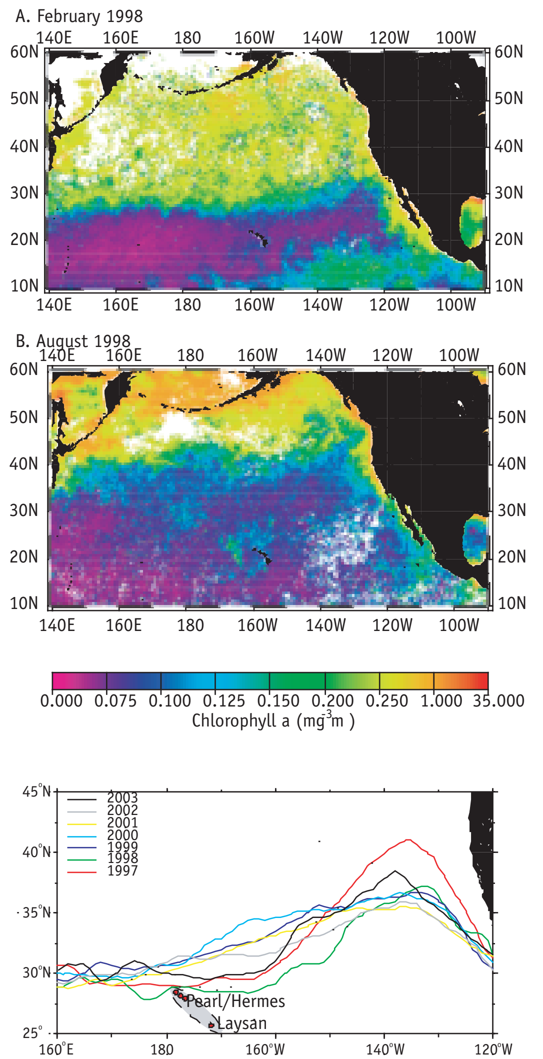
While plankton dynamics in the Transition Zone have been poorly studied when compared to the adjacent subarctic and subtropical waters to the north and south, respectively, it's evident that the Transition Zone is heavily influenced by high gradient regions of horizontal oceanographic variability; i.e., large-scale frontal systems (biological as well as physical) and mesoscale dynamic features (such as meanders, eddies, and jets) where productivity is enhanced and so much of the ecosystem energy is mobilized.

Phytoplankton With limited information available from direct observations, satellite remote sensing of surface chl-a densities provides our best insight into the phytoplankton dynamics of the Transition Zone. In the subtropical central Pacific, surface chl-*a* concentrations are generally <0.15 $mg \cdot m^{-3}$ and northward towards the subarctic are >0.25 $mg \cdot m^{-3}$.



[Figure 140] False color image of basinwide sea surface temperature (°C) structure for (A) late winter-early spring, e.g., March-April 1992 and (B) summer, e.g., August 1991. The satellite SST data are weekly averaged 18 km gridded daytime multichannel SST (MCSST) from archived Tiros-N/NOAA Advanced Very High Resolution Radiometer (AVHRR).

Between these regions of high/low surface chlorophyll lies a sharp basin-wide surface chl-a front, the Transition Zone Chlorophyll Front (TZCF). The TZCF seasonally oscillates north to south about 1000 km with a latitudinal minimum in January-February and maximum in July-August (Figure 141). This biological front also exhibits considerable interannual variations in position, meandering, and gradient strengths. For example, prior to 1999, the southern minimum of the TZCF resided below 30°N, reaching the waters close to and including the NW end of the Hawaiian Archipelago while positionally constrained to a southern minimum at about 30°N in the following years (1999 to 2003) (Figure 141).



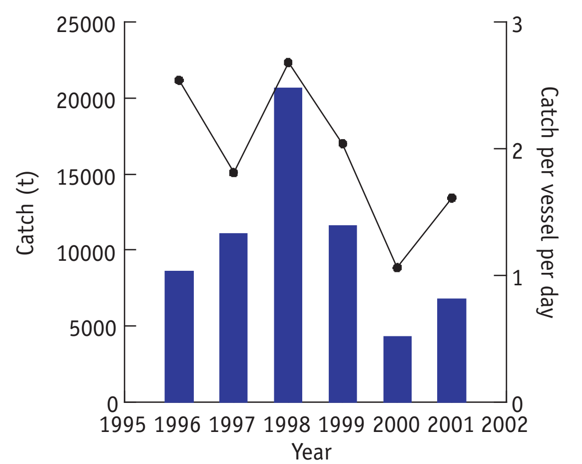
[Figure 141] Surface chlorophyll density (mg·m^{-3}) estimated from SeaWiFS ocean color for (A) February and (B) August in the North Pacific and (C) the southern minimum of the Transition Zone Chlorophyll Front (TZCF) defined as the 0.2 mg·m^{-3} contour for 1997-2003.[380]

Large scale oceanic thermohaline fronts in the Transition Zone, particularly at the STFZ, and associated high gradient mesoscale features often give rise to localized regions of higher productivity, leading to aggregation and development of a forage base. In stratified, oligotrophic waters such as found during the summer, recycling of nutrients between the grazers and phytoplankton typically maintains primary production at uniform low levels. Transient episodes of upwelled nutrient-rich water from mesoscale events, particularly strong cyclonic eddies and meanders, have been shown to induce 'new' production, thus providing a mechanism to shorten the trophic pathway and facilitate energy transfer.

Zooplankton Very limited information is available regarding the status of macro-zooplankton or micronekton (which includes juvenile forms of Subarctic and Transitional nektonic and micronektonic species that undergo extensive latitudinal/longitudinal migrations to preferred feeding and reproductive habitats as well as adult and young mesopelagic animals that compose the sonic scattering layer (SSL) in the region). A PICES Working Group will soon report on status of the micronekton resources in the North Pacific, including the Transition Zone.

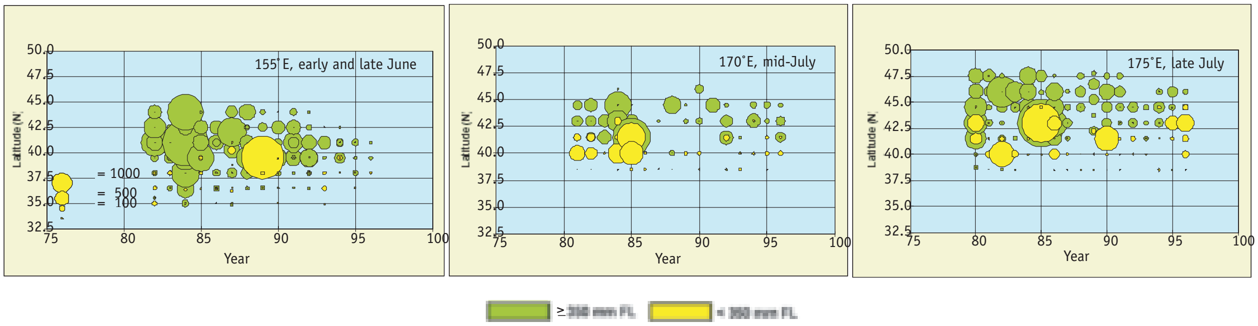
Fish and Invertebrates

Much of our present knowledge of the fish and commercial invertebrates in the Transition Zone can be attributed to surveys conducted by Hokkaido University and by a spatially extensive, temporally intensive, but short-lived monitoring by scientific observers of the high-seas commercial driftnet fisheries for flying squid, *Ommastrephes bartramii*, and for tunas and billfishes during 1990-91.[282]



[Figure 142] Catch and catch per vessel per day of flying squid (*Ommastrephes bartrami*) by Japanese jig fishery[381]

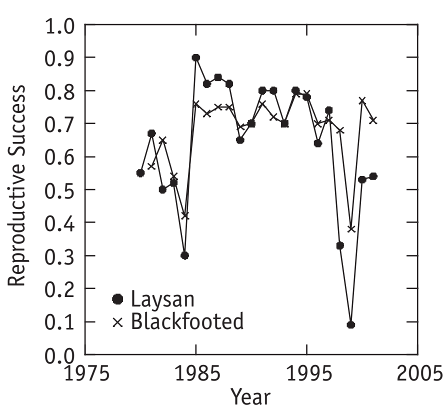
Commercial fisheries currently known to operate in the Transition Zone include the Japanese and U.S. longline fishery for tunas and billfishes, the U.S. troll fishery for albacore tuna (*Thunnus alalunga*), and the Japanese (and to a lesser extent, U.S.) jig fishery for flying squid. Recently, hundreds of Chinese squid jigging vessels began operating in the Transition Zone, however catch information for this fishery is currently not available. For the Japanese central North Pacific squid jigging fishery, CPUE has declined in 2000 and has remained low (Figure 142). The status of the tuna fisheries are described elsewhere in this volume in a chapter prepared by the Inter-American Tropical Tuna Commission.



[Figure 143] Catch per set of Pacific pomfret (*Brama japonica*) by size (green: fish ≥350 mm FL: yellow: fish <350 mm FL) and by latitude (°N) for the 1981-96 T/S Hokusei Maru research gillnet time series along 155°E (left), 170°E (center), and 175°E (right) longitudes.

Marine Birds and Mammals

Seabirds Populations of Laysan albatross, *Phoebastria immutabilis*, and blackfooted albatross, *P. nigripes*, populations breed in the Hawaiian Archipelago and forage in the North Pacific Transition Zone. A comparison of annual reproductive success (proportion of chicks fledged per egg laid) of each species at French Frigate Shoals in the northwestern Hawaiian Islands indicates strong coherence between the two species that is especially evident during two years of very low reproductive success (1984 and 1999). Interestingly, both years of low reproductive success occurred about one year after major ENSO events. Other seabird species such as red-footed boobies, *Sula sula*; red-tailed tropicbirds, *Phaethon rubricauda*; and black noddies, *Anous tenuirostris*, also exhibited very low reproductive success in 1998-99, but not in 1984.[382]



[Figure 144] Temporal trends in reproductive success of blackfooted and Laysan albatrosses monitored at French Frigate Shoals in the northwestern Hawaiian Islands, 1980-2001.[383]

Mammals A status of marine mammals for the North Pacific including the Transition Zone has been compiled elsewhere.[305]

Turtles Two species of sea turtles are common occupants of Transition Zone waters: loggerhead turtles, *Caretta caretta*, and leatherback turtles, *Dermochelys coriacea*. Loggerheads in particular appear to exploit the TZCF as a migration pathway and as forage habitat.[384] Interactions of loggerhead turtles with commercial surface longline fisheries targeting swordfish in the southern Transition Zone have led to a closure of the U.S. fishery. While deep longline sets continue to be set in the region for tuna, turtle interactions have been dramatically reduced.

issues

While the TZCF is readily monitored by satellite remote sensing of ocean color, very little in situ information has been gathered to advance our understanding of the ecosystem dynamics associated with this feature.

How does variability in the position, strength, and behavior of the TZCF impact the Transition ecosystem? Some current evidence suggests that the degree of meandering of the TZCF is a manifestation of enhanced physical convergence and divergence and facilitates trophic transfer at this specialized habitat. Field work designated to examine the TZCF ecosystem dynamics including community faunal composition, secondary production, etc. are needed.

What is the impact of climate variability on key oceanic habitats (e.g., fronts and frontal systems). Variations in latitudinal position, degree of meandering, intensification of the currents flow field, and coupled biological responses to the environment associated with changing regimes need addressing.

Biological time series are most difficult to come by. The Hokkaido University/Japan Fisheries Agency meridional hydrographic-research gillnet survey time series should be closely examined for possible use in assessing the status of the Transition Zone ecosystem. Cursory examination of Pacific pomfret catches appears to capture the transition from the more productive regime brought about by the 1977-88 North Pacific climate event characterized by an intensification of the Aleutian Low Pressure System[385] to the less productive period since and hypothesized return to pre-1976 levels (Figure 143). Support for the time series needs to be considered.

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