OCEANOGRAPHY OF A HERRING SPAWNING GROUND AND ROE FISHERY IN THE STRAIT OF GEORGIA, B.C.

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INTRODUCTION

In March and April 1980, a preliminary study of oceanographic and water quality conditions was conducted at a spawning ground on the east side of Denman Island in the Strait of Georgia (Fig. 1). The object of the study was to investigate the possible changes in water quality due to fallout of dead herring from gillnets being used in the roe fishery. For example, decomposing carcasses could consume oxygen and introduce excess nutrients in bottom water, thus possibly 'souring' the ground for subsequent spawning. Since there are only a few data (Outram 1975) on temperature and salinity conditions at herring spawning grounds, the oceanographic information is of general ecological interest.

METHODS

Temperature and salinity measurements were obtained on 5 transects, named A through E, along the length of the east side of Denman Island from Komas Bluff to Gravelly Bay on Lambert Channel (Fig. 1). On each transect, stations were established and re-occupied on the basis of water depth at high tide: 1, 3, 5, 10, and 15 meters. An Applied Microsystems CTD instrument (Conductivity-Temperature-Depth), lowered by hand, was deployed at each station. Resolution and accuracy (by calibration) of the instrument was as follows: Temperature ± 0.03°C, ±0.01°C, Salinity ±0.07‰, ±0.03‰.

Water samples for dissolved oxygen, pH, total alkalinity, total phosphate, nitrate, and ammonia were also obtained. Depths and locations for water samples on the transects and elsewhere were arranged after consultations with divers conducting visual searches for dead herring. Very few dead fish were found, even after a very active fishery resulting in the removal of approximately 5000 t of herring. To simulate concentrations of dead fish from fallout, about 500 dead herring were dumped and subsequent samples of bottom water were obtained by divers. Water in the vicinity of a sunken and abandoned gillnet containing 500 to 1000 dead herring was also sampled.

RESULTS

Temperature and salinity

Detailed results are presented elsewhere in a data report (Levings 1982). Information from the first 3 inshore stations on each transect (1, 3, 5 m) is focused on in the present report, as this is probably where the majority of herring spawned and eggs hatched.

Over the sampling period, salinity on the more northerly transects was more variable than at locations to the south, well into Lambert Channel (Table 1). On transect A, for example, salinity range was 2.3‰ (26.2 to 28.5‰) compared to 0.5‰ on Transect D (27.3 to 27.8‰), (Table 1). Temperature was less variable, with a slightly narrower range of 1.3°C on Transect C (8.1 to 9.4°C) compared to approximately 1.8°C (8.0 to 9.8°C) at Transect D (Table 1). Variation in density showed patterns parallel to those of salinity (Table 1).

Figure 2 shows a representative vertical profile of properties. The upper 3 m was usually less saline and cooler than deep levels, resulting in a moderate pycnocline between 3 and 5 meters.

Nutrients and dissolved oxygen

In a heavy concentration of spawn on March 7, phosphate and ammonia showed a concentration peak at about 1 m (Fig. 3). Nitrate appeared to be uniformly distributed through the water column (Fig. 3). Ammonia values at 5 m over transect 'spawn', the area of dumped fish, and the abandoned net were compared. In 5 samples, there was very little variation, with a mean value of 0.044 mg L^{-1} and range from 0.036 to 0.055 mg L^{-1}.

Surface levels of phosphate and nitrate were enhanced during the time when 'white water' overlay the spawning ground. Total phosphate values rose after spawning began on March 6, increasing from approximately 0.08 mg L^{-1} on March 4 to about 0.21 mg L^{-1} on March 8 (Fig. 4a). By March 12, total phosphate levels had decreased to 0.10 mg L^{-1}. Nitrate levels showed a similar pattern, peaking at about 0.08 mg L^{-1} (Fig. 4b).

Nutrient and dissolved oxygen data are tabulated elsewhere in a data report (Levings 1982).

Dissolved oxygen values at 3 and 5 m depths, near bottom, were compared at the area of dumped fish and the abandoned net (9 samples) and adjacent transects (11 samples). As judged by a t-test, there was no significant difference ($p<0.05$) between values at the two locations (mean values 8.66 _vs_ 7.43 mg L^{-1}, respectively).

DISCUSSION

Salinity and spawning

Although further interpretation of the data are required, it is apparent that herring spawning was more intensive (Haegele, pers. comm.) at the more northerly transects where lower salinities were recorded. The fresher water in these areas may have resulted from the discharge of the Courtenay River, whose estuary is near the north end of Denman Island. On certain transects, especially B and C, fresh water seeps were noted on beaches, and these may have lowered salinities on an extremely local scale. Salinities on the south transects were in the upper end of the range reported by Outram (1975), namely 22.4 to 28.7‰. A correlation between freshwater seeps and herring spawning was also suggested by Rabin (1977) for Humboldt Bay, California. Ginzberg (1968) noted that herring sperm motility persists longer in lower salinity water and thus brackish water spawning may be an advantage for fertilizing eggs.

Nutrients from herring sex products

The nutrient information obtained in this study indicates that the nitrate and phosphate concentrations in surface water was related to milkiness, a phenomenon generally attributed to sperm density (Hourston and Rosenthal 1976). However, available biochemical information suggests that herring eggs might be the source of the phosphate. Inoue et al. (1971) found that Pacific herring eggs yielded a phosphoprotein containing 10.6% phosphorus. At that time this species' eggs contained the most phosphorus of any fish egg reported on. Ginzberg (1968) reported herring sperm are mostly composed of DNA and protamines, which are nitrogenous compounds. The seminal fluid of fish is also high in nitrogen, with a N:P ratio of 4.19 reported for Salmo fontinalis (Ginzberg 1968). The sperm and seminal fluid might, therefore, be a major contributor to the increase in nitrogen observed in this study (Fig. 4). It should also be noted that the values of nitrate reported include the effects of uptake by phytoplankton, and a diatom bloom was occurring in the study area by late March. Whether such blooms can be stimulated by the release of nitrogen from herring eggs and sperm is an intriguing question yet to be answered.

Water quality observations

As noted in the results, there was little evidence of decreases in water quality even when dead fish were artificially aggregated to simulate a "fallout" situation. If large scale effects were occurring, changes in the physical appearance of bottom sediments, decreased dissolved oxygen levels, and increased concentrations of nutrients in bottom waters would have been observed. Conditions might have been expected to resemble those in coastal waters where fish plant wastes are dumped (Dale and Dawson 1975; Champ et al. 1981).

Unlike the sitution reported by Humphreys (1977) where sunstars (Pycnopodia sp.) were observed eating dead herring, there were few predators observed by divers in this study. Carcasses obtained by divers were examined for smaller crustaceans, notably amphipods, which had been attracted to the fish. A few specimens, 1 to 5 amphipods of the family Photidae, were observed on these fish. This was far fewer than expected and less than commonly attracted to herring used for crab bait.

In summary, there was little evidence of degraded water quality or large scale effects such as predator attraction. Gillnet fallout had a minimal effect on the local benthic environment at the Denman Island spawning ground.

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Table 1. Ranges of salinity (‰), temperature (°C), and density (ρ_t) on four transects at the Denman Island-Lambert Channel herring spawning ground.

	Transect A	Transect B	Transect C	Transect D
Salinity range (‰)	26.2-28.5	27.4-28.9	26.9-28.3	27.3-27.8
Difference	2.3	1.1	1.4	0.5
Temperature range(°C)	8.1-9.4	8.0-9.9	8.3-10.2	8.0-9.8
Difference	1.3	1.9	1.9	1.8
Density range (ρ_t)	20.4-22.0	21.2-22.0	20.8-21.9	21.3-21.6
Difference	1.6	0.8	1.1	0.3
No. of sample dates (Mar. 4 to Apr. 21/81)	5	6	5	5

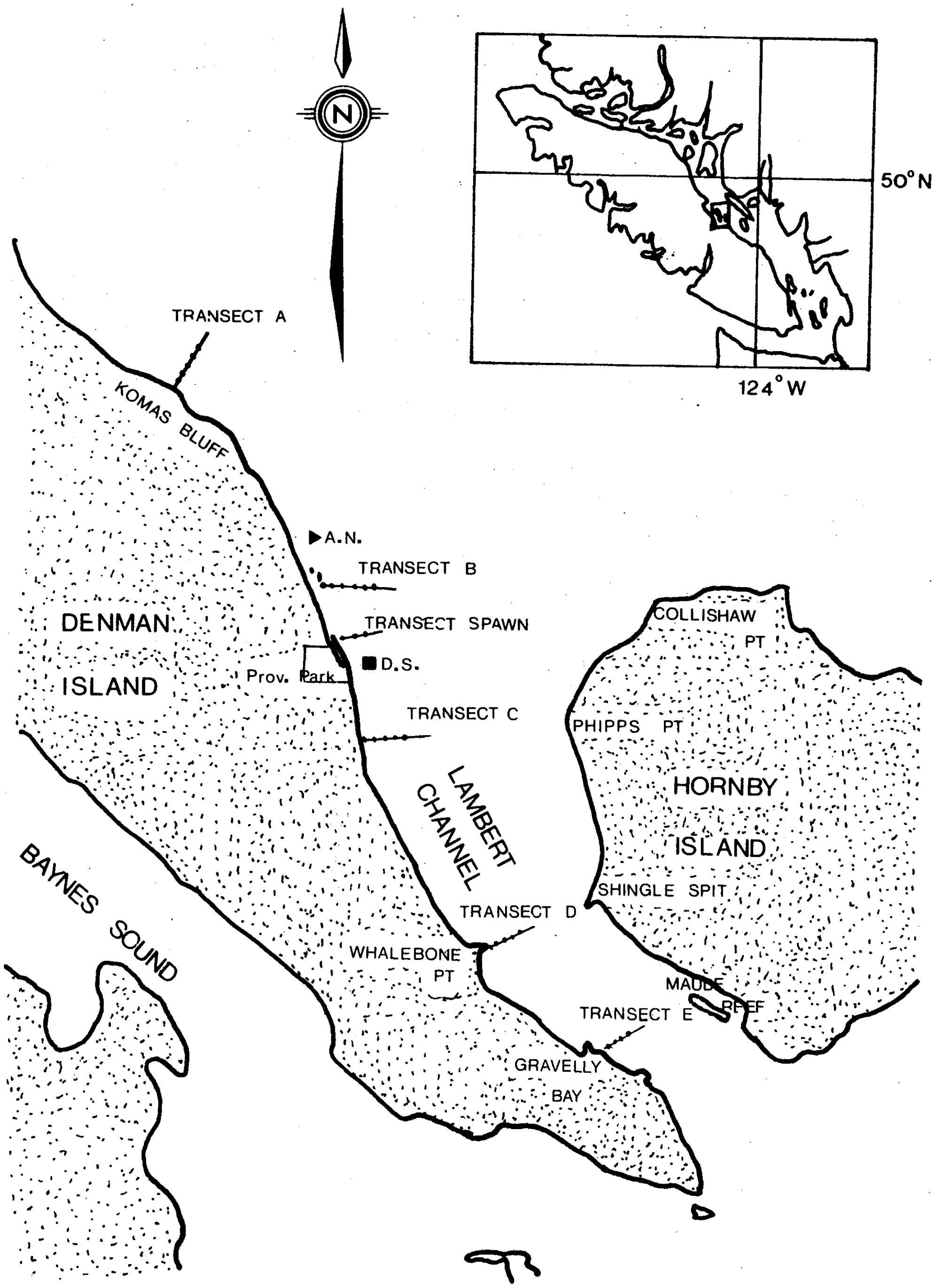

Fig. 1. Chart of the study area and sampling transects on Lambert Channel, east side of Denman. AN indicates abandoned net and DS indicates location of dumped herring.

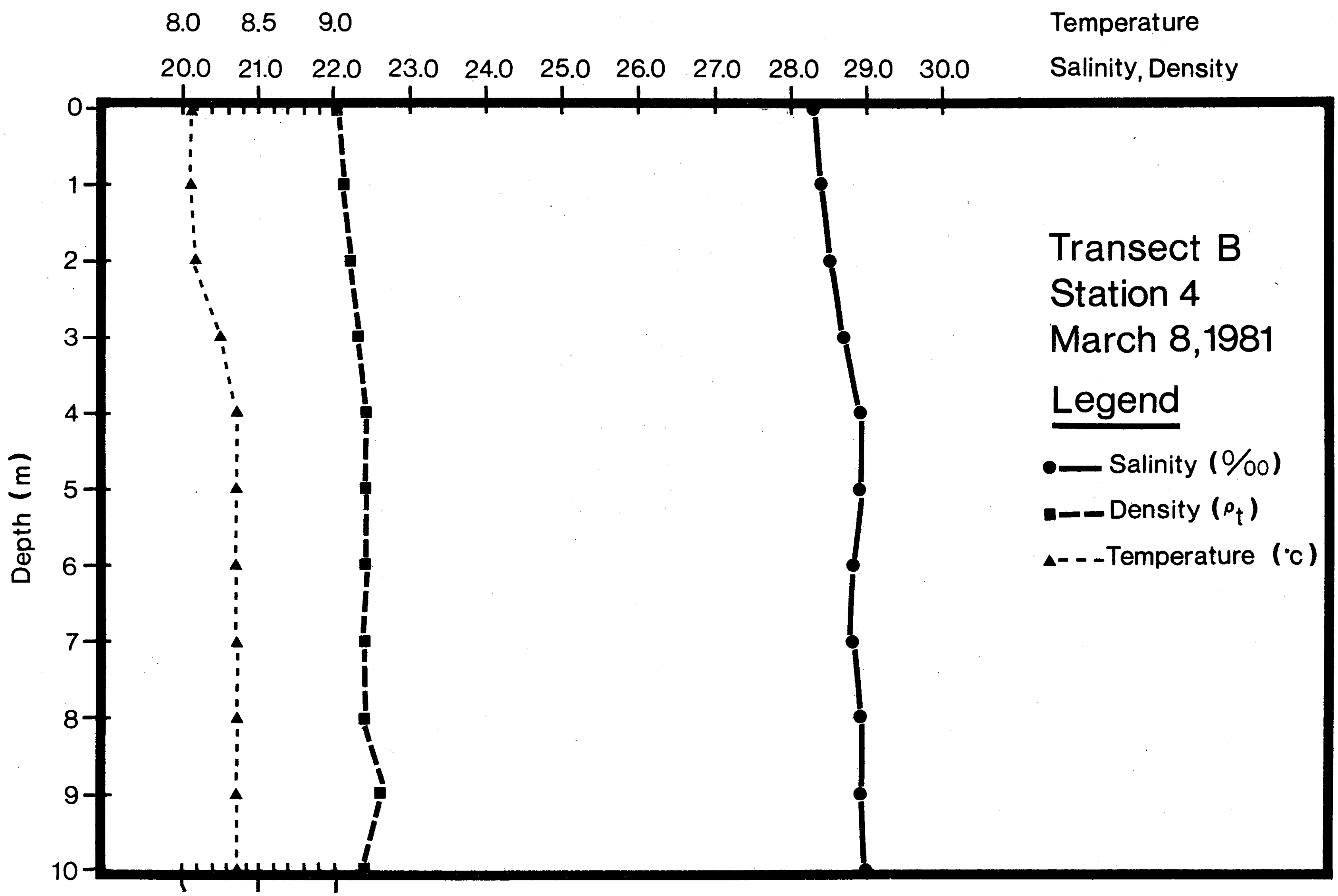

Fig. 2. Representative vertical profile of temperature, salinity, and density, at the study area. (Transect B, Station 4, March 8, 1981, 0945 h).

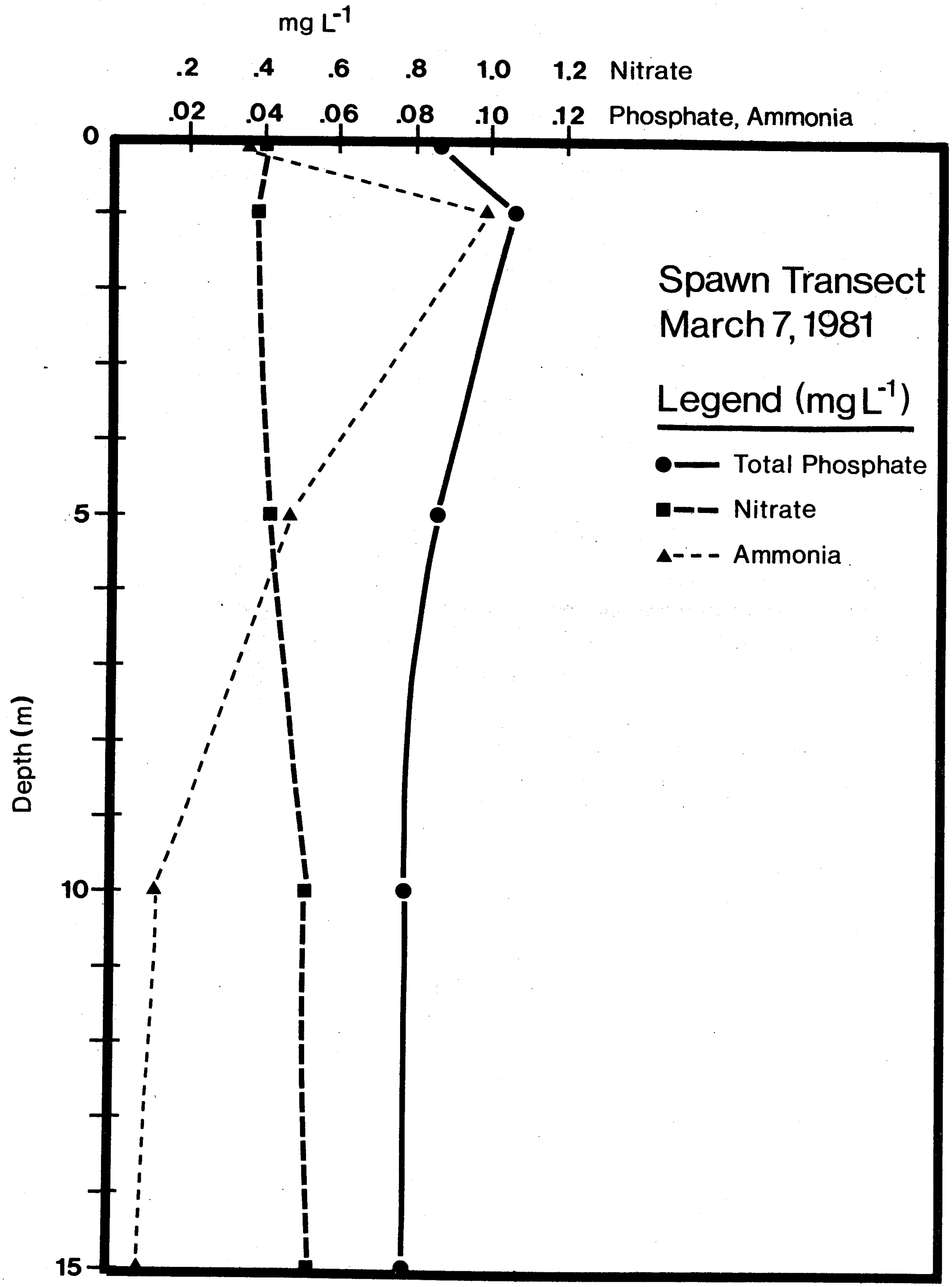

Fig. 3. Vertical distribution of total phosphate, nitrate, and ammonia at Station 5 on transect 'spawn', March 7, 1981, 1000 h.

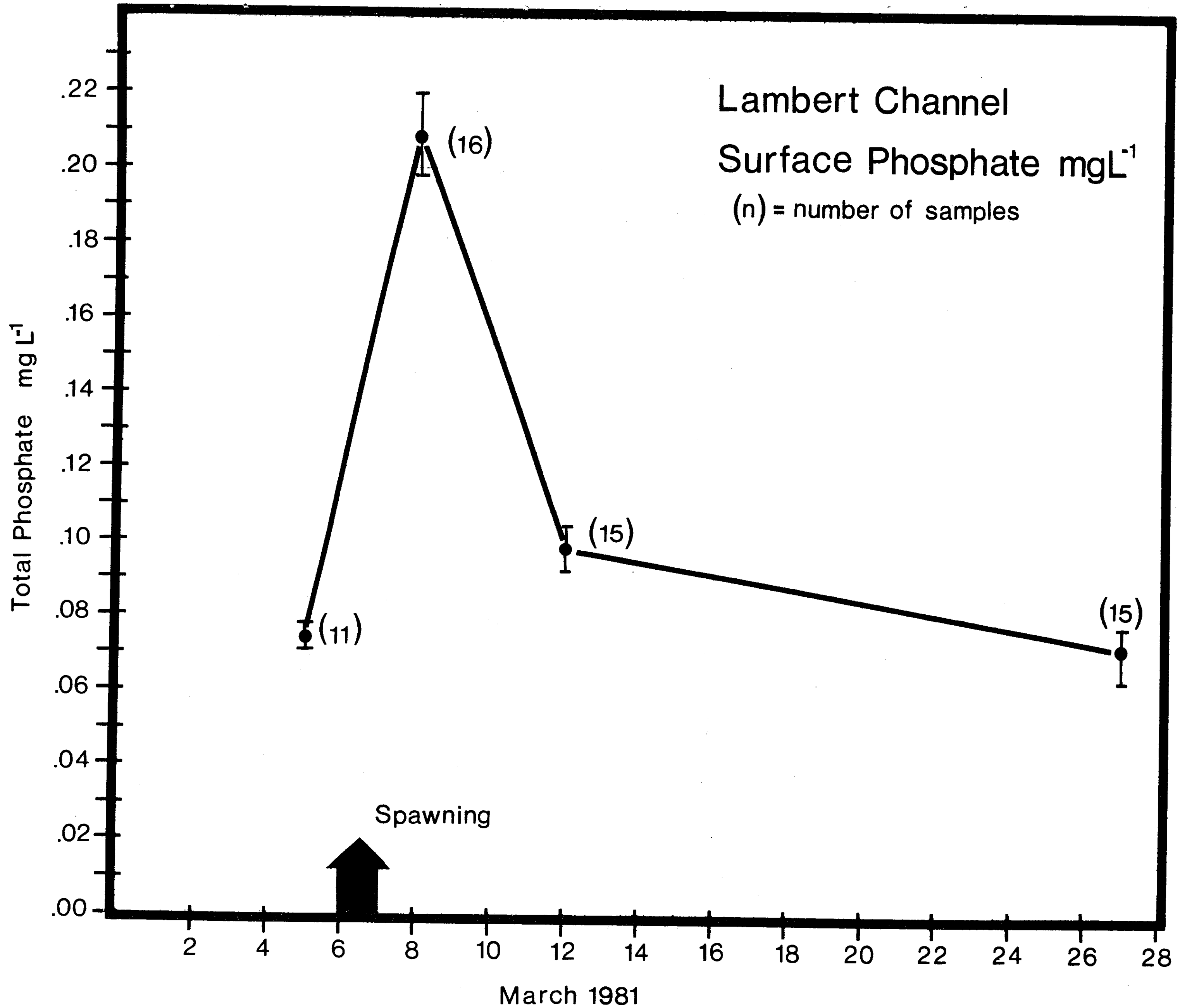

Fig. 4a. Temporal variation in total phosphate at the surface (mg L^{-1}) in Lambert Channel before, during and after herring spawning. Numbers beside data points indicate number of samples used to calculate mean values, which are shown with standard deviations.

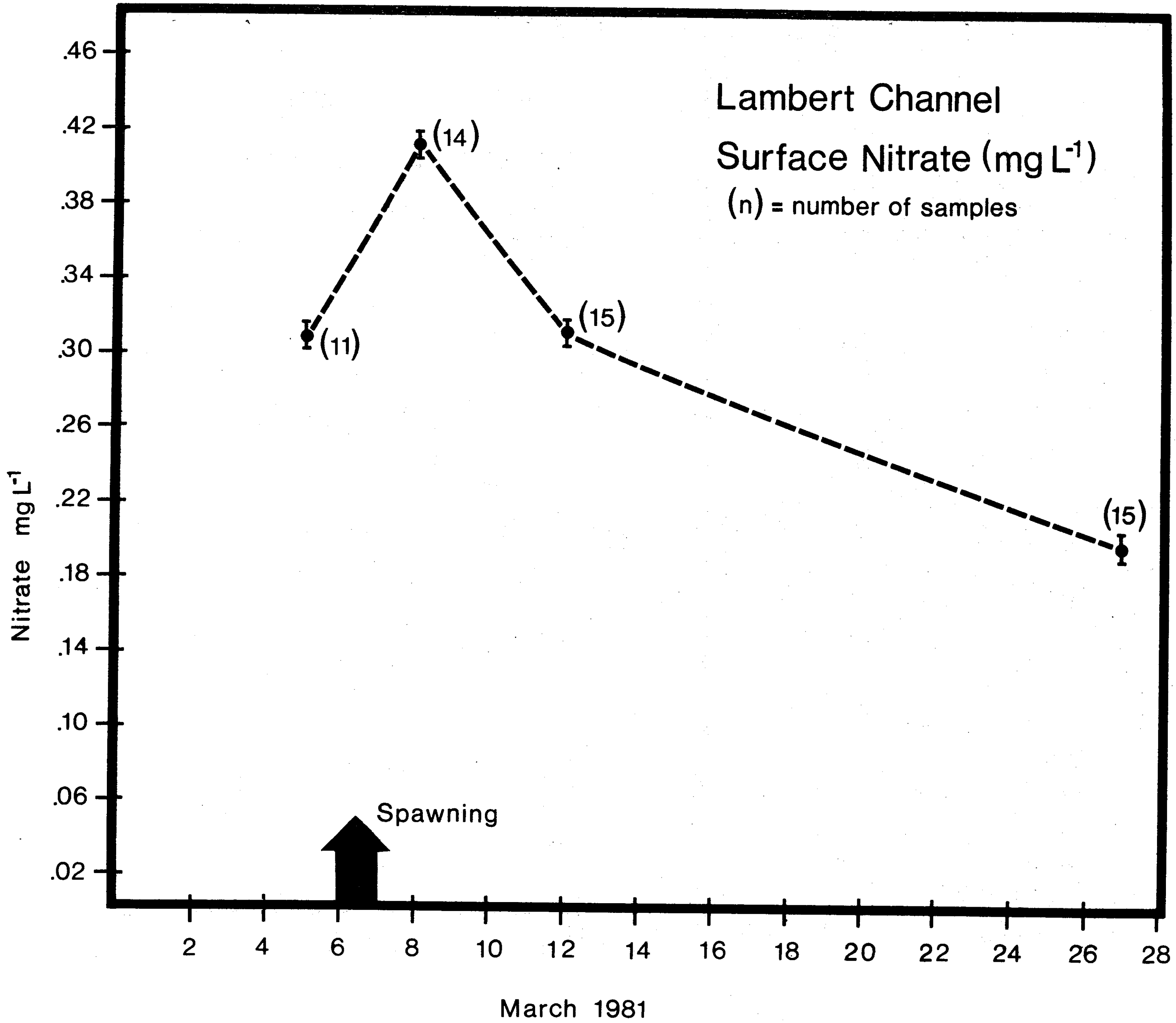

Fig. 4b. Temporal variation in surface nitrate (mg L^{-1}) in Lambert Channel before, during and after, herring spawning. Numbers beside data points indicate number of samples used to calculate mean values, which are shown with standard deviation.