Estimating the Spawning Stocks of Pacific Hake *(Merluccius productus)* and Walleye Pollock *(Theragra chalcogramma)* in the Strait of Georgia, B.C. from their Released Egg Production

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ESTIMATING THE SPAWNING STOCKS OF PACIFIC HAKE (*Merluccius productus*) AND WALLEYE POLLOCK (*Theragra chalcogramma*) IN THE STRAIT OF GEORGIA, B.C. FROM THEIR RELEASED EGG PRODUCTION

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ABSTRACT

Mason, J. C., A. C. Phillips, and O. D. Kennedy. 1984. Estimating the spawning stocks of Pacific hake (*Merluccius productus*) and walleye pollock (*Theragra chalcogramma*) in the Strait of Georgia, B. C. from their released egg production. Can. Tech. Rep. Fish. Aquat. Sci. No. 1289: 51 p.

Ichthyoplankton surveys were carried out in the Strait of Georgia, B.C. during their common spawning season (Feb.-June) for endemic stocks of Pacific hake and walleye pollock, in 1981. The objective was to estimate the magnitude of the spawning stocks in the central and southern regions of the strait by the egg production method.

A grid of 80 stations was sampled using Bongo gear every two weeks on nine cruises from late February to mid-June.

Annual released egg production amounted to 1.84×10^{13} pollock eggs and 3.78×10^{13} hake eggs. Magnitude of spawning in northern Georgia Strait south of Campbell River is estimated at <5% and <15% of that for pollock and hake, respectively, in the central and southern strait.

From associated fecundity and population parameters of sex ratio, and mean length and weight, the adult stocks are estimated to comprise 96.2 million pollock (60.5 kt) and 390 million hake (182.8 kt) in the strait south of Texada Island.

RESUME

Mason, J. C., A. C. Phillips, and O. D. Kennedy. 1984. Estimating the spawning stocks of Pacific hake (Merluccius productus) and walleye pollock (Theragra chalcogramma) in the Strait of Georgia, B. C. from their released egg production. Can. Tech. Rep. Fish. Aquat. Sci. No. 1289: 51 p.

Pendant la fraieson commune (février-juin) des stocks endémiques de merlu du Pacifique et de la morue du Pacifique occidental en 1981, des levés de l'ichtyoplancton ont été menés dans le détroit de Géorgie (C.-B.). On visait l'estimation de l'abondance des reproducteurs dans les parties centrale et méridionale du détroit, à l'aide de la méthode de production d'oeufs.

Au cours de neuf expéditions, on a échantillonné avec des filets Bongo un quadrillé de 80 stations toutes les deux semaines de la fin de février jusqu'à la mi-juin.

La production annuelle d'oeufs totalisait 1.84 x 10^{13} et 3.78 x 10^{13} pour la morue du Pacifique occidental et le merlu du Pacifique respectivement L'envergure de la fraie dans la partie septentrionale du détroit de Géorgie, au sud de la rivière Campbell, est évaluée respectivement à $< 5\%$ et à $< 15\%$ de celle du merlu et de la morue peuplant les parties centrale et méridionale du détroit.

À partir de la fécondité et des paramètres de l'ensemble sur le rapport des sexes et sur la longueur et le poids moyens, on évalue l'abondance des stocks adultes à 96.2 millions de morues (60.5 kt) et à 390 millions de merlus (182.8 kt) dans le détroit au sud de l'île Texada.

INTRODUCTION

The Strait of Georgia is a semi-enclosed, marine basin on the Pacific coast of Canada separating the southern half of Vancouver Island from the mainland of British Columbia. The strait contains resident stocks of Pacific hake and walleye pollock of sufficient magnitude to attract the attention of the domestic commercial fishing fleet. Pollock have been exploited as a secondary species in the bottom trawl fishery since the middle 1940s and used for animal food by fur ranches (Ketchen et al. 1983). They became the object of a midwater trawl fishery for human consumption after 1973 that has emphasized the Japanese roe market in recent years. Pacific hake concentrations accompanying pollock were reported by Westrheim (1974) and an experimental fishery of modest proportion began in 1979.

Development of a rational management plan for these two midwater fishes in the Strait of Georgia is precluded without reliable stock assessment procedures. Procedures employing exploitation statistics are of limited utility in the absence of a well-documented fishery and allied population statistics, hence an intensive, coordinated effort in 1981 was directed at assessing the magnitude of these stocks using three survey approaches: 1) hydroacoustical, 2) swept volume trawling, and 3) ichthyoplankton-derived released egg production.

This report deals with the ichthyoplankton survey and allied research studies on fecundity and physiological embryology. It compliments two associated reports on stock assessment by hydroacoustical (Kieser 1983) and swept volume trawling (Thompson and McFarlane 1982) techniques.

MATERIALS AND METHODS

SURVEY DESIGN AND SAMPLING METHODOLOGY

A sampling grid of 80 stations covering the central and southern parts of the strait from the southern tip of Texada Island, to the north, to Patos Island in the south (Fig. 1) was identified for routine occupancy. The grid was confined to open waters beyond the 70 fath isobath (128 m) and interstation distance ranged between 1.5-2.0 M (2.8-3.7 km). The continguous, open waters to the north of the grid area were sampled on two transect cruises through the deeper parts of northern Georgia Strait, northward to a point south of Hernando Is., circumnavigating Texada Is. The transect cruises involved 23 fixed-position stations, some 7 km apart, and were timed to bridge the period of peak spawning within the grid.

The timing of the annual spawning cycle was taken from previous ichthyoplankton surveys in 1979 and 1980 (Mason et al. 1982a,b) which indicated that both hake and pollock cycles are bracketed by the calendar period Feb. 15 - June 15, with hake spawning activity peaking some two weeks subsequent to the pollock peak, during the first week of April.

Commencing in mid-February, 1981 the 80 station grid was sampled every three weeks, progressing from northwest to southeast. Cruise completion required seven to nine days, depending on weather conditions. A total of nine grid cruises were made between Feb. 18 and June 14 (Mason et al. 1983c, d, e), supplemented by the two northern cruises in March and April (Mason et al. 1982f).

On each station, oblique tows were taken within 5 m of the sea floor, employing 0.25 m^2 Bongo samplers (McGowan and Brown 1966), after the general sampling procedure described by Smith and Richardson (1977) with the following exceptions: all sampling components were black; nets were of 351 μm Nitex and of modified SCOR design; codends were of PVC with 351 μm stainless steel mesh windows; a cylindrical weight of 75 kg was suspended 3 m below the nets. Filtration volumes averaged 224 m^3 (2 SE=16.2). Plankton catches were preserved in 5% buffered seawater formaldehyde for analysis ashore. Catches of fish eggs and larvae were standardized to no. /10 m^2 sea surface by applying a standard tow factor to the raw catches derived from the following equation:

$$SHF = \frac{\text{max. tow depth (m)}}{\text{vol. filtered (m}^3\text{)}} \times 10$$

Vertical profiles of temperature and salinity were obtained at selected stations using a Bisset-Berman STD system, standardized from Nansen casts. Vertical temperature profiles were obtained routinely at 20 stations within the grid from XBT casts.

PROCESSING OF PLANKTON SAMPLES

In the laboratory, preserved plankton samples were sorted for fish eggs and larvae, retaining the replicate samples (right net catches) for multi-purpose analyses and reference. The entire sample was processed to provide total counts, thus avoiding subsampling error. Processing time was reduced by a factor of five by employing some new techniquees (to be published elsewhere) involving: 1) serial sorting by size categories, 2) a large, partially baffled sorting tray over a light box, and 3) a vacuum-assist, controlled siphon sorting-collecting system that allows rapid manipulation, selection, and storage of target items.

The "offshore" ichthyoplankton of Georgia Strait during the period of sampling consists of a relatively short species list. Eggs and larvae of hake and pollock comprised nearly 95% of the total catches of fish eggs and larvae. The eggs and larvae of the northern smoothtongue (*Leuroglossus schmidti*) made up some 3%; the remaining 2% were eggs and larvae of several flatfishes, and larvae of Pacific herring (*Clupea pallasi*), rockfishes (*Sebastes* spp.), and marine cottids.

The pelagic eggs of hake and pollock in Georgia Strait stocks are of similar size and, apart from the single, large oil globule (0.3 μm dia.) in the hake egg, are of very similar appearance. Egg diameter ranges, means, and 2SE are 1.14 - 1.38 mm, 1.250 mm, and 6 μm for pollock, and 1.14 - 1.34 mm, 1.233 mm, and 8 μm for hake. Both eggs are spherical, have a tough, transparent and unsculptured chorion, and a narrow perivitelline space. The yolk material is clear, homogeneous, and straw-colored. The living eggs are transparent in the early stages of embryological development, rendering their detection difficult in fresh plankton collections. The eggs were sorted into three developmental stages: early (fertilization to primitive streak), middle (streak to tail flexion), and late (flexion to hatching) after Ahlstrom and Counts (1955) and Yusa (1954).

DETERMINATION OF FECUNDITY

Fresh ovaries were collected in February and March, preserved initially in 10% formaldehyde, then transferred to Gilson's fluid as modified by Simpson (1951) for four months prior to extracting the eggs. Using a subsampling procedure, the size distribution and total number of eggs in selected size categories were estimated. Potential egg retention was investigated by examining ovaries in the post-spawned state in June and July. The fecundity studies will be published separately.

PROCESSING THE CATCH DATA

For each grid cruise, the standardized egg catches by developmental stage (early, middle, and late) were logtransformed and stratified in eight log-scale abundance strata. The number of strata was set initially by examining the effect that the number of strata (3-10) had on the patterning of horizontal distribution and abundance. For the hake and pollock data sets, the spatial patternings remained intact as the number of strata was increased from three to eight but began to fragment rapidly thereafter. Therefore, mean egg catches were calculated for eight abundance strata. The products of the backtransformed stratum means or 95% confidence limits and the appropriate areal expansion factor provided the total abundance and confidence limits for each abundance stratum. Stratum totals and confidence limits were then summed to obtain the population estimate by stage for the cruise.

Annual egg production by stage was derived by integrating the area under the seasonal plot of mean daily egg population rate. The latter values were derived from the staged egg population estimates by cruise divided by the stage duration as a function of ambient temperature. State durations were determined in the laboratory at controlled temperatures. Regression equations were used to obtain durations in nature, using the ambient temperatures at depths of maximum egg abundance. Both species egg populations are confined to depths exceeding 100 m. An analysis of the vertical distribution of eggs and larvae will be published separately.

Annual production of released eggs were obtained by regressing the logtransformed annual staged egg production values against accumulated time from fertilization to hatching, using accumulated time to midstage for the actual plots. Annual production of released eggs at T_0 is estimated by the back-transformed intercept value (a) in the linear regression equation. Similarly, the population of hatched larvae was estimated from the regression equation extended to the accumulated time required to allow median hatching at the ambient temperature.

The estimates of spawning stock size were derived from the estimated annual production of released eggs and stock parameters of sex ratio, mean length and weight, and fecundity equations relating size of mature female with estimated number of yolked eggs destined for release.

STAGE DURATION ESTIMATES IN THE LABORATORY

Both hake and pollock eggs were dry-fertilized, using adult fish in spawning condition captured in the open strait and transported to the laboratory in livetanks. The fertilized eggs were transferred to constant-temperature baths and held at three temperatures (7, 8.5 and 10°C) at a salinity of 30.5°/₀₀ in meshed containers. Development was monitored at six hour intervals for the first day, then twelve hour intervals thereafter to hatching. Stage limits were determined in accumulated time from fertilization and the resulting stage duration times were regressed against temperature using logtransformed values. The resulting linear equations were then used to estimate the stage durations at ambient temperatures found at the depths of maximum egg abundance.

RESULTS AND DISCUSSION

THE ANNUAL SPAWNING CYCLE

Both species commence spawning in middle to late February. A monitor grid of nine stations occupied in 1980 in the central strait produced no eggs or larvae of either species on Jan. 31, 183 eggs and 15 larvae on Feb. 12-13, and 1431 pollock eggs but no larvae and 17,604 eggs and 6 larvae of hake on Feb. 20. Thus, the onset of spawning in 1980 took place during the first week of February. The first cruise in 1981 (Feb. 18-24) over the entire 80 station grid produced 128 pollock eggs and no larvae, and 3,825 eggs and 66 larvae of hake, suggesting comparable timing of the onset of spawning in 1980 and 1981.

Despite temporal coincidence in the onset of spawning, hake and pollock manifest some significant differences in the progression and intensity of spawning as indicated by the course of mean daily rate of egg production

(Fig. 2). Both species showed similar maximum rates (3.2 and 3.6 x 10^3 stage one eggs/10 m^2) but pollock peaked in late March, whereas hake peaked in early April and showed a more sustained production rate into the early summer. By mid-June, spawning activity had reached a low ebb when positive stations for stage one eggs of pollock were reduced to 4% and the maximum catch on station reduced to 20 eggs/10 m^2. In contrast, positive stations for hake eggs still exceeded 50% and station egg catches commonly exceeded 200 eggs/10 m^2. Thus, although nearly 99% of the pollock spawning was completed by mid-April, that for hake was not reached until mid-May and cessation of hake spawning probably occurred in late June.

HORIZONTAL DISTRIBUTION AND ABUNDANCE OF EGGS

Both species confined their spawning activities to waters deeper than 130 m. Large catches of eggs were restricted to station depths exceeding 300 m for hake and 200 m for pollock (Figs. 3 and 4). The relationship between magnitude of catch and station depth is further clarified by limiting consideration to geographical sectors C and D (Fig. 1) which enclose the general area of maximum spawning activity for both stocks.

For purposes of locational comparison, the sampling grid was sub-divided into six sectors (Fig. 1). Compared to the hake eggs which were primarily and fairly evenly distributed through sectors A to D, the pollock eggs were primarily distributed in sectors C and D, and secondarily elsewhere (Fig. 5). The largest annual mean egg catches occurred in sector C for hake and sector D for pollock. The overall geographical patterns of egg distribution in scaled categories of abundance, using the annual egg catch on station (no. eggs/10 m^2/yr) are depicted in Fig. 6. Hake spawned in the deeper waters throughout the grid area from mid-Galiano Is. westward to Texada Is. although spawning activity was depressed during their peak period of spawning in the deep waters within the boundaries of Canadian Forces Maritime Test Range Whiskey Gulf, northwest of Nanaimo. Pollock showed four areas of high spawning activity, the largest area bridging Porlier Pass from mid-Galiano Is. westward to Gabriola Is. and three smaller areas: south of Halibut Bank in mid-strait, south of Bowen Is. northwest of Vancouver, and off Mayne Is. just east of Active pass in the Southern Strait.

Within the spawning season, species egg distributions showed similarities and differences as the season progressed. At the onset of spawning, (Fig. 7) hake eggs were restricted northwest of Nanaimo and southeast of Galiano Is. (Fig. 7) and also showed two areas of localized high abundance: north of Porlier Pass and east of Halibut Bank, but were more generally distributed than were pollock eggs. Pollock eggs were almost entirely confined to offshore regions, with highest egg catches found in two areas: north of Porlier Pass and offshore midway between Gabriola Is. and Point Grey (Vancouver).

During March, the common area of high egg abundance bridging Porlier Pass expanded to the north and west (Figs. 8 and 9). By early April, it had reached Bowen Is. to the north and Texada Is. to the west (Fig. 10). By mid-April, hake eggs were in high abundance throughout the deeper waters (Fig. 11) and pollock egg abundance was declining near Porlier Pass so that by early May pollock eggs were found in generally high abundance throughout the deeper waters from Gabriola Is. to Texada Is. (Fig. 12) while high abundance of hake eggs were restricted to an area north of Gabriola Is. (Fig. 12). By mid-May, a decline in the number of positive stations, particularly in the Southern Strait, was well-established for pollock (Fig. 2) and paralleled the trend in declining relative abundance proceeding from northwest to southeast (Figs. 13 and 14). By late May, the area of maximum catches for hake eggs lay northwest of Gabriola Is. and the distribution of pollock eggs was showing retraction and general collapse also discernible in the hake egg distribution (Fig. 14). By early June, pollock eggs were found in low numbers at scattered locations, signifying that cessation of spawning was imminent, and the hake egg distribution showed continued retraction (Fig. 15).

As estimated from sigmoid plots of the accumulated percent egg production in time, spawning was 50% complete for pollock on 22 March and 99% complete by 20 April. The corresponding dates for the hake are 1 April and 15 May, respectively.

In Northern Georgia Strait, pollock eggs were either absent or present in very low numbers in most locations sampled in mid-March (Fig. 8). An area of minor abundance was found off the northwestern end of Texada Is. but maximum catches there were low (145 eggs/10 m^2) compared to catches exceeding 2-3000/10 m^2 off Nanaimo, and 40,000/10 m^2 off Galiano Is. Minor hake spawning was found throughout northern waters in mid-March except for high spawning activity northwest of Texada Is. coincident with pollock activity (Fig. 9). The highest catch of hake eggs there (73,000/10 m^2) compares favorably with the highest catches off Gabriola Is. approaching 84,000/10 m^2.

By mid-April, all northern stations produced pollock eggs north of Nanaimo to a northerly line bisecting Texada Is. that met or exceeded catches off Nanaimo and Gabriola Is. (Fig. 11). West of Lasqueti Is., including Malaspina Strait, abundance of pollock eggs was rather consistent, albeit low, in northern waters in mid-April. In contrast, hake egg abundance was consistently high throughout the northern region and catches at four stations exceeded the highest catch in the central region taken off Gabriola Is. (20,000/10 m^2) in mid-April (Fig. 11).

These distribution and abundance patterns are taken to reflect localized spawning activities of the hake and pollock stocks in Georgia Strait, although nothing can be inferred from these data regarding the movements of the adult stocks. The vertical distribution of their eggs precludes that the horizontal patterns and their changes are mere reflections of surface water transport induced by wind and tide. Both species egg populations are confined to depths exceeding 100 m over station depths exceeding 130 m, as previously stated.

PRODUCTION ESTIMATES FOR STAGED EGGS

From the staged egg population estimates from each of nine cruises spanning the reproductive season (Table 1), and regressions describing the duration of stages at temperature (Table 2), the mean daily production rates were derived (Table 3). Mean daily production plotted against time (Fig. 16) gave the mean annual production (no. eggs/10 m^2/yr) for each egg stage from the area under the production curve. Note the scale differences for the three egg stages in Fig. 16 which were selected to facilitate comparison of the production curves.

The mean annual production by stage was expanded by an areal factor (2.243×10^9 m^2 = surface area of Central and Southern Georgia Strait waters > 130 m deep) to provide estimates of the total annual production of eggs within stage.

Total annual production values were logtransformed and plotted against the mid-stage durations (hrs) as in Fig. 17. Regression equations fitting these plots were used to calculate production values for time of fertilization (T_0) and for time of median hatch (T_{200} for pollock and $T_{193.9}$ for hake). Fertilized egg production amounted to 1.84×10^{13} pollock eggs and 3.78×10^{13} hake eggs in central and southern regions of Georgia Strait (Table 4). Survival to hatching was identical for both stocks (10%), the slightly higher daily mortality rate for hake reflecting their shorter duration of embryological development at ambient temperature.

ESTIMATION OF SPAWNING STOCK SIZE

Fecundity-length relationships for the hake and pollock stocks were determined from fecundity regression equations relating the estimated number of yolked, ovarian eggs > 200 μm dia. and total length in cm. The detailed fecundity studies will be reported separately. The fecundity equations used to determine mean fecundities for the two stocks are $F=0.055FL^{3.39}$ (hake) and F2.3522FL-599713 (pollock). The calculated mean fecundities with associated stock parameters derived from research catches (McFarlane et al. 1983) are given in Table 5. The averaged-sized female pollock is almost twice as fecund as her hake counterpart.

Stock sizes for the central and southern regions of the strait were estimated from

$$N = \frac{(\text{Annual egg prod.})^2}{\text{Mean fecundity}}$$

giving 96 million pollock and 390 million hake, and a numerical stock ratio of 1:4.1 in favor of hake (Table 5). The resulting biomass estimates are 60,500 mt of pollock and 182,800 mt of hake, giving a ratio of 1:3 (Table 5).

The northern cruises coincided with maximum egg production rates within the grid, pollock on the first cruise in mid-March, and hake on the second cruise in early April. Stock sizes in the northern area were derived from areal expansion of station egg catches to provide estimates of the total populations of stage one eggs for both cruises. Expressed as percentages of the nearly-simultaneous estimates within the grid, or of those for the previous grid cruise gave ranges of >1%-7% for pollock, and 7%-14% for hake. The spawning populations present in the waters northwest of the grid (northwest of the southern tip of Texada Is.) and south of Campbell River are assumed to be >5% and >15%, respectively, of the pollock and hake stocks spawning in Central and Southern Georgia Strait. Thus, although waters of suitable spawning depth, equalling some 40% of comparable water area within the grid, are available in northern waters of the strait south of Campbell River, they are poorly utilized as spawning areas.

DISCUSSIONS AND CONCLUSIONS

The primary objective of this work was to provide estimates of the adult stocks of pollock and hake in Central and Southern Georgia Strait by the plankton method. The reliability of the estimates can best be determined by reviewing and assessing the major sources of error as to their probable magnitude.

Field sampling error stemming from contagious distribution of the eggs at depth was countered by applying a relatively-high density sampling grid that was fully occupied on each cruise, and the grid completed in some six days. The weighted 95% confidence limits for the annual egg production estimates for fertilized eggs is - 13% and +24% (pollock) and -18% and +22% (hake), applying the limits for the mid-stage one eggs (Table 4). Runs of six replicate Bongo tows on each of three selected stations within the grid showed that catches of hake and pollock eggs fell within 15-20% of the mean catches. Net clogging due to phytoplankton bloom occurred on a single cruise late in the spawning season, involved the southern area of low egg production, and >10% of the stations of the grid.

In the laboratory, we sorted the entire plankton catch and resorted to subsampling under two circumstances: 1) staging eggs - a maximum of 200 eggs/catch were staged and replication suggests a routine error magnitude of 1-2%, and 2) counting eggs - catches up to 3000 eggs were counted *in toto*, larger catches were volumetrically sub-sampled to one third of total volume and replication suggests an error magnitude of >1%. Fecundity determinations involved a subsampling routine error of >2%. Any discrepancy between potential fecundity and released egg fecundity reflecting ovarian retention and resorbtion, as has been reported for Pacific hake by Beamish and Foucher (1980) renders the mean fecundity determinations maximal, leading to conservative estimates of stock size.

Sources of error stemming from calculations based on regression equations are considered to be of minor significance as correlation coefficients exceed 0.83, with most values exceeding 0.90. Sex ratios of adult fish in research catches were weighted by CPUE data for discrete depth intervals, to account for differences in depth preference shown by the sexes during the spawning season.

Rates of egg production are potentially subject to a source of overestimation originating from the application of too high an ambient temperature during incubation, or to a time-trend in temperature increase as spawning progresses. These sources of potential error are considered minimal as both egg populations are confined to depths exceeding 100 m where horizontal and vertical temperature changes during the spawning season >0.2°C are detectable.

In conclusion, the stock estimates based on egg surveys are considered to be both reliable and conservative. They should prove to be a valuable contribution to management of these two fisheries in the Strait of Georgia. These results illustrate the utility of the plankton method for assessing stocks of midwater, pelagic fishes independent of exploitation statistics which are also insufficient or absent in developing fisheries. Finally, the results suggest that future stock conditions can be routinely monitored using truncated ichthyoplankton surveys designed to estimate annual egg production, inter-annual differences in egg production, and the causes of recruitment success or failure as such causes may operate during the early lifehistory of the species.

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REFERENCES

Ahlstrom, E. H. and R. C. Counts. 1955. Eggs and larvae of the Pacific hake Merluccius productus. U.S. Fish. Wildl. Serv. Fish. Bull. 56: 295-329.

Foucher, R. P. and R. J. Beamish. 1980. Production of nonviable oocytes by Pacific hake (Merluccius productus). Can. J. Fish. Aquat. Sci. 37: 41-48.

Ketchen, K. S., N. Bourne, and T. H. Butler. 1983. History and present status of fisheries for marine fishes and invertebrates in the Strait of Georgia, British Columbia. Can. J. Fish. Aquat. Sci. 40: 1095-1119.

Kieser, R. 1983. Hydroacoustic biomass estimates of bathypelagic groundfish in Georgia Strait, January, February, and April, 1981. Can. MS Rep. Fish. Aquat. Sci. No. 1715: 84 p.

Mason, J. C., O. D. Kennedy, and A. C. Phillips. 1982a. The Strait of Georgia Ichthyoplankton Survey, 1979. Ichthyoplankton. Can. Data Rep. Fish. Aquat. Sci. No. 359: 284 p.

Mason, J. C., O. D. Kennedy, and A. C. Phillips. 1982b. The Strait of Georgia Ichthyoplankton Survey, 1980. Ichthyoplankton. Can. Data. Rep. Fish. Aquat. Sci. No. 361: 555 p.

1982c. The Strait of Georgia Ichthyoplankton Survey, 1981. Ichthyoplankton. Cruises 1, 2, and 3 (February 18-24, March 2-10, and March 16-22). Can. Data Rep. Fish. Aquat. Sci. No. 360: 245 p.

1982d. The Strait of Georgia Ichthyoplankton Survey, 1981. Ichthyoplankton. Cruise 5, 7, and 8 (March 30-April 6, April 14-20, and April 27-May 3). Can. Data Rep. Fish. Aquat. Sci. No. 364: 243 p.

1982e. The Strait of Georgia Ichthyoplankton Survey, 1981. Ichthyoplankton. Cruise 9, 10, and 11 (May 11-15, May 25-29, and June 8-14). Can. Data Rep. Fish. Aquat. Sci. No. 363: 245 p.

1982f. The Strait of Georgia Ichthyoplankton Survey, 1981. Ichthyoplankton. Northern Cruises 3 and 6 (March 12-13 and April 9-10). Can. Data Rep. Fish. Aquat. Sci. No. 362: 49 p.

Mason, J. C., R. J. Beamish, and G. A. McFarlane. 1983. Sexual maturity, fecundity, spawning, and early life history of sablefish (Anoplopoma fimbria) off the Pacific coast of Canada. Can. J. Fish. Aquat. Sci. 40: 2126-2134.

McFarlane, G. A., W. Shaw, and R. J. Beamish. 1982. Observations on the biology and distribution of Pacific hake, walleye pollock, and spiny dogfish in the Strait of Georgia, February 20-May 2, and July 3, 1981. Can. MS Rep. Fish. Aquat. Sci. No. 1722: 109 p.

McGowan, J. A., and D. M. Brown. 1966. A new opening-closing paired zooplankton net. SIO Ref. Scripps Inst. Oceanogr. 66-23.

Simpson, A. C. 1951. The fecundity of the plaice. U. K. Min. Agric. Fish. Fish. Invest. Ser. 2, 17(5): 1-27.

Smith, P. R. and S. L. Richardson. 1977. Manual of methods for fisheries resource survey and appraisal. Part 4. Standard techniques for pelagic fish egg and larval surveys. NOAA NMFS Southw. Fish. Cent. Admin. Rep. No. 77-11.

Thompson, J. M. and G. A. McFarlane. 1982. Distribution and abundance of Pacific hake and walleye pollock in the Strait of Georgia, March 24-May 2, 1981. Can. MS Rep. Fish. Aquat. Sci. No. 1661: 79 p.

Westrheim, S. J. 1974. Exploration of deep-water trawling grounds in the Strait of Georgia in 1974. Fish. Res. Bd. Can. MS Rep. No. 1320: 25 p.

Yusa, T. 1954. On the normal development of the fish, *Theragra chalcogramma* (Pallas), Alaska pollock. Hokaido Region. Res. Lab. Bull. 10: 1-15 p.

Table 1. Staged egg population estimates for nine cruises spanning the 1981 spawning cycle of walleye pollock and Pacific hake in Central and Southern Georgia Strait (95% C.L.).

	Walleye Pollock			Pacific Hake		
Cruise/Dates	Stage One	Stage Two	Stage Three	Stage One	Stage Two	Stage Three
1/Feb 18-24	4.24×10^{9}	4.43×10^{8}	3.23×10^{8}	2.42×10^{10}	3.78×10^{9}	3.56×10^{9}
	(3.02- 6.05)	(1.63- 6.32)	(2.20- 4.36)	(1.61- 2.70)	(3.16- 4.55)	(3.20- 4.36)
2/Mar 2-10	3.72×10^{11}	9.85×10^{10}	6.66×10^{10}	5.44×10^{11}	1.62×10^{11}	1.72×10^{11}
	(2.87- 4.83)	(6.49-18.58)	(5.35- 8.30)	(4.39- 6.74)	(1.29- 2.04)	(1.39- 2.14)
3/Mar 16-22	1.65×10^{12}	4.35×10^{11}	5.37×10^{11}	1.74×10^{12}	3.32×10^{11}	3.41×10^{11}
	(1.31- 1.65)	(3.61- 5.26)	(4.56- 6.33)	(1.33- 2.32)	(2.69- 4.76)	(2.75- 4.26)
4/Mar 30-Apr 6	5.72×10^{11}	2.78×10^{11}	6.42×10^{11}	2.35×10^{12}	5.43×10^{11}	5.56×10^{11}
	(5.01- 6.53)	(2.31- 3.36)	(5.58- 7.38)	(2.06- 2.70)	(4.71- 6.27)	(4.78- 6.49)
5/Apr 14-20	8.05×10^{10}	4.68×10^{10}	8.76×10^{10}	6.18×10^{11}	2.77×10^{11}	3.59×10^{11}
	(5.88- 7.51)	(4.10- 5.33)	(7.89- 9.72)	(5.19- 7.36)	(2.40- 3.20)	(2.99- 4.32)
6/Apr 27-May 3	2.37×10^{10}	1.14×10^{10}	1.77×10^{10}	2.20×10^{11}	9.93×10^{10}	1.11×10^{11}
	(1.97- 2.87)	(1.01- 1.30)	(1.55- 2.03)	(1.73- 2.79)	(8.41-11.75)	(0.94- 1.33)
7/May 11-15	9.15×10^{9}	4.07×10^{9}	5.04×10^{9}	1.27×10^{11}	5.03×10^{10}	7.09×10^{10}
	(6.45-14.28)	(3.14- 5.32)	(3.93- 6.53)	(0.97- 1.70)	(4.35- 5.83)	(5.96- 8.45)
8/May 25-29	3.24×10^{9}	7.59×10^{8}	1.10×10^{9}	3.35×10^{10}	1.55×10^{10}	1.98×10^{10}
	(1.78-10.13)	(6.43-10.32)	(0.87- 1.40)	(2.77- 4.05)	(1.34- 1.81)	(1.67- 2.65)
9/June 8-14	1.63×10^{8}	5.97×10^{7}	1.16×10^{8}	7.00×10^{9}	4.30×10^{9}	9.02×10^{9}
	(1.48- 2.39)	(4.59- 7.72)	(0.89- 1.71)	(5.46- 9.11)	(2.92-12.53)	(7.71-10.59)

Table 2. Regression equations for stage duration as influenced by temperature over the range 6 to 10°C, for walleye pollock and Pacific hake eggs incubated in the laboratory.

	Pollock	Hake
Stage 1	$\log_e Y = -0.444 \log_e X + 5.0163$ $r = 0.99$	$\log_e Y = -0.6886 \log_e X + 5.7788$ $r = 0.99$
Stage 2	$\log_e Y = -0.4447 \log_e X + 5.4896$ $r = 0.99$	$\log_e Y = -1.8568 \log_e X + 8.8413$ $r = 0.99$
Stage 3	$\log_e Y = -0.4385 \log_e X + 6.3070$ $r = 0.99$	$\log_e Y = -.06896 \log_e X + 6.8016$ $r = 0.99$

where Y = duration in hours and X = temperature in °C

Table 3. Daily production estimates (no. eggs/10^2) by cruise for staged eggs of walleye pollock and Pacific hake in Central and Southern Georgia Strait, 1981 (95% C.L.).

	Walleye Pollock			Pacific Hake		
Cruise	Stage One	Stage Two	Stage Three	Stage One	Stage Two	Stage Three
1	8.2	1.4	0.3	41.3	9.8	5.6
	(5.8-11.7)	(1.2-7.2)	(0.2-0.4)	(27.7-58.6)	(8.2-11.9)	(4.1-7.5)
2	719.1	316.5	61.8	832.4	420.0	222.0
	(554- 933)	(208-597)	(50-77)	(674-1032)	(336-529)	(180-278)
3	3183.2	1396.6	498.4	2666.1	862.7	440.5
	(2537-4001)	(1159-1688)	(423-588)	(2026-3546)	(699-1234)	(357-551)
4	1103.9	893.0	595.6	3597.9	1408.8	718.2
	(967-1261)	(743-1078)	(518-685)	(3130-4138)	(1226-1620)	(618-840)
5	155.5	150.2	81.3	945.6	720.0	464.1
	(114- 205)	(132-171)	(73-90)	(794-1125)	(626-825)	(385-557)
6	45.8	36.6	16.4	336.2	257.7	143.6
	(38- 56)	(32-42)	(14-19)	(266-427)	(219-304)	(121-171)
7	17.7	13.1	4.7	194.8	130.7	91.7
	(13- 28)	(10-17)	(4-6)	(148-259)	(112-152)	(77-109)
8	6.3	2.4	1.0	51.2	40.3	25.6
	(4- 20)	(2-3)	(0.8-1.3)	(43-62)	(35-47)	(22-34)
9	0.5	0.2	0.1	10.7	11.2	11.7
	(0.4-0.7)	(0.2-0.3)	(0.1-0.2)	(8.3-13.9)	(7.6-17.3)	(9.9-13.7)

Table 4. Annual production estimates for walleye pollock and Pacific hake egg at times of fertilization and hatching, percent survival to hatching, and daily mortality rate for the 1981 spawning cycle in Georgia Strait. (95% C.L. reflect those for adjacent mid-stages).

	Pollock	Hake
Annual egg production		
at fertilization	1.84×10^{13}	3.78×10^{13}
	$(1.60\text{-}2.29 \times 10^{13})$	$(3.10\text{-}4.64 \times 10^{13})$
at median hatch	1.85×10^{12}	4.0×10^{12}
	$(1.59\text{-}2.13 \times 10^{12})$	$(3.34\text{-}5.21 \times 10^{12})$
Survival to hatching	10.1%	10.6%
Daily mortality rate	23.6%	24.3%

Table 5. Stock estimates and allied statistics for the adult stocks of walleye pollock and Pacific hake in Central and Southern Georgia Strait, 1981.

	Pollock		Hake	
	male	female	male	female
Mean length (cm)	40.5	43.3	41.8	43.3
Mean weight (g)	564.2	694.4	430.5	507.1
Length-wt. equat.	$0.0076L^{3.030}$	$0.0096L^{3.057}$	$0.0155L^{2.741}$	$0.0056L^{3.029}$
Mean fecundity				
total eggs > 200 µm		382,456		193,867
eggs/g		550.8		382.3
Sex ratio	1:1		1:1	
Stock estimates				
millions of fish	48.1	48.1	195.0	195.0
total	96.2		390.0	
Biomass (kt)	27.1	33.4	83.9	98.9
total	60.5		182.8	
Stock ratios				
numerical	1:4.1			
biomass	1:3.0			

FIGURES

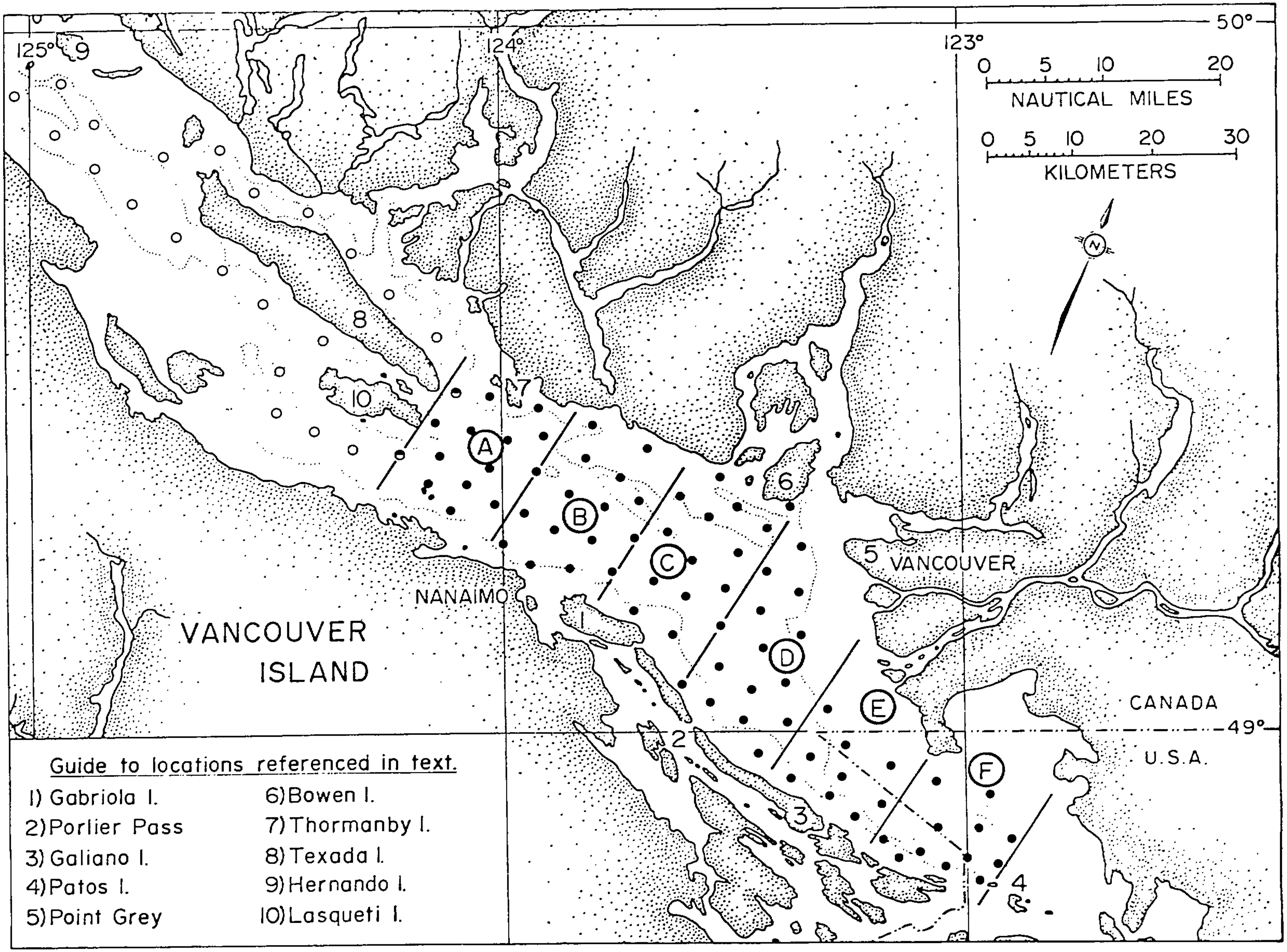


Fig. 1. The Strait of Georgia, British Columbia showing the 1981 sampling grid in the central and southern regions, the geographic boundaries of the six sectors composing it, and the transect route through the northern region of the strait. ◓ - stations common to grid and transect route.

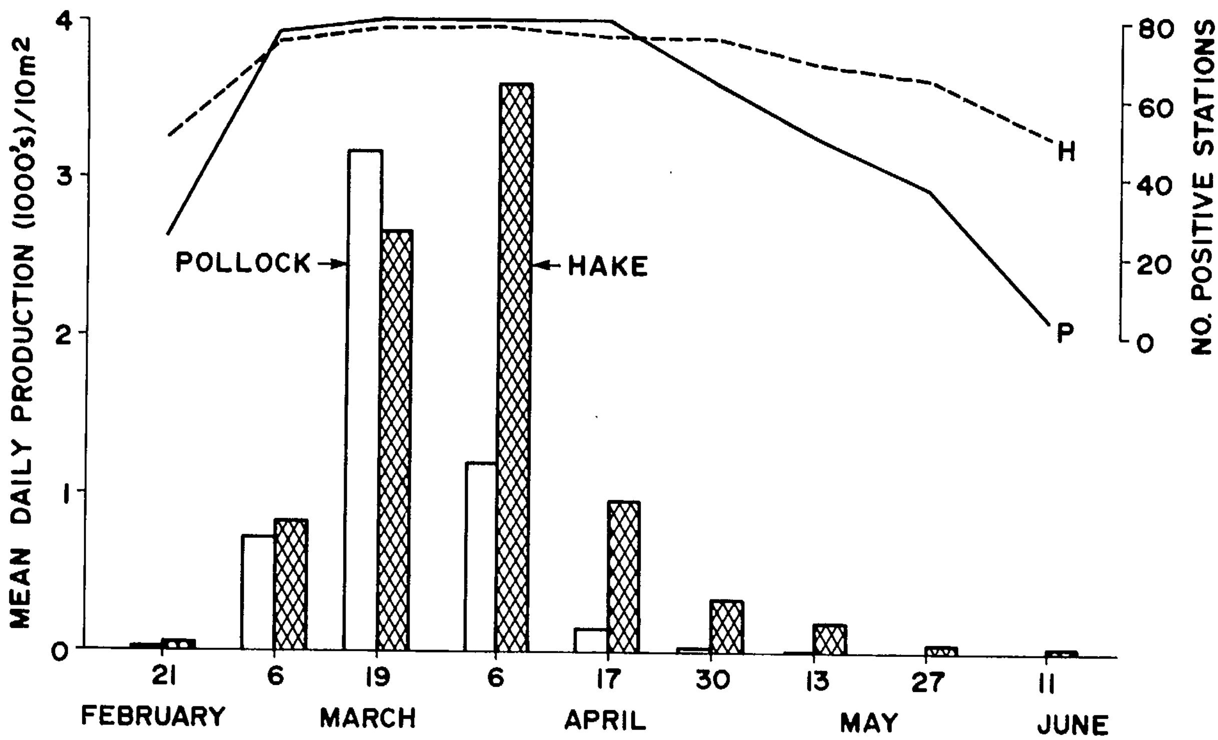


Fig. 2. The 1981 spawning cycles of walleye pollock and Pacific hake in the Strait of Georgia, B.C. as indicated by the mean daily production of stage one eggs and the number of positive stations. Open bars - pollock, hatched bars - hake.

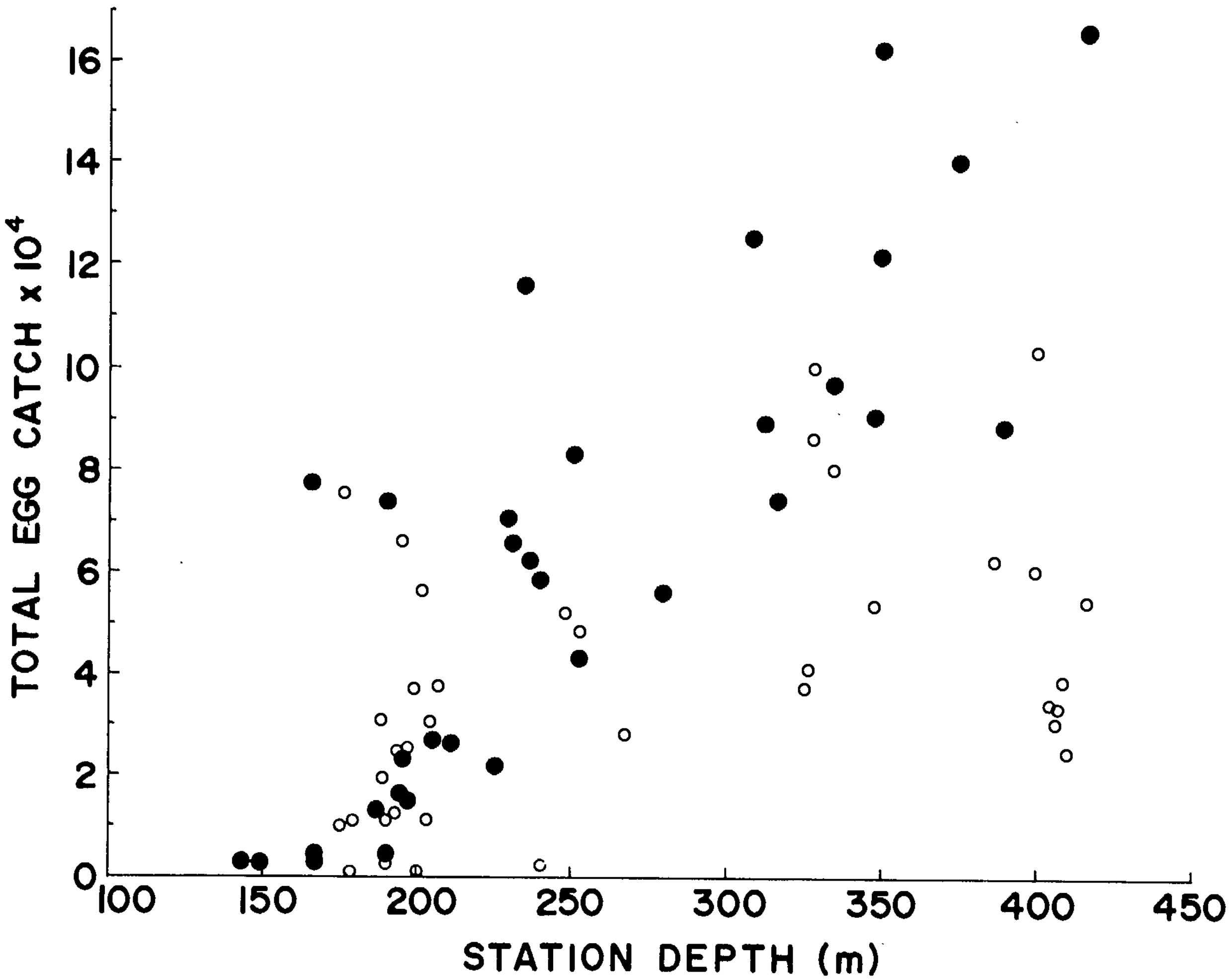


Fig. 3. The relationship between total catch of Pacific hake eggs on station and station depth. Closed circles - stations falling within sectors C and D.

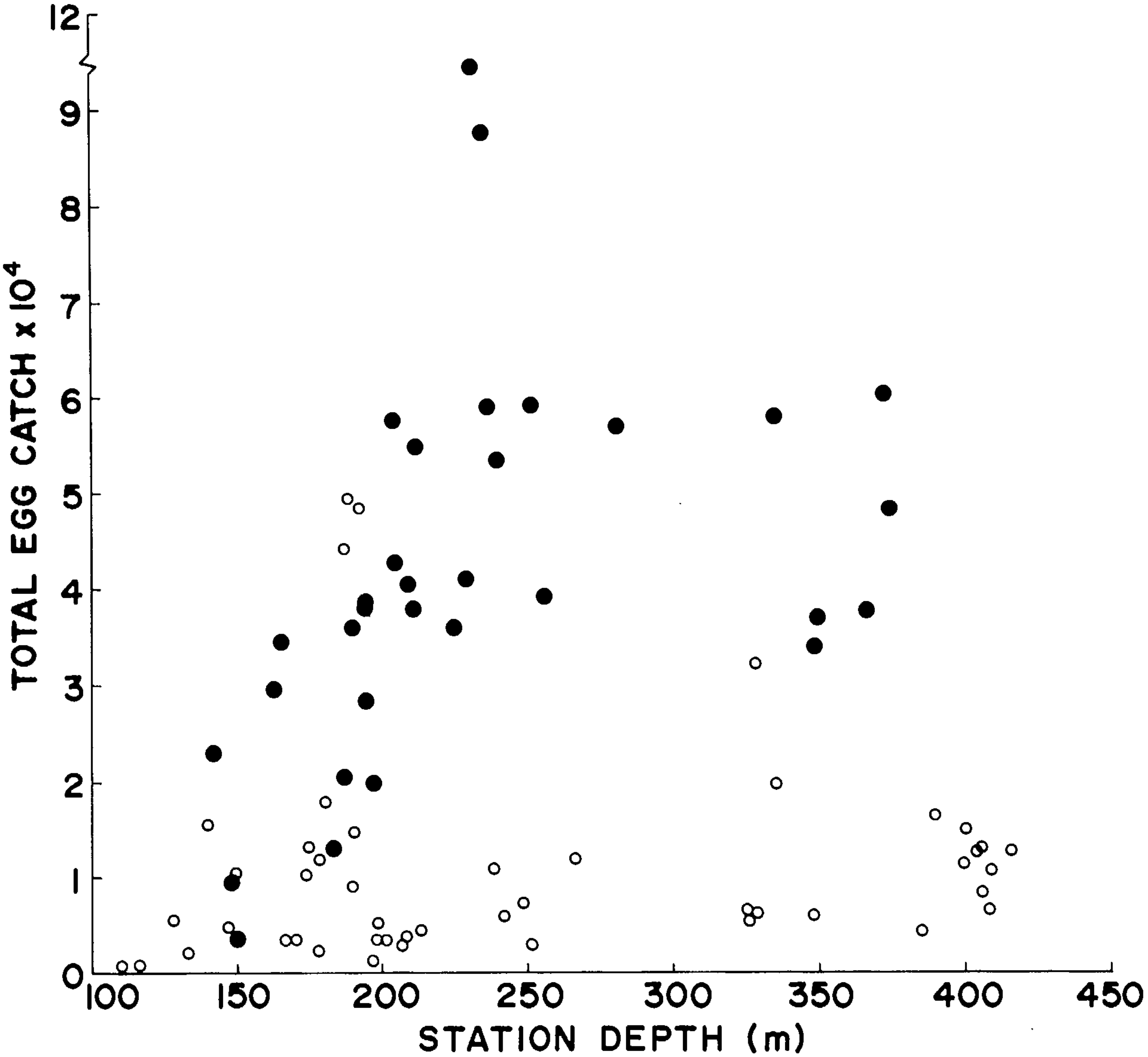


Fig. 4. The relationship between total catch of walleye pollock eggs in station and station depth. Closed circles - stations falling within sectors C and D where most spawning took place.

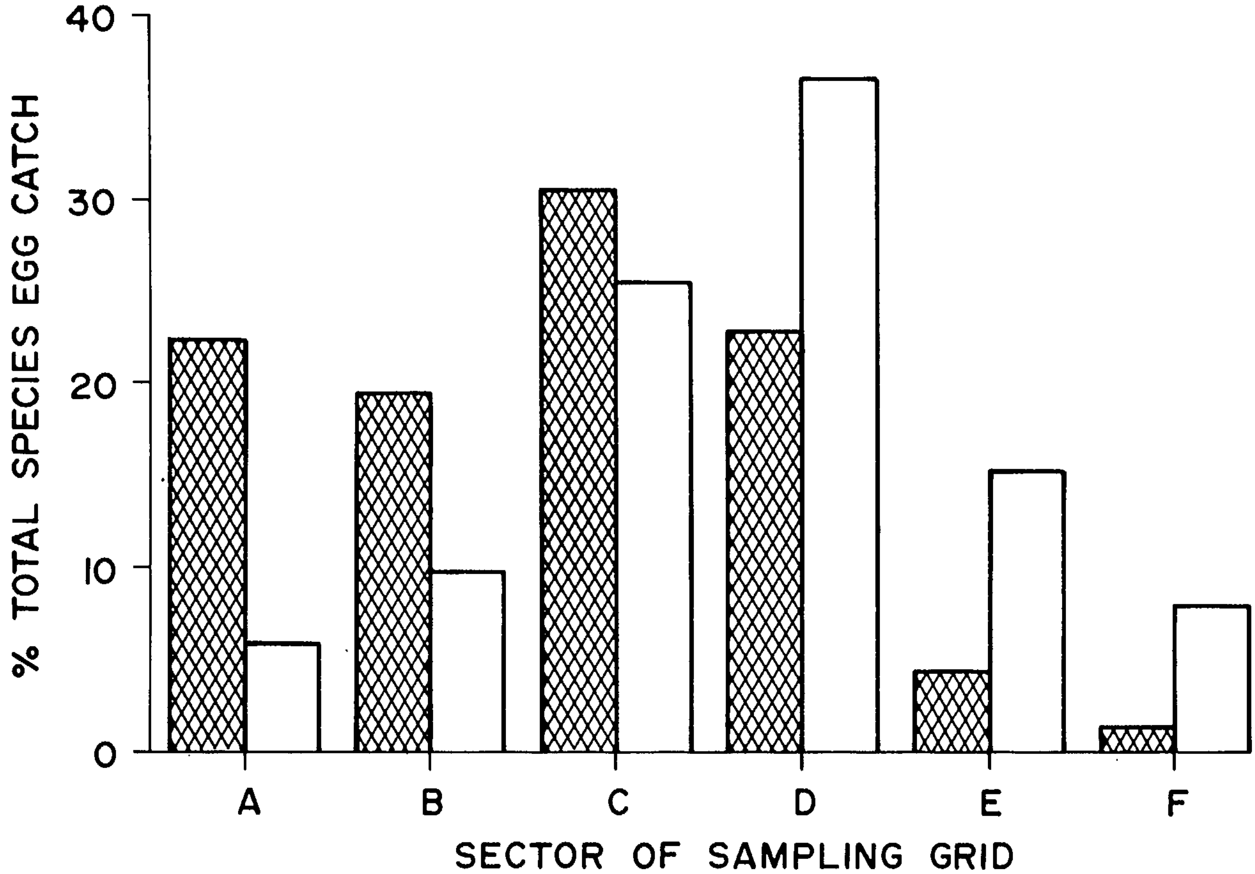
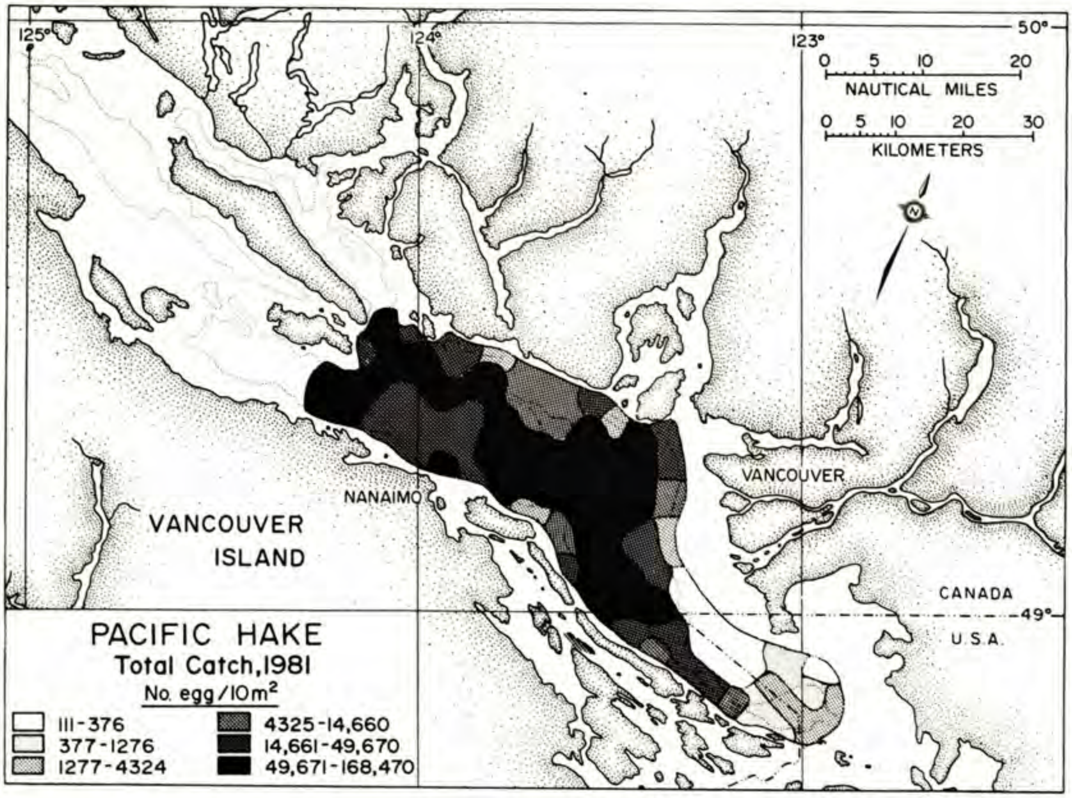
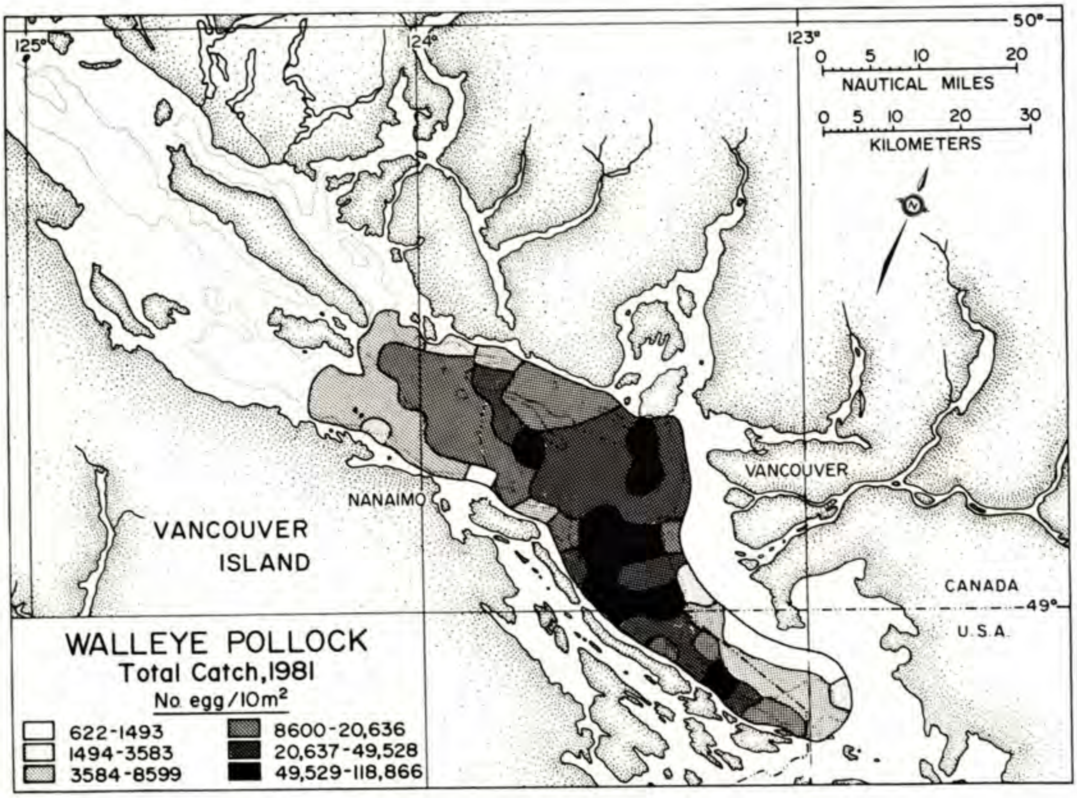


Fig. 5. Relative distribution of the total egg catches for the 1981 spawning season in Central and Southern Georgia Strait, derived from the mean egg catch/yr within each sector. Hatched bars - Pacific hake, open bars - walleye pollock.

Fig. 6. Distribution and abundance of pollock and hake eggs in Central and Southern Georgia Strait from the total catches of eggs on station, resulting from the 1981 spawning cycle.


125°
124°
123°
50°
0 5 10 20
NAUTICAL MILES
0 5 10 20 30
KILOMETERS
VANCOUVER
NANAIMO
VANCOUVER
ISLAND
CANADA
49°
U.S.A.
PACIFIC HAKE
Total Catch, 1981
No. egg/10m²
111-376
377-1276
1277-4324
4325-14,660
14,661-49,670
49,671-168,470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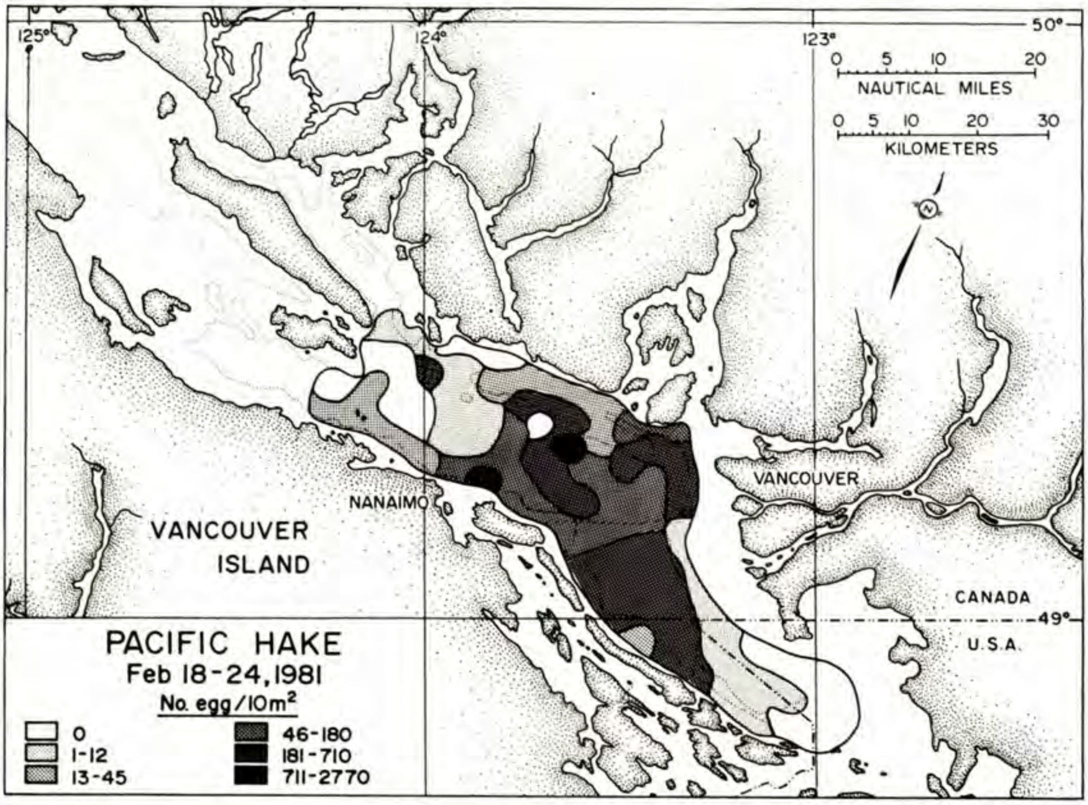
NAUTICAL MILES
0 5 10 20 30
KILOMETERS
VANCOUVER
NANAIMO
VANCOUVER
ISLAND
CANADA
49°
U.S.A.
WALLEYE POLLOCK
Total Catch, 1981
No. egg/10m²
622-1493
1494-3583
3584-8599
8600-20,636
20,637-49,528
49,529-118,866

Fig. 7. Distribution and abundance of eggs in Georgia Strait during Cruise 1, Feb. 18-24, 1981. A - walleye pollock eggs, B - Pacific hake eggs.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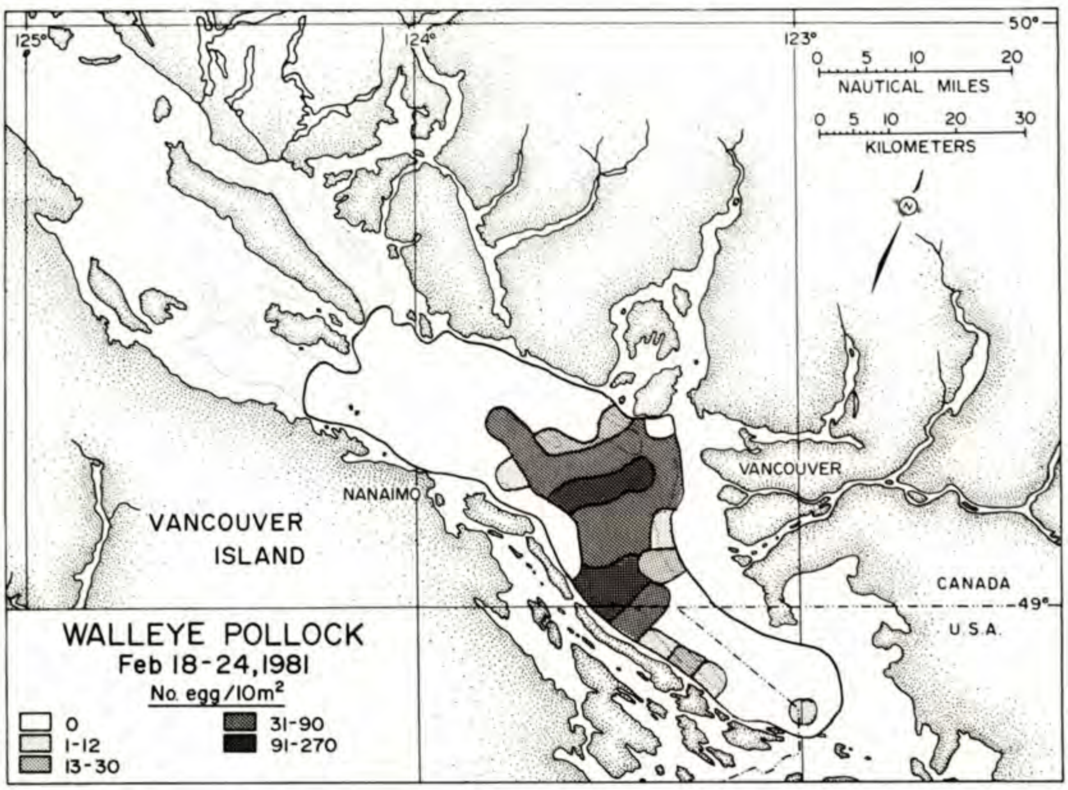
0 5 10 20
NAUTICAL MILES
0 5 10 20 30
KILOMETERS
N
VANCOUVER
NANAIMO
VANCOUVER
ISLAND
CANADA
49°
U.S.A.
PACIFIC HAKE
Feb 18-24, 1981
No. egg/10m²
0
1-12
13-45
46-180
181-710
711-2770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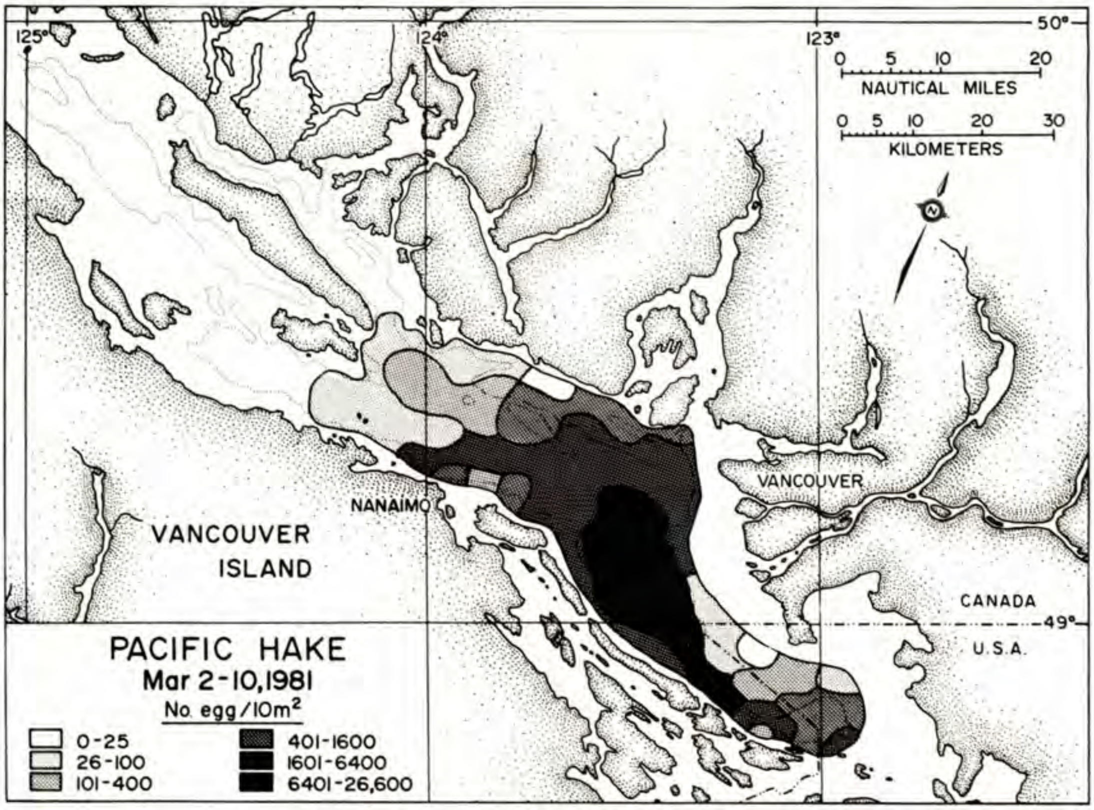
0 5 10 20
NAUTICAL MILES
0 5 10 20 30
KILOMETERS
N
VANCOUVER
NANAIMO
VANCOUVER
ISLAND
CANADA
49°
U.S.A.
WALLEYE POLLOCK
Feb 18-24, 1981
No. egg/10m²
0
1-12
13-30
31-90
91-270

Fig. 8. Distribution and abundance of eggs in Georgia Strait during Cruise 2, March 2-10, 1981. A and B as in Fig. 7.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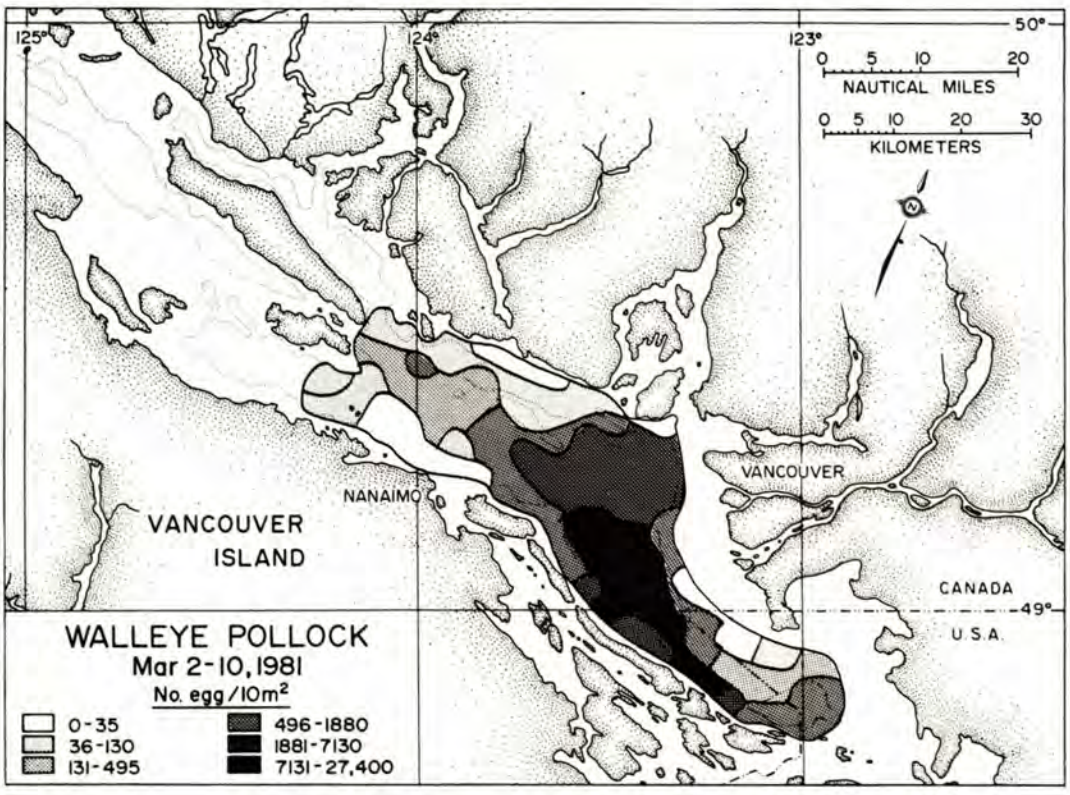
124°
123°
50°
0 5 10 20
NAUTICAL MILES
0 5 10 20 30
KILOMETERS
VANCOUVER
NANAIMO
VANCOUVER
ISLAND
CANADA
49°
U.S.A.
PACIFIC HAKE
Mar 2-10,1981
No. egg/10m²
0-25
26-100
101-400
401-1600
1601-6400
6401-26,600


125°
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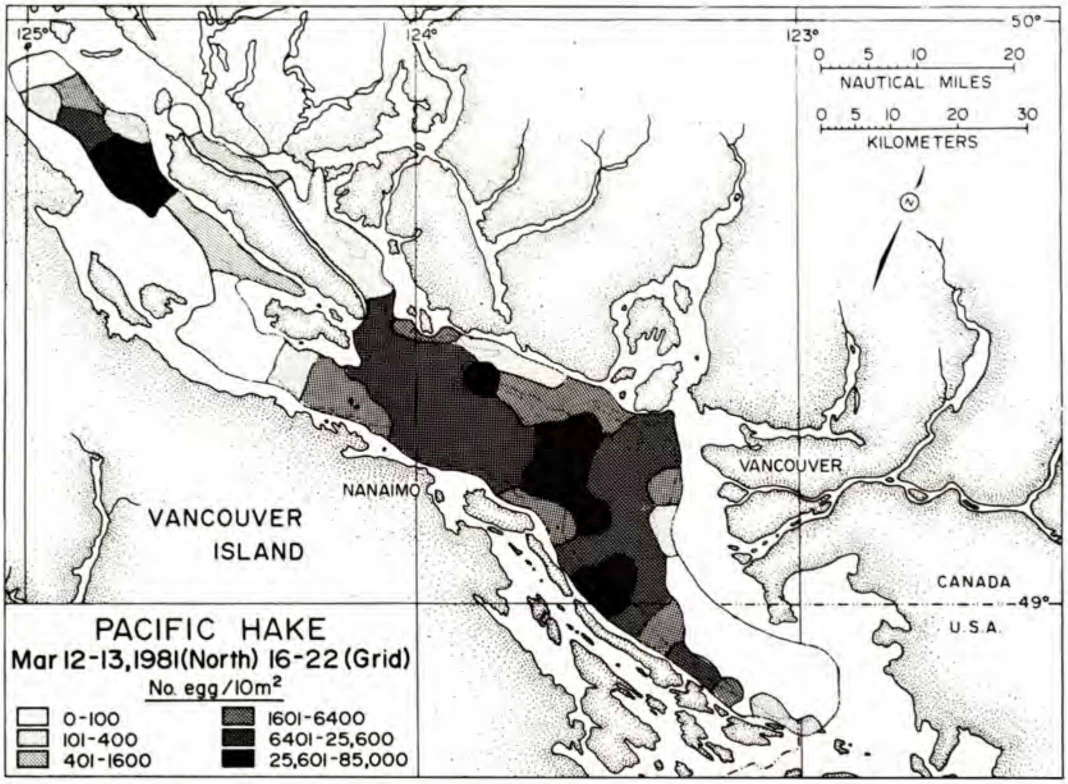
123°
50°
0 5 10 20
NAUTICAL MILES
0 5 10 20 30
KILOMETERS
VANCOUVER
NANAIMO
VANCOUVER
ISLAND
CANADA
49°
U.S.A.
WALLEYE POLLOCK
Mar 2-10,1981
No. egg/10m²
0-35
36-130
131-495
496-1880
1881-7130
7131-27,400

Fig. 9. Distribution and abundance of eggs in Georgia Strait during Cruise 3, March 12-13 (north) and March 16-22 (grid), 1981. A and B as before.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124°
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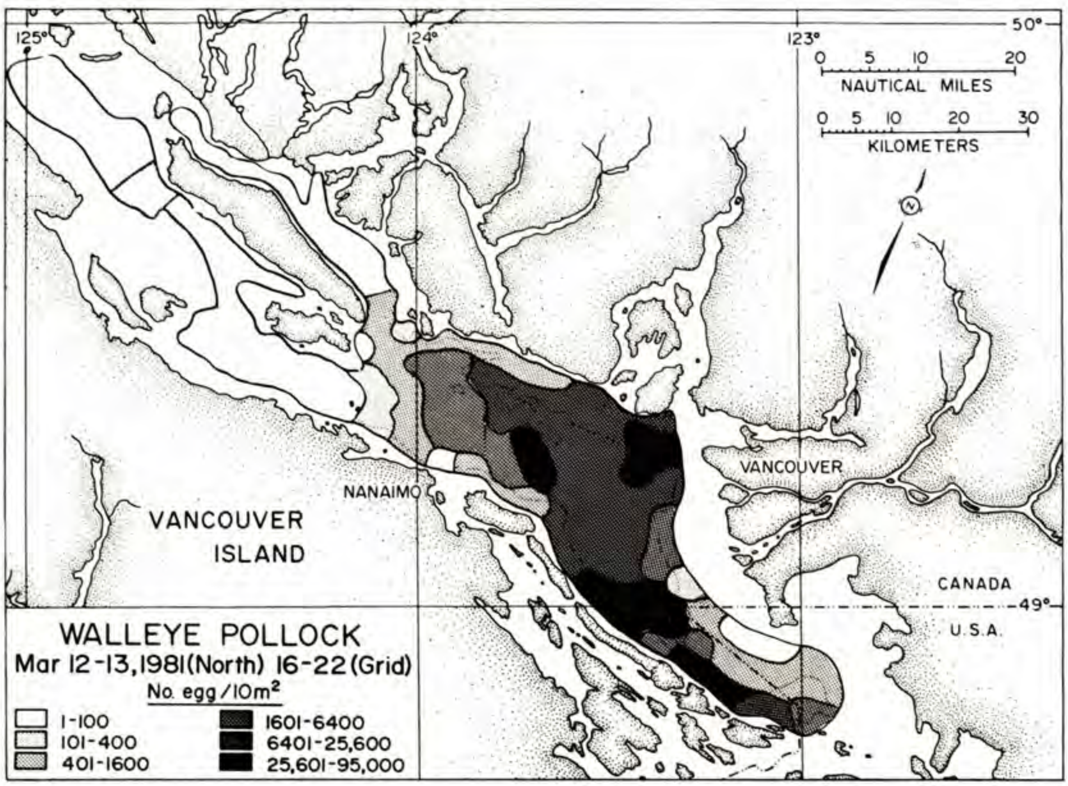
50°
0 5 10 20
NAUTICAL MILES
0 5 10 20 30
KILOMETERS
VANCOUVER
NANAIMO
VANCOUVER
ISLAND
CANADA
49°
U.S.A.
PACIFIC HAKE
Mar 12-13,1981(North) 16-22 (Grid)
No. egg/10m²
0-100
101-400
401-1600
1601-6400
6401-25,600
25,601-85,000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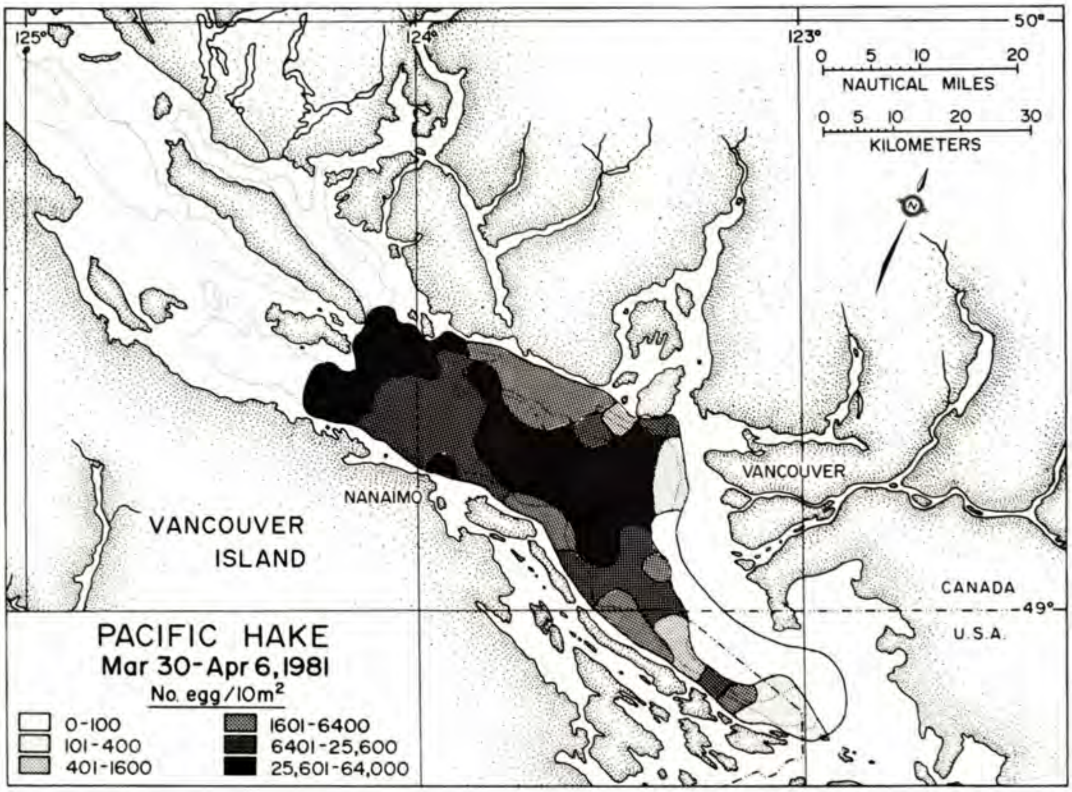
124°
123°
50°
0 5 10 20
NAUTICAL MILES
0 5 10 20 30
KILOMETERS
VANCOUVER
NANAIMO
VANCOUVER
ISLAND
CANADA
49°
U.S.A.
WALLEYE POLLOCK
Mar 12-13,1981(North) 16-22 (Grid)
No. egg/10m²
1-100
101-400
401-1600
1601-6400
6401-25,600
25,601-95,000

Fig. 10. Distribution and abundance of eggs in Georgia Strait during Cruise 4, March 30-April 6, 1981. A and B as before.


125°
124°
123°
50°
0 5 10 20
NAUTICAL MILES
0 5 10 20 30
KILOMETERS
VANCOUVER
NANAIMO
VANCOUVER
ISLAND
CANADA
49°
U.S.A.
PACIFIC HAKE
Mar 30-Apr 6, 1981
No. egg/10m²
0-100
101-400
401-1600
1601-6400
6401-25,600
25,601-64,000

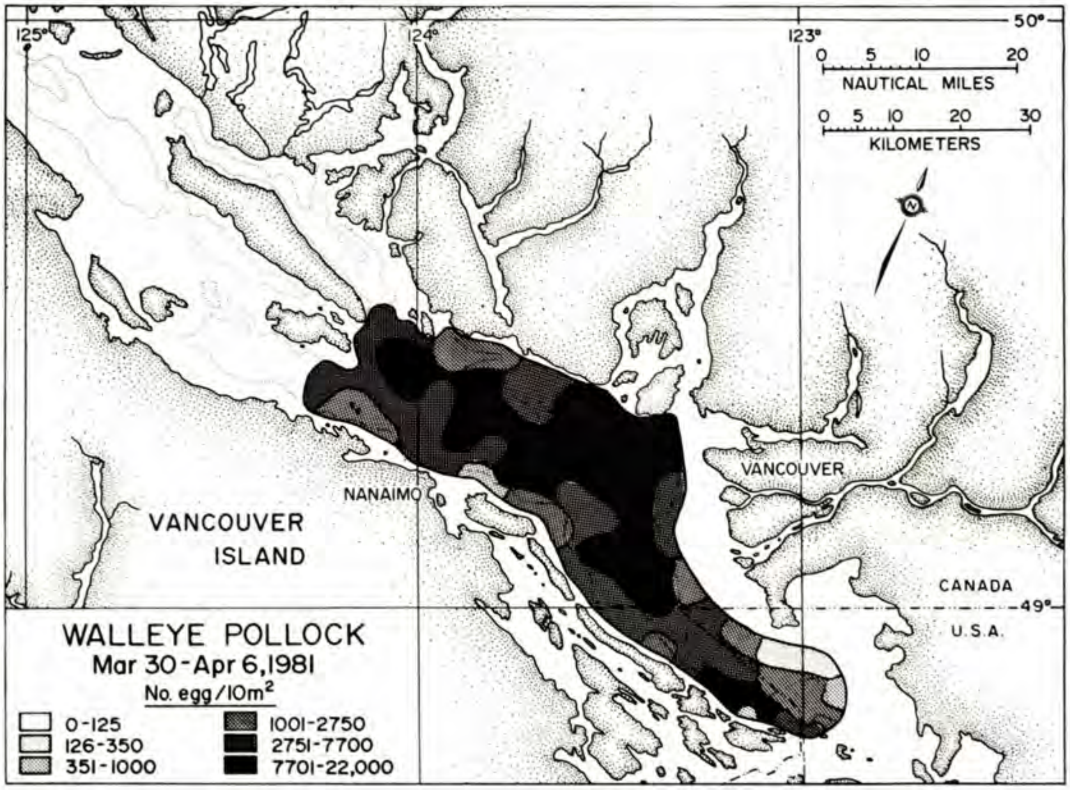
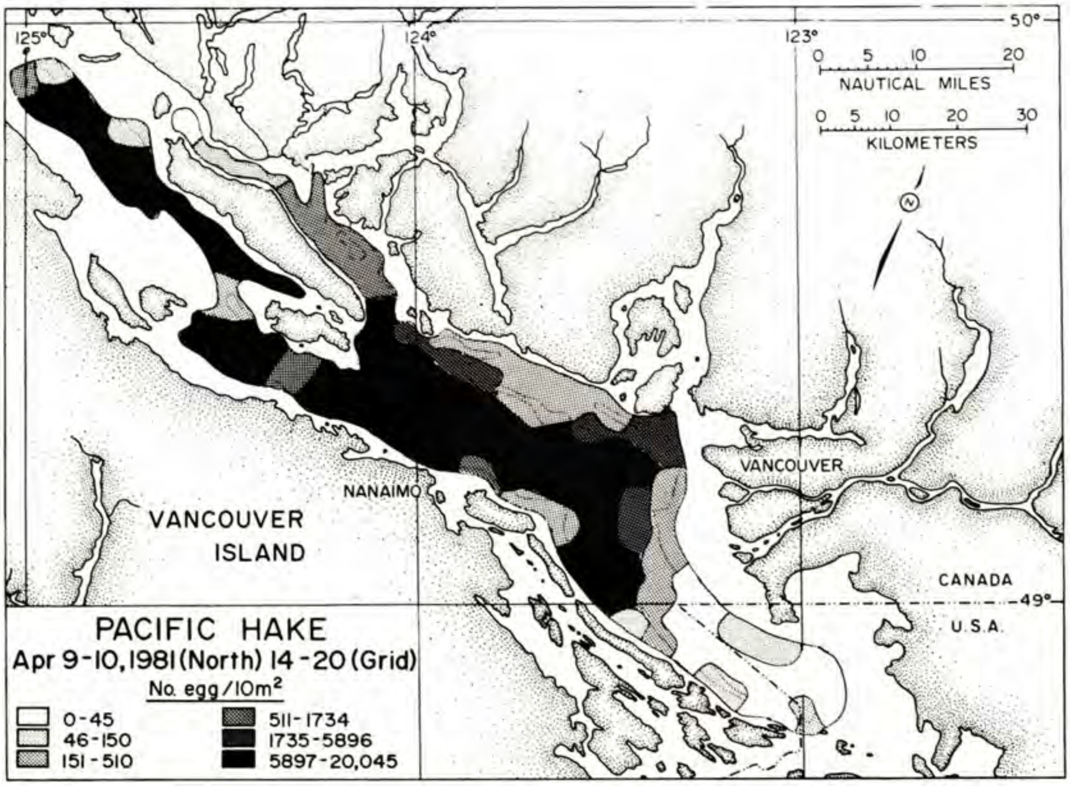

125°
124°
123°
50°
0 5 10 20
NAUTICAL MILES
0 5 10 20 30
KILOMETERS
VANCOUVER
NANAIMO
VANCOUVER
ISLAND
CANADA
49°
U.S.A.
WALLEYE POLLOCK
Mar 30-Apr 6, 1981
No. egg/10m²
0-125
126-350
351-1000
1001-2750
2751-7700
7701-22,000

Fig. 11. Distribution and abundance of eggs in Georgia Strait during Cruise 5, April 9-10 (north) and 14-20 (grid), 1981. A and B as before.


125°
124°
123°
50°
49°
0 5 10 20
NAUTICAL MILES
0 5 10 20 30
KILOMETERS
VANCOUVER
NANAIMO
VANCOUVER
ISLAND
CANADA
U.S.A.
PACIFIC HAKE
Apr 9-10, 1981 (North) 14-20 (Grid)
No. egg/10m²
0-45
46-150
151-510
511-1734
1735-5896
5897-20,045

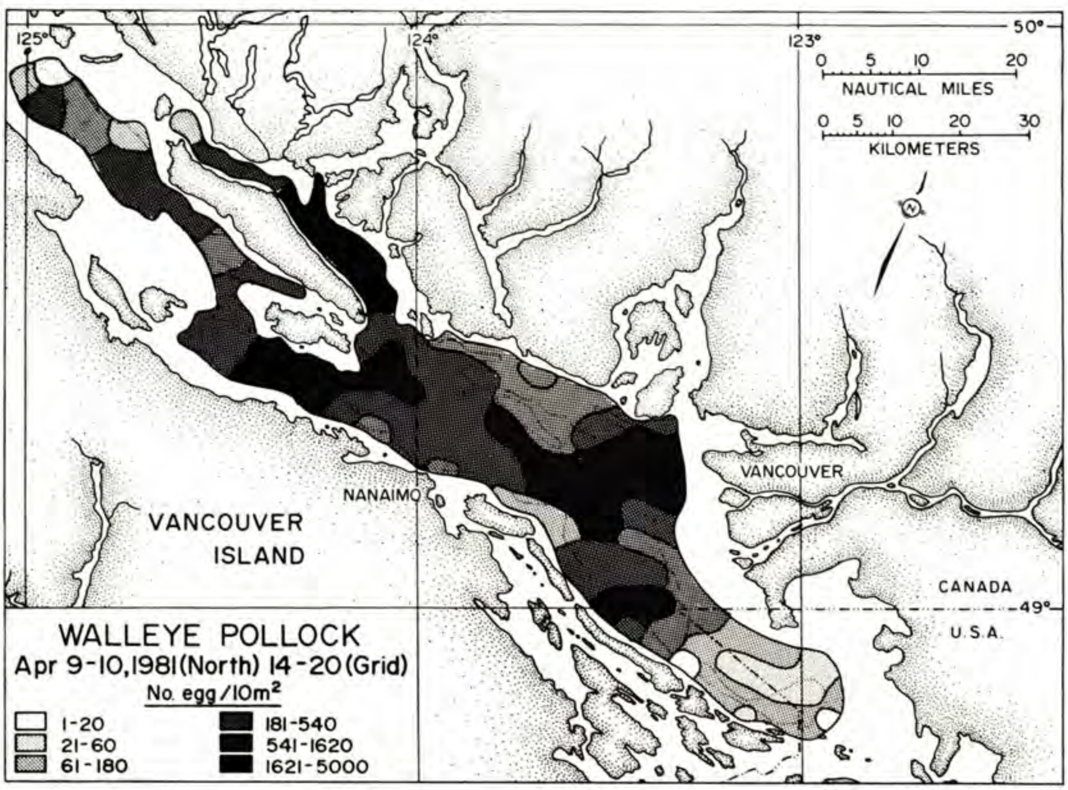
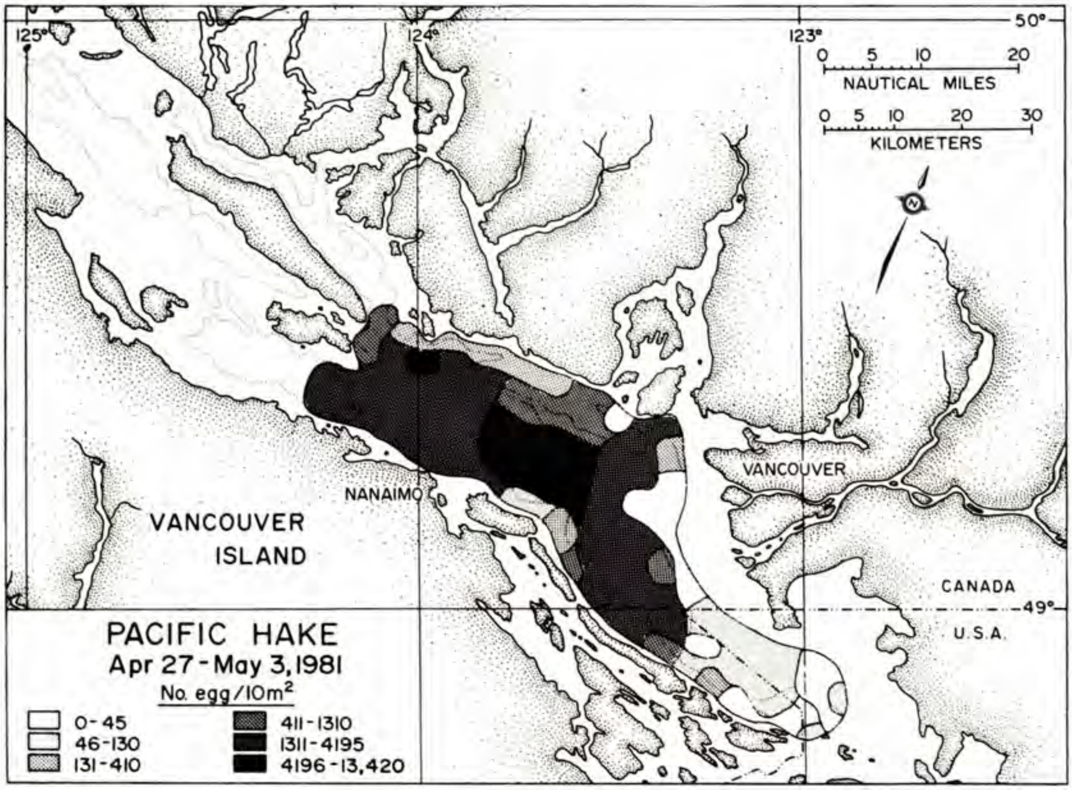
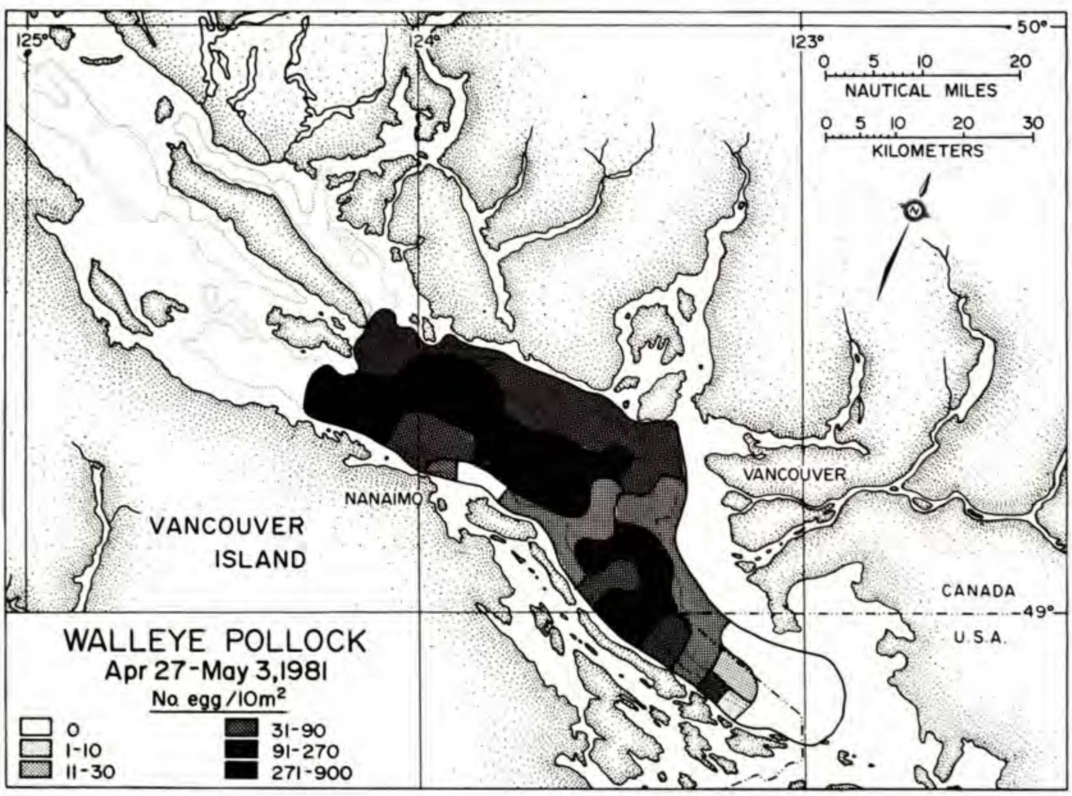

125°
124°
123°
50°
49°
0 5 10 20
NAUTICAL MILES
0 5 10 20 30
KILOMETERS
VANCOUVER
NANAIMO
VANCOUVER
ISLAND
CANADA
U.S.A.
WALLEYE POLLOCK
Apr 9-10, 1981 (North) 14-20 (Grid)
No. egg/10m²
1-20
21-60
61-180
181-540
541-1620
1621-5000

Fig. 12. Distribution and abundance of eggs in Georgia Strait during Cruise 6, April 27-May 3, 1981. A and B as before.

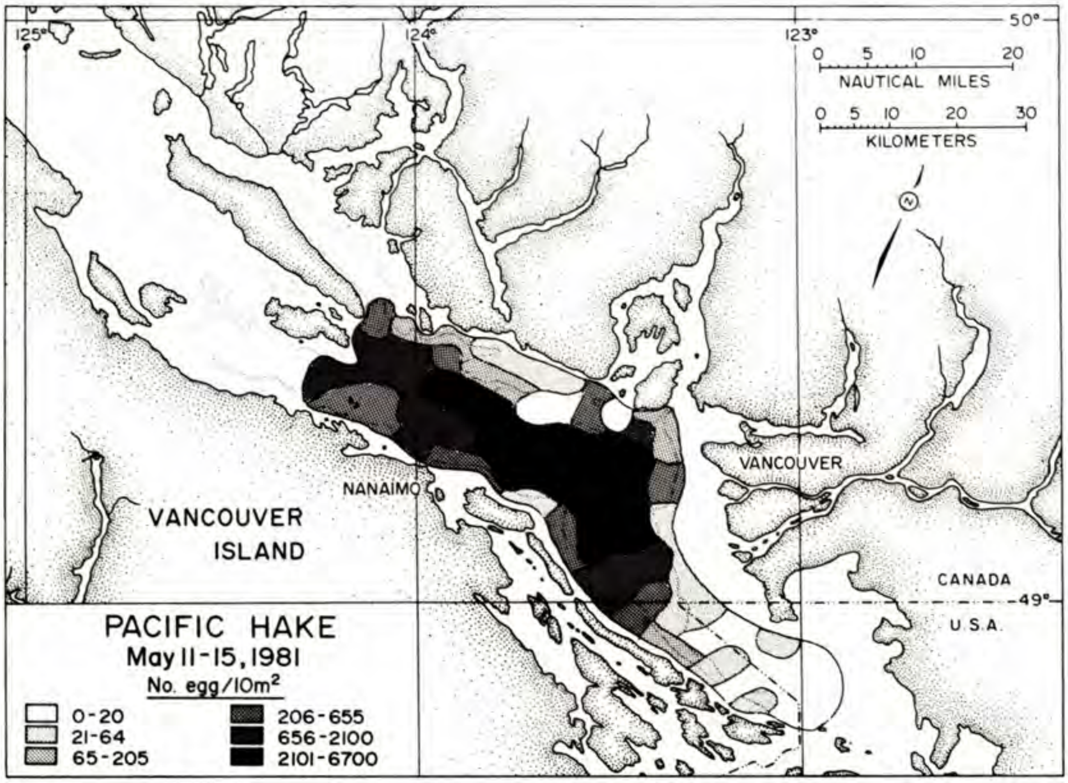


125°
124°
123°
50°
49°
0 5 10 20
NAUTICAL MILES
0 5 10 20 30
KILOMETERS
VANCOUVER
NANAIMO
VANCOUVER
ISLAND
CANADA
U.S.A.
PACIFIC HAKE
Apr 27 - May 3, 1981
No. egg/10m²
0-45
46-130
131-410
411-1310
1311-4195
4196-13,420

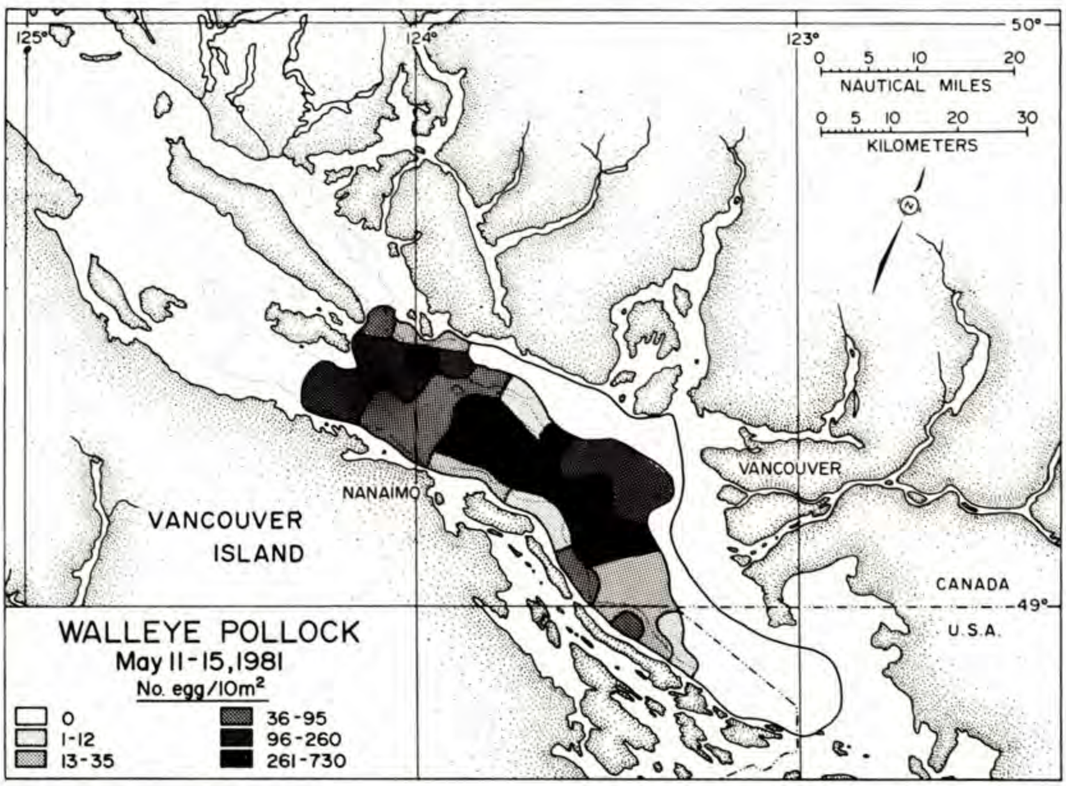


125°
124°
123°
50°
49°
0 5 10 20
NAUTICAL MILES
0 5 10 20 30
KILOMETERS
VANCOUVER
NANAIMO
VANCOUVER
ISLAND
CANADA
U.S.A.
WALLEYE POLLOCK
Apr 27 - May 3, 1981
No. egg/10m²
0
1-10
11-30
31-90
91-270
271-900

Fig. 13. Distribution and abundance of eggs in Georgia Strait during Cruise 7, May 11-15, 1981. A and B as before.

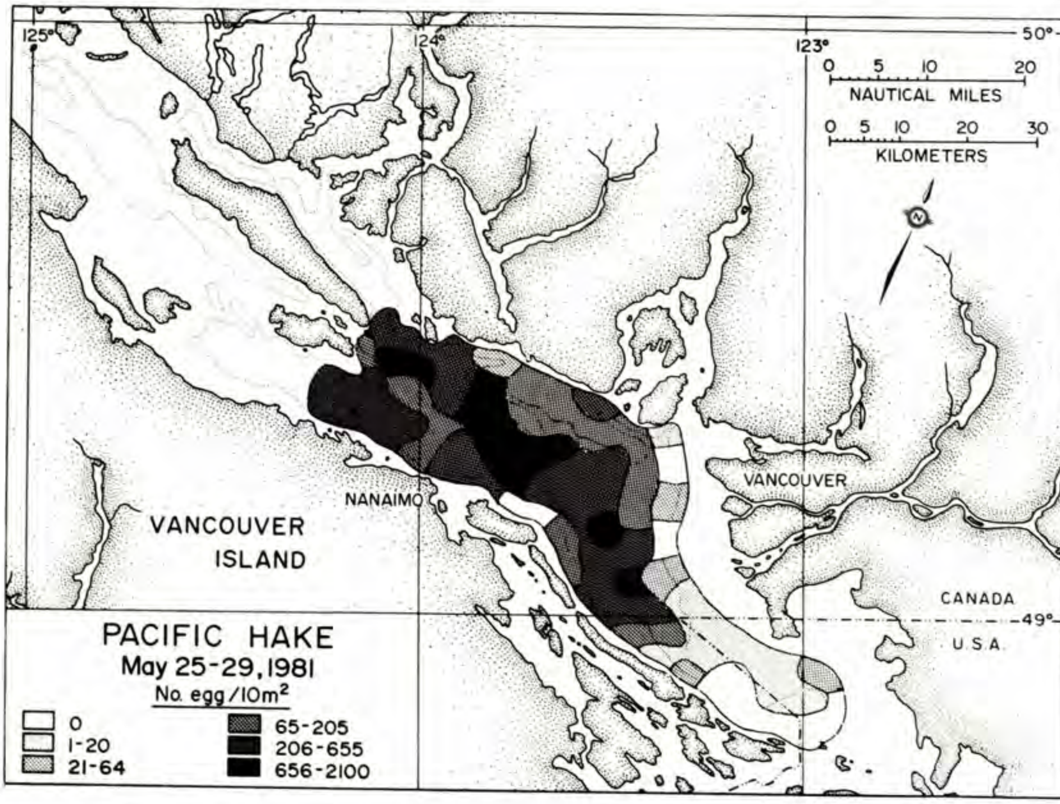


125°
124°
123°
50°
0 5 10 20
NAUTICAL MILES
0 5 10 20 30
KILOMETERS
VANCOUVER
NANAIMO
VANCOUVER
ISLAND
CANADA
49°
U.S.A.
PACIFIC HAKE
May 11-15, 1981
No. egg/10m²
0-20
21-64
65-205
206-655
656-2100
2101-6700



125°
124°
123°
50°
0 5 10 20
NAUTICAL MILES
0 5 10 20 30
KILOMETERS
VANCOUVER
NANAIMO
VANCOUVER
ISLAND
CANADA
49°
U.S.A.
WALLEYE POLLOCK
May 11-15, 1981
No. egg/10m²
0
1-12
13-35
36-95
96-260
261-730

Fig. 14. Distribution and abundance of eggs in Georgia Strait during Cruise 8, May 25-29, 1981. A and B as before.


125°
124°
123°
50°
49°
0 5 10 20
NAUTICAL MILES
0 5 10 20 30
KILOMETERS
NANAIMO
VANCOUVER
VANCOUVER
ISLAND
CANADA
U.S.A.
PACIFIC HAKE
May 25-29, 1981
No. egg/10m²
0
1-20
21-64
65-205
206-655
656-2100

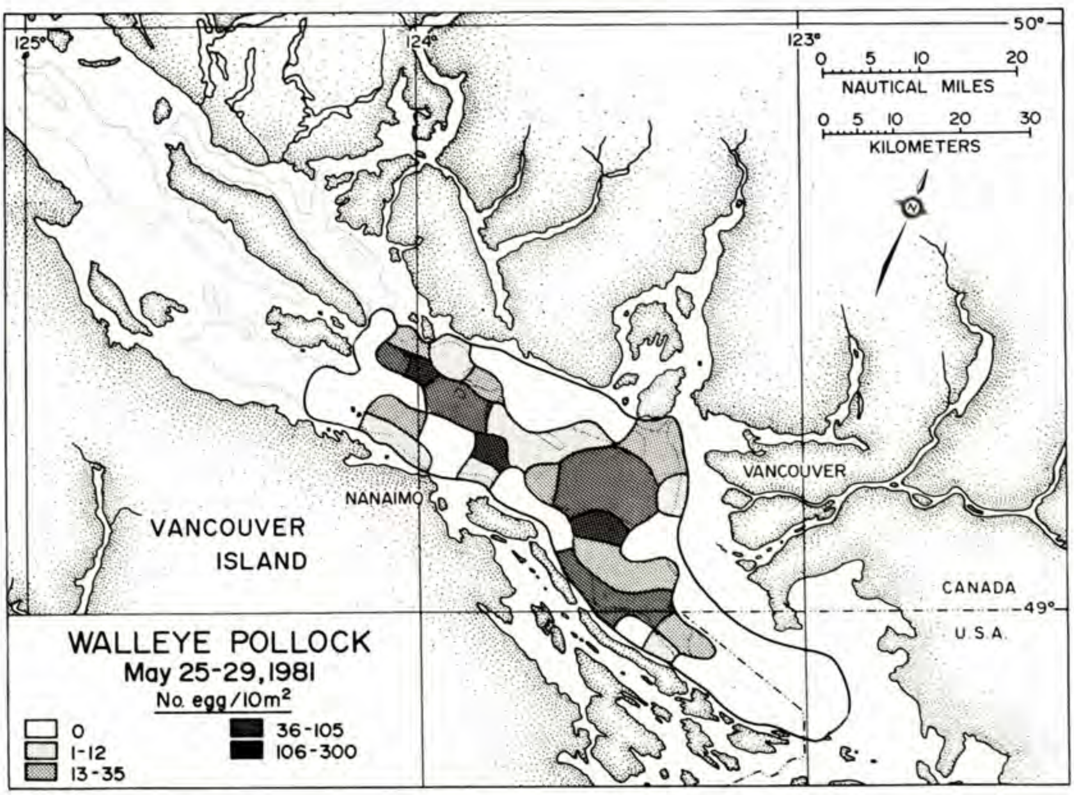
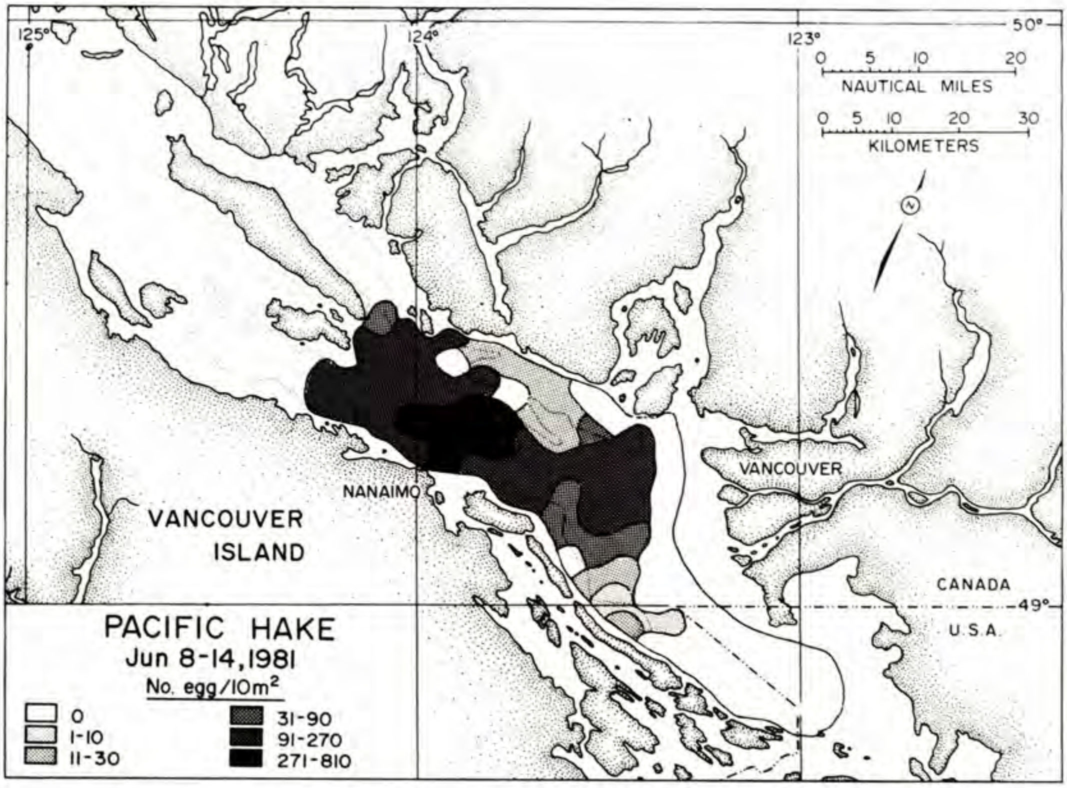
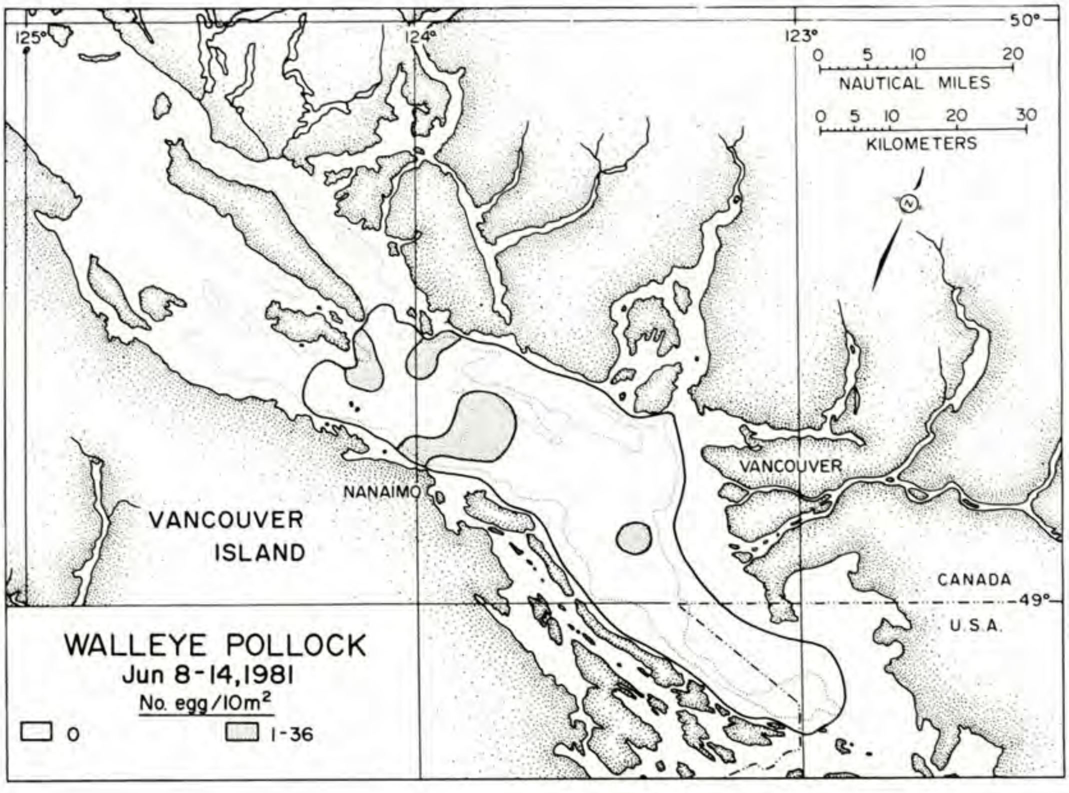

125°
124°
123°
50°
49°
0 5 10 20
NAUTICAL MILES
0 5 10 20 30
KILOMETERS
NANAIMO
VANCOUVER
VANCOUVER
ISLAND
CANADA
U.S.A.
WALLEYE POLLOCK
May 25-29, 1981
No. egg/10m²
0
1-12
13-35
36-105
106-300

Fig. 15. Distribution and abundance of eggs in Georgia Strait during Cruise 9, June 8-14, 1981. A and B as before.


125°
124°
123°
50°
49°
0 5 10 20
NAUTICAL MILES
0 5 10 20 30
KILOMETERS
VANCOUVER
NANAIMO
VANCOUVER
ISLAND
CANADA
U.S.A.
PACIFIC HAKE
Jun 8-14,1981
No. egg/10m²
0
1-10
11-30
31-90
91-270
271-810


125°
124°
123°
50°
49°
0 5 10 20
NAUTICAL MILES
0 5 10 20 30
KILOMETERS
VANCOUVER
NANAIMO
VANCOUVER
ISLAND
CANADA
U.S.A.
WALLEYE POLLOCK
Jun 8-14,1981
No. egg/10m²
0
1-36

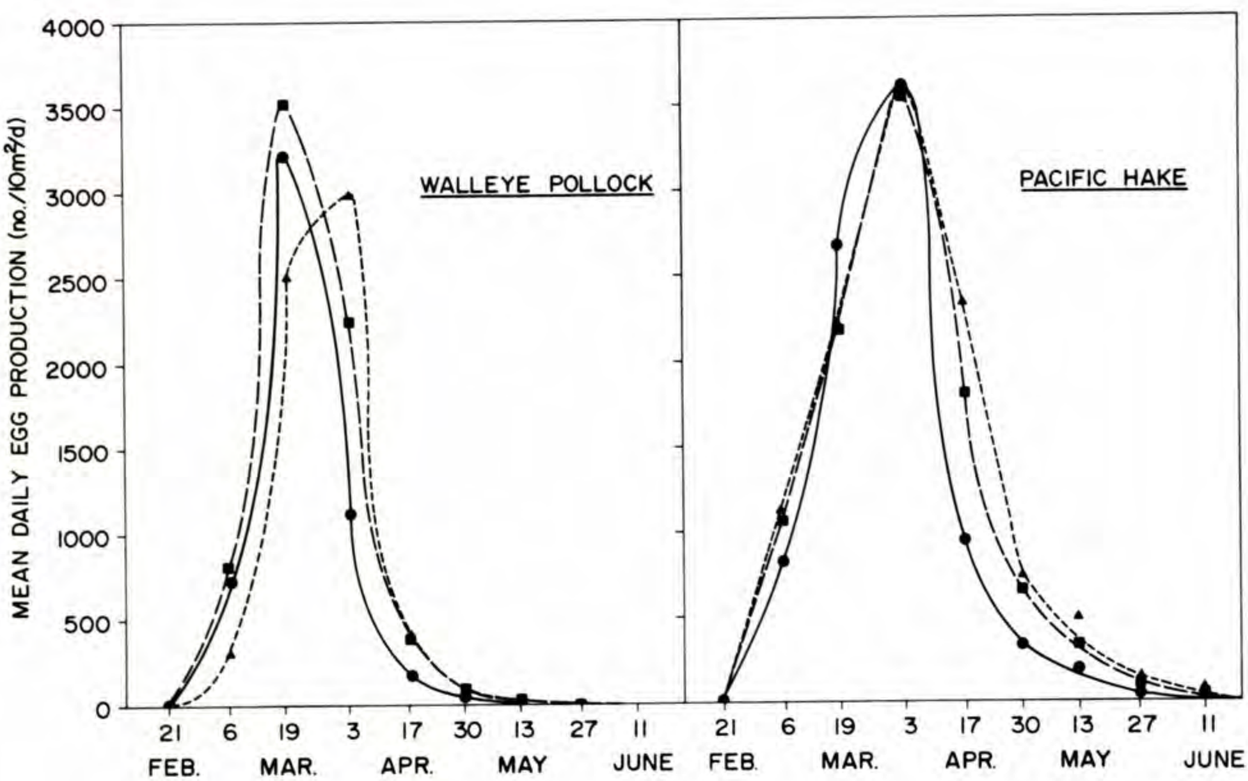


Fig. 16. Mean daily production rates for pollock and hake eggs in Central and Southern Georgia Strait during the 1981 spawning. Production rate scales for stages two and three are 40% and 20%, respectively, of the scale depicted for stage one eggs. Symbols as follows: ■ - stage one; ● - stage two; and ▲ - stage three.

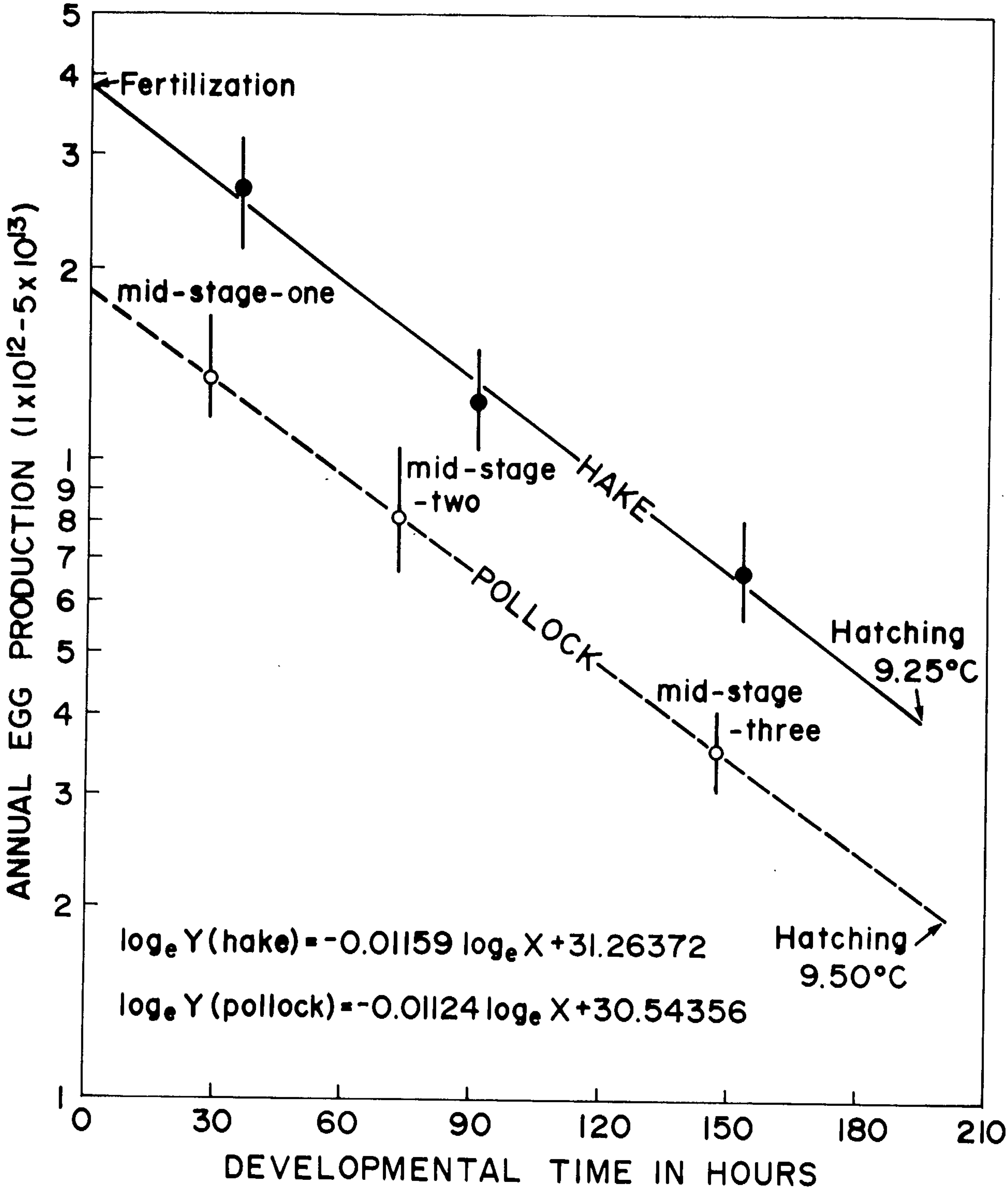


Fig. 17. Estimated decline of the 1981 production of walleye pollock and Pacific hake eggs through three embryological stages prior to hatching. Vertical bars indicate 95% C.L. of the estimate.