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OSMOREGULATION IN THE BROOK TROUT, (Salvelinus fontinalis)

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Migration of brook trout (Salvelinus fontinalis) into sea water can result in exceptional growth and high return rates, making this a potentially valuable species for sea ranching, fish farming and enhancement programs. Sea ranching experiments conducted at the Matamek Research Station indicate the prevalence of these qualities under conditions of artificial transplantation. Economic development of commercial ventures will require knowledge of optimum sea water stocking procedures. To this end, we have investigated the role of size, age and photoperiod in determining the ability of brook trout to osmoregulate and grow in sea water.

Ten thousand fry were divided into fast and slow growing groups using feeding rate to control growth. Fish were further divided into two photoperiods; one of normal (annually cycling) daylength and a second three months out of phase with normal. Fish from each group were exposed to seawater using a step-wise acclimation procedure (10→20→32^{o}/oo). Growth and survival were monitored for 20 days. Osmoregulatory ability was judged by changes in plasma concentrations of Na^+, Cl^-, K^+, Mg^{++}, osmotic concentration and gill Na^+-K^+ ATPase after 4 and 20 days in sea water.

Increased size results in increased sea water survivorship and osmoregulatory ability (see Figures 1 and 2). Growth rate and age have no detectable effect on osmoregulation. Photoperiod effects osmoregulation by controlling maturation; ripe males have significantly decreased survival time (Figure 3) and increased plasma osmotic concentrations (Table 1). Plasma osmotic concentration after 4 days in seawater correlate with sea water surivorship and can be used to predict osmoregulatory ability of experimental groups or natural populations of brook trout (see Figure 1). The predominant role of size in determining osmoregulatory ability indicates that accelerated growth rates, which produce larger fish at any age, will result in individuals that can more successfully adapt to sea water.

Activity of gill Na^{+}-K^{+} ATPase in brook trout in freshwater is similar to other freshwater teleosts, ranging from 5 to 12 $\mu M\ P_i \cdot mg\ prot.^{-1} \cdot hr^{-1}$. Enzyme activity increases with increasing body size, until a maximum freshwater value is reached. Unlike smolting salmonids, no spring-time peak in activity is present. Thyroxine levels in slow growing fish are lower than fast growers at all sampling periods. Gill Na^{+}-K^{+} ATPase levels increase under hypersaline conditions, rising at rates similar to other euryhaline teleosts, to levels of 40-60 $\mu M\ P_i \cdot mg\ prot.^{-1} \cdot hr^{-1}$ after 20 days in 32 $^{0}/oo$ seawater.

Method of sea water acclimation had a significant effect on survivorship. Fish acclimated at intermediate salinities (one week in $10^{0}/oo$, one week in $20^{0}/oo$) had higher mean survival times, greater percentage survival and lower plasma osmotic concentrations after 24 hours in sea water, relative to fish transferred directly to sea water. Gill Na^{+}-K^{+} ATPase activity increased from 10 to 17 $\mu M\ P_i \cdot mg\ prot.^{-1} \cdot hr^{-1}$ when fish are acclimated for one week in $20^{0}/oo$. These results indicate that an increased acclimation time in intermediate salinities result in increased physiological preparedness and sea water survivorship for every size class.

Within group variations in osmoregulatory ability exist and cannot be explained by variations in size or sex. This indicates a considerable natural genetic variation that could provide a basis for selective breeding of sea-run brook trout. Attempts are being made to preserve a broodstock consisting of individuals with exceptional osmoregulatory ability.

The results cited above have important implications for sea water stocking of brook trout. Large fish will adapt more readily to sea water, so that increased growth will result in greater sea water survival. However, during a declining photoperiod, increased size will also lead to greater percentages of maturing fish which has a negative effect on osmoregulatory ability and sea water survival. Acclimation at intermediate salinities elevates gill Na^+-K^+ ATPase and increases survival in full strength sea water.

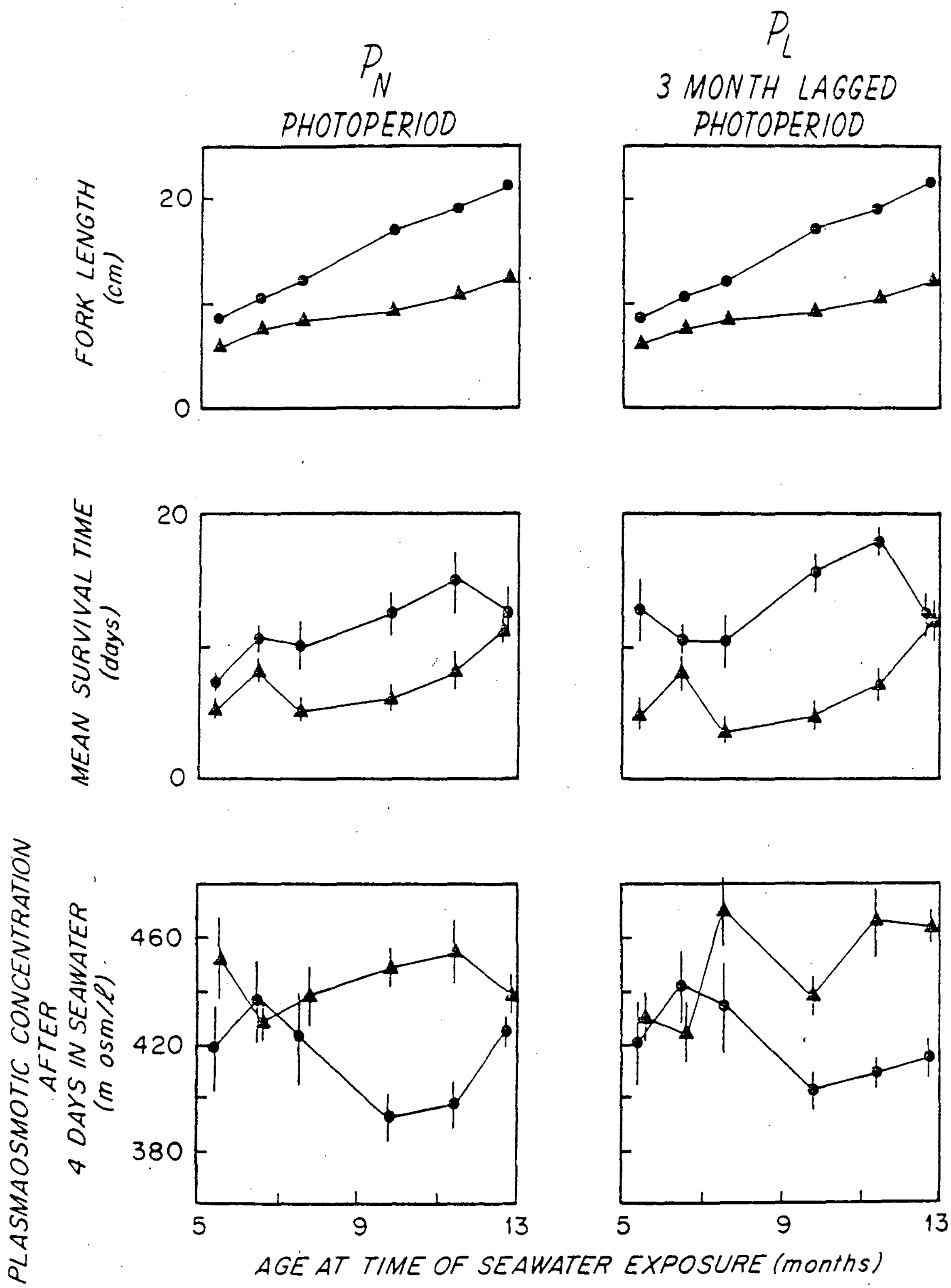
Several questions still remain: (1) the physiological basis for differences in osmoregulatory ability between mature males and females may provide insight into mechanisms controlling osmoregulation in salmonids and implies sexual differences in migratory behavior and life history strategy. (2) Stress due to freshwater readaptation (hyperosmoregulation) needs to be investigated for its possible effect on returning stocks of sea-run brook trout. (3) What are the physiological differences, if any, that exist between anadromous (e.g. Moisie River) and non-anadromous (e.g. Matamek River) stocks of brook trout? Continued research and data analysis in our laboratory should help answer these and other basic questions related to salmonid osmoregulation.

Figure Caption

Figure 1. Size at time of sea water exposure, mean survival time in seawater and plasma osmotic concentration after 4 days in 32 o/oo seawater versus age at time of seawater entry. All fish were acclimated to 32o/oo seawater in a stepwise fashion (see text). Closed circles represent fast growing fish and closed triangles represent slow growing fish.

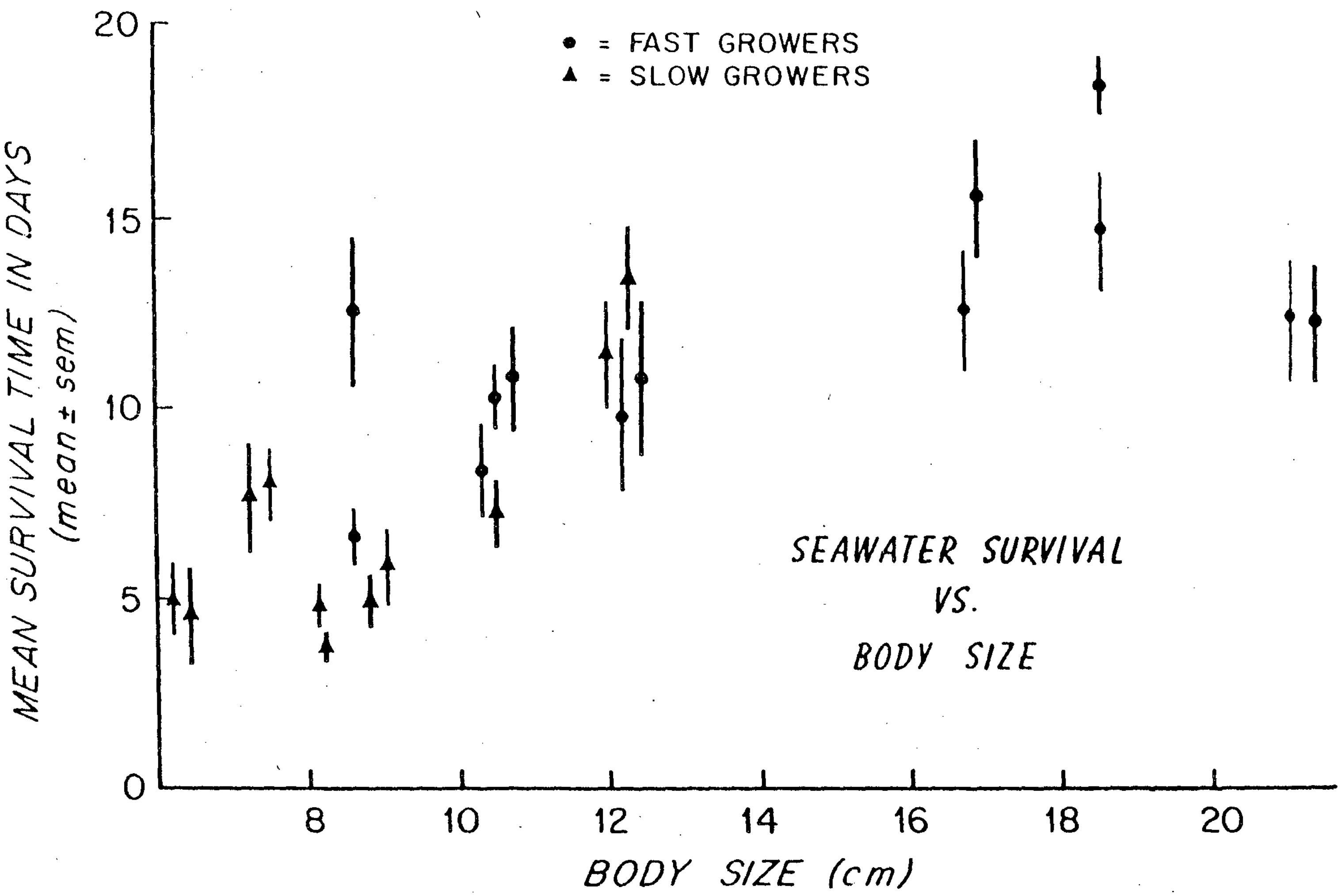
Figure 2. Body size versus mean survival time in seawater. All fish were acclimated to 32o/oo seawater in a stepwise fashion. Duration of exposure was 20 days which represented maximum seawater survival time.

Figure 3. Mean seawater survival time for brook trout maintained under two photoperiod regimes. Experiments were conducted in November and both groups were in a declining photoperiod. The female category represents both mature and immature females.



P_N
PHOTOPERIOD
P_L
3 MONTH LAGGED
PHOTOPERIOD
FORK LENGTH
(cm)
20
0
MEAN SURVIVAL TIME
(days)
20
0
PLASMAOSMOTIC CONCENTRATION
AFTER
4 DAYS IN SEAWATER
(m osm/ℓ)
460
420
380
5
9
13
5
9
13
AGE AT TIME OF SEAWATER EXPOSURE (months)

FIGURE 1



● = FAST GROWERS
▲ = SLOW GROWERS
MEAN SURVIVAL TIME IN DAYS
(mean ± sem)
20
15
10
5
0
8
10
12
14
16
18
20
BODY SIZE (cm)
SEAWATER SURVIVAL
VS.
BODY SIZE

FIGURE 2

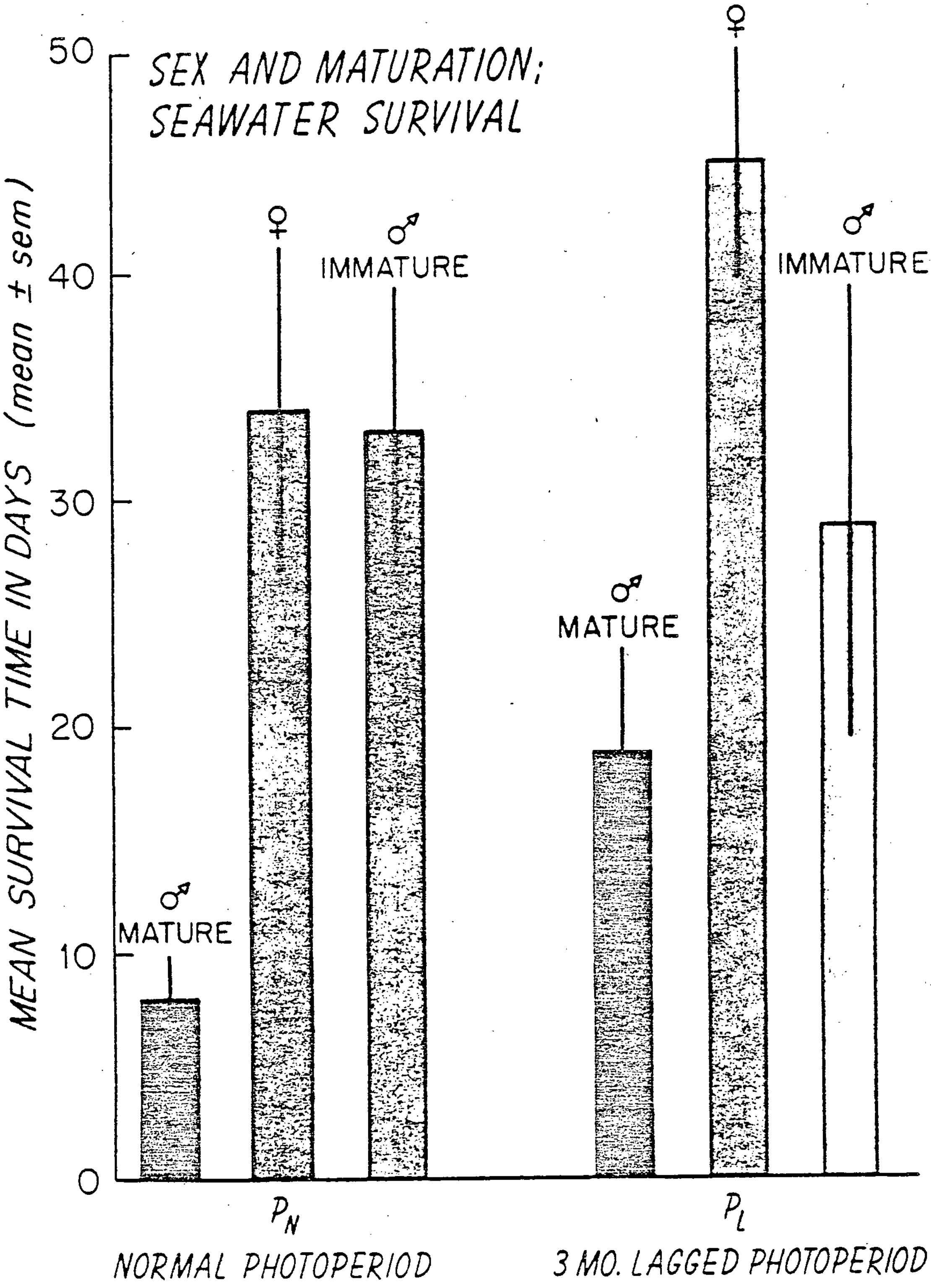

SEX AND MATURATION;
SEAWATER SURVIVAL
MEAN SURVIVAL TIME IN DAYS (mean ± sem)
50
40
30
20
10
0
♂
MATURE
♀
♂
IMMATURE
♂
MATURE
♀
♂
IMMATURE
P_N
NORMAL PHOTOPERIOD
P_L
3 MO. LAGGED PHOTOPERIOD

FIGURE 3

Table 1. Physiological comparison of mature females and mature males after 4 days in 32o/oo seawater. Fish were acclimated to 32o/oo sea water in a stepwise fashion (see text).

	Males	Females
Plasma Osmotic Concentration (mOsm/l)	427* ± 8.7	401* ± 4.0
Gonadosomatic Index (% body wt)	2.8 ± 0.2	9.0 ± 2.4
Length (cm)	21.4 ± 0.4	21.0 ± 0.3
Weight (g)	109.2 ±10.4	105.3 ± 8.5

*Significantly different at 95% confidence level. Values are expressed as means ± standard errors.