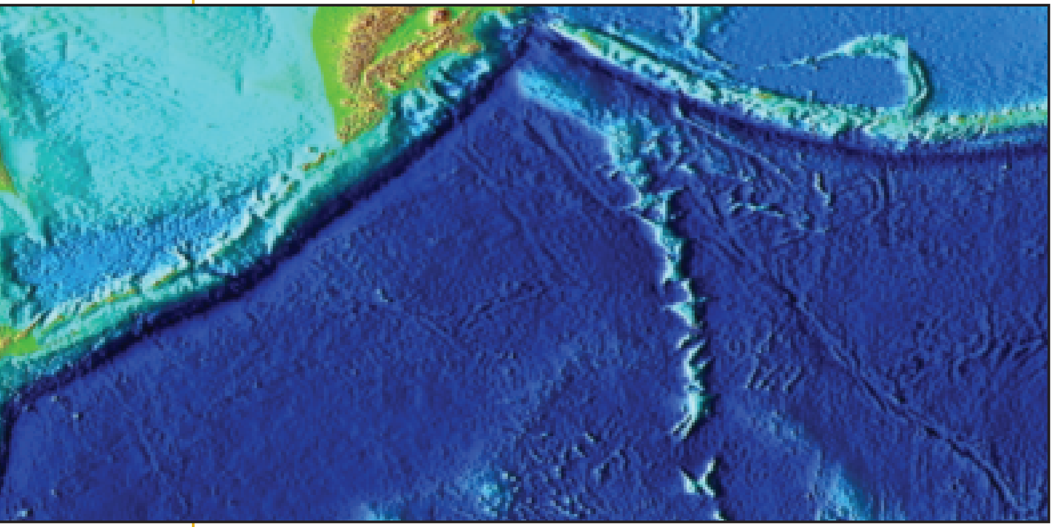
Western Subarctic Gyre

highlights



- The Western Subartic Gyre has large seasonal changes in ocean circulation that are the dynamic mechanism of gyre-gyre interaction and the drive pump of the conveyer-belt deep circulation at its terminus.
- Time series of sea surface temperature anomalies in the Subarctic Pacific changed sign from negative to positive in the mid-1950s, to negative in the mid-1960s, and again to positive around 1980.
- Phytoplankton and zooplankton biomass decreased after the 1976/77 climate regime shift in the western Subarctic Pacific suggesting that biological productivity decreased during this period.
- The most abundant epipelagic nekton species were Pacific salmon, followed by Pacific saury, Atka mackerel, Pacific pomfret, and blue shark (based on surface gillnet sampling). Neon flying squid, boreal clubhook squid, and boreopacific gonate squid were abundant squid species.
- Fourteen marine mammal species were reported, but only sperm whale (*Physeter macrocephalus*) had estimates of abundance: 2,323 in number and 5,248 $x10^3$ mt in biomass during summer.

background

The Subarctic Pacific is a large cyclonic gyre surrounded on the north by coastline and boundary currents, and on the south by subtropical waters.

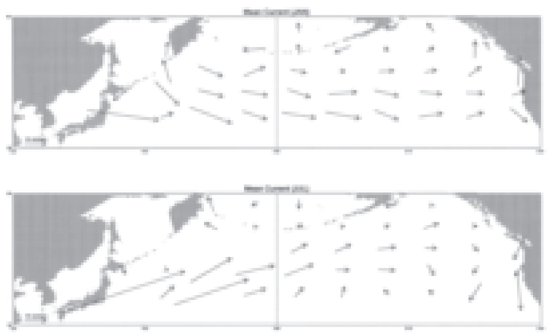
The main gyre is constricted at its longitudinal center by the Aleutian Islands, which causes a re-circulation as two sub-gyres: the Western Subarctic and Alaskan Gyres. These two subarctic gyres are biologically distinct, supporting different species and production patterns from plankton through predatory marine mammals.[196,197]

Status and Trends

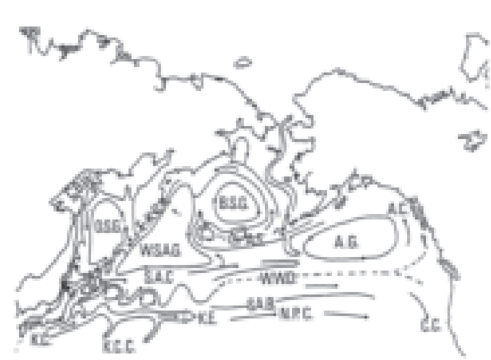
Hydrography

Basin-scale circulation of the northern North Pacific has large seasonal variation. Ocean currents in the summer and winter (Figure 85),[198,199] obtained by subtracting Ekman drift from drifter data, show quite different patterns from the classical synoptic chart of basin scale circulation.[200,201] The latter has two major trans-Pacific currents, the North Pacific Current and the Subarctic Current, separated by the West Wind Drift or by the transition zone (Figure 86). Comparing these two figures, the North Pacific Current corresponds to the current axis driven by winter winds, and the current identified as Subarctic Current corresponds to the current driven by summer winds. As boundaries, the North Pacific Current is both the northern edge of the Subtropical Circulation and the southern edge of the Subarctic Circulation in winter. The Subarctic Current is both the northern edge of the subtropical circulation and the southern edge of Subarctic Circulation in summer. This big seasonal change in circulation is the dynamic mechanism of gyre-gyre interaction and drive pump of conveyor-belt deep circulation at its terminal. Physical oceanographic theory indicates that the line of zero wind stress curl corresponds to the boundary between the Subtropical Circulation and the Subarctic Circulation. Interannual variation of the curl of the wind stress in winter (average of December-February) and summer (average of June-August)[202] (Figure 87) indicates that the location of the zero line of wind stress curl is rather stable in the eastern Pacific in summer, indicating the dominant effect of the Aleutian Low.

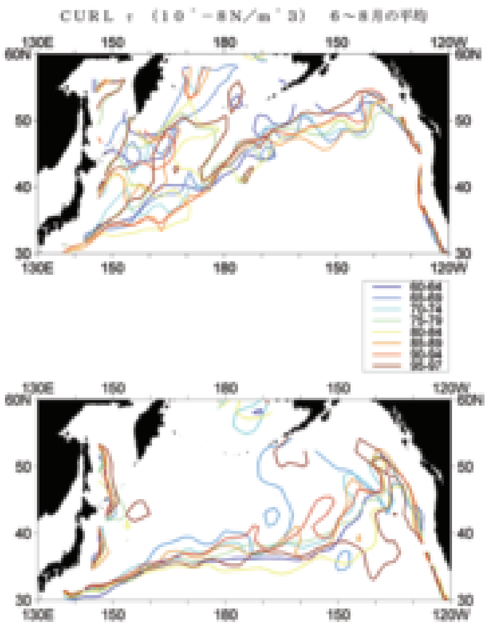
The location of the zero line in the western Pacific in winter is stable, indicating the dominant effect of the Siberian High. The location of the bifurcation of the transpacific current at the eastside of the North Pacific also changes seasonally with the change of the wind stress field, which suggests that the seasonal change of transpacific current bifurcation is driven by a fast barotropic response to the wind.



[Figure 85] Mean current field derived from drifter tracks in January (Upper panel) and July (Lower panel).



[Figure 86] Circulation system in the northern North Pacific.[201]

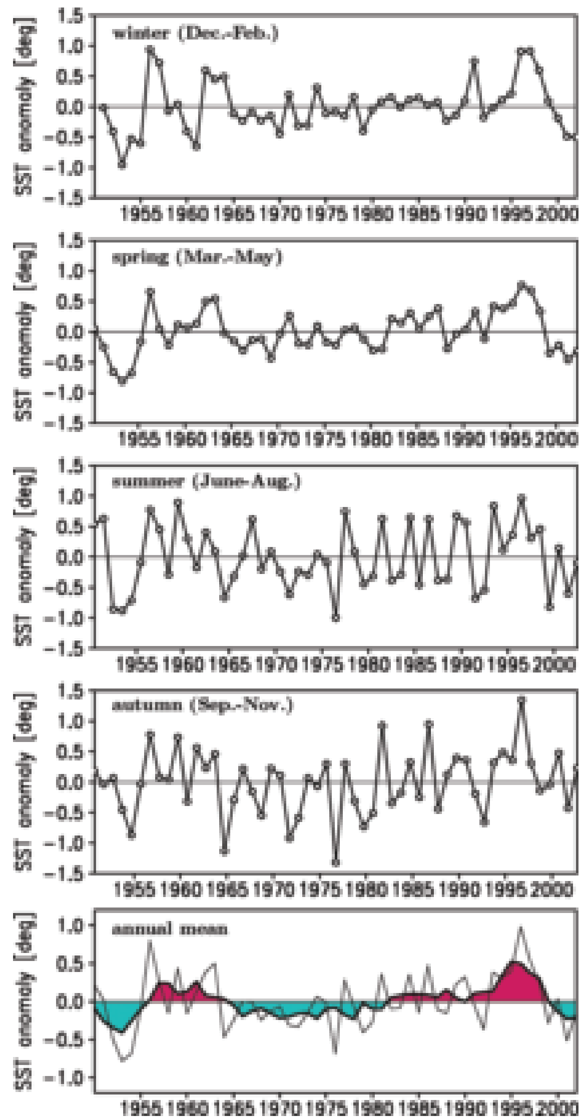


[Figure 87] Line of zero - wind stress curl in the northern North Pacific

Decadal-interdecadal variability of atmosphere-ocean climate system in the North Pacific has been of great interest in recent years. In 400-m temperature field, decadal signal is found in the western Subarctic region. Long-term variability of 400-m temperature in the western Subarctic region is documented.

Recent studies show that the variation of sea surface temperature (SST) on a decadal scale is remarkable in the central North Pacific, associated with the change of atmospheric fields. Analyses of upper layer temperature suggest that the thermal anomalies in the wintertime mixed layer over the central North Pacific can be subducted into the main thermocline and transported downward and equatorward[203,204]. Thermal anomalies rotate clockwise around the subtropical gyre at depth of 250 m.[205] An intensification of the basin-scale decadal signal at a depth of 400 m toward the western side of the North Pacific (north of 30°N) was documented with a lag of 4-5 years relative to the decadal variation of the basin-wide wind stress curl pattern.[206,207]

Time series of sea surface temperature (SST) anomalies in the western Subarctic gyre shows interdecadal variability (Figure 88). The annual mean anomaly changed its sign from negative to positive in the mid-1950s, to negative in the mid-1960s, and again to positive around 1980. The interdecadal fluctuation is similar to the time series of the leading principal mode of 6-year lowpass-filtered SST over the Pacific domain,[208] suggesting that the SST fluctuation in the western Subarctic gyre is a part of SST fluctuation in the whole North Pacific on an interdecadal time scale. The annual mean SST displays a gradual cooling after 1996, and has been below normal since 1999.



[Figure 88] Areal averaged SST anomaly (C°) in 48-53°N, 164-170°E. Thin line denotes annual mean anomaly and thick line its 5-year running mean in the bottom figure. Anomaly is a departure from the averaged temperature in 1950-2002.

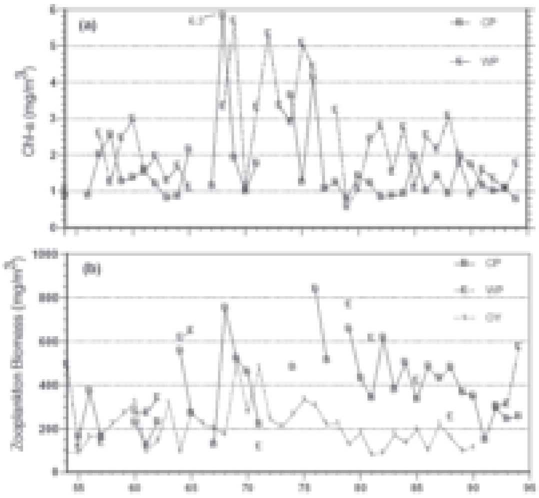
Chemistry

No Data.

Plankton

Much of the Subarctic North Pacific Ocean, including the western Subarctic Pacific is characterized as an HNLC (High Nutrient Low Chlorophyll) area.[209] Size composition of the phytoplankton in the western North Pacific is also similar to the other HNLC areas where nano-sized phytoplankton dominates throughout year.[210,211]

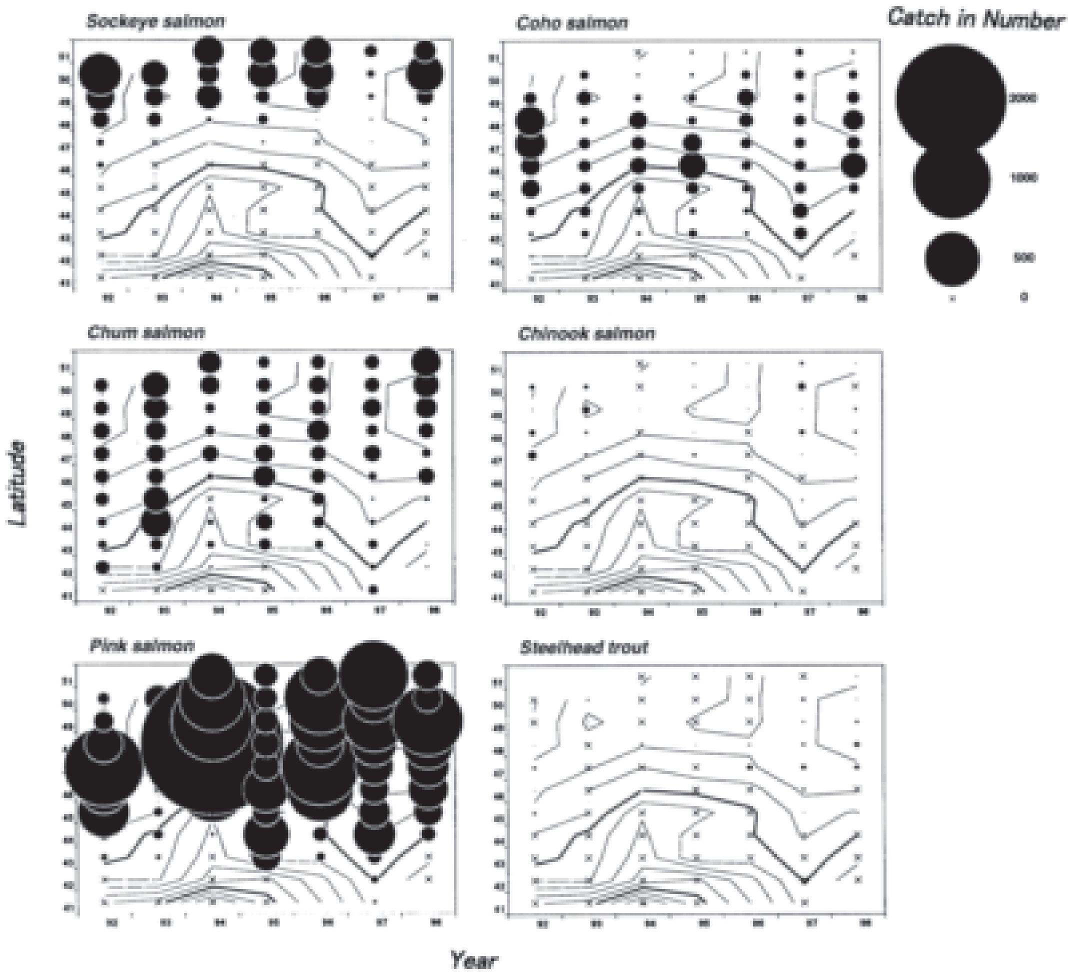
Mesozooplankton biomass is slightly higher in the western than in the eastern Subarctic Pacific, and is lower than in the Bering Sea.[212] Species composition of the mesozooplankton community is similar to that of other Subarctic North Pacific areas. *Neocalanus* spp. copepods dominate in the western Subarctic Pacific.[213] Study of long term variation in the phytoplankton and zooplankton are few in the western Subarctic Pacific because the sampling frequency is low. Limited information indicates that surface chlorophyll concentration (estimated from Secchi disc depth) had high values from the late 1960s to the early 1970s and decreased in the 1980s, sustaining low value until 1990s (Figure 89). Mesozooplankton biomass also had relatively high value in 1970s and decreased in 1980s.[212] It was reported that biological productivity increased after the 1976/77 climatic regime shift in the eastern Subarctic Pacific.[286] However, the phytoplankton and zooplankton decreased after 1976/77 climate regime shift in the western Subarctic Pacific so it may have decreased the biological productivity in the western Subarctic Pacific.



[Figure 89] Chlorophyll-a and zooplankton biomass time series for the Central Pacific, Western Pacific and Oyashio regions.[212]

Fish and Invertebrates

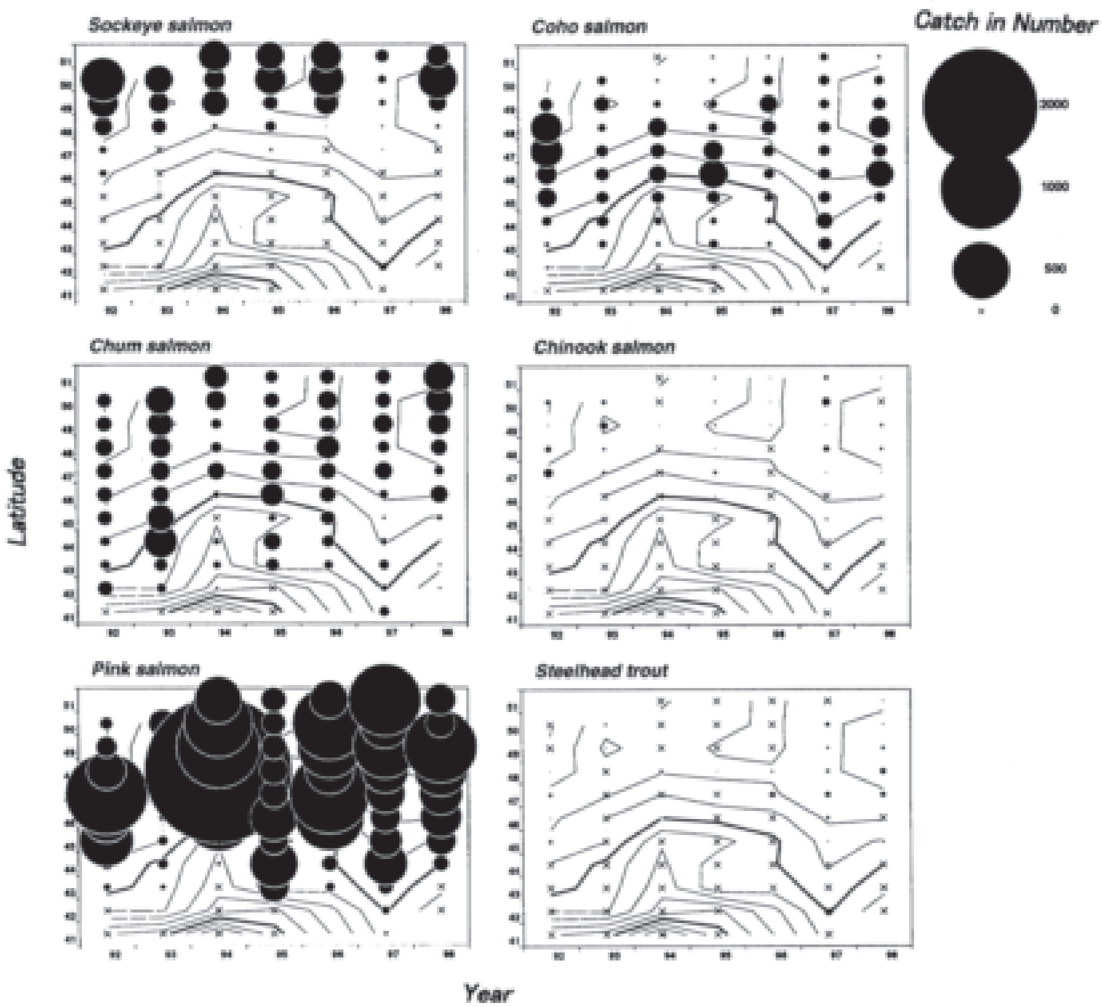
In the western Subarctic Gyre, pink salmon (*O. gorbuscha*) is the most abundant species of Pacific salmon, followed by chum (*O. keta*), sockeye (*O. nerka*), coho (*O. kisutch*), chinook salmon (*O. tshawytscha*), and steelhead trout (*O. mykiss*) (Figure 90). Masu salmon (*O. masou*) are distributed only in coastal waters off Japan and Russia in the western North Pacific.[214] Japanese and Russian fisheries harvest Pacific salmon in coastal waters and offshore regions within the 200-mile zone of both nations after the high seas salmon fisheries were closed in 1993. Generally, pink and chum salmon stocks in Japan and the Russian Far East have been at high levels since the 1990s[215] (see also *Pacific salmon* chapter in this report).



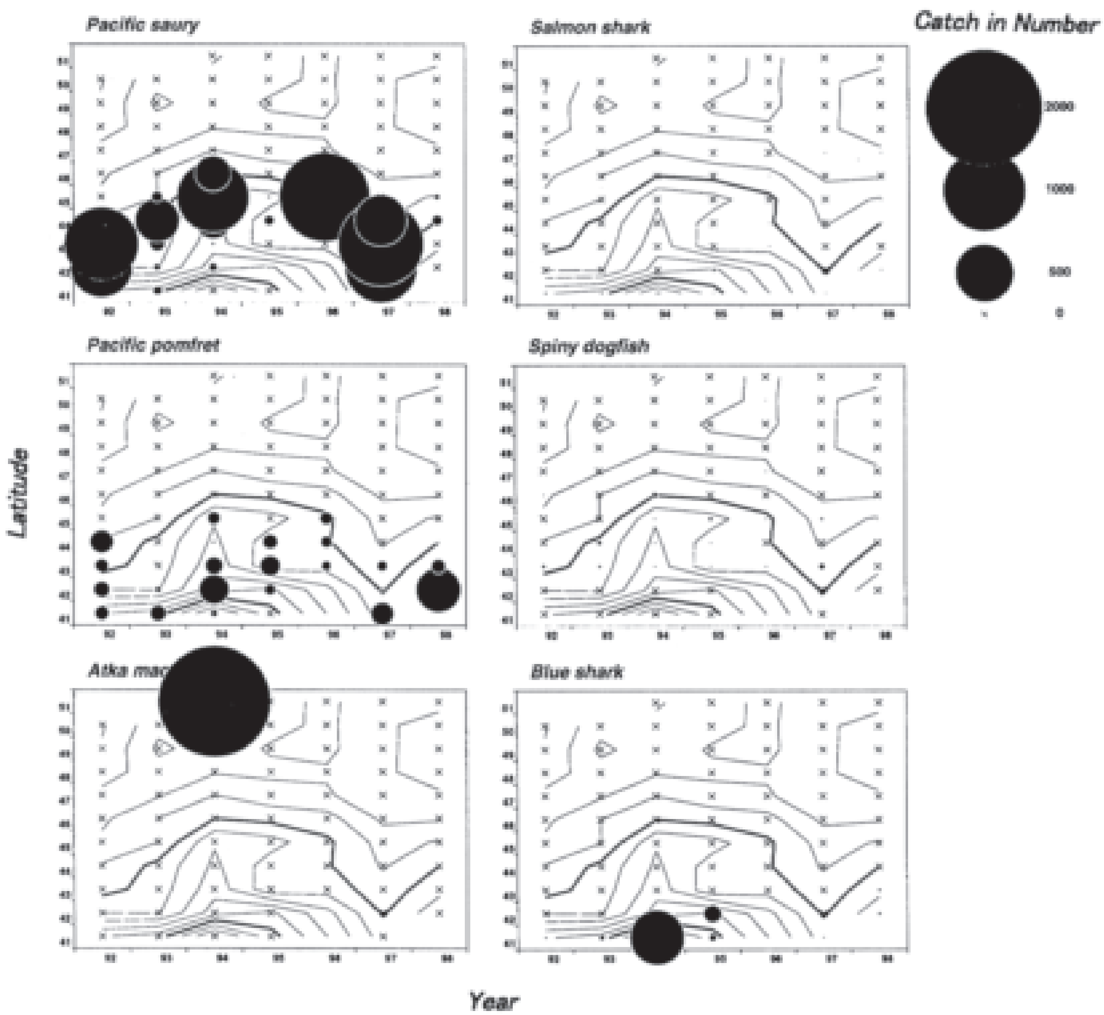
[Figure 90] Distribution of Pacific salmon along a transect at 165°E from 41°N to 51°N in July from 1992 to 1998.[216] The thicker contour in the centre of each panel is the 10° C sea surface temperature contour. Temperature contours increase (decrease) by 1° C intervals toward the south (North).

Fishes and squids were collected using surface gillnets along a north-south transect at 165°E longitude, between 41°-51°N latitude during the summers of 1992-1998. The transect crosses the Subtropical North Pacific (STNP), the Transition Domain (TD), and the Western Subarctic Gyre (WSG). Twenty-six fish species, 4 squid species, 1 marine mammal species and some other unidentified fish and seabirds were collected. Pacific salmon were the most abundant (68% by number), followed by Pacific saury (Cololabis saira, 16%), Atka mackerel (*Pleurogrammus monopterygius*, 5%), Pacific pomfret (*Brama japonica*, 3%), and blue shark (*Prionace glauca*, 1%). Abundant squid species included neon flying squid (*Ommastrephes bartramii*, 2%), boreal clubhook squid (*Onychoteuthis borealijaponica*, 2%), and boreopacific gonate squid (*Gonatopsis borealis*, 1%).

Pacific salmon were distributed in the TD and WSG; sockeye salmon (6%), chum (7%), pink (50%), and coho salmon (5%) were distributed in this order of dominance from north to south. Pink salmon showed a clear year-to-year variation in abundance that was higher in even years than in odd years. Boreopacific gonate squid were distributed mainly in the WSG at sea surface temperatures (SST) below 10°C, but also occurred in the TD in 1997. Neon flying squid were distributed in the TD at 10-15°C SST, and were abundant in 1994 and 1996. Boreal clubhook squid and Pacific pomfret occurred in the TD, and Pacific saury were distributed south of the 10°C SST isotherm. In 1994 Atka mackerel were abundant at 51ºN, where the northern part of WSG flows westward, and blue sharks were caught at 42ºN in 1993. These results indicate that each species has a specific distribution pattern related to oceanographic structure (Figure 90 - Figure 92).



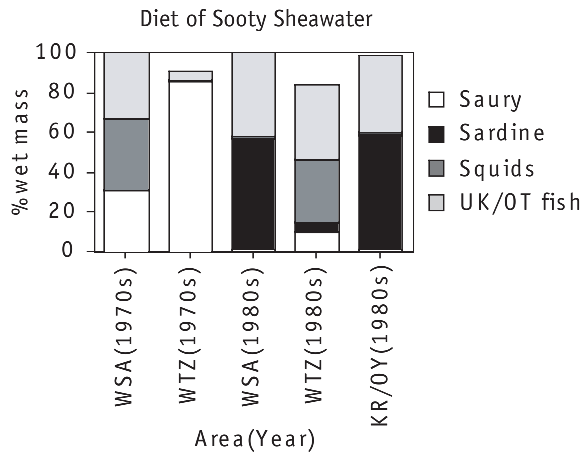
[Figure 91] Distribution of pelagic fishes along the transect at 165°E from 41°N to 51°N in July from 1992 to 1998.[216] The thicker contour in the centre of each panel is the 10° C sea surface temperature contour. Temperature contours increase (decrease) by 1° C intervals toward the south (North).



[Figure 92] Distribution of pelagic squids and other animals along the transect at 165°E from 41°N to 51°N in July from 1992 to 1998.[216] The thicker contour in the centre of each panel is the 10° C sea surface temperature contour. Temperature contours increase (decrease) by 1° C intervals toward the south (North).

Marine Birds and Mammals

Seabirds There is no available data on the distribution and diet of seabirds in the western Subarctic during the 1990s. During the 1970s, research on common murres (*Uria aalge*), thick-billed murres (*Uria lomvia*), and short-tailed shearwaters (*Puffinus tenuirostris*) was conducted mainly in the Okhotsk Sea and the northwestern Bering Sea. The distribution and diet of sooty sheawaters (*Puffinus griseus*) during the 1970-1980s were well studied in the western Subarctic, the western transition zone and the Kuroshio/Oyashio Current zones.[217] The main diet of sooty shearwaters in summer in these regions is fish but they also feed on squid. In 1975-1980, sooty sheawaters fed mainly on Pacific saury in the western transition zone (including the Transitional Domain and Subtropical Zone) and the western Subarctic current region. In 1982, 1985-1989, they fed mainly on Japanese sardine in the western Subarctic, western transition and Kuroshio/Oyashio confluence regions.[218] In 1982, 1985-1989, they fed on some squid in the western transition zone but they rarely did in the western Subarctic and Kuroshio/Oyashio zones (Figure 93).



[Figure 93] Diets of sooty shearwaters in different years/regions in western Pacific ecological zones

Mammals In the Western Subarctic Pacific, 14 marine mammal species were reported, but only sperm whale (*Physeter macrocephalus*) had estimates of abundance as 2,323 in number and 5,248 x10^3 million t in biomass during summer. Total prey consumption by this species during summer was estimated as 180x10^3 million t.[305]

issues

Although salmon research vessels collected various biological data in the western Subarctic Pacific in the past, there has been insufficient monitoring in recent years, especially on the high seas.

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