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Serum Steroid Hormone Profiles of Pacific Salmon During Overwintering in the North Pacific Ocean

by

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ABSTRACT

Serum steroid hormone {17α,20β-dihydroxy-4-pregnen-3-one (DHP), estoradiol-17β (E_2), 11-ketotestosterone (11-KT), and testosterone (T)} profiles of 5 species of Pacific salmon (chinook, chum, coho, pink, and sockeye salmon) during overwintering in 3 different sampling areas of the North Pacific Ocean in January, 1996, were examined in order to clarify the relationship between their age and gonadal development. No significant differences in any serum steroid hormone levels was observed in 3 species (chinook, coho, and pink salmon) of the same age among 3 sampling areas. In contrast, quite interesting differences of serum levels of 11-KT and T in males and those of E_2 and T in females were detected among different ages of chum and sockeye salmon during overwintering. These findings are discussed in relation to the shift from feeding migration to spawning migration of salmonids.

INTODUCTION

Pacific salmon (*Oncorynchus* spp.) have an amazing ability to migrate a long distance from the North Pacific Ocean to their natal streams for spawning after a few years of oceanic feeding migration. Although the shift from feeding migration to spawning migration is considered to relate with the onset of gonadal maturation, the physiological controlling mechanisms of this shift are still uncertain. Moreover, one of the most urgent problems of salmonid stocks in the North Pacific Ocean to be resolved is the sensational phenomenon of decreasing body size and increasing age of salmonids which can initiate spawning migration (Ishida et al., 1993; Kaeriyama, 1996).

In our previous studies (Ueda et al., 1984; 1991a; 1991b), we investigated changes in serum steroid hormone {17α,20β-dihydroxy-4-pregnen-3-one (DHP), estoradiol-17β (E_2), 11-ketotestosterone (11-KT), and testosterone (T)} levels during spawning migration of Japanese strain chum

salmon by radioimmunoassay techniques, and found that T and 11-KT levels in males and E_2 levels in females increased from the North-West Pacific Ocean to the coastal sea, but decreased during upstream migration of their maternal river when DHP levels in both sexes elevated dramatically. These data showed a close correlation between changes of steroid hormone profiles and gonadal development and maturation after the onset of spawning migration of chum salmon.

To date, however, no study has analysed steroid hormone profiles of any Pacific salmon during overwintering, especially at the onset of gonadal development. For the first step to clarify the physiological controlling mechanisms of the shift from feeding migraiton to spawning migration, the present study was conducted to measure serum concentrations of T, 11-KT, DHP in male and E2, T, DHP in female of 5 *Oncorhynchus* species during overwintering in the North Pacific Ocean with special reference to their ages.

MATERIALS AND METHODS

In Pacific salmon, five species (chinook salmon, *O. tshawytscha*; chum salmon, *O. keta*; coho salmon, *O. kisutch*; pink salmon, *O. gorbuscha*; sockeye salmon, *O. nerka*) of both sexes from 1 to 5 years old were collected by a surface trolling net (NST-60-K1, Nichimou Co.Ltd) at 15 sampling stations from 44.31N-160.00E to 50.04N-144.59W from January 11 to 25, 1996 during the 4th research cruise of Kaiyo maru. These stations were divided into following 3 sampling areas, the West-North Pacific Ocean (from 44.31N-160.00E to 45.58N-165.03E; St. 1 and 2), the Middle-North Pacific Ocean (from 47.30N-168.09W to 50.00N-162.57W; St. 3 and 4-1), and the Gulf of Alaska (from 54.21N-148.12W to 48.29N-144.48W; St. 4-3 and 5).

Blood of 90 salmonids (10 chinook salmon, 32 chum salmon, 26 coho salmon, 9 pink salmon, and 13 sockeye salmon) was collected from the caudal vasculatre. After centrifugation (3500 rpm for 15 minutes), the serum samples were stored at -85 C until the steroid hormone analyses were

performed. Serum levels of various steroid hormones (E2, DHP, 11-KT, T) were measured by radioimmunoassay methods described previously (Kagawa et al., 1982; Young et al., 1983; Ueda et al., 1991b).

Gonadal development was estimanted by the gonadosomatic index (GSI, gonad wt x 100/body wt). And, several scales removed from the dorso-lateral side of each fish were used for age determination.

RESULTS AND DISCUSSION

Profiles of serum steroid hormone in the different areas of the North Pacific Ocean

Figure 1 shows sampling areas and total numbers of Pacific salmon whose blood samples were collected in each station during the research cruise of Kaiyo maru in January 1996. In the West-North area, many juvenile chum and pink salmon (1-year-old) and a few juvenile chinook salmon (1-year-old) were captured. In the Middle-North area, many juvenile pink and coho salmon (1-yera-old), and a few young immature chum and sockeye salmon (2-year-old) were caught. In the Gulf of Alaska, a few old immature chum and sockeye salmon (over 3-year-old) and many juvenile coho and pind salmon (1-year-old) were sampled.

The numbers of 3 species (chinook, coho, and pink salmon) were too small to correlate with their age, serum steroid hormone levels of these species were analysed among their sampling stations. There were no significant differences in any serum steroid hormone levels of 3 species of the same age among 3 different sampling areas (Figs. 2-4). These data suggest that serum steroid hormone levels of salmonids derived from differnt strains might not change appreciable during overwintering in the North Pacifc Ocean. However, the number of blood samples of the present study were relatively small, so further hormonal analyses should definitely be carried out by adding many blood samples from different areas. Moreover, it is highly important to

establish the simple methods to clarify the origin of each strain of salmonids.

Relations between serum steroid hormone levels and the age in salmon

Differences in the GSI and serum steroid hormone levels were analyzed in chum salmon among different ages (Fig. 5). In males, the GSI valules were very low and did not present any differences among the ages. Although serum levels of DHP were also extremely low in all ages, those of 11-KT increased over 3-year-old. Serum T levels also increased in 3- and 4-year-old. In one 5-year-old male, the meaning of decreases of serum 11-KT and T levels should be elucidated by adding number of older salmon samples. In females, the GSI values showed a gradual increase in parallel with the age. Over 3-year-old, serum T levels also displayed a stedy increase, and those of E_2 showed a slight increase. Low levels of serum DHP were maintained in all ages.

Differences in the GSI and serum steroid hormone levels were examined in sockeye salmon among different ages (Fig. 6). Similar to male chum salmon, the GSI values and serum DHP levels in male sockeye salmon were very low. Serum 11-KT and T levels displayed sharp increases from 2-year-old and 3-year-old, respectively. In females, slight increases of the GSI valules and serum E_2 levels were observed, and a drastic increase of serum T levels was measured in 3-year-old.

Serum steroid hormone concentrations of Japanese strain chum salmon (from 3- to 5-year-old) during spawning migration in the West-North Paficif Ocean (from 41.30N-156.30E to 45.32N-173.31E) in May and June 1982 have been reported in our previous studies (Ueda et al., 1991a and 1991b). The present results demonstrated for the first time differences in serum concentrations of gonadal steroid hormones among different ages of chum and sockeye salmon during overwintering in the North Pacific Ocean. Since DHP has been clearly proved to be involved in the process of final testicular and ovarian maturation in salmonids, the constant low levels of DHP in the present study was

coincided with no signs of gonadal maturation. In contrast, the increase of serum levels of 11-KT in males and those of E_2 in females indicated that the early phase of gonadal development might have already occurred from 2- or 3-year-old fish of both species. Gonadal histological observations should be examined to detect any signs of the onset of gonadal development. It might be of quite interest that serum T levels increased in chum and sockeye salmon of both sexes from 3-year-old. The physiological roles of T in gametogenesis as well as metabolism are still quite unknown, and should be studied in connection with body size and age of salmonids.

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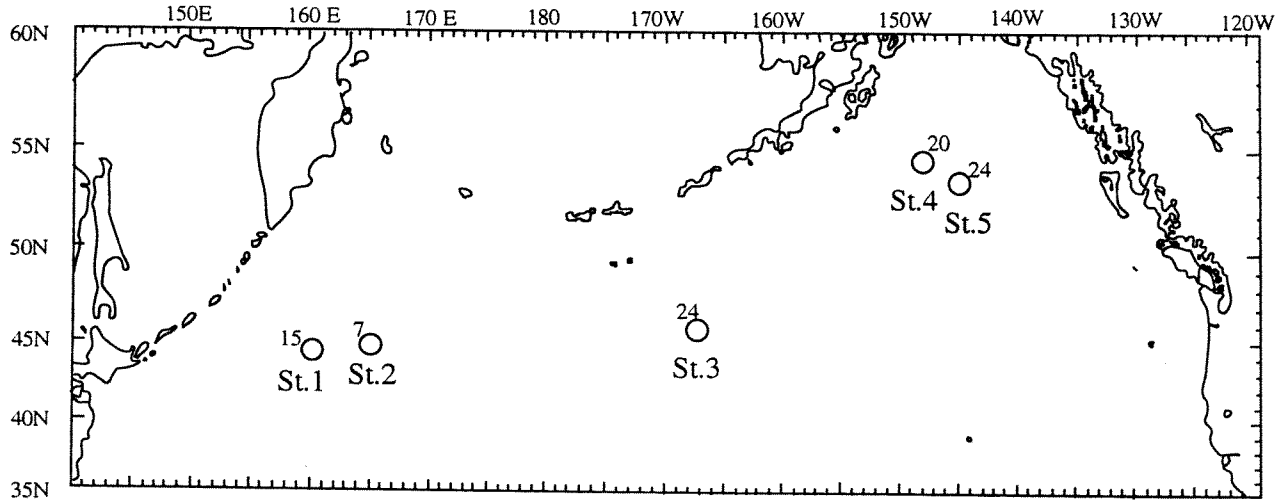

Fig.1. Sampling stations (St) and numbers of 5 species of Pacific salmon whose blood samples were collected in the North Pacific Ocean during the cruise of Kaiyou maru in January, 1996.

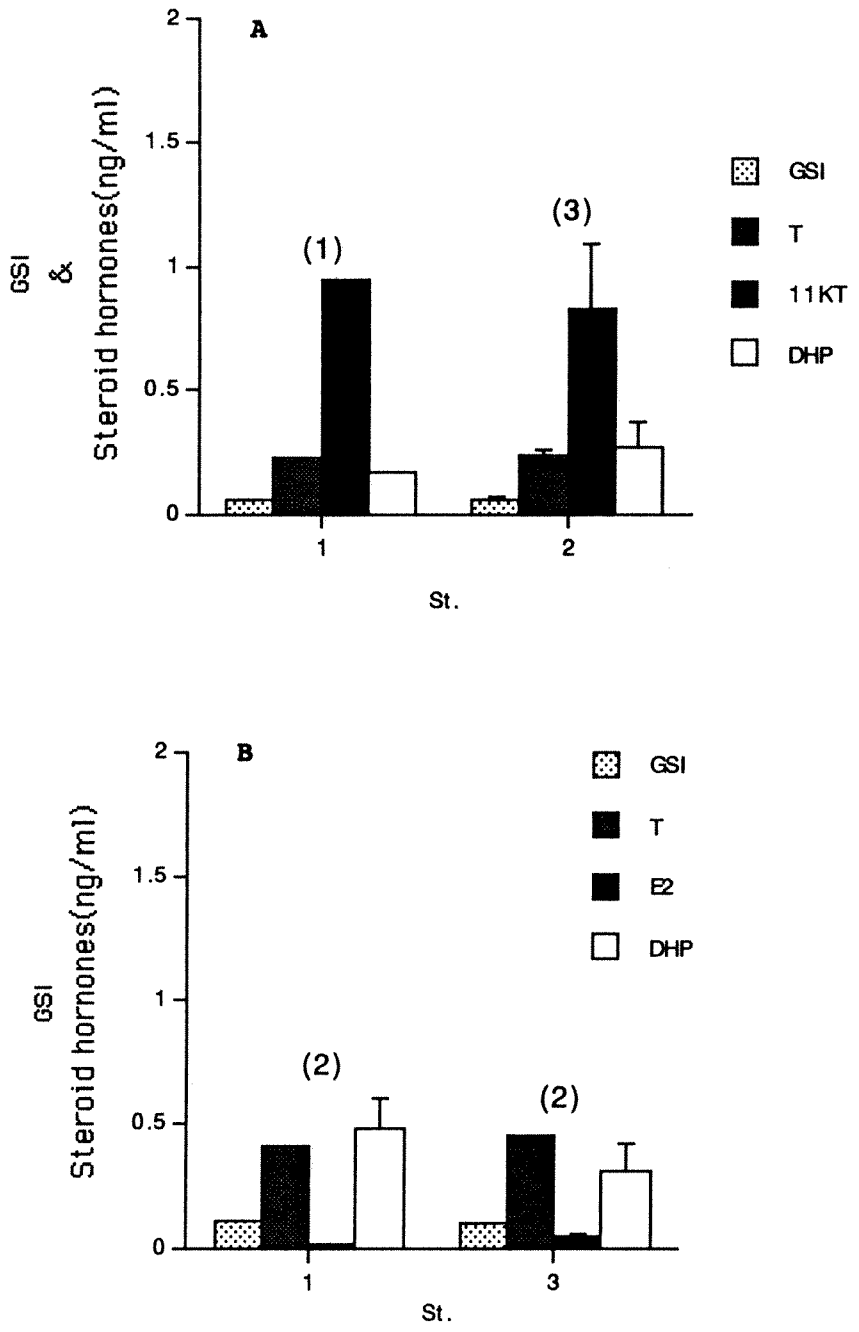

Fig. 2. Differences in the gonadosomatic index (GSI) and serum steroid hormone(DHP:17α,20β-dihydroxy-4-pregnen-3-one; E2:estradiol-17β; 11-KT:11-ketotestosterone; T: testosterone) levels male (A) and female (B) chinook salmon among different sampling stations during overwintering in January,1996. Each value represents the means ± SEM of the indicated number of samples shown in parentheses.

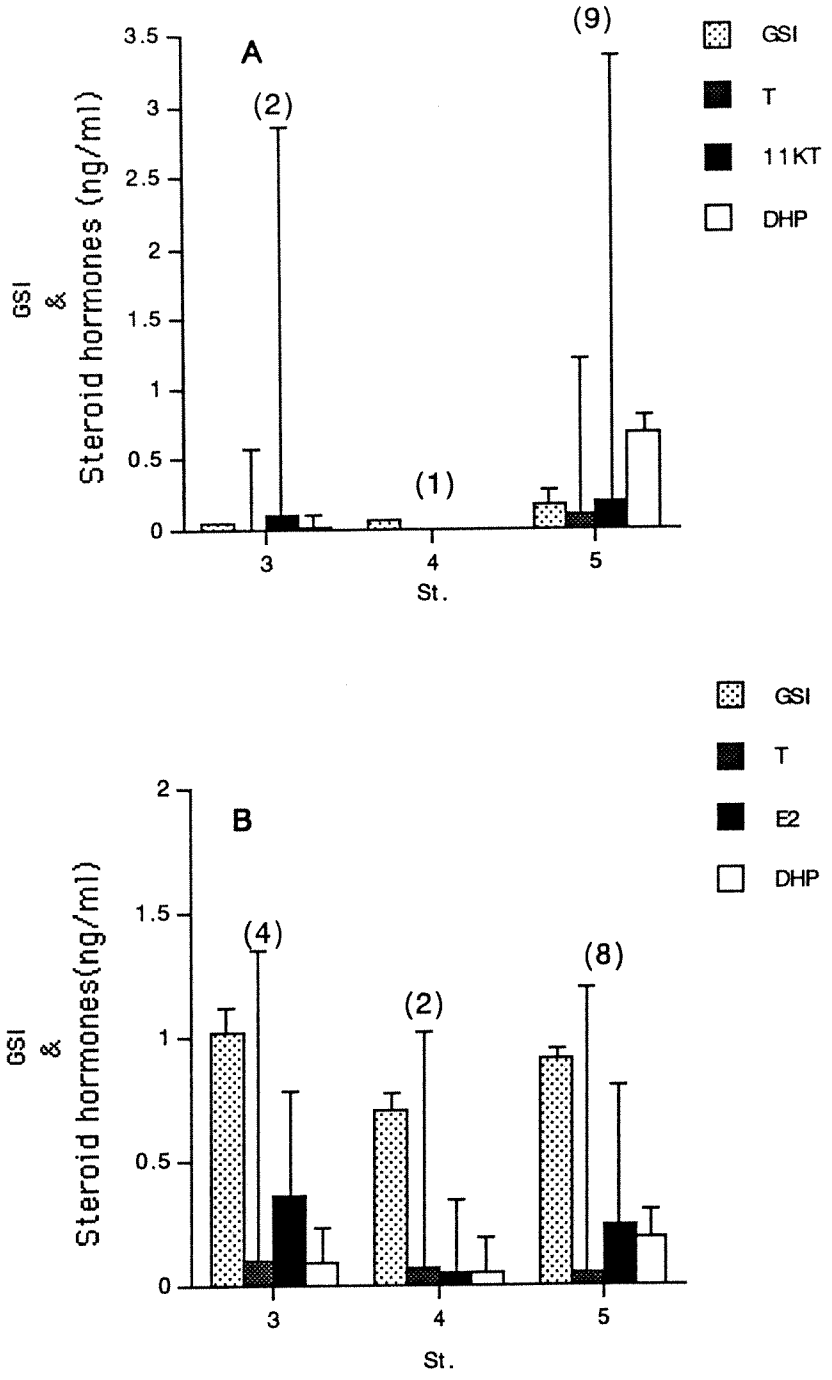

Fig. 3. Differences in the gonadosomatic index (GSI) and serum steroid hormone(DHP:17α,20β-dihydroxy-4-pregnen-3-one; E2:estradiol-17β; 11-KT:11-ketotestosterone; T: testosterone) levels male (A) and female (B) coho salmon among different sampling stations during overwintering in January,1996. Each value represents the means ± SEM of the indicated number of samples shown in parentheses.

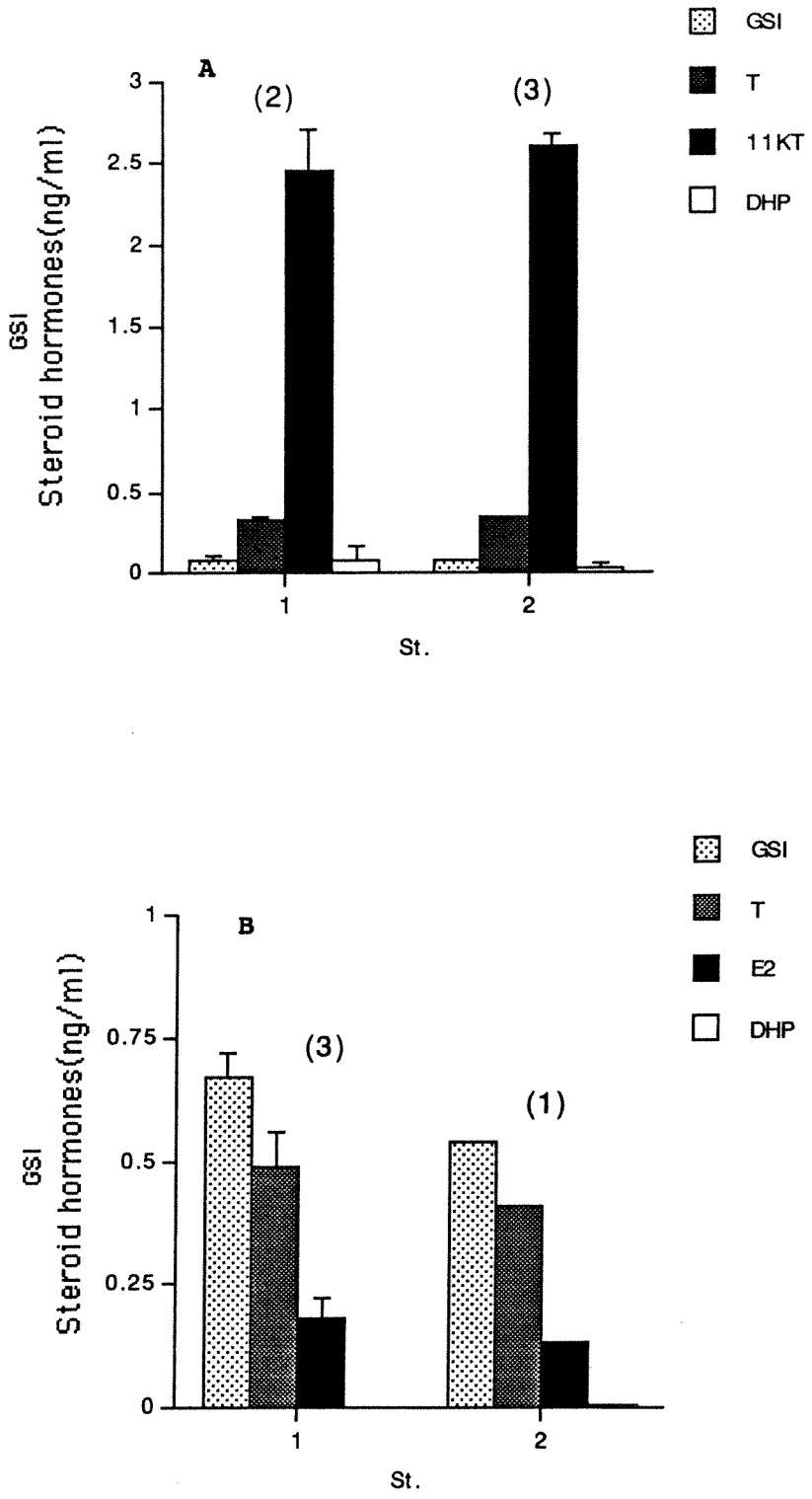

Fig. 4. Differences in the gonadosomatic index (GSI) and serum steroid hormone(DHP:17α,20β-dihydroxy-4-pregnen-3-one; E2:estradiol-17β; 11-KT:11-ketotestosterone; T: testosterone) levels male (A) and female (B) pink salmon among different sampling stations during overwintering in January,1996. Each value represents the means ± SEM of the indicated number of samples shown in parentheses.

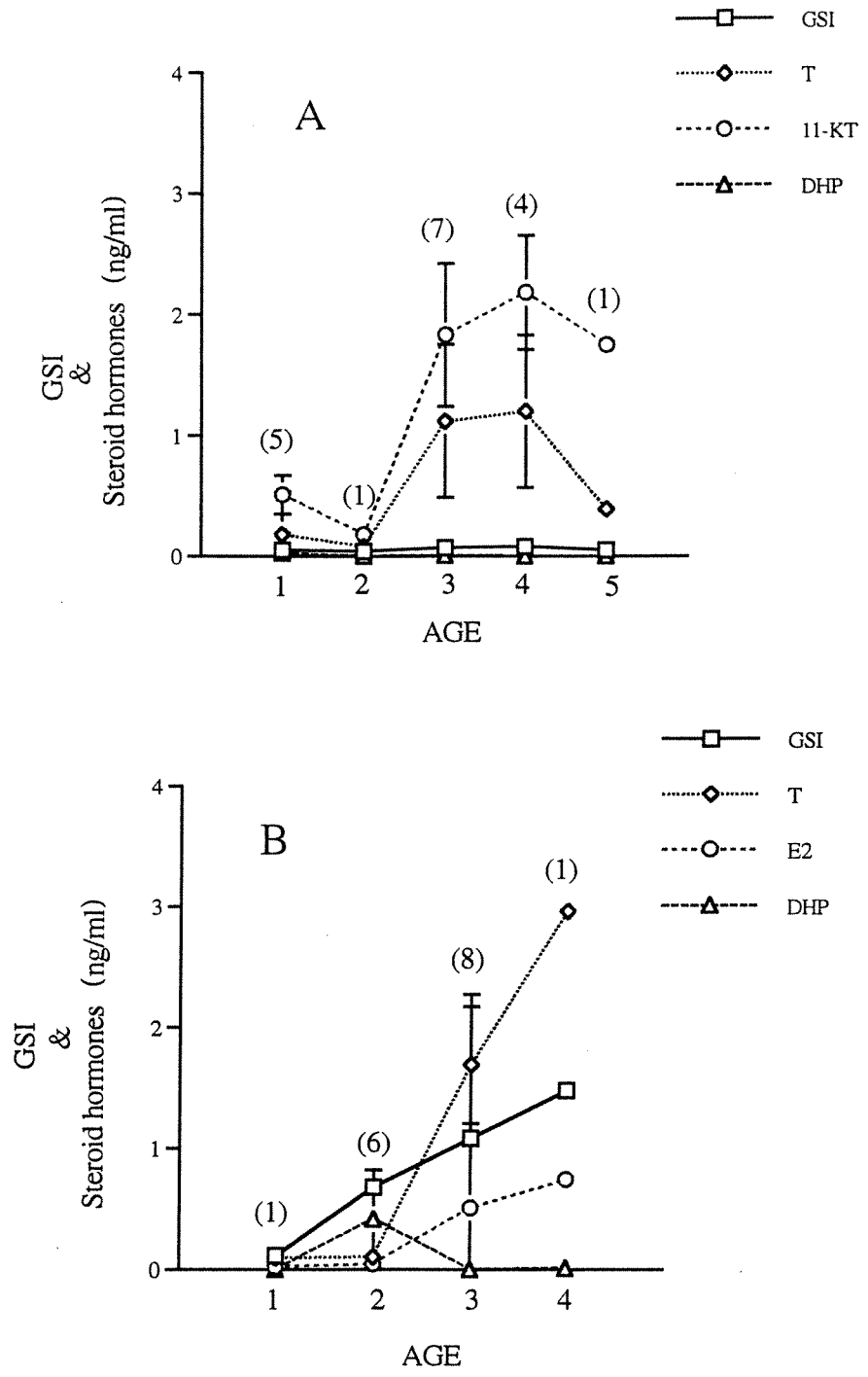

Fig. 5. Differences in the gonadosomatic index (GSI) and serum steroid hormone (DHP: 17α,20β-dihydroxy-4-pregnen-3-one; E_2: estradiol-17β; 11-KT: 11-keto testosterone; T: testosterone) levels among different ages of male (A) and female (B) chum salmon during overwintering in January, 1996. Each value represents the mean ± SEM of the indicated number of samples shown in the parentheses.

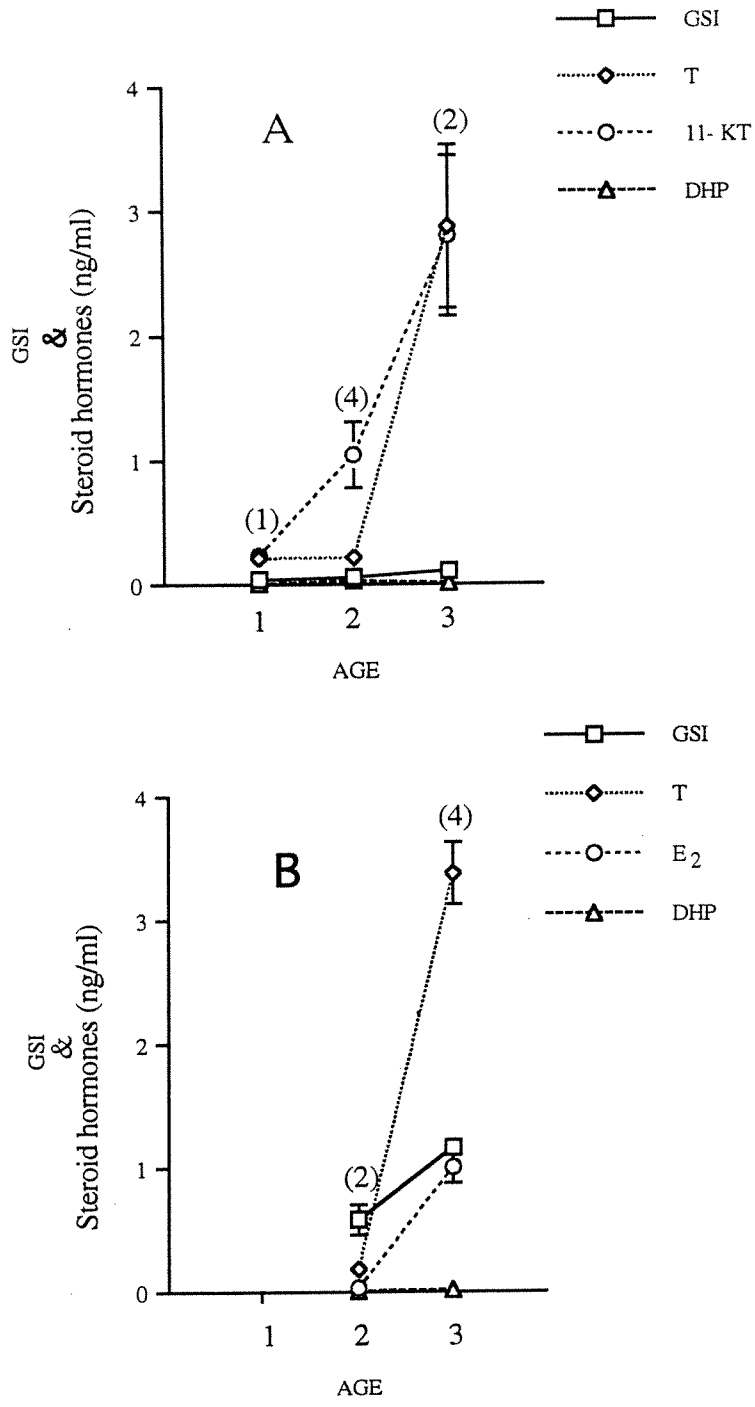

Fig. 6. Differences in the gonadosomatic index (GSI) and serum steroid hormone (DHP: 17α,20β-dihydroxy-4-pregnen-3-one; E_2: estradiol-17β; 11-KT: 11-keto testosterone; T: testosterone) levels among different ages of male (A) and female (B) sockeye salmon during overwintering in January, 1996. Each value represents the mean ± SEM of the indicated number of samples shown in the parentheses.