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A summary of research results by Japan related to the NPAFC Science Plan, from 1992 to 1997

by

Fisheries Agency of Japan

Ministry of Agriculture, Forestry and Fisheries
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The abstracts included are listed under the following categories:

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5. Mortality
6. Stock Interaction
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8. Physical-biological Interaction and Productivity
9. Climate Change Effects
10. Regime Effects
11. Miscellaneous

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1. Spatial Distribution

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1.1

TI: Homing behavior and vertical movements of four species of Pacific salmon (*Oncorhynchus* spp.) in the central Bering Sea

AU: Miki Ogura

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SO: Can. J. Fish. Aquat. Sci. 52: 532-540

PY: 1995

LA: English

DT: J

AB: Four sockeye salmon (*Oncorhynchus nerka*), two chum salmon (*O. keta*), three pink salmon (*O. gorbuscha*), and four chinook salmon (*O. tshawytscha*) with depth-sensing ultrasonic transmitters were tracked in the central Bering Sea to examine migration in the open sea. Ground speeds of maturing sockeye, chum, and pink salmon were at 0.54-0.66 m/s (0.88-1.17 fork lengths/s). Chinook salmon, probably immature fish, moved more slowly (0.34 m/s). Maturing individuals moved in particular directions and maintained their ground speeds and directions during day and night. The results also suggested that salmon had a compass orientation ability functioning without celestial information. Sockeye, chum, and pink salmon showed strong surface preferences but chinook salmon swam deeper (30-35 m) than did the other species.

KW: homing behavior, vertical movements, ultrasonic transmitters, Pacific salmon, Bering Sea

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1.2

TI: Change in the known ocean distribution of Japanese chum salmon relation to the progress of stock enhancement

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SO: Can. J. Fish. Aquat. Sci. 51:501-505

PY: 1994

LA: English

DT: J

AB: New information on the ocean distribution of maturing Japanese chum salmon, *Oncorhynchus keta*, based on offshore tagging experiments conducted from 1956 to 1 991 is summarized. Of 138 039 chum released in the North Pacific Ocean and its adjacent seas, 663 fish were recovered along the Japanese coast in the year of tagging and up to March of the next year. The distrihution area of maturing Japanese chum indicated by these tag recoveries extended much further south and west than shown in previous studies. The central and western North Pacific Ocean now form important parts of the range. We conclude that extensive stock enhancement of chum in Japan is associated with enlargement of the known distribution area of maturing Japanese chum in the North Pacific Ocean.

KW: tagging experiments, ocean distribution, Japanese chum salmon, stock enhancement

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1.3

TI: Swimming behavior of coho salmon, *Oncorhynchus kisutch*, in the open sea as determined by ultrasonic telemetry

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SO: Can. J. Fish. Aquat. Sci. 49: 453-457.

PY: 1992

LA: English

DT: J

AB: Four coho salmon, *Oncorhynchus kisutch*, with depth-sensing ultrasonic transmitters were tracked in the central North Pacific Ocean during June and early July 1989. The average swimming depths of the fish ranged from 7.1 to 13.4 m, and they spent 72.3-92.8% of the time in the upper 15 m of the water column; maximum depths were 53-74 m. Average ground speeds ranged from 0.29 to 0.40 ms^{1}. Although swimming depths during the day were deeper than at night, one coho salmon tracked for 5 d showed no regular daily patterns of horizontal or vertical movements.

KW: swimming behavior, coho salmon, ultrasonic telemetry, horizontal or vertical movements

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1.4

TI: Summer distribution and migration routes of juvenile chum salmon (*Oncorhynchus keta*) originating from rivers in Japan

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SO: Bull. Nat. Res. Inst. Far Seas Fish., No. 33: 139-147.

PY: 1996

LA: English

DT: R

AB: To clarify the migration routes of juvenile chum salmon (*Oncorhynchus keta*) originating from Japanese rivers, Japan-Russia cooperative surveys were undertaken in waters off southeastern Hokkaido, Sakhalin, and the Kuril Islands (excluding the 12 nautical mile (about 22krn) zone of Russia), using a purse seine, a surface trawl net, dip-nets, and drift net in the summers of 1988-1992. Chum juveniles were caught in nearshore waters of southeastern Hokkaido and coastal waters (> about 22km) of the Kunashiri and Iturup Islands. In contrast, no juvenile was found in offshore waters (> about 46km) of the Sea of Okhotsk and the Pacific Ocean. We proposed following two hypotheses for the migration routes of juvenile chum salmon after they enter these coastal waters based on these findings. The first hypothesis is that juvenile chum salmon migrate to offshore waters of the Sea of Okhotsk and the second hypothesis is that they move within coastal (territorial) waters off the Kuril Islands.

KW: migration, *Oncorhynchus*, chum salmon, juvenile, Okhotsk

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1.5

TI: Distribution and biology of epipelagic animals in the northern North Pacific Ocean and adjacent seas-I. Fishes and squids in the southern Okhotsk Sea and western North Pacific Ocean off the Kuril Islands in the autumn of 1993.

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SO: Bull. Nat. Res. Inst. Far Seas Fish., No. 33: 149-170.

PY: 1996

LA: English

DT: R

AB: A surface-trawl survey was conducted by the R/V *Kaiyo maru* in the southern Okhotsk Sea and western North Pacific Ocean off the Kuril Islands in October and November 1993. The distributions and abundances of the species caught are described and discussed. Twenty-four fish species (1 lamprey, 1 shark, and 22 teleosts) and one squid species were identified. Juvenile Pacific salmon (6 species of the genus *Oncorhynchus*) were the most abundant, followed by myctophids, juvenile arabesque greenling (*Pleurogrammus azonus*), and gonatids including boreopacific gonate squid (*Gonatopsis borealis*) and probably schoolmaster gonate squid (*Berryteuthis magister*). Northern smoothtongue (*Leuroglossus schmidti*) were also abundant. Juvenile arabesque greenling were abundantly taken in the Okhotsk Sea in October but disappeared from the surface waters in November because they settled on the bottom. There were marked differences in the oceanic distribution of arabesque greenling and Atka mackerel (*P. monopterygius*), suggesting that these species segregate their habitats. Northern smoothtongue mostly occurred in the Okhotsk Sea, and myctophids were caught in the North Pacific Ocean. We conclude that the surface layer of the southern Okhotsk Sea provides favorable habitats for the feeding and growth of juvenile salmonids, arabesque greenling, and other epipelagic migratory species from summer to mid-autumn but ends its role in late autumn with decreasing sea-surface temperatures.

KW: oceanic distribution, Pacific salmon, epipelagic fishes and squids, Okhotsk Sea, North Pacific Ocean

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1.6

TI: The first recc ery of tagged masu salmon (*Oncorhynchus masou*) in waters offshore of the Sea of Okhotsk

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SO: Scientific Reports of the Hokkaido Fish Hatchery No.49:59-62

PY: 1995

LA: English

DT: R

AB: A tagged domestic masu salmon released from southwestern Hokkaido was recovered from waters offshore of the Sea of Okhotsk. This paper is the first record of the masu salmon in the area that originated in Japan.

KW: *Oncorhynchus masou*, release of smolts, masu salmon migration

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1.7

TI: Deepwater migrations of chum salmon (*Oncorhynchus keta*) along the Pacific coast of northern Japan.

AU: Yasuhiro Ueno

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OA: none

OA: none

SO: Can. J. Fish. Aquat. Sci. 49: 2307-2312

PY: 1992

LA: English

DT: J

AB: Mature chum salmon (*Oncorhynchus keta*) were caught in bottom trawls off lwate Prefecture, northern Japan, in autumn. To document the incidence and depth distrihution of these catches, records were kept of salmon caught hy five trawlers that fished along the Pacific coast of northern Honshu during Septemher December 1986. During this period, 4337 chum salmon were caught at bottom depths ranging from 150 to 460 m with most taken from 200 to 350 m. Gonads and stomach contents were examined for 100 of these salmon. All were mature and close to spawning. Tbirty-nine of the 100 stomachs examined were empty and the remaining 61 contained only a small quantity of food, averaging 2.4 g. Chum salmon may move at these depths to avoid the high temperatures of surface waters (12-20°C) found in this area and to follow temperatures close to their thermal preferendum (3-11°C) which are found near bottom. This phenomenon appears to be an adaptation of chum salmon near the southern limit of their range.

KW: deepwater migrations, chum salmon, northern Japan, thermal preferendum

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1.8

TI: Summer microhabitat use and diet of four sympatric stream-dwelling salmonids in a Kamchatkan stream.

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SO: Fisheries Science 61: 926-930.

PY: 1995

LA: English

DT: J

AB: Resource utilization by four sympatric. stream-dwelling salmonids. masu salmon. coho salmon, steelhead trout, and Dolly Varden, was studied by underwater observations of microhabitat use and foraging bebavior, and dietary analyses. in a third order tributary of he Bolyschaya River on the Kamcbatka Peninsula, Russia in summer, 1993.

KW: summer microhabitat, sympatric stream-dwelling salmonids, Kamchatkan stream

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1.9

TI: Studies on the ecology and resource of maturing chum salmon off the Pacific coast of northern Honshu

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OA: none

OA: none

SO: Bull. Nat. Res. Inst. Far Seas Fish.,No. 30:79-206

PY: 1993

LA: Japanese

DT: R

AB: Pacific salmon (*Oncorhynchus* spp.) generally migrate to sea after a short freshwater life and rapidly grow during their oceanic life. After two to six years at sea, they return to their natal hreeding grounds to spawn. Chum salmon (*O. keta*) are the most abundant species among Pacific salmon originating in Japan. The annual catch of chum salmon in Japan increased exponentially after 1970. reaching 29 millions individuals by 1981. The recent increases in Japanese chum salmon have been brought about by increases in the number of fry released, and by improvements in the feeding and handling techniques for the fry after emergence. Hokkaido bas always had major stocks of chum salmon in Japan, however, the numbers of chum salmon returning to the Pacific coast of Honshu (Aomori, Iwate, Miyagi, Fukushima, Ibaraki, and Chiba Prefectures) rapidly increased to over 7 millions per year after 1981. These areas currently produce 20-40% of total chum salmon catch in Japan. Japan's major salmon fishery employs set nets in inshore waters. A longline fishery is also used to take chum salmon in some parts of coastal waters off northern Japan. The importance of conducting basic research on chum salmon returning to Japanese coastal waters has increased, because directed fishing for salmon on the high seas is prohibited by international treaty after 1992. In this paper, I deal with the distribution, migration, biological characteristics, and fishing management of maturing chum salmon along the Pacific coast of Honshu, with particular emphasis on the central area, Iwate Prefecture.

(1) Methods : Longline and drift nets operations were conducted to investigate the distribution, migration, biological characters (age, fork length, body weight, sex, gonad weight, stomach content, and weight of stomach and pyloric caeca) of maturing chum salmon present in the surface layers of coastal waters off Iwate in the autumns of 1981-86. To clarify the deep water distribution of maturing chum salmon, the by-catch of bottom trawlers fishing for groundfish off the coast of Iwate in 1986 and 1988 was examined. I also reviewed the distribution of maturing chum salmon in offshore waters of the Pacific coasts of Aomori and Hokkaido using published reports.

(2) Distribution of maturing chum salmon : Based on the results of fishing experiments using drift nets and longlines, and the by-catch of the trawl nets, maturing chum salmon were distributed and migrated southwestwards within the Oyashio area of waters off southeastern Hokkaido and Aomori. They appear to avoid the warm surface waters (12-20°C) of coastal waters off Iwate Prefecture that are present at this time by moving to cold deep waters (3-11°C, > 200 m). After the gonad development is completed, they are assumed to move to nearshore areas and ascend to the surface to find their natal river using their olfactory sense.

(3) Migration of maturing chum salmon by tagging experiments : Tagging experiments were conducted along the coast of Iwate each autumn from 1981 to 1986. Of the 3,441 individuals tagged, about 38% were recaptured. Most of recoveries were reported by set nets, while a few of recoveries by river fisheries and longlines. Tags were recovered from an area extending from off the coast of Chiba on the Pacific coast of northern Japan to off the coast of Yamagata on the Japan Sea coast. Most (97.5%) of the fish were recaptured in the coastal waters and rivers of Iwate. Distribution of recoveries showed that a large number of the salmon entered northern coastal waters off Iwate, and that majority of them then migrated to central and southern coastal waters off Iwate. Only a small number migrated to the Sea of Japan. In addition, only a small proportion of the fish returning to coastal waters between Miyagi and Chiba were believed to pass trough the coastal waters of Iwate. The period between release and recapture and daily movements were also examined using the tag recovery data. The tag recoveries suggest that maturing chum salmon begin to actively migrate to find their natal river when they are within a range of 30 km south or north

of the river mouth.

(4) Age, size, maturity, and feeding habits : The present analysis, based on biological data collected from maturing chum salmon caught in coastal waters off Iwate, indicates that mean fork length of the samples has decreased over time while mean age of the samples has increased. Gonad indices for four groups of chum salmon (A : rivers in Iwate, B : coastal waters of Iwaie, C : deep waters off Iwate, D : waters off southeastern Hokkaido) were compared. Gonad index was largest for A, and B was similar to A. The gonad index was smallest for D, and C was intermediate between B and C. This result supports my hypothesis that chum salmon migrate from waters off southeastern Hokkaido through deep water off Iwate to reach the coastal waters and rivers of Iwate. The sexual maturity of chum salmon was inversely correlated with the level of digestive activity, with protease activities within stomach and pyloric caeca gradually decreasing as gonads develop. Average stomach content weight of autumn-caught chum salmon was also a very small, suggesting that maturing chum salmon feed very little. Feeding on longline baits by maturing chum salmon seems therefore to be a result not so much of hunger as a conditioned response.

(5) Fishing managements : The catch of maturing chum salmon by longline seems to be limited by their restricted surface distribution in coastal waters, and by the reduced feeding activity that occurs as sexual maturation begins. To assess how coastal fisheries (set nets and longlines) affected the survival, I considered a method for estimating the non-fishing mortality (M, /day) and the time dependent mortality coefficients for coastal fisheries (F, /day) and river fisheries (R, /day from tag recoveries using a method by Hearn et al. (1987), and the catch equation. I applied this method to the actual tag recapture data from the coastal waters of Iwate. Assuming that 75% of all the recaptured fi h are reported, M was estimated to be 0.086, and estimates of F varied from 0.051 to 0.247 with a mean of 0.100. The estimate of F is very large relative to estimates for coastal fisheries in other areas. This is consistent with the results of the tagging experiments, where a majority of the tag recoveries are reported within a short period (about 15 days) after release. For estimating the proportion of tagged fish by the natal river area, I examined two different methods. The first method provided estimates of the proportion returning to different river areas directly using the estimated fishing and non-fishing mortality coefficients. The second method provided estimates of this proportion based on final day recapture data, 24 days after release, in order to avoid duplicate corrections for the fishing mortalities. The true proportion of chum salmon destined to return to each natal river area must lie between these two estimates, because the first method provides overestimates of the proportion

in the earlier period of the experiments, while the second method provides overestimates of the proportion in the later period. Using both methods jointly, the origins of fish tagged in each area were quantitatively estimated. About 10% of the fish caught in coastal waters of northern Iwate were calculated to have originated from rivers in northern Iwate, about 10% from rivers in Aomori and along the Japan Sea coast, 40-60% from ·ivers in mid-Iwate, and 10-30% from rivers in southern Iwate. About 40% of fish caught in coastal waters of mid-Iwate in November originated from rivers in mid-Iwate region, and 50% from rivers in southern Iwate. In December, 70-90% of them were estimated to have originated from rivers in mid-Iwate, while about 60-90% of fish caught in coastal waters off southern Iwate were estimated to have originated from rivers in that area. Coastal fisheries in northern areas therefore appear to intercept many fish originating from the southern areas, while fisheries in southern areas mainly catch fish of local origin. In total, about 95% of fish tagged in coastal waters off Iwate were estimated to have originated from rivers in Iwate, 2-30% from rivers in Aomori or along the Japan Sea coast, and 2 % from rivers between Miyagi and Cbiha. These two methods are thought to be useful in estimating tbe mixing rates of chum salmon originating from rivers in the different areas.

(6) Summary : Basic distribution, migration, and biological characteristics of maturing chum salmon in coastal waters off the Pacific coast of northern Japan were determined using the experimental fishing, tagging experiments, and research on trawl by-catch. The catch of maturi ·g chum by longlines seems to be limited by their restricted surface distribution in coastal waters, and by the reduced feeding activity that occurs as sexual maturation begins. A method for estimating the fishing intensities of the coastal and river fisheries, and two methods for quantitative analyses of the results from the tagging experiments were proposed. Coastal fisheries off northern Iwate Prefecture capture chum returning to a number of areas ; in contrast, chum salmon fisheries taking place off southern Iwate capture fish largely of local origin.

KW: ecology, maturing chum salmon, northern Honshu, distribution, migration, feeding habits, fishing mangements

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1.10

TI: Migratory behavior of Pacific salmon (*Oncorhynchus* spp.) in the open sea

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OA: none

OA: none

SO: Bull. Nat. Res. Inst. Far Seas Fish., No. 31:1-139

PY: 1994

LA: Japanese

DT: R

AB: Pacific salmon spend most of their life in the ocean and return to their natal stream to spawn, but the migratory mechanisms of salmon in the ocean are not well understood and there have been no direct observations on their migratory behavior in the open sea. In this paper, tag release and ultrasonic telemetry data were analyzed to provide new information on the migratory behavior and distribution of Pacific salmon in the North Pacific Ocean.

(1) Ocean distribution of maturing salmonids : Data from the high seas salmon tagging experiments conducted under the auspices of the International North Pacific Fisheries Commission were analyzed. From 1956 to 1991, a total of 414, 085 salmonids (117,519 sockeye, 139,547 chum, 136,075 pink, 15,671 coho, 3,354 chinook, and 1,919 steelhead trout) were tagged and released in the Bering Sea and North Pacific Ocean. Of these tagged fish, 5,053 sockeye, 1,867 chum, 4,185 pink, 894 coho, 73 chinook, and 60 steelhead trout were recovered in the year of tagging and up to March of the next year. These recovery data from maturing fish were used to update previously published information on the ocean distribution of major stocks of sockeye, chum, pink, and coho salmon. This new information is summarized as follows : The known distribution of sockeye salmon originating from western Kamchatka was extended to the southeast in the western North Pacific. The known distribution of southwestern Alaska sockeye was extended toward the south in the central North Pacific. The known distribution of Japanese chum salmon extended much farther to the south and west than had been shown in previous studies, and the central and western North Pacific Ocean was shown to be an important part of their range. Chum salmon originating from the Kuril Islands, Primore, and south Sakhalin were also widely distributed in the central North Pacific. The known distribution of northwestern Alaska chum salmon was extended to the southwest in the central North Pacific. The distribution of pink salmon originating from the Asian coast west of western Kamchatka was extended eastward. East Kamchatka and western Alaska pink salmon were distributed in the central North Pacific. All new information on coho salmon was obtained from fish released in the central North Pacific, and coho salmon originating from the Asian continent and western Alaska were distributed in this area.

(2) Change in the known ocean distribution of Japanese chum salmon in relation to

increased production of hatchery salmon : To clarify the changes in the known ocean distribution of Japanese chum salmon that have occurred since artificial enhancement of Japanese chum salmon became pronounced in the 1970s, tag recovery rates and biological information were compared for two time periods, 1956-1970 and 1971-1991. Tag recovery rates along the Japanese coast were consistently higher after 1971 than before 1970. In contrast, tag recovery rates in Russia were lower after 1971 than before 1970. Although othe factors, such as the tagging mortality rate, the tag shedding rate, the exploitation rate of the stock in coastal areas, and the reporting rate for tags found, may account for some of the change in the numbers of tagged chum recovered, the recent increase in recovery rates of tagged Japanese chum is likely due to the higher proportion of Japanese chum in the North Pacific that resulted from the increase in hatchery production of chum salmon in Japan. Fork lengths of chum salmon distributed in the western and central North pacific were significantly smaller than those in other areas. The return migration pattern of chum salmon from the western and central North Pacific cannot be explained simply on the basis of the ocean currents of the North Pacific, as previously suggested in the literature.

(3) Migration rate of maturing Pacific salmon : Migration rates for each stock were calculated by release month on the basis of days between tagging and recovery and the shortest distance between tagging and recovery location. In general, migration rates increased later in the season, and averaged about 50 km/day in June and July. The maximum rate for individual fish was about 80 km/day for many stocks. Assuming that salmon swim in one direction and swim continuously during day and night, 0.58 and 0.93 m/s were calculated as the swimming speed for the average and maximum migration rates, respectively. This is roughly equivalent to the optimal swimming speed estimated by laboratory studies.

(4) Horizontal movement of Pacific salmon shown by ultrasonic telemetry : To examine detailed migratory behavior of Pacific salmon in the open sea, 23 individuals from six salmon species (sockeye, chum, pink, coho, chinook, and steelhead) with depth sensing ultrasonic transmitters were tracked in the central Bering Sea and North Pacific Ocean during a total of 1,138 hours. Maturing sockeye, chum, and pink salmon tracked in the Bering Sea swam at 0.54-0.66m/s. They moved in fixed directions and maintained their swimming speeds and directions during day and night. These swimming speeds were consistent with the average migration rates of tagged salmon. Maturing chum, coho, and steelhead trout tracked in the North Pacific were considered to be in the early period of their homing migration and moved more slowly (0.31-0.43m/s) than maturing sockeye, chum, and pink salmon in the Bering Sea. Immature chinook salmon and

steelhead trout also swam slowly. They did not maintain fixed directions, and no daily pattern of horizontal movement was observed.

(5) Vertical distribution and movement of Pacific salmon shown by ultrasonic telemetry : Tracking data showed that Pacific salmon were distributed mostly in the upper 50 m of the water column. Sockeye, pink, coho, and steelhead showed strong surface preferences, and they spent more than 70% of their time in the upper 10 m. Chum salmon also swam near the surface, but tended to swim at a deeper layer than sockeye, pink, coho, and steelhead. In contrast with these five species chinook salmon had an obviously different vertical distribution, with their main swimming depth being 20-40 m. The speeds of vertical movement were calculated for dives or ascents of more than 10 m. Average speeds of vertical movement were similar for all species, and ranged from 0.10 to 0.19 m/ s. Maximum speeds of vertical movement observed were less than 0.75 m/s except for sockeye salmon. Three sockeye salmon made four rapid dives and ascents, and the maximum speeds of vertical movements were 2.19 m/s for dives and 1.41 m/s for ascents.

KW: ocean distribution, migration rate, horizontal and vertical movement, Pacific salmon

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2. Growth and Maturity

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2.1

TI: Reproductive characteristics of mature female chum salmon (*Oncorhynchus keta*) in the Pinacheva River, Kamchatka

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SO: Scientific Reports of the Hokkaido Salmon Hatchery No. 49: 55-59

PY: 1995

LA: English

DT: R

AB: Reproductive characteristics were examined for mature female chum salmon (*Oncorhynchus keta*) collected in the Pinacheva River, Kamchatka, in August 1994. Age 0.4 fish (71.7%) were the most abundant age group, followed by age 0.3 (20.8%) and age 0.5 (7.5%) fish. Average fork lengths and body weights were: 61.1cm and 2.8 kg for age 0.3 fish, 61.4 cm and 2.8 kg for age 0.4 fish, and 65.5 cm and 3.5 kg for age 0.5 fish, respectively. Absolute fecundity (AFC) and relative fecundity (RFC) showed a significant positive relationship with fork length (FL): AFC=8.16 x FL - 3.006 and RFC=0.0891 x FL - 17.33. Egg diameter ranged from 7.10-8.75 (mean 7.88) mm. The relationship between fork length and egg diameter was not statistically significant.

KW: fecundity, egg diameter, female chum salmon, Pinacheva River, Kamchatka

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2.2

TI: Recent changes in age and size of chum salmon (*Oncorhynchus keta*) in the North Pacific Ocean and possihle causes

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SO: Can. J. Fish. Aquat. Sci. 50:290-295

PY: 1993

LA: English

DT: J

AB: Changes in age composition and size of adult chum salmon (*Oncorhynchus keta*) from rivers in Japan, Russia, and Canada were examined based on body weight and scale measurement data collected from 1953 to 1988. A significant increase in mean age was found in Japanese and Russian stocks after 1970 when the number of Japanese chum salmon began to increase exponentially, but not in the Canadian stock. Significant decreases in mean body weight, mean scale radius, and mean width of the third-year zones of age 4 chum salmon also occurred in Japanese and Russian stocks after 1970. Based on the Japanese salmon research vessel data from 1972 to 1988, significant negative relationships between catch-per-unit-effort and mean body weight of chum salmon were observed in summer in the central North Pacific Ocean where the distribution of Japanese and Russian stocks overlaps. These results suggest that density dependence is one of the possible causes for the recent changes in age and size of chum salmon in the North Pacific Ocean.

KW: age, size, chum salmon, North Pacific Ocean, density dependence

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2.3

TI: Allometric back-calculation of individual growth for chum salmon otolith during early life

AU: Masa-aki Fukuwaka

AF: Research Division, Hokkaido Salmon Hatchery, Fisheries Agency of Japan, 2-2 Nakanoshima, Toyohira-ku, Sapporo 062, Japan

OA: none

OA: none

SO: Scientific Reports of the Hokkaido Salmon Hatchery No. 50: 113-116

PY: 1996

LA: English

DT: R

AB: Otolith growth and rate of increment formation in juvenile chum salmon were examined to determine whether otoliths could be used to back-calculate body sizes at various juvenile life history stages. Sagittal otoliths were firstly observed in newly hatched chum alevines. At that time, the fish had an average total length of 19.5 mm and their sagittae were approximately 0.312 mm long. As the fish grew, the relationship between body length (L in mm) and sagitta length (O in mm) was allometric and equaled: $O = 0.312 + 0.0359 * (L - 19.5)^{0.790}$. Increment periodicity was found to occur on a daily basis and was ascertained by performing a fluorescent marking experiment. The results of this work show that individual growth in juvenile chum salmon can be estimated by features readily detected in their otoliths.

KW: back-calculation, chum salmon, otolith

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2.4

TI: Variation in body size, fecundity, and egg size of sockeye and kokanee salmon, *Oncorhynchus nerka*, released from hatchery.

AU: Masahide Kaeriyama

AF: National Salmon Hatchery, 2-2 Nakanoshima, Toyohira-ku, Sapporo 062, Japan

OA: Shigehiko Urawa, Masa-aki Fukuwaka

OA: National Salmon Hatchery

SO: Scientific Report of Hokkaido Salmon Hatchery (49): 1-9.

PY: 1995

LA: English

DT: R

AB: Adult sockeye salmon returning to the Bibi River, which were originally derived from Lake Shikotsu kokanee salmon, and adult kokanee salmon in Lake Shikotsu were examined for variation in body size, fecundity, and egg size. Both groups of adult originated from hatchery-released juveniles. Lager adult females bad higher fecundity. Fecundity and fork length fitted allometric formula within each population. There was no relationship between fork length and egg size in Lake Shikotsu kokanee salmon or in age-1.1 sockeye salmon from the Bibi River although the sockeye salmon were approximately 65% larger in fork lengtb than the kokanee salmon. Age-1.2 sockeye salmon, bowever, had eggs about 12% larger than did kokanee and age-1.1 sockeye salmon.

KW: body size, fecundity, egg size, sockeye, kokanee salmon

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3. Feeding Ecology

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3.1

TI: Diel feeding habits of sockeye and chum salmon in the Bering Sea during the summer

AU: Teruo Azuma

AF: National Research Institute of Far Seas Fisheries, Japan Fisheries Agency, 5-7-1, Orido, Shimizu, Japan 424

OA: none

OA: none

SO: Nippon Suisan Gakkaishi 58(11): 2019-2025.

PY: 1992

LA: English

DT: J

AB: Diel feeding habits of sockeye salmon *Oncorhynchus nerka* and chum salmon *O. keta* in the Bering Sea during the summer were investigated by four parameters: the frequency of empty tomachs, stomach content weight, digestion stage, and pH of the inner wall of the blind sac in the stomach. Stomach samples were obtained at various times of day from gillnet surveys. Sockeye and chum salmon exhibited similar diel feeding patterns, although each of the four parameters of sockeye salmon fluctuated more distinctly than in chum salmon. Based on the present results together with previous knowledge it is hypothesized that the two species obtain metabolic energy in different ways: sockeye salmon feed on more nutritious food organisms than chum salmon, but are inferior to chum salmon in digestion abilities. Chum salmon can utilize peculiar or poorly nutritious food organisms such as jellyfish, on which other salmonid fish seldom feed, with the help of physiologically and morphologically greater digestion abilities.

KW: diel feeding habits, sockeye salmon, chum salmon, Bering Sea, physiological and morphological digestion abilities

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3.2

TI: Change in chı ın salmon (*Oncorhynchus keta*)stomach contents associated with fluctuation of pink salmon (*O. gorbuscha*) abundance in the central subarctic Pacific and Bering Sea

AU: Kazuaki Tadokoro

AF: Ocean Research Institute, University of Tokyo, Nakano-ku, Tokyo 164, Japan

OA: Yukimasa Ishida

OA: National Research Institute of Far Seas Fisheries, Japan Fisheries Agency, 5-7-1, Orido, Shimizu, Japan 424

OA: Nancy D. Davis

OA: University of Washington, Fisheries Research Institute, Box 357980, Seattle, Washington 98195-7890, USA

OA: Shoji Ueyanagi

OA: School of Marine Science and Technology, Tokai University, 3-20-1 Orido, Shimizu 424, Japan

OA: Takashige Sugimoto

OA: Ocean Research Institute, University of Tokyo, Nakano-ku, Tokyo 164, Japan

SO: Fish. Oceanogr. 5:2 , 89-99

PY: 1996

LA: English

DT: J

AB: The abundance and stomach contents of salmonids (*Oncorhynchus* spp.) and the biomass of prey organisms were examined in the central subarctic Pacific and Bering Sea in the summer of 1991 and 1992. Salmonids were caught by surface longline using the same level of fishing effort. Chum (*O. keta*) and pink (*O. gorbuscha*) salmon were the predominant species, representing 44% and 36% of the total catch (n = 1275) in 1991. In 1992, chum salmon composed 85% of the total catch (n = 603), but the catch of pink salmon decreased to 1% of the total catch due to the odd/even year fluctuation of Asian pink salmon abundance in the study area. It was found that chum salmon changed their dominant diet from gelatinous zooplankton (pteropods, appendicularians, jellyfishes, chaetognaths, polychaetes and unidentified materials) in 1991, when pink salmon were abundant, to a diet of crustaceans (euphausiids, copepods, amphipods, ostracods, mysids and decapods) in 1992, when pink salmon were less abundant. Local crustacean biomass (wet weight; mg m^{-3}) had significant negative correlation with the CPUE (catch number per 30 hachi) of pink salmon in 1991 ($r = 0.586$; $P = 0.026$) and that of chum salmon in 1992($r = 0.616$; $P = 0.014$). There may be a limitation in the available prey resource for production of salmonids.

KW: salmon, food habit, central subarctic Pacific, density-dependent growth

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3.2

TI: A record of the Japanese anchovy *Engraulis japonicus* from the stomachs of salmonids in offshore waters of the North Pacific Ocean

AU: Kazuya Nagasawa

AF: National Research Institute of Far Seas Fisheries, Japan Fisheries Agency, 5-7- 1, Orido, Shimizu, Japan 424

OA: Teruo Azuma

OA: National Research Institute of Far Seas Fisheries, Japan Fisheries Agency, 5-7- 1, Orido, Shimizu, Japan 424

SO: Bull. Biogeogr. Soc. Japan 47 (15): 123-125

PY: 1992

LA: English

DT: J

AB: Sixteen specimens of the Japanese anchovy, *Engraulis japonicus* Temminck et Schlegel, 83.0-98.9 mm in standard length, were found and briefly described from the stomachs of chum salmon (*Oncorhynchus keta*) and sockeye salmon (*O. nerka*) captured at 49°30'N and 166°30'E in the North Pacific Ocean on July 10, 1990. This finding remarkably extends the known geographical range of *E. japonicus* to the northeast and constitutes the northeasternmost record of this species. The offshore occurrence of *E. japonicus* is caused by enlarged range due to increased population size in Pacific waters of . apan after the late l 980s.

KW: Japanese anchovy, stomachs of salmonids, North Pacific Ocean

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4. Abundance, monitoring, and forecasting

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4.1

TI: Population dynamics and stock management of hatchery-reared salmons in Japan

AU: Masahide Kaeriyama

AF: National Salmon Hatchery, 2-2 Nakanoshima, Toyohira-ku, Sapporo 062, Japan

OA: none

OA: none

SO: Bull. Natl. Res. Inst. Aquacult., Suppl. 2: 11-15.

PY: 1996

LA: English

DT: R

AB: Life histories of sockeye and chum salmon, which feed on zooplankton and conduct school-behavior, are affected by the population density dependence related to intraspecific competition. This competition affects not only the individual growth rate and maturation but also the distribution and migration of populations. Life histories of sockeye and chum salmon are considered to be subject to a conditional strategy. These salmonids take residence or migration tactics by available resource. This strategy conforms to the ideal free distribution model. On the other hand, intraspecific competition leads to population density effects such as changes in individual growth and age composition in chum salmon population.

KW: hatchery-reared salmons, intraspecific competition, intraspecific competition

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4.2

TI: Effects of population density and habitat environment on life history strategy and migration of juvenile sockeye (*Oncorhynchus nerka*) and chum salmon (*O. keta*)

AU: Masahide Kaeriyama

AF: National Salmon Hatchery, 2-2 Nakanoshima, Toyohira-ku, Sapporo 062, Japan

OA: none

OA: none

SO: Scientific Report of Hokkaido Salmon Hatchery (50): 101-111..

PY: 1996

LA: English

DT: R

AB: Life histories of juvenile sockeye and chum salmon show a conditional strategy which have two tactics of residence and migration. They usually remain in lake and river if they can sufficiently obtain their resources such as food and habitat, whereas salmon migrate seaward when they do not have enough those resources satisfying their energy metabolism. Their migration pattern, controlled by effects of "prior residence" and "precedent migration", may involve a trade-off between the profitability of resource acquisition and risks such as osmoregulation, energetic demands of swimming, exposure to predators, and mobilization to non-adaptable habitat by water current.

KW: life history strategy, residence, migration, juvenile sockeye and chum salmon

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5. Mortality

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5.1

TI: Predation by fishes and seabirds on juvenile chum salmon (*Oncorhynchus keta*) in coastal waters of Japan: a review

AU: Kazuya Nagasawa

AF: National Research Institute of Far Seas Fisheries, Japan Fisheries Agency, 5-7- 1. Orido, Shimizu, Japan 424

OA: Masahide Kaeriyama

OA: Research Division, Hokkaido Salmon Hatchery, Fisheries Agency of Japan, 2-2 Nakanoshima, Toyohira-ku, Sapporo 062, Japan

SO: Scientific Reports of the Hokkaido Salmon Hatchery No. 49: 41-53

PY: 1995

LA: Japanese

DT: R

AB: This review examines available literature on the fauna and diets of fishes and seabirds in coastal waters of northern Japan from spring to summer and discusses the impact of fish and seabird predation on chum salmon (*Oncorhynchus keta*) populations in Japan. Over 90 fish species have been reported to occur with chum salmon juveniles. Among these species, fishes recorded as predators are only 4 species: Japanese dace (*Tribolodon hakonensis*) at estuaries, and Arabesque greenling (*Pleurogrammus azonus*), Japanese flounder (*Paralichthys olivaceus*), and pink salmon (*O. gorbuscha*) at sea. Fish predation may cause substantial loss of juveniles at sites where these fishes, particularly Arabesque greenling and Japanese dace, are abundant. However, there is n) evidence that fish predation has much impact on the number of returning adult salmon in Japan. The release of hatchery-reared, large-sized juveniles possibly reduces the mortality by fish predation. Rhinoceros auklets (*Cerorhinca monocerata*) and black-tailed gulls (*Larus crassirostris*) have been recorded as predators of juvenile chum salmon. These seabirds breed abundantly in northern Japan, and the impact of their predation on Japanese chum salmon populations may be significant. More field and experimental work is needed to evaluate the mortality of Japanese chum salmon juveniles caused by predation by fishes and seabirds.

KW: predation, fishes and seabirds, juvenile chum salmon

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5.2

TI: The abundance and distribution of *Lepeophtheirus salmonis* (Copepoda: Caligidae) on six sp :ies of Pacific salmon in offshore North Pacific Ocean and Bering Sea

AU: Kazuya Nagasawa

AF: National Research Institute of Far Seas Fisheries, Japan Fisheries Agency, 5-7-1, Orido, Shimizu, Japan 424

OA: Yukimasa Ishida, Miki Ogura, Kazuaki Tadokoro and Kazuhiko Hiramatsu

OA:

SO: Pathogens of wild and farmed fish: Sea lice [edited by G. A. Boxshall and D. Defaye]

PY: 1993

LA: English

DT: B

AB: Examination of six species of Pacific salmon (genus *Oncorhynchus*) captured with long-lines from offshore waters of the North Pacific Ocean and Bering Sea revealed a marked difference in the prevalence, mean intensity and abundance of *Lepeophtheirus salmonis* infection between host species. Pink salmon (*O. gorbuscha*) had highest prevalence, mean intensity and abundance, followed by chinook salmon (*O.*

tschawytscha) and steelhead trout (*O. mykiss*). Relatively high levels of infection were found on coho (*O. kisutch*) and chum (*O. keta*) salmon. Sockeye salmon (*O. nerka*) were very rarely infected. About 78% and 15% of the *L. salmonis* found occurred on pink and chum salmon, respectively; the remaining four species of salmonids carried only about 6% of copepods. The infection level increased with host ocean age and size. The frequency distributions of *L. salmonis* within salmonid populations and wit 'in ocean-age groups of chum salmon is described by the negative binomial. Pink and chum salmon, especially pink salmon. are considered the most important hosts of *L. salmonis*.

KW: *Lepeophtheirus salmonis*, Pacific salmon, North Pacific Ocean. Bering Sea

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5.3

TI: Additional fish predators of juvenile chum salmon (*Oncorhynchus keta*) in coastal waters of Japan, with a note on the importance as predators of juvenile masu salmon (*O. masou*)

AU: Kazuya Nagasawa

AF: National Researcb Institute of Far Seas Fisheries, Japan Fisheries Agency, 5-7-1. Orido, Sbimizu, Japan 424

OA: Hiroshi Mayama

OA: Research Divi sion, Hokkaido Salmon Hatchery, Fisheries Agency of Japan, 2-2 Nakanoshima, Toyohira-ku, Sapporo 062. Japan

SO: Tech. Rep. Hokkaido Salmon Hatchery (166):29-33

PY: 1997

LA: Japanese

DT: R

AB: The following five species are added as fish predators of juvenile chum salmon (*Olecorhynchus keta*) in coastal waters of Japan: spiny dogfish (*Squalus acanthias*), Japanese sea perch (*Lateolabrax japonicus*), Far Eastern dace (*Tribolodon brandti*), whitespotted charr (*Salvelinus leucomaenis*), and masu salmon (*O. masou*). These species were not listed hy Nagasawa and Kaeriyama (1995, Sci. Rep. Hokkaido Salmon Hatchery. No. 49: 41-53) who recognized the four fish species (Japanese dace [*T. hakoleensis*], Japanese halihut [*Paralichthys olivacaeus*], arabesque greenling [*Pleurogrammus azonus*], and pink salmon [*O. gorbuscha*]). Among these fishes, juvenile masu salmon have been reported to feed on chum salmon juveniles in various waters off the Pacific and Japan-Sea coasts of northern Japan. and it seems possible that they serve as one of significant predators of chum salmon juveniles in Japan.

KW: fish predators, juvenile chum salmon, juvenile masu salmon

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5.4

TI: Distribution of pelagic elasmobranchs caught by salmon research gillnets in the North Pacific

AU: Hideki Nakan ,

AF: National Research Institute of Far Seas Fisheries, Orido, Shimizu, Shizuoka 424, Japan

OA: Kazuya Nagasawa

OA: National Research Institute of Far Seas Fisheries, Orido, Shimizu, Shizuoka 424, Japan

SO: Fishcries Science 62(5): 860-865

PY: 1996

LA: English

DT: J

AB: The distribution of pelagic elasmobranchs was analyzed using bycatch data from the high seas salmon surveys by research gillnets from 1981 to 1991 in the North Pacific Ocean and the Bering Sea. Five species of sharks and one stingray were reported. Blue and salmon sharks and spiny dogfish were dominant and constituted 98% of the total shark catch. It is considered that the research area includes the southern part of the distribution for spiny dogfish and salmon sharks and the northern part of that for blue, shortfin mako, cookiecutter sharks and pelagic stingrays. These elasmobranchs showed spa-tial segregation by species in distribution according to oceanographic conditions. Intraspecific sexual and growth dependent segregations were also confirmed. Length frequency distributions of blue and salmon sharks suggest that their nursery grounds exist around the transitional domain of the subarctic boundary.

KW: distribution, elasmobranchs, salmon survey, segregation, nursery ground, North Pacific

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8. Physical-biological Interaction and Productivity

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8.1

TI: Potential influence of North Pacific sea-surface temperatures on increased production of chum salmon (*Oncorhynchus keta*) from Japan

AU: Yukimasa Ishida

AF: National Research Institute of Far Seas Fisheries, Japan Fisheries Agency, 5-7-1.

Orido, Shimizu, Japan 424

OA: David W. Welch

OA: Pacific Biological Station, Department of Fisheries and Oceans, Nanaimo, British Columbia, Canada V9R 5K6

OA: Miki Ogura

OA: National Research Institute of Far Seas Fisheries, Japan Fisheries Agency, 5-7- 1, Orido, Shimizu, Japan 424

SO: In R.J. Beamish [ed.] Climate change and northern fish populations. Can. Spec. Publ. Fish. Aquat. Sci. 121: 271-275

PY: 1995

LA: English

DT: J

AB: We examined the potential influence of changes in sea-surface temperature (SST) in the North Pacific Ocean on Japanese chum salmon (*Oncorhynchus keta*) adult return rates and growth rates. SST near the Kuril Islands in July and SST in the central North Pacific in winter and spring showed significant decreasing trends from 1947 to 1988. Average return rate after the mid- 1960s was higher than that occurring before the mid-1960s, when most juveniles were not fed prior to release. Return rate was negatively correlated with SST near the Kuril Islands and in the central North Pacific after the mid- 1960s, but not before. Growth was positively correlated with spring SST in the central North Pacific. The present results and previously reported negative correlations between growth and fish density suggest that chum salmon production is enhanced in Japan by hatchery technology but that yields have been reduced by declining growth rates caused by decreasing SST and increasing fish density in the central North Pacific.

KW: potential influence, sea-surface temperatures, production of chum salmon

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8.2

TI: Productivity of picoplankton compared with that of larger phytoplankton in the subarctic region

AU: Akihiro Shiomoto

AF: National Research Institute of Far Seas Fisheries, Japan Fisheries Agency, 5-7- 1, Orido, Shimizu, Japan 424

OA: Kazuaki Tadokoro

OA: National Research Institute of Far Seas Fisheries, Japan Fisheries Agency, 5-7- 1, Orido, Shimizu, Japan 424

OA: Kojo Monaka. Masaaki Nanba
OA: Kagawa University, 2393 Ikenoto. Miki-cho, Kida-gun, Kagawa, 761-07 Japan
SO: Journal of Plankton Research Vol.19 no.7 pp.907-916
PY: 1997
LA: English
DT: J
AB: We determined the productivity (μ g C μ g^{-1} Chl a h^{-1}) of size-fractionated phytoplankton in the northern North Pacific and the Bering Sea in summer and winter. Picoplankton (<2 μ m) were more productive than larger sized phytoplankton (2-10 and 10-200 μ m) in the subtropical region, where the in situ temperature was >10°C: whereas picoplankton in the subarctic region were similar in productivity or less productive than larger sized plankton, where the *in situ* temperature was <10°C. The result from the subtropical region in this study agrees with previous results from tropical and sub-tropical waters, which indicate that phytoplankton productivity tends to decrease with increasing cell size. The result from the subarctic region, however, differs from previous results. We observed a positive linear regression for *in situ* temperature and picoplankton productivity, but this trend was not seen in the larger sized phytoplankton. The results show that the productivity of picoplankton is markedly influenced by *in situ* temperature compared with that of larger sized plankton. Low temperature appears to account largely for the observation that the productivity of picoplankton is not significantly higher than that of larger sized phytoplankton in th subarctic region.
KW: productivity, picoplankton, larger phytoplankton, subarctic region
****

8.3

TI: Trophic relations in the subarctic North Pacific ecosystem: possible feeding effect from pink salmon

AU: Akihiro Shiomoto
AF: National Research Institute of Far Seas Fisheries, Japan Fisheries Agency, 5-7-1, Orido, Shimizu, Japan 424
OA: Kazuaki Tadokoro, Kazuwa Nagasawa, Yukimasa Ishida
OA: National Research Institute of Far Seas Fisheries, Japan Fisheries Agency, 5-7-1, Orido, Shimizu, Japan 424
SO: Mar. Ecol. Prog. Ser. Vol. 150: 75-85
PY: 1997
LA: English

DT: J

AB: Year-to-year variations in biomass of phytoplankton (surface chlorophyll *a* concentration) and macrozooplankton (wet weight obtained by NORPAC net operation above 150 m), and abundance of pink salmon (catch per unit effnrt of pink salmon) from 1985 to 1994 in th^ subarctic North Pacific in summer were studied. After 1989, phytoplankton biomass and pink salmon abundance showed corresponding yearly patterns, whereas the pattern shown by macrozoopldnkton biomass was always the inverse of that shown by phytoplankton and salmon. We suggest that macrozooplankton biomass remained low when pink salmon was abundant due to the intense feeding impact of pink salmon, which in turn allowed phytopldnkton biomass to remain high as d result of the lesser grazing effect of macrozoopldnkton. The opposite phenomenon probably occurred when pink salmon was not abundant. Prior to 1989, macrozooplankton biomass was at a rather high level while phytoplankton biomass and pink salmon abundance were low. We suggest thdt mdCrozooplankton biomass remained high due to a lesser feeding impact of the pink salmon, and phytoplankton biomass remained low due to the intense grazing effect of macrozooplankton. Our study therefore shows the possibility that the feeding effect from the pink salmon controls summer macrozoo- and phytoplankton biomass in the subarctic North Pacific.

KW: phytoplankton, zooplankton, pink salmon, grazing, feeding, trophic relation, subarctic ecosystem

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8.4

TI: Climate and weather effects on the chlorophyll concentration in the northwestern North Pacific

AU: Takashige Sugimoto

AF: Ocean Research Institute, University of Tokyo, Nakano-ku, Tokyo 164, Japan

OA: Kazuaki Tadokoro, Yasuo Furushima

OA: Ocean Research Institute, University of Tokyo, Nakano-ku, Tokyo 164, Japan

SO: Biogeochemical Processes and Ocean Flux in the Western Pacific, Eds. H. Sakai and Y. Nozaki, pp. 575-592

PY: 1995

LA: English

DT: B

AB: In the northern half of the subtropical gyre, vertical mixing due to winter cooling extends to at least 150-200 m. The surface chlorophyll concentration is largest in winter and it is twice as high in warm calm winters than in cold and windy winters.

In contrast, in the southern half of the subtropical gyre, the thermocline and the subsurface chlorophyll maximum at about 100 m depth persist in winter, and annual and interannual variations are not so clear. In the central and western subarctic water, the surface chlorophyll concentration in summer shows interdecadal scale variation, having significant correlation with variation in the northern hemisphere zonal index of the meander pattern of the westerly jet (NHZI). During the decade of negative values of NHZI under enhanced meander of the westerly, the chlorophyll concentration decreases to less than one half of that during positive values of NHZI. On shorter time scales, the start of the phytoplankton bloom in spring might be controlled by the competition between the increasing surface heating and the strong vertical mixing due to the cold air outbreaks. However, the tendency of high nutrients low chlorophyll concentration under stratified condition in mid May and early June in the western subarctic gyre is similar to that observed at station P in the Alaskan gyre.
KW: Climate and weather effects, chlorophyll concentration, northwestern North Pacific
****

8.5

TI: Interannual-interdecadal variations in zooplankton biomass, chlorophyll concentration and physical environment in the subarctic Pacific and Bering Sea

AU: Takashige Sugimoto

AF: Ocean Research Institute, University of Tokyo, Nakano-ku, Tokyo 164, Japan

OA: Kazuaki Tadokoro

OA: Ocean Research Institute, University of Tokyo, Nakano-ku, Tokyo 164, Japan

SO: Fish. Oceanogr . 6:2: 74-93

PY: 1997

LA: English

DT: J

AB: Interannual, decadal and interdecadal variations in summer plankton biomass during 1954-1994 in the whole subarctic Pacific and Bering Sea were compared among regions as well as with climatic and oceanographic conditions. The zooplankton biomass and chlorophyll concentration during the mid 1960s to early 1970s in the central and western subarctic Pacific were a few times higher than those in the preceding and following decades. The values in the eastern Bering Sea and eastern subarctic Pacific also increased in the mid 1960s, but remained at an elevated level until the end of the 1980s. These decades of higher and mid plankton biomass levels during the mid 1960s to early 1970s and mid 1970s to late 1980s correspond to the period of positive and negative values of the Northern Hemisphere zonal index (NHZI), respectively. In the decadal scale, one can see a significant positive correlation between the summer plankton biomass and the wind speed during winters in the eastern Bering Sea. The effect of grazing by biennially fluctuating Asian pink salmon on zooplankton biomass and its effect on chlorophyll concentration in the central subarctic Pacific is also significant.

KW: chlorophyll cc centration, climate change, interannual variation, interdecadal variation, pink salmon, subarctic Pacific, zooplankton biomass

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11. Miscellaneous

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11.1

TI: Biological variation among salmon caught in the Bering Sea during the summer

AU: Teruo Azuma

AF: National Research Institute of Far Seas Fisheries, Japan Fisheries Agency, 5-7- 1, Orido, Shimizu, Japan 424

OA: none

OA: none

SO: Nippon Suisan Gakkaishi 58(10): 1807-1818.

PY: 1992

LA: English

DT: J

AB: Sockeye *Oncorhynchus nerka*, chum *O. keta*, and pink salmon *O. gorbuscha* caught by surface gillnets in the Bering Sea during the summers of 1987 and 1988 were investigated to clarify the extent of the biological variation among individuals of each species. Between fishing dates, chum salmon showed differences in age composition and pink salmon in sex ratio, while sockeye salmon showed none in either category. The mean gonad weight of the three species changed as the dates proceeded, although chum salmon did not exhibit clear modal increases in the gonad weight through the survey period. Diurnal differences in sex ratio and mean gonad weight were only recognized in chum and male pink salmon, respectively. Different ocean age groups of sockeye and chum salmon were observed concomitantly, even in a single short-period catch (2-3 hours in soaking time of the gillnets). The three salmonids showed marked differences in biological variety beyond the specific difference simply predicted from the age variation; the most heterogeneous species was chum, while the least was pink salmon.

KW: age composition, sex ratio, gonad weight, sockeye, chum, pink salmon
****

11.2

TI: Do Pacific salmon (*Oncorhynchus* spp.) steal bait from surface longlines at sea?

AU: Kazuya Nagasawa

AF: National Rese rch Institute of Far Seas Fisheries, Japan Fisheries Agency, 5-7-1, Orido, Shimizu, Japan 424

OA: Kazuaki Tadokoro

OA: Ocean Research Institute, University of Tokyo, Nakano-ku, Tokyo 164, Japan

SO: Fisheries Research 26: 381 -384

PY: 1996

LA: English

DT: J

AB: Examination of stomach contents of Pacific salmon (*Oncorhynchus* spp.) caught with surface longlines in the Bering Sea revealed that baitfish, Japanese anchovy *Engraulis japonicus*, was frequently found in the stomachs. The percentage occurrence of baitfish found in salmon stomachs did not differ significantly between species: chum (*Oncorhynchus keta*, 19.2%), pink (*Oncorhynchus gorbuscha*, 17.5%), sockeye (*Oncorhynchus nerka*, 17.5%), and chinook salmon (*Oncorhynchus tshawytscha*, 30.0%). When baitfish was/were observed in the salmon stomachs, usually one anchov was present, but the stomach of one chum salmon contained six anchovies. During longline retrieval, one salmon (species unknown) was observed to remove the anchovy from the hook without becoming hooked. It is thus concluded that salmon are successful in stealing baitfish from longline hooks for a short soaking period (about 1 h).

KW: bait stealing, surface longline, Pacific salmon, *Oncorhynchus* spp.
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11.3

TI: Development of ultrasonic telemetry technique for investigating the magnetic sense of salmonids

AU: Akira Yano

AF: Graduate School of Science and Technology, Chiba University, Inage, Chiba 263, Japan

OA: Miki Ogura

OA: Tohoku National Fisheries Research Institute, Fisheries Agency of Japan, Shinhama, Shiogama, Miyagi 985, Japan

OA: Atsushi Sato

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OA: Yo Sakaki

OA: Faculty of Engineering, Chiba University, Inage, Chiba 263, Japan

OA: Masatoshi Ban

OA: Hokkaido Salmon Hatchery, Fisheries Agency of Japan, Toyohira, Sapporo 062, Japan

OA: Kazuya Nagasawa

OA: National Research Institute of Far Seas Fisheries, Fisheries Agency of Japan, Orido, Shimizu, Shizuoka 424, Japan

SO: Fisheries Science 62(5): 698-704

PY: 1996

LA: English

DT: J

AB: We developed an ultrasonic telemetry technique for investigating the magnetic sense of the ocean migrating adult salmonids and applied it to maturing chum salmon *Oncorhynchus keta* off the Kuril Islands in the western North Pacific in September 1994. We made artificial magnetic field generators, consisting of an electromagnetic coil and a drive circuit, which periodically disturb the geomagnetic field around their heads. Tracking w s carried out under the following three conditions. Condition 1: the coil and drive circuit were attached to the head and back of three salmon, respectively and an ultrasonic transmitter was also inserted into the stomach for tracking. Condition 2: the dummy coil and drive circuit were attached to the head and back of other three salmon, respectively and an ultrasonic transmitter was also inserted into the stomach. Condition 3: only either a transmitter or a transmitter and the dummy drive circuit were attached to the remaining two salmon. We collected information on the horizontal and vertical movements of the fish. Most salmon moved in southerly directions and swam upper 40 m. The average ground speeds ranged from 1.11-1.84 fork length/s for magnetically disturbed salmon (condition 1) and 0.96-1.65 fork length/s for the others (conditions 2 and 3). No significant differences with respect to horizontal movement, vertical movement, and/or swimming speed were found between the magnetically disturbed salmon and the others. The attached devices might give no serious damage to the swimming activity of salmon.

KW: chum salmon, ultrasonic telemetry, western North Pacific, compass orientation, earth's magnetic field

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11-4

TI: Anadromous sockeye salmon (*Oncorhynchus nerka*) derived from nonanadromous kokanees: life history in Lake Toro.

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OA: National Salmon Hatchery

SO: Scientific Rep· rts of the Hokkaido Salmon Hatchery, (46): 157-174.

PY: 1992

LA: English

DT: R

AB: Life history of sockeye salmon derived from kokanee salmon was investigated in Lake Toro of the Kushiro River System. Juvenile sockeyes released to Lake Toya as underyearlings (age 0.0) in late fall showed two life-history patterns: anadromous sockeye and nonanadromous kokanee types. Their growth curves fit periodic von Bertalanffy's curves, hut sockeye grew lineally more than kokanees. Seasonal change in growth rate of sockeye showed a constant periodicity, but that of kokanee showed extreme fluctuations and gradually decreased with time. Life history patterns of sockeye salmon may be influenced hy the genetics of the original stock as well as by the lacustrine environment.

KW: anadromous sc :keye salmon, nonanadromous kokanees, Lake Toro.

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11-5

TI: Ecology of salmonids in the North Pacific Ocean.

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OA: none

OA: none

SO: Environmental Biology of Fishes 42: 105-108.

PY: 1995

LA: English

DT: R

AB: Pearcy's "ocean ecology of North Pacific salmonids" was reviewed.

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11-6

TI: A study on the mesh selectivity of salmon research gillnets

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OA: none

OA: none

SO: Bull. Nat. Res Inst. Far Seas Fish., No.33: 17-122

PY: 1996

LA: Japanese

DT: R

AB: Pacific salmon species, genus *Oncorhynchus*, spend the greater part of their life in the ocean before they return to rivers to spawn in fresh water. Therefore, biological data are required not only for the freshwater life stage but also for the ocean life stage in order to manage rationally fishery resources of these species. It is important to know the status of fish populations in the sea apart from commercial catches landed, although an analysis of commercial landings is also needed to investigate biomass dynamics. Drift gillnets are effective fishing gear for catching salmon species in the surface layer of the
ocean. But a sample obtained by a single mesh size gillnet gives a biased estimate of the population because the gillnet selectively catches fish only suitable for its mesh size.
It is essential to obtain a representative unbiased sample in order to get unbiased estimates of the siz composition, age composition, sex ratio, maturity stage, relative abundance, etc., at sea. For this research purpose, the author proposed a non-selective gillnet that is composed of ten gangs of the same number of tans. Each gang consists of different mesh sizes in a geometric series progressively increasing by 14%, namely, 48, 55, 63, 72, 82, 93, 106, 121, 138, and 157 mm. The test fishing was conducted in 1971 by using research gillnets consisting of ten different mesh sizes that were designed to get a flat composite selectivity for salmon ranging from 25-70 cm in fork length; a theoretically expected selectivity curve was verified from the data from the test fishing. Based on this test, research gillnets of ten mesh sizes were introduced in 1972 to all salmon research vessels of Japan. In this paper, mesh selectivity curves, growth equations, offshore distribution, and yearly fluctuations of a relative abundance index, etc., were analyzed by using a large quantity of data obtained from the research gillnets during the years 1972 to 1984.
(I) Comparisons were made among selectivity curves estimated by four different methods by applying them to the same data of size composition of immature chum salmon. The curve estimated by Kitahara's method is similar to that yielded by Ishida's

method. The curve estimated by Holt's method shows that the slope of the ascending arm is less steep, and the efficiency is optimum over a narrower size range than that produced by Ishida's method. The slope of the left arm in the curve estimated by Gulland-Harding's method is similar to that estimated by Holt's method, but the range of selection extends to larger fish. For purposes of comparison the selectivity curves used in this paper are derived by Ishida's method.

(2) Among the selectivity curves of the specific mesh net for pink salmon by time periods, it can be noted that the selectivity curves vary seasonally even for the same species, and that the nets are relatively more efficient in catching smaller fish as the season progresses. This is seen in the curves derived from the data by both Type A (121 mm mesh-series) and Type B (114 mm mesh-series). This phenomenon would be caused mainly by the increase in condition factor (fatness) of the fish as the season progresses.

(3) In order to examine the accuracy of estimated selectivity curves for pink salmon, the author used data from four research vessels equipped with longlines fished in waters west of 165° E and south of 48° N, and another five research vessels equipped with four different mesh (68 mm, 85 mm, 100 mm, 111-115 mm) gillnets fished in almost the same waters and the same time period. First, the selectivity curve was applied to the size composition of pink salmon caught on longlines, and the ratio of CPUE by mesh size was calculated. Assuming that the size composition of fish caught on longlines is representative of the population, the expected ratio was compared to the observed ratio for fish taken by each mesh. It may be concluded from the analysis given above that expected ratios generally agree with the observed ratios, except in April for the 68 mm mesh, and in May for the 85 mm mesh. While the selectivity curve was estimated from the combined data for April and May because of the need for larger sample sizes, it was applied to data for April and for May separately. This may partly explain the discrepancies mentioned above. To examine this point, by using the same procedure as a fore-mentioned, the expected mean length of fish was compared with the observed mean length. It is noted that there is an obvious trend in the results of t-tests applied to each pair of figures by month. Namely, in April and in May when Curve I was applied, expected means were always larger than observed ones, where lengths differed significantly. In June and July when Curve II was applied, expected means were smaller in June and larger in July than the observed ones. It may be concluded that the differences may vanish if sufficient monthly data can be obtained to estimate the selectivity curve. When the relative efficiency of a small mesh decreases and the relative efficiency of the next larger mesh increases, the fork length corresponding to the point of intersection of those two size frequency curves represents the fork length at

which the catch efficiency of these two meshes is equal. Applying this relationship to size frequency of pink salmon in May in the western North Pacific, it was suggested that expected mean length, by using Curve I, which was estimated from combined data in April and May, may lead to an overestimate. The selectivity curve combining 10 different mesh sizes in a geometric progression shows less change by season. Namely, individual curves for each mesh size move equally toward the left side with time and thus are mutually compensating. As a result, the seasonal difference in the combined selectivity curve appears only at the ends of the curve. In the range of 28-68 cm fork length, coefficients of variation for the mean of compound relative efficiency are 0.0133-0.0345 and the combined curve is almost flat. It is, therefore, concluded that the research gillnet is non-selective. There is a high correlation (r=0.988) between the pink salmon CPUE of the Type A net and that of the Type C net at each fishing station, and the regression line almost falls on a 45° line through the origin. Mean fork lengths of fish caught by Type A and Type C nets were 35.5 cm and 3;5.6 cm, respectively, and there was no significant difference between them. The coefficient of variation for the mean of the compound relative efficiency of Type A net is less than 0.0848 of Type C net. In other words, Type A net is more non-selective than Type C net for pink salmon.

(4) Although chum salmon of four ages occurred in the research waters, catches by each mesh size differed distinctly in age and size composition as a result of mesh selectivity. There is no significant difference between the optimum length of Curve I estimated from small fish data and Curve 2 estimated from large fish data. There are differences in the slope of the arms of both curves. Curve I has a steeper slope than Curve 2, especially in the left arm. This difference results from differences in the condition factor of the fish. There is a high correlation (r=0.990) between the chum salmon CPUE of the Type A net and that of the Type C net at each fishing station, and the regression line almost falls on a 45° line through the origin. There was no significant difference between mean fork lengths of fish caught by Type A and Type C nets. The coefficient of variation for the mean of compound relative efficiency of Type A net is 0.1256 and slightly smaller than 0.1426 of Type C net. In other words, Type A net is slightly more non-selective than Type C net for chum salmon.

(5) In the experimental fishing, it is a rule that the same number of tans of nets should be used for each mesh size, and all fish caught should be subjected to biological measurements. However, the actual case sometimes deviates from the rule unavoidably. The number of tans of various mesh sizes differs, or certain mesh sizes are absent, or the proportion of the catch sampled varies. In order to evaluate an estimate from incomplete data, tests of three cases were made. The result from complete data was

considered as the <"standard" for the evaluation. The first test was to sample 30 fish or less for biological measurement data from the catch, by each mesh size, in order to evaluate the accuracy of the estimate obtained from partially sampled data. The second test was to eliminate all data obtained from fish caught by the 72 mm mesh net. The third test was to adjust for the absence of 72 mm mesh data by a procedure which had three steps, i.e., es' mation of the selectivity curve from data excluding the 72 mm mesh net, estimation of size composition of the population, and estimation of expected catches by the 72 mm mesh net. In three tests, items examined were age composition, percentage of immature fish, mean fork length by age-maturity group, and mean fork length for all age groups pooled. As a result, it is noted that adjustment of the data to estimate the age and size composition is difficult when the number of tans and the proportion of the catch sampled vary. In addition, adjustment for the absence of a particular mesh net is impossible if basic data are not broken down by mesh size. However, an unbiased estimate can be obtained without a breakdown of catch by mesh size as long as the same number of tans are fished and the total catch is measured.

(6) Massive data from a total of 653,200 fish were obtained by the research gillnets of 10 mesh sizes during the years 1972 to 1984, and classified by species, year, month, mesh size, and fork length. By using these massive data, monthly selectivity curves from May to August were estimated for 11 species-size categories : namely, pink salmon of even- and odd-numbered years, chum salmon of small, medium, and large fish, sockeye salmon of small, m lium, and large fish, coho salmon, and small and large chinook salmon. The selectivity curve for pink salmon obtained from data pooled for all months as well as even-and odd-numbered years is useful as a universal curve, although the slope of the left and right arms are slightly less steep than in monthly curves. The shape of the selectivity curve for large chum salmon in this paper is similar to those of small and medium-sized chum and sockeye salmon. On the other hand, the shape of selectivity curves for large sockeye salmon and coho salmon indicate a feature in which the right arm spreads laterally because the netting mechanism in these cases is considered to be not only "gilling" but also "entangling" by means of "teeth" and "snout". Therefore, it is inferred that the shape of the selectivity curve for large chum salmon approaches that of large sockeye salmon, if sampling encounters well-matured chum salmon having developed secondary sexual characters. In general, there are two types of selectivity curve : i.e., the a-type curve which is fitted to selectivities by mesh size for fixed body length and the p-type curve which is fitted to selectivity on body length for a fixed mesh size. Both types of selectivity curve were estimated for each species-size category, and it was noted that a feature of the right arm of the a-type curve appeared

as a feature of the left arm of the P-type curve and the significance of features was essentially the same in both types.

(7)The maximum mesh size of 5-1/4 inch (133 mm) of the INPFC standard research gillnets is too small to obtain representative samples of large sockeye salmon, and there is thus a weak point in the INPFC research gillnets in which the combined selectivity curve of 4 different mesh sizes is less flat. Therefore, growth curves of salmon estimated from data by the INPFC nets have contained a bias caused by the basic data. As representative massive data were obtained from the newly introduced research gillnets of 10 mesh sizes in a geometric progression, it is appropriate to estimate new growth curves by using these data. The following growth equations were estimated for sockeye and chum salmon that winter more than once in the ocean before maturation.

sockeye, female, immature : $L(t) = 556\ [1 - e^{-0.89(t-0.901)}]$

sockeye, female, maturing : $L(t) = 630[1 - e^{-0.80(t-0.481)}]$

sockeye, male, immature : $L(t) = 594[1 - e^{-082(t-0.874)}]$

sockeye, male, maturing : $L(t) = 662[1 - e^{-092(t-1.004)}]$

chum, female, immature : $L(t) = 604[1 - e^{-0.60(t-0.621)}]$

churn, female, maturing : $L(t) = 666[1 - e^{-0.54(t+0.123)}]$

chum, male, immature : $L(t) = 656[1 - e^{-0.51(t-0.561)}]$

chum, male, maturing : $L(t) = 697[1 - e^{-0.06(t-0.580)}]$

In the above equations, L indicates fork length in mm and t indicates age at the time in July.

(8) The percentage of sets in which target species were caught (the rate of success) were calculated at each 1°C class of sea temperature. Based on the lower limit of the temperature range in which the rate of success was more than 50, the preferred temperature ranges for each species were : sockeye salmon, 3-9°C ; chinook salmon, 4-9°C ; pink salmon, 3-10°C ; chum salmon, 1-12°C ; coho salmon, 6-12°C ; and flying squid, more than 12°C. Most of the chinook salmon caught in this study area and time period were immature, and maturing chinook salmon have already migrated northward and passed through the study area by this season. Except for this point, the above mentioned results coincide with the characteristic distribution area of each species. Namely, coho salmon, having a high preferred temperature, occupy the most southern part of the salmon distribution area ; sockeye salmon, having a low preferred temperature, occupy the most northern part of the salmon distribution area; and chum and pink salmon, having a medium preferred temperature, occupy the middle area between both of them. In addition, the characteristic distribution area of each species agrees with the peculiarity of up-stream migration time periods of each species.

Namely, the order of return migrations to the Kamchatka-Okhotsk coast is as follows : chinook salmon return earliest, then sockeye salmon, pink salmon, and chum salmon with coho salmon migrating last. This order of migration corresponds to the preferred temperatures and offshore distribution positions. There are differences of preferred temperature range and offshore distribution area between immature and maturing fish of even the same species. Based on CPUE distribution of immature and maturing chum salmon caught by 1) mesh-size research gillnets, it was noted that immature cburn salmon occurred in the southeastern part of the chum salmon distribution area in May, occupied the main part of the area south of 50°N and east of 170°E in June as if immature fish fill up an area vacated by maturing fish and extended throughout the whole offshore area in mid-July replacing maturing fish, which shifted to the coastal waters. These results indicated the offshore distribution pattern of immature chum salmon in May to July more clearly than results reported in the INPFC comprehensive report of chum salmon by Neave et. al. (1976). In other words, this paper provided new information on offshore distribution of immature and maturing chum salmon in the North Pacific.

(9) Relative abundance indices of immature sockeye salmon caught by the 10-mesh type of research gillnets in central Aleutian waters indicate a high correlation with inshore run size of sockeye salmon in Bristol Bay in the following year. Data of immature sockeye salmon wer : obtained in the waters of longitude 175°E to 175°W and latitude 50°N to 52°N from July 1 to August 10 during the years 1972 to 1986. These data indicated a closer correlation with Bristol sockeye(salmon than did data from U. S. purse seine research, and provided further valuable information after the discontinuance of the U. S. purse seine research project. The relationship between mean CPUE of age .1 immature sockeye salmon in Aleutian waters (X_1) and the number of age . 2 sockeye in the run to Bristol Bay in the following year (Y_1) is as follows :

$Y_1 = 3.98 + 15.54 X_1$ (coefficient r= 0.66)

The relationship between mean CPUE of age .2 immature sockeye salmon in Aleutian waters (X_2) and the number of age . 3 sockeye in the run to Bristol Bay in the following year (Y_2) is as follows :

$Y_2 = 5.39 + 3.11 X_2$ (coefficient r= 0.63)

Although the cause of the difference in incline between the two regression lines is unknown at present, considering each ocean age group separately reveals significant correlation of abundance indices between offshore immature fish and the following year's inshore run, and the correlations are useful for prediction of inshore run size and assessment of stock condition. Summarizing the above, it is best to combine several mesh sizes in geometric progression in order to sample salmon at sea with equal catchability. It is concluded that research gillnets with 10 mesh sizes .which were proposed by the author and introduced after the feasibility tests, are suitable from a practical aspect and useful as sampling gear to improve research efficiency for pelagic fishes.

KW: mesh selectivity, salmon research gillnets, selectivity curves, growth curves, preferred temperature range, relative abundance index of salmon

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